September 2, 2021

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

Re: Potter Valley Project (Project No. 77-285)

Dear Secretary Bose:

Mendocino County Inland Water and Power Commission, Sonoma County Water Agency, California Trout, Inc., the County of Humboldt, and the Round Valley Indian Tribes (NOI Parties) hereby request that the Federal Energy Regulatory Commission (Commission) grant an abeyance in the schedule established by the Revised Process Plan and Schedule (June 3, 2020) for relicensing the Potter Valley Project (Project). The NOI Parties specifically request that the abeyance continue until May 31, 2022, at which time they will provide further notice regarding our plans. The NOI Parties will use this abeyance to further evaluate how this project would best fit into a comprehensive strategy to manage worsening crises in anadromous fisheries and water supply reliability in the Eel and Russian River Basins.

In January 2019, Pacific Gas and Electric Company (PG&E) stated its intent not to seek a new license. That June, the NOI Parties filed a Notice of Intent and began to pursue relicensing of the Project to implement a Two-Basin Solution. We stated that a New License Application would be designed to provide significant benefits to the Eel River Basin (as the water source) and the Russian Basin (below the powerplant), and specifically to continue power generation, restore anadromous fisheries, and maintain water supply reliability. In May 2020, the NOI Parties completed a Feasibility Study Report. We made preliminary findings that we could achieve these objectives if the project were modified to remove Scott Dam and modernize Van Arsdale Diversion. On the basis, the NOI Parties proposed modifications to PG&E's 2018 Study Plan; completed and filed the Initial Study Report in September 2020; and engaged in consultation with agencies and other stakeholders pursuant to 18 C.F.R. § 5.15. The Commission issued its Study Plan Determination on March 16, 2021.

Since that time, the NOI Parties have not been able to secure the funds to undertake studies per the Study Plan Determination, at estimated cost of $18 million for two years. The individual NOI Parties do not have surplus funds to cover the work. We have made substantial efforts but have not yet secured public and philanthropic funds for that work. In May PG&E declined to fund such work.

Our 2020 Feasibility Study Report was scoping level. While it contained preliminary information on ownership costs and risks, the information does not have the specificity and confidence interval needed for the Regional Entity to commit to the submittal of a New License Application. The estimates for certain of the complex capital improvements were plus or minus 100%, a bracket appropriate for scoping but not for an ownership commitment. Further, the NOI Parties know that future Project costs will be materially different than current. The NOI Parties expect to propose significant capital modifications; the Regional Entity will be different from PG&E, as a utility, with respect to borrowing, taxes, insurance, and other financial considerations; and climate change is altering the hydrology of the Eel River Basin to an extent that materially affects power generation and water supply reliability.

During this period ending May 31, 2022, the NOI Parties will undertake due diligence tasks that will further evaluate how to meet the goals of the Two-Basin Solution. The NOI Parties have been informed that the State of California's Fiscal Year 2021-2022 budget (as enacted June 28, 2021) includes approximately $2.7 million for studies related to the Two-Basin Solution. Such funds are necessary to begin implementing the Study Plan Determination, as well as undertaking the due diligence related to ownership costs and risks. We also expect to confirm the availability of federal funds under Section 1109, Title XI (Western Water and Indian Affairs) of the Consolidated Appropriations Act of 2021.

In the course of the proposed due diligence, the NOI Parties will evaluate the feasibility of continued diversion for water supply in a license surrender scenario. In that scenario, a Regional Entity would own and operate a diversion facility at Van Arsdale, under authority of state law. Our 2020 Feasibility Study Report addressed this scenario at a scoping level. We subsequently prepared Technical Memoranda (attached) to provide additional details. Through the proposed further due diligence, we will determine whether PG&E's water rights would reliably support continued diversion for water supply once license surrender were effective. We will also develop firm estimates of the ownership costs and risks associated with such non-power operation of a diversion facility.

By statute PG&E is barred from seeking or obtaining a new license for this Project. It is prepared to begin license surrender if the NOI Parties withdraw our Notice of Intent or otherwise do not file a New License Application. A license surrender proceeding is the legal alternative to relicensing. Under the statute and the Commission's policy and practice, that proceeding (once started) would be an irrevocable event certainly resulting in license surrender. However, the NOI Parties do not (and cannot) know what the conditions of license surrender would be. Even if we did, we do not have actionable estimates of ownership costs and risks associated with any future diversion for water supply. In sum, based on the available information, the NOI Parties have not resolved among us the comparative feasibility of a new license versus license surrender to advance a Two-Basin Solution. We emphasize that this comparison is strictly from the perspective of the Regional Entity as potential owner, understanding that the Commission will determine the public interest.

The NOI Parties understand that the Integrated Licensing Process has specified intervals and steps to assure timely licensing decisions. And time matters for other reasons. The fisheries in the Eel River Basin are in poor to perilous condition.This threatens the interests of the Round Valley Indian Tribes, other tribes, Humboldt County, and commercial and private fishermen. In turn, water supply in the upper Russian Basin is at a low point unprecedented in living memory. Lake Mendocino may run dry for the first time since construction in 1958. Climate change is a key driver for these worsening crises. In all of these respects, time is of the essence to resolve the future of this Project, and the NOI Parties are committed to expediting all of the work streams described in this letter.

In sum, the NOI Parties request an abeyance in this proceeding until May 31, 2022, so that the parties may further evaluate how the Project would best contribute to a comprehensive strategy to manage the emerging crises in fisheries and water resources management in both basins. The NOI Parties respectfully request that the Commission use its authority under 18 C.F.R. § 5.29(f)(2) to suspend the Process Plan and Schedule as proposed here.

Thank you for your consideration. Please contact Mike Swiger at mas@vnf.com or (202) 298-1891 with any questions about this submittal.

Respectfully submitted,

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CC: Service List, Project No. 77-285

Attachments

TECHNICAL MEMORANDUM ◦ JULY 2021

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

P R E P A R E D F O R

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

P R E P A R E D B Y

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 (partial)	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 (partial)						

[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]	Span									Span	Peak	Peak
Spawning[1,2,3]	Span	Span									Peak	Peak
Incubation[5]	Span	Span	Span	Span							Span	Span
Fry rearing[1,2,5,6]		Span	Span	Span	Span	Span						
Juvenile outmigration[1,2,6]			Span	Peak	Peak	Span	Span					

[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)

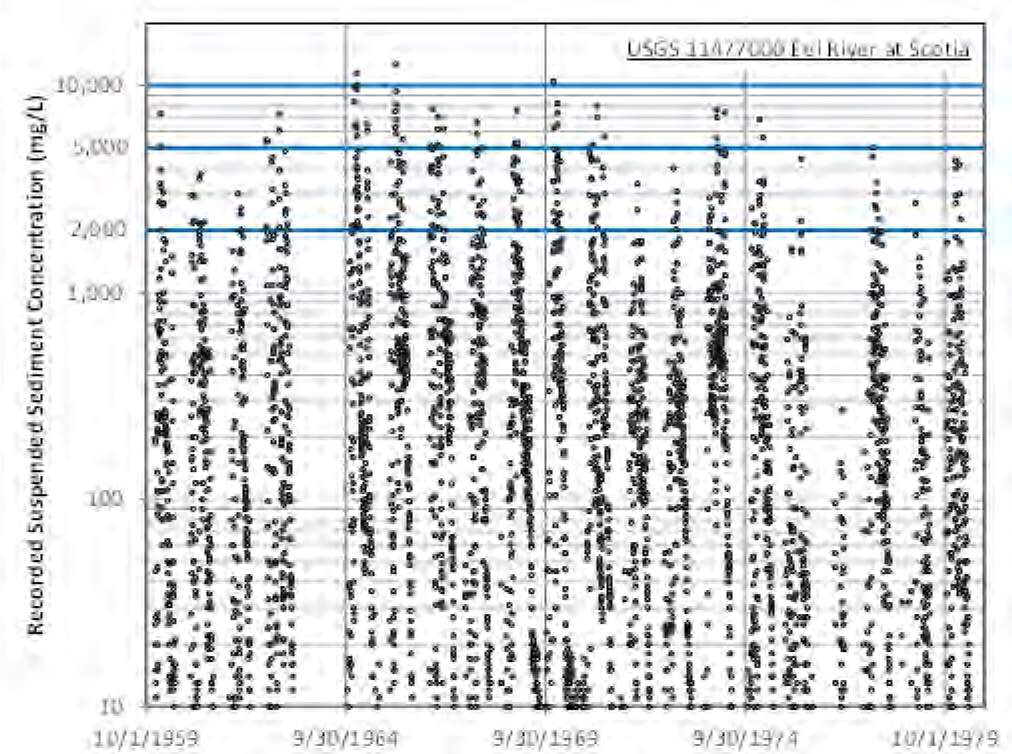

Figure 2. Recorded suspended sediment concentration at USGS gage 11477000 (Eel River at Scotia) (Horizontal blue lines highlight suspended sediment concentration thresholds of 10,000, 5,000, and 2,000 milligrams per liter [mg/L]).

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 $\mathrm{SEV} = b_0 + b_1 \log C + b_2 \log\ D$ 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.

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

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.

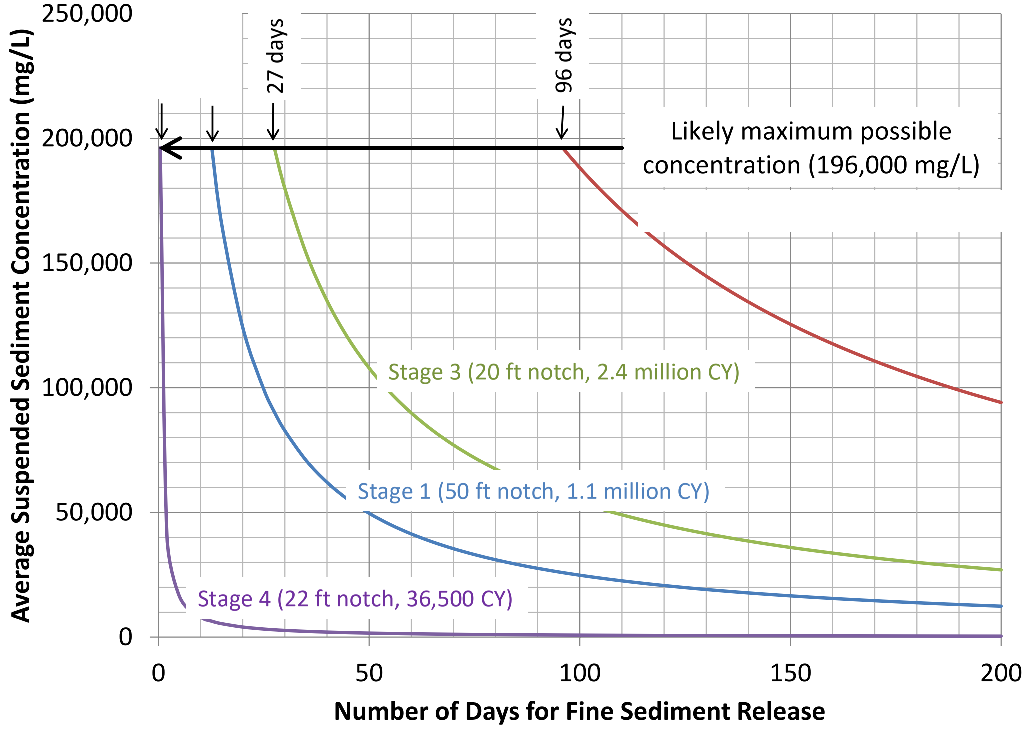

Figure 3. Suspended sediment concentration vs. duration of average suspended sediment concentration for the four-stage dam removal alternative at a flow of 133 cubic feet per second (assuming fine sediment release occurs only during lake level drawdown). Each removal stage would occur in the spring of 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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TECHNICAL MEMORANDUM ◦ JULY 2021

Analyses of Fine Sediment Erosion 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

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Cover photo: Scott Dam on the Eel River, California. Photograph from CalTrout (caltrout.org, accessed September 1, 2020).

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 (Figure 1) 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.

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. Scott Dam (see cover photograph) is a located at river mile (RM) 168.5 on the Eel River and impounds Lake Pillsbury (Figure 1) 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 1922 (PG&E 2017). By 2015, the storage capacity of Lake Pillsbury was reduced to 76,876 acre-ft at the same pool level (McBain and Princeton Hydro 2019) 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. 2021). This Technical Memorandum provides an order-of-magnitude analysis for the erosion of fine sediment from the 21 million CY of sediment stored in Lake Pillsbury following the proposed removal of Scott Dam under two possible dam removal alternatives: a vertical notch alternative that would result in a one-time fine sediment release, and a staged removal alternative that would result in multiple fine sediment releases. Scott Dam removal would release a substantial amount of the sediment stored in the Lake Pillsbury impoundment downstream through natural erosion (i.e., no mechanical sediment removal or stabilization prior to dam removal), and this Technical Memorandum focuses on the general magnitude of suspended sediment concentration and duration of high suspended sediment concentration impact.

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[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] The sediment accumulation calculated by differencing storage values calculated 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.

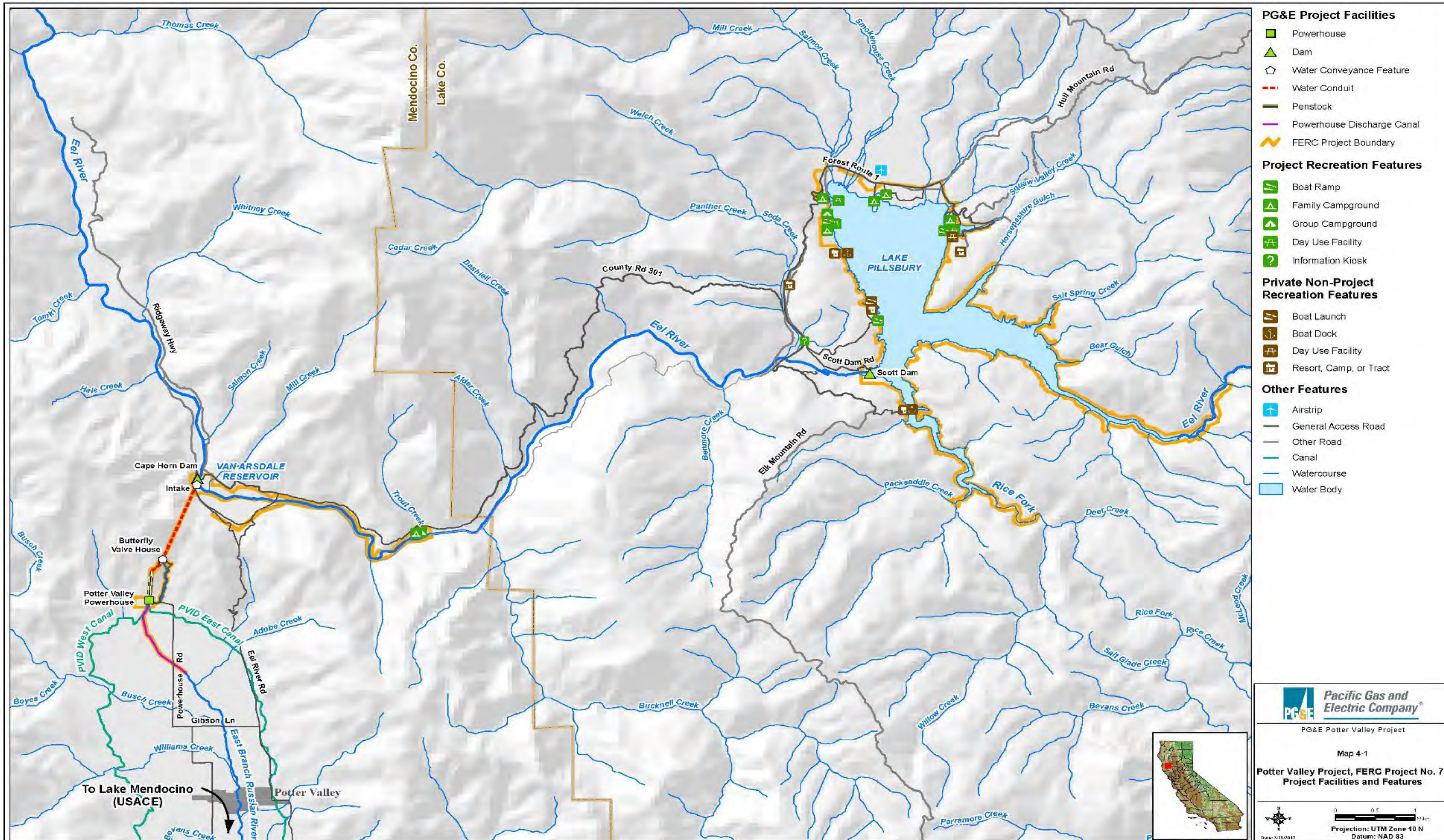

Figure 1. Scott Dam and Lake Pillsbury vicinity, Eel River, California. Figure adapted from PG&E (2017).

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2 METHOD OF ANALYSES

Although numerical modeling has been the primary tool for predicting sediment transport following dam removal (e.g., BOR 1996, 2004, 2011; Stillwater Sciences 2000, 2008; Bountry and Randle 2001; MEI 2003; Cui et al. 2006a, 2006b, 2014, 2018; Langendoen et al. 2005; Cui and Wilcox 2008; Langendoen 2010; Bountry et al. 2013), there are challenges for simulating the erosion of fine sediments, primarily because their release is often driven by a rapid erosional process not addressed by traditional sediment transport theory, making the modeling results unreliable (Cui et al. 2017). Realizing that precise quantification of fine sediment transport is rarely necessary and to avoid the difficulty of numerical modeling, Cui et al. (2017) applied an empirical approach to assess the likely magnitude and duration of high suspended sediment concentration following the proposed removal of Matilija Dam in Southern California, which proved to be adequate to address the potential environmental impacts of alternative scenarios for planning and design purposes. The analyses of Cui et al. (2017) relied on three components to inform the likely magnitude and duration of high suspended sediment concentration following Matilija Dam removal: (1) a two-phase conceptual model (TPCM) for fine sediment erosion from an impoundment following a rapid dam removal; (2) general principles governing geomorphic processes of fine sediment erosion from the reservoir sediment deposit; 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. A combination of these three components provided order-of-magnitude estimates that were adequate and sufficient for the project to move forward. It is our belief that the method of analyses used in Cui et al. (2017) is still appropriate for similar conditions and there are no recent additional advances in fine sediment transport theory to warrant significant amendment to the analyses, although minor adaptions may be appropriate when applied elsewhere due to site specific differences.

A TPCM for fine sediment erosion following dam removal (Cui et al. 2017) addresses dam removal alternatives that would quickly lower the base level control (lake surface elevation in our case) at the dam site to a level that would allow for natural erosion of the bottom-set fine sediment deposit (Figure 2) down to the pre-dam riverbed and historical channel. A TPCM can be adapted to a more general form of base level lowering that may not erode the fine sediment down to the pre-dam riverbed (e.g., notching part of the dam to release part of the fine sediment in storage).

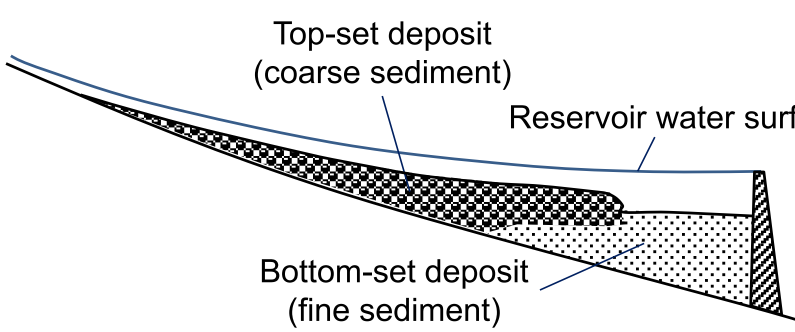

Figure 2. Sketch of a typical reservoir deposit, showing the coarse top-set deposit and fine bottom-set deposit, adapted from Cui et al. (2017).

As illustrated in Figure 3a, years of dam operation results in the accumulation of sediment (mostly fine sediment, plus a small fraction of coarse particles) that can completely bury the historical main channel, and also elevate the historical floodplains or high terraces that were not usually accessible by the flow prior to dam construction. Following a quick lowering of base level control, either by removing a section of the dam to its base or by opening large tunnels near the base of the dam, the flow rapidly cuts through the sediment deposit as a result of the suddenly increased shear stress driven by the significantly elevated local bed slope (Figure 3b). This process is termed Phase 1 erosion and occurs before the flow reaches the pre-dam historical channel bed that prevents further channel degradation and lateral channel migration. During Phase 1 erosion, the flow is in contact with the sediment deposit, which provides virtually unlimited fine sediment supply. The erosion of fine sediment during Phase 1 erosion is "transported limited", meaning the amount of fine sediment transport is determined by the hydraulic sediment transport carrying capacity of the flow.

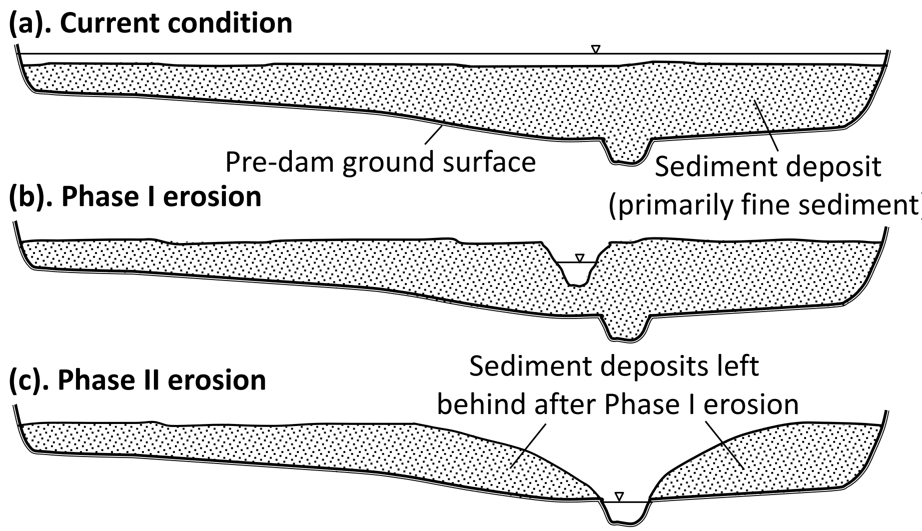

Figure 3. Phase 1 and Phase 2 erosion following dam removal. (a) Reservoir sediment deposit with dam in place; (b). Phase 1 erosion when fine sediment is directly accessible to the flow, presenting a virtually unlimited supply of sediment with transport limited only by the capacity and rate of discharge; and (c) Phase 2 erosion when fine sediment is no longer directly accessible to the flow. Figure adapted from Cui et al. (2017).

Based on the work of Chang (1963), Cui et al. (2017) provided the following equation (Equation 1) to quantify the fine sediment carrying capacity during Phase 1 erosion:

$$C = \begin{cases} 50\left(\frac{V^3}{gHv_s}\right)^{1.55}, & \frac{V^3}{gHv_s} \leq 10 \\ 135\left[ln\left(\frac{V^3}{gHv_s}\right)\right]^{3.1}, & 10 < \frac{V^3}{gHv_s} \leq 100 \\ 620\left(\frac{V^3}{gHv_s}\right)^{0.7}, & \frac{V^3}{gHv_s} > 100 \end{cases} \quad \text{Equation 1}$$

in which *C* denotes suspended sediment concentration in milligrams per liter (mg/L); *V* denotes mean velocity of the flow; *g* denotes acceleration of gravity; *H* denotes mean water depth; and v_s denotes settling velocity of sediment particles.

Once the flow reaches the pre-dam historical channel (or other non-erodible surface), the fine sediment deposits become inaccessible to the flow and fine sediment transport becomes supply limited. This is termed Phase 2 erosion, during which fine sediment transport and suspended sediment concentration is determined by how quickly the fine sediment can be delivered into the main channel through out-of-channel processes (Figure 3c). Cui et al. (2017) noted that there are two primary mechanisms for such processes: (1) bank slumping as water drains out of the deposits, driven by gravity; and (2) local surface erosion during precipitation. The duration of bank slumping is primarily determined by how fast the deposit will be drained to a water content that allows the deposits to maintain their stability. Based on observations of Hengshan Reservoir sediment sluicing, Cui et al. (2017) reasoned that the duration of Phase 2 erosion due to bank slumping would be short (i.e., most likely on the order of hours and at most a couple of days) for the Matilija Dam removal project, and this conclusion should be applicable for other projects as there is minimal site-specific parameter applied in the reasoning. Cui et al. (2017) also derived a maximum possible duration of impact determined by the finite volume of fine sediment deposit left to erode after Phase 1 erosion. Additionally, Cui et al. (2017) assumed the rate for sediment to slump into the main channel for fluvial transport likely decreases approximately exponentially over time, similar to many natural processes (e.g., Graf 1977, Collins et al. 2017). The rate of sediment delivery is derived as follows:

$$E = E_0 exp[-k(t - t_0)] \quad \text{Equation 2}$$

in which *E* denotes the rate of sediment delivery to the channel (mass per unit time); E_0 denotes *E* at the beginning of Phase 2 erosion and is assumed to equal the fine sediment transport rate at the end of Phase 1; *t* denotes time following the start of sediment erosion; t_0 denotes the duration of Phase 1 erosion; and *k* defines the rate of exponential decaying of sediment erosion and delivery to the channel during Phase 2 erosion.

Because there is finite volume of fine sediment that is available for delivery to the channel, a slowly decreasing erosion rate (i.e., a smaller *k* value) would keep the erosion rate high, but as a result will exhaust the sediment source more quickly (Figure 4a). A faster decrease of the erosion rate (i.e., a higher *k* value), on the other hand, would more quickly reduce the suspended sediment concentration to a level that is insignificant compared to the background conditions (Figure 4b). Thus, the worst-case-scenario (i.e., the longest possible duration of discernable impacts from Phase 2 erosion) would be that erosion rate declines such that the sediment source exhausts at the exact time when the suspended sediment concentration reaches a defined “insignificant” or non-impact level (i.e., $k = k_i$ in Figure 4). Based on above reasoning, Cui et al. (2017) derived the following equation (Equation 3) to quantify the likely maximum duration of impacts:

$$t_i = t_0 + \frac{M_2}{C_1 Q_{w1} - C_i Q_{wi}} ln \frac{C_1 Q_{w1}}{C_i Q_{wi}} \qquad \text{Equation 3}$$

in which C_i denotes the incremental suspended sediment concentration that is defined to be minimal (or acceptable) increase in impact to the downstream environment relative to background conditions (referred to as critical suspended sediment concentration hereafter); C_1 denotes suspended sediment concentration at the end of Phase 1 erosion; Q_{w1} denotes water discharge at the end of Phase 1 erosion; Q_{wi} denotes water discharge at the time incremental suspended sediment concentration reached the non-impact level; k_i denotes the exponential coefficient that would result in the longest possible duration of impact; t_i denotes the longest possible impact duration for combined Phase 1 and Phase 2 erosion; and M_2 denotes the total mass of fine sediment deposit that will be eroded during Phase 2 erosion.

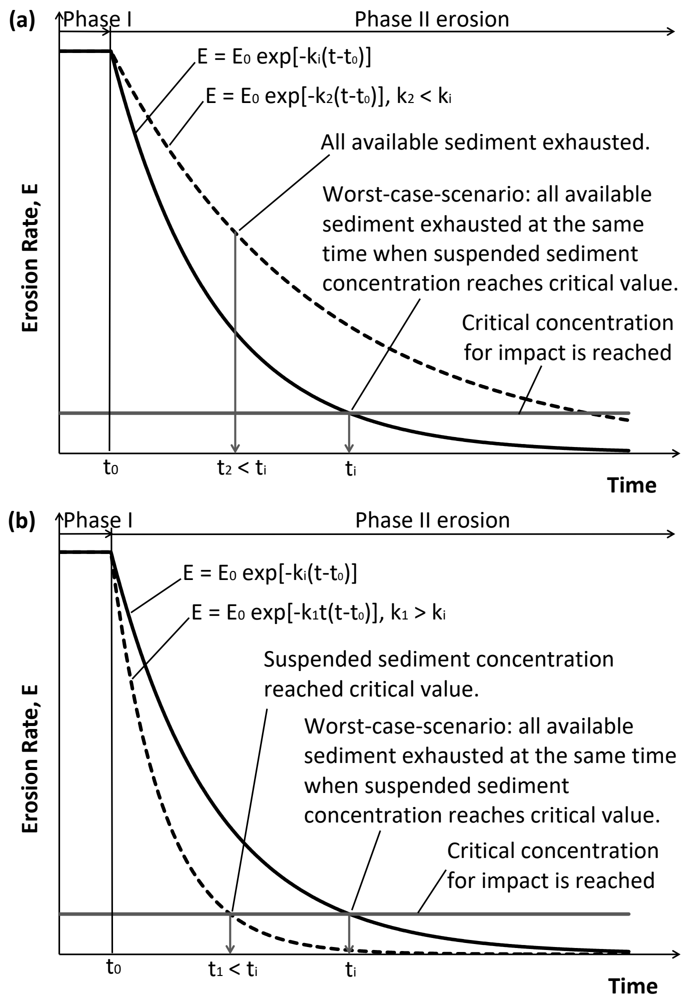

Figure 4. Illustration of the concept of maximum potential duration for Phase 2 erosion: (a) a slower decrease in erosion rate would result in quicker exhaustion of sediment source; and (b) a faster decrease in erosion rate would result in quicker realization of critical suspended sediment concentration for impact. Figure adapted from Cui et al. (2017).

For erosion due to surface erosion during precipitation, Cui et al. (2017) noted that the surface area of the newly exposed land is only a small fraction of the upstream drainage area and the natural sediment production in the watershed is high. The combination of these two conditions made the increased suspended sediment due to surface erosion of the newly exposed land during precipitation insignificant and negligible.

Below we provide a summary of Lake Pillsbury sedimentation (Section 3) and analyses for two dam removal alternatives for Scott Dam (Section 4), with adaptations where necessary.

3 LAKE PILLSBURY SEDIMENTATION

An estimated 21 million CY of sediment was accumulated in Lake Pillsbury between 1922 and 2015 based on the most recent analyses, among which 12 million CY was estimated to be available for fluvial transport downstream following dam removal (Stillwater Sciences et al. 2021). Although sediment accumulation within Lake Pillsbury continued after 2015 and will continue until the day the dam is removed, the 2015 estimates will not be extrapolated primarily because the increased deposit after 2015 was assumed small compared to the existing deposit, and the accuracy of the analyses is only on the order-of-magnitude level. In addition, we will make more conservative assumptions[3], wherever possible, that will more than compensate the neglected future fine sediment deposits to ensure that the results of the analyses are on the conservative side.

Two sources exist for grain size distribution of the Lake Pillsbury sediment deposit: U.S. Geologic Survey (USGS; 1964) and Geosyntec (2020). Neither is comprehensive, and both the USGS and Geosyntec samples were collected from only shallow cores. The USGS (1964) samples included 24 density samples collected using calibrated density probe and 26 grain size samples collected using a split-core sampler suspended by boat-mounted streamflow-measuring equipment that likely penetrated only shallow depths into the deposits. Dry density of the USGS (1964) samples ranged between 1,096 and 2,349 pounds per cubic yard (lb/CY; 41–87 pounds per cubic foot [lb/ft^3]) with an average density of 1,590 lb/CY (59 lb/ft^3). Median grain size of the samples ranged between 0.0031 and 0.32 millimeters (mm) with an overall median value of 0.011 mm. The Geosyntec (2020) sampling did not provide dry density and grain size distribution information, but the fractions of silt and clay data from the samples were consistent with the data provided in USGS (1964). With additional sediment sampling still in the planning stage and with the logical assumption that continued sediment accumulation after the USGS (1964) study would be similar to that which occurred prior to the 1964 study, the dry density and median grain size information from USGS (1964) discussed above is used as input for analyses provided in this Technical Memorandum. Future refinements/updates to the analyses may be warranted if it is determined that new information collected during the subsequent studies might change the results and conclusions of the analyses presented in this report.

[3] Conservative means that the estimated duration of impact will be longer than the actual impact duration because the primary purpose of the alternative is to minimize the duration of impact. This applies for all occasions in this document.

4 SCOTT DAM REMOVAL ALTERNATIVES

There have been several preliminary dam removal alternatives for discussion regarding Scott Dam removal (e.g., McMillen Jacobs Associates 2018, McBain and Princeton Hydro 2019), many of which would manage the lake deposits in such a way that variable amounts of erosion of fine sediment would occur (i.e., mechanically remove or stabilize most sediment prior or during removal). This report focuses on two dam removal alternatives that would release fine sediment downstream through natural erosion: (1) a new vertical notching dam removal alternative proposed in this document, and (2) a four-stage dam removal alternative described in McBain and Princeton Hydro (2019). The two alternatives are discussed briefly below.

4.1 Vertical Notching Dam Removal Alternative

Dam removal with the vertical notching alternative would start in late spring during the low flow season (May through November), by drawing the lake level down to approximately 1,781 ft elevation (~1,860 ft PG&E elevation) using the existing valve located near the right bank, and potentially the grizzly and/or sluice outlets if functional (Figure 5a,b). Dam removal would occur concurrently with lake level drawdown, mostly working dry above lake surface level. Minimal wet operation may be needed once the outlets are becoming inadequate to keep up with the drawdown or unable to drawdown to the designed removal elevation due to their limited capacity or unexpected blockage of valve inlet by woody debris. A section of the dam would be removed a few feet (exact value to be determined) lower than the rest of the dam to allow for overflow that exceeds the capacity of the outlets and to keep the rest of the section dry (Figure 5b). The rationale for selecting 1,781 ft elevation as the target for initial drawdown is because this lake level was reached during the drought of 2014, and thus it is likely that the drawdown will result in minimal sediment release. Once the top of the dam is removed, vertical holes would be drilled from the top of the remaining dam to reach the pre-dam riverbed elevation of 1,709 ft (1,787.7 ft PG&E elevation) for a narrow section of the dam (the notching section hereafter, section width to be determined, but will likely be on the order of 10–20 ft) (Figure 5c). Concurrent with the drilling, the lower spillway within the notching section would be removed using hydraulic hammers and explosives to finish the preparation for final dam removal and sediment release (Figure 5c). To start the final dam removal, explosives would be installed into the holes drilled earlier just before the first winter storm event or preferably before a forecasted target high flow event, and the section would be blasted open to allow for sediment erosion and quick lake drawdown (Figure 5d). The section width would be determined later to ensure the action will not result in unacceptable flooding risks downstream. It is our initial judgement that blasting a vertical notch on the dam would be unlikely to destabilize the remainder sections of the dam because Scott Dam is a concrete gravity dam, but additional assessment is needed by dam safety engineers if this removal method is deemed as potentially feasible. Once the vertical notch is open, the remaining of the dam can be removed using hydraulic hammers or other mechanical methods deemed appropriate (Figure 5e). This method would result in a single high turbidity event similar to that of the proposed Matilija Dam removal project described in Cui et al. (2017).

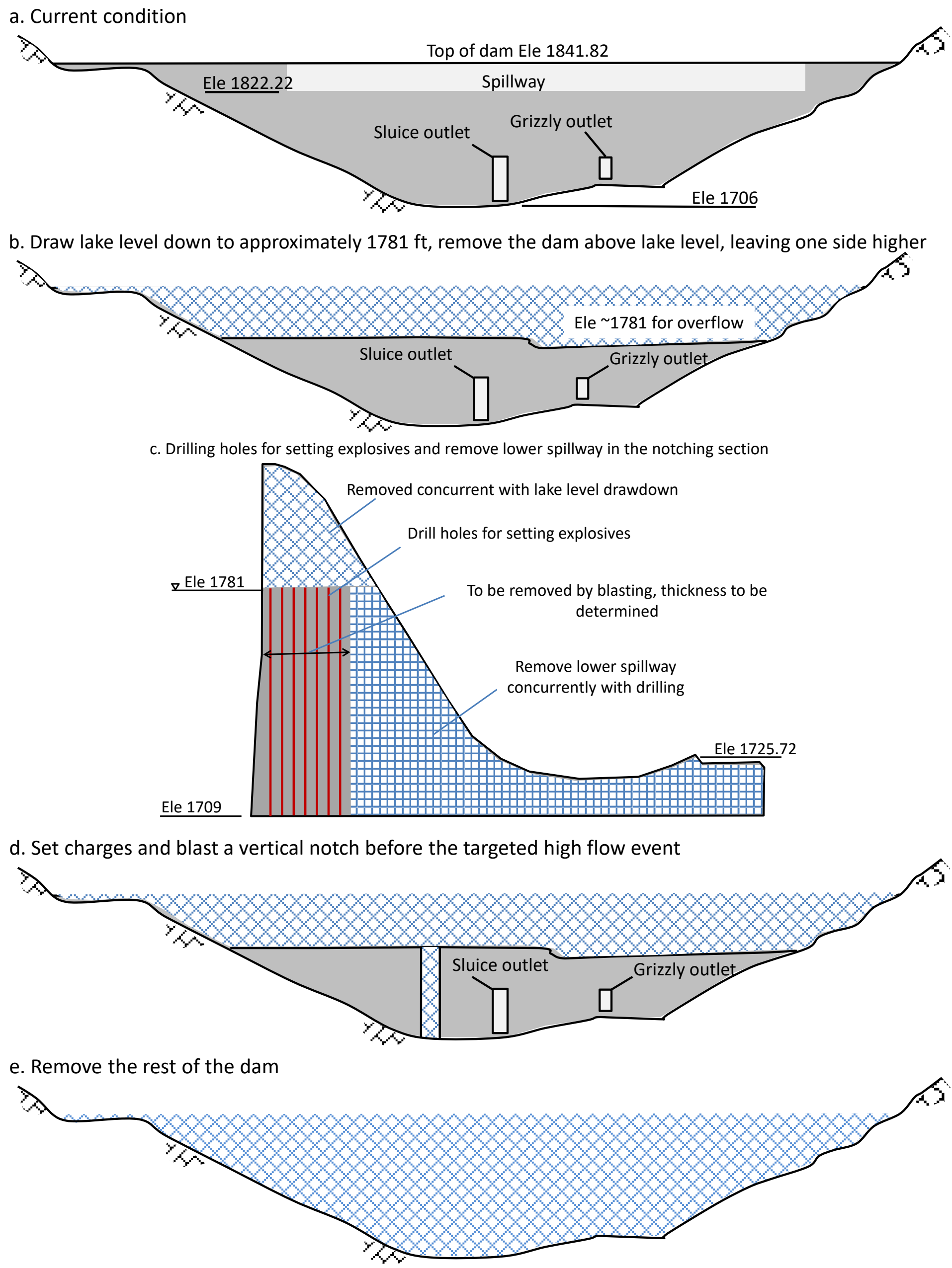

Figure 5. Schematics illustrating the proposed vertical notching alternative for Scott Dam removal for rapid sediment evacuation from Lake Pillsbury. (a) Current Scott Dam cross section; (b) draw lake level down using available outlets during the low flow season (May through November), to an elevation of approximately 1,781 ft, remove the portion of the dam above lake level after drawdown, leaving one side (the one that is more easily accessible) of the dam a few feet higher so that high flow passes only through the other side; (c) and (d) drill holes and remove lower spillway in the notching section, install explosives in the holes and blast open a vertical notch just before the first winter storm event or before a forecasted target high flow event to allow for quick sediment erosion and lake drawdown; and (e) remove the remaining portion of the dam to complete dam removal. Note (c) is a profile view rather than a cross section view, and thus has a different scale from the other sketches.

Another method that could achieve the same effect on sediment transport would be to blast open tunnels near the base of the dam prior to the first winter storm event or preferably prior to a forecasted target high flow event similar to that proposed for Matilija Dam removal (Cui et al. 2017), but the cost associated with tunnel construction is most likely much higher than the vertical notching alternative, unless it can be accomplished with the existing Sluice and Grizzly outlets (*i.e.*, one or both outlets can be opened either mechanically or by blasting, and the combined capacity of the outlets is adequate to accommodate the design flow as open channel flow). If, however, Scott Dam is reenforced with steel bars, which is extremely unlikely, the proposed vertical notching alternative may become infeasible, and tunneling through the base of the dam may become a preferred method for quick fine sediment release. In that case, the analyses and results provided in this Technical Memorandum will be equally applicable without the need for additional adjustments.

4.2 Four-stage Dam Removal Alternative

The four-stage dam removal alternative as described in MA & PH (2019) would remove the dam through successive notching, removing the dam to 1771.22 ft (1,768.3 ft NVGD29 elevation, 1,850 ft PG&E elevation), 1751.22 ft (1,748.3 ft NVGD29 elevation, 1,830 ft PG&E elevation), 1731.22 ft (1,728.3 ft NVGD29 elevation, 1,810 ft PG&E elevation), and 1708.92 ft (1,706.0 ft NVGD29 elevation, 1,787.7 ft PG&E elevation) in four dry seasons. Refined analysis that assumed removing the dam to a certain elevation would release all reservoir deposits above that elevation resulted in 1.1 million CY, 8.5 million CY, 2.4 million CY, and 36.5 thousand CY sediment release for Stage 1, 2, 3 and 4 removal, respectively (Stillwater Sciences et al. 2021). For safety reasons, dam removal and sediment mobilization would occur during the low flow season (May through November) when the discharge in the river is low. The staged removal would be completed in multiple years: following the completion of one stage of removal, personnel and equipment would be demobilized, allowing the winter high flow to pass over the partially removed dam, and the next stage of removal would occur during the next low flow season or seasons.

5 ANALYSES OF FINE SEDIMENT EROSION DURING SCOTT DAM REMOVAL

Below we start the analyses with the vertical notching alternative because the TPCM of Cui et al. (2017) briefly described in Section 2 above can be directly applied under this alternative.

5.1 Fine Sediment Erosion under Vertical Notching Alternative

Equation (1) needs to be closed with Manning's equation below in conjunction with a series of assumptions on the value of parameters to provide some useful information regarding the potential magnitude of high suspended sediment concentration and potential duration of impact following dam removal.

$$Q_w = \frac{1.48}{n} B H^{5/3} S^{1/2} \qquad \text{Equation 4}$$

in which Q_w denotes water discharge; n denotes Manning's n; B denotes channel width; H denotes average water depth; and S denotes channel gradient. Equation (4) is expressed in imperial unit with water discharge in cfs and channel width and water depth in feet. It also needs to convert suspended sediment concentration to the rate of fine sediment erosion with

$$Q_s = CQ_w/\rho_d$$ Equation 5

In which Q_s denotes the rate of fine sediment erosion expressed as bulk volume per unit time; C denotes suspended sediment concentration expressed as dry mass per unit volume, and ρ_d denotes dry density of the sediment deposit (dry mass per unit bulk volume). The duration of Phase 1 erosion is then calculated as

$$t_0 = M_1/Q_s$$ Equation 6

In which t_0 denotes Phase 1 erosion duration; and M_1 denotes the bulk volume of Phase 1 fine sediment erosion. The parameters used for evaluation are discussed below:

5.1.1 Water Discharge (Q_w)

The intention of the vertical notching alternative is to minimize the duration of high suspended sediment concentration through rapid sediment evacuation as a measure to minimize the downstream ecological impacts. As such, it is advantageous to initiate sediment mobilization (i.e., to blast open the vertical notch) prior to a large storm event that would provide high discharge that lasts for a relatively long period of time. Here we use the simulated unimpaired water discharge into Lake Pillsbury (Addley et al. 2019) for analysis as water discharge in the study reach will revert back to unimpaired flow following Scott Dam removal.

Figure 6 shows the unimpaired annual maximum daily average discharge downstream of Scott Dam, and Figure 7 shows the number of days unimpaired water discharge exceeds 2,000 cfs. Data in Figure 6 and Figure 7 indicates that a 2,000 cfs daily average discharge is exceeded for almost all the water years, with durations longer than at least 5 days for most of these years. With that, we selected 2,000 cfs as our target dam removal water discharge for examination. We also examine 1,000 cfs and 5,000 cfs to provide a range of sensitivity as what would likely occur if water discharge is significantly lower or higher than the 2,000 cfs target discharge.

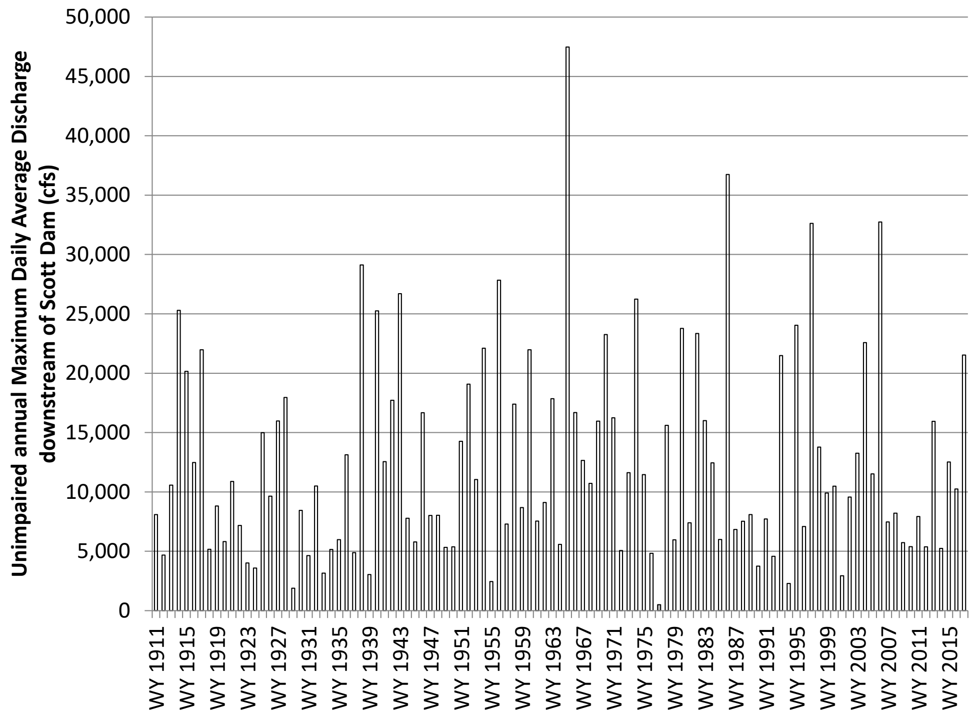

Figure 6. Annual maximum daily average discharge downstream of Scott Dam, based on simulated unimpaired daily average discharge series (Addley et al. 2019).

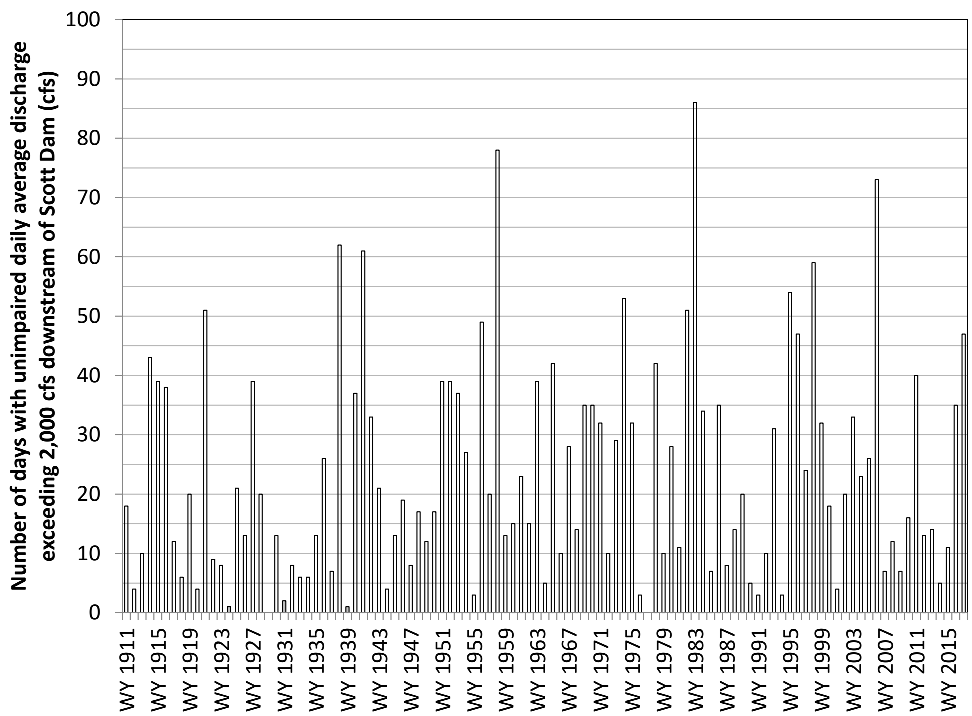

Figure 7. Number of days with unimpaired daily average discharge downstream of Scott Dam exceeds 2,000 cfs, based on simulated unimpaired daily average discharge series (Addley et al. 2019).

5.1.2 Channel Width (B)

Base level would be lowered by approximately 70 ft following the blast opening of the vertical notch, resulting in rapid down cutting of the reservoir sediment deposits, which in turn will promote the formation of a narrow active channel. For the analyses here, we assume an active channel width of 300 ft, which is the estimated bankfull width of the Eel River downstream of Scott Dam. The actual active channel width formed following the opening of the vertical notch cannot be accurately assessed, but is expected to be significantly narrower than this assumed value based on Google Earth aerial photographs of recent years. Using a larger width value for analysis will result in conservative assessment of the impact.

5.1.3 Channel Gradient (S)

With the rapid down cutting of the reservoir sediment deposit, channel gradient would become much steeper than the ambient channel gradient in the area of active sediment erosion. For the analysis here, we assume a channel gradient of 0.01, which is the minimal reach average channel gradient of the tributaries entering Lake Pillsbury just upstream of the inundated area (Figure 8). The local channel gradient with active sediment erosion is expected to be much steeper than this assumed value. Using a lower channel gradient value for analysis will result in conservative assessment of the impact (see Section 3 for definition of conservative assessment).

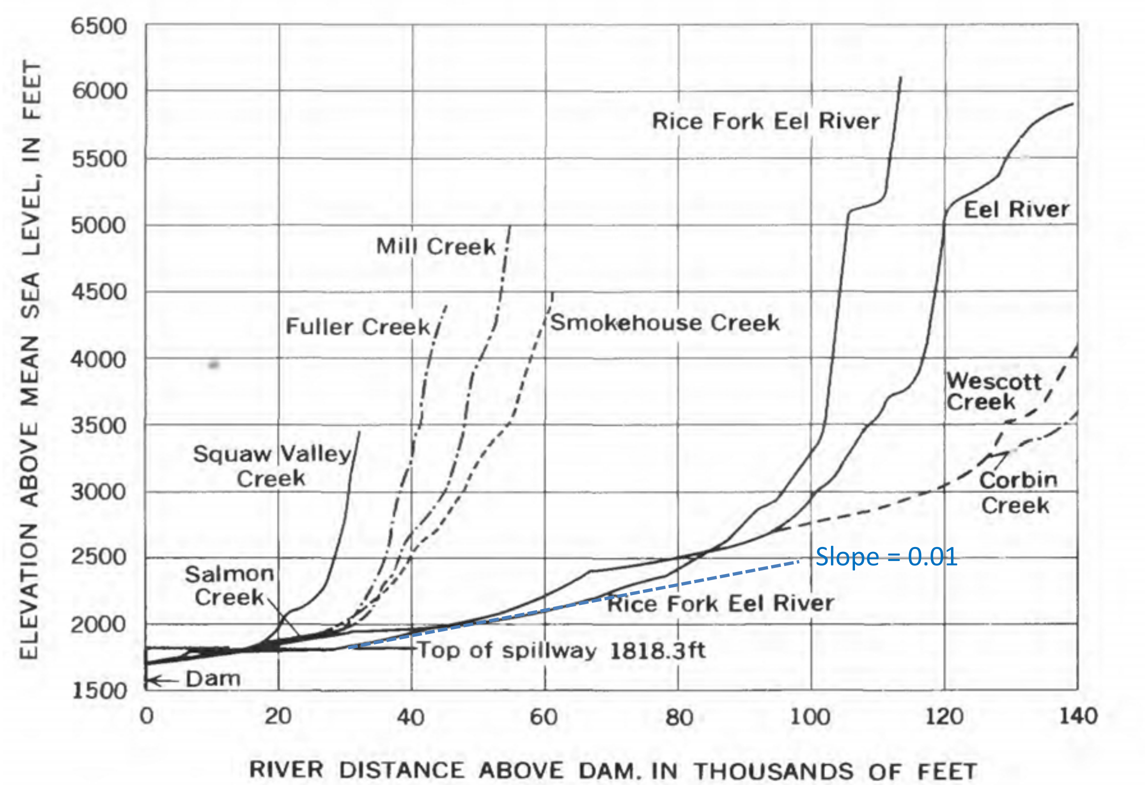

Figure 8. Longitudinal profile of the tributaries entering Lake Pillsbury, showing a minimum slope of 0.01 just above the inundation zone. Figure adapted from USGS (1964).

5.1.4 Settling Velocity of Sediment Particles (v_s)

We use the median value of the 0.011 mm median grain size of the 26 USGS (1964) samples as a representative of the sediment particles to calculate the particle settling velocity. Applying the procedures of Dietrich (1982) using the 0.011 mm particle size resulted in a settling velocity of 3.58×10^{-4} ft/s (1.09×10^{-4} m/s).

5.1.5 Dry Density of the Sediment Deposit (ρ_d)

We use the average dry density of the USGS (1964) samples (1,590 lb/CY, or 943,000 mg/L) for analyses. Note that the calculated Phase 1 erosion suspended sediment concentration must be limited to within the 943,000 mg/L level as the suspended sediment concentration cannot exceed the dry density of the deposits.

5.1.6 Volume of Phase 1 Sediment Erosion (M_1)

An estimated 12 million CY of sediment can potentially be mobilized, which includes both fine and coarse sediment (Stillwater Sciences et al. 2021). For the Phase 1 erosion calculation, we assume all the 12 million CY of sediment erosion will be fine sediment, and all of which will be eroded during Phase 1 erosion. This would result in a conservative impact assessment because the actual Phase 1 fine sediment erosion will likely be smaller. In addition, we also provide an estimate assuming 21 million CY Phase 1 fine sediment erosion, which is the absolute (and impossible) maximum, just to illustrate that the duration for Phase 1 erosion cannot be overly long.

5.1.7 Manning's n (n)

Manning's n value is assumed to be 0.025, a typical value for straight channels (e.g., Henderson 1966).

5.1.8 Results

Table 1 below provides the calculated magnitude of suspended sediment concentration and duration for Phase 1 erosion assuming 12 million CY Phase 1 fine sediment erosion, indicating that opening the vertical notch under 2,000 cfs flow would result in approximately 600,000 mg/L suspended sediment concentration with less than 3 days Phase 1 erosion. If water discharge is only 1,000 cfs, the suspended sediment concentration would be between 400,000 and 500,000 mg/L with less than 8 days of Phase 1 erosion. If water discharge is 5,000 cfs, the suspended sediment concentration would be 900,000 mg/L during Phase 1 erosion that would last for approximately a full day following the opening of the vertical notch.

Table 1. Calculated magnitude of suspended sediment concentration and duration for Phase 1 erosion for 12 million CY fine Phase 1 sediment erosion under the vertical notching dam removal alternative.

Water discharge (cfs)	**1,000**	**2,000**	**5,000**
Suspended sediment concentration (mg/L)	457,800	612,500	900,000
Duration of Phase 1 erosion (days)	7.7	2.9	0.8

Although the assumptions used for the assessment provided in Table 1 are most likely already conservative (i.e., over-estimated Phase 1 erosion duration, and assumptions with channel width and channel gradient), we also provide the calculated Phase 1 erosion duration in case the Phase 1 erosion volume is 21 million CY, which is the total estimated volume of sediment deposition

(Table 2). Note this is the absolute maximum and an impossible scenario, but the results demonstrate that Phase 1 erosion will not be more than a few days even if some of our parameters in the calculation happen to be assigned on the less conservative side, which we do not believe to be the case.

Table 2. Calculated duration of Phase 1 erosion assuming the absolute (and impossible) 21 million CY Phase 1 fine sediment erosion under the vertical notching dam removal alternative.

Water discharge (cfs)	**1,000**	**2,000**	**5,000**
Duration of Phase 1 erosion (days)	13.5	5.0	1.4

Note: Calculated magnitude of suspended sediment concentrations are identical to that provided in Table 1

For Phase 2 erosion, the assessment of Cui et al. (2017) that it would last only for a few hours, and a few days at most, is applicable for Scott Dam removal because their reasoning used minimal site-specific information, with the only mentioned site-specific information being the median size of the fine sediment deposit. Ironically, the Matilija sediment deposit in Cui et al. (2017) has an identical median size as Scott Dam fine sediment deposit (i.e., both are 0.011 mm). We can also apply the limitation analysis of Cui et al. (2017), briefly described in Section 2 and Figure 4, to calculate a maximum possible (but most likely improbable) Phase 2 impact duration. To do that, we need to assign a critical suspended sediment concentration (C_i in Equation 3), with impact to fisheries and other resources becoming acceptable once the suspended sediment concentration become lower than this critical value. Examinations of the recorded suspended sediment concentration at USGS gage 11477000 (Eel River at Scotia) in Figure 9 indicate that suspended sediment in the Eel River exceeds 5,000 mg/L in many of the recorded years, and the highest recorded suspended sediment concentration exceeds 10,000 mg/L. Here we assume that a relatively high but short duration suspended sediment concentration on the order of 5,000 mg/L would be acceptable to fisheries and other resources due to the anticipated post-project benefit, and therefore assigned 5,000 mg/L as the critical concentration. We further assumed that water discharge would be kept at 2,000 cfs during the entire period of fine sediment erosion. Applying these assumptions to Equation 3 resulted in a maximum possible duration of Phase 2 impact on the order of a few days (Figure 10). Note that it is unclear what volume of fine sediment erosion would occur during Phase 2 erosion, but given that the Lake Pillsbury deposit is very deep (> 40 ft in some area), it is expected that the majority of the sediment erosion would occur during Phase 1 erosion, resulting in a very small amount of Phase 2 erosion and tight limitation to its duration. In case of a 2 million CY Phase 2 erosion, for example, the duration of impact would be limited to within 2 days based on the results in Figure 10.

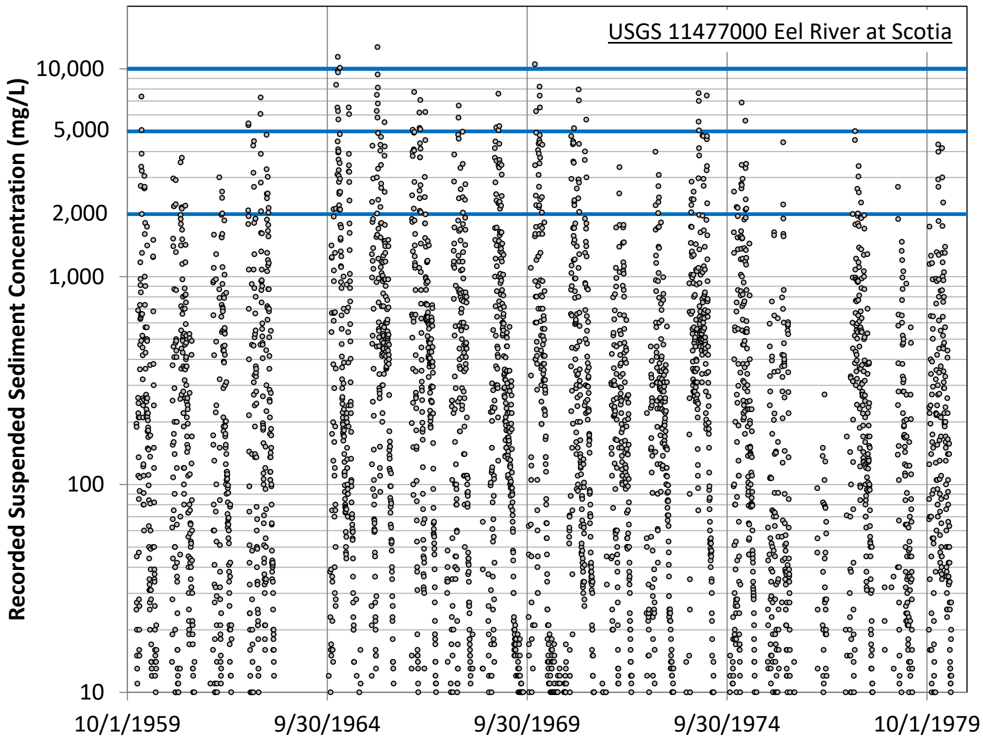

Figure 9. Recorded suspended sediment concentration at USGS gage 11477000 (Eel River at Scotia) (Horizontal blue lines highlight suspended sediment concentration thresholds of 10,000, 5,000, and 2,000 milligrams per liter [mg/L]).

As discussed earlier, surface erosion of the exposed impoundment deposits during precipitation after dam removal would also contribute additional fine sediment supply, but the area of the newly exposed land following dam removal (< 2,300 acres) would be only a small fraction (approximately 1%) of the catchment area upstream of Scott Dam (approximately 289 mi^2). This, in combination with the fact that the Eel River has a high ambient sediment production should make the impact from the additional Phase 2 suspended sediment contribution due to precipitation and surface runoff negligible, especially when compared with the extremely high suspended sediment concentration in the first few days following dam removal. In addition, Phase 1 and Phase 2 erosion mainly addresses the erosion of the bottom-set deposit (Figure 2) that is composed primarily of silt, clay and fine sand. Upon the conclusion of Phase 1 and Phase 2 erosion, the top-set deposit (Figure 2), which is composed primarily of gravel and perhaps coarser sand, will continue to degrade during high flow events, releasing fine sediment previously locked within the deposits. The increased suspended sediment concentration due to top-set erosion, however, is expected to have minimal impact for two reasons: (1) the amount of fine sediment content in the top-set deposit is much smaller compared to the bottom-set deposit; and (2) significant top-set erosion occurs only during high flow events, during which ambient suspended sediment concentration is high, and the large discharge would also make the increased suspended sediment concentration from top-set erosion low. In short, we do not expect significant impact from increased suspended sediment concentration once Phase 1 and Phase 2 erosion is concluded for the case of vertical notching alternative.

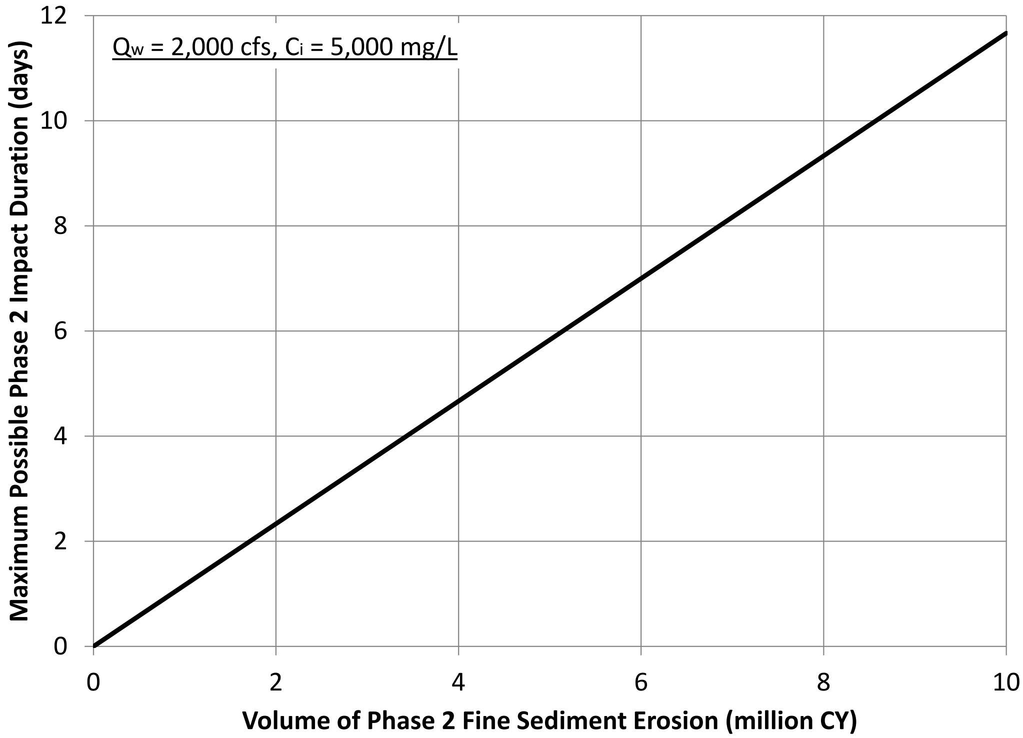

Figure 10. Calculated maximum possible duration of Phase 2 erosion duration based on Equation 2 under 2,000 cfs water discharge; actual Phase 2 erosion is expected to last for a few hours.

5.2 Fine Sediment Erosion Under Four-stage Removal Alternative

There are two major differences in fine sediment erosion between the four-stage removal alternative to be analyzed in this section and the vertical notching alternative analyzed in the previous section: (a) vertical notching would release fine sediment before a relatively large flow event while staged removal would likely release fine sediment primarily during low flow seasons; and (b) vertical notching would result in a single major sediment release event while staged removal would result in multiple fine sediment release events.

Figure 11 below shows the recorded monthly average discharge downstream of Scott Dam, indicating that the low flow season is between May and November, and the average unimpaired discharge during this period is 133 cfs. In the analysis below we assume that dam removal work would be conducted during this low flow period, and the discharge would be kept at a constant value of 133 cfs for simplicity.

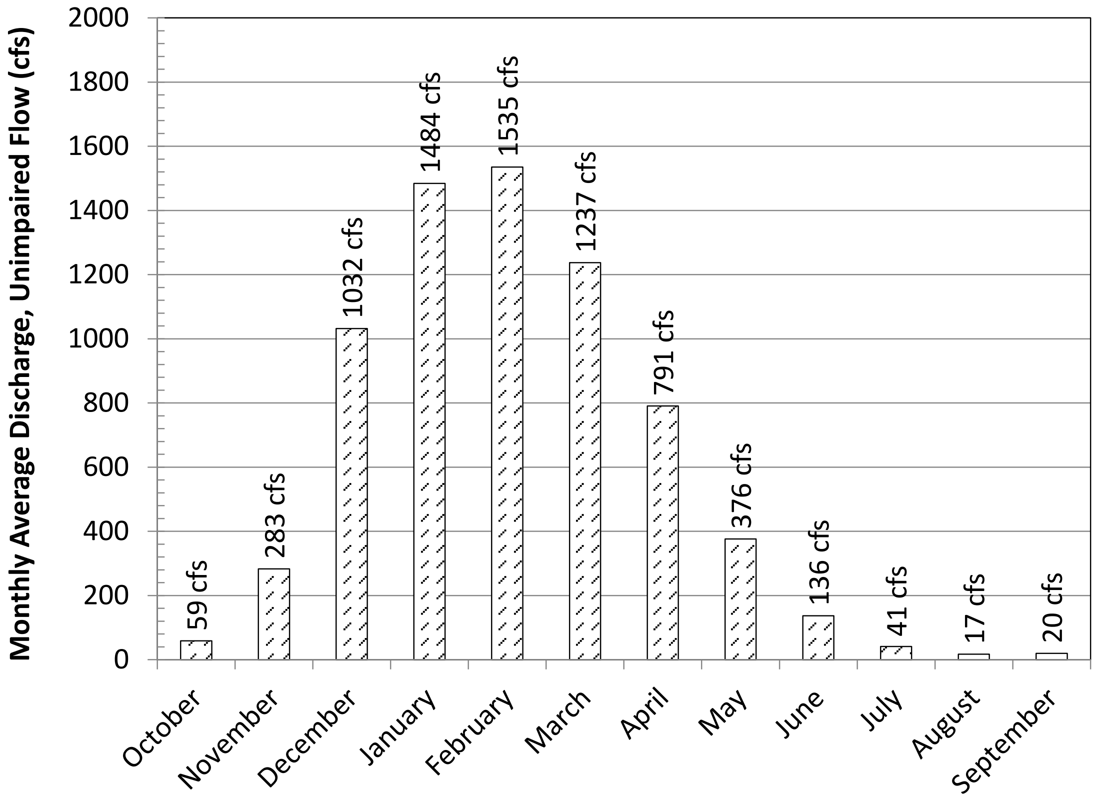

Figure 11. Unimpaired monthly average water discharge downstream of Scott Dam based on simulated unimpaired discharge series WY 1911–2017 (Addley et al. 2019), indicating staged removal and lake drawdown will likely occur in the low flow season of May through November (the assumed construction season). Figure provided by McBain Associates.

With the progress in dam removal during the assumed May through November construction season, base level would be lowered gradually using the existing valve and overflow if the valve capacity is inadequate to keep up with the lowering of the dam surface. The initial part of the removal (prior to Lake Pillsbury Lake level reaching 1,781 ft, as discussed above in Section 4.1) would result in minimal release of fine sediment deposited in the impoundment as the water depth is still relatively deep and shear stress relatively low, but at certain point significant fine sediment erosion would start to occur as shear stress continuously increase with the lake level drawdown. If the rate of dam lowering is quick enough, the equations for TPCM Phase 1 erosion analysis presented above (i.e., Equations 1, 4, and 5) can be used to provide an estimated suspended sediment concentration. Applying the same channel width and channel gradient as used in Section 5.1 and change water discharge to 133 cfs would result in a suspended sediment concentration value of 196,000 mg/L. But in general, the rate of dam lowering is likely much slower than what is needed to maintain this erosion rate, resulting in a suspended sediment concentration lower than the above calculated value. A more precise suspended sediment concentration, however, cannot be estimated reliably due to limitations in current sediment transport theory. With the estimated volume of fine sediment erosion discussed in Section 4.2 and applying Equation (6), a suspended concentration – impact duration (number of days for fine sediment release) curve can be developed for each stage of dam removal, as shown in Figure 12.

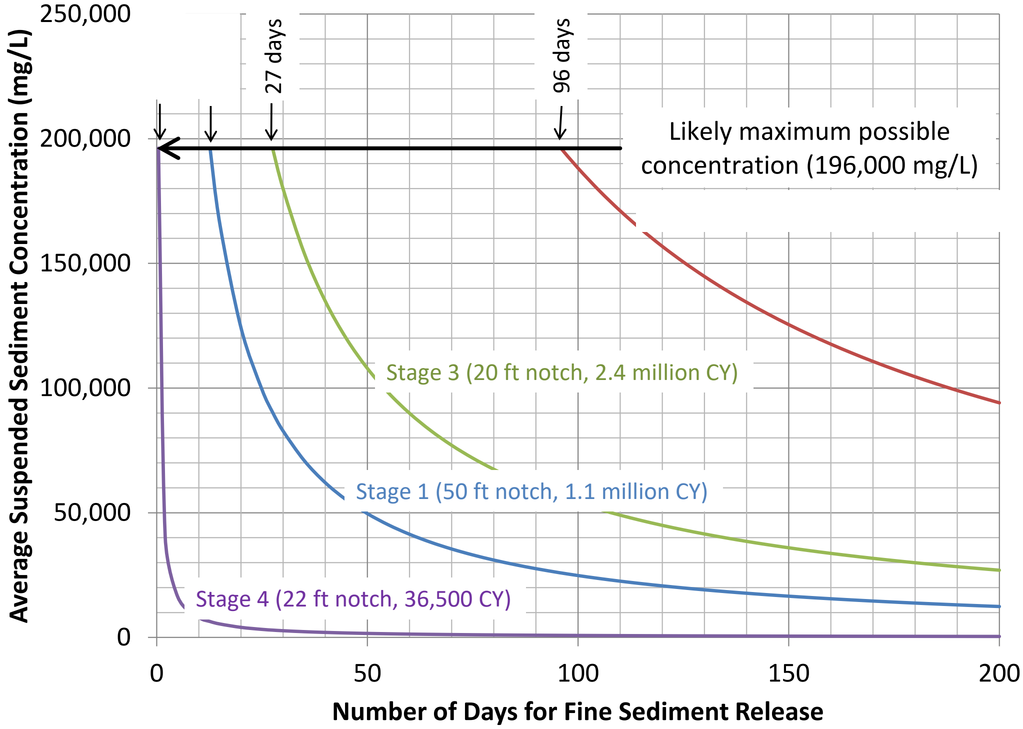

Figure 12. Suspended sediment concentration vs. duration of high suspended sediment concentration for the four-stage dam removal alternative at 133 cfs discharge, assuming sediment release occurs only during lake level drawdown.

In the absence of reliable estimate of the suspended sediment concentration, the curves presented in Figure 12 would be useful to develop some "what-if" scenarios to inform the potential downstream impacts. For example, results in Figure 12 indicate that there would be a minimum of 136 days (13 days + 96 days + 27 days + 10 hours ≈ 136 days) of fine sediment release for the four stages of dam removal with likely maximum suspended concentration of 196,000 mg/L. Note in Figure 12, the suspended sediment concentration is inversely correlated to the duration of number of days of fine sediment release because the concentration is constrained by the available sediment in each notching phase. If, for example, the suspended sediment concentration is kept at 100,000 mg/L, there would be 25 days of fine sediment release during Stage 1 removal, 189 days during Stage 2, 52 days during Stage 3, 1 day during Stage 4, or a combined 267 days of high turbidity impact compared to the 118 days for the case of 196,000 mg/L suspended sediment concentration.

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. 2021), and the actual volume release will certainly differ. Stage 1, for example, removes the dam to an elevation of 1,771.22 ft, which is only approximately 10 ft lower than the 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 is likely very few to no days with elevated suspended sediment concentration during the construction season. 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 we redistribute the volume of erosion amongst the four construction seasons.

It needs to be realized that the actual case will be significantly complicated, with both the lake lowering speed and water discharge varying over time. The estimated average inflow for the dry season (July through September), for example, is only 34 cfs (Figure 11), which is significantly lower than the 133 cfs used for the calculations presented above. With a lower inflow during the dry season, suspended sediment concentration is likely somewhat lower than that at 133 cfs, but probably not significantly lower (i.e., still on the same order of magnitude): a lower water discharge will result in a lower (and still unknown) channel gradient, which would drive down the suspended sediment concentration; meanwhile, a lower discharge would also result in a narrower channel, which would drive up the suspended sediment concentration and canceling part of the effect from the decreased channel gradient. As a result, the combined effect of a lower channel gradient and narrower channel for a 34 cfs discharge would likely result a suspended sediment concentration that is only marginally lower than that at 133 cfs. As a demonstration, reducing both the channel gradient and channel width to half of that used for early calculations (i.e., change channel gradient and channel width to 0.005 and 150 ft, respectively) and use a discharge of 34 cfs would result in a calculated maximum suspended sediment concentration of 83,000 mg/L, or about half of what was calculated for the 133 cfs discharge. With a lower discharge and high volume of available fine sediment for erosion, it is almost guaranteed that high suspended sediment concentration would persist during the entire low flow season (i.e., May through September). Despite the high suspended sediment concentration during the low flow season, 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 winter high flow events and during subsequent seasons. Because of that, it is expected that an acute peak high suspended sediment concentration event would occur during the first winter high flow event, eroding a significant amount of fine sediment. The suspended sediment concentration during this 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).

It is useful to note that the above analysis is based on the worst-case-scenario assumptions that did not consider the trapping of sediment in the deeper part of the lake during the early phases of dam removal and the possible occurrence of higher flows during the construction season. The trapping of the mobilized fine sediment in the deeper part of Lake Pillsbury during dam deconstruction can potentially lower the suspended sediment concentration downstream of the dam during construction, and the trapped sediment can be released during winter high flow events or in the later phases of the deconstruction. However, given the fine sized particles in the deposit (median size = 0.011 mm, with settling velocity for the median sized particles = 3.58×10^{-4} ft/s), the majority of the mobilized fine sediment will pass the dam without settling, and the contribution from the trapping to suspended sediment concentration is likely minor. Relatively high flow during the construction season is likely a stronger contributor toward the lowering of the impact of suspended sediment concentration: a high flow would erode more sediment in a shorter period of time, resulting in a relatively lower suspended sediment concentration after the high flow event (i.e., instead of being in a constant state of high suspended sediment concentration, there would be periods of high and low suspended sediment concentration due to occasional high flow events during the construction season). Because of the uncertainties associated with potential high flows during construction season, it is recommended that the potential beneficial impact associated with the occurrence of high flow events during construction season not be considered for subsequent analysis as a conservative measure so that the actual duration of impact would not be longer than estimated by the analysis.

6 SUMMARY

Removing Scott Dam with the proposed vertical notching alternative would result in a one time high suspended sediment concentration 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 water discharge following notch opening is around the targeted 2,000 cfs (Table 1). If the discharge following notch opening is only 1,000 cfs, however, the suspended sediment concentration would be reduced to 400,000–500,000 mg/L that would most likely last for approximately 9 days (8 days Phase 1 erosion, 1 day Phase 2 erosion). If the discharge following notch opening is 5,000 cfs, the suspended sediment concentration would be increased to approximately 900,000 mg/L that would most likely last for approximately 2 days (1 day Phase 1 erosion, 1 day Phase 2 erosion). A higher discharge following notch opening would result in higher suspended sediment concentration up to a little bit more than 900,000 mg/L and would shorten the duration of the high suspended sediment and turbidity.

Removing Scott Dam with the proposed four-stage alternative 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 at least 136 days that spans four water years, if the rate of notching is adequately fast. The most likely result under this alternative, however, is a suspended sediment concentration lower than 196,000 mg/L that last significantly longer. Assuming a constant 100,000 mg/L suspended sediment concentration, for example, the combined duration in the four water years for dam removal could potentially exceed 267 days. A faster notching would mean a higher suspended sediment concentration but shorter impact duration (but still longer than 118 days); a slower notching would mean a lower suspended sediment concentration but increased duration of impact. In the absence of mechanical sediment removal and disposal, there is no method that we can think of to reduce the magnitude of suspended sediment concentration and shorten the impact duration simultaneously under the natural sediment erosion scenario.

The potential impact to fisheries resources for the vertical notching and four-stage removal alternatives will be presented in a separate technical memorandum (Stillwater Sciences 2021 — *Analyses of fine sediment erosion effects on aquatic species following the proposed Scott Dam removal*.).

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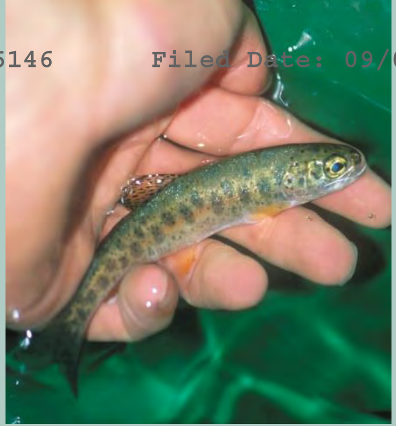
Water Supply Reliability



Fishery Restoration

Science & Engineering

Stakeholder Participation

Power Generation

POTTER VALLEY PROJECT TECHNICAL STUDIES

Lake Pillsbury Sediment Management Discussion

Lisa K. Stromme, PE – Senior Water Resources Engineer

Dr. Yantao Cui, PE – Senior Hydraulic Engineer

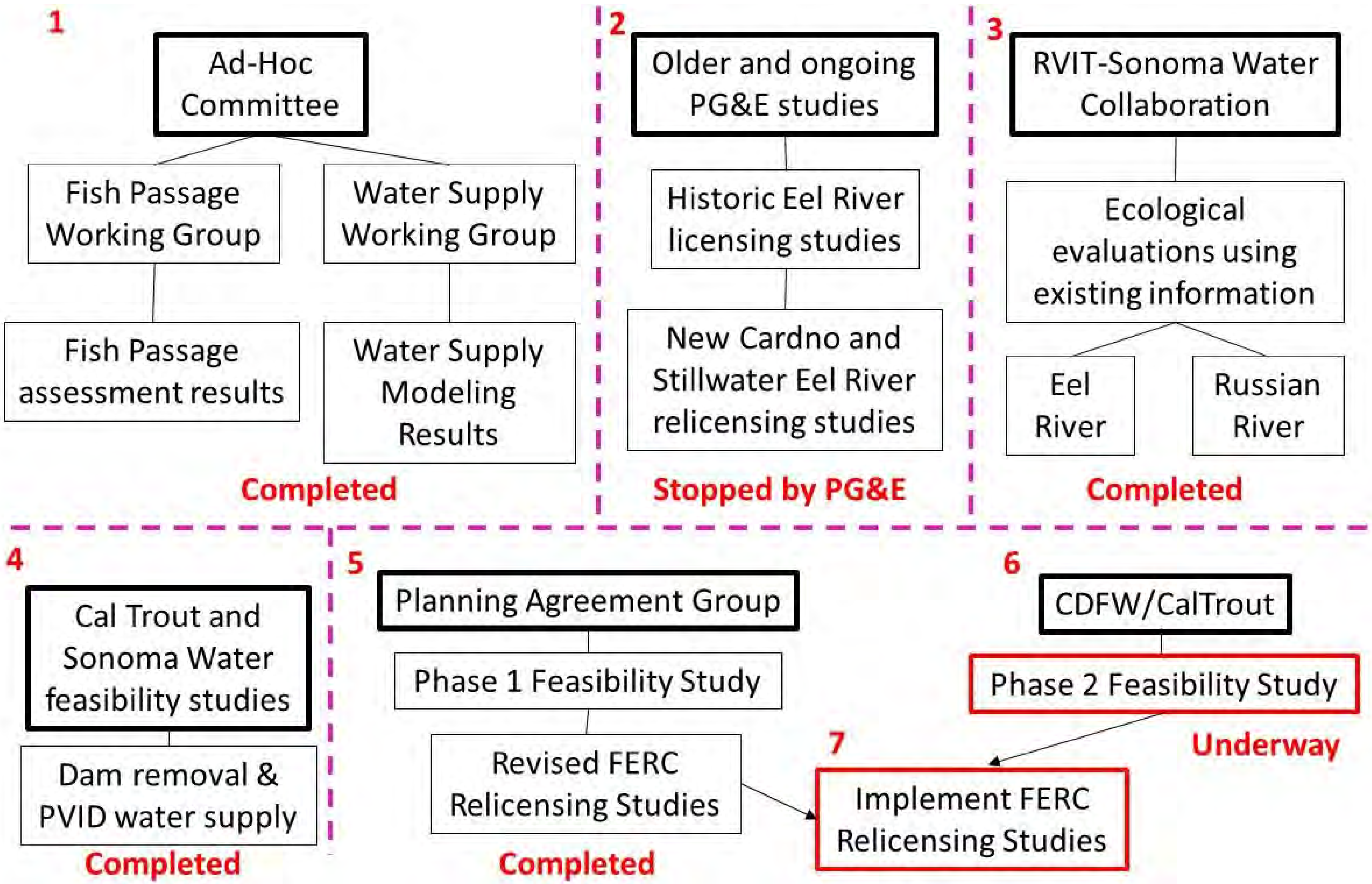
Fred Meyer – Stream Restoration Designer

Scott McBain – Fluvial Geomorphologist

Laura Wildman, PE – Civil Engineer

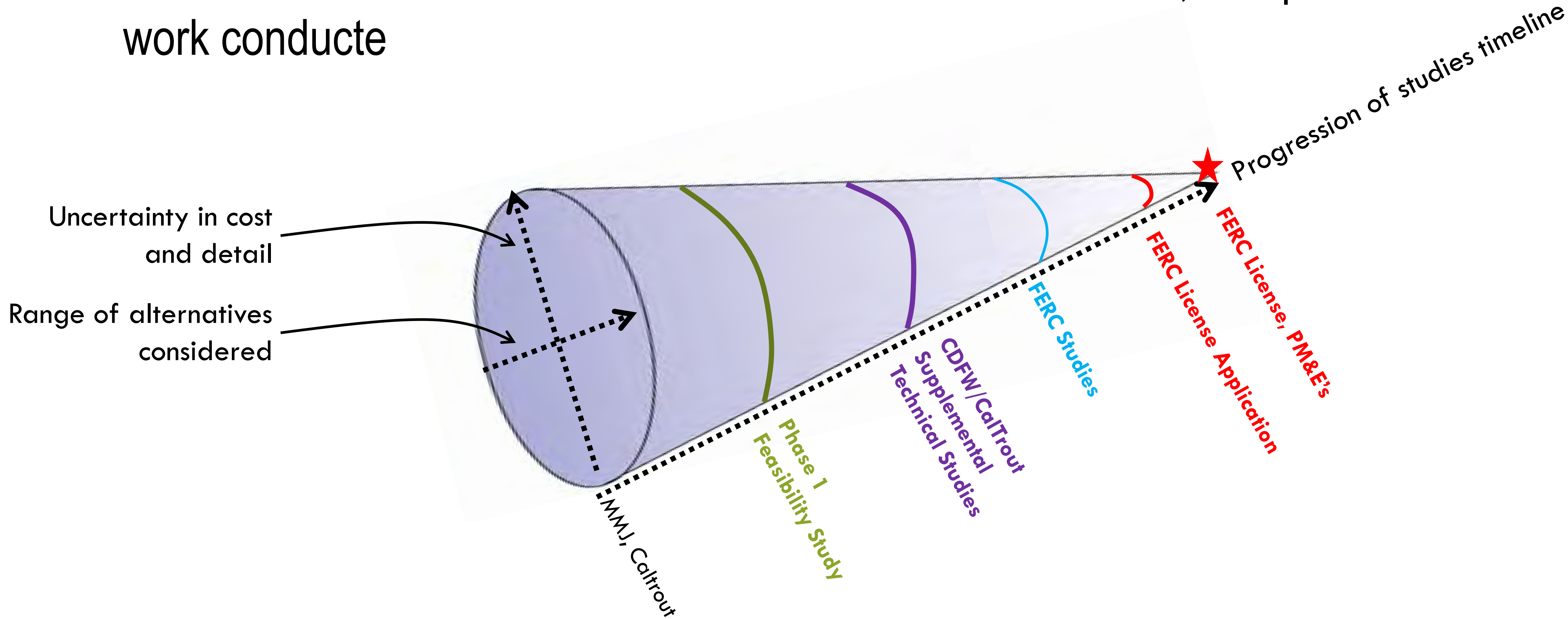
California Trout 50 For 50 Years. Forever. | Stillwater Sciences | McBain Associates Applied River Sciences | McMillen Jacobs Associates

Overview of where we are



Meeting Objectives

- Provide an overview of work conducted to date on Feasibility Studies
- Facilitate a technical discussion of work conducted to date, and potential work conducte



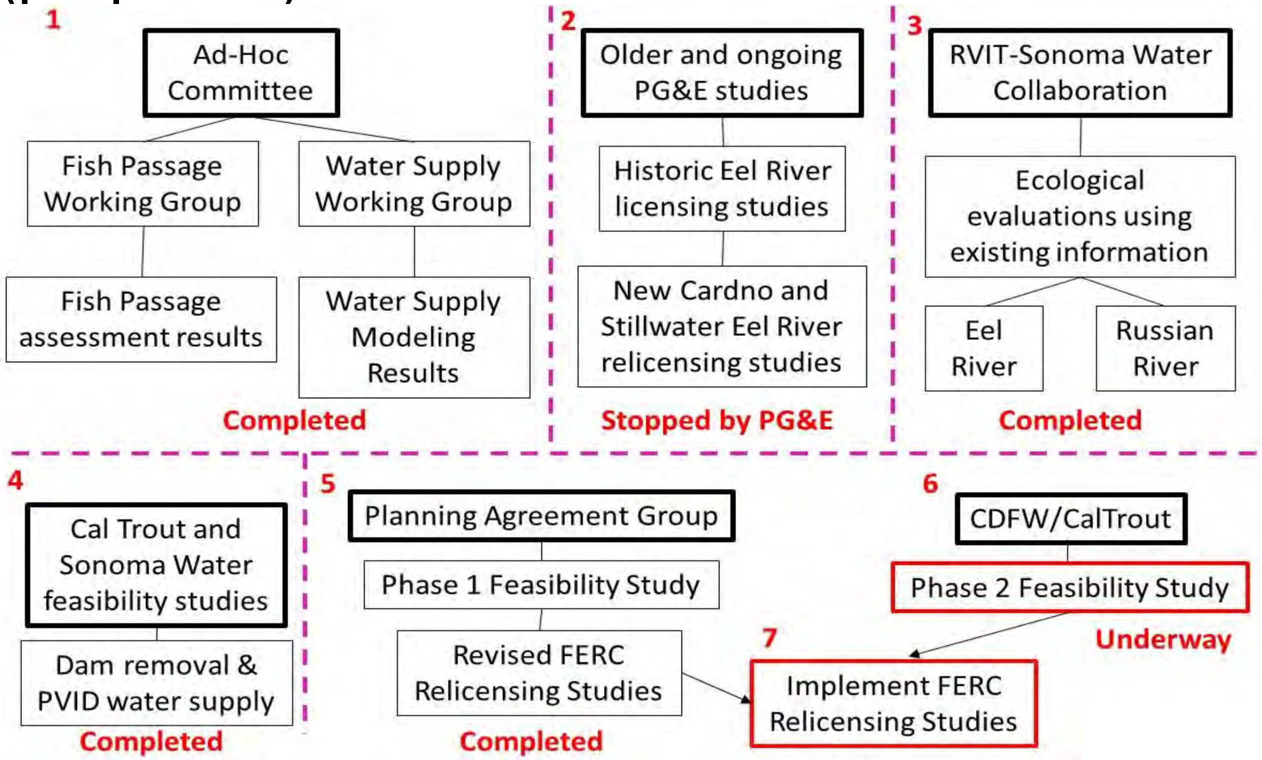
Components of Presentation

- Part 1: Overview of work completed to date
- Part 2: Overview of Lake Pillsbury Sediment Storage Calculations
- Part 3: Overview of Lake Pillsbury "mobile sediment" Calculations
- Part 4: Overview of Potential Sediment Management Options with different Scott Dam Decommissioning Options
- Part 5: Suspended Sediment Concentration Analysis for different Scott Dam Decommissioning Options
- Part 6: Study AQ12 overview and discussion

Part 1: Overview of work completed to date

Part 1: Overview of Work Completed to Date

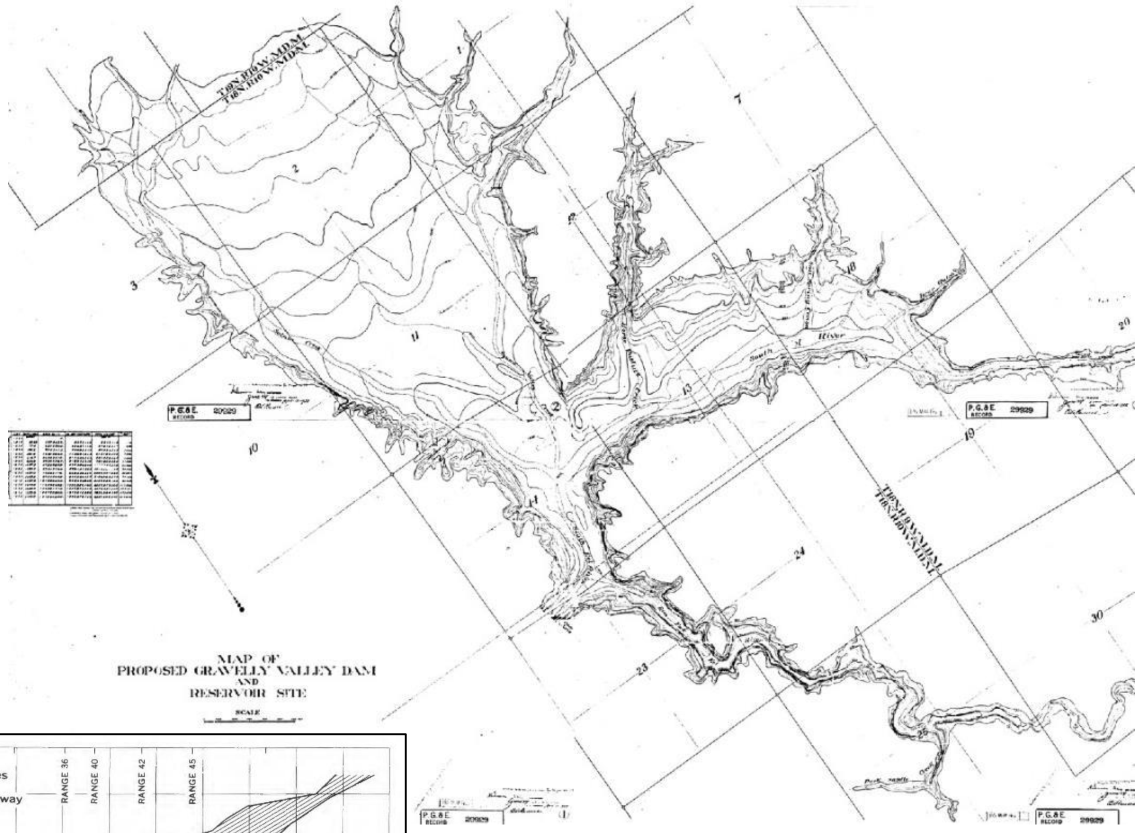
- CalTrout and Sonoma Water Initial Feasibility Studies (2018-2019)
- NOI Parties Feasibility Study Phase 1 (2020)
- Subsequent Internal Review as part of PVP Technical Studies (now)
- FERC Relicensing Study AQ4 and AQ12 (proposed)

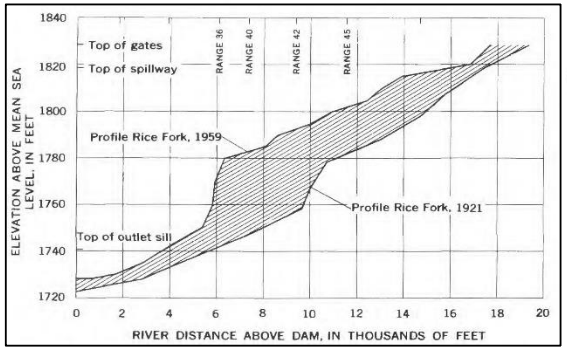


Part 2: Overview of Lake Pillsbury Sediment Storage Calculations

Data Sources: 1921-22 and 2015-16

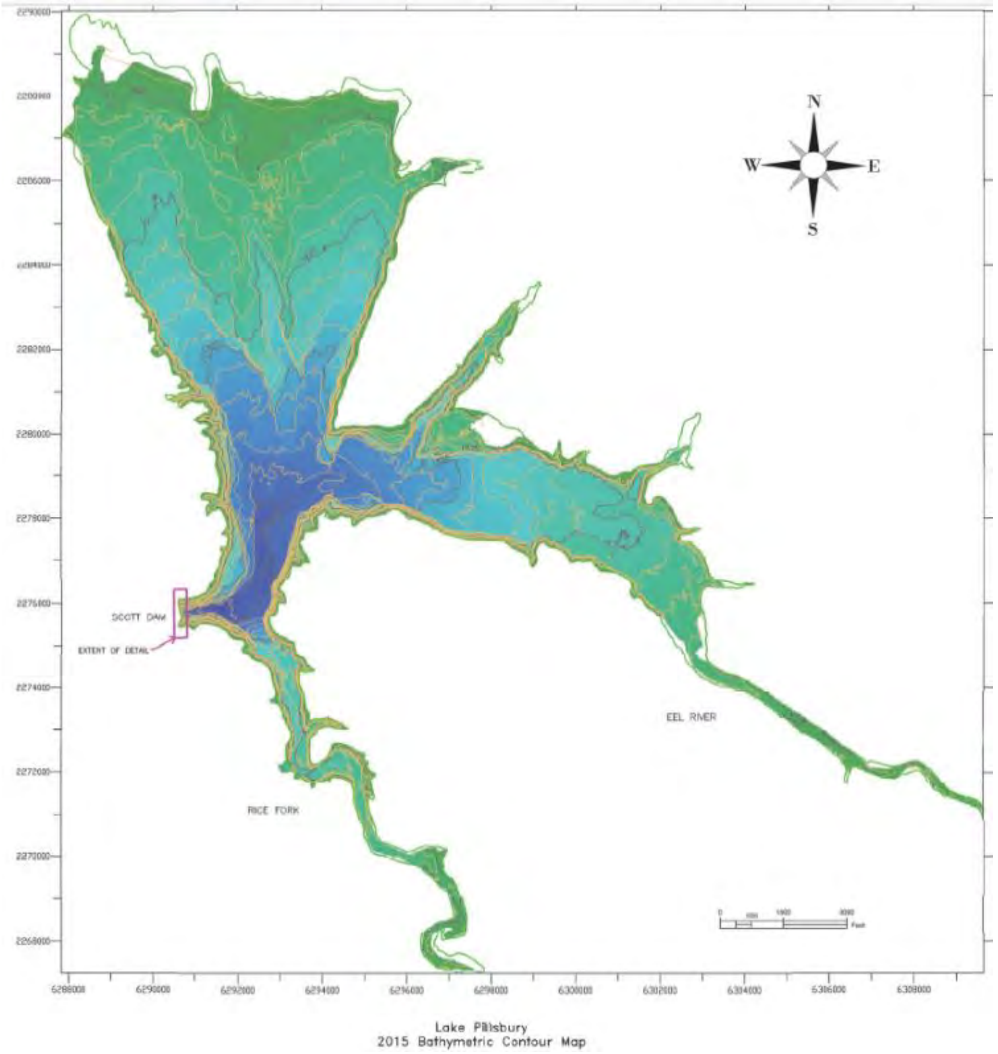
1922 Topography (USGS)



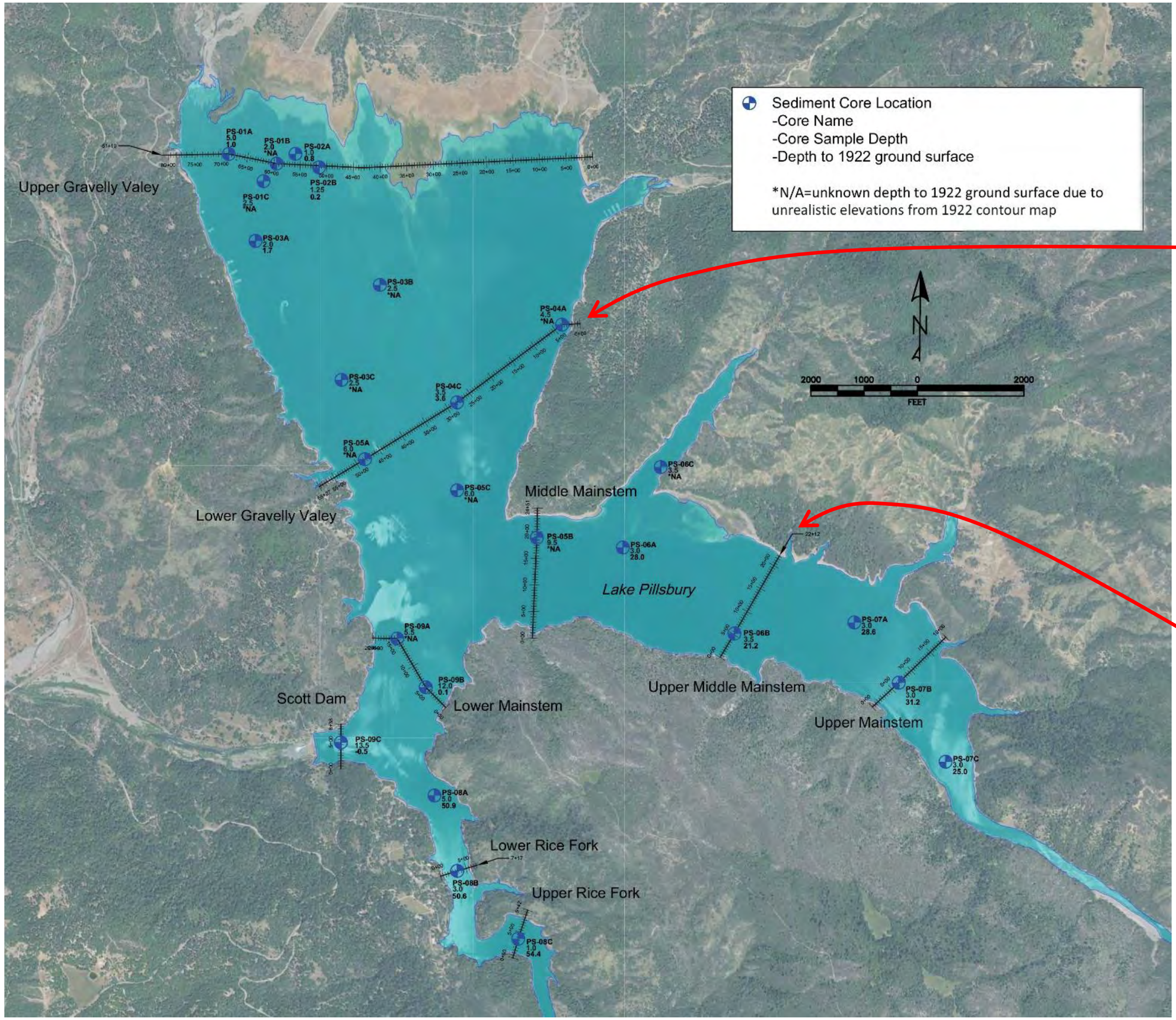


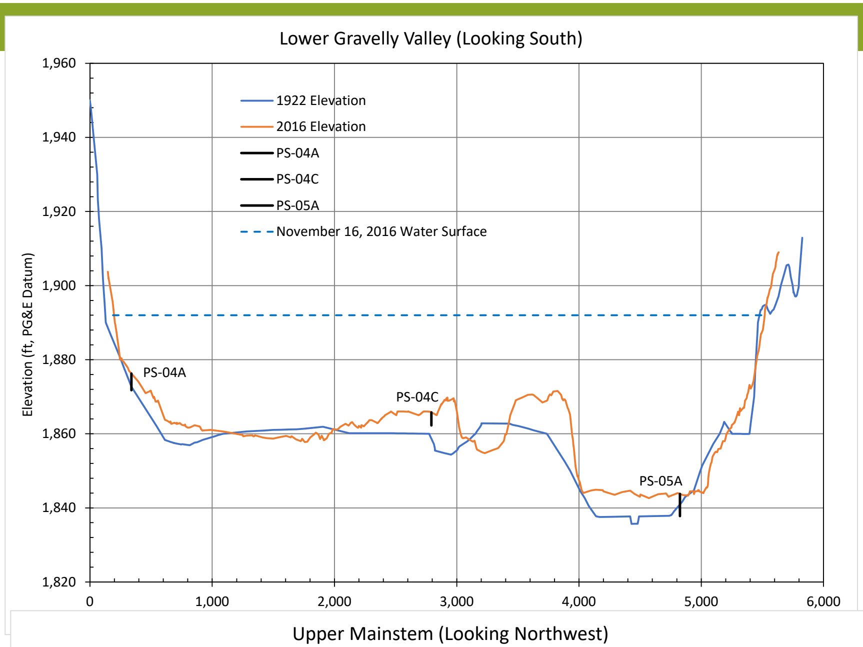
1921 Rice Fork Channel Profile (USGS)

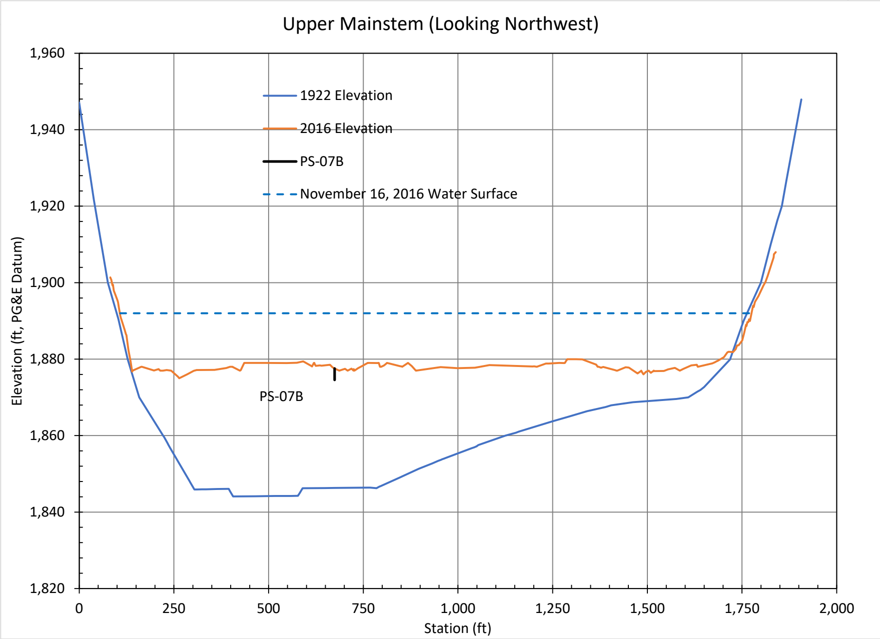
2015-16 Bathymetry (PG&E)



1922-2015 Comparison







Part 2: Overview of Lake Pillsbury Sediment Storage Calculations

Two methods were used to estimate total sediment volume within Lake Pillsbury:

1. Digitized 1922 surface was subtracted from the 2015 DTM and bounded by the 2015 reservoir slope toe. Result: 22,000,000 cu yds.
2. Each surface – 1922 digitized surface and the 2015 DTM were subtracted from a surface plane with the assigned maximum reservoir height of 1910 ft. The two results were subtracted. Result: 20,500,000 cu yds.
3. Used 21,000,000 cy yds for the Feasibility Study.

QUESTIONS?

Part 3: Overview of Lake Pillsbury "Mobile Sediment" Calculations

How Do We Expect Lake Pillsbury Sediment to be Eroded, and How Much?

We have learned a lot about sediment mobility post-dam removal through recently completed dam removal projects.

Example #1:
Wide impoundments with deep sediment depths (>> bankfull channel depth) = Transport a significant percentage of the impounded sediment.
We can equate this scenario to Eel River within Lake Pillsbury.

Example #2:
Wide impoundments w/ shallow sediment depths (< or = bankfull channel depth) = Transport only a small percentage of the impounded sediment.
We can equate this scenario to Salmon Creek within Lake Pillsbury.

Example #3:
Narrowly confined impoundments regardless of sediment depth = Often transport 100% of impounded sediment.
We can equate this scenario to the Rice Fork within Lake Pillsbury.

Note: other scenarios exist, but we are focusing on those that apply to the removal of Scott Dam.

Example #1 – Lake Mills: Glines Canyon Dam Removal

Wide Impoundment, Deep Sediment: Lake Mills draining post Glines Canyon Dam Removal on the Elwha River.

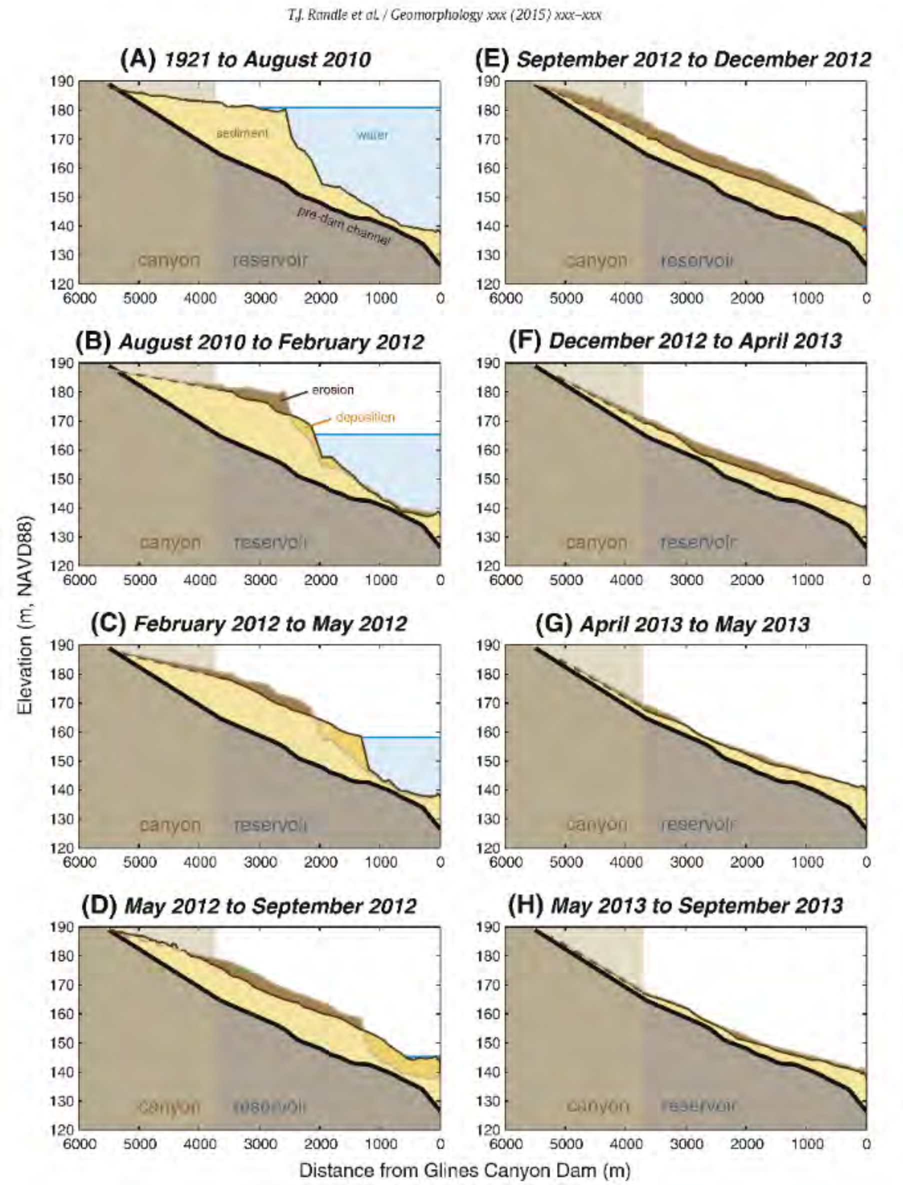
As the channel first down cuts into the impounded sediment, it creates a wide braided channel with a much flatter slope. The channel actively moves within the braided channel width transporting a significant amount of sediment and developing highly erosive terraces as it continues to down cut. This process continues until the slopes start to steepen and eventually the pre-dam riverbed and floodplain elevations are reached.

Example #1 – Lake Mills: Glines Canyon Dam Removal

Lake Mills Draining & Sediment Mobilizing Post-Glines Canyon Dam Removal.

Example #1 – Lake Mills: Glines Canyon Dam Removal

Lake Mills Draining & Mobilizing Sediment Post Dam Removal.



Similar to Eel River Arm Upstream of Scott Dam

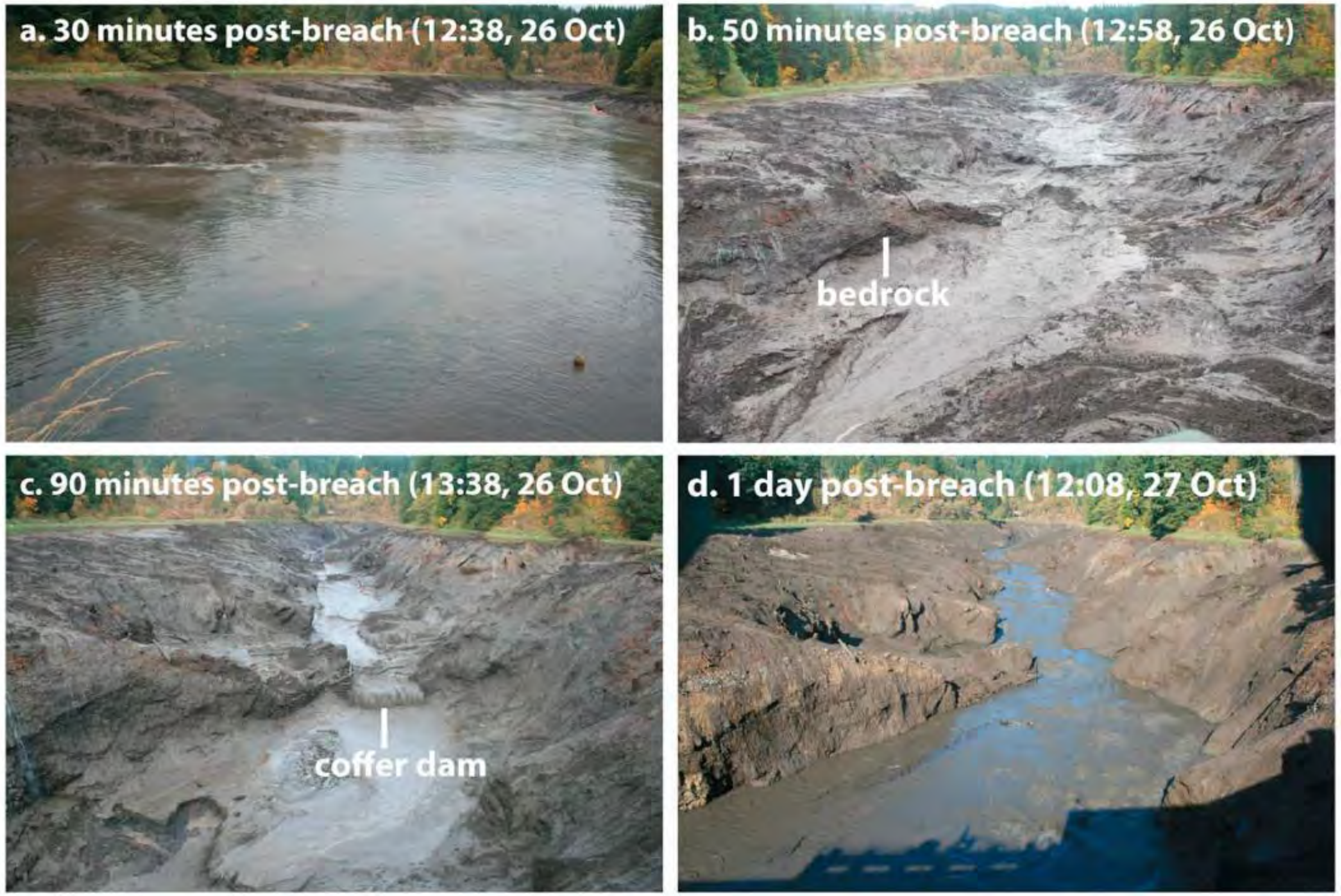
Example #2 – Tannery Brook Dam Removal

Wide impoundment, shallow sediment:
Tannery Brook Dam removal and pond draining post dam removal.

Similar to Gravelly Valley Tributaries

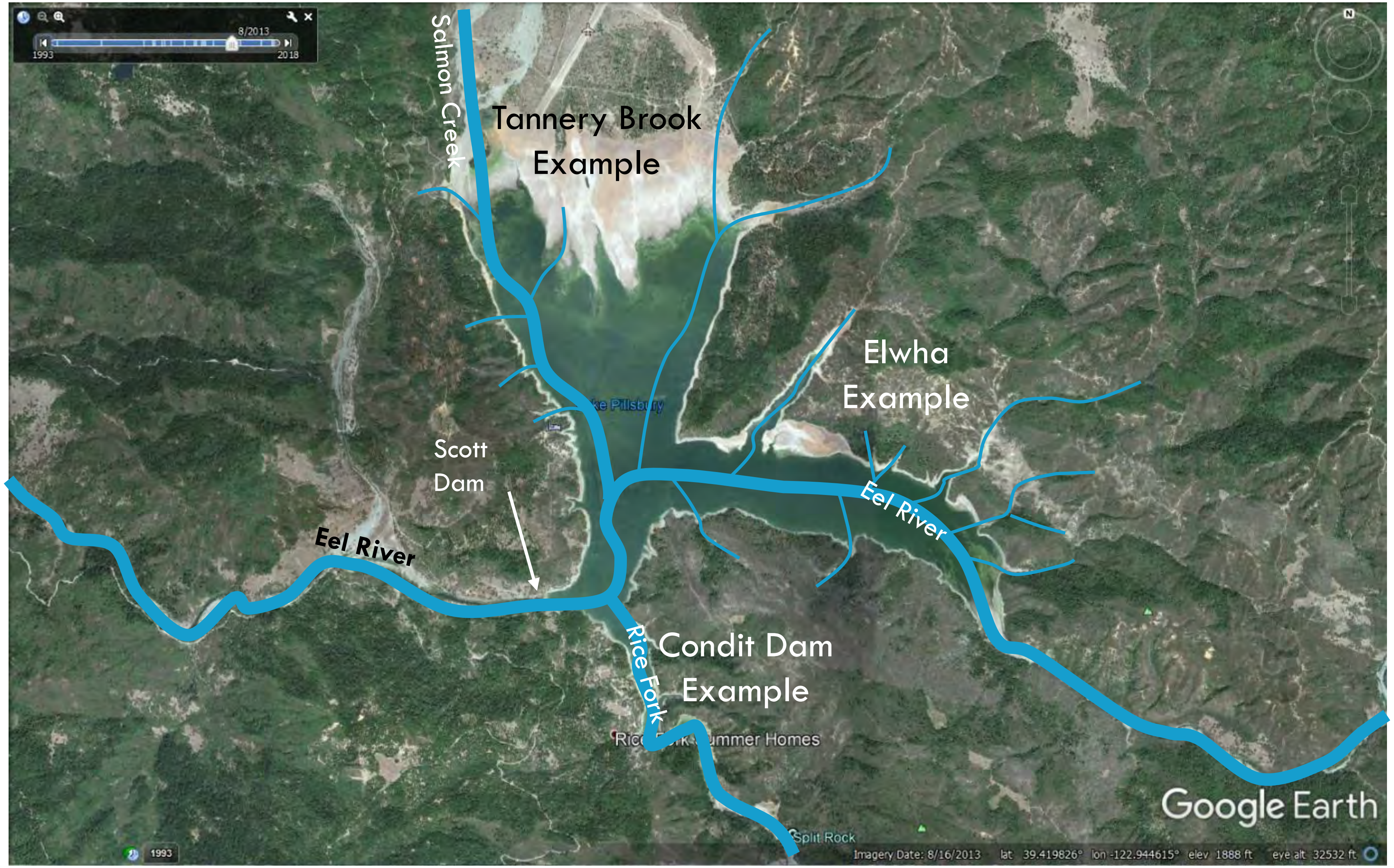
Example #3 – Condit Dam Removal

Condit Dam Removal: Narrowly Confined Valley = All Impounded Sediment Mobilizes



Similar to Rice Fork Tributary

Application to the Eel River: Planform



Needs:

1) Vertical incision process and depth
2) Lateral migration process and width
3) Side-slope assumptions
4) Volume Calculations

Observations from Lake Pillsbury during 2013-14 drought (9,000 ac-ft)

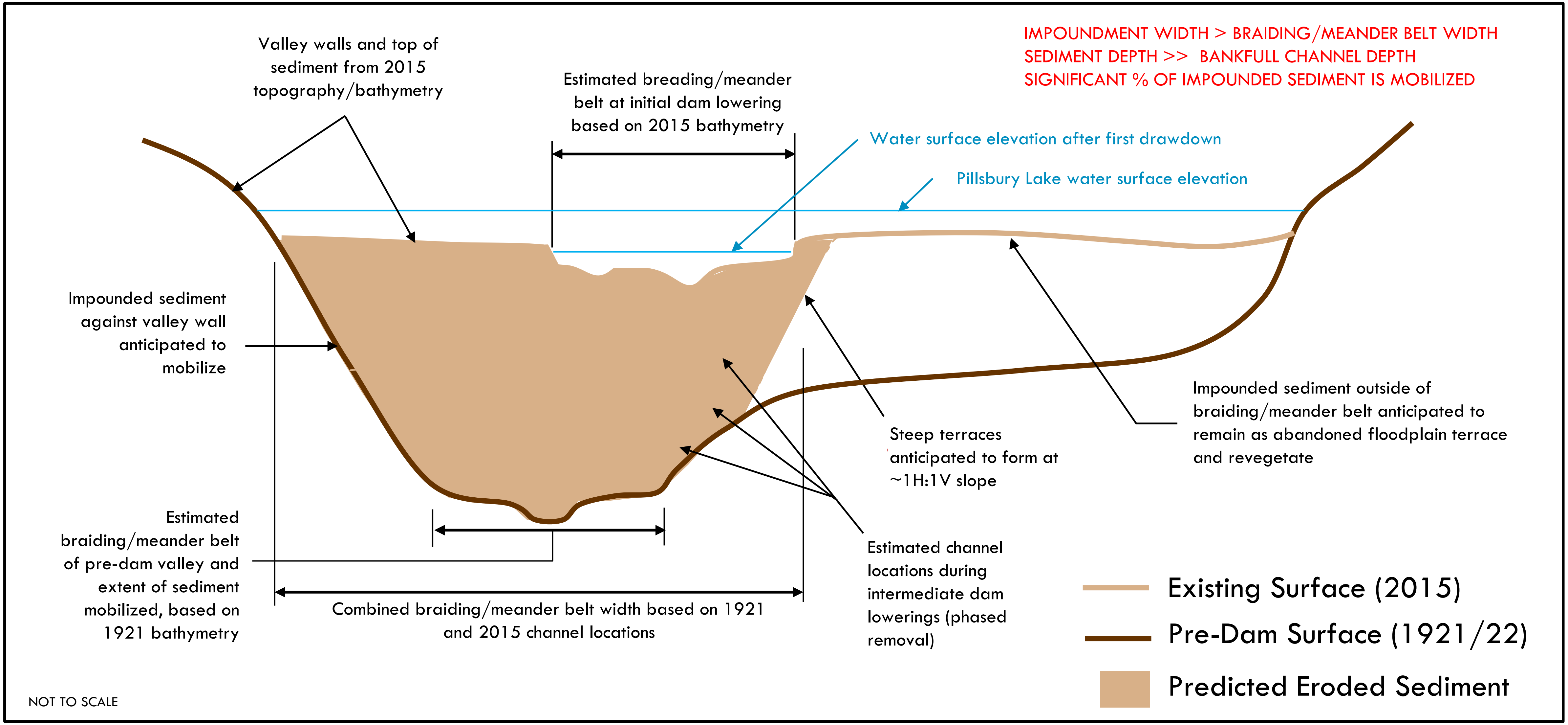
Mobile Sediment Volume Analysis Methods

- Mobile sediment boundaries were digitized in AutoCAD for the Rice Fork, Salmon Creek, Squaw Valley Creek, & main-stem Eel River.
- Recent bathymetry digitized in AutoCAD from PG&E 2015 bathymetric map. Historic valley bottoms and channel alignments were digitized in AutoCAD using USGS 1921 Survey data.
- Bankfull widths for Rice Fork, Eel River, and Salmon Creek calculated from regional hydraulic geometry relationship (Bieger et al. 2015) with watershed size calculated from USGS StreamStats. Braiding/meander belt widths were approximated based on bankfull width (Williams 1986).
- **Rice Fork**: Braiding/meander belt width = valley bottom width, so all impounded sediment has the potential to mobilize. Volume = difference between 2015 bathymetry and 1921 survey data.
- **Salmon Creek & Squaw Valley Creek**: Braiding/meander belt width < valley bottom width, so less sediment has potential to mobilize. Volume = difference between 2015 bathymetry and 1921 survey data, within braiding/meander belt width, with 1H:1V side slopes.
- **Eel River**: Braiding/meander belt width < valley bottom width, but initial braiding/meander belt is offset from final channel alignment; so combined braiding/meander belt is wider, and more sediment has potential to mobilize. Volume = difference between 2015 bathymetry and 1921 survey data, within the outer edges of both braiding/meander belt widths, with 1H:1V side slopes.

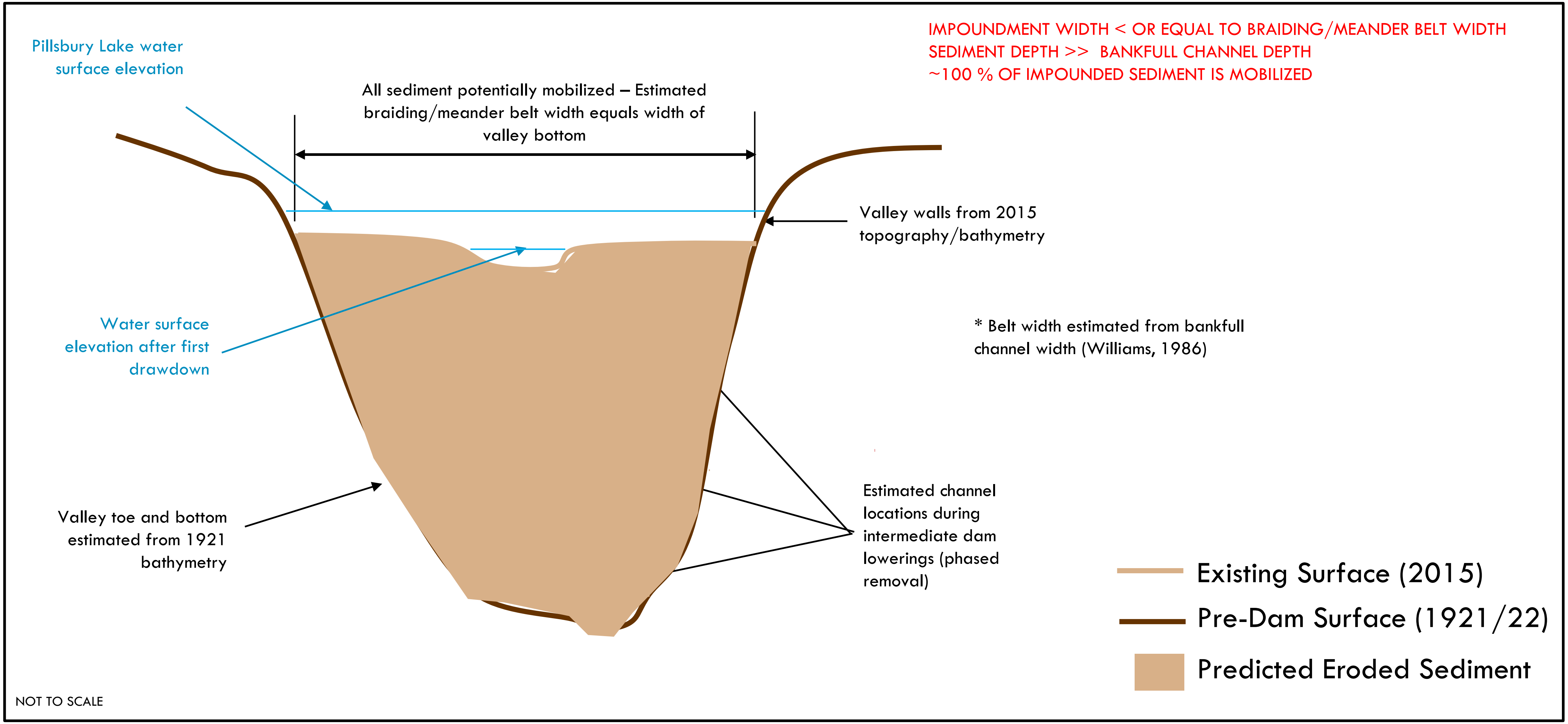
Mobile Sediment Volume Analysis Assumptions

- Analysis assumes that all sediment outside the mobile boundary will be stabilized in place through natural revegetation and/or planting of riparian vegetation.
- Analysis assumes that the river channel width after decommissioning will eventually return to historic channel width and location.
- Assumes a river bank side-slope of 1:1.
- Does not account for sediment accumulation that has occurred after the 2015 bathymetric survey.
- Does not provide an estimate for the area and extent of riparian vegetation/topsoil that may be needed for stabilizing old lakebed and riparian forest recovery.

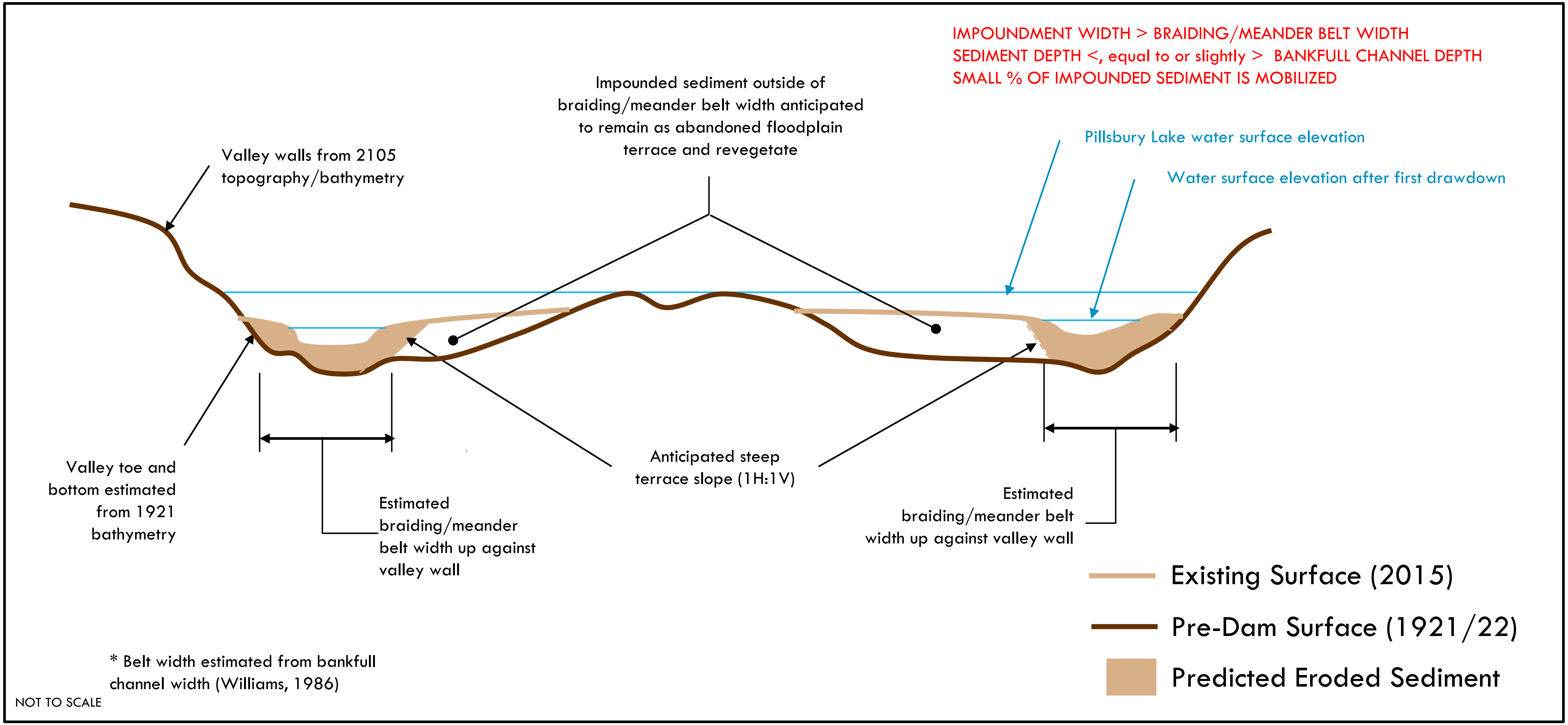
Conceptual Sediment Erosion: Eel River



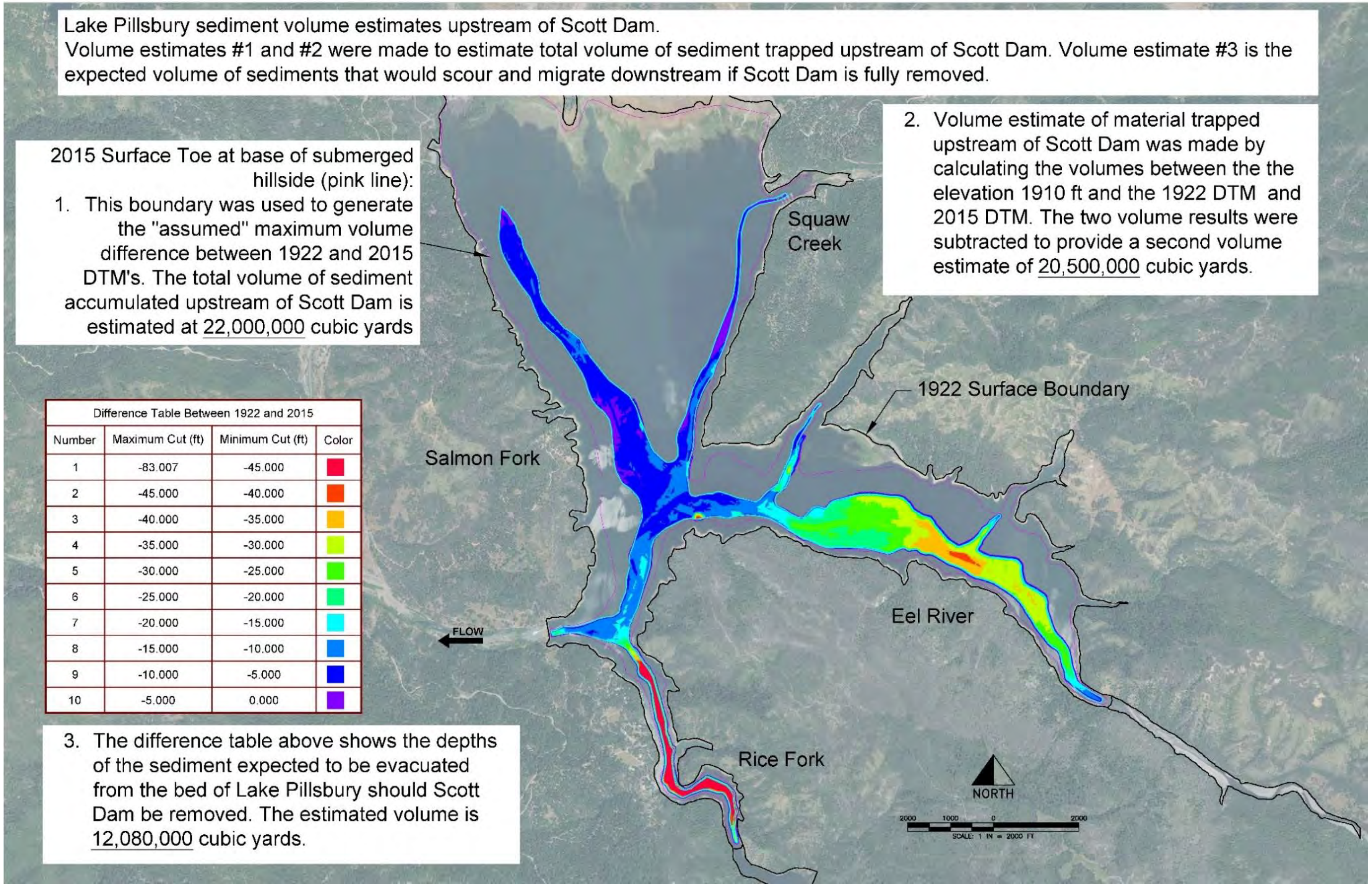
Conceptual Sediment Erosion: Rice Fork



Conceptual Sediment Erosion: Gravelly Valley Tributaries



Results



Difference Table Between 1922 and 2015

Number	Maximum Cut (ft)	Minimum Cut (ft)	Color
1	-83.007	-45.000	
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10	-5.000	0.000	

- Varying meander belt widths based on three examples
- Depth based on 1921/22 bathymetry and profile surveys
- **Best estimate is approximately 12,000,000 cu yds of "erodible sediment"**

QUESTIONS?

Part 4: Overview of Potential Sediment Management Options with different Scott Dam Decommissioning Options

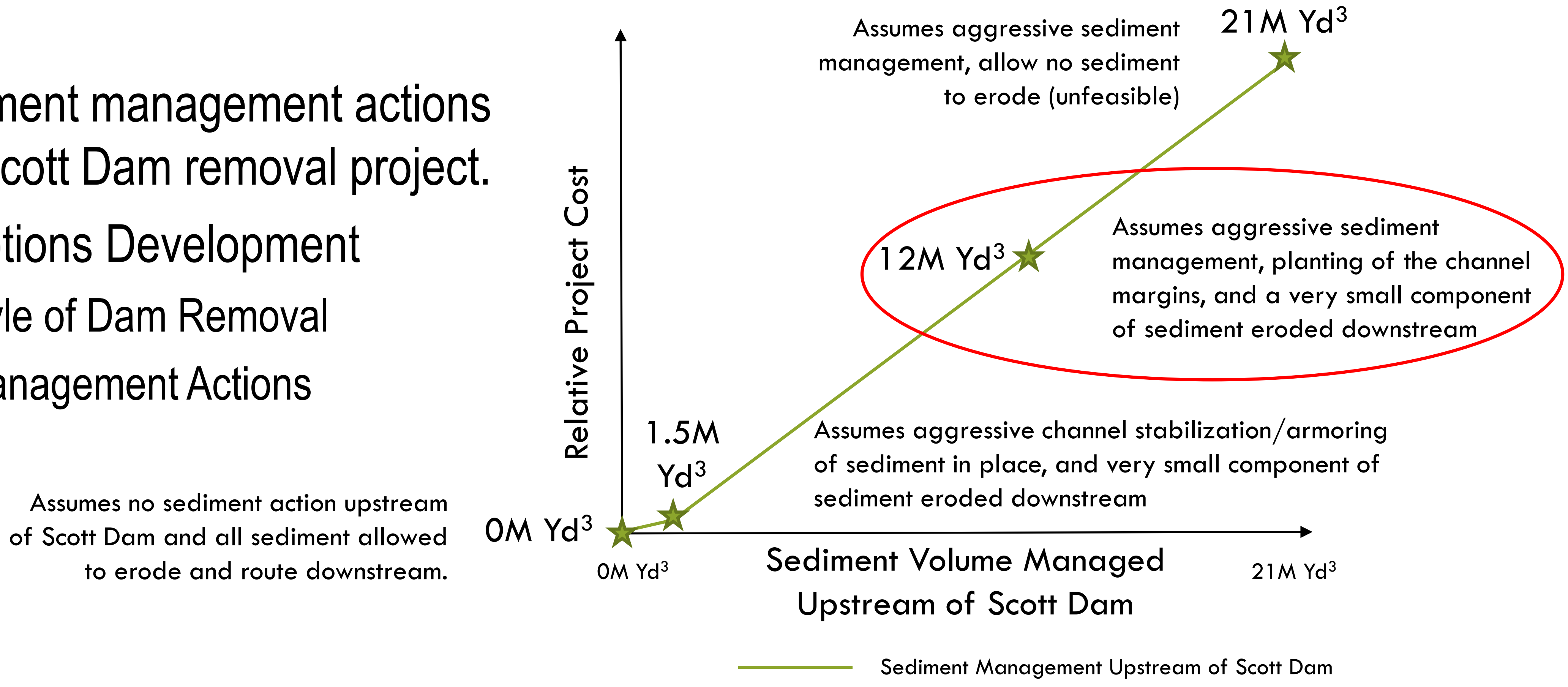
Part 4: Sediment Management Options

Sediment Management Planning Goal:

Identify the sediment management actions needed for the Scott Dam removal project.

Management Options Development

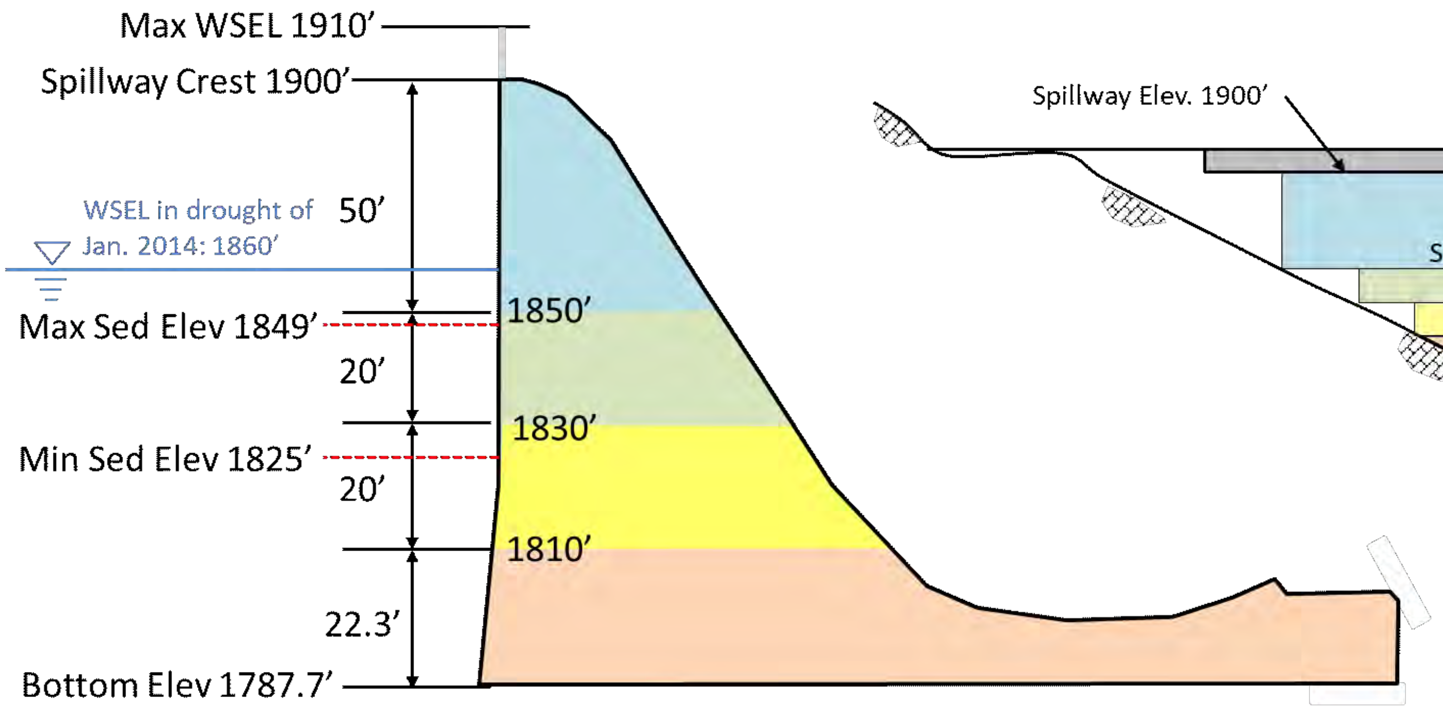
- Rate and Style of Dam Removal
- Sediment Management Actions



Rate and Style of Dam Removal

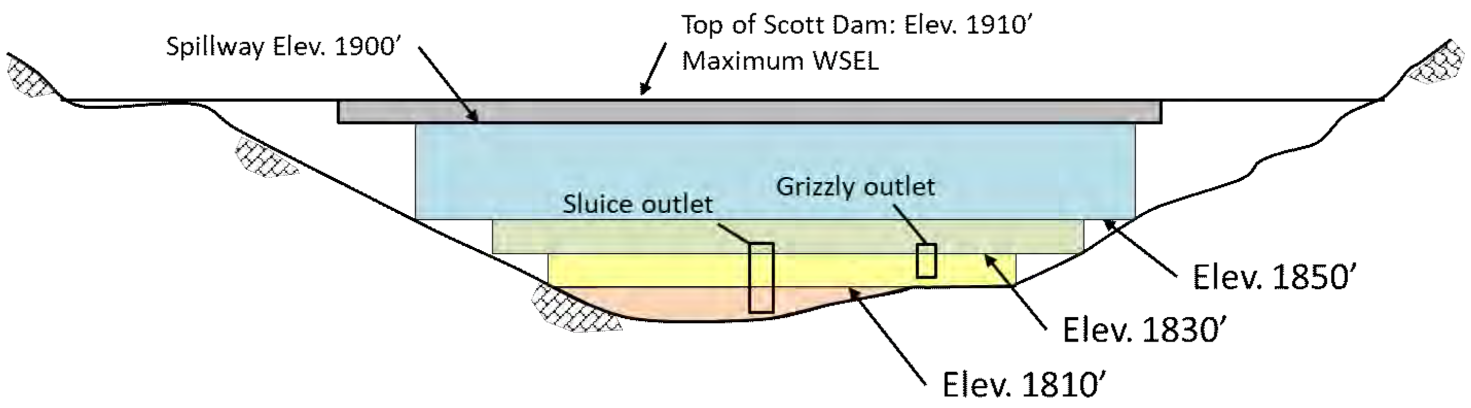
Rapid Dam Removal – One Year Duration

Phased Dam Removal – Four Year Duration



Elevations are in PG&E Datum

Scott Dam is a cyclopean concrete, ogee gravity dam ~130 ft in height with a total length of 805 ft



Elevations are in PGE vertical datum: Subtract 81.5 ft to get to NGVD29

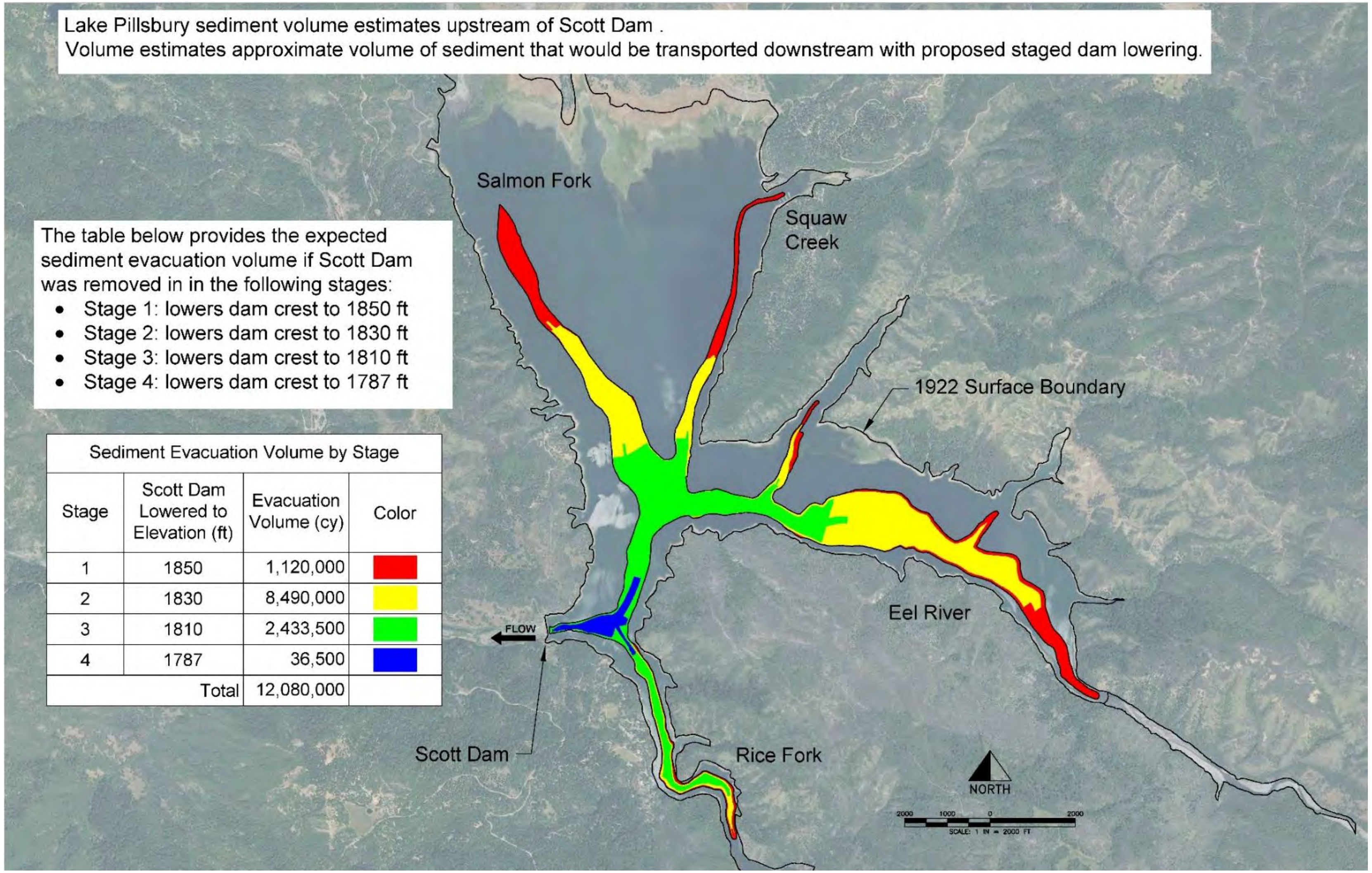
Sediment Management Actions

Sediment Retention

- Surface Stabilization
- Sediment Relocation

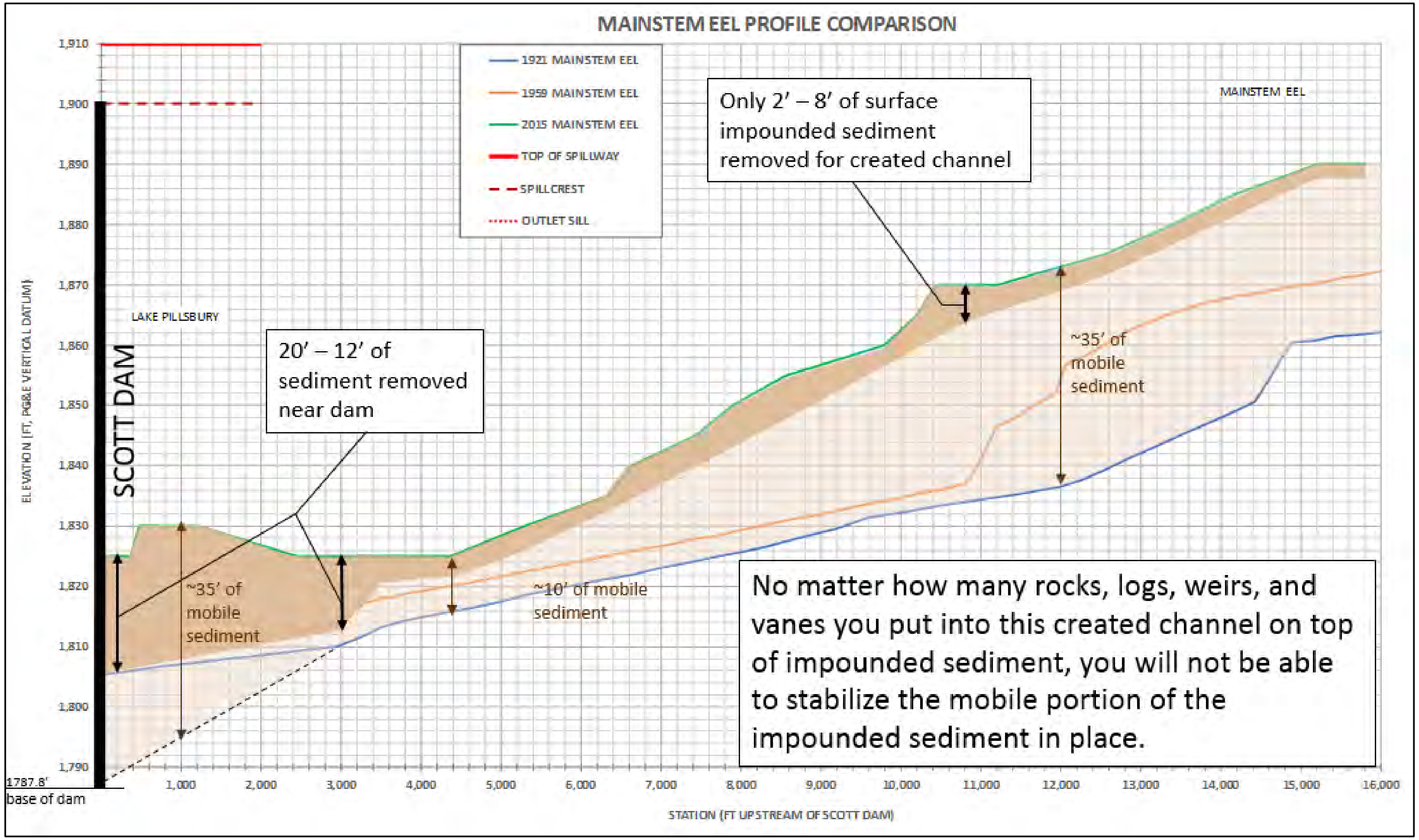
Sediment Release

- Rapid Dam Removal
- Phased Dam Removal



Elevations are in PGE vertical datum: Subtract 81.5 ft to get to NGVD29

Surface Stabilization – Mainstem Eel River



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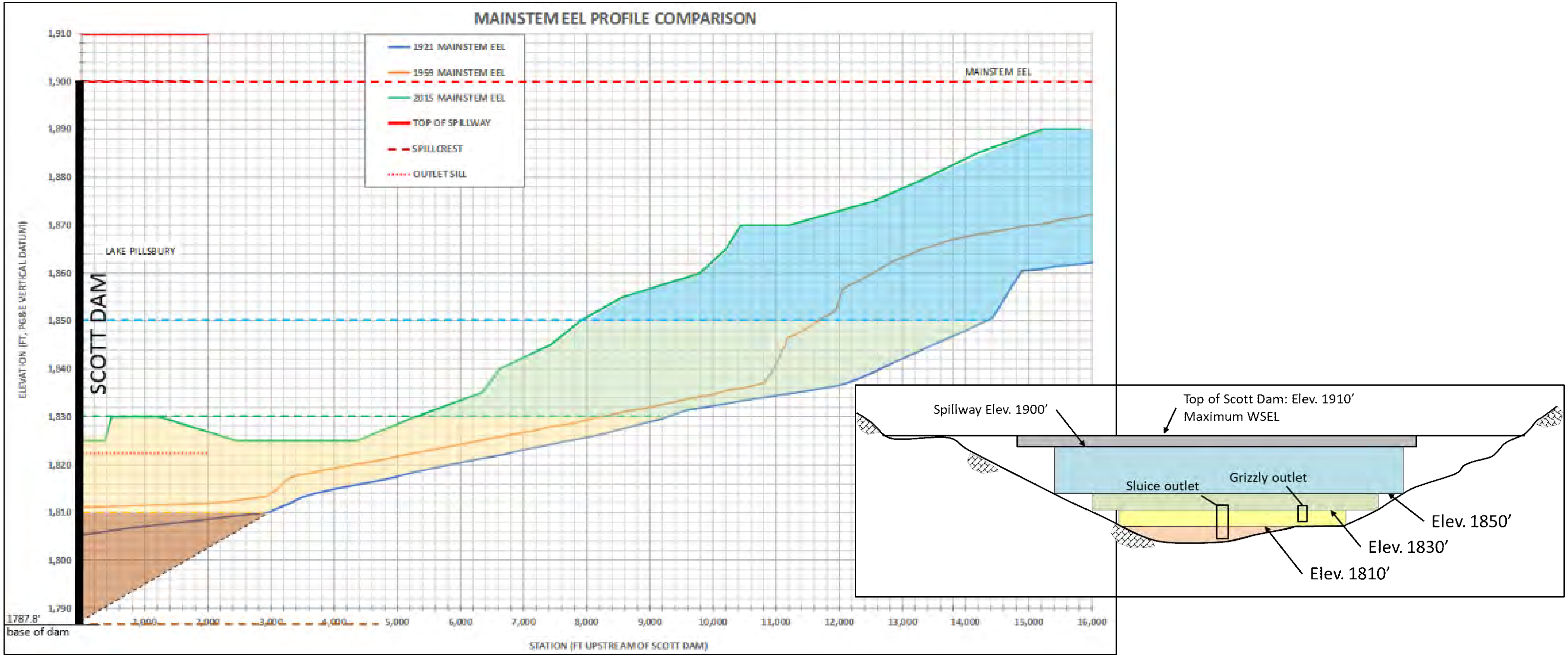
Sediment Relocation – Mainstem Eel River



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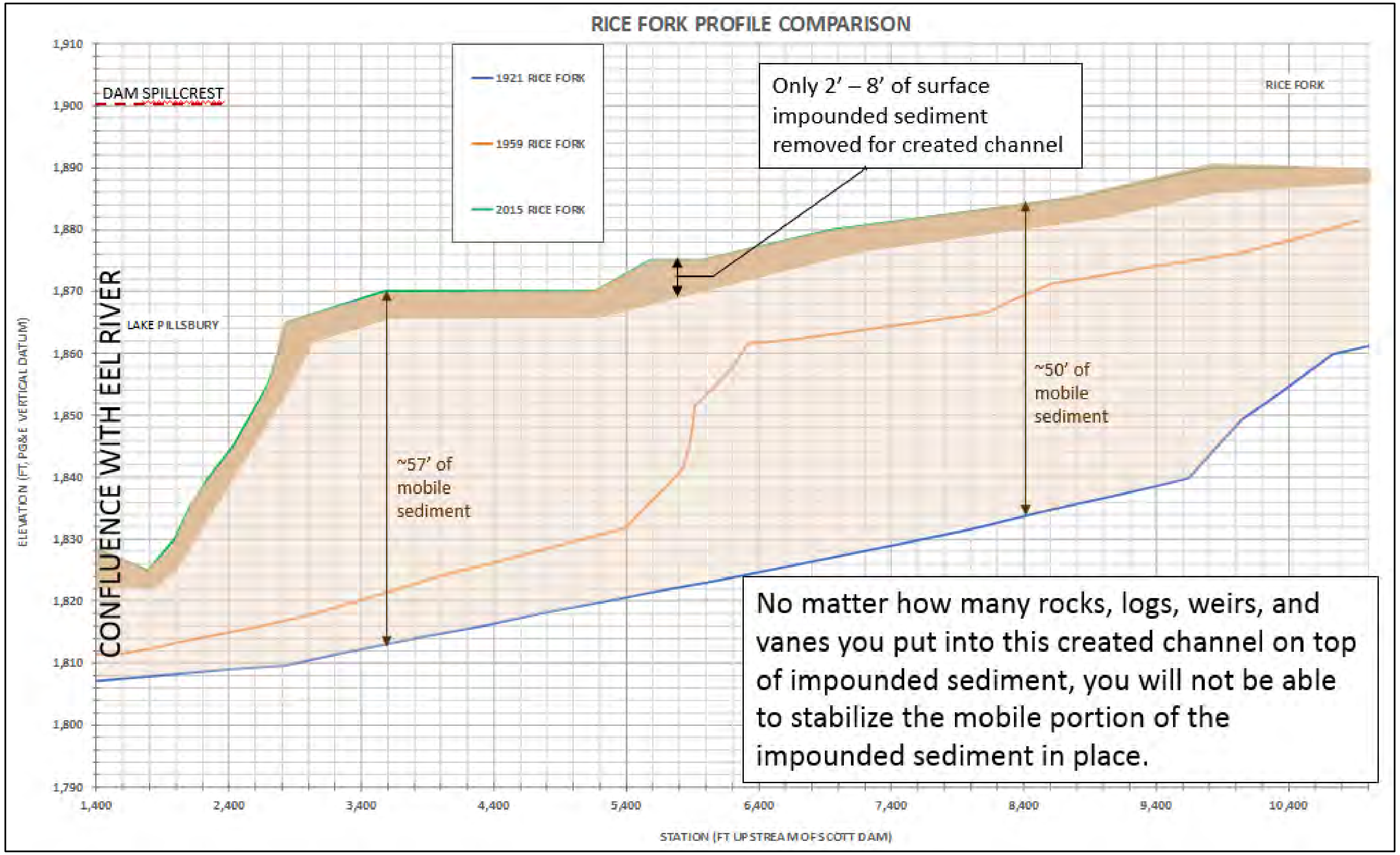
Surface Stabilization – Rice Fork



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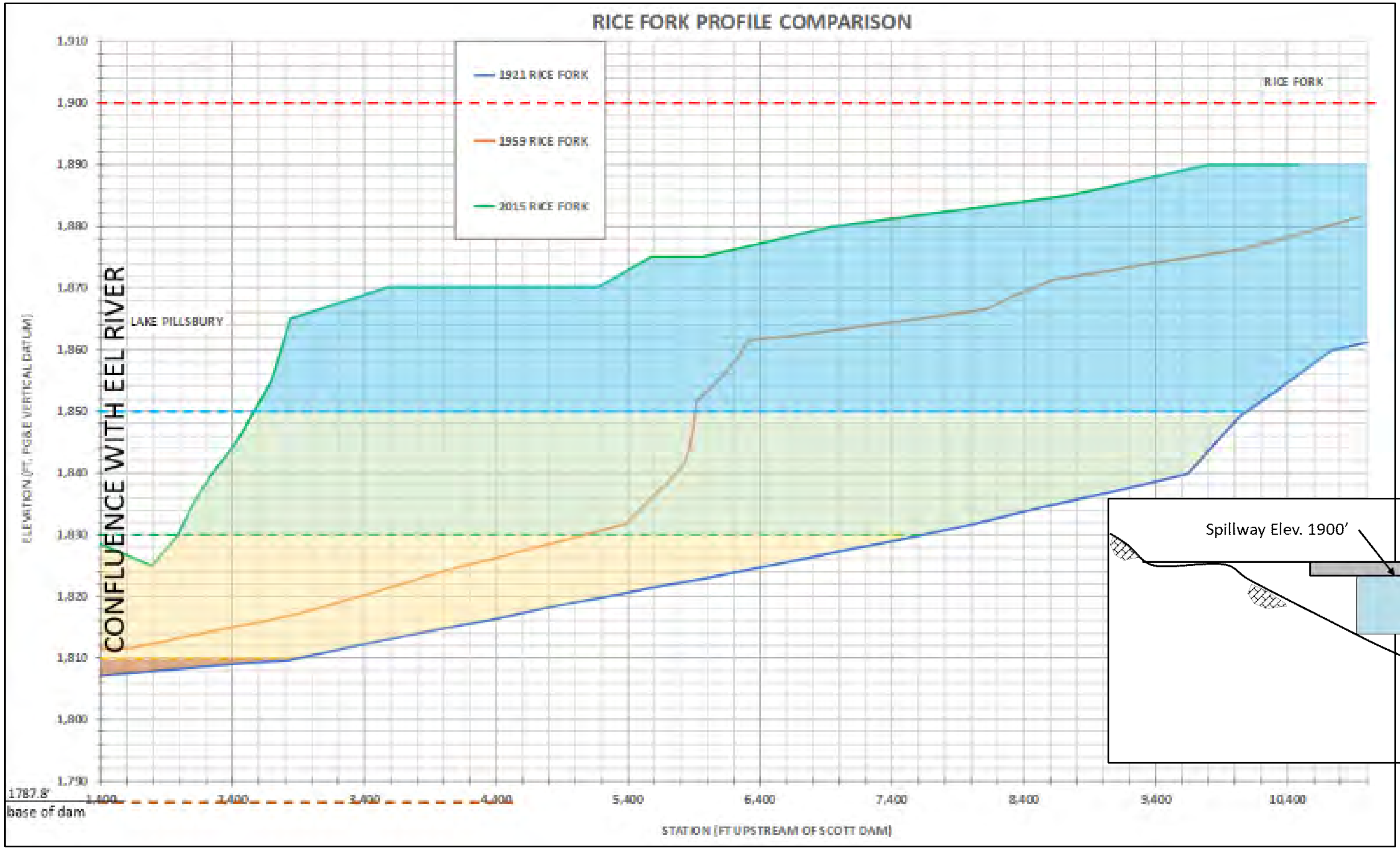
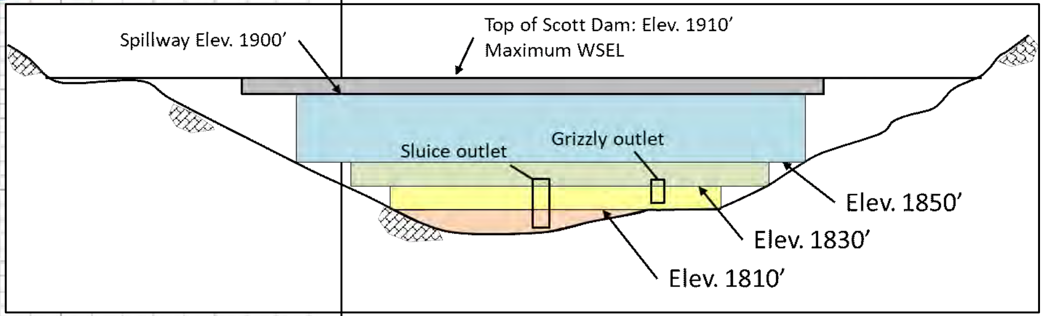
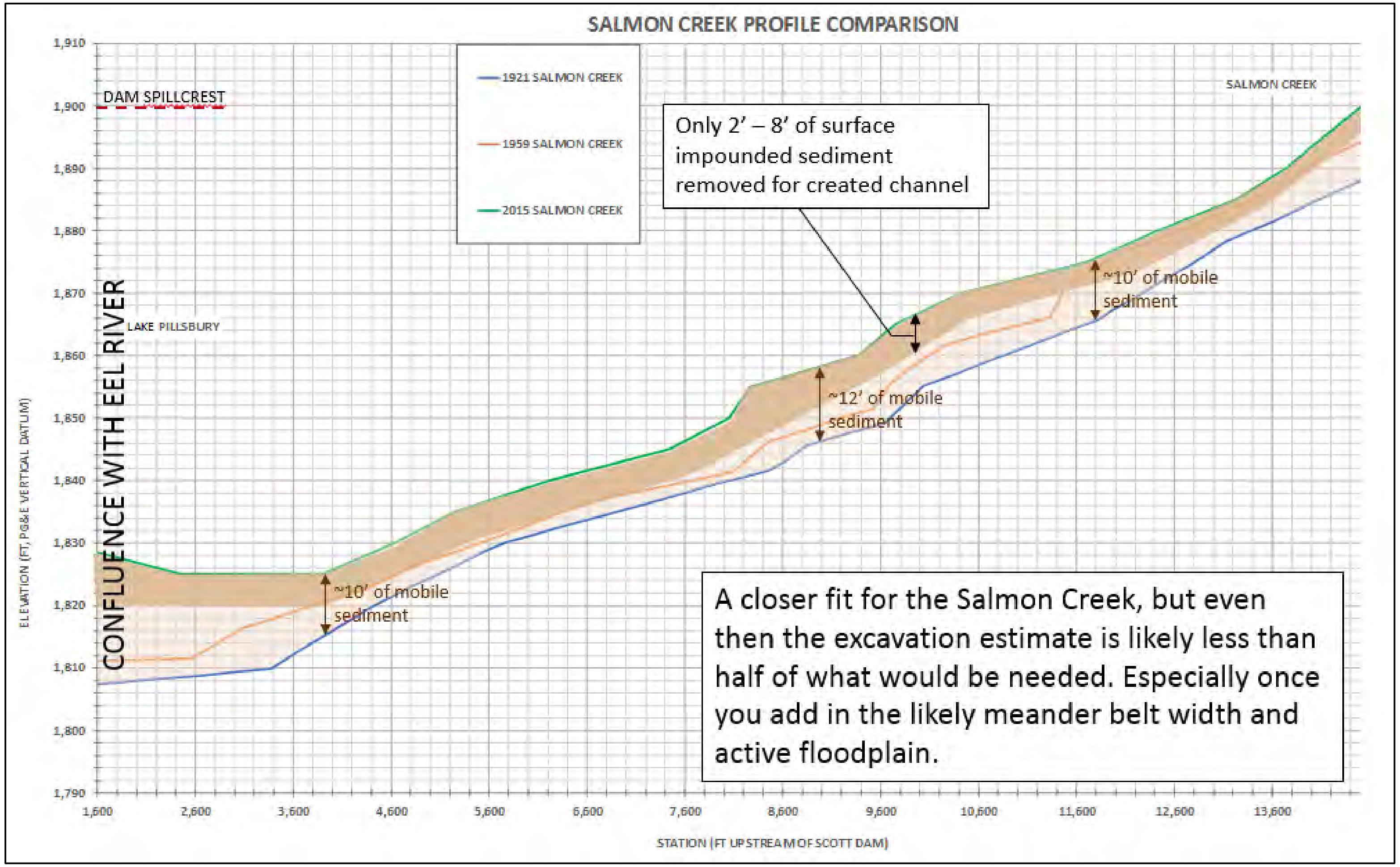
Sediment Relocation – Rice Fork





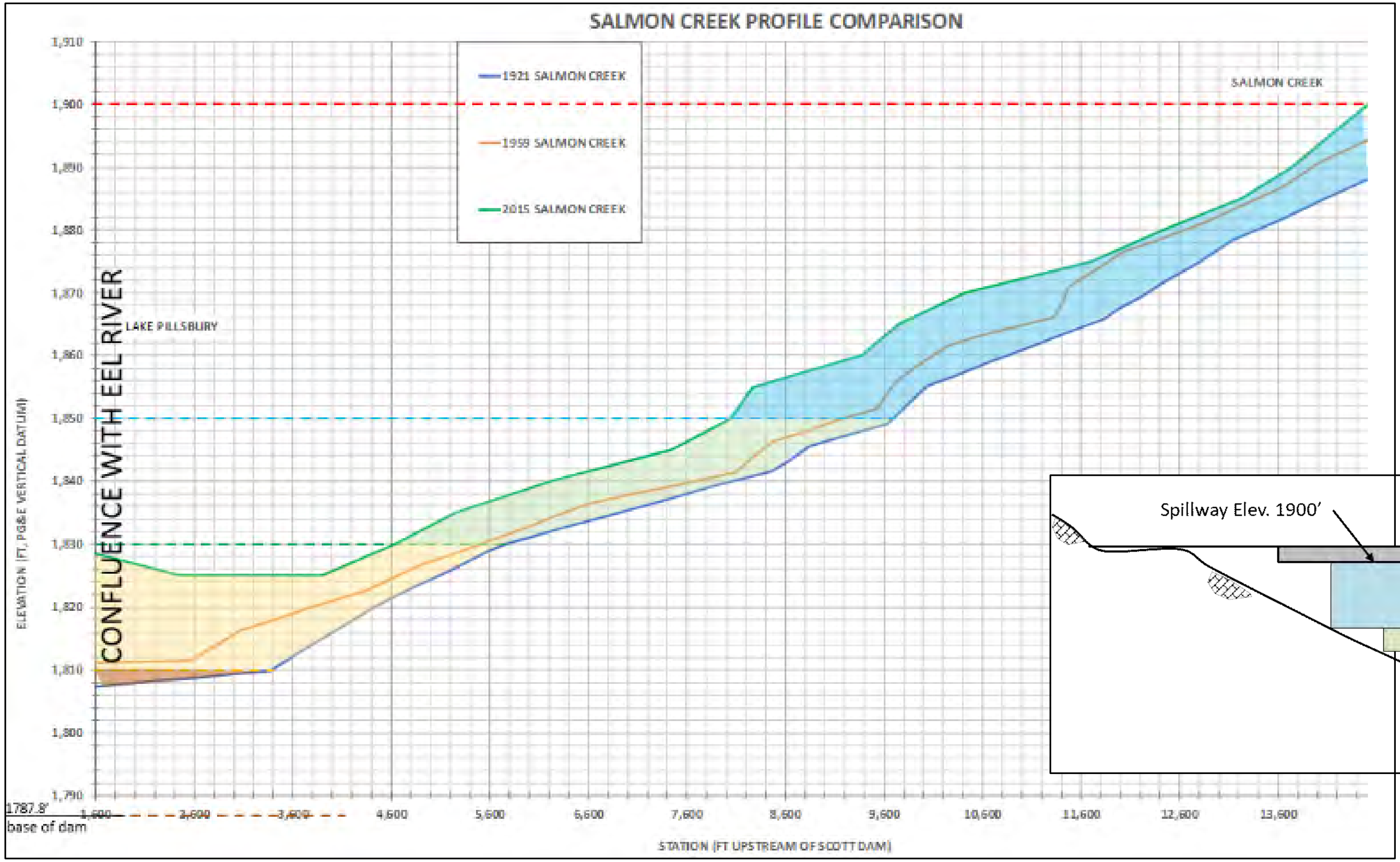
Elevations are in PGE vertical datum: Subtract 81.5 ft to get to NGVD29

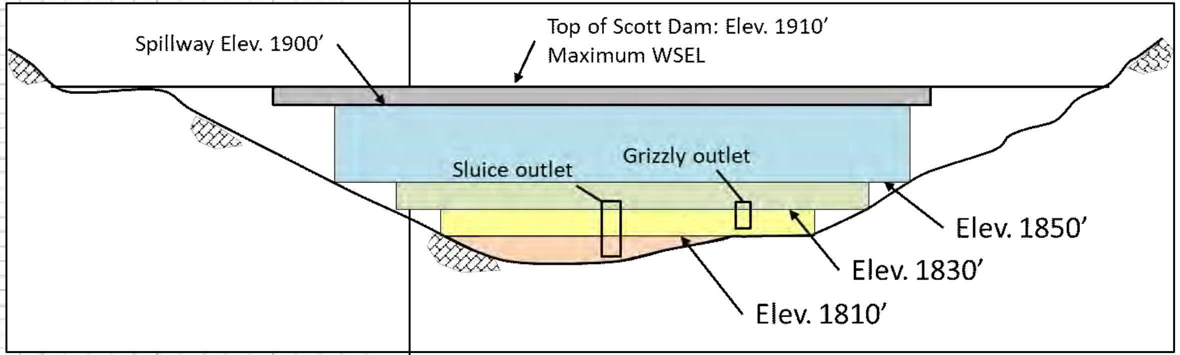
Surface Stabilization – Salmon Creek



Elevations are in PGE vertical datum: Subtract 81.5 ft to get to NGVD29

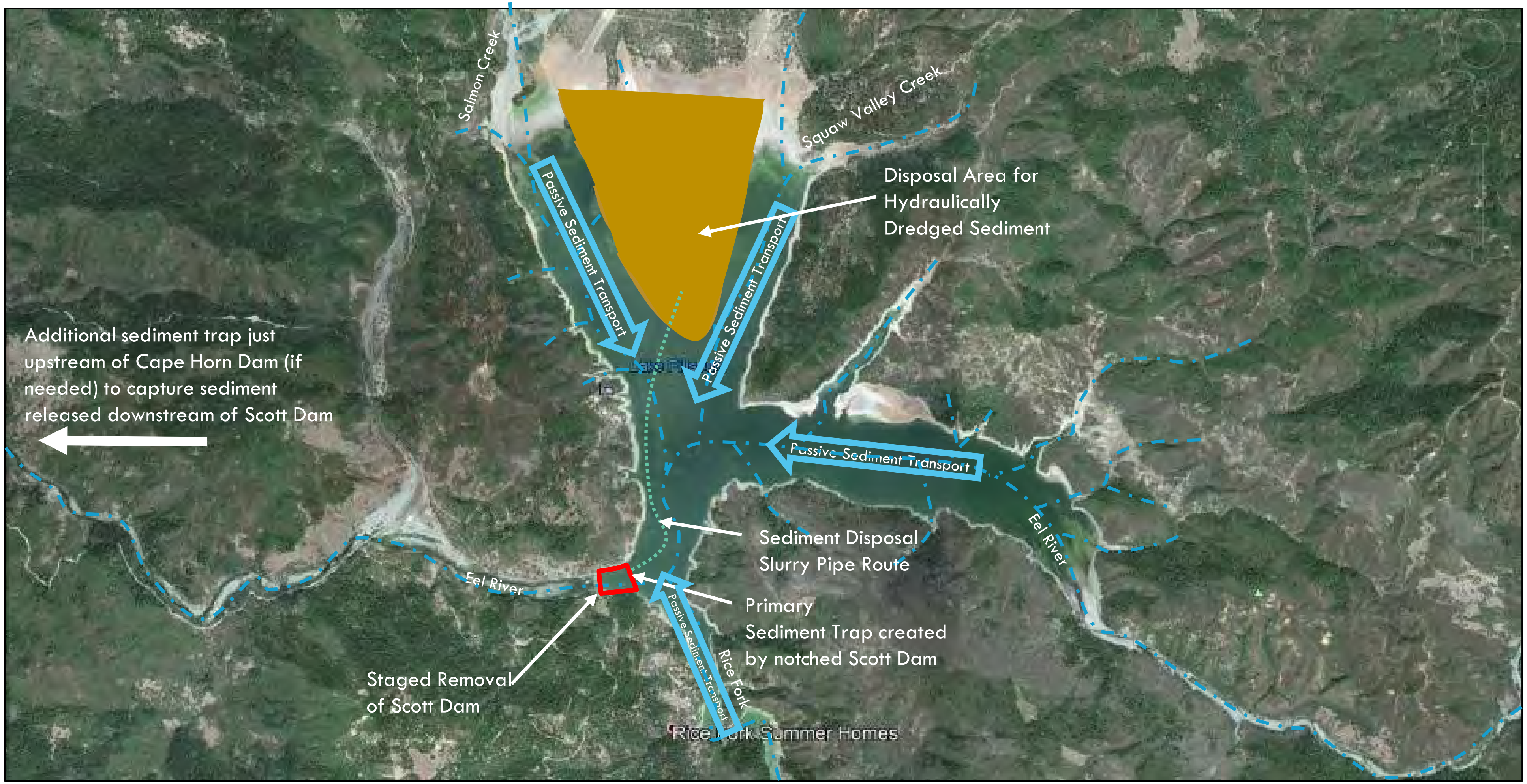
Sediment Relocation – Salmon Creek





Elevations are in PGE vertical datum: Subtract 81.5 ft to get to NGVD29

Phased Removal with Mobile Sediment Relocation



Sediment Relocation

Sediment Removal from Lake Pillsbury

- Hydraulic Dredging/Sluicing
- Mechanical Excavation

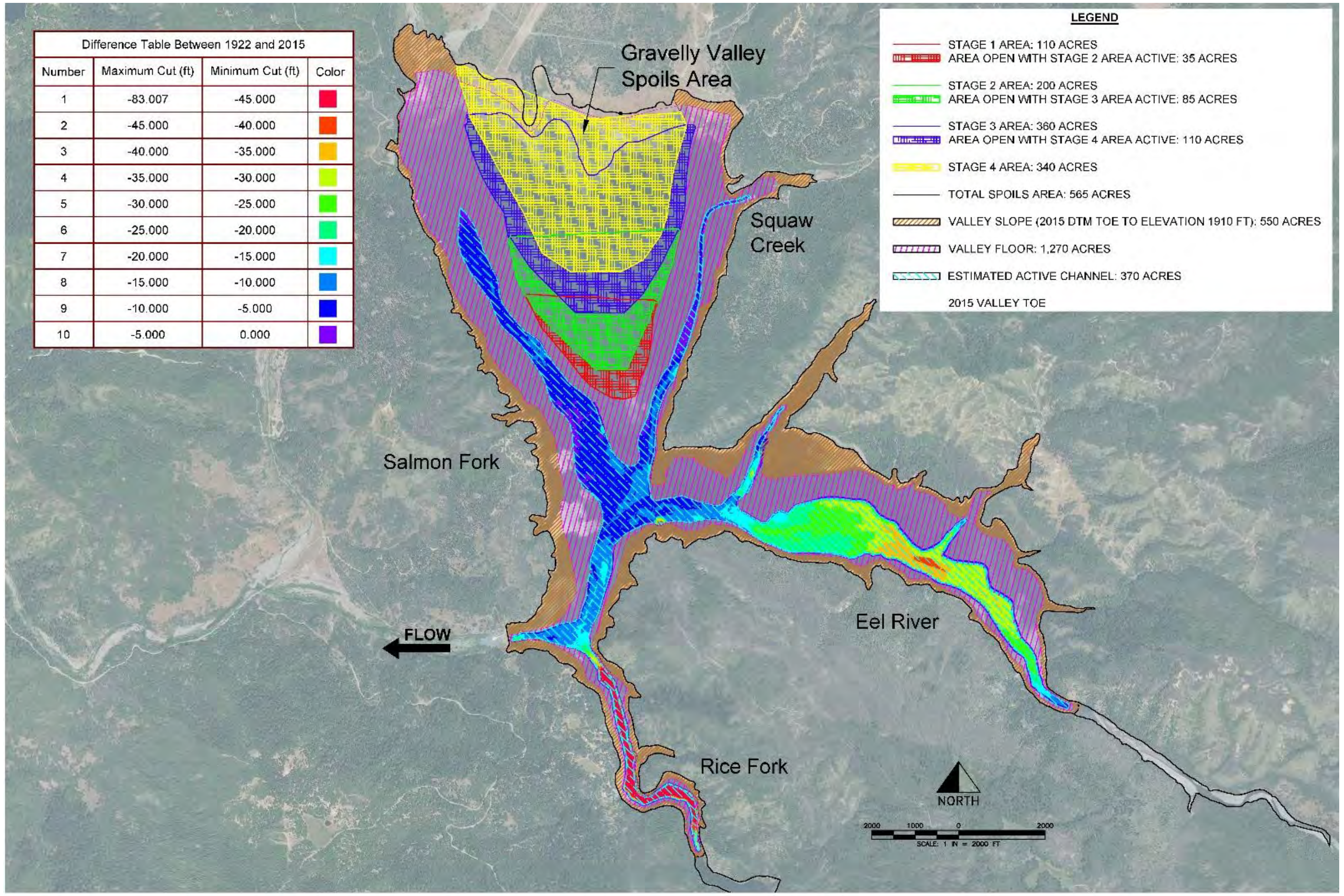
Sediment Transport to Disposal Area

- Transport via Pipeline
- Transport via Off-Highway Hauling

Sediment Disposal

- Gravelly Valley Disposal Area

Gravelly Valley Disposal Area – Staged Placement



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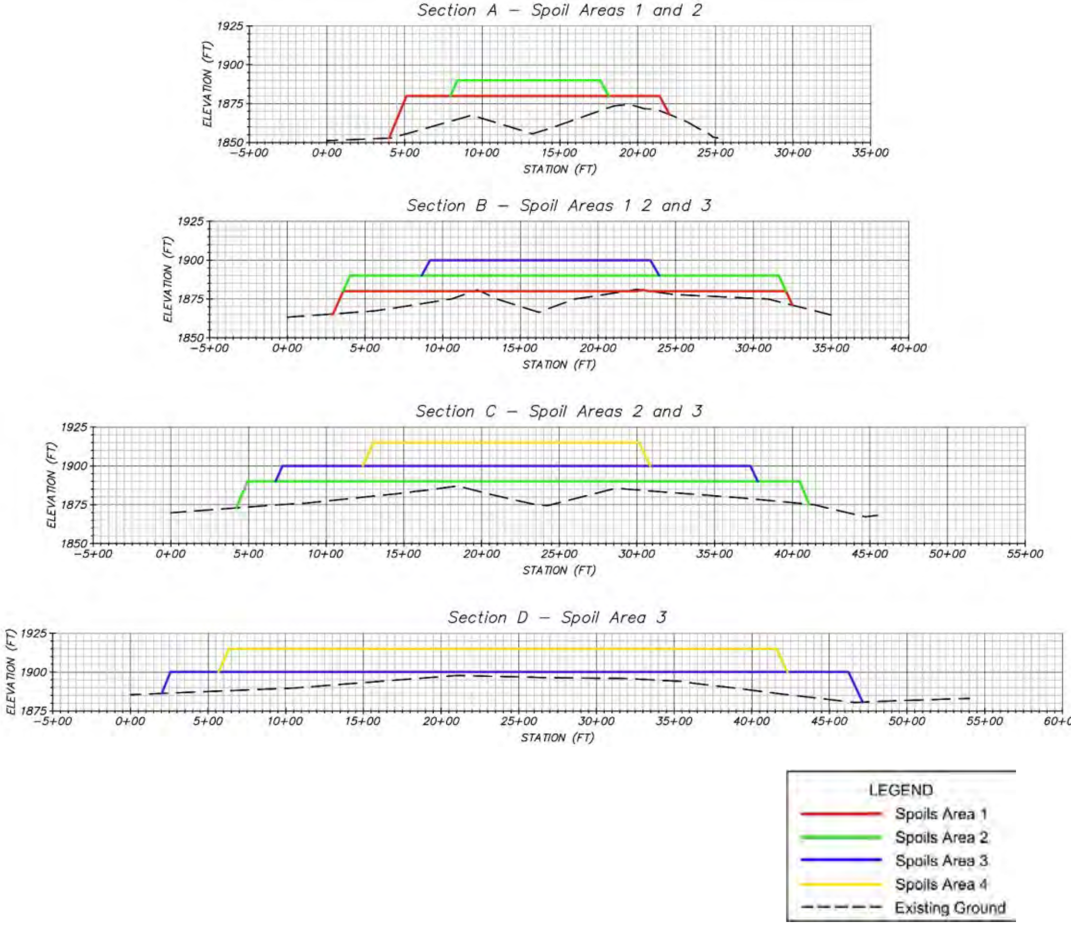
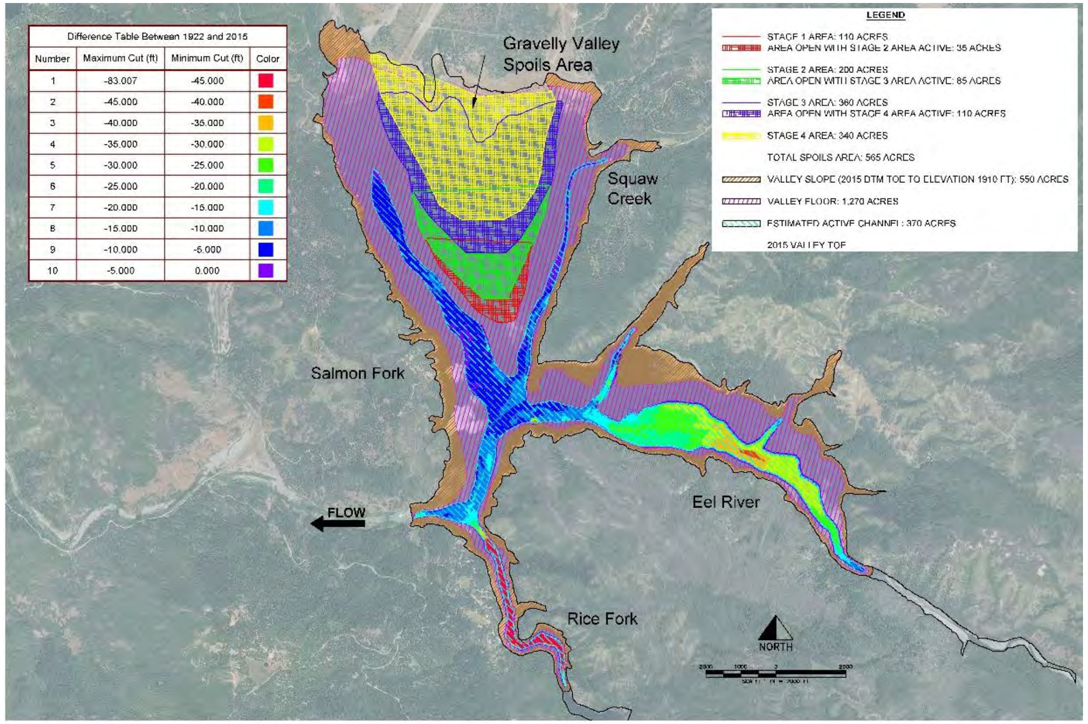


Elevations are in PGE vertical datum: Subtract 81.5 ft to get to NGVD29

Gravelly Valley Disposal Area – Storage Capacity



Difference Table Between 1922 and 2015

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8	-15.000	-10.000	
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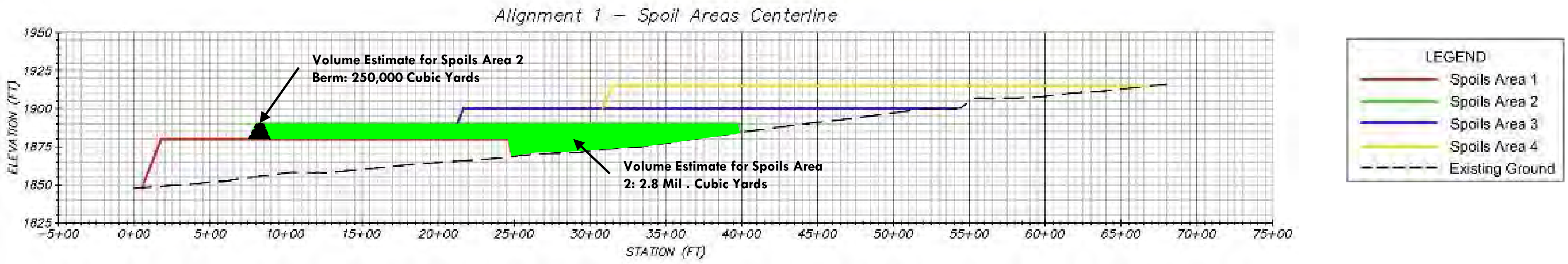
10	-5.000	0.000	

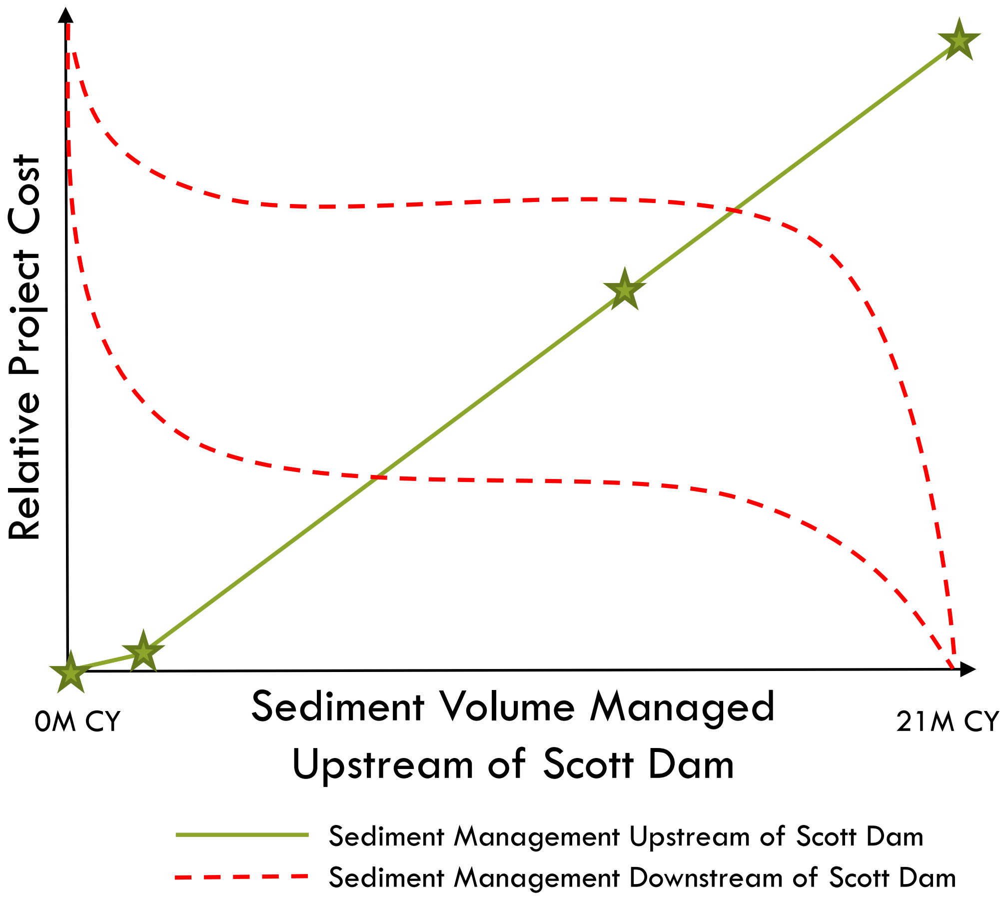
CONCLUSION: There is sufficient space to spoil 16 million CY of sediments at Gravelly Valley spoils area



Elevations are in PGE vertical datum: Subtract 81.5 ft to get to NGVD29

Sediment Management Assessment

Sediment Management Downstream of Scott Dam



Downstream Considerations

- Amount of Sediment Released
- Timing of Sediment Released
- Characteristics of Sediment Released
- Possible Contaminants Released
- Potential Duration of Sediment Release
- Potential Location(s) of Sediment Impacts
- Potential Timing of Sediment Impacts

Part 5: Suspended Sediment Concentration Analysis for different Scott Dam Decommissioning Options

Objective and Scenarios

Provide an "order of magnitude" analysis for the natural erosion of fine sediment expected from Lake Pillsbury from Scott Dam removal

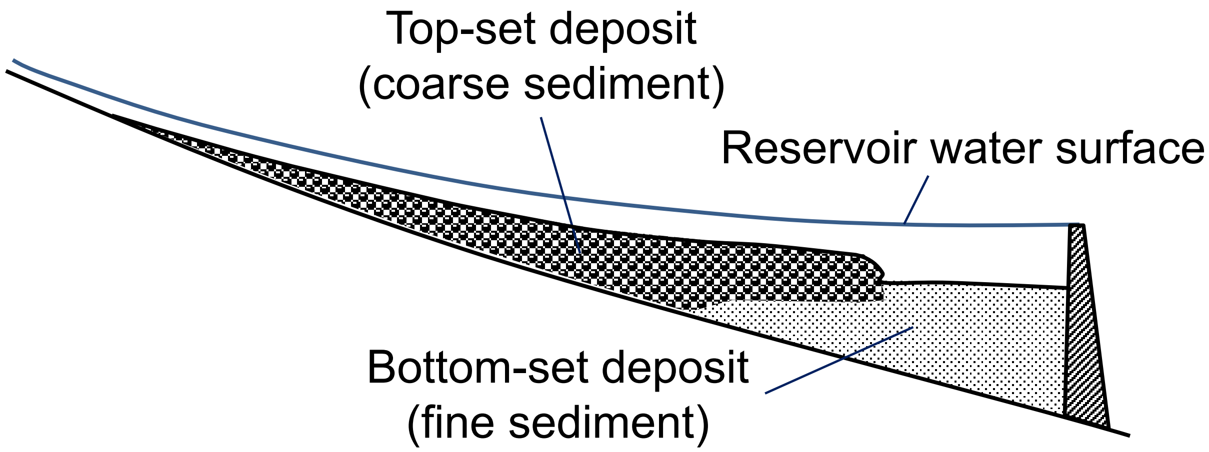
Initial Scenarios

Scenario #1: Rapid removal of Scott Dam (1 year), rapid erosion of Lake Pillsbury sediment

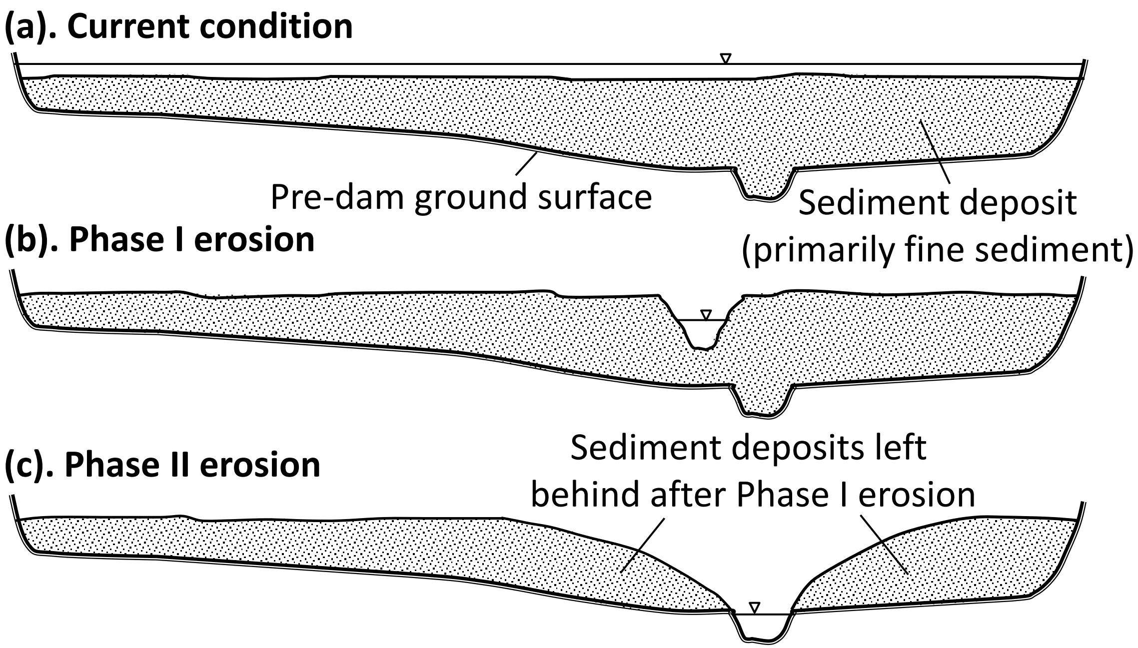
Scenario #2: Phased removal of Scott Dam (4 years), extended erosion of Lake Pillsbury sediment

Conceptual Models: Reservoir stratigraphy and incision process

Stratigraphy



Incision Process

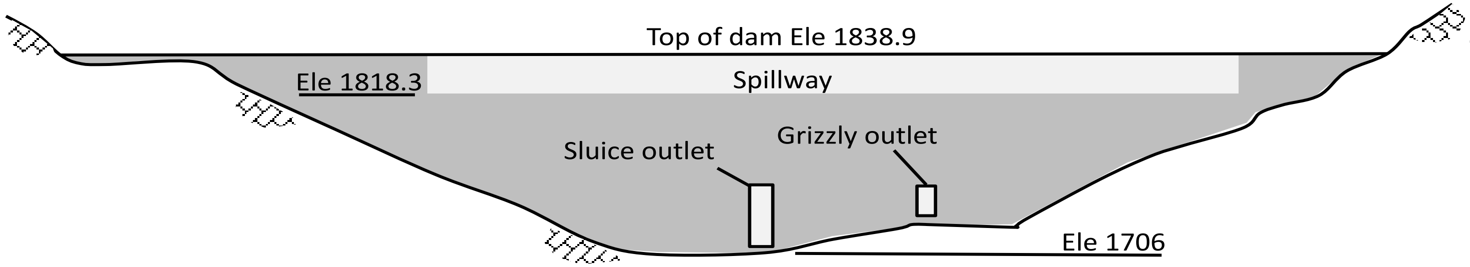


Conceptual model

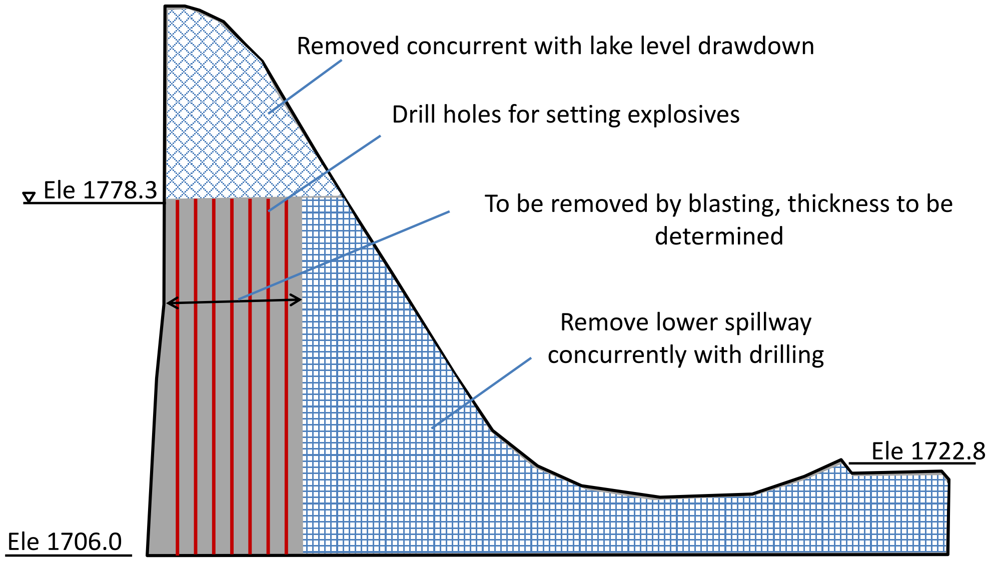
- Rapid removal via Vertical Notching:
  - Rapid erosion of all erodible reservoir sediments (n=1)
  - Erosion would occur during first winter storms
  - Extremely high suspended sediment concentration
  - Shorter duration of high suspended sediment concentration
- Phased removal:
  - Repeated rapid erosion of reservoir sediments with each notching event (n=4)
  - Erosion would occur over multiple years and seasons
  - High suspended sediment concentration
  - Longer duration of high suspended sediment concentration

Potential Scott Dam Vertical Notching Process

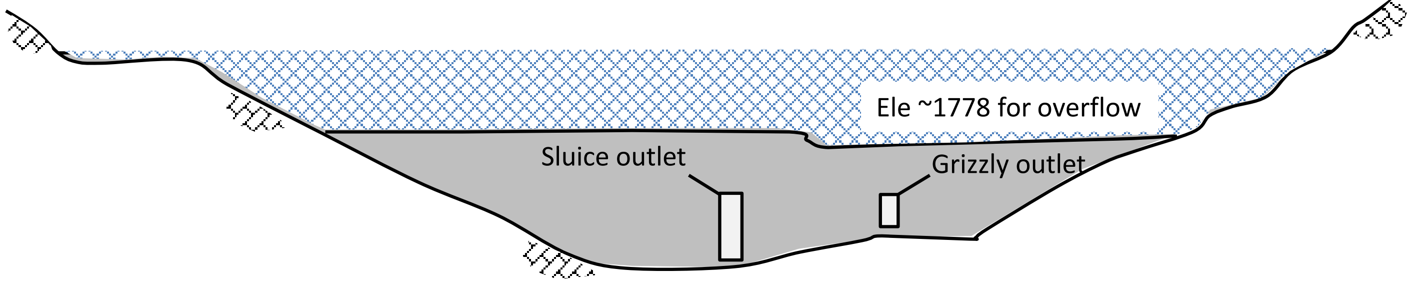
a. Current condition



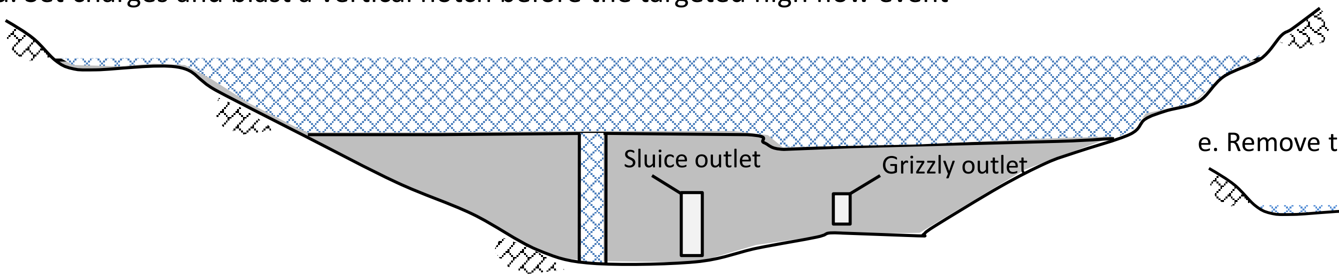
c. Drilling holes for setting explosives and remove lower spillway in the notching section



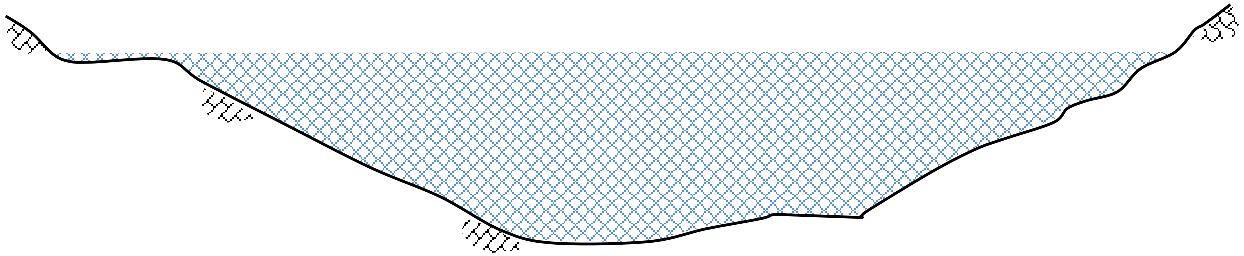
b. Draw lake level down to approximately 1778 ft, remove the dam above lake level, leaving one side higher



d. Set charges and blast a vertical notch before the targeted high flow event



e. Remove the rest of the dam



Elevations are in NGVD29 datum: Add 81.5 ft to get to PGE vertical datum

Governing Equations

$$C = \begin{cases} 50\left(\frac{V^3}{gHv_s}\right)^{1.55}, & \frac{V^3}{gHv_s} \le 10 \\ 135\left[ln\left(\frac{V^3}{gHv_s}\right)\right]^{3.1}, & 10 < \frac{V^3}{gHv_s} \le 100 \\ 620\left(\frac{V^3}{gHv_s}\right)^{0.7}, & \frac{V^3}{gHv_s} > 100 \end{cases}$$

Computing suspended sediment concentration based on velocity, depth, and settling velocity of particle based on grain size of sediments in reservoir

$$Q_w = \frac{1.48}{n} BH^{5/3} S^{1/2}$$

Mannings equation to compute velocity based on slope, assumed channel width, and water depth

Compute Suspended Sediment Concentration

Compute Phase 1 erosion duration

$$Q_s = CQ_w/\rho_d$$

Computes suspended sediment transport rate based on concentration, flow, and sediment density

$$t_0 = M_1/Q_s$$

Computes Phase 1 erosion time based on volume of fine sediment in reservoir and suspended sediment transport rate

Assumptions

	Rapid Vertical Notching	Phased Removal
Years for removal and erosion	1	4
	1,000 cfs to 3,000 cfs	
Channel Width	300 ft	300 ft
Channel Gradient	0.01 (1%)	0.01 (1%)
Median grain size	0.11 mm	0.11 mm
Settling velocity	0.000358 ft/sec	0.000358 ft/sec
Sediment dry density	1,590 lb/cu yd	1,590 lb/cu yd
Volume of sediment to be eroded	12,000,000 cu yd	12,000,000 cu yd

Results: Rapid removal via Vertical Notching

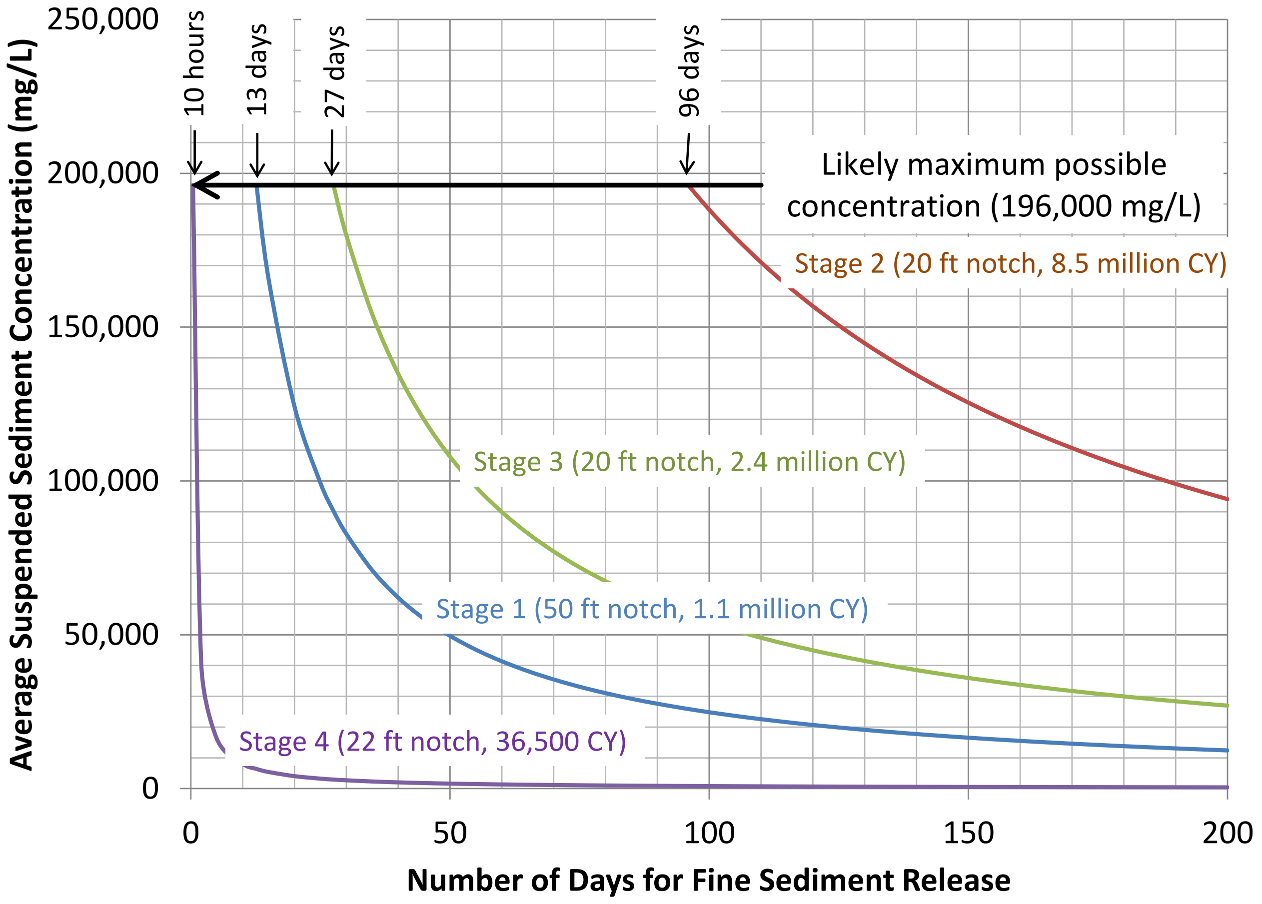
Water discharge	1,000 cfs	2,000 cfs	5,000 cfs
Suspended sediment concentration (mg/L)	457,800	612,500	900,000
Duration of Phase 1 erosion (days)	7.7	2.9	0.8

Conservative Assumptions:

- Phase 1 erosion duration is likely over-estimated
- Channel width may be wider than actual
- Channel gradient assumption may be steeper than actual
- Assumes all 12 million cu yd is fine sediment

Results: 4-Stage Phased Removal

- Maximum computed suspended sediment concentration of 196,000 mg/L
- Duration of maximum suspended sediment concentration varies due to differential volumes in each dam notching phase.
- Longest duration = 96 days for first notching phase, only 10 days for final notching phase
- Total duration ~ 136 days with concentrations = 196,000 mg/L
- Duration of suspended sediment over 50,000 mg/l is hundreds of days, particularly during the first notching phase



Summary

- As found at other dam removal sites, there is a tradeoff between the two dam removal strategies
- Rapid Removal: concentrations > 400,000 mg/L depending on flow during erosional event, but duration is much shorter than Phased Removal (8 days compared to hundreds of days of elevated concentrations)
- Phased Removal: lower concentrations (~200,000 mg/L), but much longer duration (>100 days)
- Next Step: conduct initial biological assessment of these results (February)

QUESTIONS?

Part 6: Study AQ12 Overview and Discussion

Overview of Study AQ12 components

- **Sediment Transport Modeling downstream of Scott Dam**
- **Suspended Sediment Concentrations downstream of Scott Dam**
- Multi-dimensional Hydraulic Modeling at key downstream locations
- **Lake Pillsbury Sediment Management Assessment**
- Lake Pillsbury Vegetation Management Assessment
- Surface Water Diversion and Groundwater Supply Review

Sediment Transport Modeling downstream of Scott Dam

- Supplemental bathymetric surveys to refine topography
- Additional reservoir sediment sampling to better assess grain size and stratigraphy
- 1-D coarse sediment transport modeling from Scott Dam to Middle Fork Eel
  - Different dam decommissioning scenarios
  - Different hydrologic scenarios
  - Focus at key infrastructure (Diversion, fish ladder, bridges)
  - May transition to multi-dimensional modeling depending on 1-D results
- Comparison of sediment yield changes at downstream locations

Suspended Sediment Concentrations downstream of Scott Dam

- Refinement of computations shown today based on improved sediment stratigraphy/composition
- Comparison of sediment release to downstream suspended sediment concentrations
- Biological evaluation of computed suspended sediment concentrations compared to background concentrations
- Evaluate different dam decommissioning alternatives

Lake Pillsbury Sediment Management Assessment

- Refine sediment management volumes based on:
  - Refined results of predicted sediment evaluation from Lake Pillsbury
  - Assessment of potential geomorphic and biological changes downstream
  - Assessment of potential changes in water supply reliability at downstream diversions
  - Refinement in Scott Dam decommissioning strategy
  - Refinements in sediment management approaches and resulting cost
- Final Sediment Management Plan would be part of Protection, Mitigation, and Enhancement (PM&E) measures

Wrap up and Next Steps

- Lake Pillsbury Revegetation Considerations: tomorrow
- Additional Technical Workgroup meetings for this and other topics
  - CDFW/Caltrout Supplemental Feasibility Study: Now→May 2021
  - NOI Parties FERC Study Plan: TBD, sometime in 2021
- Completion of CDFW/CalTrout Supplemental Feasibility Study: June 2021

Water Supply Reliability

Fishery Restoration

Science & Engineering

Stakeholder Participation

Power Generation

POTTER VALLEY PROJECT TECHNICAL STUDIES

Lake Pillsbury Vegetation Management Discussion

John Bair – Senior Riparian Ecologist

Amy Livingston – Riparian Botanist

Scott McBain – Fluvial Geomorphologist

Meeting Objectives

- Provide an overview of potential Lake Pillsbury Revegetation options assessed by the Feasibility Study
- Provide an overview of anticipated changes to riparian vegetation upstream and downstream of Scott Dam after decommissioning
- Facilitate a technical discussion of these revegetation options to inform anticipated work conducted as part of FERC studies (study AQ12)

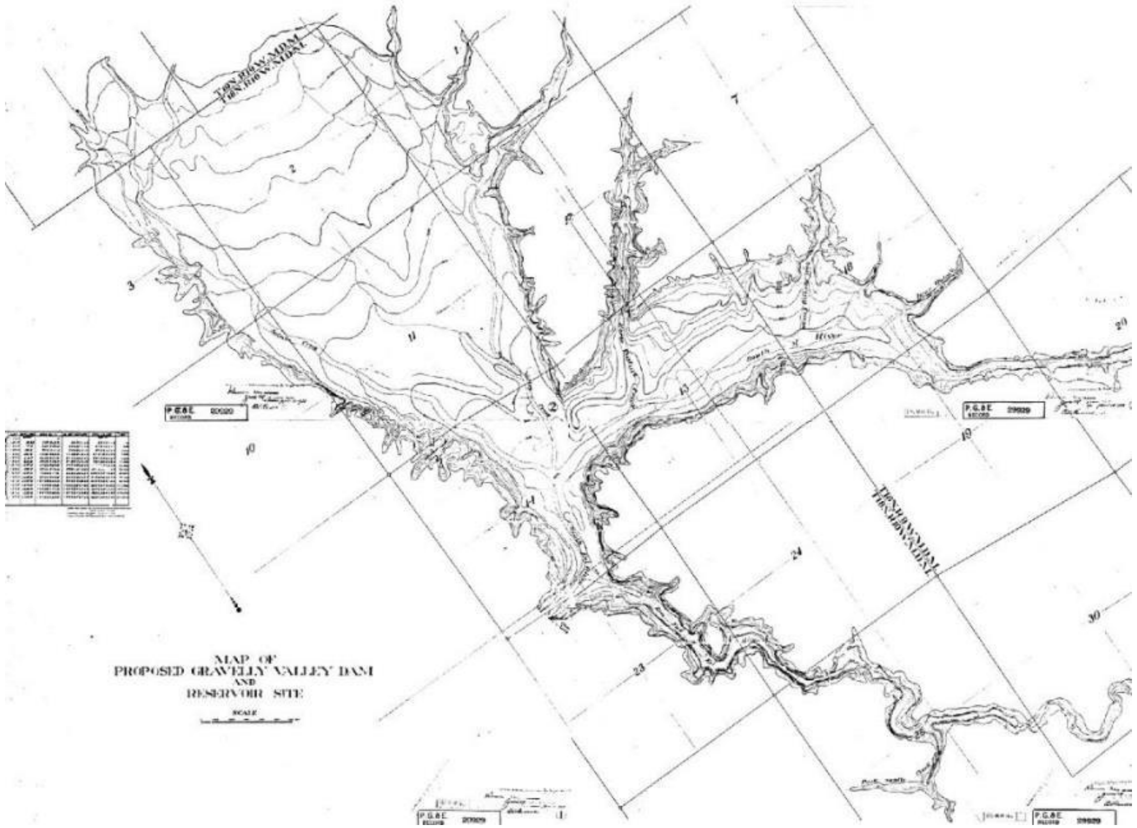
Components of Presentation

- Part 1: Overview of Potential Scott Dam Removal and Lake Pillsbury Sediment Management considerations
- Part 2: Revegetation Components
  - Comparison to Similar Projects and Costs
  - Hypothesized Outcomes Post Dam Removal
  - Revised Unit Costs
  - Future Studies/Next Steps

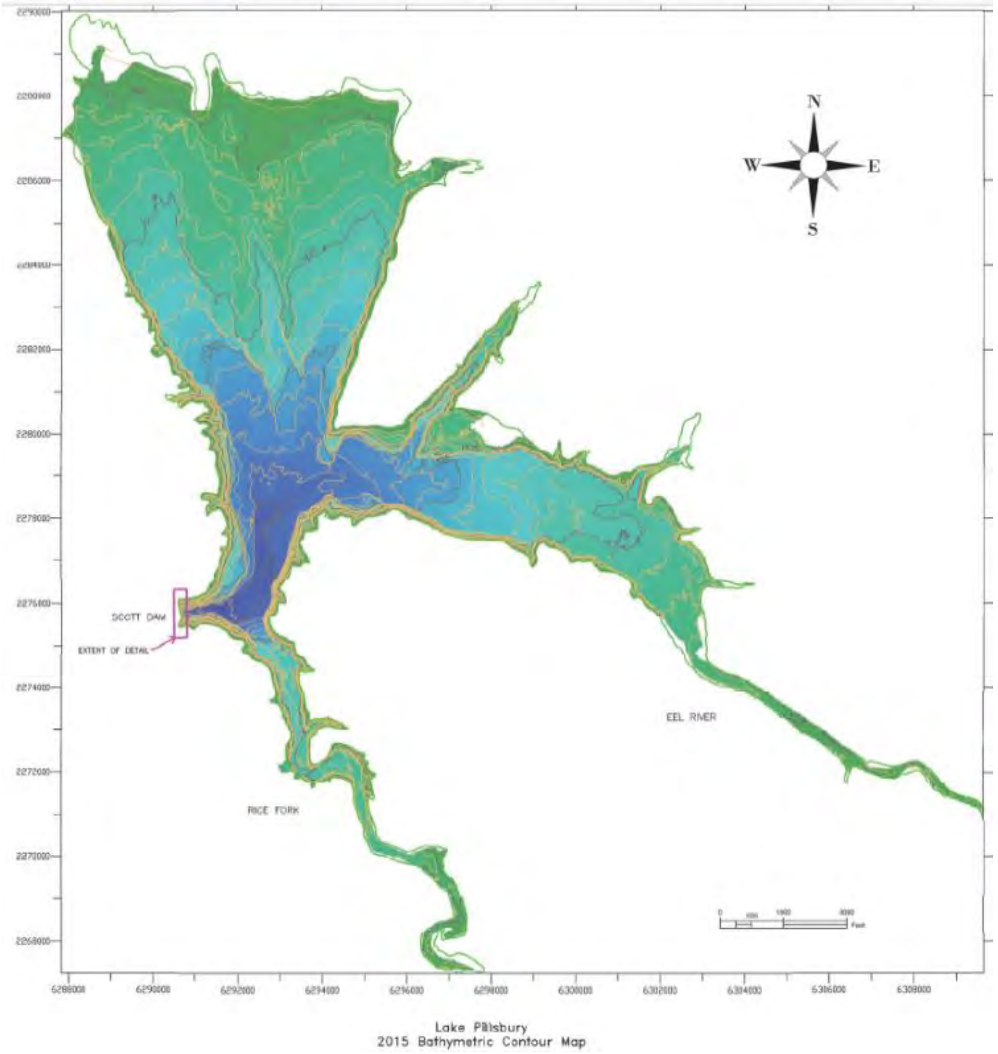
Part 1: Overview of Lake Pillsbury Sediment Management Considerations

How much sediment is stored in Lake Pillsbury?

1922 Topography (USGS)

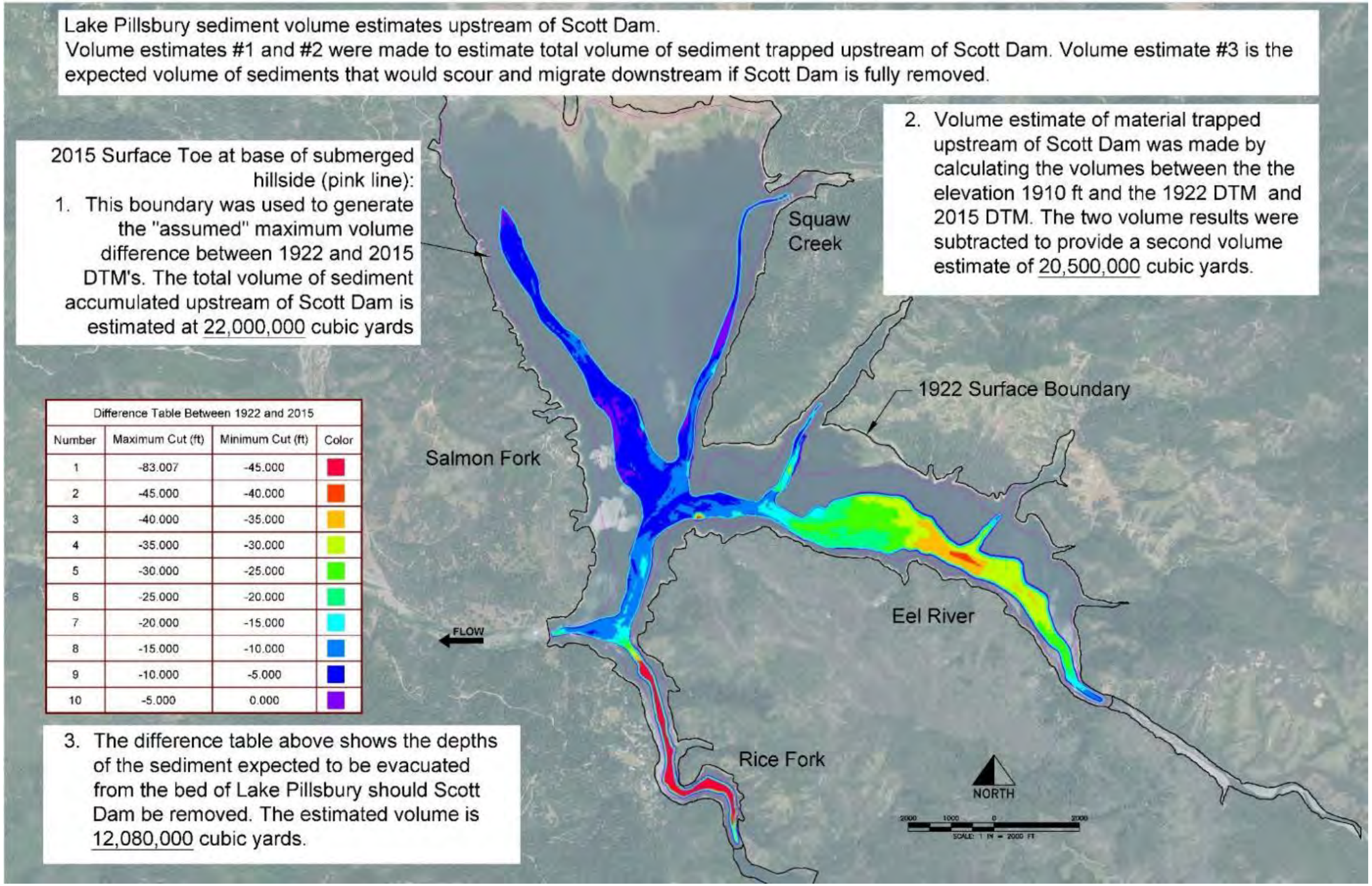


2015-16 Bathymetry (PG&E)



~21 million cubic yards

How much of this sediment could be easily eroded with Scott Dam removal?



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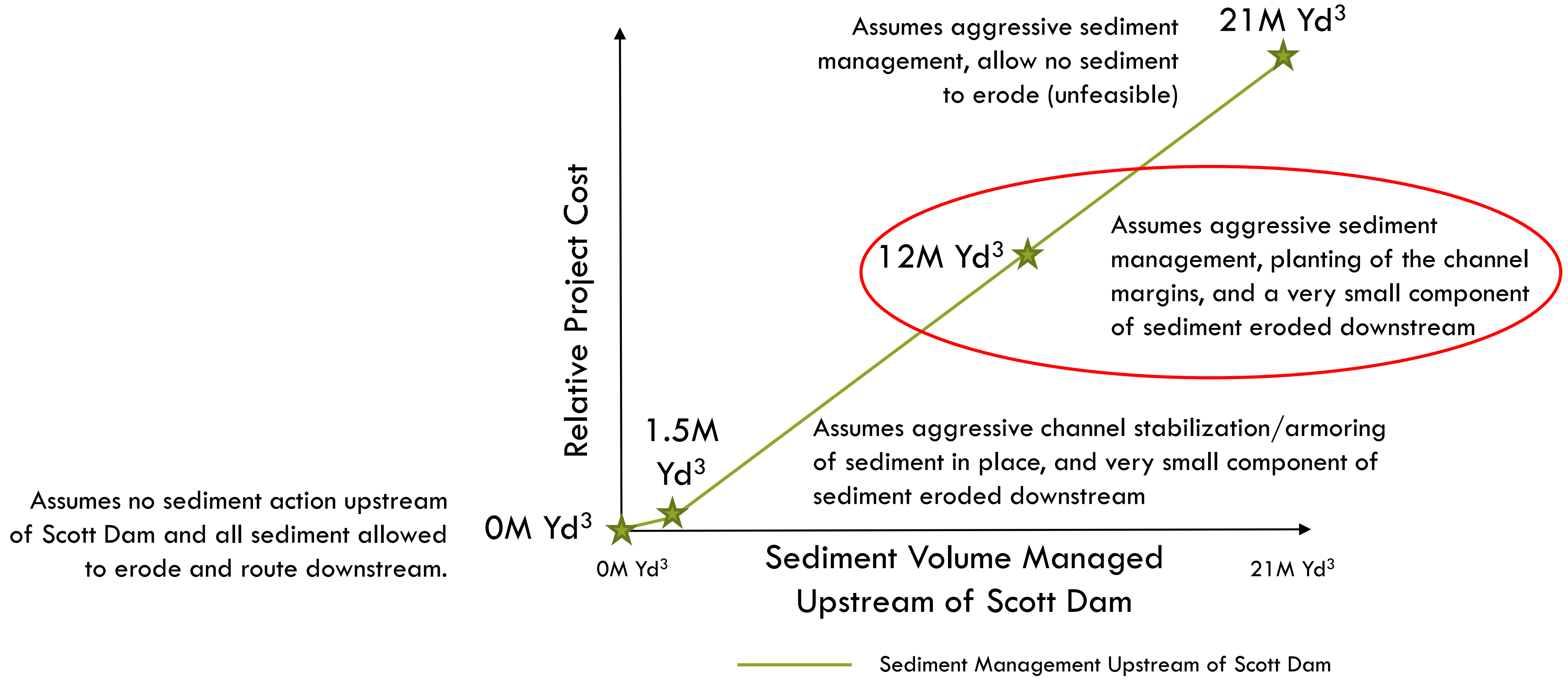
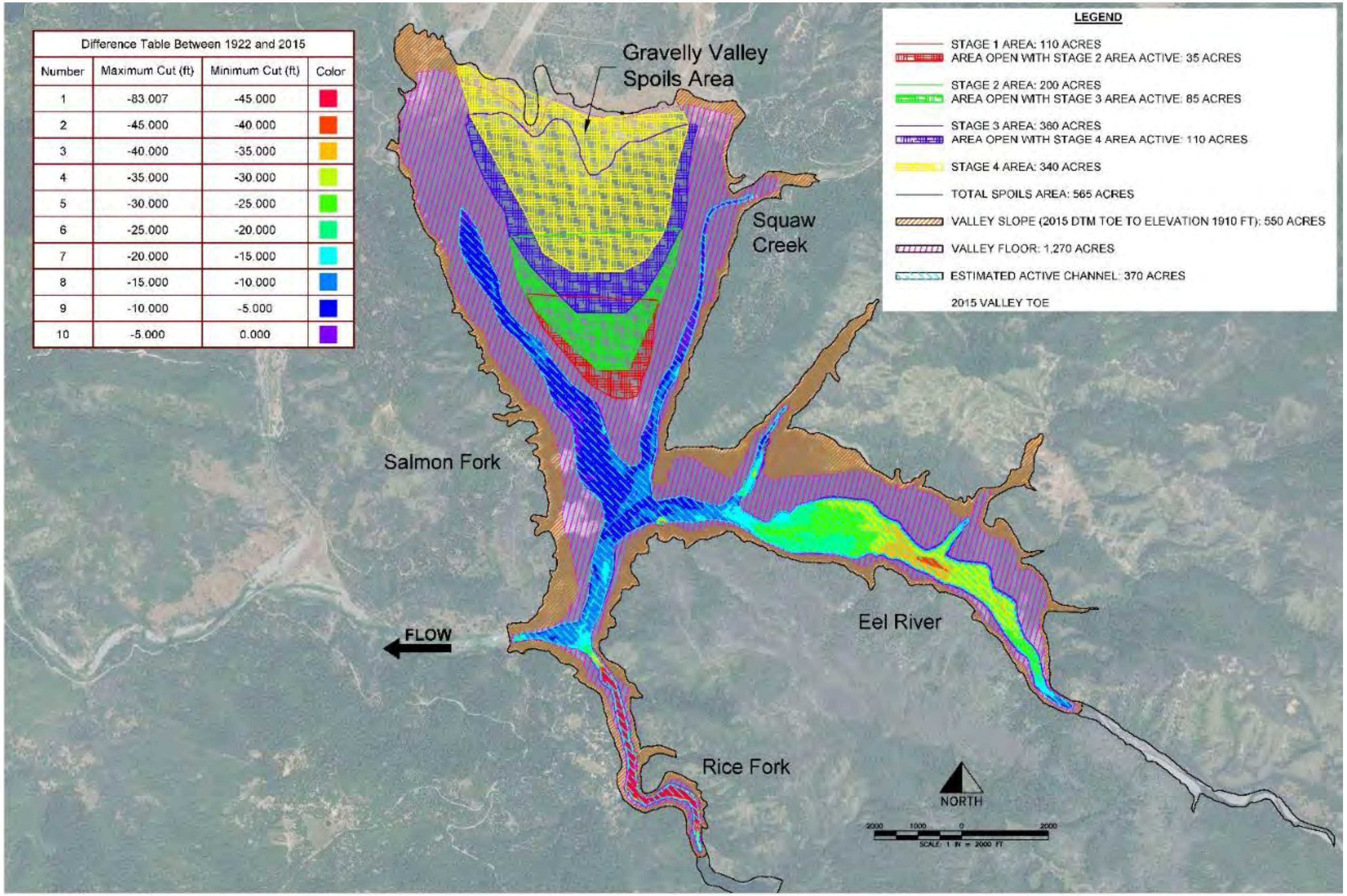
- Varying meander belt widths based on three examples
- Depth based on 1921/22 bathymetry and profile surveys
- **Best estimate is approximately 12,000,000 cu yds of "erodible sediment"**

How could we manage this sediment?



Where could we stockpile this material?



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Potential Lake Pillsbury Revegetation needs

- Dam site after decommissioning?
- Sediment Management spoils area?
- New riparian corridor?
- Upland areas?
- Elk considerations?
- Others?

Part 2: Overview of Lake Pillsbury Vegetation Management Considerations

Feasibility Study Workplan Objectives

- Update preliminary cost estimate from Tech Memo #2
- Develop a potential vision of post-Lake Pillsbury vegetation recovery
- Develop more detail in potential revegetation strategies
- Solicit agency input on potential vision and revegetation strategies
- Compile pertinent literature on reservoir bottomland revegetation
- Utilize Agency input to begin refining revegetation planning options

Elwha River Dam Removal Lakebed Recovery

- Overview of Elwha dam removal revegetation projects
  - Strategy to plant trees, shrubs, and seeds on ~441 acres
  - Planted NPS nursery grown materials at ~700 plants per acre
  - Installed with NPS, Tribal and volunteer support
  - Invasive management not included in initial costs
  - Included seeding

- Compare and contrast between Lake Pillsbury and the Elwha Project
  - Smaller watershed completely within NPS ownership
  - Project size about 30% of Lake Pillsbury (Two smaller areas to recover)
  - Project Stakeholders (NPS and local Tribes)
  - Revegetated in two phases over many years
  - More forgiving environment (rainfall, low fire frequency)

Klamath River Dam Removal Lakebed Recovery

- Overview Klamath dam removal revegetation projects; Definite Plan
  - Strategy to plant dominant sage scrub, conifer forest, riparian species and seed
  - Modest amount of private and government nursery grown container plants
  - Installed with Tribal labor sources
  - Relies on two or three iterations of seeding overtime
  - Invasive management part of estimated costs

- Compare and contrast between Lake Pillsbury and the Klamath Project
  - Second largest river in California
  - Many Project Stakeholders (Yurok, Private Utility, USFS, Private landowners, USBR)
  - Revegetated in short period in an arid environment
  - Multiple landowners within project area and within the entire drainage
  - Similar to Lake Pillsbury in size and socio-political climate

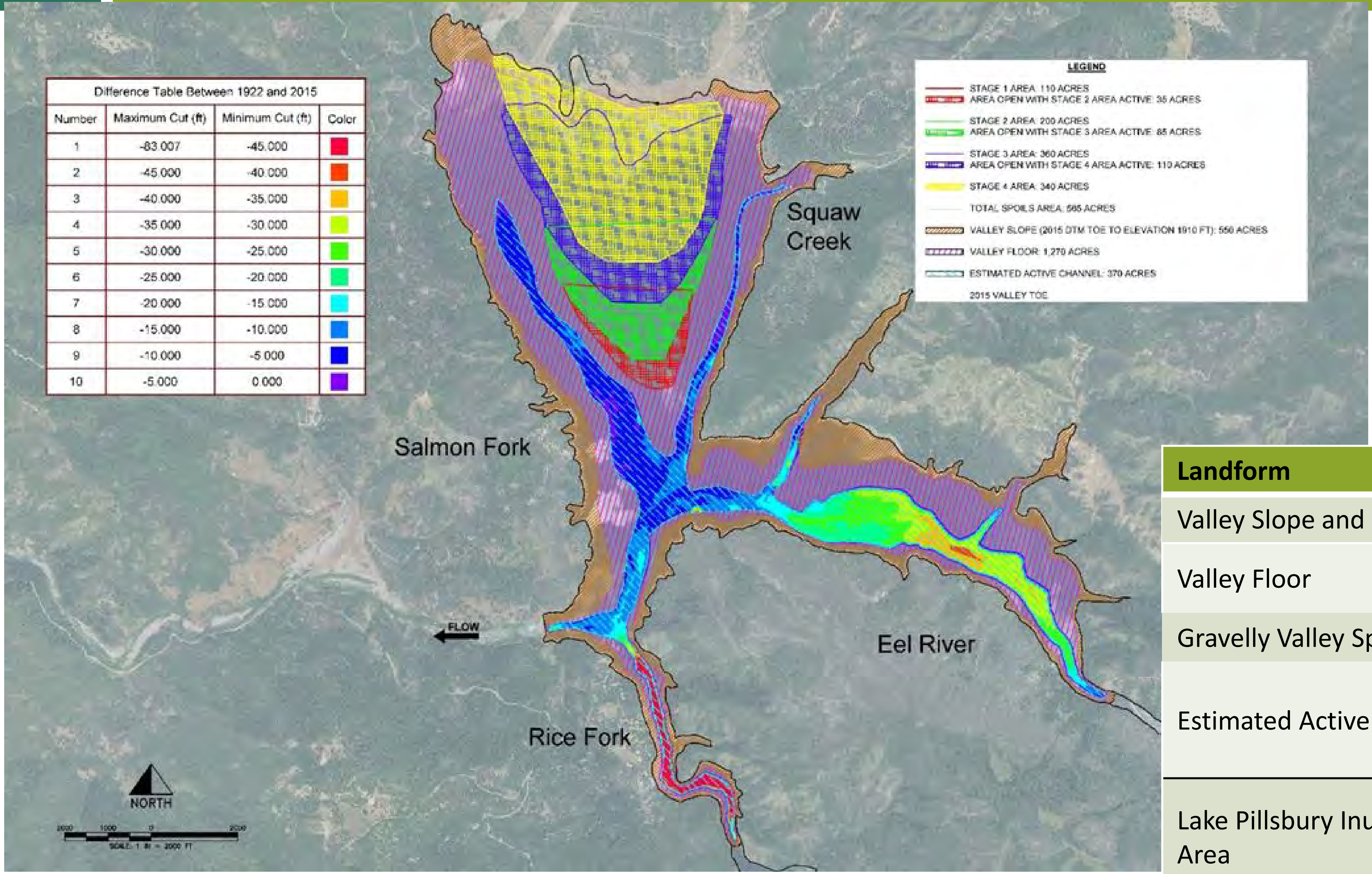
Feasibility Study Technical Memorandum #2: Initial Vegetation Recovery Concepts

The potential goal of revegetation is to recover the disturbance footprint within and around Lake Pillsbury with ecologically functioning vegetation that provides terrestrial and aquatic habitat and will meet agency desires for post-dam removal land condition.

Lake Pillsbury

- Revegetate with dominant species and seed co-dominant or commonly associated species.
- Recover woody vegetation on valley slopes and valley floor.
- Allow the active channel area to passively recover.
- Recover sediment management areas with grasslands and woody plants.
- Intensive Non-native Invasive Plant Species management.

Initial Recovery Strategy (for 12 million cu yds sediment management option)



Landform	Area	Recovery
Valley Slope and Hillsides	550 acres	Revegetate
Valley Floor	1,270 acres	Revegetate
Gravelly Valley Spoils Area	570 acres	Revegetate
Estimated Active Channel	370 Acres	Passive Recovery
Lake Pillsbury Inundation Area	2,760 acres	Combination of Passive and active

Feasibility Study Technical Memorandum #2

- Initial recovery approach was assumed to be “one size fits all”
- Initial cost estimate assumptions
  - one planting density everywhere
  - tree planting and seeding everywhere except for the active channel in the valley floor
  - one price for nursery grown materials
  - no labor overtime
  - no equipment
  - no per diem/lodging

- More tailored approach to be developed with agency input

Feasibility Study Technical Memorandum #2: Preliminary Unit Costs

- Developed unit costs for revegetation/recovery approaches
  - Evaluated two different prevailing wage labor costs assuming level of effort is like more intensive restoration project regionally
  - Compared seeding and mulching to hydroseeding costs
  - Included non-native invasive plant management
  - Included sediment management (erosion control then revegetation)
  - Compared preliminary cost estimates to Elwha and other unpublished unit costs

Source	Project	Revegetation Per Acre Unit Cost	Cost to Revegetate Project Area
From TM#2	Elwha Actual Unit Cost	$18,300	$43,737,000
From TM#2	Unpublished Local Unit Cost	$8,200	$19,598,000
From TM#2	Jan 2020 Preliminary Bottoms Up Cost estimate Group 3	$20,921	$50,000,000
From TM#2	Jan 2020 Preliminary Bottoms Up Cost estimate Group 7	$17,991	$43,000,000

Phase 2 Feasibility Study

- Information gaps and uncertainties
  - Specific lakebed recovery objectives/management priorities
  - How much passive vs active restoration
  - Planting needs- vegetation types, densities, locations
  - USFS and CDFW Input

Hypothesized evolution once dam is removed

- Lake Pillsbury
  - Sediment and dust management
  - Exposed lakebed will need active rehabilitation
  - Wildlife habitat rehabilitation

Hypothesized evolution once dam is removed

- Eel River within Reservoir
  - Rapid recovery (potentially from existing seed banks in exposed lakebed sediment)
  - Sparse riparian vegetation similar to what is upstream of lake now

Hypothesized evolution once dam is removed

- Eel River below Scott Dam
  - Riparian loss downstream of dam due to reduced flow volumes and streamflow during growing season
  - Riparian loss downstream of dam due to increased high flows and sediment supply during winter high flow season

Lakebed and Hillslope Recovery Concepts

- Valley slope and hillsides are mixed conifer forest
  - Reasonable to expect same pattern down to the valley floor
- Valley floor was most likely oak grassland
  - Observations during field visit
  - Likely similar to Round Valley
  - Oak stumps in lake inundation footprint

Elk Management

- Elk currently utilize lake during summer months for aquatic veg forage and temperature refuge and would not have those resources available with dam removal
- Elk herd effects on restoration efforts will need to be included
  - Loss of available forage during summer/fall months would put more pressure on lakebed revegetation
  - Elk eat reforested conifers at the south end of the lake and would eat planted trees
  - Could potentially lose all plantings in a season
- Elk will need to be actively managed
- Evaluate the trade offs of deferring revegetation or including annual losses in recovery

Phase 2 Feasibility Study Revised Unit Costs

- Revised unit costs for revegetation/recovery approaches
  - Updated labor to reflect tree planting at 786 plants per acre (~8 ft o.c.)
  - Updated labor rates to reflect August 2020 wages
  - Updated nonnative invasive management to reflect low invasive abundance field observations
  - Updated plant material costs to reflect reforestation tree costs regionally and not restoration nursery stock
- Assume Planting area = 2,390 acres

Source	Project	Revegetation Per Acre Unit Cost	Cost to Revegetate Project Area
From TM#2	Elwha Actual Unit Cost	$18,300	$43,700,000
From TM#2	Unpublished Local Unit Cost	$8,200	$19,600,000
Revised	December 2020 Revised Bottoms Up Average Cost estimate Group 3	$8,069	$19,300,000
Revised	December 2020 Revise Bottoms Up Cost estimate Group 7	$7,566	$18,000,000

FERC Study AQ 12 Assessments

- Compile information (other dam removals, flows, photographs, etc.)
- Solar radiation evaluation
- Lakebed sediment assessments
- Non-native Invasive Species management
- Riparian hardwood phenology evaluation
- Identify appropriate plant species
- Integrate with sediment management strategies
- Assess landscape opportunities
- AQ12 will not be a plan but will inform a plan (PM&E's)

Next Steps

- Define desired future conditions
  - Habitat types and functions
- Developing broad management objectives
  - Elk
  - Riparian and wetland vegetation
  - Landscape form and function
- Refine broad revegetation concepts
  - Identify the “Must Do” actions (e.g., dust abatement, non-native species management)
  - Identify the “Nice to Do” actions (e.g., elk habitat creation)
  - Vegetation patterns and plant species
  - Needs further agency input to better define and detail to the potential revegetation vision
  - Location and types of revegetation
- If time allows, refinement of AQ 12 tasks on riparian vegetation assessment subtask

Additional Feedback

- E-mail comments/suggestions to John, Scott, Dirk, and Darren

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