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Federal Energy Regulatory Commission
Attn: Debbie-Anne A. Reese
FERC Secretary
888 First Street NE, Room 1A
Rockville, MD 20852

23 July 2026

Filed Via: www.ferc.gov
Project No. P-77-332

RE: NEPA Scoping Comments of PCFFA and IFR on PG&E *Application for Surrender of License and Application for Non-Project Use of Project Lands (Filed 7/25/25) ("LSA")(P-77-332); & Notice of Application for Non-Capacity Amendment of License (P-77-318)*

To the FERC Staff:

The Pacific Coast Federation of Fishermen's Associations (PCFFA) is a major U.S. west coast trade organization representing the interests of ocean commercial fishing families, and is led by active working fishermen's port associations throughout California. Our individual members are mostly family-owned and operated fishing businesses that have historically relied upon once-abundant wild Pacific salmon stocks to harvest for all or part of their livelihoods and to deliver high-quality seafood to America's tables.

Our family fishing business members depend upon robust salmon populations in the ocean, which can only exist when supported by healthy in-river habitats from which anadromous salmon must come. Historically, one of the main sources of the salmon that our industry and the commercial ocean salmon fisheries our members have depended upon for their livelihoods were the salmon originating in the Eel River watershed, which once supported (before the building of the Potter Valley Project Dams and its associated major water withdrawals) the fourth largest salmon runs in the continental United States. The Eel River is also the third largest river entirely in the State of California.

Institute for Fisheries Resources (IFR), PCFFA's sister organization, is a fishing industry-based, non-profit California Public Benefit corporation that advocates for policies to protect, restore and maintain viable salmon stocks at levels beyond the standards required for mere de-listing under the Endangered Species Act (ESA). Successful salmon restoration <u>must</u> include sustainable ocean abundances to support commercial fishing and coastal communities that depend on those fish for their livelihoods.

Together, our two organizations have long supported the removal of the Potter Valley Project (PVP) dams. We are also focused on ensuring that restoration and reintroduction planning is sufficient to support the long-term recovery of Eel River salmon at levels that will result in meaningful ocean harvest. This restoration effort must include a fully developed reintroduction plan that uses all appropriate science-based methods to speed rebuilding of Eel River salmon to harvestable abundance.

Our members clearly have an economic stake in the outcome of this FERC process. This is why our two organizations are not only Intervenor-Parties in the ongoing FERC proceeding regarding the adverse impacts on ESA-listed salmonids caused by this FERC Project No. 77 license, but are also Plaintiffs on these same issues in three parallel, ongoing U.S. Federal Court litigation actions, i.e., two lawsuits against FERC,[1] and another one against PG&E itself.[2] Many of our individual members are also PG&E ratepayers and customers.

We also have considerable experience with dam removal projects generally, including the successful removal in 2024 of the four lower Klamath hydropower dams, which blocked the once abundant salmon runs of the Klamath River for more than 110 years. **We support a thorough and complete NEPA analysis of PG&E's Proposed Potter Valley Project Dam Removal Action**, including clearly separating dam decommissioning from the proposed New Eel-Russian Facility (NERF) water diversion proposal. We also support the "Rapid Dam Removal" option as outlined in the License Surrender Application (LSA).

In prior comments dated 1 December 2025, we asked the Commission to take four actions essential to a lawful and effective license surrender. First, the Commission should remove PG&E's proposed pre-condition linking dam removal to the construction of the separate and uncertain NERF, so that license surrender is not dependent on a complex and uncertain project outside PG&E's control. Second, the Commission should, as mitigation for more than 110 years of habitat destruction by the Potter Valley Project, require salmon protection, reintroduction, and restoration measures that support water quality, sediment management, and long-term recovery of Eel River salmon to levels that can sustain harvest, including consultation with the Pacific Fishery Management Council (PFMC) on fishery impacts, and also including the requirement that PG&E develop and implement a comprehensive salmon reintroduction plan that uses science-based tools to speed rebuilding toward a harvestable surplus. Third, the Commission should require mitigation

[1] *Friends of the Eel River, Pacific Coast Federation of Fishermen's Associations, Institute for Fisheries Resources, California Trout and Trout Unlimited vs. FERC*, in the 9th Circuit Court of Appeals Cases No. 22-1589 & Case. No. 22-70182.

[2] *Friends of the Eel River, Pacific Coast Federation of Fishermen's Associations, Institute for Fisheries Resources, California Trout and Trout Unlimited vs. Pacific Gas & Electric Company*, and in the U.S. District Court, Northern District of California (Eureka-McKinleyville Division) as Case No. 23-cv-02379.

for the long-term socio-economic harm the Potter Valley Project has imposed on ocean salmon fisheries and ensure that PG&E's restoration actions support rebuilding harvestable salmon populations. Fourth, the Commission should require updated and enforceable plans to suppress invasive predatory species released during drawdown and dam removal. These predators (particularly the pikeminnow) are invasive species that have found fresh-water reservoir habitat conducive to their spread, that predate on native fish such as salmonids. We reiterate these requests herein.

In these comments we will focus primarily on the impacts of the Potter Valley Project dam removal action on: (1) Eel River water quality and water use; (2) Eel River fish (particularly salmonids) and aquatic resources, and; (3) mitigating or reversing the severe adverse socio-economic impacts the Potter Valley Project has had on our commercial fishing industry and the benefits to our industry that would likely accrue from the decommissioning and removal of the Potter Valley Project dams.

Since there are two distinct projects outlined in the LSA, we will discuss the decommissioning and removal of the Potter Valley Project dams first, and separately provide our comments regarding the very different, non-PG&E project known as the New Eel-Russian Facility (NERF), which is proposed to be owned and operated not by PG&E, but rather by a newly formed entity known as the Eel-Russian Project Authority (ERPA).

FERC has very broad discretion to include a range of protective and mitigation measures in a license surrender and termination approval. FERC's regulations pertaining to the license surrender and termination of a licensed hydropower project are found in the Federal Power Act (FPA) regulations at 18 CFR Chapter 1, Subchapter B, Part 6 – *Surrender or Termination of License*. Section 6.2 of the FPA Regulations states the following:

> *Licenses may be surrendered only upon the fulfillment by the licensee of such obligations under the license as the Commission may prescribe, and, if the project works authorized under the license have been constructed in whole or in part, upon such conditions with respect to the disposition of such works as may be determined by the Commission. Where project works have been constructed on lands of the United States the licensee will be required to restore the lands to a condition satisfactory to the Department having supervision over such lands and annual charges will continue until such restoration has been satisfactorily completed.*

However, PG&E has noted in its Application [(LSA pg. 3-2] that its draft *Decommissioning Plan*, and associated *Restoration Plan*, included in this Surrender Application "will be more fully developed in coordination with the resource agencies, Tribes, and other interested parties, as appropriate, as the surrender process proceeds." Many of these plans still remain incomplete and will require further development before their environmental and socio-economic impacts can properly or fully be assessed by FERC Staff.

Those two key Plans in particular need to prioritize salmonid habitat restoration, including appropriate water quality mitigation measures to protect salmonids from dam removal impacts such as heightened sediment loads and increased predation from invasive species. FERC should require PG&E to consult with the National Marine Fisheries Service (NMFS) and the PFMC on how best to protect Eel River-limited salmon fisheries through the dam removal process. The PFMC was Congressionally created under the *Magnuson-Stevens Fishery Conservation and Management Act* (16 U.S.C. § 1801, *et seq.)* specifically to advise the U.S. Secretary of Commerce on how best to manage the mixed-stock ocean salmon fisheries to which Eel River-origin Chinook and Coho have historically been important contributors.

In addition to these requirements, any license surrender must include a comprehensive salmon reintroduction plan that restores Eel River salmon to levels that can sustain commercial harvest. Habitat restoration alone is not enough to rebuild these depleted runs within a timeframe meaningful to fishing communities. A full suite of science-based reintroduction tools must be considered, including trap-and-haul of adults, juvenile hatch boxes, egg injection, and other early life-stage enhancement methods, with clear performance benchmarks tied to harvestable abundance. Without a dedicated and enforceable reintroduction framework, the benefits of dam removal for ocean fisheries will fall short of what is needed to rebuild a viable salmon fishery.

Today it is now clearer than ever that all the PVP dams' removals are necessary for recovery of the Eel River's now ESA-listed salmonids. Both the Scott Dam and Cape Horn Dam are clearly at the end of their engineered lifespan.

SCOPING MUST CONSIDER THE DAMAGES OF PROJECT DAMS ON WEST COAST OCEAN SALMON FISHERIES OVER TIME AS WELL AS THE ENORMOUS PUBLIC BENEFITS SALMONID RECOVERY WOULD PROVIDE

Adverse effects of the PVP dams are not limited to the footprint of the dam sites. Decades of sediment trapping and temperature stratification behind Scott Dam have contributed to deteriorated water quality – temperature, turbidity, and dissolved oxygen levels that killed adults and juvenile salmon – far downstream of the dam sites. Massive water diversions from the Eel River for many decades also exacerbated these impacts, killing off the salmonids (Chinook, Coho and steelhead) that were once incredibly abundant in that highly productive watershed.

PG&E's decision to surrender its operating license with FERC presents an unprecedented opportunity to restore the Eel River ecosystem and to rebuild the salmon fisheries, fleets, and communities that depend on it. The outcome of this FERC process will determine whether the Eel River can function again as a healthy salmon system that supports river and coastal communities or if it will forever remain in the degraded condition caused by this Project.

The Eel River once supported some of California's most productive salmon runs, with historic returns estimated at up to 800,000 returning Chinook salmon adults annually.[3] For more

[3] For historical population estimates, see Ronald M. Yoshiyama & Peter Moyle, *Historical Review of Eel River Anadromous Salmonids, With Emphasis on Chinook Salmon, Coho Salmon and Steelhead*, UC Davis Center for Watershed Sciences Working Paper (Feb. 1, 2010). Available online at: https://eelriver.org/wp-content/uploads/2024/03/Yoshiyama-Moyle_Historical-Reivew-of-Eel-River-Anadromous-Salmonids-Final-Report-2010.pdf.

than 100 years, however, PVP **has blocked approximately 288 stream miles** of high-quality salmonid habitat, and also required the diversion of large volumes of water through a tunnel into the Russian River basin, for decades greatly reducing flows necessary for sustaining Eel River salmonid populations.

The cumulative impacts of over 100 years of these Eel River diversions and blockages have nearly wiped out what were once among the most important salmon runs on the West Coast. Chinook and Coho salmon, as well as steelhead, were all once abundant in the Eel River, but now all three of these native Eel River salmonid species are federally listed under the Endangered Species Act (ESA). These losses continue to contribute to increasingly limited harvest opportunities for California's commercial salmon fleet. **Indeed, the economic losses to coastal salmon-dependent communities from near-total destruction of Eel River salmon fisheries over the past decades has been a very steep price, including at least $93 million/year in lost coastal economics benefits and the loss of the equivalent of some 1,504 family-wage jobs.[4]**

A full accounting of these losses also highlights a clear path to reversing them. While clearly necessary, however, dam removal alone will not restore harvestable salmon abundance. Repairing the long-term economic damages to ocean fisheries the Potter Valley Project imposed on the region also demands a comprehensive reintroduction program that could restore Eel River salmon to levels that can once again sustain valuable and widespread commercial harvests. This requires proactive measures, not passive hopes of natural return. FERC should require PG&E to support science-based reintroduction methods capable of rebuilding abundance at a pace that reflects the scale of the harm.

It is critical that any economic analysis of Eel River dam removal or other water quality impacts include impacts to ocean fisheries. Too often, only terrestrial economies are considered when looking at FERC project impacts, at the expense of fish populations and those who depend upon them. Because salmon from different watersheds inter-mix in our ocean fisheries and travel great distances, declines in abundance of Eel River salmon runs ripple through ocean fisheries throughout California and Oregon and the coastal communities they support.

The near-total losses of the once abundant Eel River salmon runs constrain northern California and Oregon ocean salmon fisheries in two ways: (1) the direct loss of fish from the Eel River, which can no longer be harvested because they no longer exist, but also; (2) the indirect loss of access to other, more abundant, but intermingling stocks, because our ocean fisheries are managed, restricted, and sometimes closed entirely in order to protect the least abundant stocks.

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[4] See for instance *A River in the Balance: The Benefits and Costs of Restoring Natural Water Flows to the Eel River*, Center for Environmental Economic Development (CEED), Summer 2002 (https://eelriver.org/wp-content/uploads/2022/10/EelEconReport2002.pdf), citations on page 12 under "Market Value of the Entire Eel River Fishery," which was $50 million/year in 2002 dollars. In today's June, 2026 dollars, according to the US Bureau of Labor Statistics Inflation Calculator (https://www.bls.gov/data/inflation_calculator.htm) estimated Eel River salmon-related fisheries economic losses are now about $93 million/year, and the median household income in Humboldt County as of 2026 is $61,160 as a definition of a "family-wage job." Dividing that figure into $93 million/year in losses = 1,504 lost family-wage jobs.

In northern California this weakest stock management limiting factor is usually the ESA-listed California Coastal Chinook (CCC) or the Southern Oregon/Northern California Coho (SONCC) from the Eel River.[5] Our ability to harvest more abundant stocks (from the Sacramento or Klamath Rivers, for example) is now always limited under weak stock management restrictions in order to protect threatened CCC or SONCC runs. Protecting those damaged Eel River runs from further decline is essential, but rebuilding Eel River salmon populations to harvestable levels is just as critical to restoring ocean fisheries. Greater abundance of Eel River Chinook, for example, could reopen fishery access to many otherwise closed (but still abundant) mixed-stock ocean fisheries.

There is ample precedent to consider the socio-economic impacts to ocean fisheries in the FERC NEPA analysis, and this impact (as well as the enormous socio-economic and ecological benefits from reversing these impacts) should be included in any legitimate costs vs. benefits analysis for Eel River dam removal. For instance, impacts of prior losses and future benefits of salmon productivity were well within the scope of NEPA analysis for the recent Klamath Hydropower Project dam removal FERC process. Long-term improvements to water quality, ecosystem recovery, and resulting renewed ocean salmon fishing opportunities must also be considered as major beneficial impacts when compared to the No Action Alternative.

FERC must give weight to the broad public interest standard associated with the dramatic increase in salmon, and steelhead that would accrue from restoring access to almost 300 stream-miles of historical habitat. Benefits will include significant increase in revenues and catch for recreational and commercial fishing and economic enhancement to local and regional restaurants and tourist destinations resulting from increased abundance of salmon and steelhead. Salmon harvest represents interstate commerce and should be protected by FERC. The American public will also benefit from appreciable improvement to habitats and populations of ESA listed species. Federal and state taxpayers have invested over a billion dollars (Pacific Coast Salmon Restoration Fund and CalFed) in improving conditions for salmon along the west coast. Completely removing both dams on the Eel River will protect and enhance this substantial public investment. To be clear, in a license surrender, the "comprehensive development/public interest standard under FPA §§ 4(e) and 10(a) do not apply; a "broad" public interest applies. Duke Energy Carolinas, LLC, 123 FERC ¶ 61,069 (2008).

Leaving the PVP dams in place has been and would continue to be very costly to river and coastal salmon-based communities. The economic importance of functioning and productive natural environments is well established. Natural Resource Economists remind us that any legitimate costs-benefits analysis (especially for salmon restoration projects) must include both the

[5] Indeed, Southern Oregon/Northern California Coho (SONCC) and other once-abundant California Coho salmon runs have been so damaged for so many years, that there is no allowed direct fishing of Coho salmon any more in California waters, and even incidental (i.e., unintended) accidental harvests of Coho in other fisheries is strictly capped, and exceeding that cap can result in major restrictions in otherwise unrelated fisheries.

costs of the *status quo* to ocean salmon fisheries and communities, as well as the benefits that would accrue to those same communities from successful salmon restoration.[6]

Any legitimate socio-economic analysis of dam removal on the Eel River must also include commercial fishing representatives, including the PFMC, in order to understand the economic losses sustained by our coastal fishing communities. The recent extent of these impacts can also be estimated from PFMC fisheries abundance and landings data by region, which has been collected and maintained since at least 1976.

The geographic scope of any legitimate FERC and NEPA socio-economic impacts analysis should also not be limited to just the physical dam sites but should also include the full Eel River watershed and impacts on the coastal communities influenced by ocean salmon fisheries supported by highly migratory Eel River salmon stocks. NEPA requires FERC to consider both direct and reasonably foreseeable indirect effects of a project. That analysis should thus extend beyond merely construction impacts to include downstream and ocean impacts of improved Eel River salmon runs, since those are predictable and reasonably foreseeable results of better water quality and restored fish passage in the Eel River. Impacts of the PVP must be considered wholistically, and restoration measures must correspondingly apply to the entire Eel River watershed through the estuary. Because Eel River origin salmon migrate far up and down the coast, the impacts of the Project on Eel River salmon habitat and water flows that salmon need to survive has far reaching socio-economic impacts all up and down the coastline.

PG&E benefited from power generation at PVP for decades and now that power generation is no longer possible and water levels at Scott Dam are lowered for seismic safety reasons, PG&E has made the very reasonable business decision to decommission the dams. The socio-economic positive economic benefits to our west coast salmon fisheries that will result are real and quantifiable, and would provide a net benefit to society as a whole through restored salmon fisheries that deliver high quality seafood to America's tables. Those benefits must be included in FERC's costs vs. benefits and impacts NEPA analysis.

PG&E also consistently underestimates the salmonid habitat currently blocked by the PVP. Throughout its LSA, PG&E refers to "50+ miles" of additional salmonid habitat that would be opened up from the removal of the PVP dams. This is a considerable underestimate, which leads to understated economic benefits from restoring salmonids to their once native habitat. A more comprehensive as well as precise analysis conducted in 2017 by Emily Jeanne Cooper (*An Estimation of Potential Salmonid Habitat Capacity in the Upper Mainstem Eel River, California*,) concluded that, using three independent models, the amount of potential spawning and rearing habitat above the impassable Scott Dam would be between 55-79 miles for Chinook salmon, and potential steelhead habitat was between 198-288 miles. Steelhead are economically important to

[6] See *A Letter from Economists to Governors of Oregon (Kitzhaber), California (Wilson), Washington (Loche) and Alaska (Knowles) and Premier of British Columbia (Clark).* (Sept. 9, 1998) (https://ifrfish.org/wp-content/uploads/2023/01/Economists-Salmon-Letter-Sept-1998-1.pdf) and *A Letter from Economists to President Bush and the Governors of Eleven Western States Regarding the Economic Importance of the West's Natural Environment.* (December 3, 2003) (https://ifrfish.org/wp-content/uploads/2023/01/Economists-Letter-Dec-2003-1.pdf).

support valuable in-river recreational and Tribal fisheries, while Chinook primarily support ocean commercial fisheries.[7] Assessing the costs vs. the benefits of PVP dam removal requires the use of the full range of available habitat modeling that is represented by that study. A copy of that study is enclosed as **Attachment H**.

SALMON RECOVERY SHOULD BE THE MAJOR MITIGATION GOAL

We have seen from the recent Klamath dam removals that salmonids return to upper watersheds volitionally, often within days of regaining open passage. There is great hope in the inherent ability of these Eel River native salmon to return to their traditional spawning grounds, once they have renewed access. However, with solely volitional return and no assistance, it may take many years to fully recover these populations which have been reduced to a fraction of their historical abundance. Sustained and more rapid recovery, however, will require many more thousands of adults returning to the spawning grounds each year in order to support fisheries. As mitigation for the damages done to our ocean salmon fisheries over the past 100 years, PG&E should be required to fund targeted, active methods of salmon reintroduction to rebuild salmon populations to harvestable numbers as soon as feasible. These methods could include adult trap-and-haul above Scott Dam before dam removal, stream side incubation of juveniles, or egg injection into gravel as examples.

Restoring healthy, sustainable, and harvestable salmonid populations to the Eel River should be the ultimate measure of success for PVP dam removal. It makes little sense to provide just enough water or habitat to prevent salmon extinction but never enough for actual recovery, thus keeping these vital stocks in a chronically depleted condition that cannot sustain fisheries. *Recovery must be the clear goal.* A comprehensive salmon reintroduction plan must therefore be part of this effort, using proven science-based tools to boost early survival and speed rebuilding toward a harvestable surplus. We support scientifically-based, measurable water quality goals to support fish populations, but true Eel River salmon recovery will only be achieved when ocean fisheries and coastal communities are thriving and once again supported by abundant Eel River salmon.

Successful dam removal plans must therefore be paired with an Eel River comprehensive salmon reintroduction program designed to achieve <u>harvestable abundances</u>, not simply the minimum levels needed for ESA delisting. Re-establishing salmon abundances at levels that support commercial harvests and food production may require the full range of science-based tools, including early life stage out planting methods such as hatch boxes and egg injection and, if necessary, hatchery or rearing infrastructure. These tools improve survival during the early phases of restoration while still supporting natural production. A complete *Salmonid Reintroduction Plan* is essential for the long-term success of dam removal and should be included by FERC as a required element of the license surrender.

In summary, salmonid habitat restoration of PVP-impacted sites both behind the dams and downstream of Scott Dam must accompany removal. Revegetation efforts, improved fish passage,

[7] Eel River Coho salmon habitat was not specifically assessed in that study.

and better habitat connectivity should all be actively managed and monitored for results and, while we are not asking that PG&E itself implement such a *Salmonid Restoration Plan*, it is reasonable that such mitigation and restoration efforts should be funded by PG&E for at least ten (10) years after dam removal. Such an Eel River salmonid habitat restoration effort would be similar to the 2200-acre salmon habitat restoration efforts included in the Klamath Dam Removal project, which also included 8 to 10 years of continued Company funding for various mitigation measures (such as for the Fall Creek Hatchery) after the year of actual dam removals.

Short-term success metrics, immediately following dam removal, should include counts of returning adult salmonids to the Eel River, as well as counts for numbers spawning above former dam sites. Monitoring for long-term success metrics, e.g., within ten (10) years post dam removal, should also include ascertaining the success of sustained production of fish populations sufficient to: (1) support managed harvest of Eel River fish and other stocks of CCC; (2) reduce management pressures on other abundant stocks in mixed-stock ocean fisheries, and; (3) advance recovery and delisting plans for CCC and SONCC populations. *Both SONCC and CCC salmon populations have existing NMFS Recovery Plans, and all PG&E's salmon habitat restoration efforts should be consistent with those existing Recovery Plans.*

In short, water quality in the Eel River after dam removals must be evaluated for its real-world ability to not only sustain salmon populations at minimum levels, but ultimately to support healthy fisheries. If initial restoration efforts do not meet minimal production goals for Chinook and Coho salmon, then additional FERC mitigation obligations, such as salmon egg out planting and gravel injection, a conservation hatchery, or trucking of smolts to the estuary to offset predation and poor water conditions created by dams or exacerbated by dam removals must then be considered.

FERC should also specifically require PG&E to consult with the PFMC regarding: (a) dam decommissioning and removal effects on salmon Essential Fish Habitat (EFH), which the Council has designated (as noted on pg. 3-3) for the Eel River, estuary, and nearshore area; (b) minimizing adverse impacts on Eel River salmon stocks whose lack of abundance affects ocean mixed-stock salmon fisheries, and; (c) maximizing the restoration of access to, and ecological carrying capacity of, salmonid spawning and rearing areas that would be affected by dam removals, both upstream and downstream of the current dam locations.

FERC SHOULD ALSO ANALYZE DAM SURRENDER AND DECOMMISSIONING WITHOUT THE NEW EEL RUSSIAN FACILITY

As a preliminary matter, there is an issue of grave project management concern to address first and foremost, and that is that PG&E in its current LSA is proposing the wrong sequencing of events. It is poor policy and raises serious legal concerns for FERC to tie PG&E's current FERC License with the newly proposed and highly uncertain NERF project over which PG&E has no ownership or control, and which is not only expensive but may take many years to achieve, *if it is ever achieved at all*.

The issue is that under the LSA PG&E is proposing, that the completed NERF construction would be made a prerequisite for License Surrender: The LSA at page 1-1 in the *Introduction* states as follows:

> "With the filing of this Surrender Application, PG&E requests the Commission include a condition in the License Surrender Order to remove all lands and Project works necessary for the NERF from the Project boundary and FERC jurisdiction immediately after the following actions are completed: (1) PG&E has completed decommissioning work at Cape Horn Dam and other Project works necessary for the NERF, **(2) the NERF has been constructed**, and (3) PG&E has filed a completion report with FERC on these actions, as described in Volume II, Section 2.1.2.1, Surrender of License." [LSA pg. 1-1 – objectionable section highlighted]

NERF is a separately proposed project, is entirely outside of PG&E's ownership or control and is not within the scope of the existing FERC hydropower license, lacks confirmed funding and defined timelines, requires multiple state and federal permits that have not yet been obtained (or even applied for), and faces significant uncertainty regarding implementation. It is poor policy and raises legal concerns for PG&E to link surrender of its FERC license to the problematical future construction of this facility. Under this proposed precondition, if NERF is never constructed, the affected lands and the FERC license itself *are effectively stuck in limbo*.

The NERF agreement that PG&E relies upon in its decommissioning plan has been incorporated by FERC as its preferred action under NEPA. The agreement states that licensed lands and facilities shall not be transferred until and unless ERPA notifies FERC that the NERF is completed and operational. **This pre-approval action unlawfully established ERPA's approval as a prerequisite for FERC to exercise federal discretion in determining when and if FERC will transfer licensed lands and facilities to ERPA.** This, in effect, gives ERPA the authority to approve a FERC action and therefore, amounts to an unlawful delegation of authority from FERC to ERPA. Only Congress can do this. This unlawful delegation also allows ERPA, should it decide that a delay in license surrender is in its interest, to avoid surrender and decommissioning and allow the project to operate under annual licenses indefinitely. For instance, acquiring necessary water rights alone could take decades to complete and trigger an adjudication of the basin. Such an action or power by ERPA would deprive PG&E of agency guaranteed under section 6 of the Federal Power Act (FPA) because it would 1) require PG&E to keep, operate and maintain the project against its will; and 2) violate the provision of section 6 that the licensee develops its decommissioning plan.

FERC maintains jurisdiction over the project through end-of-project-life decisions and implementation and will not terminate jurisdiction over the project until the surrender conditions are fulfilled—

- Portland Gen. Elec. Co., 107 FERC ¶ 61,158 (2004).

- Niagara Mohawk Power Corp., 89 FERC ¶ 61,003 (1999).

This sort of pre-requisite conditioning of license surrender to uncertain third-party actions is not only bad policy but bad economics, given that PG&E's ratepayers would continue to pay indefinitely for the costs of PG&E keeping any remnants of a Potter Valley Project that generates no power, and currently costs its ratepayers several millions of dollars every year in maintenance costs but with no economic return. Indeed, the California Public Utility Commission ratepayer watchdog agency would also likely oppose such a pre-condition, for the same reason, as unfair to the Company's ratepayers.

Additionally, it is problematic that the land on which NERF is to be built will not actually transfer under this pre-condition to NERF's owner (the ERPA entity) until "NERF has been constructed." But it would likely be impossible to finance the construction of NERF without clear prior title to the land on which it is to be constructed. This is a sequencing issue that leads to a circular reasoning dilemma.

At a minimum, this Condition (2) above should be stricken by FERC as a precondition to removing these lands from the current FERC license once actual dam removal Conditions (1) and (3) have in fact been performed. Removing Condition (2) from the equation means that PG&E can complete its responsibilities and exit the Eel River Basin once the PVP dams are removed. But retaining Condition (2) ties PG&E indefinitely to the Eel Basin and the FERC license while awaiting the full construction of a NERF project that may never happen.

The Final LSA significantly departs from the PG&E *Initial Draft Surrender Application and Conceptual Decommissioning Plan* (issued Nov. 2023) which did NOT contain any linkages or preconditions related to the NERF project. Indeed, PG&E leadership at that time asserted repeatedly and publicly that they considered that the NERF proposal was a separate project and would require its own permits and was not in any way to be a pre-condition to dam removal. In our letter to PG&E (not filed with FERC) dated December 22, 2023, commenting on that PG&E Initial Draft, PCFFA/IFR noted:

> "**Keep Dam Removal and Direction Processes Separate:** Moreover, we strongly support PG&E's stated intention to separate dam removal from the process of developing any later diversion to the Russian River, in order to avoid potentially years of delay. The current proposal for continuing any Eel River water diversions after Project removal is controversial, poorly defined, may be very costly, and is uncertain in multiple ways. It is inherently a process fraught with likely delays, and likely to be hotly debated not only in the public arena but in the Courts. Entangling PG&E's business affairs with such a dubious and complex process will not serve the interests of PG&E's ratepayer and will not resolve the company's need to eliminate its liability for a failed facility that amounts to a drain on company resources."

This concern is as true today as it was then, if not more so, as the difficulties and projected expenses of the NERF proposal continue to mount.

If there is no separation in the FERC NEPA process between the dam decommissioning process that FERC has jurisdiction over, and the NERF process which is wholly outside FERC authority, then if the NERF process fails (which could be years down the road), FERC will necessarily have to redo its NEPA analysis solely based on dam decommissioning and removal, potentially losing years of time in the process.

For these reasons, as part of its NEPA analysis FERC should include and separately analyze the Alternative reasonably foreseeable option that dam decommissioning and License Surrender might well proceed without the NERF alternative ever receiving approvals, permits or fundings that are inherently uncertain.

FERC also states that the "dams out without a NERF facility" alternative was not considered because it would not allow for compliance with existing water contracts. However, PG&E's water contracts all terminated with the license and PG&E's water rights for non-consumptive power generation would also terminate. Therefore, FERC's reasoning is flawed. Because PG&E's decommissioning plan and hence FERC's proposed action presumes the transfer of existing water rights and contacts and or the acquisition of new water rights and contracts, FERC must not adopt PG&E's decommissioning plan. FERC must not engage in state water rights issues determinations as Section 27 of the Federal Power Act (FPA) expressly prohibits the Commission from adjudicating water rights or interfering with the state laws "relating to control, appropriation, use, or distribution of water used in irrigation or for municipal or other uses, or any vested rights acquired therein." 16 U.S.C. § 821; As such, the Commission has no authority in the disposition of water rights, and it is an issue that must be adjudicated by the State of California.

Clearly, an alternative that includes full removal of all facilities without the construction of a NERF is an obvious and reasonable alternative for purposes of NEPA and must be included in this NEPA analysis.

See for instance previous 40 C.F.R. § 1502.14(c). That requirement had already been narrowed considerably by courts, which have recognized that evaluation of alternatives that the lead agency does not have the authority to require is a largely meaningless exercise. *See, e.g., City of Alexandria v. Slater*, 198 F.3d 862, 869 (D.C. Cir. 1999).

As a general legal argument, the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 4321 *et seq*.) is the foundation of modern American environmental protection in the United States and its commonwealths, territories, and possessions. The implementing regulations for NEPA require that Federal action agencies must analyze the direct and indirect environmental effects and cumulative impacts of project alternatives and connected actions.

Under § 102 (2) (c) of NEPA, a "detailed statement" of "alternatives to the proposed action" is central to the NEPA document and forms the basis for any subsequent Record of Decision. The NEPA document's analysis should be sufficiently detailed to reveal the agency's comparative evaluation of the environmental benefits, costs and risks of the proposed action and each reasonable alternative. NEPA's alternatives requirement is subject to a "rule of reason" and that necessarily governs which alternatives the agency must discuss, and the extent to which it must discuss them.[8] Given the national priority to conserve listed species established by the ESA, as indicated by the Supreme Court in *Tennessee Valley Authority v. Hill*, and NMFS's Recovery Plan, dam removal should be considered a reasonable alternative to be analyzed (437 U.S.

[8] In its document, "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations" the CEQ states: "The degree of analysis devoted to each alternative in the EIS is to be substantially similar to that devoted to the 'proposed action'." Section 1502.14 is titled "Alternatives including the proposed action" to reflect such comparable treatment. Section 1502.14(b) specifically requires "substantial treatment" in the EIS of each alternative including the proposed action. This regulation does not dictate an amount of information to be provided, but rather, prescribes a level of treatment, which may in turn require varying amounts of information, to enable a reviewer to evaluate and compare alternatives." Id.

153). Further, FERC has the authority (and statutory obligations under section 10(a)(1) of the FPA) to consider dam decommissioning without the NERF. [9, 10]

Further, under current National Environmental Policy Act (NEPA) rules and Supreme Court precedent, federal agencies may categorically eliminate reasonable alternatives that fall outside their regulatory jurisdiction. NEPA reviews are now strictly bounded to the environmental impacts of actions over which the acting federal agency has actual authority and control.[11] Because the NERF will require new permitting and water rights, outside FERC's jurisdiction, FERC must consider a dam removal alternative that does not require the NERF. FERC will not engage in state water rights disputes – Section 27 of the Federal Power Act (FPA) expressly prohibits the Commission from adjudicating water rights or interfering with the state laws "relating to control, appropriation, use, or distribution of water used in irrigation or for municipal or other uses, or any vested rights acquired therein." 16 U.S.C. § 821. As such, the Commission has no authority in the disposition of water rights, and it is an issue that must be adjudicated solely by the State of California.

We strongly recommend that the draft and Final NEPA document include the full range of alternatives identified by agencies, Tribes and non-governmental organizations (NGO) through this surrender process and be updated to reflect the full range of reasonable alternatives and issues identified – including dam removals without the NERF at all.

And because it pertains to the Proposed Action, if the NERF is analyzed then FERC's NEPA analysis must also include a full accounting of all water rights and contracts necessary for operation of the NERF because existing contracts and water rights are inadequate to cover NERF operations post-license surrender. FERC, however, although it has no jurisdiction over water rights, as noted above, if the NERF is considered under NEPA then the existence (or lack) of sufficient water rights to supply the NERF is of direct relevance to dam removal studies under NEPA.

ANALYZING WATER QUALITY IMPACTS

Minimizing Adverse Sediment Impacts on Lower River Salmonids

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[9] *See* S. Rep. No. 307, 93d Cong., 1st Sess. 3 (1973) (stating "[a]ll agencies, departments, and other instrumentalities of the Federal government are directed to cooperate in the implementation of the goals of this Act").

[10] See FERC *Policy Statement on Decommissioning*, RM-93-23-000. Further, many new licenses contain broad provisions authorizing FERC oversight, to the point of reserving authority to require project decommissioning in certain cases. *See, e.g.,* 66 F.E.R.C. ¶ 61,316 (March 18, 1994) (license order for Reusens Hydropower Project).

[11] In the Edwards Dam proceeding FERC found that fish protection devices at the project were economically infeasible and thus inconsistent with his obligation "to make licensing decisions that represent the best comprehensive use of the waterway". Accordingly, FERC ordered the project decommissioned and the structures removed. 65 F.E.R.C. at 64,083; see Federal Power Act § 10(a), 16 U.S.C. § 803(a) (1988). See also previous 40 C.F.R. § 1502.14(c). That requirement had already been narrowed considerably by courts, which have recognized that evaluation of alternatives that the lead agency does not have the authority to require is a largely meaningless exercise. *See, e.g., City of Alexandria v. Slater*, 198 F.3d 862, 869 (D.C. Cir. 1999).

Dam removal on the Eel River will, in the short-term, affect key water quality parameters such as temperature, dissolved oxygen, turbidity, and flow timing, all of which are critical to salmonids and most of which are physically and biologically interrelated. These short-term effects may include elevated sediment and turbidity levels that could harm fish and other organisms if not managed carefully. It is estimated by PG&E that Scott Dam has impounded at least 12 million cubic yards of sediment.[12] Reservoir drawdown and dam removal must be planned and executed to minimize damage to salmonid populations from sudden sediment spikes that may be fatal to salmonids at some life stages.

These water quality risks can be managed effectively. Recent dam removals on the Klamath River demonstrated that a strong, well-designed sediment management process can greatly limit sediment impacts on fish. See the *Erosion and Sediment Control Plan* developed in the Klamath Project.[13] In that dam removal case, sediment outflows were simply timed to have the least impact on migrating salmon. There is an adequate period in the summer months, between spring juvenile Chinook out-migration and fall adult Chinook return, which constitutes the ideal timing for any potentially negative sediment effects. Coho salmon, which spawn and rear mostly in tributaries and not the mainstem river as do Chinook, are generally going to be less affected by sediment surges confined to the mainstream beds for very short periods of time.

However, rivers like the Eel naturally move large amounts of sediment; it is the artificial trapping of sediment behind Scott Dam that disrupts that balance. Once the dams are removed, the Eel River's sediment system can return to its natural state, which supported healthy salmonid populations for millennia. And in the Klamath example, otherwise detrimental sediment surges (and accompanying low dissolved oxygen levels) lasted only for a handful of days or hours because they were specifically timed to either not disturb in-river juveniles (which were not actually present during those windows), or to flush out the sediment as fast as possible by taking advantage of storm surges.

But all these dam removal water quality impacts will be short-term. Short-term disturbances are an acceptable tradeoff for long-term habitat recovery. This is true of state water quality laws as well as FERC policy. The California North Coast Regional Water Quality Control Board's Restoration Policy (2015) states this principle explicitly:

> "Boards may permit or certify restoration projects that result in significant and sometimes unavoidable impacts (including temporary exceedances of water quality objectives) if it is shown that the project will result in long-term protection of beneficial uses and water quality."

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[12] See LSA pg. 5-6, Sec. 5.2.1.1.1.

[13] Available as Exhibit C to the Klamath River Renewal Corporation 2021 *Amended Application for License Surrender*, at: https://klamathrenewal.org/wp-content/uploads/2021/02/EX-C-Erosion-and-Sediment-Control-Plan-Feb2021.pdf.

The California State Water Quality Control Board is currently still considering a Potter Valley Project 401 Certification permit, including appropriate water quality protection provisions, with this long-term benefits policy in mind.

PG&E in its LSA also notes (Sec. 6.2.2 Water Quality; pgs. 6-1 to 6-3) that:

> "While the resulting condition and restoration of the Eel River compared to unimpaired conditions would have an unavoidable adverse effect on water temperature [and other water quality parameters], the change to natural conditions, overall, is considered to be a positive effect on the Eel River. In addition, the removal of the dams would improve access for anadromous fish and resident fish to 50+ mi. of spawning, thermal refugia, and rearing habitat above Scott Dam."

We note that, as clearly demonstrated with the recent Klamath Dam removals, it is far less impactful on downriver ESA-listed salmonids to have one, short-time period of very high sediment loads that can be timed to avoid key migration windows, than to produce several (even though individually smaller) sediment spikes spread over a long period of time, thus doing more lasting damage to in-river fish during several life stages or even over several years.

Fortunately, anticipated sediment releases are largely under human control, and can be timed to maximize sediment flushing through the system at times when fish impacts would be minimal. Salmon biologists can identify the best timing to avoid or mitigate sediment surge impacts on any particular life-stage of these migratory species. PG&E should be required to consult with both the California Department of Fish & Wildlife (CDFW), and NMFS on how best to protect salmon in the Eel River through timing of sediment flushing and recovery periods.

We therefore support the Rapid Dam Removal process (see LSA pg. 5-6) for the removal of Scott Dam as described in the Draft LSA *over no more than two years* in order to minimize sediment impacts on salmonids during various life-stages, with several provisos: (a) a *Sediment Control Plan* must be developed to minimize the impacts of released sediment loads from Scott Dam such as through timing of sediment releases so as to minimize the time and degree of impact of excessive sediment loads on salmonids within the river system at those times; (b) timing of maximum sediment releases to correspond with wet-season conditions during which times the Eel River naturally carries as much sediment as possible harmlessly out to the estuary; (c) PG&E must implement sediment control measures (such as speedy reseeding and replanting of emerged mudflats) designed to quickly stabilize the new river boundaries and thus to minimize the later release of more sediment downstream; and (d) PG&E must also contribute to the restoration of downstream salmonid-supporting riverine ecosystems in ways that will improve salmonid habitat carrying capacity and production as compared to the current *status quo*.

Attached with these comments, for reference, is the July, 2021, Technical Memorandum titled *Analyses of Fine Sediment Erosion Effects on Aquatic Species Following the Proposed Dam Removal, Eel River, California*, prepared by Stillwater Sciences. (See **Attachment C**). That Report contains numerous good suggestions for how to minimize dam removal-caused sediment impacts on salmonids.

We also support PG&E's elimination and rejection of the "Phased Scott Dam Removal Alternative" as noted by the Applicant as a potential alternative. That alternative, i.e., removing Scott Dam over three years or more in phased deconstruction would tend to spread out unavoidable sediments impacts over a three-year+ period, which would be unacceptable for salmonids with a three-year life-cycle. The reasons PG&E listed for eliminating this alternative (see LSA pg. 5-11) were as follows:

> "Under this alternative, sediment would be released from the dam during more than one year, as would occur under the Proposed Action. This would result in increased turbidity and suspended sediment and adversely impact water quality parameters that would affect environmental and cultural resources below Scott Dam over a longer duration compared to the Proposed Action. As this alternative would not eliminate the potential for unavoidable adverse effects to environmental resources compared to the Proposed Action and would not meet PG&E's interest to remove the dams as quickly as possible, it has been eliminated from further consideration."

Rivers typically move great volumes of sediment through natural erosion, and the Eel River was originally the transport corridor for very high natural sediment loads. The natural and total amounts of sediment loading of a pre-dam Eel River should be the baseline for considering impacts of additional sediment loads from dam removals. At least one 10-year detailed sediment transportation study concluded that the Eel River basin is naturally very sediment rich, with an estimated 16 million tons of sediment transported annually by the river. (Brown and Ritter (1971)

> "The Eel River draining the Coast Range of northwestern California has the highest recorded average suspended sediment yield per drainage area of any river of its size or larger unaffected by volcanic eruptions or active glaciers in the conterminous United States (1,720 t/km^{2}yr from 9,390 km^2; (Brown and Ritter (1971))"

Whether a sediment surge exceeds the range of normal (especially wet year) sediment loads must be determined by comparison to past sediment load history, which varies considerably river-by-river. The Brown and Ritter (1971), *Sediment Transport and Turbidity in the Eel River Basin, California* key sediment transport study discussing the history of sediment transport in the Eel River under various rainfall conditions is enclosed with these comments as ATTACHMENT 1, sub-Attachment F. The magnitude of sediment surge impacts on salmonids should be assessed against this average sediment loading phenomenon specific to the Eel River.

PG&E's and FERC's engineering and biologist teams should also reference the Klamath Dam Removal Project's "Sediment and Erosion Control Plan" which is available online as Exhibit C – *Erosion & Sediment Control Plan* and Exhibit L – *Sediment Deposit Remediation Plan*, all in the Klamath River Renewal Corporation's (KRRC) Nov. 2020 Definite Plan and Feb. 2021 Supplemental Plans available online at:

https://klamathrenewal.org/definite-decommissioning-plan-overview/

The Klamath Project Definite Plan is an excellent model for other, much smaller dam removal projects like this one.

OTHER RESTORATION ISSUES TO ANALYZE UNDER NEPA

Meeting Both Upstream and Downstream Restoration Obligations: In the Application's *Introduction* [LSA pg. 1-1] there is a list of "Proposed Actions under the Application for Surrender of License" that includes the following:

> "Restoration of the remnant inundation zone of Lake Pillsbury reservoir and Van Arsdale Reservoir, including adjacent riparian, wetlands, and upland areas affected by the decommissioning."

This restoration goal is incomplete as it omits all downriver impacts in areas below the Scott Dam that are nonetheless affected by the decommissioning. Those proposed actions should therefore read as follows:

> "Restoration of the remnant inundation zone of Lake Pillsbury reservoir and Van Arsdale Reservoir, including adjacent riparian, wetlands, and upland **and downriver** areas affected by the decommissioning." [inserted language in bold]

Because sediments will be moving downriver (not upriver) these downriver impacts of decommissioning are also vitally important to identify, mitigate, or avoid.

Scientific Peer Review Process (See LSA pg. 5-7): PG&E should also develop its Restoration Plans specifically with the goal of re-establishing ecologically effective salmonid spawning and rearing habitat through a scientific peer-reviewed process similar to that used in the Klamath Dam Removal Project (see FERC Project Dockets Nos. P-2082 and P-14803). This recent Klamath experience was an excellent model for peer-review of the science behind restoration planning. Such a scientific peer-review inevitably provides better science to guide river restoration efforts and to make those efforts far more effective.

Additions to Table 5-2 (LSA pg. 5-8): To Scott Dam and Cape Horn Dam "restoration goals" should also add (as it is for Lake Pillsbury reservoir and Van Arsdale Reservoir), the specific goal of:

> "Removal of fish passage barriers created by dam removal in the Eel River, including upstream of the former dam and at downstream tributary confluences, and reestablishment of known critical riffles."

This goal was conspicuously but without explanation not included in the statement for the Scott Dam and Cape Horn Dams goals by location, but should be explicitly listed as part of all those restoration efforts in all locations. Ensuring complete, functional passage at all former barrier sites is also a foundational requirement for any comprehensive salmon reintroduction program.

Pikeminnow Suppression: In LSA section 6.2.*3 Fish and Aquatic Resources,* it was noted that a short-term unavoidable adverse effect to fish and aquatic resources from the release of non-native species, including Sacramento pikeminnow (*Ptychocheilus grandis*) and largemouth bass (*Micropterus salmoides*), from Lake Pillsbury reservoir into the Eel River during winter spill events following the lowering of Scott Dam and during the release of storage and sediment from Scott Dam (Phases 1 and 2a). [LSA pg. 6-2]

There are a number of potential mitigation measures that have been or could be taken to reduce the population of predatory pikeminnow entering the Eel River from Lake Pillsbury, some of which have been developed by the Wiyot Tribe and are described in the LSA on PDF page 465 [LSA pg.2.2.3.3-78], including reference to a PG&E pikeminnow monitoring and suppression program according to its *Pikeminnow Adaptive Management and Suppression Operation Plan* in 2019.

Sacramento pikeminnow are a warm-water fish that thrive in warm-water lakes like Lake Pillsbury reservoir, but apparently do not do well against competition from salmonids in the salmonids' normal cold-water habitat. *The pikeminnow invasive species problem in Lake Pillsbury was created by, and is a direct result of, the artificially warm-water conditions of Lake Pillsbury in which this warm-water fish survives and has multiplied.* Part of PG&E's responsibility to mitigate the harms its Lake Pillsbury reservoir has inflicted on local people, fish populations and fisheries is to take active steps to eradicate pikeminnow in Lake Pillsbury reservoir, or at the least to minimize and mitigate for their presence in the Eel River after dam removals. But meaningful pikeminnow suppression measures are almost completely missing in the LSA. FERC should at the minimum require PG&E to redraft, revise, update, and fund its *Pikeminnow Adaptive Management and Suppression Operation Plan* to FERC's current conditions and timelines as part of its Project decommissioning and Scott Dam removal and mitigation operations, and to fund implementation of that Plan for a period of at least ten (10) years after physical dam removals.

A similar invasive species predation prevention *Suppression Plan* should also be developed for largemouth bass, with similar funding conditions.

COMMENTS ON THE NEW EEL-RUSSIAN FACILITY (NERF)

For more than 110 years, large volumes of Eel River water have been taken (to the great detriment of the Eel River's once abundant salmon fisheries) from the hydrological top of the Eel River watershed, where it was then forced through a tunnel at Cape Horn Dam to be used for hydropower production at the FERC-licensed Potter Valley Hydropower Project, now owned and operated by PG&E. None of this was planned decades ago with any thought or analysis of likely impacts on Eel River fish populations in mind.

This diversion, allowed by a water right dated 1905 for up to 340 cfs in flows (= 246,148 acre-feet/year), **from 1922 to 2006 took an average of about 150,000 acre-feet/year of water out of the Eel River during those years.**[14] This has had devastating impacts on Eel River-based salmon fisheries. However, once this Eel River water was through the turbines, and had been delivered to the Russian River, it had in the past always been classed as "abandoned water," and was then used to gravity feed Lake Mendocino Reservoir, which in turn provides multiple water

[14] Though this original amount has been greatly reduced today in accordance with ESA requirements, see Attachment I.

diversions to downriver (mostly agricultural) water users in the Russian River watershed. This is how Russian River water users have become dependent on water they were never originally entitled to, but effectively just confiscated for 110 years from a hydrologically separate river basin, to the severe detriment of that Eel River's native salmon runs.

The primary argument for retention of the Eel River dams is access Eel River water by Russian River and Potter Valley water users. Russian River and Potter Valley farms never paid for that water, but it was never without a cost. Indeed, the Eel River salmon fisheries and those who rely on them have paid – and continue to pay – a very steep price in lost coastal salmon fisheries economics benefits and the loss of more than 1,500 salmon-supported jobs (see footnote 4).

The water flows now in debate are only relatively small in volume as compared to past history of massive diversions. As shown in **Attachment I**, diversions from the Eel River have been restricted by NMFS since 2006 under the ESA. The PG&E FERC license has been amended with these updated diversion restrictions in order to meet the most basic water survival requirements of the several ESA-protected salmonid species in the Eel River.

Changes in PVP Diversions of Eel River Water over Time

Time Spans	Annual PVP Diversions (acre-ft.)
1922 – 2006 Average	150,000
2007 – 2020 Average	64,000
2021 – 2022 Average	40,000

In other words, the Eel River diversions have already been reduced by about 74% from their historic baseline of 1922 through 2006 just in order to meet the minimum and most basic water needs of the three ESA-listed salmonid species in the Eel River that NMFS deemed necessary just to prevent their extinction.

There has been some attempt to demonstrate on the basis of hydrological science that there may be some "surplus water" in some (i.e., very wet) years above and beyond the optimum (not minimum) flows that salmonids need in order to eventually recover a significant portion of their original abundance. *That science, however, is still not publicly available, nor has it been peer-reviewed.* Nor is it clear that, given likely reductions in regional rainfall and increases in evapotranspiration projected under multiple climate change scenarios, that any such surplus water today (if it exists at all) would still be available over the projected 50-year life expectancy of the NERF project. Additionally, NERF has not been shown to be a cost-effective way of delivering that likely minimal volume of water as compared to multiple (and likely cheaper) alternatives such as aggressive water conservation, aquifer groundwater recharge and storage, and/or the raising of Coyote Dam so that Lake Mendocino can actually increase its limited storage capacity to what it was originally designed for.[15]

[15] It is likely that Coyote Dam will have to be raised in any event, as otherwise any "surplus water" from the NERF project may be unstorable in wet years, again limiting its usefulness.

All these unknowns make any realistic NEPA analysis of the NERF project highly uncertain to impossible. This uncertainty also makes financing what could be a very expensive infrastructure construction project in order to obtain what is likely to be a small and decreasing amount of water problematic at best. Given these many controversies over NERF, it will likely be challenged in Court. All these uncertainties associated with NERF are other good reasons for FERC not requiring nor allowing NERF construction to be a pre-requisite for any other actions (including dam decommissioning and removals) by PG&E under the current FERC license.

To conclude, we ask the Commission to approve license surrender without tying dam removal to the uncertain and non-PG&E NERF proposal, and to require restoration, mitigation, and reintroduction measures that directly support the recovery of Eel River salmon to levels that can sustain harvest. The FERC NEPA analysis should also be restructured accordingly, including analyzing the impacts of dam removals without the NERF spinoff project, or its analysis could become more or less meaningless as well as misleading by not analyzing a situation quite likely to actually take place, i.e., no NERF approvals.

FERC has both the authority and responsibility to ensure that this license surrender and dam decommissioning project results in real restoration of the Eel River system, including water quality protections, sediment management, reintroduction planning, and mitigation for the long-term harm this project has imposed on valuable ocean salmon fisheries. Removing the dams, restoring salmon access to their historic habitat, suppressing invasive predators, and implementing a robust salmon recovery and reintroduction program are essential outcomes of this process. With the right FERC conditions in place, this license surrender can finally put the Eel River and the coastal communities that depend on it back on a path to recovery. This is an investment in time and energy that FERC should by all means make in its NEPA analysis, if it is to remain relevant.

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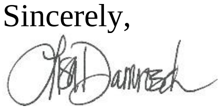
Sincerely,



Lisa Damrosch
Executive Director
PCFFA-IFR

ATTACHMENTS

Attachment A — Letter April 12, 2023, from CA Dept. of Water Resources re: Scott Dam.

Attachment B – FERC Dam Seismic Safety Inspection Report (Sept 1, 2022).

Attachment C – July, 2021, Technical Memorandum titled *Analyses of Fine Sediment Erosion Effects on Aquatic Species Following the Proposed Dam Removal, Eel River, California*, prepared by Stillwater Sciences.

Attachment D – Feb. 21, 2019, *Significant Dam Safety (and Water System Reliability) Issues at Potter Valley Project's Scott Dam Have Yet to be Addressed*, By Scott Greacen, Friends of the Eel River Conservation Director.

Attachment E– Letter to FERC from Friends of the Eel River (June 30, 2023) related to seismic safety and other concerns about Scott Dam and Lake Pillsbury.

Attachment F – Brown and Ritter (1971), *Sediment Transport and Turbidity in the Eel River Basin, California.*

Attachment G – *Copies of letters from Rep. Mike Thompson to California Dept. of Forestry and Fire Protection and U.S. Forest Service re: Fire Risk Management Plans (2023).*

Attachment H – *An Estimation of Potential Salmonid Habitat Capacity in the Upper Mainstem Eel River, California*, a Masters Thesis by Emily Jeanne Cooper (May, 2017).

Attachment I – Chart: *Reduced Potter Valley Water Diversions (1922-2022).*

Attachment A – Letter April 12, 2023, from CA Dept. of Water Resources re: Scott Dam

STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY **GAVIN NEWSOM,** *Governor*

DEPARTMENT OF WATER RESOURCES
P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

April 12, 2023

Mr. Jan Nimick, Vice President
Power Generation
Pacific Gas and Electric Company
Mail Code N11E
Post Office Box 770000
San Francisco, California 94177-0001

Attention: Mr. David Ritzman
Chief Dam Safety Engineer

Scott Dam, No. 97-101
Lake County

Dear Mr. Nimick:

This is in response to Mr. David Ritzman's letter dated March 17, 2023, to the Division of Safety of Dams (DSOD) that enclosed a technical memorandum titled *Scott Dam Simplified 2-D Stability Evaluation* prepared by Gannett Fleming, Inc. (Gannett Fleming) and dated March 14, 2023. This study is part of Pacific Gas and Electric Company's (PG&E) ongoing reevaluation of the dam that was initiated in response to DSOD's letter dated January 22, 2021, to address potential dam safety concerns.

Gannett Fleming's simplified seismic stability analysis of the dam suggests that the dam may become structurally unstable for seismic loads estimated at a return period of 850 years when the reservoir is at Elevation 1,910.00. Based on the analysis results and as an interim risk reduction measure, PG&E intends to leave the spillway gates open year-round under a 10-foot reservoir restriction that results in the reservoir being maintained continually at Elevation 1,900.00. At this reservoir elevation, Gannett Fleming's analysis showed an improvement of the dam's performance under a major earthquake event.

Based on dam safety, DSOD concurs with PG&E's proposed 10-foot reservoir restriction as an interim risk reduction measure. Therefore, DSOD is restricting the year-round operation of the reservoir of Scott Dam to Elevation 1900.00, the spillway crest, which is 24.58 feet below the dam crest. This reservoir restriction may be revisited as conditions warrant and will remain in effect until PG&E receives DSOD's written approval authorizing a different level of reservoir storage.

Additionally, as discussed with Mr. David Ritzman on March 16, 2023, based on the seismic deficiency identified by Gannett Fleming, DSOD's condition assessment rating for the dam has been changed from "Satisfactory" to "Fair." Definitions of condition assessment ratings are available on our website at www.water.ca.gov/damsafety.

DSOD appreciates your continued diligence and looks forward to working with PG&E on the ongoing reevaluation of Scott Dam. If you have any questions or need additional information, you may contact Project Engineer Ian Maki at (916) 820-7795 or Re-evaluation Engineering Branch Manager Ariya Balakrishnan at (916) 607-5439.

Sincerely,

Sharon K. Tapia

Sharon K. Tapia, P.E.
Division Manager
Division of Safety of Dams

cc: Mr. Frank L. Blackett, P.E.
Regional Engineer
Federal Energy Regulatory Commission
Division of Dam Safety and Inspections
San Francisco Regional Office
100 First Street, Suite 2300
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Mr. Kyle Muteff, Staff Counsel
Office of the General Counsel
California Department of Water Resources
Kyle.Muteff@water.ca.gov

Mr. Casey Meredith, Program Manager I
Dam Safety Planning Division
California Governor's Office of Emergency Services
3650 Schriever Avenue
Mather, California 95655

Attachment B – FERC Dam Seismic Safety Inspection Report (Sept 1, 2022)

DAM SAFETY INSPECTION REPORT
FEDERAL ENERGY REGULATORY COMMISSION
OFFICE OF ENERGY PROJECTS
DIVISION OF DAM SAFETY AND INSPECTIONS
San Francisco Regional Office

Project Name:	Potter Valley		**Project No.**	00077-CA
Licensee:	Pacific Gas & Electric Company (PG&E)			
Location:	Eel River & Russian River	Mendocino & Lake		CA
	(River or Waterway)	(County)		(State)

Dam No.	Dam Name	NATDAM#	Hazard Potential	FERC Internal Performance Measure
00077-01-01	Cape Horn	CA00399	High	Under Remediation
	HW: 1,490.73 ft	**TW:** N/A	**Flow:** 21.98 cfs	
00077-02-01	Scott	CA00398	High	Under Investigation
	HW: 1,808.22 ft	**TW:** N/A	**Flow:** 84.84 cfs	

Report Period:	From 07/30/2019	to 09/01/2022		
Inspected by:	Ryan Tom		**Date:**	09/01/2022
Accompanied By:	PG&E – TK Vaught, Matthew Colwell, Chris Tomes, Jackie Pope, Andrew Garcia			
Weather:	Sunny, 100s High			

Attachment C – July, 2021, Technical Memorandum titled *Analyses of Fine Sediment Erosion Effects on Aquatic Species Following the Proposed Dam Removal, Eel River, California*, prepared by Stillwater Sciences

TECHNICAL MEMORANDUM ◦ JULY 2021

Analyses of Fine Sediment Erosion Effects on Aquatic Species Following the Proposed Scott Dam Removal, Eel River, California

PREPARED FOR

Two-Basin Solution Partners
California Trout
Humboldt County
Mendocino County Inland Water and Power Commission
Round Valley Indian Tribes
Sonoma County Water Agency

PREPARED BY

Stillwater Sciences
850 G Street, Suite K
Arcata, CA 95521

Suggested citation:
Stillwater Sciences. 2021. Analyses of Fine Sediment Erosion Effects on Aquatic Species Following the Proposed Scott Dam Removal, Eel River, California. Prepared for Two-Basin Solution Partners. July.

Cover photos: Scott Dam, Eel River, California (top left); turbid high flows over Cape Horn Dam February 14, 2019 (daily average flow 13,400 cfs, peak flow 16,500 cfs, photo courtesy of CDFW) (top right); Eel River downstream of Scott Dam (bottom)

Table of Contents

Tables

Figures

1 INTRODUCTION

1.1 Background

The Potter Valley Project (Project) is an inter-basin hydroelectric project located 15 miles northeast of Ukiah that annually diverts approximately 60,000 acre-feet (ac-ft) of water from the upper Eel River to the upper Russian River. Project features include Scott Dam, a 130-foot-tall concrete gravity dam that impounds Lake Pillsbury, a 2,300-acre storage reservoir; Cape Horn Dam that impounds the 106-acre Van Arsdale Reservoir; and a diversion system that diverts water from the Eel River at Van Arsdale Intake to the Project's powerhouse located in the headwaters of the Russian River watershed. The Project began diverting water in 1908 when Cape Horn Dam and the Van Arsdale Diversion were built. Scott Dam was built in 1922 approximately 12 miles upstream of Cape Horn Dam at river mile (RM) 168.5.

Pacific Gas and Electric Company's (PG&E's) Project license expires in 2022. PG&E filed a Pre-Application Document (PAD) and Notice of Intent (NOI) to formally initiate the relicensing process for the Project in April 2017. PG&E withdrew its NOI and PAD and discontinued its efforts to relicense the Project in January 2019, and in March 2019, the Federal Energy Regulatory Commission (FERC) issued a notice soliciting interested potential applicants other than PG&E to file an NOI and PAD. In May 2019, the Two-Basin Solution Partners (Partners) entered into a Planning Agreement to explore pathways to obtain a new license for the Project. In June 2019, the Partners filed a NOI with FERC stating the intent to undertake a Feasibility Study of a potential licensing proposal for the Project. The Feasibility Study examined the practicability of potential actions in meeting agreed upon common goals and to inform the Partners of cost and performance tradeoffs associated with those actions. Phase 1 of the Feasibility Study, completed and filed with FERC in May 2020, included the following key elements: (1) a Regional Entity that will apply for the new license and assume the new license if issued, (2) a Project Plan, (3) a Fisheries Restoration Plan, (4) an Application Study Plan, and (5) a Financial Plan. Phase 2 of the Feasibility Study was initiated in April 2020 with grant funding from the California Department of Fish and Wildlife to supplement technical analyses conducted during Phase 1, and to conduct new technical analyses.

This Technical Memorandum was prepared for the Partners by the Consultant Team to supplement technical analyses performed during Phase 1 of the Feasibility Study. The information provided in this document is a continuation of work along a path starting with preliminary analyses of feasibility, transitioning towards more refined analyses of a focused project plan and implementation of the best possible project that meets programmatic goals in a cost-effective manner. This Technical Memorandum is informational, is not binding of any of the Partners, and will not be filed with FERC as the basis for compliance under the Integrated License Process or other FERC regulations. While this Technical Memorandum contributes to the information available to the Partners, the Partners have not solely relied on this document for justification for any decision they have made or will make regarding FERC filings or cooperative agreements. More detailed environmental and engineering studies will be conducted during implementation of the FERC study and outside of the FERC process. Accordingly, this Technical Memorandum reflects a step that will be expanded and built upon through additional studies, analysis, synthesis, and ultimately decisions by the Partners on proceeding with a Project Plan.

Figure 1. Potter Valley Project vicinity.

1.2 Purpose

The potential removal of Scott Dam is being studied because it is considered the most effective and reliable approach to provide successful upstream and downstream fish passage and restore anadromous fish access to the 289-square-mile watershed upstream of the dam. However, removal of Scott Dam would result in the release of substantial coarse and fine sediment that has accumulated in the reservoir since its construction, potentially harming the same fish populations anticipated to benefit from restored fish passage. Elevated levels of suspended sediment have been shown to have adverse effects on anadromous salmonids, with greater negative effects associated with higher suspended sediment concentrations (SSCs). This technical memorandum describes an assessment of potential effects of fine sediment release into the Eel River downstream of Scott Dam following dam removal on steelhead (*Oncorhynchus mykiss*), Chinook Salmon (*O. tshawytscha*), and Coho Salmon *(O. kisutch)* populations. This general assessment is based on the order-of-magnitude analysis for the erosion of fine sediment and potential suspended sediment concentrations following the proposed removal of Scott Dam under rapid and phased removal alternatives (Stillwater Sciences 2021).

1.3 Sediment Storage

Scott Dam impounds Lake Pillsbury with a storage capacity of 94,400 acre-feet (acre-ft) at the top of the spillway (i.e., 1,821.12 ft elevation[1]) upon its completion in 1921 (PG&E 2017). By 2015, the storage capacity of Lake Pillsbury was reduced to 76,876 acre-ft at the same pool level (PG&E 2017) due to sedimentation. Although these storage capacities imply a minimum[2] 2015 Lake Pillsbury sediment deposition volume of 17,524 acre-ft (i.e., the difference between 94,400 and 76,876 acre-ft, or 28.3 million cubic yards [CY]), the most recent, more refined analyses that combine Digital Elevation Model (DEM) data and thalweg survey data estimate a 2015 sediment deposition volume of 13,016 acre-ft (21 million CY; Stillwater Sciences et al. 2021a).

1.4 Dam Removal

Several preliminary Scott Dam removal alternatives have been developed (e.g., McMillen Jacobs Associates 2018, McBain Associates and Princeton Hydro 2019), some of which would manage the reservoir sediment deposit in such a way that minimal erosion of fine sediment would occur (i.e., mechanically remove or stabilize most sediment prior to or during removal). This technical memorandum focuses on two of the most promising dam removal alternatives identified by Stillwater Sciences (2021) and McBain Associates and Princeton Hydro (2019) that would release fine sediment downstream through natural erosion, including: (1) a four-stage dam removal alternative ("four-stage alternative") described in McBain Associates and Princeton Hydro (2019), and (2) a rapid vertical notching dam removal alternative ("vertical notching alternative") proposed in Stillwater Sciences (2021); both of these alternatives are described in more detail in Stillwater Sciences (2021). A third rapid removal alternative would be blasting open tunnels near the base of the dam prior to a target high flow event ("tunneling alternative") with identical fine sediment transport processes compared with the vertical notching alternative (Stillwater Sciences

[1] NAVD88 datum is used throughout the report unless labeled otherwise. At Scott Dam site, add 78.78 ft to NAVD88 elevation to convert to Pacific Gas and Electric Company (PG&E) elevation. Other relevant documents may also have used NVGD29 elevations. Subtract 81.7 ft from PG&E elevations or subtract 2.92 ft from NAVD88 elevations to obtain NVGD29 elevations.

[2] Sediment accumulation calculated by differencing storage values at different times is generally less than the actual amount of sediment accumulation because sediment deposition upstream of the storage area, which is generally a small fraction of the overall sediment deposition, is not accounted for.

2021), and as such, its impact to aquatic resources would be identical to that of vertical notching alternative.

1.5 Objectives

This assessment is intended to describe the range of potential effects on focal species of releasing fine sediments considering two dam removal alternatives. The species selected for analysis include anadromous salmonids in the Eel River watershed that could be impacted from fine sediment release. These species were selected because models to assess the severity of effects of fine sediment on these species have been developed and are available. The life history timing of these species in the Eel River will be described and used to identify species and life stages that are particularly vulnerable to potential impacts of fine sediment release following dam removal. The analysis results will be used to identify critical uncertainties and opportunities to reduce potential impacts.

2 LIFE HISTORY AND DISTRIBUTION OF FOCAL SPECIES IN THE EEL RIVER

Describing the life history timing and seasonal distribution of focal fish species in the Eel River is critical for assessing the potential adverse biological effects of fine sediments related to dam removal alternatives. Life history timing, distribution, and other information relevant to assessing impacts of fine sediment on winter- and summer-run steelhead, fall-run Chinook Salmon, and Coho Salmon are provided in the sections that follow. Generalized life history timing for each species in the Eel River watershed is described, with a focus on known timing of use and seasonal distribution in the Eel River from Scott Dam downstream to the Middle Fork Eel River (Upper Eel River), where potential impacts of fine sediment release to the mainstem Eel River are expected to be greatest. The species life history timing reported here is consistent with Stillwater Sciences et al. (2021b).

2.1 Steelhead

Steelhead in the Eel River watershed can be broadly divided into two life history types or runs based on migration timing: the winter-run and summer-run (Moyle et al. 2017). Winter-run steelhead, which are more abundant and widely distributed across the Eel River watershed than summer-run, enter freshwater as sexually mature adults from late fall through spring and spawn shortly thereafter (Busby et al. 1996, VTN 1982, Kajtaniak and Gruver 2020). Summer-run steelhead enter freshwater as sexually mature adults in spring and early summer and hold until spawning the following winter or spring (Roelofs 1983, Barnhart 1991, Moyle et al. 2017). In the Eel River watershed, holding and spawning summer-run steelhead are currently restricted primarily to cooler, upper reaches of the Middle Fork Eel River and Van Duzen River (Kannry et al. 2020). However, recent genetic evidence indicates that summer-run steelhead historically occurred in reaches upstream of Lake Pillsbury (Kannry et al. 2020), where there is thermally suitable holding habitat (Cooper et al. 2020, Fitzgerald et al. 2020). Although not recently reported in the Upper Eel River, some adult summer-run steelhead were documented in 1985 during trapping at the Van Arsdale Fisheries Station (VAFS) and were also anecdotally reported upstream of Cape Horn Dam around that time (SEC 1998, NMFS 2016). Based on the current low abundance in the Upper Eel River, impacts of suspended sediment following potential dam removal are unlikely to affect summer-run steelhead; therefore, this assessment is focused on winter-run steelhead.

2.1.1 Winter-run Steelhead

The generalized life history timing for each life stage of winter-run steelhead in the Eel River watershed is presented in Table 1. Adult winter-run steelhead enter freshwater as sexually mature adults from November through April, typically moving upstream during or following increases in streamflow associated with winter rainfall (Trush 1991, Busby et al. 1996, Kajtaniak and Gruver 2020). The first adult steelhead typically arrive at VAFS at Cape Horn Dam between mid-November and mid-December, depending in part on stream flows (VTN 1982, SEC 1998, CDFW unpub. data). Larger numbers of adults do not typically arrive until early January, with peak counts occurring in February and March. In most years, the last individuals are counted at VAFS between early April and early May (SEC 1998, CDFW unpub. data).

Winter-run steelhead can spawn between November and May, with peak spawning in the Upper Eel River typically occurring from January through March (VTN 1982, Busby et al. 1996, Table 1). Limited surveys conducted by VTN (1982) documented adult steelhead and redds in several tributaries between Scott Dam and Outlet Creek, with more spawning found in larger tributaries such as Soda Creek and Tomki Creek. Winter-run steelhead presumably spawn in all streams in the Upper Eel River with access and suitable spawning habitat. VTN (1982) did not document mainstem spawning due to turbid conditions but suggested that considerable numbers of steelhead spawn in the mainstem Eel River upstream of Cape Horn Dam based on the number of adults counted at VAFS versus those observed spawning in tributaries. Relative use of tributaries versus mainstem reaches for spawning is expected to be partly dictated by streamflow conditions, where higher flows would promote greater tributary use (Moyle et al. 2017).

Unlike salmon, not all steelhead die after spawning. Some individuals emigrate back to the ocean and spawn again in subsequent years (Moyle et al. 2017). In the upper South Fork Eel River, Trush (1991) found that individual steelhead typically entered spawning tributaries, spawned, and moved back downstream within a 1–2-week period. These outmigrating adults, or "kelts", are thought to migrate to the ocean relatively rapidly after spawning, typically no later than May (Teo et al. 2013, Moyle et al. 2017). Based on this timing, kelts may be present in the mainstem Upper Eel River from February through May.

Steelhead eggs incubate in redds for 3–14 weeks after spawning, depending on water temperatures (Shapovalov and Taft 1954, Barnhart 1991). After hatching, alevins remain in the gravel for an additional 2–5 weeks while absorbing their yolk sacs, and then emerge in spring or early summer (Barnhart 1991). After emergence, steelhead fry move to shallow-water, low-velocity habitats, such as stream margins and off-channel habitats (Hartman 1965, Fontaine 1988). As fry grow and improve their swimming abilities throughout the summer and fall, they increasingly show a preference for higher water velocity and deeper mid-channel areas with cover such as cobble and boulders (Hartman 1965, Everest and Chapman 1972, Fontaine 1988). Juvenile steelhead in northern California typically rear in freshwater for two years before migrating to the ocean (Hopelain 1998, Moyle et al. 2017). In the Upper Eel River, individuals rearing in tributaries generally rear for two or three years before outmigrating to the ocean, whereas individuals rearing in the mainstem Eel River between Scott Dam and Cape Horn Dam often migrate after a single year due to superior growth conditions (SEC 1998). Therefore, juvenile steelhead are present in portions of the mainstem Upper Eel River and its spawning tributaries throughout the entire year where streamflow and water temperature allow (VTN 1982, SEC 1998, PG&E 2018). Relatively high densities of juvenile steelhead are typically present during summer in the reach between Scott Dam and Cape Horn Dam (SEC 1998, PG&E 2020). In general, due to high water temperatures and large numbers of predatory Sacramento Pikeminnow (*Ptychocheilus grandis*), mainstem Upper Eel River summer densities of juvenile steelhead decline substantially downstream of Cape Horn Dam, with very few or no individuals present at sites downstream of Thomas Creek (approximately 8 RM downstream of Cape Horn Dam) (PG&E 2018). Winter rearing densities of juvenile steelhead in the mainstem Upper Eel River are unknown, but juveniles are presumably present throughout the entire mainstem Upper Eel River as water temperatures become more suitable in the fall and through the winter.

Salmonid smolt outmigrant trapping data from the Upper Eel River indicate that steelhead smolt outmigration generally occurs from March through mid-June, and peaks in April and May (VTN 1982, Beak 1986, SEC 1998). Historical sampling indicates that juvenile steelhead were abundant in the Eel River estuary from mid-May through mid-July (Murphy and DeWitt 1951, as cited in SEC 1998), suggesting they spend time in the estuary prior to entering the ocean.

Table 1. Generalized life history timing of winter-run steelhead in the Eel River watershed.

Life stage	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult migration[1,2,3]	Peak	Peak	Peak	Span	Span						Span (late)	Span
Spawning[1,3,4]	Peak	Peak	Peak	Span	Span							Span
Adult outmigration (kelt)[2,5, 6]		Span	Span	Span	Span							
Incubation[7,8]	Span	Span	Span	Span	Span	Span						
Fry[9]			Span	Span	Span	Span	Span					
Juvenile rearing[1,2,6]	Span	Span	Span	Span	Span	Span	Span	Span	Span	Span	Span	Span
Smolt outmigration[1,2,10]			Span	Peak	Peak	Span (early)						

[1] VTN (1982)
[2] SEC (1998)
[3] CDFW (1998–2017)
[4] Busby et al. (1996)
[5] Teo et al. 2013
[6] Moyle et al. 2017
[7] Shapovalov and Taft (1954)
[8] Barnhart (1991)
[9] assumed based on expected time of emergence from spawning gravels
[10] Beak (1986)

= Span of activity
= Peak of activity

2.1.2 Summer-run Steelhead

As noted above (Section 1.4.1), the potential effects analysis of releasing fine sediment on Eel River steelhead is focused on winter-run steelhead. Summer-run steelhead are generally not expected to hold or spawn in the mainstem Upper Eel River, and potential effects on juvenile rearing would be similar to winter-run steelhead. However, the life history timing and seasonal distribution of summer-run steelhead in the Eel River is summarized below for reference.

The generalized life history timing for summer-run steelhead life stages in the Eel River watershed is presented in Table 2. Summer-run steelhead in Northern California enter freshwater and migrate upstream as sexually immature adults in spring and early summer, typically during the snow melt period between April and late June (Everest 1973, Busby et al. 1996, Moyle et al. 2017). Therefore, migrating adult summer-run steelhead belonging to the Middle Fork Eel River population may be present in the mainstem Eel River during the April to late June period. If adult summer-run steelhead still return to the Upper Eel River in some years as was reported in 1985 (Jones 1992, SEC 1998, NMFS 2016), they could be migrating upstream during the same April to late June period.

After migrating into cool headwater reaches, summer-run steelhead spend the summer and early fall holding in deep pools before spawning between early winter and spring (Everest 1973, Roelofs 1983, Barnhart 1991, Moyle et al. 2017). In the Upper Eel River, adult summer-run steelhead documented in summer 1985 were reported to be holding between Cape Horn Dam and Soda Creek, with the vast majority in Van Arsdale Reservoir (Jones 1992). Based on preference for cold water habitats, holding adult summer-run steelhead in the Upper Eel River would be expected to be distributed upstream of Cape Horn Dam where cool water releases from Lake Pillsbury moderate warm summer water temperatures.

Table 2. Generalized life history timing of summer-run steelhead in the Eel River watershed.

Life stage	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Summer-run adult migration[1,2,3]												
Summer-run holding[3,4,5]												
Fall-run & half-pounder entry & holding in lower Eel [4,6,7]												
Spawning[3,4,5]												
Adult outmigration (kelt)[3,8,9]												
Incubation[5,10]												
Fry[11]												
Juvenile rearing[3,8]												
Smolt outmigration[8,12,13]												

[1] Everest (1973)
[2] Busby et al. (1996)
[3] Moyle et al (2017)
[4] Roelofs (1983)
[5] Barnhart (1991)
[6] Kajtaniak and Gruver (2020)
[7] Hodge et al. (2014)
[8] SEC (1998)
[9] Teo et al. (2013)
[10] Shapovalov and Taft (1954)
[11] assumed based on expected time of fry emergence
[12] VTN (1982)
[13] Beak (1986)

= Span of activity
= Peak of activity

Summer-run steelhead are thought to leave mainstem holding pools and migrate into spawning streams following late fall or early winter rain events (Everest 1973). In general, summer-run steelhead are thought to spawn primarily in small headwater streams, some of which become intermittent or go dry in the summer (Everest 1973). Like winter-run steelhead, some individuals emigrate back to the ocean after spawning (Roelofs 1983, Moyle et al. 2017).

The life history timing and seasonal distribution for fry, juvenile rearing, and smolt outmigration for summer-run steelhead is presumably the same as that described for winter-run steelhead above.

The lower mainstem Eel River downstream of the South Fork Eel River also has a component of the steelhead run that enters freshwater from mid-summer through early fall (Roelofs 1983, Kajtaniak and Gruver 2020), similar to that observed in the Klamath River basin, where they enter freshwater from July through October (Hopelain 1998). These individuals, sometimes referred to as the "fall-run", generally stage in the lower mainstem Eel River downstream of the Van Duzen River. The extent to which this component of the run migrates into the Upper Eel River is unknown, but they would not be expected to move into that part of the basin until the first fall freshets occur (typically November or December). This component of the run is often considered to be part of the summer-run population (Everest 1973, Roelofs 1983) and thus is included in this section (Table 1).

The Eel River watershed steelhead population also displays the "half-pounder" life-history variant, where some individuals return to freshwater in the summer or fall after only two to four months in the ocean, spend the fall and winter feeding in the river, then emigrate back to the ocean again the following spring (Busby et al. 1996, Hodge et al. 2014). Summer-run, fall-run, and winter-run steelhead are all thought to exhibit this life history strategy, but it appears to be most closely associated with the fall-run (Everest 1973, Hodge et al. 2014, Peterson et al. 2017).

2.2 Chinook Salmon

The generalized life history timing for each life stage of fall-run Chinook Salmon in the Eel River watershed is presented in Table 3. Adults leave the ocean and enter the estuary and lower reaches of the Eel River as early as September, but stage there until cued to migrate upstream by increasing stream flows associated with the first substantial fall rains, which typically do not occur until late October or early November (VTN 1982, Moyle et al. 2017, Kajtaniak and Gruver 2020). The first adult Chinook Salmon have been documented arriving at VAFS as early as mid-October and as late as late December, but the first individuals typically arrive between late October and late November, a timing largely controlled by timing and magnitude of fall freshets and increased stream flows (VTN 1982, SEC 1998, CDFW unpub. data). Timing of the first adults arriving at VAFS and Tomki Creek, a major spawning tributary, generally occur with a few days of each other (SEC 1998). Peak migration into the Upper Eel River typically occurs in November and December (SEC 1998, CDFW unpub. data). The last adult Chinook Salmon typically arrive at VAFS between late December and mid-January, but they have been documented as late as February (SEC 1998, CDFW unpub. data).

Fall-run Chinook Salmon generally spawn between November and January, but small numbers of live adults have been documented in early February (SEC 1998). Peak spawning in the Upper Eel River typically occurs between mid-November and late December (VTN 1982, SEC 1998).

Upstream of the Middle Fork Eel River, Chinook Salmon spawn primarily in the mainstem Eel River and its largest tributaries, Outlook Creek and Tomki Creek (SEC 1998, PG&E 2017).

Significant spawning occurs in the mainstem Upper Eel River, both upstream and downstream of Cape Horn Dam (VTN 1982).

Fall-run Chinook Salmon embryos typically hatch approximately 40–60 days after spawning and remain in gravels as alevins for another 30–40 days before emerging as fry (Moyle et al. 2017). Based on spawning timing and capture of fry in outmigrant traps, some eggs and alevins are expected to be in spawning gravels from November through early April (VTN 1982, Beak 1986).

Juvenile fall-run Chinook Salmon in the Upper Eel River display the ocean-type life history, where juveniles migrate to the estuary or ocean within weeks or a few months of emergence (VTN 1982, Beak 1986, Healey 1991, SEC 1998). Evidence from outmigrant trapping at various sites in the Upper Eel River and in Tomki Creek, as well as limited spring snorkel surveys downstream of Outlet Creek, suggest that some rearing Chinook Salmon fry may be present in the Upper Eel River and Tomki Creek between early March and early July, but most individuals emigrate in April and May as water temperatures begin to increase (VTN 1982, Beak 1986, SEC 1998). Notably, artificially cool water temperatures between Scott Dam and Cape Horn Dam may delay juvenile outmigration from that reach and create a situation where downstream temperatures exceed lethal thresholds (SEC 1998, PG&E 2017).

Table 3. Generalized life history timing of fall-run Chinook Salmon in the Eel River watershed.

Life stage	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult migration[1,2,3,4]												
Spawning[1,2,3]												
Incubation[5]												
Fry rearing[1,2,5,6]												
Juvenile outmigration[1,2,6]												

1 VTN (1982)
2 SEC (1998)
3 PG&E (2017)
4 CDFW (1996–2017)
5 Moyle et al. 2017 and assumed based on spawning time and presence of fry reported by VTN (1982) and Beak (1986)
6 Beak (1986)

= Span of activity
= Peak of activity

2.3 Coho Salmon

Viable Coho Salmon populations historically occurred in both the Outlook Creek and Tomki Creek watersheds, and the species utilized the mainstem Eel River primarily as a migratory corridor (Brown et al. 1994, NMFS 2014). Coho Salmon were also reportedly historically documented in Indian Creek, a mainstem tributary upstream of Outlet Creek (Brown et al. 1994). Coho Salmon have not been documented in Tomki Creek since before 1979, except for one observation in 1996 in its tributary, Cave Creek, and are presumed to be extirpated there (Garwood 2012, NMFS 2014). Coho Salmon have been documented in Outlet Creek and several of its tributaries as recently as the early 2000s, but population abundance is thought to be very low and possibly missing two year-classes (Garwood 2012, NMFS 2014). Forty-seven adult Coho Salmon were documented in the mainstem Eel River at VAFS during the 1946–1947 season but have not been documented since (Brown et al. 1994). Because of their potential future presence in the Upper Eel River watershed, the species is included herein.

The generalized life history timing for Coho Salmon life stages in the Eel River watershed is presented in Table 4, drawing largely from information in the South Fork Eel River or other northern California populations where more extensive monitoring data are available. Adults typically enter freshwater and migrate upstream to spawning tributaries from November through February (Ricker et al. 2014, Moyle et al. 2017, Guczek et al. 2019). Spawning occurs from November through February, peaking in December and January (Ricker et al. 2014, Guczek et al. 2019). Following deposition in spawning gravels, Coho Salmon eggs incubate for 6–12 weeks before hatching, with incubation time being inversely related to water temperature (Murray and McPhail 1988, Moyle et al. 2017). After hatching, alevins (or sac fry) remain in the spawning gravels while undergoing further development and absorption of the yolk sac for another 4–8 weeks before emerging as fry (Murray and McPhail 1988, Moyle et al. 2017). Based on expected spawning timing, the incubation period, and timing that newly emerged fry are captured during outmigrant trapping, developing Coho Salmon eggs or alevins may be present in spawning gravels from approximately November through May (Murray and McPhail 1988, Mendocino Redwood Company 2002, Vaughn 2005, Moyle et al. 2017). In the Upper Eel River, all Coho Salmon spawning and incubation is expected to occur in tributaries rather than the mainstem.

Following emergence from spawning gravels, juvenile Coho Salmon in larger river systems can display a variety of life history strategies including (1) rearing in natal streams for approximately 1-year before outmigrating to the ocean in the spring; (2) leaving natal streams in the spring soon after emergence and rearing in cool non-natal tributaries or the estuary prior to entering the ocean the following spring or summer; and (3) leaving natal tributaries in the fall or early winter as flows increase and water temperatures decrease and overwintering in suitable low-velocity habitats along in the mainstem corridor, low gradient non-natal tributaries, or in the estuary (Jones et al. 2014, Bennett et al. 2015, Rebenack et al. 2015, Soto et al. 2016). The extent to which these life history strategies are expressed in the Upper Eel River is uncertain. However, based on juvenile monitoring in the Klamath River (Soto et al. 2016), it is possible that Coho Salmon fry or juveniles rear in or move through the mainstem Eel River corridor anytime water temperatures are suitably cool (i.e., generally October through May). Based on rotary screw trapping data from spawning tributaries in the South Fork Eel River and other northern California streams, most individuals are expected to move downstream through the mainstem as one-year-old smolt between March and June, with peak smolt outmigration in April and May (Mendocino Redwood Company 2002, Vaughn 2005, Ricker et al. 2014).

Table 4. Generalized life history periodicity of Coho Salmon in the Eel River watershed based primarily on the South Fork Eel River and other northern California streams.

Species	Life stage	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coho Salmon	Adult migration[1,2]												
	Spawning[1,2]												
	Incubation[3,4]												
	Juvenile rearing[1,4]												
	Smolt outmigration[1,5,6]												

[1] Ricker et al. (2014)
[2] Guczek et al. (2019)
[3] Murray and McPhail (1988)
[4] Moyle et al. (2017)
[5] Mendocino Redwood Company (2002)
[6] Vaughn (2005)

= Span of activity
= Peak of activity

3 METHODS

This evaluation assessed the effects of increased fine sediments on winter-run steelhead, fall-run Chinook Salmon, and Coho Salmon downstream of Scott Dam following two dam removal alternatives. We analyzed the effects of elevated SSC predicted by Stillwater Sciences (2021) on each life stage of all three focal fish species and their in-river life stages, including adults, eggs/alevins, and juveniles[3].

3.1 Suspended Sediment Modeling

Stillwater Sciences (2021) provided analyses for two Scott Dam removal alternatives, using a method proposed and previously applied for Matilija Dam removal by Cui et al. (2017) that relied on three components to inform the likely magnitude and duration of high SSCs: (1) a two-phase conceptual model for reservoir sediment erosion following a sudden release of fine sediment following dam removal; (2) general principles governing geomorphic processes; and (3) comparison of results from the analyses with observations in rivers during flood events, during reservoir drawdown for sediment sluicing, and following dam removal.

[3] In this document, juvenile steelhead refers to both young-of-the-year (YOY) and age 1+/2+, unless indicated separately. YOY are age 0+ individuals less than one year old at the time of impact that hatched the previous spring or early summer and are the offspring of adults that spawned the previous winter or early spring. Age 1+/2+ refers to all pre-smolt juveniles one year old or older. YOY are likely to be between 3 and 9 months old at the time of impact, and age 1+/2+ are likely between 1.25 and 2.5 years old.

The Stillwater Sciences (2021) analyses applied conservative assumptions wherever uncertainties arose in parameters, and the results should be considered accurate to an order of magnitude[4] and very conservative (i.e., the actual duration of impact is most likely much shorter than estimated through the analyses). The results are useful for identifying the seasonality, frequency, and potential worst-case scenario for suspended sediment impacts on focal species. Although the results are only accurate to an order of magnitude when viewing each alternative independently, results from the analyses are relatively strong and informative when used to compare relative differences among alternatives. That is, results such as the SSC for alternative A is higher than alternative B, or impact duration for alternative A is shorter than alternative B should be considered as extremely reliable and not be questioned on the basis that the analyses are only accurate to an order of magnitude.

The calculated magnitude of SSC and duration were used to predict potential impacts on focal species under the two dam removal alternatives described in Section 1.3. Three flow assumptions (1,000; 2,000; and 5,000 cubic feet per second [cfs]) were considered for the vertical notching alternative, and estimated SSCs associated with these flows would reach several hundred thousand milligrams per liter that lasts for several days. A 133 cfs flow was considered for the four-stage alternative, as fine sediment release would primarily occur during the low flow construction season. The estimated SSC for the four-stage alternative is lower compared with the vertical notching alternative; however, elevated SSCs under the four-stage alternative would last much longer (four consecutive water years). More details of the estimated SSC and duration is described in Section 3.1.

3.2 Effects Analysis

Based on the scientific literature, the most commonly observed effects of suspended sediment on anadromous salmonids include: (1) avoidance of turbid waters in migrating adults resulting in delay or straying, (2) avoidance or alarm reactions by juveniles, (3) displacement of juveniles, (4) reduced feeding and growth, (5) physiological stress and respiratory impairment, (6) damage to gills, (7) reduced tolerance to disease and toxicants, (8) reduced survival, and (9) direct mortality (Newcombe and Jensen 1996).

Information on both concentration and duration of suspended sediment is important for understanding the potential severity of its effects on salmonids (Newcombe and MacDonald 1991). Herbert and Merkens (1961) stated that "there is no doubt that many species of fresh-water fish can withstand extremely high concentrations of suspended solids for short periods, but this does not mean that much lower concentrations are harmless to fish which remain in contact with them for a very long time." Effects of suspended sediment on fish may be increased if toxics or other stressors (e.g., water temperature, disease) are present as well. Turbidity can function as cover to reduce predation at some life stages, not only in riverine, but also in estuary and nearshore marine environments (Gregory and Levings 1998, Wilber and Clarke 2001, Gadomski and Parsley 2005). Some salmonid species have been shown to be attracted to turbid water over clear water, which may reflect its use as cover (Gradall and Swenson 1982, Cyrus and Blaber 1992, both as cited in Wilber and Clarke 2001). This analysis will consider water temperature and turbidity as potential cover qualitatively, in assessing the potential effects of a suspended sediment pulse on anadromous salmonid populations.

[4] In general, parameters relating to sediment transport rate (such as SSC) in sediment transport models are considered accurate to a factor of 2 to 3. Here "order of magnitude" accuracy means that results of the analyses may not be as accurate as what was considered for sediment transport models primarily due to the lack of basic research in the subject.

Determining the SSCs that cause direct lethal effects in salmonids has generally been based on laboratory studies experimenting with exposures to concentrations of suspended sediment over 1,000 milligrams per liter (mg/L) and usually much higher. According to Sigler et al. (1984), "yearling and older salmonids can survive high concentrations of suspended sediment for considerable periods, and acute lethal effects generally occur only if concentrations exceed 20,000 ppm[5] (see reviews by Cordone and Kelly 1961, Sorenson et al. 1977)." For 36-hour exposures using juvenile Chinook (*O. tshawytscha*) and Sockeye Salmon (*O. nerka*), Newcombe and Flagg (1983) reported 10% mortality at concentrations of 1,400 mg/L, 50% mortality at 9,400 mg/L, and 90% mortality at 39,400 mg/L. Concentrations of 82,000 mg/L resulted in 60% mortality after 6-hours exposure. Estimated concentrations of 207,000 mg/L resulted in 100% mortality in one hour. Stober et al. (1981) reported mortality rates of 50% for juvenile Chinook and Coho Salmon exposed to 500–1,000 mg/L for 96 hours; however. From the results of these and other studies, it appears that relatively short-term exposures to increases in SSC under 500–600 mg/L would not likely result in substantial direct mortality to either juvenile or adult anadromous salmonids in the Eel River. If the duration of exposure is extended, however, some direct mortality is expected. Exposures of 19 days to SSC of 90–270 mg/L and higher have been reported as resulting in mortality to juvenile rainbow trout by Herbert and Merkens (1961). Less information is available on the effects of suspended sediment or turbidity on newly emerged salmonid fry (Sigler et al. 1984).

For comparison, daily mean suspended sediment concentration measured in the Eel River at Scotia between 1960 and 1980 (USGS gage 11477000) annually exceed 1,000 mg/L, and occasionally exceed 10,000 mg/L (Figure 2); levels high enough to result in sublethal and lethal impacts to focal species on an nearly annual basis.

[5] Parts per million (ppm) is equivalent to milligrams per liter (mg/L)

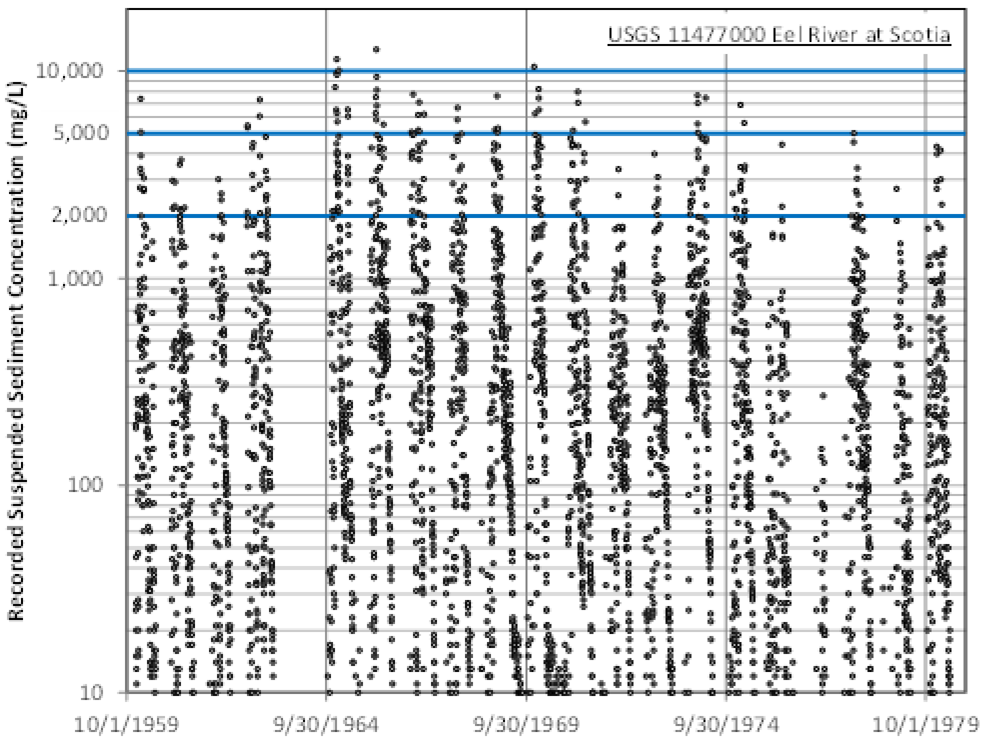

Figure 2. Recorded suspended sediment concentration at USGS gage 11477000 (Eel River at Scotia) (Horizontal blue lines highlight suspended sediment concentration thresholds of 10,000, 5,000, and 2,000 milligrams per liter [mg/L]).

Potential population-level effects of fine sediment released from dam removal activities for a given species not only depend on their abundance, distribution, and life stages present, but also on the timing, duration, and concentration of suspended sediment released. In this analysis, the results of Newcombe and Jensen (1996) were used to assess impacts of SSC on the focal fish species and life stages. Newcombe and Jensen (1996) reviewed and synthesized 80 published reports of fish responses to suspended sediment in streams and estuaries and established a set of equations to calculate "severity of ill effect (SEV)" indices (Table 5) for various species and life stages based on the duration of exposure and concentration of suspended sediment present. The SEV provides a ranking of the effects of SSC on salmonid species, as calculated by any of six equations that address various taxonomic groups of fishes, life stages of species within those groups, and particle sizes of suspended sediments. Newcombe and Jensen (1996) collected data on fish effects (on the SEV scale), suspended sediment concentration (C, [mg/L]), and suspended sediment exposure time (D, hr), from a large number of papers dealing with many salmonid fishes at various life stages. They fit models of the form $\text{SEV} = b_0 + b_1 \log C + b_2 \log D$ to these data for adults, juveniles, and eggs/alevins life stages, where "*b*" are terms for regression coefficients based on selection of the best performing model. These data all consider constant concentration values. Following Newcombe and MacDonald (1991), models of the form in Equation (1) are applied.

$$\text{SEV} = b_0 + b_1 \text{Ln (CD)} \qquad \text{Equation 1}$$

Based on selection of the best performing model, regression coefficients for adults are b_0=2.030; b_1=0.611, juveniles are b_0=0.978; b_1=0.681, and eggs/alevins are b_0=7.200; b_1=0.436. CD is calculated as the total mass of sediment to be eroded (M) and the discharge rate to be maintained (Q) for each alternative.

As an example calculation for SEV for adult salmonids under vertical notching alternative, M = 12,000,000 CY, which is converted to metric, and assuming a density of 943,000 mg/L resulting in a value of 8.65×10^{15} mg. Discharge rate (Q) is 1,000 cfs, which calculates as 2,446,575,546 L/d, and therefore CD = 3,536,250 mg/L×d. Using the regression coefficients for adult salmonids of b_0=2.030; b_1=0.611, $\text{SEV} = 2.03 + 0.611 \times \text{Ln}(3{,}536{,}250 \times 24) \doteq 13.25$.

The result of this approach is a life-stage-specific prediction of the severity of ill effects on the focal species in the Eel River based on the results of the general fine sediment release analysis described in Section 2.2. The indices used by Newcombe and Jensen (1996) have become a standard for selecting management-related turbidity and suspended sediment criteria (e.g., Walters et al. 2001), and their report remains the best available source for determining effects of SSC on salmonids (Berry et al. 2003). However, there are inherent sources of uncertainty in this application of the model. Newcombe and Jensen (1996) base much of their analysis on laboratory studies that were conducted in controlled environments over short durations, mostly examining acute lethal impacts of non-fluctuating concentrations of suspended sediment. This analysis is a relatively simple application of the Newcombe and Jensen (1996) model, in that predictions are provided for only a few assumed flows, rather than evaluating modeling predictions assuming an entire hydrograph for multiple potential water years. Background turbidity also is not accounted for in the analysis. In addition, Newcombe and Jensen (1996) do not explicitly address the translation of sublethal severity levels into population-level effects. As Gregory et al. (1993) note in their review of Newcombe and Jensen (1996), the approach simplifies the effects of suspended sediment, and in doing so, assumes all effects of suspended sediment are negative, despite literature to the contrary. This exaggerates the effects of suspended sediment, particularly for lower concentrations and durations of exposure. The predictions of mortality at high concentrations and durations of exposure are considered more certain than the predictions of sublethal effects. In this application, sublethal effects resulting from exposure to lower concentrations are included because of the concern that sublethal impacts of suspended sediment could be adverse in conjunction with high water temperature for some life stages (Bozek and Young 1994).

Table 5. Scale of the severity of ill effects associated with excess suspended sediment (based on Newcombe and Jensen 1996).

Category of effect	Severity	Description
No effect	0	No behavioral effects
Behavioral effects	1	Alarm reaction
	2	Abandonment of cover
	3	Avoidance response
Sublethal effects	4	Short-term reduction in feeding rates Short-term reduction in feeding success
	5	Minor physiological stress: • Increase in rate of coughing • Increased respiration rate
	6	Moderate physiological stress
	7	Moderate habitat degradation Impaired homing
	8	Indications of major physiological stress: • Long-term reduction in feeding rate • Long-term reduction in feeding success

Category of effect	Severity	Description
		• Poor condition
Lethal effects	9	Reduced growth rate: • Delayed hatching • Reduced fish density
	10	Increased predation of affected fish 0–20% mortality
	11	>20–40% mortality
	12	>40–60% mortality
	13	>60–80% mortality
	14	>80–100% mortality

4 RESULTS

The results of the assessment are presented in three parts. First, an overview of the predicted magnitude and duration of SSCs for the two dam removal alternatives analyzed (vertical notch and four-stage removal) is presented based on the fine sediment erosion analysis reported in Stillwater Sciences (2021). Second, a hydrologic analysis identifying the frequency and timing of potential flow thresholds for vertical notch removal is presented to inform the potential timing of sediment release as it relates to the species and life stages that could be affected. Third, the estimated effects of predicted SSCs on focal species and life stages are presented for the two dam removal alternatives analyzed.

4.1 Overview of Predicted Suspended Sediment Concentrations

The following overview draws directly from the analyses reported in Stillwater Sciences (2021). Removing Scott Dam with the proposed vertical notching alternative would result in a rapid, one-time increase in high SSC during a winter storm event on the order of 600,000 mg/L that would most likely last for approximately 4 days (3 days Phase 1 erosion, 1 day Phase 2 erosion) if streamflow following notch opening is around the targeted 2,000 cfs (Table 6). If the discharge following notch opening is only 1,000 cfs, however, the SSC would be reduced to about 450,000 mg/L, which would most likely last for approximately 9 days (8 days Phase 1 erosion, 1 day Phase 2 erosion). If the streamflow following notch opening is 5,000 cfs, the SSC would be increased to approximately 900,000 mg/L, which would most likely last for approximately 2 days (1 day Phase 1 erosion, 1 day Phase 2 erosion). A higher streamflow following notch opening would result in SSC up to slightly more than 900,000 mg/L and would shorten the duration of the high suspended sediment and turbidity. Based on available streamflow data (see Section 4.2), it is anticipated that SSC resulting from Scott Dam removal would be substantially diluted (by around 70 percent) downstream of the Middle Fork Eel River since the Middle Fork Eel River provides substantial accretion flow in all seasons.

Table 6. Calculated magnitude of suspended sediment concentration and duration for Phase 1 erosion for 12 million cubic yards fine sediment erosion (vertical notching alternative).

Concentration/ Duration	Streamflow into Lake Pillsbury		
	1,000 cfs	2,000 cfs	5,000 cfs
Suspended sediment concentration (mg/L)	457,800	612,500	900,000
Duration of Phase 1 erosion (days)	7.7	2.9	0.8

Note: 12 million cubic yards is the total volume of erosion estimated by Stillwater Sciences et al. (2021a) that included both fine and coarse sediment. The amount of fine sediment erosion is most likely less than 12 million CY.

Removing Scott Dam with the proposed four-stage alternative (one stage per year) would result in fine sediment erosion during the low flow season (May through November) up to approximately 196,000 mg/L for a combined duration of more than 100 days that spans four water years if the rate of notching is adequately fast. The most likely scenario, however, is an SSC lower than 196,000 mg/L that lasts significantly longer (Figure 3). In a likely scenario of 100,000 mg/L SSC, for example, the combined duration in the four water years could potentially exceed 250 days. A faster notching would mean higher SSC but shorter impact duration (but still longer than 100 days), and slower notching would mean a lower SSC but increased duration of impact. In the absence of mechanical sediment removal and disposal, there is no known method to reduce the magnitude of SSC and shorten the impact duration simultaneously.

Note the above discussions are entirely based on the volume of sediment erosion during different stages of dam removal estimated from GIS analysis (Stillwater Sciences et al. 2021a), and the actual volume released will certainly differ. Stage 1, for example, removes the dam to an elevation of 1,771.12 ft, which is only about 10 ft lower than the reservoir pool level during the summer of 2014 drought. As a result, the amount of fine sediment release is likely much smaller than the 1.1 million CY assumed in the analysis, and there would likely be very few to no days with elevated suspended sediment concentration during Stage 1 removal. However, the smaller amount of assumed sediment release during Stage 1 removal implies the amount of sediment erosion during the next three stages would need to be higher than assumed in the analysis, meaning more days of high suspended sediment concentration during these stages. Because of that, the combined number of days with high suspended sediment concentration during all four construction seasons should be similar if the volume of erosion amongst the four construction seasons is distributed differently.

Despite the high suspended sediment concentration during the summer months, the amount of fine sediment erosion is limited due to the low water discharge throughout the season. During the dry season of July through September, for example, a 34 cfs water discharge combined with an 83,000 mg/L suspended sediment concentration would result in only approximately 700 tons of fine sediment erosion, leaving much of fine sediment for erosion during the following winter high flow season. Because of that, it is expected that an acute peak high suspended sediment concentration event would occur during the first winter high flow event (particularly in years 2, 3, and 4), eroding a significant amount of fine sediment. The suspended sediment concentration during this initial high flow event is expected to be somewhat similar to that of the vertical notching alternative, perhaps with a slightly lower magnitude and significantly shorter duration because the amount of sediment release is much less than that for vertical notching alternative (i.e., fine sediment release in four years instead of one single event).

As described for the vertical notching alternative, it is anticipated that potential impacts from high suspended sediment concentrations would be greatest upstream of the Middle Fork Eel River, with some dilution of suspended sediment downstream of the Middle Fork confluence.

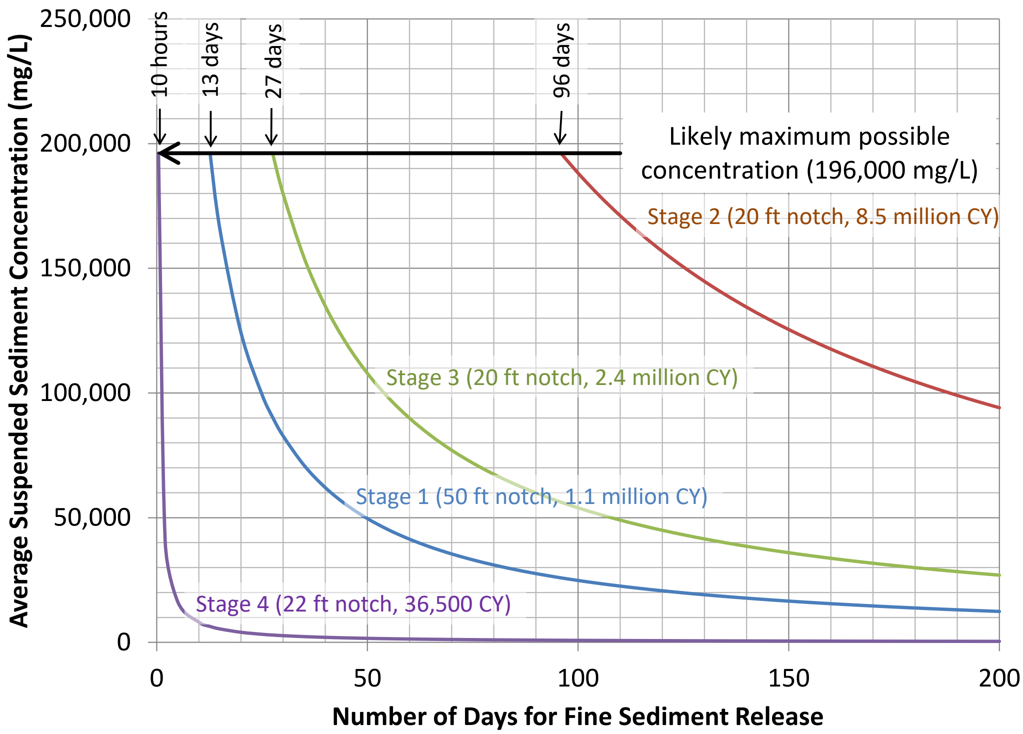

Figure 3. Suspended sediment concentration vs. duration of average suspended sediment concentration for the four-stage dam removal alternative at a flow of 133 cubic feet per second (assuming fine sediment release occurs only during lake level drawdown). Each removal stage would occur in the spring of four consecutive years with sediment erosion occurring after notching through November.

4.2 Hydrologic Analysis

To identify the frequency and timing of potential flow thresholds for the vertical notching alternative, a hydrologic analysis was conducted to inform the potential timing of sediment release as it relates to the focal species and life stages that could be affected. Based on the unimpaired hydrology for the Eel River at Scott Dam from 1911 to 2017 (Addley et al. 2019), a 2-year exceedance annual maximum daily flow is 10,240 cfs. The three flows assessed in the vertical notching alternative are 1,000 cfs, 2,000 cfs, and 5,000 cfs. A daily maximum flow of 1,000 cfs occurred in all years, 2,000 cfs is exceeded 99% of years, and 5,000 cfs is exceeded 98% of years (Table 7). A daily maximum flow of 1,000 cfs has a nearly 40% probability of occurring by the end of November, and in most years (>70%) will have occurred by the end of December (Table 7). A daily maximum flow of 2,000 cfs is more likely to occur by the end of December (59% of years), and nearly certainly by the end of January (82% of years). A daily maximum flow of 5,000 cfs has around a 40% chance of occurring by the end of December, and is more likely (>65%) to occur by the end of January (Table 7).

Table 7. Probability of maximum daily flows assessed in vertical notching alternative occurring within fall and winter months (October through March) at Scott Dam. Based on unimpaired hydrology for the Eel River at Scott Dam from 1911 to 2017 (Addley et al. 2019).

Month	1,000 cfs	2,000 cfs	5,000 cfs
October	9%	4%	2%
November	40%	24%	11%
December	71%	59%	43%
January	90%	82%	67%
February	98%	96%	90%
March	100%	99%	98%

cfs = cubic feet per second

Thirteen years of mean daily flow records (2008 through 2020) from two stream flow gages (gage E11 [Eel River downstream of Cape Horn Dam] and USGS gage 11473900 [Middle Fork Eel River Near Dos Rios]) were summarized to assess dilution of suspended sediment following removal of Scott Dam downstream to the confluence with the Middle Fork Eel River. For the period of November through January when flows are between 1,000 and 5,000 cfs, discharge at the Middle Fork Eel River was between 0.9 to 12.2 times higher than discharge downstream of Cape Horn Dam, averaging 2.5 times higher.

4.3 Predicted Effects on Focal Species

Applying the Newcombe and Jensen (1996) approach to assess effects on the SEV scale based on suspended sediment concentration (C, mg/L) and suspended sediment exposure time (D, hr) suggests that the high concentration and short duration of fine sediment release predicted under the vertical notching alternative would result in high levels of mortality for those species and life stages exposed during winter (Table 8).

Table 8. Summary of predicted Newcombe and Jensen Severity Index (SEV) and anticipated effects on focal salmonid species based on the vertical notching alternative.

Life stage	Estimated streamflow into Lake Pillsbury and estimated effect of rapid sediment release under the Vertical Notching Alternative					
	1,000 cfs (458,000 mg/L for 185 hr)		2,000 cfs (613,000 mg/L for 69 hr)		5,000 cfs (900,000 mg/L for 19 hr)	
	SEV	Effects	SEV	Effects	SEV	Effects
Adult	13	>60–80% mortality	13	>60–80% mortality	12	>40–60% mortality
Juvenile	13	>60–80% mortality	13	>60–80% mortality	12	>40–60% mortality
Eggs and alevin	14	>80–100% mortality	14	>80–100% mortality	14	>80–100% mortality

cfs = cubic feet per second

Under the four-stage alternative, the high concentration of fine sediment release would result in high levels of mortality for those species and life stages exposed during four consecutive summers (May through November) (Table 9). The implications for the focal species and life stages potentially exposed under each alternative are discussed below.

Table 9. Summary of predicted Newcombe and Jensen Severity Index (SEV) and anticipated effects on focal salmonid species based on the four-stage dam removal alternative occurring over four water years.

Life stage	Dam Removal Stage							
	Stage 1 (196,000 mg/L for 10 hours)		Stage 2 (196,000 mg/L for 13 days)		Stage 3 (196,000 mg/L for 27 days)		Stage 4 (196,000 mg/L for 96 days)	
	SEV	Effects	SEV	Effects	SEV	Effects	SEV	Effects
Adult	13	>60–80% mortality	14	>60–80% mortality	13	>40–60% mortality	11	>20–40% mortality
Juvenile	13	>60–80% mortality	14	>60–80% mortality	14	>40–60% mortality	11	>20–40% mortality
Eggs and alevin	14	>80–100% mortality	14	>80–100% mortality	14	>80–100% mortality	14	>80–100% mortality

4.3.1 Steelhead

4.3.1.1 Vertical Notching Alternative

Adult winter-run steelhead migrate through the mainstem Eel River between late November and May (Table 1) during or following high flow events. Suspended sediment released under the vertical notching alternative may occur early as November, and is nearly certain to occur by the end of January (see Section 4.2); therefore, a component of the adult migrant population would likely be exposed to lethal SSCs under the vertical notching alternative, resulting in substantial mortality for exposed adults (Table 9). However, due to a relatively prolonged migratory season and short duration of suspended sediment impacts, a substantial proportion of adults will likely have migrated through the mainstem and into tributaries prior to the suspended sediment pulse or will migrate following the pulse event. The spatial distribution of steelhead also ensures that a component of the run will migrate up the South Fork Eel River or within numerous other large and small tributaries. In addition, because the fine sediment release for this alternative would occur during winter, tributary accretion flow with relatively low SSCs is expected to provide local refuge at tributary confluences from high SSC in the mainstem, as illustrated for example in Figure 4. The Upper Eel River has substantial streamflow accretion from numerous tributaries that is estimated to dilute SSC by about 70 percent by the Middle Fork Eel River (Section 4.2). While potential impacts to adult steelhead in the mainstem will be lessened by dilution and access to tributary inflow as refuge habitat, lethal impacts are still predicted during the peak sediment release (1–8 days depending on flow, see Table 6).

Figure 4. Example of the confluence of two rivers following a storm event on April 15, 2021. The river with clear water is Qingshuijiang (Clear Water River), and the one with turbid water is Xiaojiang (Little River). The rivers are located in Jinping County, Guizhou Province, China. (Source: Jinping County Information Center, Guizhou Province, China, image downloaded from https://www.sohu.com/a/461365210_162758 on April 18, 2021).

Most steelhead spawning occurs in tributaries, and therefore most incubating eggs will avoid impacts of the peak suspended sediment in mainstem. However, considerable numbers of steelhead spawn in the mainstem Eel River above Cape Horn Dam based on the number of adults counted at VAFS versus observed spawning in tributaries, and those redds that are constructed prior to the release of sediment will likely suffer nearly complete mortality from high SSC and coarse sediment deposition.

Kelts may be present in the mainstem Upper Eel River from February through May. Depending on the timing of the fine sediment release, it is possible that relatively few kelts will be in the mainstem during the short duration of elevated sediment if it occurs during an early winter storm (i.e., before February, which is likely as described in Section 4.2), and likely few will be impacted overall.

Steelhead fry rearing in the Eel River watershed generally occurs in tributaries and based on spawning and emergence timing, occurs primarily from March through July. The first high flow event of the year of the vertical notching alternative is nearly certain to occur prior to March (see Section 4.2), and therefore steelhead fry will most likely avoid impacts. In the Upper Eel River, individuals rearing in tributaries generally rear for two or three years before migrating to the ocean, whereas individuals rearing in the mainstem between Scott Dam and Cape Horn Dam often migrate after a single year due to superior growth conditions (SEC 1998). These age 1+ juveniles rearing in the mainstem Upper Eel River would likely suffer high levels of mortality unless they are able to find refuge in tributaries or associated low-SSC inflow at tributary confluences. However, most juvenile rearing occurs in tributaries, and therefore most individuals would not be in the mainstem during the suspended sediment pulse and would be unaffected. In addition, as described for adults above, dilution and low-SSC flow entering from tributaries is expected to provide refuge from highly elevated SSC in the mainstem.

Steelhead smolt outmigration generally occurs from March through mid-June, with a peak in April and May (Table 1). Because fine sediment release from the vertical notching alternative will nearly certainly occur during an early winter flow event by the end of January (Section 4.2), smolts would likely avoid impacts of highly elevated SSC in the mainstem.

In general, the short-term impacts of suspended sediment resulting from the vertical notching alternative on steelhead are likely to result in substantial mortality for any adults migrating, eggs and alevin in constructed redds, and juveniles rearing in the mainstem. However, there are several aspects of steelhead life history in the Eel River watershed that would ameliorate these impacts. The broad spatial distribution of steelhead in the Eel River watershed and their diverse life history patterns suggests that a large proportion of adults, eggs and alevin, and juveniles that would otherwise be in the mainstem would avoid the most serious effects of high SSC resulting from the vertical notching alternative by: (1) spawning in tributaries, (2) remaining in tributaries for extended juvenile rearing, (3) rearing farther downstream where SSC will be lower due to dilution, and/or (4) moving out of the mainstem into tributaries during periods of elevated suspended sediment or finding refuge in low-SSC flow entering the mainstem at tributary confluences.

4.3.1.2 Four-stage Alternative

The four-stage alternative would have similar impacts to steelhead as the vertical notching alternative described above, since dam removal during the dry season would leave much of the fine sediment behind for erosion during subsequent winter high flow seasons (up to four years). In addition, the four-stage alternative would have a summer suspended sediment release. Based on the summer removal timing of the four-stage alternative, adult, kelt, incubating eggs, alevin, and steelhead fry (primary rearing occurs in tributaries) would avoid the impacts of the summer fine sediment release. Juveniles rearing in the mainstem during summer would suffer high levels of mortality for at least three consecutive summers (since the first stage is anticipated to have little sediment release), affecting at least three generations of production. However, most juvenile rearing occurs in tributaries, therefore, most individuals would not be in the mainstem during the suspended sediment pulse and would be unaffected.

Steelhead smolt outmigration generally occurs from March through mid-June, with a peak in April and May. Based on the summer timing of fine sediment release from the four-stage alternative, smolt outmigration could be completed prior to SSCs increasing.

In general, the short-term impacts of suspended sediment resulting from the four-stage alternative on steelhead are likely to result in substantial mortality for any adults migrating, eggs and alevin in constructed redds, and juveniles rearing in the mainstem for three consecutive years, affecting multiple generations in the mainstem Upper Eel River. However, there are several aspects of steelhead life history in the Eel River watershed that would ameliorate these impacts. The broad spatial distribution of steelhead in the Eel River watershed and their diverse life history patterns suggests that most juveniles that would otherwise be in the mainstem would avoid the most serious effects of high SSC resulting from the four-stage alternative by: (1) remaining in tributaries for extended rearing, (2) rearing farther downstream where SSC would be lower due to dilution, and/or (3) moving out of the mainstem into tributaries during periods of elevated suspended sediment.

4.3.2 Chinook Salmon

4.3.2.1 Vertical Notching Alternative

Adult Chinook Salmon typically migrate through the mainstem Eel River during fall flow events mostly in November and December and have generally completed migration by mid-January. Suspended sediment released under the vertical notching alternative may occur early as November and is nearly certain to occur by the end of January (see Section 4.2). Therefore, a component of the adult migrant population is likely to be exposed to lethal SSC under the vertical notching alternative, resulting in substantial mortality for exposed adults (Table 9). The spatial distribution of Chinook Salmon ensures that a component of the run will migrate up the South Fork Eel River or within tributaries in the mainstem, including Outlook and Tomki creeks. In addition, because the timing of fine sediment release for this alternative would occur during winter, there is expected to be low-SSC flow entering from the tributaries to provide significant local refuge from high SSC in the mainstem (e.g., Figure 4). The Upper Eel River has substantial streamflow accretion from numerous tributaries that is estimated to dilute SSC by about 70% by the Middle Fork Eel River (Section 4.2). While potential impacts in the mainstem will be lessened by dilution and access to refuge habitat, lethal impacts are still predicted for adult Chinook Salmon in the mainstem during the peak sediment release.

Most Chinook Salmon spawning occurs in the mainstem, and therefore most incubating eggs will be exposed to impacts of the elevated suspended sediment, resulting in nearly complete mortality. Although few fry would be produced from the mainstem (due to poor redd survival), substantial numbers of fry would be produced from Outlook and Tomki creeks, and would enter the mainstem to emigrate as smolts mostly in April and May after the pulse in highly elevated suspended sediment would have occurred.

In general, the impacts of suspended sediment resulting from the vertical notching alternative on Chinook Salmon are likely to result in substantial mortality for a small proportion of the adult migrants, any redds constructed in the mainstem Upper Eel River, and a low likelihood of impacts on other life stages. Overall, the Chinook Salmon population is anticipated to suffer a minor short-term impact in the mainstem Upper Eel River for one generation of production and, due to the spatial distribution of Chinook Salmon in the watershed, would be expected to recover quickly.

4.3.2.2 Four-stage Alternative

The four-stage alternative would have similar impacts to Chinook Salmon as for to the vertical notching alternative described above, since removal during the dry season would leave much of fine sediment for erosion during the winter high flow events and during next seasons (up to four years). In addition, the four-stage alternative would have a summer suspended sediment release. Based on the summer removal timing of the four-stage alternative, Chinook Salmon incubating eggs and fry would avoid the impacts of fine sediment release. Adult migration generally starts in October and based on the timing of fine sediment release from the four-stage alternative, adult migration would likely begin after primary impacts would occur. Most Chinook Salmon smolts emigrate in April and May, therefore, emigration would likely be completed prior to increased SSCs.

In general, the short-term impacts of suspended sediment resulting from the four-stage alternative on Chinook Salmon are likely to result in are likely to result in substantial mortality for a small proportion of the adult migrants, any redds constructed in the mainstem Upper Eel River, and a low likelihood of impacts on other life stages; for three consecutive years.

4.3.3 Coho Salmon

4.3.3.1 Vertical Notching Alternative

Adult Coho Salmon typically migrate through the mainstem Eel River from November through February; therefore, a component of the adult migrant population would likely be exposed to lethal SSC under the vertical notching alternative, resulting in substantial mortality for exposed adults (Table 9). However, due to a prolonged migratory season and the short duration of sediment impacts, most adults will likely have the opportunity to migrate through the mainstem into tributaries prior to the pulse in sediment or will migrate following the event. The broad spatial distribution of Coho Salmon ensures that a component of the run will migrate to tributaries within the lower mainstem Eel River, South Fork Eel River, or within tributaries to the mainstem Upper Eel River (e.g., Outlook and Tomki creeks). In addition, because the fine sediment release for this alternative would occur during winter, there would be relatively low-SSC flow entering from tributaries that is expected to provide significant refuge from high SSC in the mainstem (e.g., Figure 4). The Upper Eel River has substantial streamflow accretion from numerous tributaries that is estimated to dilute SSC by about 70% by the Middle Fork Eel River (Section 4.2). While potential impacts in the mainstem will be lessened by dilution and access to refuge habitat, lethal impacts are still predicted for adult Coho Salmon in the mainstem during the peak sediment release.

Coho Salmon spawning and fry rearing in the Upper Eel River typically occurs in tributaries and not the mainstem, and therefore incubating eggs and fry would avoid impacts of the elevated sediment. Coho Salmon juvenile rearing in the mainstem Upper Eel River can occur during winter, and those individuals exposed would likely suffer high levels of mortality. However, most juvenile rearing occurs in tributaries, and therefore most individuals would not be in the mainstem during the fine sediment pulse and would be unaffected.

Coho Salmon smolt outmigration generally occurs from March through June. Because fine sediment release from the vertical notching alternative will likely occur during an early winter flow event, smolts would likely avoid impacts of highly elevated suspended sediment in the mainstem.

In general, the short-term impacts of high suspended sediment resulting from the vertical notching alternative on Coho Salmon are likely to result in high mortality for a small portion of migrating adults and high mortality for the few juveniles rearing in the mainstem Eel River during winter. There are several aspects of Coho Salmon life history in the Eel River watershed that would ameliorate these impacts. The broad spatial distribution of steelhead in the Eel River watershed suggests that most adults, redds, fry, and juveniles would avoid the effects of highly elevated SSCs by spawning and rearing in tributaries. In addition, recent observations of Coho Salmon in the Upper Eel River are rare and these populations are presumed to be very small or potentially extirpated (NMFS 2014), and thus there are very few, if any, Coho Salmon would potentially be impacted by fine sediment released under the vertical notching alternative.

4.3.3.2 Four-stage Alternative

The four-stage alternative would have similar impacts to Coho Salmon as for to the vertical notching alternative described above, since removal during the dry season would leave much of fine sediment for erosion during the winter high flow events and during next seasons (up to four years). In addition, the four-stage alternative would have a summer suspended sediment release. Based on the summer removal timing of the four-stage alternative, migrating adult Coho Salmon would avoid the impacts of fine sediment release. Incubating eggs and fry would avoid impacts since spawning and fry rearing occurs primarily within tributaries. Juveniles typically rear in tributaries but may occur in mainstem Eel River from October through May when water temperatures are suitable. Therefore, potentially a small component of juveniles could be exposed to high SSC (and suffer high levels of mortality) for three consecutive years if the stages of removal and fine sediment release were to occur in early fall rather than summer.

Coho Salmon smolt outmigration generally occurs from March through June. Based on the summer timing of fine sediment release from the four-stage alternative, smolt outmigration could be completed prior to increased SSC.

In general, the short-term impacts of suspended sediment resulting from the four-stage alternative on Coho Salmon are likely to result in in high mortality for a small portion of any adults migrating and high mortality for the few juveniles rearing in the mainstem Eel River during winter. There are several aspects of Coho Salmon life history in the Eel River watershed that would ameliorate these impacts. The broad spatial distribution of steelhead in the Eel River watershed suggests that most adults, redds, fry, and juveniles would avoid the effects of high SSCs by spawning and rearing in tributaries. In addition, recent observations of Coho Salmon in the Upper Eel River are rare and these populations are presumed to be very small or potentially extirpated (NMFS 2014), and thus there are very few, if any, Coho Salmon would potentially be impacted by fine sediment released under the four-stage alternative.

5 SUMMARY

Both dam removal alternatives are estimated to result in the release of substantial volumes of fine sediment, causing particularly high SSCs and likely resulting in substantial mortality for some life stages of all species assessed. Steelhead are the most vulnerable to fine sediment release due to their extended freshwater rearing that would affect multiple cohorts. Their broad spatial distribution and life history flexibility, however, would allow a large proportion of the population to avoid the peak impact of fine sediment release, which could support a quick and strong recovery following impacts. Under the vertical notching alternative, an early winter (i.e., November through January) sediment release would have a relatively low likelihood of direct impacts on most species and life stages and would be consistent with the time of year when elevated SSC occurs under natural conditions (although natural winter SSC peaks are expected to be much lower than those predicted during dam removal). The four-stage alternative includes most of the impacts of the vertical notch alternative, with the additional impacts of multiple consecutive years, and potential for fine sediment release during summer. Overall, the key opportunities to reduce potential impacts to salmonids include a dam removal approach resembling the vertical notch alternative (or tunneling alternative) that results in a single fine sediment release event over a short duration of time (i.e., days), during early winter, and coincident with naturally high flows in the watershed. In addition to the three flow thresholds (i.e., 1,000, 2,000, and 5,000 cfs) considered in the analyses above, it may also be appropriate to consider a higher flow threshold (greater than 5,000 cfs) for initiating rapid dam removal and fine sediment release, with the understanding that the probability of occurrence decreases with increasing flow, and the occurrence timing may shift. Potential benefits to using a higher flow threshold include reducing the duration of exposure and lower predicted impacts to focal species. In addition, higher tributary flows could increase availability of relatively low-SSC refuge habitat at tributary confluences.

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Attachment D – Feb. 21, 2019, *Significant Dam Safety (and Water System Reliability) Issues at Potter Valley Project's Scott Dam Have Yet to be Addressed*, By Scott Greacen,
Friends of the Eel River Conservation Director

Significant Dam Safety (and Water System Reliability) Issues at Potter Valley Project's Scott Dam Have Yet to be Addressed

By Scott Greacen, FOER Conservation Director

The Potter Valley Project's (PVP) Scott Dam presents a range of potentially serious questions of safety and reliability.

Given the significance of the risks associated with Scott Dam and the Lake Pillsbury reservoir, proponents of keeping Scott Dam in place must bear the burden of showing it can safely be kept in place for additional decades.

PG&E has now abandoned its effort to relicense the PVP, indicating that the utility will not carry that burden of dam safety going forward, even if it could.

The failure of the Federal Energy Regulatory Commission (FERC) to address dam safety issues as part of the PVP relicensing process has deprived stakeholders and the public of information and analysis critical to assessing the potential utility, and liabilities, of Scott Dam and the Potter Valley Project as a whole.

FERC claims that its dam safety program assures the safety of Scott Dam and other federally licensed hydropower projects. However, the Oroville Dam crisis has raised grave questions about the adequacy of FERC's dam safety inspection and review program.

The classification of most dam safety related information as closely restricted Critical Energy Infrastructure Information (CEII) has contributed to the difficulty of holding PG&E and FERC accountable for their failures to fully address dam safety issues, at Scott Dam and elsewhere. CEII information restrictions also make it more difficult to show that Scott Dam can, in fact, be safely left in place.

In the following briefing document, Friends of the Eel River attempts to summarize the known dam safety and reliability issues that may affect Scott Dam and the Lake Pillsbury reservoir. Contact scott@eelriver.org for more information.

Scott Dam Has Some Serious Issues

Safety concerns around the Potter Valley Project focus primarily around Scott Dam. This is both because the 130-foot-tall concrete structure presents a number of scenarios in which dam failure may be possible, and because the potential consequences of those scenarios include significant loss of life, harm to property, and environmental damage.

The central question for Scott Dam is its capacity to withstand a significant seismic event. Earthquakes and the faults that produce them were very poorly understood when the dam was constructed in 1921. Today, we know the dam was built within miles of the most active part of the Bartlett Springs Fault.

While active research into the Bartlett Springs Fault is ongoing, one of the two current models for the fault suggests it may be capable of producing seismic events up to magnitude 7.25. Even significantly smaller earthquakes could threaten Scott Dam, by any of several mechanisms of potential failure (i.e., by direct collapse, via uplift pressures, or by triggering collapse of the landslide above the southern abutment.)

As well, there are other aspects of the PVP and its operations which raise questions of safety, reliability, and harm to the environment and public health. These include the sediment accumulating in the Lake Pillsbury reservoir, as well as the level of methylmercury in the reservoir and those sediments.

An Unsafe Dam is an Unreliable Water Supply

Dam safety matters to downstream residents on the upper mainstem Eel River. If Scott Dam fails, they'll have minutes to evacuate. But the potential instability of Scott Dam is also a problem for people on the Russian River side of the divide who depend on Eel River diversions.

An unsafe dam is also an unreliable water supply. A practical approach to Scott Dam's safety problems thus must consider not only the costs associated with preventing (or, far worse, cleaning up after) dam failure – it must also estimate the likelihood of each of potential failure modes. Scott Dam appears to present relatively numerous and likely modes of failure, expensive but uncertain options for failure prevention, and potentially ruinous liabilities.

Water supplies are important, and we invest public monies to develop and safeguard them. But even water is not infinitely valuable. We have a ready example of a dam that was just upgraded to safely handle a magnitude 7.2 earthquake: the Calaveras Dam, serving San Francisco, which was reconstructed at a cost of about $820 million. Even high estimates of the value of Eel River water to the Russian River would not support such capital expenditures.

As a water supply project, PVP should be understood as aging infrastructure, with the attendant increase in risks and costs. It is a relatively brittle system, subject to steadily increasing physical stresses.

FERC's Dam Safety Program is Opaque and Appears Inadequate After Oroville

Unfortunately, dam safety issues are not particularly easy for reporters, policy makers, and citizens to understand. Worse, the systems we have put in place to address questions of dam safety do little to make such questions — and their possible answers — easier to grasp. The routine practices of state and federal dam regulators obscure even severe threats, and make it difficult to get even basic information about the safety issues confronting a given dam.

When PG&E began the formal process to relicense the Eel River dams which it has now abandoned, conservationists urged FERC to require PG&E to evaluate problems implicating the safety and stability of Scott Dam, and thus the reliability of the PVP as a hydropower and water supply system. FERC responded that it does not consider dam safety in relicensing.

FERC's own panel of experts, convened to review the failure of its dam safety program to prevent the near-collapse of the Oroville dam emergency spillway, concluded that what were intended to be safety programs had turned into compliance programs that merely monitored information submissions.

The panel found that FERC's safety inspections are "cursory," rather than looking deeply into the dam's original design specifications or technical reports about the site's soils and geology. FERC's after-Oroville panel also specifically noted that the "overall lack of rigor" in FERC inspections could signal problems at other FERC-regulated dams. It cited dam safety incidents tied to shortcomings that similarly went undetected. "Therefore, it should be noted that this oversight appears to be of a systematic or cultural nature that needs to be somehow overcome through direction by FERC to motivate dam owners to dig deeper for a better understanding of their structures and operational risks."

The panel emphasized that all dam safety reporting should be based on engineering analyses, record keeping, and monitoring data, rather than relying on previous records. It also called for establishment of a new FERC dam safety engineering review board. To date, FERC has not responded.

Critical Dam Safety Information is Tightly Restricted, to the Detriment of Actual Dam Safety

The problems around dam safety are not limited to inadequate inspections and superficial reviews. Nearly every detailed document with any relationship to dam safety is classified as Critical Energy Infrastructure Information (CEII) and shielded from public view, on the theory that such secrecy is necessary to prevent the US energy infrastructure from potentially crippling terrorist assaults. A little-known aspect of the post 9/11 Homeland Security Act of 2002, CEII classification puts a thumb on the scales of information power, favoring already powerful utility corporations and the regulatory agencies, and keeping the press, the public, and public interest groups from even compiling basic facts about the safety and reliability of dams like Scott Dam.

Too Many Questions, Not Enough Daylight

The failure of PG&E and FERC to publicly address pressing questions of dam safety and water system reliability distorts the public conversation around the future of the Potter Valley Project.

Any entity suggesting Scott Dam be left in place at this point should be prepared to address the following issues in specific detail.

In the absence of a comprehensive and public review of the safety and reliability issues raised by Scott Dam, any proposal to maintain the status quo should be understood as an implicit demand that California taxpayers bear the burden of potential dam failure.

Public Safety and Reliability issues associated with the Potter Valley Project's Scott Dam and Lake Pillsbury Reservoir

1) Design

Scott Dam was originally designed to run straight across the Eel River Canyon. However, during construction, in the winter of 1920, high flows resulted in a very large boulder – previously assumed to be bedrock – falling down into the river channel. In response, dam builders re-designed the dam with a sharp bend near its southern abutment, to go around the rock now known as "The Knocker."
Annotated photos taken during dam construction are available here.

Potential action: Expert assessment of original and as-constructed designs.

2) Construction

In a Feb 21, 1921 memorandum to the California Railroad Commission, predecessor to today's Division of Dam Safety, a commission engineer recorded a report from San Francisco's City Engineer, Michael O'Shaughnessy (developer of the Hetch-Hetchy water system). The memo reports that O'Shaughnessy "said, in essence, that *he had been at the site and was alarmed by what he had seen of the method and character of the work done in the construction of the dam and that he seriously questioned the safety of the structure*."

Potential Action: Expert assessment of Scott Dam structure in view of concerns about original construction techniques and materials.

3) Foundation

Among the concerns with Scott Dam's construction are the quality of the rock to which it is anchored and the potential for uplift pressures from the immense mass of water impounded in the reservoir to detach the dam from its foundations. Unfortunately, the piezometers in the base of the dam, which PG&E has relied on to provide data on those uplift pressures have largely failed. PG&E now must install a new network of sensors before reliable data on uplift pressures can be generated for analysis. Letter to FERC here.

Potential Actions: Install new piezometer system. Further investigation.

4) Aging Structure

Following the Oroville Dam crisis, UC Berkeley dam safety expert Dr. Robert Bea specifically recommended FERC develop additional criteria to assess the safety of aging structures. A number of reports filed by PG&E with FERC are suggestive of issues that may be associated with an aging structure. These include decaying concrete, cracks in the structure, pipes with unknown connections, spraying leaks, and the vulnerability of the dam's only low-water outlet to sediment buildup increasing behind the dam.

Potential action: Expert assessment of dam structure, using updated standards for aging structures.

5) Landslide above Southern Abutment

The ancient landslide that brought "The Knocker" down in 1920 is still active today. In 2018, Friends of the Eel River commissioned Miller Pacific Engineering to conduct a study of the slide, its potential movement in response to disturbances including heavy rainfall and seismic activity, and the possible consequences of the slide's movement for the dam below. In summary, MPE found the slide is very likely to move in response to the kind of seismic activity that can reasonably be anticipated for the area, especially if the area is saturated by heavy rainfall. The firm suggested the resulting stresses on Scott Dam require further study.

Potential Action: Engineering analysis of Scott Dam's capacity to survive significant movement of the landslide.

6) Bartlett Springs Fault

When Scott Dam was built, plate tectonics was still a half-baked idea. In the century since, we have come to understand how faults generate earthquakes. And we have mapped the Bartlett Springs Fault. Traces of the Bartlett Springs fault lie under the Lake Pillsbury reservoir within a few miles of Scott Dam. The SFPUC is now completing the reconstruction of the Calaveras Dam to survive a magnitude 7 earthquake from the nearby Calaveras fault. The new, earthen structure cost $823 million to build.

Potential Action: Public analysis of the potential for seismic events and ground motion affecting Scott Dam and engineering analysis of the dam's capacity to survive such events.

7) Sediment Buildup in Lake Pillsbury Reservoir

Sediment buildup threatens the safe operation of Scott Dam because the only way to release water from the reservoir when water levels fall below the crest of the dam is a needle valve located near the bottom of the dam. Sediment buildup next to the dam in the reservoir threatens to bury the intake of the needle valve. Were this to occur, the needle valve could be damaged, destroyed, or obstructed, which could make it impossible to release water from Scott Dam for conveyance to Potter Valley or for downstream flows on the Eel.

As well, sediment buildup can have consequences for dam safety. Sediment buildup can change the physical pressures on dam structures, and may result in increased vulnerability to seismic events, because of the increased load of sediment deposits against the upstream face of the dam. Similarly, the consequences of dam failure for a reservoir with a lot of accumulated sediment may be more destructive than a flood alone.

Potential Action: Engineering analysis of Lake Pillsbury reservoir sediments in view of updated bathymetry.

8) Methylmercury Accumulation in Lake Pillsbury Reservoir and Sediment

In addition to the physical threat it poses to reservoir storage and dam function, sediments in the Lake Pillsbury reservoir may contain levels of highly toxic methylmercury that are dangerous to public health and wildlife.

Elemental mercury is present in some parent rock in the Eel River basin and deposited from atmospheric sources; as well, a mercury mine was located close to the Lake Pillsbury reservoir. However, the elemental form of mercury is less dangerous than the methylated form, which can be more easily absorbed by life forms, tends to bioaccumulate up food chains, and has been linked to a range of harms in many different life forms. The Lake Pillsbury reservoir, which like many reservoirs becomes eutrophic as its upper layer warms and its lower layer becomes anoxic, provides the setting in which anaerobic bacteria methylate mercury in reservoir sediments and become the means by which that methylated mercury begins to accumulate in the food chain. Mercury poses clear risks for birds, wildlife and humans which eat fish that contain mercury.

Fish taken from Lake Pillsbury show high concentrations of mercury, including the highest concentration for an individual fish in statewide sampling. Lake Pillsbury is designated as impaired for mercury under the Clean Water Act.

FERC refused to require PG&E to assay mercury levels in the Lake Pillsbury reservoir, stating that mercury is also "a dam removal question." Clearly, however, it is also a public health and wildlife health question, and just as clearly, it is an effect of the dam and its reservoir on the environment.

Action: The Coastal Conservancy has now funded a study.

9) Unreliable Safety Inspections and Review Processes

Following the near-collapse of the Oroville Dam (a structure built in 1964), a board of independent safety consultants called for a re-examination of the Federal Energy Regulatory Commission's (FERC) dam safety inspection and review process. That process of annual inspections and five-year reviews failed entirely to predict or prevent the developing hazards of the Oroville Dam's spillway, even though conservationists had raised precisely those questions in the still-ongoing FERC relicensing of that dam.

In PG&E's now-abandoned relicensing effort for the Potter Valley Project, including Scott Dam, FERC flatly denied requests by conservationists that dam safety issues be addressed. Dam safety, we are told, isn't considered in relicensing. FERC has further declined to provide any legal or regulatory support for this policy.

Potential Action: Independent Expert Review of Scott Dam Safety as Aging Structure.

10) Access to Critical Energy Infrastructure Information (CEII)

Nearly every detailed report from PG&E to FERC on any matter having to do with dam safety is restricted from public view by being classified as CEII — information that must be kept from the public, lest it be used by terrorists purportedly focused on destroying the US electrical grid. This system of information control makes it nearly impossible for the press, the public, and even elected officials to assess the adequacy of PG&E, FERC, and DSOD's dam safety actions. It does, however, make it easy for utilities and agencies to conceal even basic facts that should be central to discussions about the future of Scott

Dam and the Potter Valley Project. Congress should reconsider the utility of CEII classification for hydroelectric projects, weighing the harm to the public interest in meaningful dam safety regulation in light of the evident disinterest of international terrorist conspiracies in sabotaging American dams.

Potential Action: PG&E could release at least some documents now labeled CEII. Congress could revise CEII rules to allow effective review of dam safety and environmental impacts issues.

11) Emergency Action Plan

Among the documents which can only be accessed by signing a Non-Disclosure Agreement is PG&E's Emergency Action Plan for response to dam failure or other public safety incidents involving the Potter Valley Project. Thus, downstream residents directly implicated by the potential failure of Scott Dam can only learn the details of the Emergency Action Plan by promising not to talk about the plan to anyone, including their neighbors. Similarly, a citizens' group like Friends of the Eel River could only learn what's contained in the Emergency Action Plan by betraying our responsibility to educate the public and policy makers.

Potential Action: Prepare a public Emergency Action Plan on the basis of public information.

Attachment E– Letter to FERC from Friends of the Eel River (June 30, 2023) related to seismic safety and other concerns about Scott Dam and Lake Pillsbury

FRIENDS OF THE EEL RIVER

Working for the recovery of our Wild & Scenic River, its fisheries and communities.

Friday, June 30, 2023

Federal Energy Regulatory Commission
888 First Street. NE
Washington, DC 20426

via e-filing (FERC Docket No. P-77)

Re: Lake County Comments of April 3, 2023; the operation and future of Scott Dam and the Potter Valley Project

Dear Commissioners and staff,

The Lake County, California Counsel filed comments in this docket[1] on April 3, 2023 responding to PG&E's March 17 Dam Safety Compliance Report. Lake County's comments do not accurately reflect the facts at hand, nor the processes underway, with respect to Scott Dam and the Potter Valley Project.

Lake County Misunderstands Actions Taken to Protect Public Safety

Lake County construes PG&E's decision not to raise Scott Dam's slide gates as an attempt

> *"… to determine the future of the Lake Pillsbury Community, the economic factors which influence the County of Lake's recovery after a prolonged and destructive pandemic, what is allowed to exist in the County's ecosystem, and the very access to an available water source in a county plagued for years by drought and wildfire."*

Lake County provides no evidence for these claims. There is, however, a simpler explanation which fits the known facts — that PG&E is responding to new information about dam safety risks with an action intended to protect public safety.

PG&E's March 17 report, filed with the Commission's Division of Dam Safety and Inspections, includes a memorandum which the public cannot view because PG&E has classified it as Critical Energy Infrastructure Information (CEII). As we have previously noted, the overclassification of dam safety information as CEII presents a serious and unnecessary barrier to public understanding of the risks associated with America's aging hydroelectric dams. Many dams across the American West were, like Scott Dam, situated on

[1] *Comments of County Counsel for the County of Lake regarding PG&E's March 17, 2023, Dam Safety Compliance Report under P-77*, FERC accession number 0230403-5105.

FRIENDS OF THE EEL RIVER
707.798.6345 • foer@eelriver.org
PO Box 4945, Arcata, CA 95518

faults, because places where rivers cross faults often present, like the upper Eel, a narrow canyon downstream of a reach with substantial floodplain.

From PG&E's description, we understand that the memorandum presents the results of a simplified, two-dimensional seismic stability analysis of Scott Dam prepared by engineering consultant Gannett Fleming, Inc. (Gannett).[2] Lake County argues that "PG&E is attempting to leverage a 'simplified seismic analysis' to justify what was announced as a permanent lowering of the gates, even though the more rigorous seismic analysis has not yet been completed."

Lake County's skepticism of the Gannett memorandum was not shared by the California Division of Safety of Dams (DSOD). An April 12, 2023 letter from DSOD to PG&E's Chief Dam Safety Engineer, David Ritzman, clarifies that the Gannett "study is part of Pacific Gas and Electric Company's (PG&E) ongoing reevaluation of the dam that was initiated in response to DSOD's letter dated January 22, 2021, to address potential dam safety concerns."

DSOD further notes that it has **barred** PG&E from operating Scott Dam with the gates raised:

> *Based on dam safety, DSOD concurs with PG&E's proposed 10-foot reservoir restriction as an interim risk reduction measure.* ***Therefore, DSOD is restricting the year-round operation of the reservoir of Scott Dam to Elevation 1900.00, the spillway crest****, which is 24.58 feet below the dam crest. This reservoir restriction may be revisited as conditions warrant and will remain in effect until PG&E receives DSOD's written approval authorizing a different level of reservoir storage.* (emphasis added)

As PGE noted in its March 17 letter, the purpose of the two-dimensional analysis is "… to provide an initial understanding of the expected performance of the dam under updated seismic loading conditions ..." PG&E further explained that the "(s)eismic loads used in the analysis are developed from PG&E's recently completed deterministic seismic hazard study (dated December 2021)."

The Bartlett Springs Fault Will Produce Very Large Earthquakes, to which Scott Dam Appears Especially Vulnerable.

It has been clear for some years that the Bartlett Springs Fault, which passes directly underneath what is now the Lake Pillsbury reservoir, is capable of producing earthquakes significantly larger and more damaging than those recorded to date in Scott Dam's vicinity. As Lozos et al. noted in their 2015 publication, *Dynamic rupture models of earthquakes on the Bartlett Springs Fault, Northern California*, ***"… ground motions generated by a (Bartlett Springs Fault) earthquake may be sizeable… Our models produce a wide magnitude range: from M6.32 to M7.24…"***[3] (emphasis added).

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[2] Scott Dam Simplified 2-D Stability Evaluation (CWA 2700755491 FCA No. 2), Gannett Fleming Project No. 070867, prepared by Gannett Fleming and dated March 14, 2023.

[3] Lozos, J. C., R. A. Harris, J. R. Murray, and J. J. Lienkaemper (2015), Dynamic rupture models of earthquakes on the Bartlett Springs Fault, Northern California, *Geophys. Res. Lett.*, 42, 4343–4349, doi:10.1002/2015GL063802.

FERC's docket for the Project includes a number of filings related to assessing seismic risks at Scott Dam. See for example *Potter Valley Hydroelectric Project (FERC No. 77) 30-Day Follow-up Report on Earthquake Incident*, September 8, 2016, which documents a magnitude 5.1 earthquake approximately 10 miles southeast of Scott Dam that occurred on the evening of August 9, 2016.[4] PGE's subsequent *Potter Valley Project Annual Operations Inspection Follow-up Response*,[5] dated November 21, 2016, shows that following the August earthquake, an inspection revealed multiple new cracks and a spraying leak on the dam's face.

Considerably more detail regarding seismic risk assessment can be found in an August 31, 2020 filing, *Potter Valley River Hydroelectric Project, Scott Dam, Plan and Schedule to Address Recommendations in FERC Independent Consultant 2019 Safety Inspection Report*,[6] in which PG&E responds to FERC's recommendation R-6 as follows:

R-6. It is recommended that stability analyses of the dam for earthquake loading up to the MCE be performed using up-to-date methods of analysis. The loading should be consistent with the 2017 seismic hazard update for the dam site (PG&E, 2017b), once this study is accepted by FERC. The stability analyses should include analysis of the principal tangent and the dogleg tangent of the dam (left abutment area, including the pinnacle). The stability analysis should include predictions of stability and displacement for the dam and consider: a) the seismic response of the structure and representative base uplift conditions, b) stress nonuniformity and potential cracking at the dam base, and c) the stability of the left abutment area and downslope rockfill buttress and upslope left abutment landslide (see PFM No. 3 in Section 3.2.3 and Section 7.8.4). Additional recommended stability analysis of the downstream left abutment area is described in more detail under Recommendation R-29 below.

Response: *Loading conditions for the recommended stability analyses are dependent on the results of PG&E's 2017 seismic hazard studies, which PG&E is currently updating to address FERC review comments. After FERC has accepted the seismic hazard parameters for the site, PG&E plans to update its seismic stability analyses for Scott Dam in accordance with the following general steps:*

- *Develop an updated structural model of the dam and perform stability analyses for normal loading conditions.*
- *Using results of the accepted seismic hazard studies, model the seismic response of the structure and evaluate representative base uplift conditions.*
- *Perform seismic stability analyses of the dam for earthquake loading up to the maximum credible earthquake (MCE) using up-to-date analytical methods and tools. Analyze both the principal tangent and dogleg sections of the dam.*
- *Evaluate the seismic stability of the dam's left abutment area, including the downslope rockfill buttress (see R-29) and upslope left abutment landslide for earthquake loading up to the MCE. Based on the results of these studies, evaluate the potential effects of*

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[4] FERC accession no. 20160908-5213, document title *PGE2016-0908_PV 30Day FU Rpt Earthquake Incident.*

[5] FERC accession no. 20161121-523, document title *PGE2016-11-21_PV_AnnualOpsInspection_FollowUpResponse.*

[6] FERC accession no. 20200831-5429**,** document title *PGE2020-0831_77_Scott_P12_PS_2019SafetyInspection.* (Remarkably, this previously public document is now inaccessible on FERC's website.)

seismically induced ground movement on the stability of the dam during or immediately after the earthquake.

PG&E believes that the recommended stability analyses may take several years to complete, depending on the time and effort required to conduct prerequisite studies and develop the necessary structural models. PG&E plans to perform the stability analyses in conjunction with updated analyses for flood loading conditions (see R-4).

Assuming FERC accepts the results of PG&E's seismic hazard analysis by early 2021, PG&E plans to complete preliminary stability analyses of the dam structure and left abutment slopes (upstream and downstream) by the end of 2021. Upon completion of the preliminary analyses, PG&E will provide the results to the Part 12D IC for review. In consultation with the IC, PG&E will identify appropriate next steps to finalize the seismic stability evaluation. By February 28, 2022, PG&E plans to submit to FERC a plan and schedule to finalize the recommended stability analyses. Alternatively, if FERC acceptance of the seismic hazard study is delayed, PG&E will submit by October 31, 2021, an updated schedule for addressing R-6.

Similar language appears with respect to other portions of Scott Dam in the document. In short, while seismic hazards may have been underestimated in the past, they are hardly a novel question for Scott Dam. As the above excerpt shows, PG&E outlined its process for reassessing the safety of Scott Dam three years ago.

Imagery ©2023 CNES / Airbus, Maxar Technologies, USDA/FPAC/GEO, Map data ©2023 100 ft

Factors relevant to Scott Dam's vulnerability to seismic events have long been apparent, and indeed are clearly evident in the enclosed illustration. These factors include the 'dogleg' southern abutment of the dam referenced in FERC's recommendation R-6 above. Scott Dam had been planned to go straight across the river, a stronger configuration. But the helpful extrusion of bedrock to which builders had planned to anchor their dam proved to be a giant boulder, referenced above as 'the pinnacle.' The boulder slid down the southern side of the canyon during dam construction. Builders chose to construct the southern portion of the dam in front of the boulder, at an angle to the rest of the dam. That southern abutment of Scott Dam rests against a slope below the dam that has been showing signs of instability for years.

As a study by Miller Pacific Engineering Group commissioned by Friends of the Eel River demonstrated in 2018, the slope above Scott Dam that shifted when the pinnacle moved during dam construction is an ancient landslide, which has been moving continuously for decades, and appears vulnerable to catastrophic collapse in a big storm or a significant earthquake.[7] As well, the Miller Pacific report notes that the buildup of sediment against Scott Dam's upstream face appears to present an additional factor of potential seismic risk, as is common in aging dams.

In recent years, it has become clear that the amount and the configuration of sediment that has accumulated in the Lake Pillsbury reservoir threaten Scott Dam's ability to supply water to the rest of the Potter Valley Project. Sediment buildup around the upstream inlet to the needle valve that is Scott Dam's only low-level outlet presents an ever-increasing risk of clogging the valve, rendering the dam and the entire Potter Valley Project nonfunctional and uneconomic to repair. Meanwhile, the reservoir cannot be drained too quickly, or fully emptied, lest the piled sediments collapse, with the same effect: a clogged needle valve and an end to releases from Scott Dam.

To summarize, there are a number of compelling publicly known reasons to be concerned about seismic safety at Scott Dam, particularly given that it is a poorly constructed, aging dam never engineered to handle the stresses we now know it would be subject to when a significant quake occurs on the Bartlett Springs Fault. To our knowledge, Lake County has yet to evince concern regarding these hazards.

Dam Safety Isn't the Only Threat to Public Safety the Potter Valley Project Poses

Nor does the County appear to have addressed public safety risks associated with very high mercury levels in the Lake Pillsbury reservoir's fish. As PG&E noted in its 2017 Pre-Application Document filed with FERC,

> *Sampling of fish tissue taken from Lake Pillsbury fish has detected **high concentrations of mercury**, averaging 1.31 parts per million (ppm) in 350 millimeter (mm) largemouth bass (*Micropterus salmoides*), and **the highest concentration for an individual fish** (4.08 ppm in a 559 mm largemouth bass) in statewide sampling (Davis et al. 2009). Consequently, Lake Pillsbury is designated as impaired for mercury on the California 303(d) list.* (page 5-34, emphasis added)

These mercury levels are the consequence of the constant raising and lowering of the reservoir, an effect not observed in natural lakes. Lake County does not appear to have

[7] The Miller Pacific report can be found at https://eelriver.org/wp-content/uploads/2018/09/Miller-Pacific-Technical-Memo-re-Scott-Dam.pdf.

taken any steps to protect its citizens and visitors from mercury poisoning incurred by consuming fish caught in the Lake Pillsbury reservoir.

Lake County Does Have Other Water Sources for Wildfire Protection

Lake County's also expresses concerns regarding the availability of water to fight wildfires should the level of the Lake Pillsbury be lowered or Scott Dam removed. The County claims to have "lost 60% of its land mass due to wildfire," and asserts there are "no comparable alternative sources for additional water" should Scott Dam be removed. The County writes that "wildfire risks of this measure should not be imposed on the County of Lake." The County cites no evidence that removal of the Lake Pillsbury reservoir will present additional wildfire risks.

In fact, the 2018 Ranch Fire, at the time the largest fire in California's history, burned southeast of the Project notwithstanding the presence of the Lake Pillsbury reservoir. However, most of the Ranch Fire and the same year's River Fire were significantly closer to 68 square mile Clear Lake than to the Pillsbury reservoir, which never exceeds 3.6 square miles in surface area. It is in no way clear that removing Scott Dam would reduce any entity's ability to address wildfire risks in Lake County given the existence of Clear Lake, a fact of approximately 22 million years' duration.

Rather, there is good reason to believe that dam removal not only can but will result in significant improvements in wildfire resilience for the areas of Lake County around the Pillsbury reservoir. For example, as part of the Klamath dam removal arrangements, local communities have been made significantly more resilient to wildfire than they were previously. Lake County and the Commission should note the fire management plan filed with FERC as part of the Klamath dam removal.[8] It includes provision of water access points, firefighting vehicles and equipment, and improvements to emergency communications. We anticipate a similar plan will be implemented with the removal of the Potter Valley Project dams.

Scott Dam will be removed, and the Potter Valley Project decommissioned. What further stake does Lake County have in Cape Horn Dam?

Beyond the specific concerns expressed, however, there looms in Lake County's letter an overarching assertion that "its communities, its ecosystem, and its safety from wildfires" are placed at risk by PG&E's decision to address the seismic safety of Scott Dam, and by implication, by the pending removal of Scott Dam. Lake County has made it clear that it would prefer Scott Dam and the Pillsbury reservoir remain in place. Unfortunately, it continues to misrepresent the facts around the Project in service of that preference, to the detriment of public understanding of the choices actually at hand. In reality, Lake County is the least affected of the counties touched by the Project, drawing no water at all for irrigation use from the Eel River.

[8] https://klamathrenewal.org/fire-management-plan/.

And Scott Dam removal is now a certainty. The new understanding of the threat the Bartlett Springs Fault poses to Scott Dam only crystallizes the already-overwhelming evidence that Scott Dam cannot and will not be kept in place. In addition to the sediment issues noted above, PG&E has confirmed that it will not replace the transformer which failed in the PVP powerhouse in the summer of 2021. As the Commission is aware, PG&E is expected to submit its draft decommissioning plan for the Project by November of 2023.

Thus, to the extent there remains a significant question regarding the future of Potter Valley Project facilities, that question appears to be whether Cape Horn Dam will be removed with Scott Dam. It is not clear Lake County is in any way affected by the presence and operation of Cape Horn Dam, nor that Lake County would be impacted in any way by the removal of Cape Horn Dam.

Dam Removal Will Directly Benefit the Upper Eel River Watershed in Lake County

Lake County also stands to benefit dramatically from removal of the Eel River dams and recovery of Eel River salmon and steelhead. While Scott Dam lacks any provision for fish passage, a recent study by NMFS scientists shows that the Upper Mainstem Eel River above Scott Dam

> *… could likely support populations of winter-run steelhead, summer-run steelhead, and fall-run Chinook salmon based on the amount of thermally and geomorphically suitable habitat for multiple freshwater life stages during warm months and during drought. …In a similar system, multiple anadromous salmonid populations have recolonized – both naturally and with human assistance – the Elwha River in Washington since the removal of the Elwha Dam, which had been in place for over 100 years (Bellmore et al. 2019, McMillan et al. 2019). … Based on our evaluation of the quality and quantity of suitable habitat and potential capacity, enabling access to the blocked Upper Mainstem subbasin would be comparable to adding another Van Duzen subbasin to the Eel River Basin.*[9]

Removing the Eel River dams and allowing the recovery of salmon and steelhead in the upper Eel River would provide significant and lasting benefits to Lake County, just as it will to other Eel River communities. Salmon and steelhead are keystone species, providing vital nutrients in their upstream migrations which feed entire ecosystems.

Before Scott Dam was built, the southernmost run of summer steelhead on Earth ran up the Upper Mainstem Eel. Recent studies have confirmed that rainbow trout, the freshwater form of steelhead, trapped above Scott Dam for the last century, still have the genes which

[9] FitzGerald et al, Physical and biological constraints on the capacity for life-history expression of anadromous salmonids: an Eel River, California, case study, *Canadian Journal of Fisheries and Aquatic Sciences*, 4 December 2021, https://cdnsciencepub.com/doi/full/10.1139/cjfas-2021-0229.

could allow that run to return from extinction.[10] Lake County can take great pride in sheltering this extraordinary, endangered species.

Given the increasing weight of evidence that Scott Dam should be removed as soon as feasible, we cannot support Lake County's demands to dictate the future of the Potter Valley Project or its constituent dams. We understand that change is difficult, but we urge Lake County citizens and leaders to seize the opportunities ahead. We sincerely believe that Lake County, like the rest of the Eel River watershed, will be better off following removal of the Eel River dams.

Thank you for your patient attention.

Sincerely yours

/s/
Scott Greacen
Conservation Director

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[10] See https://eelriver.org/wp-content/uploads/2022/10/On-the-Ecology-and-Distribution-of-Steelhead-in-Californias-Eel-River-Kannry-2020.pdf.

Attachment F – Brown and Ritter (1971), *Sediment Transport and Turbidity in the Eel River Basin, California*

Sediment Transport and Turbidity in the Eel River Basin, California

By WILLIAM M. BROWN III *and* JOHN R. RITTER

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1986

Prepared in cooperation with the California Department of Water Resources

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1971

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

W. A. Radlinski, *Acting Director*

Library of Congress catalog card No. 74–174753

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 50 cents (paper cover)
Stock Number 2401–1142

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SEDIMENT TRANSPORT AND TURBIDITY IN THE EEL RIVER BASIN, CALIFORNIA

By WILLIAM M. BROWN III and JOHN R. RITTER

ABSTRACT

The Eel River has the highest recorded average annual suspended-sediment yield per square mile of drainage area of any river of its size or larger in the United States. This yield, in tons per square mile, is more than 15 times that of the Mississippi River and more than four times that of the Colorado River. The erosion rate in the Eel River basin is a major watershed-management problem.

This study was made by the U.S. Geological Survey to determine the quantity of sediment transported by streams in several areas of the Eel River basin, California. Sediment-discharge data were collected at 22 locations within the basin for various periods between 1955 and 1967. The destruction of some stations by flooding and the establishment of new stations precluded continuous records for all stations for the 12-year period. Other characteristics of the streams and the basin pertinent to sedimentation have been employed to provide complementary information to the sediment records and to aid in the analysis of sedimentation.

The Eel River basin is underlain almost entirely by the sedimentary rocks of the Franciscan Formation. Regional uplifting and faulting of these rocks have produced a rugged topography characterized by steep slopes and narrow canyons which trend northwesterly parallel to the zones of weakness associated with the faulting. Weathering of the Franciscan Formation has produced moderately deep loamy soils which are highly erodible.

The climate of the basin is one of the wettest in the State of California. Throughout the winter months, heavy rains fall during intense storms of moderate duration and produce about 9 percent of the annual runoff in the State, although the basin occupies only 2 percent of the State's land area. The coastal region of the basin is generally cool and foggy, while farther inland, temperatures are more variable and average precipitation is lower. Snow falls in the higher elevations in the eastern part of the basin, but runoff from snowmelt is minor.

The combination of geology, soil types, steep slopes, and heavy precipitation produces slumps and landslides which contribute heavily to the sediment yield of the basin. In the places where landslides are adjacent to the stream channels, sediment production is consistently higher than in other areas. Landslides occur most frequently in the Middle Fork Eel River basin and along the slopes of the main stem of the Eel River in the central part of the basin.

Average annual rainfall in the basin is about 59 inches, and average annual runoff is about 35 inches. Most runoff occurs during and shortly after the late fall and winter storms. Because of the impermeability of the soil and mantle rock, base flow is poorly sustained. Precipitation during winter storms is generally extensive over the entire basin; thus, unit runoff is not extremely variable from point to point in the basin.

During the 10-year period beginning October 1957, the Eel River discharged an average suspended load of more than 31 million tons per year according to measurements made at Eel River at Scotia, the station farthest downstream on the main stem of the Eel River. An additional suspended-sediment discharge averaging more than 1½ million tons per year during the same period was derived from the basin of the Van Duzen River, a tributary which enters the Eel River a few miles downstream from Scotia. All parts of the basin contributed to the suspended-sediment discharge at Scotia, although about two-thirds of the material came from the central one-third of the drainage area. The Eel River above its confluence with the Middle Fork Eel River contributed about 6 percent of the annual suspended load at Scotia, and the Middle Fork drainage added about 13 percent. An additional 13 percent came from the South Fork Eel River drainage. The remaining 68 percent of the annual suspended load was derived from the main stem of the Eel River between the South Fork and Middle Fork tributaries. In this vicinity, which includes the North Fork Eel River drainage, roughly equal portions of the computed load were discharged above and below Fort Seward. Most of the suspended sediment was moved by high flows, which occurred an average of 10 percent or less of the time. With few exceptions, 50 percent or more of the annual suspended load at each station was carried in fewer than 6 days during the water year.

Emphasis is given to catastrophic flooding and record sediment discharges which occurred during the period of data collection. Floods in December 1964 and January 1965 caused a suspended-sediment discharge of 160 million tons in a 30-day period at Eel River at Scotia. This amount was about 51 percent of the suspended load computed for the entire 10-year period at that station. During this same flood period, record suspended-sediment discharges occurred at all sediment stations along the Eel River and its tributaries.

Turbidity and the concentration of suspended sediment at several stations in the Eel River basin follow a linear relation which persists throughout the range of measured values of these two variables. The trend in this relation was similar for each station during each year studied, and this indicated that turbidity may be a useful index for the estimation of sediment concentration at points within the basin.

INTRODUCTION

A Missouri physician, Dr. Josiah Gregg, named the Eel River in 1849 when his exploring party encountered a small group of Indians carrying "eels" (*lampreys*) which they had caught in the river. Settlement and development along the Eel River began within the next decade, and the basin has since become an area of forest-products industry, agriculture, and recreation. The basin, whose population is 50,000, is noted for its natural resources, the most important of which are a vast supply of water and the spectacular California Redwood Forests, within which grow some of the tallest trees in the world.

The Eel River basin is a potentially significant contributor to the water resources of California. Although the basin covers only 2 percent of the land area of the State, the average annual runoff from the basin is about 9 percent of the average annual runoff in the State. However, runoff from the basin is accompanied by a discharge of suspended sediment which is the highest per square mile of drainage basin of any river the size of the Eel River or larger in the United States.

PURPOSE AND SCOPE

The potential importance of the Eel River to the water-resources development of the State of California has led to a number of studies of the Eel River basin by State and Federal agencies. Primary water needs for human consumption, industry, wildlife, and recreation imply certain water-quality requirements, and successful planning for establishing and maintaining a water supply meeting these requirements necessitates reliable information on sediment and turbidity. Part of a study aimed at creating an effective plan of development of the basin is a cooperative venture between the U.S. Geological Survey and the State of California to study sedimentation and the turbidity characteristics of the Eel River and its tributaries. Sediment yield is of great economic importance in the effective design of reservoirs and other construction on rivers, is significant in its relation to the frequent flooding along the Eel River, and has numerous attendant problems of importance to man.

The purposes of this project are to determine the quantity of sediment transported by streams in different areas of the Eel River basin, to compare sediment yields among selected regions of the basin, and to study the relation of turbidity to the concentration of suspended sediment. The data necessary for this project were obtained from sediment stations which were established at several locations in the basin (table 1). Even though many stations were discontinued or relocated as a result of the effects of the December 1964 flood, sufficient complementary records were obtained to provide a representative analysis of sedimentation. Turbidity samples were taken at several stations between 1964 and 1968 with simultaneous sediment samples and water-discharge measurements.

This report presents and interprets the data collected for this project, along with pertinent related information. Methods of analysis of these data are described in conjunction with computations, tables, and graphs.

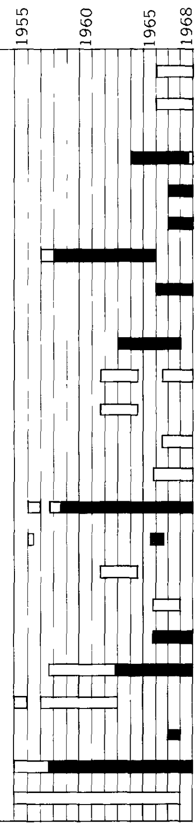
427-150 O - 71 - 2

TABLE 1.—*Periods of operation of sediment-sampling stations in the Eel River drainage basin*

Sampled daily ▬ Sampled periodically ▭

Station	Station name
11–4700	Lake Pillsbury near Potter Valley
4705	Eel River below Scott Dam, near Potter Valley
4710	Potter Valley powerhouse tailrace, near Potter Valley
4721.5	Eel River near Dos Rios
4722	Outlet Creek near Longvale
4725	Eel River above Dos Rios
4729	Black Butte River near Covelo
4730	Middle Fork Eel River below Black Butte River, near Covelo
4731	Williams Creek near Covelo
4736	Short Creek near Covelo
4737	Mill Creek near Covelo
4738	Elk Creek near Hearst
4739	Middle Fork Eel River at Dos Rios
4740	Eel River below Dos Rios
4744	Hulls Creek near Covelo
4745	North Fork Eel River near Mina
4750	Eel River at Fort Seward
4755	South Fork Eel River near Branscomb
4765	South Fork Eel River near Miranda
4766	Bull Creek near Weott
4770	Eel River at Scotia
4785	Van Duzen River near Bridgeville

Period of sampling



PREVIOUS INVESTIGATIONS

Studies of erosion and sedimentation in the Eel River basin have been a part of investigations of the northern coastal area of California since July 1958 (California Department of Water Resources, 1966, p. 2). The investigations include many aspects of development, control, and conveyance of water supplies; however, the studies of sediment within the program are more general than detailed. A report by the U.S. Department of Agriculture River Basin Planning Staff, Soil Conservation Service and Forest Service (1970), discusses recent detailed studies of soil types and erosion processes throughout the

Eel River basin. Detailed investigations of sedimentation were begun in 1957 by the U.S. Geological Survey in cooperation with the California Department of Water Resources, and information gained from these investigations has been analyzed as part of a report on the sediment yield of streams in northern coastal California (Hawley and Jones, 1969). A detailed report on many aspects of sedimentation in the Middle Fork Eel River basin is currently being prepared by J. M. Knott of the Geological Survey and will include analysis of sediment data collected since October 1957.

PERSONNEL AND ACKNOWLEDGMENTS

This report was prepared by the U.S. Geological Survey, Water Resources Division, in cooperation with the State of California Department of Water Resources as part of an investigation of the water resources of the State of California. This project was conducted under the general supervision of R. Stanley Lord, district chief in charge of water-resources investigations in California, and under the immediate supervision of L. E. Young, chief of the Menlo Park subdistrict office.

The writers wish to express their gratitude to the following individuals: C. E. Stearns, for consultation and the supply of data on soils and erosion collected by the Soil Conservation Service; G. Porterfield, J. P. Akers, B. L. Jones, and S. G. Heidel, for critical review and constructive commentary; and J. M. Knott, for providing information and computations on sediment transport in the Middle Fork Eel River, and for his review and helpful criticism of this report.

PHYSICAL SETTING

TOPOGRAPHY

The Eel River drains an area of about 3,600 square miles in the Coast Ranges of northern California and empties into the Pacific Ocean some 280 miles north of San Francisco (fig. 1). The basin is about 120 miles long, averages 30 miles in width, and is oriented in a northwesterly direction almost parallel to the Pacific coast. Regional folding and faulting have created a series of northwest-trending ridges and valleys, and a trellis drainage and erosional pattern characterizes the surface features which have formed. Elevations in the generally rugged terrain range from sea level to 7,000 feet, and the Eel River and its tributaries descend rapidly from the higher elevations in narrow, steep-walled canyons. In the coastal region south of Eureka, however, the Eel River near its delta flows in a gently sloping valley about 11 miles long that expands oceanward from 1 to 9 miles in width. Round Valley and Little Lake Valley in the southern part of

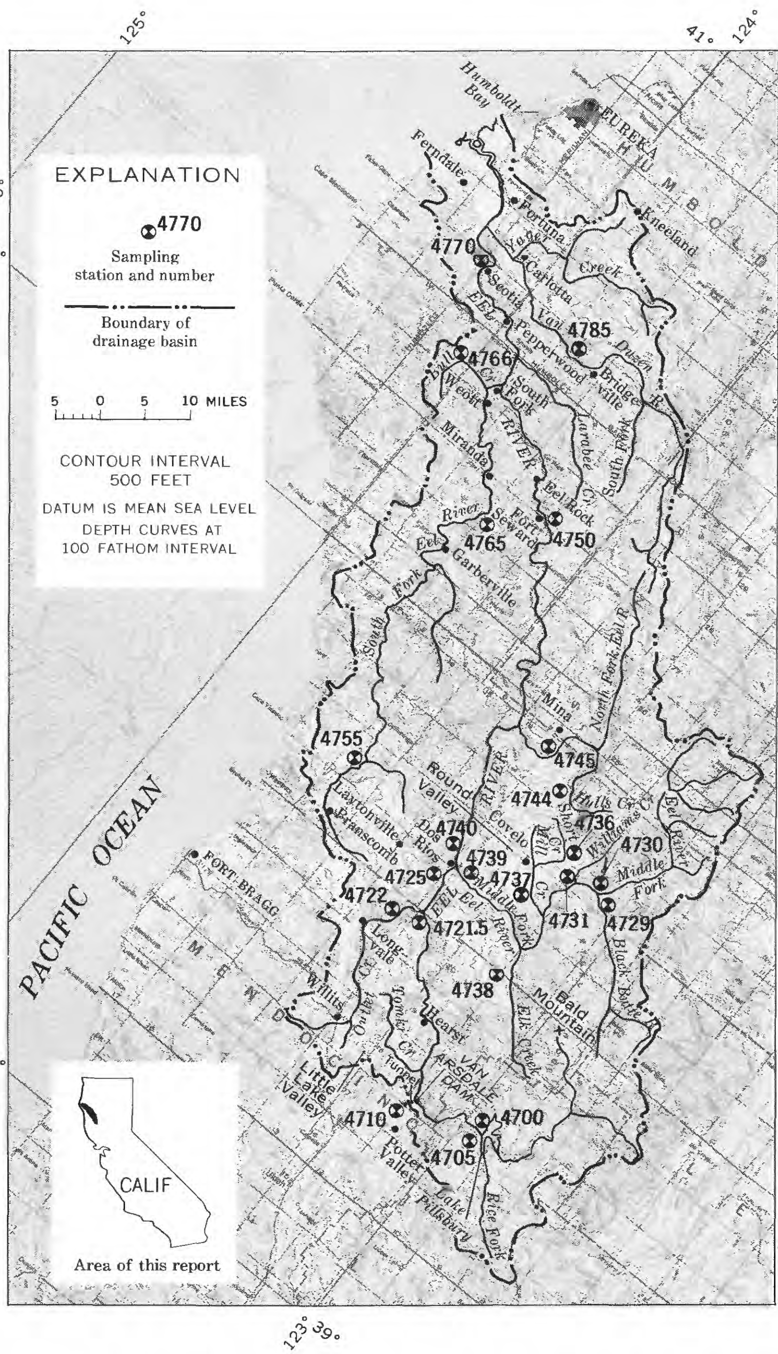


FIGURE 1.—Study area, Eel River basin. Base from U.S. Geological Survey, 1955, scale 1 :500,000.

the basin constitute the only noteworthy areas of regular topography besides the delta area. The only major surface-water features other than the rivers are Lake Pillsbury, a 2,280-acre reservior impounded behind Scott Dam on the Eel River in the southern tip of the basin, and Van Arsdale Reservoir which is just downstream of Lake Pillsbury. Cities and other manmade features constitute but a small part of the basin topography, and along with highways and railroads are confined to the lowlands along the river valleys.

CLIMATE

The climate of the Eel River basin is one of the wettest in the State of California. The average annual precipitation ranges from about 35 inches along the Pacific coast south of Humboldt Bay to more than 110 inches in the mountains southeast of Scotia (fig. 2). This precipitation is generally the result of large storms which move into California from the northwest during the late autumn and winter months. These storms produce brief, intense rains which contribute as much as 80 percent of the annual precipitation in the basin. Snow falls at higher elevations, but its quantity and contribution to runoff are usually insignificant.

The climate of the coastal region of the basin is predominantly influenced by the moist airmass over the ocean which produces onshore winds, cool foggy summers, and mild wet winters. Temperatures near the coast are moderate, ranging from 0.6°C (33°F) to 29°C (85°F) and averaging about 11°C (52°F); rainfall averages about 40 inches per year. Farther inland, the changing topography and increased distance from the ocean bring about wider temperature ranges and increased precipitation. Temperature extremes range from about −18°C (0°F) to about 43°C (110°F), and the mean annual rainfall approaches 80 inches. Because of a decrease in the amount of fog, however, the general climate of the inland part of the basin is less moist than that along the coast.

RUNOFF

The average annual runoff in the Eel River basin is approximately 35 inches on the basis of streamflow records and synthesized information for the 60-year period 1900–59 (Rantz, 1964, p. 3). The runoff has been adjusted for evaporation and change in reservoir contents of Lake Pillsbury and for diversion into the Russian River basin at the Van Arsdale Reservoir. Average annual runoff is highest in the western part of the basin and lowest in the central part; however, variations from the average are not great within each of the larger hydrologic units of the basin listed in table 2.

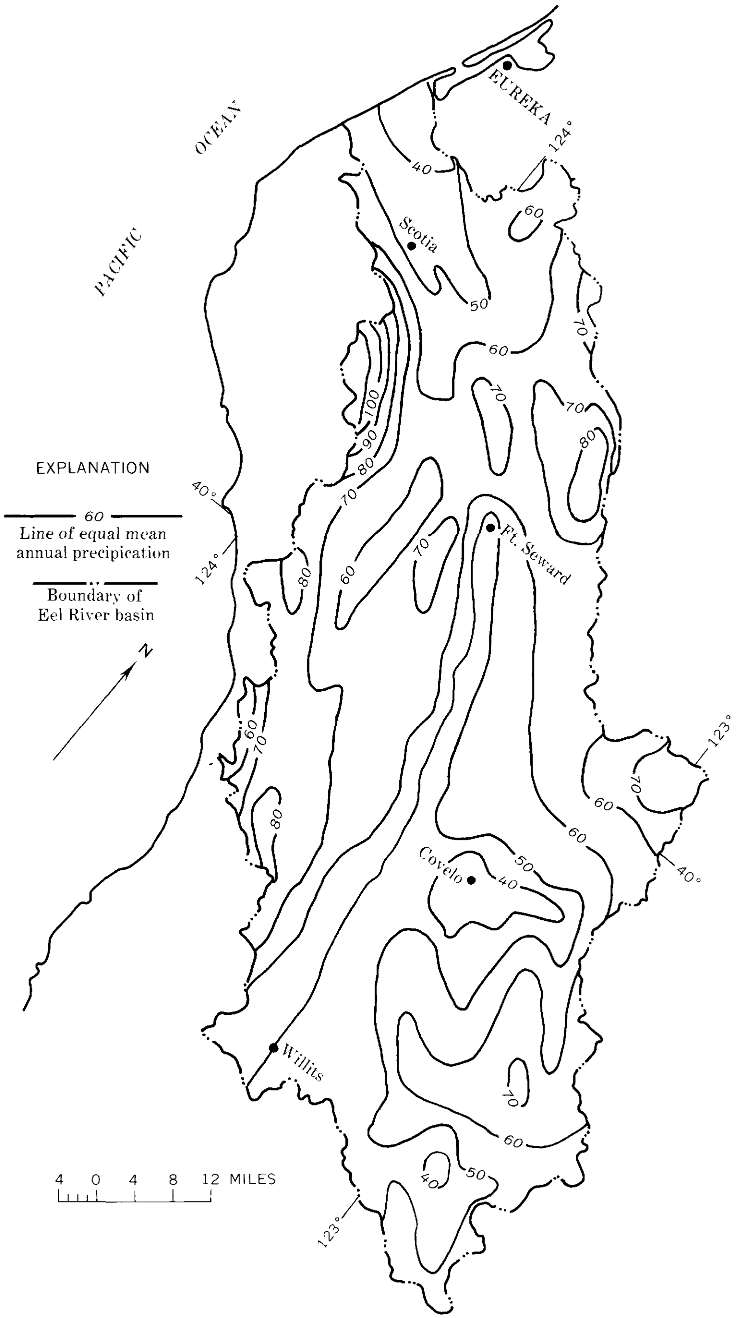


Figure 2.—Mean annual precipitation over the Eel River basin, 1900–63. (Rantz, 1968.)

TABLE 2.—*Precipitation and runoff for hydrologic units of the Eel River basin (adjusted to base period 1900–59)*

[From Rantz, 1964, table 1]

Hydrologic unit	Drainage area (sq. mi.)	Average annual precipitation (inches)	Average annual runoff	
			1,000's of acre-feet	Inches
Eel River above Middle Fork	709	52	1,140	30.2
Middle Fork Eel River above mouth	753	54	1,170	29.1
North Fork Eel River above mouth	282	59	425	28.3
South Fork Eel River above mouth	689	71	1,738	47.3
Eel River above Scotia gage	3,113	59	5,720	34.4
Van Duzen River above mouth	429	64	995	43
Eel River above mouth	3,625	59	6,808	35

The runoff throughout the basin is sustained almost entirely by overland runoff and base flow. Although snow does fall in the higher elevations of the eastern part of the basin, the runoff from snowmelt is generally insignificant. Most runoff is the result of large, general storms which affect the entire basin, and the unit frequency distribution of runoff is therefore similar for most individual streams. The ratio of precipitation to runoff varies with each storm depending upon the storm intensity and the amount of antecedent saturation of the soil. High flows diminish quickly in the absence of sustaining rainfall, and discharges drop well below their average annual values during the dry summer months, when there may be more than 200 days without significant precipitation.

Annual runoff extremes for the basin above Scotia during the period of sediment record were 20 inches in the 1964 water year and 67 inches during the 1958 water year. It is noteworthy that neither of these extremes was accompanied by the lowest or highest annual sediment discharge for the same period of record. A detailed study of the relations between runoff and sediment discharge is discussed in a subsequent section of this report (p. 22).

GEOLOGY

The rocks underlying most of the Eel River basin are a part of the Franciscan Formation, which extends over much of the northern Coast Ranges geomorphic province. This formation was described in some detail by Bailey, Irwin, and Jones (1964) and was described in general by Page (1966, p. 258) as a complex assemblage of sedimentary rocks of deep-water origin and mafic marine volcanic material, accompanied locally by masses of serpentine. Sandstone, chiefly graywacke, is the prevalent rock type in the part of the Franciscan assemblage that underlies the Eel River basin.

Upper Cretaceous and Tertiary sedimentary rocks rest on the Franciscan Formation along the western side of the basin, and al-

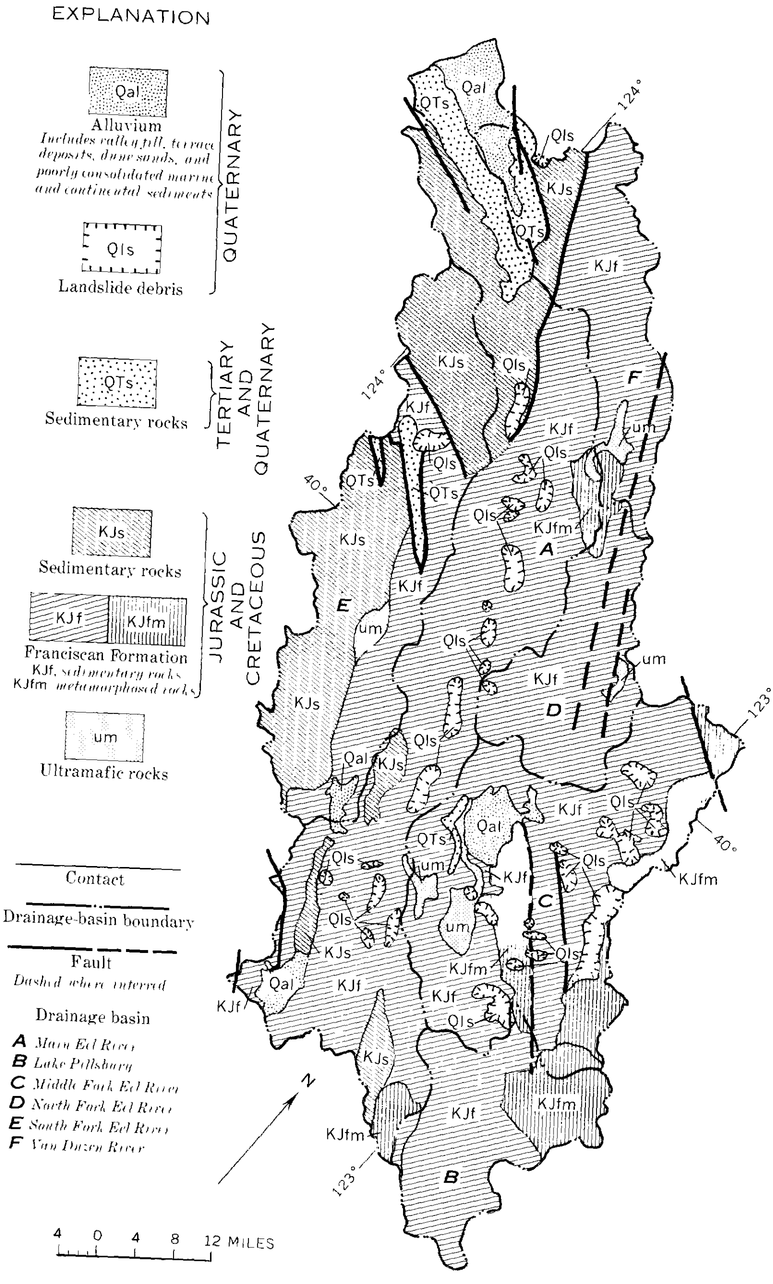


Figure 3.—General geology of the Eel River basin. Geology from California Department of Water Resources (1966).

luvial deposits are found in scattered regions of the basin, notably along the main stem of the Eel River (fig. 3).

Major structural features are formed by a complex pattern of strike-slip faulting generally oriented southeast-northwest, and the drainage patterns of the Eel River and its tributaries reflect this orientation. Topographic changes in this region are still in progress as regional uplifting and faulting, which began in the late Miocene period, continue to influence the landforms throughout the northern Coast Ranges.

Widespread areas of the Eel River basin are subject to landslides and earth flows. Combinations of uplifting topography, steep hillslopes, and the saturation of soils by rainfall contribute to mass-movement processes which are commonly augmented by the erosive action of streams along the base of the slopes. Because of their past and potential contributions of large quantities of sediment to stream channels, landslides and earth flows are of special interest in this report. For example, sediment yield is greatest in the central part of the basin along the main stem of the Eel River where large-scale sliding is common along both sides of the river for many miles.

SOILS

Although many soil types are present within the Eel River basin, the general character of soils throughout the basin is similar because the parent rocks are much the same over the entire basin. With minor variations, nearly all the soils are loamy in texture and generally range from 20 to 60 inches in depth (C. E. Stearns, written commun., 1968). These soils are generally stable with good infiltration rates and water-holding capacities, and the natural vegetal cover of the basin helps to reinforce this stability. However, the basin is often subject to a combination of conditions which tends to render these soils unstable. Soils resting on steep slopes become quickly saturated during periods of intense rainfall that follow extended periods of moderate precipitation, and severe erosion may thus occur in a very short period of time. In areas which have been subjected to heavy grazing or to deforestation by fires or lumbering practices, soils may become unstable and erosion may be severe even under normal runoff conditions.

VEGETATION

The vegetal cover of the Eel River basin includes a variety of forms, but the greater part of the basin is moderately to heavily forested with redwood and other conifers. The remaining part is covered by varying proportions of hardwood trees, chaparral, and grass.

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The distribution of these vegetation types forms four roughly defined and discontinuous belts which trend in a northwesterly direction parallel to the long axis of the basin. Along the western side grow forests of California redwoods (*Sequoia sempervirens*), the valuable and spectacular trees which are the basis of the lumber and recreation industries of the basin. The redwoods are concentrated in a large area surrounding the lower reaches of the Van Duzen and Eel Rivers, and they occupy most of the western drainage of the South Fork of the Eel River from Weott to Branscomb. The forest belt directly east of the redwood forests is predominately Douglas Fir but includes grasslands and scattered stands of pine. This belt, extending roughly from Kneeland south through Willits, reflects a change from the coastal climate to one of lower rainfall and less fog. A third zone of vegetation is less readily defined but includes a variety of hardwoods, mixed conifers, and chaparral in the central and southern parts of the basin. A woodland typified by oak, maple, and madrone extends somewhat discontinuously from Fort Seward to Potter Valley. Chaparral covers the drier areas of the southern part of the basin, especially in the vicinity of Lake Pillsbury and along Elk Creek. The fourth forest type, which consists of pines and Douglas Fir, covers the higher elevations of the eastern and southern parts of the basin. It extends over the headwaters of all the eastern drainage and constitutes commercial timberland typical of national forests.

LAND USE

Surveys of land use by the California Department of Water Resources (1965) divide land development within the Eel River basin into four major categories. Irrigated lands compose approximately 14,500 acres and include properties receiving water artificially. Dry-farmed lands are those on which farming practices are dependent upon the natural moisture supplied by ground water and precipitation. These lands cover some 32,000 acres—part concentrated in the delta area of the Eel and the remainder widely scattered throughout the basin. Urban lands compose 11,000 acres, less than 1 percent of the basin area, and are confined generally to the towns along the Eel River valley. Recreational lands make up approximately 28,200 acres of commercial and residential property, campsites, and parks. The remaining 2,272,300 acres of basin area is undeveloped and is used primarily for grazing livestock, various recreational activities, and commercial timber production.

HYDROGRAPHY

PHYSICAL CHARACTERISTICS OF STREAMS

A variety of factors influences the form and processes of natural streams, among which the most significant are precipitation and subsequent channel flow, the composition of the material forming the channel bed and banks, and the topography through which the stream flows. The following discussion describes the general and noteworthy features of the streams in the Eel River basin, and emphasizes those features that significantly affect sedimentation processes.

EEL RIVER ABOVE CONFLUENCE WITH MIDDLE FORK EEL RIVER

The upper Eel River emanates from the slopes of Bald Mountain in western Mendocino County, Calif., and flows in a southerly direction for 23 miles before turning westward and flowing into Lake Pillsbury. In this initial reach, the Eel drops through rugged, forested canyons at an average rate of 200 feet per mile (fig. 4). Several minor tributaries drain the 6,500-foot mountains which form the basin above Lake Pillsbury, and the Rice Fork of the Eel drains the chaparral-covered slopes of the southern tip of the basin, entering Lake Pillsbury from the south.

Soils through which these streams flow are primarily the deep forest soils which tend to be moderately erodible under dense forest vegeta-

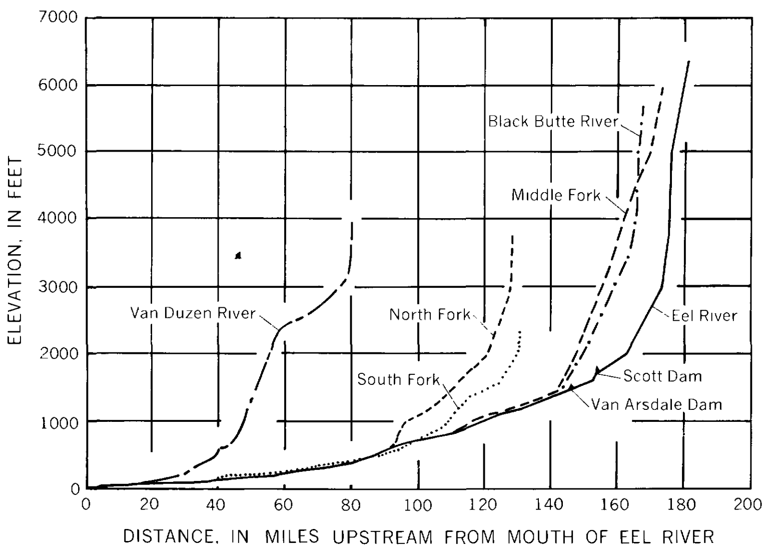

FIGURE 4.—Longitudinal profiles of streams, Eel River basin.

tion. However, a large area of highly erodible material extends south and east of Lake Pillsbury through the Rice Fork basin where the vegetal cover is predominantly chaparral. Below Lake Pillsbury, the water released at Scott Dam continues its westward flow 10 miles to Van Arsdale Reservoir where a portion of it is diverted into the Russian River basin. This diversion is a part of Pacific Gas and Electric's Potter Valley Project to supply water and power for local areas in Lake, Sonoma, and Mendocino Counties. About one-third of the average flow of the Eel River at this point is diverted into Potter Valley. Downstream from Van Arsdale Reservoir, the Eel River turns northwestward, dropping with an average slope of 16 feet per mile to its confluence with the Middle Fork of the Eel River, 55 miles downstream. Landslides and bank slumping are common along this reach, and the slopes adjacent to the river are generally composed of moderately to highly erodible soils.

Outlet Creek is the major tributary of the Eel above its confluence with Middle Fork Eel River. Outlet Creek has its source in the vicinity of Little Lake Valley and flows into the Eel from the west. Lower elevations, mild slopes, and generally less erodible materials characterize its drainage basin. Tomki Creek provides additional drainage for the steeper, forested area between Van Arsdale Dam and Little Lake Valley.

EEL RIVER BELOW CONFLUENCE WITH MIDDLE FORK EEL RIVER

From Dos Rios to its mouth at the Pacific Ocean, the Eel continues its northwesterly course at a generally regular slope of 8 feet per mile. The Eel River canyon retains its narrow, boxlike proportions throughout most of this reach until the valley begins to widen below Scotia. The North Fork Eel River and the Van Duzen River are the major tributaries entering the Eel from the east along this reach, and the South Fork Eel River provides the principal drainage from the west. The Van Duzen and South Fork Eel Rivers are discussed in separate sections within this report.

The Eel River canyon from Van Arsdale Reservoir north to Eel Rock is characterized by large-scale landsliding, and sediment records indicate that the major part of suspended-sediment discharge from the basin originates in this reach. In addition to the direct contribution of landslides to the main channel, at least 20 short steeply sloping tributaries drain two parallel ridges between which the Eel River flows from Dos Rios to the South Fork, and these streams may be major contributors of fluvial sediment by their combined effects. These smaller streams contribute sediment from side canyons, transport slide material to the main stream, and erode deposits along the channel of the Eel River as it recedes after flooding.

MIDDLE FORK EEL RIVER

The headwaters of the Middle Fork Eel River drain the forested high country of the eastern Eel River basin divide. Stream slopes of these waters are very steep, averaging approximately 140 feet per mile above the mouth of the Black Butte River. Below the Black Butte River to its confluence with the Eel near Dos Rios, the Middle Fork has a more gentle slope of about 21 feet per mile.

The headwater streams of the Middle Fork flow through areas underlain by the metamorphosed sedimentary rocks of the Franciscan Formation, but Elk Creek and the streams in the vicinity of Covelo flow through a complex structure of Quaternary alluvium, marine terrace deposits, and intrusive ultramafic material. Soils formed on the rocks of the central basin lie on gently sloping ground and are more erosion resistant than those in the upper basin. Between the mouth of Elk Creek and Dos Rios, the Middle Fork flows through a narrow canyon where it transects the ridge between adjacent fault-formed valleys.

BLACK BUTTE RIVER

The Black Butte River drains 162 square miles of steep mountain slopes and enters the Middle Fork from the south. The river has a slope of 163 feet per mile along its straight northwesterly course, and the orientation and formation of its valley are probably related to a fault which parallels the river throughout most its length. Deposits of Quaternary landslide material on the slopes along the east side of the river provide a ready source of sediment (fig. 3). The Black Butte River basin is otherwise underlain by the Franciscan sandstones, shales, and conglomerates typical of most of the rest of the Eel River basin.

SOUTH FORK EEL RIVER

The drainage of the South Fork is unique among the tributaries of the Eel, differing in form, climate, vegetation types, and underlying rock. The South Fork has an average slope of 24 feet per mile for its 92-mile length. It flows northwest parallel to the main stem of the Eel through the redwood forests which cover most of its western drainage. Underlying materials are marine sands of Cretaceous age similar to those of the Franciscan Formation but distinctive to the South Fork and lower Eel drainages (fig. 3). The soils that form on this formation are highly erodible, especially along the steeply sloping western side of the basin. The landslide topography found in many areas throughout the Eel River basin does not exist along the South Fork except in a small region north of Garberville.

VAN DUZEN RIVER

The Van Duzen River drains the northern reaches of the Eel River basin and flows out into the flat delta region of the Eel about 11 miles inland from the ocean. The river has an average slope of 59 feet per mile over its 67-mile length. Its headwaters drop quickly from the 4,000-foot elevations near the eastern boundary of the basin at a rate of 110 feet per mile over the first 15 miles, but the stream gradient decreases to less than 30 feet per mile below Bridgeville.

The Van Duzen River and its principal tributary, Yager Creek, flow through moderately sloping grassland in the central part of the drainage basin and through redwood forests in their lower reaches. Many of these grassland areas are underlain by unstable soils and are subject to erosion by gullying. The lower reaches of the basin are underlain by Quaternary terrace deposits and alluvium, and the bedrock of the upper basin contains the sandstone and conglomerate of the Franciscan Formation (fig. 3). Bank cutting and sliding are common along Yager Creek north of Carlotta and along the Van Duzen River between Carlotta and Bridgeville.

HYDRAULIC GEOMETRY

The physical characteristics of streams include the hydraulic geometry of stream channels, which is defined by the relations among certain hydraulic characteristics of the stream (Leopold and Maddock, 1953). At a given cross section, depth, width, velocity, and suspended load vary as power functions of the discharge according to equations of the following form:

$$w=aQ^b \quad (1)$$
$$d=cQ^f \quad (2)$$
$$v=kQ^m \quad (3)$$
$$L=pQ^j \quad (4)$$

where

w=width
d=mean depth=area divided by width
v=mean velocity
L=suspended-sediment load
Q=water discharge
a, c, k, p, b, f, m, and j are numerical constants.

These equations may be determined empirically by plotting data obtained from current-meter and other measurements at river cross sections. When width, depth, velocity, and suspended load are plotted against discharge on logarithmic paper, their relations to discharge are expressed by nearly straight lines.

The graphs of figure 5 illustrate the changes of width, depth, and velocity with discharge of the Eel River at Scotia. The values shown for the exponents *b*, *f*, and *m* are consistent with the nature of the channel. The steep-walled canyon restricts the channel width while the depth and velocity increase rapidly with increasing discharge. The graphs shown are for the period following the December 1964 flood; however, a comparison of these data with preflood data shows that there has been no appreciable change in the hydraulic geometry at Scotia from preflood conditions.

Table 3 lists the parameters of the hydraulic geometry at Scotia and four other stations in the Eel River basin. The data used to de-

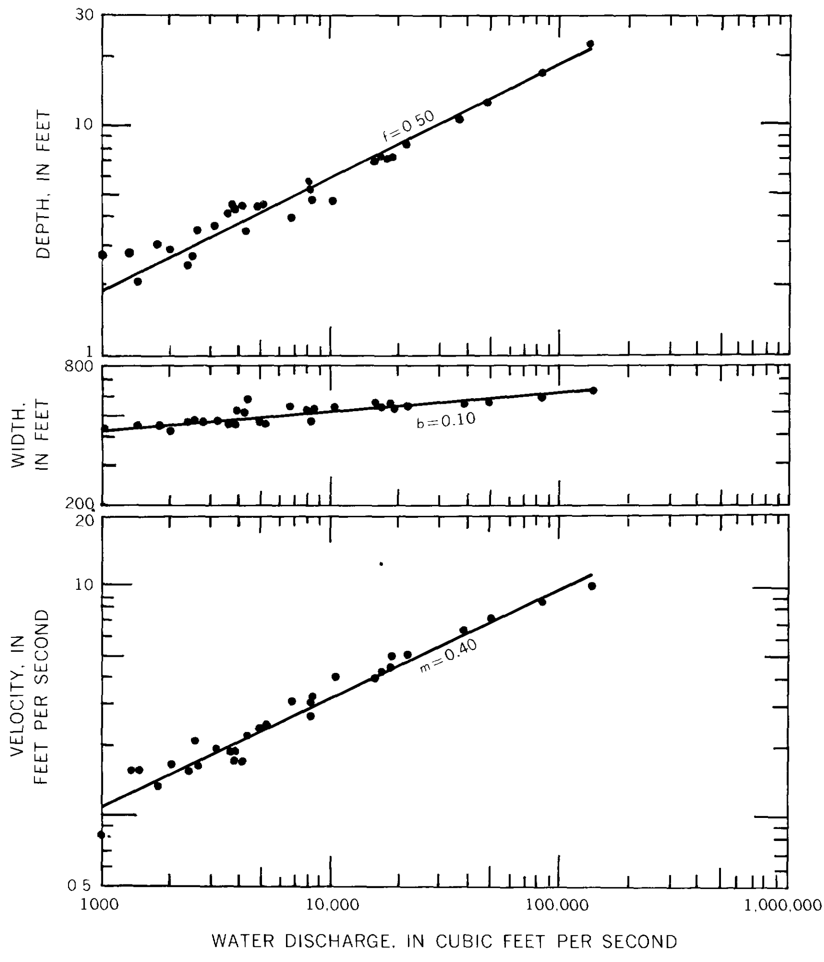

FIGURE 5.—Relation of depth, width, and velocity to discharge, Eel River at Scotia, 1965–68.

rive these parameters were collected during the period 1965–68, and the values shown typify the hydraulic geometry of these stations for this period. Although these values may not provide a visual picture of the channel conditions along the Eel River, they may be used for comparison with those of the other rivers listed.

TABLE 3.—*Rate of increase of width, velocity, and depth with discharge*

[Exponents *b*, *m*, and *f* are defined by equations 1-3 (p. 16)]

Station and location	Rate of increase with discharge (*Q*)			
	b (width)	*m* (velocity)	*f* (depth)	*Q* more than— (cfs)
Black Butte River near Covelo, Calif	0.06	0.26	0.68	750
Middle Fork Eel River below Black Butte River, near Covelo, Calif	.10	.32	.58	500
Middle Fork Eel River near Dos Rios, Calif	.14	.27	.59	1,000
Eel River at Fort Seward, Calif	.10	.54	.35	1,000
Eel River at Scotia, Calif	.10	.40	.50	1,000
Rio Grande at San Felipe, N. Mex.[1]	.22	.30	.48	
Rio Grande near Bernalillo, N. Mex.[1]	.03	.51	.46	1,000
Middle Loup River at Arcadia, Nebr.[1]	.13	.35	.52	
Moreau River near Faith, S. Dak.[1]	.10	.34	.56	400
Rio Puerco at Rio Puerco, N. Mex.[1]	.43	.41	.16	
Bighorn River at Thermopolis, Wyo.[1]	.14	.55	.31	
Powder River at Arvada, Wyo.[1]	.10	.31	.59	200
Saline River near Russell, Kans.[1]	.37	.25	.38	

[1] Leopold and Maddock (1953).

At each station on the Eel River, the velocity and depth increase with increasing discharge more rapidly than the width. Velocity increases most rapidly at Eel River at Fort Seward and does so at a rate greater than the rate of increase of the depth. Among the selected stations along the Eel River, this characteristic prevails only at Eel River at Fort Seward, perhaps because the channel is somewhat constricted at that site.

Leopold and Maddock (1953, p. 21) stated that it is typical at a given cross section of an alluvial stream for the suspended-sediment load to increase with increase in discharge, and at a more rapid rate than discharge. That is, the concentration of suspended sediment increases with discharge. At the stations in the Eel River basin, the daily suspended-sediment discharge increases as a power (j, 4) of water discharge ranging from about 1.8 in the upper parts of the sediment-transport curves to about 2.6 in the lower parts (table 4). These values are consistent with those postulated by Leopold and Maddock.

The downstream variation in suspended-sediment discharge at a given frequency of water discharge provides useful information about the nature of sediment transport in the Eel River basin. Concurrent records of suspended-sediment discharge were collected at five stations in downstream order from Black Butte River near Covelo to Eel River at Scotia for the period October 1965–September 1967. After a sediment-transport curve was plotted for each station for this period, the suspended-sediment discharge corresponding to the mean annual water discharge, Q_{mean}, at each station was taken from the curve. These values were used to plot the first graph in figure 6. The second graph in figure 6 was plotted in a similar manner; however, the water discharge used was that discharge equaled or exceeded 1 percent of the time at each station (Q_{01}). It is shown later in this report that Q_{01} produced about 50 percent of the suspended-sediment discharge for the period of record for most stations in the Eel River basin. The graphs indicate that the concentration of suspended sediment increased in a downstream direction at a given frequency of discharge

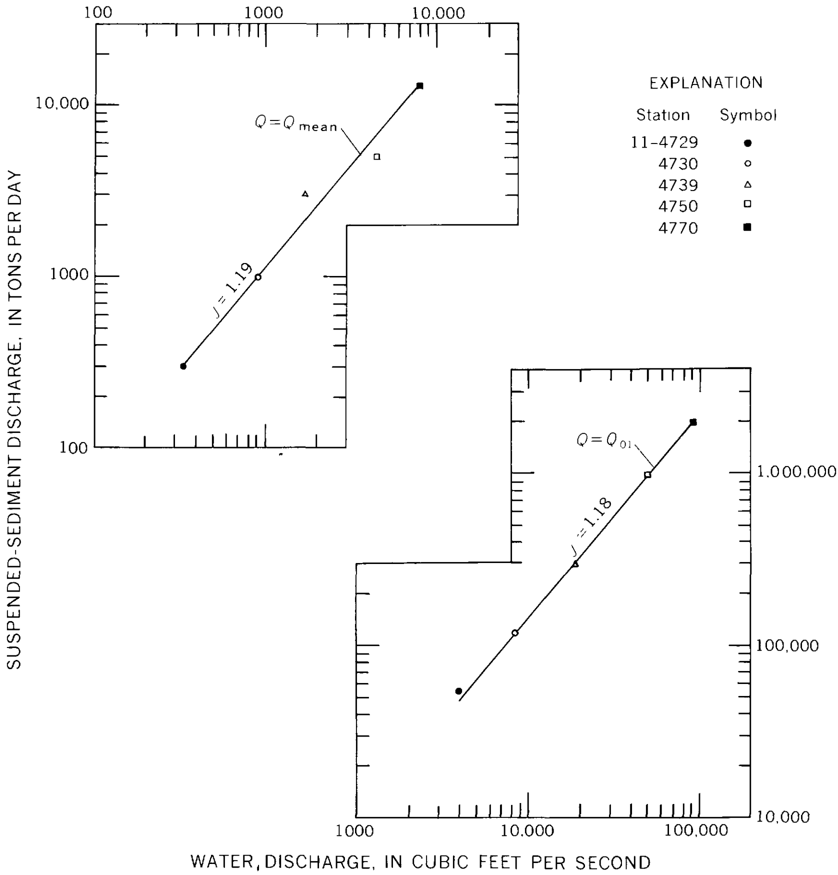

FIGURE 6.—Downstream variations in the relation between water discharge and suspended-sediment discharge in the Eel River basin, October 1965–September 1967. Q_{mean} is the mean annual discharge, and Q_{01} is the discharge equaled or exceeded 1 percent of the time for each station shown. The stations and their corresponding numbers are given in table 5.

TABLE 4.—*Rate of increase of suspended-sediment discharge with water discharge at selected stations in the Eel River basin*

Station and period of record (water years)	Range of water discharge (cfs)	Approximate value of *j* in equation 4
Black Butte River near Covelo, 1966–67	100– 1,000	2.6
Middle Fork Eel River below Black Butte River near Covelo, 1963–67	1,000– 10,000	2.2
Middle Fork Eel River near Dos Rios 1958–67	500– 5,000	2.2
	5,000– 50,000	1.8
Eel River at Fort Seward 1966–67	1,000– 10,000	2.5
	10,000–100,000	2.0
Eel River at Scotia, 1958–67	4,000– 40,000	2.3
	40,000–700,000	2.4
South Fork Eel River near Branscomb, 1963–67	200– 2,000	2.5
	2,000– 20,000	1.8

and that concentrations increased at about the same rate for discharges between Q_{mean} and Q_{01}. (The latter observation was tested, and there was no appreciable change in j for other values of Q between Q_{mean} and Q_{01}.) These phenomena are supported by the observation that the average annual yield of suspended sediment per square mile of drainage area increased with increasing drainage area (table 5). Although these empirical observations show conditions atypical of other rivers (Leopold and Maddock, 1953, p. 22), they give some insight into the unusually high capacity for sediment transport of the Eel River and its tributaries. These observations help to verify that there was less sediment-free inflow, such as ground-water inflow, than sediment-producing runoff as the drainage area increased downstream. It is possible that the erodibility of the basin changes in a downstream direction because of changing geology below Fort Seward (fig. 3), although data are insufficient to support this contention adequately.

TABLE 5.—*Downstream variations in sediment yield and hydraulic geometry, Eel River basin*

[Upper values, at Q_{mean}; lower values, at Q_{01}]

Station and No.	Average sediment yield, 1966–67 (tons per sq mi) [1]	Average sediment yield, 1963–67 (tons per sq mi) [1]	Variation in hydraulic geometry at Q_{mean} and Q_{01} (1966–67)					
			Q (cfs)	*W* (feet)	*d* (feet)	*V* (ft per sec)	*L* (tons per day)	Concentration (mg/l)
Black Butte River, near Covelo 11–4729.	4,330		338		1.0	4.0	300	330
			4,050	160	3.3	7.6	55,000	5,040
Middle Fork Eel River, below Black Butte River, near Covelo, 11–4730.	4,210	8,127	914		1.1	4.2	1,000	400
			8,500	250	3.9	8.6	120,000	5,220
Middle Fork Eel River near Dos Rios, 11–4739.	6,181	12,027	1,726		1.8	4.6	3,000	640
			19,100	275	7.7	8.8	300,000	5,810
Eel River at Fort Seward, 11–4750.	6,932		4,472		7.2	2.4	5,000	410
			50,000	350	18	8.8	1,000,000	7,410
Eel River at Scotia, 11–4770.	8,311	15,829	7,853		5.5	2.8	13,000	610
			93,400	600	18	9.0	2,000,000	7,930

[1] Values computed from data shown in table 8.

The Eel River accommodated high sediment-producing discharges in 1966 and 1967 principally by a downstream increase in depth of flow (fig. 7). At Q_{01}, depth of flow increased downstream at about twice the rate of increase in width, while the downstream rate of increase in velocity was almost negligible.

Further analysis of the hydraulic geometry of the Eel River basin is somewhat hampered by insufficient data and is generally beyond the scope of this report. However, the material presented in this section when viewed in connection with other information presented in this report and with other findings (Carlston, 1969) may be useful in future and more detailed studies of the Eel and similar rivers.

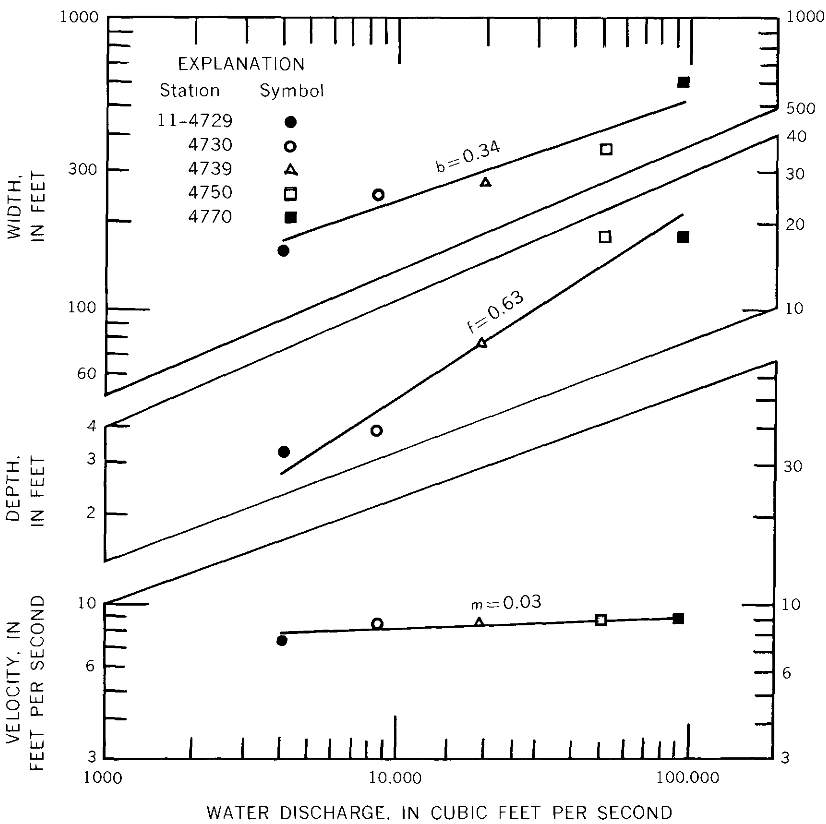

FIGURE 7.—Relation of width, depth, and velocity to discharge, showing downstream variations in the hydraulic geometry of the Eel River, October 1965–September 1967. The discharge from which the points are plotted is that discharge, Q_{01}, equaled or exceeded 1 percent of the time for each station shown.

FLUVIAL SEDIMENT

DEFINITION OF TERMS

Many terms relating to fluvial sediment are not completely standardized; the terminology used in this report is based on the following definitions:

Fluvial sediment or **sediment** is fragmental material that originates from weathering of rocks and is transported by, suspended in, or deposited by streams.

Suspended sediment or **suspended load** is sediment that moves in suspension in water and is maintained in suspension by the upward components of turbulent currents or by colloidal suspension.

Bedload or **sediment discharged as bedload** includes both the sediment that moves along in continuous contact with the streambed (contact load) and the material that bounces along the bed in short skips or leaps (saltation load).

Sediment sample is a quantity of water-sediment mixture that is collected to determine the concentration of suspended sediment, the size distribution of suspended or deposited sediment, or the specific weight of deposited sediment.

Sediment discharge is (a) rate at which dry weight of sediment passes a section of a stream or (b) quantity of sediment, as measured by dry weight or by volume, that is discharged in a given time.

Sediment-transport curve is a curve of relation between water discharge and sediment discharge. Usually the relation is between water discharge and suspended-sediment discharge, but it can be between water discharge and bedload discharge or between water discharge and total sediment discharge (sum of sediment discharge in suspension and as bedload).

Water discharge or **discharge** is the amount of water flowing in a channel expressed as volume per unit of time. The water contains both dissolved solids and suspended sediment.

The general principles of sediment-discharged measurement as well as the practical aspects of selecting sampling points and determining the frequency of sampling are discussed in several reports. A suitable reference on methods of measurement and analysis of sediment loads is Report 14 of the U.S. Inter-Agency Committee on Water Resources (1963). The procedure for the measurement of water discharge was described in detail in Corbett and others (1943).

METHODS OF COMPUTATION

Basic data which were interpreted for use in graphs and tables in this report were prepared according to standard procedures of the U.S. Geological Survey, Water Resources Division, California District. However, it is instructive to comment further on certain of these procedures and the methods of data interpretation in this report because of the record values of some of the sediment-discharge data.

The sediment yield of the Eel River basin and its subunits is determined in this report primarily from measured, computed, and estimated rates of transport of suspended sediment. These rates correspond to certain significant time periods within the years during which sediment samples were taken, and the rates can be extrapolated to other periods of time, given certain complementary information (Miller, 1951). However, an extreme flood event which occurred during the period of sediment record produced sediment-transport rates of such magnitude that their correspondence to time periods other than the period during and after the flood is somewhat obscure. Thus, the analyses here are presented on the basis of preflood and postflood sediment transport rates, with the emphasis that the characteristics of these rates are probably dissimilar. Extrapolation is performed using both preflood rates and rates for the entire period of record so that the bias of the flood effects is apparent.

Sediment-transport curves shown in this report were plotted from suspended-sediment data according to standard procedures with the following exception: The coordinates of each of the points used to define the curves represent an average value for a selected interval of water discharge and the corresponding average sediment discharge computed for that interval. These computations were performed as a part of a computer program written for this purpose, and a sample of the output of this program is shown in table 6. The data show that the upper end of the curve is defined by only a few points, and the water and sediment discharges defining some of these points are estimated or computed rather than measured directly. However, the value used to define the upper ends of curves shown in this report have not been revised to fit an assumed pattern. Only values previously computed and published have been used to maintain consistency in reports on this subject and to allow for the fact that some sediment-discharge values are affected by unusual hydrologic events. Obviously, there are limitations on the accuracy of the sediment-transport curves and the accuracy of extreme values estimated from these curves. However, the adequacy of these values cannot be intelligently evaluated until additional information is obtained on the probable accuracy of measured sediment discharge (Colby, 1956, p. 167). It should be sufficient to say that interpolation of the curves and use of the extreme values presented in this report should be done with caution and with the previous comments in mind. Extrapolation of curves shown in this report, especially at the upper end, is too likely to be in error to be useful because there are too few measured values, and many of the estimated values were the result of an extremely infrequent flood event (Helley and LaMarche, 1968).

TABLE 6.—*Sample of computer output of program designed to compute an average relation between water discharge and suspended-sediment discharge*

[A plot of Q_w versus Q_s may accompany this output at the option of the user]

11-4770. Eel River at Scotia, Calif.

[Period of daily record: October 1957-September 1967]

Range of water discharge, Q_w, in cubic feet per second	Average of discharges within range listed in column 1, in cubic feet per second	Average suspended-sediment discharge, Q_s, in tons per day, corresponding to value of Q_w in column 2	Number of days during period of record when Q_w within range listed in column 1	Percent of time Q_w equaled or exceeded
0.0- 10.0			0	100.00
10.0- 100.0	78.2	0.52	104	100.00
100.0- 200.0	146.0	0.94	759	97.15
200.0- 300.0	243.5	2.14	243	76.37
300.0- 500.0	378.2	5.82	192	69.72
500.0- 750.0	622.4	11.23	141	64.46
750.0- 1000.0	861.6	35.95	102	60.60
1000.0- 1500.0	1256.3	54.25	187	57.80
1500.0- 2000.0	1718.7	111.60	164	52.68
2000.0- 3000.0	2511.5	241.29	282	48.19
3000.0- 4000.0	3464.2	793.04	200	40.47
4000.0- 5000.0	4478.9	1621.74	174	34.99
5000.0- 6000.0	5478.2	2772.40	121	30.23
6000.0- 7000.0	6507.4	4969.24	92	26.92
7000.0- 8000.0	7486.9	5855.47	95	24.40
8000.0- 9000.0	8490.5	8170.84	59	21.80
9000.0- 10000.0	9496.3	14156.20	71	20.18
10000.0- 11000.0	10452.6	14736.31	38	18.24
11000.0- 12000.0	11461.5	20726.73	52	17.20
12000.0- 13000.0	12360.6	25039.09	33	15.77
13000.0- 14000.0	13380.0	26781.66	30	14.87
14000.0- 15000.0	14346.4	32095.36	28	14.05
15000.0- 20000.0	17406.7	51303.33	120	13.28
20000.0- 25000.0	22135.1	80425.62	74	9.99
25000.0- 30000.0	26837.2	126637.19	43	7.97
30000.0- 40000.0	34716.2	199858.06	74	6.79
40000.0- 50000.0	43915.2	295276.06	46	4.76
50000.0- 60000.0	54757.1	447514.25	35	3.50
60000.0- 70000.0	65317.4	495434.75	23	2.55
70000.0- 80000.0	72438.4	615384.56	13	1.92
80000.0- 90000.0	83707.1	906428.56	14	1.56
90000.0- 100000.0	94130.8	1273538.00	13	1.18
100000.0- 150000.0	119473.6	1904052.00	19	0.82
150000.0- 200000.0	184250.0	6262500.00	4	0.30
200000.0- 250000.0	206500.0	3540000.00	2	0.19
250000.0- 300000.0	261000.0	5995000.00	2	0.14
300000.0- 400000.0	311000.0	19000000.00	1	0.08
400000.0- 500000.0			0	0.05
500000.0- 600000.0	521000.0	40000000.00	1	0.05
600000.0- 700000.0	648000.0	57000000.00	1	0.03
700000.0- 800000.0			0	0.0
800000.0- 900000.0			0	0.0
900000.0-1000000.0			0	0.0
Total			3,652	

FLOOD OF DECEMBER 1964

In December 1964, rainfall of historically unprecedented intensity coupled with conditions favorable for heavy runoff produced record flooding in the Eel River basin, as well as in a large area of the Western United States (Rantz and Moore, 1965). Rainfall which in places exceeded 20 inches in a 48-hour period produced runoff that sent river stages 5–15 feet above previous record stages and caused severe damage in river valleys in all parts of the Eel River basin. High-velocity flow and high stages accelerated erosional processes so much that an enormous volume of soil and rock was stripped from the land and deposited downstream or carried to the sea.

Bank slumping, landslides, and channel scouring in upstream reaches contributed a record sediment load to streams throughout the basin, and the downstream deposition of this material added to the damage caused by the rampaging waters. Sediment and debris clogged bridges and culverts, forcing floodwater to overtop the structures or to seek alternative channels. In the flood plains and other areas of the lower valleys where the flow velocity decreased, sediment commonly was deposited to depths of several feet. Houses, stores, and automobiles abandoned before the rising waters were left filled with sediment and debris when the water receded (figs. 8 and 9).

The quantity and distribution of material transported during the course of the flood are best determined from the suspended-sediment discharge measurements made at gaging stations at that time. That ideal could not be realized at various stations during the 1964 flood. At every station for which sediment records were available or could be calculated, the volume of suspended sediment and the rate at which it moved exceeded all previous records. For example, a suspended-sediment discharge of 116 million tons was computed for Eel River at Scotia for a 3-day period beginning December 22, 1964. The total suspended-sediment load at this station for the previous 8 years amounted to 94 million tons.

Erosion was most severe in the eastern section of the Eel River basin where the North and Middle Forks of the Eel River were fed by runoff from the steep westward-facing slopes. These slopes, saturated by antecedent precipitation and somewhat unstable even under normal conditions, were badly eroded by landslides, slumps, and gullying in areas of sparse vegetal cover. Material derived from this type of erosion, added to the contributions from banks and channels, provided the sediment load for the steeply sloping tributaries of these two rivers.

Farther downstream in the vicinity of the confluence of the Middle Fork Eel and Black Butte Rivers, enough sediment was deposited

FIGURE 8.—Remains of the devasted town of Pepperwood on the Eel River upstream from Scotia, Feb. 5, 1965. Pepperwood was destroyed by flooding during December 1955. It was subsequently rebuilt, only to be destroyed again by the flood of December 1964.

FIGURE 9.—House engulfed by landslide associated with the December 1964 flood near the South Fork Eel River about 15 miles downstream from Garberville. A small stream is flowing over the top of a fence which once bridged the stream near where the man is standing.

as a result of the flood to raise the streambeds 6–8 feet (Hickey, 1968, p. E8). Hickey noted that in this area, channel fill continued during the following water year, probably as a result of continued erosion of material brought into upstream reaches during the 1964 flood period.

On the upper main stem of the Eel, 2 feet of sediment was deposited just above the confluence with the Middle Fork. Sediment transport and deposition from this point upstream is partly influenced by the operations of Lake Pillsbury and Van Arsdale Reservoir.

During the period December 21–30, 1964, the suspended-sediment discharge computed for Eel River at Scotia was about 145 million tons. A suspended-sediment load of about 7½ million tons was computed during this same period at Eel River above Dos Rios compared with a load of approximately 8½ million tons at Middle Fork Eel River near Dos Rios. Although measurements of sediment discharge for the flood period are not available for points along the Eel River between Dos Rios and Scotia, the difference between sediment discharges computed at these two points equals the suspended-sediment yield for the central part of the basin less material deposited along the channel. If the sediment discharge of the South Fork is taken to be approximately 19 million tons, the computed value for the sediment load derived from the central part of the basin and the North Fork

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drainage is 110 million tons, or 76 percent of the sediment load at Scotia. The sediment load estimated for the South Fork Eel River was taken as 13 percent of the load computed at Scotia on the basis of relations between past records at the two stations; however, the accuracy of this value is of minor significance in this particular example. The large sediment yield between Dos Rios and Scotia emphasizes the need for additional sediment data from along this reach.

EEL RIVER AT SCOTIA

Sediment studies began at Eel River at Scotia in September 1955. Periodic observations were made during the 1956 and 1957 water years, and a program of daily sampling was begun in October 1957. Suspended-sediment measurements are made from the bridge on U.S. Highway 101, 0.5 mile north of Scotia and 6 miles upstream from the mouth of the Van Duzen River. The Eel River channel along this reach is straight for a distance of 1,000 feet above and 1,000 feet below the bridge and has steep wooded banks which are not subject to overflow. The channel is fairly stable and the annual changes in streambed elevation are minor. The streambed is a shallow layer of gravel resting on bedrock, and the bottom topography generally consists of shifting gravel bars and exposed bedrock. Bank slumping occurs at higher stages of flow (fig. 10).

FIGURE 10.—Two views (above and facing page) of the left bank of the Eel River just upstream from the Scotia gage, Feb. 5, 1965. A fallen tree, undermined by erosion during the December 1964 flood, rests on a shelf at the transition from alluvial material to bedrock. Flow in picture above is from left to right.

During the 10-year period of daily sediment record, large variations in both runoff and sediment discharge occurred at the Scotia station. Precipitation and runoff were greatest during the 1958 water year when the total runoff was the highest for the 55-year period of record for the station. A large number of rainy days resulted from storms occurring during each month from October through April, and days of high sediment transport were more evenly distributed than in the following 9 years. Runoff was lowest in the 1964 water year, and high flows occurred only in November and January. Annual discharges within 15 percent of the mean annual flow at Scotia were measured during 3 of the 10 years of sediment record.

Suspended-sediment discharge of Eel River at Scotia was 313,900,000 tons from October 1957 through September 1967. Maximum yearly discharge was 167,800,000 tons for the 1965 water year, and the minimum yearly discharge was 4,758,000 tons during the 1962 water year. The monthly maximum suspended-sediment load was 145,700,000 tons in December 1964, and the minimum was 12.3 tons in October 1958. The maximum daily load was an estimated 57 million tons on December 23, 1964, and minimum discharge of less than 0.5 ton per day was measured nearly every year during September and October.

The relation between water discharge and suspended-sediment discharge for Eel River at Scotia is shown in figure 11. This curve represents the 10-year period of sediment record at this station and is biased by the record sediment discharges observed during the 1965 water year. The points through which the curve is drawn are plotted from the data shown in table 6.

To demonstrate the effect of the December 1964 flood on the relation between water discharge and suspended-sediment discharge at Scotia, similar computations were made for the preflood and postflood data, an the resulting curves are shown in figure 12. These data must be supplemented by additional data from the years following 1967 in order that apparent trends may be established as conclusive; however, the curves of figure 12 indicate at least a temporary change in trend. A similar change may have been associated with the large-scale flooding of 1955; however, this cannot be substantiated. Sufficient information is not available to determine the duration of these effects; thus, it is not known if the 1965–67 trend will persist for more than a short period.

The seasonal variability of sediment yield for the Eel River at Scotia and other stations is illustrated by figure 13. In every year, increased sediment yield is an immediate result of winter storms, and the greater part of the total annual load is moved during the days of maximum runoff in these storm periods. The effects of snowmelt,

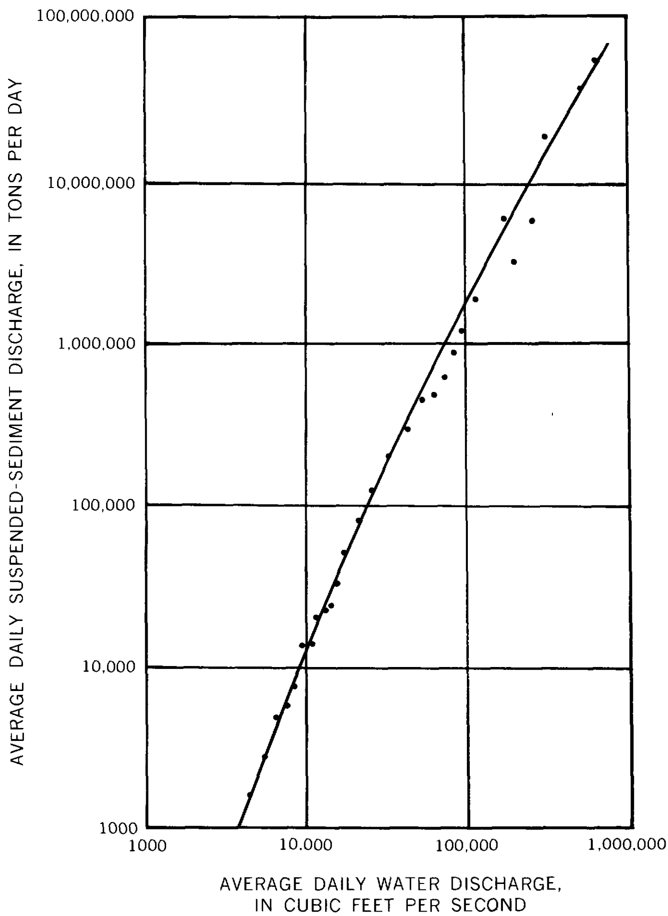

FIGURE 11.—Sediment-transport curve for Eel River at Scotia, October 1957–September 1967.

frozen ground, and runoff from ground-water inflow are usually insignificant in the movement of sediment during periods between storms. Sediment transport during the summer months is negligible.

Figure 14 indicates an approximate relation between yearly water discharge and sediment load. Because the relation between sediment discharge and streamflow is not constant throughout the year, the use of this curve for estimating periods shorter than a year would be misleading. The data are so scattered that even the estimation of annual sediment discharges is questionable, and several additional data points will be needed to define a more usable curve. Estimates or interpolation of sediment discharge may be done more accurately on a daily basis using the curves of figure 12.

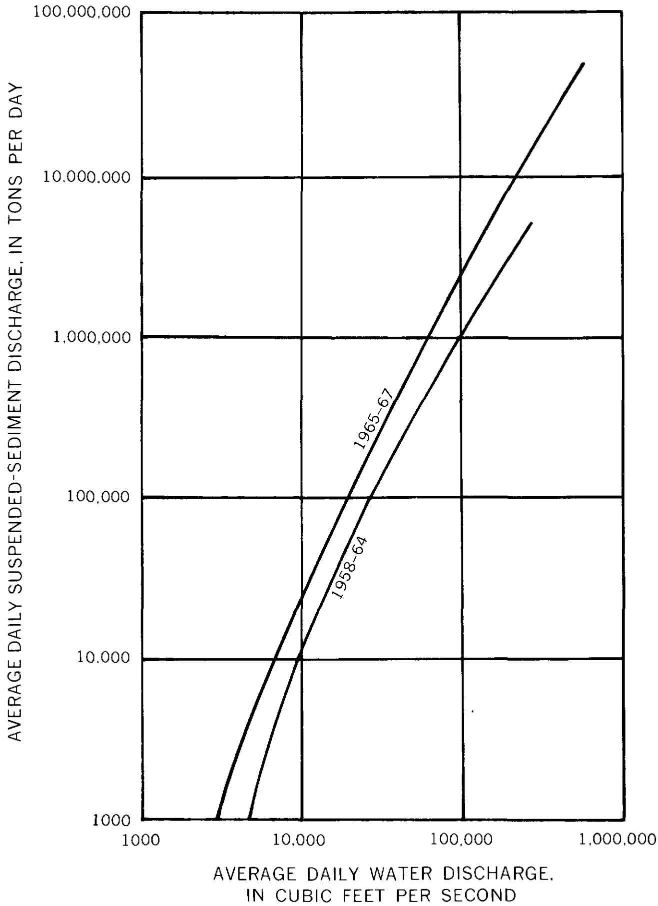

FIGURE 12.—Sediment-transport curves for Eel River at Scotia, showing the change in sediment-transport characteristics after the December 1964 flood.

The variation in particle-size distribution with water discharge for sediment carried as suspended load is shown in figure 15. The scatter of the data points renders the graph somewhat inconclusive; however, certain properties of the relations shown are noteworthy. The most obvious characteristic of the graph is the change in the amount of coarser material transported before and after the December 1964 flood at discharges above 40,000 cfs. Apparently, about 10 percent more sand and silt was carried in suspension in the period after the flood than in the period preceding it. The graph also shows that as much as 50 percent of the suspended load has been of sand size, a size

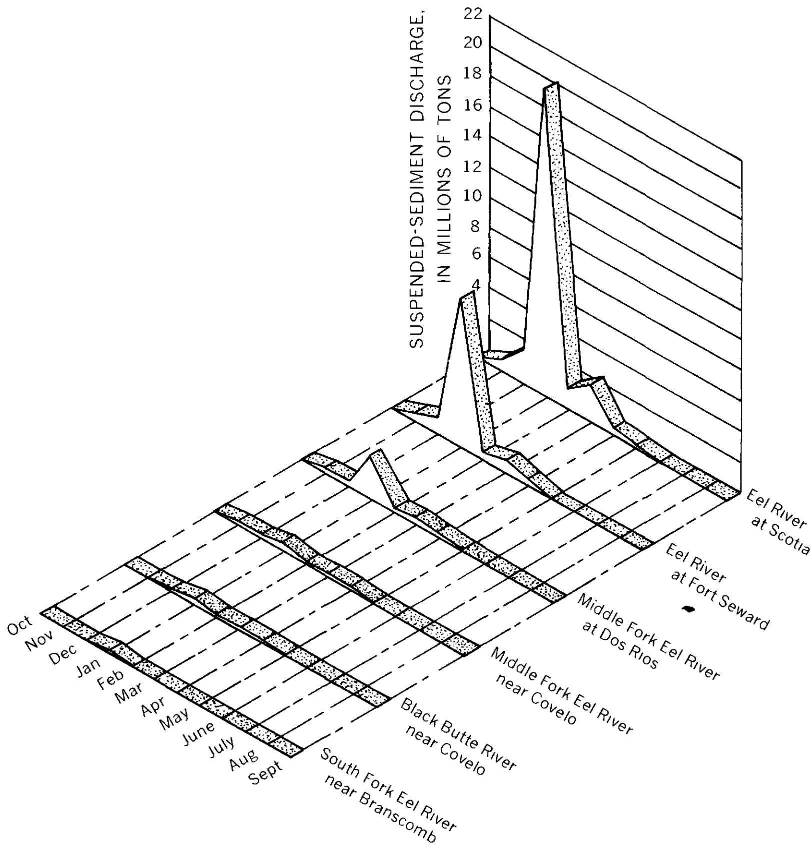

FIGURE 13.—Comparison of suspended-sediment loads of six streams in the Eel River basin, showing typical seasonal variation in sediment discharge, October 1966–September 1967.

that is usually a part of the bed material. Coarse material transported is primarily a function of flow and the availability of coarse material. Hence, the curves indicate that the quantity of coarse material available for transport increased during and after the 1965 water year.

Long-term average suspended-sediment discharges at Scotia were computed by combining the flow-duration characteristics of the water discharge for a long period of streamflow record with sediment-discharge figures taken from appropriate sediment-transport curves, according to procedures discussed by Colby (1956, p. 24). Using the curve of figure 11, the computed average suspended-sediment discharge was 23 million tons per year for the period of streamflow record 1911–14 and 1917–67 water years. Using the

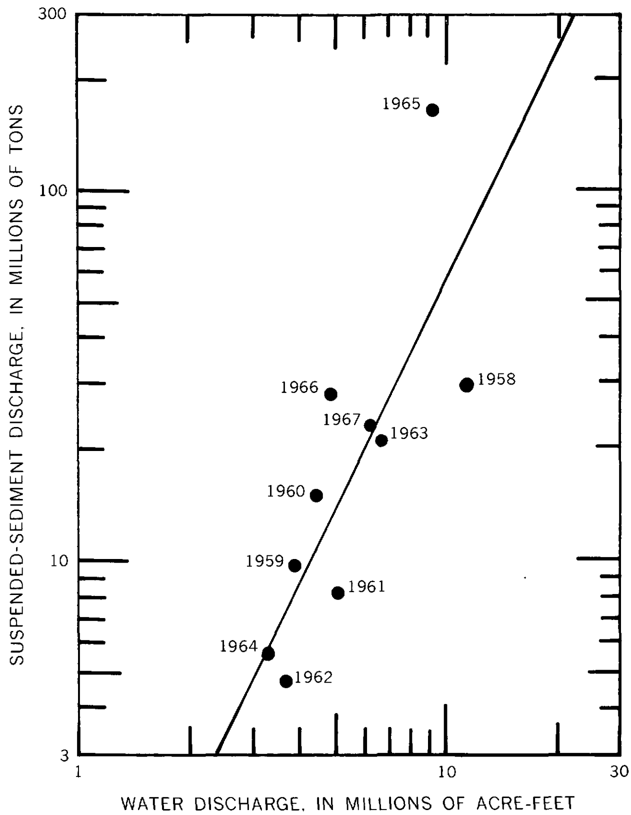

FIGURE 14.—Relation of streamflow to suspended-sediment discharge by water years, Eel River at Scotia.

sediment-transport curve shown in figure 12 for the preflood period, an average suspended-sediment discharge of 13 million tons per year was computed for the 1911–14 and 1917–64 water years.

Suspended-sediment yield for the basin above Scotia was 10,080 tons per square mile per year for the 1958–67 water years, and the yield for the preflood period, 1958–64, was 4,330 tons per square mile per year. The lower figure very nearly represents the long-term yield, which is based on preflood sediment records, and is highly significant even though it is considerably less than the flood-affected higher value. It must be emphasized that preflood sediment discharges and yields were many times greater than those for similar basins throughout the United States (Judson and Ritter, 1964). The flood effects only increased formerly excessive values.[1]

[1] Preflood yields for other stations where data are available may be computed from figures given in table 8.

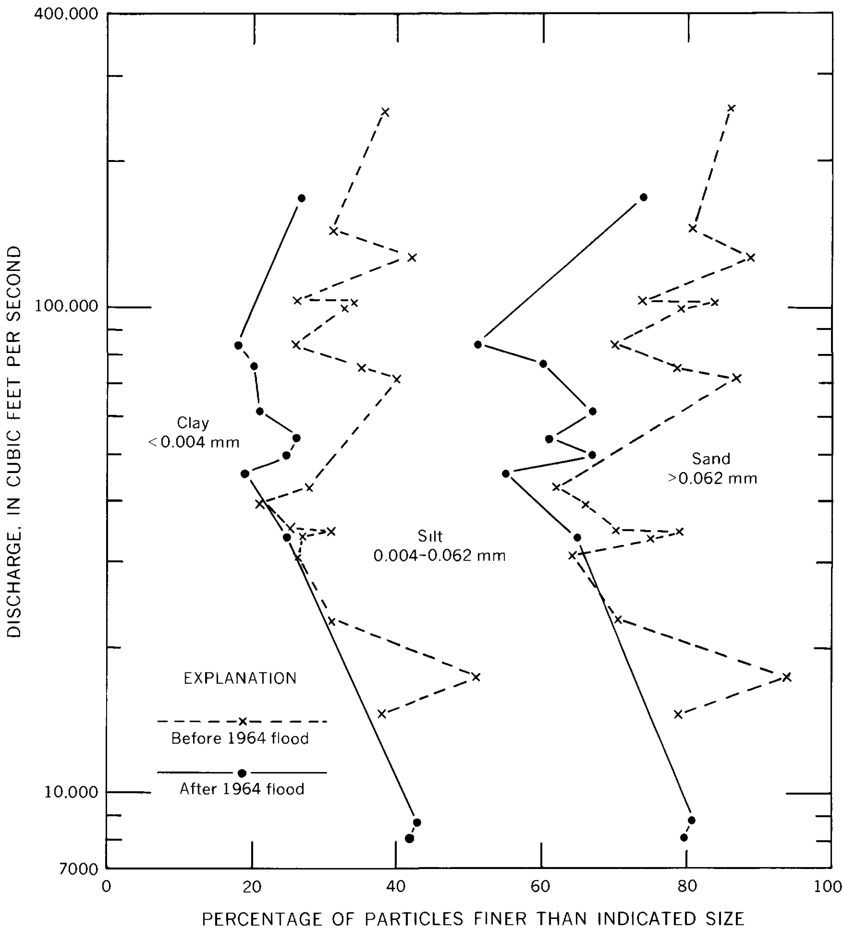

FIGURE 15.—Particle size versus water discharge, Eel River at Scotia, 1963–66.

A comparison of the sediment yield of the Eel River with other rivers of the world is shown in table 7. The figure of 10,000 tons per square mile per year for the Eel River is computed only for the period of sediment record at Eel River at Scotia. The validity of this comparison is somewhat questionable because of short periods of record and differences in methods of sampling; however, the general magnitude of the average annual suspended load figures is indicative of the extremely high sediment production of the Eel River basin.

TABLE 7.—*Suspended-sediment yields of selected rivers of the world*

[Holeman (1968)]

River and location	Drainage area (sq mi)	Average annual suspended load (tons per sq mi)	Average water discharge at mouth (10^3 cfs)	Period of sediment record
Ching—Changchiashan, China	22,000	20,500	2	1932–45
Semani—Urae Kucit, Albania	2,040	11,844		1961–63
Eel—California, U.S.A	3,113	[1] 10,000	7	[1] 1957–67
Yellow—Shenhsien, China	276,000	7,545	53	1934–42
Ganges delta—East Pakistan	409,200	4,000	498	1874–79
Colorado—Arizona, U.S.A	137,800	1,082	5.5	1925–57
Brazos—Texas, U.S.A	34,800	1,000	5.2	1924–50
Arno—San Giovanni Alla Vena, Italy	3,160	770		1936–42 1954–64
Pecos—New Mexico, U.S.A	3,970	685	.6	1948–57
Mississippi—Louisiana, U.S.A	1,244,000	277	630	1951–65
Nile—Egypt	1,150,000	100	100	1958–64

[1] Figures from this report; not shown by Holeman (1968).

MIDDLE FORK EEL RIVER NEAR DOS RIOS

Sediment studies began at Middle Fork Eel River near Dos Rios in January 1956 with periodic sampling which continued through September 1957. Daily sampling was started in October of the 1958 water year and has been continued since that time.

Sediment samples are taken at the highway bridge approximately 0.5 mile upstream from the mouth of the Middle Fork. The stream channel at this point has steep rocky banks and a gravel bed. The channel curves slightly just upstream from the bridge, and is straight for about 1,500 feet downstream of that point. The stream flows in one channel at most stages, and the steep banks are not subject to overflow. Streamflow at higher stages is characterized by high velocities and standing waves. The channel is somewhat contracted in the vicinity of the bridge, and flood stages are so high that streambed elevation changes are small relative to the depth of water. High water during the December 1964 flood reached the base of the bridge, about 68 feet above the streambed at that time. The streambed material that moves past the sediment-sampling site ranges from sand to cobbles with varying types of flow. Bank slumping is minimal in the vicinity of the bridge, and the channel geometry has remained basically unchanged over the past several years.

Runoff of the Middle Fork near Dos Rios prior to the 1966 water year was computed as the difference in runoff between stations on the Eel River downstream and upstream of the mouth of the Middle Fork. However, a streamflow gaging station was established on the Middle Fork in August 1965, and the runoff has been determined at the gage since that time. Total runoff since sediment studies began in

1957 has been about 13,620,000 acre-feet with a corresponding suspended-sediment load of 42,450,000 tons. Both the maximum annual water discharge and the maximum annual suspended-sediment discharge occurred in the 1965 water year when a load of 18,700,000 tons was moved past the gaging site by a flow of 2,768,000 acre-feet.

A sediment-transport curve for Middle Fork Eel River near Dos Rios is shown in figure 16. The curve represents 10 years of sediment data, and restrictions on its application are similar to those discussed for Eel River at Scotia. The data used to define this curve are taken from unpublished records of the U.S. Geological Survey. Figure 17 illustrates the change in the sediment-transport relation at the station due to the effects of the December 1964 flood.

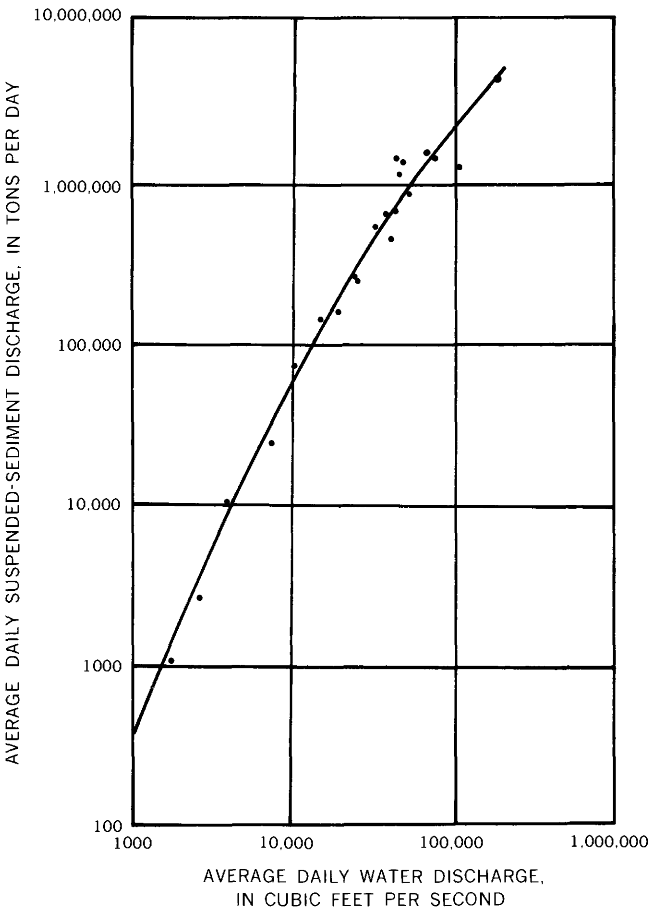

Figure 16.—Sediment-transport curve for Middle Fork Eel River near Dos Rios, October 1957–September 1967.

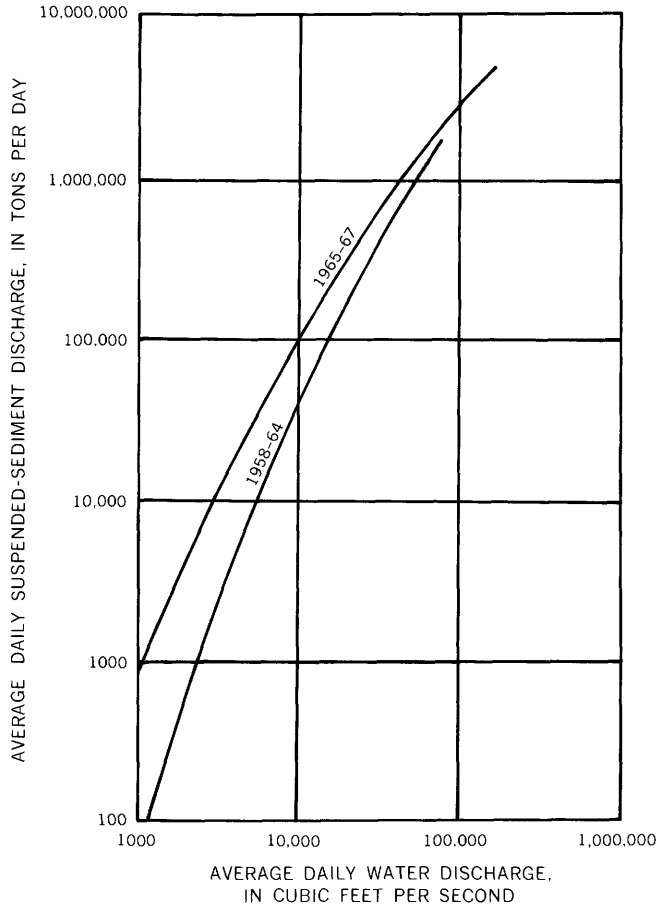

FIGURE 17.—Sediment-transport curves for Middle Fork Eel River near Dos Rios, showing the change in sediment-transport characteristics after the December 1964 flood.

Results of particle-size analyses of samples taken at Middle Fork Eel River near Dos Rios are plotted in figure 18. Two points are plotted for each sample taken to show the breakdown of percentages of sand, silt, and clay carried in suspension at different discharges, The two points chosen define the break in each sample between sand and silt and between silt and clay. The lines on this and subsequent particle-size plots in this report serve only to define general boundaries and indicate possible trends. At Middle Fork Eel River near Dos Rios, the particle-size distribution is similar for most values of water discharge, and there was no apparent change in the distribution after the flood of December 1964.

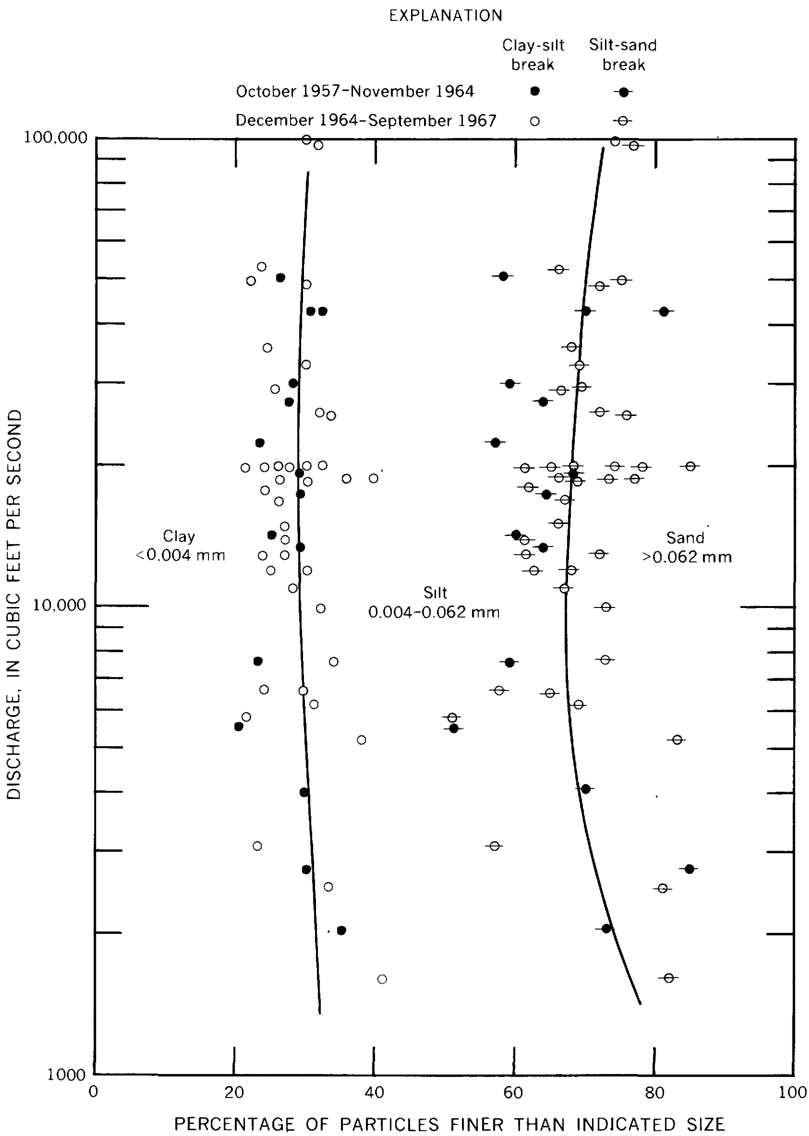

FIGURE 18.—Particle size versus water discharge, Middle Fork Eel River near Dos Rios, 1958–67. Prior to October 1965 the water discharge was estimated by the method described on page 36.

MIDDLE FORK EEL RIVER BELOW BLACK BUTTE RIVER

Upstream from Middle Fork Eel River near Dos Rios, daily sediment sampling was carried on for a 5-year period just below the confluence of the Middle Fork Eel and Black Butte Rivers. Sampling was begun in October 1962 and discontinued on September 30, 1967. The station was destroyed in the December 1964 flood, then replaced, and again destroyed by a flood in January 1967. No suitable site was found to replace the station below the Black Butte River after the 1967 event, and the station was relocated above the Black Butte River. The nature of records obtained at the new station after relocation is, of course, not equivalent to the nature of records from the previous location. Although the available data do not cover an extensive time period, they are of high value when viewed in connection with the general runoff patterns of the Middle Fork basin and the data obtained from studies near Dos Rios.

The stream channel of the Middle Fork below the Black Butte River has a shifting gravel bed and steep banks lined with boulders and brush. The stream has one channel at high stages and two at low stages. At high stages, standing waves form in the swift flow. Low-water streambed elevations remained fairly constant for the 10 years preceding the December 1964 flood, but considerable deposition has taken place since that time (figs. 19 and 20).

Extreme flows of 89,100 and 132,000 cfs occurred in December 1955 and December 1964, respectively. Daily suspended-sediment loads ranged from negligible traces on many days throughout the period of record to an estimated maximum of 2½ million tons on December 22, 1964. The smallest and largest annual loads were recorded in consecutive years. In the 1964 water year 105,300 tons of suspended sediment was discharged, whereas 10,100,000 tons was discharged during the 1965 water year.

Sediment discharge per square mile of drainage area is higher at this station than at any other station in the Eel River basin except Eel River at Scotia. An average rate of more than 8,000 tons per square mile of suspended-sediment discharge has been computed for the upper Middle Fork Eel River drainage basin for the 5-year period beginning October 1963. Storm runoff transports most of this load; 50 percent of the suspended load is transported during an average of 4 days per year. The sediment-transport curve for Middle Fork Eel River below Black Butte River is shown in figure 21, and the relation between particle size and water discharge is shown in figure 22.

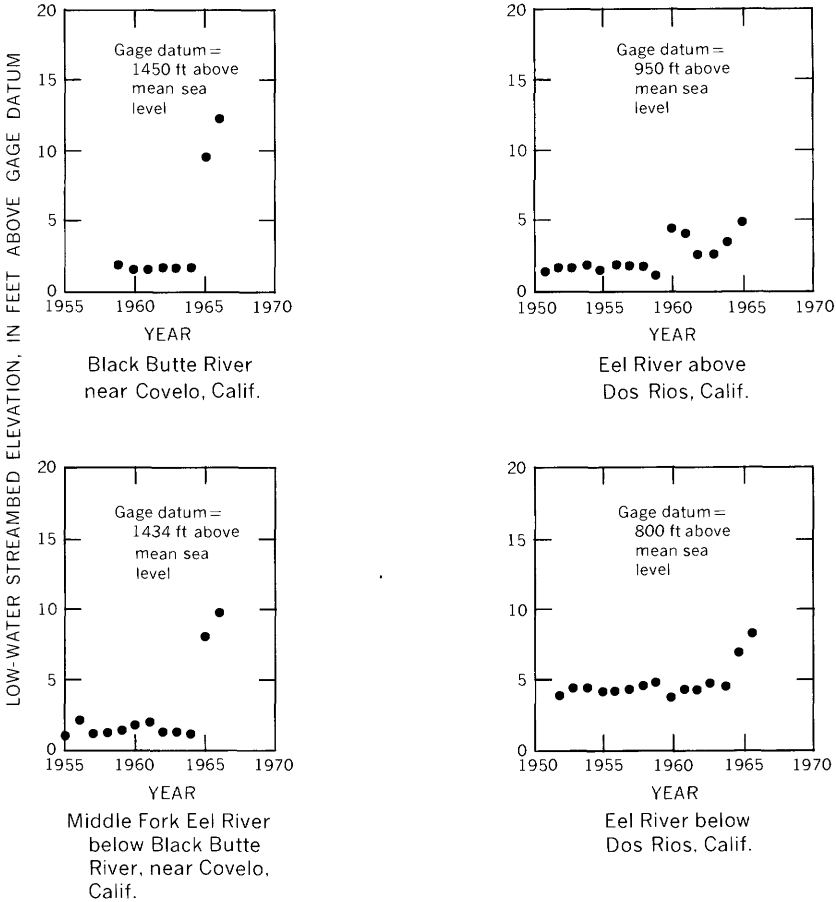

FIGURE 19.—Changes in low-water streambed elevation, by year, at four stations in the Eel River basin. From Hickey (1968).

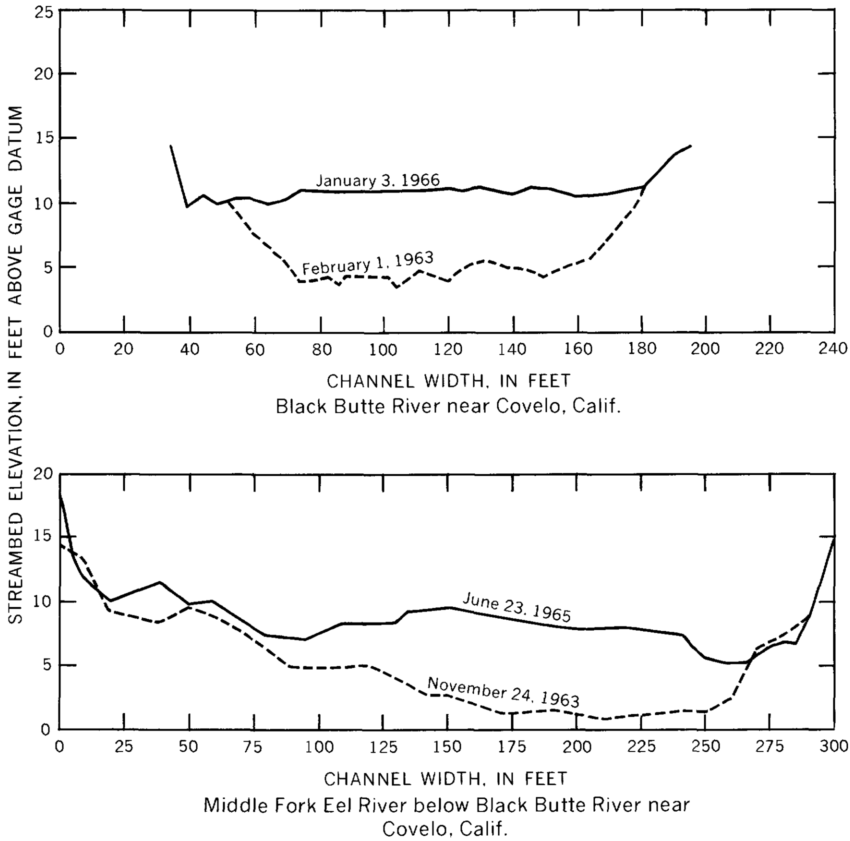

FIGURE 20.—Cross sections at selected gaging stations in the Eel River basin, showing changes attributable to record-high flows during the 1965 water year. From Hickey (1968).

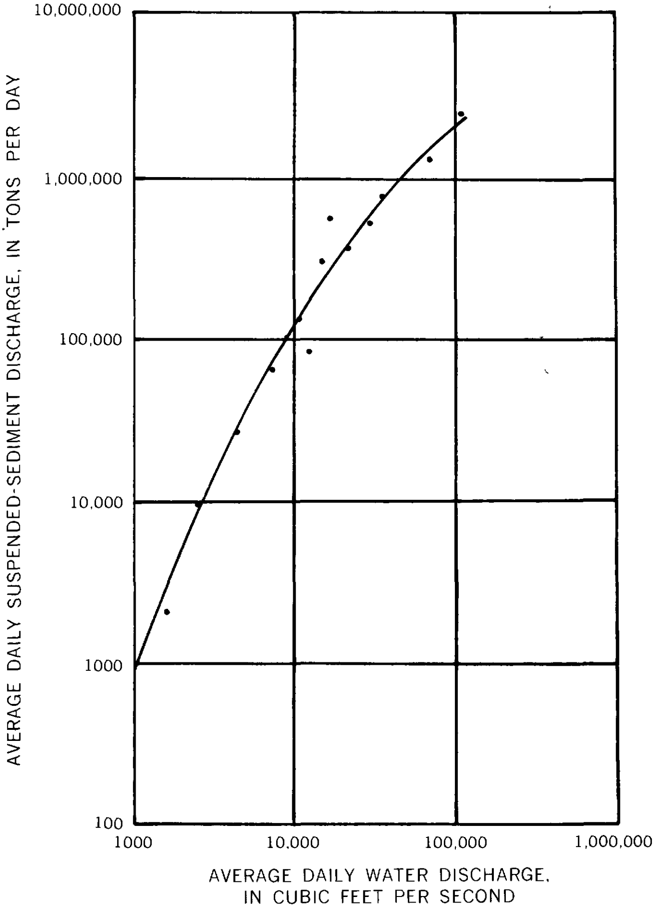

FIGURE 21.—Sediment-transport curve for Middle Fork Eel River below Black Butte River, near Covelo, 1963–67 water years.

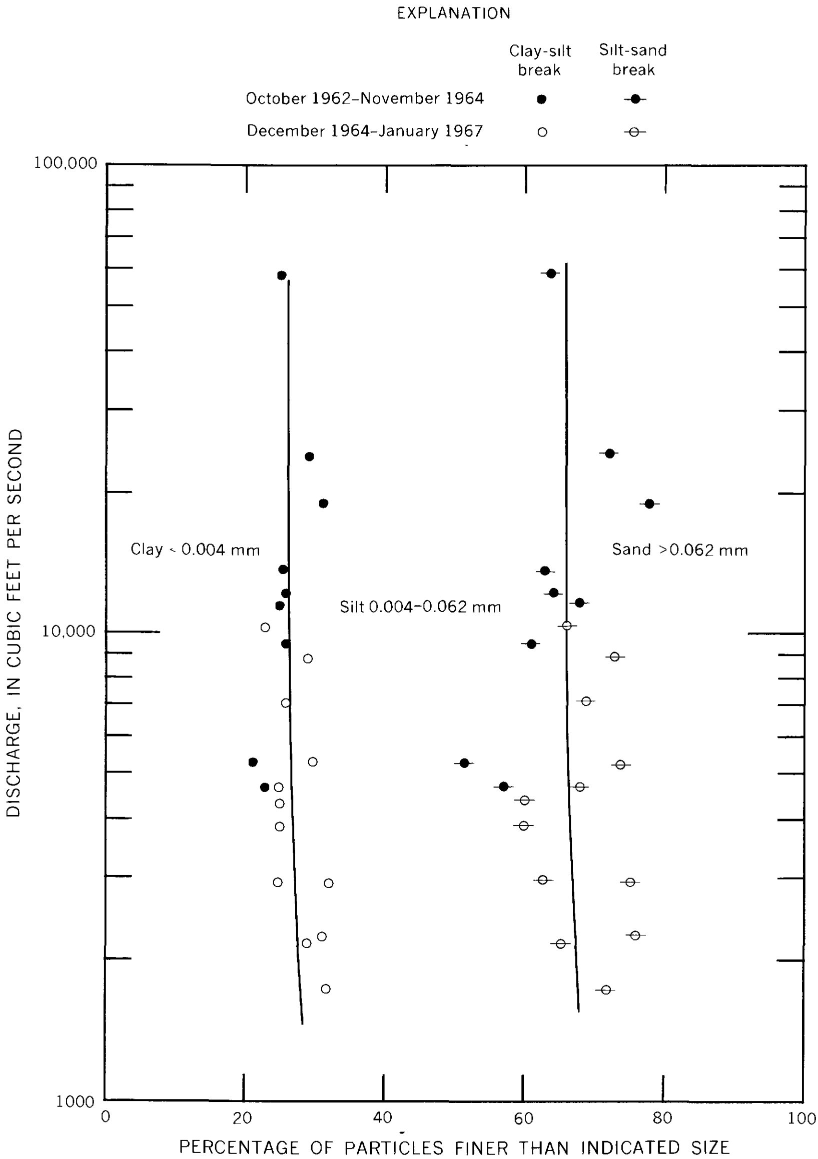

FIGURE 22.—Particle size versus water discharge, Middle Fork Eel River below Black Butte River, near Covelo, 1963–67 water years.

BLACK BUTTE RIVER

Sediment studies in the Black Butte River basin are based on suspended-sediment samples collected daily from November to April of the 1966 water year and December to September of the 1967 water year. During these periods, daily measurements of suspended load were made at the gaging station 0.5 mile upstream from the confluence of the Black Butte and Middle Fork Eel Rivers. Because of the short sampling period, only a limited amount of information is available from which to evaluate fluvial sediment characteristics. However, information from other sources, together with interstation correlation and field observations, offers alternatives in evaluating the basin sediment yield.

The channel of the Black Butte River in the vicinity of the gaging station is straight, and has steep sparsely wooded banks and a gravel bed. For the 2-year period of suspended-sediment observations, sediment deposition has occurred in this section. During the December 1964 flood, the channel bed aggraded approximately 8 feet (fig. 19), and deposition occurred subsequently as material deposited upstream in 1964 was transported downstream by high water in the 1966 and 1967 water years (Hickey, 1968). Deposition of this type is not likely to continue indefinitely; however, the time necessary for the stream to readjust itself to a configuration consistent with the changes which resulted from the flood is unknown.

The general relation between water discharge and suspended-sediment discharge is shown in figure 23 and can be considered representative only of the short term from which the data are taken. Extension of these data over past or projected flows presents many uncertainties because of the presently changing channel conditions. The relation between particle size and water discharge (fig. 24) shows a pattern similar to other stations in the Middle Fork Eel River basin; however, the number of samples is insufficient to show more than a comparison with other stations.

Runoff in the Black Butte River basin ranged from a minimum of 1.2 cfs in September 1959 to a maximum of 29,000 cfs in December 1964, during a 9-year period of record beginning in October 1956. Total runoff for the period of sediment record was 473,800 acre-feet, and the corresponding sediment discharge was calculated to be 1,405,000 tons. Maximum monthly suspended-sediment discharge was 496,200 tons in January 1967, and the maximum daily suspended-sediment discharge was 143,000 tons on January 4, 1966. Minimum loads of less than 0.1 ton were measured for many days during the summer months in 1967.

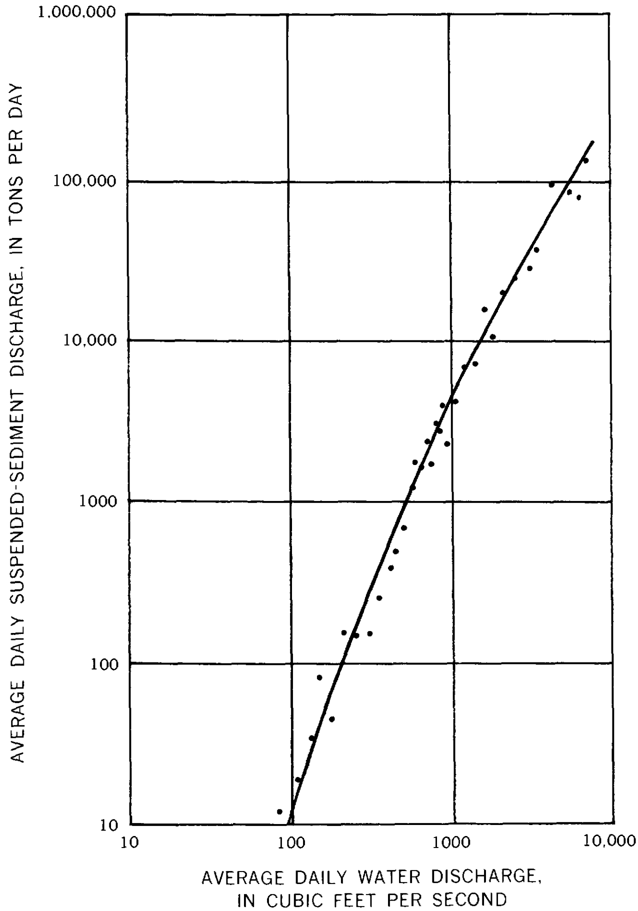

FIGURE 23.—Sediment-transport curve for Black Butte River near Covelo, November 1965–April 1966 and December 1966–September 1967.

Fluvial sediment in the Black Butte River basin is derived primarily from a large area of landslides covering the eastern slopes of the basin (fig. 3). Although the sediment removed from this slide region is not measured directly, observations of the mechanisms by which it moves show that large volumes of soil and rock will enter the stream channel under the influence of bank cutting by the stream. The already precarious stability of an earthflow is readily disturbed as the lower supporting material is removed, and residual uphill material becomes immediately susceptible to downslope movement (fig. 25).

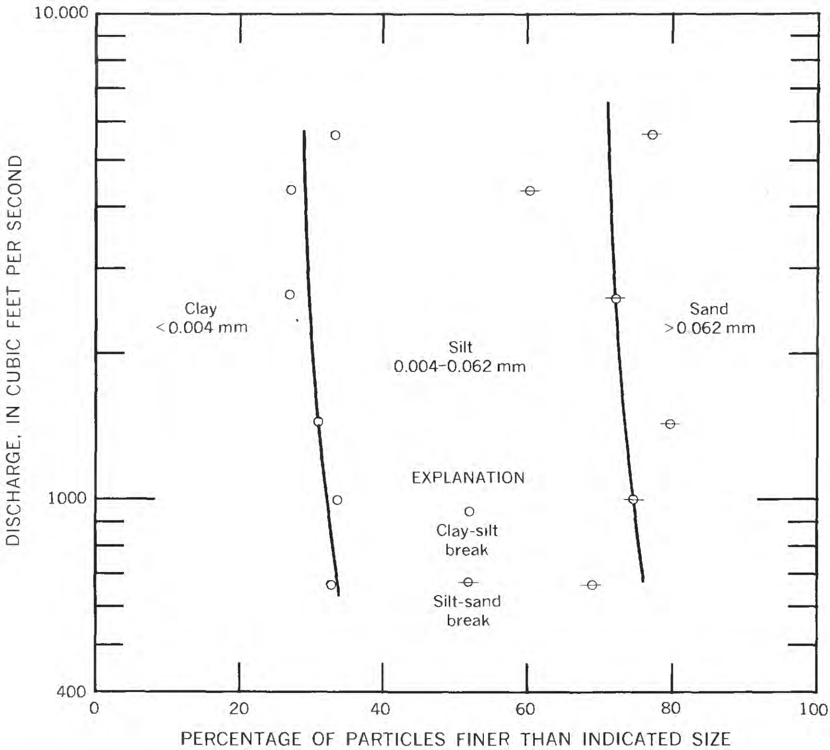

FIGURE 24.—Particle size versus water discharge, Black Butte River near Covelo, December 1966–September 1967.

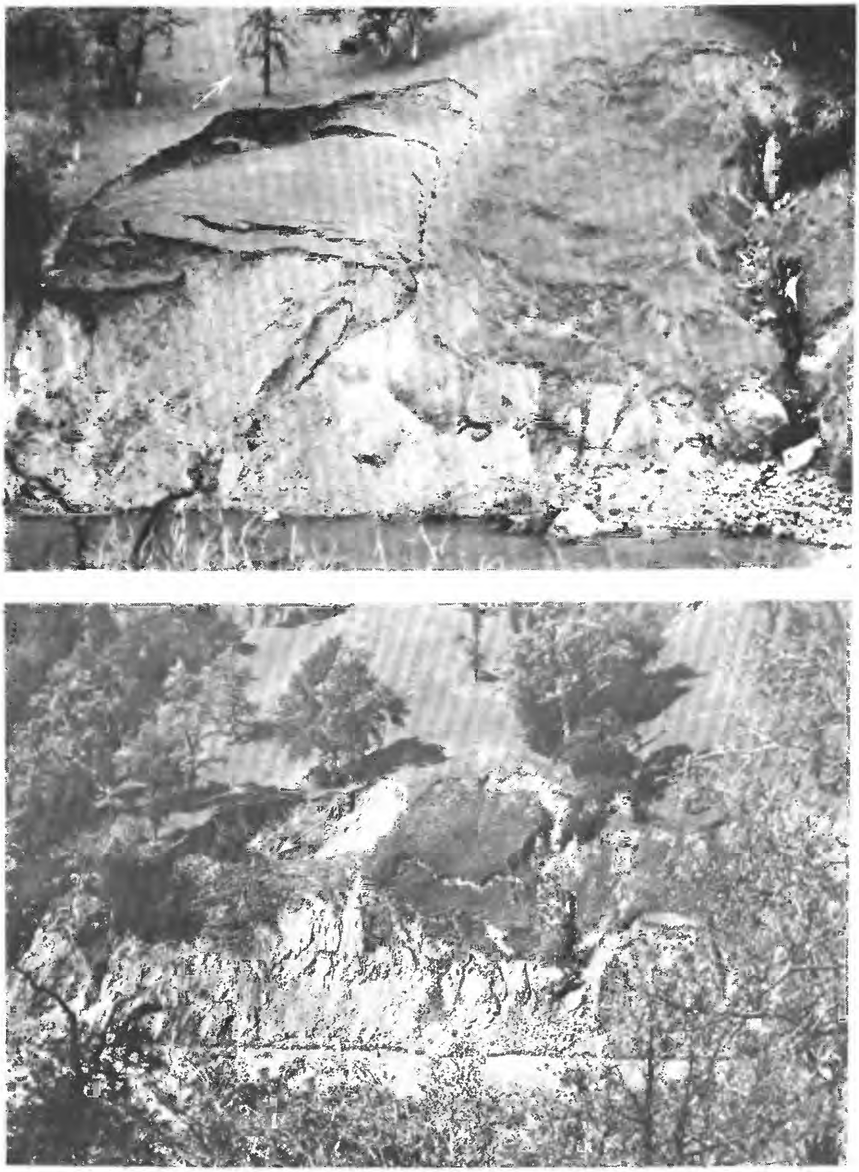

FIGURE 25.—Mass wasting adjacent to stream, typical of many locations in the Eel River basin. Comparative photographs show slide activity along the Middle Fork Eel River. *Top*, Photograph taken Apr. 23, 1968. Recent and older landsliding along the Middle Fork Eel River above the mouth of the Black Butte River. Note gullying along the older slide (at right) and the seeps at the bases of both slides. *Bottom*, Photograph taken Apr. 30, 1969. Slide in left of picture has moved several feet, toppling a tree (indicated by arrow in each photograph) which was undisturbed the previous year. Note the crack in the older slide which does not appear in the earlier picture.

EEL RIVER AT FORT SEWARD

A sediment station was established on the Eel River at Fort Seward in October 1965. Sediment samples have been collected daily at the highway bridge about 0.25 mile east of Fort Seward since that time. Information about the nature of fluvial sediment at this station is minimal because of the short period of sampling; however, sediment studies at this station do give some indication of the contribution of sediment of that part of the basin between Dos Rios and Scotia. Because of the magnitude of the sediment yield in this area, future sediment programs should emphasize the reach of the Eel River between Dos Rios and Scotia.

Varying proportions of sand and gravel make up the streambed at the gaging site. The river banks are steep and rocky and not subject to overflow. The flow is in one channel at all stages, and at higher stages the flow is swift and turbulent. At a gage height of approximately 30 feet, the flow begins to override a sharp bend in the river about 600 feet upstream of the gage and approaches the bridge at a slight angle.

Suspended-sediment discharge was 29,210,000 tons during the 2-year period of record at Fort Seward, and this discharge was about 56 percent of that recorded during the same period at Scotia. The South Fork Eel River annually contributes about 13 percent of the sediment discharge at Scotia (table 9); thus, the South Fork and the Eel River above Fort Seward had a combined suspended-sediment discharge which was about 69 percent of that at Scotia. The remaining drainage area below Fort Seward and above Scotia excluding the South Fork apparently contributed about 31 percent of the discharge at Scotia during the 2-year period, or about 17,000 tons per square mile per year from a 35-mile stretch of river draining 469 square miles. Similarly, the suspended-sediment yield between Dos Rios and Fort Seward, a reach draining 657 square miles, was about 15,000 tons per square mile per year. These yields are about twice the yield of the entire basin above Scotia during this period. This again emphasizes the importance of sediment studies in the drainage area between Dos Rios and Scotia, which includes the North Fork Eel River and Larabee Creek drainages.

A sediment-transport curve for a 2-year period of sediment record at Eel River at Fort Seward is shown in figure 26. The variation in particle-size distribution with flow is shown by figure 27.

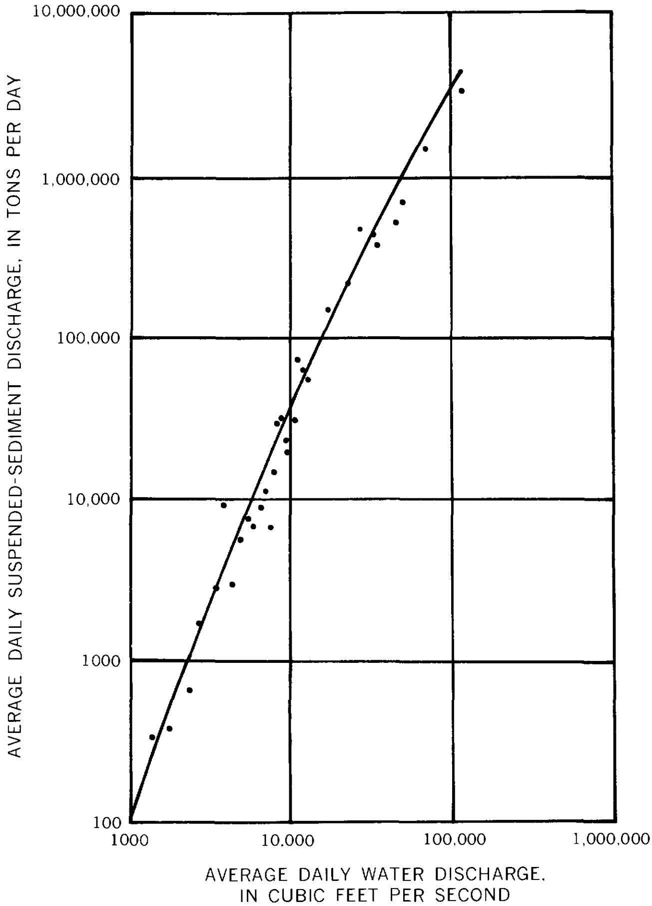

FIGURE 26.—Sediment-transport curve for Eel River at Fort Seward, 1966–67 water years.

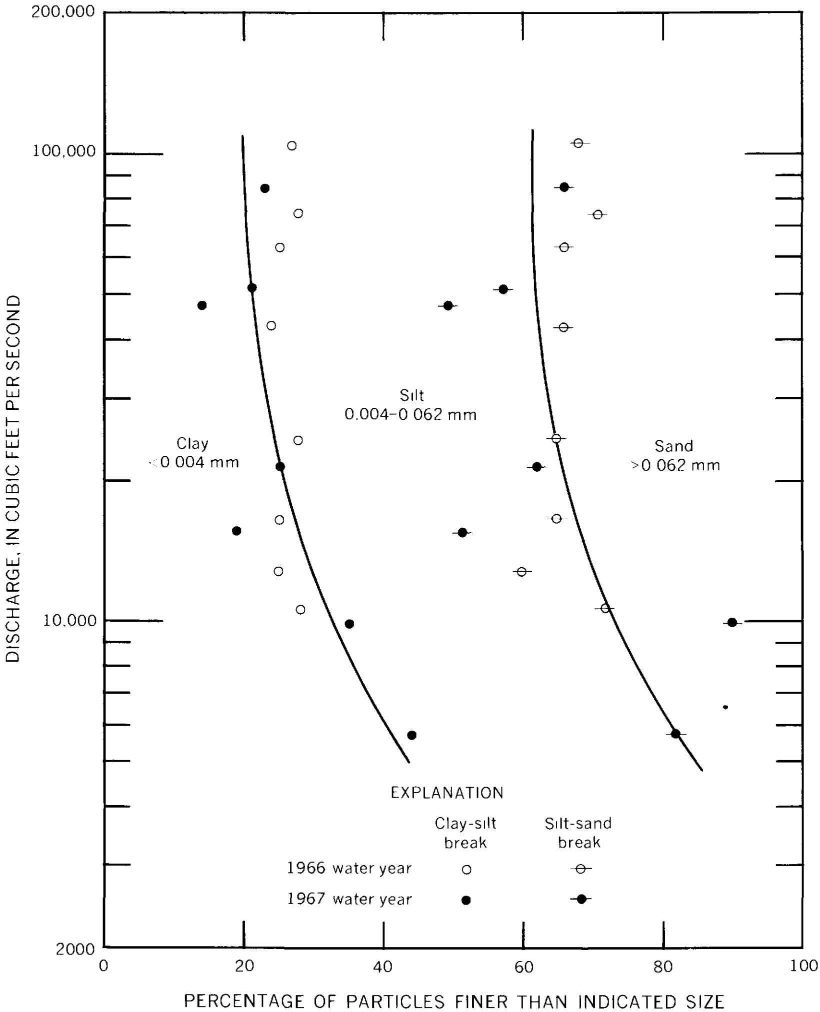

FIGURE 27.—Particle size versus water discharge, Eel River at Fork Seward. 1966–67 water years.

SOUTH FORK EEL RIVER

Sediment studies along the South Fork Eel River are based primarily on data collected at samplings stations near Branscomb and Miranda. Periodic sediment sampling was begun at South Fork Eel River near Miranda in October 1955 and continued through September 1962. South Fork Eel River near Branscomb was sampled periodically from August 1957 until a daily sampling program began in October 1962. Daily sediment sampling has been continuous at the Branscomb station since that time.

The channel bed at South Fork Eel River near Miranda is composed of gravel. The left bank of the river is wooded, and is fairly stable at all stages. The right bank is sandy up to medium stages and wooded at high stages, and the river overflows the right bank at a gage height of about 30 feet. The channel is straight for a distance of 600 feet upstream and 600 feet downstream from the measuring cableway, and flow in the channel is swift at high stages.

Computations by Hawley and Jones (1969, p. 13) from the periodic records collected at the Miranda station indicate that sediment discharge from October 1957 through September 1962 was 8,870,000 tons, or about 13 percent of the suspended-sediment discharge measured downstream at Scotia during the same period. The maximum annual load was 3,900,000 tons, which accompanied a water discharge of 2,444,000 acre-feet in the 1958 water year. Sediment data are not available subsequent to September 1962; thus, the effect of the December 1964 flood on the sediment transport at the Miranda station is unmeasured.

Upstream, at South Fork Eel River near Branscomb, the streambed consists of gravel and bedrock, and the channel has steep banks covered with undergrowth. The flow is confined to one channel at all stages.

Hawley and Jones (1969, p. 13) computed a sediment discharge of 446,000 tons at the Branscomb station for the 5-year period beginning October 1957. Suspended-sediment discharge from October 1962 through September 1967 was 800,700 tons, of which 502,800 tons was measured during the 1965 water year. Average runoff over the 10-year period was 125,200 acre-feet per year, and the maximum annual runoff was 219,200 acre-feet in the 1958 water year. The patterns of runoff and sediment discharge at the Branscomb station are similar to the patterns observed elsewhere in the basin. Maximum annual suspended-sediment discharge did not accompany the maximum annual water discharge which occurred in 1958, and the 1966 and 1967 water years exhibited comparatively high sediment discharges because of continuing adjustments of the stream to the December 1964 flood effects.

The sediment-transport curve for South Fork Eel River near Branscomb is shown in figure 28. The data from which the plot is derived are representative of the 1963–67 period and do not include the periodic data collected before October 1962. Plots of particle size versus water discharge for South Fork Eel River near Miranda and South Fork Eel River near Branscomb are shown in figures 29 and 30.

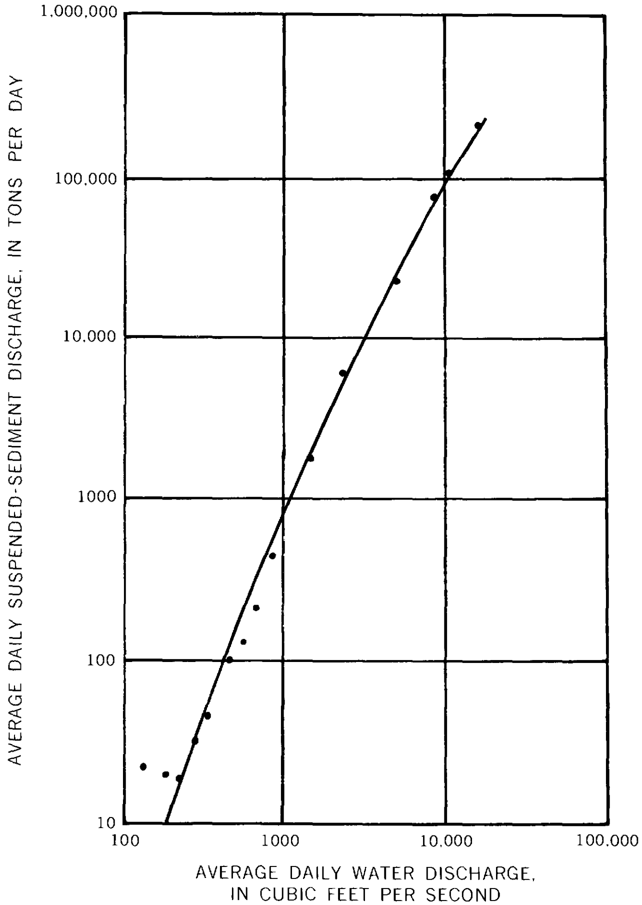

FIGURE 28.—Sediment-transport curve for South Fork Eel River near Branscomb, 1963–67 water years.

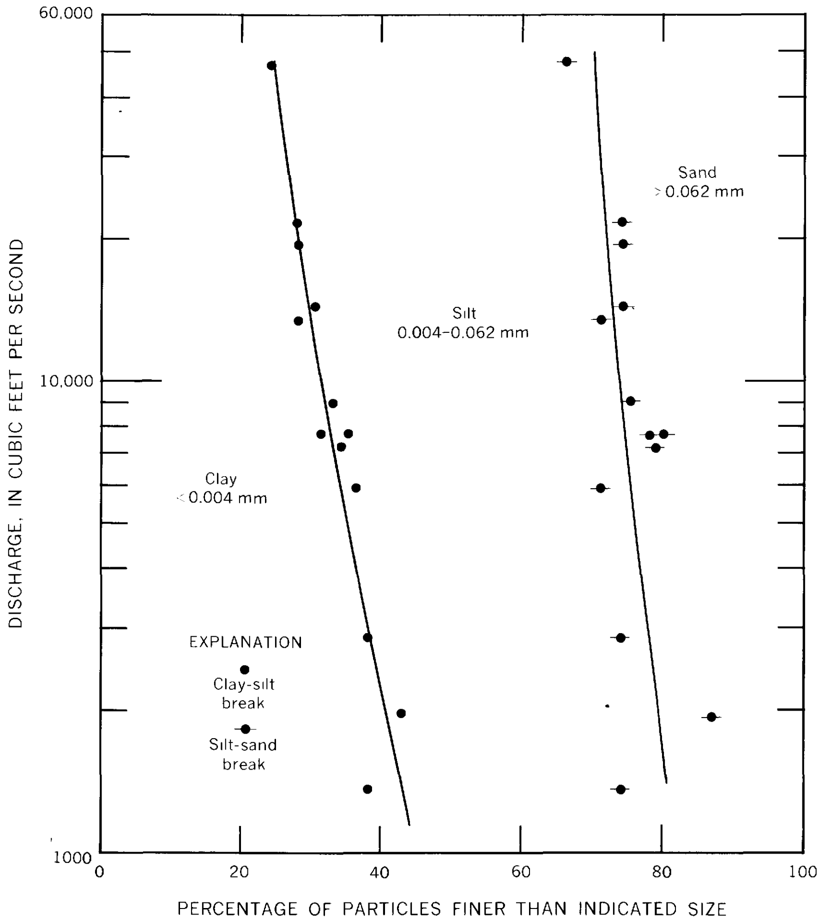

FIGURE 29.—Particle size versus water discharge, South Fork Eel River near Miranda, 1958–62 water years.

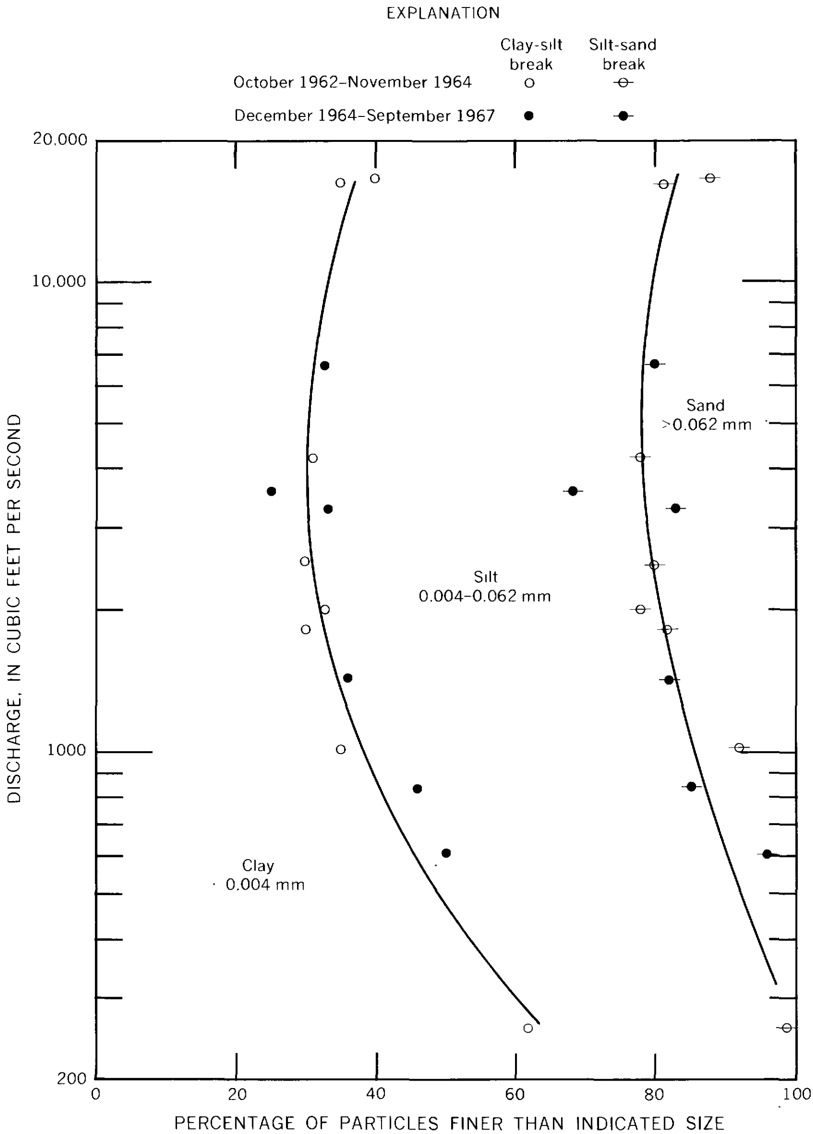

FIGURE 30.—Particle size versus water discharge, South Fork Eel River near Branscomb, 1963–67 water years.

QUANTITY AND DISTRIBUTION OF FLUVIAL SEDIMENT

The suspended-sediment discharge determined at Eel River at Scotia was 313,900,000 tons for the 10-year period beginning October 1957. By use of this figure and the data presented in table 8, the quantity and distribution of suspended-sediment discharge throughout the basin may be computed. A lack of data concurrent with the 10-year record at Scotia precludes an exact analysis of sediment sources in some areas of the basin; however, reasonable estimates and computations can be made where significant trends exist in the concurrent records of shorter periods.

The Middle Fork Eel River, which drains 24 percent of the Eel River basin above Scotia, discharged about 42 million tons, or 13.4 percent, of the suspended load at Scotia during the 10-year period of record. The suspended-sediment discharges of other subunits of the Eel River basin were not determined for a comparable period; thus, an approximation of the yields of these basins must be made by using the average percentages shown in the last column in table 9. On this basis, the Eel River above its confluence with the Middle Fork Eel River contributes about 6 percent of the annual suspended load at Scotia, although sedimentation along the upper Eel River is influenced by Lake Pillsbury, Van Arsdale Reservoir, and the diversion of water into Potter Valley. Thus, the suspended sediment derived from the upper Eel River was about 19 million tons during the period cited above.

The South Fork Eel River drains 17 percent of the basin above Scotia, and the suspended-sediment discharge of the South Fork constituted 13 percent of the discharge at Scotia from the 1958 water year through the 1962 water year. Projection of the 13 percent figure through the 1967 water year would show that the suspended sediment carried by the South Fork was about the same as that of the Middle Fork for the 10-year period. Data from South Fork Eel River near Branscomb do not show a significant change in the percentage of suspended sediment delivered downstream to Scotia in the 5 years following the discontinuation of sampling at South Fork Eel River near Miranda. Thus, a reasonable estimate of the suspended-sediment discharge of the South Fork Eel River is about 13 percent of the discharge at Scotia, which is 41 million tons for the 10-year period beginning October 1957, or about 7,600 tons per square mile per year. This figure is consistent with the figures derived for stations in the basin where preflood sediment yields were considerably less than the 10-year average sediment yield which included the 1964–65 flood period. For example, the average sediment yield at Middle Fork

TABLE 8.—*Summary of suspended-sediment and water discharge in the Eel River basin, October 1957–September 1967*

Water year	Water discharge (acre-feet)	Suspended-sediment discharge, Q_s (tons)	Suspended-sediment yield (tons per sq mi)	Days per year required for transport of 50 percent Q_s	Percent of discharge at Scotia	
					Water	Suspended-sediment, Q_s
11-4725. Eel River above Dos Rios [Drainage area, 705 sq mi]						
1958	2,051,000	2,062,000	2,925	9	17.9	7.0
1959	479,000	332,100	471	4	12.0	3.3
1960	943,700	1,803,000	2,557	2	20.8	11.9
1961	757,200	412,900	586	5	14.6	5.0
1962	630,500	430,800	611	4	16.8	9.0
1963	1,105,000	1,715,000	2,433	2	16.0	8.1
1964	376,000	240,500	341	2	11.3	4.2
1965	1,822,000	9,571,000	13,580	2	19.7	5.7
Avg	1,021,000	2,071,000	2,938	---	16.9	6.3
11-4729. Black Butte River near Covelo [Drainage area, 162 sq mi]						
1966 [1]	169,600	474,300	---	3	3.5	1.7
1967 [1]	304,200	930,800	---	5	4.8	4.0
Avg	236,900	[2] 702,100	4,330	---	4.2	2.7
11-4730. Middle Fork Eel River below Black Butte River, near Covelo [Drainage area, 367 sq mi]						
1963	829,100	1,618,000	4,409	2	12.0	7.6
1964	334,900	105,300	287	2	10.1	1.9
1965	1,339,000	10,100,000	27,520	4	14.4	6.0
1966	559,000	1,116,000	3,041	5	11.3	4.0
1967	798,700	1,974,000	5,379	7	12.5	8.4
Avg	772,100	2,983,000	8,041	---	12.5	6.0
11-4739. Middle Fork Eel River near Dos Rios [Drainage area, 745 sq mi]						
1958	[3] 2,498,000	4,157,000	5,580	---	21.8	14.1
1959	[3] 746,900	841,900	1,130	---	18.9	8.5
1960	[3] 886,000	2,649,000	3,556	---	19.6	17.5
1961	[3] 1,110,000	847,900	1,138	---	21.5	10.2
1962	[3] 857,600	579,000	777	---	22.7	12.2
1963	[3] 1,614,000	4,710,000	6,322	---	23.4	22.3
1964	[3] 647,300	759,400	1,019	---	19.4	13.4
1965	[3] 2,768,000	18,700,000	25,100	---	30.2	11.2
1966	1,062,000	4,330,000	5,812	3	21.3	15.4
1967	1,434,000	4,880,000	6,550	7	22.3	20.7
Avg	1,363,000	4,245,000	5,698	---	22.8	13.6
11-4750. Eel River at Fort Seward [Drainage area, 2,107 sq mi]						
1966	2,657,000	13,210,000	6,270	2	53.5	46.8
1967	3,818,000	16,000,000	7,594	6	59.6	68.0
Avg	3,238,000	14,600,000	6,872	---	57.0	56.0

Footnotes at end of table.

TABLE 8.—*Summary of suspended-sediment and water discharge in the Eel River basin, October 1957–September 1967*—Continued

11-4755. South Fork Eel River near Branscomb

[Drainage area, 43.9 sq mi]

Water year	Water discharge (acre-feet)	Suspended-sediment discharge, Q_s (tons)	Suspended-sediment yield (tons per sq mi)	Days per year required for transport of 50 percent Q_s	Percent of discharge at Scotia: Water	Percent of discharge at Scotia: Suspended-sediment, Q_s
1958	219,200	[4] 88,000	2,000		1.9	0.3
1959	81,590	[4] 10,000	230		2.0	.1
1960	110,300	[4] 330,000	7,500		2.4	2.2
1961	116,600	[4] 10,000	230		2.2	.1
1962	77,480	[4] 8,000	180		2.1	.2
1963	133,200	61,760	1,407	4	1.9	.3
1964	87,550	26,330	600	1	2.6	.5
1965	194,300	502,800	1,145	2	2.1	.3
1966	107,400	154,500	3,519	1	2.2	.6
1967	124,300	55,340	1,261	5	1.1	.2
Avg, 1958–67	125,200	125,000	2,850		2.1	.4
Avg, 1963–67	129,400	160,100	3,583		2.1	.3

11-4765. South Fork Eel River near Miranda

[Drainage area, 537 sq mi]

Water year	Water discharge (acre-feet)	Suspended-sediment discharge, Q_s (tons)	Suspended-sediment yield (tons per sq mi)	Days per year required for transport of 50 percent Q_s	Percent of discharge at Scotia: Water	Percent of discharge at Scotia: Suspended-sediment, Q_s
1958	2,444,000	[4] 3,900,000	7,300		21.3	13.3
1959	970,200	[4] 1,300,000	2,400		24.3	13.1
1960	1,142,000	[4] 2,000,000	3,700		25.2	13.2
1961	1,299,000	[4] 1,200,000	2,200		25.1	14.5
1962	847,000	[4] 470,000	880		22.5	9.9
Avg	1,340,000	1,774,000	3,300		23.2	13.0

11-4770. Eel River at Scotia

[Drainage area, 3,113 sq mi]

Water year	Water discharge (acre-feet)	Suspended-sediment discharge, Q_s (tons)	Suspended-sediment yield (tons per sq mi)	Days per year required for transport of 50 percent Q_s	Percent of discharge at Scotia: Water	Percent of discharge at Scotia: Suspended-sediment, Q_s
1958	11,470,000	29,420,000	9,450	12	100	100
1959	3,991,000	9,936,000	3,192	5	100	100
1960	4,532,000	15,120,000	4,857	2	100	100
1961	5,178,000	8,279,000	2,659	9	100	100
1962	3,764,000	4,758,000	1,528	6	100	100
1963	6,883,000	21,190,000	6,807	6	100	100
1964	3,329,000	5,652,000	1,816	2	100	100
1965	9,242,000	167,800,000	53,900	2	100	100
1966	4,963,000	28,220,000	9,065	3	100	100
1967	6,407,000	23,530,000	7,558	7	100	100
Avg	5,976,000	31,390,000	10,080		100	100

11-4785. Van Duzen River near Bridgeville

[Drainage area, 216 sq mi]

Water year	Water discharge (acre-feet)	Suspended-sediment discharge, Q_s (tons)	Suspended-sediment yield (tons per sq mi)	Days per year required for transport of 50 percent Q_s	Percent of discharge at Scotia: Water	Percent of discharge at Scotia: Suspended-sediment, Q_s
1958	1,006,000	[4] 2,000,000	9,260			
1959	491,200	[4] 2,600,000	12,037			
1960	467,700	[4] 2,000,000	9,260			
1961	586,200	[4] 790,000	3,657			
1962	417,600	[4] 300,000	1,389			
1963	770,600	[4] 1,000,000	4,630			
1964	455,800	[4] 800,000	3,704			
1965	791,000	[2] 3,530,000	16,343			
1966	538,000	[2] 1,350,000	6,250			
1967	617,200	[2] 1,200,000	5,555			
Avg	614,100	1,557,000	7,208			

[1] Figures based on partial records, from November to May, 1966 water year, and from November to September, 1967 water year.
[2] Computed by flow-duration and sediment-rating-curve method (Miller, 1951).
[3] Discharge computed as difference between discharges at Eel River above Dos Rios and Eel River below Dos Rios.
[4] Hawley and Jones (1969).

Eel River near Dos Rios was 2,400 tons per square mile between October 1957 and September 1962 and was increased to 5,700 tons per square mile with the inclusion of subsequent data for the 1963–67 water years.

The three basins discussed, which make up 64 percent of the Eel River basin above the Scotia gage, contributed annually an average of 32 percent of the suspended-sediment discharge computed at Scotia. The remaining suspended-sediment discharge, about 212 million tons during the 10-year period, came from an area of 1,126 square miles in the central part of the basin which includes the North Fork Eel River basin. Further division of this area to pinpoint local areas of high sediment yield cannot be done adequately using the existing data. However, records from the 1966 and 1967 water years at Eel River at Fort Seward show that during these 2 years the sediment yield was divided about equally between the parts of this central area above and below Fort Seward.

Sediment yield is greatest in those parts of the basin where earthflows and landslides are adjacent to the stream channels. According to Soil Conservation Service studies (file data, 1968), streambank erosion at higher flows produces between 60 and 65 percent of the sediment yield in the basin; however, the combined effects of the erosion of channels and landslide debris contribute about 90 percent of the fluvial sediment in the basin. Ephemeral runoff from watershed slopes and roads accounts for the remaining 10 percent.

SEDIMENTATION IN LAKE PILLSBURY

Lake Pillsbury on the upper Eel River is an important source of information concerning the effects of reservoirs on sedimentation. Few data on reservoir sedimentation are available for northern coastal California watersheds; thus, past and present studies of Lake Pillsbury provide the principal usable data for planning additional reservoir projects along the Eel River.

Lake Pillsbury is the larger of two reservoirs which make up a part of the Potter Valley Project, a multiple-use facility designed to provide for irrigation and recreation needs and power development in the vicinity of the upper Eel River and Russian River basins. The drainage area of the lake encompasses 288 square miles of steep rugged terrain in which the maximum basin relief is about 5,200 feet. The lake is fed principally by the Eel and Rice Fork Eel Rivers, both of which have slopes greater than 160 feet per mile above the lake. Most of the sediment supplied to Lake Pillsbury is derived from the erosion of stream channels and the erosion of lands from which protective vegetal cover has been removed.

The accumulation and distribution of sediment in the reservoir were studied in some detail by Porterfield and Dunnam (1964) to evaluate changes which had taken place since water storage began in 1921. Data from their report show a sediment inflow between 1921 and 1959 of about 343,000 tons per year, of which 94 percent was deposited within the reservoir. The sediment inflow was computed using sediment-accumulation figures and a specific weight for sediment of 73 pounds per cubic foot (Porterfield and Dunnam, 1964, p. EE45). Thus, the average sediment load passing through the reservoir and carried downstream was about 21,000 tons per year and was composed primarily of sediment finer than sand. Most sediment of sand size and larger drops out of suspension in the lake.

Reservoir design in the Eel River basin should take into account the high trap efficiency observed at Lake Pillsbury as well as other factors which affect reservoir sedimentation such as bank slides, the effect of wave action on bank erosion, and reservoir orientation with respect to inflowing streams. Discussion and computations provided in the report by Porterfield and Dunnam, combined with a knowledge of sedimentation rates, provide useful information for future reservoir studies.

TURBIDITY

Part of the studies aimed at the development of northern coastal California watersheds is a study of the causes and effects of turbidity in streams and reservoirs. Turbidity may limit the use of water for public consumption, and it may make water unsatisfactory for recreational uses such as fishing. Recognizing that turbidity could be a major problem in the development of northern coastal streams, State and Federal agencies have initiated various sampling programs and other studies to gain more information about turbidity. The U.S. Geological Survey in cooperation with the State of California has collected turbidity samples and has made field turbidity measurements at several stations in the Eel River watershed. Turbidity measurement was begun in the latter part of the 1964 water year and was continued through the 1968 water year at several stations. The 1964 data were collected after most of the runoff for that water year had already occurred; thus, those data are considered incomplete and are not used in this report.

Turbidity was defined by Rainwater and Thatcher (1960, p. 289) as "the optical property of a suspension with reference to the extent to which the penetration of light is inhibited by the presence of insoluble material." Turbidity may be defined less precisely as an unclear condition or cloudiness of water. During the drier months of the year when runoff is low, turbidity in the streams and reservoirs of the Eel River basin is caused primarily by the presence of phytoplankton and other micro-organisms which proliferate in the presence of sunlight. During the rainy months when runoff is high, suspended sediment is the chief cause of turbidity. Phytoplankton, which usually is made up of diatoms and other algae, needs light to survive. The presence of suspended sediment in the winter months obstructs the passage of sunlight and precludes the reproduction of the phytoplankton. Thus, turbidity during periods of high suspended-sediment discharge may be attributed almost entirely to suspended sediment, and the effect of diatoms upon the turbidity during these periods may be considered negligible.

Turbidity measurements were made with a Hellige turbidimeter prior to August 1966 and thereafter with a Hach turbidimeter model 1860. Both of these instruments employ a nephelometric or light-scattering principle in which a light beam is reflected or scattered by particles in suspension, and the intensity of this reflected light is compared with a standard. In the Hellige turbidimeter, the slit width that controls the amount of light passing up through the solution is controlled by a knob on the side of the instrument. This knob is calibrated in arbitrary units from standard solutions, and the readings from the knob are converted to milligrams per liter turbidity by means of appropriate curves developed in the laboratory. The transmitted light is viewed as a circle of light in a field of Tyndall light (Rainwater and Thatcher, 1960, p. 70–71). In the Hach instrument, the light scattered at right angles to the light beam is received by two photoelectric cells and converted into an electrical signal which is measured on a precalibrated meter to indicate turbidity units. The Hach turbidimeter, in contrast to the Hellige instrument, does not require operator judgment or interpretation; thus, the results obtained with the Hach turbidimeter are probably more consistent than those obtained with the Hellige turbidimeter. The Hach instrument measures turbidity in Jackson Turbidity Units (JTU's) as defined by Newell (1902); however, a calibration between JTU's and milligrams per liter silica from standard silica suspensions was made in the Geological Survey so that consistency might be maintained in the publication of turbidity data.

RELATION BETWEEN TURBIDITY AND THE CONCENTRATION OF SUSPENDED SEDIMENT

The turbidity, density, and other fluid properties of a water and sediment mixture are related to the concentration of suspended sediment. The relation between turbidity and concentration of suspended sediment for stations along the Eel River is typified by figure 21.

The data are taken from turbidity and concentration measurements made on individual samples, and an apparent trend exists when these data are plotted on full logarithmic paper. The scatter of points for the station used in figure 31 is characteristic of all the stations from which data were collected; however, with sufficient data, curves may be obtained which are usable approximations of the turbidity-concentration relation.

A rapid and simple method was used to obtain approximate curves for six stations along the Eel River for a variety of different periods and conditions. Turbidity and concentration data were recorded on punched cards, and these data were manipulated in appropriate computer programs for regression analyses and other studies. Linear

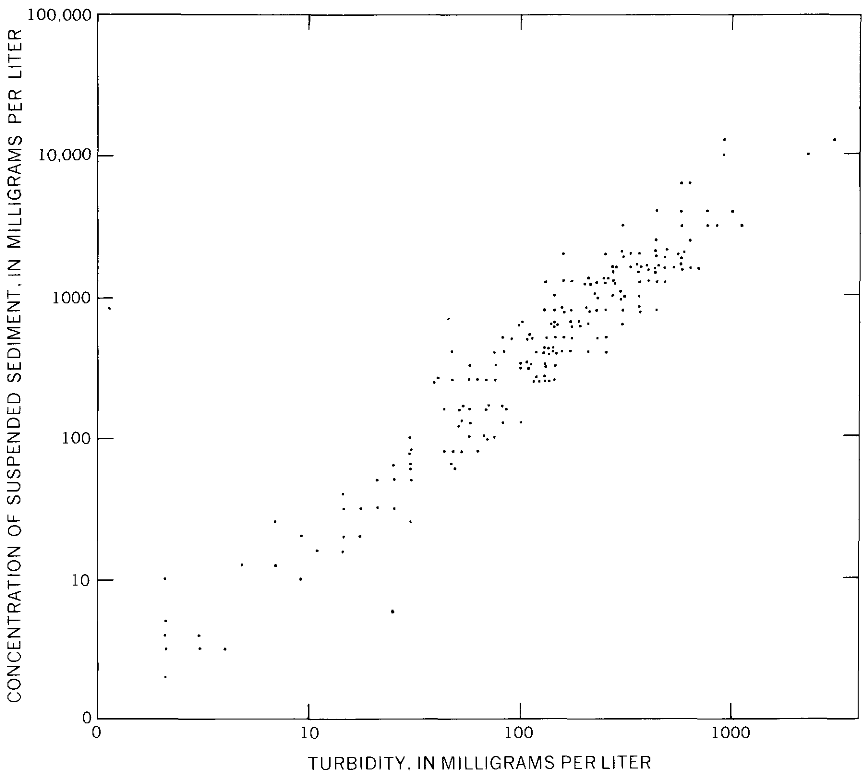

FIGURE 31.—Plot of turbidity versus concentration, showing trend typical of stations in the Eel River basin. Data are taken from observations at Middle Fork Eel River near Dos Dios during the 1966 water year.

logarithmic equations for each water year of record for each station studied were computed by a least-squares regression analysis, and the graphs of these equations are shown in figure 32. Some of the statistical parameters of the regressions are tabulated in table 9 to

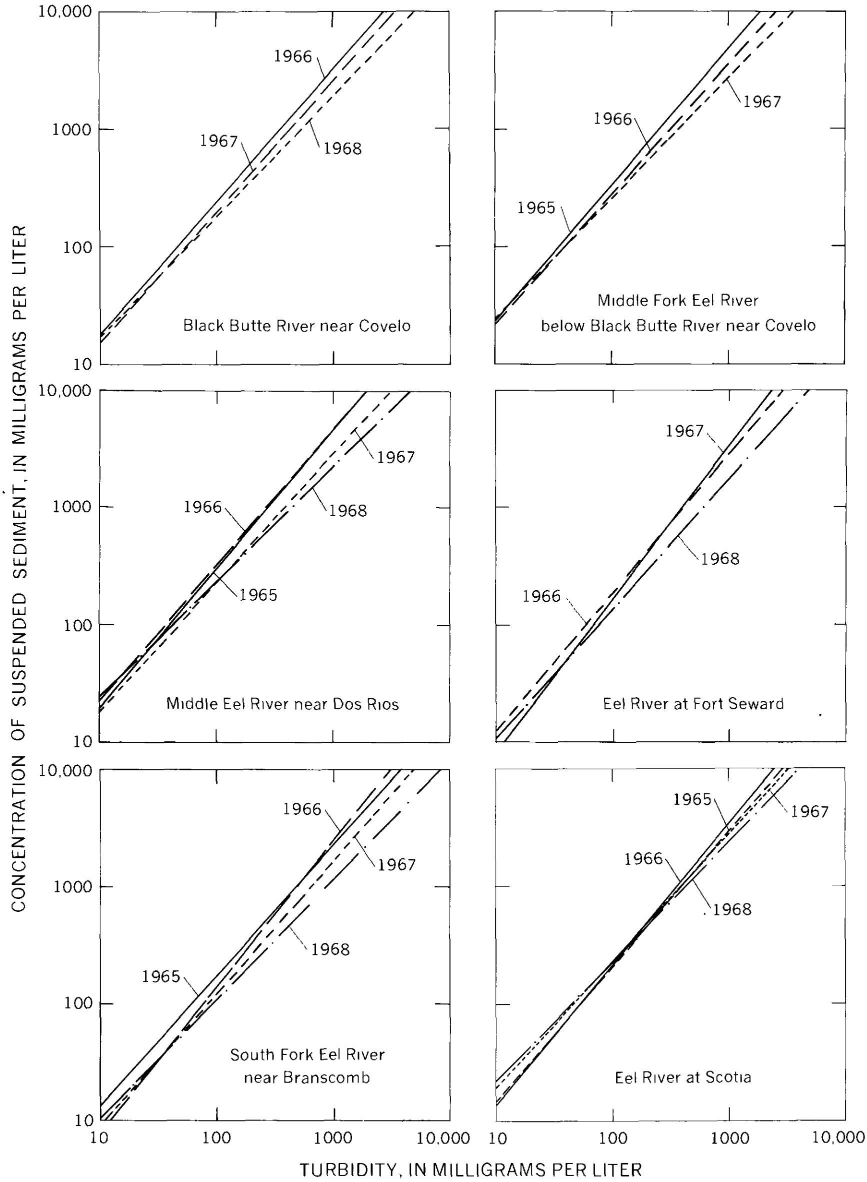

FIGURE 32.—Regression curves of the approximate relation between concentration and turbidity for successive water years.

TABLE 9.—*Regression equations and selected related statistics for the relation between concentration and turbidity at various stations along the Eel River*

Station No.	Station Location	Water year	Equation for concentration-turbidity relation (least-squares computation)	Number of observations	Correlation coefficient	Degrees of freedom	Standard error of estimate (log units)
11-4729	Black Butte River near Covelo.	1966	$C=1.220(T)^{1.108}$	102	0.9706	99	0.19462
		1967	$1.255(T)^{1.134}$	125	.9758	122	.18608
		1968	$1.540(T)^{1.034}$	116	.9792	113	.19573
11-4730	Middle Fork Eel River below Black Butte River near Covelo.	1965	$1.649(T)^{1.150}$	187	.9764	184	.23352
		1966	$1.736(T)^{1.102}$	162	.9717	159	.21897
		1967	$2.290(T)^{1.021}$	124	.9765	121	.20034
11-4739	Middle Fork Eel River near Dos Rios.	1965	$1.275(T)^{1.182}$	198	.9784	195	.23477
		1966	$1.521(T)^{1.160}$	249	.9820	246	.21492
		1967	$1.434(T)^{1.100}$	205	.9754	202	.17357
		1968	$2.351(T)^{0.995}$	145	.9736	142	.21175
11-4750	Eel River at Fort Seward.	1966	$.863(T)^{1.171}$	240	.9505	237	.31626
		1967	$.381(T)^{1.134}$	175	.9826	172	.19059
		1968	$.818(T)^{1.114}$	167	.9761	164	.18126
11-4755	South Fork Eel River near Branscomb.	1965	$1.025(T)^{1.117}$	37	.9662	34	.15615
		1966	$.862(T)^{1.057}$	45	.9672	42	.18738
		1967	$1.073(T)^{1.014}$	72	.9700	69	.16146
		1968	$.875(T)^{1.022}$	53	.9582	50	.14491
11-4770	Eel River at Scotia....	1965	$.984(T)^{1.160}$	243	.9593	240	.26993
		1966	$.837(T)^{1.203}$	210	.9739	207	.21311
		1967	$1.554(T)^{1.081}$	170	.9727	167	.24148
		1968	$2.327(T)^{1.005}$	109	.9723	106	.23510

indicate the degree of correlation between turbidity and concentration, and a confidence interval for values which may be estimated from the equations.

The turbidity-concentration relation is very consistent for each station and throughout the basin. The slopes of the regression lines are much the same for all stations and for all the observed periods. However, there is an apparent trend for concentration to decrease slightly for a given value of turbidity with each succeeding year. In general, the computed slopes for the 1965 and 1966 water years are steeper than slopes computed for the 1967 and 1968 water years.[2] The regression lines not only have similar slopes, but they are also clustered about a common region of the graph. In virtually all the observed cases, the value of concentration is higher than the corresponding value of turbidity.

The year-by-year differences in the relations at each station are shown in figure 33. The graphs show that for a given value of turbidity, concentration is higher at stations on the Middle Fork Eel River and lower at South Fork Eel River near Branscomb than at the stations on the main stem of the Eel River.

The significance of the data presented in this section is apparent in the consistency of the form and correlation of the concentration-

[2] This effect may be related to the percentage of sand carried in suspension, although data are too limited to verify this assumption. The authors have observed that turbidity is higher at a given concentration for a water and sediment mixture which contains only silt and clay than for a mixture containing mostly sand.

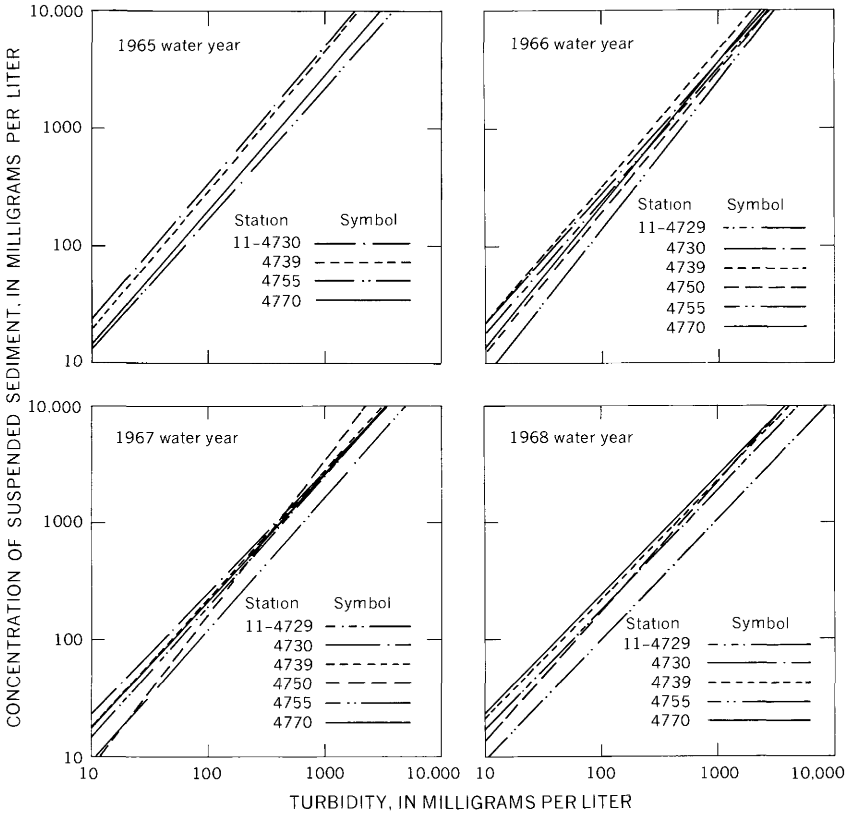

FIGURE 33.—Regression curves of the station-by-station relations between concentration and turbidity, Eel River basin.

turbidity relation throughout the Eel River basin. In the absence of a sediment-measurement program in the future, or at certain key sites within the basin where sediment sampling is not done, turbidity data might be used to obtain at least an approximation of suspended-sediment discharge. However, the concentration-turbidity relations obtained for the Eel River basin should not be used as indices for studies in other similar basins. For example, studies on the Russian River basin, which is immediately south of the Eel River basin and in a similar geologic and climatological evironment, show that the value of turbidity is higher than the graphically corresponding value of concentration for many of the stations observed.

The relations between turbidity and other properties and characteristics of a water and sediment mixture were of some interest in the study leading to this report, and are of special interest in a more detailed study currently being made of turbidity and its relation to suspended sediment. In the course of study of turbidity in the Eel River basin, many of these relations were explored, including the relations among turbidity, concentration and particle size of the suspended sediment, specific conductance of the water and sediment mixture, and depth of flow. Although certain trends existed among the relations developed, it was decided that the data were insufficient to provide conclusive information within the scope of this report other than the concentration-turbidity plots shown. More detailed aspects of turbidity are being studied, and a report in progress by the authors on turbidity in the Russian River basin will include comparisons of turbidity relations with several parameters in both the Russian and Eel River basins.

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U. S. GOVERNMENT PRINTING OFFICE : 1971 O - 427-150

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[Italic page numbers indicate major references]

U.S. GOVERNMENT PRINTING OFFICE: 1971 O—427-150

Attachment G – *Copies of letters from Rep. Mike Thompson to California Dept. of Forestry and Fire Protection and U.S. Forest Service re: Fire Risk Management Plans (2023)*

MIKE THOMPSON
4TH DISTRICT, CALIFORNIA

COMMITTEE ON WAYS AND MEANS
SUBCOMMITTEE ON TAX POLICY
RANKING MEMBER
SUBCOMMITTEE ON HEALTH

CONGRESS OF THE UNITED STATES
HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

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CAPITOL OFFICE:
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WASHINGTON, DC 20515
(202) 225-3311

WEB: http://mikethompson.house.gov

P-77-001

October 5, 2023

Chairman Willie L. Phillips
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

RECEIVED
By The Federal Energy Regulatory Commission Office of External Affairs at 9:19 am, Oct 06, 2023

Chairman Phillips:

As you are aware, Pacific Gas & Electric (PG&E) is in the process of surrendering its license of Scott Dam which holds Lake Pillsbury in Lake County, California. During the surrender evaluation process, I want to ensure that the Federal Energy Regulatory Commission is apprised of all the relevant information to make an informed decision.

Lake Pillsbury has provided a valuable water resource to both state and federal firefighting agencies in recent years to combat wildfires in the region. As climate change increases the risk of larger and more frequent wildfires, a potential loss of this valuable resource should be taken into consideration in determining the surrender process and mitigation efforts.

For the commission's review, I am attaching letters that I wrote to the California Department of Forestry and Fire Protection and the United States Forest Service on the potential loss of Lake Pillsbury as well as their responses.

Thank you for your attention to this matter and do not hesitate to contact myself or my staff should the commission have further questions.

Sincerely

Mike Thompson

MIKE THOMPSON
Member of Congress

CC: Commissioner James Danley, Commissioner Allison Clements, and Commissioner Mark C. Christie

MIKE THOMPSON
4TH DISTRICT, CALIFORNIA

COMMITTEE ON WAYS AND MEANS
SUBCOMMITTEE ON TAX POLICY
RANKING MEMBER
SUBCOMMITTEE ON HEALTH

CONGRESS OF THE UNITED STATES
HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

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WEB: https://mikethompson.house.gov/

The Hon. Randy Moore
Chief
United States Forest Service
201 14th Street SW
Washington, DC 20227

RE: Lake Pillsbury Firefighting Resource

Dear Chief Moore:

Thank you for your work in preparing and addressing the current fire season in California. As you are likely aware, Scott Dam and Lake Pillsbury, located in Mendocino National Forest, have served and continue to serve as a significant water resource for firefighting operations. Recent decisions by Pacific Gas and Electric (PG&E) to decommission Scott Dam has caused significant concerns by local government officials and residents. Among these concerns is the loss a reliable firefighting resource.

Should PG&E decommission Scott Dam, there would no longer be a sizable body of water to be used to fill firefighting aircraft and vehicles. It is important that the United States Forest Service account for this potential outcome and put forward contingency plans to ensure that fire protection services will not see a decline.

Therefore, I would like a response to the following questions:

(1) Can the United States Forest Service provide statistics on how Lake Pillsbury has been utilized in the past few fire seasons, including during the Mendocino Complex Fire?

(2) Does the United States Forest Service have contingency plans currently in place to provide fire protection services should Scott Dam be removed, and if so, what are they?

Thank you in advance for your prompt response to these concerns. As always, I look forward to working with you to ensure the United States Forest Service can adequately combat the ever-growing threat of wild fires.

Sincerely,

Mike Thompson

MIKE THOMPSON
Member of Congress

MIKE THOMPSON
4TH DISTRICT, CALIFORNIA

COMMITTEE ON WAYS AND MEANS
SUBCOMMITTEE ON TAX POLICY
RANKING MEMBER
SUBCOMMITTEE ON HEALTH

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The Hon. Joe Tyler
Director/Fire Chief
Department of Forestry and Fire Protection
715 P Street
Sacramento, CA 95814

RE: Lake Pillsbury Firefighting Resource

Dear Chief Tyler:

Thank you for your work in preparing and addressing the current fire season in California. As you are likely aware, Scott Dam and Lake Pillsbury, located in Lake County, have served and continue to serve as a significant water resource for firefighting operations. Recent decisions by Pacific Gas and Electric (PG&E) to decommission Scott Dam has caused significant concerns by local government officials and residents. Among these concerns is the loss a reliable firefighting resource.

Should PG&E decommission Scott Dam, there would no longer be a sizable body of water to be used to fill firefighting aircraft and vehicles. It is important that the CAL FIRE account for this potential outcome and put forward contingency plans to ensure that fire protection services will not see a decline in capabilities.

Therefore, I would like a response to the following questions:

(1) Can CAL FIRE provide statistics on how Lake Pillsbury has been utilized in the past few fire seasons, including during the Mendocino Complex Fire?

(2) Does CAL FIRE have contingency plans currently in place to provide fire protection services should Scott Dam be removed, and if so, what are they?

Thank you in advance for your prompt response to these concerns. As always, I look forward to working with you to ensure CAL FIRE can adequately combat the ever-growing threat of wildfires.

Sincerely,

Mike Thompson

MIKE THOMPSON
Member of Congress

USDA United States Department of Agriculture | Forest Service | Washington Office | 1400 Independence Avenue, SW
Washington, D.C. 20250

File Code: 5100 (8906558)
Date: September 15, 2023

The Honorable Mike Thompson
U.S. House of Representatives
268 Cannon House Office Building
Washington, D.C. 20515

Dear Congressman Thompson:

Thank you for your letter of August 9, 2023, to the U.S. Department of Agriculture's Forest Service, regarding firefighting capabilities connected to Pacific Gas and Electric's decision to decommission Scott Dam on the Mendocino National Forest.

The Forest Service consistently uses Lake Pillsbury to fight wildfires in the area. While we do not have precise statistics about Lake Pillsbury's use in the past few fire seasons, we did use it throughout the duration of the Mendocino Complex Fire. The Mendocino National Forest also drafts water downstream of Scott Dam for wildfires; that water source will be compromised if the dam is removed. In addition, the California Department of Forestry and Fire Protection also regularly uses Lake Pillsbury for firefighting operations.

The Forest Service is working with Pacific Gas and Electric to incorporate Agency concerns into the decommission plan for the Federal Energy Regulatory Commission approval. This effort includes exploring the use of a large water tank that is accessible by helicopter.

The Forest Service will use several approaches to mitigate any reduction in firefighting capabilities created by the removal of Scott Dam. The Mendocino National Forest will continue to provide staffing for nearby critical fire stations, including the Soda Creek Station near Scott Dam. We will use bucketed helicopters when conditions permit. The Mendocino National Forest will also continue critical wildfire risk reduction projects in the area, including prescribed fire when conditions permit.

Thank you for your continued support as we confront the wildfire crisis together. If you or your staff have any further questions, please contact Jacob Donnay, Director of Legislative Affairs, at (202) 205–1617 or jacob.donnay@usda.gov.

Sincerely,

RANDY MOORE
Chief

STATE OF CALIFORNIA—NATURAL RESOURCES AGENCY

Gavin Newsom, Governor

DEPARTMENT OF FORESTRY AND FIRE PROTECTION
P.O. Box 944246
SACRAMENTO, CA 94244-2460
(916) 653-7772
Website: www.fire.ca.gov

August 16, 2023

The Honorable Mike Thompson
268 Cannon House Office Building
Washington, D.C. 20515

Dear Congressman Thompson,

Thank you for the opportunity to provide information on CAL FIRE's use of Lake Pillsbury and potential impacts to the Department from the decommissioning of Scott Dam. Please see below for responses to the questions from your letter received on August 9, 2023.

(1) Can CAL FIRE provide statistics on how Lake Pillsbury has been utilized in the past few fire seasons, including during the Mendocino Complex Fire?

CAL FIRE uses all available water sources when responding to incidents in the greater Lake County region, including Lake Pillsbury and Clear Lake. Clear Lake is a much larger body of water and offers a more central location for CAL FIRE's use on incidents throughout the region. While CAL FIRE has utilized Lake Pillsbury in the past for incident response on fires such as the Mendocino Complex in 2018 and the August Complex in 2020, statistics on water usage are not collected since it is drawn from a public source instead of private property, where there is no expectation to reimburse for the water used.

(2) Does CAL FIRE have contingency plans currently in place to provide fire protection services should Scott Dam be removed, and if so, what are they?

CAL FIRE has expanded its aerial firefighting capabilities using the S-70i CAL FIRE Hawk, which allows for larger amounts of water to be drawn from Clear Lake and delivered more quickly to incidents within the region. For these reasons, CAL FIRE believes that the decommissioning of Scott Dam will not adversely impact CAL FIRE's ability to provide an adequate and effective firefighting capability throughout the region.

It is important to note that the land surrounding Lake Pillsbury is Federal Responsibility Area, and therefore under the jurisdiction of the US Forest Service (USFS). CAL FIRE coordinates closely with the USFS and assists on incidents that threaten State Responsibility Area, or when requested by the USFS. As such, the loss of Lake Pillsbury may be more impactful to the USFS. CAL FIRE cannot address whether that impact requires any contingency plans on their behalf.

I hope this information has been helpful. Please do not hesitate to reach out if you have any additional questions.

Sincerely,

DocuSigned by:
Joe Tyler
CBDA1BA279214A1...

Joe Tyler
DIRECTOR/FIRE CHIEF

Attachment H – *An Estimation of Potential Salmonid Habitat Capacity in the Upper Mainstem Eel River, California*, a Master's Thesis by Emily Jeanne Cooper (May, 2017)

AN ESTIMATION OF POTENTIAL SALMONID HABITAT CAPACITY IN THE UPPER MAINSTEM EEL RIVER, CALIFORNIA

Thesis · May 2017

1 author:

Emily J. Cooper-Hertel
Watershed Research and Training Center

AN ESTIMATION OF POTENTIAL SALMONID HABITAT CAPACITY IN THE UPPER MAINSTEM EEL RIVER, CALIFORNIA

By

Emily Jeanne Cooper

A Thesis Presented to

The Faculty of Humboldt State University

In Partial Fulfillment of the Requirements for the Degree

Master of Science in Natural Resources: Environmental and Natural Resource Science

Committee Membership

Dr. Alison O'Dowd, Committee Chair

Dr. James Graham, Committee Member

Dr. Darren Ward, Committee Member

Dr. Alison O'Dowd, Graduate Coordinator

May 2017

ABSTRACT

AN ESTIMATION OF POTENTIAL SALMONID HABITAT CAPACITY
IN THE UPPER MAINSTEM EEL RIVER, CALIFORNIA

Emily Jeanne Cooper

In Northern California's Eel River watershed, the two dams that make up the Potter Valley Project (PVP) restrict the distribution and production of anadromous salmonids, and current populations of Chinook Salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) in the upper mainstem Eel River are in need of recovery. In anticipation of the upcoming FERC relicensing of the PVP, this project provides an estimation of the extent of potential salmonid habitat and its capacity for steelhead trout and Chinook Salmon in the upper mainstem Eel River watershed above the impassable Scott Dam. Using three fish passage scenarios, potential Chinook Salmon habitat was estimated between 89-127 km (55-79 mi) for spawning and rearing; potential steelhead trout habitat was estimated between 318-463 km (198-288 mi) for spawning and between 179-291 km (111-181 mi) for rearing. Rearing habitat capacity was modeled with the Unit Characteristic Method, which used surrogate fish density values specific to habitat units (i.e. pools, riffles, runs) that were adjusted by measured habitat conditions. Redd capacity was modeled and resulted in up to ten times the number of spawners compared to those recruited from parr capacity estimates using life stage-specific survival rates. Capacity for rearing juveniles was suggested to be most limiting to production for both

Chinook Salmon and steelhead trout, although more accurate survival rates for all life stages for each species is needed. Ample potential spawning habitat, however, suggests an opportunity for spawners to saturate the stream seedbank for egg recruits, and as rearing capacity is reached in the streams above Scott Dam, subsequent juveniles may then emigrate to non-natal habitat downstream of Scott Dam.

ACKNOWLEDGEMENTS

I would like to thank my thesis advisor, Dr. Alison O'Dowd, for offering me this amazing research opportunity and for her continued support and motivation throughout this project, as well as my thesis committee members, Dr. James Graham and Dr. Darren Ward, whose help I couldn't have been without. I am truly grateful to have studied under the generous guidance of each of my committee members and their wealth of knowledge. This project was funded by several organizations, including: California Trout; National Marine Fisheries Service; the Hispanic-Serving Institution's Education Program Grant no. 2015-38422-24058 from the USDA National Institute of Food and Agriculture; Council on Ocean Affairs, Science, and Technology; and the Research, Scholarship, and Creative Activities Program at Humboldt State University. I would also like to extend a special thanks to Darren Mierau at CalTrout and Josh Fuller at NMFS for their distinctive vision and vested interest with regard to this research. Other support and collaboration came from Mendocino National Forest Service; Ross Taylor and Associates; California Department of Fish and Wildlife; Native Fish Society; Cramer Fish Sciences; Northfork Studios; Scott McBain; and Sonoma County Water Agency. I would also like to thank my field crew members, including Erik Daniels, Ariel Dasher, Erik Kenas, and Mason Price for all of their indispensable, hard work. I also thank my family, loved ones, and fellow graduate students for their encouragement and support while I took on the endeavors of graduate research science.

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INTRODUCTION

Salmonid populations native to western North America are subject to a combination of anthropogenic manipulations including agriculture, flood control, logging, mining, development, fish hatcheries, climate change impacts, and dams and diversions (Rosenfeld et al., 2000; Burnett et al., 2007). As a result, 81% of anadromous taxa are threatened with extinction in California (Katz et al., 2013). Dams regulate most major waterways in California, and salmonid population decline is linked to the changes caused by stream regulation (Katz et al., 2013; Quiñones et al., 2014). Large flood control and hydroelectric dams have contributed to freshwater habitat degradation and species decline through watershed fragmentation, disruption of natural flow regimes, interference with nutrient distribution, inundation of stream habitat directly upstream of a dam, and blockage from historical salmonid spawning and rearing habitat (Sheer & Steel, 2006; Quiñones et al., 2014). Not only have these effects reduced salmonid population production, but they have also impacted life history diversity in local fish populations, which historically thrived under California's diverse Mediterranean climate of wet winters and hot, dry summers (Katz et al., 2013).

Anadromous salmonid populations in the Eel River watershed in Northern California have been impacted by two dams that are part of a water storage, diversion, and hydropower complex known as the Potter Valley Project (PVP) (USFS & BLM, 1995). With historical production estimates at nearly 1 million fish annually, the Eel River contained some of the West Coast's most abundant runs of anadromous salmon and trout, including Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*), winter and summer steelhead trout (*O. mykiss*), and coastal cutthroat trout (*O. clarki*) (Yoshiyama & Moyle, 2010). Coho Salmon, Chinook Salmon, and steelhead trout are currently between 1-3% of their historic populations and are federally listed as threatened in the Eel River watershed (Yoshiyama & Moyle, 2010; NMFS, 2012). Salmonid populations in the upper mainstem Eel River watershed consist of fall-run Chinook Salmon and winter-run steelhead trout. There have been few observations of Coho Salmon or cutthroat trout in the upper mainstem Eel River over the past few decades, likely because this reach of the river extends beyond present Coho Salmon and cutthroat trout distribution (Xanthippe, 2004; PVID, 2016).

As salmonid populations throughout Pacific Coast watersheds have been increasingly listed under the Federal Endangered Species Act, fisheries management has responded with recovery strategies involving passage and habitat restoration that reintroduces anadromous salmon and trout into their historic habitats (Hanrahan et al., 2004; Pess et al., 2008, NMFS, 2015). Planning restoration and reintroduction efforts often involves efforts to predict the increase in salmon production associated with enhanced access to habitat. Several past efforts have estimated the potential amount of habitat and salmonid production upstream of Scott Dam. These estimates, however, were calculated with large-scale habitat measurements and relatively simple methodologies, resulting in discrepancies as to how much habitat and production potential there is for anadromous salmonids under current conditions.

Literature Review

Previous Assessments in the Upper Eel River Watershed

Previous salmonid habitat assessments conducted in the watershed area upstream of Scott Dam were done to estimate potential salmonid abundance, but results are inconsistent among these efforts. Abundance estimations vary in part due to approaches ranging in their consideration of abundance as minimum, average, or maximum salmonid production. A study conducted by Venture Tech Network (VTN) in 1982 quantified a total of 35.7 miles of major channel habitat and an additional 22.7 miles (totaling 58.4 miles, or ~94 km) of minor channel habitat being blocked above Scott Dam (VTN, 1982). The assessment methods for the VTN (1982) study consisted of reconnaissance level air surveys along with ground-level surveys in select locations, and results included the identification of barriers to anadromy in the waterways upstream of Lake Pillsbury along both the mainstem Eel River as well as the Rice Fork tributary. In 1995, the US Forest Service (USFS) and Bureau of Land Management (BLM) released a "Watershed Analysis Report for the Upper Main Eel River Watershed," in which they estimated about 100 miles (160 km) of anadromous fish habitat being blocked by Scott Dam, but methods for this estimate were not elaborated upon (USFS and BLM, 1995). In 1999, the Center for Ecosystem Management and Restoration (CEMAR) provided a synthesis of information on historical distribution and current status of both anadromous and resident *O. mykiss* in the upper mainstem Eel River both upstream and downstream of the Potter Valley Project (Becker and Reining, 1999). The CEMAR study reports distribution and use of almost all streams by resident rainbow trout and anadromous steelhead trout both historically and currently above Lake Pillsbury, beyond those barriers to migration classified by the VTN (1982) report.

VTN estimated potential abundance from historical and current scenarios for habitat conditions and with density values derived from spawner surveys in other streams of the Eel River watershed, resulting in a historical estimate of 3,356 steelhead trout spawners and 2,499 Chinook Salmon spawners and a current estimate of 1,499 steelhead trout spawners and 1,250 Chinook Salmon spawners (VTN, 1982). Some unpublished data from California Department of Fish and Game (1979) estimates historical abundance in the watershed area above Scott Dam to be 2,500 steelhead trout and 2,300 Chinook Salmon. While historical estimates made by VTN and CDFG are relatively close for Chinook Salmon (difference of ~200 spawners), historical estimates for steelhead trout have a larger difference (~850 spawners). Estimates for current abundance are close to half of those for historical abundance. These disparities and their applications for management are unclear, therefore creating the necessity for a more rigorous effort to estimate potential salmonid abundance upstream of Scott Dam.

An additional approach for estimating potential habitat and abundance comes from the Intrinsic Potential (IP) Model developed by NMFS (2016). The IP Model maps potential stream habitat in a Geographic Information System (GIS) and estimates potential abundance from other data containing spawners per linear unit. IP Modeling utilizes large-scale habitat suitability indices including slope, valley constraint, and annual discharge to determine the potential range of accessible habitat for salmonids (NMFS, 2005; Burnett et al., 2007). The IP Model uses a 10m resolution Digital Elevation Model (DEM) to determine channel gradient for an entire stream network in GIS. Habitat requirements for a salmonid species of interest are evaluated using IP parameters, and areas upstream of identified barriers for migration are omitted. Each segment of stream within the model's data frame is assigned a score from 0 – 1, with 1 being the highest qualification for intrinsic potential of salmonid habitat. Then, the model calculates a total IP-km value, which includes the sum of each stream segment length multiplied by its IP score. The IP-km value is considered the amount of stream length that provides suitable salmonid habitat, which can differ from the total stream length mapped. The IP model is designed for estimating potential adult fish density per 1 km stream segment based on its habitat suitability parameters and rating scale related to abundance (NMFS, 2005). In the upper mainstem Eel River watershed, NMFS estimated 20 spawners per 306 IP-km for steelhead trout and 20 spawners per 103 IP-km for Chinook Salmon (Spence et al., 2008 & 2012). The IP Model resulted in estimates of 6,120 steelhead trout spawners and 2,060 Chinook Salmon spawners.

Drawbacks of the IP model include overestimation of suitable habitat, limited accuracy of habitat characteristics at the reach level, limited application of habitat suitability parameters, and assuming a standard number of spawners per IP-km across a large scale (Sheer et. al, 2008). Over-prediction of suitable habitat could be caused by suitability curves attributed to the IP score whose parameter thresholds may not be sensitive enough to reflect actual habitat use by fish (Sheer et al., 2008). Furthermore, because the IP Model is built from a 10m resolution DEM, the model could be too coarse to capture important small-scale physical habitat features within the $100m^2$ pixels that make up the elevation model. As a result, the coarse resolution could affect the utility of the IP score. Many studies have measured relationships between small-scale physical habitat characteristics and juvenile salmonid abundance and found positive associations with large woody debris (LWD), undercut banks, and pool habitat (Rosenfeld et al., 2000; Polivka et al., 2014; Gallagher et al., 2014). Such habitat parameters that affect fish abundance may not be captured by the coarse spatial resolution of the IP model. As understanding ecosystems on a larger, meso-habitat scale is important for considering large populations, meaningful small-scale habitat requirements must not be overlooked, as they contribute to what defines the suitability parameters that shape a habitat-abundance model. In addition to large-scale habitat features, quantifying small-scale habitat features (i.e. habitat unit composition, substrate composition and embeddedness, and instream shelter features) as they relate to salmonid abundance at different life history stages provide parameters necessary for assessing habitat-population dynamics and estimating potential production in prioritized watersheds (Anlauf-Dunn et al., 2014).

Biology of Salmonids as a Foundation for Modeling Population Capacity

Understanding the myriad of salmonid life history strategies both within and among species is essential for assessing habitat conditions and modeling habitat-abundance relationships as they pertain to population recovery. Instream habitat conditions change as seasonal flows vary, so salmonid species occupy streams in different ways depending on discharge, temperature, dissolved oxygen levels, food abundance, time of year, and life stage (Dill et al., 1981; Keleher and Rahel, 1994; Spence et al., 1996; McCullough, 1999; Nicola et al., 2015). Thus, when assessing spawning and rearing habitat, temporal instream conditions must be considered for each salmonid species and life stage of interest. Spawning occurs during fall and early winter high flows for fall-run Chinook Salmon, and winter steelhead trout spawn in late winter to spring (Quinn et al., 2002). Steelhead trout generally spawn in stream gradients from 2-7%, but possibly up to 12%, so their distribution extends farther upstream than that of Chinook Salmon, who spawn in gradients from 0-2% but possibly up to 5% (Merz, 2001; NMFS, 2005; Cooney and Holzer, 2006). Emergence, rearing, and emigration of salmonids are highly variable not only among species but also within a single species due to life history plasticity and local adaptations in response to environmental variation (Waples et al., 2001; Beckman et al., 2003; Quinn, 2005).

The juvenile stages of life for Chinook Salmon and steelhead trout from egg to emigrant respond to spatio-temporal changes in habitat conditions. Fall-run Chinook Salmon eggs are spawned in the mainstem and larger drainages of a watershed and emerge in the spring; juveniles usually begin migrating out to sea within a few weeks or months of emergence (Healey, 1991; Moyle, 2002; CDFW, 2016). In contrast, steelhead trout juveniles that emerge in the spring typically occupy pool habitats throughout summer and winter as young-of-the-year and can remain in freshwater for one to three or more years before beginning their oceanic journey (Quinn, 2005). Limiting factors change throughout the year for salmonid juveniles rearing in streams. During winter and spring, large woody debris (LWD), boulders, and interstitial spaces in cobble and gravel substrate act as instream shelter providing velocity variability and high flow refugia necessary for juvenile survival (Cunjak, 1996; Hillman et al., 1987; Solazzi et al., 2000). During summer and fall, juvenile salmonids become susceptible to rising temperatures, loss of habitat connectivity, and an increasing demand for territory size while space becomes decreasingly available (Keleher and Rahel, 1996; Isaak et al, 2007; Cramer and Ackerman, 2009a; Ayllon et al., 2012). Emigration timing is dependent upon growth rate and cues from temperature and discharge conditions (Beckman et al., 1998; Quinn, 2005; Berggren and Filardo, 2011).

Salmonid redd-building requires suitable-sized streambed substrate, and that substrate is typically deposited from high flows at the transition zone between a pool and the downstream riffle (CDFW, 2004). Although gravel size is the most important variable for redd selection, pool tailout areas are also important in that they are consistently reported as having highest redd densities because of the presence of suitable spawning gravel and appropriate depth and velocity requirements (Baxter and Hauer, 2000; Mull and Willzbach, 2007; Cramer et al., 2012). Increasing embeddedness from fine sediment within the substrate degrades redd-building conditions for spawners and decreases survival rates for salmonid eggs living in the benthos by blocking hyporheic exchange of oxygen, flow, and light (Keeley, 1996; Suttle et al. 2004; Allan and Castillo, 2007; Wilzbach and Cummins, 2008). Thus, substrate composition and embeddedness are key characteristics for quantifying potential spawner habitat.

Typically occurring between 10s to 100s of meters in length, habitat units (e.g. pool, riffle, and flatwater) are functions of geomorphic and hydraulic conditions that change spatio-temporally with varying discharge, and fish occupy different habitat unit types at different life stages (Rosenfeld et al., 2011). Therefore, salmonid habitat can be measured by identifying habitat units in response to how they are selected by salmonids. The distribution and proportion of habitat units within a stream reach at low flows can be used to approximate the quantity of juvenile summertime-rearing habitat (NMFS, 2015). Quantifying winter and spring rearing habitat capacity must reflect how habitat type composition changes with seasonal variation in discharge to estimate seasonal habitat use by salmonids (Rosenfeld et al., 2011). Two studies conducted by Rosenfeld et al. (2007, 2011) compared rates of change in hydraulic conditions (e.g. velocity, wetted width, and depth) at low flows compared to high flows. These hydraulic conditions distinguished individual habitat units at lower flows; however, at higher flows, increases in velocity, wetted width, and depth caused habitat units to converge and become less distinguished. These rates of change in hydraulic conditions were then quantified specific to habitat unit type. By applying the rates of hydraulic change specific to habitat unit types, different flow conditions can be modeled from stream measurements that lack a temporal resolution representative of seasonal flow variation (Rosenfeld, 2007).

Understanding the biological nature of Chinook Salmon and steelhead trout and how their habitat use changes among life stages is essential to modeling their potential habitat use in the upper mainstem Eel River upstream of Scott Dam. Relating habitat use to habitat availability from other studies identifies potential limitations to population production both spatially and temporally. Habitat conditions and their relationship to habitat use and fish density may then be modeled to estimate potential capacity, or maximum potential production, for anadromous salmonids in the study area.

Research Objectives

Populations of native salmonids in the Eel River have been affected by degraded habitat conditions; as a result, these populations require recovery management. Since its construction in 1922, Scott Dam has completely blocked passage to habitat historically used by migrating salmonids. Now that the Potter Valley Project is approaching a 50-year Federal Energy Regulatory Commission (FERC) license renewal in 2022, there is a need for current, sound science that quantifies potential salmonid habitat extent and capacity upstream of Scott Dam. The National Marine Fisheries Service (NMFS) multispecies salmonid recovery plan assigned a high priority to population recovery in the upper Eel River, calling for measures in addition to those that previously existed in response to the relicensing decision for the Potter Valley Project (NMFS, 2016). With regard to informing the PVP relicensing decision and recovery management for anadromous salmonid populations in the upper mainstem Eel River, the objectives of this research were to assess and quantify the habitat upstream of Scott Dam and estimate the potential population capacity of juvenile parr and spawners for steelhead trout and Chinook Salmon if access to the area were restored.

METHODS

Study Area

The Eel River watershed is the third largest watershed located entirely within California, draining about 9,542 km^2 (FOER, 2016). This coastal watershed is comprised of five major tributaries and the mainstem, totaling 1,288 river km spanning from the headwaters at 1,640 m elevation in the coast mountain ranges of western Mendocino County to the Pacific Ocean near Fortuna, California. The upper mainstem Eel River is the area upstream of the confluence with the Middle Fork Eel River, south east of Dos Rios, California within the North Mountain Interior diversity stratum (NMFS, 2015). This stratum coined by NMFS includes watersheds draining relatively high elevation mountains in some areas of the Eel River watershed as well as in the Klamath mountains ecoregion (NMFS, 2015). Scott Dam is located at an elevation of 554 m (1,818 ft) along the upper mainstem Eel River at river km 260, and the study area is located in the watershed area upstream of Scott Dam (Figure 1). Lake Pillsbury, the reservoir formed by Scott Dam, accumulates water from the upper mainstem Eel River and a major tributary known as the Rice Fork, and both of these river segments receive water from many minor tributaries, making up a drainage area of about 746 km^2 (Brown and Ritter, 1986). The study area falls entirely within land federally managed by the U.S. Forest Service in the Mendocino National Forest, with the exception of some private inholdings where land use is considered either rural residential or agricultural (USDA, 2015).

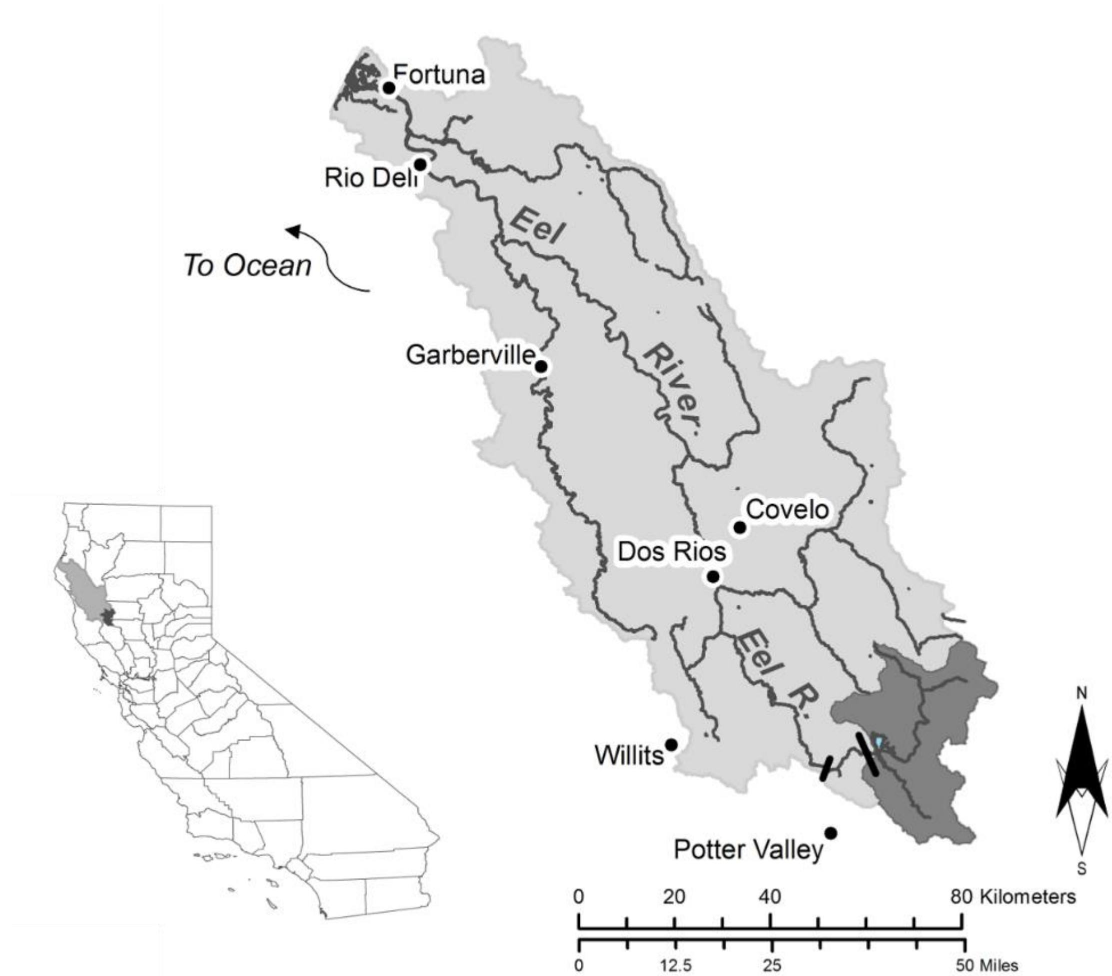

Figure 1. The study area is located in northern California denoted by the dark outline in the lower left inset. The Eel River watershed is represented by the lightly shaded area with surrounding cities labeled next to black dots. Waterways in the Eel River watershed are represented in dark gray lines. The darker shaded watershed area represents the study area. Dark lines perpendicular to the mainstem Eel River represent Cape Horn Dam and Scott Dam on the left and right, respectively. Spatial Reference: World Geodetic System 1984 (WGS84), Universal Transverse Mercator (UTM) Zone 10 North (NHD, 2016; ERCZO, 2016).

The underlying geology of the Eel River watershed consists almost entirely of the Franciscan assemblage, whose rocks are predominantly sandstone and shale (Lisle, 2013). Combinations of extreme precipitation events, steep hillslopes, and uplifting topography result in mass soil and sediment movements commonly occurring throughout the watershed (Brown and Ritter, 1986; Lisle, 2013). Compared to other rivers of similar size in the continental U. S., the Eel River has the highest sediment yield per unit area, with an estimated annual sediment load of 1720 tons/km^2 (Brown and Ritter, 1986).

The coast mountain ranges are characterized by a Mediterranean climate with extreme differences in rainfall and temperatures between seasons (Cid et al., 2017). Average annual precipitation is 120 mm, falling during winter months primarily as rain along with some snow (NOAA, 2017). Land cover includes mixed conifer forests found on north facing slopes and oak woodlands typically occurring on drier, south facing slopes.

Survey Design

Initially, the IP Model was used for determining potential distribution of Chinook Salmon and steelhead trout upstream of Scott Dam by identifying potential barriers to anadromy throughout the stream network. An area known as Bloody Rock roughs was originally identified as a migration barrier along the mainstem Eel for both Chinook Salmon and steelhead trout. Because suitable spawning and rearing habitat occurs upstream of Bloody Rock roughs, this potential barrier was evaluated using ground-based passage assessments to validate the habitat mapped in the IP Model. This potential barrier was observed by myself and another HSU student on 20 February, 2016 during high winter flows (11.50 cubic m/s, or 400 cfs, located 0.5 km downstream of the falls) with photo documentation and field measurements including vertical height, horizontal width, and depth of staging pool, using methods from Gunther et al. (2000) in the *Assessment of Fish Upstream Migration at Natural Barriers in the Upper Alameda Creek Sub-Watershed* (SFPUC, 2010; Appendix I). The site was again assessed by myself and other expert fisheries biologists from NFMS and fish passage expert Ross Taylor on 17 May, 2016 during lower flows (1.64 cms, or 58 cfs).

The stream network contained within the study site was then stratified into a total of 11 different "Reach Types" based on gradient and drainage area data derived from stream attributes in the IP model (Table 1). Stream gradient was included as a stratification variable due to its correlation with velocity, substrate composition, channel morphology, and stream habitat types; stream size measured in drainage area was included due to its correlation with channel morphology, habitat types, habitat stability, and discharge (Higgins et al., 2005). Stream gradient and drainage area categories were identified based on relationships to salmonid habitat use and geomorphology found in other studies (Higgins et al., 2005; Stillwater Sciences, 2013; Lane and Sandoval, 2014).

Table 1. Reach Type strata and their descriptions for streams in the upper mainstem Eel River upstream of Scott Dam.

Reach Type ID	Reach Type Description	Gradient	Drainage Area
1.2	Low Gradient, Small Catchment	0 - 2%	2 - 10 sq. km
1.3	Low Gradient, Medium Catchment	0 - 2%	10 - 100 sq. km
1.4	Low Gradient, Large Catchment	0 - 2%	>100 sq. km
2.1	Medium Gradient, Very Small Catchment	2 - 7%	0 - 2 sq. km
2.2	Medium Gradient, Small Catchment	2 - 7%	2 - 10 sq. km
2.3	Medium Gradient, Medium Catchment	2 - 7%	10 - 100 sq. km
3.1	High Gradient, Very Small Catchment	7 - 12%	0 - 2 sq. km
3.2	High Gradient, Small Catchment	7 - 12%	2 - 10 sq. km
3.3	High Gradient, Medium Catchment	7 - 12%	10 - 100 sq. km
4.1	Very High Gradient, Very Small Catchment	> 12%	0 - 2 sq. km
4.2	Very High Gradient, Small Catchment	> 12%	2 - 10 sq. km

After the streams were stratified into Reach Types, a randomized subsample of 25 survey locations allocated proportional to the frequency by stream length of each Reach Type was generated using a stratified, equal probability Generalized Random Tessellation Stratified (GRTS) method for a linear resource in program Rstudio version 1.0.136 with the spsurvey package (Kincaid, 2015). Five times the number of survey locations within Reach Type stratum were also assigned as oversample sites for backup.

Field surveys were conducted during the months of late June – early August 2016, following protocols adapted from California Department of Fish and Wildlife's *California Salmonid Stream Habitat Restoration Manual, Part III* (2004). Starting downstream and working in an upstream direction, each habitat unit encountered in a survey was classified as a pool, riffle, cascade, flatwater, or dry unit using a 10% sampling method derived from Hankin and Reeves (1988). The 10% sampling method required measuring all habitat variables for the first type of habitat unit encountered per ten habitat units. Repeated habitat units within a set of ten habitat units in a survey reach were only measured for length and width. A random number between one and ten was chosen, and its corresponding habitat unit in a set of ten units along a survey reach was also measured for all habitat variables. Habitat variables measured included instream cover with LWD and boulders, streambed substrate composition, canopy cover, discharge, and water quality variables such as temperature, pH, and turbidity. Each fully surveyed habitat unit was measured for length, mean wetted width, mean and maximum depth, percent canopy cover, percent cover from boulders, and received a shelter rating for cover provided by LWD. Criteria for LWD included wood that was either submerged or located within one meter of the wetted surface and at least 30 cm in diameter and three meters long. All pool habitat units were surveyed for pool tailout substrate composition via pebble counts using the Wentworth Scale, embeddedness in the pool tailout, bankfull width and depth, and temperature (Wentworth, 1992; CDFW, 2004). Substrate composition for riffles, cascades, flatwater, and dry units was estimated visually. Each type of visual estimate was conducted by the same observer for consistency when possible; otherwise, additional observers for visual estimates were calibrated to fellow observers' estimates with trial runs. Reach scale measurements were taken at the start of each habitat survey, including streamflow, temperature, pH, and a turbidity sample from the nearest upstream pool tailout area.

Analysis

Habitat data were summarized by Reach Type according to all measured variables. Analysis methods including Analysis of Variance (ANOVA), Multiple Analysis of Variance (MANOVA) and Linear Discriminant Analysis (LDA) were used to test for significant differences in the measured habitat variables and grouping among stratified Reach Types. These analyses were used to validate possible lumping of Reach Types and extrapolation of survey data onto unsurveyed streams in corresponding Reach Types.

The Unit Characteristic Method (UCM), developed by Cramer and Ackerman (2009a), is a capacity estimation model that incorporates habitat suitability indices into its functions. The core of the model multiplies a baseline standardized fish density by a measured habitat unit area, and the density values are then adjusted according to scalar values of habitat parameters (i.e. fish cover, depth, substrate, etc.) derived from habitat suitability indices (Equations 1-3, Figures 2-4) (Cramer and Ackerman, 2009b). The scalar values can be greater than one depending on the curve of the habitat parameter. The standardized fish density values specific to habitat unit types built into this model are derived from a previous study that observed juvenile salmonid densities in six Oregon streams over several years that were believed to be at maximum parr production (Johnson et al., 1993).

$$\textbf{Parr Capacity}_i = \left(\sum area_k \cdot den_j \cdot chnl_{jk} \cdot dep_{jk} \cdot cvr_{jk}\right) \cdot prod_i \qquad \textit{(Equation 1)}$$

Where;

i = stream reach. "Reach" is a sequence of channel units that compose a geomorphically homogenous segment of the stream network,
j = habitat unit type (i.e. pool, riffle, cascade, flatwater, or dry),
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 2:

$$prod_i = turb_i \cdot drift_i \cdot fines_i \cdot pH_i \qquad \textit{(Equation 2)}$$

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
pH = pH during summer low flow;

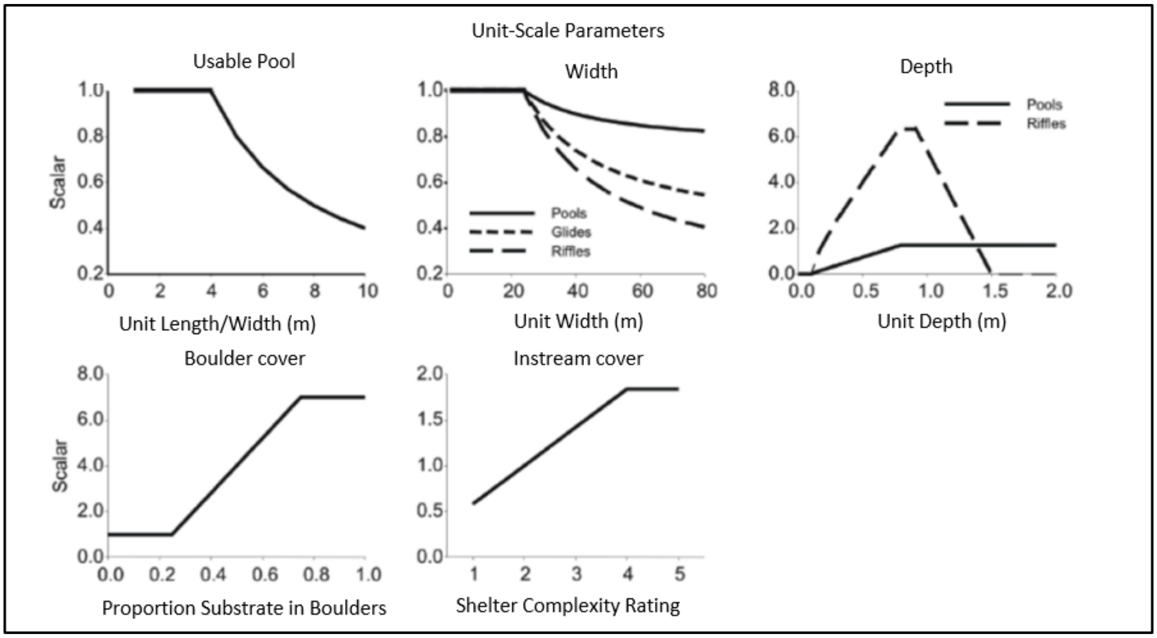

Figure 2. Habitat-parr density relationships used in unit-scale adjustments for the UCM. The y-axis represents habitat parameters in scalar values. These scalars are multiplied by parr/m^2, which adjusts the overall parr density. The Usable Pool and Width curves are used in the unit area parameter. Note that some scalar values can be greater than one. (from Cramer and Ackerman, 2009b).

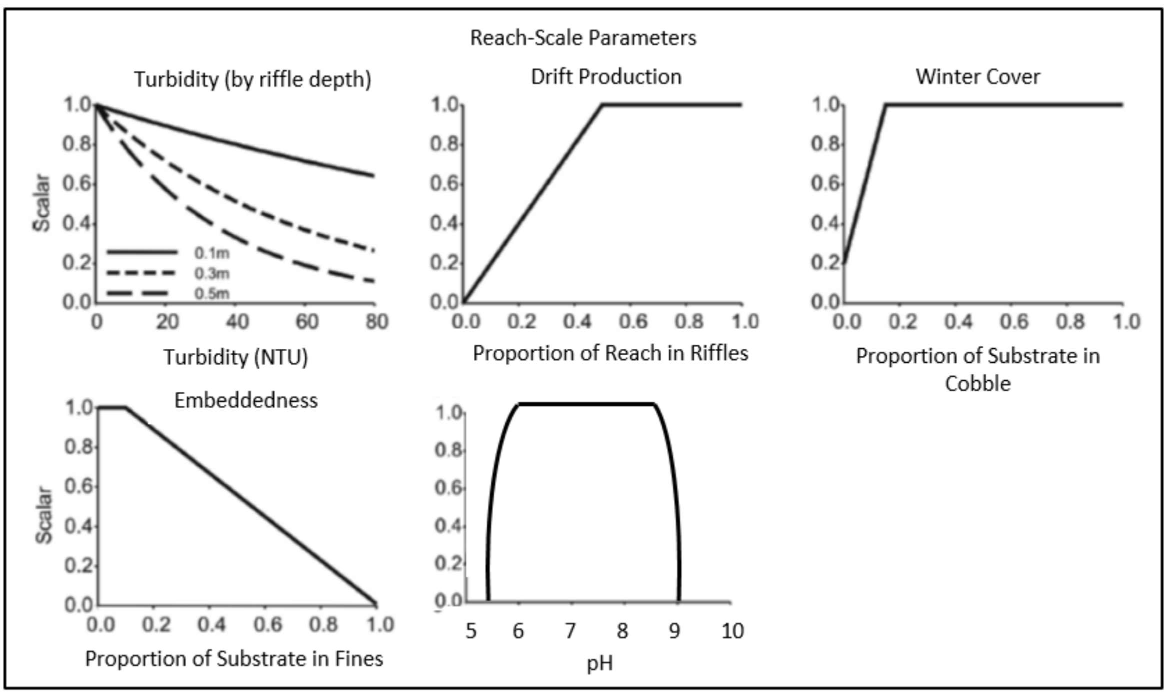

Figure 3. Habitat-parr density relationships used in the reach-scale adjustments for the UCM. The y-axis represents habitat parameters in scalar values. These scalars are multiplied by parr/m^2, which adjusts the overall parr density (from Cramer and Ackerman, 2009b and Raleigh et al., 1986).

Temperature limitations were incorporated into the model at the reach scale using limitations that Cramer et al. (2012) identified for Coho salmon. It was assumed that steelhead trout and Chinook Salmon experience similar temperature limitations for UCM analysis. A temperature-density relationship was derived from data that observed no Coho juveniles above 23 °C; the data also suggests that at 20 °C, mean parr densities were 30% of densities at optimum temperatures (Equation 3, Figure 4) (Cramer et al., 2012). The temperature scalar has a near optimum value of 0.95 at 16 °C and reduces to 0.05 at 23 °C. These temperature criteria are similar to observations from other studies on steelhead trout and Chinook Salmon temperature requirements (Myrick and Cech, 2004; Richter and Kolmes, 2006).

$$\boldsymbol{T_{si} = \frac{1}{1+e^{-a-bT}}} \qquad \textbf{\textit{(Equation 3)}}$$

where
Tsi = Temperature scalar for capacity for reach *i* in a given week.
a = intercept of logit(*Tsi*) = 19.63;
b = slope of logit(*Tsi*) = -0.98;
T = WAT for reach *i* in a given week.
This scalar is then multiplied by the habitat capacity for rearing in the reach.

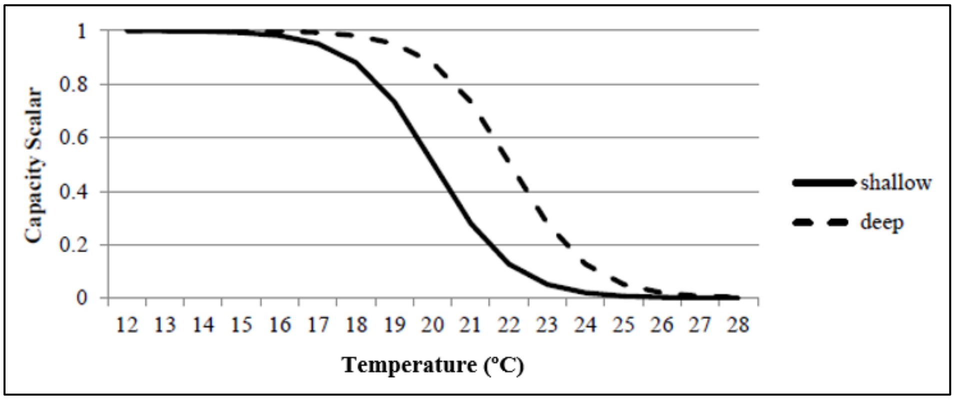

Figure 4. Effect of temperature on parr rearing capacity for Coho. Maximum Weekly Average Temperature (MWAT) is expressed as the summer maximum of the 7-day running average. Dashed line applies to pools >1m deep, which thermal stratification is assumed where a thermal refuge is provided at a depth that is 2°C cooler than surface flow (from Cramer et al., 2012).

After identifying conditions in the streams above Scott Dam as limiting to the parr life stage for each species of interest, subsequent life stages from the estimated maximum parr population were then estimated using survival rates between each life stage. This approach, similarly discussed in Rosenfeld (2003), sums composition of stream habitat units (i.e. pools, riffles, glides) multiplied by standardized densities specific to habitat units, resulting in reach-scale carrying capacity estimates that may then be summed by reach for watershed-scale capacity estimates. Despite inherent assumptions from using standardized density values derived from other watersheds, the UCM is designed to reflect local habitat conditions by using stream survey data as model inputs, which then adjust a given standard density value.

The UCM model was applied to each survey dataset by writing the appropriate functions for each unit-scale parameter and passing them through a “while loop” in program Rstudio version 1.0.136. Reach-scale adjustments were applied to the unit-scale adjustment output for each survey site in Microsoft Excel 2013. Once the UCM was applied to each survey dataset, estimated density values (parr/m^2) were averaged among survey reaches within the same Reach Type and the standard deviation of density values within a Reach Type was calculated. Remaining unsurveyed streams were assigned lengths from the IP Model, but they required wetted area in order to extrapolate the UCM parr/m^2 values. Wetted width measurements from each habitat unit were averaged among surveys in the same Reach Type and extrapolated onto unsurveyed streams of corresponding Reach Types. This met the stream area requirement for density extrapolation to calculate a watershed-scale estimate of potential density for juvenile steelhead trout and Chinook Salmon expressed in fish/m^2. The average density by Reach Type was multiplied by the total stream area of the respective Reach Type to calculate potential capacity in number of fish. The standard deviation calculated by stratified Reach Type densities reflected the range around average density values for extrapolation, and those standard deviations were passed on to capacity calculations to reflect some uncertainty around final estimates for total number of fish.

Habitat measurements were conducted during summer low-flow conditions not only for feasibility but also because these conditions typically represent the most capacity-limiting stage for steelhead trout who oversummer in streams (Cramer and Ackerman, 2009a). However, to estimate potential capacity for Chinook Salmon juveniles, survey flow conditions were converted to stream rearing conditions for Chinook Salmon, which typically peak in May. Because there are no stream gauges upstream of Scott Dam, streamflow conditions were modeled from a surrogate location in the Eel River watershed. Due to its unimpaired flows and watershed similarities to the upper mainstem Eel River, USGS mean daily flow data collected near the mouth of the Middle Fork Eel River were used. These data were arranged to plot exceedance probability by month according to timing of peak use by species and life stage (Figure 5).

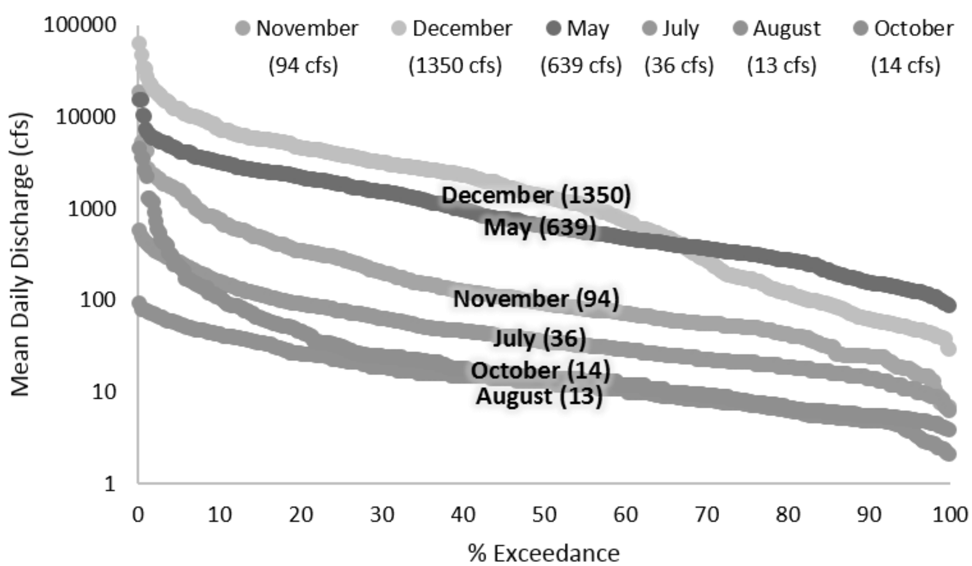

Figure 5. Exceedance probability flows from Middle Fork Eel River USGS gauge 11473900, including mean daily flow data from years 2000-2017. Fifty percent exceedance flows from select months were converted by watershed area to estimate Chinook Salmon parr rearing conditions from summer survey conditions in the upper mainstem Eel River study site.

Fifty percent exceedance flow values were then converted by drainage area to streams in the study area. Assuming 50% exceedance flows for springtime Chinook Salmon rearing, models for hydraulic geometry from Rosenfeld (2007) and described in Cramer et al. (2012) were applied to predict differences in width and depth at higher flows specific to habitat units (Figure 6).

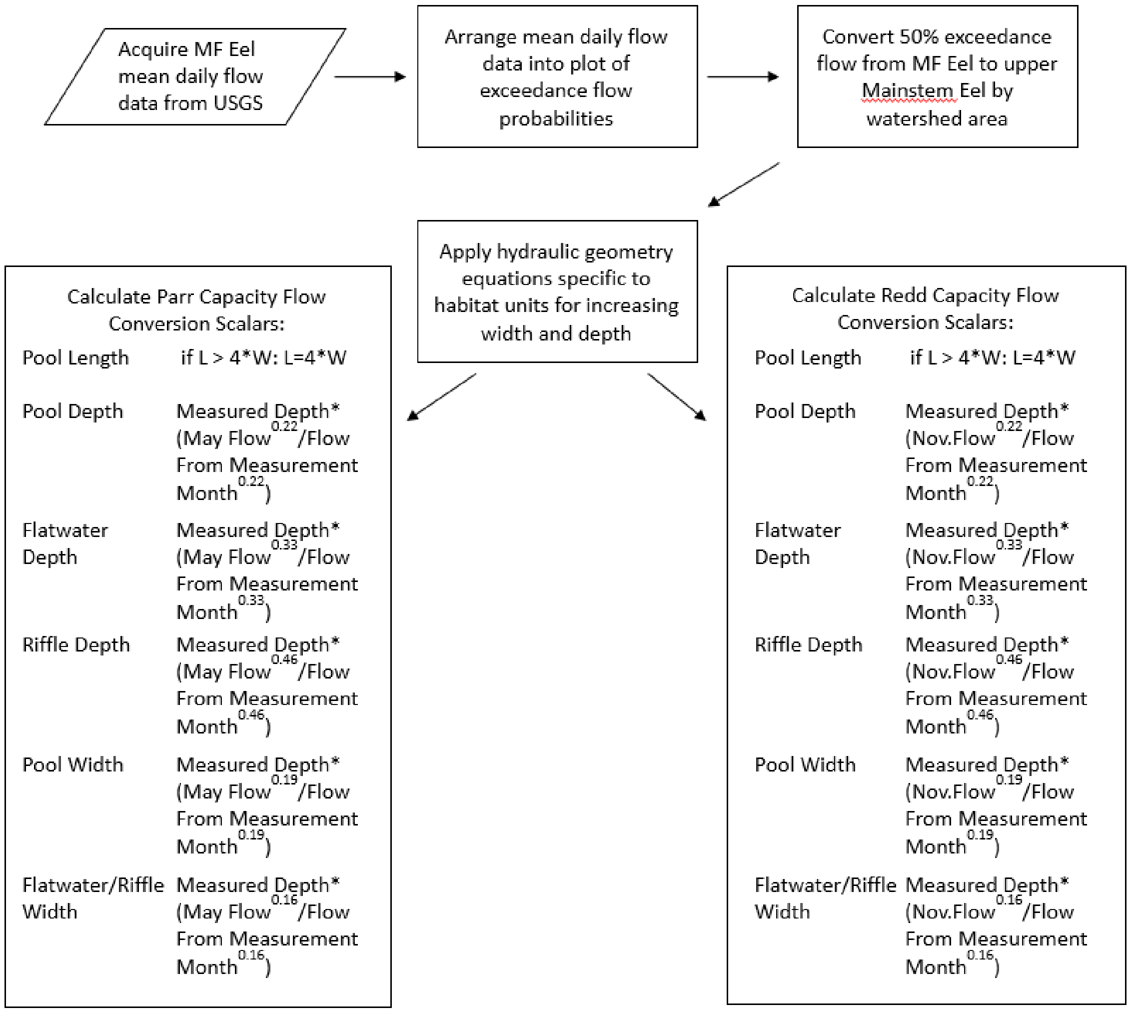

Figure 6. Flow chart of methods used to model temporal flow conditions in the upper mainstem Eel River from data in the Middle Fork (MF) Eel River. Fifty percent exceedance flows were used in conversion scalar functions. Conversion scalar functions used to scale Chinook Salmon parr and redd densities based on habitat unit types and temporal flow conditions are listed. L=unit length, W=unit width, D=unit depth. Habitat unit measurements are in meters, and flow measurements are in cfs. Pools units use maximum depth and riffles and flatwater units use mean depth (adapted from Cramer et al., 2012).

Juvenile population capacity estimates for both steelhead trout and Chinook Salmon were calculated with standardized density values specific to habitat units found in Cramer and Ackerman (2009a, b). Three applications of parameter adjustments were analyzed for parr capacity: 1) Unit-scale (i.e. usable area, depth, LWD & Boulder cover);

2) Unit & Reach-scale without drift (i.e. usable area, depth, LWD & boulder cover; turbidity, fines, pH, winter cover); and 3) Unit & Reach-scale with drift (i.e. usable area, depth, LWD & boulder cover; turbidity, fines, pH, winter cover, proportion drift habitat). The second application which excluded the drift parameter was analyzed due to the uncertain representation of proportion of riffle habitat as fish food availability. These sets of parameters were modeled to evaluate different effects on parr density estimates.

Estimates for capacity of steelhead trout and Chinook Salmon juveniles were then converted to number of spawners. The spawner conversions were calculated using different survival rates from the literature for Chinook Salmon and steelhead trout and with a set of potential life history variations for steelhead trout, and survival rate sensitivity was analyzed as varying survival rates from parr to adult found in the literature affected the overall total capacity estimates (Lister and Walker, 1966; Johnson et al., 1993; Cramer et al., 2002; Quinn, 2005; Rawding et al., 2010; Cramer et al., 2012).

In addition to modeling potential capacity at the parr life stage for both steelhead trout and Chinook Salmon, potential spawner carrying capacity was modeled to test whether suitable spawning habitat in the study site may instead be more limiting for potential production. Potential redd capacity was estimated by first modeling higher flows typical of spawning season for all survey data (with methods similar to modeling flows during Chinook Salmon parr rearing), followed by identifying spawning criteria outlined in the UCM (Table 2) (Cramer et al., 2012). Potential spawning grounds were first characterized by the presence of suitable spawning substrate with less than 40% fine substrate in each surveyed habitat unit, as outlined in the UCM redd capacity protocol

(Cramer et al., 2012). Any units that contained more than 40% fines or less than the minimum required depths were excluded. Spawnable area was calculated specific to habitat unit type and adjusted with a scalar for fines greater than 25% due to the degradation of spawning conditions where fines are more than 25% of the substrate. Once all spawning conditions were identified, the total suitable area identified among all survey habitat units was summed for the entire survey reach. Long-term studies which identified territory size for several species of salmonid spawners found that about four times the size of the redd area is required for total spawner territory area, so redd capacity was calculated by dividing the sum of total suitable spawning area by four times the average redd area for each species (Equation 4) (Burner, 1951; Keeley and Slaney, 1996; Cramer et al., 2012).

Table 2. Habitat suitability criteria used for modeling potential spawner capacity in the upper mainstem Eel River, CA. Adapted from: Cramer et al. (2012) and USFWS (2011).

Habitat Attribute	Chinook Salmon	Steelhead trout	Source(s)
Stream Gradient (%)	0 - 5	2 - 12	Merz, 2001; NMFS, 2005; Cooney & Holzer, 2006
Substrate Size (cm)	1.9 - 15.0	0.25 - 12.5	Keely & Slaney, 1996; Kondolf, 2000; USFWS, 2011
Depth (cm)	30.5	15.2	Swift 1979, USFWS, 2011
Redd Territory Area (m^2)	20.0	11.7	Burner, 1951; Keely & Slaney, 1996

Redd Capacity = Σ Qualifying Spawnable Area / (4 * Avg. Redd Area) ***(Equation 4)***

Where
Avg Redd Area is specific to a given species

Redd density was calculated by dividing the redd capacity by the total survey area with flow conditions representative of peak spawning season. Spawning capacity was calculated by assuming two spawners per redd (Grove et al., 2001; Ettlinger et al., 2015). The redd densities were averaged among surveys within a Reach Type stratum and extrapolated to corresponding Reach Type streams not surveyed. Watershed-scale redd capacity was calculated by multiplying redd densities to entire stream network where appropriate. The resulting redd capacity was compared to the spawner estimates converted from parr capacity to determine the most limiting habitat conditions for Chinook Salmon capacity in the study site.

Potential habitat distribution and capacity estimates upstream of Scott Dam were applied to three scenarios. The first scenario (Scenario 1) considers passage restoration at Scott Dam via dam removal and does not consider Bloody Rock roughs a barrier. This includes stream habitat currently inundated by Lake Pillsbury, habitat along the mainstem Eel River and its tributaries below and above Bloody Rock roughs, as well as the Rice Fork and its tributaries. The second scenario (Scenario 2) considers passage restoration via fish ladder at Scott Dam, omitting inundated streams but including all other habitat in the first scenario. The third scenario (Scenario 3) considers passage restoration at Scott Dam via dam removal with abnormally dry winter-spring conditions that would not allow passage upstream of the partial barrier at Bloody Rock roughs. Scenario 3 includes stream habitat currently inundated by Lake Pillsbury, habitat along the mainstem Eel River and its tributaries up to Bloody Rock roughs, and the Rice Fork and its tributaries.

Capacity estimates generated from UCM models were analyzed for identifying whether rearing or spawning conditions were the most limiting for capacity. The capacity limiting estimates were then compared to estimates made from past assessments. The parr capacity estimates were also spatially compared to IP scores, and the relationship between relatively high parr densities and high IP scores (IP >0.5) was modeled with Generalized Additive Modeling in program R version 1.0.136 with package mgcv. Areas of spatial overlap between high densities and high IP scores were mapped.

Finally, data from observed adults at Benbow Dam Fisheries Station (BDFS) on the South Fork Eel River were used to calculate number of fish per unit of drainage area (Yoshiyama and Moyle, 2010). Assuming these maximum recorded values represent potential capacity, or maximum density, for spawners, calculations provided fish/km^2 values that were then multiplied by the drainage area of the study area upstream of Scott Dam. Similarly, mean values of fish counts from BDFS data were also converted to fish/km^2 for a representation of potential average spawner density in the streams above Scott Dam. Additionally, fish counts at Cape Horn Dam's Van Arsdale Fisheries Station (VAFS) located 19.3 river km (12 river mi) downstream of Scott Dam on the upper mainstem Eel River were analyzed. These data from both Benbow Dam and Cape Horn Dam fish ladders were evaluated as indices for potential spawner production in the upper mainstem Eel River upstream of Scott Dam.

RESULTS

Survey Design

Three scenarios for potential distribution of Chinook Salmon and steelhead trout in the study area streams resulted from GIS and ground-based assessments. Fish passage assessments conducted by this research at Bloody Rock roughs reclassified the roughs as a temporal barrier that both species may pass during high flows typical of upstream migration. When flow conditions are passable at Bloody Rock roughs, the potential stream habitat increased by 48% and 46% for Chinook Salmon and steelhead trout, respectively (Figure 7).

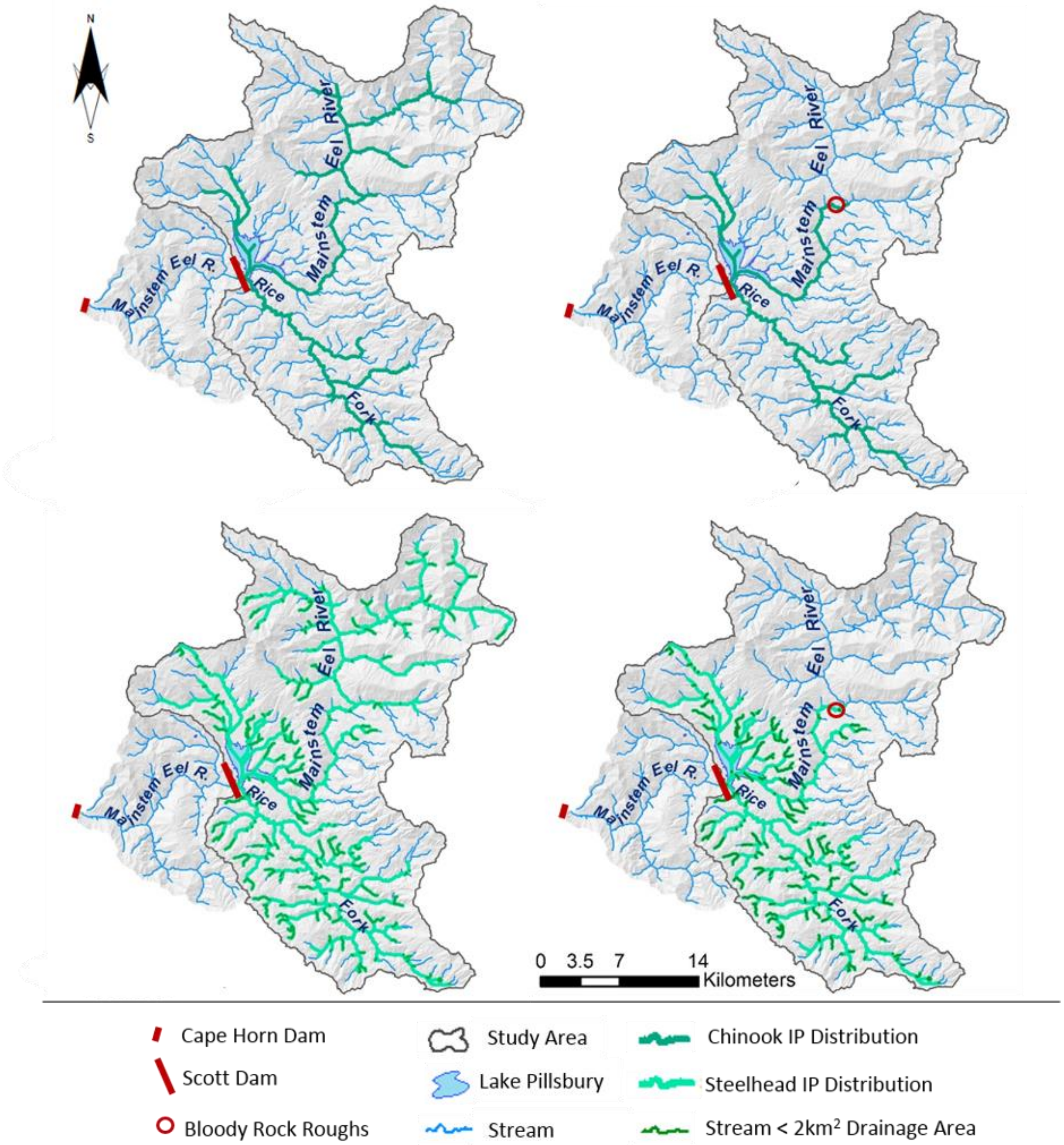

Figure 7. Intrinsic Potential distribution of Chinook Salmon (upper two maps) and steelhead trout (lower two maps) upstream of Scott Dam under two passage scenarios. The first passage scenario on the left represents removal of Scott Dam with restored access to streams above Scott Dam, including those currently inundated by Lake Pillsbury. Scenario 3 on the right represents removal of Scott Dam with restored access to streams above Scott Dam, including those inundated, but considers Bloody Rock Roughs the upper extent along the mainstem Eel River. Streams < $2km^2$ depicted in lower two maps were excluded from steelhead trout parr distribution. Spatial reference: WGS 84, UTM Zone 10 North. (NMFS, 2016; National Map, 2016).

The concatenation of four incremental categories of drainage area and gradient resulted in 11 possible Reach Types in the study area streams (Figure 8). Lower gradient and large to medium-sized streams were the most common by length. Some Reach Types were excluded due to comprising such small proportions of total stream lengths in the study site. Field habitat surveys resulted in 20 wetted stream reaches totaling 13.2 stream km and 11 completely dry stream reaches totaling 6.3 stream km (Figure 8).

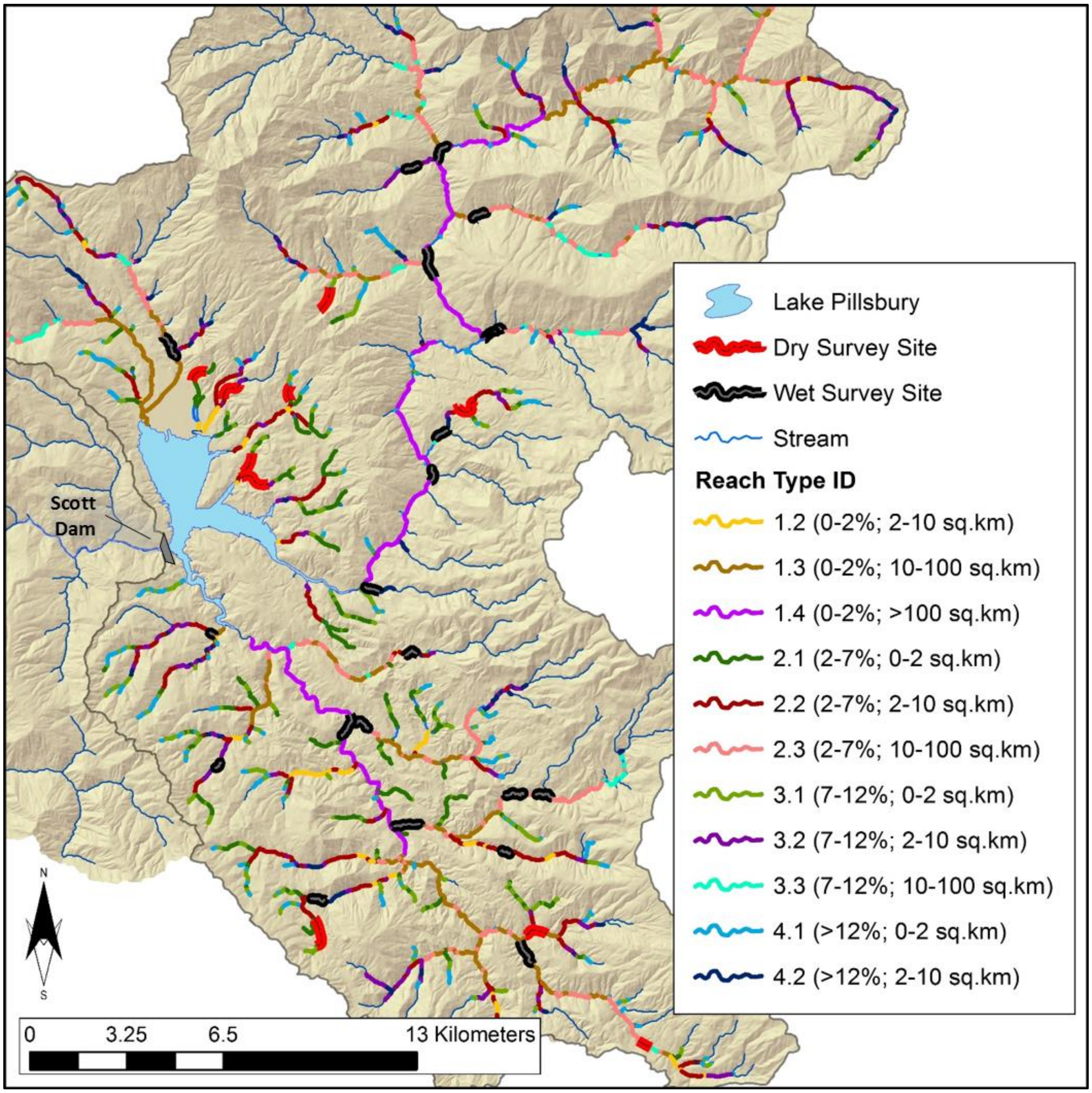

Figure 8. Spatial distribution of Reach Type stratification within the study area in the upper Eel River watershed, CA. Low Gradient, Large Catchment occurs along mainstem and lower Rice Fork; Low Gradient, Medium Catchment occurs in Corbin Creek, in tributaries north of Lake Pillsbury, and the upper Rice Fork; Low Gradient, Small Catchment occurs in smaller tributaries of the Rice Fork; Medium Gradient, Very Small Catchment occurs in small tributaries along the Rice Fork and around Lake Pillsbury; Medium Gradient, Small Catchment occurs along upper portions of large tributaries in the Rice Fork; Medium Gradient, Medium Catchment occurs in tributaries along Rice Fork and the mainstem Eel; High-Very High Gradient Reach Types are all dispersed along headwater streams throughout the watershed. Ground-based stream habitat surveys conducted during summer 2016 are represented in thick black lines for wetted habitat and thick red lines for completely dry habitat. Spatial reference: WGS84, UTM Zone 10 North (NMFS, 2016).

Potential spawning and rearing distribution for steelhead trout and Chinook Salmon was quantified under all fish passage scenarios. Other Reach Types, typically those with smaller drainage areas (<2 km^2), were observed completely without summertime surface flow and deemed unsuitable for steelhead trout summertime rearing. Consequently, these streams were excluded from potential steelhead trout rearing habitat and density estimations. Among all three passage scenarios, potential habitat distribution ranged between 291 – 463 km (181 – 288 mi) for steelhead trout and 89 – 127 km (55 – 79) for Chinook Salmon (Table 3). According to the IP Model, Scott Dam's reservoir, Lake Pillsbury, currently inundates about 27 km (17 mi) of stream habitat for steelhead trout and 16 km (10) for Chinook Salmon. In the event that the Bloody Rock Roughs becomes a barrier, 145 km of stream habitat becomes inaccessible for steelhead trout and 38 km for Chinook Salmon.

Table 3. Potential river km of habitat estimated for three scenarios in the upper mainstem Eel River.

Scenario:	1	2	3
	Removal of Scott Dam (includes waterways inundated by Lake Pillsbury)	Installation of Fish Ladder at Scott Dam to allow passage	Lower flow years when Bloody Rock roughs is a barrier to migration and limits access to upstream waterways
Chinook $Salmon_{spawn}$	127	111	89
Chinook $Salmon_{rear}$	127	111	89
Steelhead $trout_{spawn}$	463	437	318
Steelhead $trout_{rear}$	291	233	179

Analysis

Data collected during stream habitat surveys were evaluated by Reach Type with summaries of habitat unit composition as well as all other measured variables. Habitat unit composition was dominated by pools in survey reaches with a 0-2% gradient, and the proportion of fastwater habitat (riffles and cascades) was higher in reaches with gradients > 2% (Figure 9). Flatwater habitat units were nearly as frequent as pool units in low gradient reaches (0-2% gradient) and became less frequent as both gradient and drainage area increased. Other habitat variables measured in surveys were summarized by Reach Type (Table 4). Due to the large number of habitat covariates measured, multivariate analysis was necessary for further validation of Reach Type distinction for the purposes of extrapolating habitat data.

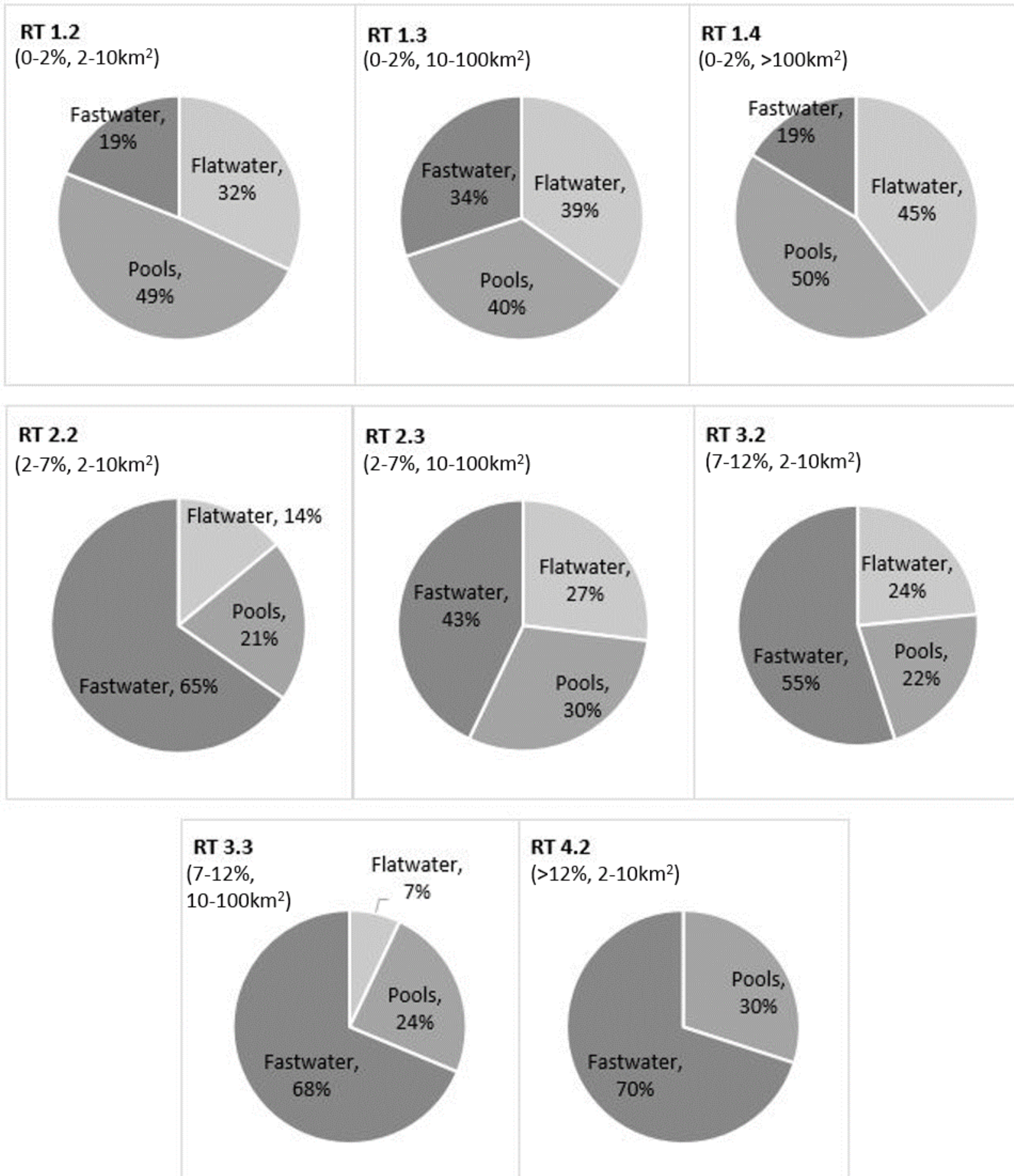

Figure 9. Habitat unit composition summarized from summer 2016 survey data among Reach Type strata in the upper mainstem Eel River, CA. Fastwater includes riffles and cascades, and flatwater includes glides and runs.

Table 4. Habitat variables measured in stream surveys conducted during summer months of 2016 in the upper Eel River watershed upstream of Scott Dam. Length, width, and depths measured in m. Values are averaged at the unit and reach scales (SD).

Reach Type	**1.2 (0-2%, 2-10km2)**	**1.3 (0-2%, 10-100km2)**	**1.4 (0-2%, >100km2)**	**2.2 (2-7%, 2-10km2)**	**2.3 (7-2%, 10-100km2)**	**3.2 (7-12%, 2-10km2)**	**3.3 (7-12%, 10-100km2)**	**4.2 (>12%, 2-10km2)**
***N* Surveys**	1	4	4	3	4	2	1	1
Total Reach Length	187	3,615	3060	1552	2545	902	528	623
Avg. Unit Wetted Width	2.26 (1.29)	3.60 (2.0)	8.67 (3.2)	2.67 (0.8)	4.15 (1.58)	2.70 (1.06)	3.60 (1.58)	1.93 (0.94)
Avg. Unit Mean Depth	0.18 (0.08)	0.23 (0.15)	0.45 (0.28)	0.25 (0.11)	0.34 (0.19)	0.27 (0.14)	0.32 (0.16)	0.20 (0.14)
Pool Max Depth	0.38 (0.09)	0.59 (0.22)	1.03 (0.55)	0.54 (0.22)	0.70 (0.36)	0.60 (0.21)	0.59 (0.22)	0.48 (0.17)
% Shelter	37% (27%)	36% (23%)	54% (19%)	48% (25%)	22% (21%)	29% (14%)	63% (25%)	31% (20%)
% Boulder Cover	0	14% (12%)	23% (19%)	21% (18%)	14% (14%)	16% (10%)	41% (23%)	24% (16%)
% Canopy	48% (34%)	49% (33%)	25% (23%)	62% (21%)	40% (38%)	74% (23%)	42% (26%)	77% (25%)
pH	6.5	7.4 (0.5)	7.7 (0.6)	7.5 (0.5)	7.3 (0.5)	6.5	8.2	6.5
Turbidity in NTU	0.7	0.3 (0.1)	2.4 (3.3)	0.6 (0.3)	0.7 (0.5)	-	1.2	0.71
CFS	0.15	2.65 (3.78)	6.25 (1.82)	1.54 (0.71)	2.92 (1.06)	0.04 (0.02)	0.63	0.05
Temperature ^{0}C	21.4 (1.4)	17.9 (3.3)	20.2 (2.8)	16.2 (1.2)	15.1 (1.2)	14.5 (0.6)	18.2 (1.3)	14.9 (1.3)
Survey Time in Hours	2.75	7.4 (1.8)	6.2 (1.8)	6.4 (1.0)	7.2 (1.4)	4.8 (0.6)	6.5	5.5

Covariates including unit area, mean depth, instream cover, percent fine substrate, and proportion of pools and fastwater habitat were analyzed in a Linear Discriminant Analysis (LDA) for discriminating groups among Reach Types with program RStudio packages Mass, GGplot2, Scales, gridExtra, and RColorBrewer (Figure 10). The first two discriminant functions explained 89% of the variability in group discrimination, and the model had an overall accuracy of 80%. The multivariate analysis of habitat covariates between Reach Types lead to lumping together select Reach Type strata, resulting in five total Reach Type categories for data extrapolation: High to Very High Gradient, Medium to Small Catchment (7-12% and >12%, 2-10 km^2 and 10-100 km^2); Low Gradient, Large Catchment (0-2%, >100km^2); Medium to High Gradient, Small Catchment (2-7% and 7-12%, 2-10km^2); Medium Gradient, Medium Catchment (2-7%, 10-100 km^2); and Low Gradient, Medium Catchment (0-2%, 10-100 km^2).

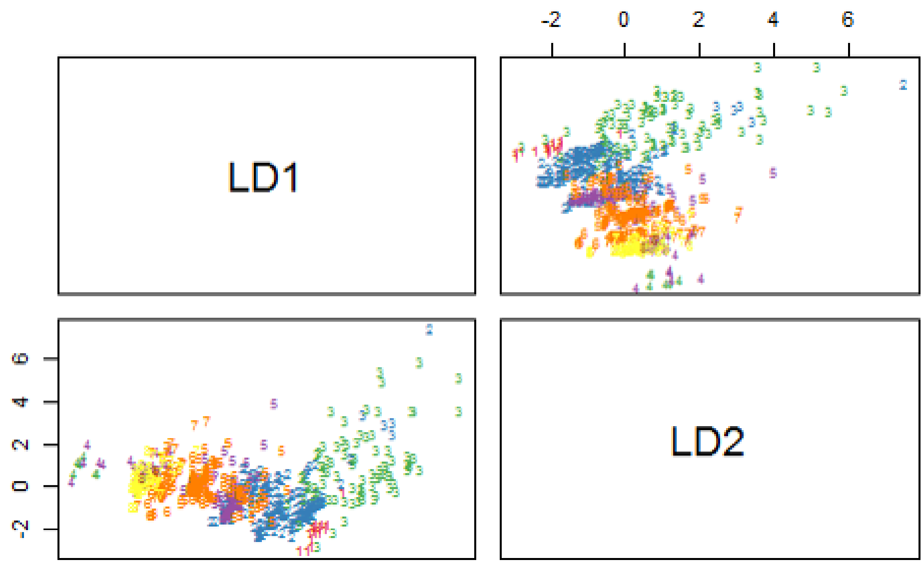

Figure 10. Linear discriminant functions 1 and 2 from the LDA model to discriminate Reach Types (represented in colors). LD1 and LD2 together explained 80 and 9% of the variability, respectively. Eight Reach Types of the highest frequency by length in the study area were surveyed and represented in this model. Note the grouping of each color in the plot, which represents the discrimination between Reach Types. Plot colored numbers represent the following Reach Types: 1= RT 0-2%, 2-10km^2; 2= RT 0-2%, 2-10km^2; 3= RT 0-2%, >100km^2; 4= RT 2-7%, 2-10km^2; 5= RT 2-7%, 10-100km^2; 6= RT 7-12%, 2-10km^2; 7= RT 7-12%, 10-100km^2; 8= RT >12%, 2-10km^2.

The UCM model adjusted steelhead trout and Chinook Salmon parr capacities using both unit-scale and reach-scale parameters measured during field surveys, and effects on model outputs were evaluated with the application of different parameters (Figures 11-14). Of the three applications of model parameters in analysis, the application including usable area, depth, LWD & boulder cover, turbidity, fines, pH, winter cover, and temperature was used. The drift parameter was eliminated due to its uncertain representation of salmonid food availability. Utilizing all parameter adjustments without the drift parameter resulted in 0.02 fish/m^2 – 0.11 fish/m^2 in Scenarios 1 & 2 and 0.01 – 0.05 fish/m^2 in Scenario 3 for steelhead trout parr (Figures

11-12). For Chinook Salmon parr, densities fell between 0.02 fish/m^2 – 0.27 fish/m^2 in Scenarios 1, 2, and 3 when densities were adjusted with all parameters except the dirft parameter (Figures 13-14).

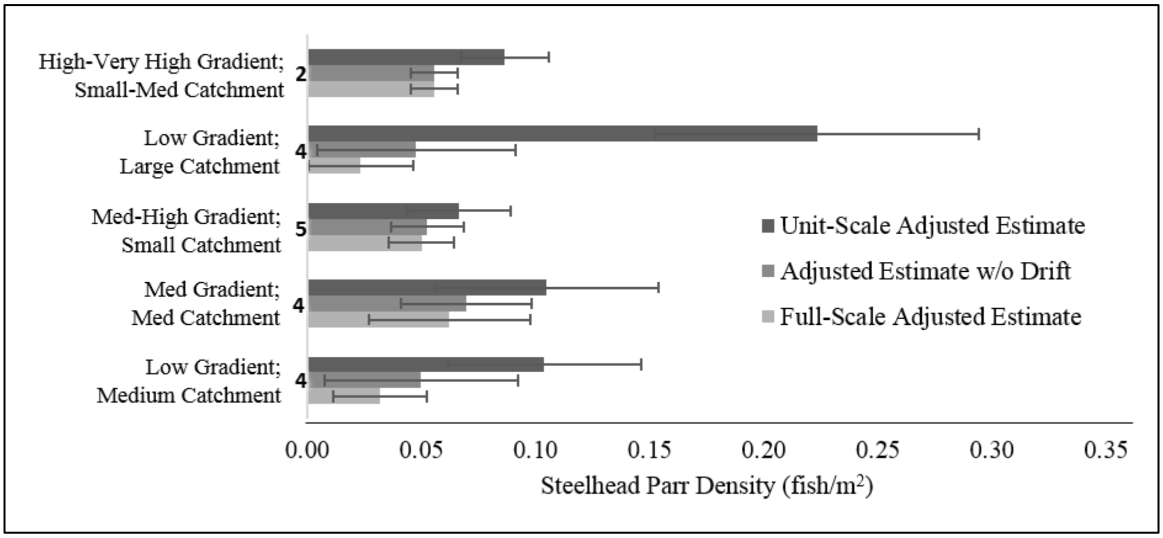

Figure 11. UCM estimated steelhead trout parr mean densities among Reach Types in the upper mainstem Eel River, CA under Scenario 1 where removal of Scott Dam restores access to habitat inundated by Lake Pillsbury, Rice Fork and its tributaries, and the mainstem Eel and its tributaries below and above Bloody Rock roughs. Unit-scale adjusted estimate includes unit-scale parameters only; adjusted estimate w/o drift includes unit- and reach-scale parameters except drift; full-scale adjusted estimate includes all unit- and reach-scale parameters. Error bars represent 1 standard deviation of reach-scale density for surveys within a Reach Type. *N* surveys denoted along y axis.

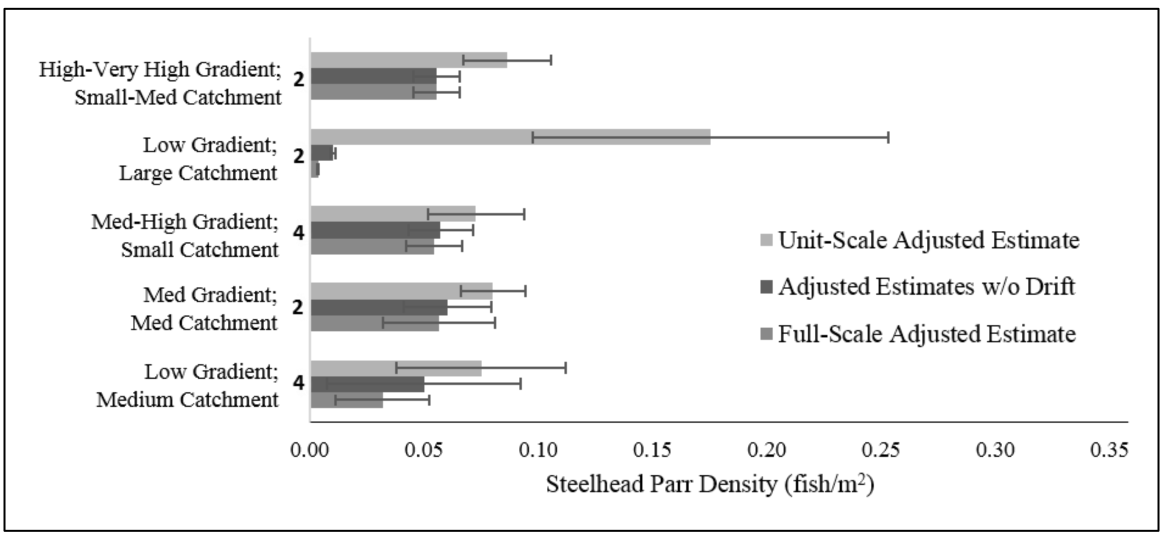

Figure 12. UCM estimated steelhead trout parr mean densities among Reach Types in the upper mainstem Eel River, CA under Scenario 3 where removal of Scott Dam restores access to habitat inundated by Lake Pillsbury, Rice Fork and its tributaries, and the mainstem Eel and its tributaries below Bloody Rock roughs. Unit-scale adjusted estimate includes unit-scale parameters only; adjusted estimate w/o drift includes unit- and reach-scale parameters except drift; full-scale adjusted estimate includes all unit- and reach-scale parameters. Error bars represent 1 standard deviation of reach-scale density for surveys within a Reach Type. *N* surveys denoted along y axis.

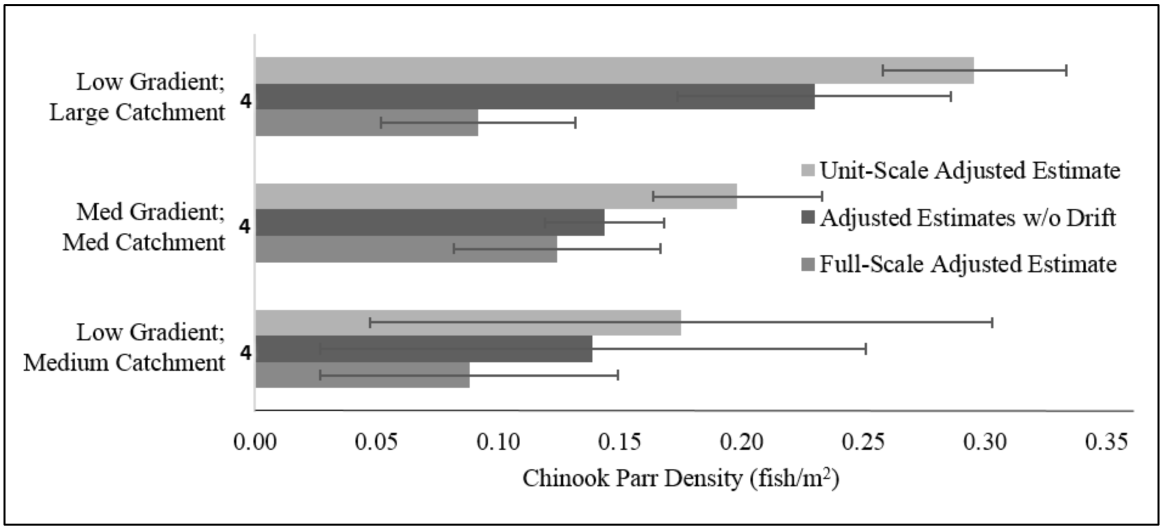

Figure 13. UCM estimated Chinook Salmon parr mean densities among Reach Types in the upper mainstem Eel River, CA under Scenario 1 where removal of Scott Dam restores access to habitat inundated by Lake Pillsbury, Rice Fork and its tributaries, and the mainstem Eel and its tributaries below and above Bloody Rock roughs. Unit-scale adjusted estimate includes unit-scale parameters only; adjusted estimate w/o drift includes unit- and reach-scale parameters except drift; full-scale adjusted estimate includes all unit- and reach-scale parameters. Error bars represent 1 standard deviation of reach-scale density for surveys within a Reach Type. *N* surveys denoted along y axis.

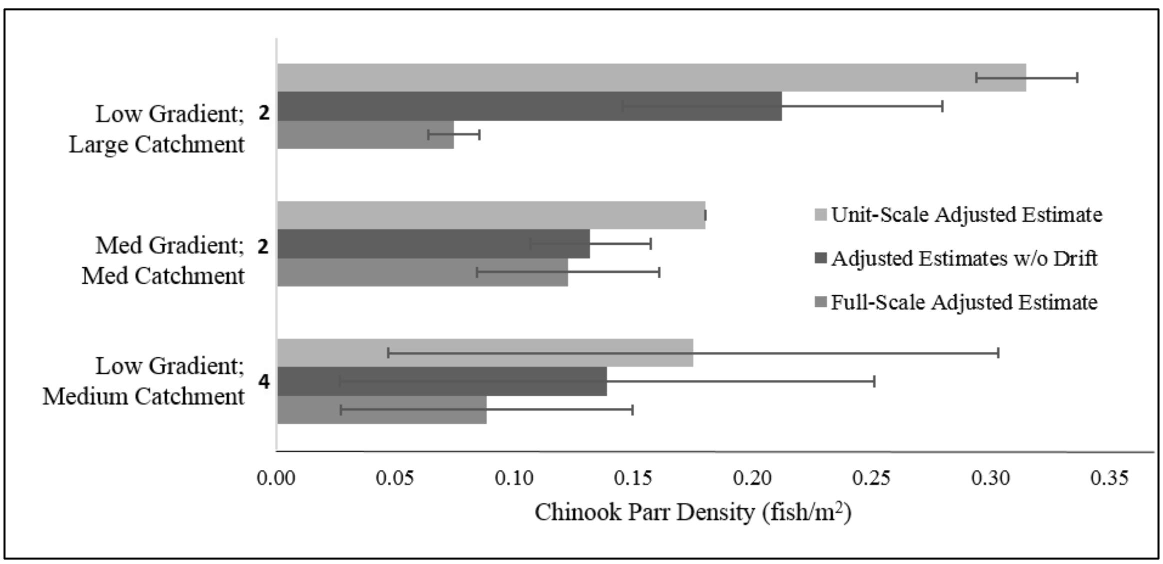

Figure 14. UCM estimated Chinook Salmon parr mean densities among Reach Types in the upper mainstem Eel River, CA under Scenario 3 where removal of Scott Dam restores access to habitat inundated by Lake Pillsbury, Rice Fork and its tributaries, and the mainstem Eel and its tributaries below Bloody Rock roughs. Unit-scale adjusted estimate includes unit-scale parameters only; adjusted estimate w/o drift includes unit- and reach-scale parameters except drift; full-scale adjusted estimate includes all unit- and reach-scale parameters. Error bars represent 1 standard deviation of reach-scale density for surveys within a Reach Type. *N* surveys denoted along y axis.

Mean densities among Reach Types in Scenarios 1 and 2 did not differ, but the capacity outputs were slightly different due to the difference in total habitat area. Extrapolating densities stratified by Reach Type for Scenario 1 resulted in a capacity of 57,374 steelhead trout parr and 201,426 Chinook Salmon parr at the watershed scale. For steelhead trout parr, Scenario 1 estimates were decreased by about 10% and 40% in Scenarios 2 and 3, respectively (Table 5). Chinook Salmon parr estimates from Scenario 1 were decreased by about 20% and 32% in Scenarios 2 and 3, respectively (Table 6).

Table 5. Steelhead trout parr stratified mean densities generated by the UCM, along with length of habitat by Reach Type streams that fall within steelhead trout parr habitat. Steelhead trout parr capacity is shown in mean stratified density (1SD) and recruited spawners reflect watershed-scale estimate for each scenario.

	Scenario 1		**Scenario 2**		**Scenario 3**	
	Removal of Scott Dam (includes waterways inundated by Lake Pillsbury)		Installation of Fish Ladder at Scott Dam to allow passage		Lower flow years when Bloody Rock roughs is a barrier to migration and limits access to upstream waterways	
	Mean Density (fish/m^2)	Stream Habitat (km)	Mean Density (fish/m^2)	Stream Habitat (km)	Mean Density (fish/m^2)	Stream Habitat (km)
RT 1.3	0.05	48.9	0.05	48.9	0.05	36.757
RT 2.3	0.07	51.6	0.07	51.6	0.06	27.505
RT 3.2 & 2.2	0.06	97.1	0.06	97.1	0.06	72.757
RT 1.4	0.05	61.9	0.05	34.9	0.01	22.861
RT 3.3 & 4.2	0.06	31.7	0.06	31.7	0.06	18.555
Total Stream km		291.2		232.5		178.435
Parr Capacity	57,374 (SD 32,081)		49,858 (SD 25,497)		27,848 (SD 9,982)	
Spawners Recruited from Parr Capacity with 13% ocean survival	1,044-2,088*		907-1,815*		507-1,014*	

*Range reflects differing survival rates based on proportion of cohort that emigrates at different ages.

Table 6. Chinook Salmon parr mean densities generated by the UCM and length of habitat by Reach Type streams that fall within Chinook Salmon parr habitat. Chinook Salmon parr capacity is shown in mean stratified density (1SD) and recruited spawners reflect watershed-scale estimate for each scenario.

	Scenario 1		**Scenario 2**		**Scenario 3**	
	Removal of Scott Dam (includes waterways inundated by Lake Pillsbury)		Installation of Fish Ladder at Scott Dam to allow passage		Lower flow years when Bloody Rock roughs is a barrier to migration and limits access to upstream waterways	
	Mean Density (fish/m^2)	Stream Habitat (km)	Mean Density (fish/m^2)	Stream Habitat (km)	Mean Density (fish/m^2)	Stream Habitat (km)
RT 1.3	0.14	40.7	0.14	40.7	0.14	29.3
RT 2.3	0.15	35.6	0.15	35.6	0.13	20.5
RT 1.4	0.23	50.9	0.23	34.9	0.21	38.9
Total Stream km		127.2		111.2		88.7
Parr Capacity	201,426 (SD 67,550)		160,322 (SD 55,295)		65,200 (SD 18,901)	
Spawners Recruited from Parr Capacity with 3% ocean survival	4,593		3,655		1,487	

Using life stage-specific survival rates for each species, the parr estimates in each scenario were converted to spawners. Survival rates for steelhead trout conversions varied based on proportion of cohort that emigrates as either parr or smolts (Table 7) (Johnson and Cooper, 1995; Cramer et al., 2012). A survival rate of 28% for steelhead trout parr to smolt was used and a range of smolt to adult survival rates including 1.5%, 13%, and 20% were used to estimate spawner recruits from juvenile capacity estimates (Table 6) (Johnson and Cooper, 1995; Cramer et al., 2003; Quinn, 2005; Cramer et al., 2012; Anderson and Ward, 2016). For Chinook Salmon, a survival rate of 76% from parr to smolt was used and a range of smolt to adult survival rates including 1.5%, 3%, and 4% were used to estimate spawner recruits from juvenile capacity estimates (Table 8) (Quinn, 2005; Rawding et al., 2010; Cramer and Ackerman, 2012; Moore et al., 2014; Anderson and Ward, 2016).

Table 7. Watershed-Scale capacity estimate for juvenile steelhead trout under Scenario 1 where removal of Scott Dam restores access to habitat inundated by Lake Pillsbury, Rice Fork and its tributaries, and the mainstem Eel and its tributaries below and above Bloody Rock roughs in the upper mainstem Eel River, CA, and its conversion to number of adults based on survival rates for each life stage between parr and adult. Ocean survival rates (smolt to adult) from various sources were analyzed.

Steelhead trout Juvenile Survival Rate Conversion to Spawners from a Parr Capacity of 57,374 fish

Parr to Smolt Survival 28%	Additional Year of Rearing Survival 50%		Smolt to Adult Survival 1.5% (Cramer and Ackerman, 2012)	Smolt to Adult Survival 13% (Quinn, 2005; Anderson and Ward, 2016*)	Smolt to Adult Survival 20% (Moore et al., 2014)
16,065	100% Smolt age 2+ outmigration	8,032	120	1,044	1,606
	75% Smolt age 2+ outmigration	10,040	151	1,305	2,008
	50% Smolt age 2+ outmigration	12,049	181	1,566	2,410
	25% Smolt age 2+ outmigration	14,057	211	1,827	2,811
	100% Parr age 1+ outmigration	16,065	241	2,088	3,213

*Steelhead trout and Chinook Salmon ocean survival calculated from Freshwater Creek smolt abundance divided by adult abundance from years 2007-2015 resulted in an average 13% steelhead trout ocean survival rate.

Table 8. Watershed-Scale capacity estimate for juvenile Chinook Salmon under Scenario 1 where removal of Scott Dam restores access to habitat inundated by Lake Pillsbury, Rice Fork and its tributaries, and the mainstem Eel and its tributaries below and above Bloody Rock roughs in the upper mainstem Eel River, CA, and its conversion to number of adults based on survival rates for each life stage between parr and adult. Ocean survival rates (smolt to adult) from various sources were analyzed for converting number of spawners from a parr capacity estimate of 201,426 fish.

Parr to Smolt Survival 76%	Smolt to Adult Survival 1.5% (Rawding et al., 2010)	Smolt to Adult Survival 3% (Quinn, 2005)	Smolt to Adult Suvival 4% (Anderson and Ward, 2016*)
153,084	2,296	4,593	6,123

*Steelhead trout and Chinook Salmon ocean survival calculated from Freshwater Creek smolt abundance divided by adult abundance from years 2007-2015 resulted in an average 4% Chinook Salmon ocean survival rate.

Parr densities averaged among Reach Types were assigned to all stream segments that compose lumped Reach Type strata in the study area and mapped for streams under the fish passage scenario where Scott Dam is removed and there is passage at Bloody Rock roughs. The highest stratified mean density values (0.07 parr/m^2) for steelhead trout occurred in tributaries of the mainstem Eel River as well as in tributaries of the Rice Fork (Figure 15). For Chinook Salmon, highest stratified mean density values (0.21 parr/m^2) occurred along the mainstem Eel River and lower reaches of the Rice Fork (Figure 15). Throughout the entire study area stream network, there were 210 stream km with a stratified mean density value of 0.05 parr/m^2, about 30 stream km with a mean density of 0.06 steelhead trout parr/m^2, and there were 50 stream km with the highest steelhead trout mean density at 0.07 parr/m^2. For Chinook Salmon, stratified mean densities of 0.13, 0.14, and 0.21 parr/m^2 each occurred in ~50 stream km of the study area stream network. Spatial overlap where estimated parr densities were relatively high and IP scores were >0.5 was mapped and plotted (Figures 16-17).

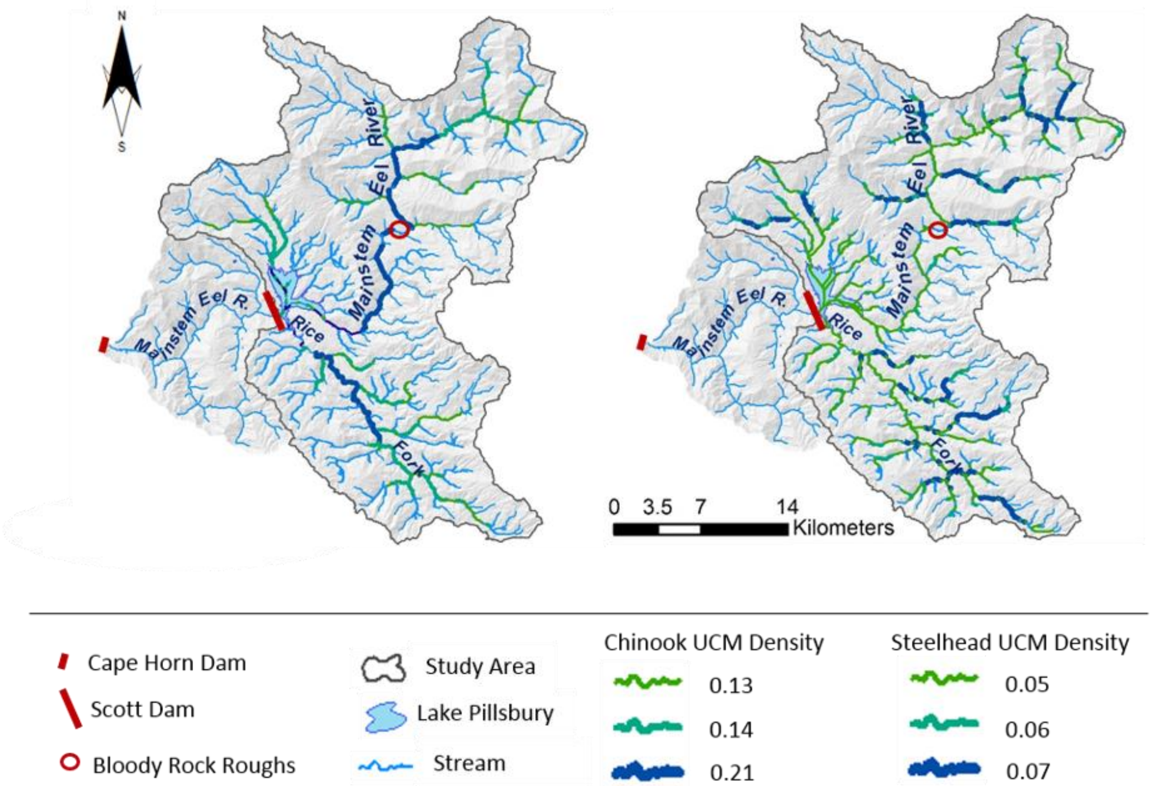

Figure 15. Spatial distribution of juvenile Chinook Salmon (left) and steelhead trout (right) densities estimated for stratified Reach Types in the Upper Eel River, CA. Higher capacity densities are represented with larger, darker stream lines. The spatial reference is WGS84, UTM Zone 10 North (National Map, 2016; USGS, 2016; Esri, USGS, NOAA, 2016).

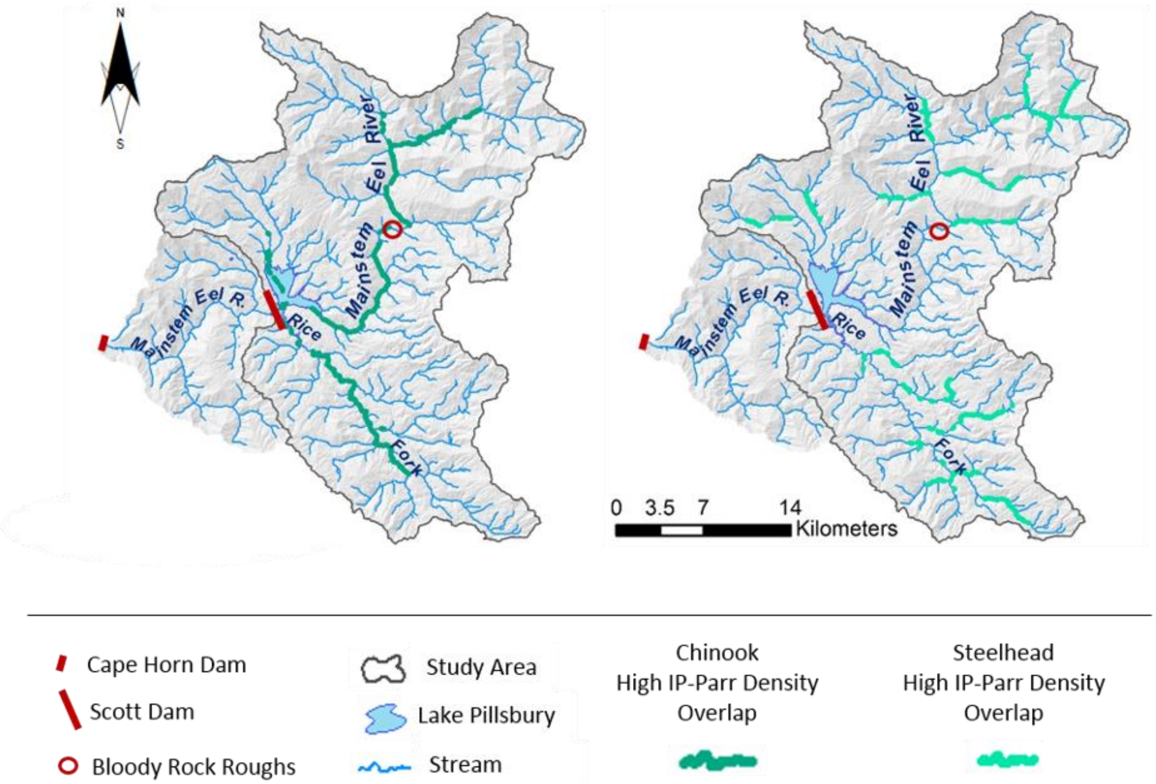

Figure 16. Spatial overlap of high IP scores (>0.5) and relatively high parr density values for Chinook Salmon (left; density >0.13) and steelhead trout (right; density >0.05) in the upper mainstem Eel River, CA. Spatial reference is WGS84, UTM Zone 10 North (National Map, 2016; USGS, 2016; NMFS, 2016).

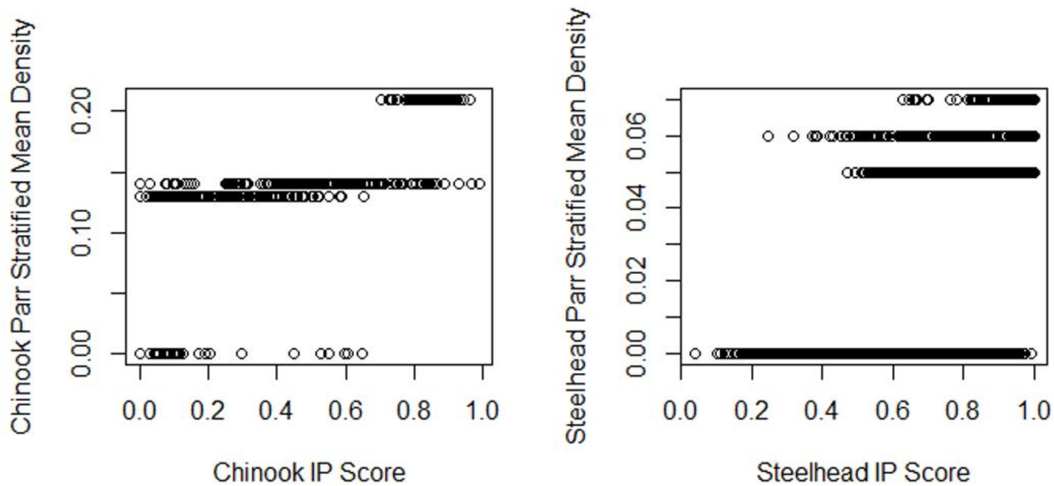

Figure 17. Plotted data for stratified mean density values of Chinook Salmon (left) and steelhead trout (right) parr in response to IP score in the upper mainstem Eel River, CA (NMFS, 2016).

The response curve of potential density in relation to IP score was analyzed with Generalized Additive Models (GAMs). A positive relationship between the predictor and response variables was expected. Several GAMs were modeled by manipulating the gamma value, and the most appropriate models for both steelhead trout and Chinook Salmon resulted in what appeared to be a positive linear relationship (Table 7 and Figure 18). The GAM for parr density in response to IP score explained 54% of the deviance for steelhead trout and 72% of the deviance for Chinook Salmon.

Table 9. Generalized Additive Models and their respective complexity and performance values for modeling the response of predicted parr density values with IP score in the upper mainstem Eel River watershed, CA. One model per species was selected based on performance where overfitting did not appear to occur and where the expected positive relationship was reflected in the plotted curve.

	Gamma	**Deviance Explained**	**AIC**
Chinook Salmon$_{GAM1}$	1.4	79%	-9,906
Chinook Salmon$_{GAM2}$	10	79%	-9,886
Chinook Salmon$_{GAM3}$	100	77%	-9,623
Chinook Salmon$_{GAM4}$	145	72%	-9,148
Steelhead trout$_{GAM1}$	1.4	56%	-26,213
Steelhead trout$_{GAM2}$	10	56%	-26,198
Steelhead trout$_{GAM3}$	40	56%	-26,018
Steelhead trout$_{GAM4}$	65	54%	-25,974

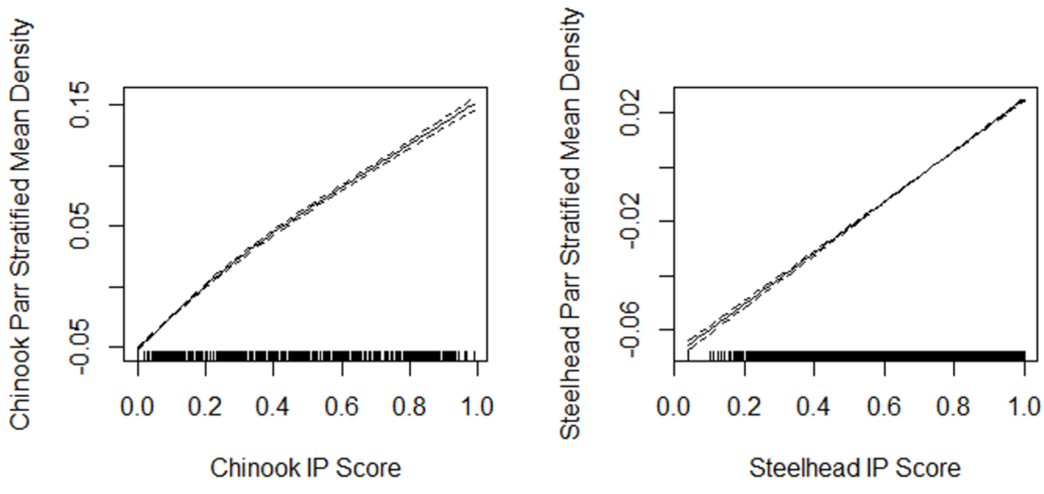

Figure 18. Generalized Additive Models of parr density in response to IP score for Chinook Salmon and steelhead trout. Chinook Salmon GAM deviance explained was 72% (gamma=145, AIC=-9148) and steelhead trout GAM deviance explained was 56% (gamma=10, AIC=-25,974). Dashed lines represent 95% confidence interval.

Habitat field data, flows modeled for the month of November, and spawning criteria were used to estimate a Chinook Salmon redd capacity of about 7,600 – 11,460 redds for the entire watershed area of the study site, depending on the fish passage scenarios. Spawner densities ranged from 60 – 80 fish/km^2, and spawner capacity resulted from the assumption of two spawners per redd (Table 10) (Grove et al., 2001; Ettlinger et al., 2015).

Table 10. Chinook Salmon redd and spawner capacity generated from UCM redd capacity model for three fish passage scenarios in the upper mainstem Eel River watershed. Redds were estimated from mean density values among stratified Reach Types (1SD of stratified densities).

		Chinook Salmon Redds	**Chinook Salmon Spawners**
Scenario 1	Removal of Scott Dam (includes waterways inundated by Lake Pillsbury)	11,460 (SD 9,232)	22,900
Scenario 2	Installation of Fish Ladder at Scott Dam to allow passage	9,285 (SD 7,172)	18,570
Scenario 3	Removal of Scott Dam; in lower flow years when Bloody Rock roughs is a barrier to migration	7,600 (SD 4,434)	15,200

Parr estimates from the UCM and their subsequent spawner recruits were used to compare to spawner estimates from past assessments (Tables 11-12). Assessments in the past estimated potential abundance upstream of Scott Dam for Chinook Salmon and steelhead trout spawners based on spawner data from other areas of the Eel River (CDFG, 1979; VTN, 1984; BLM, 1995; Becker and Reining, 2009; Higgins, 2010; NMFS, 2016; PVID, 2017). Additionally, annual fish counts for migrating adults at Van Arsdale Fisheries Station (VAFS) located upstream of the fish ladder at Cape Horn Dam were analyzed over the past 80 years for steelhead trout and 70 years for Chinook Salmon as an index for number of spawners entering the accessible streams within the Potter Valley Project (PVID, 2017). Adult counts at VAFS ranged from 31 – 9,528 steelhead trout, averaging 1,835 fish and between 0 – 3,471 Chinook Salmon, averaging 366 fish. Adult counts at Benbow Dam Fisheries Station (BDFS) on the South Fork Eel River from years 1938 – 1975 ranged from 1,847 – 25,032 steelhead trout, averaging 11,192 fish, and 473 – 21,011 Chinook Salmon, averaging 6,998 fish. Counts at BDFS are on average higher than those from VAFS in part due to the larger watershed area above BDFS. These data from BDFS converted to about 9.9 steelhead trout adults/km^2 and 6.2 Chinook Salmon adults/km^2, converting to about 7,400 steelhead trout adults and 4,620 Chinook Salmon adults potentially supported in the 746 km^2 of drainage area above Lake Pillsbury.

Table 11. Potential steelhead trout stream habitat and abundance estimates from past reports compared to those from this report in the upper mainstem Eel River watershed, CA.

Steelhead trout Habitat in Stream-km	**Steelhead trout Spawner Abundance**	***Source***
-	2,500	CDFG, 1979, unpublished
94	1,499	VTN, 1982
160		BLM, 1995
411	-	Becker and Reining, 2009
463	6,120	NMFS, 2016
-	408	PVID, 2017*
318 - 463	1,044-2,088	This research via UCM**
-	7,400	This research via conversion of spawner count data from Benbow Dam

*Includes estimates of spawners using stream habitat between Van Arsdale and Scott Dam only. PVID (2017) is an average of upstream migrant counts from 2000-2016 at Van Arsdale Fisheries Station.
**Includes estimates of spawners recruited from capacity estimate of 57,374 parr converted with a 28% parr to smolt survival rate and 13% ocean survival rate.

Table 12. Potential Chinook Salmon stream habitat and abundance estimates from past reports compared to those from this report in the upper mainstem Eel River watershed, CA.

Chinook Salmon Habitat in stream-km	**Chinook Salmon Spawner Abundance**	***Source***
-	2,300	CDFG, 1979, unpublished
94	1,250	VTN, 1982
160		BLM, 1995
-	3,092	Higgins, 2010*
127	2,060	NMFS, 2016
-	917	PVID, 2017*
89 - 127	4,593	This research via UCM**
-	4,620	This research via conversion of spawner count data from Benbow Dam

*Includes estimates of spawners using stream habitat between Van Arsdale and Scott Dam only. PVID (2017) is an average of upstream migrant counts from 2000-2016 at Van Arsdale Fisheries Station. Higgins (2010) reflects abundance estimate for habitat between dams from year 2010.
**Includes estimates of spawners recruited from capacity estimate of 201,426 parr converted with a 76% parr to smolt survival rate and 3% ocean survival rate.

DISCUSSION

Summary of Findings

Three fish passage scenarios were used to estimate the amount of potential stream habitat suitable for Chinook Salmon and steelhead trout in the upper mainstem Eel River upstream of Scott Dam. The first scenario (Scenario 1) includes passage at Scott Dam via dam removal and does not consider Bloody Rock roughs as a migrational barrier. Scenario 1 resulted in 127 km for Chinook Salmon spawning and rearing and a potential Chinook Salmon juvenile capacity of 201,426 parr which converted to about 4,593 Chinook Salmon spawners using mid-range smolt to adult survival rates. Scenario 1 resulted in 463 km for steelhead trout spawning and 291 km for steelhead trout rearing, with a potential capacity of about 57,374 steelhead trout parr and about 1,044 – 2,088 steelhead trout spawner recruits from parr capacity, depending on age of emigrants and using mid-range smolt to adult survival rates. Under the second scenario (Scenario 2), fish passage at Scott Dam is restored via fish ladder installation and Bloody Rock roughs is considered passable, so streams inundated by Lake Pillsbury are excluded. This resulted in a reduction of potential stream habitat (due to inundation by Lake Pillsbury) from Scenario 1 by about 27 km for steelhead trout with a parr capacity of 49,858 fish and about 907 – 1,815 steelhead trout spawner recruits from parr capacity, depending on age of emigrants and using mid-range smolt to adult survival rates. Scenario 2 resulted in a reduction of 16 stream km for Chinook Salmon from the first passage scenario, and parr capacity estimates were 160,322 parr and about 3,655 Chinook Salmon spawner recruits from parr capacity using mid-range smolt to adult survival rates. The third passage scenario (Scenario 3) includes passage at Scott Dam via dam removal, but considers Bloody Rock roughs a barrier for anadromy in drier years. This resulted in about a 30% reduction in potential stream spawning and rearing habitat for Chinook Salmon, about a 30% reduction in potential steelhead trout spawning habitat, and about 40% less stream habitat for potential steelhead trout rearing habitat. Steelhead trout parr capacity estimates for Scenario 3 resulted in about 27,848 parr and about 507 – 1,014 steelhead trout spawners recruited from parr capacity, depending on age of emigrants and using mid-range smolt to adult survival rates. Chinook Salmon parr capacity was estimated at 65,200 parr, and 1,487 Chinook Salmon spawners were recruited from parr capacity using mid-range smolt to adult survival rates.

Although there was not much difference in potential salmonid habitat capacity for salmonids between the first two passage scenarios, fish passage at Bloody Rock roughs did make a considerable difference in both habitat conditions and their capacity for salmonids. Habitat upstream of Bloody Rock roughs includes tributaries along the mainstem Eel where potential rearing capacities were at their highest densities for steelhead trout, so this lack of a considerable amount of quality stream habitat contributed to the larger difference observed in the scenario where Bloody Rock roughs is a barrier. Another factor that contributed to the lower potential capacity in the scenario where Bloody Rock roughs is not passable was unsuitable temperature for rearing salmonids. Streams in the Reach Type stratum Low Gradient, Large Catchment (0-2%, >100 km^2)

had a mean steelhead trout parr density of 0.05 in both scenarios where passage occurs at Bloody Rock roughs, but when the roughs are a barrier, mean steelhead trout parr density was 0.01. For Chinook Salmon, passage at Bloody Rock roughs makes a significant difference due to both quantity (38 km) and quality of stream available for spawning and rearing upstream of the roughs.

The potential fish passage scenarios used in this study include scenarios similar to what was found in past assessments. Venture Tech Network (1984) considered Bloody Rock roughs impassable, which is comparable to the third scenario in this study where the roughs are also not considered passable. However, this study considers blocked passage at Bloody Rock roughs atypical. The first two scenarios where passage at Bloody Rock roughs is allowed are therefore considered more likely, and the estimated amounts of habitat are similar to what was found from Becker and Reining (1999).

Rearing capacity for both Chinook Salmon and steelhead trout was determined more limiting than potential spawner capacity, so subsequent spawner recruits from parr capacities were used for comparing to abundance estimates from other sources. Chinook Salmon estimates generated from the UCM (4,593 spawners) were higher than all other estimates found from past assessments including those from CDFG (1979) at 2,300 spawners, VTN (1984) at 1,250 spawners, and NMFS (2016) at 2,060 spawners. Steelhead trout spawners recruited from UCM parr capacity estimates ranged between 1,044 – 2,088, which was comparable to VTN (1984) estimate of 1,499 spawners and CDFG (1979) estimate of 1,500 spawners but lower than NMFS estimate of 6,120 spawners. Upstream migrant fish counts at Van Arsdale Fisheries Station (VAFS) were averaged from the past 70-80 years as available. The counts at VAFS provided an index for salmonid production in streams between Van Arsdale and Scott Dam, and UCM-generated capacity estimates were compared by calculating potential increase in production from VAFS counts. While the VAFS counts were a useful comparison tool, the interannual variability among count data was high, so maximum potential increases generated from UCM capacity estimates would likely be variable. Further, converting the predicted parr to number of subsequent adults suggested a need for more accurate life stage specific survival rates that are representative of the upper Eel River watershed, especially for smolt to adult survival.

Streams that had both high estimated parr densities and high IP scores were identified. For both Chinook Salmon and steelhead trout, the highest stratified mean parr densities occurred only at higher IP scores, but lower estimated densities for steelhead trout occurred across the entire range of IP scores. The inconsistencies between parr densities and IP scores were analyzed with GAMs, and most of the variability for potential density in response to IP scores was explained for steelhead trout and Chinook Salmon. These areas of overlap occurred in tributaries of the mainstem Eel River mostly upstream of Bloody Rock roughs and along tributaries of the Rice Fork for steelhead trout. For Chinook Salmon, areas of overlap between high IP scores and high stratified densities occurred along the mainstem Eel and lower, larger catchment reaches of the Rice Fork. Cramer and Ackerman (2009b) suggest considering such instances of overlap as areas for conservation. In response, streams qualified for conservation upstream of Scott Dam warrant the need to restore salmonid access due to their high intrinsic and production potential. Spatial overlap between high UCM parr capacities and high IP scores for steelhead trout also occurs, but is less associated.

Assessment of Survey Design and Habitat Capacity Models

Although there was some overlap in the measured habitat characteristics among Reach Type strata after performing analyses of variance and discriminant analyses on the habitat covariates, it was apparent that utilizing gradient and drainage area as the initial distinguishing features for stratifying the study site streams was effective. Streams surveyed in Reach Type stratum Low Gradient, Large Catchment (0-2%, >100 km^2) were consistently the most distinguished by habitat variables among streams in all other strata. Although geomorphic covariates such as depth, wetted width, and unit composition tended to be more distinguished among strata, there were other habitat covariates such as embeddedness and percent fish cover that varied both within and among reaches. This ultimately created variation in the UCM-generated density values within surveys of a Reach Type.

Overall, the reach-scale adjustments in the UCM reduced parr capacity the most. Temperature in the UCM is the most restrictive parameter for steelhead trout parr capacity, which is reflective of studies that have found summertime rearing conditions to be the most limiting for juvenile salmonids (Cramer & Ackerman, 2009a). Rearing habitat conditions for steelhead trout parr were most unsuitable in lower gradient, large drainage area streams, typically occurring along the mainstem or lower reaches of the Rice Fork. Summer temperatures exceeding suitable conditions (>18 ºC) were observed in some areas of these streams, and this resulted in reduced capacity potential for over-summering steelhead trout. The temperature aspect of the UCM model separates it from other approaches such as those made by CDFG (1979), VTN (1984), and the NMFS IP Model (2016), which may be why the UCM estimates for steelhead trout are considerably low compared to other estimates made in the past (Table 9). Furthermore, survey data used in UCM estimates for this research reflect conditions after multiple years of drought, which may have also contributed to lower flows and warmer temperatures and thus lower estimates of capacity. UCM parr estimates for Chinook Salmon, however, fall within or close to past estimates. Chinook Salmon rearing conditions that peak in May are not subject to high temperatures, so potential capacity for Chinook Salmon parr was highest in reaches along the mainstem Eel and Rice Fork, which are typical-sized reaches for Chinook Salmon parr occupancy (Quinn, 2005). Chinook Salmon parr densities were also not as sensitive to other small-scale adjustments in the UCM model, which may explain why Chinook Salmon estimates are closer to those from the past that were based on a more large-scale habitat parameter approach.

The productivity scalar in the UCM model had a limiting effect on potential parr capacity for both species, namely due to unsuitable proportion of fish food-producing drift habitat. It was uncertain how effectively the drift parameter represents fish food availability, so estimates were modeled without the drift parameter. For both steelhead trout and Chinook Salmon parr capacity, the highest estimates were calculated from surveys in Cold Creek and upper Bear Creek in Reach Type stratum Moderate Gradient, Medium Catchment (2-7%, 10-100 km^2). The streams in this Reach Type were characterized by a high riffle-pool ratio and ample base streamflow with maximum temperatures observed below 17 ºC.

There are significant discrepancies between the UCM for parr capacity versus redd capacity. Redd capacity estimates result in a spawner capacity up to ten times the spawners that would be recruited from the parr capacity. This suggests that rearing conditions in the study site are more limited for salmonid production than spawning conditions. In response, the spawners derived from parr capacity estimates were applied for comparison to past assessments. Spawner estimates converted from parr capacities were put into context with a comparison to spawner counts at Van Arsdale Fisheries Station (VAFS) at Cape Horn Dam located downstream of Scott Dam. After calculating number of fish per drainage area from maximum spawner counts at Benbow Dam on the South Fork Eel River and applying that value to the drainage area of the study site, spawners recruited from UCM parr capacity were lower for steelhead trout but similar for Chinook Salmon. Under the scenario with dam removal where fish passage allows access to streams above Scott Dam including those inundated as well as passage at Bloody Rock roughs, the average spawner population entering VAFS from the past 16 years could increase up to 5.0 times for Chinook Salmon and up to 5.1 times for steelhead trout, assuming parr abundances reach full capacity and mid-range ocean survival. Likewise, there are potential increases up to 4.0 times for Chinook Salmon and up to 4.4 times for steelhead trout in the scenario with passage restoration via fish ladder at Scott Dam, and up to 1.6 times for Chinook Salmon and up to 2.5

times for steelhead trout in the scenario with passage restoration via dam removal and no passage at Bloody Rock roughs.

The potential increase in salmonid production in the upper mainstem Eel River also depends on many other factors, including downstream habitat and population conditions. Upon reintroduction of salmon and steelhead trout, UCM redd capacity results show that streams above Scott Dam would provide ample habitat for spawning, which suggests opportunity for subsequent saturation of the stream seedbank for egg recruits. Due to there being more potential spawning than rearing habitat for both Chinook Salmon and steelhead trout in the streams above Scott Dam, juvenile capacity estimates from the UCM model suggest that a proportion of the recruits from a fully seeded spawning population would have to seek habitat elsewhere, migrating downstream of Scott Dam. Such juvenile movement in response to instream rearing conditions was observed among Chinook Salmon in the Shasta River, CA (Roddam and Ward, 2015). Recent monitoring efforts from Higgins (2010) show it is typical that salmonid abundance does not reach capacity in upper Eel River streams between Scott and Cape Horn Dam in the PVP as well as downstream of the PVP, therefore potentially allowing habitat to be utilized by emigrants produced in the streams above Scott Dam. Although salmonid density may not reach capacity upon recolonization in streams above Scott Dam, restoring access to the habitat is likely to increase current salmonid production in the upper Eel River, thereby aiding in recovery goals for fisheries management.

Uncertainty and Improvements

A model has been described as a set of rules that relates quantities in the model to observations made, yet there are inherent restrictions within a model's representation of a given universal phenomenon (Hawking, 1988). It is important to understand that like all models, the approach and findings in this research have some levels of uncertainty that affect the overall outcomes. The conversion of parr estimates to spawners was highly sensitive to life stage-specific survival rates, which were derived from various literature sources (Johnson et al., 1993; Quinn, 2005; Rawding et al., 2010; Cramer et al., 2003, 2012; Moore, 2014; Anderson and Ward, 2016). Survival rates are dependent upon highly variable factors found in marine and stream conditions as well as the density of previous generations as found in stock-recruitment curves, yet stock-recruitment curves are highly variable and can be unreliable for making predictions (Zhou, 2007). Steelhead trout express over 30 anadromous life history strategies (Moore et al., 2014). Estimates generated from this research used a subset of freshwater rearing life histories including some typical for steelhead trout juveniles throughout the conversions from estimated steelhead trout parr to adults. A more robust representation of the freshwater rearing strategies including juvenile movement through space and time may result in different estimates for subsequent adult numbers. Further, emigration conditions for downstream movement of juvenile salmonids affects growth rate up to smoltification, and smolt body size upon entering the ocean has been observed to have a positive relationship with number of returning adults (Koenings et al., 1993; Ward and Slaney, 1988; Ward et al., 1989). Consequently, assuming a uniform size and therefore uniform survival rate across all parr or smolts modeled from the UCM may result in an underestimation of potential number of returning adults. Smolt to adult survival should be reflective of smolt size and age, which can be measured by identifying the difference in size of emigrants in upper reaches of a watershed versus emigrant size upon ocean entry. This information could provide insight to potential improvements needed for downstream migration stream conditions such as those stream conditions within and downstream of the PVP in the mainstem Eel River. Because the magnitude of change in smolt to adult survival rate is considerably related to salmonid production, identifying potential improvements to smolt to adult survival may play an important role in increasing salmonid production in the upper mainstem Eel River (Petrosky et al., 2001). Additionally, Chinook Salmon parr estimates are subject to uncertainty in the assumption that May rearing conditions are at 50% exceedance flows. Unimpaired springtime runoff is typically high, as it is influenced by rainfall and snowmelt. However, a model that includes a more detailed reflection of temporal flow variation in response to precipitation conditions may affect the resulting Chinook Salmon parr estimates (Asarian, 2016).

Due to limited time, survey access, and funding, the habitat dataset used to model fish estimates was limited. Extrapolation of stream width measurements onto unsurveyed streams in the study area resulted in variable watershed-scale stream area, and all capacity estimations were sensitive to changes in usable area conditions.

Further, density values among reaches within the same Reach Type were variable, and this resulted in wide ranges of watershed-scale estimates for both parr and redd capacity.

Monte Carlo simulations with distributions around each parameter value would reveal model sensitivity for better quantification of model uncertainty. Quantification of field tool and observation error may be analyzed with injecting noise into all measured habitat variables as model inputs and running many iterations of those noise-injected variables with a Monte Carlo simulation. The UCM capacity outputs were highly dependent upon the standardized, static density values built into the model. Experimenting with a distribution of density values specific to habitat unit types in a Monte Carlo simulation would reveal the sensitivity of this parameter. Additionally, the habitat scalar curves associated as average habitat conditions for each model parameter assume that fish respond the same to habitat conditions throughout all streams. Injecting noise into the equations of these curves, or essentially changing the “average” habitat conditions and how they relate to fish density, may quantify even more model uncertainty.

A larger number of surveys among stratified Reach Types over several survey seasons would likely improve multivariate analyses and representation of study area for extrapolation purposes. These would be further improved with a higher resolution DEM (1m resolution) from which to generate and characterize stream conditions including stream length as well as width. Further, high resolution DEMs may offer a more accurate, three-dimensional approach. The core capacity measure in the UCM multiplies density values by area; possible improvements to salmonid habitat models may instead utilize volume of a habitat unit for measuring capacity. This may be done by making small-scale adjustments to capacity with other habitat conditions, similar to the UCM approach, but also by simulating varying discharge conditions, as done by Ayllon et al (2012). Additionally, capacity modeling would be improved by including inter- and intra-specific competition relationships as well as a bioenergetics component that is reflective of food availability in the study site. However, because body size is considered the strongest determinant for potential abundance more so than other factors such as competition and food availability, estimating capacity in response to available habitat area, as in the UCM, is a justifiable approach (Grant and Kramer, 1990; Keeley and Grant, 1995; Keeley and McPhail, 1998).

Finally, efforts to validate the UCM model in the upper Eel River should be carried out. This should be done by conducting habitat assessments along with fish monitoring so that UCM predicted densities can be compared to observed densities. Observed densities and their relationship to model habitat parameters can be utilized for manipulating habitat scalar curves to be more representative of observed relationships in the Eel River.

CONCLUSIONS

Through a review of past and current methods for estimating potential salmonid habitat and production in the upper mainstem Eel River watershed along with ground-based surveys, potential distribution of Chinook Salmon and steelhead trout in the waterways upstream of Scott Dam was identified, and potential production under three scenarios was estimated. The habitat in the upper mainstem Eel River watershed provides cold water refugia in tributaries over summertime for steelhead trout as well as ample amounts of spawning grounds suitable for both Chinook Salmon and steelhead trout. The UCM provided a useful interpretation of habitat conditions and how they relate to potential salmonid capacity in the streams above Scott Dam. This research's modeling approach allowed for both the quantity and quality of potential habitat to be identified and mapped. However, there is room for improvement not only for understanding production response upstream of Scott Dam, but also production response downstream of the dam in the event of dam removal or adaptive flow management.

Restoring access to the habitat upstream of Scott Dam would increase exposure to unique environmental conditions which support localized adaptations and life history plasticity within upper Eel River populations that are important to the long-term persistence of pacific salmonids (Spence et al., 2008). Considering the level of population decline and habitat degradation in the Eel River, reintroduction to the habitat above Scott Dam would likely increase salmonid production, especially for Chinook Salmon, aiding in the recovery of upper mainstem Eel river populations.

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APPENDIX A

Appendix A: Reach Stratification for a GRTS survey design

1. Designate range categories in Microsoft Excel. For this, the only attribute collumns needed include: object ID, mean gradient, area (km^2), gradient category, area category, and reach type ID
    a. Gradient:
        i. 0-2%
        ii. 2-7%
        iii. 7-12%
        iv. >12%

        =IF(B2<0.02,1,IF(B2<0.07,2,IF(B2<0.12,3, IF(B2<20,4))))

    b. Drainage Area (km^2):
        i. 0-2
        ii. 2-10
        iii. 10-100
        iv. >100

        =IF(C2<10,1, IF(C2<100,2, IF(C2<250, 3, IF(C2<100000,4))))

    c. Combine gradient and area categories into one column of values:
        =CONCATENATE(D2,".", E2)

    d. IP score Category
        i. 0-0.33 low
        ii. 0.33-0.66 medium
        iii. 0.66-1 high

        =IF(E2<0.33,1,IF(E2<0.66,2,IF(E2<1,3)))

    e. Convert concatenated values into numbers, make new file with ObjectID, Reach Type ID, and IP Cat columns for joining to attribute table in ArcMap

2. Join excel file to attribute table of shapefile in ArcMap

   a. Open ArcMap, right click IP streams layer, click joins and relates
   b. Join attributes from a table, choose field as "OBJECTID"
   c. Browse for appropriate excel file (StrataJoinTable.xls)
   d. Double check attribute table to make sure it worked

3. Add XY coordinates to attribute table
   a. Open attribute table
   b. Top left icon drop down
   c. Add field > Name: Start_X,
   d. Type: Double > click OK
   e. Rt click new column in att. Table > Calculate Geometry > yes
   f. Property: Y (or X) coordinate of line start
   g. Use coordinate system of data source
   h. Repeat starting from c. for Start_Y coordinate

4. Export into new shapefile
   a. "U:\ejc485\Master's Thesis\GRTS\GRTS_Streams_1"
   b. "U:/ejc485/Master's Thesis/GRTS/GRTS_Streams_1"

5. Translate spatial data into R
   a. Open .R code in RStudio
   b. Use proper file path and file name for code
      i. To copy file path: shift + rt click folder with shapefiles in it and click "copy as path" –Then you can paste wherever you want
   c. Change backslashes to forward slashes for R code (see 4.b.)
   d. Run the code after installing all packages

6. Run GRTS
   a. Generate lengths table, which will give you output of lengths of each Reach Type
      i. Copy the output, save to .txt or .csv file, convert to .xlsx file
      ii. Identify proportion of Reach Type occurrence in stream data frame

APPENDIX B

Appendix B: R code for GRTS stratified, equal probability with an oversample survey design

```
install.packages("rgdal")
install.packages("rgeos")
install.packages("geosphere")
install.packages("raster")
install.packages("spdep")
install.packages("spsurvey")

library(sp)
library(rgdal)
library(spsurvey)

# The first argument is the name of the directory where the data is
# stored. If your data is already in the R working directory, just use
# '.'. The second argument is the name of the shapefile without the
# extension (.shp)
pts <- readOGR("U:/ejc485/Master's Thesis/GRTS/GRTS_Streams_1_1",
"GRTS_Streams_1_1", verbose = FALSE)
lin <- readOGR("U:/ejc485/Master's Thesis/GRTS/GRTS_Streams_1_1",
"GRTS_Streams_1_1", verbose = FALSE)

#Plotting spatial data
maxXY<- pmax(bbox(pts)[,2], bbox(lin)[,2], bbox(pol)[,2])
minXY<- pmin(bbox(pts)[,1], bbox(lin)[,1], bbox(pol)[,1])
plot(pol, xlim = c(minXY[1], maxXY[1]), ylim = c(minXY[2], maxXY[2]))
plot(lin, add = TRUE)
plot(pts, add = TRUE)


###########################################

##View data frame
View(lin)
View(pts)
```

```
sp2shape(sp.obj=lin, shpfilename="GRTS_Streams_1")

att=read.dbf("GRTS_Streams_1")   #read attribute table from shapefile
head(att)  #display initial six lines in attribute data frame

#display number of stream segments cross-classified by the strata (combos) and
#multidensity (IP) categories
TypeVsIPTable=addmargins(table("Reach Type"=att$REACH_TYPE_ID, "IP
score"=att$IP_CAT))
TypeVsIPTable

#display sum of lengths among each Reach Type
ReachTypeLengths=tapply(att$LENGTH, list(att$REACH_TYPE_ID), sum)
ReachTypeLengths


#summarize frame stream length by stratum and multidensity category
lengths<-tapply(att$LENGTH, list(att$REACH_TYPE_ID, att$IP_CAT), sum)
lengths

lengths=lengths[,c("1","2","3")]
lengths

lengths=na.omit(lengths)
lengths

lengths=addmargins(lengths)
lengths

lengths<-round(lengths,2)
lengths

names(dimnames(lengths))<-list("Reach Type", "IP score")
lengths
```

```
###############################
#Stratified, equal probability GRTS survey design with an oversample

#create the design list
stratdsgn<-list(
                    "1.1"=list(panel=c(PanelOne=0), seltype="Equal", over=0),
                    "1.2"=list(panel=c(PanelOne=2), seltype="Equal", over=10),
                    "1.3"=list(panel=c(PanelOne=3), seltype="Equal", over=15),
                    "1.4"=list(panel=c(PanelOne=3), seltype="Equal", over=15),
                    "2.1"=list(panel=c(PanelOne=5), seltype="Equal", over=25),
                    "2.2"=list(panel=c(PanelOne=7), seltype="Equal", over=35),
                    "2.3"=list(panel=c(PanelOne=3), seltype="Equal", over=15),
                    "2.4"=list(panel=c(PanelOne=0), seltype="Equal", over=0),
                    "3.1"=list(panel=c(PanelOne=5), seltype="Equal", over=25),
                    "3.2"=list(panel=c(PanelOne=5), seltype="Equal", over=25),
                    "3.3"=list(panel=c(PanelOne=1), seltype="Equal", over=5),
                    "3.4"=list(panel=c(PanelOne=0), seltype="Equal", over=0),
                    "4.1"=list(panel=c(PanelOne=4), seltype="Equal", over=20),
                    "4.2"=list(panel=c(PanelOne=2), seltype="Equal", over=10),
                    "4.3"=list(panel=c(PanelOne=0), seltype="Equal", over=0),
                    "4.4"=list(panel=c(PanelOne=0), seltype="Equal", over=0))

att=na.omit(att)

#select the sample
SurveySites<-grts(design = stratdsgn,
          DesignID = "STRATIFIED",
          type.frame = "linear",
          src.frame = "shapefile",
          in.shape = "GRTS_Streams_1",
          att.frame = att,
          stratum = "REACH_TYPE_ID",
          shapefile = FALSE)

head(SurveySites@data)
summary(SurveySites)
plot(SurveySites)

# write out a new shapefile (including .prj component)
writeOGR(lin, ".", "GRTS_Streams_4Survey", driver="ESRI Shapefile")
```

APPENDIX C

Appendix C: R code for multivariate analysis of habitat data

```
#################### LDA #####################
attach(LDA_HabData)
detach(LDA_HabData)

install.packages("MASS")
library(MASS)
install.packages("ggplot2")
library(ggplot2)
install.packages("scales")
library(scales)
install.packages("gridExtra")
library(gridExtra)

ldamodel= lda(G~ $`Unit Length`, NewData$`Unit Width`, NewData$`Unit Area`,
NewData$`Unit Mean Depth`, NewData$`Cover (%Shelter)`, NewData$`%Pools`,
data=LDA_HabData)
ldamodel
par(mfrow=c(1,1))
plot(ldamodel)


################ plotting the model #################
#select the colors that will be used
library(RColorBrewer)
#all palette available from RColorBrewer
display.brewer.all()
#we will select the first 8 colors in the Set1 palette
cols<-brewer.pal(n=8,name="Set1")
#cols contain the names of 8 different colors
#create a color vector corresponding to levels in the T1 variable in dat
cols_t1<-cols[LDA_HabData$G]
#plot
plot(ldamodel, data=LDA_HabData,col=cols_t1, pch=16)

######### a measure of model accuracy ##############
prop.lda = ldamodel$svd^2/sum(ldamodel$svd^2)
prop.lda
```

```
ldapred= predict(ldamodel, LDA_HabData)
ldapred

ldaclass= ldapred$class
ldaclass

##Determine how well model1 fits
ldatable= table(ldaclass, LDA_HabData$G)
ldatable

accuracy= sum(diag(ldatable))/sum(ldatable)*100
accuracy


#################### MANOVA ########################
hab.manova1= manova(cbind(NewData$`Unit Length`, NewData$`Unit Width`,
NewData$`Unit Area`, NewData$`Unit Mean Depth`, NewData$`Cover (%Shelter)`,
NewData$`%Pools`)~ NewData$`Reach Type ID`, data = NewData)
summary(hab.manova1)

summary.aov(hab.manova1)

plot(hab.manova1)
```

APPENDIX D

Appendix D: Formulas, definitions, and values of parameters of the UCM model (Cramer and Ackerman, 2009).

UNIT SCALE PARAMETERS

den (fish/m2)

Unit Name	Unit ID	Steelhead Parr Density	SD	Chinook Parr Density	SD
Backwaters	6	0.05	0.02	0.13	0.05
Cascades	2	0.03	0.02	0.024	0.01
Flatwater	3	0.08	0.04	0.07	0.02
Pools	4, 5	0.17	0.20	0.24	0.10
Riffles	1	0.03	0.02	0.024	0.01

chnl

Glides	If W > 24: (W - 24)*.35/W + 24/W
Pools	if W > 24: (W - 24)*.75/W + 24/W
	if L > 4*W: L = 4*W
Riffles	if W > 24: (W-24)*.15/W + 24/W
	where W = wetted width of unit in meters

dep

Pools & Glides	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 >0.8: 0.22/0.17
Riffles	If D is < 0.1: 0.0 * D
	If D is 0.10 - 0.16: (0.5*D - 0.5)/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*D + 0.485)/0.03
If D is >1.50: 0

where D = depth in meters

cvr

Pools & 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

Riffles
If Bpr < 0.25: 1.0
If Bpr is 0.25 - 0.75: 1 + 12*(Bpr = 0.25)
If Bpr is > 0.75: 7.0

where Bpr = proportion of substrate in riffles comprised of boulders

REACH SCALE PARAMETERS: multiply by unit-scale capacity adjustment
prod = (turb*drift*fines*alk)

turb

if Dr is < 0.3m: 10^(2-(1+0.024*N)*0.1)/10^2-0.1
If Dr is 0.3-0.5m: 10^(2-(1+0.024*N)*0.3))/10^2-0.3
If Dr is > 0.5m: 10^(2-(1+0.024*N)*0.5))/10^2-0.5

where Dr = mean depth of riffles within the reach
whre N = NTU

drift

If Rp > 0.5: 1.0
If Rp is ≤ 0.5: 0.1+1.8*Rp
where Rp = proportion of reach surface area that is riffle or cascade

fines

If Fp is <0.1: 1.0

REACH SCALE PARAMETERS: multiply by unit-scale capacity adjustment

If Fp is ≥0.1: 1.11 - 1.1*Fp

where Fp = proportion of substrate in riffles that is comprised of fines

alk

(mgCaCO3/l)^0.45/4.48

winter

If Cp < 0.15: 0.20 + (Cp)/0.15*0.8

If Cp > 0.15: 1.0

where Cp = Proportion of substrate in the stream comprised of cobbles

temp

Tsi = 1/(1+e^-a-bTi)

where

Tsi = Temp scalar for capacity for reach i in a given week

a = intercept of logit(Tsi) = 19.63

b = slope of logit(Tsi) = -0.98

T = weekly average temperature (WAT) for reach i in a given week

APPENDIX E

Appendix E: R code for UCM parr capacity baseline model

```
########################################################################
########################################################################
#############################Unit Scale Capacity#########################
#################Area * Density * Channel * Depth * Cover####################
########################################################################
########################################################################


################################################################
######################Standardized Density######################
################################################################

Den = function(Area_use, Unit.Name)
  {
   print(Area_use)
    if(Unit.Name =="Riffle") value= (Area_use*0.03)
    else if(Unit.Name == "Cascade") value= (Area_use*0.03)
    else if(Unit.Name == "Pool") value= (Area_use*0.17)
    else if(Unit.Name == "Flatwater") value= (Area_use*0.08)
    else value=0

    return(value)
  }

TestDen = Den(100, "Pool")
print(TestDen)


################################################################
#######################Usable Channel Parameter#################
################################################################

ChnlFlat= function(Width, Unit.Name)
{
  if(Unit.Name == "Flatwater")
  {
    if(Width >24) value=((Width - 24)*0.35/Width + 24/Width)
```

```
  }
 return(value)
}

Test01= ChnlFlat(28, "Flatwater")
print(Test01)


ChnlPool= function(Width, Unit.Name)
{
 if(Unit.Name == "Pool")
  {
   if(Width > 24) value=((Width - 24)*0.75/Width + 24/Width)

   else if(Length > 4*Width) value= 4*Width
  }
 return(value)
}

Test02= ChnlPool(28, "Pool")
print(Test02)


ChnlRif= function(Width, Unit.Name)
{
 if(Unit.Name == "Riffle")
  {
   if(Width > 24) value = ((Width-24)*0.15/Width + 24/Width)
  }
 return(value)
}

Test03= ChnlRif(28, "Riffle")
print(Test03)



####################################################################
#########################Depth Parameter#########################
###################################################################

######################Depth Pools########################
```

```
DepPool = function(MaxDep_m, Unit.Name)
{
  if(Unit.Name == "Pool")
  {
    if(MaxDep_m <0.1) value=0*MaxDep_m

    else if(MaxDep_m <0.8) value= (0.3*MaxDep_m - 0.027)/.17

    else value= (0.22/.17)
  }
  else
  {
    print(paste("DepPoolunknown unit name", Unit.Name))
  }
  return(value)
}

Test04= DepPool(.9, "Pool")

print(Test04)


#######################Depth Flatwater#######################

DepFlat = function(Dep_m, Unit.Name)
{
  if(Unit.Name == "Flatwater")
  {
    if(Dep_m <0.1) value=0*Dep_m

    else if(Dep_m <0.8) value= (0.3*Dep_m - 0.027)/.17

    else value= (0.22/.17)  #when >=0.8
  }
  return(value)
}

Test05= DepFlat(0.32, "Flatwater")
print(Test05)


######################Depth Riffles##########################
DepRif = function(Dep_m, Unit.Name)
```

```
{
 if((Unit.Name == "Riffle")|(Unit.Name == "Cascade"))
 {
  if(Dep_m < 0.1) value=0*Dep_m

  else if(Dep_m <0.16) value= ((0.5*Dep_m - 0.05)/0.03)

  else if(Dep_m <0.3) value= ((0.29*Dep_m - 0.017)/0.03)

  else if(Dep_m <0.8) value= ((0.25*Dep_m - 0.003)/0.03)

  else if(Dep_m <0.9) value= (0.2/0.03)

  else if(Dep_m <1.5) value= ((-0.32*Dep_m +0.485)/0.03)

  else value= 0   ##when >=1.5
 }
 return(value)
}

Test06= DepRif(0.23, "Riffle")
print(Test06)


################################################################
#########################Cover Parameter########################
################################################################


#############################Shelter Rating for Pools &
Glides#############################

CvrPoolFlat = function(ShelterVal, Unit.Name)
{
 if((Unit.Name == "Pool")|(Unit.Name == "Flatwater")|(Unit.Name == "Dry"))
 {
  if(ShelterVal== 0) value=0

  else if(ShelterVal < 2) value= 0.58

  else if(ShelterVal < 3) value= 1.00

  else if(ShelterVal < 4) value= 1.42
```

```
    else value= 1.84 #when >=4

  }
  return(value)
}

Test07= CvrPoolFlat(0, "Dry")

print(Test07)


######################Proportion Boulders in Riffles########################

CvrRiffle = function(X.boulders, Unit.Name)
{
  if((Unit.Name =="Riffle")|(Unit.Name == "Cascade"))
    {
      if(X.boulders < 0.25) value=1.0

      else if(X.boulders<0.75) value=(1+12*(X.boulders- 0.25))

      else value= 7.0      ###when >=0.75
    }
    return(value)
}

Test08= CvrRiffle(.5, "Cascade")
print(Test08)


########################################################################
############################## While loop ################################
########### For running above functions with each habitat unit in dataset ###########
########################################################################

numrows=nrow(S235_Analysis_1)
#numrows=1
print(numrows)
  i=0
SumDensity=0
while(i<numrows)
{
```

```
  print("#####")
  row=S235_Analysis_1[i+1, ]                ############ row is actually collumn "i"
starting at 1

  ###Density * Area_use for each habitat unit
  Area_use=row[7]
  Unit.Name=row[2]
  Density=Den(Area_use, Unit.Name)             ############## setting Density = Den
function from above
  print(Unit.Name)
  print(paste("Density=",Density))


  ## Depth Scalar for each habitat unit
  if (Unit.Name=="Riffle")
  {
    Dep_m=row[8]
    Unit.Name=row[2]
    MeanDepthDensity=DepRif(Dep_m, Unit.Name)    ############ setting
MeanDepthDensity equal to DepRif function from above
    print(Unit.Name)
    print(paste("DepthScalar=",MeanDepthDensity))

    Density=Density*MeanDepthDensity
  }
  else  if (Unit.Name=="Pool")
  {
    print("Calling DepPool")
    MaxDep_m=row[9]
    Unit.Name=row[2]
    print(Unit.Name)
    MaxDep_mDensity=DepPool(MaxDep_m, Unit.Name)          ########### setting
MaxDep_mDensity equal to DepPool function from above
    print(paste("DepthScalar=",MaxDep_mDensity))

    Density=Density*MaxDep_mDensity

  }
  else if (Unit.Name=="Flatwater")
  {
    print("Calling DepFlat")
    Dep_m=row[8]
    Unit.Name=row[2]
```

```
    print(Unit.Name)
    MeanDepthFlatDensity= DepFlat(Dep_m, Unit.Name)
    print(paste("DepthScalar=",MeanDepthFlatDensity))

    Density=Density*MeanDepthFlatDensity
  }

  if((Unit.Name == "Pool")|(Unit.Name == "Flatwater")|(Unit.Name == "Dry"))
  {
    print("Calling ShelterVal")
    ShelterVal=row[16]
    Unit.Name=row[2]
    print(Unit.Name)
    ShelterScalar=CvrPoolFlat(ShelterVal, Unit.Name)
    print(paste("ShelterScalar=",ShelterScalar))


    Density=Density*ShelterScalar

  }
  else
  {
    print("Calling CvrRiffle")
    X.boulders=row[24]
    Unit.Name=row[2]
    print(Unit.Name)
    na.omit(X.boulders)
    CvrRiffleScalar=CvrRiffle(X.boulders, Unit.Name)
    print(paste("BoulderScalar=",CvrRiffleScalar))

    Density=Density*CvrRiffleScalar

  }
print(Density)
SumDensity= Density+SumDensity

  i=i+1
}
print(SumDensity)
TotalArea_use= sum(S235_Analysis_1$Area_use)
print(TotalArea_use)
SumDensity/TotalArea_use
```

APPENDIX F

Appendix F: R code for GAM analysis of predicted densities in response to IP scores

```
attach(DensityStreams_4IPAnalysis)
install.packages("mgcv")
library(mgcv)

#### Plot the data
plot(Chinook SalmonData$CH_DEN~log(Chinook SalmonData$CHK_IP_CUR),
xlab="Chinook Salmon IP Score", ylab="Chinook Salmon Parr Stratified Mean Density")
plot(ST_DEN~ST_IP_CURV, data = DensityStreams_4IPAnalysis, xlab="Steelhead
trout IP Score", ylab="Steelhead trout Parr Stratified Mean Density")

#### Chinook Salmon parr density - IP relationship GAM
GAM.Chinook Salmon= gam(CH_DEN~s(CHK_IP_CUR), data = Chinook SalmonData,
gamma = 100)
plot(GAM.Chinook Salmon, xlab="Chinook Salmon IP Score", ylab="Chinook Salmon
Parr Stratified Mean Density")
summary(GAM.Chinook Salmon)
AIC(GAM.Chinook Salmon)

#### Steelhead trout parr density – IP relationship GAM
GAM.Steelhead trout=gam(ST_DEN~s(ST_IP_CURV), data =
DensityStreams_4IPAnalysis, gamma = 40)
plot(GAM.Steelhead trout, xlab="Steelhead trout IP Score", ylab="Steelhead trout Parr
Stratified Mean Density")
summary(GAM.Steelhead trout)
AIC(GAM.Steelhead trout)
```

APPENDIX G

Appendix G: Habitat Survey Data

Reach Type ID	Reach Type	Site Name	Stream Name	Unit #	Unit Type	Unit Name	Unit Length	Unit Width	Unit Area	Unit Mean Depth	Unit Max Depth	Cover (%Shelter)	Cover (%Boulders/BR)	Canopy Cover	Pool Temp	Air Temp	% Fines	Survey Reach Area	Ph	Turbidity	CFS	Survey Time
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	1	5	Pool	17	1.5	25.5	0.18	0.27	80	0	95	22	35	0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	2	1	Riffle	1	0.5	0.5	0.12	0.13	10		10			0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	3	4	Pool	8.7	2.47	21.489	0.14	0.25	60	0	95			0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	4	4	Pool	13	2.73	35.49	0.28	0.44	30		50			0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	5	1	Riffle	22	2.8	61.6	0.10	0.15	10					0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	6	5	Pool	10.5	2	21	0.25	0.46	70		70			0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	7	3	Flatwater	21.5	2.2	47.3	0.18	0.30	30	0				0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	8	4	Pool	11.5	2.7	31.05	0.31	0.48	20	0	20			0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	9	1	Riffle	11	0.8	8.8	0.06	0.08	5					0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	9.1	1	Riffle	15	0.8	12	0.06	0.08	30			23	35	0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	10	6	Pool	7	5.85	40.95	0.28	0.43	75	0	80			0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	11	3	Flatwater	26	3.17	82.42	0.15	0.24	15	0	20			0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	12	4	Pool	9.8	2.9	28.42	0.19	0.30	45	0	10	20.5		0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	13	3	Flatwater	5.5	1.85	10.175	0.13	0.18	10					0.33	438	6.5	0.7	0.15	2.75
1.2	0-2%, 2-10km2	S029	Packsaddle Cr	14	5	Pool	7	1.65	11.55	0.26	0.41	70	0	30	20	30	0.33	438	6.5	0.7	0.15	2.75
1.3	0-2%, 10-100km2	S021	Bear Cr	1	1	Riffle	27.9	3.97	110.763	0.23	0.32	10	0	40		16	0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	1.1	6	Pool	12.2	2.36	28.792	0.23	0.42	35	5	80			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	1.2	1	Riffle	14.4	2.53	36.432	0.09	0.12	20					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	2	3	Flatwater	21.8	5.64	122.952	0.32	0.78	5	0	50			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	3	1	Riffle	40	3.63	145.2	0.23	0.29	15					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	4	4	Pool	14	4.24	59.36	0.49	0.76	65	0	75			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	5	3	Flatwater	19	3.1	58.9	0.31	0.39	10					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	6	1	Riffle	9.75	4.04	39.39	0.20	0.29	20					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	7	5	Pool	20	4.6	92	0.30	0.55	55	0	40			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	8	1	Riffle	10.6	3.8	40.28	0.30	0.47	15					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	9	5	Pool	15.2	5.39	81.928	0.34	0.48	35	0			20	0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	10	1	Riffle	20.8	5	104	0.21	0.26	15	5				0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	11	5	Pool	14.5	4.6	66.7	0.34	0.44	45					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	12	1	Riffle	8.2	4.1	33.62	0.17	0.26	20					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	13	4	Pool	8.53	5.5	46.915	0.66	1.04	35	0	80			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	14	3	Flatwater	25	4.12	103	0.43	0.83	25	0	90			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	15	5	Pool	6.4	2.2	14.08	0.52	0.79	30					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	16	1	Riffle	15.6	4.1	63.96	0.15	0.19	10					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	17	4	Pool	25.3	5.4	136.62	0.40	0.61	10					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	18	1	Riffle	19.5	4	78	0.23	0.34	10					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	19	5	Pool	13.5	4.3	58.05	0.62	1.13	20	5	90		21	0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	20	3	Flatwater	66	3.9	257.4	0.27	0.42	35	0	75			0.22	4253	6.5	0.25	9.94	9.5

1.3	0-2%, 10-100km2	S021	Bear Cr	21	1	Riffle	35.5	5.8	205.9	0.16	0.24	15	2	60			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	22	3	Flatwater	37	5.3	196.1	0.16	0.21	50					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	23	4	Pool	9.3	3.13	29.109	0.35	0.44	30	0	70			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	24	1	Riffle	11	4.1	45.1	0.50	0.57	30					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	25	5	Pool	8.1	3.8	30.78	0.64	0.85	40					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	26	1	Riffle	29	4.1	118.9	0.26	0.29	40					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	27	5	Pool	12	4	48	0.45	0.75	50					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	28	3	Flatwater	20	3.08	61.6	0.42	0.61	70				22	0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	29	1	Riffle	38.5	3.57	137.445	0.28	0.32	61	5	90			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	30	3	Flatwater	94	6.18	580.92	0.16	0.25	25	0	80			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	31	1	Riffle	18	5.6	100.8	0.16	0.20	50					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	32	3	Flatwater	35.8	6.28	224.824	0.14	0.22	30					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	33	5	Pool	18	4.71	84.78	0.49	0.76	50	0	90			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	34	1	Riffle	11.7	4.71	55.107	0.01	0.21	30	0				0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	35	3	Flatwater	42	4.05	170.1	0.26	0.40	30					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	36	5	Pool	16.5	3.7	61.05	0.36	0.53	50		85			0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	37	3	Flatwater	50	4.6	230	0.27	0.33	30					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S021	Bear Cr	38	1	Riffle	20	4.69	93.8	0.14	0.17	10					0.22	4253	6.5	0.25	9.94	9.5
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	1	1	Riffle	46.2	4.3	198.66	0.15	0.24	25	20	5		18.5	0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	2	3	Flatwater	11.5	3.2	36.8	0.28	0.40	15	15	0			0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	3	1	Riffle	21.6	4.3	92.88	0.15	0.24	30					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	4	5	Pool	11.1	3.1	34.41	0.31	0.54	45	10	10	19.5		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	5	1	Riffle	6	4.3	25.8	0.15	0.24	30					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	6	5	Pool	9.1	2	18.2	0.22	0.34	50	5	25	19.5		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	7	1	Riffle	4	4.3	17.2	0.15	0.24	30					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	8	5	Pool	26	6.5	169	0.65	1.40	55	35	2	19		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	9	7	Dry	49.5		0	0.00	0.00	0					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	10	1	Riffle	19.4	4.3	83.42	0.15	0.24	30					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	11	3	Flatwater	20.6	2.7	55.62	0.19	0.29	65	0	30		31.5	0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	12	1	Riffle	15.5	4.8	74.4	0.14	0.25	10	8	5			0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	13	4	Pool	28.5	5.1	145.35	0.49	0.64	40	0	10	20		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	14	1	Riffle	69	4.8	331.2	0.14	0.25	10					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	15	5	Pool	23.5	5.6	131.6	0.25	0.52	65	5	5	20		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	16	1	Riffle	20.1	4.8	96.48	0.14	0.25	10					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	17	7	Dry	4.6		0	0.00	0.00	0					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	18	5	Pool	30.3	4.8	145.44	0.36	0.55	50	5	5	20.5		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	19	1	Riffle	3.5	4.8	16.8	0.14	0.25	10					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	20	5	Pool	8.6	3.7	31.82	0.41	0.62	95	35	40	20		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	21	5	Pool	12.6	3	37.8	0.35	0.61	50	45	0	21	31.5	0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	22	7	Dry	5.2		0	0.00	0.00	0					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	23	3	Flatwater	4.5	1	4.5	0.19	0.29	5	0				0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	24	1	Riffle	12.3	1.5	18.45	0.08	0.13	75	0	40			0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	25	5	Pool	17.8	2.6	46.28	0.26	0.47	55	20	10	20		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	26	3	Flatwater	14.5	1	14.5	0.19	0.29	10					0.38	2770	7.4	0.2	0.06	4.6

1.3	0-2%, 10-100km2	S016	Smokehouse Cr	27	7	Dry	55.1		0	0.00	0.00	0					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	28	4	Pool	19.5	4.9	95.55	0.50	0.85	15	10	5	21.5		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	29	1	Riffle	9.5	1.5	14.25	0.08	0.13	70					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	30	7	Dry	107.2		171.52	0.00	0.00	0	0				0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	30.1	5	Pool	9.7	1.6	11.64	0.17	0.24	55	5	80	21.5	33	0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	31	1	Riffle	15	1.2	78	0.07	0.10	25	0	75			0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	32	3	Flatwater	18.3	5.2	82.35	0.15	0.31	20	5	35	0.3		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	33	4	Pool	17.4	4.5	31.32	0.27	0.47	15	5	7	24		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	34	1	Riffle	10.6	1.8	59.36	0.11	0.15	10		0			0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	35	4	Pool	43	5.6	51.6	0.30	0.46	45	15	30	23		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	36	1	Riffle	39.2	1.2	168.56	0.07	0.10	10					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	37	4	Pool	20.3	4.3	36.54	0.38	0.73	15	5	60	21		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	38	1	Riffle	25.8	1.8	85.14	0.07	0.10	10					0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S016	Smokehouse Cr	39	5	Pool	17.5	3.3	57.75	0.20	0.30	45	20	15	20		0.38	2770	7.4	0.2	0.06	4.6
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	1	3	Flatwater	12.7	2.2	27.94	0.15	0.30	35	15	25		14.1	0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	2	1	Riffle	6.7	2.2	14.74	0.08	0.21	35	25	15			0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	3	5	Pool	10	2.5	25	0.30	0.82	55	20	5	16		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	4	1	Riffle	20.7	2.2	45.54	0.08	0.21	30					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	5	4	Pool	27	3.8	102.6	0.34	0.61	67	25	50	15		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	6	3	Flatwater	25.5	2.2	56.1	0.15	0.30	30					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	7	1	Riffle	13.5	2.2	29.7	0.08	0.21	30					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	8	5	Pool	14.7	3	44.1	0.41	0.91	87	35	5	15		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	9	1	Riffle	15.5	2.2	34.1	0.08	0.21	30					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	10	5	Pool	11.4	2.8	31.92	0.17	0.34	45	20	10	16		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	11	1	Riffle	56	2.5	140	0.14	0.21	45	25	40		20	0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	12	5	Pool	10.2	3.5	35.7	0.24	0.46	35	25	90	16		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	13	3	Flatwater	15.5	3.8	58.9	0.08	0.21	15	5	10			0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	14	5	Pool	18	3	54	0.05	0.73	75	20	60	15		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	15	1	Riffle	27.5	2.5	68.75	0.14	0.21	50					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	16	3	Flatwater	55	3.8	209	0.08	0.21	10					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	17	4	Pool	13.5	2.1	28.35	0.34	0.49	75	23	30	18		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	18	1	Riffle	7	22.5	157.5	0.14	0.21	50					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	19	3	Flatwater	27	2.8	75.6	0.08	0.21	10					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	20	5	Pool	8.5	2.4	20.4	0.15	0.27	55	20	90	19		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	21	1	Riffle	35	2.5	87.5	0.09	0.12	35	20	40		23	0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	21.1	5	Pool	6	1.8	10.8	0.14	0.43	35	10	10	19		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	21.2	6	Pool	4	2	8	0.20	0.46	40	10	5	19.5		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	21.3	1	Riffle	12.3	0.5	6.15	0.10	0.13	30					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	22	3	Flatwater	8.9	1	8.9	0.12	0.15	5	5	5			0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	23	5	Pool	2	2	4	0.12	0.34	10	0	5	19		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	24	1	Riffle	5	2.5	12.5	0.09	0.12	30					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	25	3	Flatwater	14.2	1	14.2	0.12	0.15	10	0				0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	26	5	Pool	13.2	4.7	62.04	0.61	0.73	65	20	90	18.5		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	27	1	Riffle	6.2	2.5	15.5	0.09	0.12	30					0.33	2608	7.5	0.29	0.24	6.5

1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	28	4	Pool	9.5	2.5	23.75	0.29	0.40	45	5	50	20	28	0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	29	1	Riffle	5	1	5	0.05	0.06	0		0			0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	30	5	Pool	11	3.2	35.2	0.21	0.43	95	10	60	20		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	31	3	Flatwater	8	2	16	0.11	0.12	70	0	40			0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	32	5	Pool	14	2.8	39.2	0.20	0.34	95	5	30	18		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	32.1	3	Flatwater	11	2	22	0.11	0.12	70					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	33	5	Pool	15.9	3.8	60.42	0.27	0.40	45	10	40	20		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	34	1	Riffle	57.5	2	115	0.05	0.06	10					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	35	4	Pool	11.7	4.5	52.65	0.32	0.61	45	15	30	20		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	36	3	Flatwater	48	2	96	0.11	0.12	70					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	37	1	Riffle	20	1.8	36	0.08	0.12	20	15	5		30	0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	38	4	Pool	17.5	3.6	63	0.18	0.26	15	10	20	20		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	39	3	Flatwater	14	4.7	65.8	0.17	0.30	35	25	95			0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	40	1	Riffle	7.5	1.8	13.5	0.08	0.12	30					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	41	5	Pool	10	3.1	31	0.23	0.37	75	15	95	18		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	42	1	Riffle	15	1.8	27	0.08	0.12	30					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	43	7	Dry	6	6	36	0.00	0.00	0					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	44	4	Pool	31	5.3	164.3	0.27	0.85	80	5	40	20		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	45	1	Riffle	12	1.8	21.6	0.08	0.12	30					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	46	7	Dry	4	6	24	0.00	0.00	0					0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	47	1	Riffle	13.2	1.5	19.8	0.05	0.18	40	0	30		32	0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	48	4	Pool	24.8	3.35	83.08	0.24	0.49	65	0	35	20		0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	49	1	Riffle	12	1.2	14.4	0.08	0.15	5	0	50			0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	50	3	Flatwater	13.5	3.6	48.6	0.14	0.23	20	0	5			0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S018	Rice Fork at Salt Cr	51	1	Riffle	15	0.35	5.25	0.24	0.15	30		60			0.33	2608	7.5	0.29	0.24	6.5
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	1	1	Riffle	19.2	3.1	59.52	0.09	0.15	25	0	20		13.3	0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	2	5	Pool	30	2.5	75	0.26	0.37	85	0	80	15		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	3	1	Riffle	20	3.1	62	0.09	0.15	30					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	4	4	Pool	14.4	3.2	46.08	0.24	0.49	20	0	95	15		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	5	1	Riffle	6	3.1	18.6	0.09	0.15	30					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	6	5	Pool	9	2.8	25.2	0.20	0.61	20	0	90	15		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	7	5	Pool	14.5	2.1	30.45	0.26	0.58	40	0	85	15		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	8	1	Riffle	9.7	3.1	30.07	0.09	0.15	30					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	9	4	Pool	18	3.5	63	0.59	0.64	25	0	100	15		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	9.1	6	Pool	7	1.5	10.5	0.08	0.18	5	0	90	16		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	10	1	Riffle	7.5	2.9	21.75	0.29	0.52	22	0	80		21	0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	11	4	Pool	18	9	162	0.23	0.46	45	20	95	15.5		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	12	3	Flatwater	13.7	4.3	58.91	0.11	0.15	10	0	60			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	13	1	Riffle	22.8	2.9	66.12	0.29	0.52	20					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	14	4	Pool	46	4.3	197.8	0.30	0.82	85	35	90	16		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	15	1	Riffle	12	2.9	34.8	0.29	0.52	30					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	16	5	Pool	14.5	3.6	52.2	0.23	0.49	20	0	80	16		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	17	1	Riffle	5.6	2.9	16.24	0.29	0.52	30					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	18	4	Pool	16.6	4.2	69.72	0.38	0.98	55	35	50	16		0.22	3390	7.9	0.35	1.72	8.6

1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	19	1	Riffle	4.9	2.9	14.21	0.29	0.52	20					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	20	4	Pool	16.7	4.1	68.47	0.21	0.40	35	15	95	16	23	0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	21	1	Riffle	14	3.6	50.4	0.14	0.24	25	5	80			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	22	4	Pool	11.7	3	35.1	0.24	0.46	30	10	95	16		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	23	1	Riffle	7.3	3.6	26.28	0.14	0.24	30					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	24	5	Pool	6	2.2	13.2	0.26	0.43	20	5	15	16		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	25	1	Riffle	4.5	3.6	16.2	0.14	0.24	30					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	26	5	Pool	20.6	7	144.2	0.08	0.40	65	45	60	16		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	27	3	Flatwater	14	4.1	57.4	0.15	0.37	50	30	80			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	28	5	Pool	12	6	72	0.76	1.07	75	50	95			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	29	1	Riffle	4	3.6	14.4	0.14	0.24	30					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	30	5	Pool	7.1	3.1	22.01	0.34	0.52	85	60	95	17	28	0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	31	3	Flatwater	20.3	3.4	69.02	0.46	0.58	60	35	55			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	32	5	Pool	10.3	5.2	53.56	0.30	0.67	72	60	20	18		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	33	2	Cascade	11.7	3.2	37.44	0.21	0.30	75	40	75			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	34	3	Flatwater	8.4	3.4	28.56	0.46	0.58	50					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	35	1	Riffle	23.6	4.5	106.2	0.11	0.21	45	10	60			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	35.1	5	Pool	7	5	35	0.27	0.82	80	60	60	18		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	36	5	Pool	20	4	80	0.17	0.24	45	10	50	18.5		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	37	4	Pool	20	5.7	114	0.21	0.82	90	45	95	18.5		0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	38	1	Riffle	5	4.5	22.5	0.11	0.21	50					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	39	5	Pool	9	5.4	48.6	0.70	0.91	45	30	10		30	0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	40	5	Pool	10.5	5.3	55.65	0.21	0.55	65	50	16			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	41	5	Pool	17.5	3.8	66.5	0.35	0.91	50	20	35			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	42	1	Riffle	10.5	4	42	0.06	0.27	25	5	90			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	43	5	Pool	11.7	5.7	66.69	0.64	0.67	70	30	35			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	44	5	Pool	12.2	3	36.6	0.64	0.70	50	30	5			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	45	3	Flatwater	8.6	4.2	36.12	0.23	0.37	25	10	70			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	46	2	Cascade	15	4.4	66	0.27	0.64	80	60	5			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	47	4	Pool	15.9	3.8	60.42	0.26	0.55	60	20	90			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	48	3	Flatwater	33	4.2	138.6	0.23	0.37	30					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	49	1	Riffle	31	2.5	77.5	0.14	0.24	35	8	45		30	0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	49.1	6	Pool	4.5	1	4.5	0.27	0.52	50	0	45			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	50	4	Pool	40.5	4.8	194.4	0.29	0.70	40	15	10			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	51	1	Riffle	13.9	2.5	34.75	0.14	0.24	30					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	51.1	5	Pool	12.2	3.5	42.7	0.29	0.64	25	5	100			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	52	5	Pool	7.2	4	28.8	0.26	0.49	25	15	85			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	53	5	Pool	22	4	88	0.58	0.67	50	40	40			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	54	1	Riffle	5.5	2.5	13.75	0.14	0.24	30					0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	55	5	Pool	18	3.6	64.8	0.27	0.73	50	30	80			0.22	3390	7.9	0.35	1.72	8.6
1.3	0-2%, 10-100km2	S013	Rice Cr at mouth	56	3	Flatwater	14.5	3	43.5	0.15	0.21	10	5	90			0.22	3390	7.9	0.35	1.72	8.6
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	1	3	Flatwater	88.7	12.2	1082.14	0.40	0.44	15	3	10	16	22.8	0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	2	1	Riffle	43	12.8	550.4	0.28	0.38	26	10	10			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	3	3	Flatwater	103	11.4	1174.2	0.30	0.46	20	10	15			0.31	6271	6.5	0.57	11.33	5.5

1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	4	5	Pool	17	12.9	219.3	0.66	0.88	40	20	10			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	5	3	Flatwater	52	8.6	447.2	0.32	0.34	15	5	5			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	6	1	Riffle	21.5	13.8	296.7	0.47	0.67	55	15	60			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	7	3	Flatwater	29	9.3	269.7	0.22	0.37	25	0	10			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	8	5	Pool	35	10.2	357	0.46	0.67	60	5	20			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	9	4	Pool	37	10.2	377.4	0.62	0.98	35	5	15			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	10	3	Flatwater	23.5	5.4	126.9	0.34	0.43	40	5	70			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	11	1	Riffle	36.5	5.2	189.8	0.12	0.14	40	5	75	19	29.4	0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	11.1	6	Pool	6	2.5	15	0.08	0.08	65	0	75			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	12	3	Flatwater	86.2	9.4	810.28	0.23	0.26	45	5	35			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	13	1	Riffle	24	7	168	0.23	0.28	75	20	55			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	14	5	Pool	16	5.6	89.6	0.57	0.93	65	10	15			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S038	Mainstem at Horse Cr	15	3	Flatwater	19	5.1	96.9	0.34	0.42	30	15	70			0.31	6271	6.5	0.57	11.33	5.5
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	1	2	Cascade	26	7.1	184.6	0.40	0.59	55	45	5	16.5	12	0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	2	5	Pool	7.5	8.5	63.75	0.61	1.07	65	60	2	17		0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	3	4	Pool	30	8.3	249	0.73	1.10	65	60	15	17.5		0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	4	1	Riffle	11.3	3.3	37.29	0.40	0.64	60	50	3			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	5	5	Pool	11	6.1	67.1	0.55	0.88	40	35	2	18		0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	6	3	Flatwater	20	8	160	0.37	0.50	20	15	2			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	7	4	Pool	22	9.9	217.8	0.47	0.84	25	15	10	18		0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	8	5	Pool	15.5	8.5	131.75	0.68	1.25	80	55	25	18.5		0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	9	3	Flatwater	12.5	5.35	66.875	0.29	0.43	50	5	20			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	10	1	Riffle	6.7	5.8	38.86	0.16	0.27	45	5	25			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	11	5	Pool	15.6	6.05	94.38	0.58	0.99	75	55	5	19.5	22	0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	12	1	Riffle	48	8.35	400.8	0.34	0.64	85	40	10			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	13	3	Flatwater	34.5	19	655.5	0.34	0.66	40	5	15			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	14	4	Pool	80	18	1440	1.30	2.83	60	15	25	18.5		0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	15	1	Riffle	60	10.6	636	0.27	0.44	35	20	15			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	16	4	Pool	100	14	1400	0.98	1.45	60	30	25	20.5		0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	17	3	Flatwater	53	6	318	0.45	0.64	55	45	10			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	18	2	Cascade	20.5	4.1	84.05	0.25	0.49	65	50	5			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	19	4	Pool	46	13	598	1.33	2.62	60	15	15	20.5		0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	20	3	Flatwater	85	10.5	892.5	0.58	1.11	55	20	10			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	21	1	Riffle	37.4	6.3	235.62	0.46	0.61	70	50	7		29.1	0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	22	3	Flatwater	41	5.8	237.8	0.26	0.45	45	10	5			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	23	1	Riffle	47.5	6.4	304	0.39	0.65	70	45	5			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	24	5	Pool	14.2	10.4	147.68	0.39	0.64	40	30	15	24		0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	25	5	Pool	18.6	11.5	213.9	0.66	0.93	35	25	10	24		0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	26	5	Pool	23.9	7.8	186.42	0.32	0.56	75	40	25			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	27	1	Riffle	95.2	7.8	742.56	0.32	0.56	50	45	20			0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S037	Mainstem at Rattlesnake Cr	27.1	6	Pool	20	13	260	0.49	0.79	80	45	15	23		0.22	10064	8	0.24	3.8	8
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	1	3	Flatwater	22.3	6.8	151.64	0.45	0.64	75	60		20	29	0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	2	1	Riffle	4.5	9.8	44.1	0.34	0.64	75	25				0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	3	5	Pool	13.5	10.5	141.75	0.58	0.99	80	25				0.50	5668	8.1		5.34	3

1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	4	1	Riffle	7.5	9.8	73.5	0.40	0.64	70	60				0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	5	4	Pool	98	14	1372	0.73	1.10	55	40				0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	5.1	6	Pool	20	5.5	110	0.52	0.64	40	30				0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	6	1	Riffle	15	9.8	147	0.16	0.27	70	55				0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	7	3	Flatwater	24.2	6.8	164.56	0.29	0.43	70	50				0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	8	1	Riffle	22.5	9.8	220.5	0.46	0.64	75	20				0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	9	4	Pool	145	14	2030	1.37	1.62	60	30				0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	10	1	Riffle	7.8	7.8	60.84	0.37	0.55	60	35		25	36.5	0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	11	5	Pool	40	12.1	484	1.16	1.37	60	45				0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	12	5	Pool	20.2	12.5	252.5	1.10	1.28	60	35				0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S040	Mainstem at Copper Butte Cr	13	2	Cascade	49.5	8.4	415.8	0.55	0.70	75	60				0.50	5668	8.1		5.34	3
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	1	1	Riffle	22.4	3.55	79.52	0.15	0.25	30	0	70		21	0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	2	4	Pool	67	8.8	589.6	0.46	0.73	60	15	50	19.5		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	2.1	5	Pool	14.5	4.3	62.35	0.59	0.81	45	10	75	18		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	3	3	Flatwater	16	5.8	92.8	0.49	0.73	75	10	35	18.5		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	4	1	Riffle	24.5	6.7	164.15	0.19	0.27	60	10	25			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	5	4	Pool	72	7.8	561.6	0.56	1.07	75	15	25	19		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	6	1	Riffle	12	9	108	0.21	0.40	10	0	5			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	7	5	Pool	26	6.2	161.2	0.27	0.46	20	5	2	20		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	8	3	Flatwater	27.5	8.2	225.5	0.21	0.34	50	0	60			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	9	1	Riffle	15.5	7.5	116.25	0.15	0.18	65	5	30			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	10	3	Flatwater	34.5	8.3	286.35	0.16	0.37	55	5	25		30	0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	11	5	Pool	49.5	8.3	410.85	0.37	0.59	65	5	25	25		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	12	1	Riffle	9	5	45	0.09	0.12	85	0	85			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	13	4	Pool	70	7.8	546	0.50	0.76	60	5	25	25		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	14	1	Riffle	18.5	9.2	170.2	0.05	0.24	30	0	20			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	15	3	Flatwater	111	8.3	921.3	0.34	0.46	50	10	5			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	16	5	Pool	28	7.1	198.8	0.53	0.91	65	5	50	24		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	17	7	Pool	11		0	0.00	0.00	0	0	35			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	18	3	Flatwater	15.5	6.2	96.1	0.14	0.27	20	5	35			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	19	5	Pool	13	6.8	88.4	0.32	0.50	20	10	20	26		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	20	3	Flatwater	67	6	402	0.22	0.49	45	10	35		31	0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	20.1	5	Pool	10	5	50	0.39	0.55	35	20	0	24		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	21	5	Pool	37	9.9	366.3	0.51	0.79	55	20	10	25		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	22	3	Flatwater	31	7.7	238.7	0.30	0.46	35	10	2			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	23	1	Riffle	5	2.5	12.5	0.10	0.15	25	0	10			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	24	5	Pool	37	4.5	166.5	0.34	0.46	43	15	5	23		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	25	1	Riffle	8.7	1.5	13.05	0.21	0.46	0	0	0			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	26	5	Pool	30	10.6	318	1.04	1.74	90	45	10	22		0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	27	1	Riffle	20.7	6.3	130.41	0.30	0.49	45	35	50			0.22	6828	7.9	7.6	1.11	6.75
1.4	0-2%, >100km2	S035	Rice Fork at Rice Cr	28	5	Pool	25.5	8.1	206.55	0.41	0.70	50	25	55	22		0.22	6828	7.9	7.6	1.11	6.75
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	1	4	Pool	1.9	1.4	2.66	0.15	0.20	0	25	50		68	0.17	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	2	2	Cascade	10.7	3.3	35.31	0.16	0.19	55	15	60				1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	3	4	Pool	8.7	1.9	16.53	0.17	0.22	20	5	70			0.33	1438	7.1	0.31	0.622	8

2.2	2-7%, 2-10km2	S084	Blue Slides Cr	4	2	Cascade	8.3	1.8	14.94	0.16	0.18	0						1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	5	1	Riffle	25.5	2.1	53.55	0.17	0.28	30	10	60				1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	6	5	Pool	7.6	2.4	18.24	0.17	0.34	20	15	70			0.33	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	7	1	Riffle	21	2.7	56.7	0.16	0.34	30		0				1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	8	4	Pool	4.2	2.3	9.66	0.26	0.37	10	0				0.17	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	9	2	Cascade	18.9	3.9	73.71	0.13	0.23	75	15					1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	10	6	Pool	6.2	1.93	11.966	0.20	0.23	15	10	60			0.17	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	11	4	Pool	6	2.5	15	0.23	0.30	40	0	80		72	0.17	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	12	1	Riffle	60	3.27	196.2	0.16	0.29	35	10	60				1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	13	4	Pool	2.5	2.9	7.25	0.22	0.30	30					0.33	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	14	1	Riffle	22.9	2.1	48.09	0.14	0.23	30						1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	15	4	Pool	4.5	3	13.5	0.20	0.41	10					0.17	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	16	1	Riffle	12.5	2.4	30	0.13	0.18	30						1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	17	4	Pool	2.5	1.4	3.5	0.11	0.38	10					0.17	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	18	1	Riffle	45	2.3	103.5	0.22	0.29	60						1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	19	6	Pool	3.5	2.2	7.7	0.21	0.28	70	10	30				1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	20	1	Riffle	10	1.9	19	0.15	0.23	15	10					1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	21	5	Pool	7	3.4	23.8	0.36	0.47	40	0	40		75	0.17	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	22	1	Riffle	32	1.7	54.4	0.17	0.31	25	5	60				1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	23	5	Pool	4.5	3.2	14.4	0.17	0.30	35	10				0.33	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	24	6	Pool	6.7	3.5	23.45	0.23	0.54	45	0	90				1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	25	1	Riffle	33.5	2.6	87.1	0.17	0.34							1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	26	5	Pool	4	1.9	7.6	0.29	0.39						0.33	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	27	1	Riffle	52	3.1	161.2	0.26	0.52							1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	28	5	Pool	7.4	2.7	19.98	0.22	0.34						0.33	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	29	1	Riffle	83	3.6	298.8	0.18	0.29							1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S084	Blue Slides Cr	30	5	Pool	3.5	3	10.5	0.25	0.41						0.33	1438	7.1	0.31	0.622	8
2.2	2-7%, 2-10km2	S081	Deer Cr	1	2	Cascade	5.6	3.7	20.72	0.19	0.29	50	20	75		18.3	0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	2	1	Riffle	9.5	3.3	31.35	0.19	0.30	30	5	80			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	3	5	Pool	5	3.6	18	0.33	0.46	50	30	40	14.5		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	4	2	Cascade	6	3.7	22.2	0.19	0.29	60					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	5	5	Pool	5	1.8	9	0.31	0.43	40	0	85	14.5		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	6	1	Riffle	6	3.3	19.8	0.19	0.30	30					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	7	3	Flatwater	8.5	2.3	19.55	0.19	0.24	25	5	90			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	8	2	Cascade	6.2	3.7	22.94	0.19	0.29	40					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	8.1	1	Riffle	6.2	1.6	9.92	0.19	0.30	30					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	9	5	Pool	4.7	3.2	15.04	0.28	0.43	55	15	85	14.5		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	10	1	Riffle	9.4	3	28.2	0.10	0.18	5		70		21	0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	10.1	5	Pool	2.1	3	6.3	0.26	0.40	60		85	15		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	11	5	Pool	5	4.2	21	0.56	0.94	65	50	60	15		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	12	5	Pool	7.3	3	21.9	0.42	0.78	60	50	70	15.5		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	13	2	Cascade	16.8	2.9	48.72	0.28	0.46	50	25	75			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	14	3	Flatwater	14	2.6	36.4	0.29	0.46	20	10	70			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	15	2	Cascade	6.5	2.9	18.85	0.28	0.46	50					0.26	1333	7.2	1.01	1.33	5.5

2.2	2-7%, 2-10km2	S081	Deer Cr	16	5	Pool	10	2.1	21	0.66	1.05	90	80	70	15.5		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	17	1	Riffle	13.5	3	40.5	0.10	0.18	10					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	18	5	Pool	6.9	2.3	15.87	0.25	0.53	40	5	75	16		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	19	1	Riffle	6	1.3	7.8	0.15	0.21	20		60		26.7	0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	20	5	Pool	6	2.1	12.6	0.24	0.43	85	60	65	15.5		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	21	1	Riffle	6.6	1.3	8.58	0.15	0.21	10					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	22	6	Pool	5.3	1.7	9.01	0.20	0.27	75	5	75			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	22.1	3	Flatwater	6	1.5	9	0.18	0.22	30		90			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	23	1	Riffle	18.7	1.3	24.31	0.15	0.21	15					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	24	2	Cascade	11	3.3	36.3	0.21	0.32	65	15	75			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	25	5	Pool	5.3	4	21.2	0.48	0.82	60	45	60	15.5		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	26	3	Flatwater	48	1.5	72	0.18	0.22	30					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	27	5	Pool	6.8	3.5	23.8	0.44	0.76	70	50	70	16		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	28	2	Cascade	9.6	3.6	34.56	0.24	0.40	50	40	65		29.4	0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	29	3	Flatwater	10.6	3.6	38.16	0.16	0.25	10	5	80			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	30	5	Pool	5.9	4.3	25.37	0.31	0.60	30	10	90	16.5		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	31	1	Riffle	4	1.5	6	0.19	0.25	25		95			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	32	5	Pool	12.5	2.3	28.75	0.24	0.37	40	5	75	16.5		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	33	1	Riffle	3.9	1.5	5.85	0.19	0.25	30					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	34	5	Pool	7.4	3.5	25.9	0.30	0.51	20	0	90	16.5		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	35	1	Riffle	16.5	1.5	24.75	0.19	0.25	35					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	36	3	Flatwater	16.5	3.6	59.4	0.16	0.25	10					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	37	1	Riffle	17	1.5	25.5	0.19	0.25	10					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	38	5	Pool	8.4	3.9	32.76	0.44	0.89	55	40	70	16.5	32.2	0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	39	1	Riffle	12	2.3	27.6	0.21	0.32	20	5	80			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	40	3	Flatwater	14.8	2.4	35.52	0.18	0.26	30	5	80			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	41	1	Riffle	14.5	2.3	33.35	0.21	0.32	20					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	42	5	Pool	5.5	2.2	12.1	0.27	0.55	75	5	50	16.5		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	43	5	Pool	5.6	3.2	17.92	0.48	0.79	40	20	90	17		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	44	1	Riffle	4.8	2.3	11.04	0.21	0.32	10					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	45	5	Pool	5	4	20	0.26	0.49	65	25	90	17		0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	46	3	Flatwater	25	2.4	60	0.18	0.26	30					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	47	2	Cascade	3.2	2.6	8.32	0.14	0.18	50	30	80			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	48	4	Pool	7	3.3	23.1	0.34	0.58	45	5	60	17	35	0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	49	1	Riffle	7.5	2	15	0.12	0.18	25	5	30			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	50	3	Flatwater	23.7	3	71.1	0.31	0.46	45	5	70			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	51	2	Cascade	6.8	1	6.8	0.19	0.21	50	30	85			0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S081	Deer Cr	52	1	Riffle	6.3	2	12.6	0.12	0.18	30					0.26	1333	7.2	1.01	1.33	5.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	1	5	Pool	5.3	2.5	13.25	0.24	0.85	50	25	35	15.5	27	0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	2	1	Riffle	12	1.8	21.6	0.24	0.46	65	20	35			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	3	5	Pool	7	2.55	17.85	0.24	0.37	65	30				0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	4	1	Riffle	10	1.8	18	0.24	0.46	70		45			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	5	5	Pool	5.2	2.1	10.92	0.38	0.46	60	25				0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	6	1	Riffle	7.6	1.8	13.68	0.24	0.46	70		35			0.26	1397	8.1	0.33	2.46	6.5

2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	7	5	Pool	3.7	2.8	10.36	0.43	0.76	80	25				0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	8	1	Riffle	8	1.8	14.4	0.24	0.46	70	0	45			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	9	3	Flatwater	6	3	18	0.18	0.24	55	45	70			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	10	5	Pool	5.7	2.4	13.68	0.38	0.61	75	15	20			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	11	2	Cascade	13	2.7	35.1	0.24	0.52	80	50	35	17.5	32	0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	12	3	Flatwater	6	2.1	12.6	0.23	0.38	15	5	75			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	13	5	Pool	4.5	3	13.5	0.38	0.55	60	40				0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	14	2	Cascade	33	2.7	89.1	0.24	0.52	80		40			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	15	5	Pool	7.7	2.4	18.48	0.26	0.38	65	5	60			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	16	5	Pool	5	2.5	12.5	0.40	0.82	75	50				0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	17	2	Cascade	13.5	2.7	36.45	0.24	0.52	80					0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	18	3	Flatwater	12.5	2.1	26.25	0.23	0.38	15					0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	19	2	Cascade	19	2.7	51.3	0.24	0.52	80		15			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	20	4	Pool	4.3	2.5	10.75	0.53	0.67	60	5	40			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	21	1	Riffle	8	2	16	0.24	0.49	35	5	65	18		0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	22	2	Cascade	8	3	24	0.23	0.29	80	50	30		32	0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	23	4	Pool	8	2.5	20	0.32	0.49	85	20				0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	24	2	Cascade	6.7	3	20.1	0.23	0.29	80		50			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	25	5	Pool	4.1	2.6	10.66	0.34	0.54	65	20				0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	26	1	Riffle	24	2	48	0.24	0.49	35		8			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	27	4	Pool	4.3	2.8	12.04	0.38	0.64	55	20				0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	28	2	Cascade	5.6	3	16.8	0.23	0.29	80		55			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	29	5	Pool	4.6	2.7	12.42	0.69	0.91	65	30	60			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	30	1	Riffle	42	1.2	50.4	0.55	0.49	80		60			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	31	5	Pool	5.7	3	17.1	0.40	0.55	55	10	70	18.5		0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	32	3	Flatwater	20.7	3.2	66.24	0.21	0.43	85	15	85		32	0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	33	5	Pool	5.5	2.5	13.75	0.34	0.56	45	5	80			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	34	1	Riffle	48.8	3.2	156.16	0.17	0.27	80	20	60			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	35	2	Cascade	12	5	60	0.20	0.24	70	45	40			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	36	5	Pool	9	3.5	31.5	0.37	0.70	75	55				0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	37	3	Flatwater	6.4	3.2	20.48	0.21	0.43	85					0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	38	2	Cascade	6.5	5	32.5	0.20	0.24	70					0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	39	3	Flatwater	8	3.2	25.6	0.21	0.43	85					0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	40	1	Riffle	20	3.2	64	0.17	0.27	50		45			0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	41	2	Cascade	29	3.5	101.5	0.18	0.34	90	50	65	18.5	30	0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	42	5	Pool	5.7	4.6	26.22	0.41	0.70	90	55				0.26	1397	8.1	0.33	2.46	6.5
2.2	2-7%, 2-10km2	S119	Thistle Glade Cr	43	2	Cascade	26.8	3.5	93.8	0.18	0.34	90					0.26	1397	8.1	0.33	2.46	6.5
2.3	2-7%, 10-100km2	S134	Cold Cr	1	1	Riffle	38.4	4	153.6	0.17	0.24	55	35	8		13.8		4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	2	5	Pool	5.6	3.2	17.92	0.31	0.44	4	25	9	13		0.33	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	3	2	Cascade	32.9	4.2	138.18	0.21	0.38	85	5	8				4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	3.1	5	Pool	5.3	2.4	12.72	0.32	0.47	5	25	9	13		0.33	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	3.2	5	Pool	3	5	15	0.30	0.44	8	4	7	13		0.33	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	4	4	Pool	25	5.3	132.5	0.71	1.67	85	4	5	13.5		0.33	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	5	2	Cascade	11.7	4.2	49.14	0.21	0.38	85						4001	7.6	0.37	1.54	6.75

2.3	2-7%, 10-100km2	S134	Cold Cr	6	1	Riffle	38	4	152	0.17	0.24	5						4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	7	5	Pool	15.4	5.7	87.78	0.39	0.59	35	2	85	13.5		0.50	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	8	1	Riffle	24.5	4	98	0.17	0.24	5	2					4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	9	2	Cascade	5.5	4.6	232.3	0.27	0.53	75	4	8		17.4		4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	9.1	5	Pool	7	3.5	24.5	0.45	0.62	75	65	85	13.5		0.17	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	1	3	Flatwater	16	4.7	75.2	0.48	0.91	4	25	75				4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	11	5	Pool	7	2.5	17.5	0.30	0.53	45	3	9	13.5		0.33	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	12	2	Cascade	13.7	4.6	63.2	0.27	0.53	75						4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	13	5	Pool	15	7.8	117	0.37	0.56	75	5	85			0.33	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	14	1	Riffle	2	1.5	3	0.12	0.17	15	1	9				4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	15	5	Pool	25.8	6.8	175.44	0.69	1.82	7	25	85	14		0.17	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	16	2	Cascade	64.5	4.6	296.7	0.27	0.53	75						4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	17	4	Pool	17.3	6.6	114.18	0.43	0.69	6	4	25	14.5		0.33	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	18	2	Cascade	21.8	4.8	14.64	0.23	0.34	3	25	75		23		4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	19	4	Pool	15	5.5	82.5	0.48	0.71	4	2	75	14.5		0.50	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	2	2	Cascade	36	4.8	172.8	0.23	0.34	3						4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	21	5	Pool	9	3.2	28.8	0.36	0.65	55	55	3	15		0.50	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	22	4	Pool	3	6.5	195	0.54	0.93	65	3	8	14.5		0.17	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	23	3	Flatwater	88.5	2.9	256.65	0.34	0.55	75	45	7				4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	23.1	6	Pool	5.1	4.1	2.91	0.32	0.41	6	5	9	14.5		0.17	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	24	4	Pool	21	5.3	111.3	1.00	1.52	8	15	6	15.5		0.33	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	25	2	Cascade	22.7	4.8	18.96	0.23	0.34	3						4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	26	4	Pool	28	5.8	162.4	0.42	0.85	65	25	7	15		0.17	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	27	2	Cascade	17	2.8	47.6	0.36	0.49	6	55	85		25		4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	28	3	Flatwater	3	4.4	132	0.42	0.66	6	15	75				4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	29	2	Cascade	18.8	14.8	278.24	0.43	0.69	7	5	65				4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	3	1	Riffle	15	4	6	0.24	0.35	25	2	6				4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S134	Cold Cr	31	4	Pool	2	13.2	264	1.25	2.44	75	25	4	15.5		0.50	4001	7.6	0.37	1.54	6.75
2.3	2-7%, 10-100km2	S021	Bear Cr	1	4	Pool	11.5	3.1	35.65	0.41	0.58	25	1	5	13	18	0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	2	4	Pool	8.5	4.9	41.65	0.48	0.55	35			13		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	3	3	Flatwater	8.5	3	25.5	0.34	0.46	55	3	75			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	4	1	Riffle	16.2	2.8	45.36	0.21	0.29	61	3	85			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	5	5	Pool	8	2.8	22.4	0.44	0.73	6	55	75	13		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	6	3	Flatwater	11	3	33	0.34	0.46	55					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	7	1	Riffle	3.5	2.8	9.8	0.21	0.29	5					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	8	5	Pool	8	3.8	3.4	0.42	0.71	6		9	13		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	9	2	Cascade	22	2.8	61.6	0.33	0.53	55	25	9			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	10	1	Riffle	14	2.8	39.2	0.34	0.29	4					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	11	5	Pool	1	3.8	38	0.35	0.52	65	5	7	13	18	0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	12	2	Cascade	8.8	3	26.4	0.27	0.41	45	3	85			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	13	3	Flatwater	9.5	4.1	38.95	0.25	0.36	2	15	85			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	14	4	Pool	8.5	3.9	33.15	0.41	0.76	35	25	9	13		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	15	2	Cascade	6	3	18	0.27	0.41	2					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	16	5	Pool	9.5	4.3	4.85	0.45	0.87	6		8	13		0.26	3080	7	0.49	4.01	8.75

2.3	2-7%, 10-100km2	S021	Bear Cr	17	2	Cascade	28	3	84	0.27	0.41	45					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	18	5	Pool	5.3	3.8	2.14	0.43	0.58	5	3	7	14		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	19	5	Pool	7	4.5	31.5	0.57	0.70	55		75	14		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	20	3	Flatwater	15.5	4.1	63.55	0.25	0.36	2					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	21	5	Pool	11.7	5.3	62.1	0.37	0.69	55	4	8	14	24	0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	22	2	Cascade	68	5.6	38.8	0.59	0.79	65	4	75			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	23	5	Pool	9.5	3.5	33.25	0.45	0.55	4	25	8	14.5		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	24	2	Cascade	1.4	5.6	58.24	0.59	0.79	65					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	25	1	Riffle	26	4.1	16.6	0.28	0.43	25	15	3			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	26	5	Pool	3.5	6.2	21.7	0.33	0.53	3	2	4	14.5		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	27	1	Riffle	14.5	4.1	59.45	0.28	0.43	25		7			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	28	4	Pool	5.3	3	15.9	0.27	0.49	3	2		14.5		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	29	1	Riffle	28	4.1	114.8	0.28	0.43	25					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	29.1	6	Pool	3.5	1.75	6.125	0.21	0.27	25					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	29.2	6	Pool	3	1	3	0.21	0.21	25				29	0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	30	4	Pool	8	4.6	36.8	0.36	0.58	45	25	55	15		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	31	1	Riffle	5	3	15	0.18	0.28	35	2	3			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	32	5	Pool	7.5	3.2	24	0.33	0.52	3	1	4	16		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	33	1	Riffle	5	3	15	0.18	0.28	35					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	34	3	Flatwater	23.6	2.6	61.36	0.36	0.53	25	2	8			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	35	1	Riffle	5	3	15	0.18	0.28	35					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	36	5	Pool	8.9	4.2	37.38	0.45	0.79	3		85	16		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	37	3	Flatwater	11.5	2.6	29.9	0.36	0.53	25					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	38	1	Riffle	7	3	21	0.18	0.28	35					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	39	3	Flatwater	8	3.4	27.2	0.34	0.43	3	2	75		29	0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	4	1	Riffle	8	3.8	3.4	0.18	0.26	2	15	85			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	41	4	Pool	8.8	3.6	31.68	0.25	0.37	25	25	6	16.5		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	42	1	Riffle	6.5	3.8	24.7	0.18	0.26	2					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	43	5	Pool	6	4.3	25.8	0.59	0.73	4	3	4	16		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	44	1	Riffle	13	3.8	49.4	0.18	0.26	2					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	45	3	Flatwater	32	3.4	18.8	0.34	0.43	3					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	46	4	Pool	11	2.9	31.9	0.38	0.62	25		7	16.5		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	47	1	Riffle	12	3.8	45.6	0.18	0.26	2					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	48	5	Pool	9	3.2	28.8	0.40	0.55	55	35	7	16.5		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	49	1	Riffle	7.6	3.1	23.56	0.17	0.24	45	4	7		31	0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	50	5	Pool	4.4	3.6	15.84	0.26	0.38	1	1	6	16.5		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	51	5	Pool	9.7	4.6	44.62	0.34	0.52	35	3	85	16.5		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	52	2	Cascade	16	5.4	86.4	0.24	0.40	55	45	8			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	53	5	Pool	12	4.2	5.4	0.34	0.52	85	65	7	16.5		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	54	1	Riffle	4.7	3.1	14.57	0.17	0.24	45					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	54.1	6	Pool	3.5	2	7	0.24	0.35	2					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	55	2	Cascade	1.6	5.4	57.24	0.24	0.40	55					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	56	5	Pool	14	4.7	65.8	0.27	0.55	4	3	9	16.5		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	57	2	Cascade	18	5.4	97.2	0.24	0.40	55				31	0.26	3080	7	0.49	4.01	8.75

2.3	2-7%, 10-100km2	S021	Bear Cr	58	4	Pool	2.5	4.4	9.2	0.40	0.76	5	3	7	17		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	59	1	Riffle	6.5	3.3	21.45	0.18	0.35	17	1	7			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	60	5	Pool	1	2.3	23	0.29	0.55	3	25	4	17		0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	61	2	Cascade	21	4.6	96.6	0.28	0.49	5	25	7			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	62	3	Flatwater	13.5	3.6	48.6	0.27	0.36	5	5	4			0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	63	2	Cascade	13	4.6	59.8	0.28	0.49	5					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	64	1	Riffle	5.3	3.3	17.49	0.18	0.35	17					0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S021	Bear Cr	65	5	Pool	7.2	4	28.8	0.79	1.23	4	2	8	17	29	0.26	3080	7	0.49	4.01	8.75
2.3	2-7%, 10-100km2	S189	Anderson Cr	1	4	Pool	7.1	3.41	24.211	0.27	0.37	4	5	1	15.5	26.7	0.17	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	2	1	Riffle	5.8	1.99	11.542	0.23	0.27	15	5	1				3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	3	5	Pool	14.8	4.1	6.68	0.35	0.61	3	2	5	15.5		0.17	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	4	1	Riffle	38	4.2	159.6	0.25	0.29	2						3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	5	4	Pool	6.2	2.9	17.98	0.49	0.55	5			15.5		0.17	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	6	1	Riffle	27	2.88	77.76	0.25	0.45	1						3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	6.1	6	Pool	15	2	3	0.33	0.48	5	2	2	15.5		0.17	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	7	3	Flatwater	5.5	4.3	217.15	0.35	0.43	5	25	25				3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	8	4	Pool	17.5	3.88	67.9	0.41	0.59	4			15.5		0.17	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	9	1	Riffle	18.8	5.96	112.48	0.23	0.34	6						3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	10	4	Pool	18.5	4.7	86.95	0.68	0.76	4	5	65	15.5	28	0.17	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	11	1	Riffle	5	3	15	0.23	0.32	3	15					3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	12	4	Pool	6.5	4.1	26.65	0.43	0.58	5			15.5		0.17	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	13	1	Riffle	8	6	48	0.27	0.34	1						3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	14	4	Pool	19	5	95	0.46	0.58	3			15.5		0.33	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	15	3	Flatwater	72	6	432	0.27	0.37	3	1	6				3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	16	4	Pool	6.2	3.38	2.956	0.34	0.40	6			15.5		0.17	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	17	3	Flatwater	87.5	5.2	455	0.32	0.48	2						3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	18	4	Pool	12.5	4.8	6	0.78	1.36	4		75	15.5		0.33	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	19	3	Flatwater	75	6.1	457.5	0.39	0.55	4						3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	20	5	Pool	8.6	5.7	49.2	0.68	0.91	4	1	15	15.5	29.5	0.17	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	21	1	Riffle	32	5.7	182.4	0.28	0.35	5	3	7				3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	22	4	Pool	17.5	6.6	115.5	0.73	0.79	45	35	85	15.5		0.17	3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S189	Anderson Cr	23	1	Riffle	33	6.53	215.49	0.26	0.49	4						3038	6.5	0.43	1.64	6
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	1	1	Riffle	39	4.5	175.5	0.21	0.40	35	25	95	14.5	16.5		2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	2	4	Pool	19.5	3.7	72.15	0.27	0.43	45	2	95			0.17	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	3	1	Riffle	6.4	4.5	271.8	0.21	0.40	3			14.5			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	4	4	Pool	1.5	3.5	36.75	0.38	0.43	25	5	95			0.33	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	5	1	Riffle	32.4	4.5	145.8	0.21	0.40	3			15			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	6	4	Pool	13	3.3	42.9	0.49	0.49	35	2	95			0.17	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	7	1	Riffle	32.5	3.5	113.75	0.21	0.40	3			15			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	8	4	Pool	9.5	4.8	45.6	1.58	1.58	8	45	7			0.50	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	9	1	Riffle	7.5	3.5	26.25	0.21	0.40	3			15			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	1	5	Pool	9.7	3	29.1	0.76	0.76	4	35	95	15		0.50	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	11	5	Pool	5.8	3.5	2.3	0.37	0.55	3	2	25		20	0.50	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	12	1	Riffle	14.8	2.9	42.92	0.18	0.46	3	15	45	15			2673	8.1	1.51	3.06	5.5

2.3	2-7%, 10-100km2	S131	Bear Cr Upper	13	4	Pool	1.2	6.2	63.24	0.44	1.19	45	3	95			0.33	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	14	3	Flatwater	19	5	95	0.24	0.46	35	3	75	15.5			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	15	4	Pool	23.5	4	94	0.41	0.98	55	25	7			0.50	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	16	1	Riffle	8.6	2.9	24.94	0.18	0.46	3			15.5			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	17	5	Pool	9.7	3.4	32.98	0.26	0.57	35	3	1			0.67	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	18	2	Cascade	5	2.2	11	0.23	0.46	65	5	95				2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	19	3	Flatwater	38	2.9	11.2	0.18	0.46	3			16			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	2	5	Pool	1	4.1	41	0.35	0.79	45	25	95			0.33	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	21	1	Riffle	9.5	3.5	33.25	0.18	0.35	25	2	95		22		2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	22	3	Flatwater	46	3.8	174.8	0.24	0.49	3	15	95	16			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	23	4	Pool	14	4.1	57.4	0.32	0.65	4	2	95			0.33	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	24	1	Riffle	16.2	3.5	56.7	0.18	0.35	3			16.5			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	25	5	Pool	5.9	4.5	26.55	0.24	0.49	25	1	95			0.17	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	26	3	Flatwater	23	3.8	87.4	0.24	0.49	3			16.5			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	27	5	Pool	8.5	4.2	35.7	0.35	0.52	35	15	95			0.33	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	28	1	Riffle	3.5	3.5	12.25	0.18	0.35	3			16.5			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	29	5	Pool	5	4.3	21.5	0.26	0.52	15	15	95			0.33	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	3	3	Flatwater	44	3.8	167.2	0.24	0.49	3			16.5			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	31	4	Pool	9	5.6	5.4	0.41	0.79	4	3	95		25	0.17	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	32	1	Riffle	1	5	5	0.15	0.21	3	25	95				2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	33	3	Flatwater	14.4	5	72	0.18	0.37	15	1	9				2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	34	1	Riffle	12	5	6	0.15	0.21	3			16.5			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	35	5	Pool	6.1	3.3	2.13	0.21	0.70	4	1	95			0.33	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	36	1	Riffle	1	3.4	34	0.15	0.21	3			17			2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	37	5	Pool	6.5	3.6	23.4	0.15	0.65	25	1	8			0.33	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	38	3	Flatwater	35	3.4	119	0.18	0.37	1						2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	39	5	Pool	7	3.8	26.6	0.40	0.55	4	35	95			0.33	2673	8.1	1.51	3.06	5.5
2.3	2-7%, 10-100km2	S131	Bear Cr Upper	4	1	Riffle	1	5	5	0.15	0.21	3						2673	8.1	1.51	3.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	1	5	Pool	5.29	2.9	15.341	0.38	0.62	20	15	90	13.5	25.5	0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	2	3	Flatwater	12	2.2	26.4	0.21	0.30	15	10	90			0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	3	5	Pool	6.7	5.58	37.386	0.56	0.82	30					0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	4	2	Cascade	52.8	2.54	134.112	0.42	0.76	30	15	75			0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	5	5	Pool	4.7	2.7	12.69	0.46	0.55	21					0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	6	1	Riffle	8.6	2.4	20.64	0.13	0.16	25	5	80			0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	6.1	6	Pool	4.3	1.95	8.385	0.39	0.60	50	30	90			0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	7	4	Pool	7.5	2.56	19.2	0.54	0.75	30	5	80			0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	8	3	Flatwater	113	2.7	305.1	0.21	0.37	15		60			0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	9	2	Cascade	20.7	2.6	53.82	0.20	0.27	30					0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	10	4	Pool	6.58	3.46	22.7668	0.24	0.47	25	5	55		26.7	0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	11	1	Riffle	8.04	2.9	23.316	0.18	0.20	15	10	80			0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	12	3	Flatwater	15.3	3.3	50.49	0.31	0.52	15	5	70			0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	13	1	Riffle	40	4.12	164.8	0.24	0.43	15					0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	14	4	Pool	8.96	3.55	31.808	0.41	0.80	25					0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	15	2	Cascade	51.5	2.2	113.3	0.28	0.46	35	20	75			0.26	1531		0.33	0.06	5.5

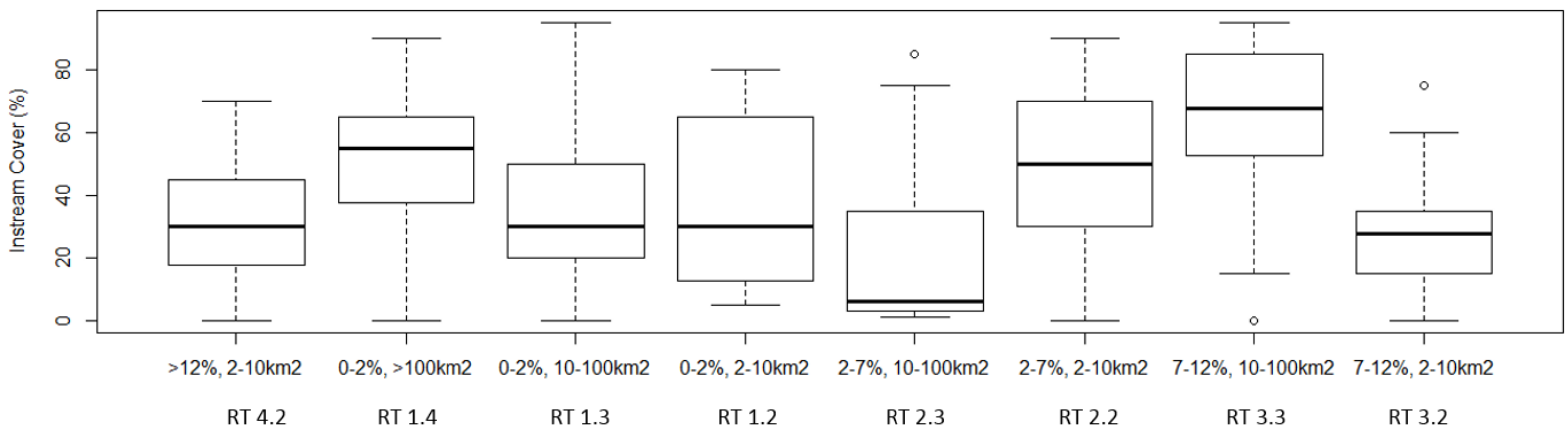
3.2	7-12%, 2-10km2	S123	Horse Cr	16	5	Pool	5.75	2.6	14.95	0.34	0.56	35	10	10			0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	17	2	Cascade	55.8	3.83	213.714	0.30	0.46	35					0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	18	4	Pool	8.7	4	34.8	0.36	0.49	30					0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S123	Horse Cr	19	3	Flatwater	99	2.3	227.7	0.29	0.40	15					0.26	1531		0.33	0.06	5.5
3.2	7-12%, 2-10km2	S188	Willow Cr	1	1	Riffle	7.9	1.5	11.85	0.09	0.17	30	15	45		35	0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	2	2	Cascade	10	3.33	33.3	0.19	0.29	25	15	15			0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	3	1	Riffle	17.5	1.6	28	0.16	0.27	30	10	35			0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	4	7	Dry	4.8	0	0	0.00	0.00	0					0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	5	5	Pool	4.1	5.65	23.165	0.12	0.16	30	0	45	15		0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	6	1	Riffle	12.7	2.45	31.115	0.09	0.15	10	10	85			0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	7	4	Pool	4.2	3.8	15.96	0.19	0.26	30	15	95	15		0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	8	1	Riffle	9	1.67	15.03	0.09	0.14	10	10				0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	9	4	Pool	5.3	2.73	14.469	0.37	0.59	20	15	95	15		0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	10	3	Flatwater	12.5	2.6	32.5	0.19	0.30	30					0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	11	4	Pool	5	2	10	0.50	0.70	40	35	95	14	36	0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	12	1	Riffle	2	2	4	0.15	0.18	20	20	95			0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	13	4	Pool	6	2.2	13.2	0.51	0.77	40		95	15		0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	14	1	Riffle	3.8	2.07	7.866	0.09	0.15	10		90			0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	15	5	Pool	3.8	4	15.2	0.37	0.70	45	30	95	14		0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	16	1	Riffle	4	1.05	4.2	0.21	0.46	10					0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	17	5	Pool	6	2.93	17.58	0.53	1.02	75	20	85	14		0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	18	3	Flatwater	4.5	2.2	9.9	0.27	0.40	40	15	80			0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	19	1	Riffle	20.5	2.6	53.3	0.21	0.34	50	10				0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	20	5	Pool	8	2	16	0.27	0.38	35	15	80	15		0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	21	1	Riffle	20.5	1.27	26.035	0.17	0.26	50	35	80		35	0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	22	5	Pool	7	2.75	19.25	0.32	0.54	55	35	80	14		0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	23	2	Cascade	38	1.96	74.48	0.20	0.28	30	30	85			0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	24	7	Dry	6.7		0	0.00	0.00	0					0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	25	5	Pool	3.6	1.3	4.68	0.17	0.20	50		80			0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	26	2	Cascade	17.2	2.03	34.916	0.25	0.40	20		75			0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	27	5	Pool	10.5	2.07	21.735	0.23	0.47	60		95	15		0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	28	2	Cascade	15	2.17	32.55	0.23	0.43	25					0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	28.1	6	Pool	3	2.5	7.5	0.25	0.41	10	5	95	13		0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	29	7	Dry	6.8	0	0	0.00	0.00	0					0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	30	5	Pool	1.5	1.4	2.1	0.23	0.31	10	10	90	13.5	32.2	0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	31	7	Dry	14.8	0	0	0.00	0.00	0	0				0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	32	2	Cascade	17	1.6	27.2	0.32	0.51	30	30				0.22	607			0.02	4.25
3.2	7-12%, 2-10km2	S188	Willow Cr	33	7	Dry	53	0	0	0.00	0.00	0	0				0.22	607			0.02	4.25
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	1	5	Pool	4	4.5	18	0.49	0.65	80	75	35	16	25	0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	1.1	1	Riffle	6	3	18	0.18	0.30	75	50	45			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	2	2	Cascade	11	7.9	86.9	0.47	0.79	95	70	60			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	3	5	Pool	5.5	5.3	29.15	0.43	0.67	90	75	5			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	4	5	Pool	6.7	4.8	32.16	0.50	0.79	85	75	2			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	5	5	Pool	4.3	3.6	15.48	0.49	0.67	95	75	35			0.34	2124	8.24	1.16	0.63	6.5

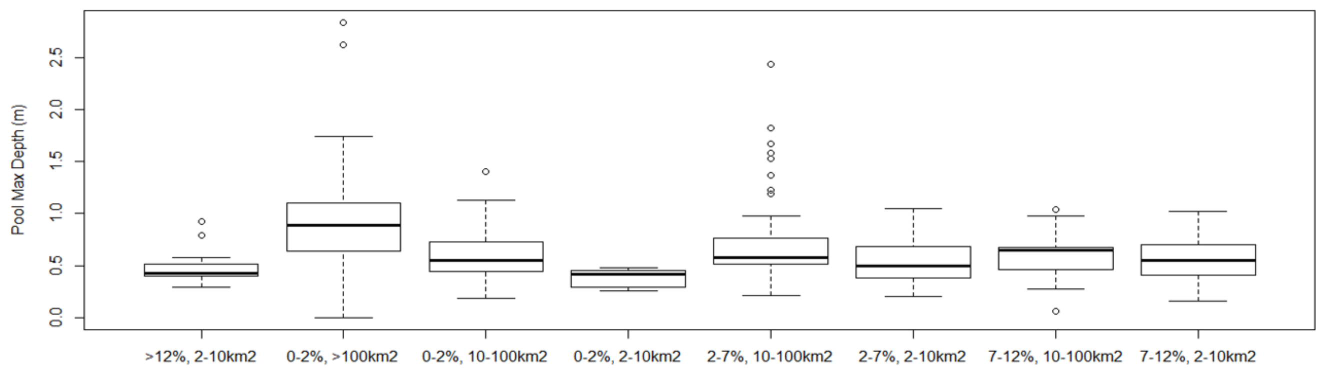
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	6	2	Cascade	43.5	7.9	343.65	0.47	0.79	90	25				0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	7	4	Pool	5	3	15	0.37	0.49	60	35	45			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	8	2	Cascade	15.3	1.5	22.95	0.12	0.18	55	10	7			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	9	5	Pool	8	0.65	5.2	0.29	0.67	50	25	35			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	10	1	Riffle	3.5	1.8	6.3	0.11	0.27	25	10	70	18.2	29	0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	11	4	Pool	7	3.6	25.2	0.73	0.98	85	70	70			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	12	1	Riffle	10.7	1.8	19.26	0.11	0.27	25					0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	13	3	Flatwater	15.3	3.6	55.08	0.15	0.34	20	10	20			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	13.1	6	Pool	2	2	4	0.23	0.27	15	10	60			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	14	3	Flatwater	11	3.6	39.6	0.15	0.34	30					0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	15	4	Pool	8.5	4	34	0.27	0.37	55	45	80			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	16	3	Flatwater	7.8	3.6	28.08	0.15	0.27	20					0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	17	5	Pool	8.2	3.6	29.52	0.43	0.06	85	70	60			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	18	5	Pool	8.2	4.6	37.72	0.53	0.58	60	50	75			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	19	2	Cascade	29.5	3.8	112.1	0.23	0.34	60	40	70	19	30	0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	20	4	Pool	4.3	6.2	26.66	0.18	0.70	60	35	55			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	21	2	Cascade	48	3.8	182.4	0.23	0.34	60	45	0			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	22	5	Pool	9	4.2	37.8	0.46	0.66	80	10	30			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	23	2	Cascade	7.5	3.8	28.5	0.23	0.34	70		0			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	24	5	Pool	10	3.6	36	0.40	0.64	90	65	35			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	25	2	Cascade	31	3.8	117.8	0.23	0.34	70		0			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	26	5	Pool	3.6	4.1	14.76	0.69	1.04	75	45	70			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	27	5	Pool	5.2	4.2	21.84	0.43	0.67	70	55	25			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	28	1	Riffle	4	1	4	0.49	0.64	30		25			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	29	4	Pool	8.8	4.2	36.96	0.53	0.70	55	35	80	19	30	0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	30	1	Riffle	24	7	168	0.20	0.76	90	10	2			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	31	5	Pool	6	2	12	0.38	0.43	60	25	30			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	32	2	Cascade	8.8	1.8	15.84	0.24	0.40	80	55	70			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	33	1	Riffle	22.5	2.5	56.25	0.20	0.76	90					0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	34	5	Pool	5	2.4	12	0.23	0.37	55	20	45			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	35	3	Flatwater	10	2.3	23	0.23	0.37	70	40	70			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	36	1	Riffle	12	2.5	30	0.20	0.76	90					0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	37	3	Flatwater	5.8	2.3	13.34	0.23	0.37	70					0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	38	4	Pool	4.5	2.6	11.7	0.37	0.49	25	25	35			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	39	1	Riffle	34.6	3.9	134.94	0.18	0.34	65	25	60	19	30	0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	40	4	Pool	7.5	3.4	25.5	0.38	0.58	45	20	75			0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	41	1	Riffle	26	3.9	101.4	0.18	0.30	0					0.34	2124	8.24	1.16	0.63	6.5
3.3	7-12%, 10-100km2	S202	Skeleton Glade Cr	42	5	Pool	9	4	36	0.30	0.46	95	70	30			0.34	2124	8.24	1.16	0.63	6.5
4.2	>12%, 2-10km2	S235	Soda Cr	1	7	Dry	19.8	0	0	0.00	0.00	0				24	0.22	677	6.5	0.71	0.05	5.5
4.2	>12%, 2-10km2	S235	Soda Cr	2	2	Cascade	17	1.4	23.8	0.25	0.34	45	20	75			0.22	677	6.5	0.71	0.05	5.5
4.2	>12%, 2-10km2	S235	Soda Cr	3	5	Pool	5.2	2.27	11.804	0.28	0.50	35	30	60	16		0.22	677	6.5	0.71	0.05	5.5
4.2	>12%, 2-10km2	S235	Soda Cr	4	2	Cascade	37	1.4	51.8	0.26	0.34	45					0.22	677	6.5	0.71	0.05	5.5
4.2	>12%, 2-10km2	S235	Soda Cr	5	1	Riffle	15	1.57	23.55	0.10	0.17	40	30	95			0.22	677	6.5	0.71	0.05	5.5
4.2	>12%, 2-10km2	S235	Soda Cr	6	7	Dry	8	0	0	0.00	0.00	0					0.22	677	6.5	0.71	0.05	5.5

4.2 >12%, 2-10km2	S235	Soda Cr	7	2	Cascade	21	1.4	29.4	0.25	0.34	50					0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	8	5	Pool	4.5	2.4	10.8	0.34	0.45	30	25	80	15		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	9	1	Riffle	15	1.57	23.55	0.10	0.17	15					0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	10	4	Pool	4.8	2	9.6	0.15	0.29	10	10	60	16		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	11	1	Riffle	5	1	5	0.07	0.08	25	20	50		26	0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	12	5	Pool	5	2.5	12.5	0.20	0.32	25	20	15	15.5		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	13	7	Dry	38		0	0.00	0.00	0	0				0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	14	5	Pool	6.5	1.93	12.545	0.25	0.35	40	40	85	15		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	15	2	Cascade	19	1.5	28.5	0.24	0.40	40	0	40			0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	16	7	Dry	4.5		0	0.00	0.00	0	0				0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	17	1	Riffle	10.5	1	10.5	0.07	0.08	25	0				0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	18	4	Pool	5.5	2.8	15.4	0.49	0.79	50	45	90	15		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	19	7	Dry	45		0	0.00	0.00	0	0				0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	20	5	Pool	1.7	1.5	2.55	0.34	0.40	55	40	90	14		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	21	1	Riffle	3.5	1.35	4.725	0.10	0.18	25	25	95		27	0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	22	5	Pool	4.2	3.75	15.75	0.30	0.52	30	30	90	13.5		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	23	2	Cascade	15	1.2	18	0.26	0.50	70	65	90			0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	24	4	Pool	4.6	2.17	9.982	0.29	0.43	20	20	85	14.5		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	25	2	Cascade	12	1.2	14.4	0.27	0.50	60					0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	26	5	Pool	4.8	4.7	22.56	0.56	0.92	50	50	90	13.5		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	27	2	Cascade	41.5	1.9	78.85	0.25	0.50	65					0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	27.1	6	Pool	3.8	2.1	7.98	0.30	0.41	35	20	95	14		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	28	5	Pool	5	3	15	0.44	0.58	40		95	15		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	29	1	Riffle	5.5	1.4	7.7	0.11	0.18	25					0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	30	5	Pool	2.8	1.2	3.36	0.23	0.31	25	15	95	15	29	0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	31	7	Dry	34.5		0	0.00	0.00	0					0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	32	5	Pool	3.6	2	7.2	0.24	0.43	25	25	5	18		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	33	7	Dry	37.5		0	0.00	0.00	0					0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	34	2	Cascade	7.3	1.75	12.775	0.12	0.20	45	45	95			0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	35	5	Pool	5.8	3.55	20.59	0.31	0.53	30	30	90	13.5		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	36	2	Cascade	28	1.75	49	0.12	0.20	50					0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	37	7	Dry	48.5		0	0.00	0.00	0					0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	37.1	6	Pool	4	2.8	11.2	0.32	0.40	25	15	95	13		0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	38	1	Riffle	15	2.3	34.5	0.18	0.26	60	20	80			0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	39	5	Pool	5.5	2.65	14.575	0.27	0.46	20	10	70	17	28	0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	40	1	Riffle	22	2.6	57.2	0.18	0.20	55	30	85			0.22	677	6.5	0.71	0.05	5.5
4.2 >12%, 2-10km2	S235	Soda Cr	41	7	Dry	20.3		0	0.00	0.00	0	0				0.22	677	6.5	0.71	0.05	5.5

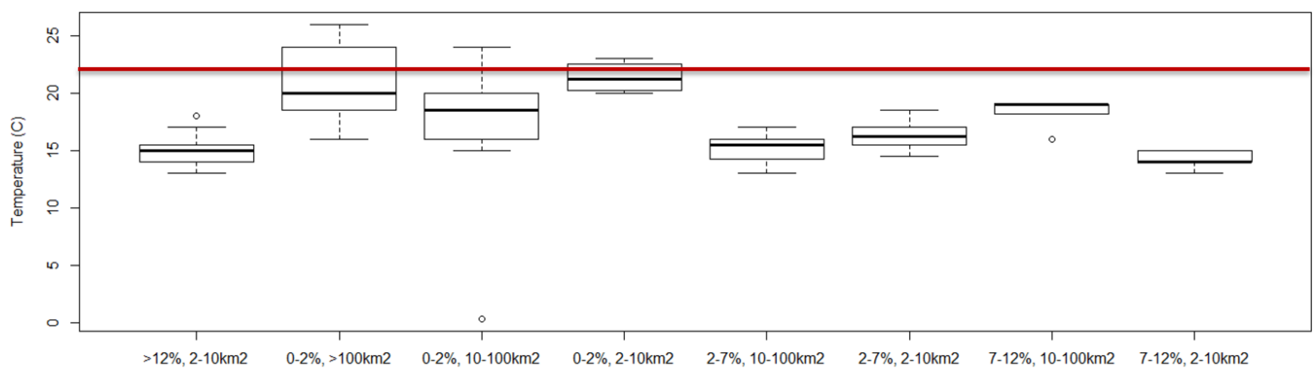
APPENDIX H

Appendix H: Summarized habitat data. The red line in temperature plot indicates a threshold for unsuitable stream temperature for salmonids.

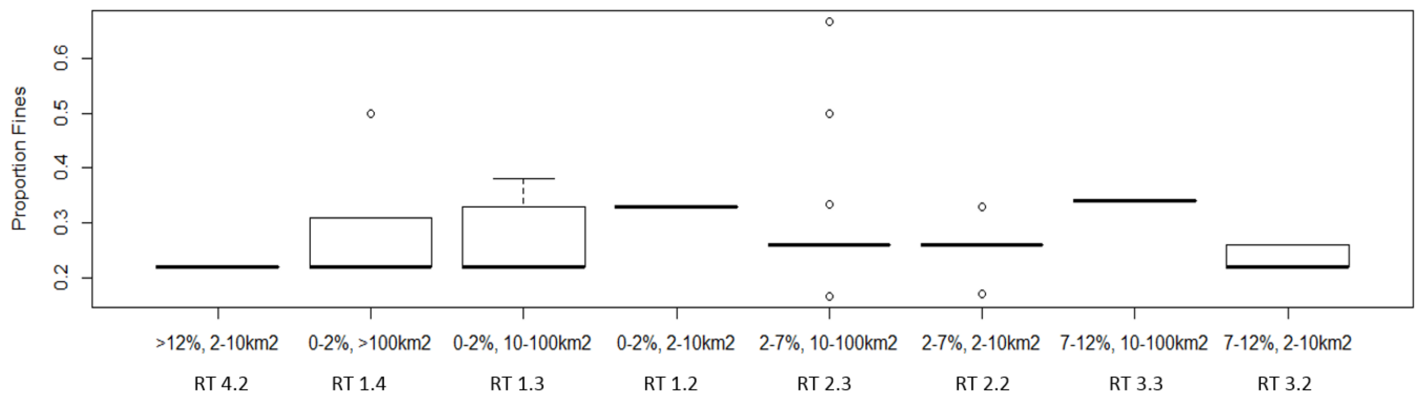


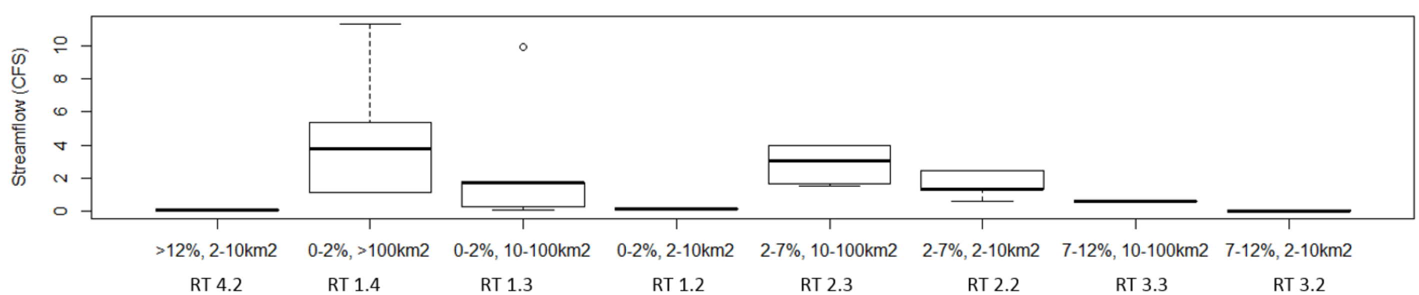


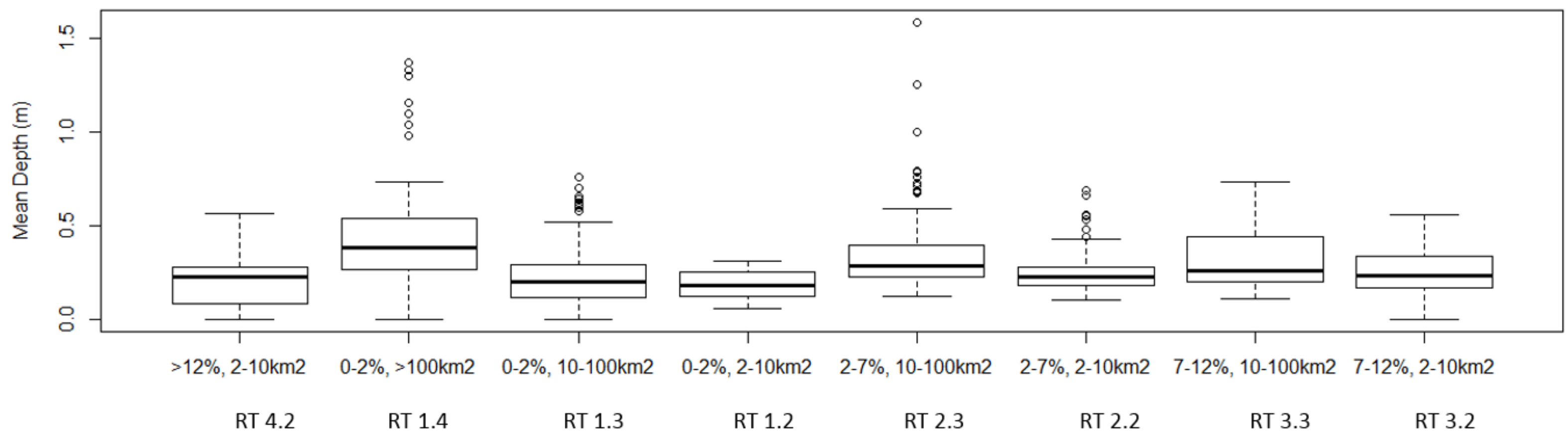
RT 4.2 RT 1.4 RT 1.3 RT 1.2 RT 2.3 RT 2.2 RT 3.3 RT 3.2



RT 4.2 RT 1.4 RT 1.3 RT 1.2 RT 2.3 RT 2.2 RT 3.3 RT 3.2


Proportion Fines
0.2
0.3
0.4
0.5
0.6
>12%, 2-10km2
0-2%, >100km2
0-2%, 10-100km2
0-2%, 2-10km2
2-7%, 10-100km2
2-7%, 2-10km2
7-12%, 10-100km2
7-12%, 2-10km2
RT 4.2
RT 1.4
RT 1.3
RT 1.2
RT 2.3
RT 2.2
RT 3.3
RT 3.2


Streamflow (CFS)
0
2
4
6
8
10
>12%, 2-10km2
0-2%, >100km2
0-2%, 10-100km2
0-2%, 2-10km2
2-7%, 10-100km2
2-7%, 2-10km2
7-12%, 10-100km2
7-12%, 2-10km2
RT 4.2
RT 1.4
RT 1.3
RT 1.2
RT 2.3
RT 2.2
RT 3.3
RT 3.2



Mean Depth (m)
0.0
0.5
1.0
1.5
>12%, 2-10km2
0-2%, >100km2
0-2%, 10-100km2
0-2%, 2-10km2
2-7%, 10-100km2
2-7%, 2-10km2
7-12%, 10-100km2
7-12%, 2-10km2
RT 4.2
RT 1.4
RT 1.3
RT 1.2
RT 2.3
RT 2.2
RT 3.3
RT 3.2

APPENDIX I

Appendix I: Fieldwork Photos

Corbin Creek, looking upstream

Rice Creek, looking upstream

Bear Creek (lower), looking upstream

Bear Creek (upper), looking upstream

Bear Creek (upper), looking upstream

Cold Creek, looking upstream

Skeleton Glade, looking downstream

Soda Creek, looking upstream

Smokehouse Creek, looking upstream

Mainstem at Rattlesnake Creek, looking upstream

Mainstem at Copper Butte Creek, looking upstream

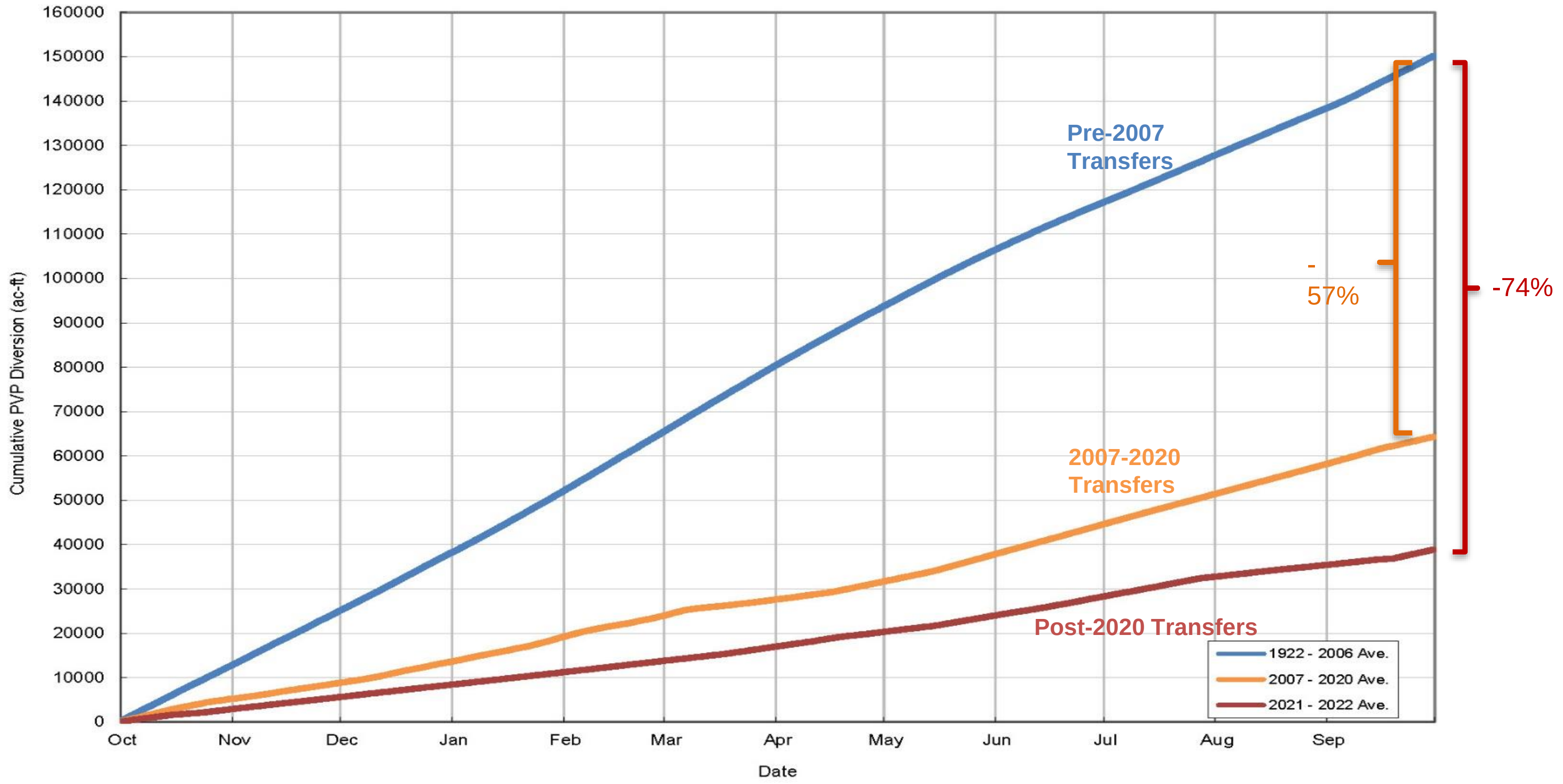
Bloody Rock Roughs, looking upstream; 20 February 2016; 11.50 cubic m/s, or 400 cfs (Photo: Erik Kenas)

Bloody Rock Roughs, looking upstream; 20 February 2016; 11.50 cubic m/s, or 400 cfs (Photo: Erik Kenas)

Bloody Rock roughs, looking upstream; 17 May 2016; 1.64 cms, or 58 cfs

Attachment I – Chart: *Reduced Potter Valley Water Diversions (1922-2022)*

Reduced Potter Valley Project Diversions



Month (Oct-Sep)