APPENDIX A

CALIFORNIA TROUT

Final Project Report

Title:	Elk River Watershed Stewardship Program
Grantee Name:	California Trout, Inc.
Date:	Friday March 13, 2020; amended July 8, 2022
Watershed:	Elk River (HUC-12 - 110.000201, 202, 301, 302, 401, 402)
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I. Problem Statement & Relevant Issues

The North Coast Regional Water Quality Control Board (RWQCB) placed the Elk River on the Clean Water Act (CWA) Section 303(d) list of impaired water bodies in 1998. Water quality objectives are exceeded for sediment, suspended material, settleable matter, and turbidity, resulting in adverse impacts to several beneficial uses, including domestic water supplies; agricultural water supplies; cold water habitat; spawning, reproduction and early development; rare, threatened, or endangered species; and recreation.

The upper Elk River watershed is actively managed for timber production by Humboldt Redwood Company (75%) and Green Diamond Resource Company (7%). The upper watershed also includes the Bureau of Land Management Headwaters Forest Reserve (13%), with the remaining 5% comprising a combination of non-industrial timberlands, private residences, and agricultural land uses.

Delivery of sediment from the upper watershed has significantly aggraded the channel bed and banks, resulting in reduced channel capacity and an increase in nuisance[1] flooding which poses health and safety risks to residents, and impacts property value and land management. According to residents, reduced channel capacity has increased the flood stage in the North Fork Elk River by between two and three feet in the last three decades. Locations which historically flooded approximately every other year on average now flood up to six times per year with increased flood extent and duration. Roadways are frequently inundated to the extent that access (including emergency access) is impeded. Homes, driveways, ancillary structures, fields, drinking water systems, and septic systems are all impacted. Due to ongoing sedimentation and aggradation, nuisance flooding continues to worsen in both frequency, duration, and magnitude. Residents experience flooding differently depending on their location in the watershed and have different levels of awareness and concern about the increasing flood levels.

The source of aggradation is complex but is generally understood to be caused by a series of sedimentation events following clear cutting (liquidation logging) conducted in the late 1980s and 90s by Pacific Lumber Company (PALCO) when it was owned and operated by Maxxam Corporation. The majority of the watershed continues to be actively managed for industrial timber.

Since 1997, the4 effects of timber harvesting on water quality and endangered species activities has been better regulated. Timber harvesting activities are regulated under the California Forest Practices Act via Timber Harvest Plans approved by the California Department of Forestry and Fire, including

[1] California Water Code §13050 defines nuisance to mean anything which meets all of the following requirements:

1. Is injurious to the health, or is indecent or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property.
2. Affects at the same time an entire community or neighborhood, or any considerable number of persons, although the extent of the annoyance or damage inflicted in individuals may be unequal.
3. Occurs during, or as a result of, the treatment or disposal of waste.

associated environmental review documents, habitat conservation plans, and incidental take permits. Water quality associated with timber harvest is currently regulated under the federal Clean Water Act and California Porter Cologne Water Quality Control Act via waste discharge requirements and associated harvest limits. Despite the efforts of regulatory programs, downstream landowners continue to be adversely impacted by legacy sediment pollution and ongoing discharges of sediment from the upper watershed.

While a combination of regulation, altered management, and drier water years have generally helped to reduce sediment deposition in some years, data indicate that the channel, banks, and floodplain continue to aggrade. Large wet weather events have not scoured excess stored sediment out of the river channel over time as anticipated.

An evaluation of historical cross-sectional data indicates there is approximately 640,000 cubic yards (yd^3) of excess stored sediment in the Elk River channel, including more than 280,000 yd^3 in the lower North Fork Elk River, nearly 100,000 yd^3 in the lower South Fork Elk River, and nearly 260,000 yd^3 in the upper Mainstem Elk River (North Coast Regional Water Quality Control Board (NCRWQCB), 2013).

As a result, the Elk River is aggraded beginning approximately 10.4 miles upstream of the river mouth and throughout the low gradient channels. This area is referred to as the "impacted reach" (Figure 1) which generally Includes the lower North Fork Elk River approximately downstream of the Bridge Creek confluence, Lower South Fork Elk River downstream of approximately the Tom's Gulch confluence, and the mainstem Elk River from the confluence of the north and south forks downstream to Humboldt Bay.

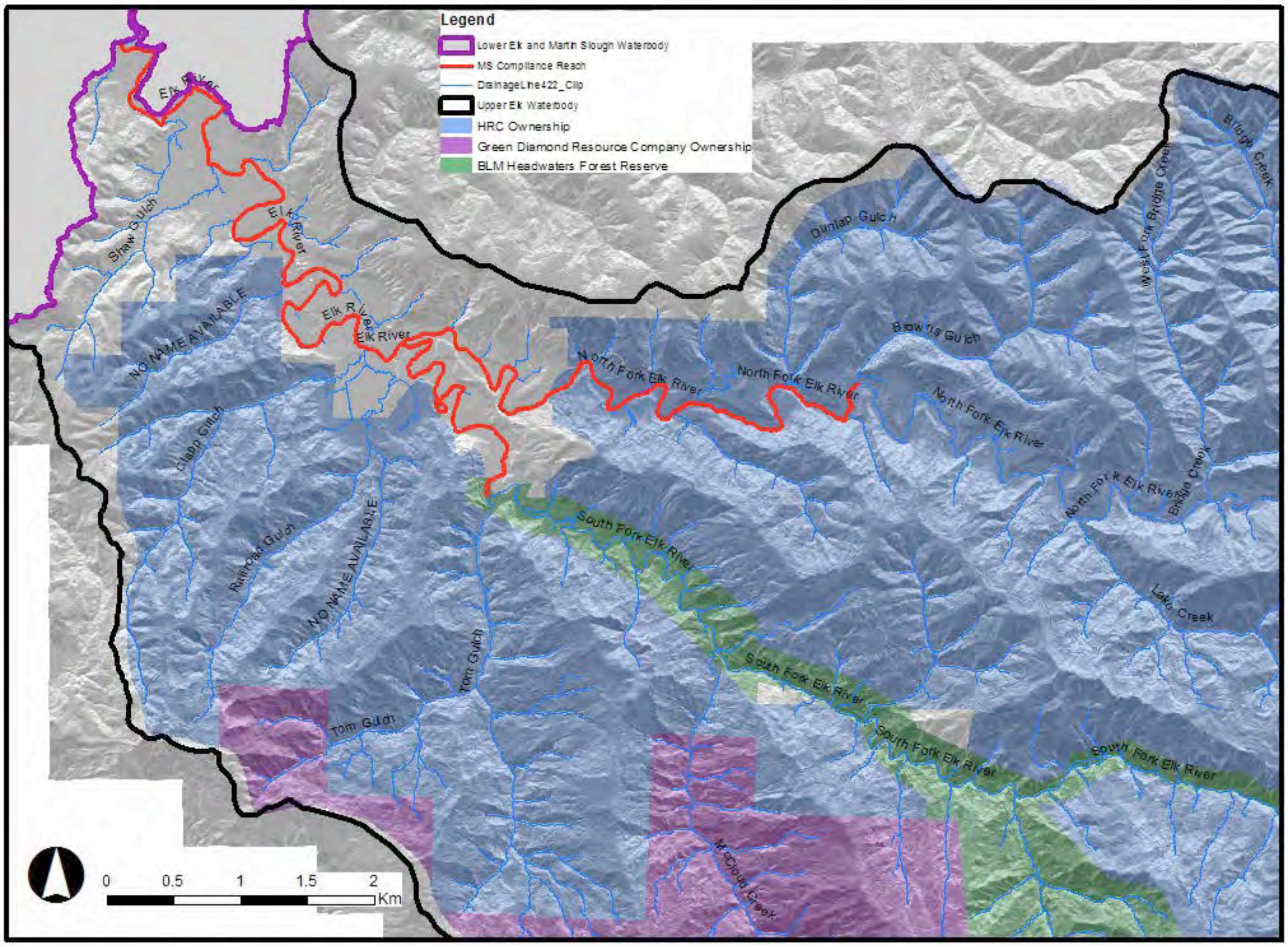

Figure 1. Upper Elk River watershed "impacted reach" (in red)

The impacted reach has been identified as impaired for sediment as a result of three related factors:

1) Excess sediment has been deposited on the bed, banks, and floodplain, reducing channel conveyance;
2) Sediment delivered from the upper watershed is predominated by very fine particles, embedding gravel; and
3) Deposited material is easily colonized by in-channel vegetation (such as sedge and shallow-rooted willows), which anchor the material in place and reduces its ability to remobilize and be transported out of the river system.

It is estimated that in-stream sediment deposits have reduced channel cross-sectional area by at least 35% in the upper mainstem Elk River. This deposition has caused diminished flow conveyance resulting in frequent, extensive flooding that poses health and safety risks and constitutes a nuisance[2]

[2] California Water Code §13050 defines nuisance to mean anything which meets all of the following requirements:

condition. Roads, access (including emergency access), property, domestic and agricultural water supply, septic systems, and land management are all impacted. In addition, the sedimentation impacts salmon habitat, filling-in and silting over deep pools and gravel bars previously provided important salmonid habitat.

To alleviate a sudden and dramatic increase in flooding, Elk River residents proposed mechanical removal of in-channel sediment deposits in the heavily impaired middle reach in 2004 (following the extreme sedimentation events). In 2008, the North Coast RWQCB convened a Technical Advisory Committee (TAC) and initiated technical studies related to sediment source analysis, including the **Upper Elk River: Technical Analysis for Sediment** (TetraTech, 2015).

A **Sediment TMDL for the Upper Elk River** was released by the North Coast RWQCB in 2013 and an **Action Plan** to satisfy the requirements of the Porter Cologne Water Quality Control Act was approved in 2016. The Action Plan is an adaptive management approach that identifies a combination of regulatory and non-regulatory actions that will lead to the attainment of water quality objectives, recovery of beneficial uses, and prevention of nuisance conditions. The **Program of Implementation** includes three main components intended to inform the restoration strategy:

1. Control of sediment delivery from industrial timbering sources in the Upper Elk River Watershed (Humboldt Redwood Company and Green Diamond Resource Company), via Waste Discharge Requirements (WDRs), waivers, or other orders;
2. Assessment of sediment remediation and channel restoration options via the **Elk River Recovery Assessment** (e.g., analyzing the fate of excess sediment and nuisance flooding); and
3. Implementation of a recovery program through the **Elk River Watershed Stewardship Program** (the first phase of which is which is funded under grant agreement D1713106 and is the subject of this Project Report).

The Elk River Recovery Assessment (SWRCB Agreement #13087110), completed in 2018, involved:

- Analysis of the system-wide fate and transport of sediment deposited in the Elk River channel since approximately 1988 during Maxaam's ownership);
- Development of a sophisticated hydrodynamic and sediment transport model (HST Model) specific to the Elk River watershed, and analysis of various "Management Scenarios" developed under the guidance of a Technical Advisory Committee (the Elk River TAC), and including two HST Model analyses – (1) the "No Action" (Existing Conditions) and (2) the "Modified Channel" (In-channel Sediment Removal) scenarios.

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1. Is injurious to the health, or is indecent or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property.
2. Affects at the same time an entire community or neighborhood, or any considerable number of persons, although the extent of the annoyance or damage inflicted in individuals may be unequal.
3. Occurs during, or as a result of, the treatment or disposal of waste.

- Production of a technical report - the **Elk River Recovery Assessment: Recovery Framework** (CalTrout et. al, 2018).

A Conceptual Model of Hydrodynamic Sediment Transport was developed under the ERRA to characterize existing conditions. The conceptual model defines river reaches based on similar geomorphic forms and processes (Figure 2). Chapter 7 of the ERRA Recovery Framework defined Restoration goals for each defined reach which were further developed under the Elk River Watershed Stewardship Program.

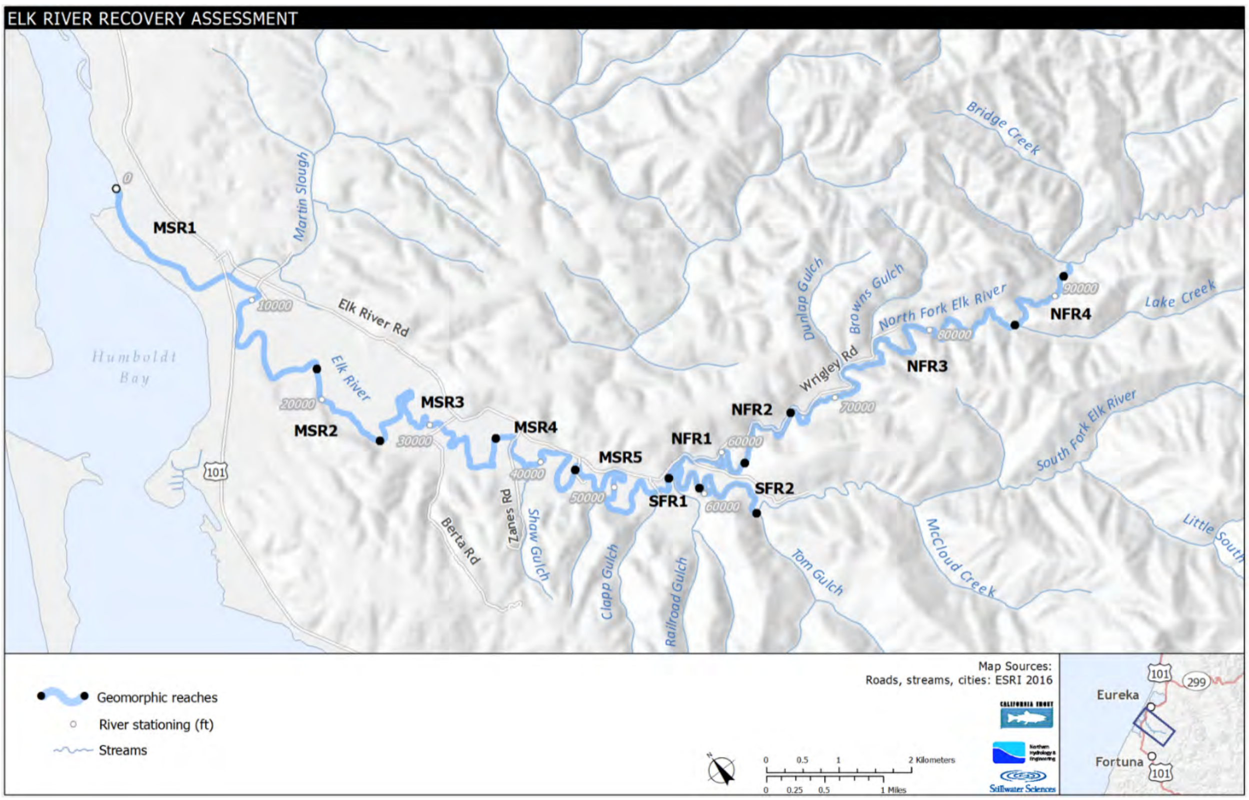

Figure 2. Elk River geomorphic reaches

II. Project Goals

The following section describes the purpose, goal, and reach-specific objectives of the Elk River Watershed Stewardship Program which will guide development and analysis of a Preferred Recovery Strategy.

Purpose

The purpose of the Elk River Watershed Stewardship Program is to engage community members, residents, scientists, land managers, and regulatory agencies in a collaborative planning process that seeks to:

1. Promote shared understanding and seek agreements among diverse participants;
2. Identify strategies and solutions to:
    a. Improve the hydrologic processes, water quality, and habitat functions of Elk River;
    b. Reduce nuisance flooding and improve transportation routes during high water conditions; and
    c. Improve residential and agricultural water supplies.
3. Promote coordinated monitoring and adaptive management.
4. Ensure that individual actions fit together and collectively yield the greatest benefit.

Goal

The Elk River Watershed Stewardship Program will work to accomplish the following goal:

> *Develop a landowner-supported, multi-objective approach to reduce nuisance flooding and recover impaired beneficial uses. This approach ideally will balance flood protection and natural resource enhancement and provide for programmatic long-term regulatory permits and environmental compliance for implementation of the Proposed Recovery Strategy.*

Objectives

Attendant to the Program goal, the following are river-wide objectives of the Elk River Watershed Stewardship Program:

- Coordinate directly with watershed residents, local, state, and federal resource agency staff, and other stakeholders to solicit input and transmit information on recovery program activities;
- Provide an umbrella under which specific working groups form to coordinate resource management issues in a collaborative and transparent way;
- Build partnerships, interpret technical studies, and identify actions that are feasible, fundable, and broadly supported by stakeholders;
- Identify design approaches and associated mitigation that are acceptable to both landowners and permitting agencies;
- establish a river-wide coordinated monitoring and adaptive management program to enable evaluation of remediation actions, track trends in water quality and habitat characteristics, and targeted populations of protected species.

Reach-Specific Recovery Plan Objectives

Lower Valley and Tidal Reaches (MSR 1-2)

- [eco] maintain existing tidal inundation and expand tidal prism where feasible, to restore natural tidal marsh and estuarine functions; and restore seasonal freshwater wetlands, ponds, and aquatic habitats, to increase resiliency of native fish and wildlife species dependent on these habitats;

- [land] protect the productivity and long-term sustainability of existing agricultural operations, protect existing rural residential land uses, and provide access to potable domestic and agricultural water supplies;
- [wq] protect and restore water quality from impairment by suspended sediment and turbidity, water temperature, salinity, and coliform bacteria (impairment = anthropogenic alteration from natural water quality regimes);
- [fp] improve connectivity and drainage of winter flooding by maintaining and improving flood-flow pathways, and upgrading drainage infrastructure (culverts, tidegates, bridges, etc.) and removing where feasible;
- [hab] restore high quality winter and summer rearing habitat for juvenile salmon and steelhead, within tidal creeks and slough channels, in off-channel freshwater ponds, and in the mainstem Elk River;
- [veg] Restore and maintain healthy and mature vegetation assemblages, including a mosaic of native riparian hardwood and conifer species with a minimum 50-100 ft wide streamside management areas; manage and prevent vegetation growth within the stream channel;

<u>Middle Valley Reach (MSR 3-4)</u>

- [eco] restore and maintain a natural riverine and riparian corridor along Elk River, with natural flood-flow and sediment regimes, seasonal freshwater wetlands, ponds, and aquatic habitats, and buffered protection from agricultural land uses, to increase resiliency of native fish and wildlife species dependent on these habitats;
- [land] protect the productivity and long-term sustainability of existing agricultural operations, protect existing rural residential land uses, and provide access to potable domestic and agricultural water supplies;
- [wq] protect and restore water quality from impairment by suspended sediment and turbidity, water temperature, dissolved oxygen, and coliform bacteria (impairment = anthropogenic alteration from natural water quality regimes);
- [fp] increase channel capacity and conveyance of flood flows of approximately a 1.5-year flood recurrence, while maintaining connectivity with flood-flow pathways across large swaths of floodplain to promote natural sedimentation processes, and minimize/avoid stranding of juvenile salmon and steelhead;
- [nuis] reduce/prevent nuisance flooding (e.g., of roadways, residential and agricultural infrastructure) by restoring channel conveyance capacity, maintaining and improving floodplain flow pathways, and upgrading drainage infrastructure (culverts, tidegates, bridges, etc.);
- [veg] Restore and maintain healthy and mature vegetation assemblages, including a mosaic of native riparian hardwood and conifer species with a minimum 50-100 ft wide streamside

management areas; manage and prevent/suppress vegetation growth within the stream channel;

Confined Mainstem Reach (MSR 5)

- [eco] restore a natural form and function to the river channel, including: deep pools and gravelly riffles, connectivity to floodplain benches, natural rates of sediment aggradation, and medium-to-large wood jams that provide geomorphic and habitat functions;
- [land] maintain opportunities for agricultural land uses, protect existing rural residential land uses, and provide access to potable domestic and agricultural water supplies;
- [wq] protect and restore water quality from impairment by suspended sediment and turbidity, water temperature, dissolved oxygen, and coliform bacteria (impairment = anthropogenic alteration from natural water quality regimes);
- [fp] increase channel capacity and conveyance of flood flows of approximately a 1.5-year flood recurrence, while maintaining connectivity with flood-flow pathways across large swaths of floodplain to promote natural sedimentation processes, and minimize/avoid stranding of juvenile salmon and steelhead;
- [nuis] reduce/prevent nuisance flooding (e.g., of roadways, residential and agricultural infrastructure) by restoring channel conveyance capacity, maintaining and improving floodplain flow pathways, and upgrading drainage infrastructure (culverts, tidegates, bridges, etc.);
- [veg] restore and maintain mature vegetation assemblages, including a mosaic of native riparian hardwood and conifer species with a minimum 50-100 ft wide streamside management areas; manage and prevent/suppress vegetation growth within the stream channel; reduce the density and distribution of plantation redwoods;

North Fork Reaches (NFR 1-2)

- [eco] restore a natural form and function to the river channel, including: deep pools and gravelly riffles, connectivity to floodplain benches, natural rates of sediment aggradation, and medium-to-large wood jams that provide geomorphic and habitat functions;
- [land] maintain opportunities for agricultural land uses, protect existing rural residential land uses, and provide access to potable domestic and agricultural water supplies;
- [wq] protect and restore water quality from impairment by suspended sediment and turbidity, water temperature, dissolved oxygen, and coliform bacteria (impairment = anthropogenic alteration from natural water quality regimes);
- [fp] increase channel capacity and conveyance of flood flows of approximately a 1.5-year flood recurrence, while maintaining connectivity with flood-flow pathways across the floodplain to promote natural sedimentation processes, and minimize/avoid stranding of juvenile salmon and steelhead;

- [sed] create low-elevation off-channel habitat and sediment trapping features, to reduce the supply of fine sediment from mainstem and high priority tributaries into downstream mainstem reaches; consider periodic mechanical removal of captured sediment to maintain storage capacity;
- [nuis] reduce/prevent nuisance flooding (e.g., of roadways, residential and agricultural infrastructure) by restoring channel conveyance capacity, maintaining and improving floodplain flow pathways, and upgrading drainage infrastructure (culverts, tidegates, bridges, etc.);
- [veg] restore and maintain mature vegetation assemblages, including a mosaic of native riparian hardwood and conifer species with a minimum 50-100 ft wide streamside management areas; manage and prevent/suppress vegetation growth within the stream channel;

South Fork Reaches (NFR 1-2)

- [eco] restore a natural form and function to the river channel, including: deep pools and gravelly riffles, connectivity to floodplain benches, natural rates of sediment aggradation, and medium-to-large wood jams that provide geomorphic and habitat functions;
- [land] maintain opportunities for agricultural land uses, protect existing rural residential land uses, and provide access to potable domestic and agricultural water supplies;
- [wq] protect and restore water quality from impairment by suspended sediment and turbidity, water temperature, dissolved oxygen, and coliform bacteria (impairment = anthropogenic alteration from natural water quality regimes);
- [fp] increase channel capacity and conveyance of flood flows of approximately a 1.5-year flood recurrence, while maintaining connectivity with flood-flow pathways across floodplains to promote natural sedimentation processes, and minimize/avoid stranding of juvenile salmon and steelhead;
- [sed] create low-elevation off-channel habitat and sediment trapping features, to reduce the supply of fine sediment from mainstem and high priority tributaries into downstream mainstem reaches; consider periodic mechanical removal of captured sediment to maintain storage capacity;
- [nuis] reduce/prevent nuisance flooding (e.g., of roadways, residential and agricultural infrastructure) by restoring channel conveyance capacity, maintaining and improving floodplain flow pathways, and upgrading drainage infrastructure (culverts, tidegates, bridges, etc.);
- [veg] restore and maintain mature vegetation assemblages, including a mosaic of native riparian hardwood and conifer species with a minimum 50-100 ft wide streamside management areas; manage and prevent/suppress vegetation growth within the stream channel;

North Fork HRC (NFR 3-4)

- [eco] restore a natural form and function to the river channel, including: deep pools and gravelly riffles, connectivity to floodplain benches, natural rates of sediment aggradation, and medium-to-large wood jams that provide geomorphic and habitat functions;
- [wq] protect and restore water quality from impairment by suspended sediment and turbidity, water temperature, and dissolved oxygen;
- [fp] increase channel capacity and conveyance of flood flows of approximately a 1.5-year flood recurrence, while maintaining connectivity with flood-flow pathways across floodplains to promote natural sedimentation processes, and minimize/avoid stranding of juvenile salmon and steelhead;
- [sed] create low-elevation off-channel habitat and sediment trapping features, to reduce the supply of fine sediment from mainstem and high priority tributaries into downstream mainstem reaches; consider periodic mechanical removal of captured sediment to maintain storage capacity;
- [veg] restore and maintain mature vegetation assemblages, including a mosaic of native riparian hardwood and conifer species with a minimum 100 ft wide streamside management areas [as required in the HRC WDR]; manage and prevent/suppress vegetation growth within the stream channel;

Other considerations:

- Maintain/increase channel complexity
- Restore extent of slough channel networks across tidal marsh areas
- Reduce invasive, non-native vegetation
- Maintain streamflow gaging, SSC and turbidity gaging, salmonid habitat and juvenile/adult abundance monitoring
- Maintain 100-yr flood protection for residential areas
- Remove constraints to natural channel and floodplain function, such as bank revetments, dikes, and levees; culverts, drainage ditches, and channels; bridge and road infrastructure;

III. Project Description - Elk River Stewardship Program

In 2014, at the initiation of the Elk River Recovery Assessment technical study, the North Coast Regional Board and their project partners recognized the need to accompany the proposed technical studies with extensive and coordinated outreach to the Elk River community. That community includes, first and foremost, the landowners along the Elk River who are most affected by the ongoing degradation, nuisance flooding, and tightened regulations, and who are key to moving forward with actions to rehabilitate this watershed. The Elk River community also includes regulatory agencies with public trust responsibilities in the watershed, conservation stakeholders with interest in promoting recovery of the Elk River, and other citizens with varying interest in the watershed.

This outreach program is ***the Elk River Watershed Stewardship Program***. Under Grant Agreement No. D1713106 provided in 2019 to California Trout (CalTrout) and their technical team of Northern Hydrology and Engineering and Stillwater Sciences, this program is bringing results of the Recovery Assessment technical information to the landowners, agencies, and stakeholders for the explicit purpose of building the necessary foundation for implementing projects and activities to enhance conditions in the Elk River Watershed and achieve the goals of the sediment Total Maximum Daily Load (TMDL) for the Upper Elk River.

The Elk River Stewardship Program has now become the center of a broad community-based effort to restore beneficial uses of water in Elk River, protect people in this watershed from impaired water quality, nuisance flooding, and other property risks and damage, and to bring back native salmonids, riparian habitat, and overall ecosystem health to the Elk River. This is a large and ambitious program that, to succeed, will require extensive support from the broader Elk River community, leadership from the water boards and other resource agencies, and public funding from grant programs.

The Stewardship Program is a planning project intended to build the necessary foundation for implementing projects and activities to address impaired water quality, water supply, and nuisance flooding. Per the Scope of Work for Agreement #D1713106, "*the contractor will identify and evaluate a minimum of three river reach-specific potential remediation areas, project types, and individual projects using information provided by the ERRA Recovery Framework and stakeholders to identify a Proposed Recovery Strategy, including detailed descriptions of specific actions or sets of actions.*"

Extensive landowner outreach is the backbone of the Stewardship Program. To keep stakeholders informed and solicit input, outreach has generally focused on the findings and recommendations of the Recovery Assessment, and individual meetings with landowners to identify recovery actions that are acceptable to the landowner. These recovery actions were vetted with regulatory agencies and technical specialists before being compiled into a watershed-wide set of Actions that was presented at a public meeting on February 27, 2020. The actions presented have preliminary landowner support and comprise the Proposed Recovery Strategy which is the final deliverable associated with this contract.

Actions included in the Proposed Recovery Strategy consist of:

- in-channel sediment removal;
- new channel construction (e.g. bypass channels);
- on-channel or off-channel sediment detention basins;
- levee construction or modification;
- vegetation management (removal and maintenance of in-channel vegetation);
- infrastructure improvements (such as culvert replacement, raising of roads, houses, and bridges);

- topographic modifications to redirect flood flow; and
- the creation of floodplain swales to reconnect the river to the floodplain and keep the river in the channel, to the extent possible.

In the next phase of work funded under SWRCB Agreement #19023110, the Proposed Recovery Strategy will be analyzed with the HST Model developed under the ERRA, analyzed against previous model runs (including the 100-year flood modeled under this contract), and presented to the public in late-2020. In the next planning phase, the Proposed Recovery Strategy will be expanded into an **Elk River Recovery Plan** incorporating phasing, funding, permitting, and cost considerations.

IV. Project Evaluation and Effectiveness (results of PAEP)

Per the approved Project Assessment and Evaluation Plan (PAEP), the Elk River Watershed Stewardship Program includes three Project goals:

Table 1: Elk River Watershed Stewardship Program goals as defined in the PAEP

Project Goal	Desired Outcomes	Output Indicators	Targets
Facilitate landowner and community participation in implementation planning for community health and safety projects (RWQCB lead).	Implementation strategies supported by the community that address major flooding of roads and infrastructure, and impairment of the domestic water supply.	▪ Community dialogue ▪ Identification, concurrence, and prioritization of projects needed to address flooding and domestic water supply needs. ▪ Action plans for implementing next-steps.	The primary specific measurement for success is to have implementable strategies in-hand, supported by landowners, agencies, and stakeholders, with adequate funding identified to accomplish the needed actions.
Facilitate community and agency participation in implementation planning for large- scale sediment remediation and recovery of beneficial uses.	Implementation strategies (regulatory compliance, funding, construction phasing, etc.) supported by the community and permitting agencies	▪ Regulatory constraints analysis describing feasible and appropriate pathways for remediation implementation ▪ Funding strategy for phased, large-scale project implementation. ▪ Community and agency supported solutions to sediment re-use options.	

Facilitate stakeholder participation in implementation planning for a watershed-wide integrated monitoring and adaptive management program.	Broad stakeholder concurrence on a sustainable monitoring program (i.e., fundable over the long-term) that integrates regulatory programs, remediation implementation, and adaptive management data needs.	▪ Monitoring and adaptive management plan that identifies goals, objectives, primary assumptions, hypotheses, methods, metrics, analytical pathways, expected results, feedback loops, targeted outcomes, success or failure end posts.	

SWRCB Agreement D1713106 is a planning project, therefore associated environmental benefits are not quantifiable. However, the workplan being implemented is intended to identify actions that will lead to the recovery of beneficial uses.

It is important to note that the Scope of Work proposed under Agreement D1713106 was not entirely funded, thus the Action Plan and Monitoring Plan were pulled from the scope of work and funded under a separate agreement (SWRCB Agreement 19023110). Therefore, some of the PAEP goals referenced in Table 1 related to the Monitoring Plan, Action Plan, and Adaptive Management were not completed under Agreement D1713106 and are therefore not discussed in this reporting.

The qualitative success of the project in meeting the project goals as defined in the PAEP are described in more detail below:

Project Goal 1: Facilitate landowner and community participation in implementation planning for community health and safety projects (RWQCB lead).

Under Task 3.5.1 CalTrout is scoped to convene a minimum of four meetings with the Health and Safety Workgroup, focusing on water supply, nuisance flooding, and road access issues. The Health and Safety workgroup was led by the North Coast RWQCB with support provided NHE to conduct modeling analysis for potential health and safety projects. Implementation strategies that address road flooding, impaired access, and necessary infrastructure improvements are incorporated into the Action Plan being developed under Agreement #19023110. Landowner outreach conducted under this contract (Agreement D1713106) has assisted in this effort by obtaining information during landowner interviews regarding the locations of water infrastructure including diversions, pump systems, drainage systems, and culverts. Landowners are also being asked if they would be willing to provide alternative access through their properties during flood events (unlocking gates and providing access on private roads).

The Grant Manager approved the use of a portion of Task 4.2 funding to model the 100-year flood and prepare a technical report. The 100-year modeling is complete, and the technical report is currently being prepared. The technical report will be provided to the RWQCB for use in discussing the 100-year flood analysis and FEMA implications with the Humboldt County Public Works Department.

The Department of Public Works serves as the flood control district for Humboldt County as there is no separate agency and will be key in implementing actions related to roadways. Members of the Project team met with Hank Seeman, Deputy Director of Public Works, on May 28, 2019 to discuss the findings of the ERRA and the workplan for the reconvened Stewardship Program. The Project Director met with Hank Seeman again on January 30, 2020 to discuss the status of the outreach program, Stewardship actions being proposed related to improvements in County infrastructure, and recommendations related to the 100-year modeling results and associated technical memo.

The domestic water supply of Elk River residents with water rights is impaired as a result of the sediment deposition. The RWQCB is spearheading the effort to identify and evaluate methods to restore the domestic water supply, including potentially extending municipal water via the Humboldt Community Services District system and installing storage tanks in the upper watershed with gravity fed distribution systems.

Project Goal 2: Facilitate community and agency participation in implementation planning for large- scale sediment remediation and recovery of beneficial uses.

Under Task 3.5.2, CalTrout was tasked to convene and facilitate a minimum of four meetings with the Sediment Remediation Workgroup focused on sediment remediation, floodwater conveyance, sediment transport, and ecosystem function. The Sediment Remediation Workgroup was renamed the Sediment *and Habitat* Working Group to explicitly acknowledge the Program's important habitat restoration objectives. Per the Scope of Work, "*at least two of the four meetings shall include presentations on outputs of the Recovery Assessment Plan*" and "*At least one of the four meetings will include a design charrette process focused on sediment remediation issues*."

Recommendations for different types of reach specific recovery actions are presented in Tables 7-1, 7-2, and 7-3 of the ERRA Implementation Framework. Sediment and Habitat Working Group #1 was held in December 2018 and presented the ERRA findings to the Technical Advisory Committee (TAC). A questionnaire was distributed to the TAC to determine their level of support for the ERRA findings, with comments received from Redwood Sciences Lab, USFWS, CDFW, US Forest Service, USGS, NOAA/NMFS, and others.

Sediment and Habitat Working Group #2 was held in July 2019 and presented landowner-supported concepts between US Highway 101 and Showers Road to CDFW. Important outcomes of this meeting were general concurrence with the preliminary concepts, and agreement to concurrently develop a vegetation management strategy with sideboards that landowners could adhere to (similar to a programmatic permit).

Sediment and Habitat Working Group #3 was held in September 2019. Consultation with NMFS was conducted separately from consultation with CDFW due to different interpretations of the causes of impairment. These issues were resolved after the Project Team described the conceptual model of existing conditions and presented our interpretation of historical ecology of Elk River to NMFS staff.

Sediment and Habitat Working Group #4 was held in October 2019 and presented landowner approved concepts to CDFW and NMFS in a charrette format. Reach-specific concept review included the lower valley/tidal reaches (MSR 1-2) including the State-owned CDFW Wildlife Area, mainstem reach (MSR 5), and the South Fork (SFR 1-2). The Stewardship Program Goals and Objectives were also provided for review and feedback.

Two additional Sediment and Habitat Working Group Meetings were held in November 2019 and December 2019 The meetings reviewed the Stewardship Program Goals and Objectives, discussed how the parameters of the vegetation management-only modeling scenario would be defined, and requested agency input on the landowner-approved concepts (prior to their presentation at the February 2020 public meeting). With a solid understanding of the Stewardship Program, agencies were invited to participate in the February 2020 public meeting regarding the Proposed Recovery Strategy with CDFW, NMFS, USFWS, and Humboldt County represented.

The Project Team also presented the findings of the ERRA to NMFS on May 21, 2019 and to the North Coast RWQCB Board members on February 21, 2019. Both these meetings were out of scope items and held in Santa Rosa, CA.

<u>Project Goal 3</u>: Facilitate stakeholder participation in implementation planning for a watershed-wide integrated monitoring and adaptive management program.

As previously noted, tasks related to development of the Monitoring Plan and Action Plan were pulled from the workplan for Agreement D1713106 and funded under a separate contract with a longer timeline. These tasks were completed under SWRCB Agreement 19023110 in 2020 and 2021.

Under Task 3.4, CalTrout was tasked to convene a minimum of two (2) meetings to inform stakeholders of Stewardship Program goals and to develop a shared vision for the desired future conditions of the Elk River Watershed. Under Task 3.6, CalTrout was tasked to coordinate additional meetings with a minimum of five individual landowners, landowner groups, and agencies regarding planning and design for recovery assessment pilot sediment remediation projects and full-scale sediment remediation projects.

Landowner outreach - **Throughout 2019, the Project Team has maintained frequent and ongoing dialogue with approximately 50 river-adjacent landowners located throughout the watershed**, with this outreach effort extending well beyond the original intent and Grant Agreement scope of work. In general, this outreach program has focused on the lower mainstem (estuarine reach), South Fork and North Fork, and upper mainstem, and was conducted in that order.

Development of sediment remediation and habitat enhancement concepts in consultation with landowners is an iterative process and is ongoing. At the outset of landowner outreach activities, the Steering Committee agreed to a step-by-step process for discussing participation in the Stewardship Program with landowners:

1. Solicit general interest in participating in the Stewardship Program;
2. Conduct site-visits to understand land uses, infrastructure, degree of impairment, and other considerations;
3. Develop preliminary concepts for remediation actions; and
4. Present site-specific preliminary concepts to landowners and obtaining their buy-in before presenting the draft concepts to agencies or the public.

In addition, two public meetings were held on June 12, 2019 and February 27, 2020 to present the findings and recommendations of the ERRA and lay out the Stewardship Program process (June 12, 2019) and present the landowner-supported actions (February 27, 2020).

Lessons Learned

Lessons learned that could be applied to other watersheds include the following:

Schedule Impact of Slow Contracting – The contract for the Stewardship Program was signed by CalTrout in October 2018 and the SWRCB in November 2018. Between October and December 2018, CalTrout finalized the Grant Agreement, executed subcontract agreements with Northern Hydrology & Engineering (NHE) and Stillwater Sciences, held a Steering Committee meeting, and presented the findings of the ERRA to the TAC. Delays in contract execution essentially compressed a two-year timeline into one year and meant that essentially the entire Scope of Work had to be completed in 2019, such that the Proposed Recovery

Strategy (the final deliverable associated with this contract) could be compiled and vetted with stakeholders in early-2020.

General Bottom-up Approach – At the outset of the Stewardship Program, the Steering Committee agreed to a bottom-up process of developing project-specific alternatives in consultation with landowners and doing so in a confidential setting until the landowner agreed that the property-specific actions could be shared with neighbors, agencies, and the general public. This approach proved to be more effective than the top down approach previously utilized, which was more focused on process and developing a consensus-based solution before engaging with landowners individually.

Individual Landowner outreach is more expensive - The iterative process of individual landowner was determined to be essential to a successful outcome but proved to be more labor intensive and take longer than anticipated compared to the small number of group meetings originally scoped and resulted in the landowner-approved concepts being presented to agency representatives and the general public later than anticipated, resulting in less time to compile the Proposed Recovery Strategy Report (included in Draft format as **Appendix D**).

Agency consultation not captured within established Technical Advisory Committee – Outreach to regulatory agencies on the findings of the Elk River Recovery Assessment was absolutely necessary to secure agreement on the findings of the ERRA Recovery Framework and establish a basis of understanding for the development of preliminary concept designs. The original scope of work assumed agency consultation could be completed via the Technical Advisory Committee convened under the ERRA. However, the TAC Participants were ultimately not the same staff that will be permitting Stewardship Actions and the results of the TAC were not communicated down to agencies by TAC members. This required the Project team to use limited budget to separately present the findings of the ERRA and justification for the Elk River Stewardship Program to agency representatives who would be involved in future permitting.

Project Management– The contract agreement states that the grantee shall "Notify the Grant Manager at least fifteen (15) working days in advance of upcoming meetings, workshops, and trainings" Due to the fast pace and flexibility needed to schedule landowner meetings, it was not possible to provide the Grant Manager with 15-days advance notice of all upcoming meetings.

Website not suitable means of outreach to rural landowners – Per Task 2.5, CalTrout is scoped to "develop a website that contains an overview of the Stewardship Program, maps, web links, reports, monitoring results, and data; post monitoring data and reports and other appropriate documents that educate stakeholders on activities being conducted or proposed in the Watershed to website." Because the majority of the landowners are older ranchers and many landowners do not have internet access, it was agreed with the Grant Manager that a website as defined in the Scope of Work would not be an effective method of outreach and communication, and was thus not developed under this contract.

V. Public Outreach

Steering Committee members included staff from CalTrout, Northern Hydrology and Engineering, and Stillwater Sciences. These scientists were the principal participants in public and individual meetings related to the findings of the ERRA, identifying recovery activities that are acceptable to participating landowners, and resolving regulatory and technical issues in consultation with agencies and stakeholders.

A list of Technical Advisory Committee meetings hosted under the Elk River Recovery Assessment, and Stewardship Steering Committee, Stakeholder, and Landowner individual meetings is provided in Table 2. Phone consultations are not included.

Table 2. List of meetings hosted by the Elk River Stewardship Project Team 2015-2020.

Meeting #	Elk River Recovery Assessment Technical Advisory Committee Meetings	
TAC-1	Technical Advisory Committee Meeting #1	12-7-2015
TAC-2	Technical Advisory Committee Meeting #2	11-10-2016
TAC-3	Technical Advisory Committee Meeting #3	12-9-2016
TAC-4	Technical Advisory Committee Meeting #4	12-5-2017
TAC-5	Technical Advisory Committee Meeting #4	12-13-2018
	Stewardship Task 2.1 Steering Committee Meetings	
1	Steering Committee Meeting	11-26-2018
2	Steering Committee Meeting	1-10-2019
3	Steering Committee Meeting	2-1-2019
4	Steering Committee Meeting	2-28-2019
5	Steering Committee Meeting	3-7-2019
6	Steering Committee Meeting	3-14-2019
7	Steering Committee Meeting	3-22-2019
8	Steering Committee Meeting	5-8-2019
9	Steering Committee Meeting	5-15-2019
10	Steering Committee Meeting	5-21-2019
11	Steering Committee Meeting	6-4-2019
12	Steering Committee Meeting	6-11-2019
13	Steering Committee Meeting	6-24-2019
14	Steering Committee Meeting	7-8-2019
15	Steering Committee Meeting	7-12-2019
16	Steering Committee Meeting	7-22-2019
17	Steering Committee Meeting	8-26-2019
18	Steering Committee Meeting	9-3-2019
19	Steering Committee Meeting	9-23-2019
20	Steering Committee Meeting	10-15-2019
21	Steering Committee Meeting	11-18-2019
22	Steering Committee Meeting	12-2-2019
23	Steering Committee Meeting	1-7-2020
24	Steering Committee Meeting	1-14-2020
25	Monitoring Framework Meeting	1-27-2020
26	Steering Committee Meeting	1-29-2020
27	Steering Committee Meeting	2-10-2020
28	Steering Committee Meeting	2-25-2020
	Stewardship Task 3.4 Stakeholder Meetings	**Date**
1	Natural Resources Conservation Service	2-12-2019
2	NC RWQCB Board Hearing: Present ERRA results	2-21-2019
3	Humboldt County, Hank Seeman	4-16-2019
4	California Department of Fish and Wildlife (CDFW)	4-18-2019
5	NMFS (Presentation on ERRA findings to RWQCB in Santa Rosa)	5-21-2019
6	Public Meeting	6-12-2019
7	CDFW (Preliminary Concepts from Showers Road to US 101: Design Charrette)	7-16-2019
8	National Marine Fisheries Service (NMFS)	9-4-2019
9	National Marine Fisheries Service (NMFS)	9-19-2019
10	McBain Associates re Elk River Vegetation Management Concepts	10-11-2019

11	CDFW Regional Manager (Tina Bartlett)	10-26-2019
12	CDFW & NMFS Field Review of MSR5 Concepts	11-13-2019
13	Natural Resources Conservation Service #2	1-28-2020
14	Hank Seemann (Humboldt County Public Works)	1-30-2020
15	Environmental Protection Information Center (EPIC)	2-3-2020
16	CA State Coastal Conservancy (Discuss Funding for Pilot Projects)	2-13-2020
17	Humboldt County Supervisory Rex Bohn and Hank Seemann	2-14-2020
18	Felice Pace (North Coast Instream Flow Coalition)	2-14-2020
19	HSU Dr Darren Ward and Allison O'Dowd (Discuss Monitoring Program)	2-26-2020
20	Public Meeting	2-27-2020
	Stewardship Task 3.5 Sediment Remediation and Habitat Rehabilitation Workgroup Meetings	
1	Regional Water Board Hearing and Salt River Tour with Stakeholders	6-19-2019
2	TAC Meeting #5 (SHWG Meeting #1)	12-13-2018
3	NMFS and CDFW Recovery Planning Consultation Meeting #1	10-31-2019
4	NMFS and CDFW Elk River Recovery Planning Consultation Meeting #2	11-19-2019
5	NMFS and CDFW Elk River Recovery Planning Consultation Meeting #3	12-11-2019
	Stewardship Task 3.6 Individual *and Group* Landowner Meetings	
1	Save the Redwoods League (landowner on SF Elk River)	2-5-2019
2	Humboldt Redwoods Company	2-12-2019
3	*Group landowner meeting, Lower Elk Valley (downstream of Zanes Road Bridge to Highway 101)*	3-27-2019
4	*Group landowner meeting, Middle and Upper Reaches Elk Valley (Elk River Courts and above)*	3-28-2019
5	Mazzuchi-Ehrhardt Tour with Save the Redwoods League and BLM	4-16-2019
6	Robert Prior	5-7-2019
7	Joe Alexandre (Sea Mist Organic Dairy)	6-18-2019
8	Claire Josephine (Elk River Courts)	6-18-2019
9	Truman Vromman	8-1-2019
10	Joe Alexandre	8-6-2019
11	Robert Prior	8-6-2019
12	Greg Shanahan	8-6-2019
13	Kristy Wrigley	8-13-2019
14	Randall Younger	9-15-2019
15	Kristy Wrigley (field visit from Elk River Courts up)	9-16-2019
16	Jesse Noell	10-1-2019
17	John Estevo	10-1-2019
18	CDFW Lands Program re Elk River Wildlife Area	10-15-2019
19	Save the Redwoods League	10-23-2019
20	Larry Ward	10-29-2019
21	SF Elk River Landowner Group Meeting	10-29-2019
22	Erling Dellabalma	11-5-2019
23	Carol Jepsen	11-5-2019
24	Brad Gordon	11-6-2019
25	Save the Redwoods League and BLM	11-8-2019
26	Gareth Ehrhardt	11-11-2019
27	Humboldt Redwood Company, TU, McBain Associates	12-2-2019
28	Gene Sinestraro	12-10-2019
29	*North Fork Landowners (concept review)*	12-19-2019
30	Erling Dellabalma	1-16-2020

31	Lane Russ	1-16-2020
32	Larry Ward and Steven Painter	1-16-2020
33	Sami Osman	1-24-2020
34	Everett Ayers and David Lemm	1-29-2020
35	Cynthia Nichols and Steve Cave	2-7-2020
36	John Estevo	2-7-2020
37	David and Teresa Francheschi	2-14-2020
	GRAND TOTAL of MEETINGS = 95	

VI. Conclusions

Next Steps

As previously noted, the property-specific actions presented **Proposed Recovery Strategy** have preliminary landowner support. Landowners have approved sharing these actions publicly and including them in the modeling analysis to be conducted in the next planning phase (funded under SWRCB Agreement #19023110). Under Agreement #19023110, the Proposed Recovery Strategy will be run through the HST model developed under the ERRA, analyzed against previous model runs (including the 100-year flood modeled under this contract and a Vegetation Management model run to be developed later), and presented to the public in mid-2020. Also under Agreement #19023110, the Proposed Recovery Strategy will be expanded into an **Elk River Recovery Plan** incorporating phasing, permitting, cost, funding, and other considerations necessary to implement the actions being proposed.

A portion of D1713106 funding originally scoped for analysis of the Proposed Recovery Strategy was utilized for modeling 100-year flood conditions utilizing the HST model developed under the ERRA. There is currently funding to run two more scenarios through the HST in the next planning phase (SWRCB Agreement 19023110), including a "Vegetation Management only" alternative, and the landowner-supported "Preferred Recovery Strategy" developed under D1713106. A **Recovery Plan** (described as an Action Plan in the Scope of Work) for implementation of the "Preferred Recovery Strategy" is the final deliverable associated with the next planning phase (SWRCB Agreement 19023110) and will present an integrated, landowner-supported action informed by predictive modeling of hydraulic and geomorphic response, including phasing, monitoring, permitting, funding and other considerations. Other activities to be conducted in the next planning phase include development of a comprehensive Monitoring Framework and development of a study plans for salmonid population modeling and climate change considerations.

In future planning phase, CalTrout will seek funding for:

- Development of a Baseline Conditions Report to support environmental compliance and conservation planning

- Programmatic environmental review of the Proposed Recovery Strategy
- Modeling of additional management scenarios
- Funding for design and implementation of other projects to support implementation of the Recovery Plan such as the Save the Redwood League property; MSR5 reach owned by Kristy Wrigley, and CDFW Wildlife Area property.

Below is a list of data needs for the Elk River, compiled by the Project team:

- Sediment storage and geomorphic data;
- Updated LiDAR and bathymetry;
- Detailed channel surveys for engineering design and construction documents;
- Summer flows system wide;
- Winter flows and continuous SSC/turbidity below Steel Bridge;
- Basic water quality parameters (both continuous and grab samples) and toxics of water and substrate system wide. We need to understand low DO mechanism;
- Sediment oxygen demand studies (e.g. SOD chambers, of good sediment assessment to understand sediment water quality dynamics);
- Fisheries information (salmonid life stage, food sources, recruitment, etc.);
- Basic stream ecology information (macro-invertebrates, and all other aquatic species);
- Channel and floodplain vegetation mapping. Need to determine if this a significant fish food source, or the source of the low DO, or both;
- Timber cruises (sample measurement of stand used to estimate the amount of standing timber that the forest contains) for existing Redwood plantation area (e.g. Wrigley properties within MSR5).
- New tidal dynamics at Elk Estuary under sea level rise;
- Assessment of all landowners water supply/sources and onsite wastewater system information;
- Detailed historical ecology assessment of Elk River;
- Summer flows and sediment loads from tributaries;
- Infrastructure (levees, tide gates, drainage) mapping in lower valley

Schedule

The general sequence of Elk River Recovery planning phases is depicted below.

Phase 1 – Elk River Recovery Assessment 2014-2018
Empirical Data Collection
Hydrodynamic and Sediment Transport Model Analyses
Recovery Framework Report (March 2019)

Phase 2 - Preferred Recovery Strategy 2019-2020
Site-Specific Actions in Consultation with Landowners and Regulatory Agencies
Modeling and Analysis of Preferred Recovery Strategy

Phase 3 – Elk River Recovery Plan end of 2022
Draft Project Description of Landowner Supported Actions
Regulatory Compliance Strategy

Phase 4 – Programmatic Environmental Review
CEQA EIR
ESA and CESA Consultation

Phase 5 – Engineering and Project Refinement
Engineering Design of Landowner Supported Actions
Permitting

Phased Implementation of Projects
Multiple Funding and Implementation Partners
Robust Monitoring and Adaptive Management Framework

Budget

Table 3. Project Final Budget

	Agreement No.:	D1713106				
	Grantee:	California Trout, Inc.				
		Personnel Services	**Operating Expenses**	**Professional/ Consultant Services**	**Indirect Costs**	**Total**
	Line Item Allotments	**$66,272.00**	**$3,668.00**	**$158,557.00**	**$22,849.00**	**$251,346.00**
Invoice No.	**Billing Period**					
1	10/1/18-12/31/18	$2,000.56	$0.00	$10,099.25	$1,209.98	**$13,309.79**
2	1/1/19-1/31/19	$991.40	$0.00	$1,192.00	$218.34	**$2,401.74**
3	2/1/19-2/28/19	$3,917.77	$432.83	$13,053.00	$1,740.36	**$19,143.96**
4	3/1/19-3/31/19	$4,541.74	$487.01	$11,761.83	$1,679.06	**$18,469.64**
5	4/1/19-4/30/19	$2,524.40	$267.95	$3,354.73	$614.71	**$6,761.79**
6	5/1/19-6/30/19	$10,841.95	$778.54	$9,177.81	$2,079.83	**$22,878.13**
7	7/1/19-8/31/19	$8,257.82	$28.02	$21,696.80	$2,998.26	**$32,980.90**
8	9/1/19-9/30/19	$5,282.38	$0.00	$9,720.13	$1,500.25	**$16,502.76**
9	10/1/19-10/31/19	$7,332.18	$35.96	$12,993.56	$2,036.17	**$22,397.87**
10	11/1/19-11/30/19	$3,455.63	$107.30	$15,971.95	$1,953.49	**$21,488.37**
11	12/1/19-12/31/19	$4,073.23	$77.34	$16,926.75	$2,107.73	**$23,185.05**
12	1/1/20-1/31/20	$5,007.27	$78.20	$20,891.70	$2,597.72	**$28,574.89**
13	2/1/20-2/29-20	$7,930.00	$668.51	$12,539.50	$2,113.10	**$23,251.11**
	Total Amount Spent	**$66,156.33**	**$2,961.66**	**$159,379.01**	**$22,849.00**	**$251,346.00**

Appendices

List of Deliverables	Appendix A
Stakeholder Mailing List	Appendix B
Newsletter	Appendix C
Preferred Recovery Strategy Report	Appendix D
100-year Flood Modeling Results Technical Memorandum	Appendix E

If you have any questions, please contact the Darren Mierau, Project Director at any time.

Sincerely,

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North Coast Director
California Trout Inc.
Office: 707.825.0420 / Cell: 707.845.7810
email: dmierau@caltrout.org
1380 9th Street, Arcata, CA 95521

Report Prepared By:
Darren Mierau

VII. Appendix A: List of Deliverables

PLANS AND GENERAL COMPLIANCE REQUIREMENTS
All HUC-12s for Project Site
Stream Reach for Project Site and Monitoring Locations
Project Assessment and Evaluation Plan (PAEP)
Copy of final CEQA/NEPA Documentation

PROJECT-SPECIFIC REQUIREMENTS
Notification of Upcoming Meetings, Workshops, and Trainings
Steering Committee Activities
List of Members with their Organizational Affiliation and Roles and Responsibilities
Agenda, Meeting Minutes, and Sign-in Sheets
Operating Agreement
Schedule of Activities and Updates
Link to Stewardship website and Updates
Stakeholder Outreach and Coordination
Newsletter
Statement of Principles and Expectations
List of Identified Stakeholders
Agendas, Meeting Minutes, Sign-in Sheets, and Handouts
Develop Proposed Recovery Strategy and Monitoring Plan Framework
Potential Strategies and/or Projects
List of Project Types, Individual Projects, and Criteria
Preferred Strategy and Monitoring Framework (Monitoring Framework Annotated outline only)

INVOICING and PROGRESS REPORTS
Progress Reports by the twentieth (20th) of the month
F.1. Progress Report #1 (Oct-Dec 2018)
F.1. Progress Report #2 (Jan 2019)
F.1. Progress Report #3 (Feb 2019)
F.1. Progress Report #4 (March 2019)
F.1. Progress Report #5 (April 2019)
F.1. Progress Report #6 (May/June 2019)
F.1. Progress Report #7 (July/August 2019)
F.1. Progress Report #8 (September 2019)
F.1. Progress Report #9 (October 2019)
F.1. Progress Report #10 (November 2019)
F.1. Progress Report #11 (December 2019)
F.1. Progress Report #12 (January 2020)
F.1. Progress Report #13 (February 2020)

ANNUAL PROGRESS SUMMARIES
Natural Resource Project Inventory (NRPI) Project Survey (if applicable)
Final Project Report
Draft Elk River Stewardship: Recovery Strategy

VIII. Appendix B: Stakeholder List

[Provided Separately]

IX. Appendix C: Elk River Stewardship Newsletter

[Provided Separately]

X. Appendix D: Elk River Stewardship: Recovery Plan (DRAFT Recovery Strategy)

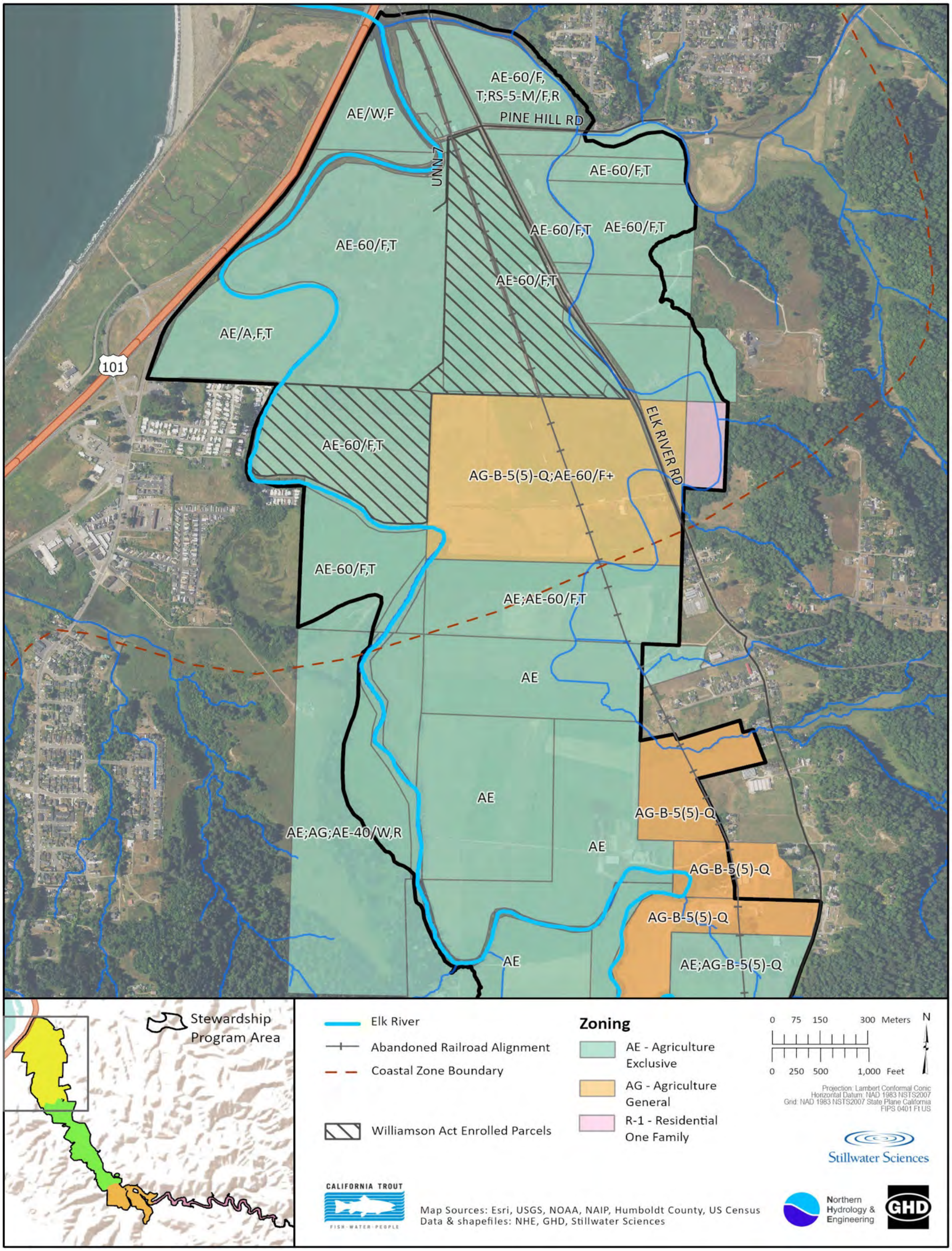
[Provided Separately]

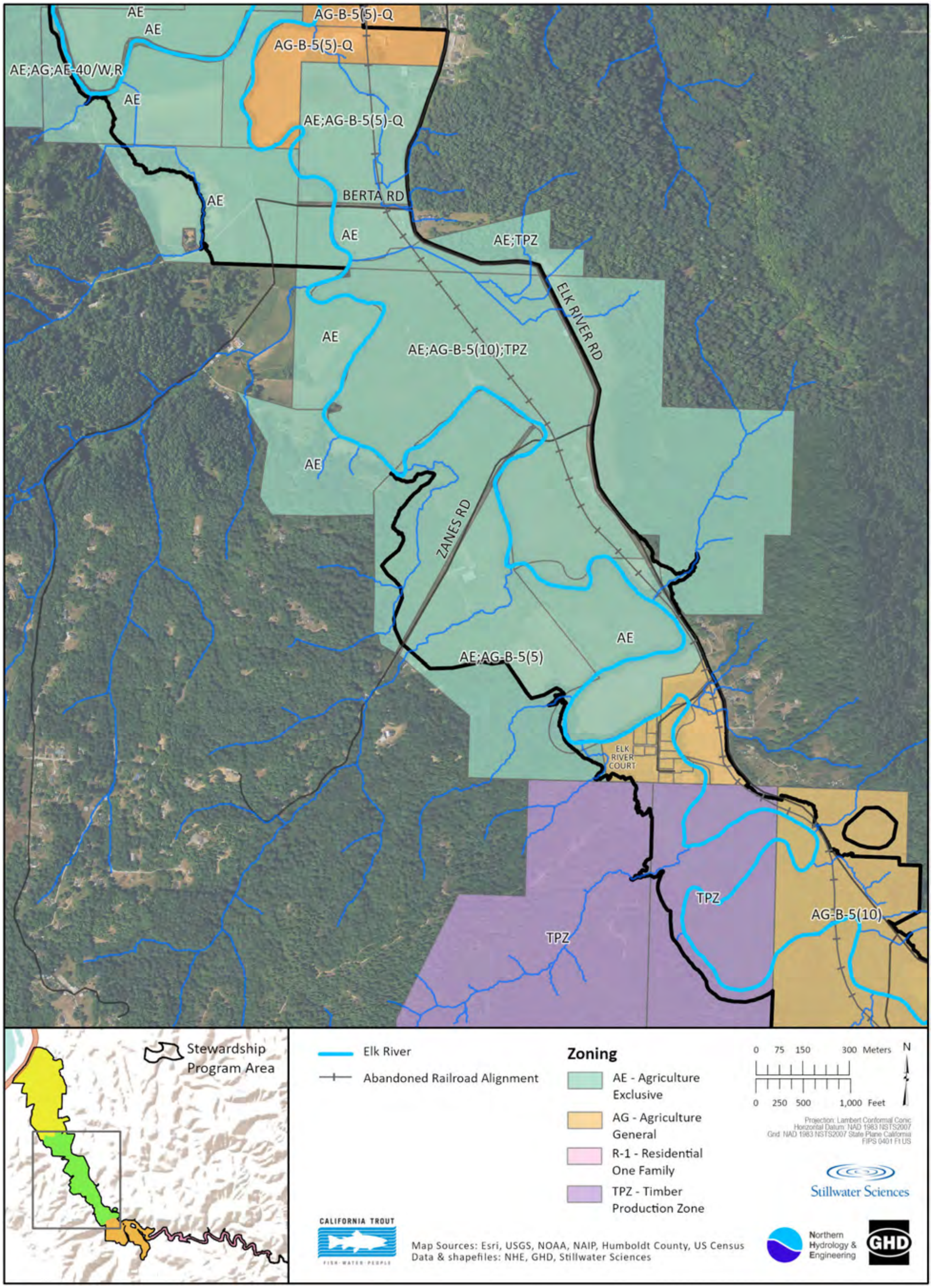
XI. Appendix E: Elk River Flood Modeling Technical Memorandum

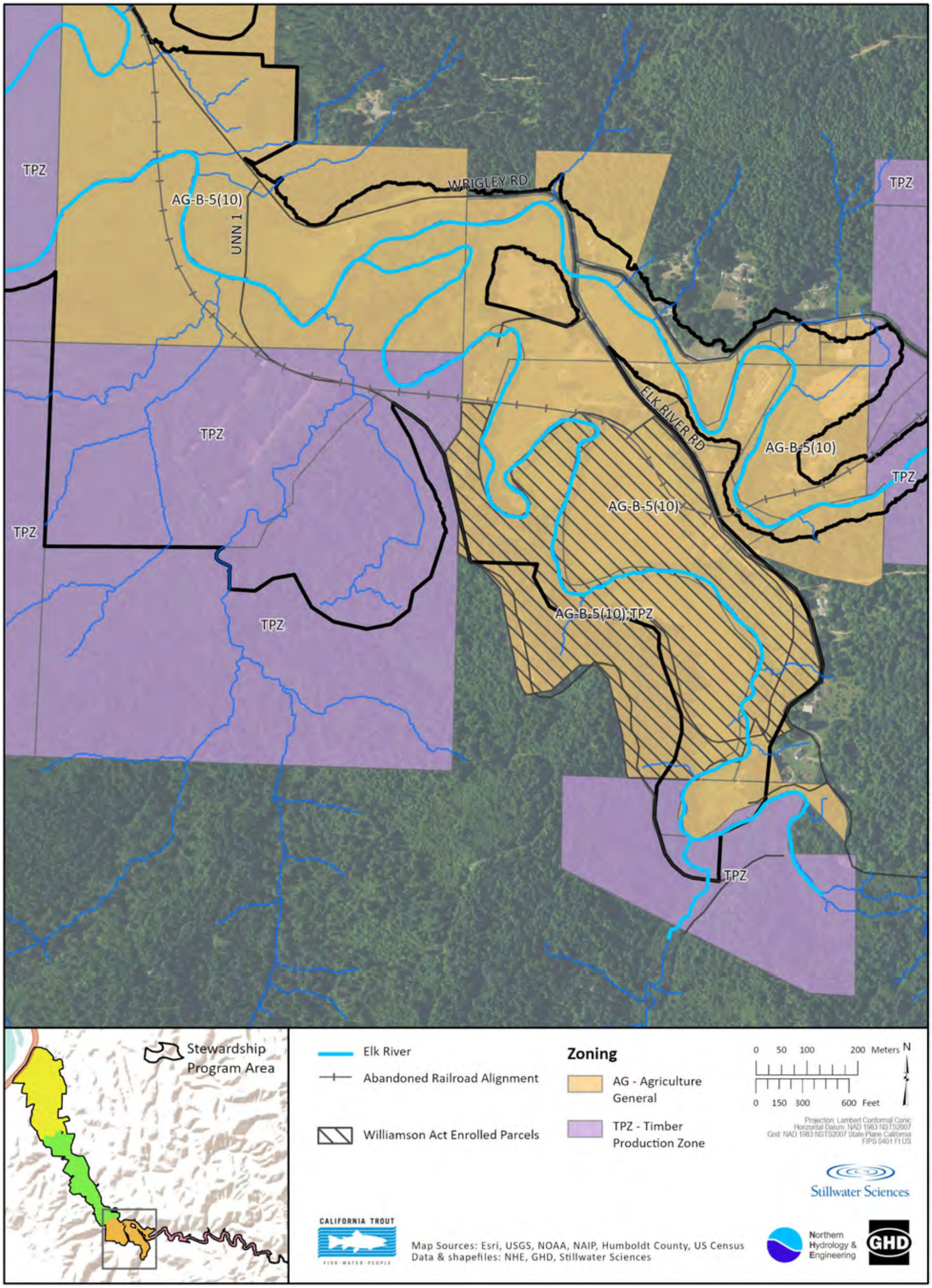
[Provided Separately]

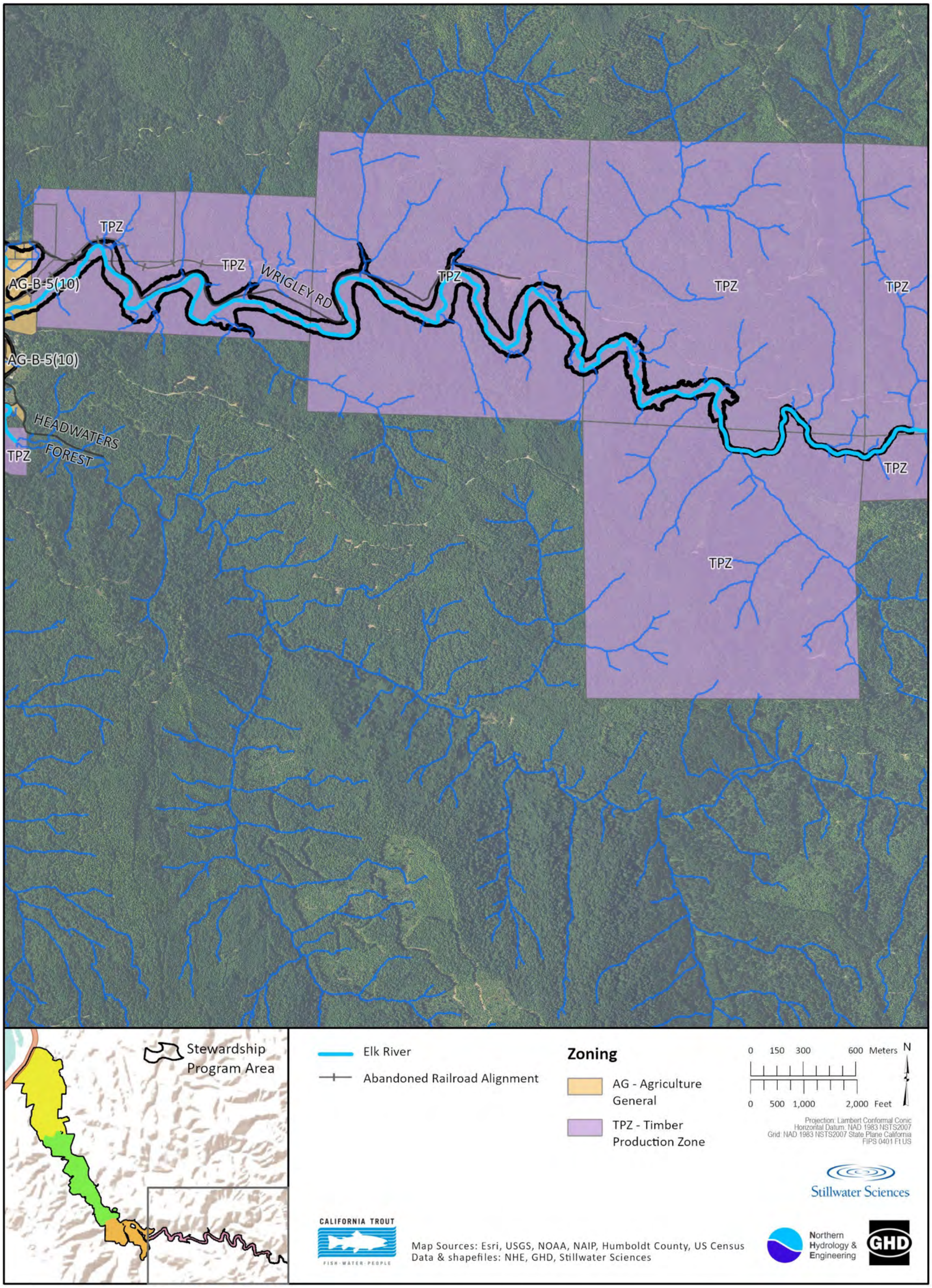
APPENDIX B

Appendix B. Zoning and Land Use Designations for the Elk River Stewardship Program Area.




AE
AE
AG-B-5(5)-Q
AG-B-5(5)-Q
AE;AG;AE-40/W,R
AE
AE;AG-B-5(5)-Q
BERTA RD
AE
AE
AE;TPZ
ELK RIVER RD
AE
AE;AG-B-5(10);TPZ
AE
ZANES RD
AE
AE;AG-B-5(5)
ELK RIVER COURT
TPZ
TPZ
AG-B-5(10)
Stewardship Program Area
Elk River
Abandoned Railroad Alignment
Zoning
AE - Agriculture Exclusive
AG - Agriculture General
R-1 - Residential One Family
TPZ - Timber Production Zone
0 75 150 300 Meters
0 250 500 1,000 Feet
N
Projection: Lambert Conformal Conic
Horizontal Datum: NAD 1983 NSRS2007
Grid: NAD 1983 NSRS2007 State Plane California FIPS 0401 Ft US
Stillwater Sciences
CALIFORNIA TROUT
FISH · WATER · PEOPLE
Map Sources: Esri, USGS, NOAA, NAIP, Humboldt County, US Census
Data & shapefiles: NHE, GHD, Stillwater Sciences
Northern Hydrology & Engineering
GHD


TPZ
AG-B-5(10)
UNN 1
WRIGLEY RD
TPZ
ELK RIVER RD
AG-B-5(10)
TPZ
TPZ
AG-B-5(10)
TPZ
AG-B-5(10);TPZ
TPZ
TPZ
Stewardship Program Area
Elk River
Abandoned Railroad Alignment
Williamson Act Enrolled Parcels
Zoning
AG - Agriculture General
TPZ - Timber Production Zone
0 50 100 200 Meters
0 150 300 600 Feet
N
Projection: Lambert Conformal Conic
Horizontal Datum: NAD 1983 NSTS2007
Grid: NAD 1983 NSTS2007 State Plane California
FIPS 0401 Ft US
Stillwater Sciences
CALIFORNIA TROUT
FISH · WATER · PEOPLE
Map Sources: Esri, USGS, NOAA, NAIP, Humboldt County, US Census
Data & shapefiles: NHE, GHD, Stillwater Sciences
Northern Hydrology & Engineering
GHD


TPZ
TPZ
WRIGLEY RD
TPZ
TPZ
TPZ
AG-B-5(10)
AG-B-5(10)
HEADWATERS
FOREST
TPZ
TPZ
TPZ
Stewardship Program Area
Elk River
Abandoned Railroad Alignment
Zoning
AG - Agriculture General
TPZ - Timber Production Zone
0 150 300 600 Meters
0 500 1,000 2,000 Feet
N
Projection: Lambert Conformal Conic
Horizontal Datum: NAD 1983 NSTS2007
Grid: NAD 1983 NSTS2007 State Plane California FIPS 0401 Ft US
Stillwater Sciences
CALIFORNIA TROUT
FISH · WATER · PEOPLE
Map Sources: Esri, USGS, NOAA, NAIP, Humboldt County, US Census
Data & shapefiles: NHE, GHD, Stillwater Sciences
Northern Hydrology & Engineering
GHD

APPENDIX C

Basis of 100% Engineering Designs

Elk River Sediment Remediation Pilot Implementation Projects
Wrigley Orchard Reach
State Water Resources Control Board Grant Agreement No. D1513103

Prepared for

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615 11th Street
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State Water Resources Control Board
5550 Skyline Boulevard, Suite A
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Prepared by

Northern Hydrology & Engineering
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March 2020

Basis of 100% Engineering Designs

Elk River Sediment Remediation Pilot Implementation Projects
Wrigley Orchard Reach
State Water Resources Control Board Grant Agreement No. D1513103

Prepared for

CALIFORNIA TROUT
FISH · WATER · PEOPLE

California Trout, Inc.

CALIFORNIA
Water Boards

State Water Resources Control Board

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Northern
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Engineering

PROFESSIONAL GEOLOGIST
JAY DOUGLAS STALLMAN
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Stillwater Sciences

March 2020

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Appendix A: Engineering Designs (April 1, 2020)

LIST OF ACRONYMS

ac	Acres
AGR	Agricultural water supplies
CalTrout	California Trout, Inc.
CEQA	California Environmental Quality Act
COLD	Cold water habitat
cm	Centimeters
CY	Cubic yard
D_{50}	Median grain size
DEM	Digital elevation model
DO	Dissolved oxygen
EFDC	Environmental Fluid Dynamics Code
ERRA	Elk River Recovery Assessment
ft	Feet
GPS	Global Positioning System
HPGN	High Precision Geodetic Network
HST	Hydrodynamic and Sediment Transport
km	Kilometer
LiDAR	Light detection and ranging
m	Meter
m/s	Meters per second
mi^2	Square mile
mm	Millimeter
MUN	Municipal water supplies
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NGS	National Geodetic Survey
NHE	Northern Hydrology & Engineering
NOAA	National Oceanic and Atmospheric Administration
PALCO	Pacific Lumber Company
PID	Permanent identifier
RARE	Rare, threatened, or endangered species
RCAA	Redwood Community Action Agency
REC-1 and -2	Recreation
RS	River station
RWQCB	Regional Water Quality Control Board, North Coast Region
SOD	Sediment oxygen demand
SPWN	Spawning, reproduction and early development
SR	Sediment remediation
SWRCB	State Water Resources Control Board
SWS	Stillwater Sciences
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
WY	Water year

1. INTRODUCTION

The Elk River is the largest tributary to Humboldt Bay, draining a 58.3 square mile (mi^2) watershed in Humboldt County, California. The basin drains westward across the seaward slope of the outer Coast Range to the coastal plain and into Humboldt Bay, near the city of Eureka (Figure 1). The greater Elk River basin can be divided into four main areas: (1) North Fork Elk River (22.5 mi^2), (2) South Fork Elk River (19.5 mi^2), (3) Mainstem Elk River downstream of the North Fork Elk River and South Fork Elk River confluence (10.4 mi^2), and (4) Martin Slough (5.9 mi^2).

In 2016, California Trout, Inc. (CalTrout) received a grant from the SWRCB Timber Regulation and Forest Restoration Fund, Agreement No. D1513103, to implement two Sediment Remediation Pilot Implementation Projects in North Fork Elk River (Pilot Projects). CalTrout contracted Northern Hydrology & Engineering (NHE) and Stillwater Sciences (SWS) to develop engineering designs for the Pilot Projects. Two pilot projects (Wrigley Orchard and Flood Curve were advanced to 65% designs (NHE and SWS, 2019). One project has advanced to 100% designs (Wrigley Orchard) and described herein. The project area is privately owned and located along the channel and floodplain of North Fork Elk River (Figure 1).

1.1 Project Background

The Elk River watershed has undergone several extensive anthropogenic disturbances over the last century and a half. Commercial timber harvest beginning in the late 1800s severely altered natural hillslope processes and significantly changed sediment supply, transport, and depositional processes in stream channels and on floodplains. Stream channels were historically maintained relatively clean of large wood to facilitate transporting logs downstream. Timber harvesting and consequent management-related sediment loading markedly increased from 1988 to 1997 when Maxxam Corporation owned and managed Pacific Lumber Company (PALCO). During this time, PALCO adopted more aggressive road building and silvicultural practices, accelerating the annual average harvest rate by approximately five times the previous long-term. During this period of accelerated harvest, Elk River experienced several years of large storm events. The significant rainfall that occurred across this highly disturbed landscape during these years resulted in numerous large landslides, unprecedented sediment delivery to the upper Elk River and its tributaries, and significant sedimentation in lower channel reaches. Elevated sediment loads and channel sedimentation continued through the last decade of the 20th century. Humboldt Redwood Company, the current owner of former PALCO lands, and is working to mitigate controllable sediment sources. Severe stream channel aggradation has increased the incidence of nuisance flooding, affecting the use of, and access to property, and increasing the risk to human health and welfare. Fields, roadways, driveways, homes, and septic systems are frequently inundated. Overbank flooding onto roads and private properties in some locations in Elk River now occur several times a year. Sediment discharges and sedimentation have adversely impacted several specific beneficial uses of Elk River, including domestic water supplies; agricultural water supplies; cold water habitat; spawning, reproduction and early development; rare, threatened, or endangered species; and recreation.

The North Coast Regional Water Quality Control Board (Regional Water Board) and the U.S. Environmental Protection Agency (USEPA) listed the Elk River watershed as a sediment-impaired waterbody in 1998 under the Clean Water Act Section 303(d). Following this designation, several studies, including scientific review panels and technical advisory committees, were conducted to: (1) better understand the aquatic habitat conditions and physical processes necessary to evaluate the potential effects of sediment reduction measures and other direct actions designed to hasten recovery of beneficial

Figure 1. Location map.

uses of water in the lower Elk River, and (2) develop appropriate and effective measures that will require an integrated, system-wide, and scientifically-based planning effort informed by predictive modeling of geomorphic and biological responses to treatment alternatives. Background documents include:

- 2000 – Staff Report for Proposed Regional Water Board Actions in the North Fork Elk River, Bear Creek, Freshwater Creek, Jordan Creek and Stitz Creek Watersheds
- 2002 – Independent Scientific Review Panel's Final Report on Sediment Impairment and Effects on Beneficial Uses of the Elk River and Stitz, Bear, Jordan and Freshwater Creeks
- 2003 – Independent Scientific Review Panel's Phase II of the Final Report on Sediment Impairment and Effects on Beneficial Uses of the Elk River and Stitz, Bear, Jordan and Freshwater Creeks
- 2004 – Preliminary Assessment of Flooding in Lower Elk River
- 2011 – Upper Elk River Source Analysis
- 2012 – Elk River Restoration Summit
- 2013 – Salmon Forever's Annual Report on Channel Aggradation in Freshwater Creek and Elk River
- 2013 – Salmon Forever's 2013 Annual Report on Suspended Sediment, Peak Flows, and Trends in Elk River and Freshwater Creek, Humboldt County, California
- 2013 – Elk River Hydrodynamic and Sediment Transport Modeling Pilot Project complete
- 2017 – First Pilot Sediment Removal Implementation Project complete (2017 Steel Bridge Pilot Project)
- 2018 – Action Plan for the Upper Elk River Sediment TMDL approved by U.S. Environmental Protection Agency, Office of Administrative Law
- 2018 – Elk River Recovery Assessment (ERRA) and Elk River Framework (Recovery Framework) complete

Supporting documents can be found at:
https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/elk_river/

The work that has been conducted to date has informed the development of the Pilot Projects by documenting the impairment that has occurred at this particular location and identifying potential actions that may improve conditions. The actions recommended in the Recovery Framework for the channel reach where the Pilot Projects are located include (1) channel rehabilitation with specific actions of removing sediment, adding large wood; (2) infrastructure modifications necessary to accommodate wood; and (3) vegetation modifications that include maintaining and promoting the growth of a patchwork of conifer and hardwood dominated riparian zone and discouraging vegetation within the active channel.

1.2 Project Objectives

The primary objective of the Pilot Projects is to demonstrate the effectiveness of on-the-ground sediment remediation actions through implementation and monitoring to improve beneficial uses, including domestic water supplies (MUN), agricultural water supplies (AGR), cold water habitat (COLD); spawning, reproduction and early development (SPWN); rare, threatened, or endangered species (RARE), and recreation (REC-1 and REC-2) and reduce nuisance flooding. The improvements are expected to be incremental due to the project size and practical constraints on actions that can be implemented in isolation. These small-scale projects will develop the strategies and validate tools necessary to implement larger-scale projects to more fully recover beneficial uses and reduce nuisance flooding.

Attendant to the goal of the Pilot Projects, more specific objectives for the Pilot Projects are to:

- reduce the frequency and duration of nuisance flooding by lowering water levels,
- reconstruct a natural channel morphology of riffle-pool sequences, with deep pools (>3-6 ft deep), fine gravel-bedded riffles, and abundant large wood habitat structures,
- enhance winter and summer juvenile salmonid habitat by expanding rearing habitat area and increasing winter habitat refugia related to large wood structures and off-channel areas,
- monitor annual rates and volumes of sediment aggradation in re-constructed channels and lowered floodplains, and the persistence and utilization of rehabilitated habitat features,
- improve low Dissolved Oxygen (DO) concentrations during the summer low-flow rearing season,
- maintain existing riparian habitat and enhance riparian understory and canopy species diversity,
- avoid short-term and long-term impacts to private property and public infrastructure, and
- determine the regulatory compliance pathways for addressing construction-related impacts from project implementation, including environmental constraints, CEQA compliance, regulatory permit conditions, sediment disposal options, construction logistics, and cost details.

1.3 Project Opportunities and Constraints

The following opportunities were considered in the engineering designs:

- excavation of low elevation floodplain benches to increase channel conveyance during high flows, provide winter high-flow refugia, and create conditions for off-channel sediment deposition zones,
- excavation and re-contouring of in-channel fine sediment deposits, and
- installation of large wood pieces to provide juvenile salmonid rearing habitat.

The project is constrained by the sites' existing conditions, including, but not limited to:

- landownership, utilities and other infrastructure, and property boundaries, including access to proposed grading areas,
- project area flora and fauna, including resident and seasonal species, state and federally listed threatened and endangered aquatic and terrestrial species, rare plants, and invasive species,
- geology and geomorphology, both within in the project area, the greater landscape, and influenced by upslope and upstream sources and impacts,
- surface hydrology,
- channel and floodplain hydraulics,
- water quality,
- construction costs, and
- constructability

The previous lists are not inclusive of all potential project opportunities and constraints.

1.4 Project Limitations

The majority of the recommendations from the Recovery Framework (CalTrout et al. 2018) will be applied as part of the Pilot Projects; however, there are limitations to full implementation of the Recovery Framework recommendations. All aggraded sediment deposits cannot be removed from the channel. Lowering the entire channel bed to a pre-1988 channel condition in the North Fork, without treating downstream reaches, would result in a large in-channel basin, which would encourage more rapid sediment aggradation within the reach.

2. EXISTING CONDITIONS

2.1 Climate

The climate in Elk River can be characterized by the National Oceanic & Atmospheric Administration (NOAA) cooperative weather gauge station, located in Eureka, California at Woodley Island. The gauge recorded precipitation, temperature, and snowfall from January 1, 1906 to the present. Normal precipitation relative to the 1981-2010 epoch indicate that the average annual precipitation is 40 inches and the wet season is from October to May, when 95% of the rainfall occurs (NCDC 2017). Temperatures range from a mean daily maximum of 64.3 °F in August to a mean daily minimum in December of 40.6 °F (NCDC 2017).

2.2 Project Coordinate System and Survey Control

Project control points were established by Points West Surveying (PWS) in January 2008. The project coordinate system is California State Plane Zone 1 (NAD83 [2007]) U.S. Survey Feet and was derived from Global Positioning System (GPS) observations holding the HPGN-D monument at Spruce Point fixed (National Geodetic Survey [NGS] Permanent Identifier [PID] AC9253). Distances calculated from coordinates are grid. Elevations are reported in US survey feet, relative to the North American Vertical Datum of 1988 (NAVD88) based on a GPS tie to the NGS vertical control monument PID LV1183. Survey control point data for project implementation are shown on the 100% designs (Appendix A, Sheet C1).

2.3 Topography

Existing base topography within the Pilot Project area was mapped from the 2005 Light Detection and Ranging (LiDAR) data (Sanborn 2005). Channel cross-sections and longitudinal profiles were used to develop designs; however, design surfaces were incorporated into the existing topography, consisting of the LiDAR dataset only. Cross-sections were a combination of the 2005 LiDAR and site-specific topography surveyed in 2002 and 2011-2017. Longitudinal channel profiles were surveyed by Redwood Community Action Agency (RCAA) in 2012.

2.4 Geology

Geology in the Elk River basin is predominantly comprised of the Franciscan Complex Central Belt, the Yager terrane, and the Wildcat Group (Ogle 1953; McLaughlin et al. 2000, Marshall and Mendes 2005). The dominant geologic unit in the Elk River Basin is the Wildcat Group, a thick sequence of marine siltstone and fine-grained sandstone. The Wildcat Group typically consists of poorly indurated siltstone and fine-grained silty sandstone that weathers to granular, non-cohesive, non-plastic clayey silts and clayey sands. Wildcat Group terrain is characterized by steep and dissected topography sculpted by debris sliding and is known for historically high erosion rates associated with headwall swales, hollows and inner gorges. Franciscan Complex Central Belt is an accretionary mélange enclosing blocks of more coherent sandstone, greenstone, and chert. Large, deep-seated landslides and earthflows are common in the Central belt Franciscan complex. The Yager terrane is highly folded and sheared argillite and sandstone turbidites with minor pebbly conglomerate. The sandstone facies commonly forms cliff units and exerts local base level control where streams have incised through younger, less resistant overlap deposits. The argillite facies is typically deeply weathered, promoting deep-seated flow failures on moderately steep slopes.

The Wrigley Orchard Project in North Fork Elk River occur within a narrow alluvial valley at the inland extent of the coastal plain. The project reach is formed within thick, fine-grained (predominantly sand and silt) Holocene alluvium. The channel is confined in places by either Quaternary river terraces or steep hillslopes. Quaternary river terraces typically have up to two meters of stratified and partially indurated sand and gravel overlying a bedrock strath cut into the Wildcat Group. Bounding hillslopes in the project reaches typically have one to two meters of soil mantling bedrock of the Wildcat Group.

2.5 Large Woody Debris

Large wood inventories are used to develop a standard number and size of wood pieces that are expected over a length of channel to provide good to excellent habitat for salmonid species. These targets can be used to evaluate the conditions in a channel reach and to estimate salmonid habitat quality dependent on the hydraulic function, channel complexity, cover, and refugia furnished by large wood. The wood inventories for the Pilot Projects reference the *Desired Salmonid Freshwater Habitat Conditions for Sediment-related Indices* publication from the Regional Water Board (2006) to define large wood key pieces based on volume that varies with bankfull width. Top of bank width was used as a proxy for bankfull width. Volumes were calculated for individual pieces using estimated wood length and diameter. Volumes were calculated for pieces in jams using mid-point volumes for each size class.

2.6 Geomorphic Setting

The current geomorphic conditions within Wrigley Orchard reach was mapped and described. The Pilot Project is located within these reaches; however, do not account for the entire surveyed reach. Field surveys occurred on March 17, 2017 at the Wrigley Orchard reach. The surveys occurred during winter baseflow conditions during the receding tail of a small flow event. Some areas of the channel were not wadable, and turbid conditions throughout the two sites limited visibility below the water surface.

Field mapping of geomorphic features in planform was conducted at a scale of 1 inch equals 40 ft. Base information on mapping tiles included two-foot elevation contours generated from a digital elevation model (DEM) developed from the LiDAR data (Sanborn 2005), locations of surveyed cross-sections and reference control points, channel centerline stationing, existing roads, and footprints of conceptual design features (e.g., widened channel geometry, floodplain grading, pool excavation, and fill sites). The mapping and associated data collection during the field assessment included identifying and describing features within the channel, banks, floodplains, and adjacent hillslopes, where appropriate and feasible. The field effort focused on mapping and describing the following features:

- Channel morphology
- Water edge at the time of the survey
- Surface materials comprising the channel bed and banks, as well as floodplains in proposed grading areas
- The location, length, and diameter of wood larger than 1-ft diameter and longer than 6 ft that occurred within the channel and proposed grading areas
- The general location and orientation of smaller woody debris within the channel
- Spatial extent and description of live vegetation within the channel and proposed grading areas that had the potential to affect the flow field and channel morphology
- Inset floodplains and terraces
- Bank erosion related to channel scour and/or mass failure
- Hillslope mass wasting or instability

- The potential for destabilization of the bank or hillslope through the removal of specific live or dead wood within proposed grading zones
- Infrastructure locations (e.g. pump intakes, utilities)

The results of the geomorphic mapping and interpretation of geomorphic processes informed development of project goals, criteria, constraints, and engineering designs at the Pilot Project site.

The following sections qualitatively describe the geomorphic setting pertinent to hydraulic and geomorphic processes in each surveyed reach, including general design recommendations to achieve sediment remediation and ecological objectives, avoid and minimize future bank and hillslope instability, that exert important hydraulic and geomorphic controls or provide important ecological values.

2.6.1 Geomorphic Setting at the Wrigley Orchard Reach

The Wrigley Orchard reach occurs where North Fork Elk River transitions from a predominantly gravel bed channel within a relatively confined valley to a lower gradient channel with a predominantly fine-grained bed and relatively unconfined valley with broad floodplains. The average channel gradient through the Wrigley Orchard reach is 0.0015. Average top of bank width is 58 ft (ranging from approximately 56 to 59 ft), and average bank toe width is 23 ft (ranging from approximately 22 to 24 ft). Bed material is predominantly fine sand and silty sand with highly localized small sand and gravel deposits (D_{50}= 4 millimeters [mm]) associated with channel roughness elements (e.g., large wood pieces and jams) and planform channel curvature. The Wrigley Orchard reach can be divided into three distinct channel segments (upstream, middle, and lower) based on planform, internally-similar geomorphic features and wood loading characteristics (Figure 3). The Wrigley Orchard Pilot Project is located along 375 ft of the upper channel segment.

The 600-ft upstream channel segment (approximately river station [RS] 623+00 to 616+00) is a slightly sinuous channel defined predominantly by alternating large sand deposits, accreted to the top of bank and channel margins. The sandy bank margin deposits are characteristically convex shaped and typically support dense sedge and other herbaceous vegetation on their flanks and crest (Figure 4). Few large wood pieces occur within the channel. Scour-induced bank erosion is common on the banks opposite the sandy deposits. Several shallow pools within the upstream channel segment are predominantly associated with lateral bank scour and individual large wood pieces. Floodplains occur at similar elevations on both sides of the channel.

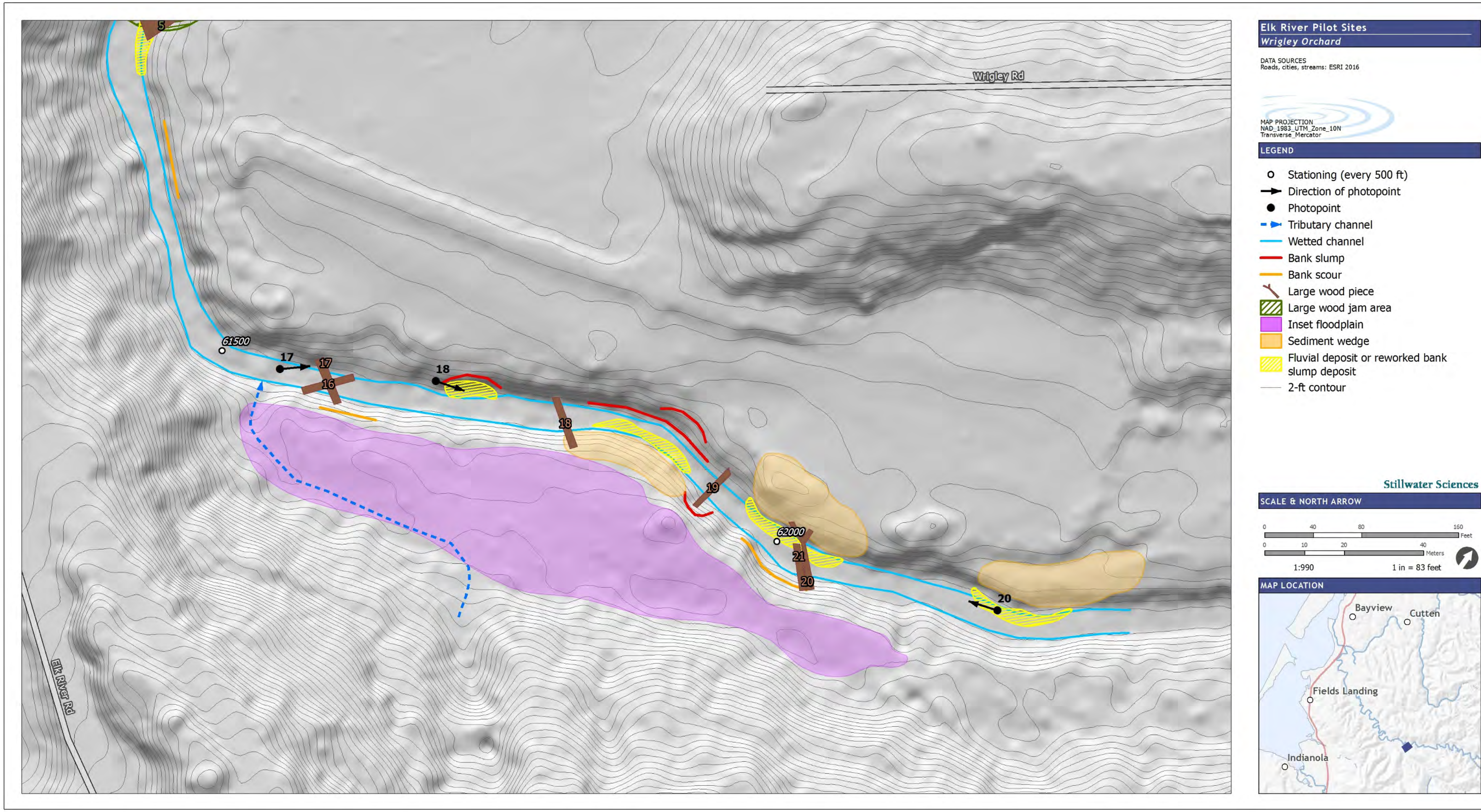

Figure 2. Geomorphic map of the Wrigley Orchard reach, including RS 615+00 to 620+00.

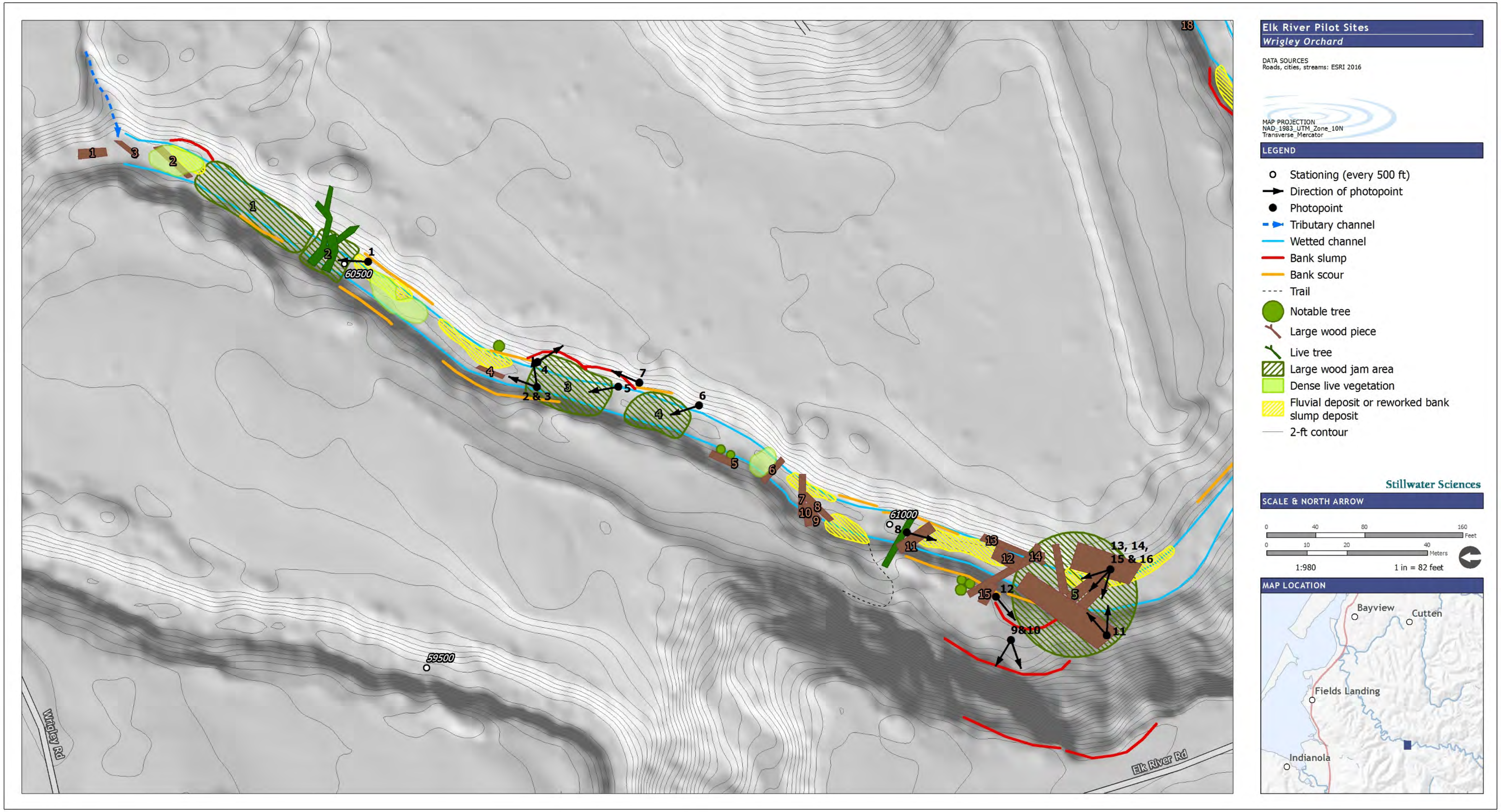

Figure 3. Geomorphic map of Wrigley Orchard reach, including RS 605+00 to 610+00.

Table 1. Summary of large wood loading in the Wrigley Orchard reach

Channel Reach	Pieces				Pieces per W_{TOB}		Pieces per 300 ft		Volume	
	Individual	Jam	Total	Key[1]	Total	Key[1]	Total	Key[1]	ft^3 / W_{TOB}	ft^3 / 300 ft
Wrigley Orchard	21	263	284	6	8.2	0.2	41.6	0.9	343	581

1. A key piece is defined based on the volume requirements in *Desired Salmonid Freshwater Habitat Conditions for Sediment-Related Indices* (RWQCB 2006), where volume required for a key piece varies with bankfull width. Top of bank width was used as a proxy for bankfull width. Volumes were calculated for individual pieces using estimated lengths and widths. Volumes were calculated for pieces in jams using mid-point volumes for each size class.

Figure 4. Sandy deposits accreted to the right bank margin in the upstream channel segment of the Wrigley Orchard reach (photo point 20 on Figure 2). Note the emergent vegetation established on the bar crest and flanks.

The 500-ft middle channel segment (approximately RS 616+00 to 611+00) is comprised of two short, sharp bends connected by a 200-ft long intervening straight channel section, effectively creating one broader meander bend with a straightened apex. The middle channel segment occurs near the downstream terminus of the levee constructed at the southern end of the orchard (Figure 2 and Figure 3). A small ephemeral tributary draining a left bank floodplain swale enters the middle channel segment at the upstream end. The left bank of this middle channel segment of the Flood Curve reach impinges on steep hillslopes and the fluvially re-worked toe of old landslide deposits that form a left bank terrace. Channel toe widths narrow in the vicinity of the landslide deposits, creating a pinch point where wood and sediment accumulates. A large sandy point bar occurs on the right bank at the inside of the meander bend. A large wood jam composed of several key pieces and numerous smaller structural pieces occurs in the general vicinity of the landslide deposits and creates the primary hydraulic control within the overall Wrigley Orchard reach (Figure 5). Upstream of this control, the channel stores more sand-size sediment in bars and sediment wedges accreted to bank margins, while downstream of this control, the channel becomes more deeply entrenched with predominantly fine sand and silt deposits accreted to steep, concave banks and little sand storage in active bars or convex bank margin deposits.

Figure 5. Large wood jam and associated right bank sandy point bar in the middle segment of the Wrigley Orchard reach (photo point 11 on Figure 3).

The 800-ft-long lower channel segment (approximately RS 611+00 to 603+00) located downstream of the large wood jam. Four wood jams, numerous large wood pieces, and abundant live woody riparian vegetation rooted in the banks all impose considerable hydraulic roughness throughout this lower channel segment (Figure 6). Channel morphology is predominantly plane bed, with an absence of deep pools despite the presence of the large wood obstructions. Rotational failures within the fine sandy and silty bank material are common throughout the reach, as is bank toe erosion from lateral scour. A small ephemeral tributary draining the right bank floodplain enters the channel segment at the downstream end.

Figure 6. Large and small wood accumulation in the downstream channel segment of the Wrigley Orchard reach (photo point 1 on Figure 3).

The following recommendations are provided for all projects implemented in the Wrigley Orchard reach:

- Decrease channel width constriction and reduce potential supply of in-channel sediment by removing sandy deposits accreted to bank margins in the upstream channel segment of the Wrigley Orchard reach;
- Consider enhancing existing pools in the upstream channel segment through excavation and/or strategic placement of large wood.

- Retain existing large wood pieces and consider adding large wood to the upstream channel segment of the Wrigley Orchard reach to increase pool depth and hydraulic complexity where there currently is little structure (e.g., RS 615+50 to 612+50).
- Consider removing the last 40-50 ft of the levee along the right bank to reduce floodplain constriction and allow for sediment removal along the left bank in the middle channel segment of the Wrigley Orchard reach. Widening the right bank in this area could help reduce the potential for more bank erosion along the left bank.
- Avoid any changes to channel geometry or large wood in the vicinity of the large wood jam located from approximately RS 612+00 to 611+00 (Figure 5). The wood jam currently provides an important hydraulic control and creates high quality aquatic habitat. The large key piece laying on and parallel to the left bank helps to stabilize the bank.
- Consider widening the channel downstream of the large wood jam by removing sediment from both banks and stabilizing the banks using wood structures.
- In the lower channel segment of the Wrigley Orchard reach, retain large wood pieces while reducing the density of small woody debris and live woody riparian vegetation that interacts with and increases resistance to in-channel flows (Figure 6).
- Avoid grading near the larger conifers and riparian hardwood trees located in the lower channel segment of the Wrigley Orchard reach.
- Bank failure in the fine-grained cohesive sediments accreted to the bank margins typically occurs as blocks or rotational slumps. Failure likely occurs during the recession limb of higher flows, during which time banks drain slowly and maintain high pore pressures but lack the resisting force of the open water column. Lay back slopes at existing bank erosion sites to approximately 1.5 horizontal: 1 vertical or shallower and consider lower gradient bank slopes where thick, fine-grained fluvial sediment is observed in cuts after reaching design grade.

2.7 Water Quality

Adequate dissolved oxygen (DO) concentrations is necessary for the survival of all life stages of salmonids (NMFS 2014). DO measurements in specific reaches of Elk River, including North Fork Elk River, indicate impairment from low DO concentrations well below Regional Water Board minimum DO standards (RWQCB 2011). Since the upstream-most measurement of DO impairment found in North Fork Elk River is upstream of potential inputs from residential on-site wastewater systems, the likely cause of the low DO concentrations is sediment oxygen demand (SOD) from decomposing organic matter in the channel bed sediment deposits. The inability of Elk River to flush fine sediment and accumulated organic matter from the low bulk density sediment bed, along with accumulations of small woody debris and dense vegetation rooted at the channel bank toe and in the bed has created a sediment bed with high organic content that exerts a large SOD impairing water column DO concentrations. DO impairment may also occur upstream and/or downstream of the locations sampled.

3. PROJECT DESIGN ELEMENTS

The Wrigley Orchard Pilot Project extends over approximately 450 stream ft. Sediment remediation approaches include pool enhancement, removal of in-channel sediment deposits, vegetation management (removal of brushy vegetation, targeting willows and blackberry), and creation of inset floodplains (lowering terraces and benches along banks). Sediment remediation prescriptions are tailored to the site topography.

3.1.1 Pool Enhancement

A single pool is proposed for construction in the North Fork Elk River channel, from approximately RS 620+75 to RS 623+50 by excavating approximately 750 CY of sediment from 0.1 ac of channel, including a large sediment deposit along the north toe of the channel. Cut material will be incorporated into the adjacent floodplain. Preferred placement of cut material is at SP6.

3.1.2 Floodplain Enhancement

Floodplain Design Element FP4

A lowered floodplain will be constructed along approximately 350 ft of the north bank of North Fork Elk River, from RS 619+00 to RS 622+50. All understory vegetation and small trees will be removed within the graded surface. Large "save" trees will be graded around, as it is feasible. Approximately 2,100 CY of sediment will be excavated from 0.6 ac of floodplain, daylighting into the river's north bank, approximately 10-13 ft above the design channel bed. Preferred placement of cut material is at SP6.

4. HYDRODYNAMIC AND SEDIMENT TRANSPORT MODEL

The hydrodynamic model assessment was conducted using the Environmental Fluid Dynamics Code (EFDC) model, which solves the three-dimensional shallow water equations of motion, and dynamically couples salinity, temperature and sediment transport. The EFDC model can be configured for one-, two- and three-dimensional simulations. The Windows-based EFDC_Explorer8.1 was used for a majority of the pre- and post-processing, and the enhanced EFDCPlus model was used in this assessment (Craig 2016).

The hydrodynamic and sediment transport (HST) model results presented in this study was developed as part of the ERRA. A summary of the ERRA HST model, including the observational data used for boundary conditions, model parameters, calibration, and validation of existing conditions is described in the Framework Recovery (CalTrout et al., 2018) and supporting presentations (available upon request). The ERRA HST model applied to the Pilot Projects 65% designs is referred to as the Sediment Remediation HST (SR HST) model. Only minor changes were made to the pilot project between the 65% and 100% designs. Therefore, modeling was not repeated. However, it is important to note that these results assume both pilot projects (Wrigley Orchard and Flood Curve) are implemented. If the Flood Curve project is not implemented, water levels in the Wrigley Orchard Reach are not likely to differ substantially from existing conditions.

The location of the Pilot Projects within the SR HST model is shown in Figure 7. The purpose of evaluating model results at this phase of the design process is to demonstrate the effects of the proposed designs to water surface elevations, in-channel velocities, and sediment transport.

Figure 7. Location map showing the extent of the ERRA HST model grid and the approximate location of the Pilot Projects.

4.1 Model Development

4.1.1 Model Input Modifications for Existing Conditions

Model inputs for the SR HST model are the same as the ERRA HST model (Figure 8). All model results are shown in metric, as that is the unit system used to run the models.

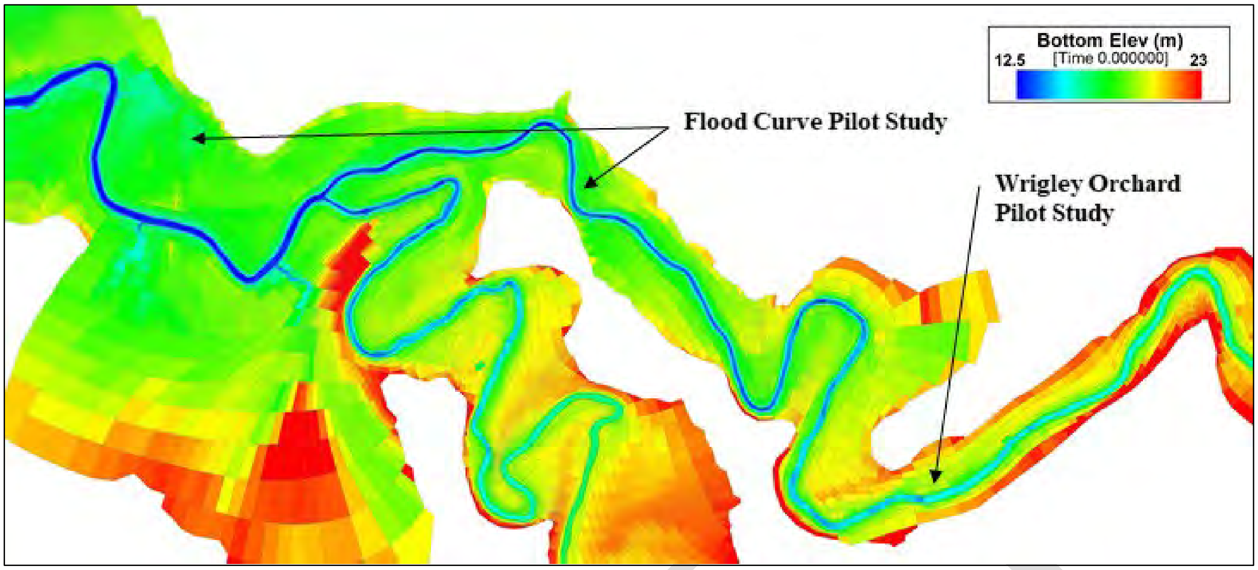

Figure 8. Model grid and existing topography of ERRA HST model in the project area.

4.1.2 Model Input Modifications for Design Conditions

The ERRA HST model was modified to create the SR HST model and simulate the revised 65% designs by adjusting the following parameters:

- The model grid was adjusted to reflect the design channel dimensions.
- Design topography was mapped to the model grid.

By using the same calibrated vegetation drag and roughness height as existing conditions, the design model results show the difference in water surface elevation, velocity, and sediment transport predictions dependent on topographic changes only. This reflects the long-term condition if no vegetation management occurs and vegetation and debris accumulations return to existing conditions. Immediately after project construction, water surfaces will likely be lower than predicted and velocities higher than predicted due to vegetation modification.

4.1.3 Existing and Design Boundary Conditions

The boundary conditions types and locations are the same as those used in the ERRA HST model (CalTrout et al. 2018). The primary modification for this analysis is that only two storms are simulated. These storms include the peak flow of record (WY 2003-2015), which occurred in WY 2003 and the peak flow that occurred in WY 2015. The peak flow in WY 2015 represents a flow that occurs frequently with less than a 2-year recurrence interval. The upstream boundary condition applied in the North Fork (immediately downstream of Lake Creek) and South Fork (immediately downstream of Tom's Gulch) are shown in
Figure 9 and Figure 10. Downstream boundary conditions consisted of Humboldt Bay tide elevations.

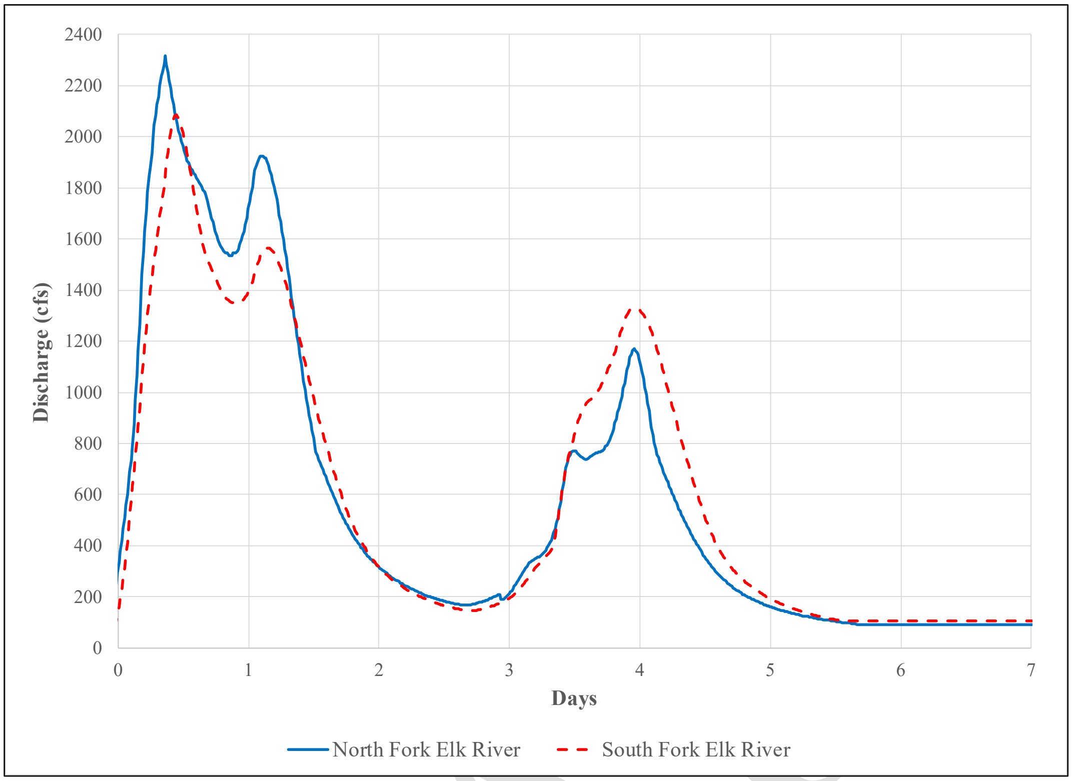

Figure 9. North Fork and South Fork Elk River hydrographs, used as input boundary conditions for the SR HST model simulation, constructed from a 7-day period, including the December 28, 2002 peak flow event (WY 2003).

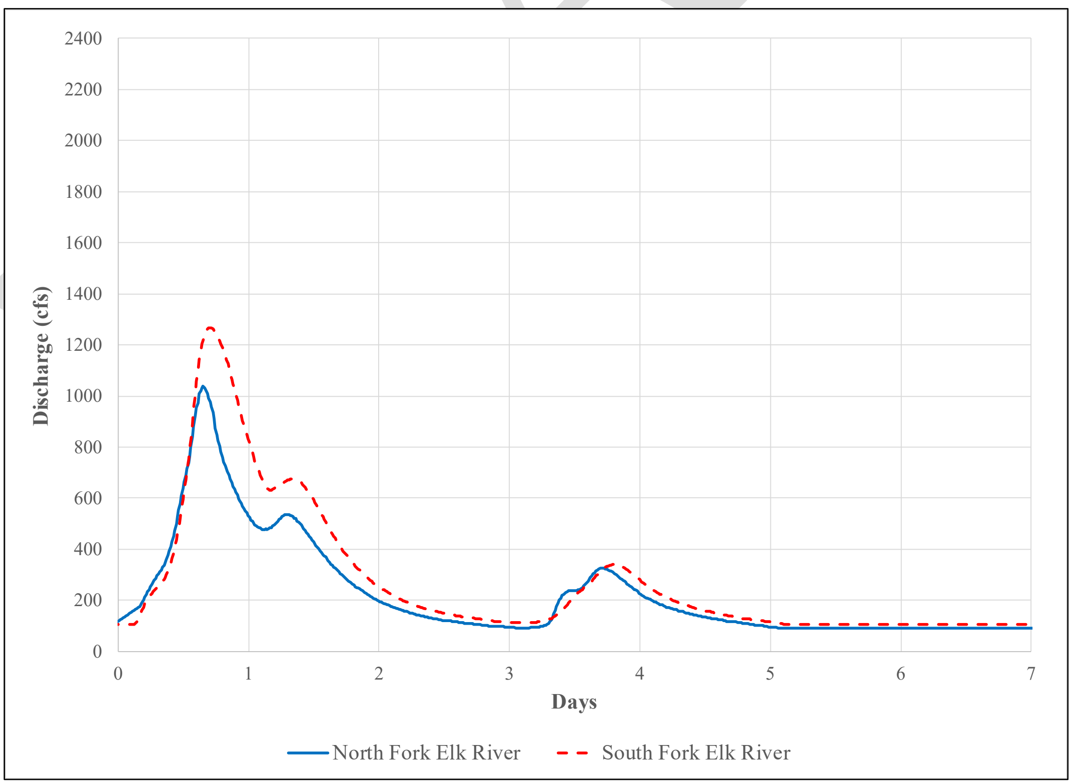

Figure 10. North Fork and South Fork Elk River hydrographs used as input boundary conditions for the SR HST model simulation, constructed from a 7-day period, including the February 6, 2015 peak flow event (WY 2015).

4.2 Predicted Effects of Proposed Designs

4.2.1 Maximum Water Surface Elevations

Water surface elevations were generated from the existing conditions (ERRA HST) and design conditions (SR HST) models for the WY 2003 and 2015 flood flow events. Maximum water levels were plotted and compared to determine the effects of the design topography on local water levels. All figures show approximate existing top of bank lines to reference the alignment of the channel.

Figure 11 shows the model simulations of the December 28, 2002 flood event maximum water surface elevations for existing and design conditions through the project reach. A difference of these results, illustrated in Figure 12, indicates that during the flood of record in WY 2003, the Pilot Projects decrease water levels upstream of the confluence. The area of greatest water level change is around and upstream of the concrete bridge, where the model results suggest that the greatest lowering of maximum water surface elevations is up to 0.11 meters (m; 0.36 ft).

Figure 13 show the model simulations of the maximum water surface elevations for existing and design conditions for the smaller design flood event that occurred on February 6, 2015. A difference of these results, illustrated in Figure 14, indicate that the Pilot Projects will lower water levels for frequent flood events (such as in WY 2015). The model results estimate that the greatest lowering of maximum water surface elevations is up to 0.15 m (0.5 ft)

Overall, the Pilot Projects are predicted to decrease flood water levels over most flow conditions, which would have a positive effect on nuisance flood conditions in the project area. As noted earlier, water levels will likely be lower than predicted due to the vegetation modifications that are not accounted for in the SR HST model. The effectiveness of the Pilot Projects to reduce nuisance flooding is greatly limited by the inability to remove all aggraded sediment within and downstream of the project reach. Treatment of the full sediment impairment as recommended by the Recovery Framework (CalTrout et al. 2018) could decrease water levels by several feet.

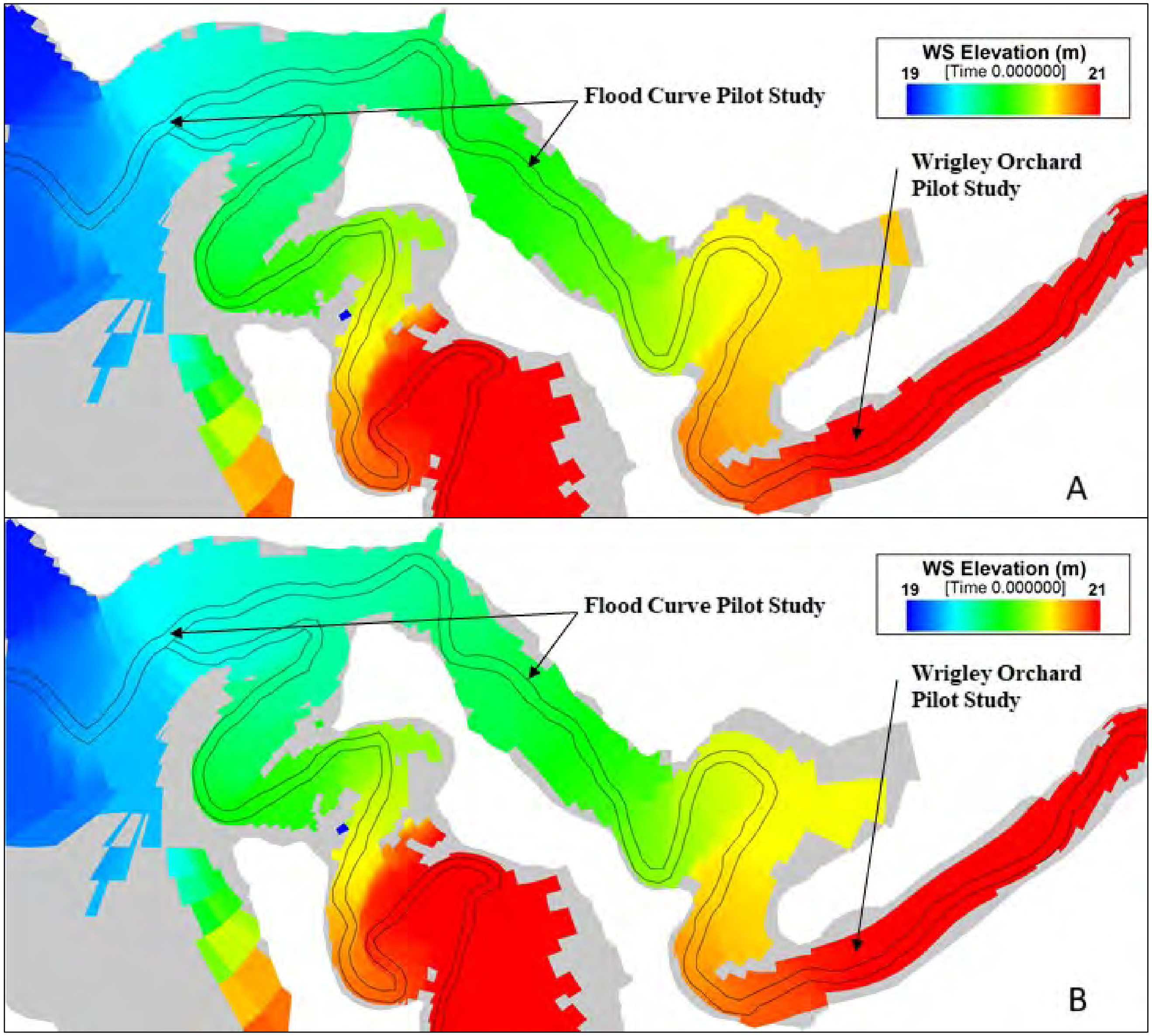

Figure 11. Maximum water surface elevations simulation for (A) the existing conditions (ERRA HST) model and (B) design conditions (SR HST) model near the peak of the December 28, 2002 flood.

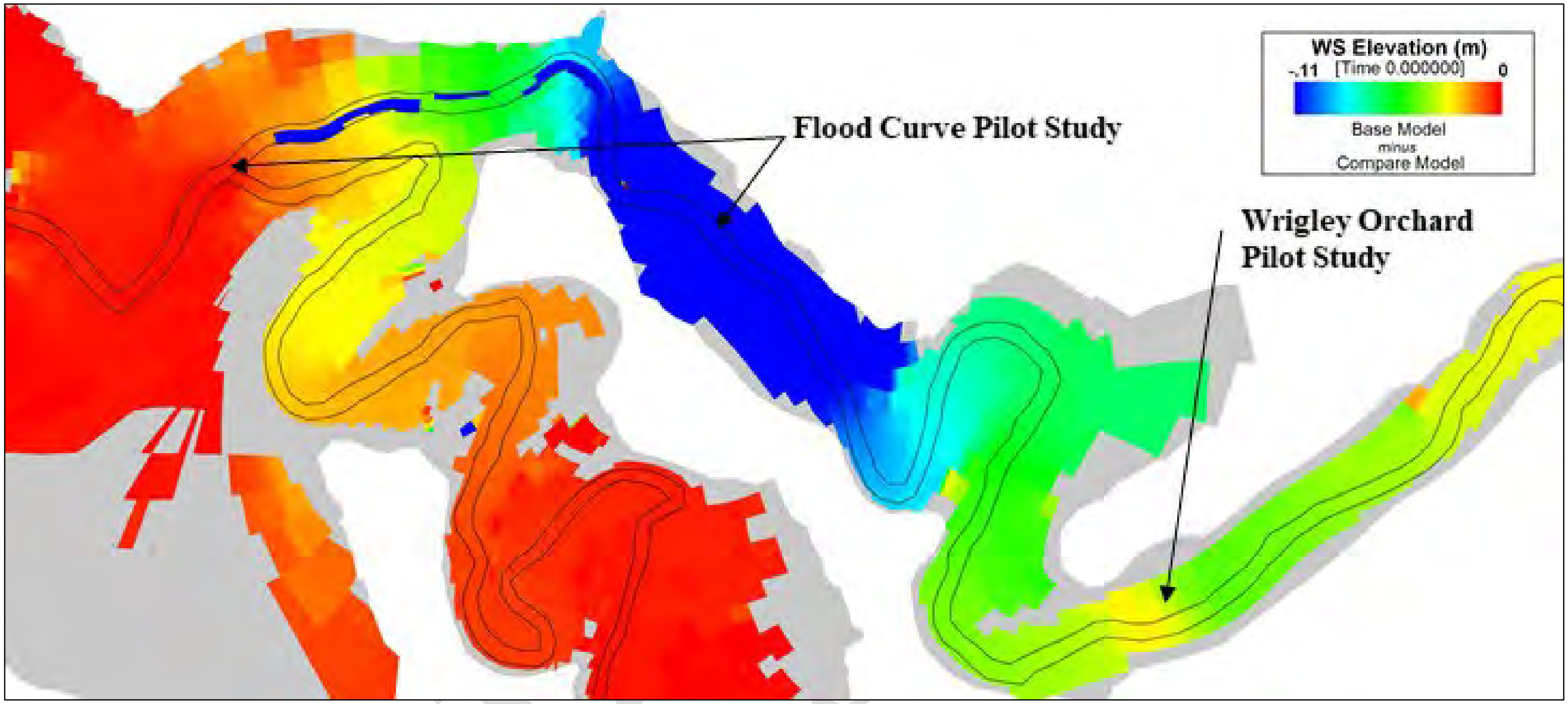

Figure 12. Difference in maximum water surface elevation between design and existing conditions (design conditions minus existing conditions) for the Pilot Projects during the December 28, 2002 flood. Blue indicates a decrease in water surface elevation and red indicates no significant change.

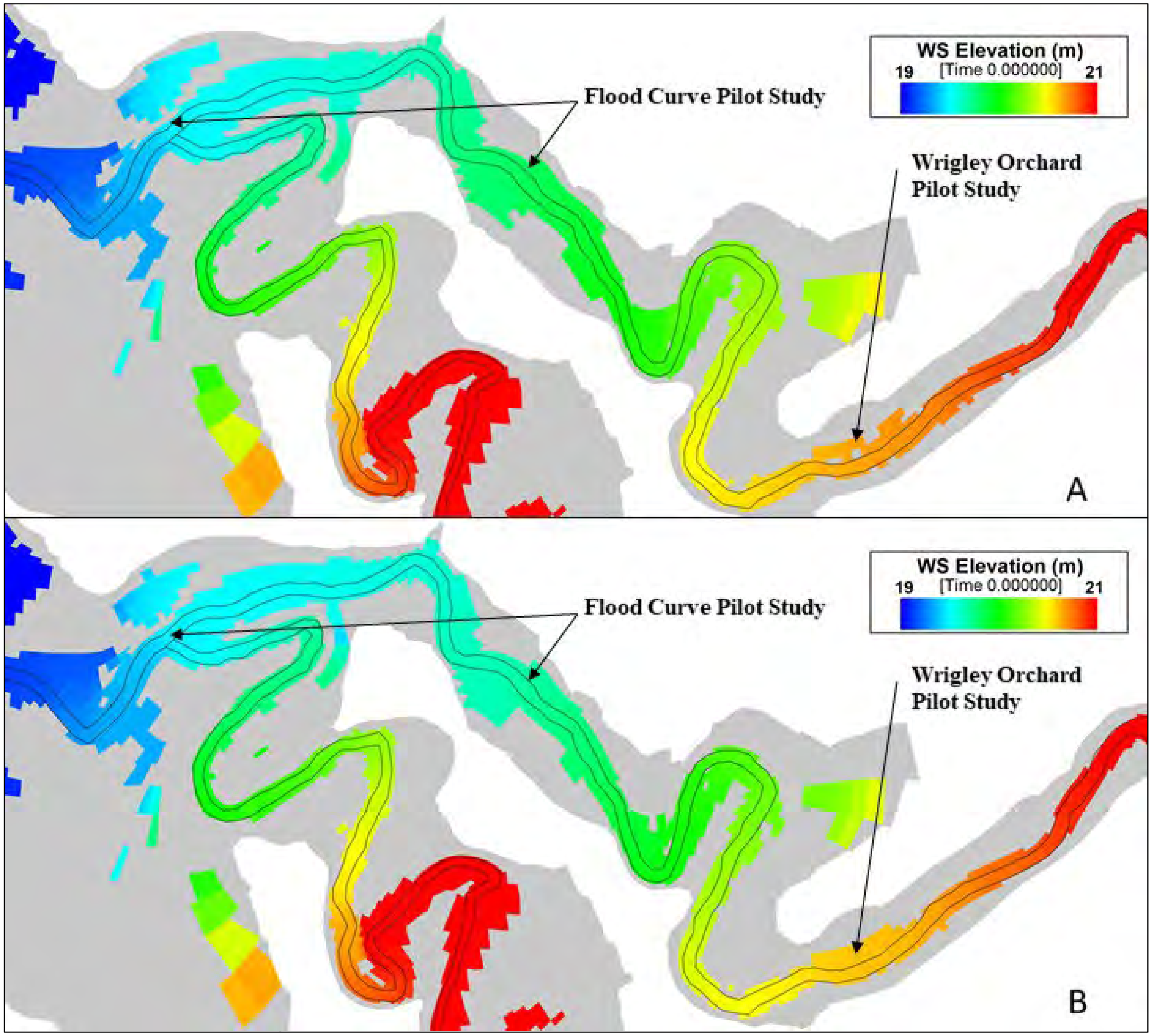

Figure 13. Maximum water surface elevations simulation for (A) the existing conditions (ERRA HST) model and (B) design conditions (SR HST) model during the February 6, 2015 flood.

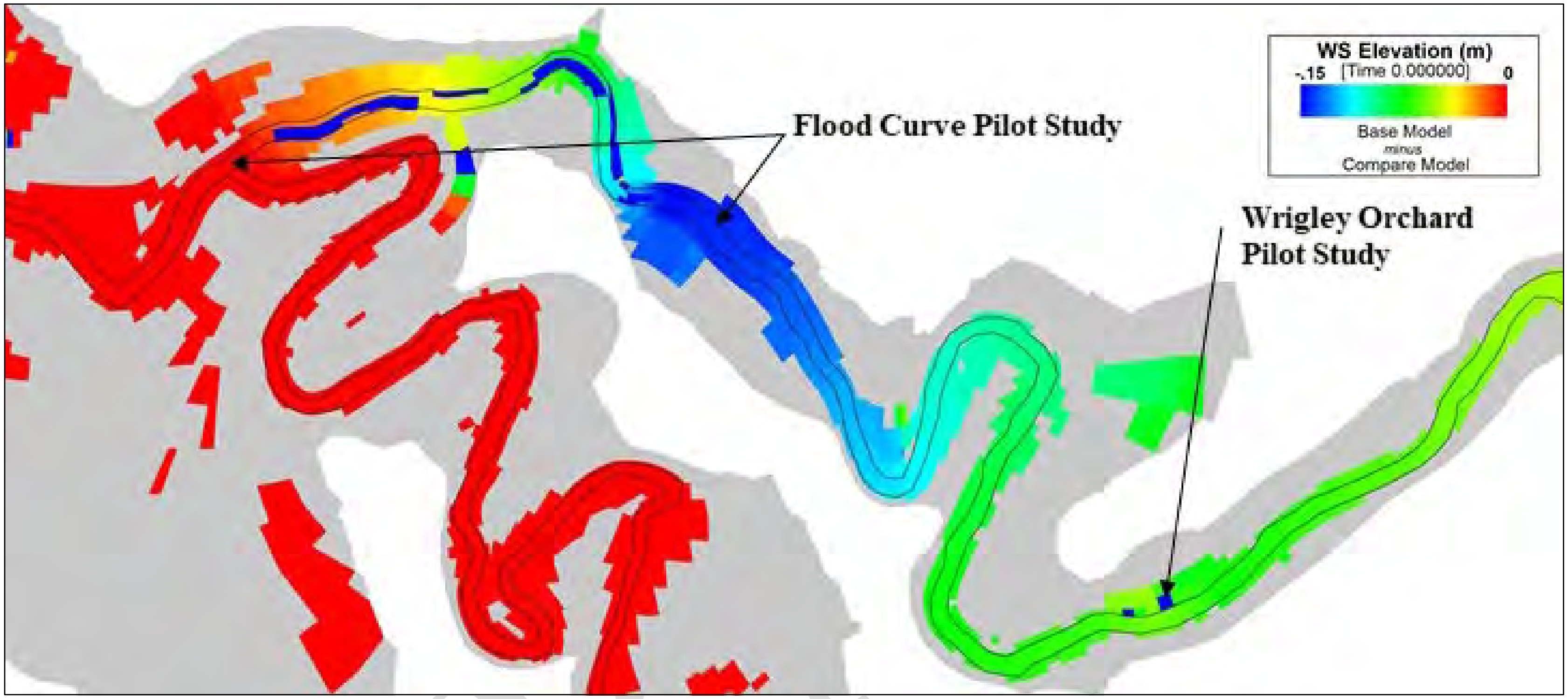

Figure 14. Difference in maximum water surface elevation between design and existing conditions (design conditions minus existing conditions) for the Pilot Projects during the February 6, 2015 flood. Blue indicates a decrease in water surface elevation and red indicates no significant change.

4.2.2 Maximum Velocities

Velocities were calculated for the existing conditions (ERRA HST) and design conditions (SR HST) models during the WY 2003 and 2015 flood flow events. Maximum velocities along the channel centerline were plotted and compared to determine the effects of the design topography on pre- and post-project channel velocities. Model simulations of the maximum velocities for existing and design conditions along the channel centerline during the December 28, 2002 flood event are illustrated through the Wrigley Orchard Pilot Project reach (Figure 15). Figure 16 shows that maximum velocities would be lowered post-project for the Wrigley Orchard Pilot Project reach, during the February 6, 2015 flood event.

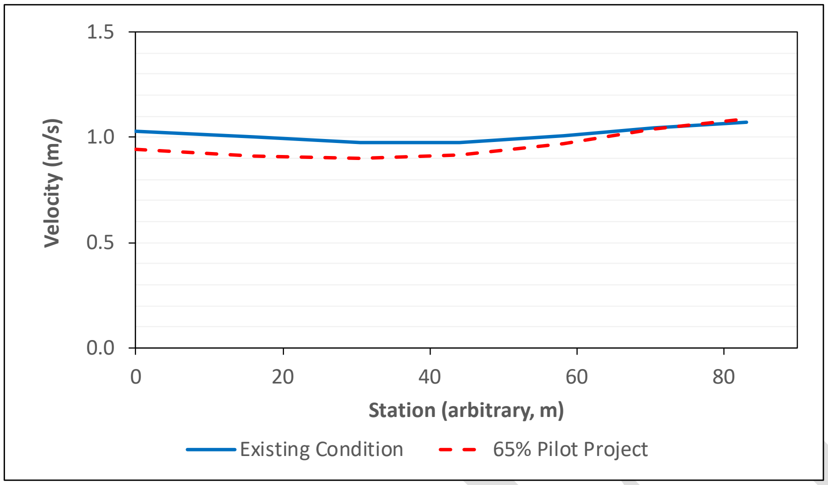

Figure 15. Maximum velocities for the existing condition (ERRA HST) model and Wrigley Orchard Pilot Project 65% design condition (SR HST) model during the December 28, 2002 flood.

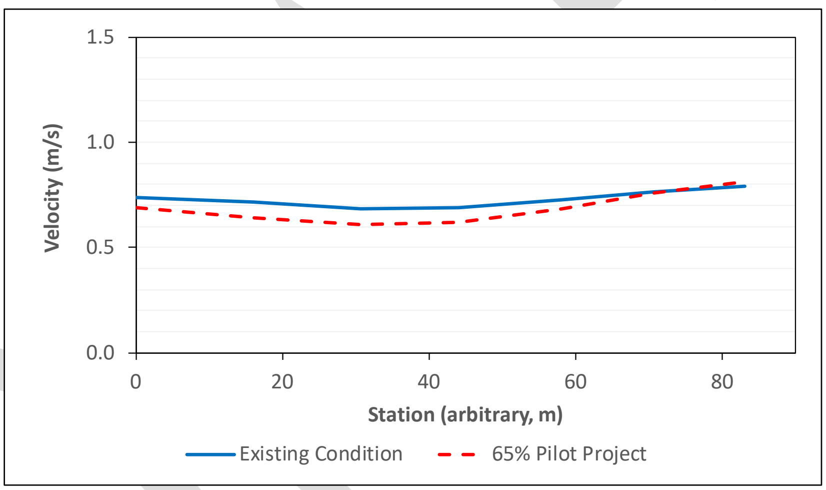

Figure 16. Maximum velocities for the existing condition (ERRA HST) model and Wrigley Orchard Pilot Project 65% design condition (SR HST) model during the February 6, 2015 flood.

Model results indicate that the Pilot Project will slightly lower in-channel velocities through the project reaches during flood flow events. Widening the channel and excavating pools without treating the full sediment impairment in Elk River, downstream of the Pilot Projects, result in lower in-channel velocities. As noted earlier, channel velocities may be higher than predicted immediately after construction due to the vegetation modifications that occur during construction which are not included in the SR HST model.

Treatment of the full sediment impairment as recommended by the Recovery Framework is predicted to increase channel velocities (CalTrout et al. 2018).

4.2.3 Sediment Transport Analysis

A sediment transport model was run for both existing and design conditions to evaluate the effects of the Pilot Projects on the sediment storage in both projects reaches. Figure 17 and Figure 18 show the average change in bed elevation by channel reach as a result of the WY 2003 and WY 2015 flood flow events, respectively. Due to the widening and deepening of the channel, the post-project velocities decrease, and sedimentation slightly increases compared to existing conditions. Sedimentation may be lower than predicted immediately after construction due to vegetation modifications that are not included in the SR HST model. Treatment of the full sediment impairment as recommended by the Recovery Framework would decrease sedimentation compared to existing conditions (CalTrout et al. 2018).

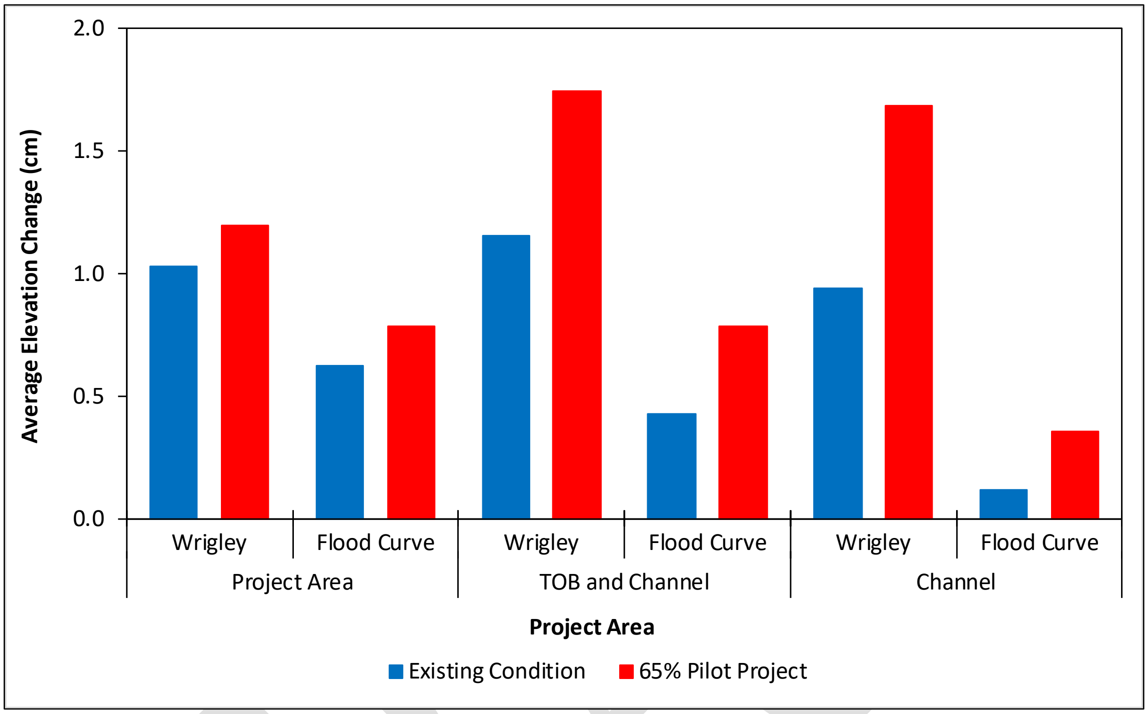

Figure 17. Changes in bed elevation for the existing condition (ERRA HST) model and Pilot Project 65% design condition (SR HST) model during the December 28, 2002 flood.

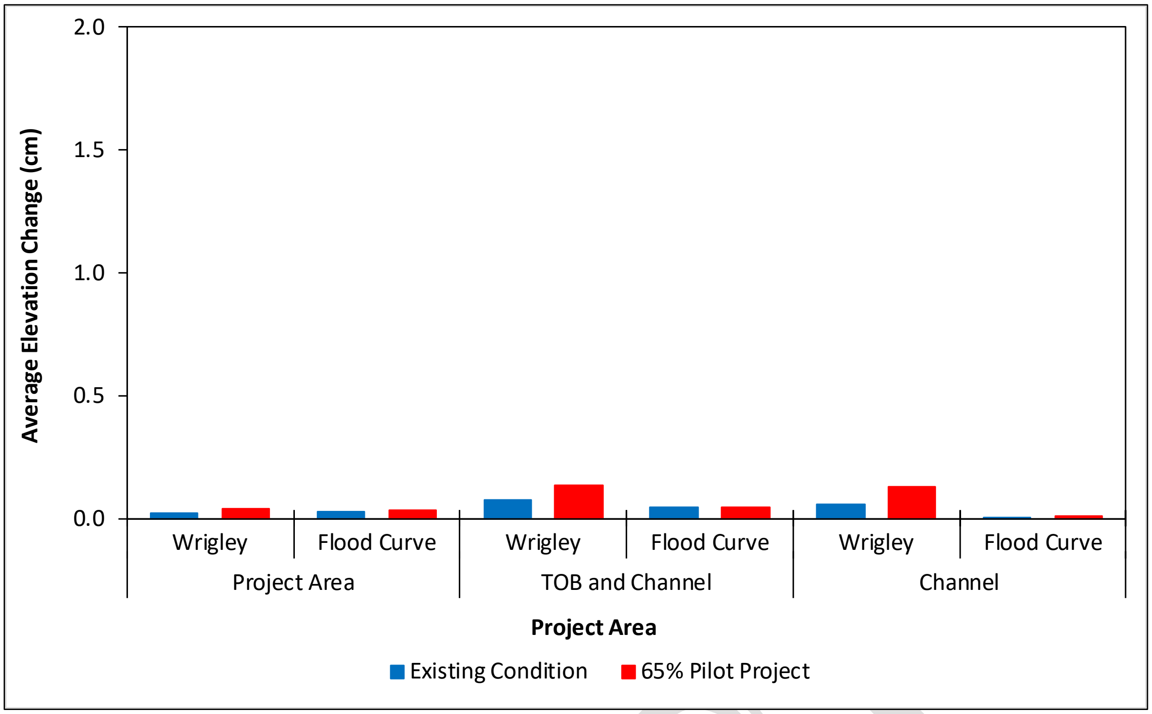

Figure 18. Changes in bed elevation for the existing condition (ERRA HST) model and Pilot Project 65% design condition (SR HST) model during the December 28, 2002 flood.

5. CONCLUSIONS

The purpose of the Pilot Project is to demonstrate the effectiveness of on-the-ground sediment remediation actions through implementation and monitoring to improve beneficial uses of Elk River, as defined by the Regional Water Board Basin Plan, and reduce nuisance flooding. These small-scale projects are intended to develop the strategies and validate tools necessary to implement larger-scale projects to more fully recover beneficial uses and reduce nuisance flooding.

As part of the initial site assessment, existing conditions were defined, including channel and floodplain topography, local geology, the geomorphic setting, including a wood inventory, and dry weather water quality. The following can be drawn from an evaluation of the river's existing condition throughout the Pilot Project reaches:

The river is aggraded with fine sediment, in-channel and over the surface of the channel banks,

- Flooding is occurring at a greater frequency than occurred prior to the sediment impairment.
- The river lacks a sufficient wood storage and supply to be considered "good" fisheries habitat,
- Dissolved oxygen concentrations in North Fork Elk River during the dry season dip well below thresholds for salmonid survival needs, based on the and the North Coast Basin Plan (RWQCB 2011).
- Low dissolved oxygen concentrations are likely due to sediment oxygen demand.

As part of the design process, hydrodynamic and sediment transport models were developed to simulate existing conditions and post-implementation conditions of the Pilot Project to evaluate the effectiveness of these small-scale projects to reduce nuisance flooding and maintain and enhance fisheries habitat. In general, the following can be concluded about the effect of implementing both Pilot Projects based on the model simulations:

- Water surface elevations will likely be lowered through the Pilot Project reaches during flood events, ranging from a maximum of 0.15 m (0.5 ft) during frequent flood events, such as the February 6, 2015 flood event and maximum of 0.11 m (0.36 ft) during more extreme flood events, such as the December 28, 2002 flood event.
- Channel velocities will decrease slightly through the Pilot Project reaches.
- Sediment will be deposited at a greater rate than existing conditions.

The project designs were revised from their original concepts to incorporate recommendations during the resource agency review, specifically, to deepen pools and incorporate large wood habitat structures into the channel designs and reduce impacts to streamside vegetation. Pool deepening would remove some of the aggraded fine sediment and may lead to an improvement in dissolved oxygen levels by reducing sediment oxygen demand. Large wood habitat structures are designed within the pool footprint, below the downstream riffle crest, and installed in a way that does not encourage wood racking during flood events, as it is a primary project objective to decrease nuisance flooding.

The purpose of the Pilot Projects is to demonstrate if the on-the-ground actions taken would effectively remediate sediment to improve beneficial uses of Elk River and reduce nuisance flooding. Improvements are expected to be incremental compared to the larger project recommended in the Recovery Framework due to the project size and practical constraints on actions that can be implemented in isolation; however, these small-scale projects will develop the strategies and validate tools necessary to implement larger-scale projects to more fully recover beneficial uses and further reduce nuisance flooding.

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SECTION 31 10 00

SITE CLEARING

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Clearing and grubbing
   2. Large tree harvesting for reuse
   3. Removal of trash and debris

1.2 LIMITATIONS

A. Environmental compliance permit requirements shall supersede these Specifications.

1.3 PROJECT CONDITIONS

A. Channel and Floodplain Construction Areas

   1. The Drawings designate channel and floodplain construction areas, which are delineated by the outside boundaries of these features.

1.4 SEQUENCING AND SCHEDULING

A. Prior to site clearing and grubbing, provide at least 48 HR advanced notice for Engineer or their representative to flag Save Trees for protection harvest trees to be for reuse.

B. Prior to site clearing and grubbing the channel construction areas, stake out the instream pool alignment and the extents of channel grading and provide at least 48 HR advanced notice for Engineer or their representative to review and approve.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Harvest Trees for Reuse

   1. Trees to be reused shall be flagged in the field by the Engineer or their representative.
   2. Trees to be reused shall be cut up into rounds no greater than 2 FT in length and then chopped into quarters.

B. Other Woody Debris and Vegetation

C. Trash and Debris

PART 3 - EXECUTION

3.1 PROTECTION

A. Protect existing Save Trees and their roots as specified or flagged on the ground. Provide fencing and necessary protections to avoid impacts.

B. Protect existing trees and other vegetation designated to remain against damage (Save Trees):
   1. Do not stockpile construction materials or excavated materials within drip line, unless designated on the Drawings.
   2. Avoid foot or vehicular traffic or parking of vehicles within drip line.

C. Repair or replace trees and vegetation designated for protection but damaged by construction operations:
   1. Repair to be performed by a qualified arborist.
   2. If disturbed or destroyed, contact CM immediately. At the direction of the CM, Contractor shall replace at own expense to full satisfaction of Engineer, Owner and controlling agencies.

D. As feasible, protect existing trees and their roots that are not identified as Save Trees during Earthwork adjacent to the construction area by methods such as avoidance, tying back branches, or trimming.

E. Protect existing surface and subsurface features on-site and adjacent to site as follows:
   1. Protect and maintain surveying benchmarks, monuments or other established reference points and property corners. If disturbed or destroyed, replace at own expense to full satisfaction of Engineer, Owner and controlling agencies.
   2. Verify location of utilities. Omission or inclusion of utility items does not constitute non-existence or definite location. Secure and examine local utility records for location data. It is the responsibility of the Contractor to notify Underground Search Alert (USA) prior to the commencement of Work to verify the location of underground utilities within the project area.
      a. Review location of nearby utility lines with Owner prior to Work.
      b. Take necessary precautions to protect existing utilities from damage due to any construction activity.
      c. Repair damages to utility items at Contractor’s expense.
      d. In case of damage, notify Owner immediately so required protective measures may be taken.
   3. Maintain free of damage any facilities not indicated to be removed. Any item known or unknown or not properly located that is inadvertently damaged shall be repaired to original condition. All repairs to be made and paid for by Contractor.
   4. Provide full access to public and private premises, fire hydrants, street crossings, sidewalks and other points as designated by Owner to prevent serious interruption of travel.

F. Salvageable items: carefully remove items to be salvaged, and store on Owner's premises at designated stockpiling locations unless otherwise directed. Live vegetation stockpiled for replanting shall be watered as needed. Coordinate with CM to identify suitable stockpile areas.

G. Prior to Work within the river channel, temporary fish removal from the channel will be completed by others.

H. While conducting Work within the Elk River channel, Best Management Practices will be employed to minimize erosion of sediment into the channel. All material eroded into the channel during construction will be removed prior to the removal of either the sediment control or fish exclusion fencing.

I. Contractor shall employ erosion control measures, as described in these Specifications and as required to comply with project permits.

3.2 CLEARING AND GRUBBING

A. Do not disturb Save Trees, which will be flagged on-site, prior to Work.

B. Grub (remove) whole trees marked to harvest for reuse.
   1. Root systems shall be cut prior to stockpiling for reuse. Tree crowns, roots and branches shall be removed and stockpiled with other woody debris.
   2. No trees will be harvested outside of the construction area.

C. Clear from within limits of construction other woody debris and vegetation not marked to remain.
   1. Other woody debris and vegetation includes trees that remain, shrubs, brush, downed timber, rotten wood, heavy growth of grass and weeds, vines, rubbish, structures and other organic debris.
   2. Other woody debris and vegetation that are not designated for protection or reuse within the construction footprint shall be removed and stockpiled in a designated area.
   3. Separately stockpile woody debris from other vegetation if grinding or burning will be used to dispose of the material.
   4. Separately stockpile non-woody organic material.
   5. Separately stockpile invasive species, including but not limited to Himalaya blackberry.
   6. Woody debris stockpiles shall be disposed of by burning, grinding or hauling off-site, as permitted by the governing agencies and Owner.

D. For erosion control purposes, clearing and grubbing shall not occur more than 15 days in advance of planned construction operations, within 25 feet of Elk River, unless, specifically approved by the Engineer.

E. Do not bury organic matter on site, unless specifically approved in each case by the Engineer.

3.3 REMOVAL AND DISPOSAL OF TRASH AND DEBRIS

A. Remove and properly dispose of trash and other debris off-site.
   1. "Trash and debris" shall mean asphalt, concrete, pipes, tires, fencing, scrap metals, plastic, and other manmade refuse.
   2. Remove all trash and debris located within the construction limits as delineated on the Drawings.

B. Dispose of waste materials, legally, off site. Burning as a means of waste disposal is not permitted, unless specified and will require permission from Owner and permits from governing agencies. Burning permits shall be submitted to Owner.

C. Asphalt and concrete may be recycled at several local aggregate plants.

3.4 CLEANING

A. Immediately clear, sweep, clean and/or flush existing access roadways and public roadways of any spilled debris and material. Road closures shall not be permitted.

3.5 ACCEPTANCE

A. To ensure compliance with these Specifications and regulatory requirements, obtain Engineer's acceptance of the extent of clearing and grubbing upon completion of the site clearing.

END OF SECTION

SECTION 31 20 00

EARTH MOVING

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:

1. Grading
2. Excavation
3. Fill and Backfill

1.2 LIMITATIONS

A. Environmental compliance permit requirements shall supersede these Specifications.

1.3 QUALITY ASSURANCE AND REFERENCES

A. *Standard Specifications* (State of California Department of Transportation, 2018).

1.4 PROJECT CONDITIONS

A. Wet Weather Conditions and River Levels

1. Excavating, filling, backfilling, and grading shall not be performed during wet weather conditions that might damage or be detrimental to the condition of existing ground, in-progress work, or completed work. When Work is interrupted by rain, freezing weather, or other conditions deemed unsuitable by the Owner, Engineer or their representative, excavating, filling, backfilling, and grading work shall not resume until the site and soil conditions (moisture content) are suitable for compaction.
2. A storm may elevate groundwater levels as the river levels rise. Contractor shall schedule excavations and grading to account for these conditions.

B. Channel and Floodplain Construction Areas

1. The Drawings designate channel and floodplain construction areas, which are delineated by their outside boundaries.
2. Drawings indicate both existing grade and finished grade required for construction of Project.

1.5 SEQUENCING AND SCHEDULING

A. Excavation within the channel construction area are affected by river levels and early season storms may deepen the river, making it challenging to perform excavation and meet water quality and erosion control permit requirements. To minimize seasonal impacts due to weather, it is recommended that the pool/channel excavation be performed as early as possible in the construction schedule.

B. The sequencing and scheduling of construction is the responsibility of Contractor. Prior to the commencement of Work, Contractor shall submit a construction schedule with a proposed sequence of construction activities for review and approval of the Engineer and Owner.

PART 2 - PRODUCTS

2.1 MATERIALS

A. On-Site Cut

1. On-site cut includes, but is not limited to:
    a. Floodplain cut material
    b. Channel cut material
2. Material cut on-site to achieve final grades shown on the Drawings will be used to accommodate all fill materials (versus imported fill materials) for construction and to fill in holes in the landscape, except for imported pea gravel.
3. On-site cut used for general fill shall meet the following criteria:
    a. Cut material may require mixing, blending, and moisture conditioning to create a suitable material that can be placed and adequately compacted.
    b. Cut material not suitable for use as fill or on-site disposal, will need to be hauled off-site.
    c. Stockpiles of cut material to be used as fill shall be mixed or blended until the material is uniform in consistency and free of large, unbroken clods of soil.
    d. Clods of soil or rock particles larger than 4 IN diameter should be broken down with heavy equipment or removed during fill placement.

B. Floodplain Cut Material

1. Floodplain material refers to the sod and soil to be cut within the floodplain construction area.
    a. Sod shall be cut from the top 3 IN of the floodplain area and stockpiled.
    b. Stockpiled sod will be used to finish grades in areas where sod will be re-established.
    c. Floodplain material cut below the sod layer will be used for floodplain fill base material.

C. Channel Cut Material

1. Channel cut material refers to the soil to be cut within the channel construction area.
2. Channel material may require aeration prior to reuse as floodplain fill.
3. Channel cut material primarily consists of fine sand and may have high concentrations of organic material.
4. Channel material may contain woody debris or other material that would not be suitable to be used as fill material or on-site disposal.
5. Channel material cut from below approximately 3 feet of existing grade may be composed of gravels suitable be reused as channel fill. Quality and quantities will be determined during construction.

D. Pea Gravel

1. Pea gravel refers to clean, imported gravel that meets the size class of pea gravel.
2. If channel gravel is not available for reuse in the channel in the quantity required, pea gravel will be imported to meet construction quantities.

PART 3 - EXECUTION

3.1 PROTECTION

A. Erosion prevention: protect stockpiles, ditches, stream banks, embankments, filled, backfilled, and graded areas to prevent erosion until such time as permanent drainage and erosion control measures have been installed.

B. Protect graded areas:

1. Protect Work areas from erosion, foot traffic by workers, equipment, stockpiling or any actions which would compact even minor areas of the surface.
2. Reshape and compact fills subjected to vehicular traffic, if grades change beyond accepted tolerances.
3. Protect graded areas prior to acceptance of work. Reestablish grades where settlement or erosion occurs.

C. Protect finished grade:

1. During construction, shape and drain embankment and excavations. Maintain ditches and drains to provide drainage at all times.
2. Repair and re-establish grades to specified tolerances at locations where completed or partially completed surfaces have become eroded, rutted, or settled due to subsequent construction operations or weather conditions.
3. Rip and backfill areas that get over-compacted during construction by equipment and trucks to native soil conditions.

D. Avoid surcharge or excavation procedures which can result in heaving, caving, or slides.

E. Contractor shall ensure that all instream construction activities comply with all regulatory and permitting conditions.

3.2 TOLERANCES

A. Channel Bottom Alignment: construct finished vertical grades within 0.1 FT of elevations indicated on Drawings.

B. Slopes and Other Graded Surfaces: construct finished vertical grades within 0.2 FT of elevations indicated on Drawings. Construct horizontal grades within 1 FT of locations indicated on Drawings.

3.3 USE OF EXPLOSIVES

A. Blasting with any type of explosive is prohibited.

3.4 QUALITY CONTROL

A. Obtain approval from Engineer or their representative with regard to suitability of soils for general fill prior to subsequent operations.

3.5 COMPACTION REQUIREMENTS

A. Filled areas within the floodplain construction area shall be constructed in 6 IN lifts.

B. Filled areas within the floodplain construction area shall be driven over twice by tracked equipment to set in place and hold grade. Filled areas are intended to be revegetated and not compacted to a density greater than 80%.

3.6 EXCAVATING

A. Excavate to lines and grades required for construction of the Work as indicated on Drawings.

B. Do not excavate or remove any material from the Work area which is not within the designated excavation limits, grade lines, or levels.

C. Excavation shall be conducted in a manner to allow materials to be segregated for reuse. Contractor shall segregate topsoil, subsurface soil, whole trees, and woody debris from the excavation into stockpiles for reuse or off-haul, as necessary.

D. Materials identified for disposal shall be kept segregated during excavation and stockpiled separately from materials that are to remain on-site.

E. Correct areas over-excavated in accordance with Filling and Backfilling in this Section.

F. Except as otherwise indicated, preserve the material below and beyond the lines of excavations. Where excavation is carried below the indicated grade, backfill to the indicated grade as herein specified using materials specified in these Specifications, or if not specified, directed by the Engineer or their representative.

G. Excavation and its restoration, when conducted for convenience of the Contractor, shall be at no additional expense to the Owner.

H. Prevent displacement or loose material from falling into excavation, maintain soil stability.

I. Notify Engineer within the same day of unexpected subsurface conditions and discontinue affected Work in area until notified to resume work.

J. Notify Engineer at least 24 HR prior to excavating channel. Allow Engineer to perform a subsurface investigation of the channel to determine if channel material may be suitable for channel gravel fill material. A subsurface investigation is expected to require local dewatering to dry the base of the excavation for viewing.

3.7 FILLING AND BACKFILLING

A. Use on-site cut for fill and backfill in the floodplain construction area.

B. Use on-site cut or imported materials for fill and backfill in the channel construction area.

C. All areas to receive fill or backfill shall be inspected by Engineer or their representative prior to fill or backfill placement. Engineer shall be notified at least 24 HR prior to the beginning of backfill operations.

D. Prepare ground surface for banks: before fill is started, scarify to a minimum depth of 6 inches. Where ground surface is steeper than one vertical to four horizontal, plow surface in a manner to bench and break up surface so that fill material will bind with existing surface.

E. Place backfill in horizontal layers of loose material and compact each layer before the next layer is placed.

F. Systematically backfill to allow maximum time for natural settlement.

G. Employ a placement method that does not disturb or damage other Work.

H. Fill areas to lines and grades indicated on Drawings.

I. Make grade changes gradual. Blend slopes into level areas.

J. Scarify subgrade surfaces of areas to be filled to a depth of 6 IN. All clods shall be broken and all rocks, hard ribs, and earth lumps over 4 IN in greatest dimension, and other unsuitable materials such as roots shall be removed and disposed.

3.8 SITE-SPECIFIC EXCAVATION, FILL AND GRADING

A. Construct Floodplain Area as Required by Drawings:
   1. Excavate floodplain sod to indicated depth and stockpile in designated area.
   2. Construct floodplain to the lines and grades shown on the Drawings.
   3. Fill with sod to finished grades, where sod is to be re-established.

B. Construct Channel Area as Required by Drawings:
   1. Excavate channel to the lines and grades shown on the Drawings.
   2. Excavate channel material and stockpile at designated floodplain stockpile area.

C. Install Embedded Whole Trees for Large Wood Placements
   1. Wood shall be embedded below finished grade into the designated bank location of the channel pool.
   2. Wood installation provisions are described in Section 353219 – Large Wood Placements.

3.9 STOCKPILING

A. Stockpile at designated areas, unless directed by Engineer.
   1. Floodplain sod shall be stockpiled in a designated area.
   2. Channel material may be stockpiled within the floodplain construction area prior to reuse.
   3. Imported pea gravel may be stockpiled in a designated area.

3.10 SPECIAL REQUIREMENTS

A. While conducting Work within the construction areas, Best Management Practices shall be employed to minimize erosion of sediment into Elk River. All material eroded into the channel construction area during construction will be removed prior to the removal of either the sediment control or fish exclusion fencing and rewatering of the channel.

B. Contractor shall employ erosion control measures as required to comply with project permits.

END OF SECTION

SECTION 35 32 19

LARGE WOOD PLACEMENT

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Placement of whole trees by embedment into the channel construction area.

1.2 PROJECT CONDITIONS

A. Channel and Floodplain Construction Areas

   1. The Drawings designate channel and floodplain construction areas, which are delineated by their outside boundaries.

1.3 PROJECT SEQUENCING AND SCHEDULING

A. Wood placement by embedment in the channel shall commence once the channel excavation is completed. This Work should occur prior to removal of the sediment control and fish exclusion fencing.

B. Prior to installing the large wood, provide at least 48 HR advanced notice for Engineer or their representative to review and approve location and alignment.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Large wood placement trees

   1. Large wood placement trees refer to whole or partial trees designated to be reused for the wood habitat structure. Root systems shall be cleared of soil debris prior to installation channel.
   2. Wood placement trees shall be approximately 24 IN diameter and 30 FT length.
   3. Wood placement trees shall be provided to the Contractor.

PART 3 - EXECUTION

3.1 PROTECTION

A. Whole trees shall be moved and placed in a manner to minimize cracking or breaking off portions of the tree during installation. If a tree is cracked or broken during installation, another tree shall be used for replacement, as available.

3.2 LARGE WOOD PLACEMENT INSTALLATION

A. One tree, referred to as the base log, shall be embedded into the channel bank at each wood placement location. See Drawing for log type and placement.

3.3 ACCEPTANCE

A. Obtain Engineer's acceptance of the location and alignment of the wood placements prior to installation.

B. Once the base log with rood wad is installed contact Engineer for an inspection. Wood should be no more than 6’ into the channel. If the specification cannot be met during installation, contact Engineer immediately.

END OF SECTION

Date: 3/31/2020
By: JKA

Elk River Pilot Project

Based on: Wrigley Orchard Plans (100% DRAFT Plans, 31 March 2020)

Wrigley Orchard

Ref	Description (Assumptions)	%	Total Restoration Cost Cost ($)	$/CY
1				
2	Mobilization/Demobilization	7.7%	14,755	5.46
3	Site Protection	15.8%	30,260	11.21
4	Site Clearing	5.1%	9,845	3.65
5	Site Demolition	0.0%	-	-
6	Site Earthwork - general grading	42.5%	81,464	30.17
7	Site Earthwork - streambed grading	4.6%	8,896	3.29
8	Large Wood Structures	3.9%	7,500	2.78
9	Infrastructure	9.4%	18,000	6.67
10	Erosion Control	0.0%	-	-
11	Revegetation	11.0%	21,095	7.81
12	**Construction Cost Sub-total (Direct Cost)**	100.0%	**191,814**	**71.04**
13				
14	**Indirect Costs**			
15	Insurance & Bonding	2.1	4,028	1.49
16	Fee	4.0	7,673	2.84
17	**Estimate Sub-total**		**203,515**	**75.38**
18	Design Contingency	10.0	20,351	7.54
19	**Estimate Sub-total**		**223,866**	**82.91**
20	2021 Escalation	5.7	12,666	4.69
21	**Estimate Sub-total**		**236,532**	**87.60**
22	Engineering Oversight	5.0	11,827	4.38
23	Construction Management	10.0	23,653	8.76
24	Post Project Monitoring (5-Yr)	LS	50,000	18.52
25	**Estimate Total by Sub-area**		**322,012**	**119.26**

Escalated Total Costs	Rate (%)	Total Cost
2020 Escalated Cost	2.8	315,592
2021 Escalated Cost	5.7	322,012
2022 Escalated Cost	8.6	328,611
2023 Escalated Cost	11.6	335,394

Elk River Pilot Project
Based on: Wrigley Orchard Plans (100% DRAFT Plans, 31 March 2020) Date: 3/31/2020
Wrigley Orchard By: JKA

Ref	Item Description (Assumptions)	Quantity	Unit	Unit Rate ($)	Total	Note
1						
2	**Wrigley Orchard**					
3	Mobilization/Demobilization	147,549	%	10.00	14,754.92	Assume % of subtotal_1
4						
5	Site Protection					
6	Construction survey	147,549	%	10.00	14,754.92	Assume % of subtotal_1
7	Construction fencing	500	LF	1.50	750.00	Approximate stream side boundary for fence
8	Dewatering, fish relocation	147,549	%	10.00	14,754.92	Assume % of subtotal_1
9	SWPPP					NIC
10						
11	Site Clearing					
12	Clearing & Grubbing vegetated areas	19,253	SF	0.10	1,925.30	Non-pasture areas (includes channel, revegetation and invasive plant areas, access road)
13	Tree Removal and stockpile	1	LS	5,000.00	5,000.00	Tree removal for salvage and chipping; or use as habitat wood
14	Cut - nonnative veg floodplain scrape (3'' thick)	101	CY	29.00	2,919.33	Remove non-native blackberry and off-haul
15						
16	Site Demolition					
17	None	0	LS	20,000.00	-	NIC
18						
19	Site Earthwork					
20	Site Cut	2,683	Total CY			Total cut
21	Cut - remove sod from floodplain and stockpile (3'' thick)	412	CY	10.00	4,115.28	Cut and stockpile sod onsite for reuse or incorporation into scrape/fill areas
22	Cut floodplain area	1,389	CY	10.00	13,894.72	Floodplain cut
23	Channel cut and overex for streambed material	882	CY	20.00	17,640.00	Channel cut
24						
25	Site Fill Total	2,721	Total CY			
26	Fill (assumed balanced)	2,309	CY	10.00	23,090.00	Floodplain fill (from floodplain and channel cut)
27	Place stockpiled sod on pasture area	412	CY	10.00	4,115.28	Integrate sod into floodplain surfaces
28						
29	Rough & Fine Grading					
30	Rough and fine grading of floodplain areas	53,167	SF	0.35	18,608.45	Additional recontouring and finishing
31						
32	Channel streambed material					
33	Import channel streambed material	139	CY	54.00	7,506.00	Import channel streambed material
34	Install - channel streambed material	139	CY	10.00	1,390.00	Install channel streambed material
35						
36	Large Wood Structures					
37	Engineered log jam	0	#	20,000.00	-	NIC
38	Habitat wood structure	1	#	7,500.00	7,500.00	Assume 1 habitat structures in pool
39						
40	Erosion Control					
41	Erosion control fabric Type 1	0	LF	44.58	-	NIC
42	Erosion control fabric Type 2	0	SY	12.53	-	NIC
43	Straw mulch on surfaces > 100-yr WSE	0	SY	2.96	-	NIC
44						
45	Fence installation					
46	Purchase materials and construct fence	600	LF	30.00	18,000.00	Fence
47						
48	Revegetation					
49	Purchase and install grass seed and mulch	1.020316804	AC	10,000.00	10,203.17	Seed and muclh floodplain surfaces
50	Purchase vegetation material	0.249586777	AC	26,342.18	6,574.66	Purchase vegetation for revegetation areas
51	Install vegetation material	0.249586777	AC	17,296.63	4,317.01	Purchase vegetation for revegetation areas
52						
53	**Sub-total_1 (earth moving)**				**147,549.20**	
54	**Sub-total_2 (all)**				**191,813.96**	

APPENDIX D

DRAFT REPORT ◦ DECEMBER 2021

South Fork Elk River 10% Design Report

PREPARED FOR

PREPARED BY

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Cover photo: Lower portion of the South Fork Elk River Project area looking downstream toward the mainstem Elk River and Humboldt Bay.

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1 INTRODUCTION

The Elk River watershed is currently the focus of intensive efforts to resolve complex watershed-wide water quality impairment issues. Collectively, these efforts include: (1) The Upper Elk River Sediment Total Maximum Daily Load (TMDL) and associated Waste Discharge Requirements (WDRs) for timber companies in the upper watershed under the authority of the North Coast Regional Water Quality Control Board and US EPA; (2) The Elk River Recovery Assessment (ERRA), a technical feasibility study of large-scale sediment remediation completed in 2018 by CalTrout and technical consultants (Project Team); and (3) The Elk River Watershed Stewardship Program (Recovery Program). The goal of the Elk River Recovery Program is to develop a landowner-supported, multi-objective approach to reduce nuisance flooding[1] and recover impaired beneficial uses that balances flood reduction, sediment remediation, and ecosystem recovery. Toward this end, the Recovery Program has engaged Elk River landowners, land managers, scientists, and resource agencies in a collaborative planning process with the following objectives:

1. Identify voluntary actions, strategies, and solutions to: (a) improve hydrologic and sediment processes, water quality conditions, and habitat functions; (b) reduce nuisance flooding[1], consequent risks to residents and properties, and improve access during high water conditions; and (c) improve domestic (drinking) and agricultural (irrigation) water supplies.
2. Design and implement voluntary actions in a coordinated, prioritized, and cost-effective manner.
3. Conduct a monitoring and adaptive management program to quantify project impacts and benefits, and track responses and outcomes of implemented actions.
4. Ensure that individual actions fit together and collectively yield the greatest benefit toward the recovery of beneficial uses[2].

Throughout 2018-2021, CalTrout and our Project Team have coordinated with landowners and regulatory agencies to share technical information on recovery program activities and solicit input.

The Elk River Recovery Program is a large and ambitious program that, to succeed, will require extensive support from the broader Elk River community (particularly river-adjacent landowners), leadership from the North Coast Regional Water Quality Control Board (NCRWQCB) and other resource agencies, and public funding (such as through grant programs).

In 2020, CalTrout was funded by SWRCB Agreement D2013113 to initiate conceptual design on the South Fork Elk River. This planning effort extends the work of the ERRA and Recovery

[1] California Water Code §13050 defines nuisance to mean anything which meets all of the following requirements:

1. Is injurious to the health, or is indecent or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property.
2. Affects at the same time an entire community or neighborhood, or any considerable number of persons, although the extent of the annoyance or damage inflicted in individuals may be unequal.
3. Occurs during, or as a result of, the treatment or disposal of waste.

[2] Beneficial uses are the cornerstone of water quality protection under the RWQCB Basin Plan for the North Coast region. Designated beneficial uses, plus water quality objectives, form the basis of water quality standards. The federal Clean Water Act and California Water Code mandate the development of water quality standards for all waterbodies within the state, including wetlands.

Program at the reach scale to further the goals of the Elk River Sediment TMDL. Building on landowner-supported concepts developed under the Elk River Recovery Program, Agreement D2013113 funding was used to develop draft conceptual designs for the South Fork Elk River from the confluence of Tom’s Gulch. Design concepts evaluated within the scope of this agreement include in-channel sediment removal (pool enhancement), channel widening (floodplain lowering), aquatic habitat restoration, vegetation management (including non-native removal), and riparian and wetland restoration. Design recommendations are based on extensive baseline condition assessments including geomorphology, inundation (at different flows), and aquatic and riparian habitat conditions. These baseline condition assessments set the context for design work. The South Fork design concepts presented were developed iteratively in consultation with landowners and agency representatives. Results of the baseline conditions assessment were presented to agency representatives at a Technical Advisory Committee meeting in April 2021 followed by a presentation of proposed recovery actions in August 2021. Landowner outreach is ongoing.

The purpose of this document is to describe the proposed recovery actions, including goals and objectives, types of recovery actions and anticipated benefits, findings of the baseline conditions assessment, and locations of recovery actions proposed within the South Fork Elk River Project area (planning reach). This report is the final deliverable associated with SWRCB Agreement D2013113 and will serve as the basis for the next design phase (currently unfunded).

The South Fork Elk River (South Fork) drains an approximately 21 square mile (mi^2) watershed in Humboldt County, California (Figure 1-1). The South Fork is a major tributary to the Elk River, which is the largest sub-basin of the Humboldt Bay watershed and the largest tributary to Humboldt Bay. Like other Humboldt Bay tributaries, the South Fork headwaters originate in the coastal hills to the east and drain northwest across the seaward slope of the outer Coast Range to the coastal plain (Figure 1-1). The upper South Fork watershed is characterized by steeper slopes and predominantly forested land cover, which transitions into low-gradient agricultural and low-density residential areas where flood elevations have substantially increased in recent decades. The South Fork watershed is characterized by a maritime coastal climate with mild wet winters and a prolonged summer dry season. Mean air temperatures at the coast fluctuate from 48° F in January to 55° F in June. Mean annual precipitation ranges from 48 inches near the North Fork confluence to 60 inches in the upper headwaters, located ~2,100 feet above sea level and approximately 1.75 miles inland. Roughly 90 percent of the annual precipitation occurs as rainfall between October and April. Intense rainfall over steep topography composed of erodible parent materials results in high sediment yields. Roughly 65% of the upper watershed is zoned as timber production zone (TPZ) owned and managed predominantly by the Humboldt Redwood Company (HRC), and to lesser extent by Green Diamond Resource Company (GDRC). The remaining portions of the South Fork Elk River watershed include the Bureau of Land Management’s (BLM) Headwaters Forest Reserve established in 1999 (34%) and a combination of private residences, and agricultural land uses (1%).

The focus of restoration and enhancement efforts for the 10% design phase is a ~9,900-ft section of the South Fork located between the confluences of the North Fork Elk River and Tom’s Gulch (Figure 1-2). Lateral project extents are roughly delineated by Elk River Road to the east and the transition to upland forest to the west. Save the Redwoods League (SRL) owns roughly 58% of the land within the Project reach, with the remainder comprised of residential (39%) and forest reserve (3%). In general, the South Fork Elk River holds significant potential to increase the quality and quantity of habitat for native salmonids and is generally characterized by high sediment load (from Tom’s Gulch), but few constraints related to nearby infrastructure and residences.

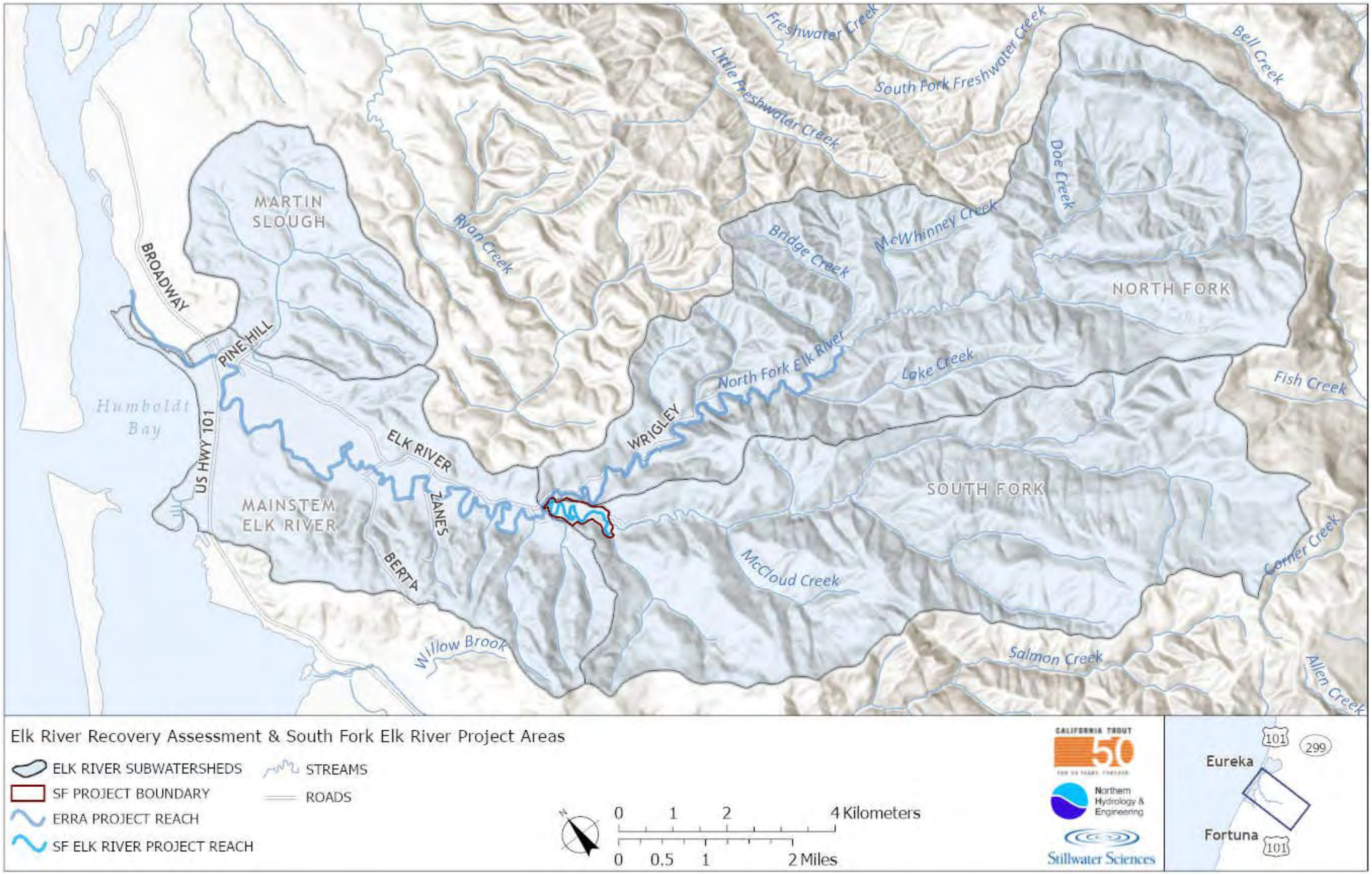


Figure 1-1. Vicinity map of the South Fork Elk River Project area.

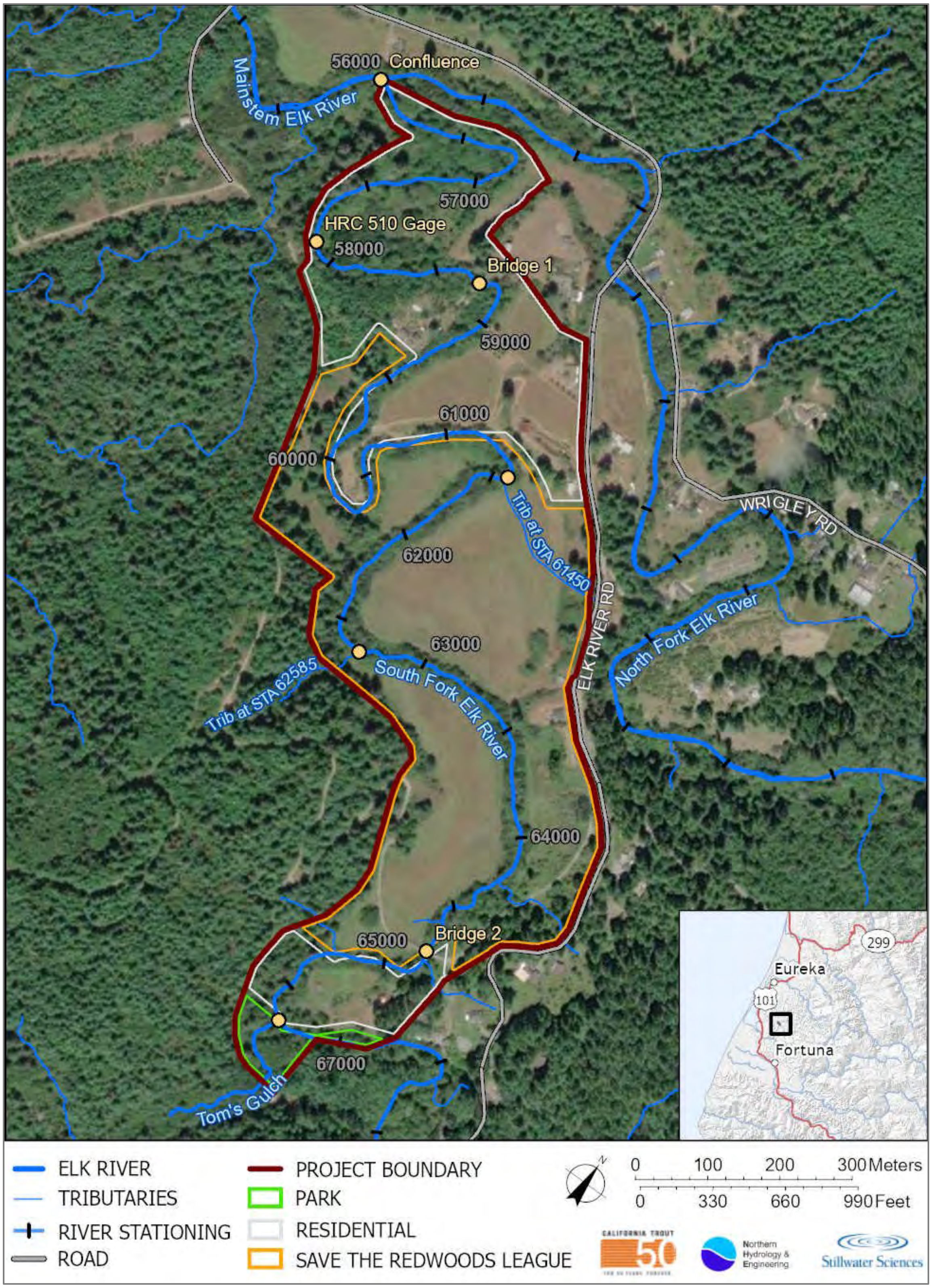


Figure 1-2. Map of the South Fork Elk River Project reach (planning reach). River stationing represents the distance (ft) upstream from the Humboldt Bay confluence.

2 EXISTING CONDITIONS

Existing conditions within the South Fork planning reach were characterized through field surveys and desktop analyses of key attributes including channel and floodplain geomorphology, hydrology and hydraulics, aquatic habitat, in-channel and riparian vegetation, and infrastructure. This baseline information was used to inform reach-specific goals and objectives, identify of opportunities and constraints, and develop habitat enhancement design concepts.

A high resolution (18MP) photo tour was created to share characteristics of the river and adjacent floodplain areas with planning partners. The photo tour includes 360-degree interactive panoramic imagery and georeferenced tags containing key field observations collected on September 15 and 23, 2020. The tour can be accessed at: https://arcgis.earthviews.com/public/elk-river-s-fork-0920#6.

2.1 Geomorphology

An understanding of geomorphology (e.g., valley bottom landforms and channel longitudinal profile, gradient, width, entrenchment, morphology, sediment composition, and bank conditions) is critical to effectively plan and design for recovery of beneficial uses and ecosystem services in the planning reach. In general, the South Fork is a very low gradient channel with slopes less than 0.5%. The lower portion of the reach (defined by a series of meander bends) is significantly entrenched with little summer rearing habitat for juvenile salmonids. Entrenchment diminishes and floodplain connectivity increases as you move upstream. Sedimentation is widespread throughout the downstream extent of the planning reach, which is most effected by backwatering from the mainstem Elk River channel. Bank erosion is nearly ubiquitous throughout the planning reach and many banks are unstable and prone to failure (resulting in an additional source of sediment to the channel).

The Elk River valley occupies a deep, structural trough formed within the coastal plain as a result of regional tectonic uplift and subsidence, faulting, and folding. The valley is a naturally occurring depocenter filled with thick, unconsolidated Late Pleistocene and younger alluvium deposited during marine transgression related to eustatic sea level changes. Geology in the Elk River basin is predominantly composed of the Wildcat Group, a thick overlap assemblage of poorly indurated marine siltstone and fine-grained sandstone; the Yager terrane, a highly folded and sheared argillite and sandstone turbidites with minor pebbly conglomerate; and the Franciscan Complex Central Belt, an accretionary mélange enclosing blocks of more coherent sandstone, greenstone, and chert (Ogle, 1953; McLaughlin et al. 2000, Marshall and Mendes 2005). Undifferentiated shallow marine and fluvial deposits of middle to late Pleistocene age cap ridges across the western portion of the watershed. The valley bottom is occupied Quaternary and Holocene alluvium, river terraces, and fan deposits. The channel within the Project reach consists of low-gradient, alluvial channel types. Bedrock is typically not observed in the channel bed or banks, except where the channel impinges on the valley sidewall.

Widespread channel aggradation has occurred throughout the Project reach from upstream sediment sources (Tetra Tech 2015, CalTrout et al. 2018). Trends in historical and contemporary sediment loading in Elk River from the mid-1950's to present describe two cycles of elevated then diminishing sediment loads corresponding to decadal changes in timber harvest rates and associated road construction. The period of accelerated timber harvest between approximately 1988 to 1997 corresponded with a series of large storm events that significantly increased management-related sediment loading to and increased aggradation in the South Fork Elk River.

Despite a decline in the rate of sediment production from the upper watershed since 1998, the South Fork Elk River within the planning reach continues to aggrade. Tom's Gulch, located at the upstream end of the Project reach, has historically delivered the highest unit-area sediment load in the watershed. Trapping sediment in Toms Gulch before it is delivered to the South Fork and creating channel conditions in the South Fork that more effectively sort sediment and maintain complex morphology are important considerations in the design of features within the planning reach.

2.1.1 Valley bottom landforms

The valley bottom in the South Fork Elk River planning reach is comprised of Holocene alluvial river terraces and fans, active floodplains inset within Holocene deposits, and the active channel entrenched within these valley bottom landforms. To characterize floodplain morphology, relative inundation potential, and existing and relict secondary flow paths within the lateral extent of the valley bottom in the Project reach, we analyzed the height of valley landforms above a reference surface defined by near channel floodplain elevations. Near channel floodplain elevations were extracted from the project Detrended Elevation Model (DEM) developed utilizing LiDAR and channel surveys. The differences resulting from subtracting the reference floodplain surface from the original DEM indicate the height of geomorphic features above or below this reference surface (Figure 2-1). The process is equivalent to removing the overall trend in down valley slope from the topography.

The pattern in relative elevations depicts a geomorphic setting with Holocene valley bottom landforms (yellow and orange colors) that historically confined the South Fork Elk River to a predominant single thread channel. In the upper half of the Project reach (upstream of about STA 62,500), the valley bottom is typically comprised of lower lying floodplain surfaces (blue and green colors) that are better connected to the channel and have more complex flood inundation patterns and high flow pathways; while in the lower half of the reach (downstream of about STA 62,500), the channel and adjacent narrow inset floodplains are typically confined by more extensive and higher Holocene fill terraces. Hydraulic modeling of inundation patterns (refer to Section 2.3.4) corroborates these interpretations of historical and current valley bottom geomorphic conditions related to flood connectivity and secondary flow paths.

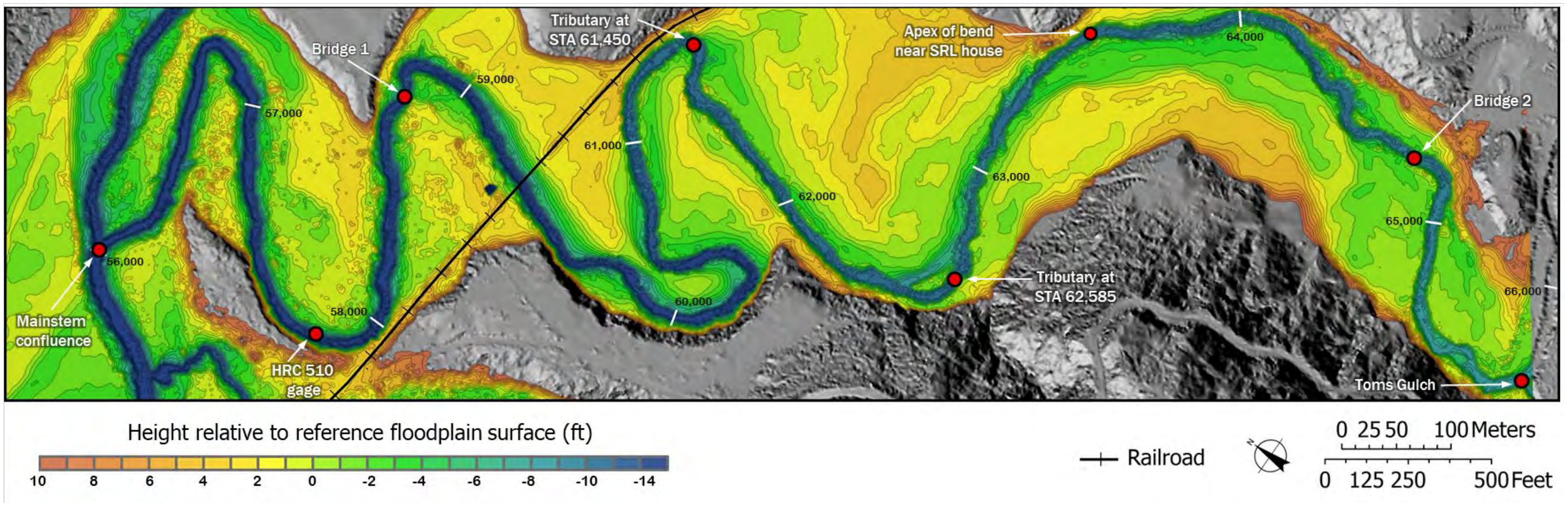


Figure 2-1. Height of valley bottom geomorphic features relative to the reference floodplain surface.

2.1.2 Channel longitudinal profile and gradient

Average channel gradient through the Project reach is 0.23 percent (Figure 2-2). A high-resolution survey of the channel thalweg profile was conducted through the lower half of the South Fork planning reach from the confluence with the mainstem Elk River upstream to approximately STA 59,836. Downstream of STA 59,836, channel gradient is controlled primarily by woody debris pieces and accumulations, as well as planform curvature (Figure 2-2). Detailed information describing the channel thalweg profile is lacking from approximately STA 59,836 and above.

2.1.3 Channel width and entrenchment

Channel geometry (e.g., width, depth, and slope) changes systematically throughout the planning reach. The typical cross section changes from a less entrenched channel with higher width-to-depth ratio and more complex active channel features in predominantly gravel-bedded reaches to a progressively more entrenched channel with lower width to-depth ratio and less complex active channel features. The width/depth ratio is key to understanding how hydraulics, flow inundation, sediment accommodation space, and aquatic habitat availability change with discharge.

Top of bank (TOB) and bank toe (TOE) lines were mapped from project LiDAR and channel cross section surveys. TOB and TOE lines were verified during field traverses and adjusted as necessary. The difference between the average TOB elevations and the thalweg profile elevation at the corresponding station describes the degree of channel entrenchment within Holocene alluvial deposits comprising the valley fill (Figure 2-3). The ratio of the TOB width to the Toe width provides a proxy for the relative steepness of the channel banks, with lower numbers (i.e., similar TOB and TOE width) representing steeper banks.

Entrenchment is relatively low in the upstream end of the reach, with a minimum of about five feet just downstream of the Bridge 2 (STA 64,446) (Figure 2-4). Low entrenchment means that the floodplain is typically more connected to the channel and experiences more frequent and longer inundation. Entrenchment increases from just upstream of the apex of the bend near the right bank high flow channel (STA 63,052) and reaches a maximum of more than 15 feet upstream of the HRC 510 gage (STA 57,932). This transitional channel segment with increasing entrenchment is typically confined by very steep, often nearly vertical bank slopes (e.g., STA 62,110 to 60,634) (Figure 2-3) and has little floodplain connectivity. The channel remains deeply entrenched from about the HRC 510 gage to the confluence with the mainstem Elk River at the downstream extent of the planning area.

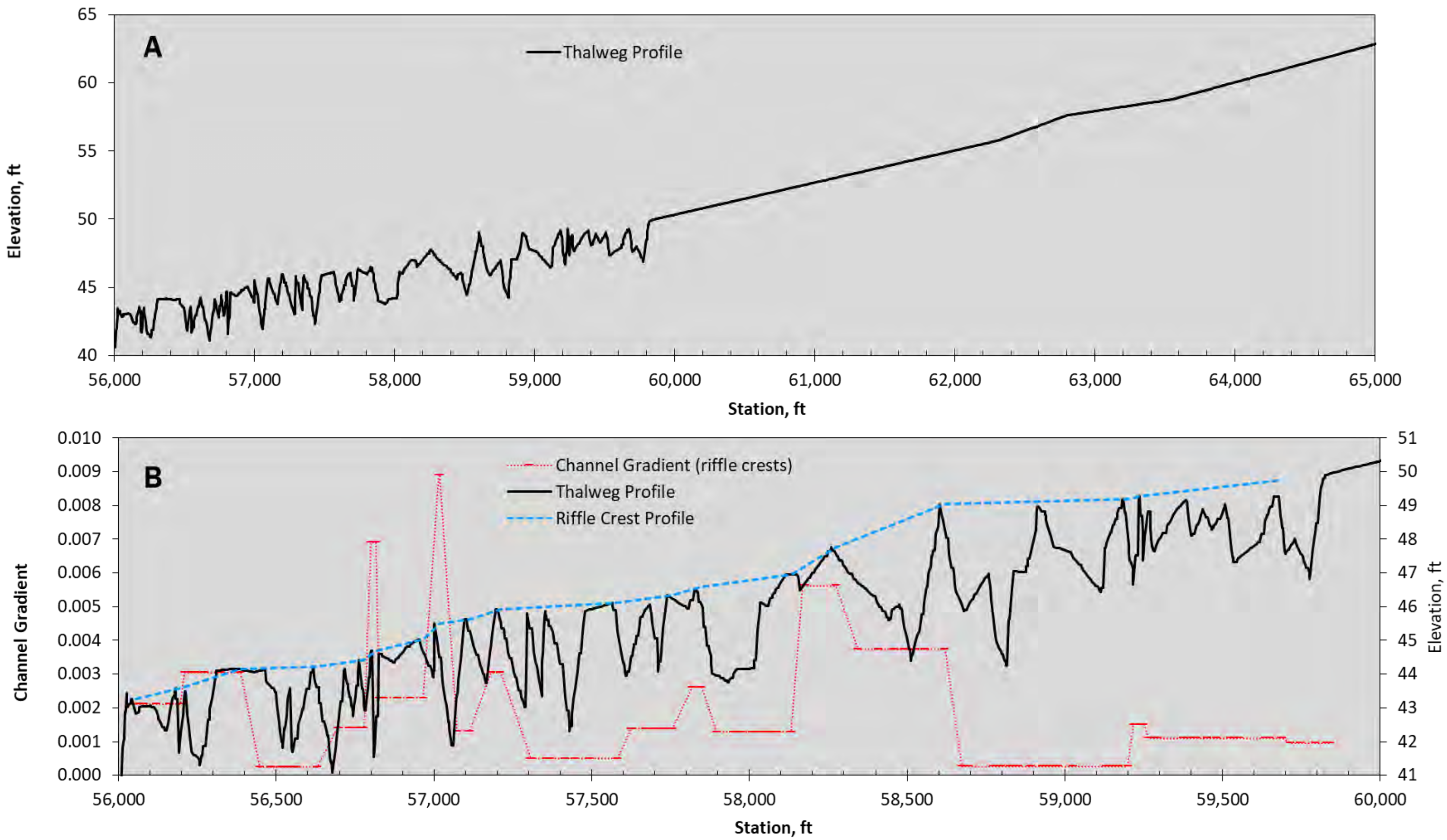


Figure 2-2. Thalweg profiles and channel gradient in the South Fork Project reach.

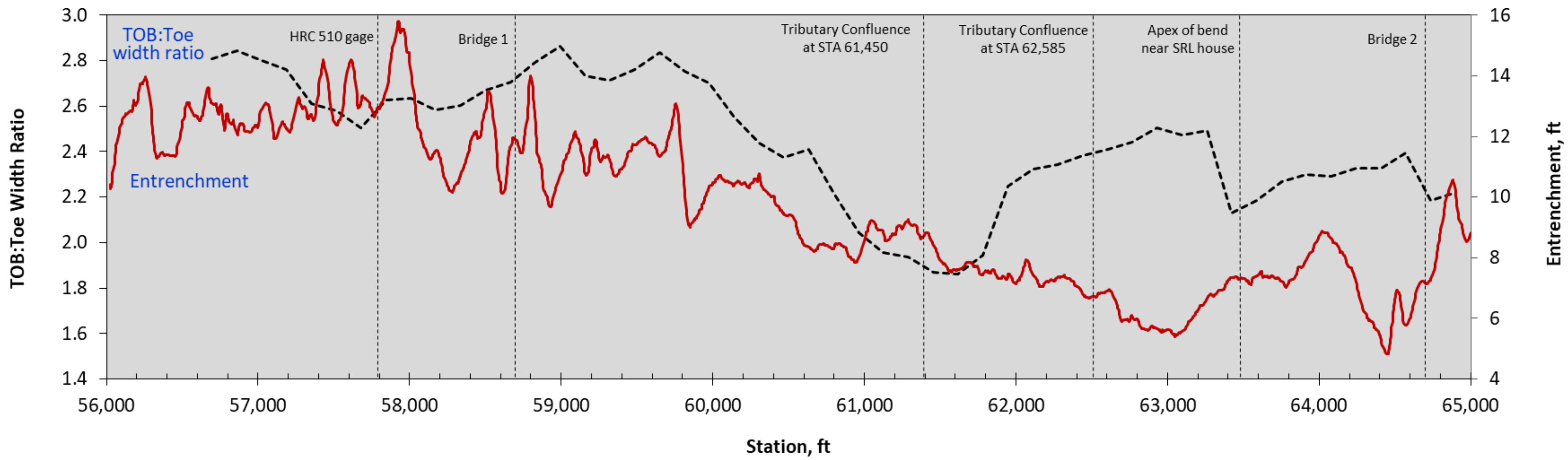


Figure 2-3. Channel TOB to Toe width ratio (dashed black line) and entrenchment (red line) in the South Fork Elk River Project reach.

(A)

(B)

(C)

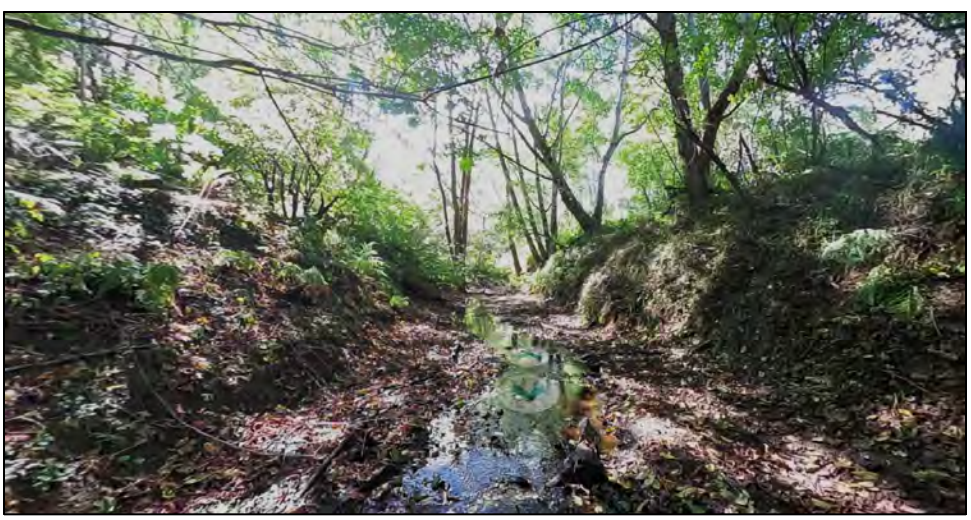


Figure 2-4. Typical channel entrenchment in the upstream (A), middle (B), and downstream (C) channel segments.

2.1.4 Channel morphology and sediment composition

The upstream end of the reach immediately upstream and downstream of Tom's Gulch is predominantly sand and gravel plane bed (Figure 2-5, Figure 2-6). Channel morphology and bed material transitions to sand and silt plane bed further downstream. Alternating sand bars are commonly forced by planform curvature. Lee and stoss deposits of patchy sand and gravel are also commonly forced by large wood pieces and debris accumulations. Sand and silt deposits are typically embedded with fine organic material. In the downstream extent of the planning reach, sand and silt deposits are commonly accreted to banks and banks toes, and channel-wide aggradation is common.

Channel banks are typically comprised of fine sand and silt, are steep to nearly vertical, and highly erodible. The ratio of the TOB width to the TOE width provides a proxy for the relative steepness of the channel banks, with lower numbers (i.e., similar TOB and TOE width) representing steeper banks (Figure 2-3). The transitional channel segment from approximately STA 62,110 to STA 60,634 has the steepest banks, often nearly vertical. Bank mass failure is common in this reach, induced by block topple through fluvial erosion at the bank toe and by rotational slumping during hydrograph recession when bank pore water pressures are high and the hydrostatic pressures imposed by the adjacent water column decline. Bank mass failure is also common in the downstream portion of the planning reach which has experienced the largest amount of channel aggradation, including widespread accretion of sand and silt deposits to the bank and bank toe. The accreted bank deposits in this lower reach are especially prone to rotational slumping, which recruits bank-stored sediment deposits and associated live vegetation to the channel bed (Figure 2-7).

(A)

(B)

(C)

Figure 2-5. Sediment storage in sand and silt plane bed and bars forced by planform curvature (A), lee and stoss deposits forced by woody debris (B), and channel wide aggradation (C).

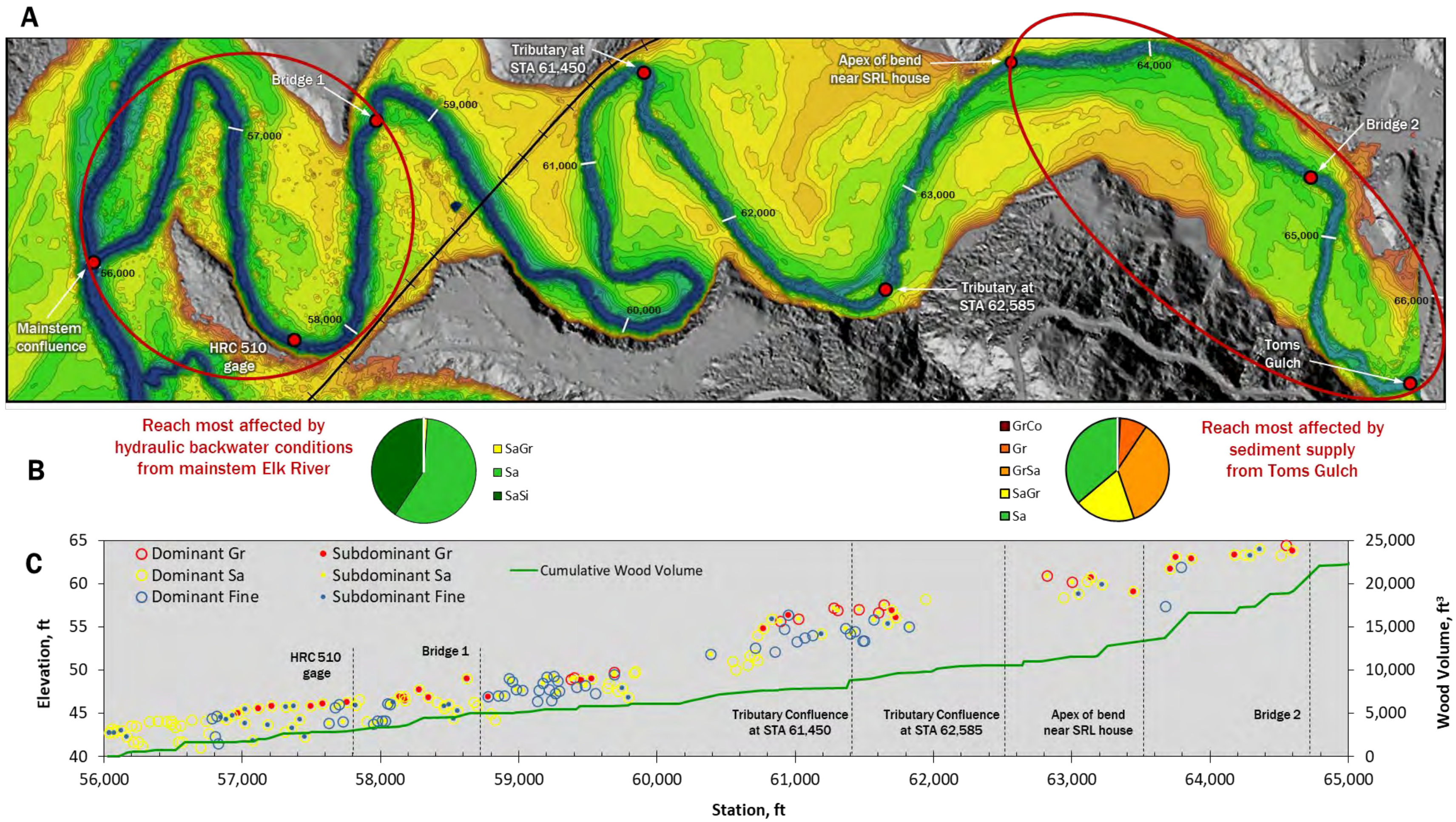


Figure 2-6. Channel bed facies and prevailing influences on sediment dynamics in the Project reaches: (A) channel segments with different primary influences on sediment dynamics, (B) characteristic facies distributions within channel segments with different controls on sediment dynamics, and (C) dominant and subdominant facies. See Section 2.4.2 for discussion of large wood.

Figure 2-7. Rotational slumping of bank accreted sand and silt deposits.

2.2 Hydrology and Hydraulics

An understanding of hydrology and hydraulics in the planning reach is critical to understand existing flooding patterns and identifying enhancement opportunities that meet the project objectives. The magnitude and frequency of stream flows also impacts the distribution of aquatic habitat and riparian forest species and structure. This section describes the hydrologic analyses conducted to estimate stream flows with specific recurrence intervals that are relevant for the design. The hydraulic analysis uses a two-dimensional hydrodynamic model to estimate water levels, depth, velocity, and inundation extents at these stream flows (design flows). This information was utilized to delineate elevation zones where mesic, transitional, and xeric vegetation zones occur (See Section 3.4.6 for more information) as well as for quantifying the area of habitat for existing and design condition.

2.2.1 Hydrology

The hydrologic analysis was guided by needs identified in the habitat assessments (riparian and salmonid habitat) and project objectives related to flooding and channel capacity. Design flow estimates are required at the model boundaries (see Section 2.2.2 for more information). The hydrologic computations include: (1) a flood-frequency analysis of annual peak flows; (2) extension of the peak flow analysis to estimate the magnitude of smaller, more frequent storms via a Log-Pearson III curve fitting procedure; and (3) a flow-duration analysis of mean daily flows.

2.2.1.1 Peak flow analysis

Streamflow data on the Elk River is limited to two time periods. The USGS maintained a streamflow gaging station on the Elk River below the North Fork/South Fork confluence (USGS 11479700 Elk River near Falk, CA) for water year (WY) 1958 to 1967, and annual peak-flow data exist for this period-of-record (POR). Since WY 2003, the Humboldt Redwood Company has maintained streamflow gaging stations on the Elk River below the North Fork/South Fork confluence (HRC509) (approximate location of the historic USGS gage), North Fork Elk River above the confluence (HRC511), and South Fork above the confluence (HRC510), and annual peak-flow estimates exist at these three locations for WY 2003 to present.

A review of published peak-flood estimates (Gotvald et al. 2012) for USGS Elk River station USGS 11479700 demonstrated that less frequent peak-flood estimates (i.e., ≤ 10% annual chance event) from a Bulletin 17B analysis (IACWD, 1982) using a Log-Pearson Type-3 distribution on the POR annual peak-flows were significantly lower than peak-flood estimates from the regional flood-frequency equations (i.e., 96-265% lower; NHE, 2020). Significant underestimation of infrequent peak-flows by the Bulletin 17B analysis did not occur for other nearby gaged streams—such as the USGS gaging station on Jacoby Creek and the USGS gaging station on Little River that has a watershed area similar in size to the Elk River (NHE, 2020).

NHE (2020) suggested that a likely explanation for the discrepancy in Bulletin 17B vs. regional regression estimates is that the Elk River gaging sites are in an area with significant overbank flows during flood events. Not only is the site inaccessible during flood events due to road flooding, but it also appears that the gaged record may have only accounted for discharge within the channel and did not accurately account for overbank flows. Accordingly, NHE (2020) concluded that conducting flood-frequency analyses with annual peak-flow data from the historic USGS Elk River gage (USGS 11479700 Elk R. nr Falk CA) would yield unreasonably low peak-flood estimates and should not be used. NHE (2020) further concluded that this same condition applies for the three active Humboldt Redwood Company Elk River gaging stations described above, and that the annual peak-flows from these stations should not be used to provide peak-flow estimates. Consequently, NHE used the regional flood-frequency equations to estimate peak-flood flows for this study.

Peak-flow estimates for larger, less frequent storms (≥ 2-year event) were computed using the regional flood-frequency equation for California (regional-equation) (Gotvald et al. 2012). Regional-equation parameters for the North Fork and South Fork Elk River, Elk River below the North Fork/South Fork confluence, and various Elk River tributaries (Table 2-1) were determined from the USGS StreamStats program (http://water.usgs.gov/osw/streamstats/).

Table 2-1. Select regional flood-frequency equation parameters and revised regional skew estimates for the Elk River at various locations.

Site	Basin area (mi^2)	Annual precipitation (in)	Mean basin elevation (ft)	% Forest	Revised USGS regional skew
Tom's Gulch	2.5	50.1	516	85.4	-0.6120
South Fork Elk River (HRC510)	19.4	57.8	990	81.5	-0.5900

To estimate peak flow for flow less than the 2-year event, we extended the regional equation flood-frequency estimates by fitting a Log Pearson Type III (LP3) curve using LP3 frequency factors (Chow et al. 1988), and the regional skew value for the site. The LP3 fitting technique uses Excel Solver to determine the mean and standard deviation of hypothetical flood values (assuming the regional skew value) that minimizes the difference between the regional equation and LP3 peak flood estimates. Figure 2-8 shows an example of the regional equation peak flood estimates and the fitted LP3 curve, and Table 2-2 summarizes the peak flow estimates conducted for the hydraulic analysis.

Table 2-2. Flood-frequency estimates at six locations along the Elk River computed via the regional regression equation and the LP3 fitted curve.

T (yr)	P (%)	Discharge (cfs)					
		Tom's Gulch	SFR HRC 510	MSR Steel Bridge	MSR Zanes Road	NFR HRC 511	NFR Concrete Bridge
500	0.2	1,250	7,820	15,400	16,200	8,530	8,660
200	0.5	1,070	6,800	13,400	14,100	7,410	7,520
100	1.0	945	6,030	11,900	12,500	6,580	6,670
50	2.0	808	5,220	10,300	10,900	5,690	5,770
25	4.0	677	4,440	8,780	9,240	4,830	4,900
10	10.0	505	3,390	6,730	7,070	3,680	3,730
5	20.0	375	2,580	5,140	5,400	2,790	2,840
2.33*	42.9	225	1,626	3,264	3,423	1,752	1,785
2	50.0	195	1,430	2,880	3,020	1,540	1,570
1.75*	57.1	165	1,228	2,474	2,592	1,319	1,345
1.5*	66.7	131	997	2,013	2,107	1,067	1,090
1.25*	80.0	87	693	1,405	1,468	738	754
1.11*	90.0	55	454	926	965	481	492
1.053*	95.0	36	313	639	665	329	337

* Estimated via fitted LP3 curve

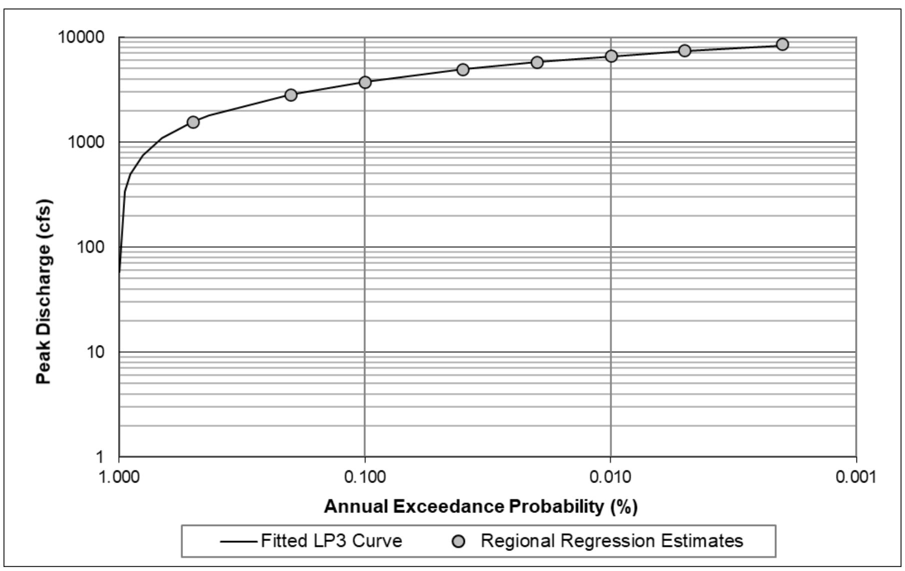


Figure 2-8. Example of flood-frequency results for the North Fork Elk River at concrete bridge for regional regression equation and fitted Log-Pearson III (LP3) curve.

Several tributaries to the North Fork Elk River and the Elk River between the North Fork/South Fork confluence and Humboldt Bay are included in the Elk River hydrodynamic and sediment transport (HST) model (Figure 2-10). Tributary flood flows were determined by calculating peak-flood estimates over the full range of design flows (e.g., 50%, 20%, 10%, 4%, 2%, and 1% annual exceedance probabilities) in the Elk River directly below the tributary confluence using the regional equation, and then subtracting the nearest upstream peak-flood estimate (Table 2-1 and Table 2-2). This approach provided tributary flood flows that were lower than the peak-flood estimates from the regional-equation for each tributary but maintained upstream to downstream continuity in peak-flood estimates along the Elk River (Table 2-2). As discussed in more detail in Section 2.2.2, it was necessary to run the H-Exp model under two coincident flood cases in order to account for substantial backwater effects at the North Fork/South Fork confluence. For Case 1, the North Fork Elk River was assumed to be at the design flow of interest (e.g., 1% annual chance peak-flood flow), whereas Case 2 assumes the South Fork Elk River is at the design flow of interest.

2.2.1.2 Annual flow-duration analysis

Unlike the above flood-frequency analysis of annual peak flows, a flow-duration analysis computes the likelihood that a particular discharge was equaled or exceeded using mean daily flows (MDF) from the full period of record. To do so, MDFs are ranked by magnitude and the annual exceedance probability of each discharge value is computed. The result is a flow-duration or cumulative frequency curve that illustrates how flow is distributed over a period (usually a year). For example, a 95% annual exceedance flow (Q95), which is often taken as the characteristic value of the minimum river flow, indicates that level of flow will be available for 95% of the year. The shape of the flow duration curve (FDC) can be affected by geology, vegetation, catchment shape, and anthropogenic disturbance and can reveal much about the hydrologic characteristics and processes in the watershed of interest. For instance, a FDC with a consistently steep slope indicates a flashy system characterized by quick runoff of excess rainfall to the stream. Conversely, flat slopes often indicate groundwater dominated systems with slower moving springs or diffuse inflow occurring along the length of the stream.

Annual and seasonal FDCs were estimated for the North Fork Elk River (HRC511), South Fork Elk (HRC510), and Elk River (HRC509) using Humboldt Redwood Company streamflow data for Water Year (WY) 2002 to 2015. The 13-year MDF short-records at each site were extended to 64 years (WY 1956–2019) using the maintenance of variance extension Type 1 (MOVE1) technique (Hirsch 1982) and the long-record USGS Little River near Trinidad station (11481200). Correlation coefficients (r) ranged from 0.90 to 0.92 between the Elk River sites and Little River near Trinidad indicating reasonable correlation between concurrent mean daily flows. The extended MDF records were used to estimate the annual and seasonal FDC (November 15 to April 30) for each site.

Figure 2-9 shows the seasonal FDC for the South Fork Elk River. The seasonal 10% exceedance flows at each site were the lowest flows simulated in the hydrodynamic model and are as follow:

- South Fork Elk River = 158 cubic feet per second (cfs) (4.46 cms)
- North Fork Elk River = 202 cfs (5.72 cms)

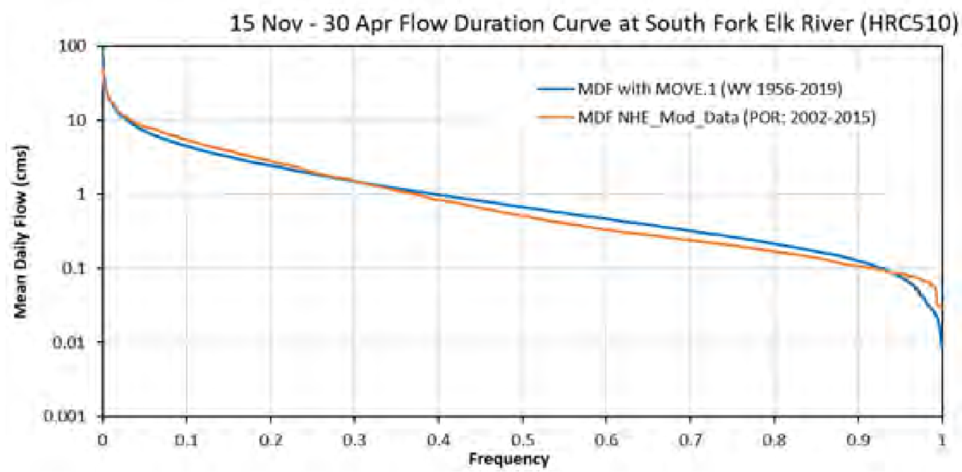


Figure 2-9. Elk River H-EXP Model grid, grid elevations and boundary conditions for the Elk River, tributaries and Humboldt Bay open boundary regions.

2.2.2 Hydraulics

A hydraulic analysis includes estimates of water levels, depth, velocity, and inundation extents at the specified design flows. This information is utilized to delineate elevation zones where distinct vegetation zones occur (See Section 3.4.6), as well as to quantify habitat conditions and flooding patterns.

This analysis uses two related models. The first is an existing unsteady two-dimensional hydrodynamic and sediment transport model (HST Model) developed as part of the Elk River Recovery Assessment (Figure 2-10) (California Trout et al. 2019). This model was used to analyze sediment basins. The existing unsteady HST Model was not configured to model larger, less frequent storms (e.g., ≤ 1% annual chance flood flows). Consequently, NHE (2020) modified the HST Model by expanding the model grid in the lower reaches of the Elk River near Humboldt Bay. The expanded HST Model, hereafter referred to as the H-Exp Model, was applied to simulate all steady-state water surface elevations and flood inundation extents for this study.

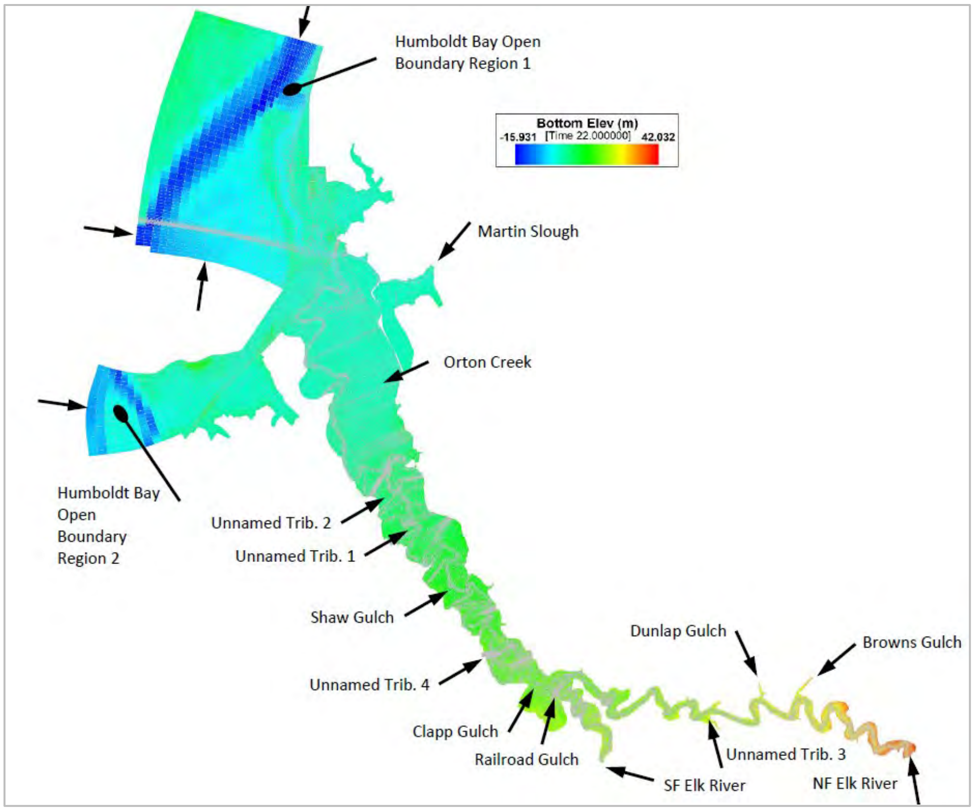


Figure 2-10. Elk River H-EXP Model grid, grid elevations and boundary conditions for the Elk River, tributaries and Humboldt Bay open boundary regions.

2.2.2.1 Boundary conditions

While the Elk River is subject to both riverine flooding and coastal extreme high-water events (storm surge), here we only consider flooding from riverine sources. To simulate riverine flooding, we modeled steady-state water surface elevations (WSE) over a range of flow magnitudes in conjunction with a representative existing condition spring tide level at the downstream boundary. The spring tide level at the downstream boundary, approximated as the mean monthly maximum water (MMMW) tide level, was derived from the Humboldt Bay sea-level rise 2D modeling work conducted by NHE (2015) for year 2012. The MMMW water levels were extracted at the corners of the two open boundary regions (Figure 2-9 and Figure 2-10) and then interpolated along each boundary edge. MMMW water levels in open boundary region 1 ranged between 7.94 and 8.02 ft, and between 7.99 and 8.01 ft in boundary region 2 (NHE 2020).

The general approach for determining peak-flood levels used two coincident flood cases for the North Fork and South Fork Elk River that consider backwater effects at the confluence of these tributaries:

- Case 1 consists of analyzing flood conditions assuming the North Fork Elk River discharge is at the 1% annual chance peak-flood, and the South Fork Elk River discharge is the difference between the 1% annual chance peak-flood for the Elk River below the confluence and the North Fork Elk River 1% annual chance peak-flood.
- Case 2 is the opposing coincident flood condition and assumes the South Fork Elk River discharge is at the 1% annual chance peak-flood, and the North Fork Elk River discharge is

the difference between the 1% annual chance peak-flood estimates below the confluence and South Fork Elk River.

All tributary flood flows downstream of the confluence were equivalent between Case 1 and Case 2. Table 2-3 and Table 2-4 provide summaries of the 1% annual chance peak-flow estimates for Case 1 and 2, respectively, as well as coincident flood flow estimates for the North Fork and South Fork Elk River, Elk River below the North Fork/South Fork confluence, and Study area tributaries. Flow boundary condition estimates were only provided for the 1% annual chance peak flows. A similar approach was conducted to determine model boundary conditions for each peak-flow or flow-duration estimate simulated.

Table 2-3. Summary of Case 1 (event condition 1) 1% annual chance of peak-flood flow and coincident flood flow estimates for the Elk River Study area (refer to Figure 3-9).

Parameter	Flood estimate (cfs)	Note
NF Elk River above confluence with SF Elk River	6,720	1% annual chance peak-flood estimate
NF Elk River below confluence with Lake Creek	5,934	NF Elk River below Lake Creek 1% peak-flood adjusted to NF Elk River 1% peak-flood
Browns Gulch	426	Difference between NF Elk River below Lake Creek and NF Elk River below Browns Gulch 1% peak-flood flows adjusted to NF Elk River 1% peak-flood
Dunlap Gulch	192	Difference between NF Elk River below Browns Gulch and NF Elk River below Dunlap Gulch 1% peak-flood flows adjusted to NF Elk River 1% peak-flood
Unnamed Tributary 3	169	Difference between NF Elk River below Dunlap Gulch and NF Elk River below Unnamed Trib 3 1% peak-flood flows adjusted to NF Elk River 1% peak-flood
SF Elk River above confluence with NF Elk River	6,030	Coincident SF Elk River flow as difference between Elk River below confluence and NF Elk River 1% peak-flood flows
Elk River below confluence of NF and SF Elk River	11,627	1% annual chance peak-flood estimate
Railroad Gulch	268	Difference between Elk River below NF and SF Elk confluence and Elk River below Railroad Gulch 1% peak-flood flows
Clapp Gulch	214	Difference between Elk River below Railroad Gulch and Elk River below Clapp Gulch 1% peak-flood flows
Unnamed Tributary 4	142	Difference between Elk River below Clapp Gulch and Elk River below Unnamed Trib 4 1% peak-flood flows
Shaw Gulch	235	Difference between Elk River below Unnamed Trib 4 and Elk River below Shaw Gulch 1% peak-flood flows
Unnamed Tributary 1	267	Difference between Elk River below Shaw Gulch and Elk River below Unnamed Trib 1 1% peak-flood flows
Unnamed Tributary 2	80	Difference between Elk River below Unnamed Trib 1 and Elk River below Unnamed Trib 2 1% peak-flood flows
Orton Creek	286	Difference between Elk River below Unnamed Trib 2 and Elk River below Orton Creek 1% peak-flood flows
Martin Slough	1,313	Difference between Elk River below Orton Creek and Elk River below Martin Slough 1% peak-flood flows

Table 2-4. Summary of Case 2 (event condition 1) 1% annual chance peak-flood flow and coincident flood flow estimates for the Elk River Study area (refer to Figure 3-9).

Parameter	Flood estimate (cfs)	Note
NF Elk River above confluence with SF Elk River	5,592	Coincident NF Elk River flow as difference between Elk River below confluence and SF Elk River 1% peak-flood flows
NF Elk River below confluence with Lake Creek	4,938	NF Elk River below Lake Creek 1% peak-flood adjusted to NF Elk River coincident flow
Browns Gulch	354	Difference between NF Elk River below Lake Creek and NF Elk River below Browns Gulch 1% peak-flood flows adjusted to NF Elk River coincident flow
Dunlap Gulch	159	Difference between NF Elk River below Browns Gulch and NF Elk River below Dunlap Gulch 1% peak-flood flows adjusted to NF Elk River coincident flow
Unnamed Tributary 3	140	Difference between NF Elk River below Dunlap Gulch and NF Elk River below Unnamed Trib 3 1% peak-flood flows adjusted to NF Elk River coincident flow
SF Elk River above confluence with NF Elk River	6,030	1% annual chance peak-flood estimate
Elk River below confluence of NF and SF Elk River	11,627	1% annual chance peak-flood estimate
Elk River tributaries below confluence of NF and SF Elk River	NA	All tributary flows below confluence of NF and SF Elk River are same as Case 1 (Table 3)

2.2.2.2 Model calibration and validation

The original HST model was calibrated and validated to a large data set of water surface elevations, velocity, discharge, and suspended sediment concentration observations in the Elk River for WY 2003 to 2015. The model calibration and validation results demonstrated high predictive skill for all simulated variables—especially water surface elevations. Please refer to California Trout (2018) and NHE (2020) for a more detailed description of model calibration and validation methods and results.

2.2.2.3 Flood elevation estimates

The H-Exp Model was used as a steady-state model with constant boundary conditions for both coincident flood cases. To account for the effects of coincident flood flows for the North Fork and South Fork Elk River, the maximum water surface elevation at each grid cell from Case 1 and Case 2 runs were combined into a single layer representing the flood elevation at each respective design flow.

2.2.2.4 Inundation mapping

Simulated water surface elevations from the existing conditions H-Exp Model were extracted from the curvilinear orthogonal grid over the range of modeled design flows. The model results were then post-processed in order to map the coarse-scale H-Exp results to the valley edge from the high-resolution LiDAR surface. Figure 2-11 depicts the inundation extents for the modeled design flows along with proposed enhancement areas that are presented in Section 3.4.

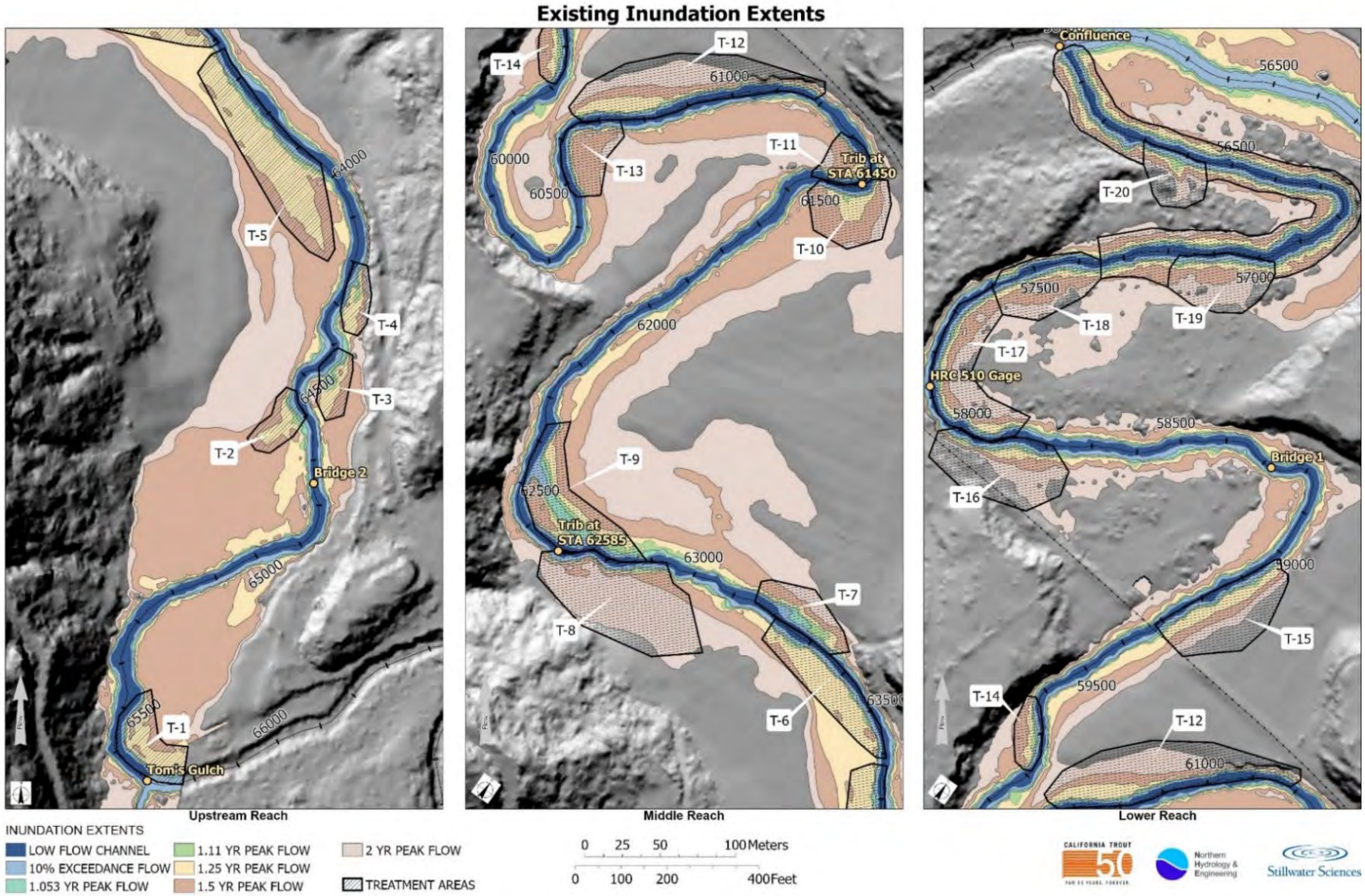


Figure 2-11. Modeled inundation extents for existing ground over a range of design flows. Hatched polygons represent boundaries of enhancement extents for proposed design sites (indicated by letter T followed by unique site number). Sites are discussed in section 3.4.

2.3 Salmonid Habitat

Land uses in the Elk River watershed over the past 150 years have impaired water quality (i.e., causing high turbidity and suspended sediment concentrations and low dissolved oxygen) and degraded stream channels and floodplains that provide critical spawning and rearing habitats for salmonids. Large inputs of fine sediment during the 1980s and 1990s, particularly from Toms Gulch, accelerated habitat degradation in the South Fork Elk River. Juvenile salmonid rearing habitat is impaired in the planning reach due to sediment aggradation and associated loss of pool habitat, reduction of large wood storage, channel simplification, and lack of habitat complexity. Fine sediment aggradation has buried or embedded riffle substrates, likely reducing benthic invertebrate productivity and diminishing food resources during critical spring and summer rearing seasons. Likewise, poor water quality resulting from acute and chronic high suspended sediment concentrations and turbidity levels likely impairs fish health and feeding success during much of the wet season. Pool depths and volumes are also significantly reduced due to sediment aggradation and channel simplification, diminishing the overall salmonid rearing habitat carrying capacity and habitat quality. The volume of large in-channel wood has been reduced throughout the planning reach, with smaller and less-persistent hardwood species (willow and alder) providing most of the current instream wood volume. Consequently, in-channel habitat complexity is significantly diminished.

This section summarizes salmonid habitat in the planning reach. Physical habitat conditions for salmonids were assessed during both the dry (summer habitat) and wet (winter habitat) seasons with the objectives of: (1) describing existing habitat conditions to improve understanding of factors limiting salmonid population productivity and inform restoration priorities, and (2) identifying opportunities and constraints to restore fish habitat. This assessment included all salmonid species with potential to utilize the reach but was focused on Coho Salmon due to the high intrinsic potential of the reach to support the species. Additionally, the assessment focused on characterizing juvenile summer and winter rearing habitats, since spawning habitat is known to be rare or absent in the planning reach due to fine sediment-deposition. Observations from the salmonid habitat and geomorphic assessments (Section 2.1) confirmed the overall rarity of spawning habitat but indicated the presence of some relatively small patches of suitably sized gravels, particularly immediately upstream and downstream of Tom's Gulch These patches are typically associated with wood accumulations and are degraded from fine sediment deposition but have high restoration potential.

2.3.1 Summer rearing habitat

Summer rearing habitat for salmonids was assessed in November 2020 when stream flow was representative of typical late-summer habitat conditions. The summer habitat assessment included comprehensive characterization of mesohabitat types (pool, flatwater, riffle) and a more descriptive assessment of summer rearing habitat quantity and quality.

Working from downstream to upstream, geomorphic habitat units in the Project reach were delineated and classified using CDFW Level II and Level IV habitat types (Flosi et al. 2010). To be included, habitat units were required to be at least as long as the active channel width. Therefore, short riffles or steps between habitat units were lumped with the unit downstream rather than being typed separately. Channel and habitat characteristics were recorded for each habitat unit, including length, mean wetted-width, maximum water depth, and pool tail crest depth where possible. Mean habitat unit length was measured using a laser rangefinder. Mean wetted width was calculated from a minimum of two representative measurements taken with a laser rangefinder or stadia rod. Water depths were recorded with a stadia rod. GPS coordinates were recorded at the downstream end of each habitat unit using a "point averaging" feature for a minimum of approximately two minutes to improve accuracy. Due to the extremely overgrown and inaccessible nature of the certain portions of the planning reach, channel characteristics could not be collected for some habitat units.

The summer habitat assessment focused on describing availability and quality of escape cover, including water depth, overhanging terrestrial vegetation, aquatic vegetation, large wood, small woody debris, and other cover elements. Water quality data were not collected for this assessment, except for limited point measurements of water temperature and observations of apparent stagnation. Findings from the limited water quality monitoring previously conducted in the Project reach are discussed below.

During the summer survey, notes and observations on the following were also recorded:

- level of canopy cover and riparian species composition,
- key locations to revisit during higher winter flows,
- presence of potentially suitable spawning habitat (based on substrate size and location within the channel)
- restoration opportunities and constraints.

As described in Section 2.3.2, large wood counts and measurements were also recorded during the summer assessment to help characterize both summer and winter habitat quality.

Overall, summer rearing habitat for juvenile salmonids was abundant and widespread in the planning reach. Large areas of suitable summer rearing habitat were observed, particularly, in pool habitats and in areas with escape cover from instream large wood or small woody debris and overhanging live trees. Ample riparian shading was also observed throughout most of the reach (see also Section 2.4.2).

Pool habitat was relatively abundant and distributed throughout the planning reach: 61 of the 100 habitat units identified were pools, which collectively comprised 82% of the channel length. Flatwater and riffles comprised 33% and 6% of the habitat units, respectively, and 15% and 3% of the overall channel length, respectively (Table 2-5).

Table 2-5. Habitat type composition by frequency and channel length recorded during November 2020 low-flow habitat surveys.

Habitat type	Number	Length (ft)	Percent of channel length
Pool	61	8,335	82%
Riffle	33	1,494	15%
Flatwater	6	286	3%
Total	**100**	**10,115**	**100%**

Maximum depths of all pools recorded were within the range suitable for supporting Coho Salmon juvenile rearing (>1 ft; Beecher et al. 2002). Numerous pools had depths greater than 3 feet, a value considered "deep" for 3rd and 4th order streams (NMFS, 2012) and capable of supporting older age classes of steelhead and Coastal Cutthroat Trout (Figure 2-12). However, there were several long sections of channel in the planning reach lacking deep pools (Figure 2-

12). Additionally, there were numerous long (100–300 ft) habitat units in the planning reach that were classified as pools, but which had only relatively short sections of functional pool habitat at the upstream end (i.e., pool head) and long, homogeneous, and relatively shallow glide-like habitats (i.e., pool tail) for the remainder of the unit.

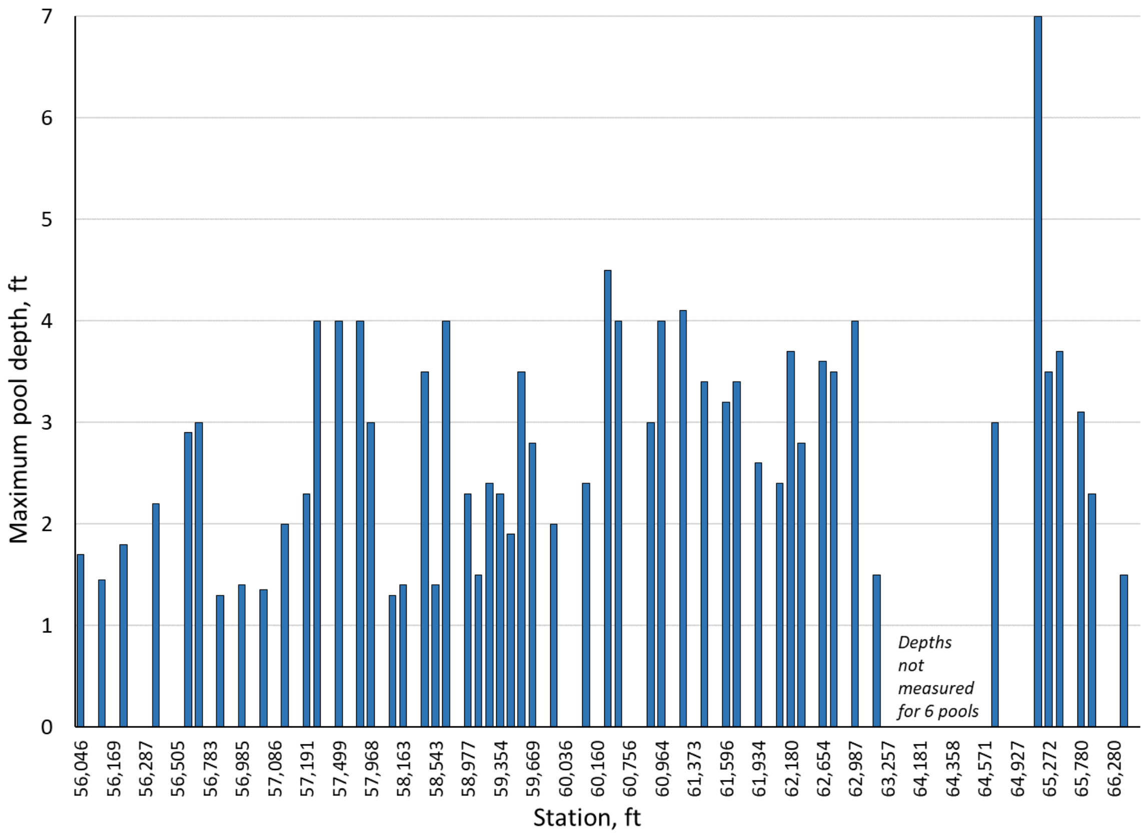


Figure 2-12. Maximum pools depths measured during the 2020 low-flow survey in the South Fork Elk River Project reach, from downstream to upstream. Depths were not measured in 6 pools due to inaccessibility of habitat units.

Results of the summer rearing assessment indicate that the planning reach has the capacity to support relatively large numbers of juvenile Coho Salmon, steelhead, and Coastal Cutthroat Trout through the summer, assuming water quality is suitable and food resources are adequate. Limited monitoring, conducted previously, suggests water temperature generally remains suitable for Coho Salmon and other salmonids (<17°C) throughout the summer, but low dissolved oxygen (DO) driven by fine sediment accumulation and low flows could limit summer fish utilization and survival during some periods (CalTrout et al. 2018). Point DO data collected by CalTrout in recent years near the downstream extent of the planning reach suggests that DO generally remains above levels that are detrimental to juvenile salmonids (approximately 5 mg/L) during the summer low-flow period in most years. However, in some years, summer and early fall DO drops to levels that limit fish utilization and survival. For example, in 2021, a historically dry water year, DO dropped to below 2 mg/L during multiple sampling events in September (CalTrout, unpub. data). Juvenile Coho Salmon have been found to tolerate lower DO levels than other salmonids, as low as 4 mg/L (Ruggerone 2000). However, in the Humboldt Bay stream-estuary ecotone, juvenile Coho have been documented in locations with DO levels as low as 3.5 mg/L

(Wallace and Allen 2015). Additional data is needed to describe seasonal and annual water quality patterns in the planning reach and better understand salmonid tolerance to DO in the Elk River watershed.

Despite the generally abundant and high-quality summer rearing habitat observed, restoration actions that increase the depth and complexity of pools would be valuable in portions of the planning reach. Additionally, increasing the frequency and length of riffle habitat may improve overall fish production by increasing prey abundance. Fine sediment aggradation has buried or embedded substrates in the few riffle habitats that are present, likely reducing benthic invertebrate productivity and diminishing food resources. Implementing restoration actions that will improve winter rearing habitat—such as through the addition of large wood—will also improve summer habitat.

2.3.2 Large wood

Quantity of instream large wood is a primary factor that determines the overall quantity and quality of salmon and steelhead habitats in coastal Northern California streams. McMahon and Reeves (1989) postulated that large wood could be considered a keystone habitat feature for salmonids because of its overwhelming influence on channel morphology (e.g., pool formation, bank condition), sediment and organic matter sorting and retention, water velocity, and availability of escape cover. Large wood quantity has been linked to overall salmonid production in streams and correlated with salmonid abundance, distribution, and survival (Sharma and Hilborn 2001). In particular, the high rates of wood loading associated with old growth forests with intact riparian areas generally leads to increased salmonid abundance and improved habitat quality (Lestelle and Cederholm 1984, Dolloff 1986, McMahon and Reeves 1989, Fausch and Northcote 1992).

Abundant large wood increases the frequency, depth, and complexity of pool habitats used by rearing juveniles and results in overall increases in reach-scale habitat diversity (e.g., pool-riffle sequences; Everest and Meehan 1981, Bisson and Sedell 1984, Flannery et al. 2017). High densities of large wood especially increase the carrying capacity for older age classes of juvenile salmonids, which typically prefer deeper habitats (Bisson et al. 1988). Winter carrying capacity and smolt production of coho salmon have been increased by adding large woody debris or creating off-channel habitat to provide refuge from high flows (Cederholm et al. 1997, Solazzi et al. 2000). Stream channels tend to be more complex and more stable with increasing volumes of large wood, and the structural complexity that provides substrate diversity, low velocity refugia during high flows, and cover from predation is also improved as compared with those conditions lacking abundant large wood (McMahon and Reeves 1989). Complex log jams with large logs and intact rootwads are particularly important for creating and maintaining stream ecosystem processes and function (Flannery et al. 2017). For these reasons, describing existing instream large wood quantity and determining the locations where instream and off-channel habitats enhancements can be created by adding large wood pieces or engineered jams is fundamental for improving fish habitat in the Project reach.

A comprehensive large wood survey was conducted during the November 2020 low flow survey to inform overall habitat complexity and relative quality of both summer and winter rearing habitat. All qualifying large wood pieces and wood jams that occurred within the bankfull channel width were counted for each habitat unit during the November 2020 low flow survey (Appendix A). The definition of what constitutes "large wood" varies across state and federal agencies, application, and context. For the purposes of this assessment, pieces longer than 1.8 m (6 ft) and greater than 0.15 m (0.5 ft) diameter at breast height (DBH) were recorded. Pieces that met the minimum size criteria were recorded if any portion of their length occurred within the bankfull channel width. Only dead wood pieces and root wads were counted, with the exception of newly fallen trees that were uprooted from the bank but still had green foliage. Live trees that appeared to have a significant influence on geomorphic, hydraulic, or fish habitat conditions were noted or photo-documented for each habitat unit. In-channel vegetation is further described in Section 2.4. Additional notes on the overall features and function of observed wood were recorded during the survey (e.g., species, stability, input mechanisms, pool formation, and sediment storage).

Using a combination of field measurements and visual estimates, wood pieces were tallied into 20 size classes based on five length classes (6–10 ft, 10–25 ft, 25–50 ft, 50–75 ft, and >75 ft) and four diameter classes (0.5–1 ft, 1–2 ft, 2–3 ft, and >3 ft). Large wood piece frequency (pieces per 100 ft), key piece frequency, wood volume, and wood jam presence and distribution were the primary metrics used to characterize large wood in each habitat unit and in the larger planning reach. A key piece can be defined as a log or root wad that: (1) is independently stable in the stream bankfull width even during larger flood events and not functionally held by another factor (e.g., not pinned by another log, buried, or trapped against a rock, etc.); and (2) is retaining, or has the potential to retain, other pieces of organic debris that are likely to become mobilized in a high flow without the key piece (Roni et al. 2015, Washington Forest Practices Board 1997). .

In the planning reach, large wood pieces were considered key pieces if they were >75 ft long and >1 ft DBH, >50 ft long and >2 ft DBH, or >25 ft long and >3 ft DBH. These key piece criteria were loosely based on length, diameter, and volume criteria presented in Fitzgerald (2004), measured bankfull width, and professional judgement about which piece sizes would be stable and trap other debris.

The midpoint of each length and width size class was used to calculate wood volumes from the tally data. For volume calculations, a length of 80 ft was applied to tallied pieces >75 ft and a diameter of 3.5 ft was applied to tallied pieces with a DBH >3.5 ft. The total volume (*V*) of each length and diameter class was calculated based on the equation for the volume of a cylinder:

$$V = \pi r^2 L$$

where *r* and *L* represent wood radius and length (ft), respectively.

All qualifying wood jams encountered were photo-documented and their locations were recorded with GPS. Wood jams were loosely defined as a group of at least three key pieces where individual pieces are touching at least one other key piece, but some wood conglomerations that did not contain three key pieces were counted as jams if they were channel spanning and relatively stable due to the presence of multiple short, large diameter pieces or live trees growing from the bank. Several representative wood jams were revisited during the winter habitat assessment and evaluated in terms of low-velocity habitat provided.

To contextualize existing conditions, the deficit of large wood in the planning reach and each habitat unit was calculated relative to regional large wood restoration targets.

2.3.2.1 Large wood quantity

Density and volume of large wood were generally low in the planning reach, with an average of 8.6 qualifying pieces counted per 100 ft and a volume of 240 ft^3 per 100 ft (Table 2-6). A considerable portion of the pieces counted were relatively small and provided minimal winter habitat function, with 45% of pieces less than 10-ft long (Figure 2-13). Only eight key pieces were counted in the entire planning reach (Table 2-6). Distribution of large wood varied longitudinally within the planning reach: nearly 50% of the wood volume and 8 of the 13 wood jams were recorded in a 2,000 ft reach from STA 63,300 to STA 65,300 (Figure 2-14). This uneven distribution appeared to be driven partially by channel geomorphology, with more wood stored in the upper portion of the reach where the channel is less entrenched and floodplains are typically better connected (Section 2.1).

Table 2-6. Number counts, linear density, and volume of large wood observed in the planning reach during November 2020 surveys.

Segment	Sum of habitat unit lengths (ft)	All large wood		Key pieces		Wood volume (ft^3)	Volume / 100 ft
		Counts	Pieces / 100 ft	Counts	Pieces / 100ft		
Confluence to Bridge 1	2,596	149	5.7	4	0.15	4,602	177
Bridge 1 to Apex Bend at STA 61,300	2,698	144	5.3	0	0.00	3,331	123
Apex Bend at STA 61,300 to Bridge 2	3,548	470	13.2	0	0.00	11,227	316
Bridge 2 to STA 66,600	1,760	150	8.5	4	0.23	6,259	356
Planning reach total	**10,602**	**913**	**8.6**	**8**	**0.08**	**25,419**	**240**

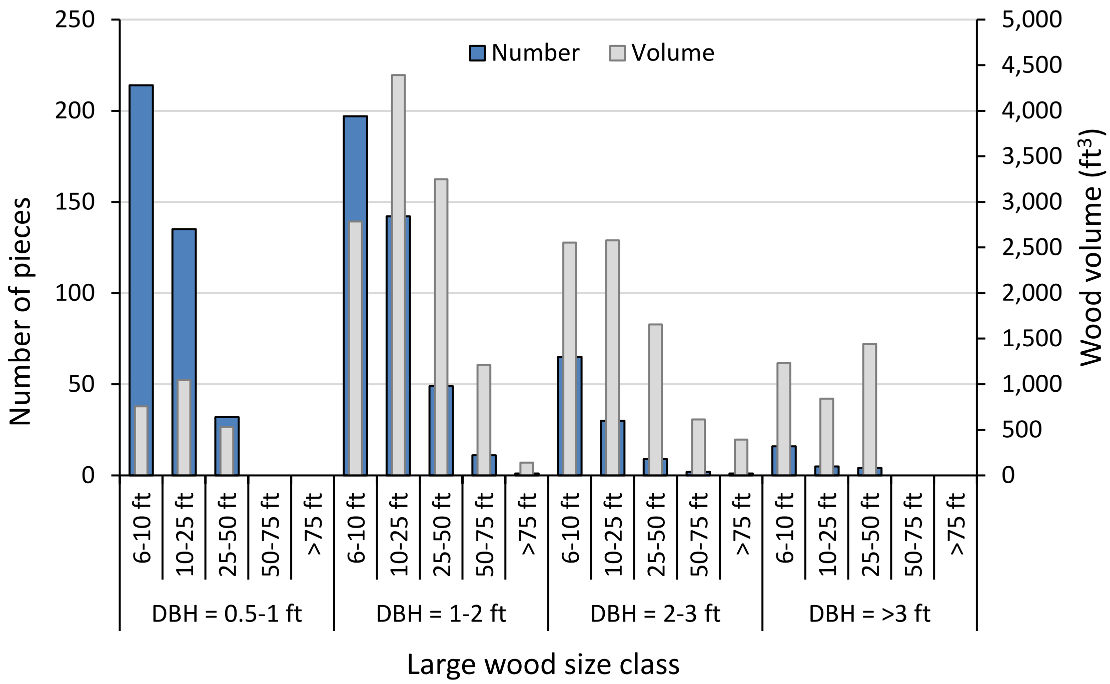


Figure 2-13. Distribution of number and volume of large wood pieces by length and diameter class in the planning reach.

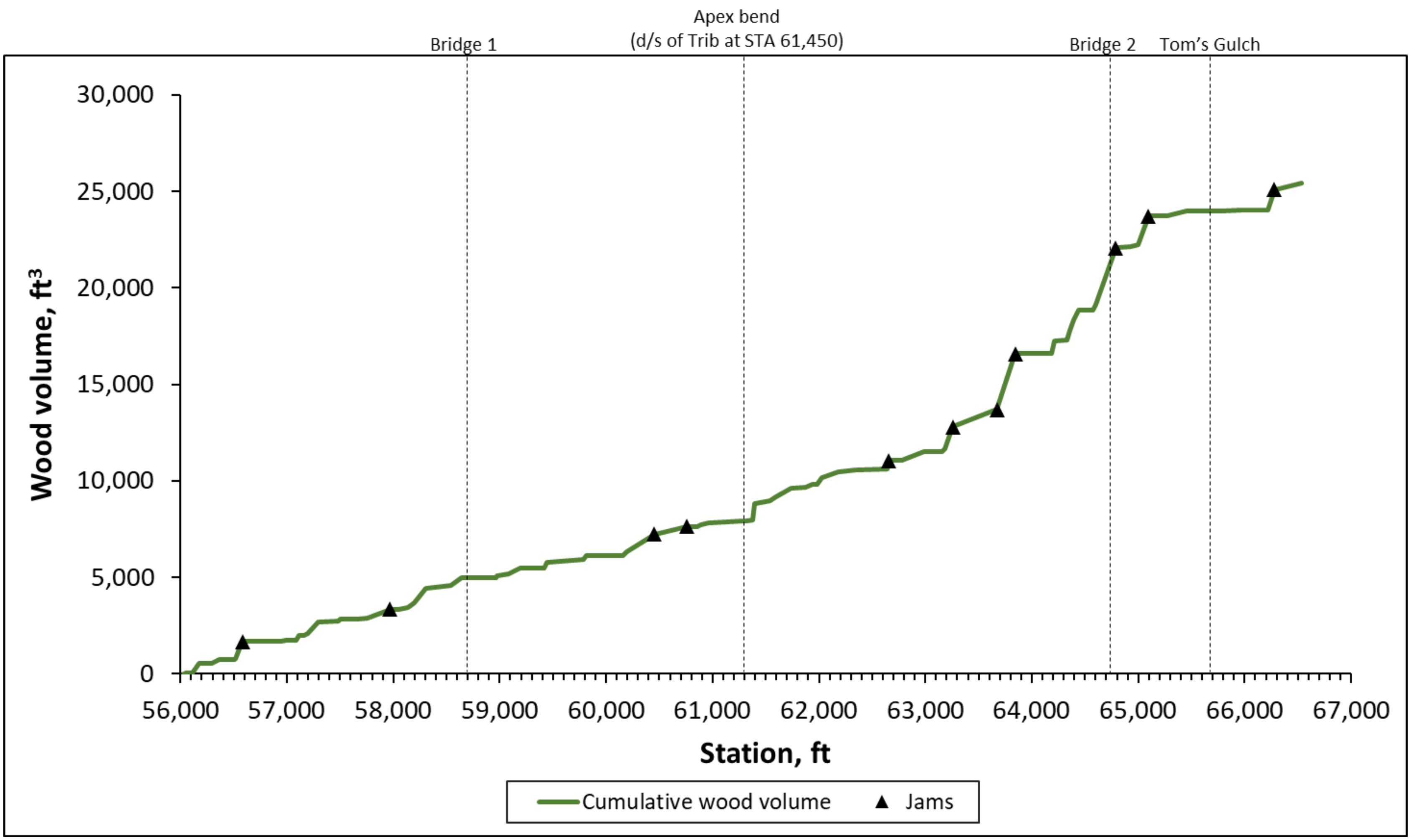


Figure 2-14. Cumulative longitudinal distribution of large wood volume and locations of wood jams in the planning reach.

2.3.2.2 Wood jams

A total of 13 wood jams were counted in the planning reach based on loose application of the criteria for qualifying as jams. Several jams were borderline and were included due to presence of associated in-channel live trees functioning as key pieces or large diameter pieces that were shorter than the key piece criteria.

Several representative wood jams were revisited in February 2021 to evaluate winter habitat function. At the flow observed (155 cfs), these jams provided relatively little to no downstream or upstream low-velocity winter rearing habitat. Even the jams that included relatively large diameter pieces (>2.5 ft) provided minimal winter rearing habitat for Coho Salmon. In some cases, the wood was floating and water appeared to be forced under it, creating significant turbulence. In other cases, wood pieces were not contiguous with the banks and too short, creating turbulence as flow skirted around the edges. Additionally, because of the steepness of the banks and channel entrenchment throughout much of the planning reach, most in-channel wood pieces did not continuously contact the bank surface and extend into the channel to create a seamless area of low velocity habitat. None of the existing wood jams observed in at winter flows created sufficient high-quality habitat to warrant avoiding modifying them during implementation (i.e., not a constraint to larger scale restoration). In several cases, it may be worth considering placing larger/longer jams or pieces at or just downstream of existing jams to help capture and stabilize existing shorter pieces or backwater the existing jams to increase the area of low velocity habitat.

2.3.2.3 Large wood deficits

Based on large wood restoration targets from regional guidance (Fitzgerald 2004) and data from Prairie Creek (Carroll and Robison 2007) and the North Fork Elk River (HRC 2015), the planning reach has a significant large wood deficit (Table 2-7). The relative wood deficit varies considerably within the Project reach. Depending on the restoration target applied, the planning reach needs between 107 and 1,181 large wood pieces, 57 to 69 key pieces, and between about 17,000 and 110,000 cubic feet of wood volume to meet targets. Observed wood volumes in Prairie Creek are considerably higher than Fitzgerald (2004) and HRC (2015) because Prairie Creek flows through a pristine old growth forest, which results in the recruitment of very large wood pieces. Figure 2-15 depicts large wood deficits for frequency, volume, and number of key pieces for each habitat unit.

Table 2-7. Large wood deficits over the Project reach relative to three different restoration targets.

Restoration target source	Restoration targets			Quantity of large wood needed to meet target in Project reach		
	Pieces / 100 ft	Key pieces / 100 ft	Volume (ft^3) / 100 ft	Pieces	Key pieces	Volume (ft^3)
Carroll and Robinson (2007)[1]	7.3	n/a	1,343	256	n/a	109,422
Fitzgerald (2004)	19	1.2	775	1,181	57	48,888
HRC (2015; NF Elk Site #214)	4.7	0.8	415	107	69	17,330

[1] Based on large wood characteristics in Prairie Creek, a pristine coastal stream.

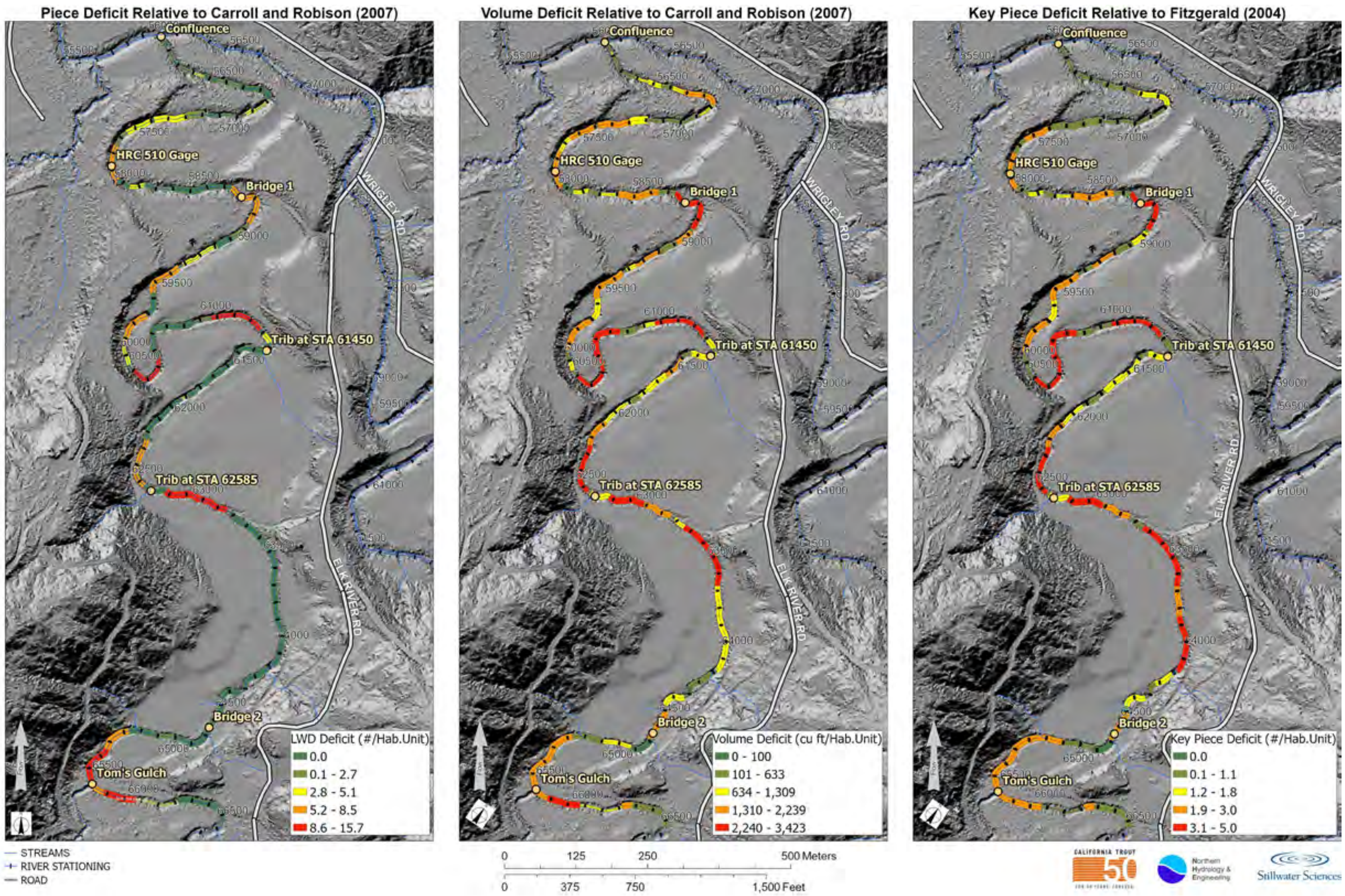


Figure 2-15. Large wood deficits for piece frequency, volume and key pieces at the habitat unit scale in the Project reach. Piece number and volume deficits are relative to Carroll and Robison's (2007) observations in Prairie Creek and key piece deficits are relative to Fitzgerald (2004) targets.

2.3.3 Winter rearing habitat

Salmonid winter rearing habitat was assessed for representative sections of the planning reach on February 3, 2021, at a streamflow of 155 cfs (10% exceedance flow). The assessment focused on characterizing quantity and quality of low-velocity winter rearing habitat for juvenile Coho Salmon, including: (1) availability of in-channel low-velocity habitat; and (2) level of connectivity with off-channel features such as alcoves, side channels, and adjacent floodplains. To help characterize the availability of in-channel low-velocity rearing habitat at the observed streamflow and calibrate the observer's eyes for estimating water velocities, a series of water velocities were measured at representative locations, from points along the bank to the thalweg. Juvenile Coho Salmon generally prefer water velocities of less than 0.6 ft/s (Beecher et al. 2002) and will often select zero velocity habitat when available (Katzman et al. 2010). Results from large wood surveys were also used to characterize in-channel winter rearing habitat potential in the Project reach.

The degree of off-channel habitat connectivity was qualitatively characterized at representative locations by observing inundation of off-channel features at the surveyed flow and assessing potential for inundation at higher streamflows. Information from the geomorphic assessment (Section 2.1) and hydraulic modeling (Section 2.2) were also used to help characterize off-channel winter habitat conditions in the planning reach and ascertain restoration potential.

Very little low-velocity habitat suitable for Coho Salmon winter rearing was observed in the representative locations assessed at the moderate stream-flows observed in February 2021. As described above, even locations with wood jams that were initially expected to provide significant habitat, contained little to no habitat with velocities preferred by Coho Salmon for winter rearing. In many locations, there were narrow (1–2 ft wide) bands of lower velocity water (<1 ft/s) along channel margins or in small areas (5–20 ft^2) associated with instream live trees or large wood. However, in general there was insufficient low-velocity habitat to support many juvenile fish through the winter. Based on observations during the moderate streamflow surveyed, we can generally assume that the area of low-velocity in-channel habitat would be equal to or less at higher streamflows (until flow inundate the few inset benches and/or adjacent floodplains).

Connected off-channel habitats are rare in the planning reach. Low elevation inset floodplains or side channels that are inundated at moderate winter base flows were infrequent. One inset floodplain with an apparent high flow side channel was observed on the right bank just downstream of Bridge 2 (Figure 1-2; STA 64,300). This site appears to inundate at moderately high flows (including the modeled 1.25 yr storm; 693 cfs; Figure 2-11) due to its relatively low elevation, likely providing a considerable area of high flow refuge habitat. However, the site was not inundated at the observed flow (155 cfs; 10% exceedance) and no suitable winter rearing habitat was apparent in the adjacent main channel. Excavating an alcove and/or deeper channel from the downstream end or creating a backwater by placing a channel spawning log jam downstream of the side channel outlet would create habitat at winter base flows and provide more seamless connectivity between the side channel and main channel habitat as flows increase.

The existing larger floodplains are mostly disconnected from the main channel at winter baseflow and moderately high flows (e.g., 693 cfs). As evidenced by inundation mapping and field observations of existing relatively lower elevation and wetter areas, there are several good opportunities to improve connectivity at lower flows and create large areas of high-quality winter rearing habitat.

In summary, the limited low-velocity habitat area, low wood densities, steep banks, high levels of entrenchment, and lack of floodplain connectivity in much of the planning reach–along with observations of large areas of high-quality summer rearing habitat–largely confirm the hypothesis that winter habitat is a key factor limiting salmonid population productivity in the South Fork Elk River. Therefore, augmenting existing habitat and creating new low-velocity winter habitat should be the focus of fish habitat restoration activities.

2.4 Vegetation

Historical land use impacts (e.g., land conversion within the valley floor, timber harvest and road use in the upstream watershed, incision, aggradation due to elevated sediment supply, and changing composition of woody debris within the channel) have decreased native vegetation community diversity, reduced and constrained the forested riparian corridor, and promoted the encroachment of live woody riparian vegetation within the channel bed and banks. The existing riparian vegetation assemblages and conditions were assessed to establish vegetation management recommendations, design constraints, and enhancement/restoration opportunities in the planning reach. This section describes the vegetation assessment that included mapping the existing vegetation communities and assessing riparian conditions as related to in-channel live wood, nonnative weed prevalence, and identifying features to retain in the design. An assessment of the adjacent floodplain as related to potential riparian enhancement and revegetation is discussed in Section 3.4.6.

2.4.1 Vegetation cover types

The publicly available vegetation mapping data set (CalVeg 2017) along with work products developed for the North Fork Elk River Pilot Project was assessed in ESRI ArcGIS. When reviewed with recent NAIP imagery, the CalVeg vegetation boundaries were not fully representative of the existing conditions within and surrounding the planning reach. As such, a vegetation community map for the South Fork Elk River was refined in ArcGIS using photo-interpretive techniques that utilized the most recent NAIP aerial imagery and the Project's photo tour that provided sufficient resolution for identifying overstory and understory riparian species assemblages. The vegetation classification followed the State of California standard vegetation classification system described in *A Manual of California Vegetation* (MCV; CNPS 2021). Identified vegetation communities using MCV classification procedures were delineated at on-screen scales between 1:1,200 and 1:5,000.

Information collected from a one-day site visit was used to refine vegetation type boundaries and collect additional verification points to assist with the photo interpretation process and accuracy. The ArcGIS Collector application was utilized on a handheld tablet (Samsung Galaxy Tablet) to review and assess the accuracy of the preliminary vegetation map boundaries. Changes to preliminary mapped polygons were recorded using GPS data on the tablet and later revised in ArcGIS. Alliance boundaries were mapped to canopy extent therefore mapped vegetation alliance boundaries may have included overstory canopy that extended over water features.

Plant species nomenclature followed The Jepson eFlora (Jepson Flora Project 2021). Vegetation alliances that were defined as sensitive natural communities–natural community types with a state ranking of S1 (critically imperiled), S2 (imperiled), or S3 (vulnerable) on CDFW's California Sensitive Natural Communities (CDFW 2021)–were also noted. No rating was provided where the eponymous species of an alliance was classified by a nonnative species (semi-natural alliances).

The vegetation map includes eight native forest vegetation alliances and associations, three native shrubland alliances, two nonnative shrubland semi-natural alliances, two herbaceous alliances, and one broad land cover type, urban/developed (Figure 2-16, Table 2-8). Nine of the vegetation alliances are considered sensitive natural communities with state ranks of 2 and 3 (CDFW 2021), covering a total of 55.3 acres (~39%) of the vegetation survey area (143.6 ac) (Table 2-8, Figure 2-16). Two vegetation alliances along with the existing nonnative pasture (annual/perennial grassland) are dominated by naturalized nonnative species (semi-natural alliances) covering a total of 55.2 acres (~38%) of the survey area. The vegetation alliances, associations, and cover types are summarized in Table 2-8.

Table 2-8. Vegetation communities within the South Fork Elk River assessment area.

Vegetation communities and cover types	Area (ac)	State rank
Abies grandis Forest Alliance	1.1	S2
Acer macrophyllum – Alnus rubra Forest Alliance	4.3	S3
Acer macrophyllum Forest Alliance	3.0	S3
Alnus rubra / Salix lasiolepis / Rubus spp. Forest Association	3.6	S3
Alnus rubra Forest Alliance	17.2	S4
Annual/Perennial Grassland	46.3	-
Cotoneaster spp. Shrubland Semi-Natural Alliance	3.0	-
Rosa californica Shrubland Alliance	0.4	S3
Rubus armeniacus Semi-Natural Shrubland Alliance	5.9	-
Rubus ursinus Shrubland Alliance	0.1	S3
Salix lasiolepis Shrubland Alliance	7.2	S4
Salix lucida Woodland Alliance	3.0	S3
Sequoia sempervirens – Alnus rubra / Rubus spectabilis Association	4.8	S3
Sequoia sempervirens Forest Alliance	35.0	S3
Urban/Developed	8.1	-
Urtica dioica Provisional Alliance	0.5	-

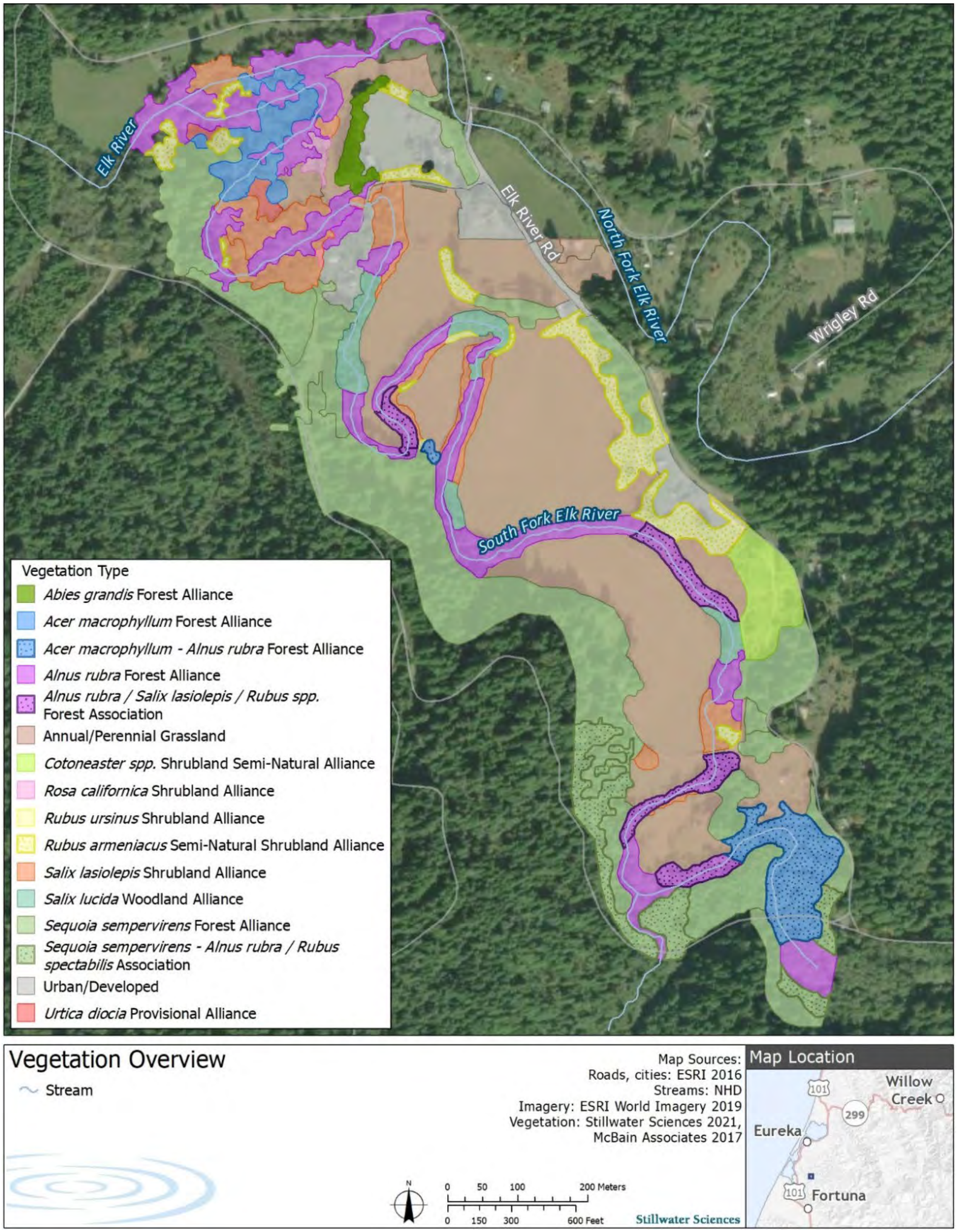


Figure 2-16. Vegetation cover types within the South Fork Elk River.

Alnus rubra Forest Alliance (red alder forest) was the most prevalent riparian community along the South Fork Project reach (Table 2-8, Figure 2-16). A relatively short-lived native hardwood (matures at 60 to 70 years old), red alder is tolerant of wet soil conditions along stream bottoms and lower slopes (Harrington 2006). Typical of alder stands located along open disturbed riparian areas (Harrington 2006), high understory cover by nonnative species was documented in the red alder forest along the narrowed riparian corridor of the Project reach. The presence and absence of prominent nonnative weeds in the riparian corridor's understory was evaluated during the riparian vegetation assessment (Section 2.4.2).

The upright growth of native *Salix lasiandra* var. *lasiandra* (Pacific willow) formed hardwood overstory in pure stands (*Salix lucida* Forest Alliance) as well as an overstory component in red alder forest along the Project reach (Figure 2-16). *Salix lasiolepis* (arroyo willow) was an abundant low to mid-story component within the documented hardwood-dominant riparian forest communities. When overstory canopy by red alder and/or Pacific willow was absent or limited, arroyo willow often formed a dense canopy over the channel. *Salix lasiolepis* Shrubland Alliance (arroyo willow thickets) was commonly noted along the outer riparian edge adjacent to the open grassland and developed/urban cover types (Figure 2-16). The presence of low to mid-story willow establishment within the channel bed and banks was evaluated for the entire Project reach and is discussed in Section 2.4.2.

Aside from where the narrow riparian corridor neared the western hillslopes covered by *Sequoia sempervirens* Forest Alliance (redwood forest), hardwood forest communities along the Project reach had low mature conifer establishment and sparse conifer recruitment. Mature redwood forest along with *Acer macrophyllum* Forest Alliance (big-leaf maple forest) formed the wider upstream riparian area. Along the downstream end of the Project reach near the confluence with the mainstem Elk River, the riparian corridor was formed by a mixture of shrubland and forested communities. Shrubland alliances included arroyo willow thickets along with upland communities *Rosa californica* (California rose briar patches) and *Rubus ursinus* (California blackberry bramble) (Figure 2-16). High-quality habitat features and integral components to the existing riparian forest communities (e.g., native multi-tiered structure, mature overstory species, species of limited distribution in the reach) were evaluated during the riparian vegetation assessment (Section 2.4.2).

Dominant stands of nonnatives *Cotoneaster* spp. (cotoneaster) and *Rubus armeniacus* (Himalayan blackberry) formed semi-natural shrubland alliances along the open upland hillslopes above the floodplain along Elk River Road and along the outer riparian corridor adjacent to open grasslands (Figure 2-16). An escaped ornamental plant originally from China, cotoneaster invades coastal areas of California often in disturbed areas, mixed evergreen forest, coastal scrub, and grasslands (DiTomaso et al. 2013). Cotoneaster formed moderate cover within an upland hillslope and some recruitment was noted within the lower adjacent riparian corridor. Another nonnative observed in the cotoneaster stand included *Cortaderia jubata* (purple pampas grass). Himalayan blackberry formed dense thickets in riparian openings, the outer riparian corridor, and open disturbed hillslopes adjacent to Elk River Road. Himalayan blackberry often hybridizes with native blackberry species and patches of the Himalayan-California blackberry hybrid were observed along the riparian corridor. Both nonnative semi-natural shrubland alliances can form dense stands that if not controlled often outcompete and displace native species.

The grassland community was best characterized as ruderal mesic meadow typical of abandoned pasture and agricultural fields and was largely composed of nonnative cool season grasses and herbs (*Dactylis glomerata* [orchard grass], *Festuca* spp. [various fescues], *Agrostis* spp. [various bentgrass]).

2.4.2 Riparian vegetation assessment

The existing condition of riparian vegetation communities along the planning reach was evaluated (i.e., presence of nonnative weeds, location of high value species) along with an in-channel live woody assessment to identify vegetation management recommendations and potential vegetation constraints and enhancement opportunities to inform the 10% design. Due to the timing of the assessment (winter 2020–2021), the photo tour of the Project reach was utilized for this purpose.

The desktop approach to assess riparian conditions from the 360-degree imagery of the photo tour required stratification of the planning reach into monitoring segments. The existing 100-foot stationing in the planning reach was used for this purpose and a total of 112 segments were generated. The stationing was loaded to the photo tour and marked the segments start and end. Utilizing the 360-degree high-resolution photographs within each channel segment the following items were assessed: (1) The occurrence and characteristics of woody riparian vegetation within the bed and banks; (2) Source and contribution to the riparian aquatic (SRA) cover attribute shaded stream surface existing woody riparian vegetation to shaded riverine aquatic cover and the potential impacts of selective vegetation removal on these aquatic and riparian ecological values; (3) The presence by nonnative weeds with significant cover, and (4) Areas with high ecological value (e.g., mature native trees, multi-layered canopy).

Live riparian woody vegetation established within the channel bed and banks increases hydraulic roughness and impacts sediment transport continuity. A coarse characterization of existing in-channel live wood was conducted to assess potential for instream vegetation management within the Project reach. In each 100-foot channel segment, live woody vegetation rooted below the top of bank was visually assessed and scored for the following vegetation attributes: (1) quantity and origin of established rooted or resprouting live woody vegetation below top of bank; and (2) structure of live woody riparian vegetation within the channel (Table 2-9). To assess shaded stream surface contribution of the live woody vegetation established within the channel in relation to adjacent riparian canopy contribution the total shaded stream surface cover of vegetation within the top of bank was scored (Table 2-9). Results from these two riparian assessments identified potential instream vegetation management constraints (e.g., areas where limited instream removal was recommended to maintain riparian coverage) and opportunities (e.g., channel segments where removal of woody riparian vegetation would deliver the greatest benefit to increased flood conveyance with less overall impact on aquatic and riparian resources).

Table 2-9. Scoring system for live woody vegetation within the Project reach.

Score	Live woody vegetation		SRA cover contribution by instream vegetation
	Within channel bank or toe of bank[1]	Structure within channel	
0	No live woody vegetation rooted in channel bed/toe bank		N/A
1	1–33% in channel bed/toe bank	1–33% low-midstory canopy cover	68–100% providing shaded stream surface cover
2	34–67% in channel bed/toe bank	34–67% low-midstory canopy cover	34–67% providing shaded stream surface cover
3	68–100% in channel bed/toe bank	68–100% low-midstory canopy cover	0–33% providing shaded stream surface cover

[1] Higher scores indicate more live woody vegetation is rooted in the channel bed and toe bank versus along the top of bank and channel bank slopes.
[2] Higher scores indicate most of the live woody vegetation in the channel is composed of low to midstory species.

The cumulative score of the live woody vegetation attributes associated with rooted origin and structure provides a general index for hydraulic roughness within the planning reach. A high cumulative score captures channel segments with high density of low to midstory woody species (e.g., arroyo willow) that suggests greater hydraulic resistance and likelihood for conditions that would exacerbate flooding and fine-grained sedimentation of the channel bed and banks. Low scores for the SRA cover attribute indicate the main origin for shaded stream cover was from low to midstory instream vegetation. These segments may benefit from retaining existing low to midstory canopy and/or supplemental riparian planting to maintain or enhance the aquatic and terrestrial ecological function (e.g., shaded stream surface cover, wildlife habitat, increased species richness) of that locale. Higher SRA cover scores indicate shaded stream cover was primarily from the adjacent riparian overstory canopy and/or from taller instream overstory vegetation and in-channel live wood management of low to midstory species would have less impact on terrestrial and aquatic resources.

The presence of prevalent nonnative species including *Rubus armeniacus* (Himalayan blackberry) and *Hedera helix* (English ivy) was noted during the photo tour. These California Invasive Plant Council (Cal-IPC) high-rated nonnatives (invasive weeds) have detrimental impacts on understory riparian native species assemblages. Both species are rated as having severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. When present, these invasive weeds often displace native species, reducing native species recruitment and overall species richness. Other notable nonnatives along the riparian corridor that were visible in the photo tour imagery were documented in the corresponding segment.

Additionally, where observed, mature stands or individuals that provided substantial riparian shade and/or structural and species diversity were noted. These features were noted as vegetation design constraints.

Figure 2-12 and Figure 2-13 provide results of the in-channel live woody vegetation assessment. Channel segments scoring four and five in Figure 2-12 indicate areas where low to midstory woody species have established within the channel bed or toe bank, often formed by fallen, sometimes channel spanning, resprouted trunks or limbs, and most of the live woody vegetation established below the top of bank was composed of low to midstory species. These areas had the highest hydraulic roughness by live woody vegetation in the Project reach. Much of the Project reach adjacent to infrastructure below STA 60,000 scored very high (4 or 5) for in-channel live wood (Figure 2-12). Other high-scoring segments were noted higher in the system and were less likely to exacerbate flooded conditions that may negatively impact Project infrastructure. Constraints to in-channel live woody vegetation management were identified in channel segments with low SRA cover scores (Figure 2-13). Instream live wood management within these segments alone, would have potential to decrease shaded stream cover and reduce the already limited riparian cover condition.

Invasive weeds Himalayan blackberry and English ivy were prevalent within the entire planning reach (Figure 2-14). Much of the reach below STA 63,000 had both invasives present within the understory greatly reducing native understory cover and limiting native recruitment. As discussed in Section 2.4.1, cotoneaster establishment was attaining high cover along an upland hillside to Elk River Road and was successfully recruiting in the lower riparian corridor (Figure 2-19). Himalayan blackberry was common along upland sloped hillsides and along the narrowed riparian corridor. One occurrence of an escaped ornamental, a bamboo species, was noted in the planning reach. Depending on growth, clumping versus spreading rhizomes, this species has the potential to spread rapidly and displace native established vegetation.

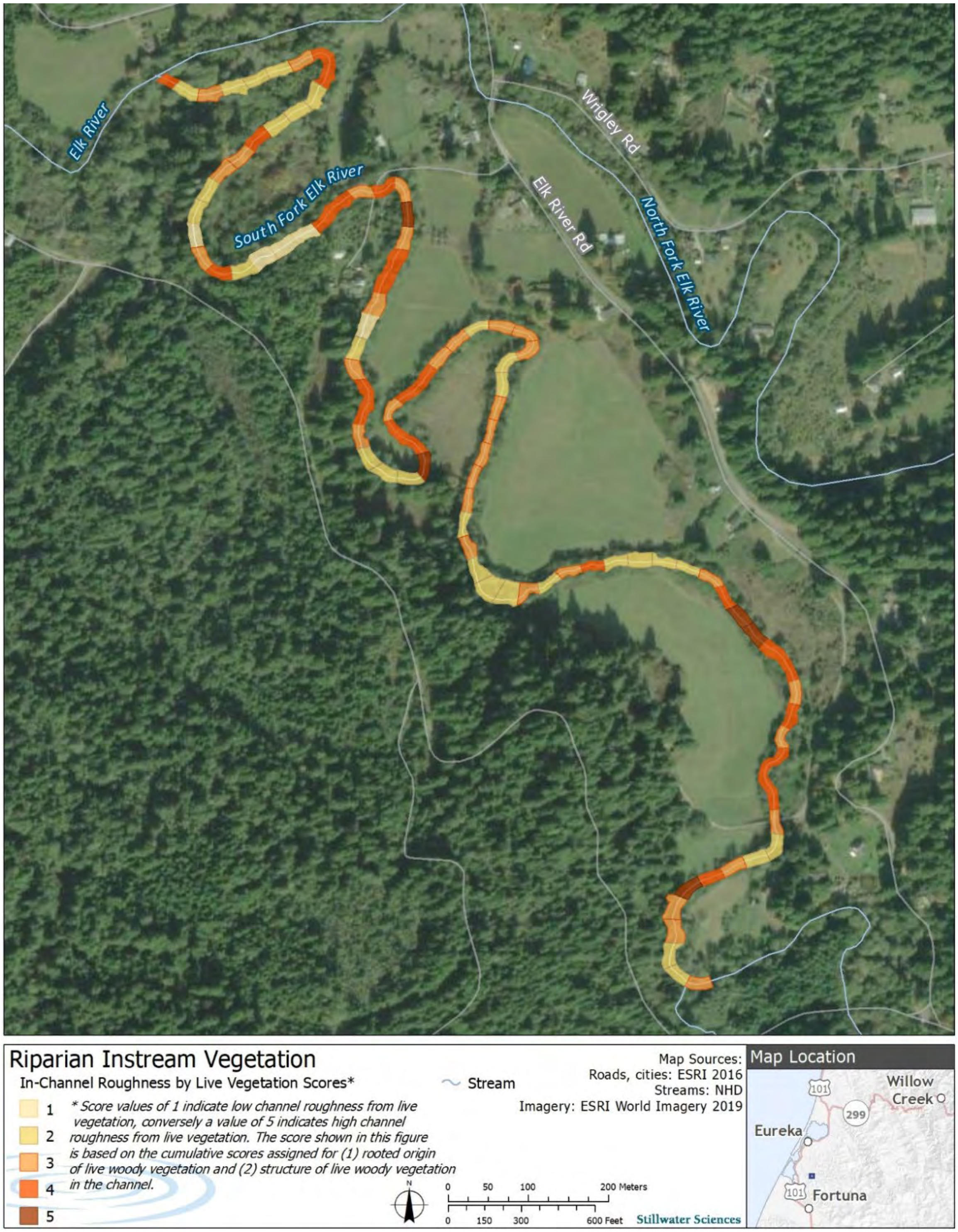


Figure 2-17. Riparian instream vegetation.

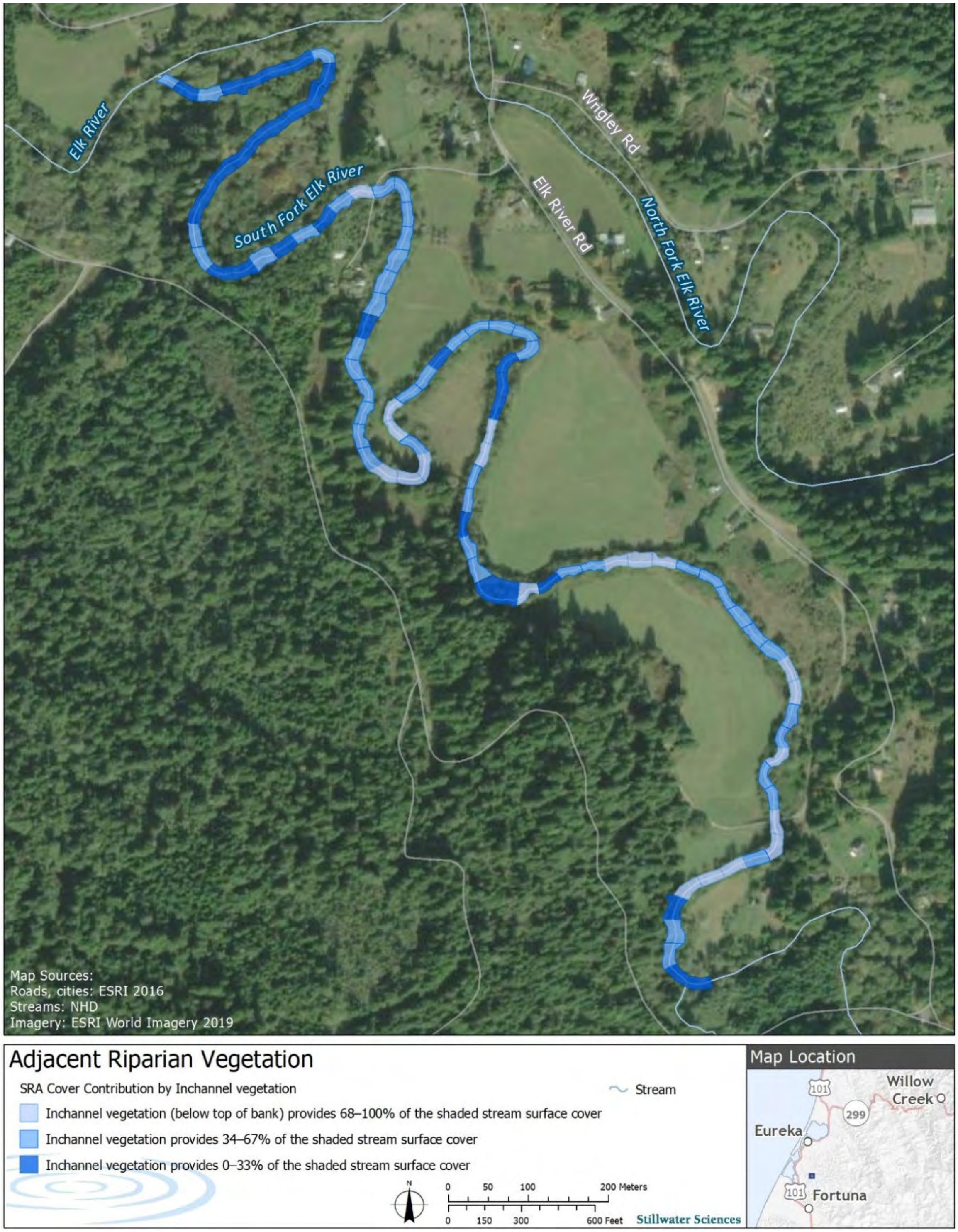


Figure 2-18. Adjacent riparian vegetation.

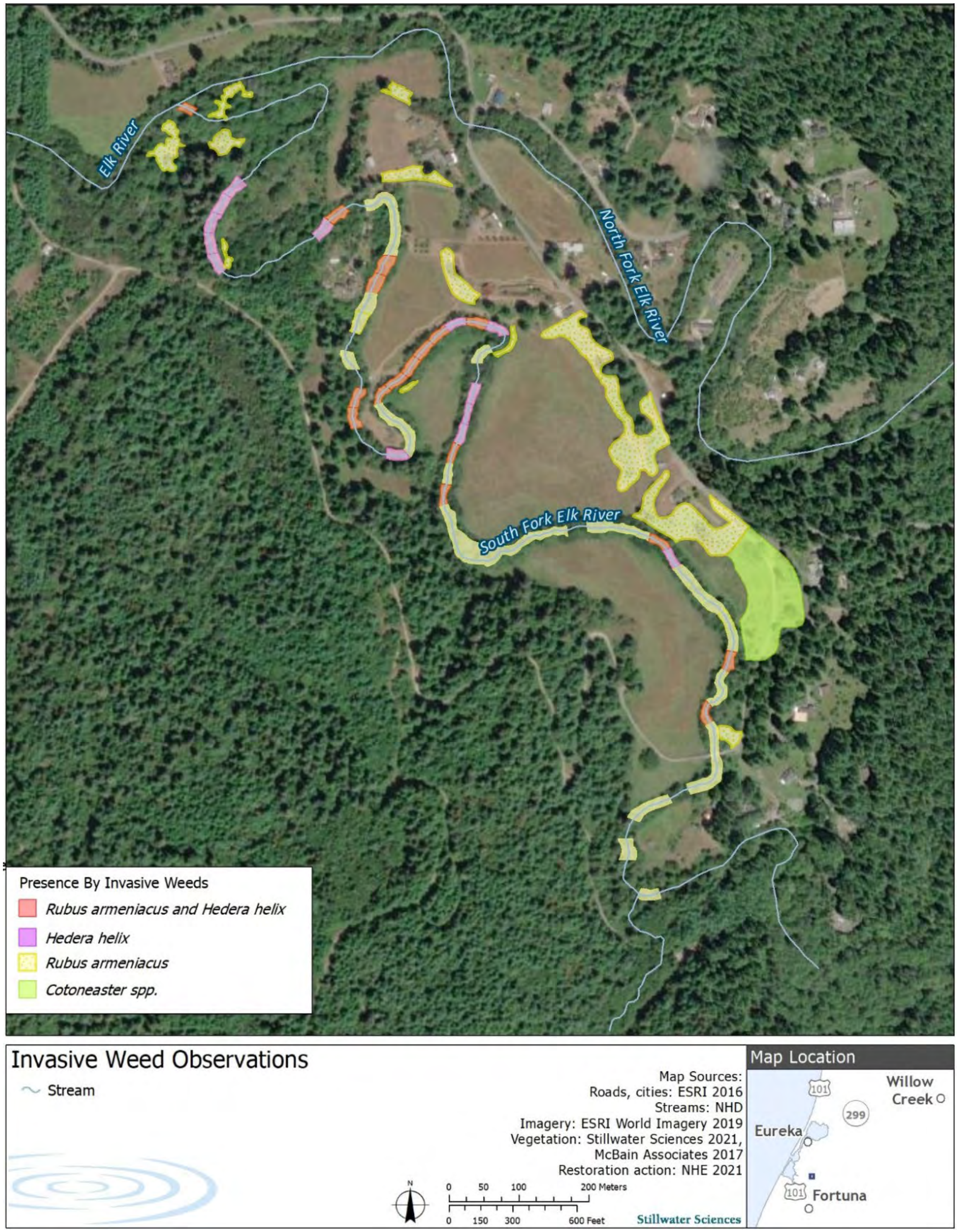


Figure 2-19. Presence of invasive weeds within the riparian corridor, documented nonnative stand types, and incidental sightings of other nonnative weeds in the Project.

2.5 Infrastructure

Infrastructure within the South Fork Project reach includes one home, two bridges, several roads, and two residential water intakes (Figure 2-20). The downstream road and bridge provide access to a residential property, while the upstream road and bridge serve both as access to private property and are utilized for commercial timber harvest. Septic systems are known to exist within the planning reach, but precise locations were not identified as part of this project. Sedimentation has impacted residential access to potable water within the planning reach. Potable water was provided by Humboldt Redwood Company via water truck. One resident reported that potable water deliveries were stopped recently. It is uncertain why service was interrupted and how many residents are currently affected.

Nuisance flooding affects landowners in the planning reach. NHE 2020 (1% Annual Chance Flood Elevation Estimates for the Lower Elk River, Humboldt County) reports one home (near STA 59,000) is at risk of flooding during the 100-year storm. In addition, access for residents is impeded during flooding of the “Elk River Flood Curve” located roughly 100 ft downstream of the North Fork Concrete Bridge at the intersection of Elk River Road and Wrigley Road.

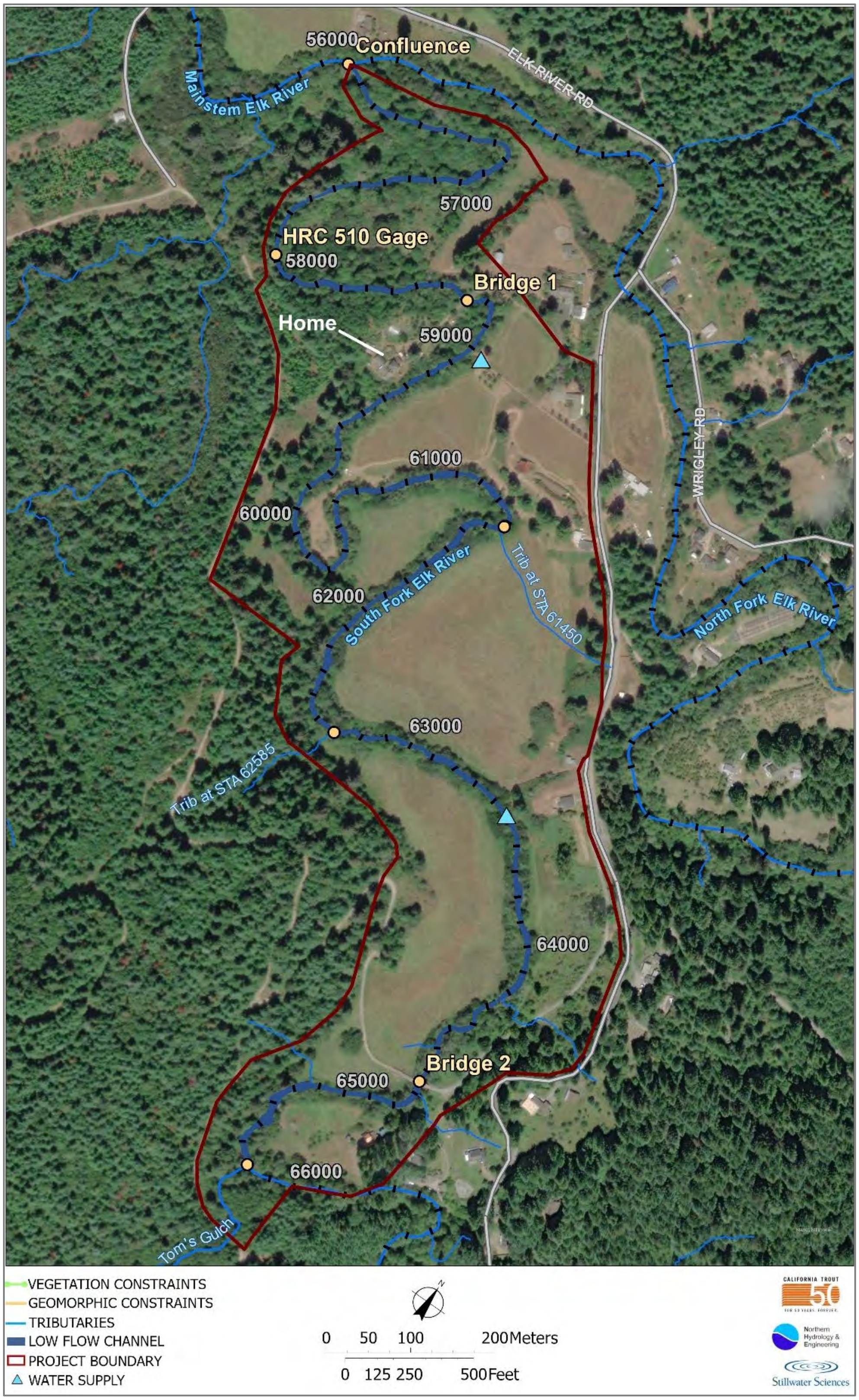


Figure 2-20. Location of infrastructure within the Project area.

3 10% DESIGNS

A key outcome of the Elk River Recovery Assessment (ERRA; CalTrout et al. 2019) was a preliminary set of goals and objectives and recommended actions that represent a Framework for recovery of beneficial uses, improved water quality, and reduced nuisance flooding in the Elk River. The ERRA was presented in public meetings, vetted by a Technical Advisory Committee of academic and technical experts, and discussed extensively during 2019–2020 in numerous individual and group meetings with Elk River property owners, timberland owners, and resource agencies.

The goals and objectives and recommended actions presented in the ERRA were further developed and tailored to the South Fork Elk River planning reach based on detailed geomorphic, habitat, and vegetation assessments. Project constraints were identified from the assessments and landowner interviews. Design recommendations were developed into design concepts suitable for the South Fork Elk River. Design concepts are developed as a "typical" action and describe the intended ecological, geomorphic, and hydraulic function, and the objective(s) the action addresses. These concepts are applied to site specific locations, referred to as "Design Sites". The "Design Sites" section details the location, size, and earthwork volume for each enhancement area.

3.1 Goals and Objectives

The following section outlines the primary goals, objectives, and design recommendations used in the 10% design phase of the South Fork Elk River Restoration Project (South Fork Design Project). Overarching project goals were developed as part of the ERRA. The South Fork Elk River Project seeks to address existing impairments by improving natural form and function to the river channel, enhancing aquatic and riparian habitat, improving water quality, and reducing nuisance flooding.

The specific objectives of the South Fork Elk River Restoration Project are multifaceted and include:

- Ecological: Restore natural channel and floodplain features and functions that support productive native aquatic and riparian ecosystems (e.g., deep pools, gravelly riffles, floodplain connectivity, large wood that provides geomorphic and habitat functions, and natural erosion/aggradation);
- Water Quality: Protect and restore water quality from impairment by suspended sediment and turbidity, water temperature, dissolved oxygen, and coliform bacteria;
- Floodplain: Increase channel conveyance capacity while maintaining or improving floodplain connectivity and high-flow refugia for juvenile fish and minimizing stranding;
- Sediment: Encourage within-reach sediment sorting to improve substrate quality and sediment trapping that reduces fine sediment supply to downstream reaches;
- Flooding: Reduce nuisance flooding by increasing channel conveyance capacity, improving floodplain connectivity, and upgrading drainage infrastructure;
- Land Use: Maintain and protect existing rural land uses and access to potable water supplies;
- Vegetation: Enhance riparian vegetation by reducing nonnative understory weeds and interplanting with native riparian hardwood and shade-tolerant conifer species, expand and restore riparian habitats into adjacent floodplain, and selective instream management to reduce live woody vegetation encroachment on the channel bed.

3.2 Design Guidelines and Constraints

3.2.1 Design recommendations

Preliminary design guidelines were developed based on geomorphic, aquatic, and vegetation assessments in South Fork Elk River and literature values (Table 3-1). These guidelines are currently at the 10% conceptual design level and are expected to be refined as the project progresses in later phases.

Table 3-1. Preliminary design recommendations and supporting information for South Fork Elk River Project 10% designs.

Feature/Issue	Guideline	Notes/References
Aquatic habitat		
Alcove, side channel, pools, riffles	Enhance features where they currently exist, or a forcing feature (large wood) is installed to maintain the feature	Recommendation from TAC and professional judgement
Target flow range for habitat restoration	Low flow—1.053 yr	Habitat enhancement actions should be designed to function optimally at these flow ranges.
Pool-to-pool spacing	1.2–4.7 channel widths	Carroll and Robison (2007); Keller et al. (1985); Montgomery et al. (1995); Buffington and Montgomery (2002)
Residual pool depth for salmonid summer rearing	2–6 ft	General guidelines based on Beecher et al. (2002) habitat preferences for juvenile Coho Salmon and NMFS (2012) habitat complexity indicators for salmonid rearing, and channel size in the Project reach. Deeper pools particularly important for age 1 and older juvenile steelhead.
Depth of alcoves at summer base flow	1-4 ft	Habitat assessment in SF Elk River
Side channel entrance inundation design flow	≤ 10% exceedance	Habitat assessment in SF Elk River
Side slopes of excavated habitat features	Use low slopes to create gradual transitions (e.g., 10H:1V) where possible	Professional judgement to maximize edge habitats
Water velocity for Coho Salmon rearing habitat	0–0.6 ft/s	Beecher et al. (2002) showed that juvenile Coho Salmon preferred water velocities < ~ 0.6 ft/s. Laboratory flume studies indicate that they will often select velocities approaching zero when given the choice (Katzman et al. 2010).

Feature/Issue	Guideline	Notes/References
Escape cover	> 30% of wetted channel area obscured by cover	Based on professional judgement and NMFS (2012) habitat complexity indicators. Primarily due to water depth, large wood, small woody debris, undercut banks, and overhanging vegetation
Winter refugia habitat	Provide high quality low-velocity (<0.6 ft/sec) habitat that is accessible/connected over the range of design flows—especially winter flows	Beecher et al. (2002), Katzman et al. (2010)
Large wood debris		
Minimum large wood size	Key Piece >75 ft long and >1 ft DBH, or >50 ft long and >2 ft DBH, or >25 ft long and >3 ft DBH.	Fitzgerald (2004) and professional judgement based on field assessment of sizes of wood that would be stable and trap other debris in the Project reach
Large wood frequency (pieces/100ft)	4.7-19.2	Fitzgerald (2004); Carroll and Robison (2007), HRC (2015)
Large wood volume (ft^3/100ft)	416-1,343	Fitzgerald (2004); Carroll and Robison (2007), HRC (2015)
Large wood key piece frequency (pieces/100ft)	0.8–1.2	Fitzgerald (2004); HRC (2015)
Large wood mobility	Variable, similar to natural systems	
Large wood decay	15–25-year period	Typical decay rates for coniferous species
Planform stability		
Avulsion across residential property	No increase in risk of avulsion across residential properties.	Address risk of avulsion through design overbank roughness created with large wood and vegetation mgmt. where possible.
Stream boundary construction techniques	Employ techniques that also provide margin shelter and riparian habitat	Employ biotechnical techniques where possible.
Riparian vegetation		
Riparian forest enhancement – Nonnative weed management	Reduce and control expansion of invasive nonnative species in the riparian understory Reduce future nonnative plant establishment in design features with upland weed removal	Requires development of a nonnative weed management strategy and implementation plan.
Riparian forest enhancement – Interplanting	In the riparian corridor, establish a more diverse habitat structure and varied native species assemblage by interplanting in the mesic frequently, infrequently, and rarely flooded planting zones.	Implement with removal of nonnatives, restore native understory and increase tree and shrub species richness. See planting palettes developed for each planting zone (Appendix B).

Feature/Issue	Guideline	Notes/References
Riparian forest enhancement – In-channel live woody vegetation management	Reduce live wood instream encroachment in areas near infrastructure with high hydraulic roughness scores (4 and 5)	Retain overstory canopy to provide adequate stream cover. Implement with other design elements.
Riparian revegetation and restoration	Expand riparian corridor into adjacent grasslands within the floodplain in transitional and xeric infrequently/rarely flooded planting zones	See planting palettes developed for each planting zone (Appendix B).

3.2.2 Design constraints

Design constraints were developed through landowner interviews and field assessments (Figure 3-1). The constraints included in this section directly affect the proposed actions. These constraints are broadly classified into five categories:

- Infrastructure
- Health and safety
- Landowner
- Geomorphology
- Vegetation

The Project actions shall protect all infrastructure in the current state, or reduce the risk to the infrastructure, including homes, bridges, roads, water supply and septic systems. One home is within the project boundary at STA 58,400. Two private bridges (Bridge 1 and Bridge 2) and roads are located in the Project area. The downstream road and Bridge 1 provide access to a residential property, while the upstream road and bridge (Bridge 2) serve both as access to private property and are utilized for commercial timber harvest. Two active water supplies were identified in the Project area at STA 59,000 and 63,500 (Figure 3-1). Septic field locations were not identified as part of this project but are not anticipated to constrain the project actions proposed. Surveys to be conducted by the Regional Water Board in early-2022 will collect additional information on the location of drinking water intakes, septic tank, and leech field locations, and record oral history on nuisance flood experience on individual properties.

Figure 3-1. Geomorphic and vegetative constraints for the project reach.

The primary health and safety constraint within the Project area is flood risk. Sediment deposition in the South Fork Elk River has increased the flood risk over time (Caltrout et al. 2019). One home is located within the Project boundary and is at risk of flooding. Access for all residents, as well as visitors of public lands upstream of the Project area (i.e. Headwaters Forest Reserve) is affected by flooding of Elk River Road in the vicinities of the North Fork and mainstem Elk River. The most frequently flooded area is just outside the Project area at the North Fork Concrete Bridge and Elk River Flood Curve. Project actions proposed shall not increase flood risk anywhere in the Elk River unless a landowner provides specific permission to do so, and that risk does not extend outside their property boundaries and does not affect flooding of public roads.

Landowners in the planning reach utilize their property for a variety of purposes. Existing and future land uses preferred by landowners will be retained. Landowners have provided additional constraints including: no grading on the left bank (STA to 58,400 to 59,400) and minimize erosion of the right bank (STA 59,700 to 60,700). Some limited bank stabilization in the form of rock slope protection exists in this location which may be modified to ensure bank stability.

Potential geomorphic constraints fall into four primary areas: channel planform, channel entrenchment, channel bank conditions, and sediment dynamics. Historically, channel planform was predominantly single thread and relatively confined by Holocene terrace and fan deposits occupying the valley floor. While opportunities exist to create more complex high flow paths within lower-lying inset floodplains, creating a valley-wide network of complex wandering, braided, and/or anastomosing channels that are inundated frequently enough to provide fisheries habitat benefits is likely infeasible and lacks historical precedent. Channel entrenchment generally increases in the downstream direction, with associated decreases in the lateral/aerial extent of frequently inundated floodplain surfaces. Creating more floodplain connectivity will require more effort (e.g., earth moving) and cost in the more entrenched downstream portion of the project reach. Channel banks throughout the project reach are typically steep, erodible, and subject to mass failure, particularly where streamflow has the potential to erode the toe and where thick sediment deposits have accreted to the bank. We have identified locations where bank erosion could destabilize adjacent hillslopes and/or increase the risk to nearby infrastructure. Lastly, high sediment supply rates from Tom’s Gulch and the upper South Fork basin, combined with the transition to a lower channel gradient in the planning reach, promotes rapid sedimentation and associated channel aggradation that can reduce the life expectancy of fisheries habitat enhancement features, particularly side channels, alcoves, and other off channel features where sediment is more likely to deposit.

Vegetation constraints in the planning reach are associated with retaining established native stands and/or intact mature individuals that provide high ecological value to the reach due to their limited establishment, contribution to shaded stream cover, and/or support for wildlife and fish habitat. Native vegetation communities that are limited in the planning reach include Pacific willow, big-leaf maple, and redwood forests. The overstory canopy associated with these communities provides a more varied structure than the predominant red alder forest documented throughout the reach. In addition, their associated understory and mid-story species assemblages increase habitat diversity. Limiting disturbance in forest communities that have intact native mid-story and understory is recommended as this structure forms high-quality terrestrial habitat for wildlife and discourages future nonnative weed establishment. Retaining overstory canopy cover over the entire South Fork Elk River channel requires limited in-channel riparian woody vegetation removal of mid-story species in areas that have low adjacent riparian cover (see Figure 3-17) and/or pairing the mid-story vegetation removal with interplanting of overstory natives along the channel bank. Other documented constraints included retaining mature native trees such as the multi-trunked big-leaf maple, tall single trunk Pacific willows rooted at the channel toe bank, areas along the floodplain with natural recruitment by native hardwoods, and small patches or individuals of mature redwood or other conifers documented along the reach.

Overall, existing salmonid habitat conditions present minimal constrains to selecting and designing restoration actions in the planning reach. Due to the overall degraded and simplified channel conditions and general paucity of suitable winter rearing habitat for salmonids across the planning reach (Section 2.3), there are very few locations where existing high-quality habitat features would limit design opportunities. Where possible, existing low velocity habitats associated with off-channel features or the small number of wood jams present should be augmented and expanded. None of the existing wood jams observed provided sufficient high-quality winter rearing habitat at a level that would warrant avoiding their modification. In several cases, it may be worth considering placing larger wood features within or just downstream of existing jams to help capture and stabilize existing shorter pieces or to backwater existing jams to increase the area of low velocity habitat associated with them.

3.3 Design Concepts

The proposed ERRA actions were adapted to create general enhancement and restoration approaches specific to the South Fork Elk River. The actions include sediment load reduction from the upper watershed, sediment remediation of in-channel aggradation, aquatic habitat restoration, floodplain connectivity and recontouring, nonnative vegetation removal, riparian habitat restoration, freshwater wetland restoration, and community health and safety improvements. The Project objectives met by the actions being proposed are summarized in Table 3-2.

Table 3-2. Summary of project objectives met by proposed enhancement actions.

Enhancement action	Project objectives (Section 3.1.2)						
	Ecological	Water quality	Floodplain	Sediment	Flooding	Land use	Vegetation
Sediment Load Reduction from Upper Watershed	X	X		X	X	X	
Sediment Remediation of In-Channel Aggradation	X	X		X	X	X	
Aquatic Habitat Restoration	X						
Floodplain Connectivity and Recontouring	X	X	X		X		X
Nonnative Vegetation Removal	X						X
Riparian Habitat Restoration	X				X		X
Freshwater Wetland Restoration	X	X	X		X		X
Community Health and Safety Measures (Nuisance flooding)					X	X	

Conceptual designs developed from these actions emphasize natural stream characteristics that emulate natural geomorphic processes to achieve project objectives (e.g., enhancing salmonid rearing habitat). Because these approaches occur within a dynamic system, they should not be expected to be static through time. However, they should provide approximately similar habitat quality and quantity through time within the planning reach. The following sections describe the proposed enhancement actions. These actions are applied to specific sites in Section 3.4.

3.3.1 Sediment load reduction from upper watershed

The transport of sediment to and within a stream channel is a natural and necessary process that helps to maintain stream complexity and habitat. It is only when there is a significant alteration in sediment supply, relative to the transport capacity of a stream, that negative consequences can occur. Recent assessments of the planning reach have indicated that suspended sediment loads in the South Fork Elk River are substantially elevated relative to other Humboldt Bay tributaries resulting in sedimentation, aggradation, reduced flow conveyance, flooding, deleterious effects on critical salmonid habitat and water supply beneficial uses, as well as other attendant issues (refer to Existing Conditions section for additional detail).

Potential actions for reducing current and legacy sediment loads deriving from the upper South Fork watershed (landscape and tributaries draining to the South Fork planning reach) can include source control, sediment removal, and sediment trapping within the upper mainstem and tributaries but are outside the scope of this planning effort.

3.3.1.1 Source control

As described in the Existing Conditions section, voluntary and regulatory efforts to control sediment loading from timberlands in the upper watershed are ongoing but have yet to achieve any meaningful reduction in sediment loading to the South Fork mainstem. However, it is anticipated that waste discharge requirements and continued implementation of erosion and sediment control best management practices will result in consequential declines in sediment loading to the South Fork Elk River over the long-term.

3.3.1.2 Sediment trapping

Sediment trapping, which reduces the mobilization, transport, and re-deposition of sediments from the upper watershed is another viable approach for addressing fine sediment impairments in the planning reach and protecting restoration efforts downstream. Sediment trapping can be accomplished by creating localized geomorphic features, such as in-channel sediment detention basins or off-channel low-elevation floodplain features, that reduce the velocity of water containing high suspended sediment concentrations and allow sediment to settle out of suspension. Sediment detention basins will vary in size and configuration depending on site-specific conditions and objectives. In general, these features will be excavated adjacent to the channel to mimic natural floodplain benches and depressions and would be inundated more frequently than the surrounding floodplains. Flow would enter these features directly from out-of-bank flow or by backwatering depending on the site-specific design configuration. Berms will not be used to confine the sediment detention features, but design contours may be incorporated to direct sediment-laden flow pathways. In some locations with appropriate vehicular access and/or designed to receive higher sediment loads, sediment may be removed periodically during the low-flow season (e.g., annually or water year dependent) to maintain adequate sediment storage capacity. Sediment detention features that incorporate long-term maintenance objectives will identify sediment re-use sites with appropriate capacity specified to support long-term maintenance. Trapping sediment in the upper watershed before it is delivered to the planning reach will help reduce the rate of in-channel sediment aggradation, and significantly improve water quality conditions if implemented at the appropriate scale and locations. In addition, sediment detention basins can be designed to mimic natural salmonid habitat features and provide valuable winter juvenile rearing habitat. Finally, the incorporation of other in-channel habitat features, such as large wood structures, can also aid in storing, sorting, scouring, and mobilizing sediment, raising water elevations, and increasing the rates of sediment deposition on floodplains. Figure 3-2 provides a conceptual overview of an off-channel sediment basin.

Figure 3-2. Planform of conceptual representation of a sediment basin at a tributary confluence. Example enhancement at site T-0 (Figure 3-16).

3.3.2 Sediment remediation of in-channel aggradation

The ERRA concluded that large-scale sediment aggradation in the South Fork Elk River has resulted in extensive impairment of the channel bed and banks, sediment composition, water quality, and aquatic habitat. Currently, most of the channel bed and banks within the planning reach are covered by deep fine-grained sediment deposits overlain by a thin veneer of poorly functioning aquatic and riparian habitat. In appropriate locations, mechanical sediment remediation is expected to be an expedient and effective action to address nuisance flooding, improve water quality, and recover key beneficial uses.

Mechanical removal of excess channel sediments will generally occur through: (1) Channel widening to increase cross-section dimensions and associated flow conveyance, and to reduce the overall volume (source) of legacy sediment available for downstream transport; (2) Recontouring of the channel bed to form a more natural riffle-pool morphology, including the excavation of pool features to enhance depth and improve aquatic habitat; and (3) Re-grading of steep, unstable streambanks to mitigate bank erosion and rotational failures, remove legacy sediment deposits, and improve connectivity to inset benches, side-channel and off-channel features and floodplains (detailed in Section 3.3.3). These “laid back” streambanks will create a gentler bank slope, with large logs and log structures inserted to create slow-water winter habitat for juvenile salmonids that is accessible across a range of stream flows.

Channel rehabilitation through mechanical sediment remediation will also entail the management of in-channel vegetation that has rooted extensively in deposited sediments, and the addition of large wood habitat features to promote sediment sorting and scour for pool maintenance, as well as to provide juvenile salmonid habitat.

3.3.3 Aquatic habitat restoration

As detailed in Sections 1 and 2, the South Fork Elk River has been impacted by a host of anthropogenic activities that have significantly degraded aquatic habitat in the planning reach. For example, juvenile salmonid rearing habitat is impaired by sediment aggradation and associated loss of pool habitat, reduction of large wood supply and storage, simplified channel morphology, and lack of habitat complexity. Similarly, fine sediment aggradation has buried or embedded substrates in many riffle habitats, likely reducing benthic invertebrate productivity and diminishing food resources. This section describes the primary habitat enhancement actions intended to address these and other impairments to aquatic habitats, including:

- Streambank recontouring
- Restoration of natural pool-riffle morphology
- Addition of large woody debris
- Enhancement or reconnection of relic side channel habitat
- Construction of alcoves and other back water features
- Tributary confluence enhancement

The primary focus of these actions is improving winter and spring rearing habitat for salmonid juvenile and pre-smolt life stages, but the actions will also provide substantial benefits to summer rearing habitat. While improving instream salmonid habitat is a primary objective of these actions, designs elements that improve habitat for other native aquatic and riparian species will be integrated.

3.3.3.1 Streambank recontouring

Some of the most diverse and productive habitats within lotic environments exist at the intersection between the streambank and water’s edge. A number of important features, such as undercut banks, overhanging vegetation, and fallen trees, enable a diversity of fish and wildlife to find food and refuge in the channel. The high productivity of this dynamic zone is largely the result of continuous change stemming from natural disturbance processes such as flood events that promote erosion. Bank erosion, often viewed in a negative light, is a natural process that promotes natural recruitment of large wood to the stream. Gravel and sediment present in eroding streambanks are also entrained by the stream, which provides a source of spawning substrate, as well as nutrients that support healthy ecosystem processes.

As documented in Section 2, much of the planning reach is characterized by steep, unstable stream banks that deliver significant quantities of fine sediment to the channel, increase in-channel water velocities in winter, limit fish access to high quality floodplain habitats, and contribute to downstream flooding. To address these issues, streambank recontouring - which entails grading and contouring to lower bank slopes to provide a more gradual transition from the channel bed to the adjacent floodplain - is proposed. Selective grading and stabilization of streambanks coupled with strategic large wood placement and riparian plantings (e.g., Figure 3-3) will provide a host of habitat benefits, including decreased in-channel velocities in winter, improved access to low-velocity refugia for rearing salmonids across a range of flows, expansion of the existing constrained riparian corridor, and higher quality habitat through enhanced nutrient deposition and higher groundwater tables. Additional benefits include enhanced channel stability, flood mitigation via energy dissipation and increased conveyance capacity, reduced excessive bank and bed erosion, and reduced mobilization of legacy sediments through removal of aggraded sediment from banks.

Proposed streambank grading and construction techniques will be focused in areas where landowner consent coincides with advantageous geomorphic characteristics and high restoration potential. The specific enhancement techniques will be site dependent (e.g., based on bank slope, substrate, shear stress conditions), but will likely involve a combination of streambank and floodplain grading, riparian planting, and installation of large wood. It should be emphasized that, in many cases, such restoration actions are intended to allow for gradual bank erosion and meander migration within the natural migration corridor, as this will provide for geomorphic diversity and habitat evolution. This technique is preferred to forcing erosion through installation of wood deflectors which would recruit more sediment into the stream. The suitability and specific enhancement techniques for proposed streambank recontouring sites will be further evaluated in later planning phases.

Figure 3-3. Conceptual depiction of streambank recontouring, riparian vegetation management, and placement of large wood on graded banks to create low velocity refugia over a range of flows. Example enhancement at Site T-12 (Figure 3-16).

3.3.3.2 Enhancement of pool-riffle morphology

Another important category of aquatic habitat enhancement entails restoring homogenous, simplified channels to a more natural and complex pool-riffle morphology that improves both winter and summer rearing habitat for salmonids and overall riverine ecosystem function. Pools offer greater depths, lower water velocities and added escape cover and thus represent important rearing habitat for juvenile salmonids and various other aquatic organisms. Riffles help control stream bed slope and elevation; and the turbulent, fast-flowing water promotes oxygenation, hydraulic diversity, and removes fine sediments. Riffles also provide important habitat for stream macroinvertebrates that are a principal food source for salmonids and other aquatic species. In the planning reach, low gradient riffles also provide some of the only suitable spawning substrates for adult salmonids.

Recent habitat surveys indicate that, because of the paucity of large wood and excessive sedimentation, (1) many pool habitats in the planning reach lack depth and habitat complexity; and (2) riffle habitat area is limited, lacking in complexity, and/or highly embedded with fine substrates. These conditions have resulted in the planning reach having a more uniform channel form characterized by long flatwater and shallow pool habitats with heightened velocities and a lack of hydraulic complexity—especially during higher winter flows (Section 2.4). Additionally, fine sediment deposition has reduced the depth and area of pool habitats and led to heightened embeddedness and a loss of complexity in riffle habitats.

Proposed actions are intended to increase the depth, frequency, complexity, and size of pool habitats, while also increasing frequency, complexity, and sediment soring in riffle habitats. Depending on site-specific constraints and channel characteristics, pool-riffle morphology development will involve pool excavation and selective grading of the channel bed and/or installation of large wood to enhance scour, maintain pool depth, and provide refugia from high flows and predators (Figure 3-4 and Figure 3-5). Spoils from pool excavation will be redistributed within the channel to create in-channel bars to enhance existing bar-pool morphology—thereby creating more habitat diversity. Channel-spanning log structures will be installed to maintain riffle crest elevations, promote sediment sorting, and provide grade control for adjacent backwater habitats (e.g., pools, alcoves). Improved quality and quantity of riffle habitat will help increase juvenile salmonid growth and survival by enhancing macroinvertebrate production immediately upstream of pool habitats where they rear and forage. Where appropriate, riffles will be constructed with a well-mixed layer of gravel and sand. This material will be generated by sorting the bed material excavated for pool enhancements into coarser and finer fractions. The coarser fraction will be used for riffle construction, while the finer fraction may be re-used on floodplains. Table 3-1 outlines key design criteria applicable to restoration of natural pool-riffle morphology.

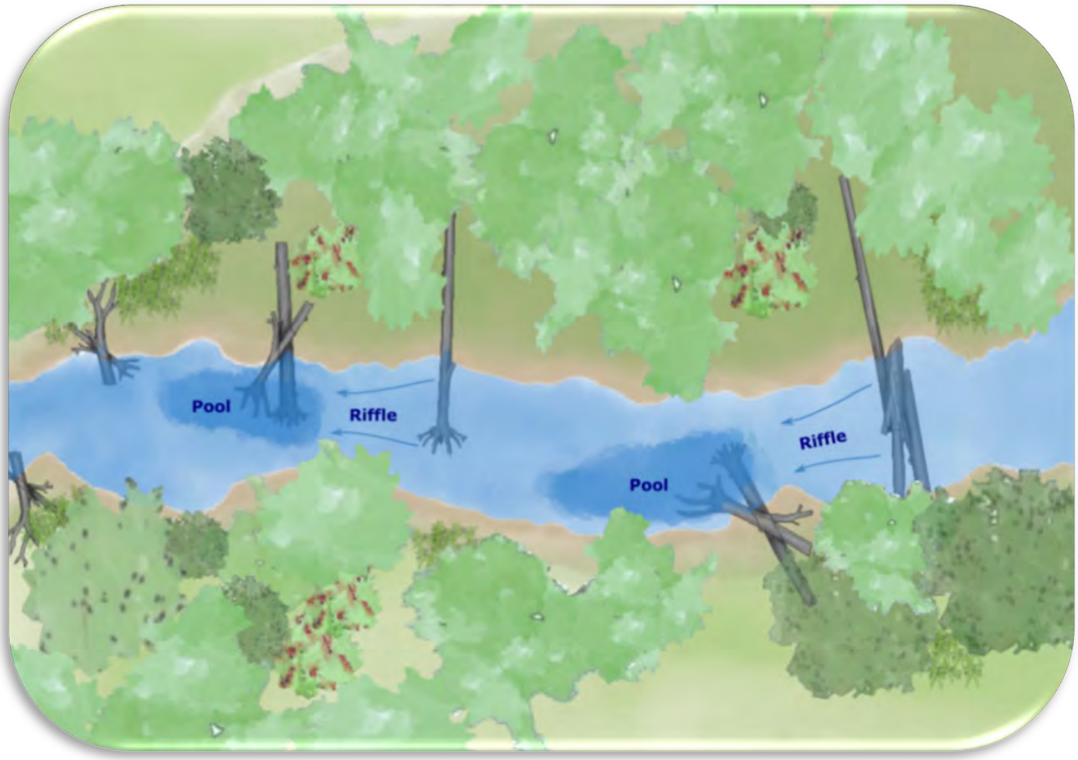


Figure 3-4. Conceptual representation of pool and riffle enhancement. Dark blue areas represent pools enhanced via deepening and addition of large wood. Example enhancement at site T-12 (Figure 3-16).

Figure 3-5. Cross-sectional view of a typical pool enhancement, including pool deepening, streambank recontouring, riparian planting, and addition of large wood to maintain pool scour and create low-velocity habitat refugia over a range of flows. Example enhancement at site T-12 (Figure 3-16).

3.3.3.3 Large wood augmentation

As described in Section 2.3, large wood plays a key role in governing geomorphic process, maintaining channel complexity, and providing high quality fish habitat in Northern California stream ecosystems. Because of the shortage and limited overall habitat function of existing wood across much of the planning reach (Section 2.3.2), large wood augmentation is a critical aquatic habitat restoration action.

The addition of large wood to stream channels generally involves the installation of log structures to enhance aquatic habitat and restore critical in-channel geomorphic processes and habitat functions. Proposed in-channel large wood augmentation will take on several different forms (e.g., strategically placed single key pieces versus channel-spanning engineered log jams) and will be used to accomplish several different restoration objectives depending on characteristics of the site. One of the primary objectives for wood structures in the planning reach is to create low-velocity winter rearing habitat for coho salmon and other salmonids, with designs intended to achieve one or more of the following: (1) create complex, low-velocity pool and bank margin habitats in areas currently lacking low velocity refugia; (2) maintain alcove inlets via flow deflection and scour and/or backwatering; (3) enhance the creation and maintenance of side channels using apex wood jams and formation of medial bars; and (4) facilitate juvenile fish access to adjacent low-velocity floodplain habitats (Figure 3-6, B and D).

Large wood augmentation in the planning reach will generally follow the design criteria detailed in Table 4 and will take one of the following forms:

- Large wood structures: A collection of one to five logs strategically placed to promote pool scour and sediment sorting and maintain alcove and side channel inlets (Figure 3-6 A and D and Figure 3-7). The installation of some small wood structures will involve the placement of larger key pieces perpendicular to flow along laid-back streambanks with a portion of the wood extending into the channel.
- Complex large wood jams: A collection of five or more logs constructed to promote channel sinuosity and hydraulic diversity, as well as initiate or stabilize a bend, fork, or bar in the channel (Figure 3-6 B)
- Channel spanning log jams: A collection of five or more logs anchored on both sides of the design channel (Figure 3-6 A and C). The objective of channel spanning features is generally to create grade control (e.g., set riffle crest elevations), create backwater conditions, promote sediment sorting, improve floodplain connectivity, define pool-riffle morphology, and create habitat complexity.

Habitat surveys indicate that the Project reach contains several raft jams (predominantly floating jams composed of shorter pieces that span the channel and are loosely anchored by bank vegetation or a key piece). While these extensive raft jams provide extensive summer cover habitat, they create minimal hydraulic diversity and refugia from higher velocity flows. Where available, large wood augmentation actions will seek to selectively remove some floating small and large woody debris from existing raft jams and integrate the material into more functional engineered habitat structures.

Notably, natural large wood jams in a dynamic riverine environment are temporary structures with longevity between 1–50 years (Hyatt and Naiman 2001). All woody structures will be installed to mirror the stability of natural wood jams using a combination of burial, wood pins, and selective ballasting. It is also important to note that placement of wood in a stream channel does not restore natural, self-sustaining wood supply, delivery, and function. This will require restoration and maintenance of riparian vegetation and natural upslope processes to ensure a sustainable, long-term source of woody debris (Roni et al. 2015). Log jam stability will be evaluated during hydraulic modeling conducted in a later planning phase.

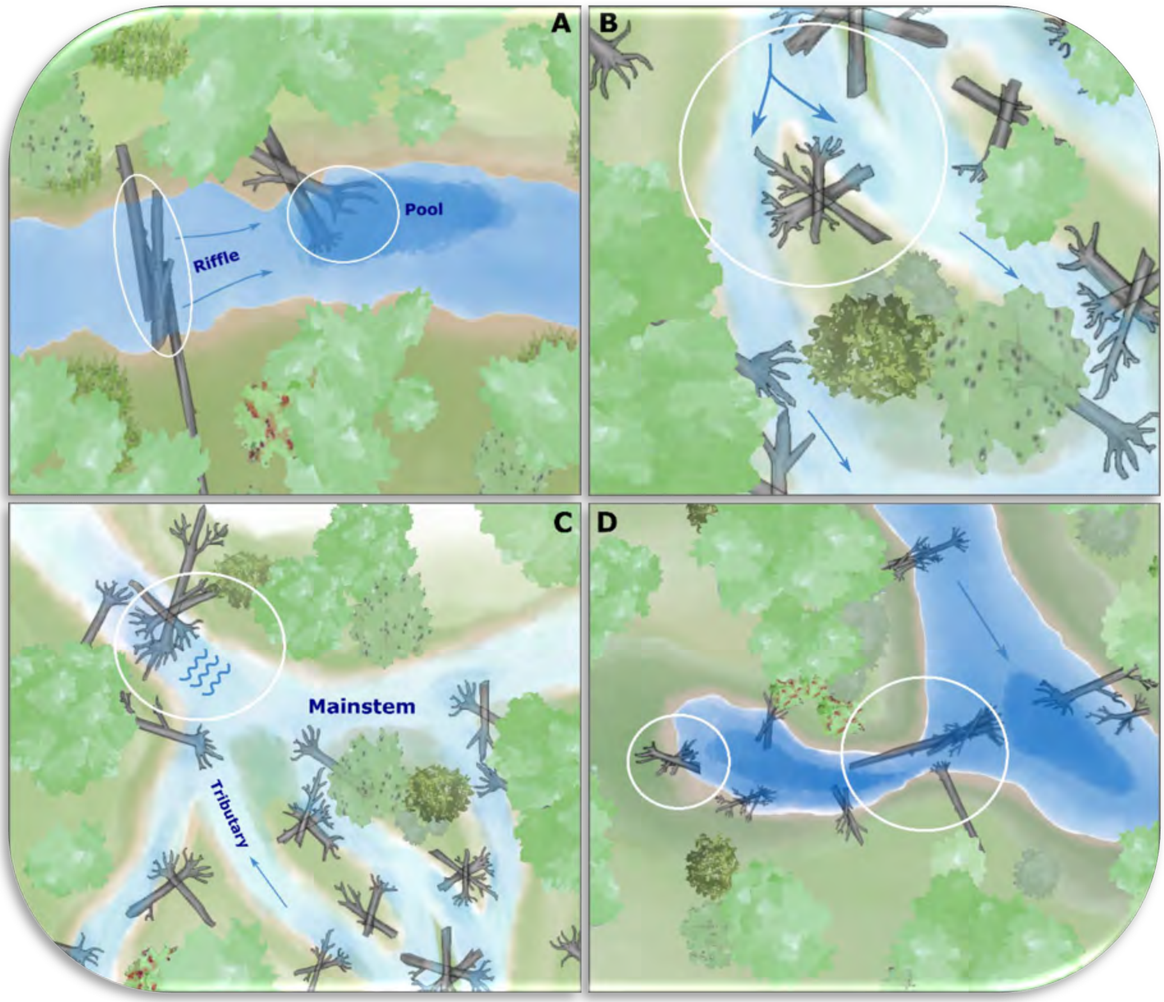


Figure 3-6. Overview of large wood geomorphic and fish habitat functions: (A) large wood and channel spanning structures to create and maintain pools, provide grade control, promote sediment sorting, and define pool-riffle morphology (example enhancement at site 3-16, Figure 2-11) ; (B) complex large wood jam to create and maintain flow splits and hydraulic diversity and stabilize channel bars (example enhancement at site T-0, Figure 3-16); (C) channel spanning large wood jam to establish grade control and create backwater conditions in confluence enhancement areas (example enhancement at site T-0, Figure 3-16); and (D) large wood structures to promote scour and maintenance of alcove entrances and create habitat complexity and cover (example enhancement at site T-4, Figure 3-16).

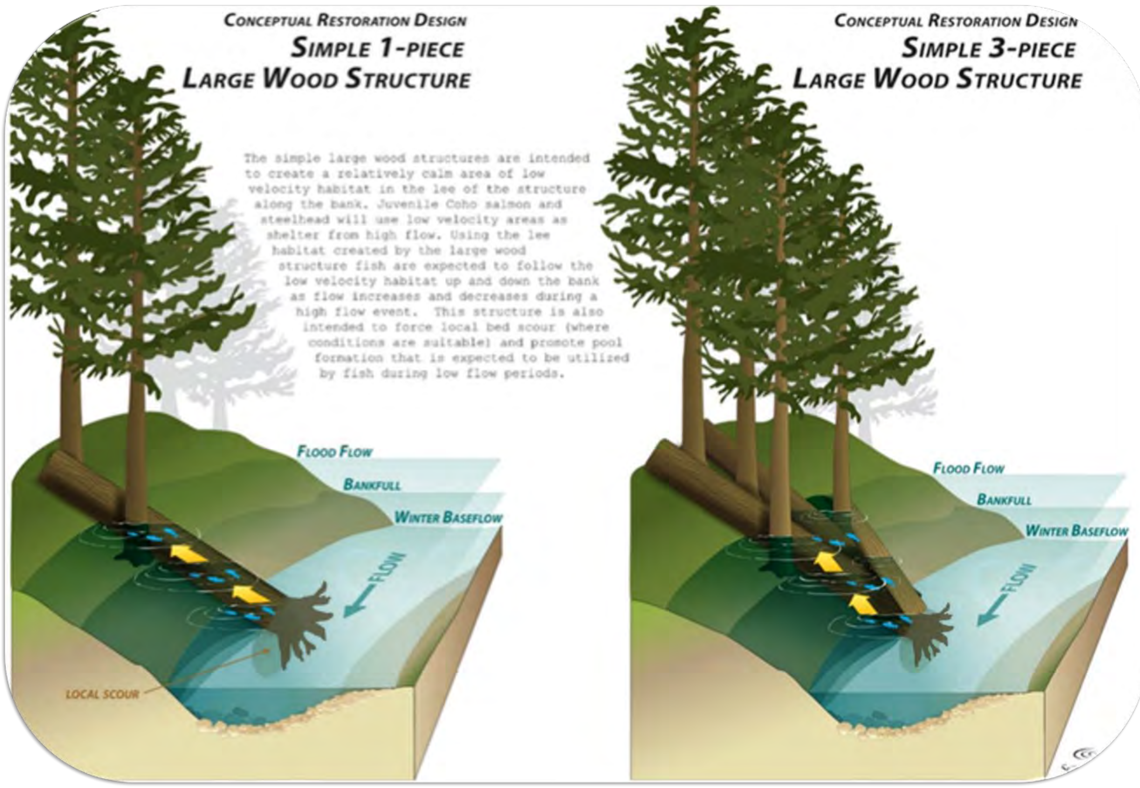


Figure 3-7. Conceptual design for large wood structures installed perpendicular to flow on re-graded streambanks to provide low velocity refugia over a range of flows.

3.3.3.4 Side channel enhancement

Side channel habitats are generally smaller wetted relics of historic river meanders across the floodplain that run roughly parallel to the mainstem. They can also form when a wood jam forms and splits flow around the jam. The split flow erodes the banks and locally widens the river channel to form two channels. Sediments are deposited in the sheltered area downstream of the jam and form a mid-channel bar. Side channels are generally connected at both ends across a range of flows; however, they may become disconnected at one end during low flow, creating an alcove at the opposite end. In either case, depositional rates in the two channels vary with one channel becoming the primary channel and the other becoming more depositional and disconnected (most often at the upstream or downstream end). Research has demonstrated that side channels in various stages of succession can create excellent spawning and rearing habitat for salmonids across a range of seasons and life history requirements (Cramer 2012). For example, observed juvenile Coho Salmon density and survival have been shown to be substantially higher within side channels and other off-channel habitats relative to main-channel habitats (Nickelson et al. 1992b, Lestelle 2007). Because side channels often possess lower flow velocities and added cover complexity, they can also provide excellent refuge during high winter flow events and facilitate access to adjacent floodplains (Cramer 2012). Additionally, Roni et al. (2002) suggest that restoration of side channels may be more effective than other techniques for Coho Salmon.

Construction of side channel habitats in the South Fork Elk River will focus primarily on reconnection of existing relic side channels to the mainstem by: (1) restoring the relative elevation of the side channel to the mainstem to promote inundation at design flows; (2)

removing flow blockages such as sediment plugs; (3) installing channel-spanning log jams on the downstream side to inundate side channels via backwatering; and/or (4) installing apex log jams to promote re-direction of flows into side channel habitats (Figure 3-8). Such actions will generally entail excavation of sediments and placement of large wood to create cover, provide scour, and help develop pool-riffle morphology and maintain habitat features in the side channel. An important consideration in designing side channel enhancement is to minimize sedimentation and blockage of inlets and outlets. Side channel outlets be located in areas with stable hydraulic control and as wide alcoves in the bank of the mainstem to maximize creation of quality aquatic habitat. Large wood should be integrated into the upstream ends of mid-channel islands to limit channel deformation during flood events and create a constriction at the upstream entrance to maintain a scoured thalweg and ensure a reliable connection to the mainstem. Competency of the side channel to mobilize sediments should be balanced with the mainstem to prevent excessive aggradation and maximize longevity of the habitat. Finally, the alignment of the side channel inlet should be orientated at oblique angles to the mainstem to limit debris blockage.

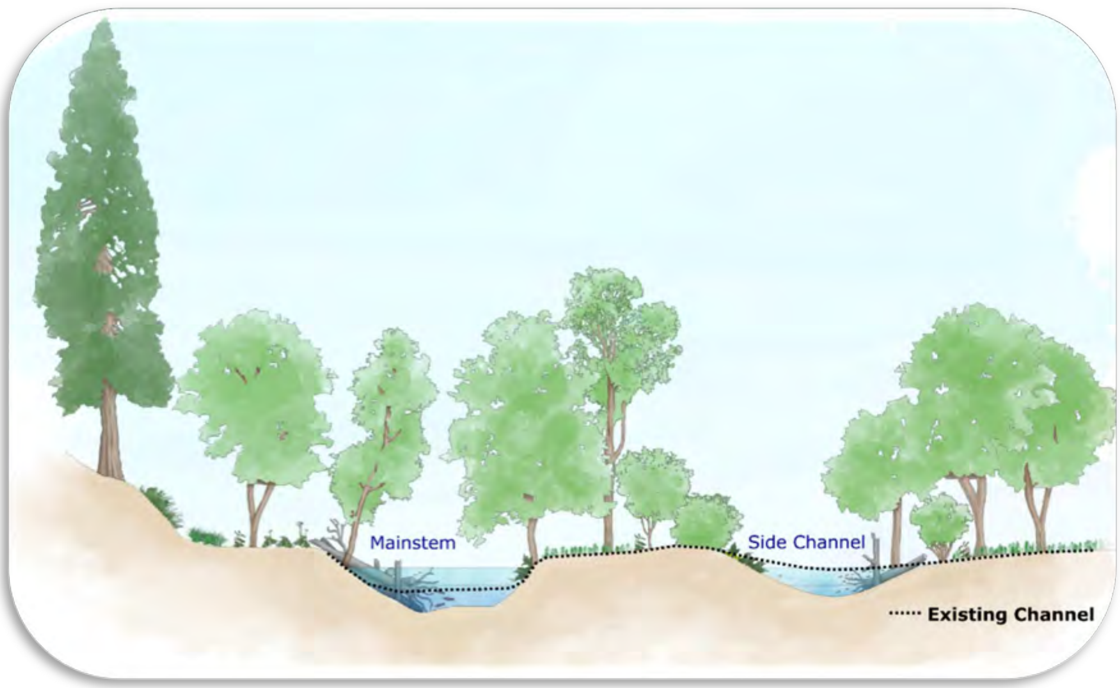


Figure 3-8. Cross-sectional illustration of proposed side channel enhancements, including excavation of relic side channel to improve connectivity with mainstem, mainstem pool enhancement, and addition of large wood to promote scour, create habitat and maintain pool depth and side channel inlets. Example enhancement at site T-9 (Figure 3-16).

3.3.3.5 Alcove creation/enhancement

Alcoves are backwater features excavated into the streambank that provide excellent off-channel flow refugia and winter rearing habitat for juvenile salmonids (Figure 3-9). When side channels become disconnected on one end, the portion of the side channel that remains inundated can function as an alcove, creating high quality low-velocity habitat. Similarly, the downstream end of a freshwater wetland often functions as alcove habitat. The slow current velocities provide superior refuge from high flows and lower turbidity that supports high densities, growth, and survival of juvenile fish, particularly Coho Salmon, relative to main channel pools (McMahon and Hartman 1989; Nickelson et al. 1992a,b; Lestelle 2007). Alcoves are generally excavated deeper than the adjacent stream channel and loaded with large wood. The added depth can provide temperature refugia, greater habitat volume, increases alcove longevity and provides a greater range of depths for woody structures that provide cover from predators. Adding or augmenting existing alcoves will be particularly valuable for juvenile salmonids in the planning reach since low-velocity winter rearing habitat is lacking. Moreover, it is likely that hydraulic modeling (during a later planning phase) will demonstrate that alcoves provide the best means of achieving the target water velocity.

Figure 3-9. Conceptual depiction of alcove feature in plan view. Alcoves will be installed in existing low elevation locations along the floodplain. Example enhancement at site T-4 (Figure 3-16).

Ideally, designed alcoves will provide high quality, low-velocity winter rearing habitat for salmonids across a range of flows, with wetted habitat area expanding with increasing stream flow. Where possible, alcoves will be integrated with other habitat features (e.g., side channel outlets or inlets to floodplain wetlands) to provide seamless fish access to larger adjacent floodplain/wetland features during high flow events (see Section 3.3.7)

Another potential benefit of constructing larger alcove habitats in the highly turbid Elk River watershed is more rapid clearing and improved feeding conditions following high flow events. Alcoves and connected floodplain/wetland features can be sited at locations that are fed by small intermittent streams or groundwater seeps to facilitate clearing following high flows and to maintain water quality during lower flows.

Alcove enhancement may involve excavation to the target design depth below the low-flow water surface elevation with gently graded banks, or by adding a channel spanning wood jam downstream to increase backwatering into an existing alcove. As previously noted, to ensure sustainable hydraulic control, alcove outlets should be in areas with robust grade control such as a riffle crest or channel-spanning log structure. It is also important to locate the outlets outside of highly depositional zones to reduce sedimentation and blockage of the outlet and isolation of the alcove from the main channel. The main body of the alcove should be located a suitable distance from the main channel to minimize the chance of channel avulsion or sedimentation during high flow events. These design guidelines will help maximize the longevity of constructed backwater habitats by reducing sedimentation and alterations to downstream hydraulic controls. Nevertheless, sedimentation in these areas will be unavoidable.

3.3.3.6 Tributary confluence enhancement

Tributary confluence areas are often ecological hot spots that create excellent habitat opportunities via complex flow and sediment depositional patterns, sediment sorting, potential for improved water quality (temperature, sediment, dissolved oxygen, etc.), wood accumulations, diverse vegetation, food sources, and high flow refugia. Small, intermittent tributaries are important for maintaining flow connectivity through off-channel habitats such as ponds and side channels and for extending the period available for rearing fish. Larger tributaries can provide similar benefits year-round while also enhancing the substrate, water quality, and rearing areas of the mainstem channel. In tributaries with poor water quality (e.g., high sediment loads), enhancement of the tributary prior to entering the mainstem is highly beneficial. Some tributaries may provide lower suspended sediment concentrations and lower water velocities during winter floods, resulting in the creation of refuge habitat from poorer mainstem conditions. For these reasons, tributary confluences should be considered high priority areas for aquatic habitat rehabilitation.

Tributary confluence enhancement actions may include, but are not limited to:

- Addition of large woody debris to expand high flow refugia, promote and stabilize flow splits, and create habitat features (Figure 3-10).
- Acceleration of sediment deposition within tributaries with high sediment loads to reduce sediment deliveries to mainstem channels.
- Combining off-channel habitat restoration with tributary confluence enhancement (Figure 3-11).

Figure 3-10. Conceptual depiction of confluence enhancement for a larger tributary involving large wood addition to promote and stabilize flow splits and medial bars, add channel complexity and create habitat. Example enhancement at site T-0 (Figure 3-16)

Figure 3-11. Conceptual depiction of confluence enhancement for a small tributary combined with off-channel restoration (alcove creation). Example enhancement at site T-4 (Figure 3-16)

3.3.4 Floodplain connectivity and recontouring

Riverine floodplains are relatively flat, low-lying areas directly adjacent to a river that inundate during high flow events. This periodic inundation creates dynamic environments that promote exchange of sediment, water, nutrients, and organisms - resulting in extraordinarily diverse and productive habitats that are key components of riverine ecosystem integrity. Unfortunately, as is the case in the Elk River watershed, floodplains and rivers are often disconnected via myriad human impacts, including engineered flood control structures (e.g., levees), channel incision, flow alteration and/or floodplain aggradation.

Selective grading of existing and potentially disconnected floodplains provides a host of benefits including: Flood mitigation via energy dissipation and flood storage, enhanced groundwater recharge, improved riparian zone habitat through nutrient deposition and higher groundwater tables, creation of low-velocity floodplain high-flow refugia for fish, and improved water quality.

Potential floodplain rehabilitation and modifications in the planning reach include: (1) grading and removal of deposited sediments to lower the floodplain elevation and increase and/or maintain the frequency and duration of inundation (2) creation or enhancement of side channels that have filled and become disconnected (Section 3.3.3.4); (3) creation of floodplain benches within the bankfull channel; and (4) creation or rehabilitation of off-channel or backwater features (e.g., alcoves and/or freshwater wetlands) that provide aquatic habitat benefits. Many of these enhancement features will entail mechanical excavation to lower the floodplain elevation and increase/maintain the frequency of inundation.

Proposed floodplain grading and construction techniques will be focused in areas where landowner consent coincides with advantageous geomorphic characteristics and high restoration potential. The specific enhancement techniques proposed will be site specific (e.g., depend on slope, substrate, local hydraulics), and will involve a combination floodplain grading, riparian planting, and installation of large wood. The suitability, restoration potential, and enhancement techniques for proposed floodplain construction sites will be further evaluated in later planning phases.

3.3.5 Non-native vegetation removal

The distribution of nonnative weeds in the planning reach is presented in Figure 2-19 (see Section 2.4.2). The prevalence of English ivy and Himalayan blackberry within the existing riparian corridor will require various management strategies to control, reduce, and remove their occurrences. Further assessment to identify abundance and density within these documented understory patches will set the priority for management, inform the most effective management activity (e.g., mechanical, chemical, cultural) at various locations, and assess the level of effort required for removal and maintenance. To the extent possible, nonnative management activities will be aligned with a future implementation phase to minimize the impact on native vegetation. Development of a nonnative weed management strategy will review access for mechanized equipment and constraints such as onsite or offsite disposal mechanisms, availability and approval for chemical herbicide application, and the potential for phased management. Best management activities to reduce the spread of nonnatives during implementation will be included in the nonnative weed management strategy. Potential actions to manage nonnative vegetation in upland areas prior to construction will also be assessed to identify the most impactful strategy to reduce nonnative weed seed sources into the lower riparian area during project implementation.

3.3.6 Riparian habitat restoration

Land-use practices have significantly altered the composition of channel and floodplain vegetation, and in many locations have constrained vegetation to a narrow strip along the channel banks or edge of the floodplain. The heavily aggraded channel conditions have promoted the encroachment of dense live woody vegetation within the channel bed and banks (Section 2.4.2), significantly affecting channel capacity, hydraulics, geomorphology, and sediment transport. Although the riparian species present are native to Elk River, the presence of high stem densities of live woody species rooted within the channel bed and banks is detrimental to aquatic habitat and riverine function.

To address flooding and improve the function of native riparian vegetation in the planning reach, the riparian corridor will be treated in select locations to remove nonnative invasive plants (see Section 3.3.5), manage in-channel live woody vegetation (Section 2.4.2), enhance the existing native plant assemblage by interplanting for varied structure, and restore the adjacent floodplain by revegetating with native plant communities to form more varied riparian habitat. The restoration goal is to improve species composition, structure, and function of the riparian ecosystem over the long-term.

Instream vegetation management in the form of thinning or removal of live wood will be focused in reaches near infrastructure that have high in-channel encroachment of low to midstory shrubs and channel-spanning fallen live wood (see in-channel live wood assessment in Section 2.4.2). Under this action, the existing overstory canopy will be preserved and high-value riparian trees (e.g., large mature individuals, uncommon natives) will be retained and prioritized. Limited removal or supplemental planting will occur in reaches with low adjacent overstory canopy (Figure 3-12).

Figure 3-12. Example of existing condition identified for in-channel live wood management (A) and post-implementation designed condition when paired with other actions (B).

Riparian enhancement will include interplanting with shade-tolerant natives in areas with low overstory cover, along disturbed banks, and where the understory has been disturbed by invasive weed management actions. Overstory canopy development will be focused on planting predominantly tall deciduous hardwood trees to maintain organic input into the system. Incorporating a patchwork of evergreen conifers will increase species richness and provide year-round cover, dense shade, as well as a future source of large wood. The riparian enhancement associated with increasing native conifer and hardwood trees and native understory species within the riparian corridor will not only increase aquatic and terrestrial resource value but also act as a long-term vegetation management strategy. The establishment of mature overstory trees will increase understory shade and thus aid in nonnative plant control and in-channel live wood establishment in the long-term.

Riparian habitat restoration activities involve the expansion of native riparian vegetation communities into the adjacent floodplain. The expansion of the narrowed riparian corridor is planned in the former pasture grasslands owned by Save the Redwoods League (SRL). Planting zones and associated planting palettes were created to inform which native species have potential to successfully establish and form more varied habitat diversity along the reach (Appendix B, Table B-1).

3.3.7 Freshwater wetland restoration

Freshwater wetlands are areas where soil is saturated and/or inundated by freshwater (from a high water table or surface water) at least periodically in order to support predominantly hydrophytic vegetation and the development of hydric soils. Although wetlands can occur in various forms and locations, this discussion is focused on palustrine emergent persistent wetlands that are found in low-lying floodplain areas proximal to rivers and streams.

Floodplain wetlands support river ecosystems by providing habitat for fish and wildlife, maintaining water quality, dissipating flood energy, and supplying nutrients and shelter that enhance fish reproductive success and growth rates. Unfortunately, human activities (e.g., agricultural drainage, levee construction, etc.), many of which are prevalent in the planning reach, have led to significant wetland loss and/or impairment.

Creation of new floodplain wetlands or the enhancement of existing wetlands will improve hydrologic connectivity, increase water retention, buffer floods, and mitigate poor water quality and lost habitat for native fish and wildlife. Hydrophytic native vegetation well-suited for these environments are included in Appendix B, Table B-2. Riparian wetland enhancement will generally occur in concert with floodplain enhancement actions (regrading and reconnecting the floodplain) and aquatic habitat restoration actions (alcove creation, large wood placement). Figure 3-13 and Figure 3-14 provide plan view and cross-sectional illustrations of a typical riparian wetland enhancement, that is connected to the mainstem at the downstream end in order to create a low-velocity alcove which provides high quality winter rearing habitat for fish (Section 3.3.3).

Similar to alcove enhancement, wetland enhancement requires robust grade control (e.g., riffle crest or channel spanning log structure) to ensure stable hydraulic control and reliable water levels. Additionally, siting constructed wetlands in locations with high water tables, springs, or intermittent tributaries will help ensure hydric soil formation and support the growth of hydrophytic vegetation. These design criteria will help maximize function and longevity of constructed wetland.

Figure 3-13. Conceptual plan view illustration of typical freshwater wetland enhancement action. Example enhancement at site T-8 (tributary entering the wetland not shown Figure 3-16).

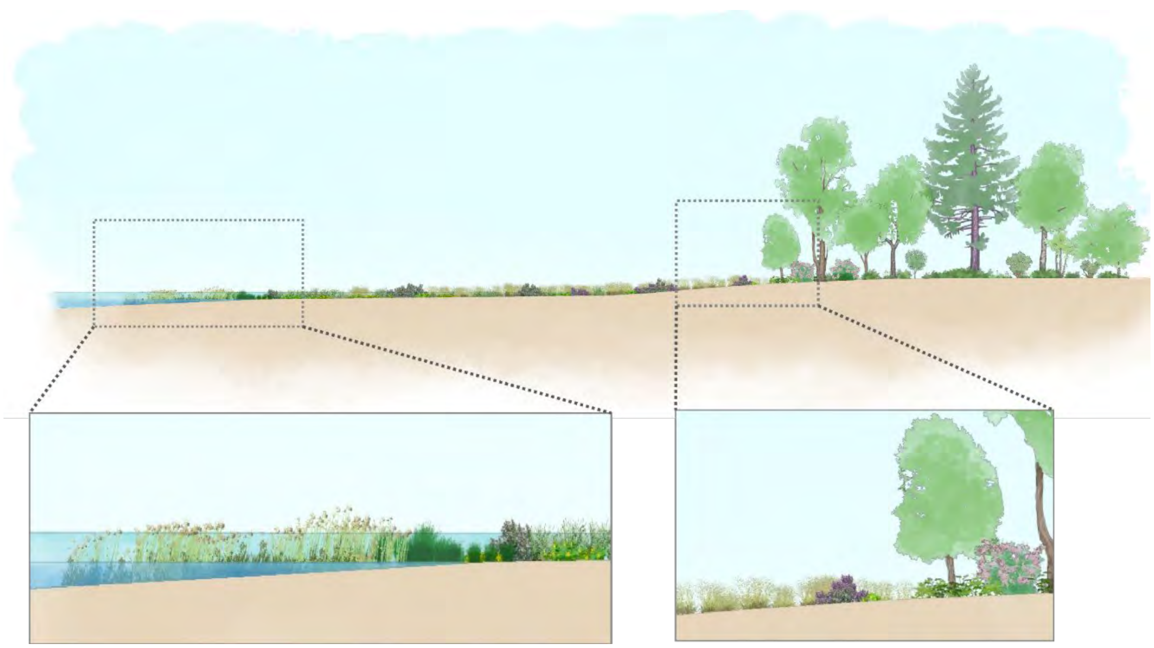


Figure 3-14. Conceptual cross-sectional view of typical freshwater wetland enhancement action.

3.3.8 Sediment re-use

Recovery actions such as sediment detention, sediment remediation of in-channel aggradation, aquatic habitat restoration, and floodplain enhancement require the excavation of sediment. Beneficial reuse of sediment will be prioritized within the planning reach. Off-site sediment disposal will be avoided, to the extent possible, however some off-hauling to off-site sediment spoil areas may be required. Sediment reuse areas will be examined in more detail during the analysis phase.

Following implementation, all spoil areas will be revegetated to support existing or planned land uses. Potential applications for sediment reuse within the planning reach include:

- Spreading material across agricultural lands to improve productivity;
- Spoiling material in targeted areas identified by landowners in order to protect infrastructure or property (e.g., associated with raising a house);
- Placement in upland areas, above the 100-year flood elevation; and
- Utilizing coarse sorted material excavated from the channel bed to enhance riffles.

3.3.9 Community health and safety measures

Nuisance Flooding: For the purposes of this report, nuisance flooding includes flooding of property, homes, roads, and bridges. Actions proposed to alleviate the threat of flooding include:

- Removal of in-channel sediment to increase channel conveyance capacity
- Floodplain and channel recontouring to increase flow conveyance
- Strategic placement of large wood structures to promote localized backwatering and floodplain storage to reduce downstream flood flow peaks
- Management of dense live woody vegetation encroachment on the channel bed and banks to reduce channel roughness
- Modifications of roads and bridges

Many Elk River property owners rely on on-site septic systems. Very little is known about potential water quality and public health risks associated with flooding of residential septic systems. Long-term solutions for these conditions are needed. Public safety contingency planning would also benefit the community to raise awareness about flood risks and thresholds for precautionary measures (such as incorporation into emergency plans and evacuation planning).

3.3.10 Domestic and agricultural water supplies

As previously noted, many landowners participating in Elk River recovery have riparian water rights and rely on the Elk River for domestic water but are no longer able to source water from the Elk River due to sedimentation which has degraded the previously deep pools in which their intake systems are located and destroyed intake pumps. One potential solution would be for the Humboldt Community Services District to extend community water up the Elk River beyond the existing terminus just below Berta Road. Alternatively, a separate community water system could be created to service a subset of the Elk River community. The North Coast RWQCB is currently coordinating with the SWRCB Division of Drinking Water to consider all options to restore the residential drinking water supply.

3.4 Enhancement Sites

General opportunities for aquatic habitat enhancement, sediment remediation, riparian habitat restoration, and non-native vegetation management were identified throughout the planning reach (Figure 3-15) based on aquatic habitat, riparian vegetation, and geomorphic assessments (Section 2), and in collaboration with private landowners and agencies . Health and Safety actions are focused on residential properties between STA 61,200 and the South Fork/Mainstem confluence. Opportunities to substantially expand freshwater wetland and riparian forest were primarily identified in the middle portion of the planning reach owned by Save the Redwood's League where former grazing pasture could be substantially expanded into a mosaic of more complex habitats. This middle reach also provides the greatest opportunity to promote a more dynamic channel and improved floodplain connectivity through targeted grading, creation of off-channel habitat, and installation of wood jams. Additional opportunities to expand the riparian zone along the stream corridor on residential properties were identified on the right bank from STA 59,000 to 62,100 and from STA 65,000 to 65,700. The confluence zone of Tom's Gulch and South Fork Elk River was identified as an area where limited sediment reduction from Tom's Gulch could occur, coupled with habitat enhancements. Sediment source reduction in the upper watershed at Tom's Gulch would benefit all downstream reaches.

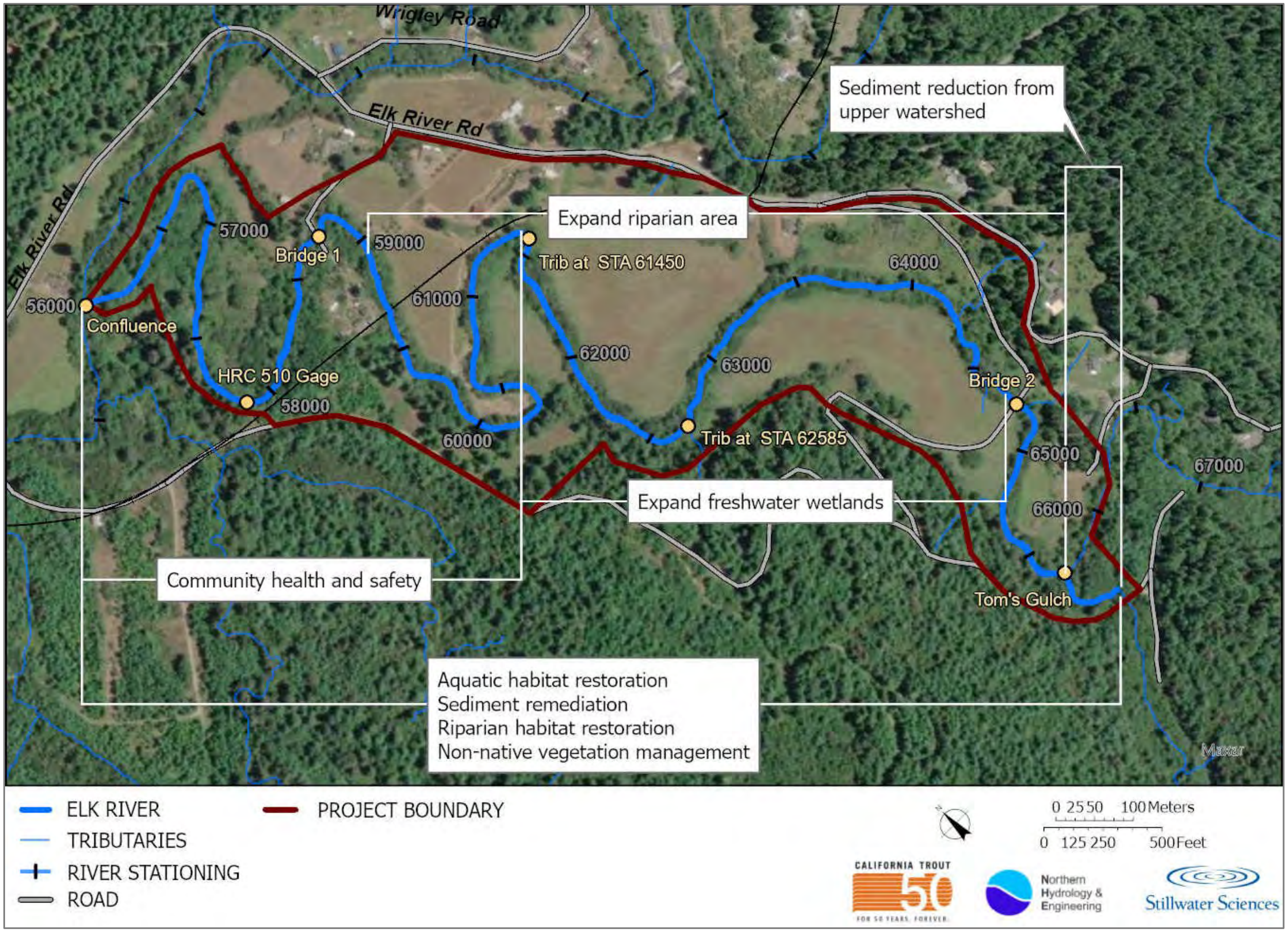


Figure 3-15. General areas identified for enhancement actions in South Fork Elk River.

Enhancement sites were identified from the photo tour and aquatic habitat, geomorphic, and vegetation assessments (Figure 3-16). Enhancement sites that require excavation generally have a similar feature, or relic feature that suggests that a similar feature existed at that location previously. For instance, a side channel exists at T-9, but has filled in so much that the channel is only inundated at higher flows (Table 3-3). The side channel enhancement includes excavating sediment from the existing side channel to activate the channel at lower flows (<10% exceedance flow) (Table 3-3).as well as removal of invasive vegetation, infilling the existing riparian corridor with native vegetation, expanding the riparian corridor, and adding large wood to reinforce the flow split (Figure 3-8). Similarly, alcove development was targeted in locations that either have an existing alcove or low-lying floodplain where an alcove previously existed. Locations where tributaries or small drainages cross the floodplain were targeted as freshwater wetland enhancement sites with alcoves at the outlet of the wetland such as enhancement site T-8 (Figure 3-13).

A description of all enhancement sites is provided in Table 3-3. Enhancement sites are labeled in order from upstream to downstream. Enhancement sites with a “T” label include earthwork. Pool-riffle enhancements occur in association with streambank recontouring (bank), side channel, and channel widening actions. Large wood augmentation occurs as a component of all aquatic enhancement (T) sites. Enhancement sites with a “V” label involve in-channel vegetation management of in-channel live wood that contributes to residential flood risk or channel impairment. Expansion of the riparian zone (new vegetation planting) and enhancement of existing vegetation occur over broad, contiguous areas of the river corridor and are not given unique enhancement labels.

In addition, Table 3-3 contains plan view of existing and design inundation extents. A legend for flows represented by different colors is provided as Figure 2-11 and range from low flow (navy blue) up to the 2-year flow (almond). Change in inundation extent is computed for the 10% exceedance flow and the 1.053-year flow. These designs flows were selected because they represent more frequent winter flows where winter refugia is currently lacking. An increase in inundation extent is considered a proxy for an increase in winter rearing habitat for the purposes of the 10% designs. A cost/benefit analysis was conducted for aquatic habitat enhancement sites and is provided as Appendix D. Cut volume is used as a proxy for “cost” and change in inundation extent is used as a proxy for “benefit”.

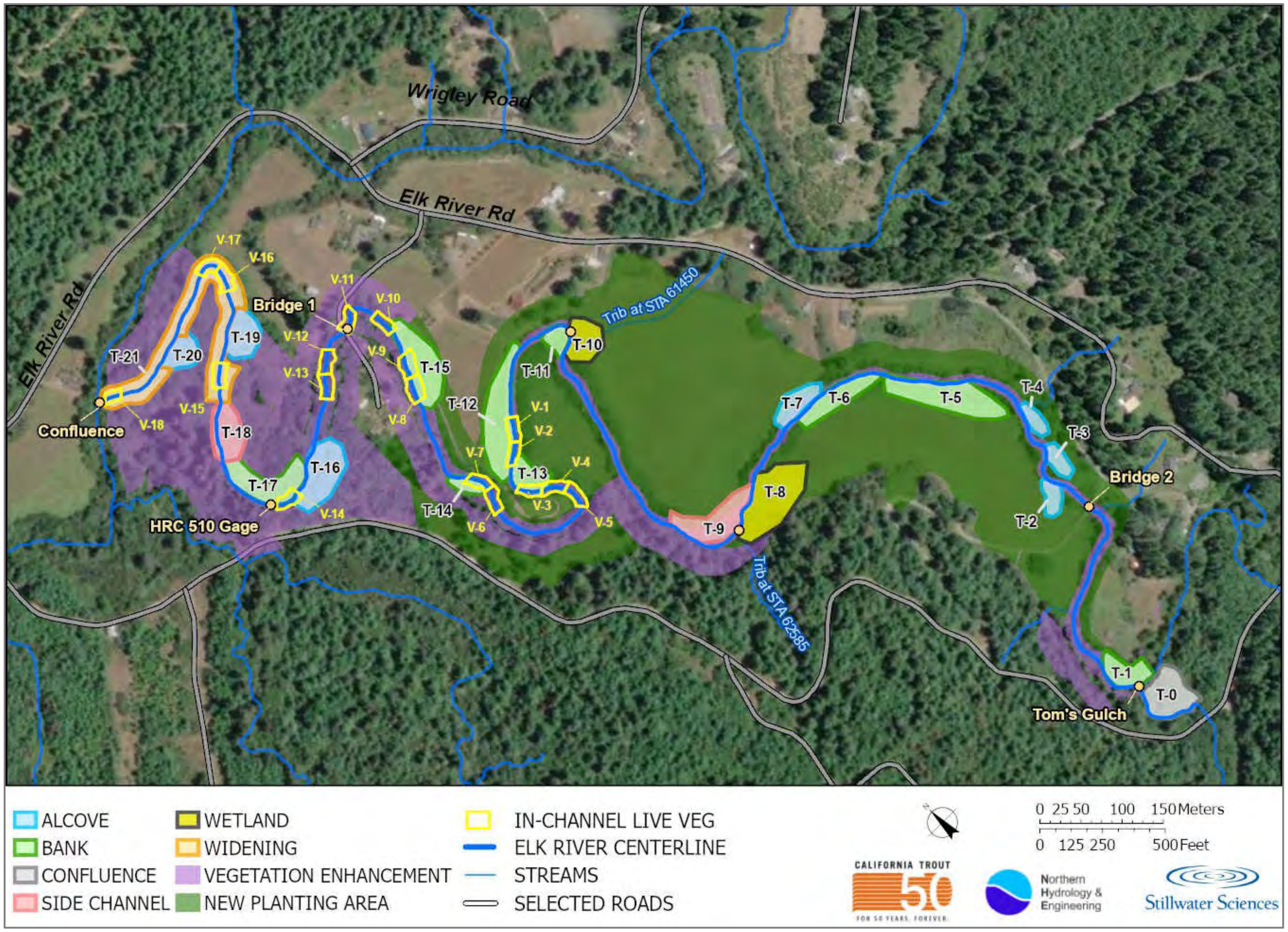
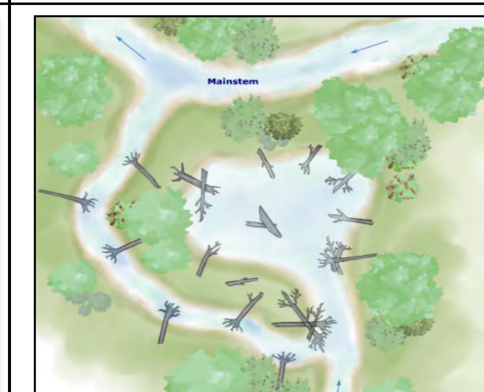
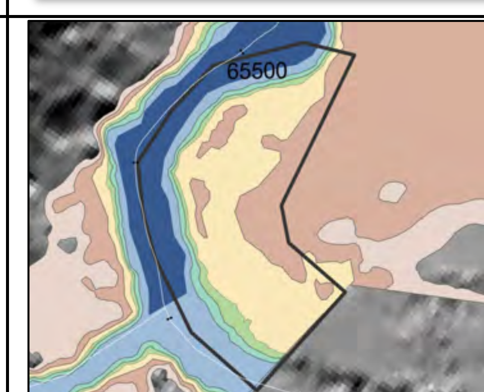
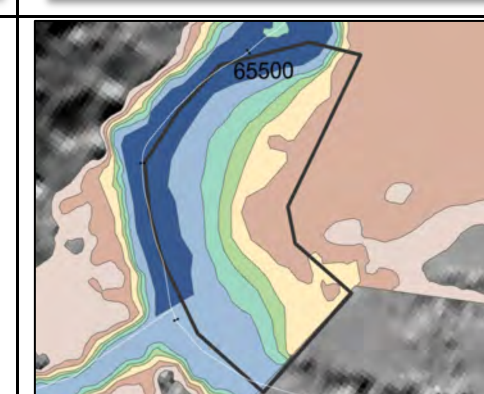
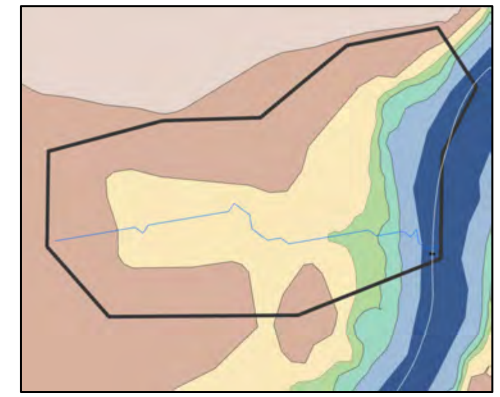
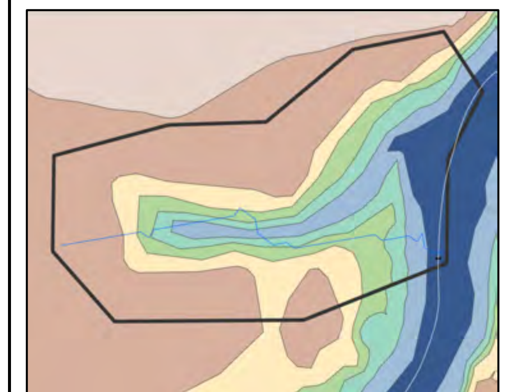
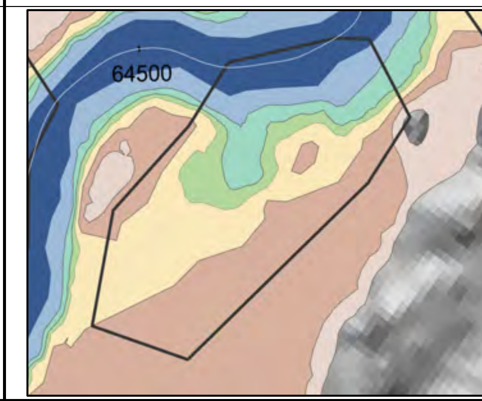
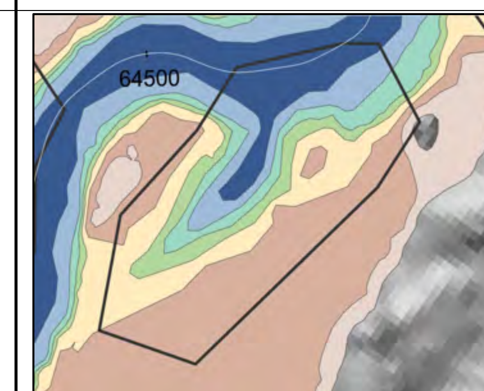
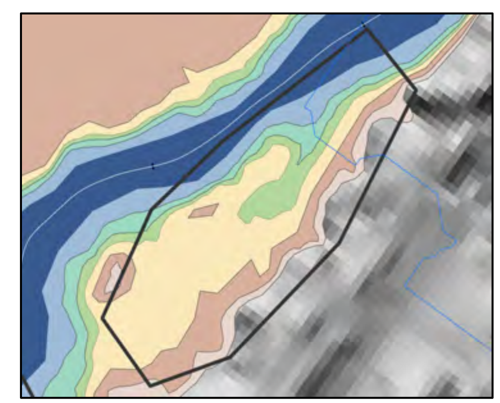
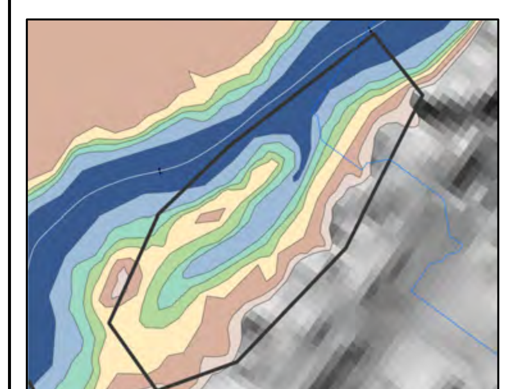
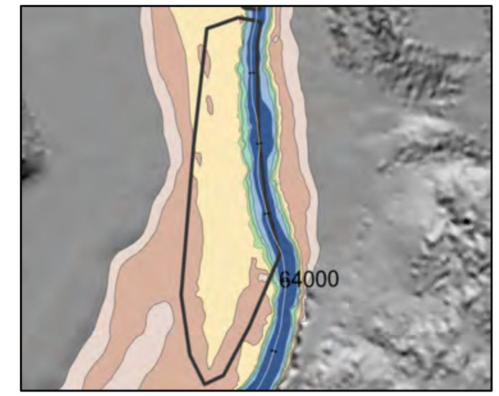
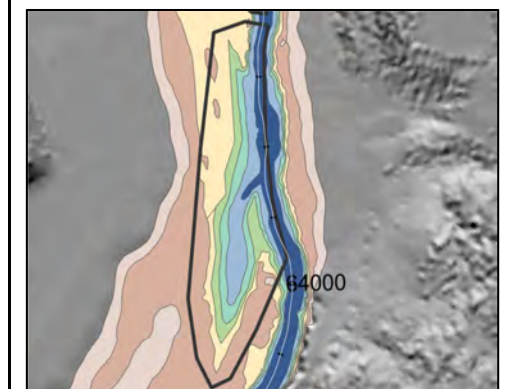
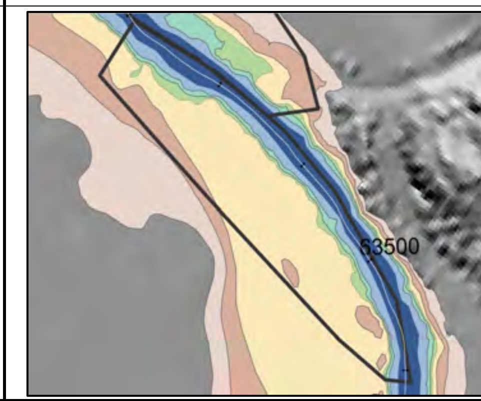
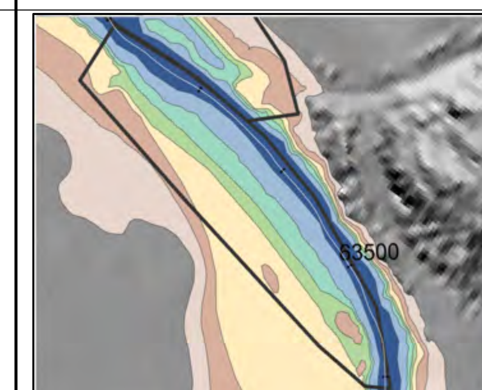
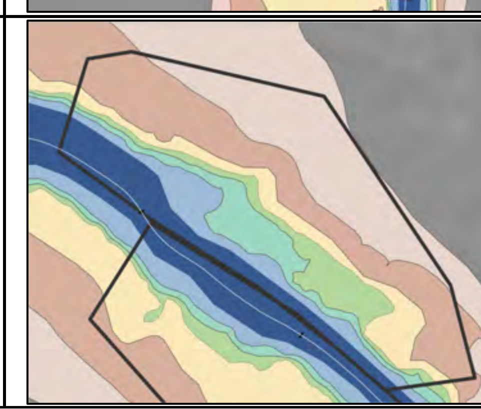
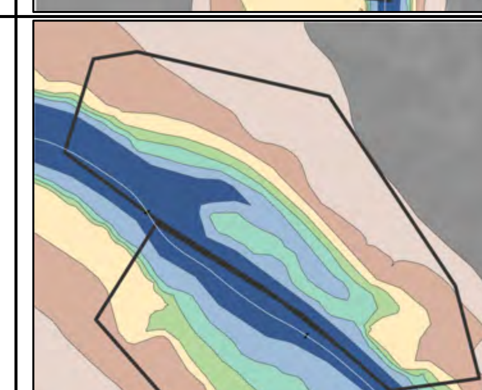


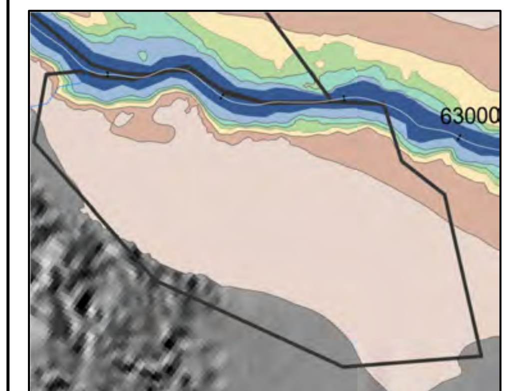
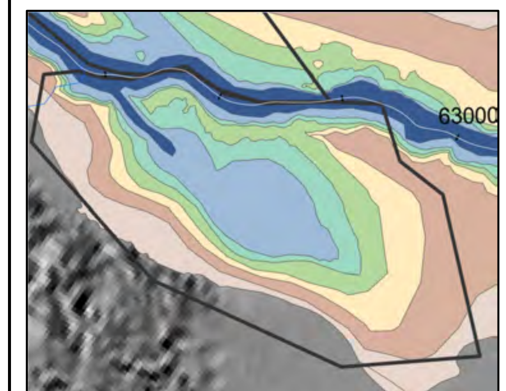
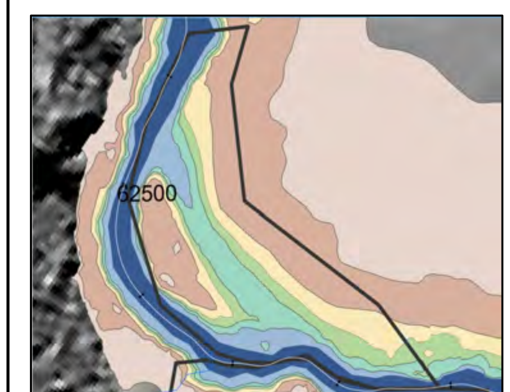
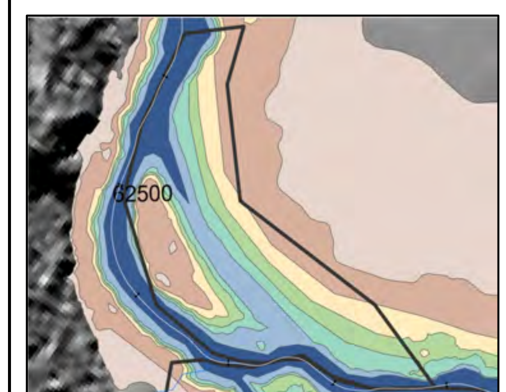
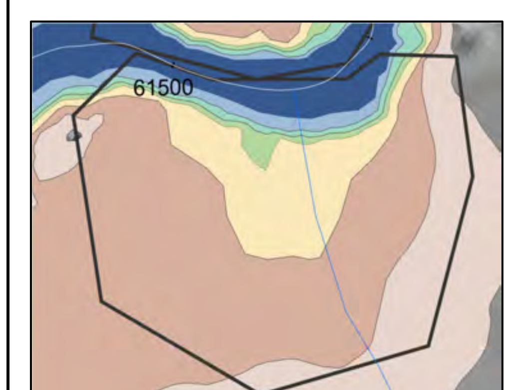
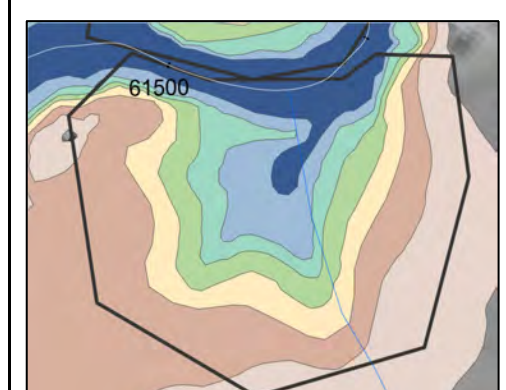
Figure 3-16. Site-specific enhancement sites in South Fork Elk River and adjacent river corridor. Pool-riffle enhancements will occur in association with streambank recontouring (bank), side channel, and channel widening actions. Large wood augmentation will occur as a component of all aquatic enhancement (T) sites. In-channel live vegetation sites (V) are delineated in yellow.

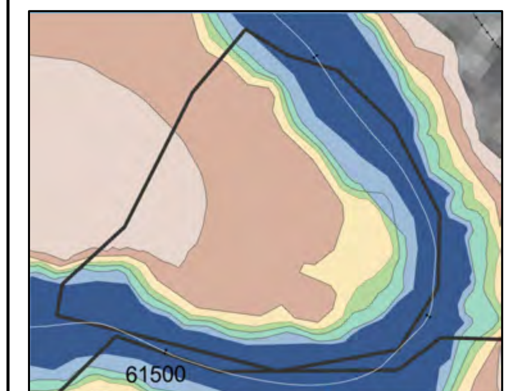
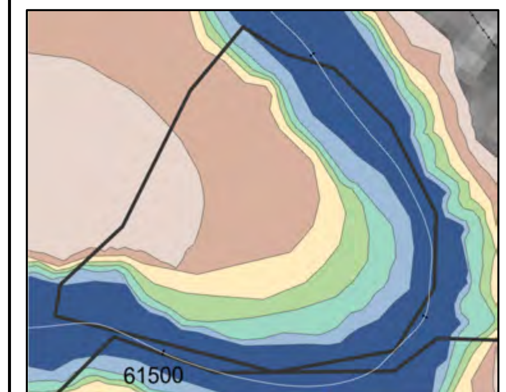
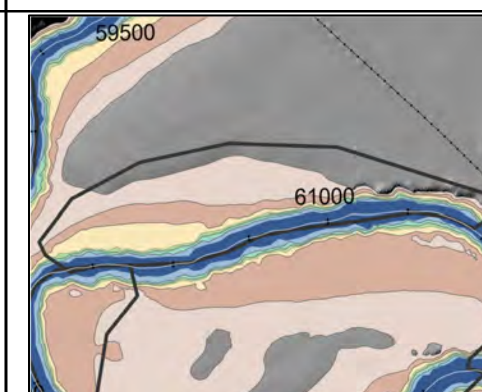
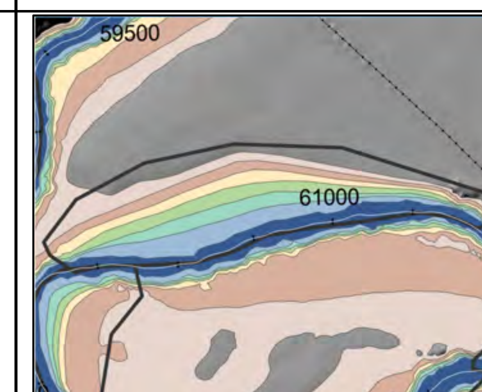
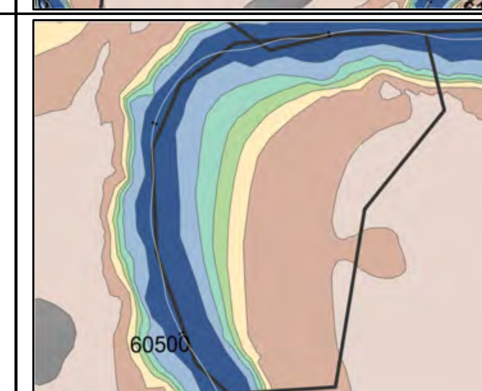
Table 3-3. Summary of design attributes for enhancement areas.

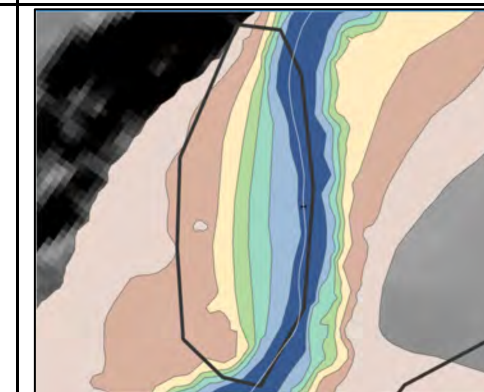
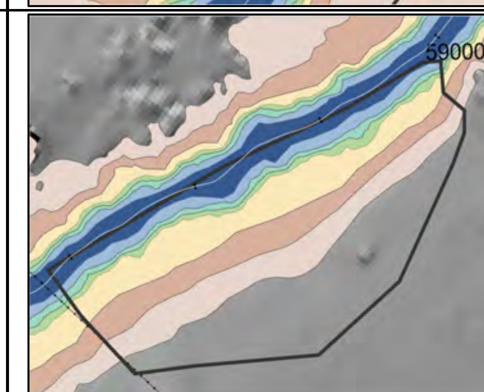
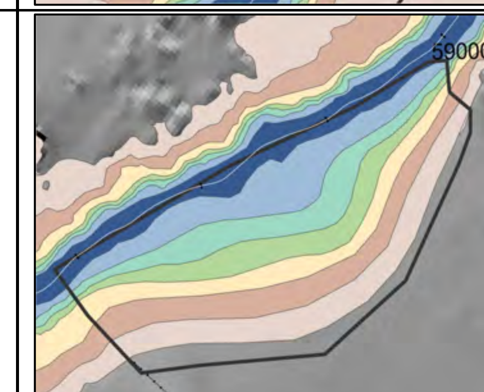
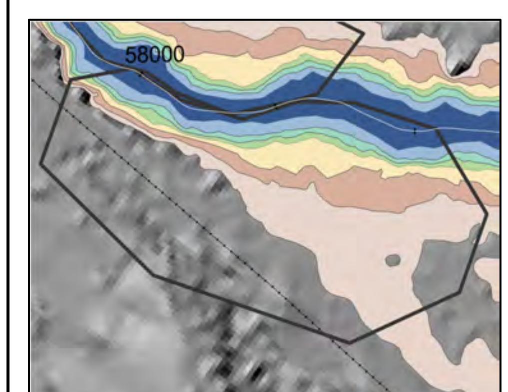
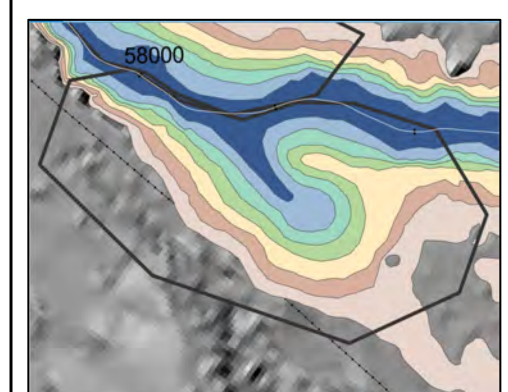
Site	Feature	Station (ft)	Length (ft)	Area (ac)	Cut volume (yd^3)	Increase in inundated area @ 10% exceedance (ft^2)	Increase in inundated area @ 1.053yr (ft^2)	Description	Existing inundation extent	Design inundation extents
T-0a	TG-Alt 1 (channels)	65,750	225	0.720	2,325	31,379	34,117	Develop complex, braided channel network that includes large wood distributed throughout and a new floodplain area with a mosaic of wetland and riparian vegetation. In this design, the Tom's Gulch channel would likely avulse across the complex delta over time. A large wood jam would be strategically constructed in South Fork Elk River downstream of the site to serve as a hydraulic control and facilitate backwatering of large areas of high-quality off-channel habitat during high flows.		
T-0b	TG-Alt 2 (pond)	65,750	225	0.720	5,271	8,700	9,459	Install off-channel pond habitat along lower Tom's Gulch to promote sediment deposition, reduce sedimentation to the mainstem and create low-velocity aquatic habitat. Retain large-diameter mature conifers. Enhance existing riparian zone by interplanting and revegetate disturbed areas with the wetland and riparian mesic planting palettes.		
T-1	Bank†	65,625	255	0.418	504	2,316	3,905	Lay back right bank to increase floodplain connectivity and reduce erosion and sedimentation. Add key pieces of large wood along bank slope perpendicular to flow to create low-velocity refuge across a range of flows. Enhance the sparse and narrow riparian overstory by interplanting with tall overstory hardwoods and expand riparian forest by revegetating adjacent floodplain with riparian mesic planting palettes.		

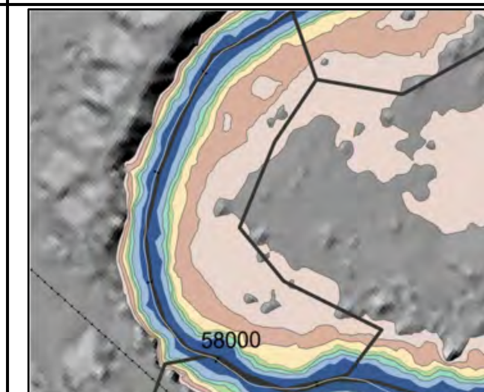
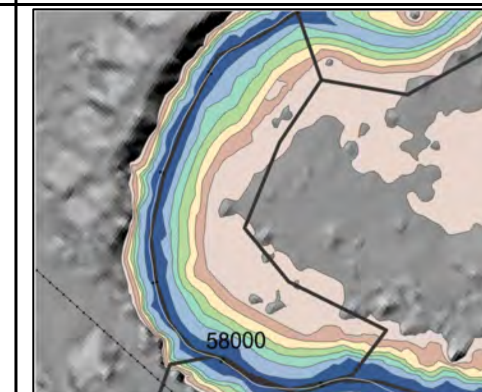
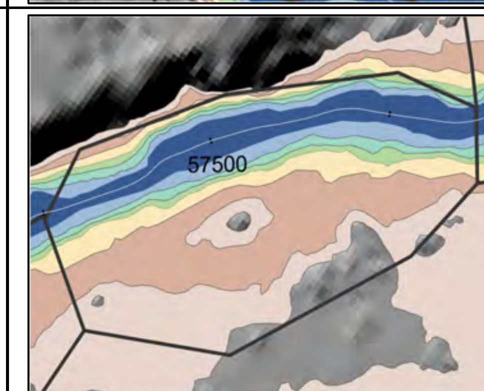
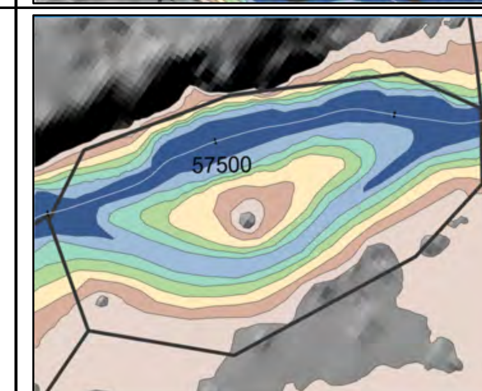
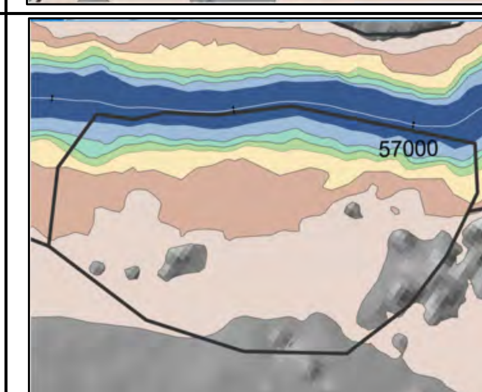
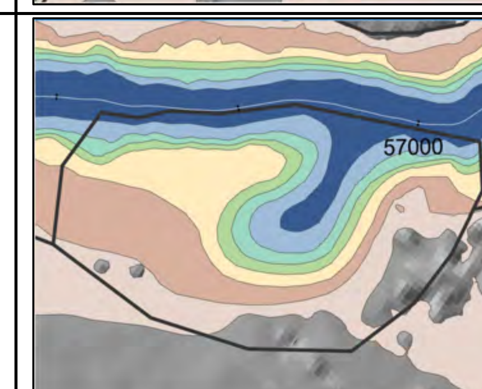
Site	Feature	Station (ft)	Length (ft)	Area (ac)	Cut volume (yd^3)	Increase in inundated area @ 10% exceedance (ft^2)	Increase in inundated area @ 1.053yr (ft^2)	Description	Existing inundation extent	Design inundation extents
T-2	Alcove	64,550	112	0.215	263	509	1,104	Create alcove at confluence of small drainage entering at downstream end of existing low-lying floodplain area. Install large wood to create cover habitat and scour to maintain alcove entrance. Consider installation of grade control (channel-spanning log jam or riffle crest) downstream of entrance. Enhance the sparse and narrow riparian overstory by interplanting with tall overstory hardwoods and expand riparian forest by revegetating adjacent floodplain with riparian mesic planting palettes.		
T-3	Alcove	64,450	162	0.210	137	749	759	Create alcove within existing low-lying inset floodplain on right bank and/or install channel spanning log jam at downstream end to create backwater and maintain grade control. Enhance the sparse and narrow riparian overstory by interplanting with tall overstory hardwoods and expand riparian forest by revegetating adjacent floodplain with riparian mesic planting palettes.		
T-4	Alcove	64,250	153	0.179	256	631	1,012	Create alcove within existing low-lying inset floodplain that is connected to main channel during winter baseflow to provide seamless connectivity into high-quality off-channel rearing habitat across a range of flows. Pair site with adjacent large wood augmentation to improve adjacent in-channel winter habitat, maintain alcove entrance, and increase frequency and extent of inundation. Reroute adjacent small tributary into alcove feature to help maintain connectivity and water quality.		

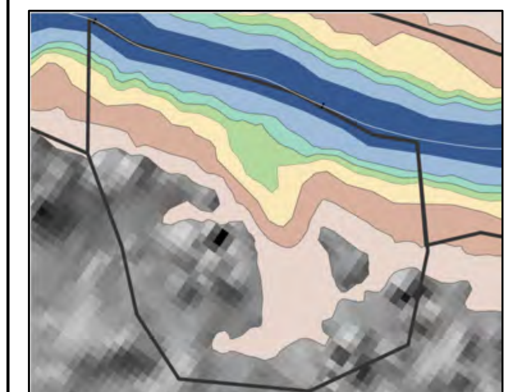
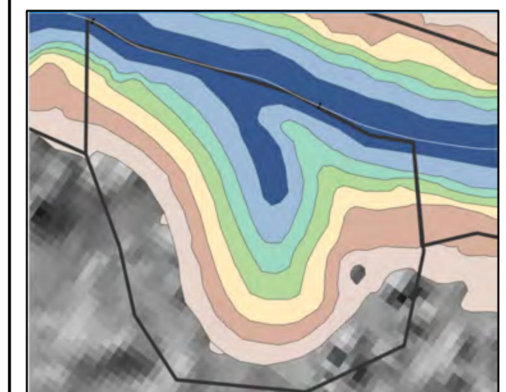
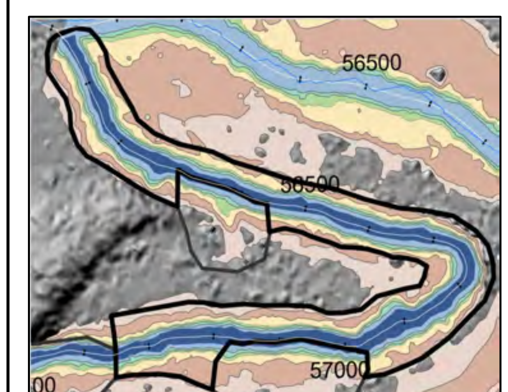
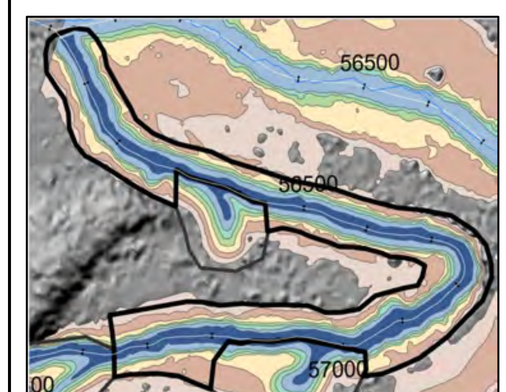
Site	Feature	Station (ft)	Length (ft)	Area (ac)	Cut volume (yd^3)	Increase in inundated area @ 10% exceedance (ft^2)	Increase in inundated area @ 1.053yr (ft^2)	Description	Existing inundation extent	Design inundation extents
T-5	Alcove/ Bank†	63,850	520	1.119	2,044	5,976	10,145	Lower and reconnect large, frequently inundated left bank floodplain and improve connectivity with existing low elevation inset bench along left bank near STA 63,700. Develop alcove habitat and build or augment existing adjacent wood jams to improve mainstem habitat and increase frequency of alcove inundation. Connect this feature with existing lower elevation wetland just downstream of the HRC bridge. Enhance sparse and narrow riparian overstory by interplanting with tall overstory hardwoods and expand riparian forest by revegetating adjacent floodplain with riparian mesic planting palettes.		
T-6	Bank†	63,400	385	0.609	1,638	2,417	5,400	Lay back left bank to increase floodplain connectivity, reduce erosion and sedimentation and enhance riparian habitat. Add large wood perpendicular to flow to create low-velocity refuge across a range of flows. Enhance sparse and narrow riparian overstory by interplanting with tall overstory hardwoods and expand riparian forest by revegetating adjacent floodplain with riparian mesic planting palettes.		
T-7	Alcove	63,250	256	0.382	262	969	1,273	Create alcove on right bank along existing low elevation bench/swale. Utilize large wood to improve habitat across a range of flows and pair with laying back bank and lowering slope if feasible. Enhance sparse and narrow riparian overstory by interplanting with tall overstory hardwoods and expand riparian forest by revegetating adjacent floodplain with riparian mesic planting palettes.		

Site	Feature	Station (ft)	Length (ft)	Area (ac)	Cut volume (yd^3)	Increase in inundated area @ 10% exceedance (ft^2)	Increase in inundated area @ 1.053yr (ft^2)	Description	Existing inundation extent	Design inundation extents
T-8	Wetland/ Alcove	62,800	408	1.229	6,087	8,145	13,622	Create left bank alcove and enhance wetland by lowering existing low-lying floodplain wetland. Create connections to main channel and facilitate inundation with channel-spanning log jams. Consider routing tributary into pond to maintain connectivity and water quality at low flow. Investigate and mitigate source of fine sediment from tributary. Decommission road along left bank and stabilize slopes at downstream end of feature. Revegetate excavated wetland alcove with wetland planting palettes based on anticipated inundation frequency and duration.		
T-9	Side Chan†	62,600	423	0.774	1,067	2,921	3,152	Enhance relic side-channel on right bank. Remove sediment deposits from side-channel outlet and construct channel-spanning wood jam (or augment existing jam) at upstream end to split flow into side-channel and facilitate inundation of adjacent proposed left bank floodplain enhancement (T-8). Place channel-spanning log jam on the downstream side of side-channel inlet to raise water surface elevation and facilitate backwater of alcove-like feature at moderate flows. Remove nonnative invasive understory in existing riparian area and interplant with shade-tolerant natives.		
T-10	Wetland/ Alcove	61,450	266	0.492	1,461	2,030	3,719	Create off-channel alcove feature connected to main-channel on downstream end of right bank floodplain. Integrate existing inset bench on right bank and connect site to existing low elevation wetland and intermittent tributary (Trib at STA 61,450) draining through field. Lower bank slope and add wood to facilitate floodplain connectivity and create low-velocity habitat over range of flows. Enhance riparian vegetation via bank lowering, plantings, bank stabilization and non-native removal.		

Site	Feature	Station (ft)	Length (ft)	Area (ac)	Cut volume (yd^3)	Increase in inundated area @ 10% exceedance (ft^2)	Increase in inundated area @ 1.053yr (ft^2)	Description	Existing inundation extent	Design inundation extents
T-11	Bank†	61,400	203	0.217	389	204	632	Lay back left bank to increase floodplain connectivity and reduce erosion and sedimentation. Add large wood perpendicular to flow to create low-velocity refuge across a range of flows. Enhance riparian vegetation via bank lowering, plantings, bank stabilization and non-native removal. Enhance sparse and narrow riparian overstory by interplanting with tall overstory hardwoods and expand riparian forest by revegetating adjacent floodplain with riparian mesic planting palettes.		
T-12	Bank†	60,900	618	1.134	5,298	5,463	8,818	Lay back right bank to increase floodplain connectivity, reduce erosion and sedimentation and enhance riparian habitat. Add large wood perpendicular to flow to create low-velocity refuge across a range of flows. Perform localized in-channel live vegetation management and sediment removal. Remove nonnative invasive understory in existing riparian area and interplant with shade-tolerant natives.		
T-13	Bank†	60,100	337	0.374	843	579	1,408	Lay back left bank to increase floodplain connectivity, reduce erosion and sedimentation and enhance riparian habitat. Add large wood perpendicular to flow to create low-velocity refuge across a range of flows. Perform localized in-channel live vegetation management and sediment removal. Remove nonnative invasive understory in existing riparian area and interplant with shade-tolerant natives.		

Site	Feature	Station (ft)	Length (ft)	Area (ac)	Cut volume (yd^3)	Increase in inundated area @ 10% exceedance (ft^2)	Increase in inundated area @ 1.053yr (ft^2)	Description	Existing inundation extent	Design inundation extents
T-14	Bank†	59,700	166	0.185	413	483	973	Lay back left bank to enhance off-channel winter rearing habitat and low-velocity refugia and augment existing low-lying left bank feature. Enhance riparian vegetation via bank lowering, plantings, bank stabilization and non-native removal. Enhance riparian vegetation via bank lowering, interplanting with mesic riparian planting palettes, bank stabilization, and nonnative invasive weed removal.		
T-15	Bank†	59,150	395	0.924	4,308	3,410	6,386	Lay back right bank to increase floodplain connectivity, reduce erosion and sedimentation and enhance riparian habitat. Add large wood perpendicular to flow to create low-velocity refuge across a range of flows. Enhance riparian vegetation via bank lowering, interplanting with mesic riparian planting palettes, bank stabilization, and nonnative invasive weed removal.		
T-16	Alcove	58,100	312	0.814	3,070	2,535	4,408	Featureless, plane-bed channel that would benefit from improved habitat complexity. Create alcove in existing low-lying left bank floodplain, lay back banks, and install key pieces of large wood along banks to increase access to velocity refugia and in the main channel to facilitate wood accumulation and backwatering of alcove. Presence of gravel suggests large wood would likely be effective at sorting into coarser patches. Enhance riparian forest by interplanting with tall hardwoods and expand riparian communities by revegetating adjacent floodplain with wetland and/or riparian mesic planting palettes.		

Site	Feature	Station (ft)	Length (ft)	Area (ac)	Cut volume (yd^3)	Increase in inundated area @ 10% exceedance (ft^2)	Increase in inundated area @ 1.053yr (ft^2)	Description	Existing inundation extent	Design inundation extents
T-17	Bank†	57,850	431	0.803	2,059	1,749	3,813	Lay back right bank to increase floodplain connectivity, reduce erosion and sedimentation and enhance riparian habitat. Add large wood perpendicular to flow to create low-velocity refuge across a range of flows. Perform localized live woody vegetation management in channel bed and sediment removal. Enhance existing riparian area by interplanting with shade-tolerant natives.		
T-18	Side Chan†	57,500	240	0.564	2,098	2,497	4,263	Re-connect side channel habitat on right bank. Install complex large wood jams to stabilize mid-channel bar, redirect flows and create scour to maintain pool depths in side channel. Install channel-spanning wood jam at downstream side to maintain grade control and ensure inundation at design flows. Integrate alcove into downstream end of side channel. Enhance existing riparian by interplanting with shade-tolerant natives on laid back streambanks.		
T-19	Alcove	57,050	258	0.501	1,731	2,357	3,395	Excavate alcove into downstream end of slump block on right bank. Install large wood to create cover habitat and scour to maintain alcove entrance. Stabilize slump block and enhance riparian vegetation by interplanting with mesic riparian planting palettes and nonnative invasive weed removal. Protect upstream face of deposit from lateral scour by placing large wood.		

Site	Feature	Station (ft)	Length (ft)	Area (ac)	Cut volume (yd³)	Increase in inundated area @ 10% exceedance (ft²)	Increase in inundated area @ 1.053yr (ft²)	Description	Existing inundation extent	Design inundation extents
T-20	Alcove	56,400	266	0.397	2,242	1,253	2,100	Excavate alcove on existing low-lying left bank feature. Install large wood to create cover habitat and scour to maintain alcove entrance. Install a channel-spanning log jam to provide mainstem habitat complexity and create grade control downstream of entrance. Further upstream (STA 56,700-56,800) add key large wood on left bank downstream of small jam/pool to create alcove habitat on inside bend and expand low-velocity habitat. Add large wood to existing jam at corner pool to take advantage of inside bend in straight reach. Enhance riparian vegetation on low elevation left bank floodplain by planting with mesic riparian and wetland palettes.		
T-21	Channel Widening†	56,000 - 57,350	1,350	2.313	2,478	3,554	3,879	Widen channel to increase conveyance capacity and reduce downstream flooding. Regrade unstable streambanks to mitigate bank erosion and rotational failures, remove legacy sediment deposits and increase floodplain connectivity. Install large wood on re-graded streambanks perpendicular to flow to create low-velocity habitat refugia over range of flows. Recontour channel bed to restore natural riffle-pool morphology, including excavation of pools and addition of large wood to enhance depth and improve aquatic habitat. Enhance riparian zone through shade-tolerant plantings, manage in-channel live woody vegetation.		

3.4.1 Sediment load reduction from tributary sites

Tom's Gulch is the largest tributary within the planning reach. The confluence zone of Tom's Gulch and South Fork Elk River was identified as an area where limited sediment reduction from Tom's Gulch could occur, coupled with habitat enhancements. Additional opportunities for sediment load reduction likely occur further upstream; however, they were not evaluated as part of this project. Sediment load reduction in the upper watershed will improve the quality and longevity of enhancement in the Project area.

This action is described in more detail in section 3.4.3 Aquatic Habitat Enhancement since the habitat enhancement components are primary and the sediment load reduction is a secondary objective. In brief, two alternatives are proposed: 1) multi-channel (Alt 1, Figure 3-17) and 2) an off-channel pond option (Alt 2, Figure 3-17). Sediment retention will occur in both areas, slowly aggrading the constructed features over time. Alt 1 will accumulate sediments from both Tom's Gulch and South Fork Elk River, while Alt 2 will accumulate sediment from Tom's Gulch only.

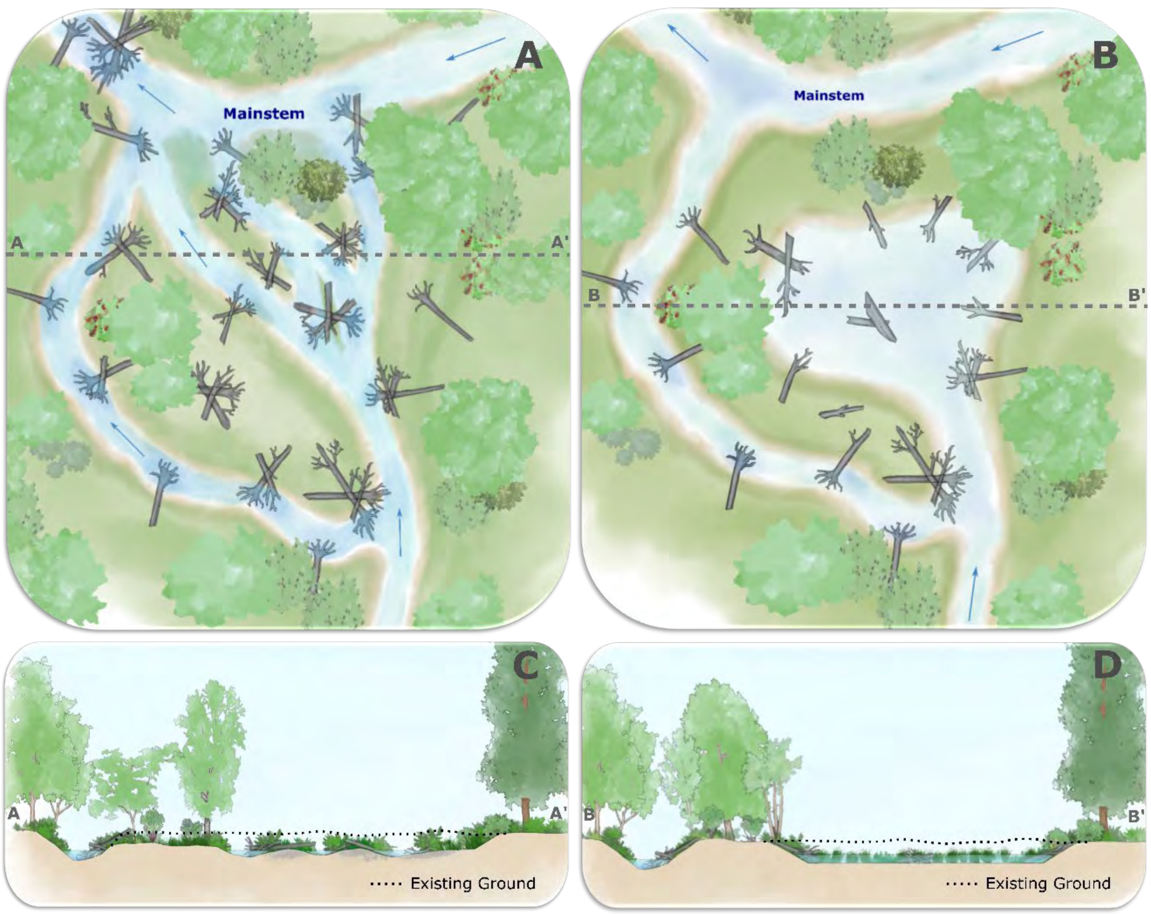


Figure 3-17. Planview and cross-sectional illustrations of confluence enhancement, which includes a multi-channel alternative (A and C, respectively) and off-channel pond alternative (B and D, respectively) at Tom's Gulch.

Both alternatives are expected to trap a small fraction of the total sediment loads generated in Tom's Gulch/South Fork and are not considered a substitute for actions that control sediment at the source. These actions will not increase the assimilative capacity of the Elk River because sedimentation will reduce the function and longevity of the habitats created. Lowering sediment deliveries from the upper watershed will improve the longevity of the constructed habitats.

Larger sediment basins were proposed in the floodplain of the South Fork Elk River immediately downstream of Tom's Gulch as a mechanism of trapping more sediment. These sediment basins were evaluated to determine whether they would be effective at reducing suspended sediment concentrations. The results of the analysis (Appendix C) indicated that off-channel sediment basins in South Fork Elk River did not significantly reduce suspended sediment concentrations and were not moved forward as part of the 10% designs.

A small tributary enters South Fork Elk River at STA 62,585. This tributary has a notably high sediment supply and has created a fan deposit on the floodplain before entering the river. Re-routing this tributary into the expanded freshwater wetland (T-8) would considerably enhance the wetland function, but only if the sediment supply from the tributary can be reduced or managed to avoid filling the wetland.

3.4.2 Sediment remediation of in-channel aggradation sites

Sediment remediated in the Project area at all enhancement sites where sediment is excavated from the channel bed and banks including aquatic enhancement sites that include streambank recontouring, side channel, alcove and pool enhancements and occur throughout the Project reach. Channel widening (T-21) is located at the downstream end of South Fork in a reach than has substantial sediment accumulation on the banks. This site was selected primarily based on sediment remediation objectives, but also provides aquatic. There are 19 sites that have sediment remediation benefits (Figure 3-16) with a total volume of approximately 31,000 CY sediment removed from the channel bed and banks.

This design will not increase the assimilative capacity of the Elk River because sedimentation will reduce the longevity of the habitats created at these sites. Lowering sediment deliveries from the upper watershed will improve the longevity of the constructed habitats.

3.4.3 Aquatic habitat sites

Aquatic habitat enhancement sites occupy 15.2 acres of the Project area with approximately 53,000 CY of excavation. (Table 3-3). The enhancement sites include stream bank recontouring (8 sites), alcove development (8 sites), side channel enhancement (2 sites), and a major tributary confluence enhancement (1 site) (Figure 3-16). Proposed freshwater wetlands (2 sites; Section 3.4.6) are also proposed to have expansive alcoves connected to the stream channel at their inlets that will provide high-quality juvenile salmonid rearing habitat across a range of flows. Pool-riffle enhancements (11 sites) will be implemented adjacent to stream bank recontouring sites, side channels, alcoves, and tributary confluences to improve main channel habitat adjacent to these sites. Pool-riffle enhancements will also be implemented within the zone targeted for channel widening (T-21; Figure 3). Large wood will be incorporated into all enhancement sites (22 sites). Side channels and alcoves enhancements will generally be implemented at locations where these features currently exist but have been filled in with sediment, making them inaccessible by fish at typical winter flows.

Example illustrations of proposed enhancements of an alcove at T-4 is provided in Figure 3-9, side channel at T-9 in Figure 3-8, freshwater wetland at T-8 in Figure 3-13 and Figure 3-14, stream bank recontouring at T-12 in Figure 3-3, and adjacent pool-riffle enhancements at T-12 in

Figure 3-4 and Figure 3-5. Detailed descriptions of all enhancement sites are provided in Table 3-3.

Two enhancement alternatives were developed for Tom's Gulch/South Fork confluence area (site T-0). This site is 0.72 acres extends along the lower ~225 ft of Tom's Gulch, from the confluence to the first road crossing over Tom's Gulch. Under existing conditions, the floodplain within this area is inundated by South Fork Elk River and Tom's Gulch. South Fork Elk River substantially backwaters the Tom's Gulch channel within the Project reach.

Alternative 1 (T-0a) consists of lowering the floodplain to develop a complex, multi-channel network, that includes large wood distributed throughout the new channel network and lowered floodplain area and planted with and a mosaic of wetland/riparian vegetation (Figure 3-17, Appendix B, Tables B-1 and B-2). The volume excavated is 5,271 CY. Tom's Gulch channel would initially occupy its existing low flow channel. As flows increase (<10% exceedance flow), Tom's Gulch would spread across the multi-channels. South Fork Elk River would also inundate the new channel network. Winter flows in Tom's Gulch and South Fork are expected to create depositional patterns across the channel network that would result in a dynamic channel pattern. Juvenile salmonids and other aquatic species could access the multi-channel area from South Fork Elk River or Tom's Gulch during winter base flow and storm flows. A large wood jam would be strategically constructed in South Fork Elk River downstream of the site to serve as a hydraulic control and facilitate backwatering of large areas of high-quality off-channel habitat at the site.

Alternative 2 (T-0a) includes retaining the existing alignment of Tom's Gulch and excavating an off-channel pond in the same footprint as Alt 1 with a total cut volume of 2,325 CY. The off-channel pond is connected to Tom's Gulch with a single inlet/outlet (Figure 3-17). Tom's Gulch channel would be enhanced with large wood and the off-channel pond includes large wood to form conditions suitable for emergent persistent hydrophyte establishment (Appendix B, Table B-2). The perimeter of the off-channel pond would be vegetated with a mix of riparian hardwood species (Appendix B, Table B-1) and any existing high value trees would be retained.

A primary focus of the aquatic habitat enhancement actions at these sites is to improve low-velocity winter rearing habitats for juvenile salmonids by constructing or enhancing existing alcove, side channel, and connected-floodplain habitats.

The hydrodynamic model described in Section 2.2.2 was used to estimate the potential increase in area of low-velocity off-channel between existing and design conditions. Inundation areas within the footprint of proposed enhancement sites during existing conditions were predicted using the hydraulic model described in Section 2.2.2. Inundation extents within the same footprint for the design concepts were approximated based on modified ground topography and existing water levels. The results of the comparison indicate that the proposed actions (i.e., alcoves, side channels, large wood additions, etc.) would result in significant increases in inundation area for smaller, more frequent flows events (Table 3-4), potentially increasing low-velocity winter rearing habitat by roughly 14–22% for flows between the 10% exceedance and 1.11-year event. It is important to note, however, that additional hydraulic modeling would need to be performed to quantify flow velocities and inundation extents more precisely in the design channel.

Table 3-4. Inundation areas of proposed enhancement footprints for existing conditions and design scenarios over the range of design flows.

Flow magnitude	Cumulative inundation area (acres)			
	Existing	Design	Difference	% Change
Low Flow Channel	4.4	4.6	0.1	3.3
10% Exceedance	8.0	9.1	1.2	14.5
1.053-year Peak Flow	9.9	11.8	1.9	19.4
1.11-year Peak Flow	11.7	14.4	2.7	22.9
1.25-year Peak Flow	18.2	20.3	2.1	11.4
1.5-year Peak Flow	32.8	34.5	1.7	5.2
2-year Peak Flow	51.3	51.7	0.5	0.9

The results of the cost/benefit analysis (Appendix D) indicate that in general, more winter rearing habitat is gained per unit of cut volume in the upper reaches of the project site relative to the lower reaches (i.e., upstream of STA 62,300; Figure 5-1). This is primarily because the lower reaches are characterized by considerably more channel entrenchment—necessitating more excavation to achieve an equivalent increase in habitat area relative to the less entrenched upper reaches. The cost-benefit analysis also underscores the fact that, with the exception of Tom's Gulch confluence actions (Alt 2 T-0-off-channel pond and Alt 1 T-0-multi-channel), enhancement of existing low elevation features such as alcoves and side channels generally yield more habitat benefit per unit cost and should therefore be prioritized (Appendix D). On average, the two design alternatives for the Tom's Gulch confluence (i.e., multi-channel and off-channel pond) offer the largest increase winter rearing habitat relative to the cost (Appendix D).

It should be noted that the habitat benefits associated with several enhancement actions are less amenable to direct quantification (e.g., vegetation mgmt.). As these actions play an integral role in long-term project success (e.g., healthy riparian vegetation provides a sustainable source for large wood recruitment), their benefits will be discussed in a qualitative sense.

3.4.4 Floodplain connectivity and recontouring sites

Increasing floodplain connectivity is primarily achieved through expansion of freshwater wetlands (2 sites), stream bank recontouring (8 sites), side channel (2 sites) and alcove enhancements (8 sites) (Figure 3-16). Reductions in water level due to increased channel conveyance are offset by the creation of lower floodplain surfaces that provide a net increase in floodplain connectivity. Expanded alcove, wetland, and side channel areas are expected to locally increase groundwater levels due to more frequent inundation. Additional areas of floodplain recontouring may be developed on SRL property during the next design phase based on agency feedback on the 10% designs.

3.4.5 Nonnative vegetation removal

Due to the expansive and significant extent of nonnative invasive weed occurrences documented throughout the South Fork Project reach the development of a nonnative weed management strategy and implementation plan will aid in identifying the best actions for successful control and removal of invasive weeds. An on-site assessment to identify abundance and density of documented understory invasive weed occurrences will inform the strategies discussed in this plan. The plan will describe various strategies for control and removal based on landowner preferred management and priority, the most effective management activity by location (e.g., mechanical, chemical, cultural), and assess the level of effort required for control and maintenance. A pre-construction weed removal effort to control nonnative seed dispersal into design features will also be evaluated. Further discussion on this plan is provided in Section 3.3.5.

3.4.6 Riparian habitat restoration sites

Instream vegetation management in the form of thinning or removal of live wood will be focused in reaches near infrastructure that have high in-channel encroachment by low to mid-story shrubs, including channel-spanning fallen live wood (e.g., Figure 3-12). The existing overstory canopy will be preserved and in-stream vegetation removal and thinning will occur alongside other actions such as laying back the channel bed, addition of large wood, and removal of nonnative invasives in the understory (desired future condition shown in Figure 3-12).

The South Fork Elk River riparian enhancement and revegetation approach included a review of the biophysical controls associated with riparian establishment (i.e., elevation above water table, flood (overland flow) frequency and duration, and soil conditions). Results from this assessment generated a series of planting zones that would guide the formation of various planting palettes based on species form (i.e., tree, shrub, herb, deciduous or evergreen) and habit (e.g., shade-tolerant, growth form, water requirement, soil preference, growth rate). Species selection would include native species known to the watershed or region.

Mesic, transitional, and xeric vegetation zone elevations were defined in the North Fork Elk River based on relative elevation above the riffle crest (used as a proxy for the summer water table and therefore assumed the driest seasonal condition) correlated with intact riparian vegetation communities along the North Fork (McBain Associates 2020). To assign planting zones in the South Fork, these defined vegetation zones (i.e., mesic, transitional, and xeric [0 to 15 feet, 15–25 feet, >25 feet height above riffle crest elevation, respectively]) were applied within the project's boundaries and overlayed with the modeled flood inundation boundaries to account for the varied annual inundation durations. The modeled inundations were assigned a generalized water regime (i.e., 10% exceedance [frequently flooded], 1.5-year flood [infrequently flooded (A)], 1.5–year to 2-year flood [infrequently flooded (B)], and all modeled inundations exceeding the 2-year flood [rarely flooded]) that further divided the three vegetation zones. Per the Natural Resources Conservation Service (NRCS) Web Soil Survey, the entire Project was mapped as Weott, 0 to 2 percent slopes. This mapped soil phase of the Weott series is associated with prime farmland (if irrigated and drained) that is formed of silt loam in the A and B soil horizons (0 to 60 inches of the soil profile) and has a hydric soil rating in the region (NRCS 2021). As such, soils were not considered restrictive, and no further division was assigned. The seven planting zones generated for the Project are provided in Figure 3-18.

Planting palettes were compiled to form riparian habitats with native species assemblages known to co-occur in the region and create a varied structure based on the assigned habitat (Appendix B, Table B-1). Planting palettes were assigned to one or more planting zones based on the existing or recommended habitat conditions within each planting zone.

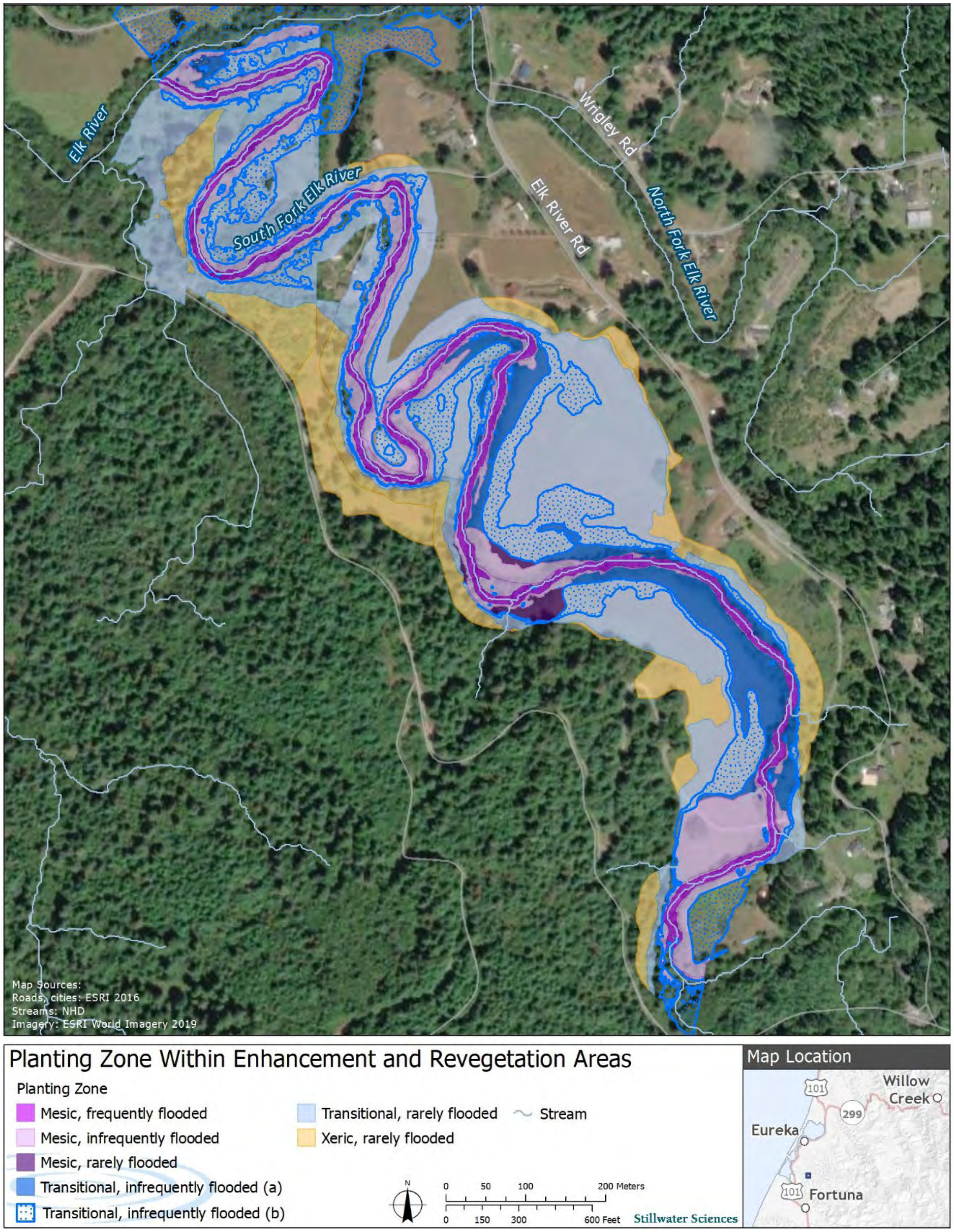


Figure 3-18. Planting zones within the riparian enhancement and revegetation areas in the Project.

Enhancement areas ideal for interplanting were defined as existing riparian forest or shrublands with low overstory cover, low species richness, lacking range in vertical structure, areas with disturbed banks, and areas where the understory will be disturbed by invasive weed management action. Features within the enhancement action area occurred in the mesic frequently and infrequently flooded planting zones (Figure 3-18). Species selected for interplanting within the riparian corridor, where existing overstory vegetation is present and understory invasive weeds will be removed, will require different traits (e.g., shade tolerant) then the revegetation action area that is void of shrub and tree cover. As such, the planting palettes associated with the enhancement areas include species tolerant of full or part-shade conditions with the ability to withstand moderate to high soil moisture and inundation rates that also have a fast growth rate and upright form. Planting palettes for mesic frequently and infrequently flooded planting zones are provided in Appendix B, Table B-1. Planting palettes in the mesic, frequently flooded zone include hardwood-only tree and shrub species whereas the mesic, infrequently flooded planting zone adds shade-tolerant evergreen conifers in addition to deciduous hardwoods. To encourage riparian hardwood dominant forest remain prevalent along the channel in future successional stages, conifer planting in the enhancement areas would occur in patches rather than in continuous bands along the reach.

SRL owns roughly 77 acres of undeveloped lands adjacent the South Fork and are supportive of restoring and maintaining riparian and seasonal wetland habitats on floodplains that were former pasture lands (i.e., revegetation area). Riparian habitat restoration activities associated with the expansion of native riparian vegetation communities into revegetation area were associated with all planting zones excluding mesic, frequently flooded (Figure 3-18, Appendix B Table B-1). Planting palettes applicable to the revegetation area are associated with varied forest and herbaceous habitats with the following characteristics:

- Riparian hardwood continuous, closed overstory canopy, low shrub cover, high herbaceous cover
- Riparian hardwood continuous overstory canopy, limited evergreen conifer component, moderate shrub cover, low herbaceous understory
- Mixed hardwood and shade-tolerant coniferous overstory, low shrub cover, high herbaceous understory
- Open herbaceous meadow, occasionally moist
- Upland coniferous forest, continuous overstory canopy, low/moderate shrub, moderate to high herbaceous cover

Recontouring of the revegetation area to form additional persistent wetland features in the floodplain may be incorporated into the design (see Section 3.4.4 and 3.4.6). The wetland planting palettes provided in Appendix B, Table B-2 would apply to any potential design features associated with this action. Terrestrial habitat structures will also be assessed and incorporated into the revegetation design. Structures such as downed wood, installed snags, and brush piles would provide additional invertebrate and amphibian habitat as well as nesting, perching, and roosting habitat for bats and birds.

Riparian enhancement and revegetation actions may differ in implementation. One phased approach to planting may resemble starting with nonnative weed management along with other channel modifications associated with Project design actions, followed by riparian enhancement interplanting and wetland creation, and then move towards the more expansive planting associated with revegetation of the floodplain. The approach for these actions will be refined in later project phases.

3.4.7 Freshwater wetland sites

Opportunities for freshwater wetland enhancement/restoration in the South Fork are primarily concentrated on SRL property. Restoring and maintaining seasonal wetland habitat is proposed in the mesic and transitional planting zones of the revegetation area (Figure 3-18). The proposed wetland features will be excavated in adjacent low-lying floodplain areas and planted with a mosaic of perennial and seasonal freshwater wetland and riparian herbs, forbs, graminoids, shrubs and tree species, with some areas maintained as open meadow (mesic grassland) habitat (Appendix B, Tables B-1 and B-2). The perennial freshwater marsh planting palette includes species well-adapted to long-duration ponding and will be suitable to deeper portions of the restored wetlands. The seasonal freshwater marsh, mesic grassland, and riparian planting palettes will be applied to the outer wetland boundaries anticipated to be seasonally inundated or saturated during a portion of the growing season. Application of these varied planting palettes is intended to form a continuous but diverse gradient of wetlands within each feature. In addition to creating high-quality wetland habitat, these features will function as alcoves where they connect to the mainstem, providing excellent off-channel rearing and high flow refugia habitat for juvenile salmonids, as well as a potential site for off-channel sediment deposition and flood storage. and Figure 3-13 and Figure 3-14 provide plan view and cross-sectional illustrations of a proposed wetland site on SRL property (STA 62,600–63,500), which is connected to the South Fork mainstem at the downstream end—creating low-velocity alcove habitat.

3.4.8 Community health and safety sites

The primary objective for improving community health and safety is to reduce nuisance flooding and restore the domestic water supply. Within the planning reach, flooding issues include flooding of one residence, nuisance flooding of property, and access problems for all residents due to flooding of the Elk River Flood Curve down to the North Fork/South Fork confluence (roughly 100ft downstream of the intersection of Elk River Road and Wrigley Road).

Infrastructure modifications to Elk River Road, the North Fork concrete bridge, and homes (i.e. house raising) in the planning reach may be an effective means of reducing flood inundation frequencies. However, these actions are outside the scope of this planning effort but are included in the Elk River Recovery Plan (CalTrout, et. al., in progress). Similarly, actions to restore the domestic water supply are outside the scope of this planning effort, therefore specific actions are not proposed. Regional Water Board staff are currently conducting health and safety surveys to collect information that will inform outreach to other agencies that have the mandate, expertise, and resources necessary to develop solutions to health and safety issues. For example, the State Water Resources Control Board Division of Drinking Water has been consulted regarding information needed to pursue drinking water supply grants.

Actions that reduce nuisance flooding are focused in the residential areas downstream of STA 61,450. Actions include channel widening (1 site) along 1,300 ft of stream channel, streambank recontouring to increases channel conveyance capacity (8 sites), and management of live woody vegetation encroachment within the channel bed (18 sites).

3.5 Project Benefits

The Project is designed to meet multiple objectives including ecological, water quality, floodplain, sediment, flooding, land-use, and vegetation as described in Section 3.1.

The Ecological objective is to restore natural channel and floodplain features and functions that support productive native aquatic and riparian ecosystems. As detailed in Sections 3.3 and 3.4, the proposed design concepts will directly address this objective, providing a host of ecological benefits for native salmonids and other aquatic and terrestrial species, including:

1. Creation of more complex in-channel habitat with more natural pool-riffle morphology and geomorphic function;
2. Increasing inundation area of and connectivity with off-channel habitat features (alcoves, side-channels, floodplain wetlands) to provide high-quality habitats for salmonid winter rearing and other species while adding to the overall complexity of the river corridor;
3. Reducing fine sediment impairments that aggrade the channel and limit macroinvertebrate and fish productivity; and
4. Improving riparian vegetation conditions (see Vegetation objective).

As described in Section 3.4.3 and Appendix D, implementing the proposed aquatic habitat restoration actions would markedly increase the area of low-velocity winter rearing habitat by increasing inundation area in the planning reach by a total of 1.2 acres (14.5%) at the 10% exceedance flow (158 cfs) and 2.7 acres (22%) at the 1.11-year recurrence interval peak flow (454 cfs).

The Water Quality objective aims to protect and restore water quality from impairment by suspended sediment and turbidity, water temperature, dissolved oxygen, and coliform bacteria. Impairments related to suspended sediment and turbidity are addressed by actions that reduce sediment supply or control erosion of stored sediments. Tributary confluence enhancements in Tom’s Gulch and tributary at STA 62,585 are intended to trap and store a portion of the sediment load prior to the tributary discharging into South Fork. Removal of unstable sediments from channel banks through stream channel recontouring would reduce the potential for sediment discharges in the channel (such as from bank failure). Increasing inundation of floodplains will provide additional areas for sediment to settle. And expanding wetland areas and alcoves will naturally filter out fine sediments.

While these actions are expected to reduce suspended sediment and turbidity, the decrease is expected to be minor because the primary sources of sediment delivery to the planning area are in the upper watershed. Dissolved oxygen levels are seasonally impaired in South Fork. Project actions may improve dissolved oxygen levels, particularly in the lower portion of the planning area (downstream of Tributary at STA 61,450) where storage of very fine sediment and organic matter across the channel bed would be reduced through actions that improve flow conveyance and sediment sorting. Water temperature and coliform are expected to remain at their current levels.

The Floodplain objective is to increase channel conveyance capacity while maintaining or improving floodplain connectivity and high flow refugia for juvenile fish and minimizing stranding. This objective is achieved through a combination of channel widening and recontouring of stream banks to improve channel conveyance capacity, which is coupled with strategic placement of large wood and alcoves to provide high flow refugia in the channel and floodplains. All Project actions that extend into the floodplain are intended to drain toward the channel and are paired, where possible, with tributary flow to minimize the risk of stranding.

The Sediment objective is to encourage sediment sorting to improve substrate quality and sediment trapping that reduces fine sediment supply to downstream reaches. This objective seeks to mitigate in-channel legacy sediment deposits, as well as reduce ongoing sedimentation issues associated with erosion of unstable streambanks and excessive sediment loading from tributaries. This objective is addressed through the addition of large wood which results in complex flow patterns that aid in sediment sorting, removal of excess fine sediment from the bed and banks, increased floodplain inundation that will aid in sediment trapping, and enhancements at tributary confluences which trap and store fine sediments.

The Flooding objective includes reducing nuisance flooding by increasing channel conveyance capacity, improving floodplain connectivity, and upgrading drainage infrastructure. Actions that address nuisance flooding include stream bank recontouring, channel widening, and selective in-channel vegetation management to reduce areas with dense live woody species encroachment on the channel bed and raising the home at risk of flooding. These actions are concentrating in the downstream of Tributary at STA 61,450. The decrease in nuisance flooding is expected to be less than reported in CalTrout et al. (2019) because the channel bed is not being lowered. This value will be quantified during the next design phase.

The Land Use objective is to maintain and protect existing rural land uses and access to potable water supplies. This objective is addressed through identifying opportunities and constraints in coordination with landowners and ensuring the Project designs complement their existing land-use and accommodate their future plans for their properties. This dialogue will be on-going throughout the design process.

The Vegetation objective is two-fold: (1) enhance the existing narrow riparian corridor by reducing nonnative understory weeds, decrease dense live woody vegetation encroachment on the channel bed, and interplant with mostly native deciduous hardwoods and some shade-tolerant conifers to promote a self-sustaining riparian forest with improved species composition and structure; and (2) expand riparian vegetation into the adjacent floodplain by revegetating with various native plant assemblages to form a complex of forested, shrubland, and herbaceous vegetation communities. These actions will improve function of the riparian ecosystem over the long-term since they will increase plant species richness, maintain shaded stream cover over the channel, stabilize streambanks, increase aquatic and terrestrial habitat diversity, provide a more varied and year-round food and shelter resource for wildlife, and limit/control the future spread of nonnative weed populations.

4 NEXT STEPS

The actions described in this report are intended to be advanced to implementation through additional phases of planning, design, and permitting with input from landowners, agencies, and other stakeholders. During the next phase of planning, site specific wood jam designs, planting layouts, enhancements for in-channel live vegetation, plans for invasive weed management, and development of riparian enhancement and revegetation implementation approach. Grading sites and volumes will be refined. Identification of fill sites, access routes, stockpile, and staging areas will be identified. Engineering plans and specifications will be developed. The following data and analyses are required to support the next phase of planning:

- Updated topography
  - Estimated volumes are based on LiDAR data collected in 2005. Limited longitudinal surveys were collected in 2012 and indicate that the channel topography may have errors on the order of several feet
- Installation of groundwater monitoring wells

  - Support revegetation designs
  - Inform feasibility assessment and design of floodplain wetlands
- Soil borings in sediment removal areas
  - Evaluation of sediments for reuse of floodplains
  - Characterize depth to confining layers which may affect subsurface flow
  - Characterize material for revegetation within deeper excavations (wetland areas)
- Hydraulic analysis
  - Evaluate the effect of the project on flood levels
  - Refine habitat analysis
  - Refine cost-benefit analysis (quantify low-velocity habitat due to enhancement actions)
  - Hydraulic analysis of log jams and in-stream structures
- Sediment transport analysis
  - Quantify sedimentation rates in enhancement areas
  - Evaluate project effect on overall sedimentation rates in the South Fork
  - Evaluate project effect on suspended sediment concentrations

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Appendices

Appendix A

Existing Large Wood Counts and Deficits by Habitat Unit

Table A-1. Existing large wood counts and deficits by habitat unit. C&R 2007 refers to Carroll & Robison 2007.

Reach (ft)	Habitat unit	Unit length (ft)	Station (ft)	Jam in unit	Existing wood counts			Existing large wood deficits		
					Count	Volume ft³	Key pieces	Count needed (C&R 2007)	Volume needed ft³ (C&R 2007)	Key pieces needed (Fitzgerald 2004)
56000 to 58400	SFE-001	34	56,031	0	0	0	0	2.2	416	0.3
56000 to 58400	SFE-002	27	56,046	0	2	39	0	0.0	294	0.2
56000 to 58400	SFE-003	63	56,072	0	0	0	0	4.1	770	0.5
56000 to 58400	SFE-004	44	56,110	0	0	0	0	2.9	536	0.4
56000 to 58400	SFE-005	36	56,169	0	4	483	1	0.0	0	0.0
56000 to 58400	SFE-006	47	56,208	0	1	31	0	2.1	540	0.4
56000 to 58400	SFE-007	28	56,247	0	1	8	0	0.8	330	0.2
56000 to 58400	SFE-008	84	56,287	0	0	0	0	5.5	1020	0.7
56000 to 58400	SFE-009	92	56,367	0	9	175	0	0.0	950	0.7
56000 to 58400	SFE-010	39	56,447	0	0	0	0	2.5	472	0.3
56000 to 58400	SFE-011	28	56,505	0	1	4	0	0.8	336	0.2
56000 to 58400	SFE-012	70	56,513	0	2	39	0	2.5	810	0.6
56000 to 58400	SFE-013	189	56,582	Y	23	887	1	0.0	1568	0.5
56000 to 58400	SFE-014	83	56,783	0	2	15	0	3.4	999	0.7
56000 to 58400	SFE-015	58	56,877	0	0	0	0	3.8	705	0.5
56000 to 58400	SFE-016	38	56,943	0	1	4	0	1.4	454	0.3
56000 to 58400	SFE-017	36	56,985	0	4	46	0	0.0	389	0.3
56000 to 58400	SFE-018	19	56,991	0	0	0	0	1.2	225	0.1
56000 to 58400	SFE-019	40	57,030	0	0	0	0	2.6	488	0.3
56000 to 58400	SFE-020	37	57,086	0	0	0	0	2.4	449	0.3
56000 to 58400	SFE-021	71	57,110	0	5	256	0	0.0	609	0.6
56000 to 58400	SFE-022	27	57,155	0	0	0	0	1.8	334	0.2
56000 to 58400	SFE-023	85	57,191	0	4	101	0	1.6	937	0.7

Reach (ft)	Habitat unit	Unit length (ft)	Station (ft)	Jam in unit	Existing **wood** counts			Existing **large wood** deficits		
					Count	Volume ft³	Key pieces	Count needed (C & R 2007)	Volume needed ft³ (C & R 2007)	Key pieces needed (Fitzgerald 2004)
56000 to 58400	SFE-024	193	57,294	0	9	607	2	5.1	1987	0.0
56000 to 58400	SFE-025	28	57,482	0	3	21	0	0.0	320	0.2
56000 to 58400	SFE-026	178	57,499	0	6	97	0	5.6	2069	1.4
56000 to 58400	SFE-027	64	57,656	0	2	11	0	2.2	766	0.5
56000 to 58400	SFE-028	212	57,753	0	6	74	0	7.8	2503	1.7
56000 to 58400	SFE-029	49	57,968	Y	17	446	0	0.0	153	0.4
56000 to 58400	SFE-030	100	58,043	0	2	7	0	4.5	1212	0.8
56000 to 58400	SFE-031	52	58,132	0	4	98	0	0.0	540	0.4
56000 to 58400	SFE-032	27	58,163	0	4	77	0	0.0	255	0.2
56000 to 58400	SFE-033	105	58,193	0	5	161	0	1.8	1117	0.8
58400 to 61300	SFE-034	249	58,309	0	27	747	0	0.0	2282	2.0
58400 to 61300	SFE-035	65	58,543	0	5	169	0	0.0	625	0.5
58400 to 61300	SFE-036	321	58,640	0	12	371	0	8.9	3532	2.6
58400 to 61300	SFE-037	18	58,961	0	0	0	0	1.2	217	0.1
58400 to 61300	SFE-038	138	58,977	0	7	111	0	2.0	1567	1.1
58400 to 61300	SFE-039	41	59,081	0	3	101	0	0.0	396	0.3
58400 to 61300	SFE-040	167	59,187	0	6	303	0	4.9	1729	1.3
58400 to 61300	SFE-041	63	59,354	0	0	0	0	4.1	767	0.5
58400 to 61300	SFE-042	23	59,414	0	0	0	0	1.5	284	0.2
58400 to 61300	SFE-043	225	59,442	0	7	314	0	7.6	2422	1.8
58400 to 61300	SFE-044	126	59,669	0	10	69	0	0.0	1466	1.0
58400 to 61300	SFE-045	23	59,790	0	5	79	0	0.0	198	0.2
58400 to 61300	SFE-046	217	59,812	0	7	199	0	7.2	2447	1.7
58400 to 61300	SFE-047	56	60,036	0	0	0	0	3.7	684	0.4

Reach (ft)	Habitat unit	Unit length (ft)	Station (ft)	Jam in unit	Existing wood counts			Existing large wood deficits		
					Count	Volume ft³	Key pieces	Count needed (C & R 2007)	Volume needed ft³ (C & R 2007)	Key pieces needed (Fitzgerald 2004)
58400 to 61300	SFE-048	57	60,086	0	0	0	0	3.7	697	0.5
58400 to 61300	SFE-049	72	60,108	0	0	0	0	4.7	878	0.6
58400 to 61300	SFE-050	31	60,160	0	0	0	0	2.0	380	0.2
58400 to 61300	SFE-051	264	60,195	0	6	166	0	11.2	3045	2.1
58400 to 61300	SFE-052	303	60,453	Y	34	912	0	0.0	2780	2.4
58400 to 61300	SFE-053	93	60,756	Y	25	402	0	0.0	732	0.7
58400 to 61300	SFE-054	21	60,849	0	1	4	0	0.4	257	0.2
58400 to 61300	SFE-055	89	60,887	0	5	100	0	0.8	983	0.7
58400 to 61300	SFE-056	315	60,964	0	9	99	0	11.5	3739	2.5
58400 to 61300	SFE-057	35	61,279	0	7	101	0	0.0	329	0.3
58400 to 61300	SFE-058	74	61,312	0	0	0	0	4.8	897	0.6
61300 to 64500	SFE-059	13	61,373	0	3	25	0	0.0	133	0.1
61300 to 64500	SFE-060	147	61,393	0	38	869	0	0.0	922	1.2
61300 to 64500	SFE-061	41	61,540	0	6	135	0	0.0	361	0.3
61300 to 64500	SFE-062	146	61,596	0	15	230	0	0.0	1551	1.2
61300 to 64500	SFE-063	121	61,736	0	9	439	0	0.0	1028	1.0
61300 to 64500	SFE-064	66	61,874	0	4	56	0	0.3	752	0.5
61300 to 64500	SFE-065	56	61,934	0	10	143	0	0.0	533	0.4
61300 to 64500	SFE-066	69	61,986	0	0	0	0	4.5	840	0.6
61300 to 64500	SFE-067	136	62,028	0	16	331	0	0.0	1330	1.1
61300 to 64500	SFE-068	173	62,180	0	16	314	0	0.0	1796	1.4
61300 to 64500	SFE-069	261	62,347	0	8	83	0	9.0	3097	2.1
61300 to 64500	SFE-070	15	62,639	0	2	34	0	0.0	142	0.1
61300 to 64500	SFE-071	133	62,654	Y	17	449	0	0.0	1165	1.1

Reach (ft)	Habitat unit	Unit length (ft)	Station (ft)	Jam in unit	Existing wood counts			Existing large wood deficits		
					Count	Volume ft³	Key pieces	Count needed (C & R 2007)	Volume needed ft³ (C & R 2007)	Key pieces needed (Fitzgerald 2004)
61300 to 64500	SFE-072	257	62,773	0	0	0	0	16.8	3133	2.1
61300 to 64500	SFE-073	11	62,984	0	17	478	0	0.0	0	0.1
61300 to 64500	SFE-074	170	62,987	0	0	0	0	11.1	2070	1.4
61300 to 64500	SFE-075	22	63,157	0	0	0	0	1.4	268	0.2
61300 to 64500	SFE-076	74	63,183	0	7	136	0	0.0	766	0.6
61300 to 64500	SFE-077	418	63,257	Y	58	1,141	0	0.0	3944	3.3
61300 to 64500	SFE-078	171	63,674	Y	37	896	0	0.0	1191	1.4
61300 to 64500	SFE-079	335	63,846	Y(3)	104	2,888	0	0.0	1195	2.7
61300 to 64500	SFE-080	44	64,181	0	1	4	0	1.8	526	0.3
61300 to 64500	SFE-081	116	64,210	borderline	22	687	0	0.0	721	0.9
61300 to 64500	SFE-082	27	64,326	0	4	46	0	0.0	284	0.2
61300 to 64500	SFE-083	42	64,358	borderline	16	500	0	0.0	13	0.3
61300 to 64500	SFE-084	49	64,398	0	19	510	0	0.0	86	0.4
61300 to 64500	SFE-085	136	64,435	0	21	514	0	0.0	1144	1.1
64500 to 66600	SFE-086	41	64,571	0	2	7	0	0.7	491	0.3
64500 to 66600	SFE-087	185	64,603	0	18	312	0	0.0	1937	1.5
64500 to 66600	SFE-088	139	64,788	Y	48	2,909	3	0.0	0	0.0
64500 to 66600	SFE-089	71	64,927	0	10	92	0	0.0	775	0.6
64500 to 66600	SFE-090	88	65,001	0	5	53	0	0.7	1019	0.7
64500 to 66600	SFE-091	177	65,095	Y	34	1,503	0	0.0	649	1.4
64500 to 66600	SFE-092	168	65,272	0	2	7	0	8.9	2033	1.3
64500 to 66600	SFE-093	223	65,447	0	4	262	0	10.6	2458	1.8
64500 to 66600	SFE-094	81	65,686	0	1	4	0	4.3	983	0.6
64500 to 66600	SFE-095	288	65,780	0	3	15	0	9.2	2272	1.5

Reach (ft)	Habitat unit	Unit length (ft)	Station (ft)	Jam in unit	Existing **wood** counts			Existing **large wood** deficits		
					Count	Volume ft^3	Key pieces	Count needed (C & R 2007)	Volume needed ft^3 (C & R 2007)	Key pieces needed (Fitzgerald 2004)
64500 to 66600	SFE-096	244	65,969	0	4	31	0	11.9	2941	2.0
64500 to 66600	SFE-097	66	66,220	0	0	0	0	4.3	802	0.5
64500 to 66600	SFE-098	256	66,280	Y	23	1,047	1	0.0	2228	1.0
64500 to 66600	SFE-099	59	66,536	0	16	336	0	0.0	379	0.5

Appendix B

Planting Palettes Associated with Riparian Enhancement and Revegetation

Table B-1. Planting palettes associated with the riparian enhancement and revegetation areas along and adjacent to the South Fork Elk River planning reach.

Scientific name	Common name	Type	Habit/Form	Material	Spacing (feet)
Planting zone: Mesic, frequently flooded **Desired future condition: Riparian hardwood continuous, closed overstory canopy, low shrub cover, high herbaceous cover** **Action: Enhancement**					
Tree (70%)					
Alnus rubra	red alder	tree	deciduous, upright	container	14
Fraxinus latifolia	Oregon ash	tree	deciduous	container	10
Salix lasiandra	Pacific willow	tree	deciduous, upright	cuttings/pole	10
Populus trichocarpa	black cottonwood	tree	deciduous, upright, upright/columnar	container/cuttings	10
Shrub (20%)					
Sambucus racemosa var. *racemosa*	red elderberry	upright shrub	deciduous	container	6
Cornus sericea subsp. *sericea*	American dogwood	multi-stemmed shrub	deciduous	container	8
Herbaceous (60%)					
Athyrium filix-femina var. *cyclosorum*	western lady fern	fern	perennial	container	4
Carex obnupta	slough sedge	sedge	perennial	plug/container	4
Equisetum arvense	common horsetail	herb	perennial	container	2–4
Juncus effusus	Pacific rush	rush	perennial	container	4
Petasites frigidus var. palmatus	western sweet coltsfoot	forb	perennial	container	4
Scirpus microcarpus	panicled bulrush	herb	perennial	plug/container	4
Tolmiea diplomenziesii	pig-a-back plant	forb	perennial	container/seed	4 ft / broadcast
Viola glabella	stream violet	forb	perennial	seed	broadcast

Scientific name	Common name	Type	Habit/Form	Material	Spacing (feet)
Planting zones: Mesic, infrequently and rarely flooded; Transitional, infrequently flooded (A) **Desired future condition: Riparian hardwood continuous overstory canopy, limited evergreen conifer component, moderate shrub cover, low herbaceous understory** **Action: Enhancement and Revegetation**					
Tree (70%)					
Alnus rubra	red alder	tree	deciduous, upright	container	14
Acer macrophyllum	big-leaf maple	tree	deciduous, multi-trunked, upright, rounded, upright columnar	container	10
Frangula purshiana	cascara	small tree	deciduous, upright	container	6
Malus fusca	Oregon crab apple	multi-stemmed shrub/small tree	deciduous	container	10
Picea sitchensis	Sitka spruce	tree	evergreen, pyramidal, upright	container	10
Populus trichocarpa	black cottonwood	tree	deciduous, upright, upright/columnar	container/cuttings	10
Salix lasiandra	Pacific willow	tree	deciduous, upright	cuttings/pole	10
Shrub (30%)					
Cornus sericea subsp. *sericea*	American dogwood	multi-stemmed shrub	deciduous	container	8
Corylus cornuta subsp. *californica*	California hazelnut	shrub to small tree	deciduous	moist, shady places	6
Lonicera involucrata	twinberry	upright shrub	deciduous	container	6
Ribes bracteosum	stink currant	tall-upright-or-arching shrub	deciduous	container	6
Rubus spectabilis	salmon berry	tall-upright and thicket forming shrub	deciduous	container	6
Rubus parviflorus	thimbleberry	thicket-forming shrub	deciduous	container/cuttings	6
Rubus ursinus	California blackberry	prostrate to decumbent shrub/vine	deciduous	container/cuttings	12
Sambucus racemosa var. *racemosa*	red elderberry	upright shrub	deciduous	container	6

Scientific name	Common name	Type	Habit/Form	Material	Spacing (feet)
Herbaceous (50%)					
Athyrium filix-femina var. *cyclosorum*	western lady fern	fern	perennial	container	4
Tellima grandiflora	fringe cups	forb	perennial	container/seed	4 ft/ broadcast
Polystichum munitum	Sword fern	fern	evergreen	container	interplanting
Planting zones: Transitional, infrequently flooded (B) **Desired Future Condition: Mixed hardwood and shade-tolerant coniferous overstory, low shrub cover, high herbaceous understory** **Action: Revegetation**					
Tree (70%)					
Acer macrophyllum	big-leaf maple	tree	deciduous, multi-trunked, upright, rounded, upright columnar	container	10
Alnus rubra	red alder	tree	deciduous, upright	container	14
Frangula purshiana	cascara	small tree	deciduous, upright	container	6
Malus fusca	Oregon crab apple	multi-stemmed shrub/small tree	deciduous	container	10
Picea sitchensis	Sitka spruce	tree	evergreen, pyramidal, upright	container	10
Sequoia sempervirens	coast redwood	tree	evergreen, upright, upright columnar	container	10
Thuja plicata	western red cedar	tree	evergreen, pyramidal, upright columnar	container	10
Shrub (20%)					
Cornus sericea subsp. *sericea*	American dogwood	multi-stemmed shrub	deciduous	container	8
Gaultheria shallon	salal	low shrub	broadleaf evergreen	container	6
Lonicera involucrata	twinberry	upright shrub	deciduous	container	6
Oemleria cerasiformis	oso berry	multi-stemmed shrub/small tree	deciduous	container	6
Ribes bracteosum	stink currant	tall-upright-or-arching shrub	deciduous	container	6

Scientific name	Common name	Type	Habit/Form	Material	Spacing (feet)
Rubus ursinus	California blackberry	prostrate to decumbent shrub/vine	deciduous	container/cuttings	12
Sambucus racemosa var. *racemosa*	red elderberry	upright shrub	deciduous	container	6
Herbaceous (60%)					
Athyrium filix-femina var. *cyclosorum*	western lady fern	fern	perennial	container	4
Carex obnupta	slough sedge	sedge	perennial	plug/container	4
Struthiopteris spicant	deer fern	fern	perennial	container	4
Tellima grandiflora	fringe cups	forb	perennial	container/seed	4 ft/ broadcast
Polystichum munitum	sword fern	fern	evergreen	container	4
Viola sempervirens	evergreen violet	forb	perennial	seed	broadcast
Planting zones: Transitional, infrequently flooded (B) and rarely flooded **Desired Future Condition: Open herbaceous meadow, occasionally moist** **Action: Revegetation:**					
Herbaceous graminoids (100%)					
Agrostis exarata	spike bent grass	grass	perennial	container/seed	4 ft / broadcast
Bromus carinatus	California brome	grass	perennial	seed	broadcast
Carex praegracilis	clustered field sedge	sedge	perennial	plug/container	1 ft / 4 ft
Deschampsia cespitosa subsp. *cespitosa*	tufted hair grass	grass	perennial	plug/container	1 ft / 4 ft
Hordeum brachyantherum subsp. *brachyantherum*	northern barley	grass	perennial	seed	broadcast
Danthonia californica	California oat grass	grass	perennial	seed	broadcast
Juncus effusus	soft rush	rush	perennial	plug/container	1 ft / 4 ft
Juncus patens	spreading rush	rush	perennial	plug/container	1 ft / 4 ft

Scientific name	Common name	Type	Habit/Form	Material	Spacing (feet)
Herbaceous forbs (100%)					
Achillea millefolium	yarrow	forb	perennial	container/seed	4 ft / broadcast
Epilobium ciliatum	fringed willow herb	forb	perennial	container	4
Lupinus bicolor	miniature lupine	forb	annual (may live 2 seasons in NCo)	seed	broadcast
Sisyrinchium bellum	western blue-eyed-grass	forb	perennial	container	2
Symphyotrichum chilense var. chilense	Pacific aster	forb	perennial	container	4
Planting zones: Transitional, rarely flooded and Xeric, rarely flooded. **Desired Future Condition: Upland coniferous forest, continuous overstory canopy, low/moderate shrub, moderate to high herbaceous cover** **Action: Revegetation**					
Tree (80%)					
Abies grandis	grand fir	tree	evergreen, pyramidal	container	10
Acer macrophyllum	big-leaf maple	tree	deciduous, multi-trunked, upright, rounded, upright columnar	container	10
Alnus rubra	red alder	tree	deciduous, upright	container	14
Thuja plicata	western red cedar	tree	evergreen, pyramidal, upright columnar	container	10
Tsuga heterophylla	western hemlock	tree	evergreen, pyramidal	container	10
Picea sitchensis	Sitka spruce	tree	evergreen, pyramidal, upright	container	10
Pseudotsuga menziesii	Douglas-fir	tree	evergreen, pyramidal, upright	container	12
Sequoia sempervirens	redwood	tree	evergreen, upright, upright columnar	container	10
Shrub (20%)					
Corylus cornuta subsp. *californica*	California hazelnut	shrub to small tree	deciduous	moist, shady places	6
Gaultheria shallon	salal	low shrub	broadleaf evergreen	container	6
Oemleria cerasiformis	oso berry	multi-stemmed shrub/small tree	deciduous	container	6

Scientific name	Common name	Type	Habit/Form	Material	Spacing (feet)
Rhododendron macrophyllum	California rhododendron	upright coarse-branched shrub	evergreen	container	6
Rubus parviflorus	thimbleberry	thicket-forming shrub	deciduous	container/cuttings	6
Rubus ursinus	California blackberry	prostrate to decumbent shrub/vine	deciduous	container/cuttings	12
Vaccinium parviflorum	red huckleberry	upright shrub	deciduous	container	6
Vaccinium ovatum	evergreen huckleberry	upright shrub	evergreen	container	6
Herbaceous (40%)					
Polystichum munitum	Sword fern	fern	evergreen	container	4
Struthiopteris spicant	deer fern	fern	perennial	container	4

Table B-2. Planting palettes associated with the wetland enhancement and creation features along and adjacent to the South Fork Elk River Project reach.

Scientific name	Common name	Wetland indicator rating (WMVC Supplement[1])	Form	Habit
Perennial freshwater marsh (at water table and regularly inundated); plugs spaced 1-2 ft on center				
Eleocharis macrostachya	pale spike rush	OBL	perennial herb	fresh wetland
Oenanthe sarmentosa	water parsley	OBL	perennial herb	streams, marshes, ponds, generally aquatic
Schoenoplectus acutus var. occidentalis	common tule	OBL	perennial herb	fresh emergent; marsh, shore
Scirpus microcarpus	panicled bulrush	OBL	perennial herb	marshes, wet meadows, streambanks, pond margins, (can become weedy)
Seasonal freshwater marsh (<3 ft above summer water table; periodically inundated); plugs/containers spaced 1-4 ft on center				
Eleocharis macrostachya	pale spike rush	OBL	perennial graminoid	fresh wetland
Erythranthe dentata	tooth-leaved monkeyflower	OBL	perennial forb	Coastal streambanks, generally in partial shade; observed beyond North coast floristic province
Juncus ensifolius	swordleaved rush	FACW	perennial graminoid	wet places
Carex obnupta	slough sedge	OBL	perennial graminoid	Moist openings, shores, redwood forest
Scirpus microcarpus	small-fruited bulrush	OBL	perennial graminoid	marshes, wet meadows, streambanks, pond margins, (can become weedy)
Viola glabella	stream violet	FACW	perennial forb	moist to wet generally shady places in forest and streambanks
Lupinus polyphyllus var. *polyphyllus*	meadow lupine, bigleaf lupine	FAC	perennial herb	summer deciduous, moist areas along streams and creeks, full sun moderate to high moisture
Petasites frigidus var. *palmatus*	western sweet coltsfoot	FACW	perennial forb	forest, streambanks, generally wet soil

Scientific name	Common name	Wetland indicator rating (WMVC Supplement[1])	Form	Habit
Calamagrostis nutkaensis	Pacific reedgrass	FACW	perennial graminoid	Wet areas, coastal woodland, inland marshes; observed beyond North coast floristic province
Juncus effusus subsp. *pacificus*	Pacific rush	FACW	perennial graminoid	Seeps, shores, marshes, generally damp sunny ground
Deschampsia cespitosa subsp. *cespitosa*	tufted hair grass	FACW	perennial graminoid	Meadows, streambanks, coastal marshes, forest, alpine
Hordeum brachyantherum subsp. *brachyantherum*	northern barley	FACW	perennial graminoid	meadows, pastures, streambanks
Danthonia californica	California oat grass	FAC	perennial graminoid	Generally moist meadows
Symphyotrichum chilense var. *chilense*	Pacific aster	FAC	perennial forb	grassland, marsh
Athyrium filix-femina var. *cyclosorum*	western lady fern	FAC	fern	along streams, seepage areas
Agrostis exarata	spike bent grass	FACW	perennial graminoid	Moist or disturbed areas, open woodland, conifer forest
Mesic grassland/moist riparian (>6ft; infrequently inundated); containers/pole cuttings spaced 6-8 ft on center				
Salix lasiandra var. lasiandra	Pacific willow	FACW	deciduous tree	wet meadows, shores, seepage areas
Oemleria cerasiformis	oso berry	FACU	shrub to small tree, winter deciduous	streambanks, coast to shaded conifer forest
Frangula purshiana	cascara	FAC	erect tall shrub to small tree, winter deciduous	shade tolerant, forest edge, low mountain slopes, moist bottomlands
Lupinus polyphyllus var. *polyphyllus*	meadow lupine, bigleaf lupine	FAC	perennial herb	summer deciduous, moist areas along streams and creeks, full sun moderate to high moisture
Ribes bracteosum	stink currant	FAC	deciduous shrub	moist forest
Corylus cornuta subsp. *californica*	California hazelnut	FACU	shrub to small tree	moist, shady places

Scientific name	Common name	Wetland indicator rating (WMVC Supplement[1])	Form	Habit
Cornus sericea	American dogwood	NL	shrub	moist places: (soils that are saturated for at least a portion of the growing season), common on the edges of lakes, ponds, within wetlands, and along streams.

[1] USACE Western Mountain Valley and Coast Regional Plant List ratings:
OBL (Obligate Wetland Plants)—Almost always occur in wetlands
FACW (Facultative Wetland Plants)—Usually occur in wetlands but may occur in non-wetlands.
FAC (Facultative Wetland Plants)—Occur in wetlands and non-wetlands.
FACU (Facultative Upland Plants)—Usually occur in non-wetlands but occasionally found in wetlands
UPL (Upland Plants)—Occur in wetlands in another region but occur almost always under natural conditions in non-wetlands in the region specified.
NL (Not Listed) —Plant species not listed are considered upland for wetland delineation purposes.

Appendix C

Sediment Basin Effectiveness Assessment

Purpose

Sediment basins were proposed in the South Fork Elk River, downstream of Tom's Gulch, the largest sediment producing tributary in the watershed. Sediment basins were evaluated early in the design process to evaluate the ability of proposed floodplain sediment basins to trap sediment and reduce suspended sediment concentration in the South Fork Elk River.

Figure C-1. HST-Model domain and test case location in the South Fork Elk River.

Model Development

The existing condition HST-Model for the Elk River was used to model sediment accumulation in the proposed sediment basins and reductions in SSC. The unsteady-flow modeling exercise was implemented as a test case in the upper reaches of the South Fork Elk River using three sediment basin configurations and two representative flow events:

<u>Basin Configurations:</u>

- Configuration I: Flow-through basin, separate inlet and outlet, intermediate weir feature (Basins 15 and 21; Figure C-2)
- Configuration II: Flow-through basin, separate inlet and outlet (Basin 22; Figure C-2)
- Configuration III: Backwater basin, continuous inlet and outlet (Basin 6; Figure C-2)

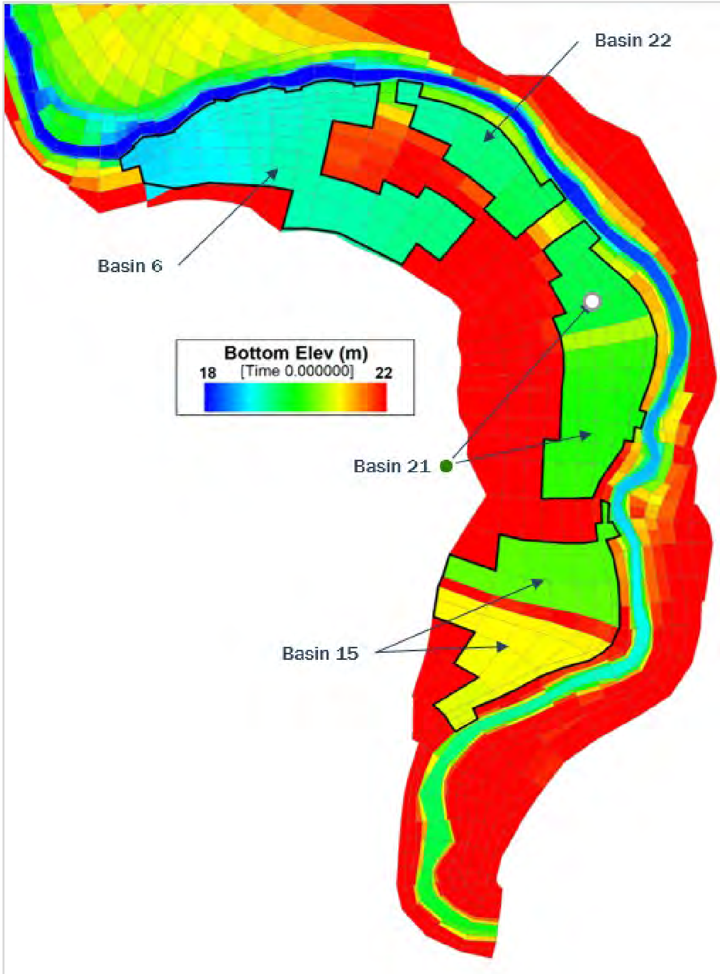


Figure C-2. Overview of sediment basin locations and topography for test case HST-Model.

<u>Modeled Flow Events:</u>

- WY 2003 peak flow (largest flow of record)
- WY 2015 peak flow (~ bankfull event)

In total, the four modeled sediment basins represented a hypothetical area of roughly 7.6 acres and an excavated volume of ~64,000 cubic yards (Table C-1). All model scenarios assumed no channel excavation.

Table C-1. Excavation areas and volumes for the four modeling sediment basins.

Basin	Excavated area (ac)	Excavated volume (cy)
6	2.63	29,851
15	2.17	13,554
21	1.9	14,322
22	0.86	6,024
Total	**7.56**	**63,751**

Sediment basin effectiveness was assessed over two key peak flow events: (1) bankfull flow (WY 2015) and (2) the largest flow of record (WY 2003). All model scenarios assumed no channel excavation.

Results

Figure C-3 illustrates sediment accumulation in the existing channel with and without the proposed sediment basins. Notably, while the HST-Model predicts that the sediment basins will enhance floodplain deposition (accumulation up to 1m), model results also suggests that the basins will cause increased in-channel sedimentation due to reduced channel flow velocities as a result of increased detention of overbank flows and concomitant declines in channel peak flow rates.

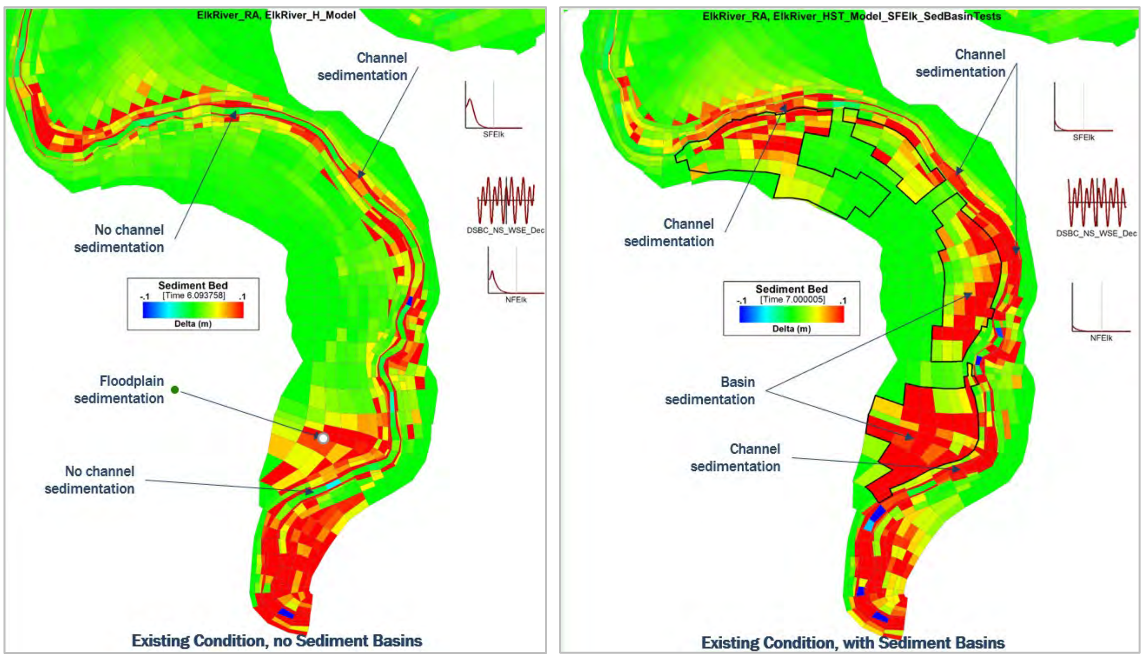


Figure C-3. HST-Model results depicting predicted sedimentation patterns for the largest flow of record (WY 2003) with and without sediment basins. Results are similar for the WY 2015 bankfull event.

Results further suggest that flow-through basins with separate inlet and outlets and an intermediate weir structure (i.e., basins 15 and 21) provided substantially more benefit (cy of sediment trapping) per unit cost (cy of excavation; Table C-2). Sediment accumulation is also predicted to be approximately 10 times greater during the WY 2003 event, suggesting a positive relationship between trapping efficiency and storm magnitude.

Table C-2. Excavation and sedimentation volumes in all model basins. Relative sediment trapping effectiveness is indicated by the benefit:cost ratio, which represents the cy of sediment trapped per cy excavated.

Basin	Excavated volume (cy)	WY 2003 Peak flow sedimentation volume (cy)	WY 2015 peak flow sedimentation volume (cy)	WY 2003 benefit:cost ratio (sedimentation vol/cut vol)
15	13,554	2,168	146	0.160
21	14,322	1,002	104	0.070
22	6,024	283	43	0.047
6	29,851	847	97	0.028
Total	**63,751**	**4,300**	**390**	**--**

Figure C-4 illustrates how the sediment basins perform over the course of a single large event (WY 2003). During the early stages of the storm (rising limb), overbank flows occur primarily in the sediment basins, which inundate relatively quickly and provide large areas of low SSC—suggesting the basins may provide water quality refugia during large flow events. However, near the peak of the storm, there is significant flow between basins and the river and basin stage is roughly equivalent and the only remaining zone of low SSC is in basin 6. As the storm recedes (falling limb), overbank flow areas are again primarily limited to the sediment basins and larger portions of the basins provide water quality refugia due to settling of sediment during basin drainage.

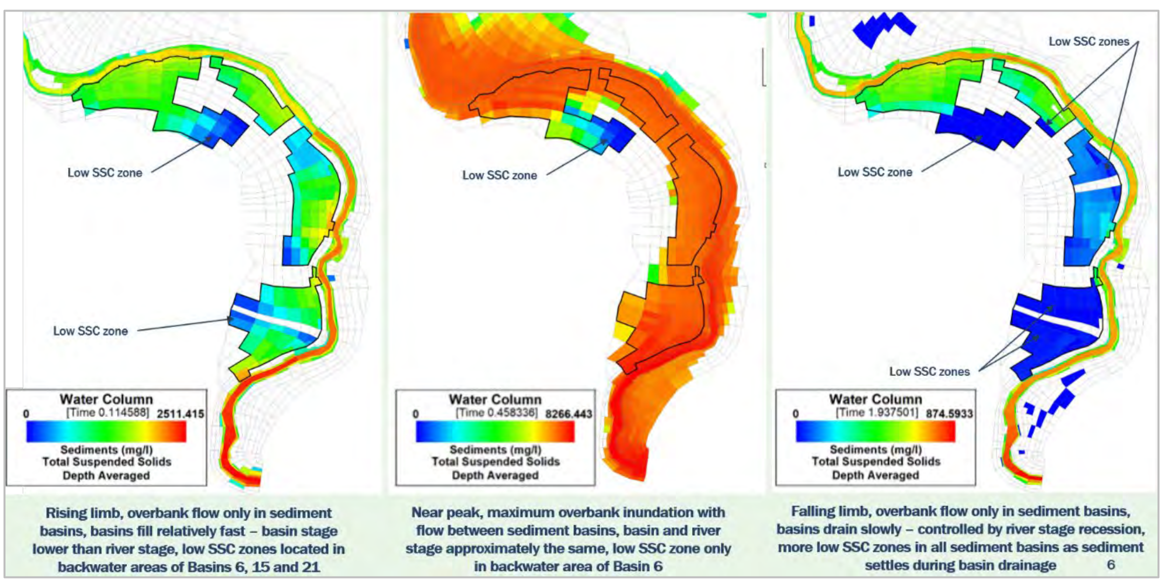


Figure C-4. Suspended sediment concentration patterns during the WY 2003 peak event. Results are similar for the 2015 WY peak event.

Overall, the HST-Model results indicate that the sediment basins would provide minimal reductions in in-channel sediment concentrations (mean reductions < 4%; Figure C-5 and Table C-3). Not only would the sediment basins require large volumetric and areal floodplain excavations, but the basins would require periodic sediment removal. This suggests the off-channel sediment basins are not a viable method for ameliorating high SSC and associated aggradation issues in the project reach.

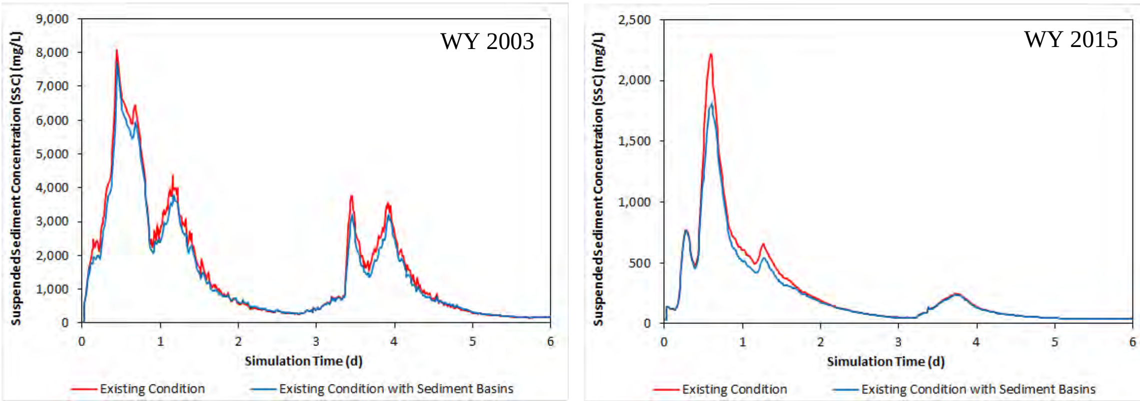


Figure C-5. HST-Model results for the WY 2003 and 2015 events depicting simulated SSC for the existing condition with and without sediment basins (red and blue lines, respectively).

Table C-3. Summary of percent reductions in suspended sediment concentrations from all off-channel sediment basins combined.

Flow event	SSC reduction (%)			
	Mean	St. dev.	Min	Max
WY 2003	3.5	8	-11.6	26.9
WY 2015	3.7	5.2	-2.6	23

Conclusions

Salient conclusions from the sediment basin effectiveness assessment include the following:

- Off-channel sediment basins demonstrated marginal sediment trapping capacity during two representative storm events.
- However, the off-channel backwater features could provide lower SSC fish habitat areas during flood events.
- Large scale floodplain sediment basins within the study area would significantly impact private property (i.e., require significant areal and volumetric excavation).
- Large commitment in land and resources required to construct/maintain floodplain sediment basins.
- Sediment basins increased in-channel sedimentation due to lower channel flow velocities—which is an unintended negative consequence of constructing floodplain sediment basins.
- Sediment source reduction and management should be focused upstream of the study area.

Appendix D

Habitat Cost Benefit Analysis

Habitat Cost Benefit Analysis

A preliminary cost-benefit analysis of proposed channel modifications is used to facilitate evaluation and prioritization of proposed project actions. The volume of excavated material (cut volume) is used as a proxy for "cost" and increase in inundation area is a proxy for habitat area at select design flows to quantify "benefit". The 10% exceedance flow and 1.053-year storm inundation areas were chosen as metrics quantifying juvenile coho winter rearing habitat area.

Table D-1 and Figure D-1 summarize the results of the cost-benefit analysis and highlight that, in general, more winter rearing habitat is gained per unit of cut volume in the upper reaches of the project site relative to the lower reaches (i.e., upstream of STA 62,300; Figure D-2). This is primarily due to the fact that the lower reaches are characterized by considerably more channel entrenchment—necessitating more excavation to achieve an equivalent increase in habitat area relative to the less entrenched upper reaches. The cost-benefit analysis also underscores the fact that, with the exception of Tom's Gulch confluence actions (Alt 2 T-0-off-channel pond and Alt 1 T-0-multi-channel), enhancement of existing low elevation features such as alcoves and side channels yield more habitat benefit per unit cost and should therefore be prioritized (Table D-2). On average, the two design alternatives for the Tom's Gulch confluence (i.e., multi-channel and off-channel pond) offer the largest increase winter rearing habitat relative to the cost of installation (Table D-2).

It should be noted that the habitat benefits associated with several enhancement actions are less amenable to direct quantification (e.g., vegetation mgmt.). As these actions play an integral role in long-term project success (e.g., healthy riparian vegetation provides a sustainable source for large wood recruitment), their benefits will be discussed in a qualitative sense.

Table D-1. Summary of cost:benefit analysis results at 10% exceedance and 1.053-year design flows. Here we are assuming that the 10% exceedance and 1.053-year flows provide a reasonable proxy for low-velocity juvenile coho winter rearing habitat area.

Site	Feature	Cut volume (ft^3)	Increase in habitat @ 10% exceedance (ft^2)	Increase in habitat @ 1.053yr (ft^2)	Benefit:cost ratio (ft^2/ft^3)
T-0b	TG – multi-channel	142,317	31,379	34,117	0.460
T-1	Bank	13,596	2,316	3,905	0.458
T-3	Alcove	3,693	749	759	0.408
T-7	Alcove	7,076	969	1,273	0.317
T-5	Alcove	55,200	5,976	10,145	0.292
T-0a	TG – off-channel pond	62,784	8,700	9,459	0.289
T-4	Alcove	6,915	631	1,012	0.238
T-2	Alcove	7,109	509	1,104	0.227
T-9	Side Chan	28,815	2,921	3,152	0.211
T-6	Bank	44,225	2,417	5,400	0.177
T-10	Alcove	39,440	2,030	3,719	0.146
T-8	Alcove	164,358	8,145	13,622	0.132
T-14	Bank	11,160	483	973	0.130
T-19	Alcove	46,738	2,357	3,395	0.123
T-18	Side Chan	56,648	2,497	4,263	0.119

Site	Feature	Cut volume (ft^3)	Increase in habitat @ 10% exceedance (ft^2)	Increase in habitat @ 1.053yr (ft^2)	Benefit:cost ratio (ft^2/ft^3)
T-21	Channel Widening	66,906	3,554	3,879	0.111
T-17	Bank	55,600	1,749	3,813	0.100
T-12	Bank	143,040	5,463	8,818	0.100
T-13	Bank	22,770	579	1,408	0.087
T-15	Bank	116,325	3,410	6,386	0.084
T-16	Alcove	82,877	2,535	4,408	0.084
T-11	Bank	10,498	204	632	0.080
T-20	Alcove	60,545	1,253	2,100	0.055

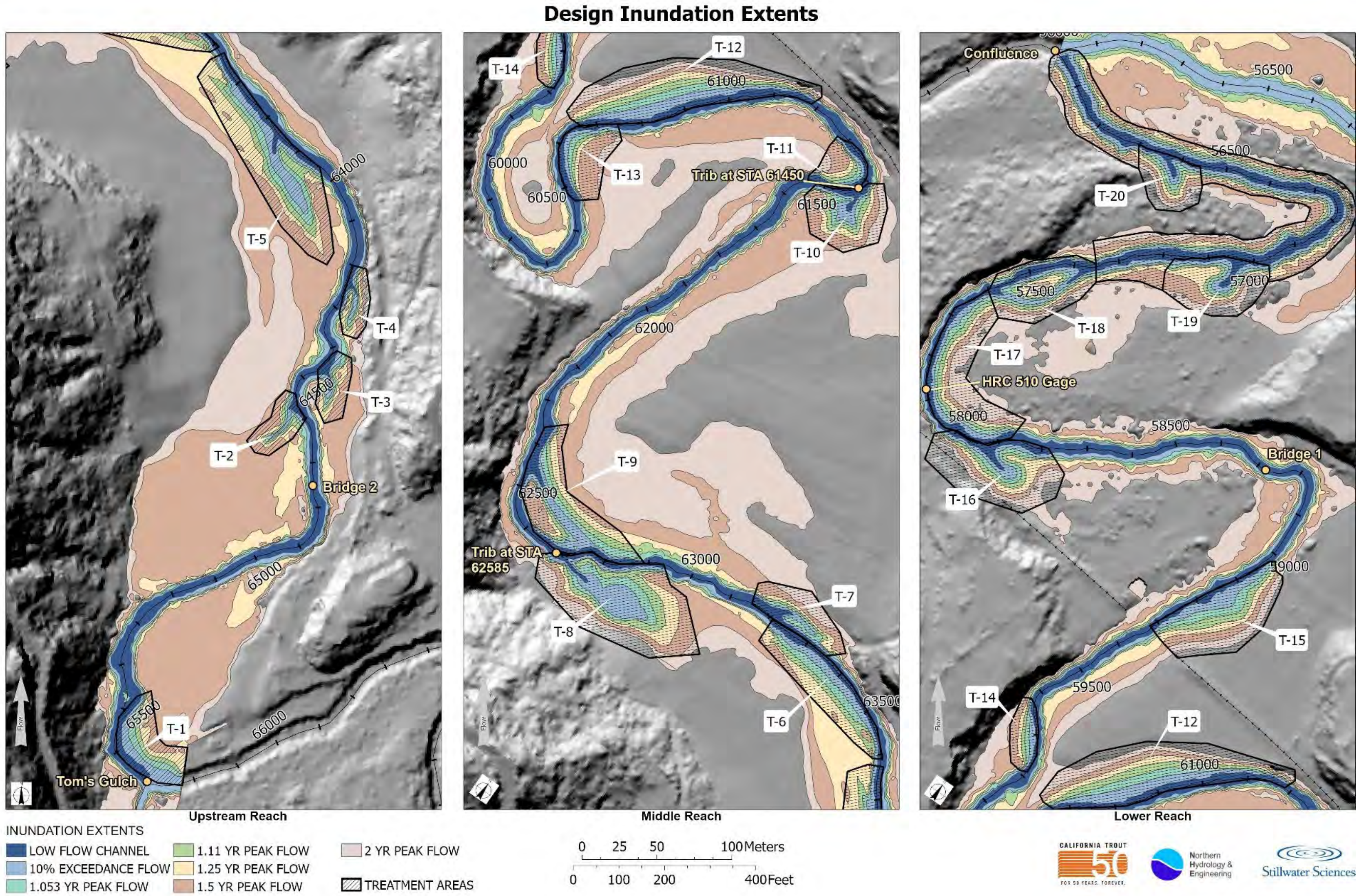


Figure D-1. Design inundation extents over the various design flows. Enhancement locations are indicated by hatched polygons.

Table D-2. Mean benefit:cost score summarized by channel enhancement type.

Enhancement type	Mean benefit:cost score (ft^2/ft^3)
Alt 1:TG – Multi-Channel	0.582
Alt 2: TG – Off-channel Pond	0.289
Alcove	0.202
Side Channel	0.165
Bank	0.152
Channel Widening	0.111

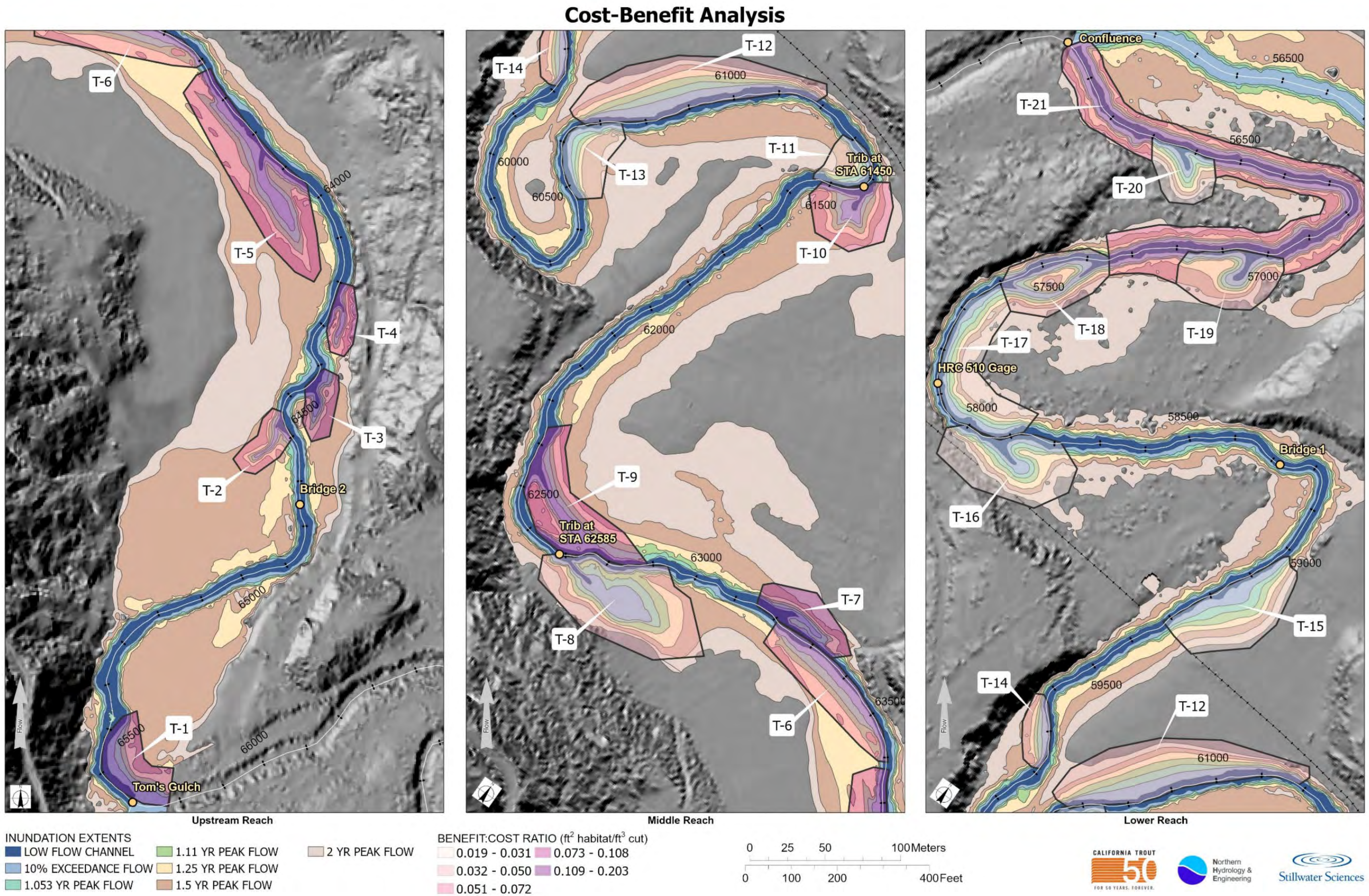
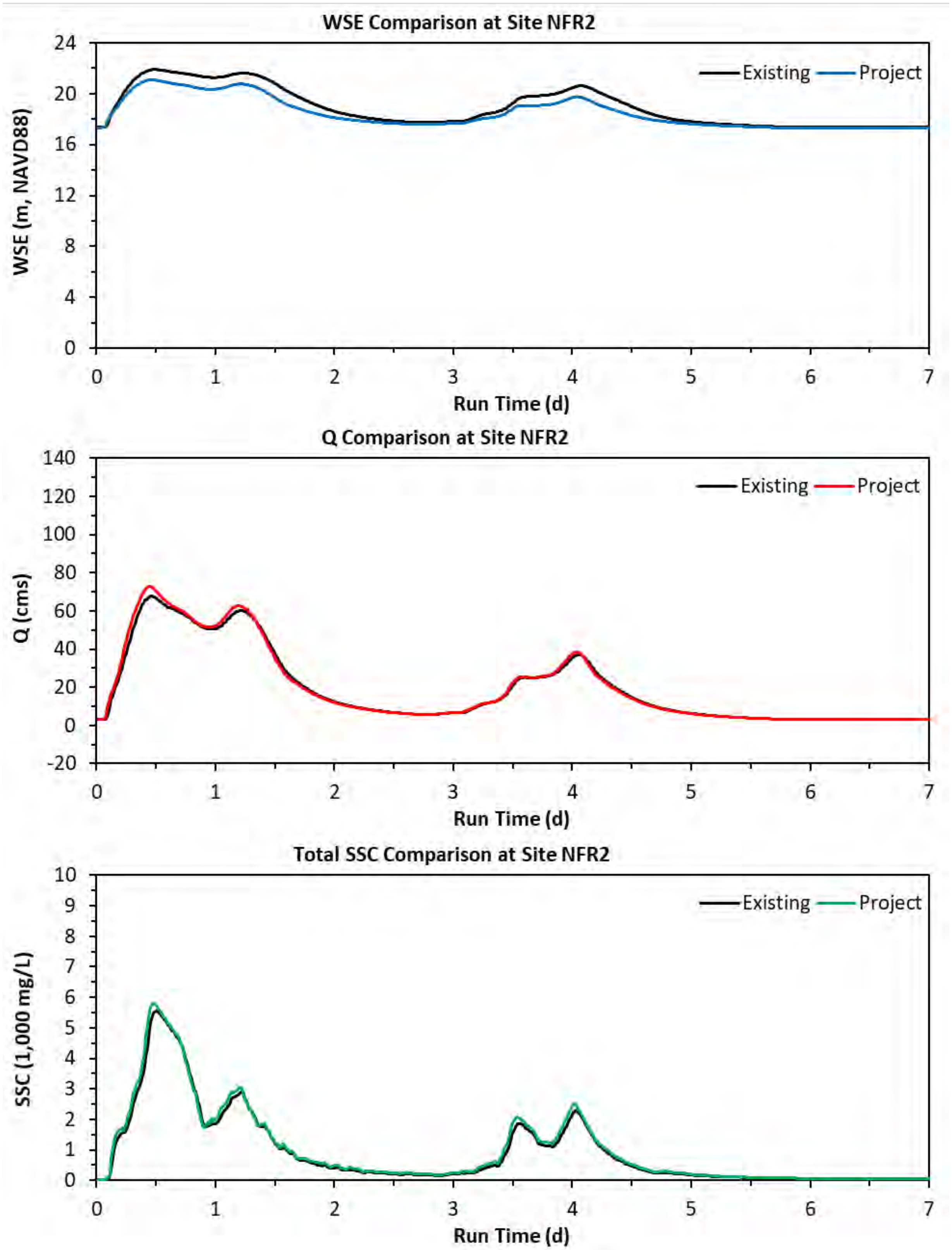


Figure D-2. Cost-benefit map overlaid on the design inundation extents. Enhancement areas are indicated by shaded polygons and labeled in ascending order in the downstream direction.

APPENDIX E


WSE Comparison at Site NFR2
Existing
Project
WSE (m, NAVD88)
24
20
16
12
8
4
0
0 1 2 3 4 5 6 7
Run Time (d)
Q Comparison at Site NFR2
Existing
Project
Q (cms)
140
120
100
80
60
40
20
0
-20
0 1 2 3 4 5 6 7
Run Time (d)
Total SSC Comparison at Site NFR2
Existing
Project
SSC (1,000 mg/L)
10
9
8
7
6
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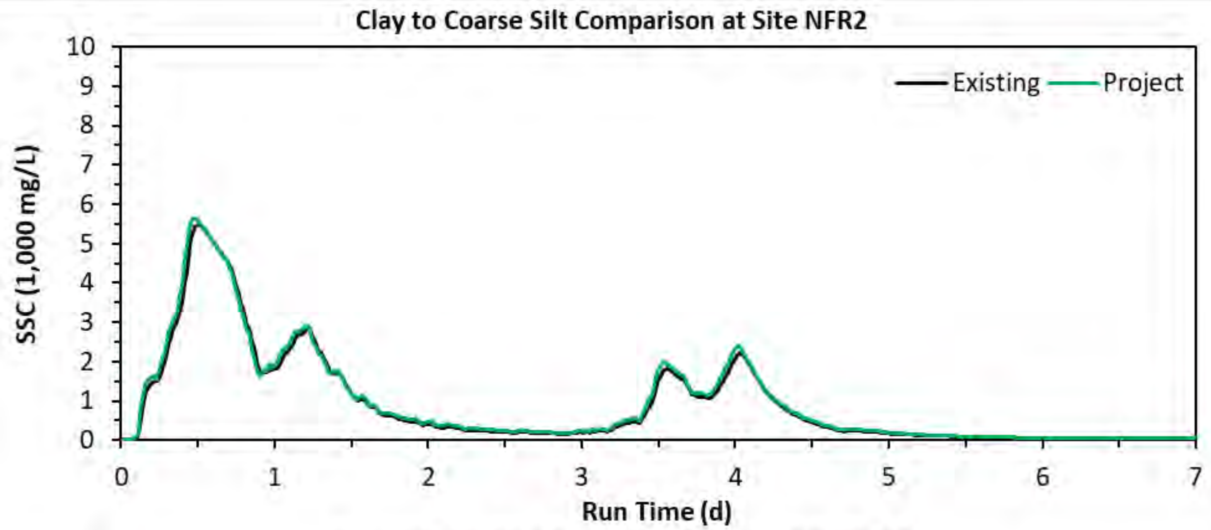
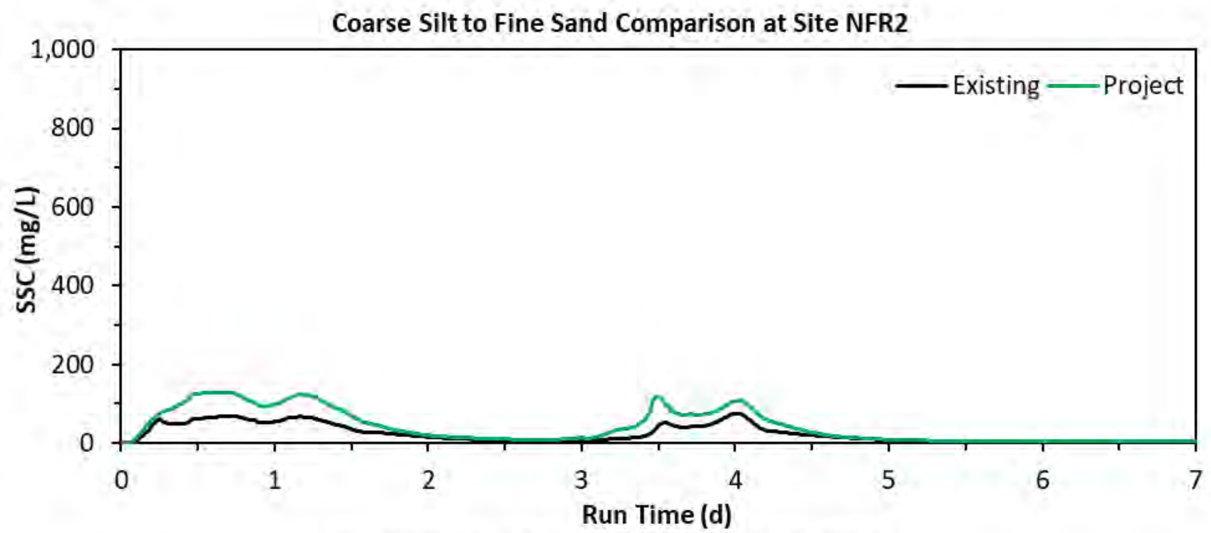
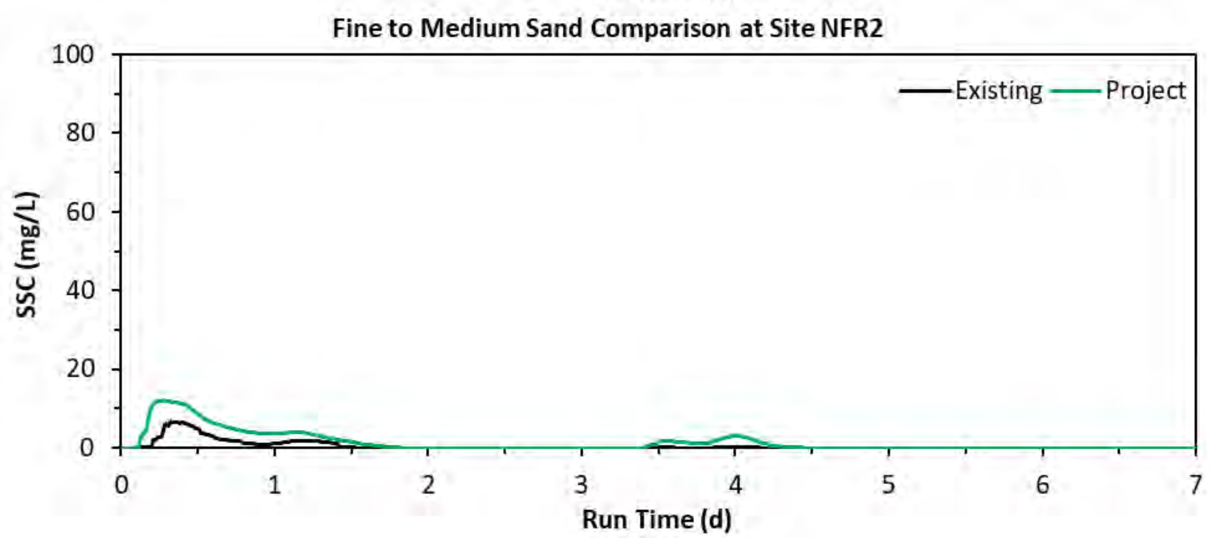
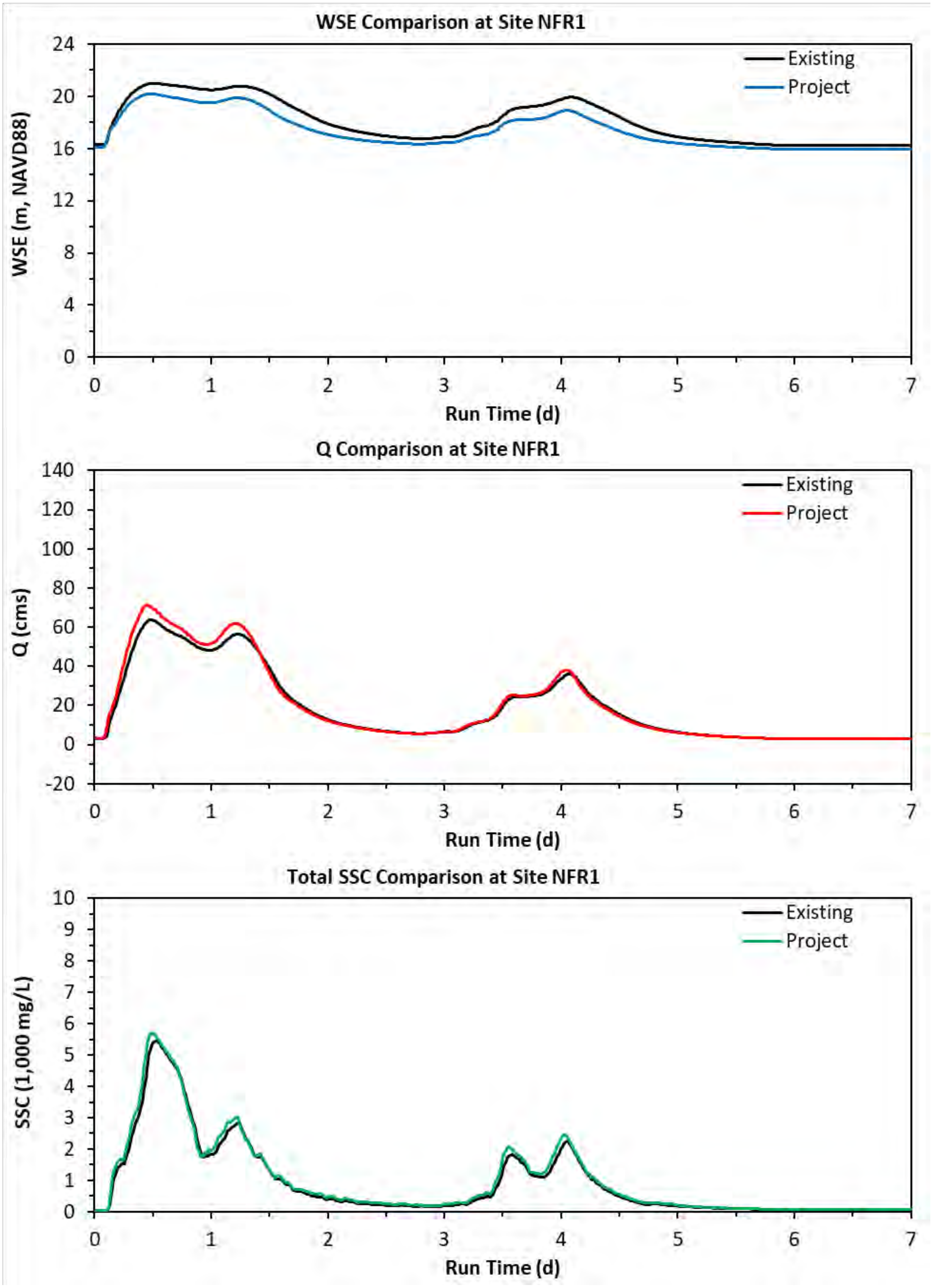
0 1 2 3 4 5 6 7
Run Time (d)


Clay to Coarse Silt Comparison at Site NFR2
SSC (1,000 mg/L)
Run Time (d)
Existing
Project


Coarse Silt to Fine Sand Comparison at Site NFR2
SSC (mg/L)
Run Time (d)
Existing
Project


Fine to Medium Sand Comparison at Site NFR2
SSC (mg/L)
Run Time (d)
Existing
Project

Summary Statistics at Site NFR2									
Constituent	**Condition**	**Average**	**Median**	**Minimum**	**Maximum**	**St Dev**	**% Avg Change**	**% Min Change**	**% Max Change**
WSE (m, NAVD88)	**EXISTING**	18.90	18.30	17.36	21.90	1.52			
	PROJECT	18.46	17.96	17.29	21.09	1.20	-2.3	-0.4	-3.7
Q (cms)	**EXISTING**	19.41	10.10	3.01	67.62	19.37			
	PROJECT	19.81	10.05	3.01	72.91	20.21	2.0	0.0	7.8
Total SSC (mg/L)	**EXISTING**	930.01	319.47	26.48	5566.80	1237.86			
	PROJECT	995.76	370.20	26.63	5788.64	1283.81	7.1	0.5	4.0
Clay to Coarse Silt	**EXISTING**	906.48	305.92	25.76	5498.93	1217.05			
	PROJECT	953.70	352.35	25.87	5653.92	1243.86	5.2	0.4	2.8
Coarse Silt to Fine Sand	**EXISTING**	23.08	12.62	0.72	75.60	22.66			
	PROJECT	40.71	17.75	0.75	129.33	41.53	76.4	4.6	71.1
Fine to Medium Sand	**EXISTING**	0.45	0.00	0.00	6.81	1.23			
	PROJECT	1.35	0.00	0.00	12.01	2.66	197.4	0.0	76.5
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									


WSE Comparison at Site NFR1
WSE (m, NAVD88)
24
20
16
12
8
4
0
Existing
Project
0 1 2 3 4 5 6 7
Run Time (d)
Q Comparison at Site NFR1
Q (cms)
140
120
100
80
60
40
20
0
-20
Existing
Project
0 1 2 3 4 5 6 7
Run Time (d)
Total SSC Comparison at Site NFR1
SSC (1,000 mg/L)
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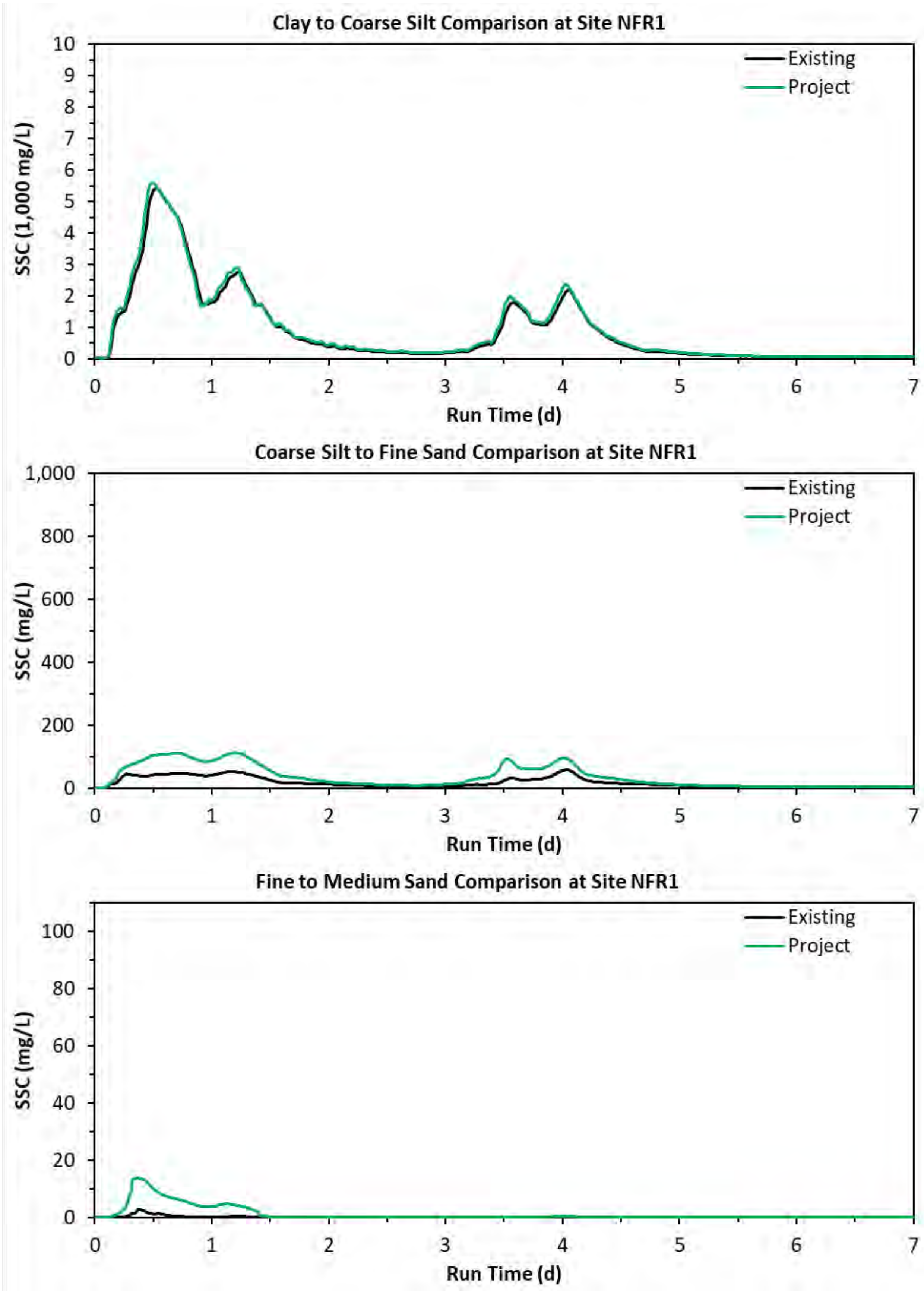
Existing
Project
0 1 2 3 4 5 6 7
Run Time (d)


Clay to Coarse Silt Comparison at Site NFR1
SSC (1,000 mg/L)
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Existing
Project
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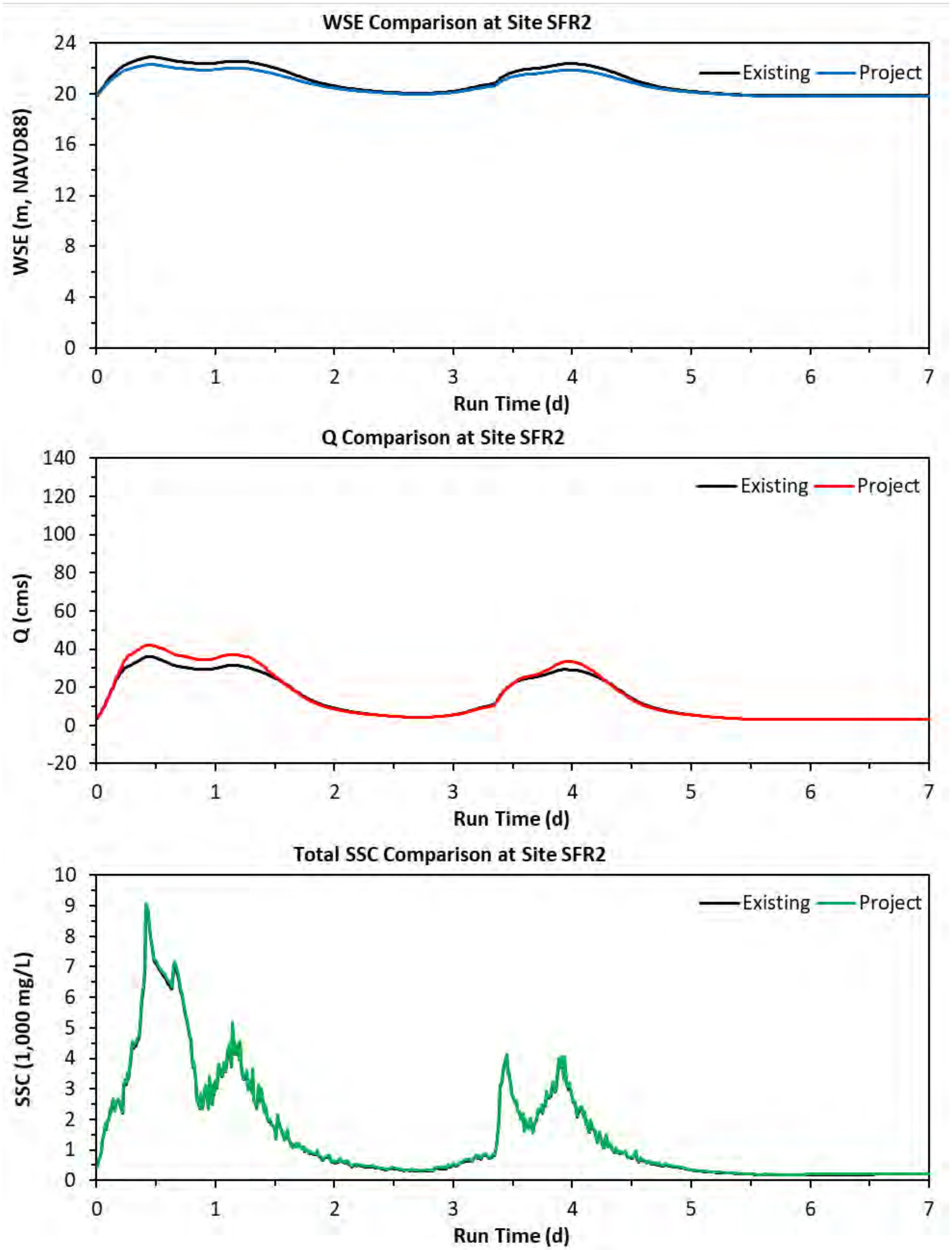
Run Time (d)
Coarse Silt to Fine Sand Comparison at Site NFR1
SSC (mg/L)
1,000
800
600
400
200
0
Existing
Project
Run Time (d)
Fine to Medium Sand Comparison at Site NFR1
SSC (mg/L)
100
80
60
40
20
0
Existing
Project
Run Time (d)

Summary Statistics at Site NFR1									
Constituent	Condition	Average	Median	Minimum	Maximum	St Dev	% Avg Change	% Min Change	% Max Change
WSE (m, NAVD88)	EXISTING	18.027	17.478	16.233	20.981	1.630			
	PROJECT	17.369	16.827	15.956	20.193	1.372	-3.7	-1.7	-3.8
Q (cms)	EXISTING	18.78	10.05	2.95	63.76	18.30			
	PROJECT	19.61	9.99	2.95	71.50	19.98	4.4	-0.3	12.1
Total SSC (mg/L)	EXISTING	914.3	311.2	26.0	5455.6	1219.7			
	PROJECT	986.7	375.0	26.5	5705.1	1272.8	7.9	1.9	4.6
Clay to Coarse Silt	EXISTING	896.9	298.8	25.3	5411.9	1205.8			
	PROJECT	950.3	356.7	25.4	5590.2	1238.5	6.0	0.2	3.3
Coarse Silt to Fine Sand (mg/L)	EXISTING	17.3	11.4	0.7	58.8	15.9			
	PROJECT	35.3	17.5	1.1	112.2	35.3	103.6	64.7	90.8
Fine to Medium Sand	EXISTING	0.11	0.00	0.00	2.78	0.37			
	PROJECT	1.09	0.00	0.00	13.69	2.68	894.1	0.0	392.3
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									


WSE Comparison at Site SFR2
WSE (m, NAVD88)
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20
16
12
8
4
0
0 1 2 3 4 5 6 7
Run Time (d)
Existing
Project
Q Comparison at Site SFR2
Q (cms)
140
120
100
80
60
40
20
0
-20
0 1 2 3 4 5 6 7
Run Time (d)
Existing
Project
Total SSC Comparison at Site SFR2
SSC (1,000 mg/L)
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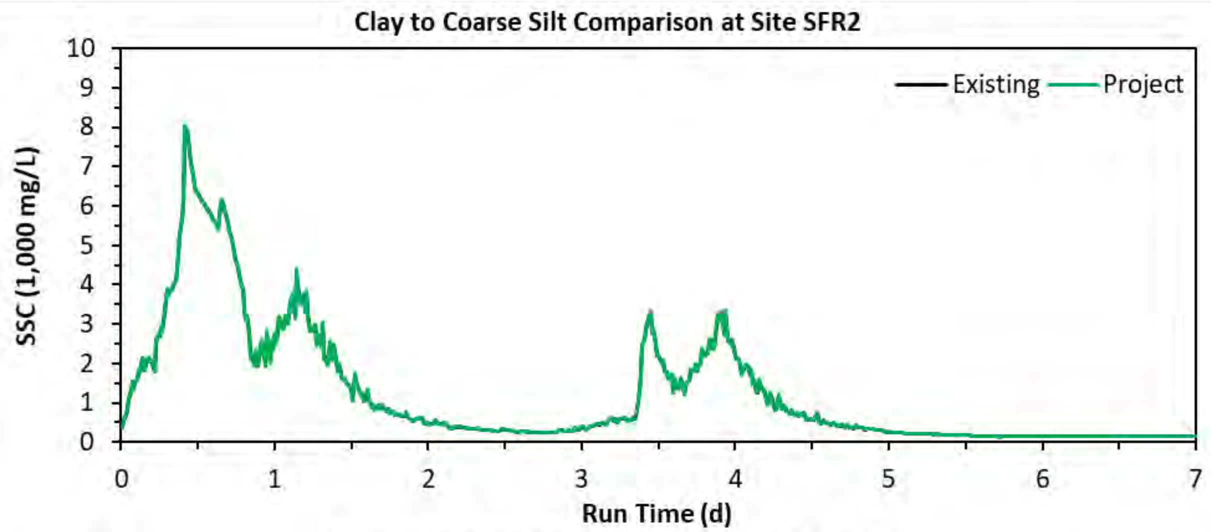
0 1 2 3 4 5 6 7
Run Time (d)
Existing
Project


Clay to Coarse Silt Comparison at Site SFR2
SSC (1,000 mg/L)
10
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Existing
Project
0
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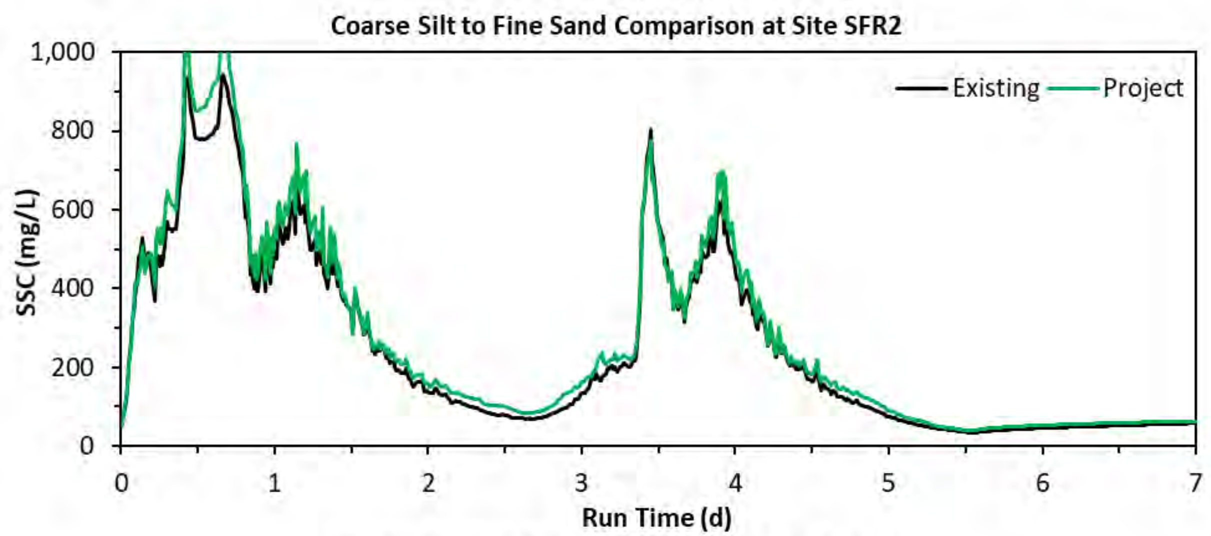
3
4
5
6
7
Run Time (d)


Coarse Silt to Fine Sand Comparison at Site SFR2
SSC (mg/L)
1,000
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600
400
200
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Existing
Project
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6
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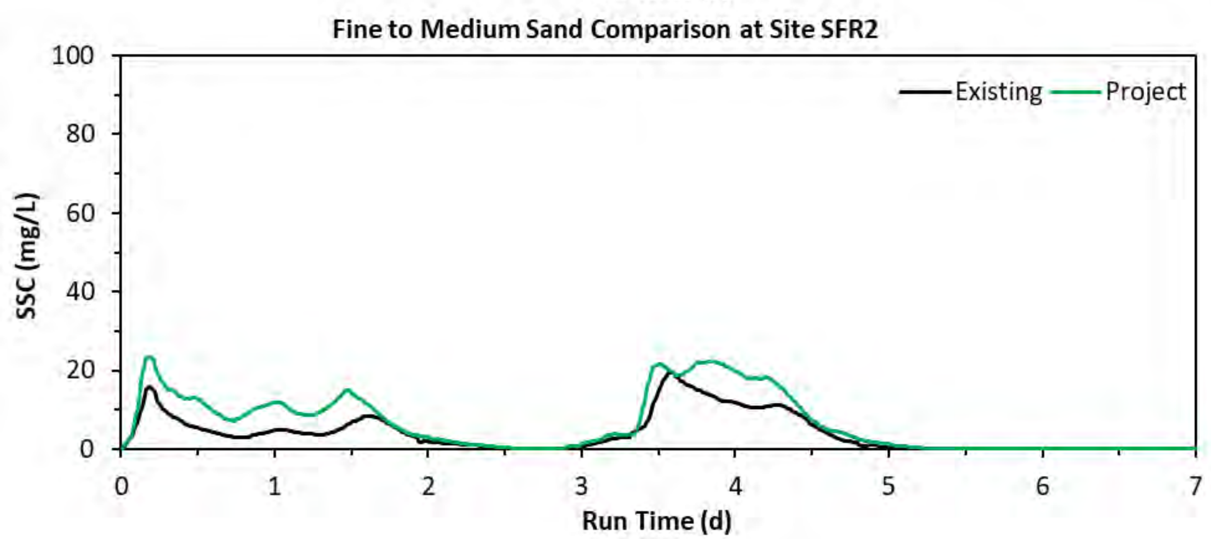
Run Time (d)


Fine to Medium Sand Comparison at Site SFR2
SSC (mg/L)
100
80
60
40
20
0
Existing
Project
0
1
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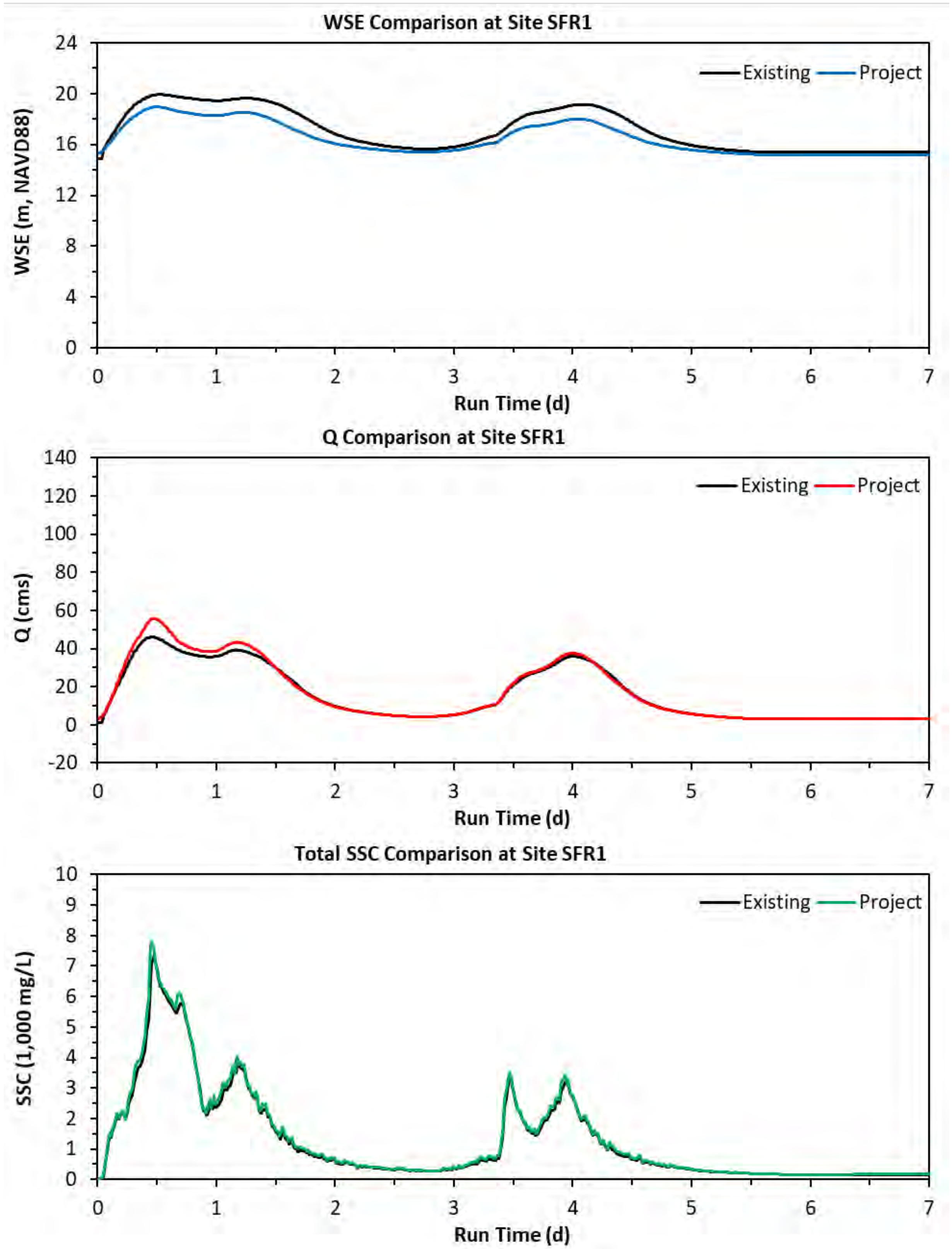
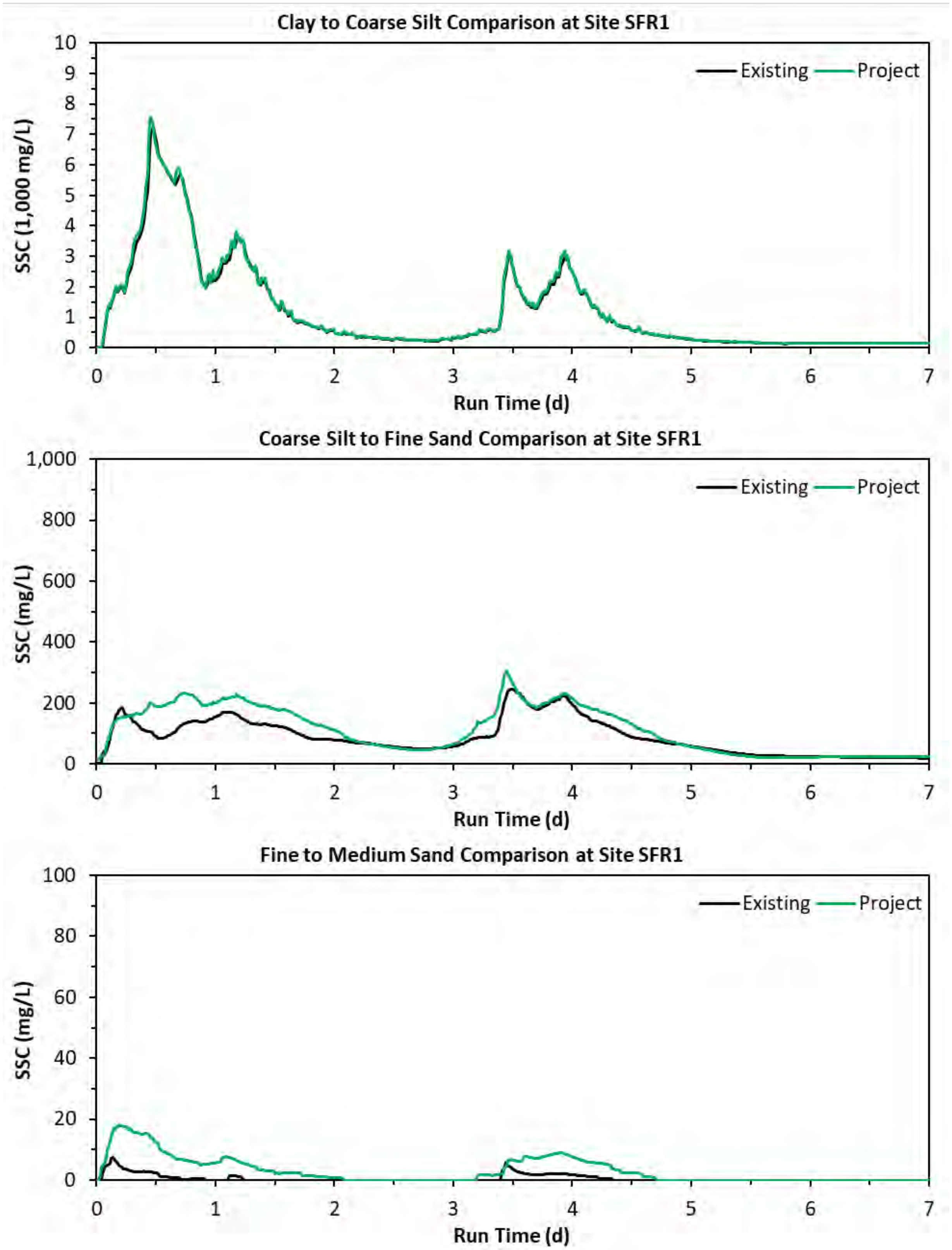
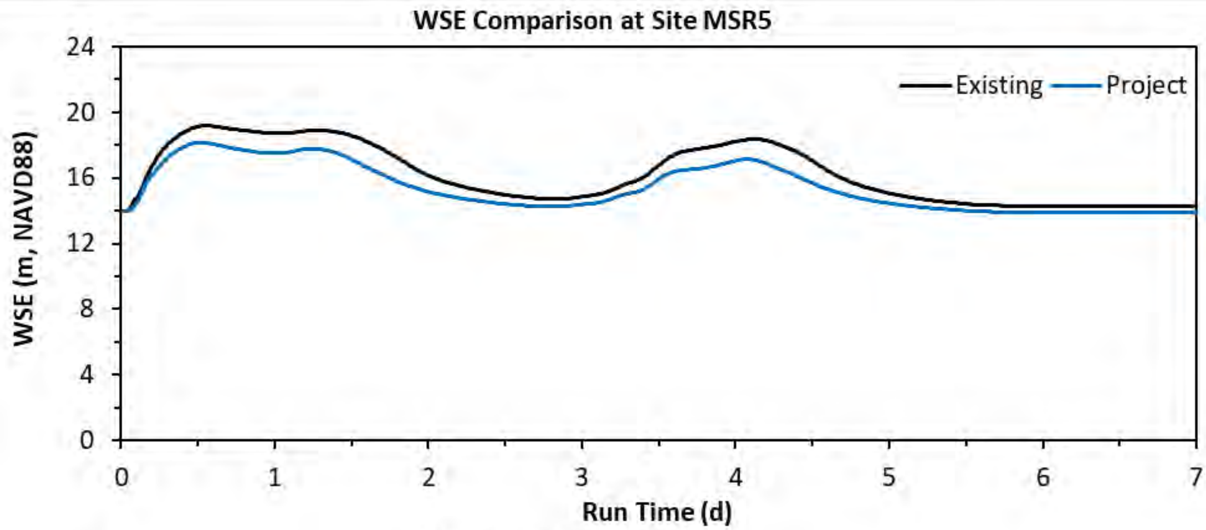
4
5
6
7
Run Time (d)

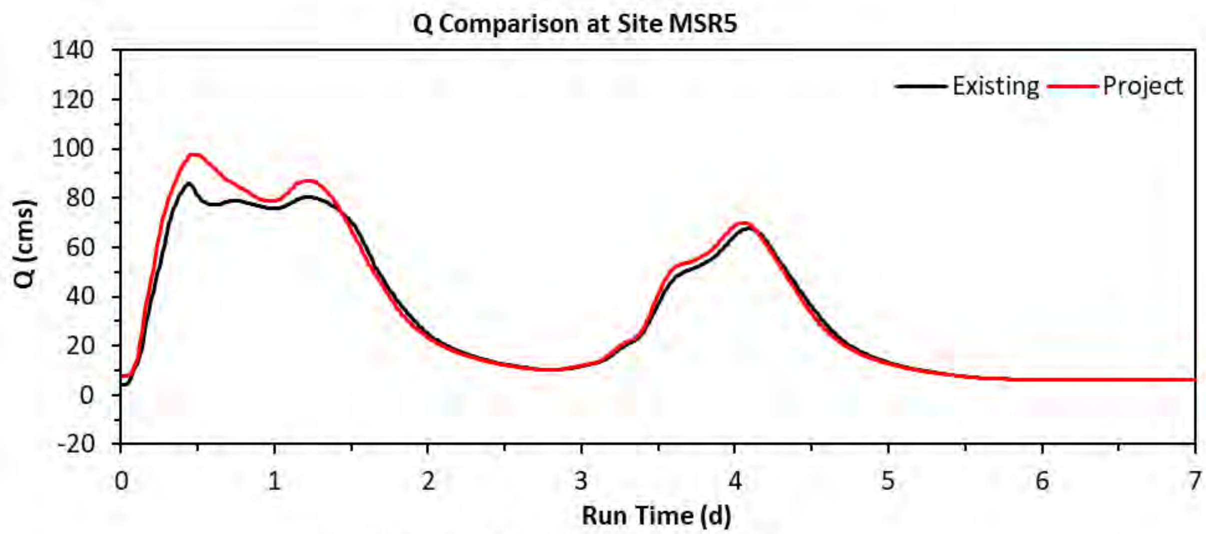
Summary Statistics at Site SFR2									
Constituent	**Condition**	**Average**	**Median**	**Minimum**	**Maximum**	**St Dev**	**% Avg Change**	**% Min Change**	**% Max Change**
WSE (m, NAVD88)	**EXISTING**	20.96	20.56	19.84	22.89	1.05			
	PROJECT	20.72	20.40	19.82	22.29	0.85	-1.1	-0.1	-2.6
Q (cms)	**EXISTING**	13.99	8.63	3.01	36.10	11.20			
	PROJECT	15.12	8.27	3.01	42.01	13.10	8.1	0.1	16.4
Total SSC (mg/L)	**EXISTING**	1482.21	619.59	170.50	8897.93	1766.16			
	PROJECT	1510.57	648.26	178.90	9058.97	1789.68	1.9	4.9	1.8
Clay to Coarse Silt	**EXISTING**	1230.46	466.45	130.95	7955.69	1542.65			
	PROJECT	1232.86	468.20	131.52	8023.08	1544.72	0.2	0.4	0.8
Coarse Silt to Fine Sand	**EXISTING**	247.76	145.51	33.84	941.91	229.90			
	PROJECT	271.24	166.40	39.40	1054.58	247.51	9.5	16.4	12.0
Fine to Medium Sand	**EXISTING**	3.99	2.04	0.00	19.57	4.78			
	PROJECT	6.47	3.25	0.03	23.38	7.16	62.4	> 1000 %	19.5
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									

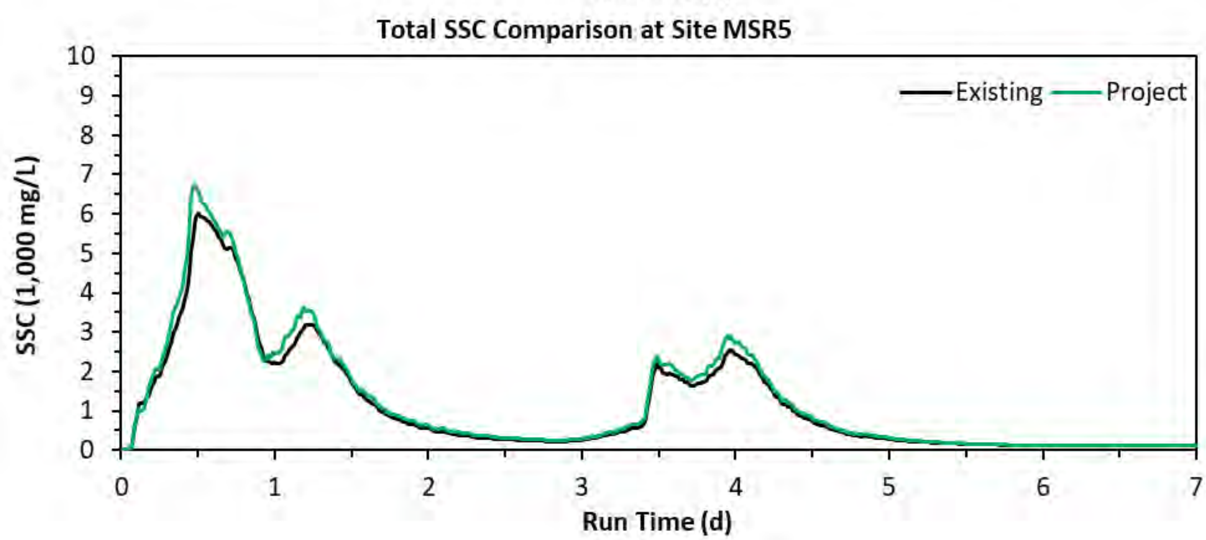

WSE Comparison at Site SFR1
Existing
Project
WSE (m, NAVD88)
24
20
16
12
8
4
0
0 1 2 3 4 5 6 7
Run Time (d)
Q Comparison at Site SFR1
Existing
Project
Q (cms)
140
120
100
80
60
40
20
0
-20
0 1 2 3 4 5 6 7
Run Time (d)
Total SSC Comparison at Site SFR1
Existing
Project
SSC (1,000 mg/L)
10
9
8
7
6
5
4
3
2
1
0
0 1 2 3 4 5 6 7
Run Time (d)

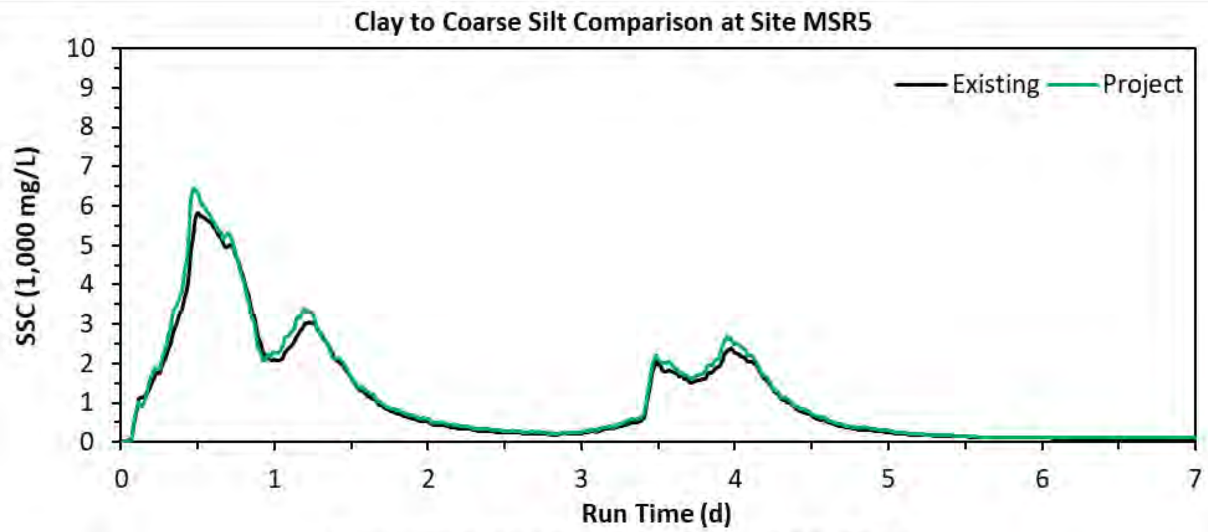

Clay to Coarse Silt Comparison at Site SFR1
Existing
Project
SSC (1,000 mg/L)
10
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
5
6
7
Run Time (d)
Coarse Silt to Fine Sand Comparison at Site SFR1
Existing
Project
SSC (mg/L)
1,000
800
600
400
200
0
0
1
2
3
4
5
6
7
Run Time (d)
Fine to Medium Sand Comparison at Site SFR1
Existing
Project
SSC (mg/L)
100
80
60
40
20
0
0
1
2
3
4
5
6
7
Run Time (d)

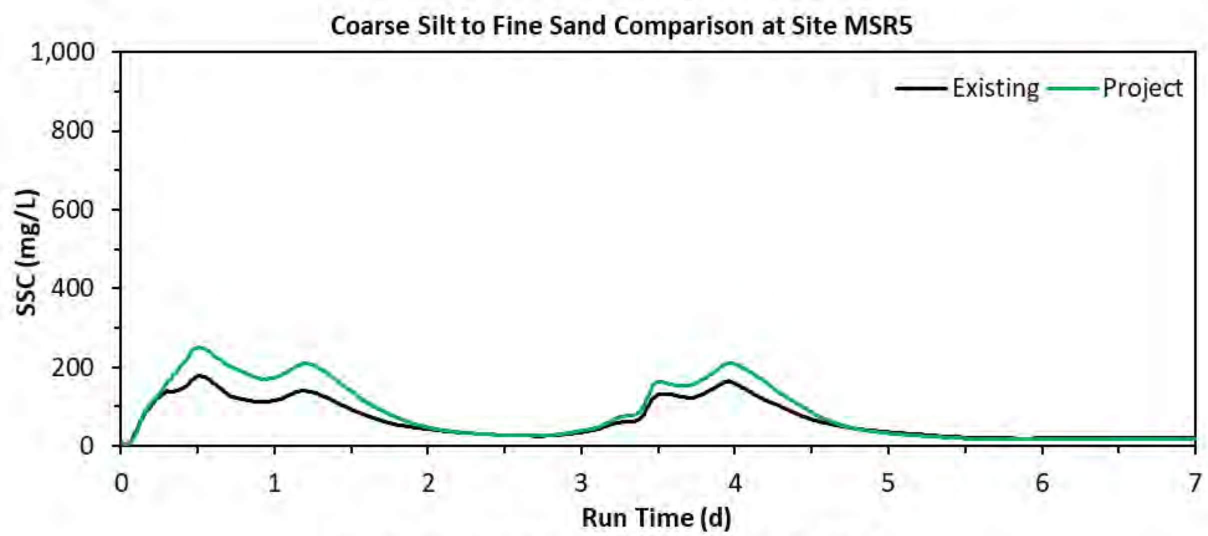
Summary Statistics at Site SFR1									
Constituent	Condition	Average	Median	Minimum	Maximum	St Dev	% Avg Change	% Min Change	% Max Change
WSE (m, NAVD88)	EXISTING	17.11	16.50	14.85	19.93	1.64			
	PROJECT	16.46	15.94	15.20	18.96	1.24	-3.8	2.4	-4.9
Q (cms)	EXISTING	15.97	8.74	0.98	45.94	13.99			
	PROJECT	16.80	8.64	2.99	55.67	15.49	5.2	204.8	21.2
Total SSC (mg/L)	EXISTING	1260.89	522.49	27.83	7302.64	1510.70			
	PROJECT	1322.17	568.40	40.38	7790.75	1574.14	4.9	45.1	6.7
Clay to Coarse Silt	EXISTING	1172.51	446.23	25.96	7203.66	1475.25			
	PROJECT	1208.44	463.01	25.92	7575.42	1513.01	3.1	-0.1	5.2
Coarse Silt to Fine Sand	EXISTING	87.81	76.72	1.88	246.29	57.82			
	PROJECT	110.71	98.17	14.06	305.67	75.89	26.1	648.5	24.1
Fine to Medium Sand	EXISTING	0.57	0.00	0.00	7.38	1.21			
	PROJECT	3.03	0.78	0.00	18.07	4.29	431.7	0.0	144.9
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									

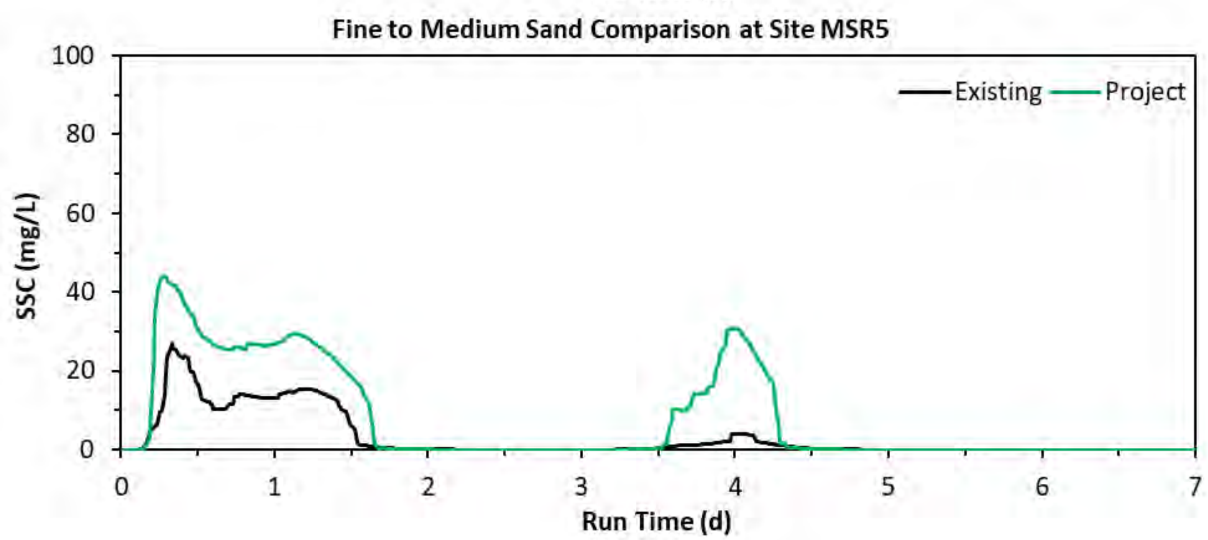

WSE Comparison at Site MSR5
Existing
Project
WSE (m, NAVD88)
24
20
16
12
8
4
0
0
1
2
3
4
5
6
7
Run Time (d)


Q Comparison at Site MSR5
Existing
Project
Q (cms)
140
120
100
80
60
40
20
0
-20
0
1
2
3
4
5
6
7
Run Time (d)

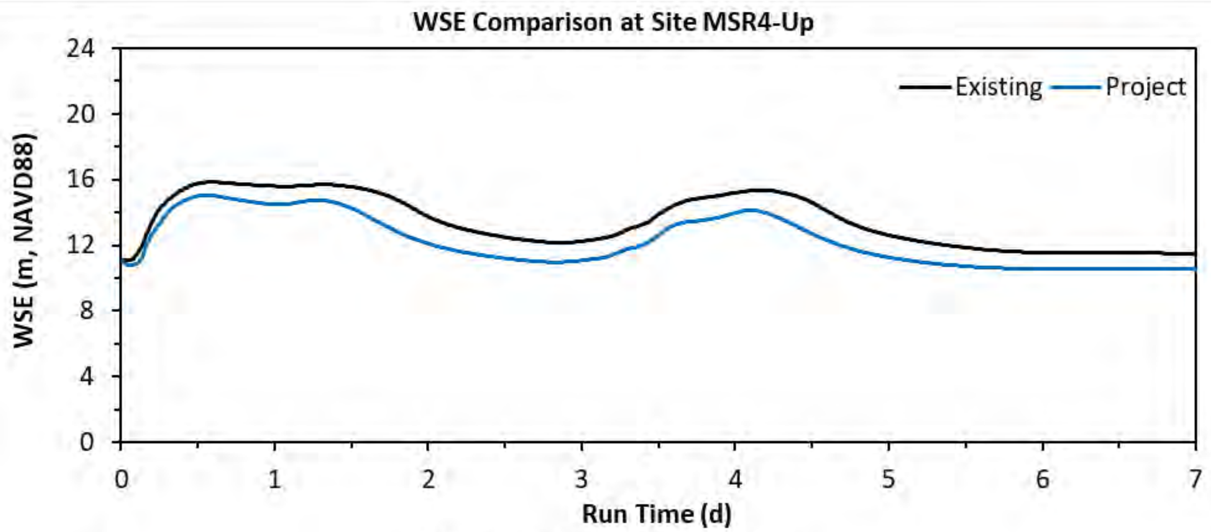

Total SSC Comparison at Site MSR5
Existing
Project
SSC (1,000 mg/L)
10
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
5
6
7
Run Time (d)

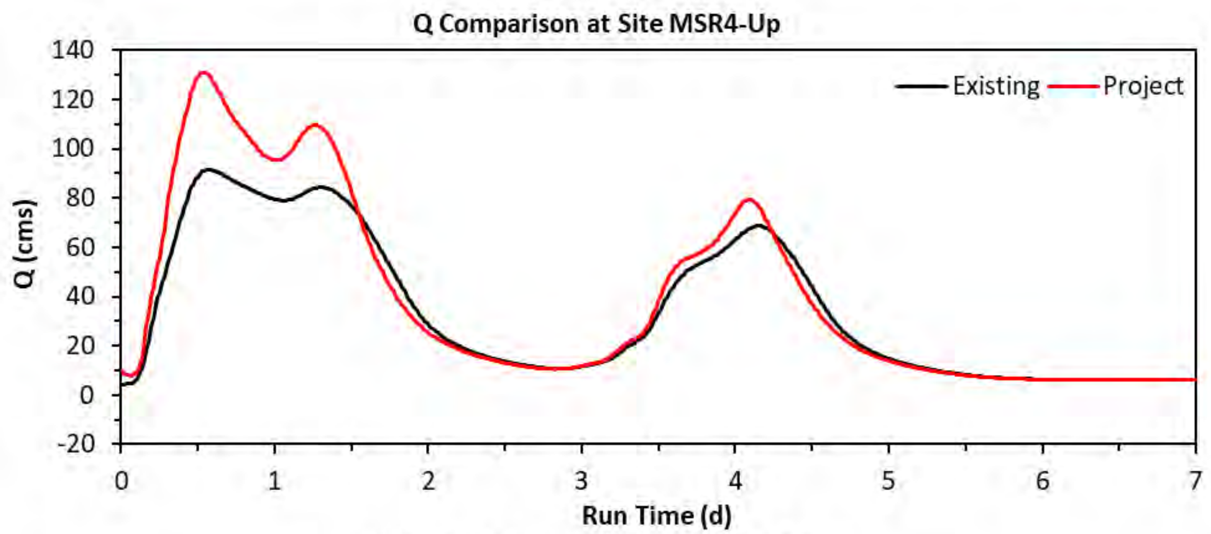

Clay to Coarse Silt Comparison at Site MSR5
Existing
Project
SSC (1,000 mg/L)
0
1
2
3
4
5
6
7
8
9
10
Run Time (d)
0
1
2
3
4
5
6
7

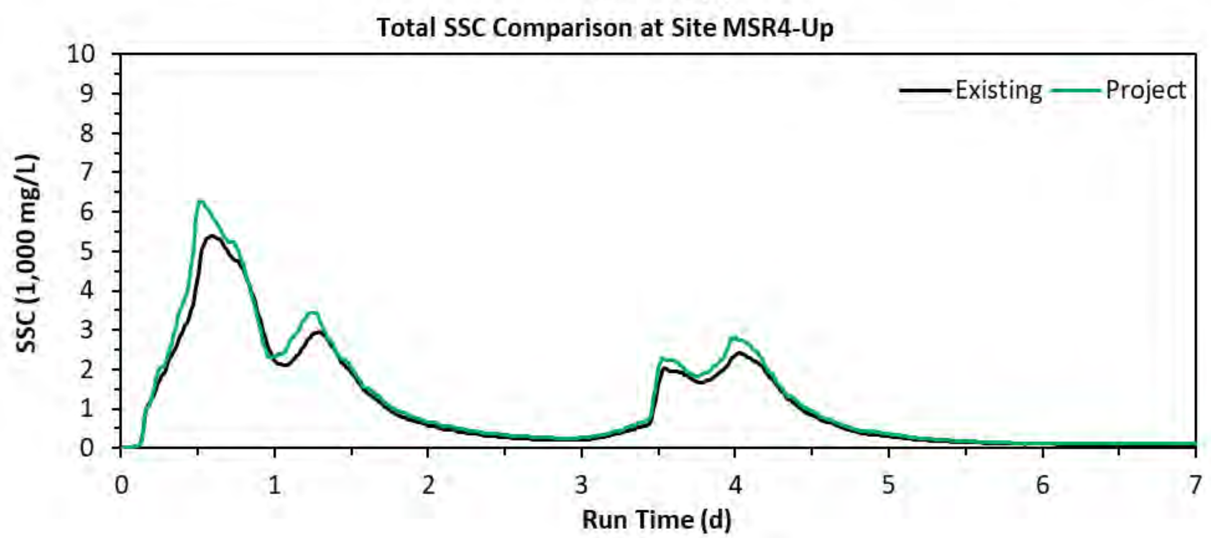

Coarse Silt to Fine Sand Comparison at Site MSR5
Existing
Project
SSC (mg/L)
0
200
400
600
800
1,000
Run Time (d)
0
1
2
3
4
5
6
7

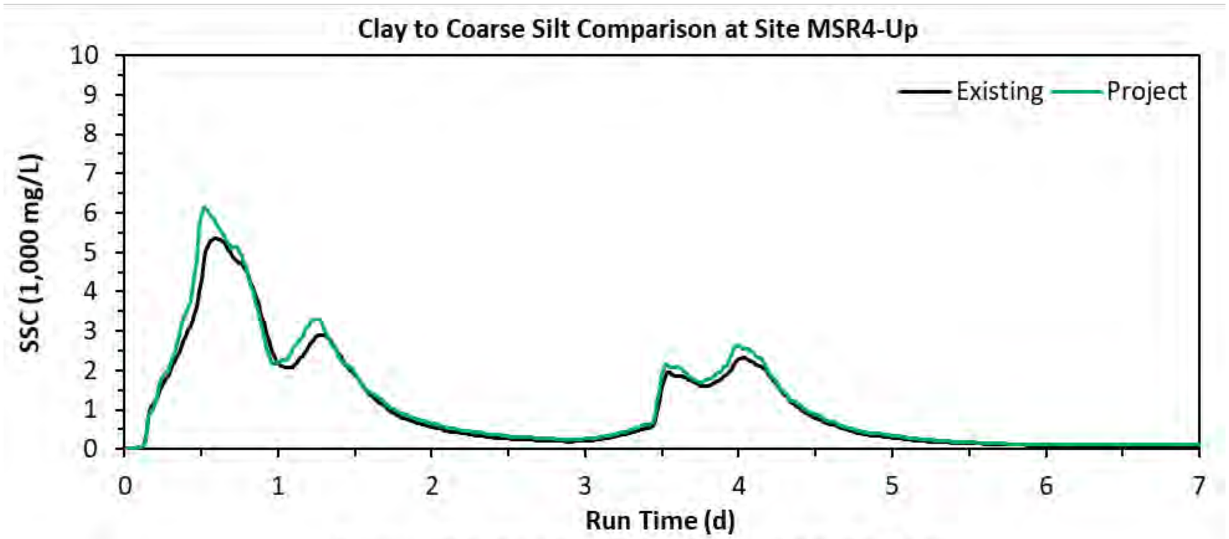

Fine to Medium Sand Comparison at Site MSR5
Existing
Project
SSC (mg/L)
0
20
40
60
80
100
Run Time (d)
0
1
2
3
4
5
6
7

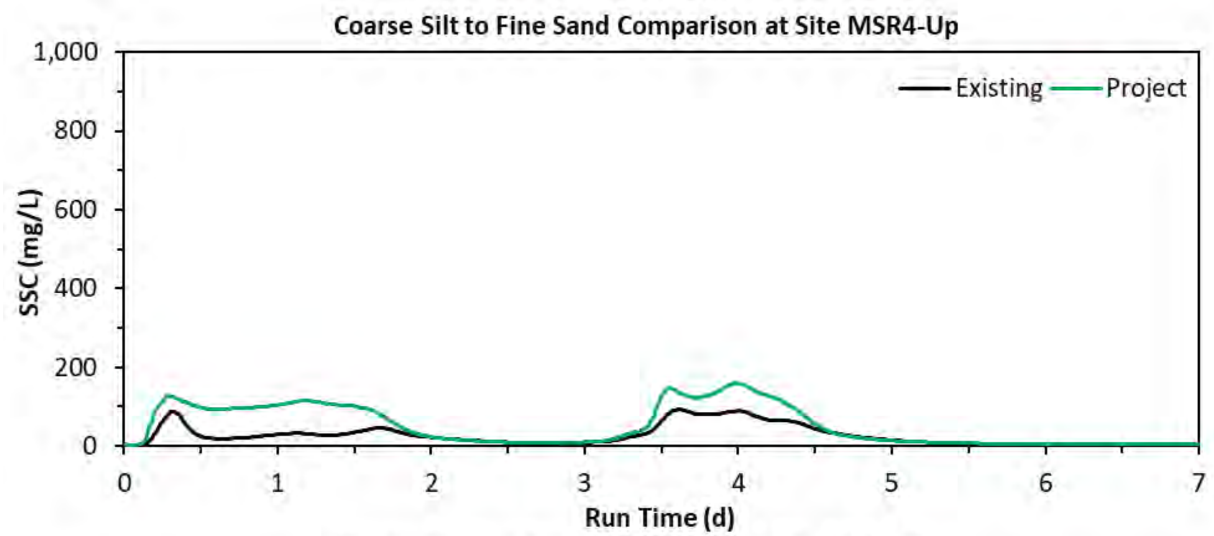
Summary Statistics at Site MSR5									
Constituent	**Condition**	**Average**	**Median**	**Minimum**	**Maximum**	**St Dev**	**% Avg Change**	**% Min Change**	**% Max Change**
WSE (m, NAVD88)	**EXISTING**	16.21	15.63	13.98	19.18	1.76			
	PROJECT	15.41	14.90	13.87	18.16	1.43	-4.9	-0.8	-5.3
Q (cms)	**EXISTING**	32.54	19.46	4.36	85.96	27.19			
	PROJECT	33.92	19.29	6.10	97.81	29.63	4.3	39.9	13.8
Total SSC (mg/L)	**EXISTING**	1139.29	456.99	37.98	6016.06	1365.04			
	PROJECT	1242.08	498.93	37.69	6729.83	1479.22	9.0	-0.8	11.9
Clay to Coarse Silt	**EXISTING**	1069.60	406.23	34.13	5821.46	1317.79			
	PROJECT	1149.33	455.24	31.18	6449.30	1402.54	7.5	-8.7	10.8
Coarse Silt to Fine Sand	**EXISTING**	66.71	45.06	2.85	178.48	48.23			
	PROJECT	85.06	48.05	5.59	249.77	72.11	27.5	96.5	39.9
Fine to Medium Sand	**EXISTING**	2.98	0.02	0.00	26.92	5.81			
	PROJECT	7.69	0.01	0.00	43.96	12.29	158.3	-17.9	63.3
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									

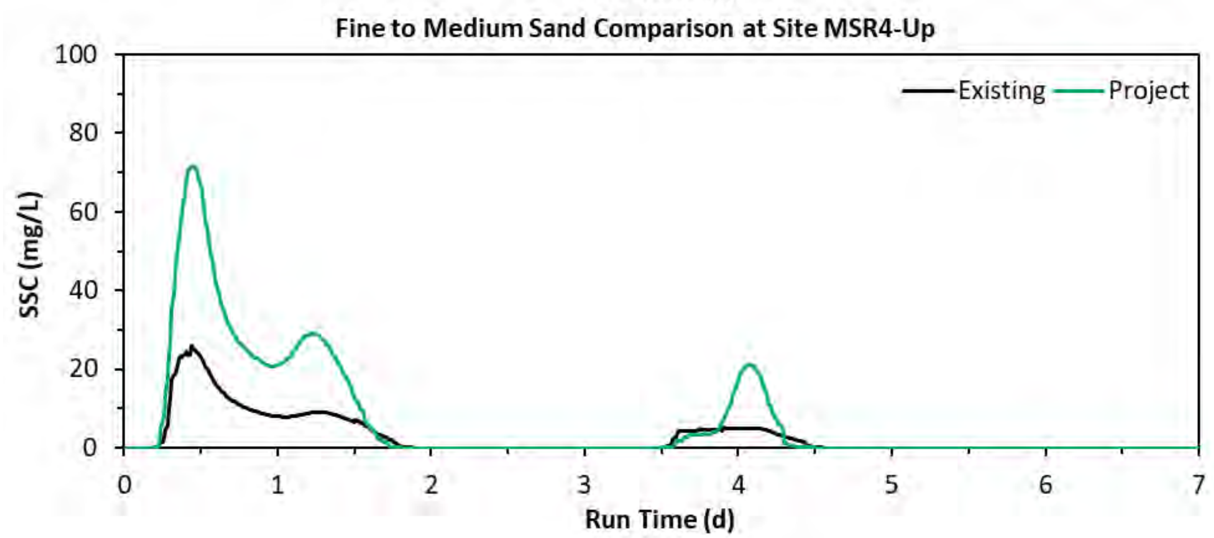

WSE Comparison at Site MSR4-Up
Existing
Project
WSE (m, NAVD88)
24
20
16
12
8
4
0
0
1
2
3
4
5
6
7
Run Time (d)


Q Comparison at Site MSR4-Up
Existing
Project
Q (cms)
140
120
100
80
60
40
20
0
-20
0
1
2
3
4
5
6
7
Run Time (d)

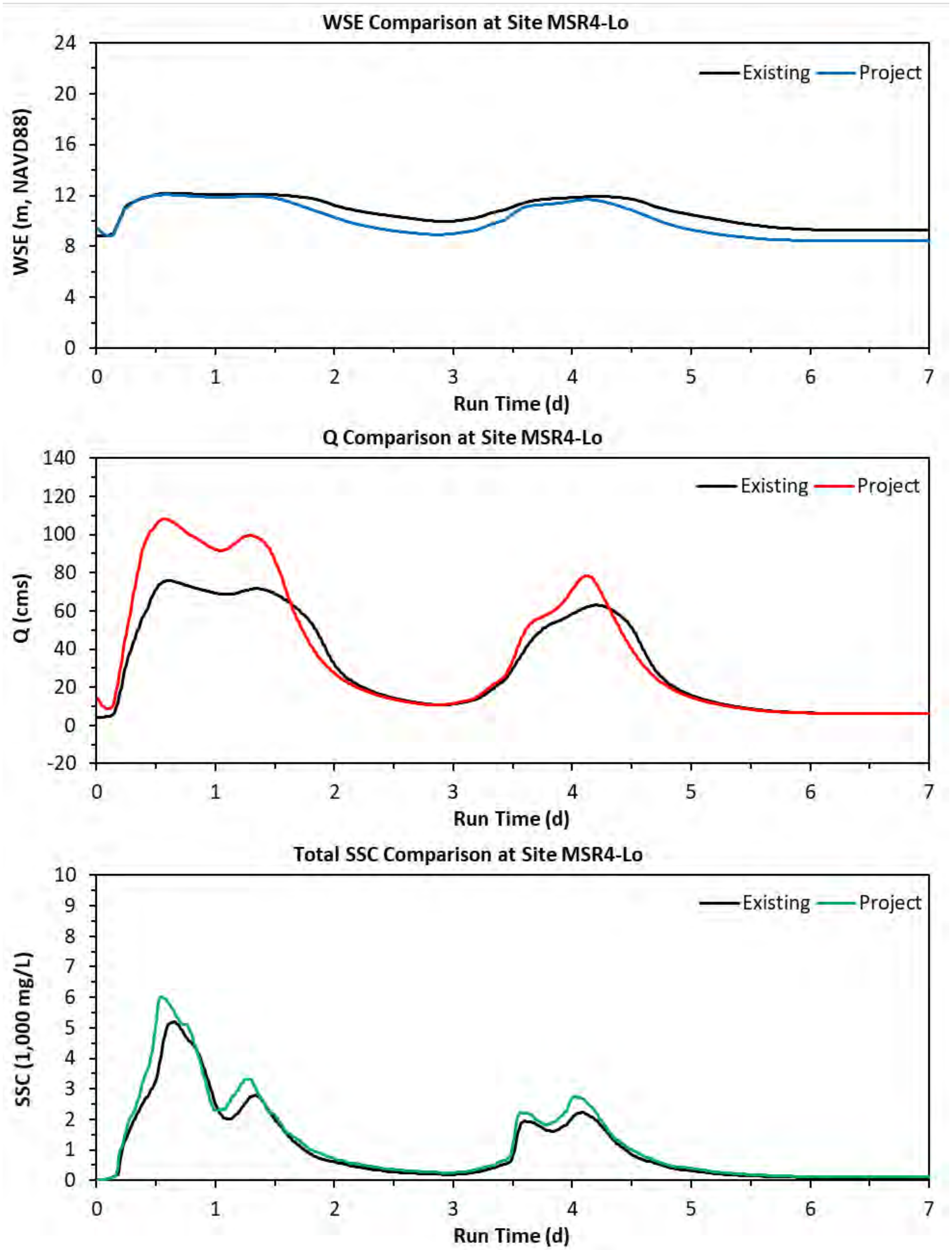

Total SSC Comparison at Site MSR4-Up
Existing
Project
SSC (1,000 mg/L)
10
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
5
6
7
Run Time (d)

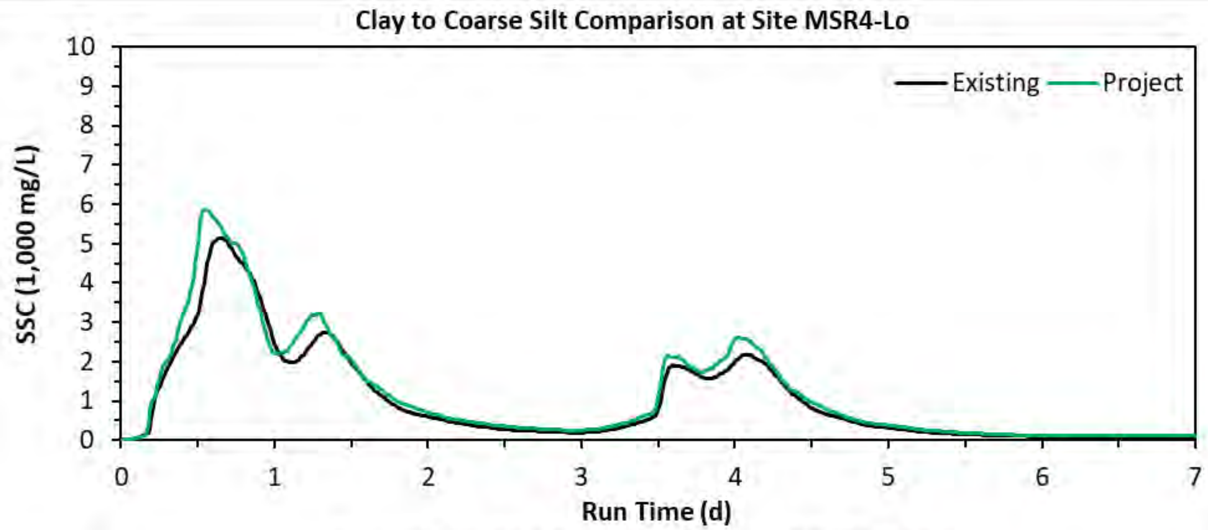

Clay to Coarse Silt Comparison at Site MSR4-Up
Existing
Project
SSC (1,000 mg/L)
Run Time (d)
0
1
2
3
4
5
6
7
8
9
10

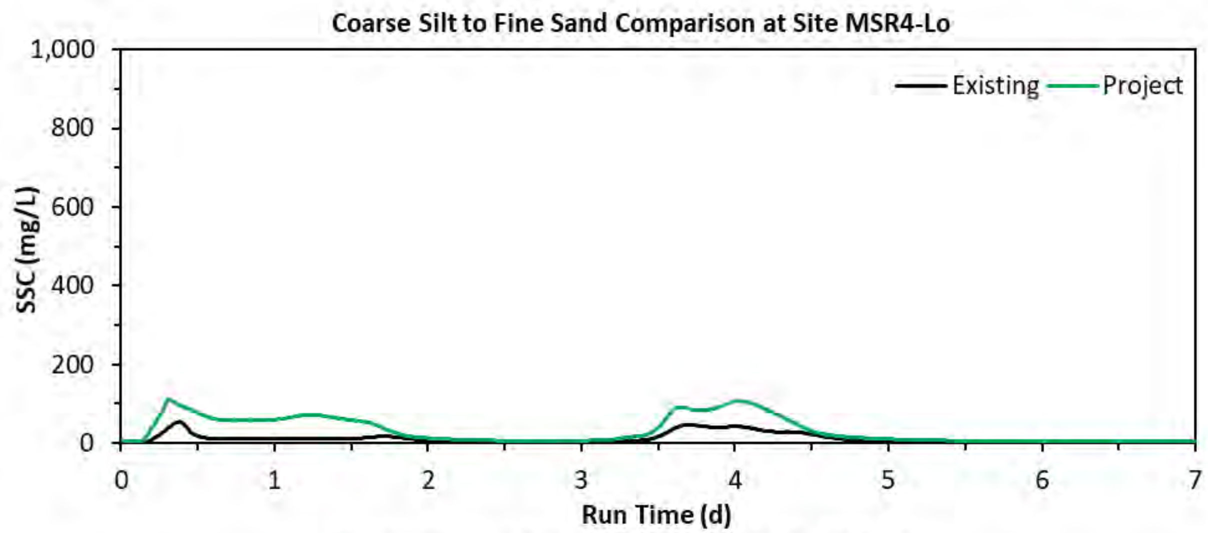

Coarse Silt to Fine Sand Comparison at Site MSR4-Up
Existing
Project
SSC (mg/L)
Run Time (d)
1,000
800
600
400
200
0

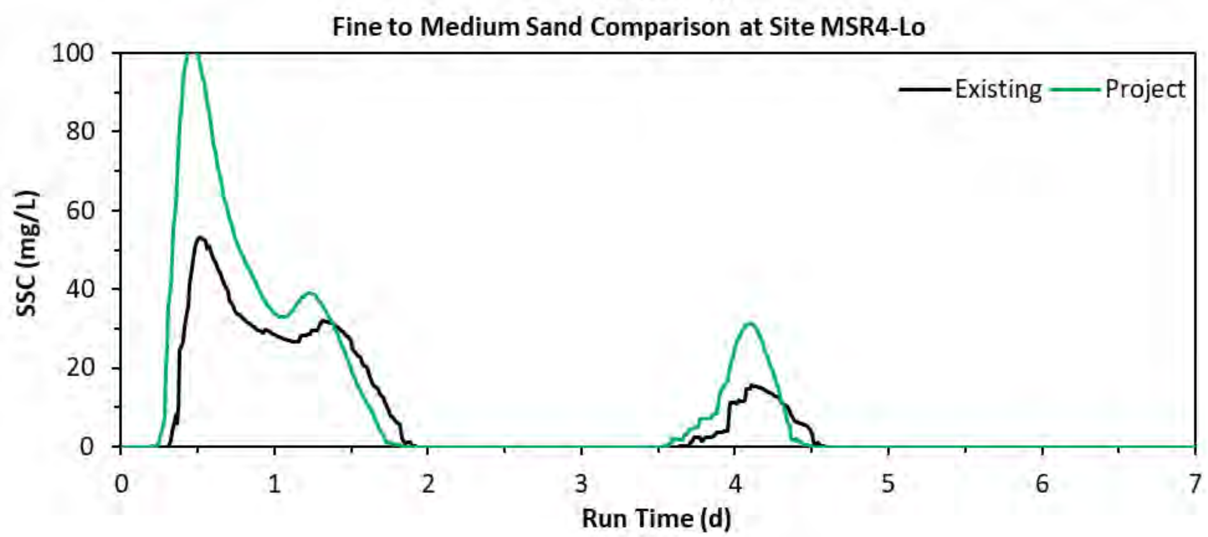

Fine to Medium Sand Comparison at Site MSR4-Up
Existing
Project
SSC (mg/L)
Run Time (d)
100
80
60
40
20
0

Summary Statistics at Site MSR4-Up									
Constituent	**Condition**	**Average**	**Median**	**Minimum**	**Maximum**	**St Dev**	**% Avg Change**	**% Min Change**	**% Max Change**
WSE (m, NAVD88)	**EXISTING**	13.44	13.07	11.09	15.84	1.58			
	PROJECT	12.24	11.72	10.54	15.04	1.54	-8.9	-5.0	-5.1
Q (cms)	**EXISTING**	34.24	20.44	4.40	91.57	28.79			
	PROJECT	38.79	20.01	6.18	131.05	37.07	13.3	40.4	43.1
Total SSC (mg/L)	**EXISTING**	1089.17	444.15	28.48	5385.26	1276.16			
	PROJECT	1222.93	513.33	29.75	6302.69	1424.95	12.3	4.5	17.0
Clay to Coarse Silt	**EXISTING**	1059.50	423.13	26.42	5350.07	1260.33			
	PROJECT	1165.54	489.53	26.47	6145.52	1374.19	10.0	0.2	14.9
Coarse Silt to Fine Sand	**EXISTING**	26.83	18.73	1.08	92.68	25.06			
	PROJECT	50.43	20.45	2.43	159.19	49.71	87.9	124.8	71.8
Fine to Medium Sand	**EXISTING**	2.84	0.00	0.00	26.18	5.20			
	PROJECT	6.96	0.00	0.00	71.75	14.20	145.1	0.0	174.1
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									

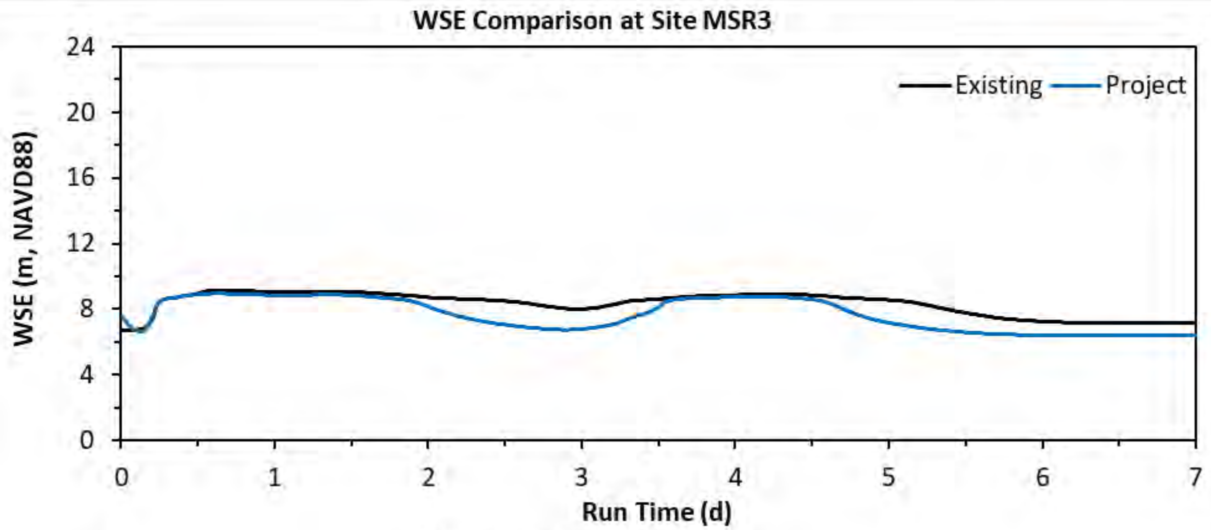

WSE Comparison at Site MSR4-Lo
WSE (m, NAVD88)
Existing
Project
Run Time (d)
Q Comparison at Site MSR4-Lo
Q (cms)
Existing
Project
Run Time (d)
Total SSC Comparison at Site MSR4-Lo
SSC (1,000 mg/L)
Existing
Project
Run Time (d)

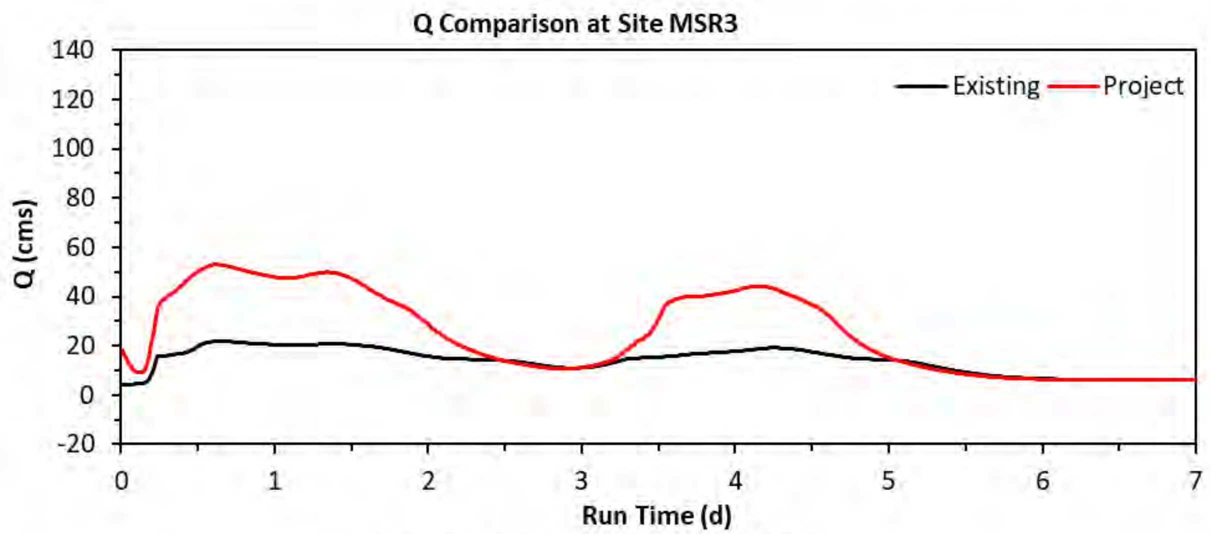

Clay to Coarse Silt Comparison at Site MSR4-Lo
Existing
Project
SSC (1,000 mg/L)
Run Time (d)
0
1
2
3
4
5
6
7
8
9
10

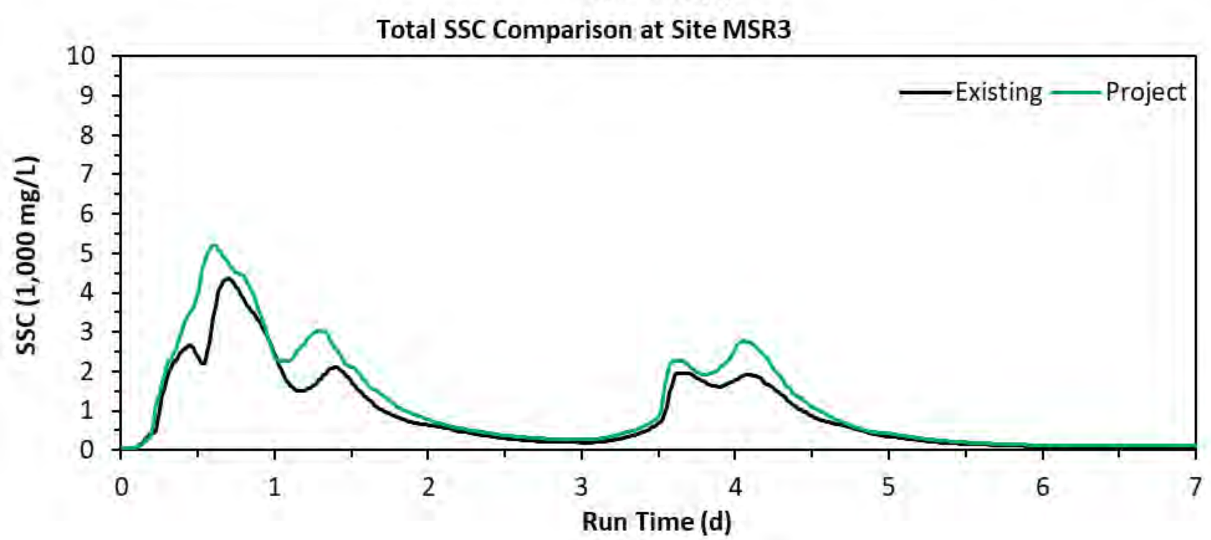

Coarse Silt to Fine Sand Comparison at Site MSR4-Lo
Existing
Project
SSC (mg/L)
Run Time (d)
0
200
400
600
800
1,000

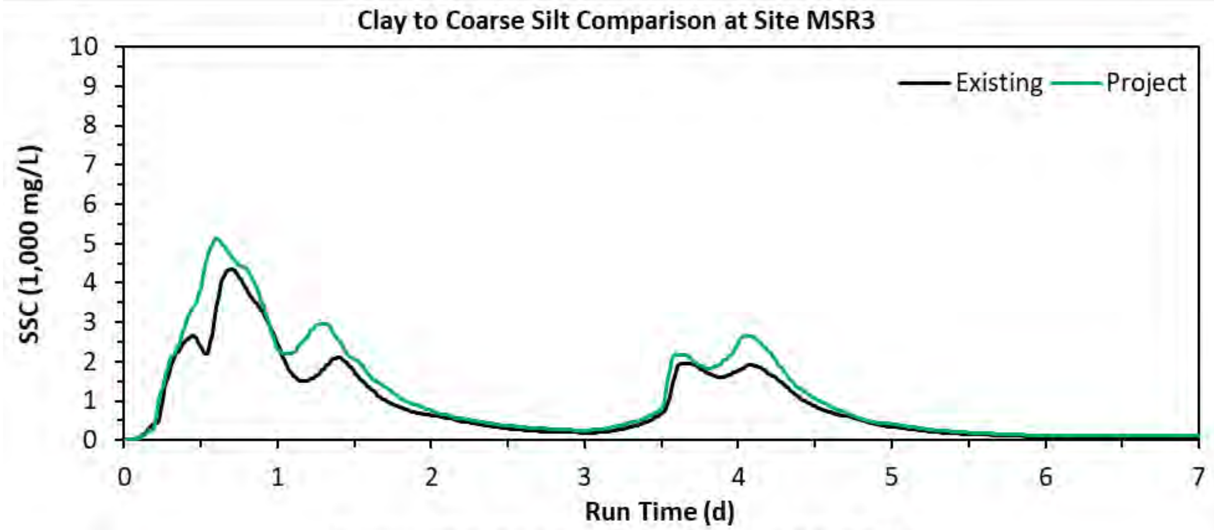

Fine to Medium Sand Comparison at Site MSR4-Lo
Existing
Project
SSC (mg/L)
Run Time (d)
0
20
40
60
80
100

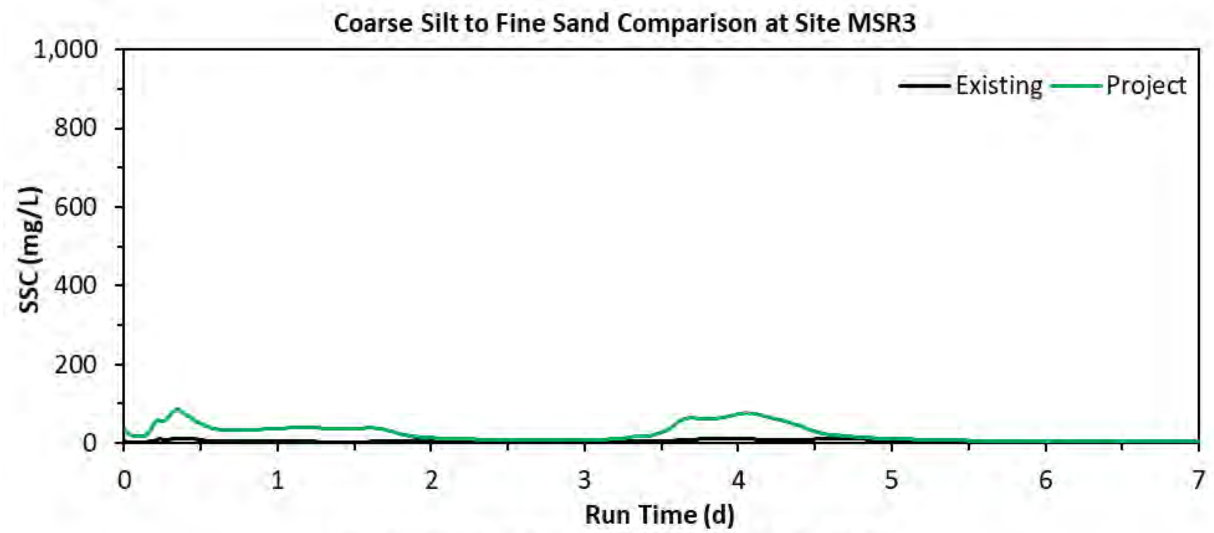
Summary Statistics at Site MSR4-Lo									
Constituent	**Condition**	**Average**	**Median**	**Minimum**	**Maximum**	**St Dev**	**% Avg Change**	**% Min Change**	**% Max Change**
WSE (m, NAVD88)	**EXISTING**	10.74	10.74	8.81	12.18	1.07			
	PROJECT	10.05	9.75	8.42	12.05	1.32	-6.5	-4.4	-1.1
Q (cms)	**EXISTING**	31.96	20.50	4.35	75.77	24.99			
	PROJECT	37.39	20.36	6.24	108.18	33.80	17.0	43.5	42.8
Total SSC (mg/L)	**EXISTING**	1038.31	426.83	27.42	5190.22	1220.53			
	PROJECT	1205.41	514.73	32.14	6024.32	1388.85	16.1	17.2	16.1
Clay to Coarse Silt	**EXISTING**	1020.13	421.66	26.32	5136.38	1202.39			
	PROJECT	1162.99	502.10	26.39	5865.77	1343.99	14.0	0.3	14.2
Coarse Silt to Fine Sand	**EXISTING**	11.00	5.00	0.72	54.10	13.13			
	PROJECT	31.54	12.06	3.59	111.66	32.42	186.7	399.4	106.4
Fine to Medium Sand	**EXISTING**	7.17	0.00	0.00	53.28	12.94			
	PROJECT	10.88	0.00	0.00	103.36	21.67	51.8	0.0	94.0
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									

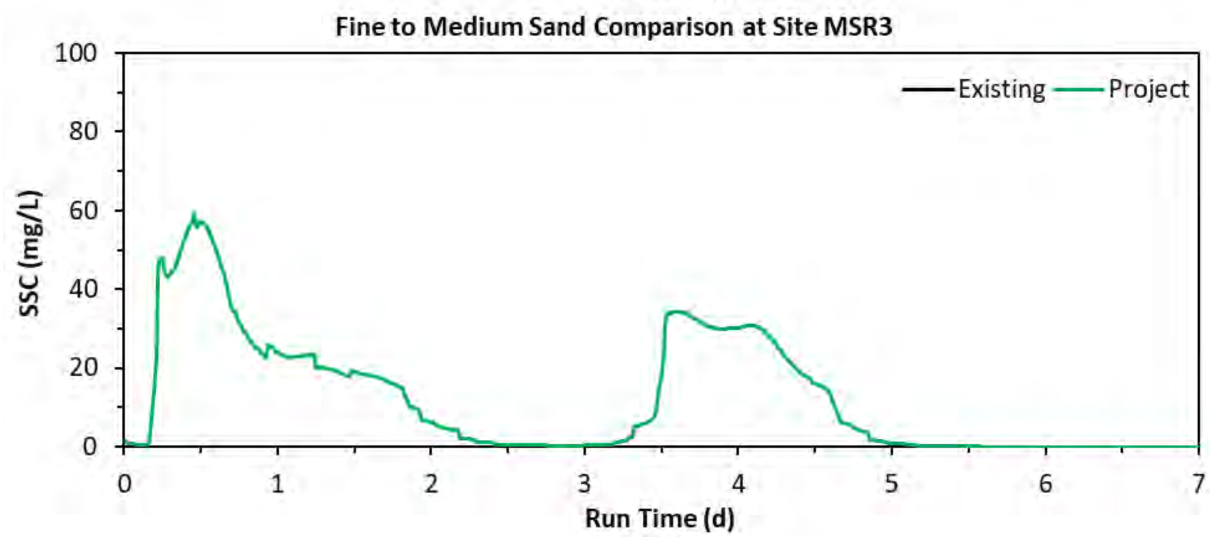

WSE Comparison at Site MSR3
Existing
Project
WSE (m, NAVD88)
Run Time (d)


Q Comparison at Site MSR3
Existing
Project
Q (cms)
Run Time (d)

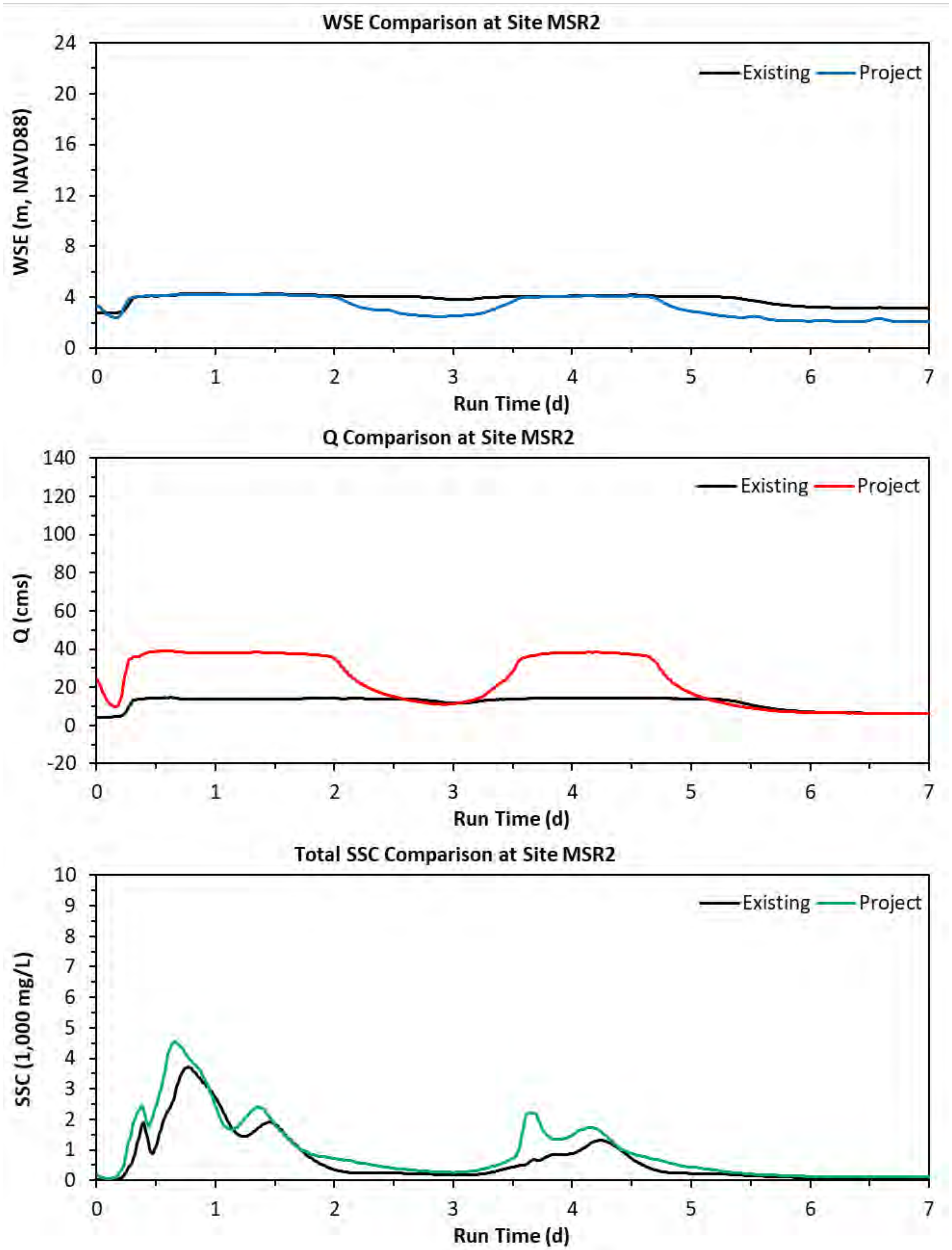

Total SSC Comparison at Site MSR3
Existing
Project
SSC (1,000 mg/L)
Run Time (d)

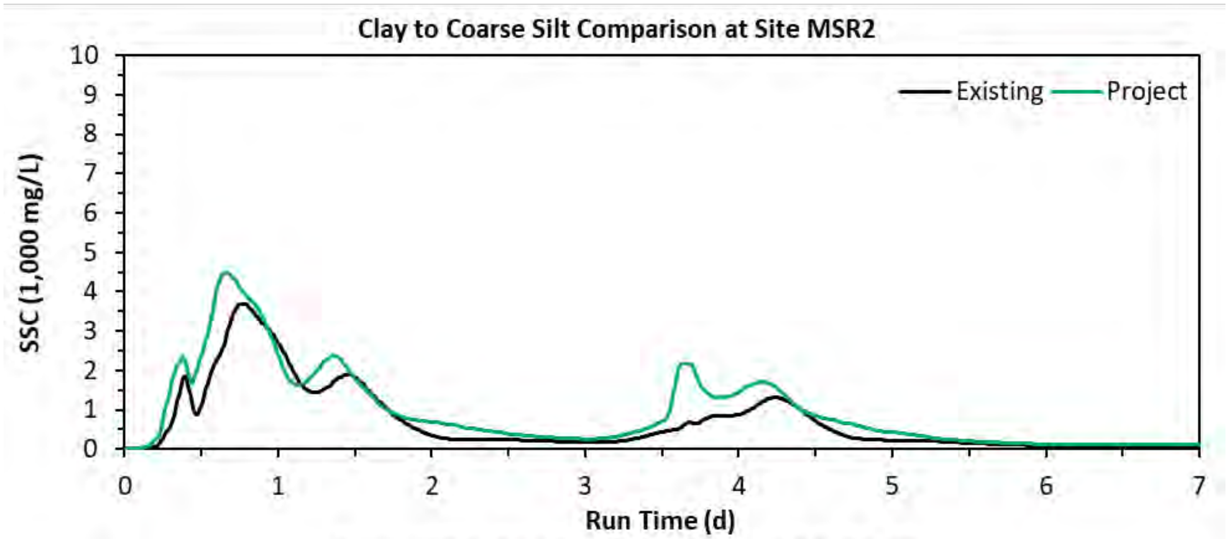

Clay to Coarse Silt Comparison at Site MSR3
SSC (1,000 mg/L)
10
9
8
7
6
5
4
3
2
1
0
Existing
Project
0
1
2
3
4
5
6
7
Run Time (d)


Coarse Silt to Fine Sand Comparison at Site MSR3
SSC (mg/L)
1,000
800
600
400
200
0
Existing
Project
0
1
2
3
4
5
6
7
Run Time (d)


Fine to Medium Sand Comparison at Site MSR3
SSC (mg/L)
100
80
60
40
20
0
Existing
Project
0
1
2
3
4
5
6
7
Run Time (d)

Summary Statistics at Site MSR3									
Constituent	**Condition**	**Average**	**Median**	**Minimum**	**Maximum**	**St Dev**	**% Avg Change**	**% Min Change**	**% Max Change**
WSE (m, NAVD88)	**EXISTING**	8.32	8.59	6.67	9.15	0.70			
	PROJECT	7.66	7.54	6.37	8.94	0.99	-7.9	-4.5	-2.3
Q (cms)	**EXISTING**	13.93	14.72	4.22	21.83	5.08			
	PROJECT	25.30	20.41	6.14	52.96	16.44	81.6	45.4	142.6
Total SSC (mg/L)	**EXISTING**	913.86	457.59	30.34	4347.99	991.47			
	PROJECT	1174.37	539.99	50.85	5206.35	1263.85	28.5	67.6	19.7
Clay to Coarse Silt	**EXISTING**	907.99	450.51	26.30	4343.57	990.88			
	PROJECT	1137.67	521.77	27.45	5121.56	1235.10	25.3	4.4	17.9
Coarse Silt to Fine Sand	**EXISTING**	5.87	4.72	2.67	11.89	2.61			
	PROJECT	24.48	14.55	4.67	86.49	21.34	317.0	74.6	627.2
Fine to Medium Sand	**EXISTING**	0.00	0.00	0.00	0.00	0.00			
	PROJECT	12.21	3.92	0.00	59.09	15.21	> 1000 %	0.0	> 1000 %
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									


WSE Comparison at Site MSR2
WSE (m, NAVD88)
24
20
16
12
8
4
0
Existing
Project
0
1
2
3
4
5
6
7
Run Time (d)
Q Comparison at Site MSR2
Q (cms)
140
120
100
80
60
40
20
0
-20
Existing
Project
0
1
2
3
4
5
6
7
Run Time (d)
Total SSC Comparison at Site MSR2
SSC (1,000 mg/L)
10
9
8
7
6
5
4
3
2
1
0
Existing
Project
0
1
2
3
4
5
6
7
Run Time (d)


Clay to Coarse Silt Comparison at Site MSR2
SSC (1,000 mg/L)
Run Time (d)
Existing
Project
10
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
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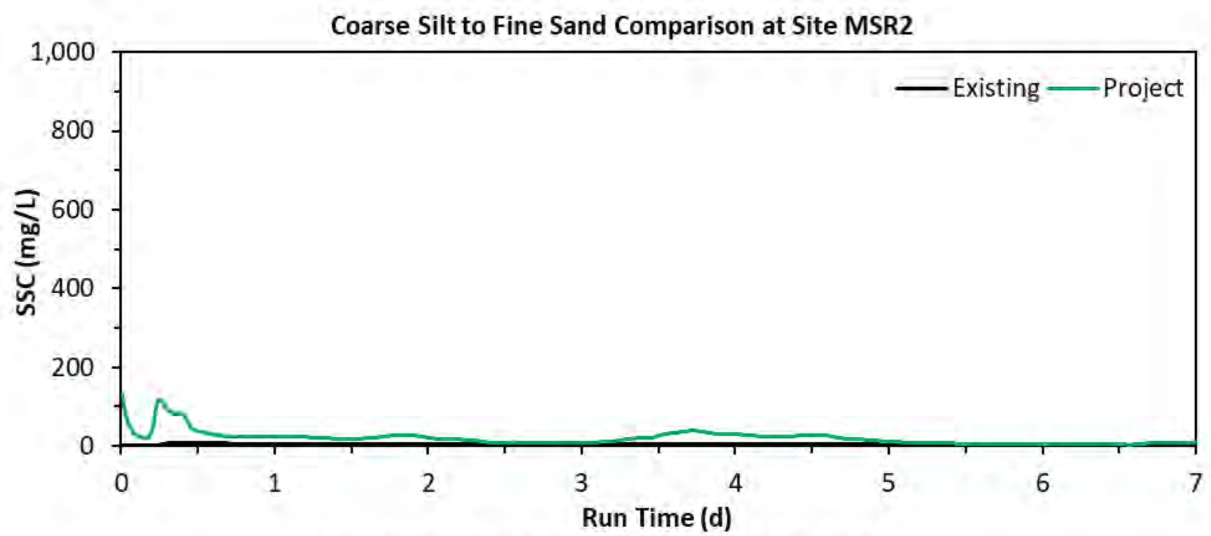
6
7


Coarse Silt to Fine Sand Comparison at Site MSR2
SSC (mg/L)
Run Time (d)
Existing
Project
1,000
800
600
400
200
0
0
1
2
3
4
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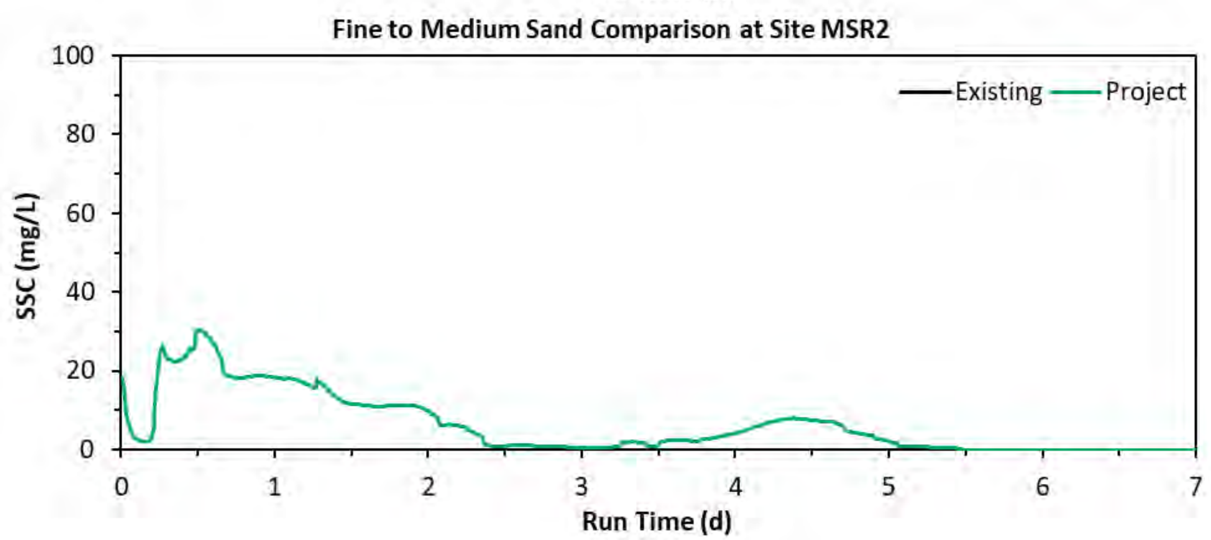
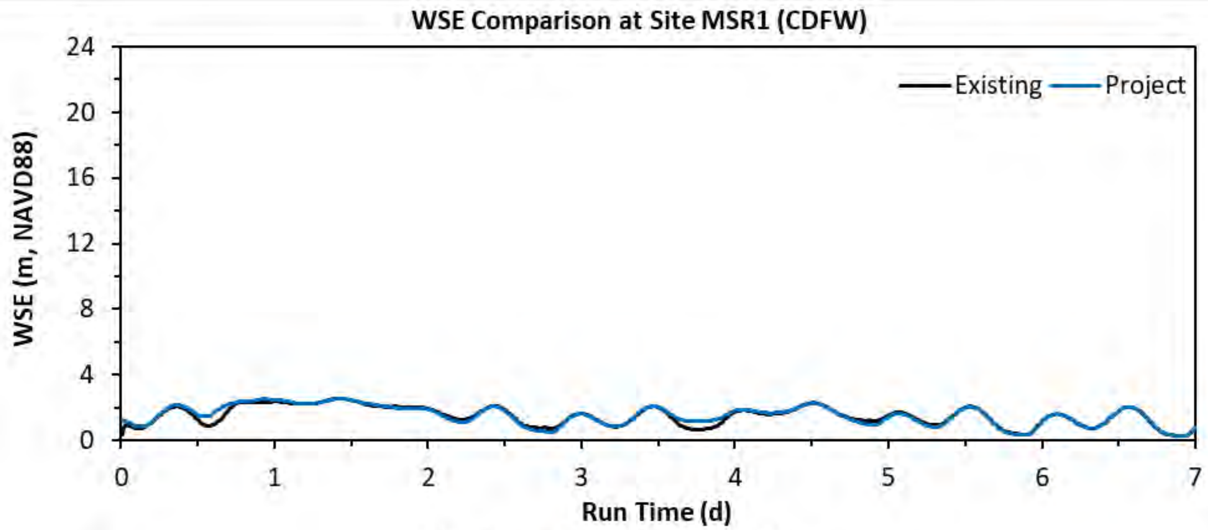
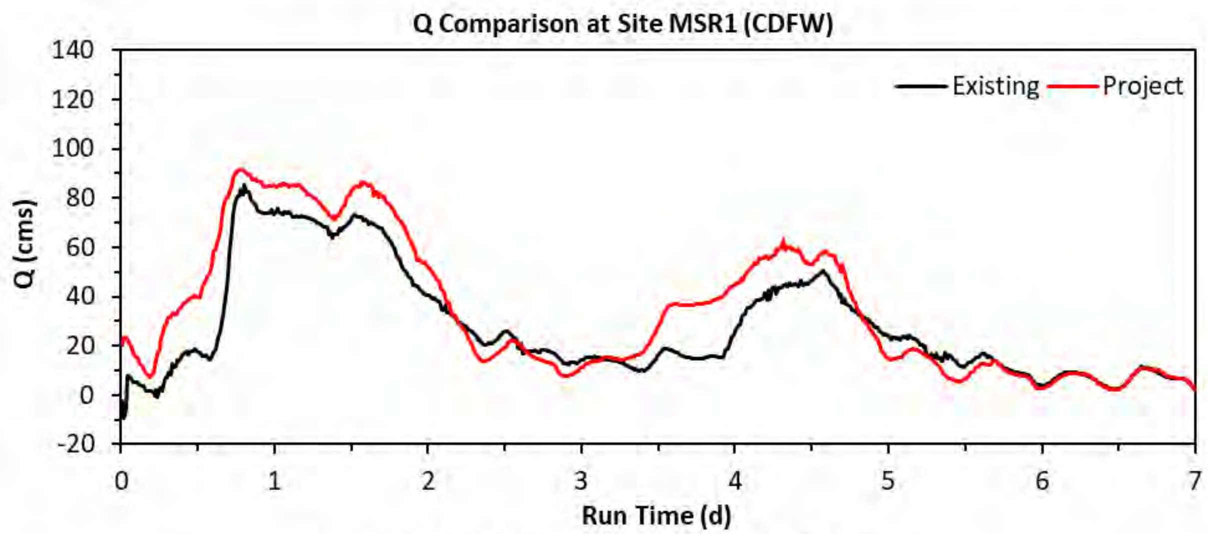
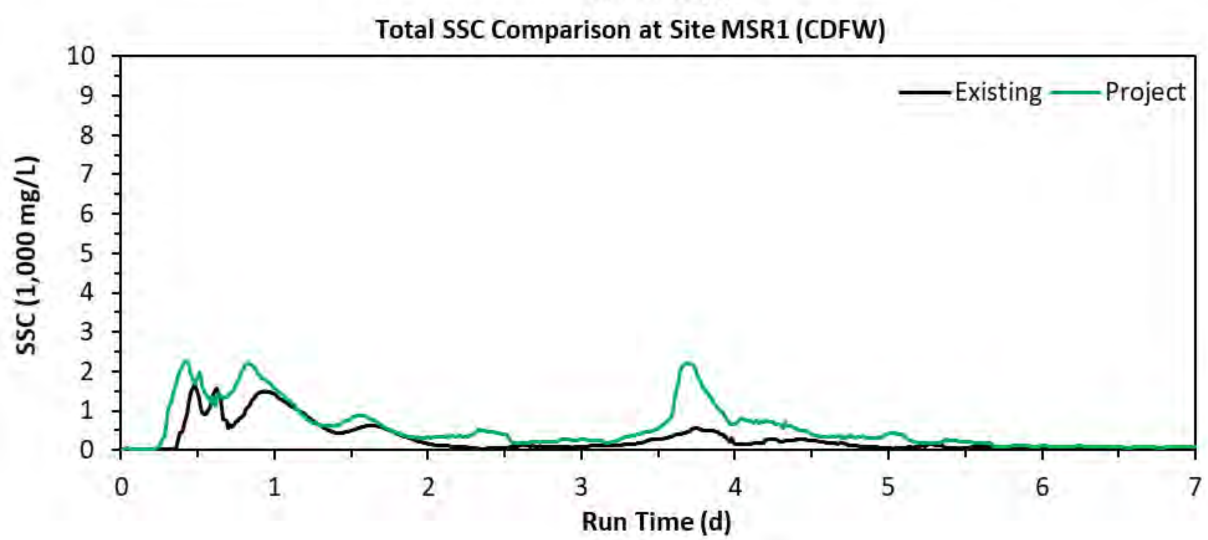
6
7


Fine to Medium Sand Comparison at Site MSR2
SSC (mg/L)
Run Time (d)
Existing
Project
100
80
60
40
20
0
0
1
2
3
4
5
6
7

Summary Statistics at Site MSR2									
Constituent	**Condition**	**Average**	**Median**	**Minimum**	**Maximum**	**St Dev**	**% Avg Change**	**% Min Change**	**% Max Change**
WSE (m, NAVD88)	**EXISTING**	3.86	4.06	2.75	4.31	0.42			
	PROJECT	3.25	3.20	2.08	4.23	0.82	-15.9	-24.2	-1.8
Q (cms)	**EXISTING**	11.97	13.79	4.26	14.59	3.13			
	PROJECT	23.35	21.76	6.35	39.07	13.14	95.1	48.8	167.8
Total SSC (mg/L)	**EXISTING**	687.09	248.89	25.27	3703.21	834.01			
	PROJECT	963.26	538.18	62.06	4530.37	1013.89	40.2	145.6	22.3
Clay to Coarse Silt	**EXISTING**	682.67	243.72	23.52	3697.26	832.74			
	PROJECT	937.28	515.33	26.65	4480.81	1000.85	37.3	13.3	21.2
Coarse Silt to Fine Sand	**EXISTING**	4.42	4.60	1.35	8.88	1.88			
	PROJECT	19.87	17.94	3.46	132.15	17.50	349.6	156.2	> 1000 %
Fine to Medium Sand	**EXISTING**	0.00	0.00	0.00	0.00	0.00			
	PROJECT	6.11	2.48	0.00	30.37	7.51	> 1000 %	0.0	> 1000 %
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									


WSE Comparison at Site MSR1 (CDFW)
Existing
Project
WSE (m, NAVD88)
24
20
16
12
8
4
0
0
1
2
3
4
5
6
7
Run Time (d)


Q Comparison at Site MSR1 (CDFW)
Existing
Project
Q (cms)
140
120
100
80
60
40
20
0
-20
0
1
2
3
4
5
6
7
Run Time (d)


Total SSC Comparison at Site MSR1 (CDFW)
Existing
Project
SSC (1,000 mg/L)
10
9
8
7
6
5
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2
1
0
0
1
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6
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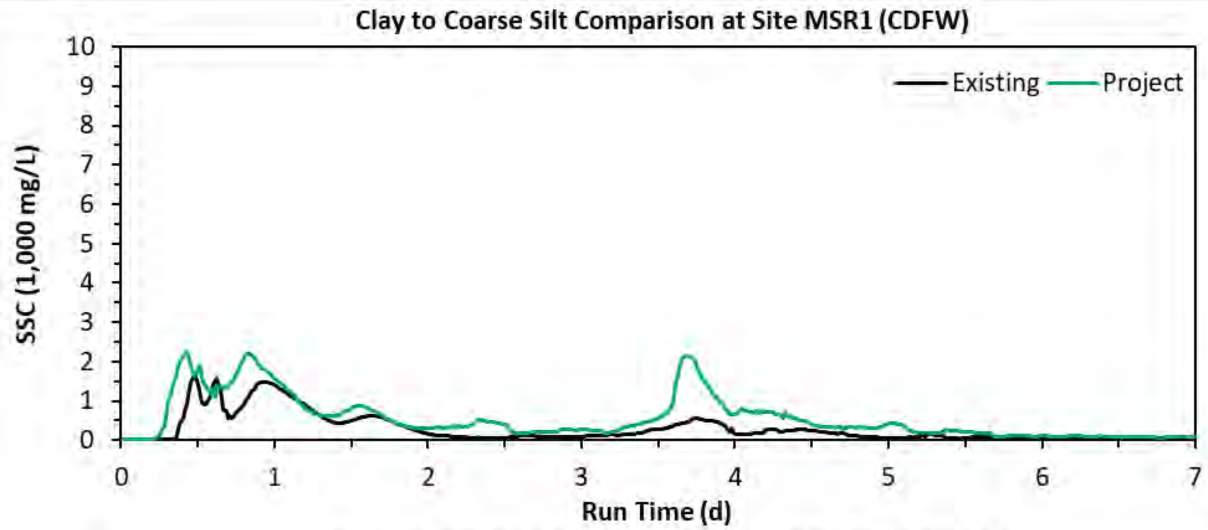
Run Time (d)


Clay to Coarse Silt Comparison at Site MSR1 (CDFW)
Existing
Project
SSC (1,000 mg/L)
10
9
8
7
6
5
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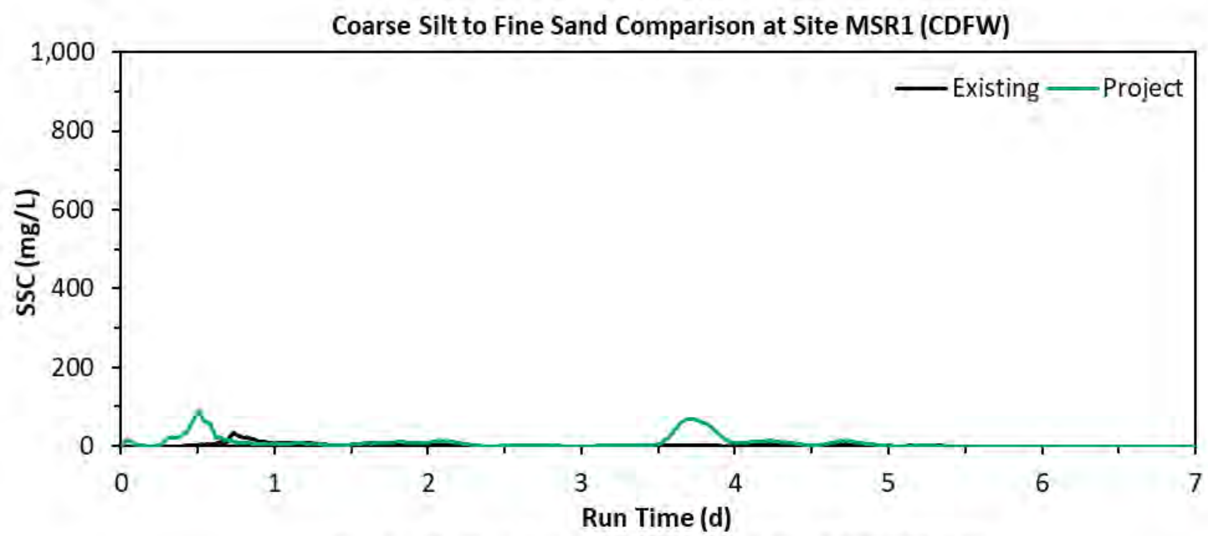
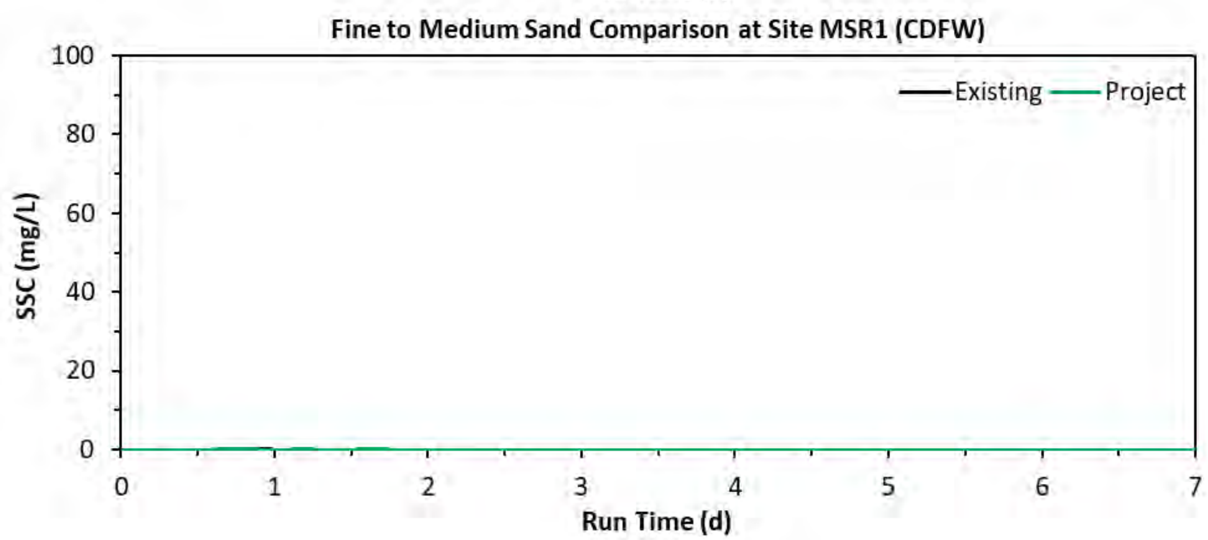
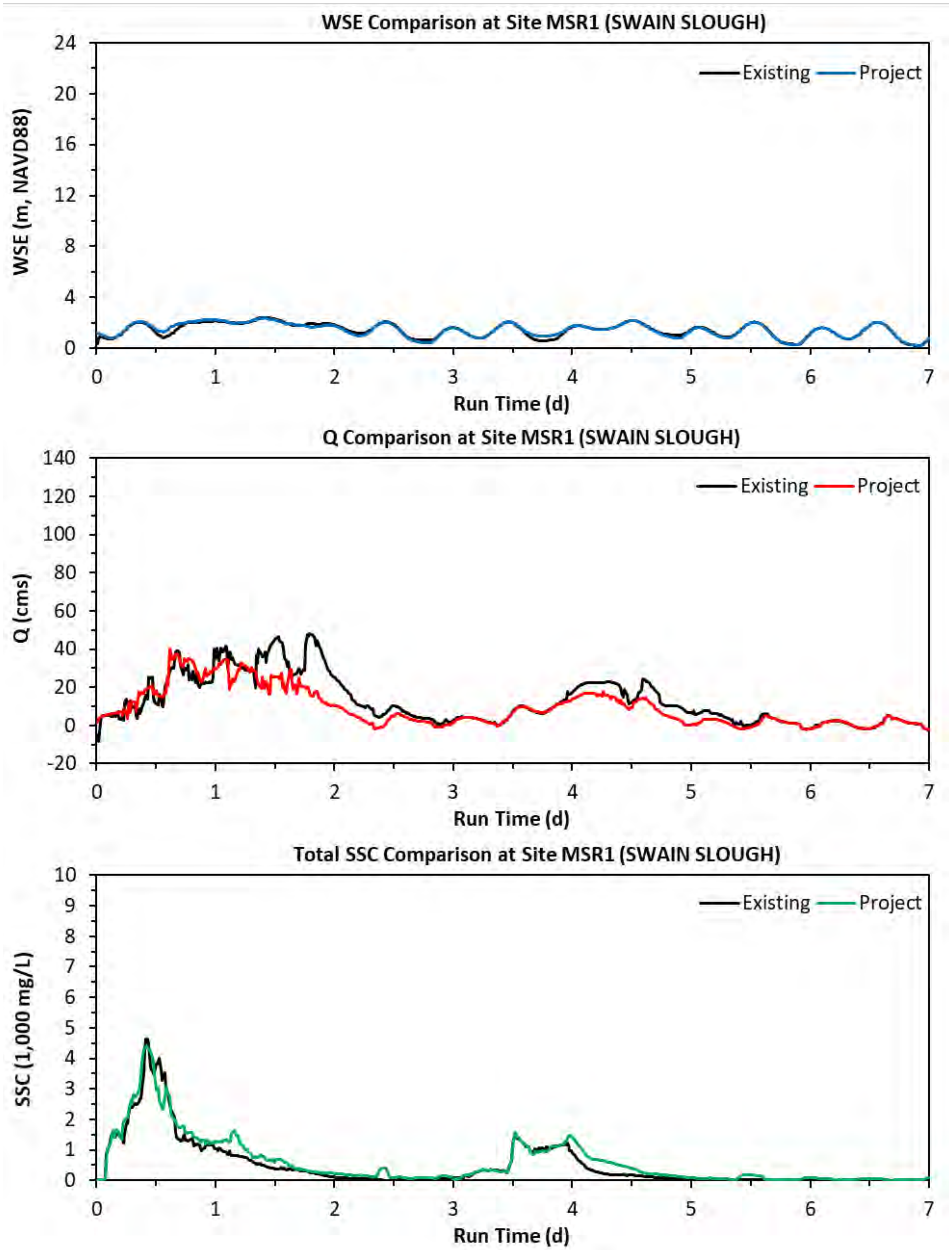
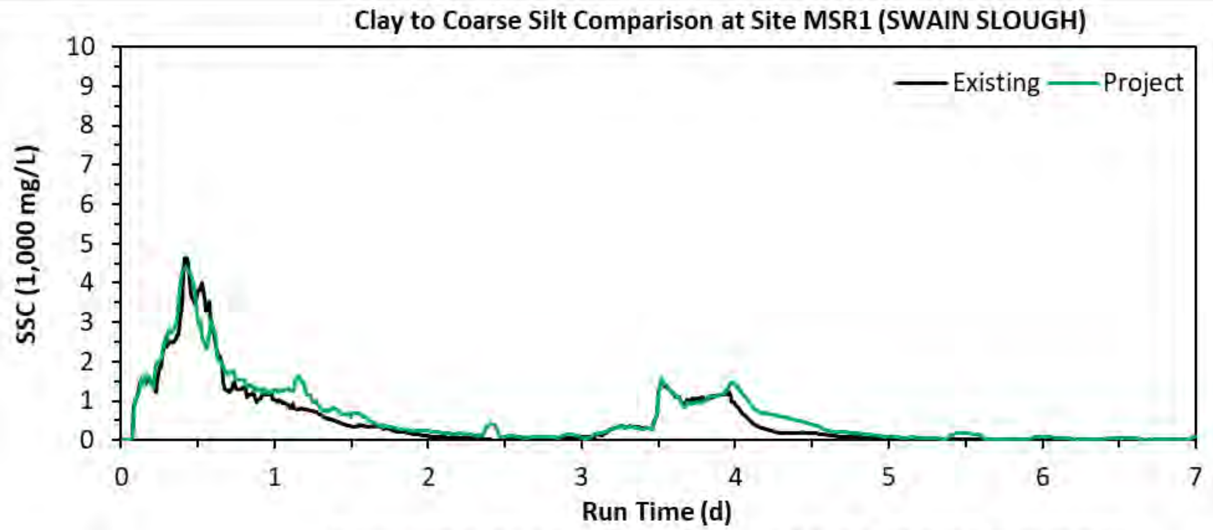
0
0
1
2
3
4
5
6
7
Run Time (d)

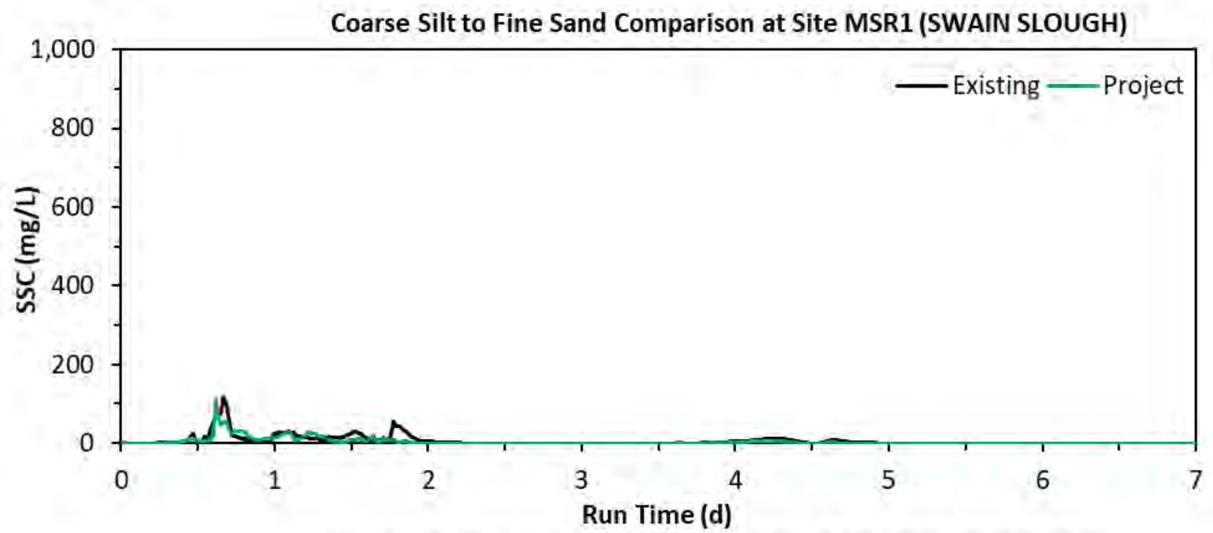

Coarse Silt to Fine Sand Comparison at Site MSR1 (CDFW)
Existing
Project
SSC (mg/L)
1,000
800
600
400
200
0
0
1
2
3
4
5
6
7
Run Time (d)

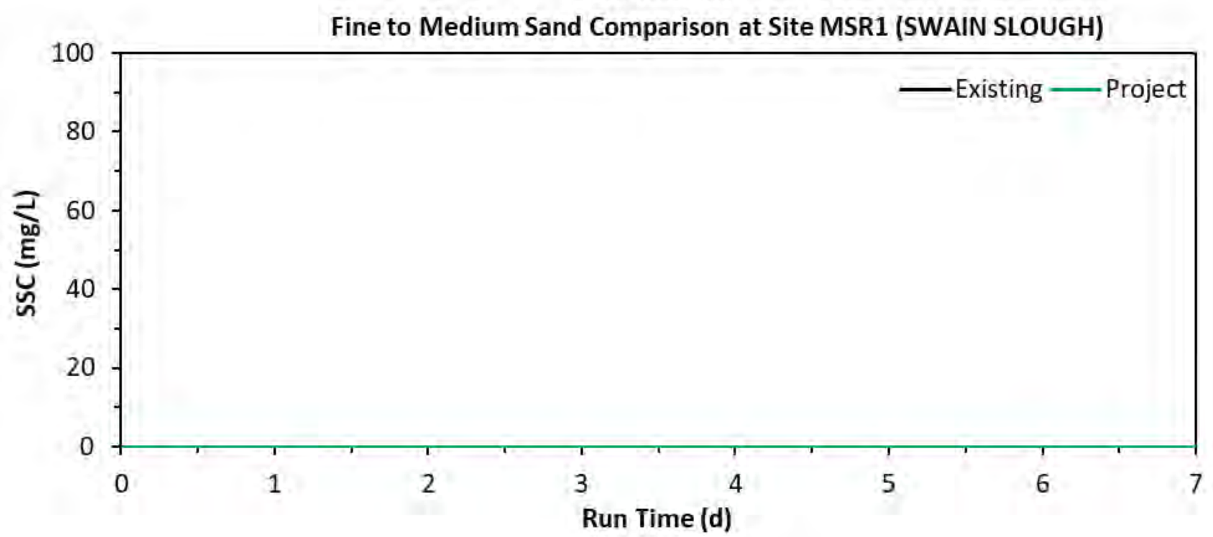

Fine to Medium Sand Comparison at Site MSR1 (CDFW)
Existing
Project
SSC (mg/L)
100
80
60
40
20
0
0
1
2
3
4
5
6
7
Run Time (d)

Summary Statistics at Site MSR1 (CDFW)									
Constituent	Condition	Average	Median	Minimum	Maximum	St Dev	% Avg Change	% Min Change	% Max Change
WSE (m, NAVD88)	EXISTING	1.49	1.54	0.26	2.54	0.58			
	PROJECT	1.52	1.56	0.27	2.53	0.59	2.0	3.8	-0.4
Q (cms)	EXISTING	27.81	17.82	-9.55	85.55	22.44			
	PROJECT	34.31	22.86	2.19	91.62	27.21	23.4	-123.0	7.1
Total SSC (mg/L)	EXISTING	289.59	119.77	13.90	1706.89	362.67			
	PROJECT	555.59	345.14	24.07	2261.29	556.07	91.9	73.1	32.5
Clay to Coarse Silt	EXISTING	287.25	118.64	13.90	1704.88	359.92			
	PROJECT	547.22	335.79	22.71	2224.50	545.52	90.5	63.3	30.5
Coarse Silt to Fine Sand	EXISTING	2.33	0.79	0.00	33.06	4.28			
	PROJECT	8.37	2.54	0.00	92.94	15.30	259.0	> 1000 %	181.1
Fine to Medium Sand	EXISTING	0.00	0.00	0.00	0.09	0.01			
	PROJECT	0.00	0.00	0.00	0.11	0.01	44.4	0.0	20.3
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									

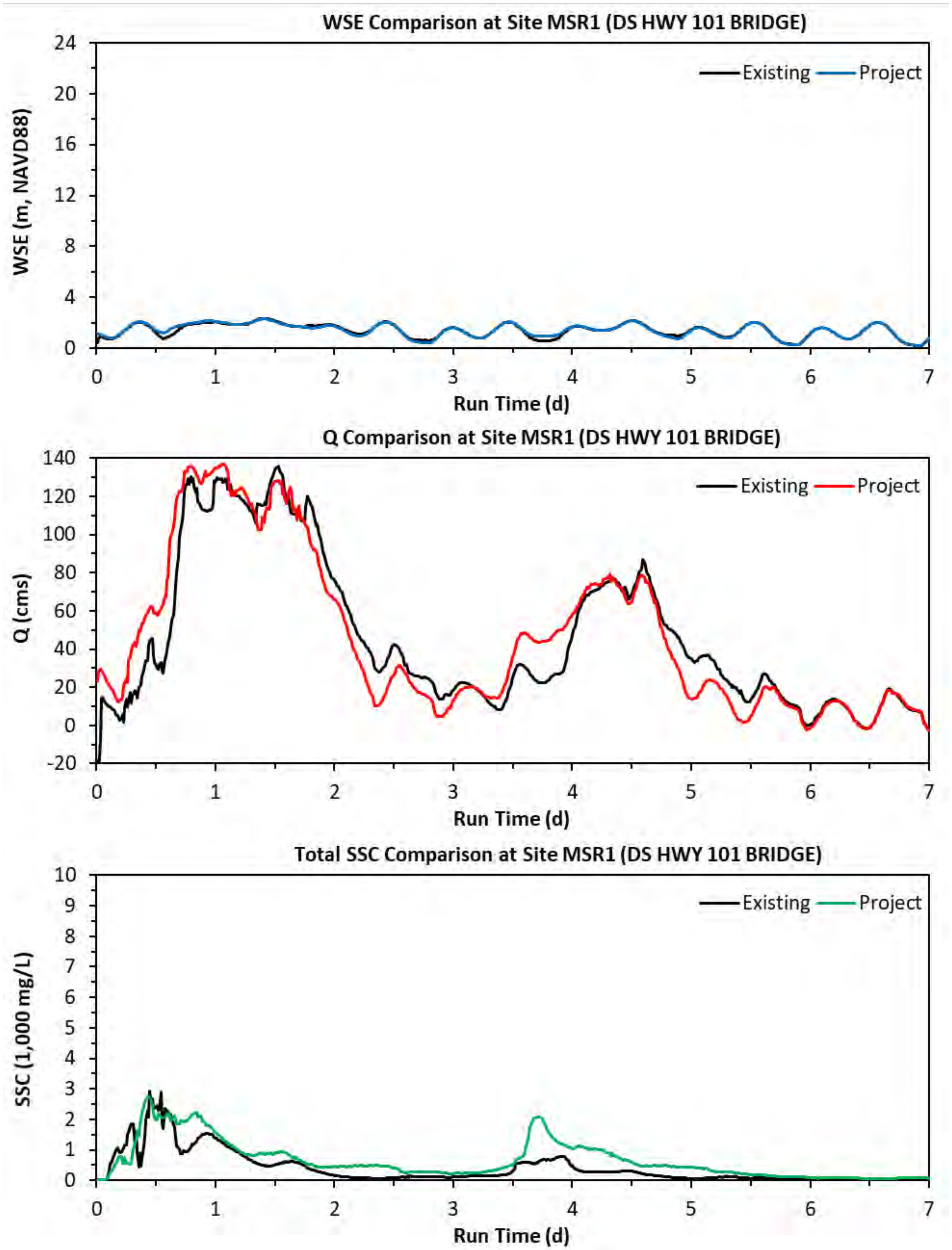

WSE Comparison at Site MSR1 (SWAIN SLOUGH)
Existing
Project
WSE (m, NAVD88)
Run Time (d)
Q Comparison at Site MSR1 (SWAIN SLOUGH)
Existing
Project
Q (cms)
Run Time (d)
Total SSC Comparison at Site MSR1 (SWAIN SLOUGH)
Existing
Project
SSC (1,000 mg/L)
Run Time (d)

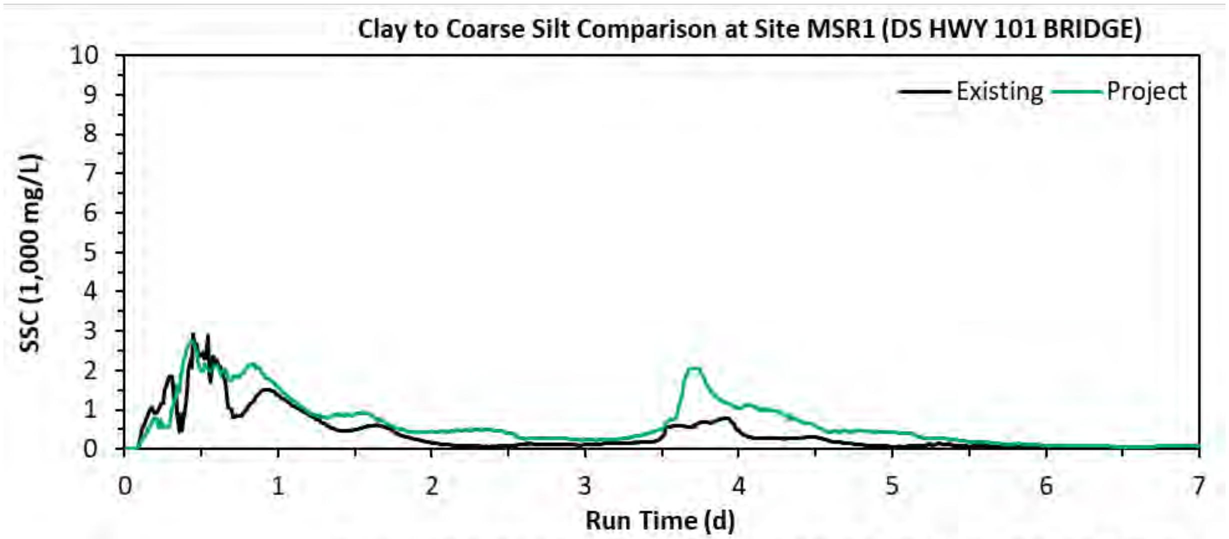

Clay to Coarse Silt Comparison at Site MSR1 (SWAIN SLOUGH)
SSC (1,000 mg/L)
Existing
Project
Run Time (d)

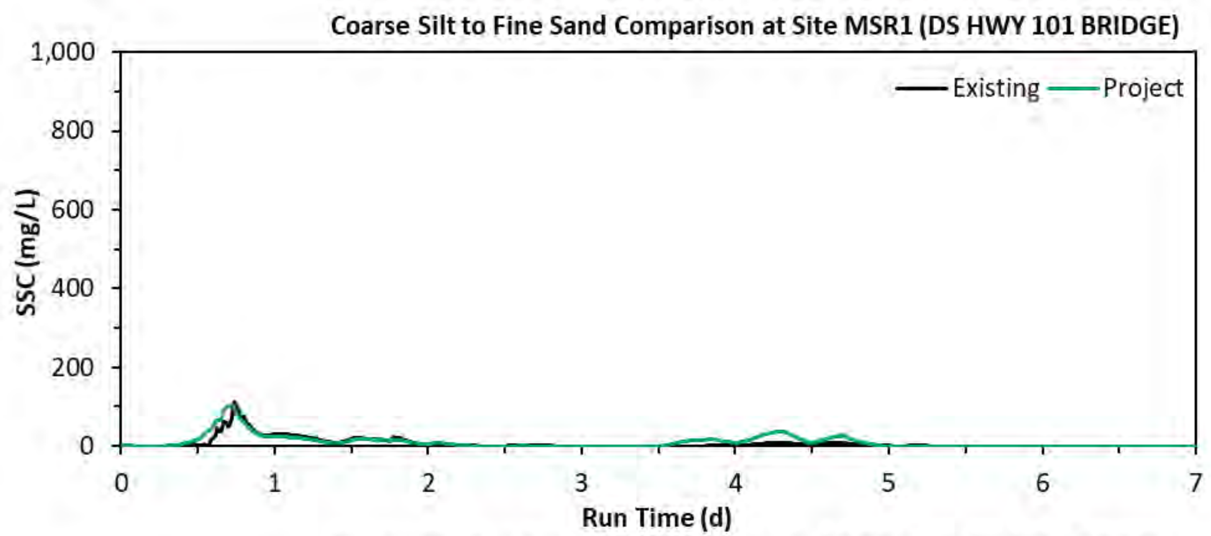

Coarse Silt to Fine Sand Comparison at Site MSR1 (SWAIN SLOUGH)
SSC (mg/L)
Existing
Project
Run Time (d)

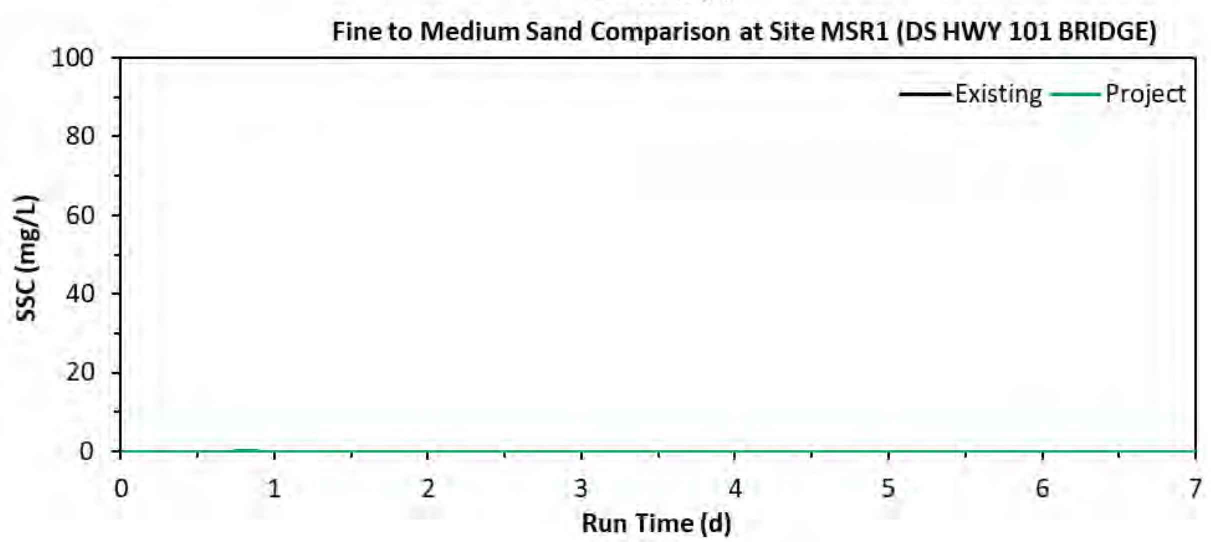

Fine to Medium Sand Comparison at Site MSR1 (SWAIN SLOUGH)
SSC (mg/L)
Existing
Project
Run Time (d)

Summary Statistics at Site MSR1 (SWAIN SLOUGH)									
Constituent	**Condition**	**Average**	**Median**	**Minimum**	**Maximum**	**St Dev**	**% Avg Change**	**% Min Change**	**% Max Change**
WSE (m, NAVD88)	**EXISTING**	1.41	1.48	0.21	2.41	0.55			
	PROJECT	1.41	1.50	0.22	2.36	0.54	0.6	4.1	-2.0
Q (cms)	**EXISTING**	12.56	7.74	-8.47	47.97	12.60			
	PROJECT	9.16	5.08	-2.32	40.04	10.01	-27.1	-72.7	-16.5
Total SSC (mg/L)	**EXISTING**	491.21	107.08	0.13	4642.38	797.87			
	PROJECT	592.82	222.96	4.96	4372.60	803.01	20.7	> 1000 %	-5.8
Clay to Coarse Silt	**EXISTING**	485.71	102.37	0.13	4641.52	794.07			
	PROJECT	589.13	222.55	4.96	4365.34	798.76	21.3	> 1000 %	-6.0
Coarse Silt to Fine Sand	**EXISTING**	5.50	0.01	0.00	117.77	13.07			
	PROJECT	3.69	0.00	0.00	112.67	9.68	-32.8	-96.3	-4.3
Fine to Medium Sand	**EXISTING**	0.00	0.00	0.00	0.00	0.00			
	PROJECT	0.00	0.00	0.00	0.00	0.00	-100.0	0.0	-99.9
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									


WSE Comparison at Site MSR1 (DS HWY 101 BRIDGE)
Existing
Project
WSE (m, NAVD88)
Run Time (d)
Q Comparison at Site MSR1 (DS HWY 101 BRIDGE)
Existing
Project
Q (cms)
Run Time (d)
Total SSC Comparison at Site MSR1 (DS HWY 101 BRIDGE)
Existing
Project
SSC (1,000 mg/L)
Run Time (d)


Clay to Coarse Silt Comparison at Site MSR1 (DS HWY 101 BRIDGE)
Existing
Project
SSC (1,000 mg/L)
Run Time (d)


Coarse Silt to Fine Sand Comparison at Site MSR1 (DS HWY 101 BRIDGE)
Existing
Project
SSC (mg/L)
Run Time (d)


Fine to Medium Sand Comparison at Site MSR1 (DS HWY 101 BRIDGE)
Existing
Project
SSC (mg/L)
Run Time (d)

Summary Statistics at Site MSR1 (DS HWY 101 BRIDGE)									
Constituent	**Condition**	**Average**	**Median**	**Minimum**	**Maximum**	**St Dev**	**% Avg Change**	**% Min Change**	**% Max Change**
WSE (m, NAVD88)	**EXISTING**	1.37	1.44	0.21	2.32	0.53			
	PROJECT	1.38	1.46	0.21	2.29	0.52	0.9	4.0	-1.3
Q (cms)	**EXISTING**	45.64	29.61	-24.42	135.88	39.50			
	PROJECT	46.14	28.61	-2.69	136.92	41.00	1.1	-89.0	0.8
Total SSC (mg/L)	**EXISTING**	403.67	147.77	21.73	2917.19	525.46			
	PROJECT	650.92	452.64	26.34	2741.72	614.78	61.2	21.2	-6.0
Clay to Coarse Silt	**EXISTING**	397.20	144.95	21.73	2913.63	519.19			
	PROJECT	641.34	444.87	25.84	2732.50	603.77	61.5	18.9	-6.2
Coarse Silt to Fine Sand	**EXISTING**	6.47	0.44	0.00	111.12	14.12			
	PROJECT	9.57	0.51	0.00	104.18	16.35	48.0	-81.3	-6.2
Fine to Medium Sand	**EXISTING**	0.00	0.00	0.00	0.03	0.00			
	PROJECT	0.00	0.00	0.00	0.02	0.00	104.2	0.0	-18.9
Note: % change is relative to existing conditions; positive value indicates increased value; negative value indicates decreased value; formula = (PROJECT - EXISTING)/EXISTING * 100									

APPENDIX F

Elk River Climate Change Pilot Study Plan: Literature Review

Introduction

Recent assessments suggest substantial changes in climate and sea levels are highly probable across California's North Coast by the end of the 21st century (e.g. higher temperatures, increased extreme weather events, accelerated sea level rise). Understanding the impacts of future climate change on Humboldt Bay and contributing tributaries (e.g. Elk River) is critical for developing mitigation and adaption strategies to protect the Bay's unique ecological resources and ensure climate resiliency for surrounding communities. While recent studies have provided valuable insights into regional sea level rise (SLR) projections, flood risk and potential impacts to infrastructure (NHE, 2015; Patton et al., 2017; NHE, 2018), there is a lack of data concerning how the Bay's unique ecosystem, hydrology and water quality may respond to future anthropogenic climate change.

The Elk River Climate Change Pilot Study Plan (CCPSP) seeks to address this knowledge gap via a 2-phase approach. Phase 1 seeks to investigate climate change impacts to the Elk River watershed and Humboldt Bay by conducting a thorough literature review aimed at: i) summarizing projections of climate-driven impacts to the Humboldt Bay region, including a review of applicable downscaled climate products, ii) conducting a review of watershed models suitable for predicting climate change impacts on the Elk River and other Humboldt Bay subbasins, and finally, iii) review the suite of potential climate change impacts that could be feasibly simulated via a coupled modeling approach, including an assessment of the various limitations and challenges associated with linking hydrologic and hydrodynamics models.

Phase 2, which is the subject of a forthcoming report, builds upon the Phase 1 results by developing a study plan for a pilot modeling framework that couples a watershed model with an existing hydrodynamic and sediment transport model for Elk River (Caltrout, 2019), and potential additional coupling to a three-dimensional hydrodynamic and transport model for Humboldt Bay. An existing Humboldt Bay three-dimensional hydrodynamic and transport model has been developed that simulates depth, velocity, salinity, and temperature (Anderson and Costello-Anderson, 2019), but it will be necessary to expand this model, or similar model, to include sediment transport in the bay. For clarity, the remainder of this report follows the task structure laid out in the Elk Stewardship Discretionary Contract (i.e. report headings correspond to the specific Tasks and sub-tasks).

Task 5.1.1 - Review of GCM Projections & Downscaling

Task Description

This sub-task entailed reviewing recent global climate model (GCM) projections and climate driver scenarios, and available downscaled data from these projections that can be directly used to support watershed modeling in the Elk River. To accomplish this task, NHE: i) summarized likely climate change outcomes for the study region, ii) reviewed downscaling approaches and datasets applicable to the study region and iii) provided recommendations regarding the most suitable downscaled climate products to support the CCPSP.

Summary of Global Climate Model Projections for the Study Region

A review of the California's Forth Climate Change Assessment for the North Coast Region (Grantham, 2018) indicates that the North Coast will likely experience 5-9° F increases in maximum annual temperatures by 2100 (Figure 1). While total annual precipitation is expected to remain substantially unchanged, the timing, duration and form of precipitation will likely change significantly. In particular, both Grantham (2018) and Persad (2020) concluded that there is a high degree of certainty that the region will experience: i) reduced snow packs accompanied by prolonged dry seasons and reduced soil moisture conditions, ii) increases in extreme precipitation events with more rainfall concentrated in the winter months, iii) higher inter-annual variability in precipitation and streamflow, and iv) increased frequency, duration and magnitude of various climate-related natural disasters (i.e. flooding, drought and wildfires). These projected climate impacts for the North Coast Region were derived from an ensemble of global climate model forecasts.

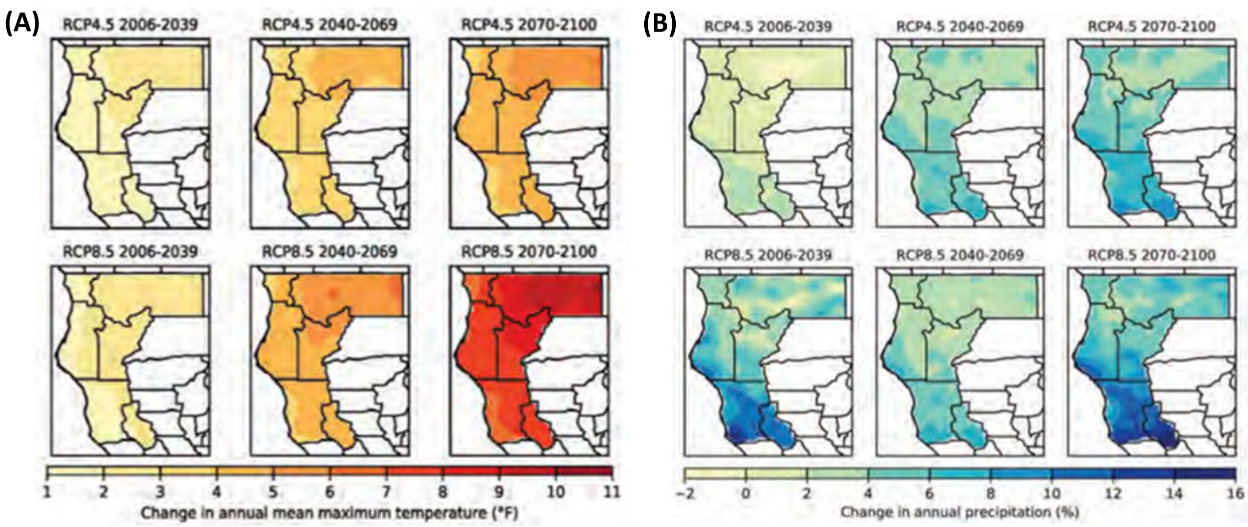


Figure 1. Projected changes in annually averaged maximum temperatures (A) and annual precipitation (B) under moderate (RCP 4.5) and business-as usual (RCP 8.5) emissions scenarios for early, mid, and end of 21st century (Source: LOCA-downscaled data from ten priority global climate models; adapted from Grantham, 2018).

Overview of Downscaled Climate Products

Many coupled ocean-atmosphere general circulation models have been developed to simulate global climate in recent decades. Likewise, a diverse set of approaches for downscaling coarse-scale model output to resolutions appropriate for regional and local-scale modeling and decision making have been proposed. Table 1 summarizes some of the most commonly cited and publicly available downscaled climate products for the contiguous United States. The Bias-Corrected Constructed Analogs (BCAAv2) method downscales to daily timesteps, which is advantageous for hydrologic model simulations. However, it does so at a relatively coarse resolution and the BCCAv2 technique tends to generate spurious low-intensity rainfall and dampens temperature and precipitation extremes that are critical for accurate hydrological modeling (Pierce et al., 2014). Dynamically downscaled products like NA-CORDEX can provide even finer-scale temporal resolutions but have a substantially coarser spatial resolution (25-50 km) and often require additional statistical bias-correction (Knowles et al., 2018). The Localized Constructed Analogues (LOCA) and Multivariate Adaptive Constructed Analogs (MACA) downscaling techniques offer several advantages over BCCAv2 and NA-CORDEX and are described in greater detail below.

Table 1. Selection of publicly available downscaled climate products for the United States and their characteristics (adapted from Lopez-Cantu et al., 2020)

Data set	GCM Models	Emissions Scenario	Downscaled Spatial Resolution (degrees)	Highest Temporal Resolution	Downscaling Technique
BCCAv2	21	2.6, 4.5, 6.0, 8.5	1/8	Daily	Statistical
MACA	20	4.5, 8.5	1/24	Daily	Statistical
LOCA	32	4.5, 8.5	1/16	Daily	Statistical
NA-CORDEX	6[ǂ]	4.5, 8.5	0.22, 0.44	Hourly	Dynamical

ǂ Number of GCM models dynamically downscaled depend on target resolution and emission scenario.

Description of Selected Climate Data Products

Localized Constructed Analogues: Cal-Adapt

The Localized Constructed Analogues method (Pierce et al., 2014) uses a spatial analog approach to translate regional patterns to local-scale features - wherein best-matching historical days are used to describe local-scale spatial relationships for each downscaled grid point. LOCA downscaling also includes frequency-dependent bias-correction to better capture natural climate variability and preserve GCM-predicted change signals (Pierce et al., 2015). Importantly, LOCA downscaling methods were adopted in both the Fourth National Climate Assessment (USGCRP, 2018) and Fourth California State Climate Assessment (Pierce et al., 2018; Figure 1). Additionally, various validation studies have demonstrated minimal bias in the LOCA-downscaled GCM output and excellent agreement with historical observations (Pierce, n.d.; Vano et al., 2020).

The LOCA-based climate projections adopted by California's Fourth Climate Change Assessment (Pierce et al. 2018) downscaled 21st century climate variables from a suite of global climate models derived from the Climate Model Intercomparison Project version 5 (CMIP5; Taylor, 2012). Of the roughly 40 GCMs in CMIP5, only 32 provided outputs at a daily time-step and of those, only 10 were selected by the California Department of Water Resources Climate Change Technical Advisory Group (2015; CCTAG) as they "performed best in simulating historical climate means and variability related to water resources and hydrologic extremes in the California region". Climate projections from these 10 coarse-resolution (~100 km) GCMs were bias corrected and downscaled to (~6 km) using the LOCA statistical method. The data cover the historical period (1950-2005) and future conditions (2006-2100) under medium (RCP 4.5) and high (RCP 8.5) emission scenarios, and include temperature, relative humidity, precipitation, wind speed and surface solar radiation.

Recognizing the need for an even more parsimonious set of GCM projections, Pierce et al. (2018) recommended the following subset of model projections as they provide a suitable range of plausible climate outcomes well-suited to California:

- HadGEM2-ES: simulates warm/dry conditions
- CNRM-CM5: simulates cooler/wetter conditions
- CanESM2: simulates average conditions

- MIROC5: simulates conditions that are most unlike the first three to best capture the range of possible scenarios.

LOCA-based climate products from the 10 CCTAG-recommended GCM models, including the 4-model subset above, are available on the Cal-Adapt website (https://cal-adapt.org) in netCDF format or as spatial subsets in raster or tabular form.

Multivariate Adaptive Constructed Analogs: UC-M

An alternative to the LOCA-based climate products are those provided by the University of California-Merced (UC-M). Offered at a finer spatial resolution (~4 km), the UC-M products were downscaled via the Multivariate Adaptive Constructed Analogs approach (Abatzoglou & Brown, 2011) from 20 CMIP5 GCMs. Similar to the Cal-Adapt products, the data cover the historical period (1950-2005) and future conditions (2006-2100) under medium (RCP 4.5) and high (RCP 8.5) emission scenarios, and include the following variables:

- T_{max} - Maximum daily temperature near surface
- T_{min} - Minimum daily temperature near surface
- Rh_{max} - Maximum daily relative humidity near surface
- Rh_{min} - Minimum daily relative humdity near surface
- H_{uss} - Average daily specific humidity near surface
- P_r - Average daily precipitation amount at surface
- R_{sds}- Average daily downward shortwave radiation at surface
- W_{as} - Average daily wind speed near surface
- U_{as} - Average daily eastward component of wind near surface
- V_{as} - Average daily northward component of wind near surface

Several studies have successfully utilized MACA-downscaled climate projections to evaluate implications for water resources across the U.S. For example, Gelda et al. (2019) applied secondary bias-correction and temporal disaggregation to the MACA dataset to generate point-scale hourly climate products specifically for use in water quality modeling.

A primary difference between MACA and LOCA is that MACA searches for analog days from any grid within the model domain, whereas LOCA identifies analog days in smaller climatically similar regions. Additionally, apart from precipitation, MACA applies a multivariate approach to downscaling multiple climate variables, while LOCA independently downscales all variables. Lopez-Cantu et al. (2020) recently evaluated the impact of several downscaling approaches on projections of precipitation extremes in the U.S. They found that MACA downscaling generally enhanced the original GCM trend for larger storm events, while LOCA preserved the original GCM change signal.

NHE Recommendation

NHE recommends the LOCA-based climate products due to their widespread use (Persad et al., 2020), substantial validation (Pierce, n.d.; Vano et al., 2020), public accessibility (e.g. https://cal-adapt.org) and adoption in national and state climate assessments (e.g. Pierce et al., 2018; USGCRP, 2018; DWR, 2019). In the interests of parsimony and computational efficiency, NHE further recommends that future coupled modeling approaches utilize the 4-model LOCA subset referenced above.

While the daily climate data provided on the Cal-Adapt website can be used to directly force watershed and statistical models of Humboldt Bay watersheds, the daily data will require temporal disaggregation to hourly time-scales for input into the Elk River hydrodynamic and sediment transport model and/or a Humboldt Bay hydrodynamic and transport model. Gelda et al., (2019) provide a number of parsimonious disaggregation models for air temperature, relative humidity, wind speed and solar radiation that do not require calibration.

Unfortunately, the Cal-Adapt climate datasets do not include atmospheric pressure data or wind direction, which are necessary inputs for the Humboldt Bay hydrodynamic and transport model. These values could be obtained directly from the appropriate GCMs at their native resolution, or, in the case of wind direction, it may be possible to incorporate the directional windspeed projections from the UC-M MACA dataset.

Task 5.1.2 – Review of Applicable Watershed Models

Task Description

This sub-task necessitated a review of applicable watershed models that are appropriate for and could be used in the Elk River and other Humboldt Bay watersheds to support future climate change modeling efforts. To accomplish this task, NHE: i) conducted a general review of watershed models that have been applied in the context of climate change assessments in the western U.S. and summarized their primary relevant characteristics, ii) examined studies that have applied hydrologic models in the Humboldt Bay region specifically, and iii) provided recommendations as to the most appropriate watershed model for coupled watershed-sediment transport and/or watershed-estuarine simulation of climate change impacts in the study region.

General Overview of Relevant Watershed Models

Determining the impacts of future climate change on the hydrological, sediment/morphological, and biogeochemical processes of the Elk River and Humboldt Bay watersheds is critical for developing mitigation and adaption strategies for water resource management and ecosystem conservation practices. Such assessments are commonly accomplished via the application of hydrologic models parameterized with downscaled climate projections to elucidate climate-driven trends in watershed-scale hydrological processes such as evapotranspiration, runoff, streamflow, and sediment loading. While myriad hydrologic models have been developed and applied for this purpose, here we focus specifically on publicly available models capable of running at high spatio-temporal resolutions to facilitate coupling with the Elk River hydrodynamic and sediment transport model and/or a Humboldt Bay hydrodynamic and transport model. Table A1 (Supplementary Material A) highlights several of the most commonly cited hydrologic and water quality models applied in the context of climate change in the western United States. Note: hereafter, we refer to watershed-scale hydrologic and water quality models collectively as watershed models.

It is evident from Table A1 that the various models span a wide range of geographic application, spatio-temporal scales and complexity in terms of parameterization, calibration and watershed discretization. In addition, most of the models were applied specifically to evaluate only streamflow responses to climate change – whereas SWAT, HSPF and GWLF were also used to evaluate how sediment, nutrients, dissolved oxygen and temperature might respond under future climate scenarios. It should be noted that of the models reviewed for this analysis, only SWAT and HSPF have been coupled with an estuarine hydrodynamic model and even further, coupled directly with EFDC, which forms the basis of the Elk River hydrodynamic and sediment transport model and the current Humboldt Bay hydrodynamic and transport model (Anderson and Costello-Anderson, 2019).

To provide additional context and insight to guide the selection of models suitable for the CCPSP, NHE refined the geographic scope of the literature review to include only relevant models applied specifically within the Humboldt Bay watershed (HBW) and within Northern California in general.

Watershed Models Applied to the Humboldt Bay Region

Our review of the relevant literature suggests that there are relatively few studies that have applied a publicly available watershed model within or proximal to the HBW. The majority of existing studies were designed solely to estimate peak flows for specific design storms to support flooding and hydraulic analyses. For example, NHE (Wood Creek and Cochran Creek enhancement projects) and Michael Love & Associates (MLA) and GHD (Martin Slough enhancement project) used HEC-HMS to model peak flow magnitudes to aid project design efforts (NHE, 2008 and 2011; MLA and GHD, 2013). Similarly, HEC-HMS and its predecessor HEC-1, were used to compute peak flows for the most recent FEMA Flood Insurance Study of Humboldt County, CA (FEMA, 2018). Importantly, these prior HEC-HMS modeling efforts were event-based as opposed to continuous simulations which are better suited for assessing long-term climate driven trends in hydrology or water quality.

To date, NHE is aware of only one published study that implemented a fully distributed hydrologic model within the HBW. Specifically, Huggett (2012) used DHSVM to simulate streamflow for six hydrologic years in McCready Creek – a tributary to Freshwater Creek. The calibrated model was marginally successful in modeling streamflow. Sub-optimal model performance was attributed to limited soils data, out-of-basin meteorological observations and inadequate representation of sub-surface hydrologic processes.

The findings of Sayama et al. (2011) may shed light on shortcomings of the DHSVM modeling effort by Huggett et al. (2012). Through an empirical analysis, they concluded that Elk River sub-basins with steeper slopes had higher water storage capacity than those with gentler gradients. The authors attribute this counter-intuitive finding to the “hydrologically active bedrock layer hypothesis” whereby runoff generation is highly influenced by a permeable bedrock zone that stores and releases precipitation. More specifically, they concluded that watersheds in the study area were capable of storing substantial amounts of precipitation until later in the wet season when it would be released as stream runoff as storage capacity was exceeded. Thus, watershed models applied in this region would likely benefit from an adequately complex representation of sub-surface hydrology capable of capturing active bedrock dynamics.

To the best of our knowledge, the only other relevant watershed modeling effort within the HBW is an ongoing analysis by the USGS that applies the grid-based distributed water balance model, BCM (Flint et al., 2013; HBHRCD, 2019; see Table A1) to assess streamflow and sediment loading under current and future climates scenarios. According to HBHRCD (2019), the BCM model was run on a daily time-step and calibrated using gaged streamflow and suspended sediment data from within the HBW and the Eel River. Flow and sediment loads were estimated for all watersheds contributing sediment to Humboldt Bay under historic climate conditions, as well as future climate projections using downscaled outputs from 10 GCMs under RCP 4.5 and 8.5 scenarios. Sediment loadings were determined using BCM predicted streamflow and existing HBW tributary sediment rating curves. Preliminary results suggest marked increases in fine sediment supply are likely across all modeled climate scenarios by 2050 (average increase in fine sediment supply ~17%). While these findings are certainly relevant and significant, they are preliminary and remain unpublished. In fact, the BCM modeling effort seems to be the subject of a protracted review process – perhaps related to the fact that calibration and validation of macro-scale grid-based models (like BCM) using streamflow data is challenging since point-scale streamflow gaging data may not be well suited to such purposes. Thus, it is difficult to ascertain whether the BCM model outputs will be available or suitable for coupling with the HST model.

Watershed Models Applied to the Northern California

Noting the general lack of published watershed modeling studies within the Elk River and Humboldt Bay regions, NHE expanded the geographic scope of its review to include Northern California in general. For example, the US Bureau of Reclamation used the variable infiltration capacity (VIC) model to examine climate change effects on streamflow and water resource sustainability in the Santa Ana River watershed (USBR, 2013). Similarly, Das et al. (2011) forced the VIC model using GCM projections and demonstrated increased flood magnitudes in the Sierra Nevada's. Sultana and Choi (2018) applied the SWAT model to assess changes in streamflow and snowmelt in the snow-dominated American River Basin in the Sierras. Hydrologic response to climate change in the Feather River basin in the Northern Sierra was studied using GCM outputs in the Precipitation-Runoff Modeling System (PRMS) model (Koczot et al. 2011; Huang et al. 2012). Although not applied in the context of climate change, Luckens (2019) and ERRP (2020) used the EPA's visualizing ecosystem land management assessments (VELMA) model to simulate streamflows in the Mad and Eel River Basins, respectively. To support variance requests to discharge rate limitations, NHE applied GWLF to estimate current watershed nutrient loads to Outlet Creek and Francis Creek, both tributaries to the Eel River (NHE 2007 and 2009).

Additional watershed modeling studies that have been applied to nearby watersheds and/or other California watersheds are provided in Supplementary Material B.

Model Selection Criteria

Based on the above literature review and consideration of the specific requirements and limitations of the CCPSP Project, NHE has formulated a set of model selection criteria. As a primary objective of the watershed modeling exercise is to provide high-resolution tributary sediment and flow boundary conditions for the Elk River hydrodynamic and sediment transport model and/or a Humboldt Bay hydrodynamic and transport model, we favored those models that met the following criteria:

- Capable of simulating hydrologic processes at the scale of the Elk River, as well as smaller sub-watersheds of Humboldt Bay (~50km^2).
- Capable of running at fine temporal resolutions (i.e. ≤ daily time-step).
- Capable of simulating both streamflow and sediment transport processes.
- Low-medium complexity to facilitate parameterization and reduce model run-times over lengthy climate projection periods.
- Publicly available and actively maintained source code to: i) facilitate future modeling exercises and scenario analyses, and ii) foster collaboration and comparison.

- Capable of continuous vs. event-based simulation.
- Has a history of application in the context of climate change and water quality.
- Ability to approximate complex sub-surface hydrology typical of the region (e.g. Sayama et al., 2011).

Although not strictly necessary for coupling with a hydrodynamic and transport model, the ability to simulate other water quality parameters (e.g. dissolved oxygen) may be important for future studies interested in exploring, for example, climate-driven changes to nutrient loading to the Elk River and Humboldt Bay. Thus, an ideal watershed model would be capable of simulating an array of water quality parameters that may be relevant for evaluating climate-driven impacts to the Elk River and Humboldt Bay estuaries.

Additionally, recent studies have demonstrated that hydrologic models that do not explicitly account for the effect of elevated CO_2 on decreased stomatal conductance and transpiration may underestimate climate-driven increases in streamflow by 3-38% and nutrient loading by 0-57% (Butcher et al., 2014). As Butcher et al. (2014) point out, many hydrologic models rely on simplified methods for estimating evapotranspiration (ET) by relating potential ET primarily to air temperature without fully accounting for other potentially important energy balance factors that may be substantially altered under future climate conditions (e.g. relative humidity). Consequently, we feel it is important that the chosen watershed model possess sufficiently complex ET and plant growth models capable of addressing CO_2 impacts on transpiration *and* incorporating additional climate variables that may mediate ET.

Another consideration is the ability and sophistication of the model regarding the simulation of erosion and sediment transport. As it is possible to utilize existing sediment rating curves to estimate tributary sediment loads, it is not strictly necessary for the watershed model to possess sediment sub-routines. In other words, it is feasible to use a watershed model only capable of computing streamflow and applying sediment rating curves to estimate sediment yield. However, this would require making the somewhat dubious assumption that the rating curves are static through time and that erosional processes (e.g. mass wasting) are unaffected by future climate conditions. Selecting a model with integrated sediment modeling capabilities may not only allow for more accurate estimation of climate-driven changes in tributary sediment yields, but may also afford the simulation of different sediment size fractions, which would further facilitate coupling with the Elk River hydrodynamic and sediment transport model.

NHE Recommendations

Based on the specific CCPSP objectives, literature review and the above criteria, NHE has reduced the number of candidate models to the Basin Characterization Model (BCM) and the Soil and Water Assessment Tool (SWAT). Our top two candidate models are described in greater detail below and ranked in order of preference.

Basin Characterization Model

NHE is awaiting publication of USGS's BCM modeling efforts in Humboldt Bay. Should the BCM model results prove acceptable (i.e. satisfactory performance for flow and sediment predictions, adequate spatio-temporal resolution, suitable range of climate change scenarios, etc.) and peer-reviewed results made available, we recommend exploring its use for generating the requisite tributary boundary conditions for the Elk River hydrodynamic and sediment transport model. This is our preferred choice as it would greatly expedite the modeling effort and would utilize results from a well-regarded watershed model developed by a respected federal agency. However, as mentioned previously, the BCM model does not internally generate sediment predictions, but was used with existing tributary sediment rating curves to estimate sediment loadings. Other potential drawbacks include: i) the inability to estimate tributary boundary conditions for other water quality constituents (e.g. temperature, nutrients) that may be relevant to future analyses of climate change implications for Humboldt Bay and ii) subbasin-based models such as SWAT have been shown to outperform grid-based models like BCM, especially in mountainous areas during winter months (Tesfa et al., 2014).

Soil and Water Assessment Tool

Should the USGS BCM model results prove inadequate or unavailable, NHE recommends the application of the Soil and Water Assessment Tool as its meets all the above selection criteria, is well respected, and is arguably the most commonly used watershed model for evaluating climate change impacts to water resources around the globe. Advantages of SWAT include:

- SWAT runs at spatio-temporal scales suitable for direct coupling with the hydrodynamic and transport models.
- In addition to modeling flow and a host of water quality parameters pertinent to the Elk River and Humboldt Bay, SWAT can simulate the transport of different sediment size fractions which is advantageous for coupling with the Elk River hydrodynamic and sediment transport model.
- SWAT is actively maintained, enhanced and endorsed by a federal agency (USDA).
- SWAT has a built-in stream temperature model – negating the need for a separate statistical or deterministic temperature model.
- SWAT has excellent user's manuals, tutorials, online support groups and guidance documents to aid future researchers and collaborators.
- There are a number of tools to aid in the parametrization, calibration, execution and post-processing of results. For example:
    - There is an R package (SWATplusR) that provides tools to link existing SWAT2012 and SWAT+ models with EFDC modeling workflows.
    - The Hydrologic and Water Quality System (Version 1.2) automates GIS analyses, and facilitates parameterization and execution of scenario analyses in SWAT. This could greatly speed up generation of required input files at HUC12 scales.
- Unlike the BCM model, several studies have linked SWAT with estuarine hydrodynamic models and specifically with EFDC-based models (Hong and Shen, 2012; Huang et al., 2016; Shin et al., 2019; Zhang et al., 2019). In fact, a recent study that successfully coupled SWAT and EFDC has made their MATLAB scripts that dynamically link the two models publicly available (Shin et al., 2019). This would greatly facilitate similar efforts for the Elk River and Humboldt Bay.
- SWAT can account for the impact of climate induced CO_2 increases on transpiration whereas GWLF and HSPF cannot (Butcher et al., 2014).
- SWAT possesses routines for modeling in-channel sediment processes, whereas GWLF does not.
- SWAT can model the transport of different sediment size fractions (i.e. via the Kodoatie method).

- SWAT has been used extensively to evaluate the effects of climate change on streamflow and sediment yield across the globe (e.g. Cousino et al., 2015; Thodsen et al., 2008; Phan et al., 2011; Zhou et al., 2017; Azari et al., 2016; Zhang et al., 2019).

Task 5.1.3 – Climate Change Impacts that Could Be Simulated with a Coupled Modeling Effort

Task Description

This sub-task necessitated a review of potential climate change impacts that could reasonably be simulated in a coupled modeling effort (watershed model and hydrodynamic and transport model coupling). To accomplish this task, NHE: i) conducted a review of EFDC model to better ascertain the full capabilities of the receiving waterbody model in regards to simulation of water quality parameters and hydrodynamic processes in the context of climate change, ii) compiled a list of key parameters and processes that could be feasibly simulated and iii) outlined a number of challenges and approaches/methods associated with the proposed coupled modeling approach. It should be noted that other hydrodynamic models (e.g. FVCOM, Delft3D) are available with similar capabilities to EFDC. However, NHE has extensive experience with EFDC, and has used it as the basis an existing hydrodynamic and sediment transport model for Elk River (Caltrout, 2019), and a three-dimensional hydrodynamic and transport model for Humboldt Bay (Anderson and Costello-Anderson, 2019).

Capabilities of the EFDC Model

In addition to 2- and 3-dimensional hydrodynamics that can incorporate tidal & tributary boundary conditions, the Environmental Fluid Dynamics Computer Code (EFDC) model can simulate a host of water quality parameters, including salinity, temperature, dissolved oxygen, nutrients, organic carbon, algae, and bacteria. The HST Model can also simulate cohesive and non-cohesive sediment transport, as well as the fate and transport of toxic contaminants in the water column and in the sediment bed. Provided adequate input data, boundary conditions and computational resources, the EFDC model is theoretically capable of simulating the impact of climate change (including sea level rise) on any of the above water quality parameters and their interactions in complex estuarine environments. This includes modeling how future changes in tributary sediment yield may interact with sea level rise to alter sediment accretion rates and marsh sustainability in the Elk River and other Humboldt Bay estuaries.

Indeed, several studies have successfully coupled EFDC with watershed models to examine the water quality and quantity impacts of climate and land use change on receiving waterbodies. For example, Zia et al. (2016), linked a watershed model and EFDC to examine the combined effects of climate and land cover/use change on hydrodynamics, nutrient fluxes, sediment transport and algal communities in Lake Champlain. Similarly, Huang et al., (2016), Shin et al., (2019) and Zhang et al. (2019) all integrated watershed models with EFDC to estimate the impact of climate change on streamflow, nutrients, and sediment in lacustrine and estuarine environments. Moreover, Estes et al. (2009) linked a semi-distributed watershed model with EFDC to predict how changes in temperature, salinity, and sediment concentrations impact submerged aquatic vegetation in Mobile Bay, AL.

Numerous other researchers have applied EFDC to evaluate the implications of climate- and subsidence-driven sea level rise (SLR). Accurate simulation of the hydrodynamic effects of SLR is critically important for the Humboldt Bay estuary and its tributaries as recent estimates suggest the Bay has the highest local SLR rate in California and up to ~4 times the long-term global rate (Patton et al., 2017). In addition, other investigators have concluded that current sediment accretion rates in Humboldt Bay will not keep pace with relative SLR and anticipate the conversion of much of the existing Bay marshes to subtidal habitat by the end of the 21st century (HBHRCD, 2019). The application of EFDC in the context of SLR is exemplified by Devkota et al. (2013) who linked SWAT model outputs with the EFDC model to quantify how climate-driven changes in freshwater inflows and SLR will affect temperatures, salinity, pollutant transport, and hydrodynamics in the Perdido and Wolf Bay estuaries in AL, USA. Similarly, Hong and Shen (2012) adapted EFDC code to model how different SLR scenarios alter salinity, stratification and residence times within the Chesapeake Bay, USA. Moreover, NHE (2015) employed a 2D configuration of the EFDC model to evaluate the combined impact of vertical land movement and SLR on inundation vulnerability for the Humboldt Bay region. Although not applied in the context of SLR, Zhu et al. (2016) also employed EFDC to assess how changes in fluvial sediment flux altered accretion rates and morphodynamics of the Changjiang Estuary, China. This study provides a blueprint for the application of EFDC to assess how SLR, climate change, and shifts in tributary sediment flux might alter marsh distribution, structure, function, and persistence in Humboldt Bay. Such an analysis would help inform mitigation strategies to ensure marsh sustainability in future decades (e.g. beneficial use of dredge spoils).

Notably, the EFDC model applications in the above analyses generally demonstrated high correlations between predicted and observed hydrodynamics and water quality constituents. Overall, the satisfactory model performance of EFDC and the wide breadth of application indicates that a coupled modeling approach should be suitable for predicting how interactions between climate change, SLR and tributary inflows will impact a number of key abiotic and biotic processes in the Elk River and Humboldt Bay.

Key Parameters and Processes that Could be Simulated

Based on the above literature review and NHE's prior use of the EFDC model, we anticipate the following parameters and processes could feasibly be simulated using the proposed coupled modeling framework:

- Tributary streamflow under future climate scenarios
- Tidal dynamics, bay/estuarine hydrodynamics, and residence times under future climate scenarios
- Tributary and estuarine water quality under future climate scenarios, including:
    - Temperature
    - Salinity
    - Depth
    - Sediment (fluvial inputs, accretion, erosion and estuarine morphodynamics)
    - Dissolved Oxygen
    - Nutrients
    - Algal community dynamics
- Eel grass community dynamics under future climate change
- Other species community dynamics under future climate change
- Sea level rise inundation and vulnerability impacts

As per Cloern et al. (2011), it may be advantageous to use these parameters to develop a set of environmental indicators that describe the status of the Elk River-Humboldt Bay Watershed-Estuary system according to broad categories for various climate scenarios. Table 3 provides an example for how the coupled modeling outputs could be grouped into environmental indicator categories to track trends in regional climate, regional hydrology, and habitat quality.

Table 2. Example of how the various coupled modeling outputs could be grouped into environmental indicator categories to track trends in regional climate, regional hydrology, and habitat quality in the Elk River-Humboldt Bay Estuary-Watershed system.

Category	Parameters
Climate	Air Temperature
	Precipitation
	Sea Level Rise
	Tidal dynamics (amplitude, frequency, etc.)
Hydrology & Hydrodynamics	Streamflow (annual, seasonal, monthly)
	Estuarine hydrodynamics, including residence times
Habitat	Riverine temperature
	Estuarine temperature
	Salinity
	Tributary sediment yield
	Estuarine sediment accretion and erosion rates
	Depth
	Dissolved oxygen
	Nutrient loading, trophic status
Ecology	Algal community dynamics
	Eel grass communities
Flood Risk	Inundation vulnerability

While it may be possible to model the majority of the above parameters simultaneously, NHE recommends a more phased, modular approach. This would entail developing a coupled base model to predict freshwater inflow, tides, inflow salinity and temperature, and sediment flux. After the base model is calibrated and validated, subsequent modeling efforts could incorporate additional key water quality parameters and processes. The modular nature of the EFDC model is well suited to the proposed phased approach as it will allow the stepwise incorporation of environmental indicators to meet specific research needs moving forward.

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Supplementary Material A – Summary of Applicable Watershed Models

Table A1. Characteristics of publicly available hydrologic models commonly applied to climate change analyses.

Model	Acronym	Complexity	Watershed Discretization	Finest Temporal Scale	Spatial Scale	Reference & Geographic Context	Simulated Parameters	Coupled with Estuarine Hydrodynamic Model	Coupled with EFDC Model
Generalized Watershed Loading Function	GWLF	Low	Lumped	Daily	Small - Large	1 - Yellow River Basin, China 2, 3 - NY, USA 4 - Conestoga River Basin, Pennsylvania, USA 5 - Lake Mälaren, Sweden	Steamflow, Sediment, Nutrients	No	
Hydrologic Engineering Center's Hydrologic Modelling System	HEC-HMS	Low - Medium	Semi-distributed, Sub-basins	Sub-daily	Small - Large	6 - Tunga–Bhadra River Basin, India 7 - Las Vegas, NV, USA 8 - Nippersink Creek watershed, IL, USA 9 - Alameda Creek, CA 10 - Atascadero Creek, CA	Peak Flows, Runoff Volumes	No	
Soil Water Assessment Tool	SWAT	Medium	Semi-distributed, Hierarchical	Daily	Small - Large	11 - Bernam River Basin, Malaysia 12 - Portland, OR, USA 13 - Mono Lake Basin, CA, USA 14 - San Joaquin Valley Basin, CA, USA 15 - Sierra Nevadas, CA, USA 16 - Apalachicola Bay, FL, USA 17 - Yuqiao Reservoir, China 18 - Ipjang Reservoir, South Korea	Steamflow, Sediment, Nutrients, Temperature, D.O.	Yes	Yes
Hydrological Simulation Program—FORTRAN	HSPF	Medium	Semi-distributed, Hierarchical	Sub-daily	Small - Large	19 - St. Louis Bay Estuary, Mississippi, USA 20 - Lake Thunderbird, OK, USA 21 - San Joaquin River Watershed, CA, USA 22 - Sacramento River Basin, CA, USA 23 - N. California Watersheds, CA, USA 24 - Kor River Basin, Iran	Streamflow, Sediment, Nutrients, Chlorophyll-a, D.O., Organic Carbon, Temperature	Yes	Yes
Variable Infiltration Capacity	VIC	Medium	Semi-distributed, Statistical	Sub-daily	Medium - Regional	25 - Sacramento River and San Joaquin River, CA, USA 26 - Pearl River, China 27 - Global 28 - Hanjiang Basin, China 29 - California, USA	Streamflow		
Precipitation-Runoff Modeling System	PRMS	Medium	Semi-distributed, Hierarchical	Daily	Small - Large	30 - Selected Basins, USA 31 - Brahmani River Basin, India 32 - Willamette River basin. OR, USA 33 - Portland, OR, USA	Streamflow		
Basin Characterization Model	BCM	High	Distributed	Sub-daily	Small - Regional	34 - California Basins, USA 35 - San Francisco Bay, CA, USA 36 - San Francisco Bay Basins, CA, USA 37 - Central Valley Basins, CA, USA	Streamflow		
Distributed Hydrology Soil Vegetation Model	DHSVM	High	Distributed	Sub-daily	Small - Medium	38 - Grande River Basin, Brazil 39 - Puget Sound Basin, WA, USA 40 - American and Middle Fork Flathead Rivers, USA 41 - HI, USA	Streamflow		

Supplementary Material A - References

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Supplementary Material B – Summary of Additional Watershed Modeling activities in Nearby or other California Watersheds

Additional watershed modeling activities in nearby and/or other California watersheds:

- Coupled the Loading Simulation Program in C++ (LSPC) with MODFLOW to simulate streamflow & groundwater interactions in the Eel River.
    - https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/cwap_enhancing/docs/draft_sf_eel_hydro_study_070717.pdf
- Application of CASA-HYDRA to all gaged watersheds in CA. Estimated flows in the Eel River and other North Coast rivers.
    - https://www.researchgate.net/publication/240792725_Modeling_River_Discharge_Rates_in_California_Watersheds
- Applied the VIC model coupled with the ANN stream temperature model to evaluate how streamflow and stream temp with respond to future climate change and water diversion/irrigation in the Eel River Basin.
    - https://link.springer.com/article/10.1007/s00477-017-1487-8
- Applied the VIC model to evaluate potential changes in runoff of California's major water supply watersheds in the 21st century.
    - https://www.mdpi.com/2073-4441/11/8/1651/htm
- Used VIC for climate change assessment in the Sacramento-San Joaquin Basin.
    - https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2004GL021462
- Application of SWAT to examine the sensitivity of streamflow response in the snow-dominated Sierra Nevada Watershed using projected CMIP5 data.
    - https://ascelibrary.org/doi/10.1061/%28ASCE%29HE.1943-5584.0001640
- Application of U.S. Geological Survey (USGS) Precipitation-Runoff Modeling System (PRMS) to examine watershed-scale response to climate change in selected basins across the United States.
    - https://journals.ametsoc.org/ei/article/15/14/1/107611/Statistical-Comparisons-of-Watershed-Scale
- Using the Precipitation-Runoff Modeling System to Predict Seasonal Water Availability in the Upper Klamath River Basin, Oregon, and California.
    - https://pubs.er.usgs.gov/publication/sir20195044

APPENDIX G

Elk River Climate Change Pilot Study Plan: Modeling Framework

1 TASK 5.2 – PILOT STUDY PLAN

1.1 Task Description

This task entails developing a concise study plan for a pilot modeling framework to address climate change impacts to the Elk River watershed. This will include: i) a brief outline of the climate data sources for model inputs, ii) recommended procedure to link the watershed and Elk River Hydrodynamic and Sediment Transport model, as well as a discussion regarding the feasibility of the linking procedure and iii) a summary of alternative plans or concepts considered.

1.2 Summary of Recommended Watershed Model Based on Literature Review

Based on the specific objectives of the Elk River Climate Change Pilot Study Plan (CCPSP), a thorough literature review, and a set of tailored model selection criteria, NHE identified the Soil Water Assessment Tool model (SWAT) and the Basin Characterization Model (BCM) as suitable candidates for off-line coupling with the Elk River Hydrodynamic and Sediment Transport model (HST) and potentially the Humboldt Bay Model (HBM; Anderson et al., 2019)).

SWAT was selected as a top candidate for a host of reasons, which are outlined in detail in the literature review (Task 5.1). An abbreviated list of the salient advantages of employing SWAT to provide key upstream boundary conditions for the HST are presented below:

- SWAT has been used extensively to evaluate the effects of climate change on streamflow and sediment yield across the globe (e.g. Azari et al., 2016; Cousino et al., 2015; Phan et al., 2011; Thodsen et al., 2008; Zhou et al., 2017; Zhang et al., 2019).
- SWAT is actively maintained, enhanced and endorsed by a federal agency (USDA).
- SWAT runs at spatio-temporal scales suitable for direct coupling with the hydrodynamic and transport models.
- In addition to modeling flow and a host of water quality parameters pertinent to the Elk River and Humboldt Bay, SWAT can simulate the transport of different sediment size fractions which is advantageous for coupling with the HST model.
- Unlike the BCM model, several studies have linked SWAT with estuarine hydrodynamic models and specifically with EFDC-based models (Hong and Shen, 2012; Huang et al., 2016; Shin et al., 2019; Zhang et al., 2019). In fact, a recent study that successfully coupled SWAT and EFDC has made their MATLAB scripts that dynamically link the two models publicly available (Shin et al., 2019). This would greatly facilitate similar efforts for the Elk River and Humboldt Bay.

- SWAT can account for the impact of climate induced CO_2 increases on transpiration whereas BCM, GWLF and HSPF cannot (Butcher et al., 2014).

The BCM model was also selected as a top candidate because it is a well-regarded model that was recently applied by the USGS to simulate flows and sediment loading to Humboldt Bay under a variety of climate change scenarios (Curtis et al., 2021). At the time of NHE's literature review, the results of the USGS's study were not made public and the associated journal article had yet to be peer-reviewed. Since then, the journal article was published and a limited set of model results were posted to an online repository. However, the posted model results for future climate conditions only contain streamflow estimates – no sediment flux data are provided. Preliminary review of the USGS's modeling efforts suggest their approach and results may be suitable for integration with the HST and/or HBM models. Nevertheless, a more rigorous review of the model results and approach are necessary to confirm the model's suitability. Use of the BCM model would also likely require coordination and collaboration with the USGS.

As the suitability of the BCM model for coupling with the HST model will require further investigation, which is outside the scope of this task, the bulk of this memo will focus on linking the SWAT and HST models. The BCM model is discussed in more detail in Part D below, which summarizes alternative plans considered.

1.3 Part A - Climate Data Sources for Model Inputs

To simulate climate change impacts to water quantity and quality at daily time-steps, SWAT requires the following daily climate inputs:

- Precipitation
- Min Temp
- Max Temp
- Solar Radiation
- Relative Humidity
- Wind Speed

Importantly, all of these climate parameters are provided by the following four GCM projections recommended in the literature review (Task 5.1):

- HadGEM2-ES: simulates warm/dry conditions
- CNRM-CM5: simulates cooler/wetter conditions
- CanESM2: simulates average conditions
- MIROC5: simulates conditions that are most unlike the first three to best capture the range of possible scenarios.

According to Pierce et al. (2018), this parsimonious set of GCM projections provide a suitable range of plausible climate outcomes well-suited to California. Climate projections from these coarse-resolution (~100 km) GCMs were bias corrected and downscaled to (~6 km) using the

LOCA statistical method. The data cover the historical period (1950-2005) and future conditions (2006-2100) under Representative Concentration Pathway (RCP) 4.5 and 8.5 emission scenarios. These two RCPs are most commonly used by researchers since RCP 4.5 is an intermediate scenario whereas RCP 8.5 is generally taken as the worst-case climate change scenario.

To simulate future climate conditions in SWAT, we would download gridded daily data for each of the selected GCM from the Cal-Adapt website (https://beta.cal-adapt.org/data/) and then use an areal average spatial interpolation technique to convert the downscaled climate parameters to sub-basin specific point estimates required by SWAT.

Additionally, recent studies have demonstrated that hydrologic models that do not explicitly account for the effect of elevated CO_2 on decreased stomatal conductance and transpiration may underestimate climate-driven increases in streamflow by 3-38% and nutrient loading by 0-57% (Butcher et al., 2014, Gunn et al., 2021). Accordingly, we would recommend adjusting the CO_2 concentration in each subbasin to reflect likely future projections. Table 1 provides a summary of historical and likely future CO_2 concentrations that may be used to parameterize future climate scenarios (Meinshausen et al., 2011).

Table 1. Summary of historical and likely future CO2 concentrations under different Representative Concentration Pathways (RCP; Meinshausen et al., 2011).

Emissions Scenario	CO_2 Concentration (ppm)		
	2005	2050	2100
Historical	379	--	--
RCP4.5	379	487	538
RCP8.5	379	541	936

The following section outlines the procedure for linking SWAT with the HST model - assuming the watershed model is running on a daily time-step. We will need to investigate the necessity of temporal disaggregation to sub-daily time scales. This may involve comparing HST model results where the upstream boundary conditions were derived from daily means vs. sub-daily inputs. It should be noted that several other applications of coupled SWAT-EFDC models successfully utilized daily time-steps for SWAT when simulating sediment dynamics and nutrients in EFDC (Shin et al., 2019; Wu et al., 2022). Should the SWAT results require disaggregation to sub-daily time-steps, we would recommend either: i) running SWAT at an hourly time-step (which would require downscaling the climate inputs to hourly scales) or ii) disaggregating the daily SWAT output to hourly scales via post-processing of daily outputs (e.g. disaggregation of daily streamflow via the steepness index unit volume hydrograph methods of Tan et al., 2007 and Lee et al., 2021). Running SWAT at sub-daily timesteps would also require the temporal disaggregation of GCM climate data to hourly time-scales. Gelda et al. (2019) provide a number of parsimonious disaggregation models for air temperature, relative humidity, wind speed and solar radiation that do not require calibration. Alternatively, Bennett et al. (2020) outline an open-source Python package that can generate spatially distributed sub-daily timeseries of precipitation, air temperature, vapor pressure, relative humidity, specific humidity, incoming shortwave radiation, outgoing longwave radiation, and air pressure.

1.3.1 Model Integration

As indicated in Figure 1, SWAT requires a combination of weather, landscape and management inputs in order to simulate hydrologic and water quality processes. Historical weather data will likely be derived from pre-formatted NOAA climate data (https://swat.tamu.edu/data/), while weather data for the future climate change scenarios will derive from the aforementioned downscaled LOCA datasets. Topography, soils and land use data will stem from the 10 m National Elevation Dataset, the SWAT US SSURGO Soils Database and the 2019 National Land Cover Dataset, respectively. The model will be calibrated and validated to observed flows and sediment data collected in the Elk River as outlined in the Elk River Recovery Assessment (ERRA; California Trout et al., 2018). Five alternative sediment routing algorithms are available in SWAT. It would be prudent to evaluate the performance of the various routing algorithms – including those that are capable of routing by particle size as this is an important input parameter for the HST model. Alternatively, total sediment loads could be partitioned into different size fractions using observed particle size distribution data (as illustrated in Figure 1). If SWAT is unable to simulate sediment dynamics with acceptable efficiency, we would recommend applying the SWAT-predicted stream discharge to existing sediment rating curves for the Elk River, similar to Curtis et al. (2021) and NHE (2022). In this scenario, separate sediment rating curves could be developed for different grain size classes (viz. ERRA) and applied to the SWAT streamflows to partition predicted sediment loads into size fractions.

Once SWAT is calibrated to historical records, the model will be run for three future climate periods: early-century (2020-2029), mid-century (2050-2059) and end-of-century (2090-2099). SWAT model results for flow and sediment from the "output.rch" file for all time periods will be reformatted for input as the upstream boundary conditions for the EFDC-based HST model (Figure 1). Existing MATLAB code that executes offline coupling of SWAT with EFDC-based models (Shin et al., 2019) will ported to either R or Python and adapted to facilitate construction of all SWAT-based input files for the HST model. Once all HST input files are built, the HST model will be calibrated (as needed for the existing Elk River HST model) and validated to historical flow and sediment data. Subsequent to acceptable calibration, the HST model will then be forced with the reformatted SWAT output from the three future climate change scenarios. Additionally, the effects of future sea level rise will be incorporated into the downstream boundary conditions of the HST model through adjustments to the morphological tide (viz. ERRA). Historic model runs for both the SWAT and HST models will be used as the baseline for comparison with all future climate scenarios.

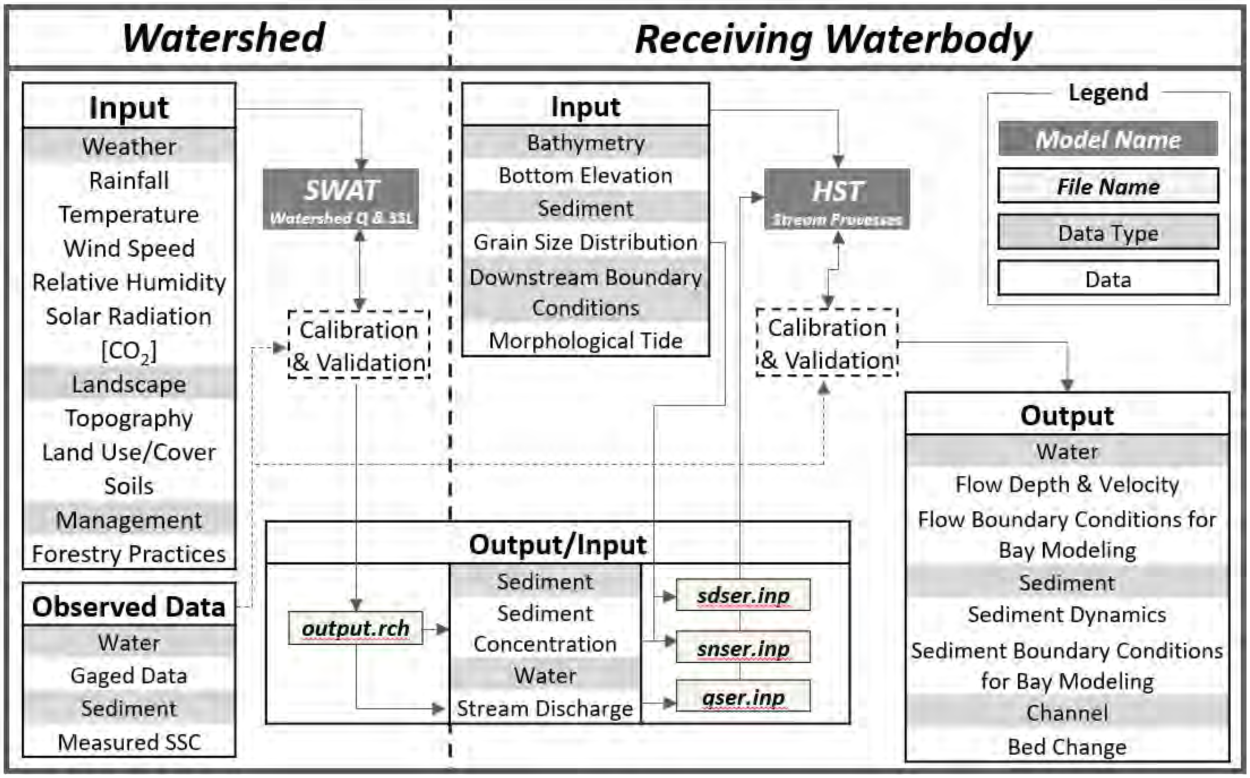

Figure 1. Proposed SWAT-HST model coupling (viz. Shin et al., 2019).

As suggested in the literature review, we anticipate that the coupled SWAT-HST model will be able to feasibly simulate the following parameters and processes:

- Elk River tributary and mainstem streamflow under future climate scenarios
- Elk River tributary and mainstem water quality under future climate scenarios, including:
  - Temperature
  - Salinity
  - Depth
  - Sediment (fluvial inputs, deposition, erosion and channel morphodynamics)
  - Dissolved Oxygen
  - Nutrients
- Sea level rise inundation and vulnerability impacts

The current Elk River HST is not developed for temperature, salinity, dissolved oxygen, and nutrients. To accommodate these water quality variables the HST model will need to be expanded, which is discussed in more detail below.

The proposed coupled modeling framework will also enable the rigorous investigation of the impact of equifinality of SWAT results on the HST model. For example, the Generalized Likelihood Uncertainty Estimation (GLUE) method could be used to quantify the uncertainty bounds of the SWAT flow and sediment flux and their propagation to the Elk River HST model.

The final outputs from SWAT or the coupled modeling exercise could be used to parameterize the upstream boundary conditions of the Humboldt Bay Model (Anderson et al., 2019) to facilitate future modeling of Humboldt Bay under various climate change scenarios. This would not only allow the simulation of climate change effects on key estuarine water quality parameters (e.g. temperature, salinity, nutrients, dissolved oxygen), but also on important ecosystem processes and biotic communities, such as algal and eel grass community dynamics, estuarine hydro- and morpho-dynamics (patterns of erosion and accretion), residence times and sea level rise inundation and vulnerability impacts.

While it may be possible to model the majority of the above parameters simultaneously, NHE recommends a more phased, modular approach. This would entail developing a coupled base model to predict freshwater inflow, tides, inflow salinity and temperature, and sediment flux. After the base model is calibrated and validated, subsequent modeling efforts could incorporate additional key water quality parameters and processes. The modular nature of the EFDC model is well suited to the proposed phased approach as it will allow the stepwise incorporation of environmental indicators to meet specific research needs moving forward.

One of the largest sources of uncertainty revolves around the ability of SWAT to accurately model sediment loading of different grain size fractions. To address this uncertainty, we have outlined a viable alternative method for applying calibrated SWAT streamflows to existing sediment rating curves. Coupled with the fact that numerous other researchers have successfully integrated SWAT with EFDC-based receiving waterbody models, we believe the proposed SWAT-HST model will offer a viable, robust, and flexible framework for simulating the impact of climate change on critical flow and water quality parameters that affect imperiled biotic communities and beneficial uses in the Elk River.

1.4 Part D – Summarize Alternative Plans, Concepts and Recommendations

As previously mentioned, NHE had selected the BCM model as a potential alternative watershed model to SWAT. Future modeling efforts in the Elk River should more deeply explore BCM's suitability for coupling with the HST model. Should the BCM model prove suitable, many of the same linking procedures will still need to be carried out.

For example, as the BCM model generated results on a daily time-step, it would be necessary to investigate the necessity of temporal disaggregation to sub-daily time scales. This would involve running the HST model using daily data aggregated from existing sub-daily input files and comparing to the existing sub-daily HST results. Should the BCM results require disaggregation to sub-daily time-steps, NHE would recommend disaggregating the daily BCM output to hourly scales via post-processing of daily outputs - similar to SWAT.

An advantage of using the USGS's Humboldt Bay BCM model is that it was already run under a range of future climate change scenarios from the same set of GCM projections NHE recommended in the literature review. The only exception is that the USGS included projections from NCAR's CCSM4 model.

A drawback of using the BCM model results is that (unlike SWAT) it may underestimate climate-driven increases in streamflow because it is not capable of incorporating the effects of elevated CO_2 on decreased stomatal conductance and transpiration. In addition, with the exception of sediment, the USGS's BCM modeling effort for Humboldt Bay did not include simulation of any water quality parameters that may be of interest as management priorities evolve in the future.

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