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Final Basis of Design Report
Smith River Estuary Backwater Habitat
Enhancement Design Project – Tedsen Property

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Cover photo: backwater entrance, view looking upstream.
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1 INTRODUCTION

The Smith River Alliance (SRA) retained Stillwater Sciences (Stillwater) for the Smith River Estuary Habitat Enhancement Design Project (estuary backwater enhancement project) with the objectives of developing designs to improve fish access, enhance seasonal off-channel rearing habitat, and improve riparian condition along a natural backwater in the Smith River estuary in northern Del Norte County. This final basis of design (BOD) report presents the preferred design alternative (Alternative 3) that was selected during Technical Advisory Committee (TAC) meetings in June and October 2020, and through additional correspondence with the TAC.

TAC members for this project include representatives from the California Department of Fish and Wildlife (CDFW) and National Oceanographic Atmospheric Administration (NOAA) Fisheries (Table 1-1). Additional project stakeholders have been involved in the planning and design process.

Table 1-1. Technical Advisory Committee members and other project stakeholders.

<table>
<thead>
<tr>
<th>Technical Advisory Committee</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Beatrijs deWaard</td>
<td>CDFW</td>
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<tr>
<td>Margaret Tauzer</td>
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<td>Bob Pagliuco</td>
<td>NOAA Fisheries</td>
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<tr>
<td>Dan Free</td>
<td>NOAA Fisheries</td>
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<table>
<thead>
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<th>Other project stakeholders</th>
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<tr>
<td>Marisa Parish Hanson</td>
<td>California Department of Parks and Recreation</td>
</tr>
<tr>
<td>Bob Tedsen</td>
<td>Landowner</td>
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</tbody>
</table>

1.1 Project Location

The project site is located in the Smith River estuary approximately three miles upstream from the mouth of the river, 0.35 miles upstream from the mouth of Yontocket Slough, 1.1 miles downstream from the mouth of Rowdy Creek, and 2.3 miles southwest of the town of Smith River in northern Del Norte County, California (Figure 1-1). The backwater is within the riparian corridor and is a long and narrow topographic depression oriented subparallel to the Smith River on its southern bank (left bank). The feature defines a high-flow path near the left bank channel margin formed during infrequent large flood events in the 1960s and 1970s and is separated from the mainstem channel by a vegetated scroll bar. This reach of the Smith River is influenced by tidal input. The project site is bordered to the south by alluvial floodplain deposits used for dairy pasture, and to the southwest by Tolowa Dunes State Park.

1.2 Need for the Project

The Smith River is the largest free-flowing intact watershed in California and is considered a premier “Salmon Stronghold” along the Pacific coast and “irreplaceable” with respect to salmonid population resiliency (Wild Salmon Center 2012). However, this recognition as critically significant salmon habitat is largely based on the rivers undammed status, because much of the upper watershed is publicly owned and holds many designations with associated protections (e.g., National Recreation Area, National and State Park, Wilderness, Wild and Scenic...
River, etc.), and because land use has changed less here than in many other California watersheds (NOAA 2014). Notwithstanding, the Smith River coastal plain and estuary, the area with the greatest potential to support coho salmon (NMFS 2014), has had large reductions in available habitats and much of those remaining have been severely degraded due to anthropogenic changes related to agriculture, timber harvest, levee, and road construction (Voight and Waldvogal 2002, NOAA 2014, Parish and Garwood 2015). These changes have resulted in reduced channel complexity, less off-channel and slough habitats, and less spatial and temporal access to remaining seasonal salmonid rearing habitats. Additional problems facing anadromous salmonids in the lower Smith River and estuary include amount of available habitat, degraded condition of riparian vegetation, and altered estuarine environment (CDFW 2004). For these reasons, the impaired condition of the lower Smith River and estuary has been identified as the most significant threat to salmonids in the basin (Voight and Waldvogal 2002, CDFW 2004, NOAA 2014, Parish and Garwood 2015).

A substantial portion of the northern estuary has been modified by flood control levees, tide gates, and riprap to control bank erosion. These modifications have severed many connections to slow water habitat and have simplified much of the aquatic habitat into a more single-thread channel that is deeper and faster during high flows (Parish and Garwood 2015). However, the south bank remains comparatively unaltered with intact riparian forests that inundate during winter high-flow events.

Construction and enhancement of off-channel habitats (including alcoves, backwaters, and oxbows) is listed as one of the highest priority recovery actions for the Smith River coho salmon population (NMFS 2014). These habitat types located in the estuary provide valuable refugia for juvenile life stages and result in increased survival, overall productivity, and life history diversity of coho salmon (Otto 1971, Koski et al. 2009, Wallace and Allen 2009, Bennett et al. 2014, NMFS 2014, Wallace et al. 2015, Levings 2016). By working with willing landowners, the project designs will address high priority recovery actions by improving the quality and quantity of off-channel habitat. The project will help SONCC coho salmon recover in the Smith River by increasing the duration and range of flows that migrating and rearing juvenile coho salmon have access to quality off-channel winter rearing habitat in the Smith River estuary. The designs will also specify new cattle exclusion fencing to protect the integrity of the backwater habitat and riparian vegetation. The designs produced by this project will advance an implementation project that will increase off-channel estuary winter rearing habitat for juvenile coho salmon. Other salmonid species in the Smith River, including Chinook salmon, steelhead and cutthroat trout, will also likely benefit from this project.
Figure 1-1. Location of the estuary backwater project area in northern Del Norte County.
2 EXISTING CONDITIONS

2.1 Geology and Tectonics

The backwater project site is located in the Smith River estuary on the Smith River coastal plain, west of the Coast Range mountains. This portion of northwestern California is in a tectonically active plate-boundary deformation zone and is defined by compression and uplift along the Cascadia subduction zone. This deformation is manifest by multiple northwest-southeast trending thrust faults (further described below) that create a dominant topographic and structural grain in the region (Kelsey and Carver 1988).

The Smith River coastal plain is located approximately 2 miles west of the Coast Range thrust fault (“South Fork fault” of Irwin 1972), along which graywacke and mélange units of the Eastern Belt of the late Mesozoic-aged Franciscan complex are thrust below Klamath Mountain ophiolite terranes (Aalto 1989) (Figure 2-1). Overlying the Franciscan complex along the coastal plain is the Pliocene-Pleistocene marine fossiliferous siltstone and sandstone St. George formation (Diller 1902, Maxson 1933, Stone 1993, Aalto et al. 1995). The St. George formation contains trace pebbles, carbonized wood, and fragmented molluscan shells; and is exposed in the wave-cut cliffs between Crescent City and Point St. George and encountered in borings beneath the coastal plain. Overlying the Franciscan complex and St. George formation is the Battery formation, which Maxson (1933) defined as poorly consolidated marine and terrigenous sands with interbedded clay. The Battery formation, which is a marine terrace deposit with interfingering dune sands and alluvial gravels, consists primarily of medium-grained sands alternating with blue-gray silty clay and imbricated gravels. The Battery formation overlies marine abrasion platforms dated at approximately 80, 105, and 125+ thousand years old (i.e., late Pleistocene) based on fossils, soil correlation, and amino acid racemization age correlation of the clam Saxidomus giganteus (Addicott 1963, Kennedy et al. 1982, Polenz and Kelsey 1999). As the coastline retreated westward following late Pleistocene sea-level high stands, the paleo Smith River incised into the Battery formation and deposited large volumes of alluvium in floodplain settings that cover the majority of the northern coastal plain (Delattre and Rosinski 2012) (Figure 2-1). The project site is located adjacent to these Holocene floodplain deposits and the modern-day Smith River mainstem channel.

Faults in the project vicinity include the Bald Mountain-Big Lagoon fault zone, Lost Man fault, and the Saint George fault (Clarke and Field 1989, Clarke 1992); all of which are offshore thrust faults located to the southwest of Crescent City. The Bald Mountain-Big Lagoon fault zone is considered late Quaternary in age, meaning it has been active in the last 700,000 years (Clarke and Field 1989). Although recent displacement along the Lost Man and Saint George faults is undifferentiated, they are considered Quaternary in age (i.e., active within the last 1.6 million years). Displacement along these thrust faults has caused the uplift of the coastal bluffs between the Crescent City harbor and Point St. George, which expose Franciscan and St. George formation rocks (Figure 2-1). Tectonic thrusting has also created the broad syncline across the coastal plain. The Rowdy Creek fault (“Smith River fault” of Clarke [1992]) has been recognized in offshore seismic lines but is queried onshore due to its lack of evidence other than the topographic transition from coastal plain to upland hillslopes (Figure 2-1). The Del Norte fault was first proposed by Maxson (1933) to account for the abrupt, north-south trending eastern boundary of the coastal plain with upland hillslopes. Some researchers have adopted Maxson’s proposed fault (Back 1957, Roberts and Dolan 1968, Stone 1993) while others have questioned the faults existence (DWR 1987, España Geotechnical Consulting 1993) due to a lack of exposure or other evidence.
Figure 2-1. Geologic map of the estuary backwater and surrounding portions of Del Norte County.
2.2 Geomorphology

A geomorphic assessment was conducted to characterize the existing geomorphology of the project area, assess risks associated with potential hazards, support an opportunities and constraints assessment, and inform project designs. Specifically, the geomorphic assessment included a topographic survey that was integrated with 2010 LiDAR data, review of existing information, and a field assessment. Existing information that was reviewed includes geologic mapping (Delattre and Rosinski 2012), geomorphic mapping (Davenport 1983), well completion reports filed with the Department of Water Resources (DWR), and a series of historical aerial photographs from 1942 to 2015.

The backwater is a long and narrow depression separated from the mainstem river channel by a vegetated scroll bar that over tops during infrequent high flows (see Figure 2-2). The scroll bar is deposited on the downstream side of a broad point bar that extends nearly 1 mile upstream to near the Rowdy Creek mouth. The backwater is bordered to the southeast by point bar deposits that support a riparian forest, to the south by floodplain dairy pastures, and to the southwest by portions of Tolowa Dunes State Park. The primary backwater feature, which is the focus of this project, extends approximately 750 feet upstream from its connection to the Smith River at the downstream end. The backwater within the project site ranges from approximately 30 to 50 feet wide. The scroll bar crest rises on average 6-8 feet above the base thalweg elevation of the backwater and the floodplain surface is on average 8 to 12 feet higher. The scroll bar is densely vegetated with riparian species dominated by willow and alder and includes other shrubs, sedges, and grasses. A mature cypress hedgerow grows on the northern edge of the floodplain along the backwater extent. Further upstream from the project area, the depression that defines the backwater channel becomes less pronounced, although a topographic expression along the scroll bar-point bar interface is evident in LiDAR data. The backwater connection to the river is at the very downstream end of the scroll bar and point bar deposits. The backwater is seasonally connected to the mainstem Smith River through its downstream connection during elevated winter and spring flows.

The Smith River channel in the project area is wide (up to 700 feet) and relatively shallow with average depths around 5 to 8 feet (during summer low-flow conditions), although portions of the channel along its right bank, upstream of the backwater reach depths of 12-14 feet (during summer low-flow conditions). This deep reach is locally known as the Piling Hole, due to the many relic pilings driven into the channel bed along the right bank. Approximately 600 feet downstream of the backwater entrance is the start of a prominent transverse riffle crest locally known as the Cattle Crossing. A deep low-flow channel runs along the left (southern) side of the riffle, which is actively eroding a tall cutbank into the floodplain and dune deposits in Tolowa Dunes State Park. The cutbank is home to the largest bank swallow (Riparia riparia) nesting colony in the Smith River (Parish and Garwood 2016).

The project area is within the tidally influenced reach of the Smith River. Salinity sampling conducted by Parish and Garwood (2015 and 2016) documented the salt wedge toe extending approximately 1.8 miles upstream of the backwater entrance in summer low-flow conditions. During winter high-flow conditions the salt wedge does not extend upstream of the Cattle Crossing riffle, although a backwatering effect of tidal inundation does influence water surface elevations in the river and backwater within the project area. The Cattle Crossing riffle crest elevation is approximately 5 feet, which is important in consideration of design grading elevations for the backwater. The existing inlet crest, or invert, elevation at the backwater entrance is approximately 8 feet and is therefore slightly higher than the elevation of a higher high tide (i.e., approximately 6.5 to 7 feet [NAVD 88]) as measured at the Crescent City tidal gage.
Figure 2.2. Geomorphic map of the estuary backwater project area.
2.2.1 Aerial photograph interpretation

LiDAR-derived topography and historical aerial photographs were reviewed to characterize the long-term geomorphic change along the backwater and Smith River estuary within the project area. Photographs were acquired from the U.S. Forest Service, California Department of Forestry, USGS, and Google Earth and include the following years: 1942, 1948, 1958, 1965, 1972, 1988, 1993, 2003, 2005, 2009, and 2015. Several aerial photographs had previously been compiled, orthorectified, and georeferenced to create the Lower Smith River Atlas (Laird and McBain & Trush 2004). Laird and McBain & Trush (2004) also digitized geomorphic and riparian features along the lower mainstem Smith River, including the channel thalweg, water’s edge, and the boundary of active channel scour with riparian vegetation.

All aerial photographs and digitized features from Laird and McBain & Trush (2004) were reviewed and select water’s edge polygons were compiled in Figure 2-3 to illustrate the dynamic nature of the Smith River within the project area. Cropped portions of each aerial photograph for the project area are located in Appendix B.

1942 and 1948 photographs

The backwater did not exist in the 1940s, and the left bank of the Smith River was approximately 200 to 300 feet north of the current backwater location. Much of the channel morphology in the project area was different than it is today. The river channel was straighter and the prominent southward lateral migration at the Cattle Crossing had not begun. The project vicinity along the lower Smith River was converting to agricultural uses, as evidenced by fences, roads, hedge rows, and managed fields. However, large portions of the floodplain pastures along both sides of the river do not appear to have been modified for agricultural use. Substantial portions of the project area were more forested with conifers and deciduous trees than occurs today. Additional cultivated fields and roads are evident in the 1948 photograph, including Pala Road, which is the current road access to the project site. A high flow channel is evident on the north bank side of the river that connected to a branch of Tillas Slough, lower in the estuary.

1958 photograph

This photograph shows substantial land use modifications that occurred in the project vicinity during the preceding decade. Portions of the floodplains on both sides of the river in the project area were logged, new roads were constructed, and agricultural activity expanded with additional fields being cultivated. This photograph documents the geomorphic change along the Smith River corridor from the 1955 flood, which is the third largest in the Smith River period of record with a flood frequency of approximately 30 years (based on a log-Pearson Type III distribution [USGS 1982]). The Smith River channel migrated southward in the project area, between 50 and 100 feet in some locations. Lateral and point bars appear larger and freshly worked, as indicated by a lack of riparian growth. The high-flow channel connecting to Tillas Slough is less evident and elsewhere along the north bank it appears that construction of private flood levees may have begun, consistent with timing discussed in previous reporting (Parish and Garwood 2015).

1965 photograph

This photograph was taken in the summer following the historic 1964 flood, which is the flood of record for the Smith River with a flood frequency of approximately 230 years (based on a log-Pearson Type III distribution [USGS 1982]). The main Smith River corridor experienced major geomorphic changes in channel alignment, pool and bar scour, floodplain scour and deposition, and eroding riparian vegetation. There is evidence of widespread flood damage to fields and roads across the Smith River coastal plain. Multiple large gravel mining operations are visible throughout the lower river and were likely supplying aggregate for constructing new roads.
(including the present-day Highway 101 [HWY 101]) and levees along the lower river and estuary. The river increased its sinuosity in the project vicinity by migrating southward near the backwater and northward further upstream. The river channel’s top of bank was within 20 to 50 feet of the backwater’s current location. New point bar and scroll bar deposits are evident on both sides of the river, opposite of the migrating banks, which is consistent with studies of scroll bar development in flume and natural settings (van de Lageweg 2014). Large areas of the floodplain surface to the southwest of the backwater had expansive fine sediment deposition. Expanded construction of the levee’s that persist to present day is evident along the north side of the river. Although not clearly discernable in the aerial photographs, it is likely that the existing anchored large wood in the river channel downstream of the backwater was placed during this period of major channel migration. According to anecdotal input from the landowners, these logs were placed in an attempt to stabilize the channel banks following the large flood-induced geomorphic changes in the 1950s and 1960s.

1972 photograph
The 1972 photograph was taken in the summer following the 1972 flood, which is the second largest on the Smith River in the period of record with a flood frequency of approximately 55 years. The Smith River and adjacent floodplains experienced even more substantial geomorphic change in the project area than following the 1964 flood. The river continued its trend of increasing sinuosity by migrating northward upstream of the project site and southward downstream of the site. This photograph is the first that documents the presence of the backwater in its present-day location, albeit with different planform dimensions. The scroll bar that separates the backwater from the river was devoid of vegetation and expanded downstream, due to the northward migration of the river’s right bank. Most notably, the river’s south bank downstream of the backwater substantially migrated further southward, up to approximately 300 feet since the 1965 photograph. Presumably much of the migration occurred during the 1972 flood. This significant lateral migration coincides with the development of the large Cattle Crossing transverse riffle. On the opposing right bank of the river, the point bar is significantly larger than in previous photographs. The levees on the north side of the river extend further up and downstream and appear intact with little to no evidence of flood impact on the pasture side. Conversely, the floodplains on the south side of the river show similar evidence of flood deposition as to the 1964 flood, although not as widespread. The series of historical photographs may suggest that the construction of extensive levees on the north side of the river, beginning in the 1950s, promoted southward migration of the channel during historic flood events in the 1950s, 1960s, and 1970s.

1988 photograph
In general, the project vicinity remained relatively comparable to conditions in the 1972 photograph. Additional ranch roads and fencing are evident and the scroll bar at the backwater site is comparable in extent to 1972 conditions. However, the scroll bar began to grow riparian vegetation and the downstream entrance into the backwater is clearly visible. The cypress hedgerow had been planted in the floodplain adjacent to the backwater. Downstream, at the Cattle Crossing riffle, the cutbank continued to migrate southward, although more locally than in previous decades, likely due to the concentrated low-flow channel running along the left bank. Large-scale gravel mining of the point bar on the opposite side of the river continued. The bar is dissected in un-natural patterns across much of its extent. The north-south trending extension of Pala Road that leads toward the backwater had been constructed.
1993 photograph
The project vicinity looks very comparable to the 1988 photograph. The very downstream portions of the scroll bar, downstream of the backwater entrance, appear to have been eroded, which is consistent with present day conditions of no sand or gravel bar deposits downstream of the backwater along the left bank. The remaining scroll bar upstream of the backwater continued to develop riparian vegetation, and the backwater entrance is still clearly visible. Agricultural activities including cultivation, fencing, and road use appear comparable to the 1988 photograph. Mining activity on the large point bar and Cattle Crossing riffle appears to be reduced compared to the previous photos.

2003 photograph
Again, the project vicinity appears comparable to conditions in previous photographs. Localized lateral migration continued along the cutbank to the south of the Cattle Crossing riffle. The scroll bar continued to develop a mature riparian forest throughout its extent as indicated by denser vegetation. The entrance into the backwater appears narrower and more closely resembles its present-day geometry.

2005, 2009, and 2015 photographs
The most substantial change seen across the 2005, 2009, and 2015 photographs is increased riparian growth across the scroll bar and continued localized lateral migration of the cutbank adjacent to the Cattle Crossing riffle. River and backwater bank positions appear unaltered across all photographs since at least the early 2000s, and only slightly altered since the major planform adjustments of the 1950s, 1960s, and 1970s that coincided with historic flood events.
Figure 2-3. Historical Smith River channel alignments in the estuary backwater project area.
2.2.2 Topography and bathymetry

Stillwater and SRA staff conducted field topographic and bathymetric surveys in the summer and fall of 2019 using a robotic total station, real-time kinematic (RTK) GPS, and single beam sonar. The primary goals of the surveys were to characterize the existing conditions topography and bathymetry to support geomorphic assessment, hydraulic modeling, and engineering designs. The surveys focused on topography of the backwater site, and bathymetry and bank topography of the Smith River along a 0.6-mile reach to develop a 2-D hydraulic model. The RTK GPS was used to establish a network of survey control points throughout the project site. Bathymetric data in the Smith River channel were collected using survey-grade single beam sonar mounted to a boat. In the office, survey data were post-processed using an RTK base station position correction from the National Geodetic Survey (NGS) Online Positioning User Service (OPUS) and aligned to the NAVD 88 vertical datum.

The field survey data were integrated with 2010 NOAA Coastal LiDAR point cloud data. The LiDAR points were shifted to better characterize local 2019 field conditions. The horizontal shift (0.12 feet south) was determined using NGS Coordinate Conversion and Transformation Tool (NCAT) to convert from the input datum (NAD83[2011]) to the output datum (NAD83[2011]) at the approximate central location of the project area. The vertical shift (+0.14 feet) was determined by comparing 2019 field-surveyed elevations collected along paved road alignments within the project area to the horizontally adjusted LiDAR point cloud data.

2.2.3 Field assessment

The geomorphic field assessment of the project area consisted of evaluating floodplain and channel morphology, assessing local drainage patterns, investigating shallow stratigraphy exposed in cutbanks, and identifying potential habitat enhancement locations. Results and interpretations from the field assessment are summarized below, beginning in the Smith River channel and moving upstream into the backwater. Refer to the final design plan set in Appendix B for elevations, slopes, and key points of interest referenced throughout the following section.

Smith River channel at backwater confluence

The Smith River channel in the vicinity of the backwater entrance is wide, shallow, and at an inflection point between major river meanders (Figures 2-2 to 2-4). During typical low flows, the river channel at the backwater entrance is approximately 700 feet wide and ranges in depth from approximately 1 to 2 feet along the south bank to 5 to 7 feet in the thalweg, which runs along the north bank. This reach of the river is tidally influenced, resulting in diurnal water level fluctuations. Channel bed substrate is dominantly sand and fine gravel along the southern channel margin at, and upstream of the backwater entrance. The bed has dune morphology in sand dominated areas, with fine gravel deposits in the dune troughs. The dunes are predominantly asymmetrical, as expected in a riverine setting. In some locations, however, the dunes are symmetrical, likely due to tidal currents moving upstream. Gravel and cobble deposits are exposed in cutbanks along the river’s south bank near the entrance to the backwater. These deposits are typically between 4 to 6 feet in elevation, placing them within the range of daily water surface elevation fluctuations during tidally influenced summer low-flow conditions. The central and northern channel bed is dominantly gravel with cobble and sand in interstitial spaces. The Cattle Crossing riffle, which begins approximately 600 feet downstream of the backwater, is dominantly cobble and gravel and is the primary hydraulic control on water surface elevation in this reach of the lower river. The next prominent riffle with hydraulic control is the Bailey riffle located approximately 2.4 miles upstream of the project site. The Cattle Crossing is an expansive transverse riffle with a high-flow thalweg across the central northern end of the riffle and a deep
low-flow side channel along the southern river bank. Concentrated flow along the southern bank has caused substantial localized lateral bank migration over the past half century. Review of historical aerial photographs shows that the bank migration is predominantly lateral and not in an up or downstream direction.

This reach of the river has a relatively small amount of large wood, although some logs are present along the channel margins and submerged in deeper pools along the north bank upstream of the backwater and in the deep south bank channel near the Cattle Crossing riffle. Additionally, there are two clusters of logs and rootwads that are anchored with pilings mid-channel near the crest of the Cattle Crossing riffle (see Section 2.2.1 Aerial photograph interpretation above for further description).

![Oblique aerial view of the project area during summer low-flow conditions](image)

**Figure 2-4.** Oblique aerial view of the project area during summer low-flow conditions, looking upstream. Backwater entrance in photo center.

**Backwater entrance**
The backwater entrance is relatively broad, with gently sloping sides (Figures 2-5 and 2-6). The backwater channel bed is dominantly sand and is nearly completely colonized by salt-tolerant sedges, rushes, and grasses. There is a marked slope up at Sta 0+50 from the river channel, at approximately 5 feet elevation, onto the backwater entrance surface, at approximately 7 feet elevation (Appendix A, Sheet 2). The backwater thalweg continues at a relatively level grade for another 100 feet before the backwater channel narrows and enters dense willow stands at approximately Sta 1+70. Minor depressions along this level grade are regularly inundated, even when the backwater lacks a surface water connection to the river (Figure 2-5). Perennial water in the backwater is supplied by main channel seepage and/or hyporheic sources. During field surveys in summer low-flow conditions, these depressions would saturate and then dry following tidal cycles. The downstream tip of the scroll bar that separates the backwater from the river is
partially vegetated with grasses and willow, although much of the ground is exposed sand. The
floodplain on the south side of the backwater entrance is densely vegetated with multi-story
riparian vegetation and the downstream extent of the mature cypress hedgerow. The backwater
entrance intersects the river channel at an angle of approximately 30 to 40 degrees.

At Sta 1+70 the backwater becomes vegetated with mature willow and the channel narrows
between the willow trunks. The entrance invert is located here with an elevation of approximately
8 feet. The backwater thalweg maintains this elevation for only 10 to 15 linear feet before
dropping to lower elevations on the upstream and downstream sides. Reed canary grass (*Phalaris
arundinacea*) is present at this relatively higher elevation, where it is subject to less saline
conditions and still receives direct sunlight from the margin of the willow stands.

![Disconnected backwater entrance in photo right during low winter flow conditions. Ponded water is from groundwater and hyporheic connection with river channel. View looking downstream.](image)

**Figure 2-5.** Disconnected backwater entrance in photo right during low winter flow conditions. Ponded water is from groundwater and hyporheic connection with river channel. View looking downstream.
Figure 2-6. Connected backwater entrance during an approximately 11% exceedance flow. View looking upstream.

**Backwater entrance to splay deposit**

Moving upstream from Sta 1+70, the backwater bed widens again and lowers in elevation in multiple “steps” from approximately 7 feet near Sta 2+00 to approximately 4.5 feet near Sta 4+30, just before the splay deposit (Appendix A, Sheet 2). During the late summer and fall surveys in 2019, the deeper pool areas along this reach of the backwater were inundated with water up to 1.5 feet deep, indicating a summer groundwater elevation of approximately 6 feet. The bed and bank substrate are dominantly fine sand, silt, and organics; although, in few locations gravel and cobble are exposed in cutbanks. The backwater side slopes are relatively steep throughout this reach and support dense riparian vegetation that is primarily mature willow. The willow continues across the crest of the scroll bar toward the river. The crest of the scroll bar is wide and gently slopes to its margins, which are relatively steeper on both the river and backwater sides. The cypress hedgerow extends along the entire length of the backwater on the floodplain. In a few locations, major cypress limbs have broken off and provide a source or large wood within the backwater habitat. The dense willow stands provide abundant small and medium wood that is overhanging and within the typical inundated footprint of the backwater throughout most of its length (Figure 2-7 to 2-9). Several large alder and willow trees have toppled into the backwater and are still alive since their rootwads have remained embedded in the side slopes (see Appendix B, Sheets 3 and 11). The rootwads of these trees provide bank stability for the backwater. Reed canary grass (RCG) is present in dispersed small patches that coincide with openings in the riparian canopy that allows sunlight to penetrate to the ground. Previous water quality measurements by Parish and Garwood (2016) documented low dissolved oxygen in this reach of the backwater, which is likely due to poor surface connection with the river and decaying vegetation.
Figure 2-7. Backwater just upstream from river confluence area (visible in upper left). Constriction centered at Sta 2+00 visible above person’s head. View looking downstream.

Figure 2-8. View of backwater looking downstream from approximately Sta 3+00. Water surface visible in lower right. Much of the backwater contains abundant medium and small wood.
Figure 2-9. View of backwater looking downstream from approximately Sta 4+20.

Splay deposit
Between approximately Sta 4+40 and 4+80, the backwater thalweg rises substantially up to 9.5 feet in elevation (Figure 2-10). This reach of the backwater is morphologically distinct from the channel form upstream and downstream and is likely a splay deposit from elevated Smith River flows overtopping the scroll bar during infrequent flood events (e.g., greater than 10-year recurrence interval). The deposit is composed of the same fine sand and silt as elsewhere along the backwater and also supports mature willow. The splay deposit is also a main transportation route for cattle from the adjacent floodplain pasture to access the river, which further contributes to bank sediment eroding into the backwater. The landowners have fencing along the northern margin of the pasture; however, it is in varying states of disrepair and cattle frequently access the backwater and river via the splay deposit.
Figure 2-10. Splay deposit from Sta 4+40 to 4+80 dissects inundated portions of the backwater. Person in photo center for scale.

Upstream of splay deposit
Upstream of the splay deposit the backwater is less well defined as a channel and the thalweg elevation is not as low as downstream of the splay. Between Sta 4+80 and 5+50 the thalweg elevation ranges between 6.5 and 8.5 feet before stepping up to a relatively level and broad surface with an elevation of 8.5 to 9 feet. The south bank side slope is comparable to lower in the backwater, however, the north bank slopes much more gradually up to a poorly defined crest of the scroll bar. Bed and bank substrate are comparable to lower in the backwater. The density and composition of riparian vegetation is generally comparable to lower in the backwater, although there are multiple open areas with just grass. Upstream from approximately Sta 6+00 the backwater becomes even less well defined and more resembles the back edge of bar as opposed to a channel. Based on LiDAR derived topography, the elevation of the scroll bar back edge gradually increases to approximately 15 feet at its upstream extent. It is unlikely that Smith River high flows enter the backwater from upstream along the scroll bar back edge, except for during infrequent flood events (e.g., greater than 10-year to 25-year recurrence interval) when the entire scroll bar is inundated.

2.3 Riparian Vegetation
The riparian vegetation field assessment was conducted in the summer of 2020 to characterize vegetation composition and structure in the project area. Results from this assessment informed the plant selection for the riparian planting plan, strategies to limit native vegetation disturbance and the spread of nonnative vegetation, and the recommended approach for revegetation.

Most of the backwater is fully shaded by a deciduous hardwood riparian forest. Riparian mid-story cover is primarily composed of *Salix sitchensis* (Sitka willow), *Salix lasiolepis* (shining willow) and *Alnus rubra* (red alder) provide moderate canopy cover in the overstory. Understory vegetative cover is sparse to moderate and includes *Marah oregana* (coast man-root), *Polystichum munitum* (western sword fern), *Urtica dioica* (stinging nettle), *Rubus ursinus* (California blackberry), *Rubus armeniacus* (Himalayan blackberry), *Scirpus microcarpus* (small-fruited bulrush), *Athyrium filix-femina* var. *cyclosorum* (lady fern), *Rubus spectabilis* (salmonberry), *Rubus parviflorus* (thimbleberry), and *Lonicera involucrata* (twinberry). The shaded channel bed is mostly unvegetated but has sparse cover by sedges. Patches of *Phalaris*
arundinacea (reed canary grass or RCG) within the backwater area are associated with gaps in the overstory canopy. Low cover by nonnatives were noted throughout the southern portion of the backwater and included Cirsium vulgare (bull thistle) and Vinca major (greater periwinkle). An established hedgerow of Hesperocyparis macrocarpa (Monterey cypress) with some understory cover by nonnative Ligustrum sp. (privet) borders the backwater area to the south. The backwater entrance is composed of herbaceous hydrophytic species common to brackish water regimes: Potentilla anserina subsp. pacifica (Pacific silverweed), Carex aquatilis var. dives (Sitka sedge), Schoenoplectus pungens var. longispicatus (common three-square bulrush), Carex obnupta (slough sedge), and Agrostis stolonifera (creeping bent-grass). Moderate cover by RCG was observed near the transition from brackish herbaceous vegetation to woody riparian cover (approximately 7 to 9 feet in elevation) from Station (Sta) 1+50 to 2+50. Vegetation along the scroll bar includes the same willow species as around the backwater, grasses, mostly Festuca arundinacea (tall fescue), and some nonnative forbs including Saponaria officinalis (bouncing-bet soapwort).

Disturbance noted within the site included trampled vegetation and compacted soils from livestock use and patches of nonnative invasive plant species.

3 HYDROLOGY AND HYDRAULICS

To understand the flow dynamics along the project reach the design team developed a 2-D hydraulic model for the 0.6-mile reach of the river within the project area using the U.S. Army Corps of Engineers’ (USACE) Hydrologic Engineering Center’s River Analysis System (HEC-RAS). HEC-RAS is widely used for floodplain mapping and estimating general flow characteristics. The 2-D model predicts depth-averaged two-dimensional velocity vectors and water surface elevation within a user-specified grid across a continuous topographic terrain model. The hydraulic model was developed as part of the 65% design process.

3.1 Hydrology

A hydrologic analysis is required to determine stream flow data that are the principle input to HEC-RAS. The Smith River has two active USGS stream flow gages. Gage No. 11532500 (Smith River near Crescent City), located in Hiouchi approximately 12.5 miles upstream of the project site, provides a continuous stage and discharge record, as well as other water quality parameters. Gage No. 11532650 (Smith River near Fort Dick) is located at the HWY 101 bridge approximately 4 miles upstream of the project site and provides a continuous stage record only. Peak flow estimates and exceedance flows were calculated for USGS Gage No. 11532500 (Smith River near Crescent City) using flood frequency and flow duration analyses. Relevant discharges at the project site were calculated using drainage-area prorations from the peak flow and exceedance flow estimates for the upstream USGS gage location. These methods are described below.

Peak streamflow and mean daily flow records were analyzed from USGS Gage No. 11532500 to produce flood frequency and flow exceedance probability estimates, respectively. Peak flow estimates from the flood frequency analysis have specific recurrence intervals, or frequencies (e.g., a 100-year peak flow has a 1% chance of occurring any year, or once in 100 years, on average). Smaller flood frequency flows with more regular recurrence intervals (i.e., 1.5- and 2-year flows) are biologically and geomorphically significant because they occur during most winters and can create high velocities capable of flushing juvenile salmonids and/or causing
mortality if insufficient low-velocity refugia habitat are available. For this analysis, we assume the 1.5-year recurrence interval flow approximates the “bankfull” flow. It is also critical to analyze flows from larger flood events ranging from 2- to 100-year recurrence intervals to determine inundation extents, flood flow velocities, erosion potential, flooding hazards for adjacent property and infrastructure, as well as the stability of the proposed design features.

The flood frequency analysis used a Log-Pearson III distribution and methods consistent with USGS Bulletin 17B (USGS 1982). For proration calculations, a drainage area of 714 square miles was used for the project site. Peak flow estimates (provided in Table 3-1) were prorated for the project site following the flow transference equation of Waananen and Crippen (1977):

\[ Q_u = Q_g (A_u/A_g)^b \]

Where: \( b = 0.87 \) for 100- to 5-year events, \( b = 0.9 \) for 2- and 1.5-year events, and \( b = 1 \) for exceedance flows

- \( Q_u \) = Ungauged discharge
- \( Q_g \) = Gauged discharge
- \( A_u \) = Ungauged drainage area
- \( A_g \) = Gauged drainage area

In addition to peak flow estimates, moderate and low flows were also calculated, and some were modeled in HEC-RAS (Tables 3-1 and 3-3). These flows correspond to upper fish passage flows, typical winter base flow, and mean summer flow. These relatively smaller flows have biological significance for fish passage and habitat enhancement objectives, especially related to over-winter rearing habitat for salmonids. The 2% exceedance flow has been identified in other coastal basins as the highest flow when fish passage is likely to occur. The 20% exceedance flow represents the typical winter base flow when juvenile salmonids may be rearing in the lower river. The mean summer flow occurs following the targeted seasonal fish rearing and outmigration period and was primarily used to inform project designs. These biologically relevant exceedance flows were calculated from the upstream USGS gage records and were prorated based on the drainage area ratio to the project site.

Because the project site is in a tidally influenced reach of the lower river, tidal input was also evaluated for a range of tide elevations using the nearby Crescent City tidal gage, which is located in the Crescent City harbor. The modeled tidal conditions include mean low water (MLW) and mean high water (MHW) (Table 3-2); and are further described below in Section 3.2 Hydraulic modeling.
### Table 3-1. Peak flow and exceedance flow estimates for the Smith River at the project site.

<table>
<thead>
<tr>
<th>Discharge location and description:</th>
<th>100-yr peak flow (cfs)</th>
<th>50-yr peak flow (cfs)</th>
<th>25-yr peak flow (cfs)</th>
<th>10-yr peak flow (cfs)</th>
<th>5-yr peak flow (cfs)</th>
<th>2-yr peak flow (cfs)</th>
<th>1.5-yr peak flow (cfs)</th>
<th>2% exceedance flow (cfs)</th>
<th>20% exceedance flow (cfs)</th>
<th>Summer mean flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prorated from USGS Gage No. 11532500 Smith River near Crescent City, CA¹</td>
<td>228,764</td>
<td>204,734</td>
<td>180,947</td>
<td>149,414</td>
<td>124,818</td>
<td>88,805</td>
<td>74,297</td>
<td>26,645</td>
<td>6,074</td>
<td>449</td>
</tr>
</tbody>
</table>

Notes:
1. Exceedance flows calculated using standard flow duration analysis and prorated for drainage area difference.
2. Average of July, August, and September monthly mean flows.
3. Log-Pearson Type III distribution based on USGS stream gage prorated for drainage area difference using USGS flow transference formula (Waananen and Crippen 1977).

### Table 3-2. Tidal elevations used for the project site.

<table>
<thead>
<tr>
<th>Tidal datum</th>
<th>Elevation, ft (NAVD 88)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean high water (MHW)</td>
<td>5.9</td>
</tr>
<tr>
<td>Mean low water (MLW)</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Notes:
1. Elevations from Crescent City tide gage.

### Table 3-3. Modeled peak flows and exceedance flows for the Smith River at the project site.

<table>
<thead>
<tr>
<th>50-yr peak flow (cfs)</th>
<th>10-yr peak flow (cfs)</th>
<th>1.1-yr peak flow (cfs)¹</th>
<th>1.9% exceedance flow (cfs)¹</th>
<th>20% exceedance flow (cfs)¹</th>
<th>Summer mean flow (cfs)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>204,734</td>
<td>149,414</td>
<td>51,773</td>
<td>28,041</td>
<td>6,074</td>
<td>449</td>
</tr>
</tbody>
</table>

Notes:
1. Discharge selected based on having a corresponding recorded water surface elevation at the project site.
2. Discharge modeled at MHW and MLW tidal conditions.
3.2 Hydraulic Modeling

The primary objectives of the 2-D hydraulic model are to:

- Estimate water surface elevations and inundation areas under different river and tidal flow regimes, which were used to refine proposed grading depths and extents in the design plans.
- Understand local-scale flow dynamics (i.e., velocity, shear stress, flow vectors) in the vicinity of the backwater entrance to inform design developments for the proposed large wood and boulder structures.

A spatially continuous topographic and bathymetric terrain model was produced from the LiDAR topography, field surveyed topography of the backwater, and field surveyed bathymetry for the Smith River. The terrain model includes approximately 0.6 miles of the Smith River and extends up to approximately 3,300 feet laterally across the floodplains on either side of the river. This terrain model was used as input in the 2-D hydraulic model. Spatially variable Manning’s n values were assigned across the model area based on channel substrate, vegetation, and land-use. Manning’s n values ranged from 0.03 (main channel) to 0.07 (thick vegetation). The flows listed in Table 3-3 were ran in the 2-D model and calibration was performed by adjusting Manning’s n values until the modeled water surface elevations closely matched calibration points, which consisted of three water level loggers installed at the site in the fall of 2019 and site observations during the summer mean flow condition. The water level logger install locations include: in the backwater near Sta 3+20, in the river near the backwater entrance, and in the river at the upstream extent of the modeled reach (see Appendix B, Sheet 2).

The MHW and MLW tidal conditions were included in the model runs for the summer mean flow and 20% exceedance flow scenarios. Tidal influence is the primary control on water surface elevation at the project site during these relatively lower flows and can fluctuate up to approximately 3 feet (between 5 – 8 feet in elevation [NAVD 88]) during large tide events.

Note that the 100-year flood discharge was not modeled due to the additional effort of modeling a flow this large in the broad alluvial floodplain setting of the lower Smith River. To accurately model the 100-year flood, the terrain model would have needed to be extended across the entire Smith River coastal plain, which would dramatically increase model run times and complicate variable manipulation during model calibration. However, a 2-D hydraulic model for the entire lower Smith River extending approximately 9 miles upstream from the mouth (which includes the project area) was developed by DHI Water & Environment in 2007 as part of a FEMA Flood Insurance Study (FIS) (DHI 2007). Similar to the model approach for this design project, the DHI model evaluated river and tidal effects. Results from DHI (2007) provide a broader context for flow conditions extending up and downstream from the project area, as well as an additional calibration check on water surface elevations for the 10-year and 50-year flood flow model scenarios.

Modeled flow velocities range from 0 to approximately 4.3 ft/sec (during the 50-year peak flow) within the river reach and 0 to approximately 1.9 ft/sec (during the 50-year peak flow) in the backwater. Typical velocities in the backwater during flow conditions when salmonids are expected to be rearing (i.e., 20% exceedance to 1.9% exceedance flows) are 0 to approximately 0.25 ft/sec. 1.1-year flood flows and lower are contained within the bankfull channel, whereas 10-year flood flows and higher expand across the floodplains on either side of the river. Proposed
conditions hydraulic modeling results are discussed below in Section 5.2 Proposed Conditions Hydraulic Modeling and are included in Appendix C. Water surface elevation and flow velocity magnitudes from the 2-D modeled 50-year flow event were used in the wood stability analyses (see Section 6.4 Large Wood Stability).

4 CONCEPTUAL DESIGN ALTERNATIVES

4.1 General Design Objectives

Conceptual design alternatives for the estuary backwater enhancement project are provided in Appendix A. The conceptual design plans focus on several key enhancement components including:

1. **Off channel seasonal rearing habitat** – seasonal winter and spring rearing are key ecological uses of estuaries, including backwaters and sloughs, for juvenile salmonids. The conceptual design plans include enhancing and expanding off channel seasonal rearing habitat. Design objectives focus on enhancing low velocity refugia by expanding high quality off channel habitat in the backwater, improving connection into the habitat, and extending habitat use into the late spring/early summer.

2. **Hydrologic connectivity** – due to the backwater’s lack of a contributing drainage area, which precludes a reliable source of flushing flows, the backwater has poor connectivity to the mainstem river during low-flow conditions. Conceptual design plans include regrading portions of the backwater entrance to increase inundation during typical winter and spring flows. The proposed grading in the backwater entrance is also designed to accommodate regular high tide conditions during any flow stage on the river.

3. **Riparian function** – in general, the backwater has good riparian function due to the dense willow at the site. Invasive reed canary grass is only minimally present in the backwater, which is unusual for the lower Smith River. The conceptual design plans account for riparian function by reducing impacts to native vegetation and thereby promoting the existing suppression of reed canary grass.

4. **Livestock exclusion** – currently, exclusion fencing along the pasture adjacent to the backwater consists of a temporary hotline. Further upstream, exclusion fencing is in various states of disrepair. Cattle regularly access the backwater and river, via the scroll bar, further exasperating sediment transport into the backwater and impacting water quality. The conceptual design plans include constructing permanent livestock exclusion fencing along the entire project corridor, from the existing State Park boundary, along the northern edge of the pasture, to an existing permanent fence line approximately 1,000 feet upstream of the project area.

4.2 Alternative 1

Conceptual design Alternative 1 (see design plans in Appendix A, Sheets 1 through 5) consists of a suite of actions that address all key enhancement components described above, including:

- Construct large wood and boulder structures in the backwater entrance from Sta 75+00 to 1+75. The structures are intended to strengthen the banks and constrict flow to promote velocities capable of sediment transport and reduce fine sediment deposition. A target velocity between 0.15 to 0.25 feet/sec is within the transport threshold range for medium grain-size sands. This design approach promotes mass balance and self-maintaining geometry at the backwater entrance.
• Construct a series of willow baffles on the river side of the scroll bar upstream of the backwater entrance to reduce flood flow velocity from the river and promote deposition of fine sediment before intersecting the backwater entrance.

• Grade the backwater entrance thalweg between Sta 0+50 to 1+75 to a depth that tapers in elevation from approximately 5 to 6 feet, moving upstream.

• Grade the backwater thalweg between Sta 1+75 to 2+40 to a depth that tapers in elevation from approximately 6 to 5 feet, moving upstream. The grading would create an entrance invert elevation of 6 feet at Sta 1+75. This elevation was selected so the backwater would inundate more frequently during winter and spring flows and during high tides (see Section 5.2 Backwater-Smith River Confluence for further discussion).

• Grade the backwater thalweg between Sta 2+40 to 4+40 to a depth ranging in elevation from approximately 4 to 5 feet. Longitudinal variation between these elevations along this reach is preferred.

• Riparian planting in areas along the backwater where existing vegetation is subject to incidental impacts during construction and to stabilize oversteepend banks (e.g., steeper than approximately 2:1 [H:V]).

• Construct livestock exclusion fencing along the backwater from the existing fence at the State Park boundary to the existing permanent fence line upstream of the site.

4.3 Alternative 2

Conceptual design Alternative 2 (see design plans in Appendix A, Sheets 1 through 4) consists of the same suite of enhancement actions as Alternative 1 with the following additions:

• Grade the backwater thalweg between Sta 4+40 to 6+00 to a depth ranging in elevation from approximately 5 to 5.5 feet. Longitudinal variation between these elevations along this reach is preferred.

• Grade a littoral bench along the northern and eastern extent of the thalweg deepening from Sta 4+40 to 6+00 with a target elevation of approximately 7 feet. The existing ground slopes in this footprint are more gradual and conducive for the proposed excavation. The elevation is designed so the bench inundates during higher flow events (i.e., approximately a 20% exceedance flow).

4.4 Alternative 3 (Preferred Alternative)

Conceptual design Alternative 3 (see design plans in Appendix A) was developed based on discussion with the TAC following the conceptual and 65% design submittals. Alternative 3 is comparable to Alternative 2, however, the main objective (and difference) of Alternative 3 is to grade the backwater deeper than the thalweg elevations proposed in Alternatives 1 and 2 in order to increase riverine and tidal exchange into the backwater. Specifically, Alternative 3 includes:

• Grade the backwater thalweg between Sta 0+40 to 1+75 from an elevation of approximately 4.5 feet to 5 feet at Sta 1+75. The target 5-foot elevation at Sta 1+75 represents the inlet crest and invert for hydraulic connectivity into the backwater. Grading should be slightly sloped to create a smooth transition from the riverbed into the backwater and promote flow from the inlet crest back down to the river during a receding hydrograph.

• Grade the backwater thalweg from Sta 1+75 to 4+85 to a target thalweg elevation of approximately 4.0 feet. Finished grade elevations will likely vary between 4.0 to 4.5 feet,
which is preferred, due to site specific variability in presence of mature riparian trees, backwater width, and existing slopes.

- Grade the backwater thalweg between Sta 4+85 to 5+90 to a depth ranging in elevation from approximately 4 to 5 feet. Longitudinal variation between these elevations along this reach is preferred.
- Grade the backwater from Sta 5+85 to 6+60 to a target elevation of 8 feet for the littoral bench, which will also extend along the north side of the backwater beginning at approximately Sta 4+85.

Other than the proposed grading depths and extents listed above, Alternative 3 includes the same suite of design features in Alternatives 1 and 2 including large wood structures, willow pole planting on the scroll bar, a littoral bench, riparian planting, and livestock exclusion fencing.

4.5 Planning-Level Construction Cost Estimate

Tables 4-1 and 4-2 provide planning-level cost estimates for Alternatives 1 and 2, respectively. Because Alternative 3 was developed following the 30% conceptual design submittal and is the preferred alternative, its cost estimate is provided below in Section 5.3 (Final Design Cost Estimate).

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Unit Cost</th>
<th>Quantity</th>
<th>Units</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>$30,000</td>
<td>1</td>
<td>LS</td>
<td>$30,000</td>
</tr>
<tr>
<td>2</td>
<td>Clearing and grubbing</td>
<td>$20,000</td>
<td>1</td>
<td>LS</td>
<td>$20,000</td>
</tr>
<tr>
<td>3</td>
<td>Dewatering</td>
<td>$30,000</td>
<td>1</td>
<td>LS</td>
<td>$30,000</td>
</tr>
<tr>
<td>4</td>
<td>Large wood structures—placed and anchored</td>
<td>$2,500</td>
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<td>each</td>
<td>$32,500</td>
</tr>
<tr>
<td>5</td>
<td>Boulders—placed and anchored</td>
<td>$150</td>
<td>20</td>
<td>Tons</td>
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<td>6</td>
<td>Re-grade backwater Sta 0+50 to 4+40</td>
<td>$70</td>
<td>600</td>
<td>CY</td>
<td>$42,000</td>
</tr>
<tr>
<td>7</td>
<td>Willow baffle structures</td>
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<td>260</td>
<td>LF</td>
<td>$7,800</td>
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<td>8</td>
<td>Mulch</td>
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<td>LS</td>
<td>$1,500</td>
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<td>9</td>
<td>Seeding</td>
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<td>11</td>
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<tr>
<td>12</td>
<td>Engineering - bid support, construction oversight, as-builts</td>
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<td>1</td>
<td>LS</td>
<td>$35,000</td>
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</tbody>
</table>

Total construction cost: $228,750
Total construction cost plus 10% contingency: $251,625
Table 4-2. Cost estimate for Alternative 2 based on 30% design.

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Unit Cost</th>
<th>Quantity</th>
<th>Units</th>
<th>Total cost</th>
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<tr>
<td>1</td>
<td>Mobilization</td>
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<td>LS</td>
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<td>Clearing and grubbing</td>
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<td>LS</td>
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<td>11</td>
<td>Exclusion fencing and gates</td>
<td>$11.50</td>
<td>1800</td>
<td>LF</td>
<td>$20,700</td>
</tr>
<tr>
<td>12</td>
<td>Permits (CDFW 1602)</td>
<td>$5,500</td>
<td>1</td>
<td>LS</td>
<td>$5,500</td>
</tr>
<tr>
<td>13</td>
<td>Engineering - bid support, construction oversight, as-buils</td>
<td>$35,000</td>
<td>1</td>
<td>LS</td>
<td>$35,000</td>
</tr>
</tbody>
</table>

Total construction cost: $249,750
Total construction cost plus 10% contingency: $274,725

5 PREFERRED ALTERNATIVE - FINAL DESIGN

5.1 Selection of a Preferred Alternative

During the first TAC meeting on June 24th, 2020 there was general consensus that the complete suite of design elements included in Alternative 2 was preferred; however, the TAC discussed the potential to grade the backwater thalweg deeper in the entrance area (approximately Sta 0+35 to 2+50) and from the splay deposit going upstream (approximately Sta 4+40 to 6+00) in order to increase riverine and tidal input into the backwater. These revisions were developed as Alternative 3, which was subsequently submitted to the TAC and advanced to the 65% design level. Multiple revisions and design options were agreed to during ongoing discussion with the TAC and project stakeholders during the 90% design review. These revisions were included in the final design planset (provided in Appendix B) and include:

- The backwater entrance channel will be graded deeper, to an approximate elevation of 4.0 feet. The grading will create a continuous profile from the river into the backwater between Sta 0+35 and 2+50. The deeper grading and continuous bed profile will further promote tidal exchange into the backwater throughout the year. Deeper grading expands
the horizontal footprint of disturbance since suitable side slopes must be maintained, therefore, short term riparian impacts will be greater. Alder and willow trees within the footprint of excavation will be impacted, which will require additional riparian planting.

- Larger alder and willow trees that are toppled during excavation should be retained with as much rootwad embedment into the finished side slopes as is feasible. The backwater currently has multiple alder and willow trees that have toppled, are sub-horizontal, are within the regularly inundated elevations of the backwater, and have fully live crowns. Some alder and willow trees will be uprooted and should be incorporated as habitat features in the backwater following the designs on Sheets 5, 6, and 12 in Appendix B. See Section 6.1.1 Riparian planting and 6.4 Large Wood Stability below for further discussion. Log structures spanning the backwater channel, which were depicted in the 90% design plans, have been removed based on the concern that they could engender debris jams.

- The layout of the large wood and boulder structures at the backwater entrance were slightly adjusted based on empirical relationships of self-sustaining tidal channel geometry described by Williams et al. (2002). This evaluation is further described below in Section 6.3 Backwater-Smith River Confluence. The structures were also revised to logs without rootwads since roots add roughness that could rack debris. Removing the rootwads is a suitable approach since these logs primary function is to promote hydro-geomorphic conditions and not habitat benefits.

- The final designs include excavating two shallow “starter” pools 1 to 1.5 feet deep within the backwater where the bed is naturally wider (approximately Sta 2+35 and 4+75) and can accommodate the additional excavation without compromising the side slopes. The intended function of the pools is to provide habitat depth variability and promote groundwater infiltration.

- The proposed willow baffles in the conceptual design alternatives have been revised to live willow stake plantings. The revision is based on the challenges of excavating baffle trenches on the crest of the narrow scroll bar, and the risk of placing willow stakes in groundwater that is saline during high tides coupled with low river flows. Shorter and narrower willow stakes can be planted with manual methods in the winter when groundwater levels are higher and less saline. See Section 6.1.1 Riparian planting below for further discussion.

- A littoral bench is included in the final design. The intended function of the bench is to provide depth variability within the backwater, particularly shallow water habitat during higher winter flows. The bench is designed at an elevation of 8 feet so it will inundate at flows equal to and greater than approximately 20% exceedance. The habitat benefits of the littoral bench are supported by fish monitoring conducted by the Mattole Salmon Group at a comparable backwater/slough enhancement project in the lower Mattole River. After Phase 1 of the Mattole project was built in 2015, monitoring in 2015-2016 found that juvenile salmonids most frequently reared in shallow water habitat vegetated by wetland emergent plants, including the backwatered area upstream of the project, which had average depths of approximately 10 inches. The Mattole project is further discussed below in Section 6.3 Backwater-Smith River Confluence.

- A sediment spoils site has been selected approximately 1,000 feet southeast of the backwater in the pasture (see Sheets 2 and 7 in Appendix B). The site is at a natural high point in the pasture and has an existing spoils mound from previous excavations. The landowner prefers this site since it serves as a cattle evacuation point when the river floods. Spoils management is further discussed below in Section 6.5 Construction Logistics.
- The water management plan includes a contingency option of pumping into the adjacent pasture during dewatering efforts in the backwater. This method will only be used when there is fresh water being pumped and not salt water during high tides. A potential dewatering sequence may include pumping freshwater into the pasture during low tides and into the temporary settling basins in the backwater during high tides.

5.2 Proposed Conditions Hydraulic Modeling

Proposed-conditions hydraulic modeling of the preferred alternative was conducted by grading the features in AutoCAD and exporting a new terrain model for import into HEC-RAS. Manning’s values were also slightly adjusted to account for large wood structures and proposed riparian planting. Modeled flow velocities under proposed conditions are very comparable to existing conditions under all flow scenarios. Modeled water surface elevation for the 1.9% exceedance flow and greater are also very comparable between existing and proposed conditions. However, modeled water surface elevation in the backwater for the lower flows (i.e., 20% exceedance and summer mean flow) are markedly higher under proposed conditions compared to existing conditions (Figure 5-1). The proposed grading substantially increases inundation within the backwater during a 20% exceedance flow at MLW and MHW.

Modeled water surface elevation and flow velocity maps of the project area are included in Appendix C. Water surface elevation and flow velocity magnitudes from the 2-D modeled 50-year flow event were used in the wood stability analyses (see Section 6.4 Large Wood Stability).
Figure 5-1. Existing and proposed future inundation in the backwater.
5.3 Final Design Cost Estimate

Table 5-1. Cost estimate based on final design.

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Unit Cost</th>
<th>Quantity</th>
<th>Units</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization</td>
<td>$35,000</td>
<td>1</td>
<td>LS</td>
<td>$35,000</td>
</tr>
<tr>
<td>2</td>
<td>Clearing and grubbing</td>
<td>$25,000</td>
<td>1</td>
<td>LS</td>
<td>$25,000</td>
</tr>
<tr>
<td>3</td>
<td>Dewatering</td>
<td>$30,000</td>
<td>1</td>
<td>LS</td>
<td>$30,000</td>
</tr>
<tr>
<td>4</td>
<td>Engineered large wood structures—placed and anchored</td>
<td>$2,000</td>
<td>14</td>
<td>each</td>
<td>$28,000</td>
</tr>
<tr>
<td>5</td>
<td>Boulders—placed</td>
<td>$150</td>
<td>51</td>
<td>Tons</td>
<td>$7,650</td>
</tr>
<tr>
<td>6</td>
<td>Earthworks</td>
<td>$70</td>
<td>2150</td>
<td>CY</td>
<td>$150,500</td>
</tr>
<tr>
<td>7</td>
<td>Non-engineered large wood structures - placed</td>
<td>$1,000</td>
<td>10</td>
<td>each</td>
<td>$10,000</td>
</tr>
<tr>
<td>8</td>
<td>Riparian planting</td>
<td>$20,000</td>
<td>1</td>
<td>LS</td>
<td>$20,000</td>
</tr>
<tr>
<td>9</td>
<td>Mulching</td>
<td>$2,500</td>
<td>1</td>
<td>LS</td>
<td>$2,500</td>
</tr>
<tr>
<td>10</td>
<td>Seeding</td>
<td>$2,000</td>
<td>1</td>
<td>LS</td>
<td>$2,000</td>
</tr>
<tr>
<td>11</td>
<td>Temporary fencing</td>
<td>$8</td>
<td>1700</td>
<td>LF</td>
<td>$13,600</td>
</tr>
<tr>
<td>12</td>
<td>Exclusion fencing and gates</td>
<td>$11.50</td>
<td>1800</td>
<td>LF</td>
<td>$20,700</td>
</tr>
<tr>
<td>13</td>
<td>Engineering - bid support, construction oversight, as-buils</td>
<td>$35,000</td>
<td>1</td>
<td>LS</td>
<td>$40,000</td>
</tr>
</tbody>
</table>

Total construction cost: $384,950
Total construction cost plus 5% contingency: $404,198

Notes:
1. Total cost estimate does not include permitting or project management.

6 DESIGN DEVELOPMENT, FEASIBILITY, AND RISK ASSESSMENT

Feasibility and risk assessments were conducted to identify opportunities and constraints at the project site, characterize existing conditions and potential risks, and to support design development consistent with project goals and appropriate risk management. The assessments were discussed with project stakeholders during the first two TAC review meetings and were further developed as design plans were advanced to the 100% level. Refer to the final design planset in Appendix B.
6.1 Riparian Vegetation Enhancement

6.1.1 Riparian planting

The project’s proposed grading will disturb existing vegetation within the backwater’s entrance and bed and banks. Vegetation restoration and enhancement efforts will include the re-establishment of brackish emergent vegetation within the graded backwater entrance, the re-establishment of the riparian forest along the impacted banks of the backwater channel, installation of live willow stakes along the scroll bar, and the removal of nonnative invasive species. The established cypress hedgerow functions as a windbreak for the adjacent pasture and will be left intact with minimal disturbance anticipated during project activities.

Removal of established native vegetation during grading activities will be limited as much as is feasible. All viable native plants within the project footprint will be salvaged prior to construction. To support rapid vegetative cover establishment, all salvaged plant material will be relocated at specific elevation grades suitable for the species immediately following regrading activities planned for early fall. Native perennial herbaceous vegetation (sedges, bulrush) at the backwater entrance will be dug up and temporarily stored on-site. After grading is completed these retained plants will be transplanted within the 5 to 8-foot elevation grade within the project footprint. Established woody shrubs and trees (mainly willows) within the project impact area will be cut to a manageable size (~ four-foot stump) and, with root ball intact, relocated to the 8 to 14-foot elevation of the regraded channel bank. If dormant, any remaining willow plant material will be cut into varying size poles/stakes for reuse. Larger woody material (i.e., red alder and willow trees) will be incorporated into the project as instream habitat enhancement structures. Where possible, the rootwads of these larger trees should remain embedded in the banks to promote continued growth even if the tree is toppled or partially toppled. Where maintaining rootwad embedment is not feasible the trees can be relocated to a preferred location along the backwater. For further discussion of this large wood see Section 6.4 Large Wood Stability.

Supplemental outplanting of procured native vegetation will occur during the wet season (i.e., November through March) when freshwater is prevalent and salinity is low. Based on previous data collection, the winter season salt wedge in the lower Smith River occurs downstream of the project site. This planting window will coincide with native willow winter dormancy and therefore live willow cuttings can be harvested from nearby riparian areas for use throughout the project. Willow poles will be collected from mature plant stock growing under similar ecological conditions as the project site (e.g., soils, depth to groundwater), at multiple sites to ensure genetic variation, and in amounts that would not permanently damage or weaken the parent material. Willow stakes should be soaked for a minimum of 24-hours prior to planting and should be installed so that the base of the cutting is at or below the water table ensuring that they will receive adequate moisture during the growing season. Mechanical equipment may be required (e.g., hydraulic auger) to achieve the desired planting depth. Willow poles will be interplanted amongst the retained and transplanted vegetation within the backwater between 8 and 14-foot elevation and in rows along the scroll bar as indicated on Sheets 10 and 11 in Appendix B. Additional species recommended for supplemental planting in the project’s riparian and brackish emergent habitats are included in Table 6-1. Planting densities and spacing recommendations provided in Table 6-1 vary by species and follow guidance from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) California Electronic Vegetative Guide (NRCS 2020). Rooted plant stock along with willow poles will be interplanted amongst the salvaged woody vegetation in the 8 to 14-foot elevation band in the project. In general, tree spacing will be 10 to 14 feet apart to establish continuous overstory canopy cover.
Shrub and herbaceous species will each be planted at lower densities to achieve approximately 30 percent cover within each strata (Table 6-1). Supplemental plantings within the emergent brackish herbaceous habitat will vary between 2 to 4 foot spacing and will be interplanted amongst any retained and naturally recruited vegetation in the 5 to 8-foot elevation band (Table 6-1).

Table 6-1. Selected native plant species for planting areas in the project.

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Form</th>
<th>Material</th>
<th>Spacing (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Riparian forest</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Trees</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alnus rubra</td>
<td>red alder</td>
<td>tree</td>
<td>container</td>
<td>14</td>
</tr>
<tr>
<td>Salix sitchensis</td>
<td>Sitka willow</td>
<td>small tree</td>
<td>cuttings/pole</td>
<td>10</td>
</tr>
<tr>
<td>Salix lasiandra</td>
<td>Pacific willow</td>
<td>tree</td>
<td>cuttings/pole</td>
<td>10</td>
</tr>
<tr>
<td><strong>Shrubs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lonicera involucrata</td>
<td>twinberry</td>
<td>shrub</td>
<td>container</td>
<td>6</td>
</tr>
<tr>
<td>Rubus parviflorus</td>
<td>thimbleberry</td>
<td>shrub</td>
<td>container</td>
<td>6</td>
</tr>
<tr>
<td><strong>Herbaceous understory</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Athyrium felix-femina</td>
<td>common lady fern</td>
<td>fern</td>
<td>container</td>
<td>interplanting</td>
</tr>
<tr>
<td>Polystichum munitum</td>
<td>sword fern</td>
<td>fern</td>
<td>container</td>
<td>interplanting</td>
</tr>
<tr>
<td><strong>Brackish emergent vegetation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juncus effusus</td>
<td>Pacific rush</td>
<td>graminoid</td>
<td>plug</td>
<td>4</td>
</tr>
<tr>
<td>Juncus lescurii</td>
<td>San Francisco rush</td>
<td>graminoid</td>
<td>plug</td>
<td>2</td>
</tr>
<tr>
<td>Carex aquatilis var. dives</td>
<td>Sitka sedge</td>
<td>graminoid</td>
<td>plug</td>
<td>4</td>
</tr>
<tr>
<td>Carex obnupta</td>
<td>slough sedge</td>
<td>graminoid</td>
<td>plug</td>
<td>4</td>
</tr>
<tr>
<td>Schoenoplectus pungens var. longispicatus</td>
<td>common three-square bulrush</td>
<td>graminoid</td>
<td>plug</td>
<td>2</td>
</tr>
<tr>
<td>Potentilla anserina subsp. pacifica</td>
<td>Pacific silverweed</td>
<td>forb</td>
<td>container</td>
<td>4</td>
</tr>
</tbody>
</table>

To the extent possible, planting material will be sourced from the California coastal lowland ecoregion (Level IV Ecoregion 1a) and locally harvested from mature parent material in varied locations within the lower Smith River to account for local adaptation of species in the region and to maintain genetic variation in the restoration area. Using locally adapted plant material will ensure better long-term establishment (Withrow-Robinson and Johnson 2006).

Establishing overstory canopy cover and increasing seasonally brackish to saline water into the backwater is anticipated to reduce the spread and establishment of nonnative reed canary grass in the project footprint. Annual site visits are recommended 1 to 3 years post-implementation to note whether woody establishment was successful by assessing gaps in overstory canopy, review overall plant survival, and observe if any nonnative invasive weeds had re-established. Adaptive management recommendations would be reviewed during this time and could include additional riparian planting or nonnative invasive weed removal.

In addition to the proposed permanent livestock exclusion fence separating the pasture from the backwater riparian corridor, temporary wildlife-exclusion fencing would be installed, where feasible, to protect the initial plantings from wildlife browsing, primarily from beaver, deer, and elk. In areas planned for riparian planting that are spatially discrete, the wildlife-exclusion
fencing would surround each planting polygon. In planting areas that are more dispersed, individual tree shelters would be installed.

The implemented project design will change the site hydrology so that riparian plantings will have access (at least seasonally) to high groundwater and/or surface flows and should reduce the need for supplemental irrigation to establish the new plantings.

### 6.1.2 Invasive weed removal

Nonnative invasive weed management should occur prior to grading activities or at the beginning of when equipment moves into a new portion of the backwater. All patches of nonnative invasive weeds will be removed from the site using manual (i.e., hand removal) and mechanized control methods. Special attention will be taken to reduce the spread of nonnative seed throughout the work site including cleaning equipment, vehicles, tools, clothing, boots, and gear after contact and off-site disposal of plant material is recommended.

Removal of *Phalaris arundinacea* (reed canary grass or RCG) within the project footprint of the backwater will allow for expanded diverse native understory and reduce further colonization of the highly invasive grass. Since RCG is primarily located within the proposed grading extents in the backwater mechanical (i.e., excavator) and manual removal methods are recommended. During mechanical removal, above-ground damage to neighboring riparian shrubs and trees should be minimized to the extent possible. Comparable to all grading work in the backwater, if damage to the riparian area is considerable (i.e., large areas without riparian cover) and/or affected native woody species are not anticipated to recover (e.g., re-sprout) then additional riparian planting may be required. The current distribution of RCG in the project area is limited due to shading provided by dense overhead canopy and, likely, elevated salinity from tidal input. The project designs will preclude further RCG growth by increasing overhead canopy in the backwater entrance area through riparian plantings and increasing salinity in the backwater due to expanded tidal exchange across a wider range of tidal conditions.

Because RCG readily propagates if improperly disposed of, it is recommended that excavated RCG be composted under a tarp for a minimum of two years in a disposal pile on higher ground away from any watercourses and flood paths. An alternative disposal method is to bury the excavated RCG in a pit, as long as the burial depth is approximately 10 feet or greater. Both disposal methods have been discussed with the landowner and a final disposal plan will be developed to comply with environmental permitting.

### 6.2 Smith River Dynamics in Project Reach

Review of historical aerial photographs indicates the lower Smith River in the project area experienced major planform adjustments between 1964 and 1972, a period of multiple record-setting high-flow events. The backwater feature first appears in an aerial photograph taken several months after the 1972 flood, the second largest in the Smith River period of record. The project area has not experienced further major planform adjustments during the 49 years since 1972, a period that included eight high-flow events with 5- to 15-year recurrence intervals. Relatively minor episodes of deposition and erosion have occurred along the downstream extent of the scroll bar; however, the backwater feature has persisted in more or less its current state. It is important to note that the varying river stage levels in the different aerial photographs gives the appearance of sedimentation and/or erosion, depending on the extent to which river bars are inundated. To account for this variability, photographs taken during similar times of the year when river stage is...
most similar were directly compared. The largest change in the elongated scroll bar since 1972 is
the growth of riparian vegetation, which currently covers nearly the entire bar surface. This
riparian colonization has occurred despite the numerous high-flow events, and further strengthens
the bar separating the backwater feature from the mainstem river. Despite relative channel
planform stability in the project area reach over the past half century, more localized sediment
dynamics are still a potential concern to the longevity of the proposed project, particularly with
regard to the entrance of the backwater. See Section 6.3 Backwater-Smith River Confluence
below for further discussion.

Bank erosion is another process that could affect the longevity of the backwater. The river’s left
bank at the Cattle Crossing riffle approximately 700 feet downstream from the backwater
entrance began eroding following the 1964–1972 period of large planform adjustment. Since that
time, the large cutbank has primarily retreated laterally with little upstream propagation. Using an
upstream propagation rate calculated from aerial photographs between 1972 and 2017, it would
take more than 350 years for bank erosion to reach the backwater entrance. Therefore, it is
unlikely that the dynamic bank erosion occurring at the Cattle Crossing would impact the
proposed project within its design lifespan.

6.3 Backwater-Smith River Confluence

Localized sediment deposition and erosion have the potential to adversely impact the project
designs, particularly at the backwater entrance. The backwater is located in an area of active
sediment transport; however, the site has remained relatively geomorphically stable for at least
the past 49 years (see Section 6.2 Smith River Dynamics in Project Reach above for further
description). The project includes multiple design elements to address potential concerns
regarding sediment deposition and erosion.

The proposed backwater thalweg grading and inlet thalweg elevations were selected so the
backwater would inundate more frequently throughout the year. The existing backwater inlet
crest elevation is approximately 8.12 feet, as was surveyed in the fall of 2019. At this elevation,
the backwater loses surface flow connection with the river at approximately a 15% exceedance
flow. An inlet crest elevation of 6 feet, which was proposed in the conceptual design plans, would
maintain connection to the river down to a 30% to 40% exceedance flow. The 5-foot inlet crest
elevation in the 65% designs would maintain river connectivity during summer mean flow
conditions, particularly during high tides, but would lose connection at low tides in the late
summer and fall. The 4-foot inlet thalweg elevation in the final designs will allow the backwater
to maintain connection to the river throughout the year with minimum depths of approximately
0.75 feet at low tides in the late summer and fall. These flow and elevation scenarios are depicted
below in Figure 6-1. The figure is a stage hydrograph of the river water surface elevation at the
backwater entrance recorded during water year 2020. The plot is color coded based on the
backwater inlet elevation under existing conditions (blue dots), the conceptual design condition
(red dots), and the final design condition (green dots). The total time the river stage is above the
specific inlet elevation is summarized in Table 6-2. Figure 6-1 also includes a stage hydrograph
from the USGS gage at HWY 101, which is upstream of the tidally influenced portion of the
lower Smith River. The USGS stage record illustrates river fluctuations without the influence of
tide.

As shown in Figure 6-1, river and tidal inundation would provide a year-round hydraulic input to
the backwater that will promote sediment transport through the entrance. Tidal fluctuations would
be the primary hydraulic input during summer and fall low flows, whereas rising and falling river
stage associated with seasonal storm events would be the primary input in winter and spring. As described above in Section 4.2 Alternative 1, the proposed large wood and boulder structures at the backwater entrance are intended to constrict flow to promote velocities capable of sediment transport and reduce fine sediment deposition, which promotes mass balance and self-maintaining geometry at the backwater entrance. The grading extents and large wood structures effectively create the geometry of the backwater entrance/outlet channel, which is defined by the depth, width, and cross-sectional area. Following project implementation, the backwater would have increased tidal channel characteristics due to a lower thalweg elevation. The design process evaluated the entrance/outlet channel geometry with consideration of previous studies of hydraulic geometry relationships for tidal channels in the San Francisco Bay (Williams et al. 2002). That study evaluated empirical correlations between channel geometry (i.e., max depth, max width, and area) and tidal exchange (or prism) to predict equilibrium cross-sectional geometry for a given tidal exchange. Tidal exchange (prism) is defined as the volume of water between mean lower low water (MLLW) and mean higher high water (MHHW) in the tidal contributing area upstream of the cross-section. Based on the tidal exchange of the backwater under proposed conditions, the empirical relationships developed by Williams et al. (2002) predict equilibrium outlet channel geometry of approximately 4 feet deep max below MHHW (6.5 feet NAVD 88), 10 feet wide max at the MHHW elevation, and 20 feet² cross-sectional area. The approximate log spacing in the large wood and boulder structure design matches the predicted 10-foot-wide channel, however, it is undersized with respect to the depth and cross-sectional area predictions. If the designs followed the predicted 4-foot depth below MHHW, the backwater entrance channel would need to be graded to 2.5 feet in elevation, which is not feasible or realistic considering the adjacent river bed at approximately 4 feet in elevation. The cross-sectional area is maximized by using roughly rectangular geometry (i.e., steep banks formed by large wood structures) with the restriction on depth. By designing the entrance channel smaller than predicted by the empirical regressions, the tidal hydraulics may scour the sand bed and erode deposits supplied from the river during winter flows. The project designs do not include hardened structures in the entrance channel bed so that it may evolve following project implementation. The large wood and boulder structures are designed to be stable and should maintain lateral spacing even if the sand bed degrades up to 1 - 2 feet.

**Table 6-2. Duration of flow-elevation ranges during water year 2020**

<table>
<thead>
<tr>
<th>Water surface elevation range, ft (NAVD 88)¹</th>
<th>Days²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage &gt; 8.12 ft</td>
<td>21</td>
</tr>
<tr>
<td>Stage &gt; 6 ft</td>
<td>147</td>
</tr>
<tr>
<td>Stage &gt; 4 ft</td>
<td>365</td>
</tr>
</tbody>
</table>

Notes:
¹ Recorded in the river at the backwater entrance.
² Total sum of days in period of record (October 11, 2019 through October 10, 2020).

Water surface elevation related to tidal influence is clearly depicted in stage hydrographs like Figure 6-1. However, salinity variability can be more dynamic due to density driven depth differentiation and river bed morphology. As described above in Section 2.2 Geomorphology, Parish and Garwood (2015 and 2016) evaluated salinity, tidal prism, and the depth of the salt wedge toe during summer and winter seasons at higher high tide events. These studies supplemented previous estuary salinity characterization efforts by Mizuno (1998). Under summer low flow conditions Parish and Garwood (2015 and 2016) found salinities of 10 to 15 parts per
thousand (PPT) at a depth of approximately 3 feet during higher high tides (i.e., approximately 8.0 feet in elevation), which corresponds to the salt wedge extending up to approximately 5 feet in elevation. Based on these measurements it is expected that the salt wedge will enter the backwater during low river flow conditions at high tides.

The willow baffles proposed in the conceptual design plans have been revised as willow stake plantings that will be installed using manual methods in the winter. Excavating trenches on the unconsolidated scroll bar adjacent to an oversteepened bank presents challenges with construction feasibility. Willow poles used in baffles would also need to be installed down to groundwater, which is likely saline during high tides in the summer. Manually installing willow stakes in the winter is feasible and increases likelihood of plant survival. Once established, the willow plantings will retain fine sediment and promote deposition for elevated river flows before reaching the backwater entrance.

A comparable project designed to enhance habitat in a backwater feature in the Mattole River estuary (led by the Mattole Salmon Group) incorporated a large, engineered wood jam to promote scour at the entrance. The project design also included a series of willow baffles on the bar just upstream of the entrance to facilitate deposition of fine sediment before reaching the backwater entrance. During the conceptual design process for this project, the design team consulted with Sam Flanagan and Michael Love (BLM geologist on the TAC and lead design engineer, respectively, for the Mattole estuary backwater enhancement project) to incorporate experience gained and lessons learned from that project.

It is possible that large wood and willow stake planting habitat enhancement investments might not persist after one or more large (e.g., above a 25-year recurrence interval flow) Smith River flood events, however, we believe that the habitat benefits of the project designs, which are important to SONCC coho recovery, outweigh the risks associated with natural geomorphic processes. The proposed willow stakes and large wood structures will help maintain this area for as long as geomorphically possible.
Figure 6-1. River stage at backwater entrance during water year 2020. Colored elevation bands correspond to backwater inlet crest: existing = 8.12 ft, Alternatives 1 and 2 = 6 ft, Alternative 3 (preferred alt.) = 4 ft. USGS stage record illustrates river fluctuations without tidal influence.
Figure 6-1 (cont.). River stage at backwater entrance during water year 2020. Colored elevation bands correspond to backwater inlet crest: existing = 8.12 ft, Alternatives 1 and 2 = 6 ft, Alternative 3 (preferred alt.) = 4 ft. USGS stage record illustrates river fluctuations without tidal influence.
6.4 Large Wood Stability

A quantitative wood stability analysis was conducted for the proposed large wood and boulder structures in the backwater entrance. The wood stability analysis is based on the methodology presented in Castro and Sampson (2001). The constants, freebody diagram, and equations from Castro and Sampson are included in Appendix D. In summary, this method uses a basic force balance approach in the vertical and horizontal directions to ensure that each wood structure will be stable during a specific flow regime. The calculation process begins with a sum of vertical forces to determine the boulder weight that is necessary to give each structure a factor of safety of 1.5 for buoyancy. Then based on these boulder weights, the factor of safety for momentum is calculated and more boulders are either added or enlarged as necessary to give each structure a momentum (sliding) factor of safety of 2.0 or greater.

The following is a list of key assumptions that provide the basis of these calculations. For specific details see results in Appendix D:

- Analysis based on 50-year flow velocity outputs from HEC-RAS 2-D model. Velocity used is the maximum from the location of the proposed structures – 1.65 ft/sec, conservatively rounded up to 2.0 ft/sec for calculations.
- All boulders and logs fully submerged.
- Channel bed and banks composed of sand and medium gravel.
- All wood is calculated as dry Douglas Fir: density = 33.7 lb/ft³ (Castro and Sampson 2001).
- Partially buried logs also receive ballast from burial.
- Variable log flow acting area considering log orientation to flood flow vectors.
- For flow force calculation on multi-log structures located along a stream bank parallel or sub-parallel to flow, calculations may assume a shadow effect (i.e., flow acts only on a portion of the log).

Incorporating large wood structures into the project designs will promote stability and longevity of the backwater entrance, as described above in Section 6.3 Backwater-Smith River Confluence. Risks associated with log instability are minimized due to the factors of safety built into the calculations and the on-site engineering and geomorphic expertise that will guide the final layout and construction of the structures. In addition, long-term stability will be achieved by proper installation guided by technical oversight and described in the final design plans and specifications. To further ensure the quality of anchoring, we strongly recommend that a contractor is selected who has previous experience with implementing instream large wood projects.

It is possible that the position of the wood structures may have minor adjustments due to scour or racking of significant new wood and debris. It is possible that minor scour and settling may help the structure stay in place because it will increase resistant forces via wedging against anchor boulders and settlement of overlying substrate. However, some structures may have the potential to rotate and/or translate if significant scour and racking of additional wood occurs, or multiple large flood events occur (e.g., greater than 25-year recurrence interval flow). For structures with significant potential for rotation and/or translation, it is recommended that anchor boulders be keyed deeply into the channel bed and bank, overlying substrate is properly compacted, and that the engineer and/or geologist is onsite for construction to ensure proper installation.
As discussed above in Section 5.1 *Selection of a Preferred Alternative* and Section 6.1.1 *Riparian planting*, the proposed grading in the backwater will impact multiple mature alder and willow trees ranging from approximately 0.75 to 1.5 feet in diameter at breast height (DBH). Care should be taken during project implementation to topple trees that are destabilized during excavation into the backwater, while maintaining rootwad embedment. The intention is to retain the tree alive to serve as aquatic habitat enhancement. The backwater currently has multiple mature alder and willow trees that have toppled, are sub-horizontal, are within the regularly inundated elevations of the backwater, and have fully live crowns (see Sheets 3 and 11 in Appendix B). These trees are a proof of concept. Trees that must be fully uprooted or are too badly damaged during toppling can be moved as desired to preferential habitat enhancement locations within the backwater. The toppled trees will be stabilized by a combination of embedded live rootwads, non-anchored pinning against other large wood and live trees, and driving cut trunks with an excavator into the bank substrate (see Sheets 5, 6, and 12 in Appendix B). Further quantitative stability analysis was not conducted for these large wood structures considering the multiple stabilization methods, the inherent variability involved in toppling and stabilizing these trees, the low velocities modeled in the backwater (less than 2 ft/sec during 50-year flood), the likelihood that mobilized trees will be retained within the backwater due to high vegetation density, and the low to negligible risk of a tree floating out of the backwater and down river (described below).

Although there is inherent uncertainty and risk associated with constructing large wood structures in active river channels (e.g., wood decay, faulty materials, contractor error, extreme flow events, etc.), we believe the proposed structures provide cost-effective enhancement objectives. Large wood structures typically have a design life of approximately 20 years due to declining strength related to wood decay, so it is critical to design the project to account for this reality. In the event of a disarticulated wood structure the risk of downstream adverse impacts is low to negligible. There are no bridges or exposed in-channel infrastructure downstream of the project area. Furthermore, the size and quantity of large wood in the proposed structures is on the low side of the range of wood material that is typically transported through the lower Smith River during large winter storms.

### 6.5 Construction Logistics

#### 6.5.1 Access

In general, access to the project site is good via Pala Road to an existing ranch access route south of the backwater. A temporary access road across the pasture would be required from Pala Road, although it should not require improvements if construction occurs during dry conditions in the late summer. It is possible that short lengths of fencing would need to be temporarily removed to facilitate equipment access. The existing fencing along the south side of the cypress hedgerow is a temporary hotline and would be replaced with a permanent fence as part of the project. The pasture is flat and provides a large staging area for equipment and materials on the immediate southern side of the cypress hedgerow.

Equipment access from the pasture into the backwater is somewhat complicated by the spacing of the cypress trunks. However, there are suitability wide enough gaps in the tree spacing to allow equipment access and care will have to be taken to minimize damage to the trees, which provide an important windbreak for the pasture (see Sheets 7-9 in Appendix B). The existing spacing between cypress trees at the backwater entrance is relatively large. The backwater entrance area is wide, has relatively gentle slopes, and has no trees. Therefore, it is reasonably feasible for equipment to construct the large wood and boulder structures, conduct grading work, construct
dewatering structures, and install turbidity screening. Accessing the river-side crest of the scroll bar with large equipment for willow baffle construction is infeasible without clearing willow due to limited open areas and uneven sandy terrain sloping into the river. This partially led to the decision to replace trenched willow baffles with manually installed willow stakes.

In the reach between the backwater entrance and splay deposit, equipment access is complicated by steep side slopes and dense willow overhanging the channel. Access for proposed grading will likely require lightweight equipment, grading temporary access ramps, and clearing riparian vegetation. Once positioned in the trough of the backwater, a small excavator could move up- and down-channel as willow openings allow. This construction approach requires careful selection of equipment access points among the cypress trees. See the proposed construction sequence on Sheets 7-9 in Appendix B. Necessary willow clearing along the backwater should preferentially remove mid-story wood with the least damage possible to upper-story canopy, to not provide more sunlight for reed canary grass growth. Equipment access into the backwater at the splay deposit and further upstream is more feasible due to gentle side slopes and larger openings in the willow.

There are no overhead power or utility lines in the project area. There are no known buried utilities in the project area, however, this question will be further discussed with the contractor prior to construction, and if needed, underground service alert (USA) will be consulted.

6.5.2 Spoils

Sediment excavated during project grading will be off hauled to a spoils site approximately 1,000 feet southeast of the backwater (see Sheets 3 and 7-9 in Appendix B). The spoils site has been used for sediment spoils in previous excavation work in the area. The site is located at a naturally high point in the pasture and there is an existing mound approximately 80 feet wide and 6 feet high. The spoils from this project will expand the mound to approximately 100 feet wide and 10 feet high in a truncated cone shape so there is a broad elevated surface above the pasture. The landowner prefers this spoils site since it does not interfere with any watercourses or flood paths, and it can serve as an evacuation point for livestock during large river floods.

Despite the planned dewatering efforts detailed on Sheets 7-9 in Appendix B, we anticipate some sediment off hauled to the spoils site will be saturated. During excavation, dump trucks hauling sediment to the spoils site will use a circular route to reduce rutting and impacts to the pasture. Spoils will be dumped into straw-bale lined decanting piles on the side of the exiting mound. Water that permeates through the bales will spread diffusely through the grass along the natural gentle slopes to the south of the mound. The initial excavations from the backwater will consist primarily of fine sediment (i.e., fine sand and silt) with high organic content. Subsurface excavation will consist primarily of coarser sand and gravels. The top layer of finer material will be temporarily stock piled near the backwater or adjacent to the spoils site. The coarser sands and gravels will be used to build up the spoils mound, which will then be top-dressed with the fine organic material. This filling sequence will promote grass growth on the mound. Once the mound has reached final grade it will be treated with best management practices (BMPs) including erosion control seed mix, straw wattles, and temporary livestock exclusion fencing. The straw bales will be used as mulch on the mound and the haul route from the backwater.
6.6 Depth to Bedrock

There are no bedrock outcrops in the project area. Bedrock outcrops on the coastal plain are isolated to dispersed relic sea stacks composed of lithologically competent Franciscan Broken formation. Nearby well-completion reports indicate the bedrock contact is multiple tens of feet below the ground surface. Therefore, it would not be expected to encounter bedrock during proposed grading.

7 REFERENCES


DHI Water & Environment. 2007. Del Norte County FIS - Final Report. FEMA Region IX.


Appendices
Appendix A

Conceptual Alternative Design Planset
Appendix B

Final Design Planset
Appendix C

HEC-RAS Hydraulic Model Outputs
Appendix D

Large Wood Stability Analysis
Appendix E

Historical Aerial Photographs
Appendix F

Construction Specifications