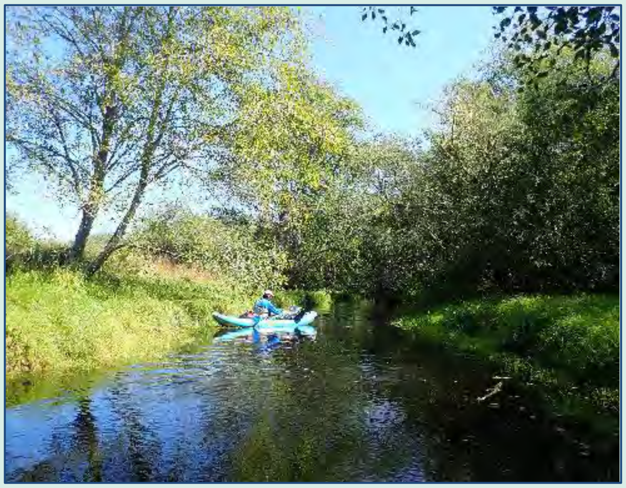
CONCEPTUAL DESIGN ALTERNATIVES REPORT ◦ MAY 2025

Lower Elk Creek Wetland Enhancement Project



PREPARED FOR

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National Fish and Wildlife Foundation
National Coastal Resilience Fund
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Cover photos: clockwise from top left – kayaker on Elk Creek in Project Area, remnant railroad trestles crossing lower Elk Creek, aerial view of Project Area with Elk Creek visible in lower right.

Table of Contents

Tables

Figures

Appendices

1 INTRODUCTION

Smith River Alliance (SRA) retained Stillwater Sciences (Stillwater) to implement the Lower Elk Creek Wetland Enhancement Project (Project), with the primary objectives of expanding off-channel aquatic habitats, enhancing wetland and riparian habitats, improving coastal resiliency, and evaluating options for improving public access within the lower Elk Creek watershed in Del Norte County, California. More specifically, the Project Area is primarily located in the Elk Creek Wetlands Wildlife Area (Wildlife Area), which is owned by the California Department of Fish and Wildlife (CDFW) and located in and adjacent to Crescent City, California. This report describes and evaluates restoration alternatives that have been advanced to a conceptual design level (i.e., 30%). The conceptual designs have been developed from field- and office-based analyses, prior work conducted in the Elk Creek Restoration Feasibility Study (further described below; SRA and Stillwater 2021), as well as consultation with a technical advisory committee (TAC).

TAC members for this project include representatives from CDFW, Elk Valley Rancheria (EVR), Tolowa Dee-ni' Nation (TDN), the City of Crescent City, and the County of Del Norte (Table 1-1).

Table 1-1. Technical Advisory Committee members.

Technical Advisory Committee	
Member	**Affiliation**
Shawn Fresz	CDFW
Nicholas Van Vleet	CDFW
Jolyon Walkley	CDFW
Frank Kemp	CDFW
Rob Jacob	EVR
Dalton Beene	TDN
Eric Wier	City of Crescent City – City Manager
Andrew Leighton	City of Crescent City – Public Works Department
Heidi Kunstal	County of Del Norte - Community Development Department

1.1 Project Location

Elk Creek is a small coastal watershed (4,735 acres) adjacent to Crescent City in Del Norte County, California (Figure 1-1). The central and lower portions of the watershed contain relatively intact wetlands and forests, known as Elk Valley, and are surrounded by urban, commercial, and rural residential development. The creek consists of multiple tributaries that drain the relatively low-lying areas north of Crescent City and the upland hillslopes to the east. These tributaries converge in Elk Valley to form the mainstem of Elk Creek. Elk Creek flows southwest and meets the Pacific Ocean just downstream from Highway (Hwy) 101 in Crescent Harbor.

The lower watershed is a composite of publicly and privately owned lands that include the CDFW Wildlife Area, the Del Norte County Fairgrounds, multiple private parcels with various types of developments (e.g., commercial, ranch, and former sawmills), and wildland (Figure 1-2). The lower watershed contains freshwater and tidal wetlands with upland forests primarily around the margins. Waterbodies in the lower watershed consist of a complex of mainstem channels, tributaries, conveyance cross channels, drainage ditches, and ponds. Many of these hydrologic features have been anthropogenically altered or constructed over the past century, or earlier, as a result of land-use conversions for urban development, sawmills, agriculture, and logging.

The Project Area is primarily located within the Wildlife Area, which is just upstream of Hwy 101 on the eastern side of Crescent City (Figure 1-1). The Project Area includes the mainstem reach of Elk Creek extending from Hwy 101 upstream to the confluence with Cross Channel 1 (CC1) and the adjacent marshes and swamps.

1.2 Need for the Project

Most of the Elk Creek watershed has been impacted by urban, residential, and industrial development; however, large portions of the middle and lower watershed, including the Wildlife Area, contain intact coastal wetlands and streams that provide ideal rearing habitat for Southern Oregon/Northern California Coast (SONCC) Coho Salmon (*Oncorhynchus kisutch*) and other salmonids. Upper tributaries in the eastern side of the watershed extend into Redwood National and State Parks (RNSP) and contain the only reaches in the basin with spawning habitat.

Considering California has lost 91 percent of its original coastal wetlands since the 1850s, Elk Creek is a unique and valuable watershed that supports all life stages of Coho Salmon, Coastal Cutthroat Trout, and other salmonids. Given the many historical modifications, as well as present and increasing development pressure in the watershed, restoration efforts are needed to improve water quality, restore salmonid access to different habitats, and improve hydrologic function while accounting for the area's vulnerability to climate change. The Lower Elk Creek Wetland Enhancement Project is a top-rated project identified in the Elk Creek Restoration Feasibility Study (hereinafter Feasibility Study), which collected and analyzed essential data on the current ecological and hydrological conditions throughout the watershed (SRA and Stillwater 2021). Results of the Feasibility Study assessments were used to work with landowners and stakeholders to identify additional restoration projects beyond the scope of the Lower Elk Creek Wetland Enhancement Project that will further improve fish passage, water quality, wetland habitat, and coastal resilience.

The majority of the Elk Creek basin is under private ownership with only 14 percent public. Approximately 40 percent of the basin has been developed (Mintier & Associates et al. 2001), primarily focused in the peripheral portions and lower (southwestern) watershed, including the Project Area. Development includes road and railroad building, filling wetlands, channelization, constructing levees, installing undersized road-stream crossings, removing riparian vegetation, logging, and constructing urban hardscapes.

The watershed has a history of alterations from timber harvest, sawmill operations, and urban development, which have reduced the quantity and quality of habitat for fish and wildlife. Past land uses in the lower watershed resulted in a complex network of channels and ponds surrounded by infilled wetlands, which present varying levels of impairment to the watershed today.

NMFS (2014) determined that the watershed has approximately 15 miles of anadromous streams, 11 of which have potential habitat for threatened SONCC Coho Salmon and 88% of which have high intrinsic potential. However, these stream lengths were determined using an outdated and inaccurate channel delineation for the basin. SRA and Stillwater (2021) estimated that there are up to approximately 26 miles of anadromous streams in the watershed. In addition to Coho

Salmon, Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*), steelhead trout (*Oncorhynchus mykiss*), and Chinook Salmon (*Oncorhynchus tshawytscha*) have all been observed in the Elk Creek basin (Chesney 1987; Burgess 1999, 2005; Garwood 2012, 2018; SRA and Stillwater 2021). CDFW recently documented seven consecutive years (Garwood 2018) and five historical years (Garwood 2012) of juvenile Coho Salmon presence in the basin. Garwood (2018) also documented juvenile Chinook Salmon and resident Coho Salmon. Fish monitoring conducted for the Feasibility Study from 2019 to 2021 documented juvenile Coho Salmon and Coastal Cutthroat Trout throughout the basin, including in areas previously undetected in the Project Area.

1.3 Prior Studies

The prior Feasibility Study culminated in a final report that was intended as a resource for restoration practitioners, community groups, and agencies interested in restoring, enhancing, and conserving Elk Creek (SRA and Stillwater 2021). It provided an overview of opportunities to promote coastal resilience, water quality, and fish and wildlife habitat. The restoration opportunities were identified and developed based on extensive existing conditions assessments conducted by SRA and Stillwater, coupled with a broad stakeholder engagement process. The report presented background information on the watershed, site characterizations, restoration project identification and scoring, and recommendations for next steps in the overall restoration efforts for the watershed—which are now underway.

This Project consists of design alternatives that collectively are a combination of several proposed projects from the Feasibility Study final report, and include Project #s 5, 6, 12, and 13 as described in Sections 4 and 5 of that report. Projects #s 5 and 6 are high scoring projects focused on restoring off-channel habitat and increasing channel complexity. Projects #12 and #13 are related to improving public access and vegetation enhancement, respectively.

This report references the Feasibility Study throughout, and the prior report should be reviewed concurrently to provide additional context and background information on Elk Creek and the overall restoration goals for the watershed.

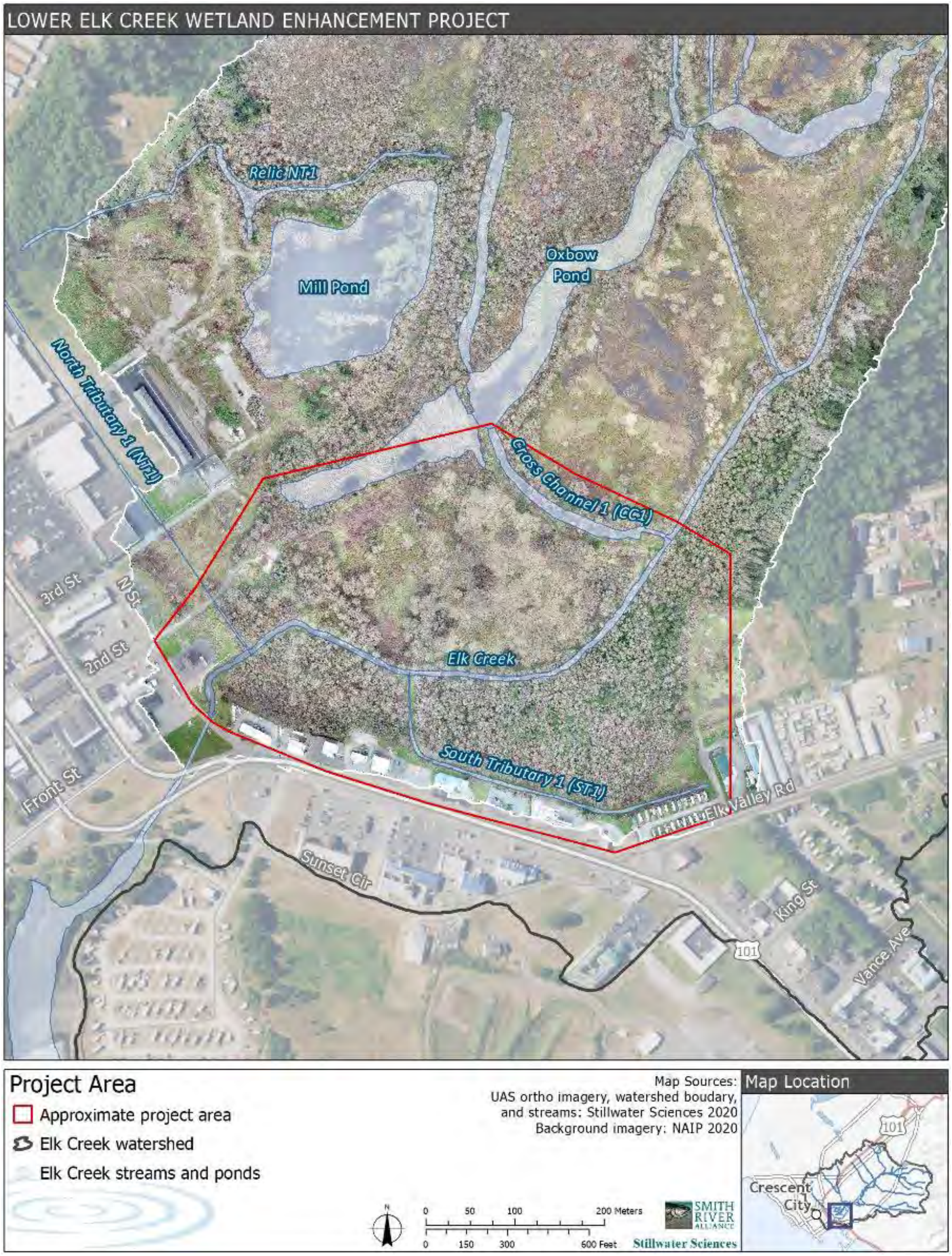

Figure 1-1. Location of the Project Area in Crescent City, CA.

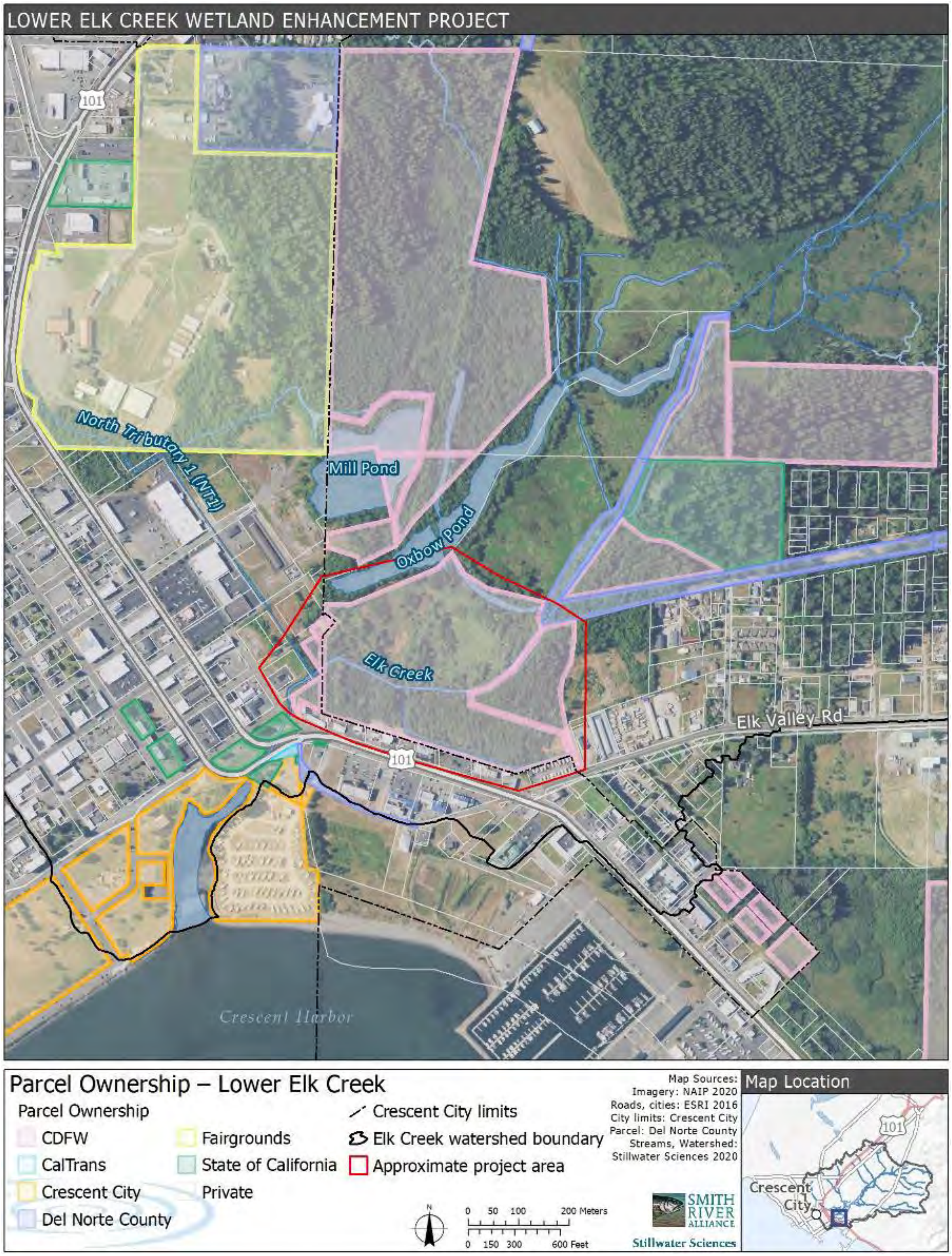

Figure 1-2. Land ownership in lower Elk Creek.

2 EXISTING CONDITIONS STUDIES AND CHARACTERIZATIONS

2.1 Geology and Tectonics

The Elk Creek watershed is located on the coastal plain adjacent to Crescent City and includes the western slope of the Coast Range mountains (Figure 2-1). The majority of the watershed is underlain by the Battery formation, which is a marine terrace deposit with interfingering dune sands and alluvial gravels and primarily consists of medium-grained sands alternating with blue-gray silty clay and imbricated gravels (Addicott 1963, Kennedy et al. 1982, Polenz and Kelsey 1999). The headwater hillslopes of the eastern Elk Creek basin are underlain by graywacke and mélange units of the Eastern Belt of the Franciscan complex (Aalto 1989). This bedrock is the only source of spawning gravel in the entire watershed (SRA and Stillwater 2021). As the coastline retreated westward following late Pleistocene sea-level high stands, the paleo Elk Creek incised into the Battery formation and developed a trellis-like drainage pattern with an extensive low-gradient wetland valley bottom (Delattre and Rosinski 2012) (Figure 2-1). The Project Area is located at the down-valley extent of the watershed just upstream of the mouth in Crescent Harbor.

See SRA and Stillwater (2021) for additional information on geology and tectonics in the Elk Creek watershed and surrounding area.

2.2 Watershed Geomorphology

Elk Creek occupies a broad, low-relief basin on the Crescent City coastal plain with elevations ranging from sea-level to approximately 650 feet, although elevations above approximately 100 feet are limited to the upland hillslopes that form the headwaters along the eastern border of the watershed (Figure 2-2). Alluvial fans are deposited at the base of the uplands where they meet the relatively flat marine terraces that form much of the coastal plain and extend across the rest of the watershed. Mainstem Elk Creek flows through a wide alluvial wetland valley bottom that has formed as the creek incises into the uplifting marine terrace.

Stream geomorphology across the watershed can be separated into three general physiographic types: mainstem Elk Creek in the center of the watershed (0–0.2% channel gradient), tributaries that drain the relatively flat northern and western portions of the watershed (0–0.5% channel gradients), and tributaries that drain the relatively steep eastern portion of the watershed (0.2 up to 10% channel gradients). See SRA and Stillwater (2021) for additional characterization of the watershed geomorphology.

The Feasibility Study final report identified previously unnamed tributaries throughout the watershed (e.g., north tributaries [NT1, NT2, etc.], south tributaries [ST1, ST2, etc.], and cross channels [CC1, CC2, etc.]) and those designations are used throughout this report and plans. See SRA and Stillwater (2021) for additional explanation of these tributary and reach designations.

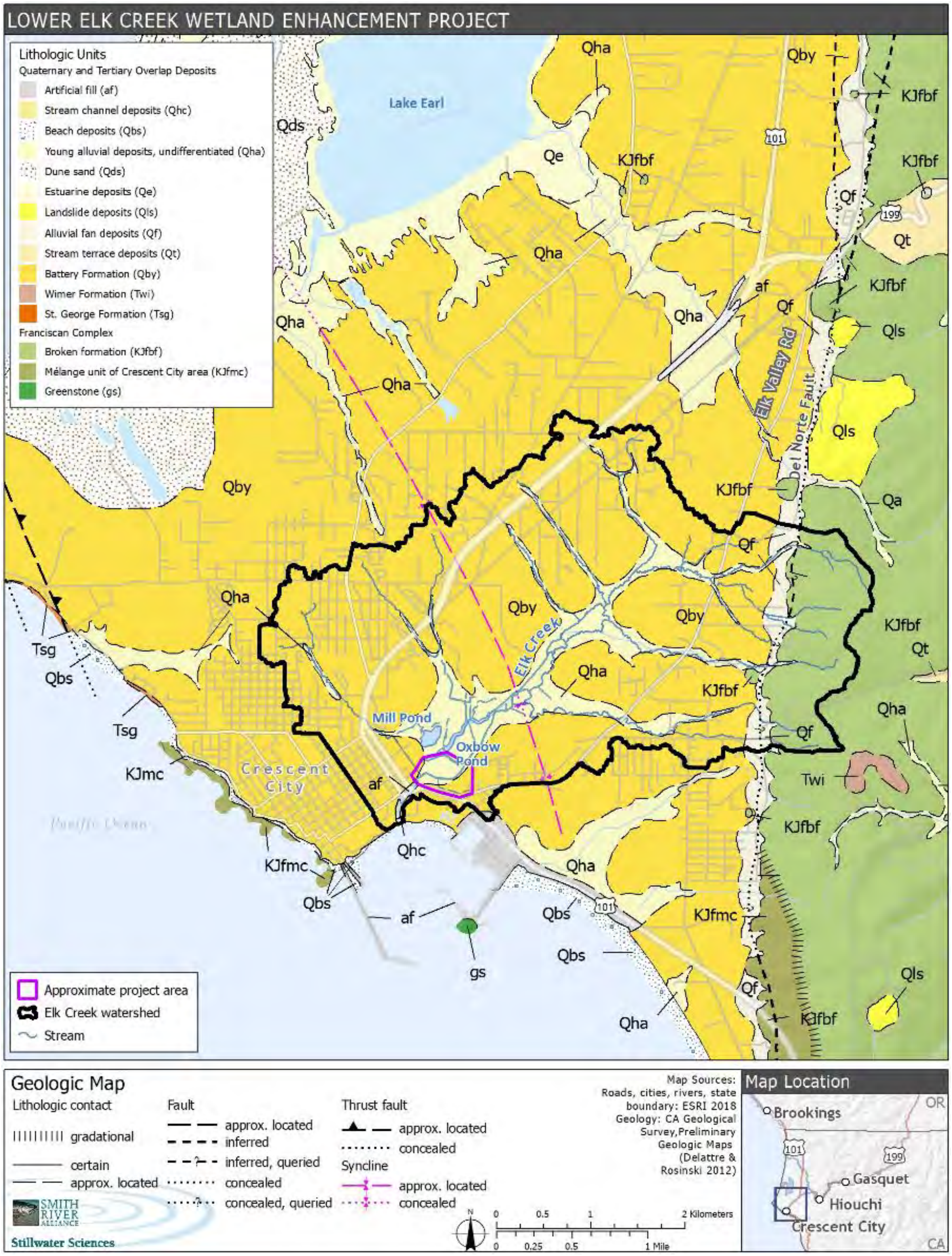

Figure 2-1. Geologic map of the Elk Creek watershed and surrounding portions of Del Norte County. The approximate Project Area is outlined in purple.

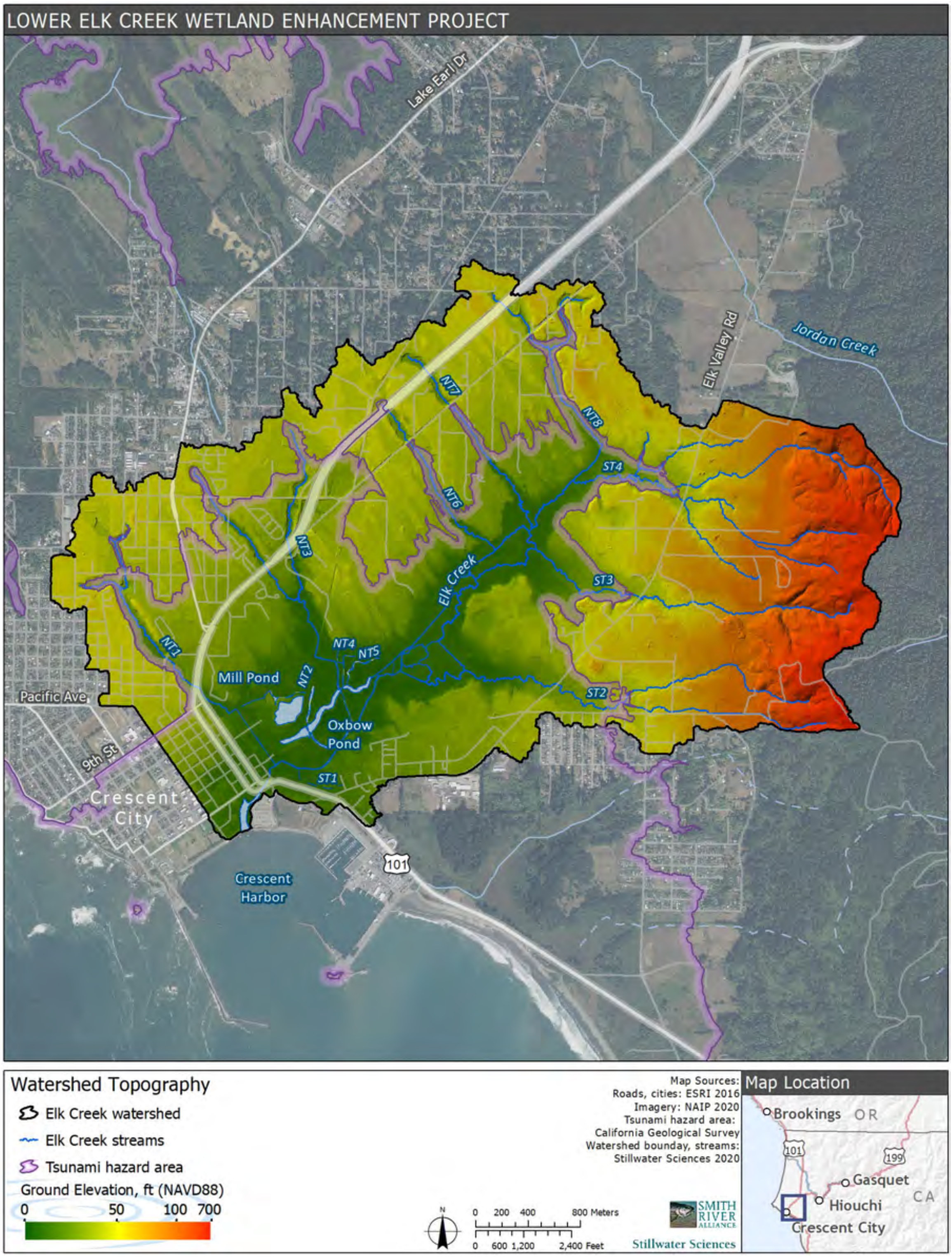

Figure 2-2. Topographic map of the Elk Creek watershed. Tsunami hazard area also shown.

2.3 Historical Conditions and Developments in the Lower Watershed

The Elk Creek watershed, and particularly the lower basin in the Project Area vicinity, has been significantly altered by various land-use developments since the arrival of European settlers around the 1850s. The earliest U.S. Coast Survey map from 1859 shows a lower Elk Creek that is already bordered by a grid of streets and city blocks of the early Crescent City townsite (Figure 2-3). The former creek channel meandered along its presumed natural path through the city blocks to the west and northwest of its current alignment. The estuary was substantially larger than its present-day condition and recent stratigraphic investigations in the lower valley indicate the area upstream of the city blocks was tidally influenced and possibly hosted a seasonal or ephemeral lagoon (Hemphill-Haley et al. 2019). Several linear ditches had already been constructed to drain the wetlands. The ditch locations generally coincide with the current alignment of the creek just upstream of the Hwy 101 crossing.

The landcover symbols in the 1859 map depict tidal marsh (i.e., closely drawn parallel horizontal lines) across the valley bottom in the Project Area, which is just upstream of the city blocks. The map also shows mixed hardwood and conifer forests likely dominated by Sitka spruce and red alder extending out from both valley margins. Such tidal forested swamps used to form the majority of coastal wetlands in the Pacific northwest, with only approximately 5% remaining today (Brophy 2019). The shoreline in Crescent Harbor extended up to the edge of the city blocks along the present-day location Front Street. Figure C-1 in Appendix C shows the shoreline and lower Elk Creek channel margins delineated with a blue line. This shoreline delineation is retained in each historical map and photograph in Appendix C to illustrate the land and stream alterations in the Elk Creek stream-estuary ecotone.

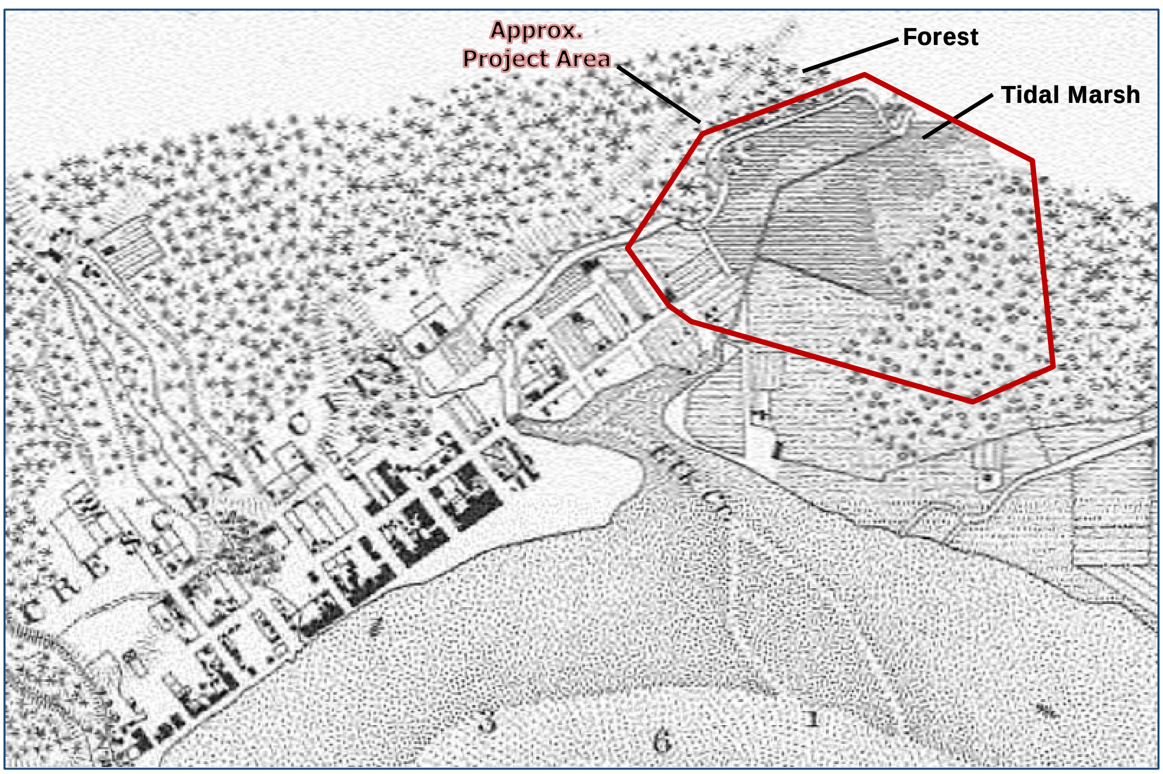

Figure 2-3. Crop from 1859 U.S. Coast Survey map. Map symbols upstream of city blocks indicate tidal marsh and mixed hardwood and conifer forest surrounding Elk Creek in the Project Area. Approximate Project Area outlined in red.

By 1928 the downtown development in Crescent City expanded, completely infilling the former Elk Creek channel and estuary where it flowed between city blocks (Figure 2-4). The creek was relocated into narrow excavated channels along the southeast margin of the lower valley. Throughout the Project Area the creek channel is bordered by levees built of spoils from excavating the new channel. The presumed former natural channel was substantially expanded by dredging to create the sequence of ponds referred to in this report as the Oxbow Pond but labeled as the Log Pond in Figure 2-4. The ponds were used for log storage by the Hobbs, Wall & Co. sawmill that was constructed in the late 1800s. Additional drainage ditches and cross channels were constructed in the Project Area vicinity to drain the fields for grazing pasture and to provide fill for the Del Norte and Southern Railroad grade that traversed the lower valley. Not evident in the historical maps but indicated by subsurface soil borings in the Project Area (Hemphill-Haley et al. 2019) and supported by the National Marine Fisheries Service (NMFS 2014), the wetlands in the lower Elk Creek valley had been filled and elevated by 1928 to create suitable land for livestock grazing. The landcover symbols in the 1928 map depict grasslands across the Project Area where there used to be a tidal marsh and spruce forest, indicating widespread wetland filling and logging to support urban, agricultural, and industrial development. The shoreline was also filled and extended up to approximately 100 feet seaward along some portions of Crescent Harbor.

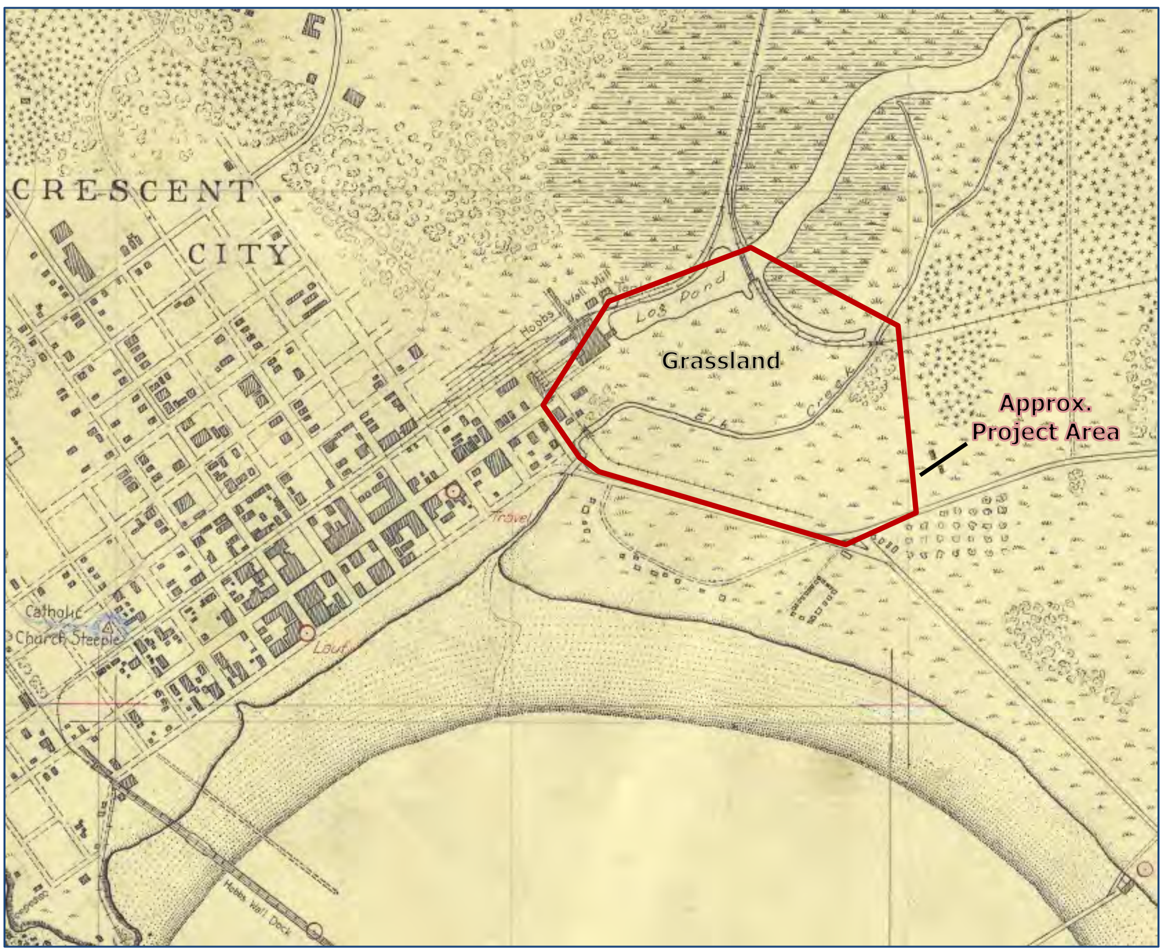

Figure 2-4. Crop from 1928 U.S. Coast and Geodetic Survey map. Map symbols upstream of city blocks indicate that tidal marshes and forests in the Project Area were converted to grasslands. Approximate Project Area outlined in red.

Following the 1964 tsunami, which destroyed downtown Crescent City and deposited a thin layer of beach sand across wetlands in the lower watershed, the City and U.S. Army Corps of Engineers responded by constructing an up to 800-foot-wide land buffer around the harbor shoreline bordered with a riprap-armored seawall. The seawall that constricted the estuary downstream of Hwy 101 (which is seen partially constructed in Figure 2-5) made it less likely for a seasonal sandbar to form, which would have dammed the creek during summer and early fall. Coupled with the earlier wetland filling upstream of the highway, these landscape alterations precluded the creation of a seasonal lagoon in the Project Area vicinity. The Mill Pond on the north side of the Project Area was constructed by the McNamara & Peepe Corporation to serve their sawmill that was built in the late 1940s. Additional sawmills were also constructed to the east of the Project Area along Elk Valley Road. The wetlands in the Project Area between Elk Creek and the Oxbow Pond were nearly treeless grass pastures in 1965 and multiple dirt roads traversed the lower valley along the channel margins.

Figure 2-5. Crop from 1965 aerial photograph. Seawalls constricted the estuary downstream of the highway while sawmilling expanded north of the Project Area.

The Hobbs, Wall & Co sawmill was decommissioned in the 1960s and in the 1980s the McNamara & Peepe sawmill was shut down and disassembled, leaving behind a legacy of soil contamination and water quality concerns from chemical applications used to preserve and process timber (see SRA and Stillwater (2021) for further discussion) (EFI 2006). With the end of commercial milling in the lower watershed and the creation of CDFW's Wildlife Area (also in the 1980s), the wetland, stream, and riparian habitats of lower Elk Creek began passively restoring to a more natural state. However, the impacts of more than a century of land-use conversion and development are still evident in the lower watershed.

2.4 Project Area Geomorphology

A geomorphic assessment was conducted to characterize the existing geomorphology of the Project Area, assess risks associated with potential hazards, support opportunities and constraints assessment, and inform project design alternatives. Specifically, the geomorphic assessment included a topographic survey, review of existing information, and a field assessment. Existing information that was reviewed includes geologic and geomorphic mapping (Davenport 1982, Delattre and Rosinski 2012), the Feasibility Study final report (SRA and Stillwater 2021), a paleo tsunami study in lower Elk Creek (Hemphill-Haley et al. 2019), and a series of historical maps and aerial photographs from 1859 to present.

The Project Area consists of mainstem Elk Creek from the upstream side of Hwy 101 to the confluence with Cross Channel 1 (CC1), a reach length of approximately 2,160 feet (Figure 2-6). The Project Area includes portions of the CDFW Wildlife Area that surround this reach of Elk Creek, which contain marsh, swamp, and upland habitats. Two tributaries flow into Elk Creek along this reach, North Tributary 1 (NT1) and South Tributary 1 (ST1). The area bordered by Elk Creek, NT1, CC1, and the Oxbow Pond is approximately 19 acres.

Additional reaches of Elk Creek upstream and downstream of the Project Area were evaluated during the geomorphic characterization to assess for reference conditions. The Project Area is primarily within the CDFW Wildlife Area, although the County owns portions of the creek channel and former railroad alignment in the northeast corner of the Project Area, and private parcels border the downstream end of Elk Creek and the Oxbow Pond (see Figure 1-2 and Figure 2-6).

General stream channel morphology of Elk Creek in the Project Area is relatively consistent due to it being a constructed channel intended to re-route streamflow around the valley margin (see Section 2.3 for additional discussion). The channel is relatively straight with very uniform geometry, consistent slope, and few pieces of large wood. Additional reach-specific geomorphic characterizations are provided below in Section 2.4.2.

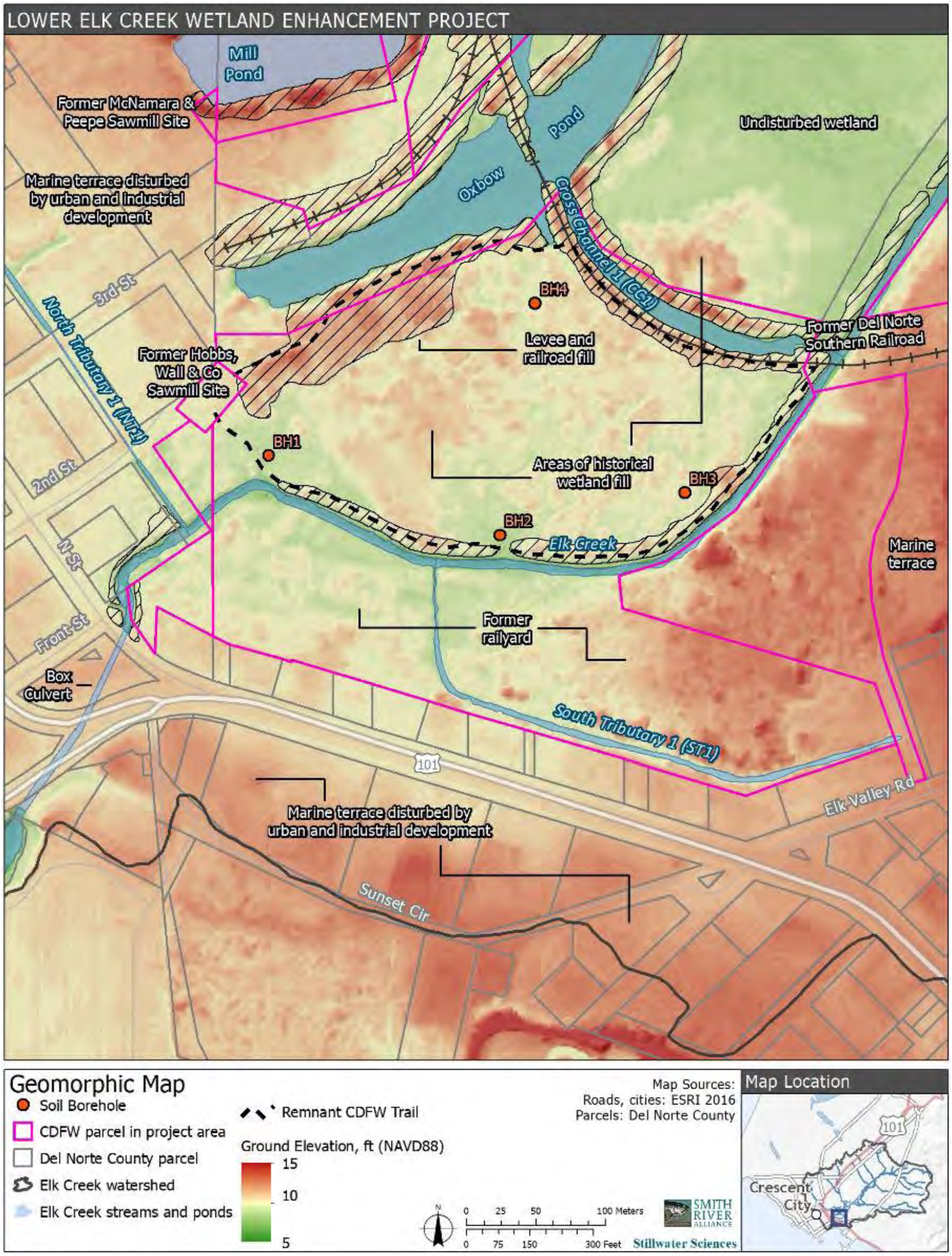

Figure 2-6. Geomorphic map of the Project Area vicinity.

2.4.1 Topography

Stillwater conducted topographic and bathymetric surveys in fall 2023 and winter 2024 using real-time kinematic global navigation satellite system (RTK-GNSS, or RTK) and single beam sonar depth sounder. The primary goals of the surveys were to characterize the existing conditions topography and bathymetry to support geomorphic assessments, hydraulic modeling, and engineering designs.

The surveys focused on complete topography and bathymetry of the Project reach, including the thalweg, channel bank tops and toes, and floodplain topography in proposed grading areas. Additional topography and bathymetry were surveyed in the channels upstream and downstream of the Project Area to be used in hydraulic modeling. These reaches include the Hwy 101 culvert and downstream channel extending out into Crescent Harbor, North Tributary 1, South Tributary 1, Cross Channel 1, the Oxbow Pond, and Elk Creek upstream of the Project Area. 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 North American Datum of 1983 (NAD83) epoch 2011 California State Plane coordination system and North American Vertical Datum of 1988 (NAVD88).

The field survey data were integrated with 2010 NOAA coastal LiDAR point cloud data. The LiDAR points were shifted to better characterize 2023/2024 field conditions by localizing the larger LiDAR dataset with the Project site. A vertical shift (+0.23 feet) was determined by comparing field-surveyed elevations collected along Hwy 101 to the LiDAR point cloud data. The combined topographic dataset was used to create the basemap “existing ground” digital terrain model (DTM), which was used in the geomorphic assessment, hydraulic modeling, and engineering design.

2.4.2 Field assessment

The geomorphic field assessment of the Project Area consisted of evaluating wetland and channel morphology, mapping anthropogenic fills (e.g., levees and railroad grades), and investigating shallow stratigraphy exposed in cutbanks and hand augered boreholes. Results and interpretations from the field assessment are summarized below and divided into informal sub-reaches based on tributary confluences. SRA and Stillwater (2021) contains additional information about geomorphology in the Project Area and lower watershed.

2.4.2.1 Highway to North Tributary 1 (NT1)

For approximately 50 feet upstream of the Hwy 101 culvert the creek bed is a roughened channel composed of angular cobbles and a few small boulders. This section of channel was presumably constructed to provide scour protection for the culvert. The riffle crest formed by the roughened channel acts as the primary hydraulic control for Elk Creek throughout the Project Area since it and the culvert are constructed at an elevation 1 to 2 feet higher than the overall channel profile (Figure 2-7 and Figure 2-8). Discussion of water levels in the Project Area is provided below in Section 2.5.5. The invert elevation and cross-sectional area of the culvert mute tidal influence in the Project Area and farther upstream. At low tides the culvert is a fish passage barrier due to high velocity and shallow depth. The culvert is also undersized based on the volume of tidal exchange that occurs upstream of the highway. SRA and Stillwater (2021) provide additional information on the tidal prism and fish passage analyses of the culvert. Replacing the culvert with a larger structure designed to improve fish passage and tidal exchange was identified as a high priority project in the Feasibility Study final report, however, it is outside the scope of this Project.

Multiple stormwater drainage networks discharge into the creek on the upstream and downstream sides of the Hwy 101 culvert. These networks consist of drop inlets and culverts that drain urban developments, city streets, and highway corridors on both sides of Elk Creek. During large floods these stormwater drainages intercept overland flow filling the lower valley in the Project Area vicinity along the margins of the urban-wildland interface.

Between the Hwy 101 culvert and NT1 confluence the creek channel is partially bordered by earthen fill and riprap levees (Figure 2-6). This reach of the creek is where multiple railroad crossings were located in the late 1800s and early 1900s (Figure 2-4). The remnants of these trestles are still in the creek today and consist of timber piles, wood beams, and channel fill (see cover photo and high points in thalweg profile on either side of Sta 20+00 in Figure 2-7).

NT1 drains one of the larger tributary basins on the north/northwest side of Elk Creek (Figure 2-2). The upper half of the tributary basin contains areas with a wide riparian corridor and extensive wetlands; however, the lower half of the basin has been completely altered due to urban and industrial development. NT1 used to flow across the area where the Mill Pond was constructed in the 1950s but was re-routed behind the highway commercial area into a long straight ditch with several undersized culverts that range from 350-600 feet long, each.

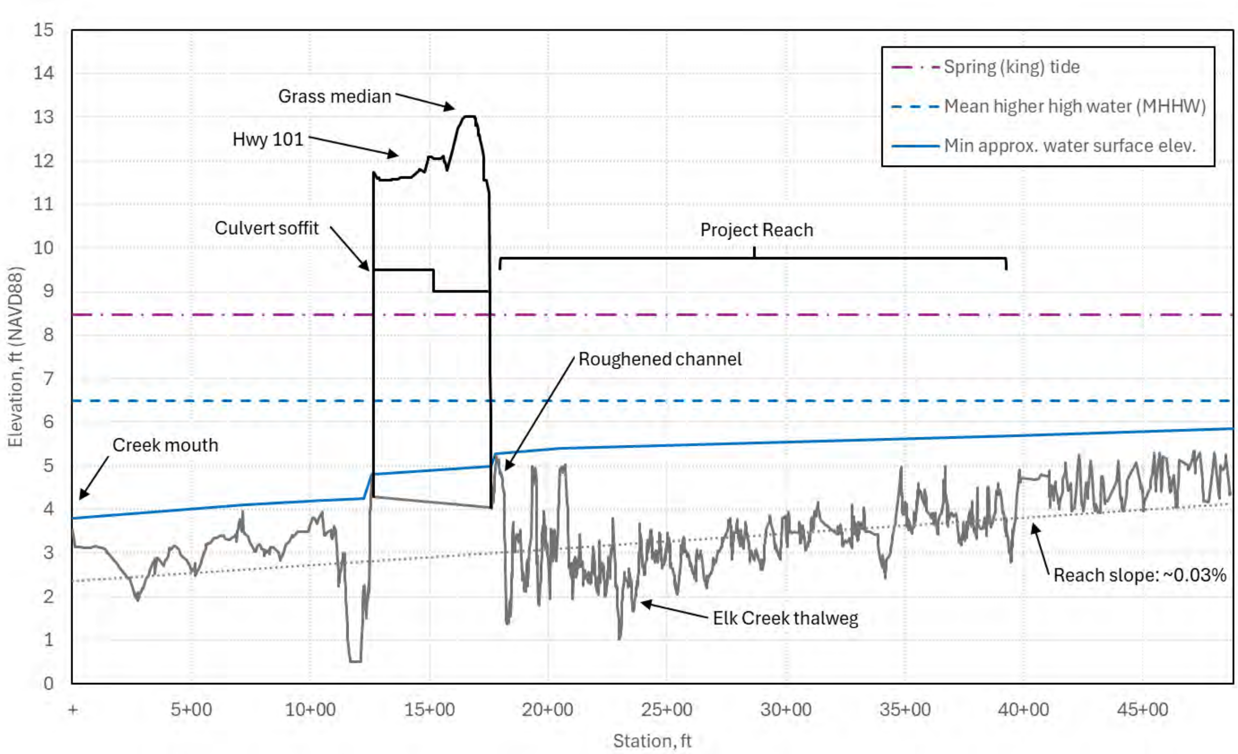

Figure 2-7. Longitudinal profile of Elk Creek in the Project Area vicinity.

Figure 2-8. Elk Creek upstream of Hwy 101 crossing. Culvert inlet headwalls and trash rack in bottom left. Roughened channel in center. View looking upstream.

2.4.2.2 North Tributary 1 (NT1) to South Tributary 1 (ST1)

Upstream of NT1 the creek is bordered by the Wildlife Area on both sides, and the channel becomes very uniform, which continues upstream through the entire Project Area. The channel typically has a bankfull width of 30 to 40 feet, steep bank slopes, and a relatively flat bottom (Figure 2-9). The channel gradient is uniform with few pools and an overall slope of approximately 0.03%. Sand, silt, and organic debris are the dominant streambed substrate.

There are relatively low-lying areas (8–9 feet elevation) in the wetlands on both sides of the creek although they are not well-connected to the mainstem channel, which is partially due to levees bordering the creek (Figure 2-6). Surface connection only occurs for brief periods (e.g., hours up to a couple of days) during prolonged heavy precipitation events or king tides. The south side of the creek is a swamp dominated by willow, alder, other woody shrubs, sedges, and invasive English ivy (see Section 2.5.6 for additional details about vegetation). The north side of the creek contains some similar swamp, open marsh areas, and more upland grassland and scrub habitat (11–13 feet elevation) across from the ST1 confluence. Reed canary grass (RCG) occurs in some low-lying areas and Himalayan blackberry tends to occur along the top of the levee (10–12 feet elevation). ST1 is a small tributary that drains the swamp on the south side of Elk Creek and parts of the commercial area along Hwy 101.

Figure 2-9. Elk Creek between NT1 and ST1. View looking downstream.

2.4.2.3 South Tributary 1 (ST1) to Cross Channel 1 (CC1)

The entire right bank (north side) along this reach is bordered by artificial levee except for one location just upstream of the ST1 confluence (Figure 2-6). This single opening in the levee allows for some surface connection between the creek and wetlands, however, it is infrequent and only occurs during prolonged heavy precipitation events and king tides. The remnant of a small footbridge from the trail constructed in the 1980s is located here. Much of the swamp and marsh north of the creek are low-lying (8–9 feet elevation) and tend to trap rainfall due to the levee separating the areas from the creek. These conditions have allowed RCG to infest the wetlands. In a couple locations in the upper half of this reach the levee is narrow and unforested (20–25 feet wide), providing good opportunities for breaching to provide better connection between the creek and wetlands.

The forest on the south side of the creek is a swamp near ST1 and becomes more upland farther upstream where the channel abuts the uplifted marine terrace (Figure 2-6). Ground elevations in the swamp range from 8–10 feet and 11–16 feet in the upland area. English ivy is pervasive throughout the forest floor and in tree canopies. The only Sitka spruce trees along Elk Creek in the Project Area occur on this more upland bank and are only a few decades old. A few more young spruce trees are located on the artificial fills on either side of CC1. This portion of the Project Area is where Sitka spruce trees in a mixed riparian forest were historically dominant but removed for agricultural and industrial development in the late 1800s and early 1900s (see Section 2.3 for further discussion).

Another remnant railroad trestle crosses Elk Creek at the upstream end of the Project Area, at the CC1 confluence (Figure 2-6). CC1 was excavated to provide drainage for the Oxbow Pond and construction fill for the railroad grade to cross the wetlands. The CC1 channel is notably entrenched between artifical levees on both sides that are generally taller and wider than the levee bordering Elk Creek downstream. Modifications to these levees were not considered for the Project restoration alternatives, aside from potentially reestablishing a public trail along the levee top. Upstream of the CC1 confluence, Elk Creek flows through County and private parcels that are outside of the Project Area. See SRA and Stillwater (2021) for additional characterizations of Elk Creek and the lower watershed upstream of the Project Area.

Figure 2-10. Elk Creek between ST1 and CC1. Alder forest infested with English ivy at right. View looking upstream.

Figure 2-11. Aerial view of CDFW Wildlife Area (foreground) in winter. Dry RCG stalks are light beige color. Elk Creek at lower right corner, Oxbow Pond at left, CC1 obscured by trees in center. View looking upvalley.

Reference sites

The geomorphic assessment included evaluating conditions in reference sites to inform the Project designs. Due to the long history of landscape alterations and habitat conversions in the Project Area vicinity (see Section 2.3), there are no undisturbed reference sites in lower Elk Creek. Farther up the valley there are some areas with no evidence of disturbance based on historical aerial photograph analysis. Sites were evaluated that are located on the flat valley bottom and along the margin of slight uplands, similar to the upstream portion of the Project Area. The reference areas are upstream of tidal influence unfortunately, and therefore do not provide an example of tidal channel forms or brackish vegetation, but instead are indicative of mixed coastal riparian forest that previously was present in the Project Area (Figure 2-12). The forest is dominated by Sitka spruce with some deciduous hardwood trees and woody shrubs, and a dense herbaceous understory with ferns and skunk cabbage. Beaver are present and downed trees create pool habitat and hydraulic diversity in the creek channel.

Additional reference sites were evaluated at Spruce Creek in the Smith River estuary. Lower Spruce Creek is a tidal swamp. The ground surface is hummocky with depressions created from upturned rootwads of downed trees. In some cases, downed trees act as nurse logs for new trees and support roots that splay out horizontally to avoid inundation from the creek (Figure 2-13). The channel is sinuous and multi-threaded in areas where it meanders around hummocks or into depressions created by upturned rootwads. Spruce Creek also has areas infested with although deeper brackish water and shade from trees are effective at limiting its distribution. Beaver are present in Spruce Creek and the area visible in Figure 2-13 is just upstream of a dam.

Figure 2-12. Reference site on Elk Creek upstream of the Project Area. Elk Creek at center, view looking downstream.

Figure 2-13. Reference site at Spruce Creek in the Smith River estuary. RCG visible in unshaded areas in background. 2-meter survey rod for scale.

2.4.3 Soils and stratigraphy

Soils and stratigraphy in the Project Area were investigated along channel cutbanks and at four hand augered boreholes (BH1-BH4). The boreholes are located in proposed excavation areas across the Project Area. Soils and stratigraphy were also characterized with support from Stillwater's engineering geologist during previous paleo tsunami studies in lower Elk Creek (Hemphill-Haley et al. 2019).

The subsurface investigation is used to characterize historical depositional environments and inform the design process by describing materials expected to be encountered during project construction, suitable uses for spoils, and potential equipment access constraints. See Figure 2-6 for locations of all boreholes and Figure 2-12 for abbreviated lithologic logs. Un-abbreviated borehole logs are provided in Appendix D.

Soils encountered in the boreholes were logged in general accordance with the Visual-Manual Procedures of ASTM D2488 and soil classifications follow the Unified Soil Classification System (USCS) (see Appendix D). The boreholes were drilled in the wet season with high groundwater levels using a hand auger with a 3.25-inch diameter bucket.

2.4.3.1 Borehole 1 (BH1)

Borehole 1 is located in the wetlands on the right (north) side of the creek approximately 60 feet offset from the channel and 2,250 feet upstream of the creek mouth. The stratigraphy consists of (from top to bottom) approximately 0.2 feet of fibrous peat overlying organic silt and fine sand with fine roots and extends to 1 foot below ground surface (bgs). Below the silt is peat that contains very uniform plant and decomposed woody fragments and a muddy matrix with some silt and fine sand. The peat contains a thin sand lens at approximately 1.3 feet bgs. The peat extends to 4 feet bgs. From 4 feet to the bottom of the hole at 5.9 feet bgs is clean fine sand that is loose and dark gray. Static groundwater was observed at 1 foot bgs.

2.4.3.2 Borehole 2 (BH2)

Borehole 2 is located in the wetlands on the right (north) side of the creek approximately 60 feet offset from the channel and 2,850 feet upstream of the creek mouth. The stratigraphy consists of (from top to bottom) approximately 1 foot of peat that contains RCG plant fragments and rhizomes in a muddy matrix with fine sand. Below the peat is fine sand that is silty and muddy, with medium dense consistency and some redoximorphic mottling. The sand contains some plant fragments and fine roots and extends to approximately 2.3 feet bgs. From 2.3 feet to the bottom of the hole at 6 feet is clean fine sand that is loose and dark gray. The sand contains occasional fine plant fragments and some thin layers of denser consistency. Static groundwater was observed at 0.4feet bgs.

2.4.3.3 Borehole 3 (BH3)

Borehole 3 is located in the wetlands on the right (north) side of the creek approximately 85 feet offset from the channel and 3,400 feet upstream of the creek mouth. The stratigraphy consists of (from top to bottom) approximately 0.4 feet of peat that contains RCG plant fragments and rhizomes in a muddy matrix with silt. The peat grades into a muddy organic silt that still contains substantial peat and extends to approximately 1.3 feet bgs. Below the peaty silt is muddy silty sand with redoximorphic mottling and some fine roots that extends to approximately 2.7 feet bgs. From 2.7 to 3.7 feet bgs is loose gray sand with little to no fines and faint redoximorphic mottling. From 3.7 to 5.5 feet bgs is loose gray fine sand with fibrous peat. From 5.5 feet to the bottom of the hole at 6.5 feet is clean fine sand that is loose and dark gray. Standing surface water was approximately 0.35 feet above the ground surface.

2.4.3.4 Borehole 4 (BH4)

Borehole 4 is located in the wetlands north of the creek near the Oxbow Pond and is approximately 660 feet from Elk Creek. The stratigraphy consists of (from top to bottom) approximately 0.5 feet of peat that contains RCG plant fragments and rhizomes in a muddy matrix with silt. Below the peat is silty sand/sandy silt that is muddy, with loose consistency and some redoximorphic mottling. The unit contains some wood fragments and fine roots and extends to approximately 3.6 feet bgs. From 3.6 feet to the bottom of the hole at 7.4 feet is clean fine sand that is loose and dark gray. The sand contains occasional fine plant fragments. Static groundwater was observed at 0.5 feet bgs.

2.4.4 Interpretation of depositional environments

The soils encountered in all four boreholes contain stratigraphy that generally records a fining-upwards sequence likely resulting from the historical land use conversions described in Section 2.3. The stratigraphy includes relatively thin modern peat overlying silts, silty sands, and massive (i.e., lack of stratigraphy) sands. The silts and sands are believed to be fill deposited to elevate and drain the former low-lying wetlands. Based on the historical analysis described in Section 2.3, this fill was likely emplaced in the late 1800s and/or early 1900s. The deeper sands encountered in the boreholes may be natural estuarine or lagoon deposits from pre-European settlement, but it is possible that they are redistributed fill. These interpretations are supported by Hemphill-Haley et al. (2019), who evaluated soil cores in the Project Area and in the marsh several hundreds of feet farther upvalley. Hemphill-Haley et al. used methods including laboratory-based particle size analysis, diatom analysis, radiocarbon dating, and radionuclide dating in their study. Hemphill-Haley et al. found comparable fill stratigraphy in the relatively higher topography on the north side of Cross Channel 1 (CC1), which generally matches the ground elevations across the Project Area on the south side of CC1 (see Figure 2-6). Farther upvalley, Hemphill-Haley et al. documented stratigraphy and diatom assemblages that indicated natural estuarine or lagoon deposits overlain by peaty deposits that varied due to changing salinities (e.g., tidal vs freshwater) and vegetation types. This area is labeled as “Undisturbed wetland” in Figure 2-6.

The peat in borehole 1 (BH1) from approximately 1 to 4 feet below ground surface is anomalous and is possibly a fill deposit of fine wood shavings from the former Hobbs, Wall & Co sawmill. The thin sand layer, or lens, at 1.3 feet below ground surface in BH1 may be a tsunami deposit, possibly from 1964. If it is a 1964 tsunami deposit, then the overlying organic silt and peat would also be fills potentially emplaced when the sawmill was decommissioned.

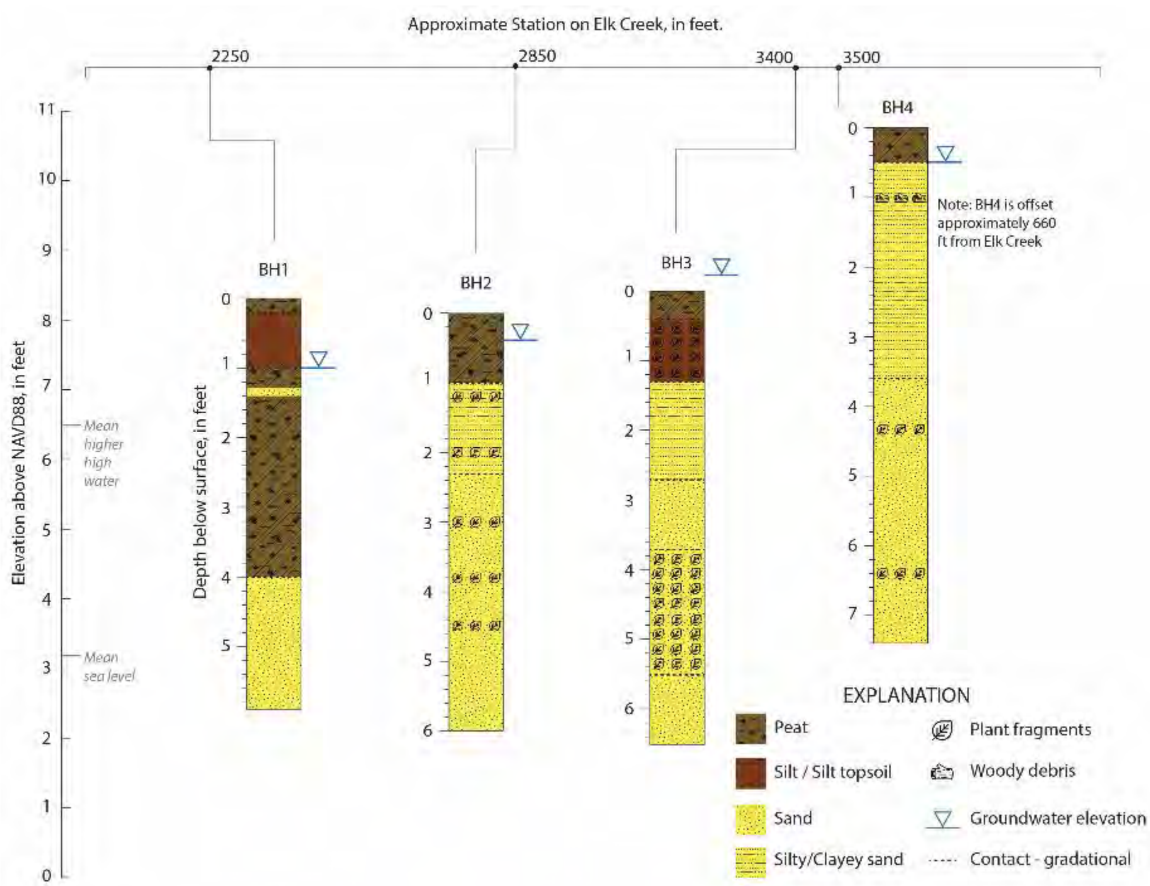

Figure 2-14. Lithologic logs of soil boreholes in the Project Area.

2.5 Hydrology

A hydrology analysis was conducted to determine stream flow data that are principal inputs to the hydraulic models (preliminary hydraulic modeling was conducted to evaluate design alternatives and is discussed in Section 2.6). Tidal datums were also considered since the Project Area is tidally influenced.

Elk Creek is ungaged, however, Stillwater conducted limited stream gaging during the Feasibility Study (described below in Section 2.5.4). Streamflows relevant for hydraulic modeling were calculated using prorations from nearby gaged streams and USGS StreamStats. Streamflow records from multiple USGS gages were used in the hydrology analysis (see Appendix B). The gages were selected based on multiple criteria including: (1) proximity to the Project Area, (2) similar topography, climate, and underlying geology to the Project Area, (3) relatively comparable drainage areas, and 4) long periods of record (i.e., ideally greater than 20 years). Peak streamflow and mean daily flow records were analyzed from the USGS gages to produce flood frequency and flow exceedance probability estimates, respectively, to be used in proration calculations. The calculated flow statistics were comparable to values obtained from USGS StreamStats.

2.5.1 Peak flows

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 flow) 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 habitats are available. For this analysis, we assume the 1.5-year recurrence interval flow approximates the "bankfull" flow. It is also critical to analyze large flood flows (e.g., 50- and 100-year recurrence interval events) to evaluate erosion potential and flooding hazards, as well as the stability of the proposed designs.

The flood frequency analysis used a Log-Pearson III distribution and methods consistent with USGS Bulletin 17C (USGS 2019). Design flows were calculated for the upstream and downstream ends of the Project Area, as well as upstream of the Oxbow Pond and for North Tributary 1 and 3. Table 2-1 provides the design flows for the downstream end of the Project Area. Peak flow estimates were prorated for the project sites 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 peak flow, b = 0.9 for 2- and 1.5-year peak flow, and b = 1 for exceedance flows

Q_u = Ungaged discharge
Q_g = Gaged discharge
A_u = Ungaged drainage area
A_g = Gaged drainage area

2.5.2 FEMA flood hazard area

The Project Area is within the FEMA 100-yr flood hazard area (FEMA Flood Insurance Study 2018). The Flood Insurance Rate Map, or FIRM, is provided in Appendix B. The FEMA flood hazard area extends across the entire Elk Creek valley bottom and is designated as Zone A, which is determined using approximate mapping methods as opposed to detailed hydraulic analysis. Preliminary hydraulic modeling of flood conditions was conducted for this Project and is discussed in Section 3.3.

2.5.3 Percent exceedance flows

In addition to peak flow estimates, smaller flows were also modeled, which correspond to biologically relevant conditions when fish are likely to be utilizing a reach (Table 3-1). The 1% and 10% exceedance flows are considered high fish passage flows for adult and juvenile salmonids, respectively (CDFW 2004). The 50% and 95% exceedance flows are considered the low fish passage flows for adult and juvenile salmonids, respectively (CDFW 2004). The 95% exceedance flow is less than the CDFW alternative minimum flows 1 cubic feet per second (cfs) for juvenile salmonids, therefore the alternative flow applies. The exceedance flows were calculated from the same regional USGS gage records as used in the peak flow analysis and were prorated based on the drainage area ratio to the Project Area. An average of the prorated USGS gage flows and StreamStats were used as input in the hydraulic modeling (described in Section 2.6).

Table 2-1. Flood frequency (peak flow) and percent exceedance flow estimates.

Flow	Downstream end of Project Area (cfs)
100-yr peak flow	2,580
50-yr peak flow	2,279
25-yr peak flow	1,972
10-yr peak flow	1,561
5-yr peak flow	1,289
2-yr peak flow	772
1.5-yr peak flow	599
1% exceedance flow	259
10% exceedance flow	66
50% exceedance flow	6.6
CDFW alternative minimum flow-juvenile salmonid[1]	1

[1] CDFW 2004.

2.5.4 Flow monitoring

Stillwater conducted a flow monitoring assessment in Elk Creek between October 2019 to February 2024. The assessment included installing a network of water level monitoring stations in the lower watershed and measuring stream discharge across a range of low to moderate flows. The assessment characterized relative surface flow patterns and discharge contributions among the various tributaries, cross channels, ponds, and mainstem creek reaches in the lower watershed. Discharge measurements were used to create a provisional rating curve for Elk Creek just upstream of Hwy 101 at low to moderate flows. These measurements were used to calibrate the hydraulic model for this Project and are provided in Section 2.6. See SRA and Stillwater (2021) for additional information on the flow monitoring assessment.

2.5.5 Project water levels and tidal datums

Water levels in the lower watershed are strongly influenced by tide, although tidal fluctuation in the stream-estuary ecotone is diminished from its former natural range due to historical wetland infilling and muting caused by the Hwy 101 culvert. Water levels were measured using a network of loggers across the lower watershed during the Feasibility Study. Figure 2-13 provides an example of water levels in the lower watershed, illustrating the influence of precipitation and tide. In the figure, the M-EC-2 data series is in Elk Creek at the North Tributary 1 confluence and M-OP-2 is in the Oxbow Pond at the Cross Channel 1 confluence. The other data series are farther upvalley. Due to the hydraulic control formed by the roughened channel just upstream of the highway, water level in Elk Creek in the Project Area never drops below approximately 5.3 feet elevation. See SRA and Stillwater (2021) for additional discussion on water levels in the lower watershed.

Tidal elevations, or datums, used in this Project are provided in Table 2-2. These elevations are relative to the NAVD88 vertical datum and are established for the Crescent City tide gage (Station 9419750), which is located in Crescent Harbor approximately one-half mile from the mouth of Elk Creek.

Table 2-2. Tidal datums for Elk Creek.

Tidal datum	Elevation, ft (NAVD88)[1]
Highest observed tide	10.28
Mean higher-high water (MHHW)	6.49
Mean high water (MHW)	5.85
Mean sea level (MSL)	3.32
Mean low water (MLW)	0.86
Mean lower-low water (MLLW)	-0.38
Lowest observed tide	-3.80

[1] Elevations for Crescent City tide gage (Station 9419750) located in Crescent Harbor.

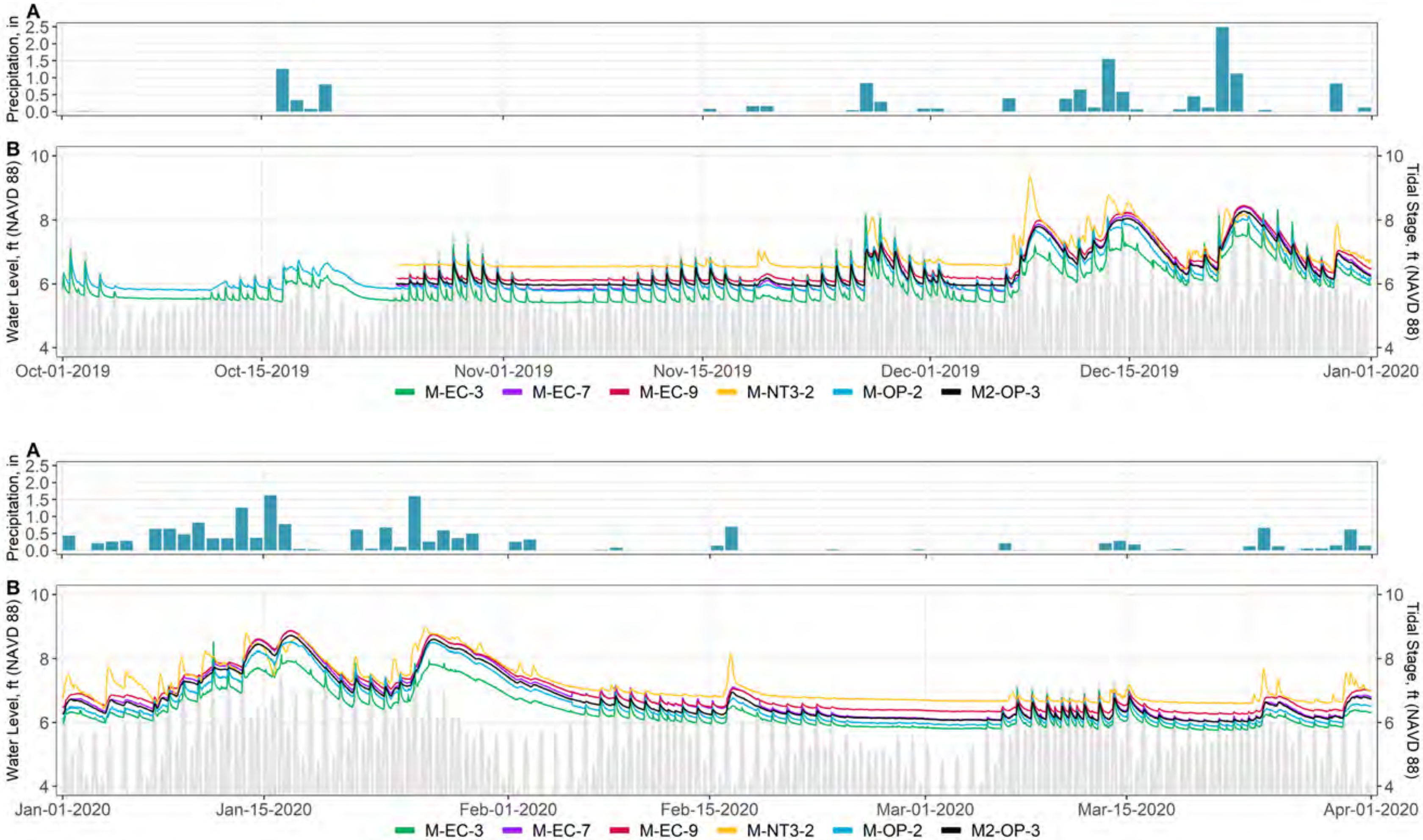

Figure 2-15. Precipitation (A) and water level (B) records from the lower watershed during WY 2020 (October 2019 to April 2020). Tidal stage from Crescent City (Station ID# 9419750) depicted by gray curve. M-EC-2 is in Elk Creek at the North Tributary 1 confluence and M-OP-2 is in the Oxbow Pond at the Cross Channel 1 confluence. The other data series are farther upvalley.

2.5.6 Projected sea level rise

The Project analyzed projected relative sea level rise according to the California Sea Level Rise Guidance (2024). The 2024 guidance is an update to the previous California Sea Level Rise Guidance issued in 2018 and incorporates significant advancements in scientific understanding and ability to project future sea level rise scenarios. The 2024 guidance analyzes five sea level scenarios for California, low to high, based on the plausible range of future sea level rise under all possible global emissions conditions. The Intermediate sea level scenario was selected to analyze for the Project. The Intermediate scenario represents the reasonable upper bound for the most likely range of sea level rise by 2100 and is suitable considering the lack of critical infrastructure in the Wildlife Area. Note that analyzing the Hwy 101 crossing is not within the scope of this Project.

For each sea level scenario, the 2024 guidance provides amounts of relative sea level rise (in feet) by decade from 2020 to 2150 for various locations across California, including Crescent City (Figure 2-14). The projections incorporate local estimates of vertical land motion determined from nearby global positioning system (GPS) stations. The vertical land motion estimates do not include the possibility of large earthquakes due to the uncertainty in predicting when such events will occur (J. Kimball, pers. comm., 2024). Hydraulic modeling was used to analyze the projected sea level rise amount for Crescent City at the 2100 time horizon (2.3 feet).

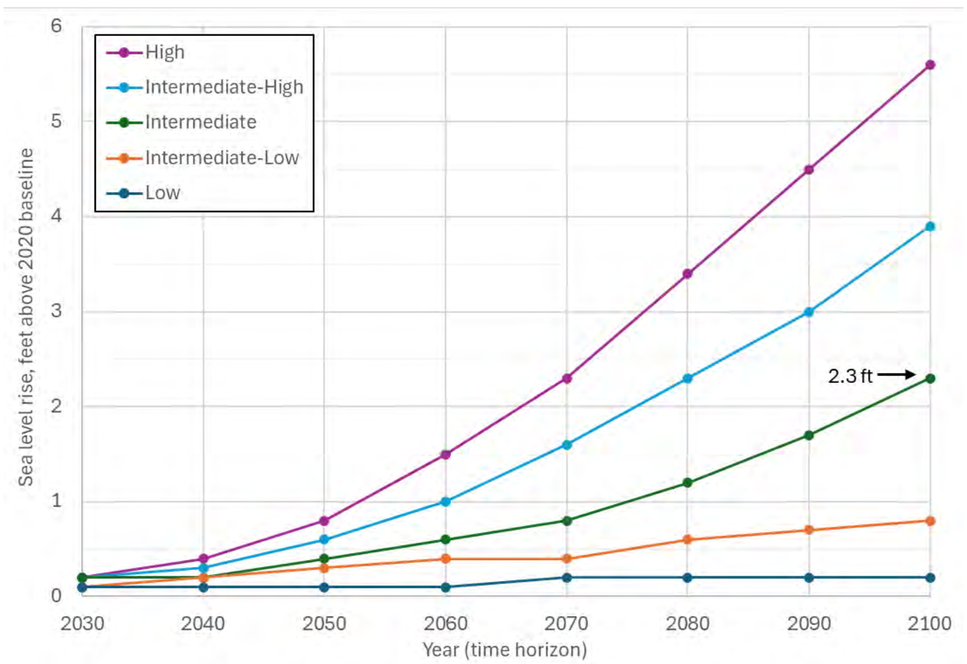

Figure 2-16. Sea level rise projections for Crescent City, adapted from California Sea Level Rise Guidance (2024). This Project incorporates projections at the 2100 time horizon (2.3 feet rise) on the Intermediate sea level scenario.

2.6 Hydraulic Modeling

This section describes hydraulic model setup, simulation, and calibration. Hydraulic model results are presented in Section 3.4, after the discussion of design alternatives.

To evaluate channel flow dynamics and habitat suitability, existing and proposed conditions hydraulics were modeled in US Army Corps of Engineers' Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 6.6 (September 2024). The HEC-RAS model describes the physical properties of streams and rivers by performing two-dimensional (2-D) hydrodynamic routing with steady or unsteady flow and has a user-defined, variably sized computational mesh to represent the terrain data. The mesh is composed of 3- to 8-sided elements built via breaklines, with prescribed node spacing and important grade breaks identified in the terrain. Tighter node spacing yields smaller elements (and thus more nodes within the mesh), which can better represent complex terrain and hydraulically sensitive features.

2.6.1 Model setup

A terrain mesh was created for the Project Area by importing LiDAR terrain, survey topography, and proposed conditions topography as a mosaic DEM (refer to Section 2.4.1) into HEC-RAS to characterize channel and floodplain geometries. The terrain surface and corresponding mesh elevations were compared to ensure the terrain was captured as accurately as possible. The same mesh was used for the existing and proposed conditions models, but the underlying DEM differed between existing and proposed meshes to reflect future constructed ground surfaces. Additionally, the proposed mesh incorporated new breaklines to accurately reflect changes in the terrain.

The upstream model extents were assigned three flow hydrograph boundary conditions to simulate the main channel and two larger tributaries (North Tributary 1 and North Tributary 3) (see Figure 2-2). The main downstream boundary condition was assigned a variable tidal stage corresponding to MLLW, MSL, MHHW, and projected SLR. Along the interface with Hwy 101 and city streets, multiple free outfall boundaries were applied to simulate runoff capture of the urban stormwater drainage system. This approach was used because flooding extents in initial model runs were greater than believed realistic, and detailed stormwater system modeling was beyond the scope of this assessment. The ground surface roughness characteristics for the models were defined in HEC-RAS with spatially discrete areas, which are a plan view of Manning's n zones and values for the model domain. Manning's values (i.e., roughness values) were assigned based on standard references (Chow 1959), field observations, and aerial imagery (Table 2-3).

Table 2-3. Manning's roughness values used in hydraulic modeling.

Land cover	Manning's roughness coefficient
Campground	0.025
Downstream Estuary	0.045
Estuarine Intertidal Emergent Wetland Persistent	0.075
Estuarine Subtidal Unconsolidated Bottom	0.06
Mixed Grass/Urban	0.035
Ocean	0.025
Palustrine Aquatic Bed	0.06
Palustrine Emergent Wetland Persistent	0.065
Palustrine Emergent Wetland Persistent – Mill Pond	0.05
Palustrine Forested Wetlands	0.09
Palustrine Scrub-Shrub Wetlands	0.065
Riverine Tidal Aquatic Bed	0.06
Riverine Tidal Streambed	0.055
Upland	0.045
Urban	0.02

2.6.2 Simulation

Computational time-steps were set to courant controlled and ranged from 0.625 to 5.0 seconds. After performing several runs, the 2-D mesh was refined by adding resolution and strategic cell center orientation to minimize inundation fragmentation. Inundation through the Project Area was modeled at five discharges ranging from 50-percent exceedance flow to the 50-year recurrence interval flood flow (Table 2-1). Mapping 2-D flow areas in HEC-RAS is based on the underlying terrain, meaning the wetted areas are based on details of the site topography rather than the computational mesh cell size. Cells can be computed as partially wet or dry. Mapping results reflect those details, rather than being limited to showing a computational cell as either all wet or all dry.

2.6.3 Calibration

Model calibration was conducted using site observations of high flow markers, water level data recorded across the Project Area, and discharge measurements taken upstream of Hwy 101 during water years (WY) 2019–2024 (Table 2-4). The flows used for model calibration range between approximately a 50% and 10% exceedance flow, representing typical baseflow and high baseflow to moderate sustained stormflow conditions, respectively. Manning's roughness values were also adjusted slightly within a reasonable range to better align modeled and observed stages. Sensitivity testing indicated that small variations in Manning's values had minimal influence on overall water surface elevations at the calibration locations, reinforcing confidence in the selected roughness values.

The model was evaluated against eight observed stage-discharge points, spanning flows from approximately 7 cfs to 79 cfs. The root mean square error (RMSE) between modeled and observed stages was 0.134 feet, indicating good agreement. Most modeled stages were within ±0.2 feet of observed values, with only two points exceeding this threshold. Residuals tended to slightly underpredict stage at higher flows, but the model remained within a reasonable error range across the calibration domain.

No discharge measurements were available for larger magnitude events; therefore, model calibration could not be extended to flood flow conditions. However, given the consistent model behavior across the observed range, the calibrated model is considered suitable for evaluating hydraulic performance for typical high-flow events.

Table 2-4. Stage and discharge measured in Elk Creek above Hwy 101.

Date	Stage (ft)	Discharge (cfs)
10/15/2019	5.592	6.8
10/25/2019	5.602	7.0
11/8/2019	5.612	7.3
2/5/2020	6.312	26.4
2/23/2021	6.612	41.8
2/5/2021	7.142	65.1
1/12/2024	7.192	66.8
2/9/2024	7.252	79.5

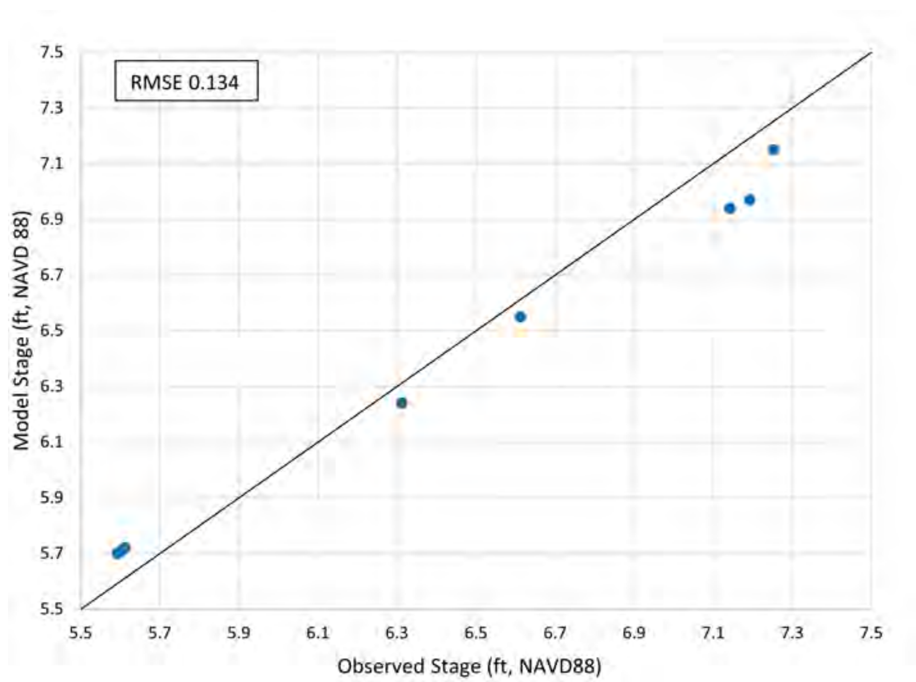

Figure 2-17. Comparison of observed and modeled water stages used for model calibration.

2.7 Vegetation

Vegetation in the Project Area is primarily composed of deciduous hardwood riparian forest and nonnative naturalized grassland, although one small marsh community was observed (.05 acres). Community types mapped in the Project Area included red alder forest (*Alnus rubra* Forest Alliance), coastal dune willow thickets (*Salix hookeriana* - *Frangula purshiana* Association), berry brambles (*Rubus ursinus* Shrubland Association), Himalayan blackberry riparian scrub (*Rubus armeniacus* Shrubland Semi-Natural Alliance), slough sedge swards (*Carex obnupta* Herbaceous Alliance), common velvet grass - sweet vernal grass meadows (*Holcus lanatus* - *Anthoxanthum odoratum* Herbaceous Semi-Natural Alliance), reed canary grass swards (*Phalaris arundinacea* Herbaceous Semi-Natural Alliance), and Kentucky bluegrass - Redtop - Creeping bentgrass meadows (*Poa pratensis* - *Agrostis gigantea* - *Agrostis stolonifera* Herbaceous Semi-Natural Alliance). Most of these vegetation communities are characterized as palustrine wetlands based on dominant vegetation and landscape position within the Project Area. Blackberry shrublands and common velvet grass - sweet vernal grass meadows are typical plant assemblages of uplands. Results from the elevation assessment conducted for the Feasibility Study indicate the mean elevation (NAVD88) for palustrine wetland types (emergent persistent, scrub/shrub, and forested) in the Project Area range from 9 to 10.3 feet with uplands averaging 12.6 feet (SRA and Stillwater 2021).

All vegetation communities mapped in the Project Area have substantial establishment by invasive plants (i.e., species rated by the California Invasive Plant Council [Cal-IPC] as high, and/or those species which are known to the region as having invasive tendencies and can be detrimental to the successful establishment of restored native plant communities). The invasive species, reed canary grass (RCG) (*Phalaris arundinacea*), is of special concern in the Project Area due to its aggressive invasion of wetland areas in the lower Elk Creek valley where it forms dense, monotypic stands that clog waterways and marshes diminishing native herbaceous communities and impairing flow conveyance. RCG forms stand-level occurrences and is prevalent throughout most of the mapped vegetation communities. Another invasive plant, English ivy (*Hedera helix*) has moderate to high cover throughout the forested community types. It was observed within many tree crowns, with extensive coverage on tree trunks as well as spreading throughout the understory where it displaces native herbaceous ground cover and engulfs native understory shrubs. Himalayan blackberry also forms stand level occurrences and was observed within riparian canopy openings along the channel. Nonnative plants including one-seed hawthorn (*Crataegus monogyna*) and English holly (*Ilex aquifolium*) were also observed.

The Feasibility Study further describes the vegetation assessment methods and results including vegetation, invasive plant, and wetland characterization maps and descriptions as well as an elevation analysis of wetland and vegetation communities in the Project Area (SRA and Stillwater 2021).

2.8 Fish Habitat and Utilization

SRA and Stillwater (2021) provide detailed assessments of fish habitat and utilization across the Elk Creek watershed including in the Project Area. In summary, the previous studies focused on characterizing juvenile salmonid rearing habitats and utilization. Despite the long history of anthropogenic disturbance, the lower watershed contains large areas of suitable summer and winter rearing habitat for Coho Salmon and other salmonids. However, in some reaches, particularly in the Project Area, quantity and quality of rearing habitat is limited by lack of channel complexity and instream large wood, limited in-channel velocity refugia during winter flows, and minimal connectivity with off-channel habitats. In other lower watershed locations outside of the Project Area, such as the Oxbow Pond and cross channels, rearing habitats are seasonally limited by salinity, high water temperatures, low dissolved oxygen, and invasive vegetation. See SRA and Stillwater (2021) for additional information about the fish habitat and utilization studies.

2.9 Public Access

As described in Section 1, the State acquired multiple parcels in the lower Elk Creek watershed in the 1980s and transferred them to CDFW to be managed as a wildlife area. Public access and recreation improvements were also made at that time and included a trail, footbridges, benches and picnic tables, informational signs, and a gazebo. Over the years, the improvements have degraded, became overgrown with vegetation, were vandalized, and/or were removed. The public parking area and trailhead were located at the end of 2nd St, which is accessed via a narrow gravel road that meanders through dense riparian vegetation, obscuring it from view of the businesses and city streets less than two blocks away (Figure 2-6). For decades the parking and trailhead area have routinely been blighted by illegal refuse dumping and camping. In the last year, CDFW has blocked 2nd St with boulders and posted No Public Access signs. Evaluating the feasibility of reestablishing improved public access is part of this Project.

3 CONCEPTUAL DESIGN ALTERNATIVES

3.1 General Design Objectives and Constraints

The following general design objectives and constraints were identified during the Feasibility Study, and throughout the existing conditions characterizations and TAC consultation process for this Project:

- Improve connections from Elk Creek to off-channel habitats across the Project Area.
- Create and enhance off-channel habitats in a portion of the stream-estuary ecotone where such habitat was likely abundant prior to European settlement.
- Create self-sustaining tidal channels and alcoves with year-round low velocity and variable depths, to provide a diversity of aquatic habitats.
- Improve flood capacity and resilience to sea level rise.
- Create long-term and self-sustainable controls on invasive vegetation, primarily for RCG, including:
    - Introduce brackish water across a wider portion of the Project Area.
    - Create deepwater conditions in wider channels to suppress reestablishment.
    - Provide benches and hummocks that will support dense multi-story native vegetation that can compete with and shade out RCG.
- Minimize impacts to native vegetation.
- Add instream large wood to increase channel complexity and provide cover for fish.
- Add downed large wood across the Project Area to provide habitat for terrestrial and avian wildlife.
- Attempt to balance earthworks and treat RCG-contaminated soils within the Wildlife Area to avoid off-hauling materials.
- Avoid or minimize converting wetlands to uplands.

- Improve public access (per CDFW's discretion) and reduce nuisance dumping at former trailhead.

3.2 Design Alternatives

The attributes of each design alternative are described below. A profile of Elk Creek with key design features is provided in Figure 3-1. Design plans are provided in Appendix A.

3.2.1 Alternative 1

Alternative 1 has topography similar to existing conditions and is the "light touch" alternative. The designs include excavating four relatively small connections (labeled as Floodplain Connection 1 through 4 in the design plans) between Elk Creek and the wetlands on the north side of the channel. The connections would either enhance (deepen and widen) existing low-lying areas or breach the artificial levee in a strategic location where the fill is narrow and adjacent to existing low elevations. The connections would be graded to approximately 6.5 feet elevation on the Elk Creek side to tie into the channel top-of-bank and coincide with the MHHW tidal datum.

The alternative includes instream large wood structures throughout Elk Creek and terrestrial wood across the Wildlife Area. The instream wood would consist primarily of two- and three-log structures anchored to timber piles driven into the creek bed and/or bank. The terrestrial structures would also include timber piles to stabilize the logs during large infrequent floods. All grading and wood structures are located on the north side of the creek to minimize heavy equipment impacts in the forest on the south side of the creek.

Invasive plant management would occur on both sides of the creek throughout the Project Area to control Himalayan blackberry, English ivy, and English holly.

Alternative 1 is drawn with Trail Option A (no trail) in the design plans although all trail options are compatible with the alternative.

3.2.2 Alternative 2

Alternative 2 includes grading multiple new tidal channels across the Project Area and has significantly more grading than Alternative 1. The channels connect to Elk Creek in the same locations as Floodplain Connections 1 through 4 described in Alternative 1. However, the channels are graded deeper in this alternative to tie into the Elk Creek thalweg (at elevations 3 and 4 feet) and provide year-round inundation across all flow and tidal scenarios. The proposed tidal channels are divided into two general grading areas, West Grading and East Grading, that are separated by the more upland central portion of the Wildlife Area.

The West Grading includes a new tidal channel and alcove at Floodplain Connection 1, a new small tidal channel emanating from North Tributary 1 (NT1), and a realigned and widened NT1 channel. The upstream ends of the new tidal channels converge at a tsunami surge bypass, which is a broad swale that gently slopes up to a wide crest, or saddle (approximately 70-100 feet wide), with a potential trail crossing before gently sloping back down and tying into the Oxbow Pond. The crest of the bypass swale is at approximately elevation 9.5 feet and would only receive flow during large floods or tsunami incursions into the lower watershed. The intention of the bypass swale is to provide flow relief for incoming tsunami surges into the large Oxbow Pond, and that would otherwise be confined by the narrow levee-lined Elk Creek channel.

The East Grading is a large multi-threaded tidal channel network that connects to Elk Creek at Floodplain Connections 2, 3, and 4. The grading includes two primary channels with cross-channel connections, benches, tributary spur channels, and three large hummock islands. The benches are designed at elevations from approximately 6.5 to 9 feet, which is below the preferred elevation for RCG and is intended to support high brackish marsh vegetation. The hummocks range from 9 to 14 feet in elevation and are intended to support riparian scrub and mixed riparian forest. The East Grading footprint is designed to coincide with the area of highest RCG abundance while minimizing impacts to existing trees. A second tsunami surge bypass swale is located at the northern edge of the East Grading.

The alternative includes the same instream and terrestrial large wood structures as Alternative 1, with additional structures in the tidal channels. Some logs along Elk Creek may need to be adjusted or shortened to accommodate the trail alignment.

The same invasive plant management as Alternative 1 would occur throughout the Project Area to control Himalayan blackberry, English ivy, and English holly.

Alternative 2 is drawn with Trail Option B (out-and-back) in the design plans although all trail options are compatible with the alternative. Trail and public access options are discussed below in Section 3.4.2.

3.2.3 Alternative 3

Alternative 3 includes tidal channels similar to Alternative 2, although in some locations in the West and East Grading areas the channel bottoms are wider and deeper (to elevation 1 foot). This grading approach uses the same limits of grading as Alternative 2 and benches are reduced in size to accommodate the wider and deeper channels. The hummock islands are also slightly reduced in area but not top elevation. Some of the large wood structures in the proposed tidal channels are moved so that they remain positioned on the channel banks. The terrestrial wood and instream structures in Elk Creek are the same as in Alternatives 1 and 2. Both tsunami surge bypass swales are the same as in Alternative 2.

This alternative is unique in that it includes channel grading on the south side of the creek. The lower 60 feet of channel in ST1 would be partially filled to create a high brackish marsh bench and a new connection channel would be graded that is deeper and wider. The new channel would provide alcove habitat and is aligned to connect to existing low-lying off-channel habitat that is currently poorly connected to Elk Creek. The design includes three log weirs in ST1 to provide bed stability across the transition to the new deeper channel and to slow flow in the tributary, which drains urban runoff along Hwy 101. The crest elevation of the weirs is only 3-4 inches above channel grade, creating relatively small pools that remain within the forested Wildlife Area.

The same invasive plant management as Alternatives 1 and 2 would occur throughout the Project Area to control Himalayan blackberry, English ivy, and English holly.

Alternative 3 is drawn with Trail Option C (loop) in the design plans although all trail options are compatible with the alternative. The tail would include three footbridges that cross Floodplain Connections 2, 3, and 4. Trail and public access options are discussed below in Section 3.4.2.

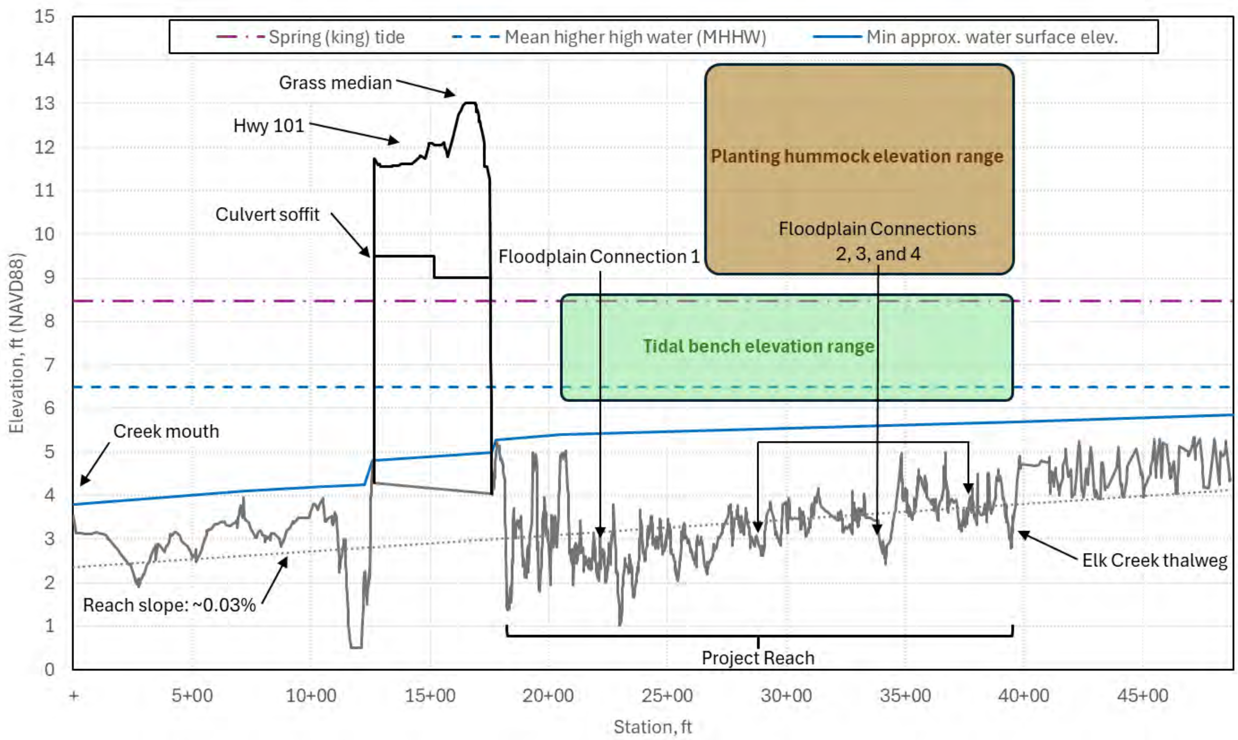

Figure 3-1. Longitudinal profile of Elk Creek and key proposed design features.

3.3 Tidal Channel Sizing

The floodplain connections where the new tidal channels in Alternatives 2 and 3 meet mainstem Elk Creek were sized based on a tidal prism analysis of hydraulic geometry relationships for tidal channels (Williams et al. 2002). Williams et al. evaluated empirical correlations between channel geometry (i.e., max depth, max width, and cross-sectional area) and tidal exchange, or prism, to predict equilibrium cross-sectional geometry for a given tidal prism. Tidal prism is defined as the volume of water between MLLW and MHHW in the tidal contributing area upstream of the cross-section. Alternatives 2 and 3 have tidal prisms of 4.8 and 5.6 acre-feet, respectively. The floodplain connections in Alternatives 2 and 3 are drawn with the same channel geometry, which is slightly larger than the dimensions predicted for the larger Alternative 3 tidal prism. This approach was used to simplify the conceptual design process and ensure the proposed footbridges are feasible with the likely largest channel geometry scenario. The size of the floodplain connections will be refined in later design phases based on the final grading footprints and tidal prism, but are not expected to be larger (i.e., wider or deeper) than what is drawn in the conceptual design plans.

3.4 Hydraulic Modeling Results

3.4.1 Fish habitat flows

Preliminary hydraulic modeling was conducted to evaluate suitable fish habitat under existing conditions and for each design alternative. Habitat was evaluated at the 10% and 50% exceedance flows with mean sea level (MSL) tidal conditions. During a typical year the 10% exceedance flow occurs 10% of the time, or about 36 cumulative days per year. In the north coast region of California, this flow typically represents sustained high baseflow or moderate stormflow during the wet season, rather than isolated peak events. The 50% exceedance flow is a relatively lower baseflow typical of spring rearing periods.

Habitat suitability criteria were selected based on published literature and are focused on juvenile Coho Salmon (Bustard and Narver 1975, Hampton 1997, Healy and Lonzarich 2000, Beecher et al. 2002, Katzman et al. 2010). *Preferred* habitat is defined as 0.5–4 feet depth and less than 0.5 ft/sec velocity, and *marginal* habitat is defined as 0.5–4 feet depth and 0.5–1.0 ft/sec velocity. These suitability criteria are also intended to apply generally to evaluating relative levels of habitat creation for other juvenile salmonids and Tidewater Goby, which are present in the Project Area. A habitat suitability index (HSI) was created by applying the suitability criteria to the hydraulic model results to evaluate and quantify the spatial extent of preferred and marginal habitats for each alternative in the Project Area. Habitat suitability results are summarized for each model scenario and design alternative in Table 3-1, Figure 3-2, and Figure 3-3.

Table 3-1. Modeled area of suitable fish habitat for existing conditions and design alternatives.

Design alternative and flow exceedance scenario[1]		Suitable habitat area (acres)		
		Preferred[2]	Marginal[3]	Total
Existing Conditions	50%	0.95	0.01	**0.96**
	10%	0.2	0.62	**0.82**
Alternative 1	50%	0.95	0.01	**0.96**
	10%	0.2	0.54	**0.75**
Alternative 2	50%	2.7	0.01	**2.71**
	10%	2.1	0.54	**2.63**
Alternative 3	50%	2.77	0.01	**2.78**
	10%	2	0.54	**2.54**

[1] Both exceedance flows modeled at mean sea level (MSL)
[2] Preferred: depth 0.5–4.0 ft, velocity <0.5 ft/s
[3] Marginal: depth 0.5–4.0 ft, velocity 0.5–1.0 ft/s

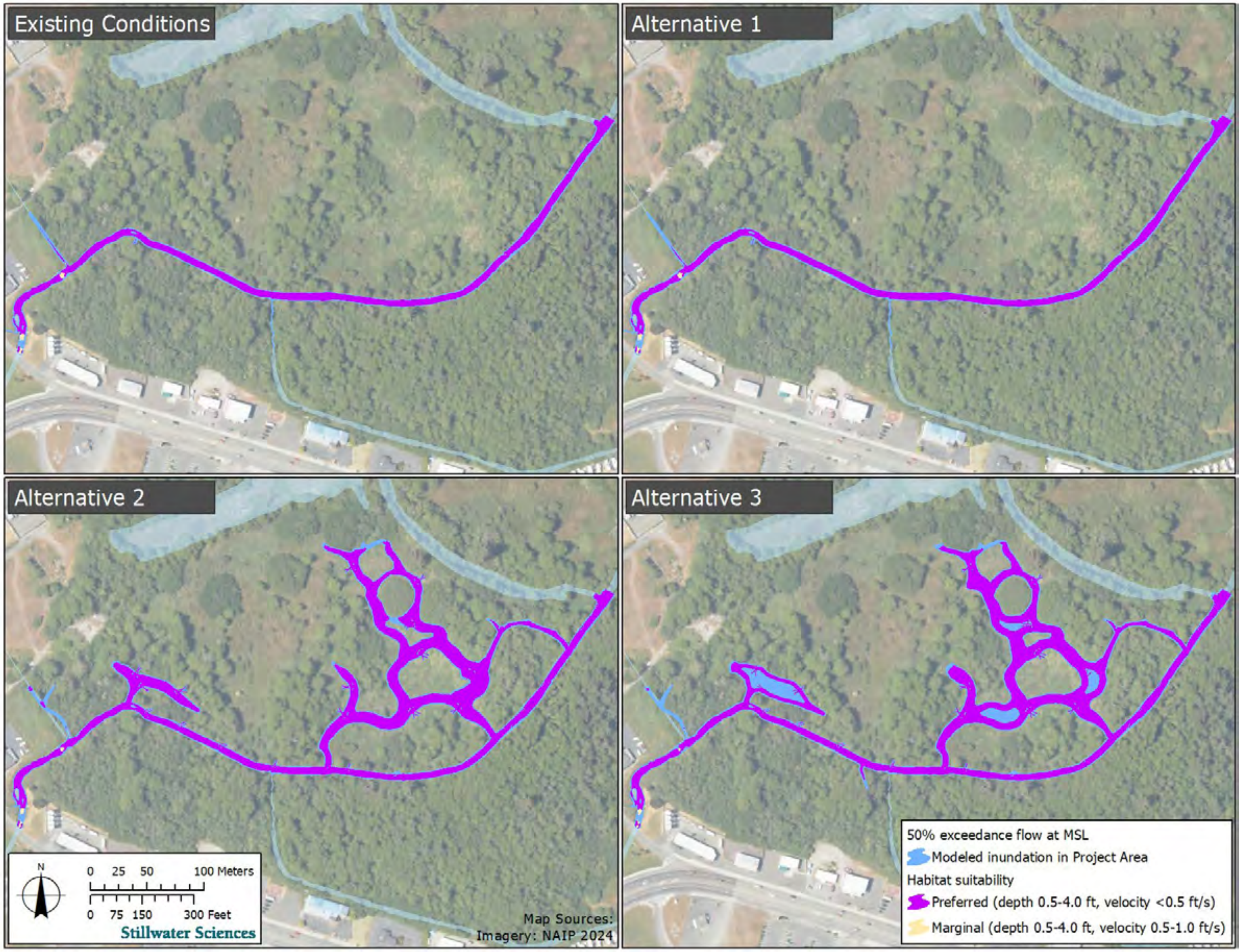

Figure 3-2. Modeled habitat suitability for design alternatives in the Project Area for the 50% exceedance flow at mean sea level.

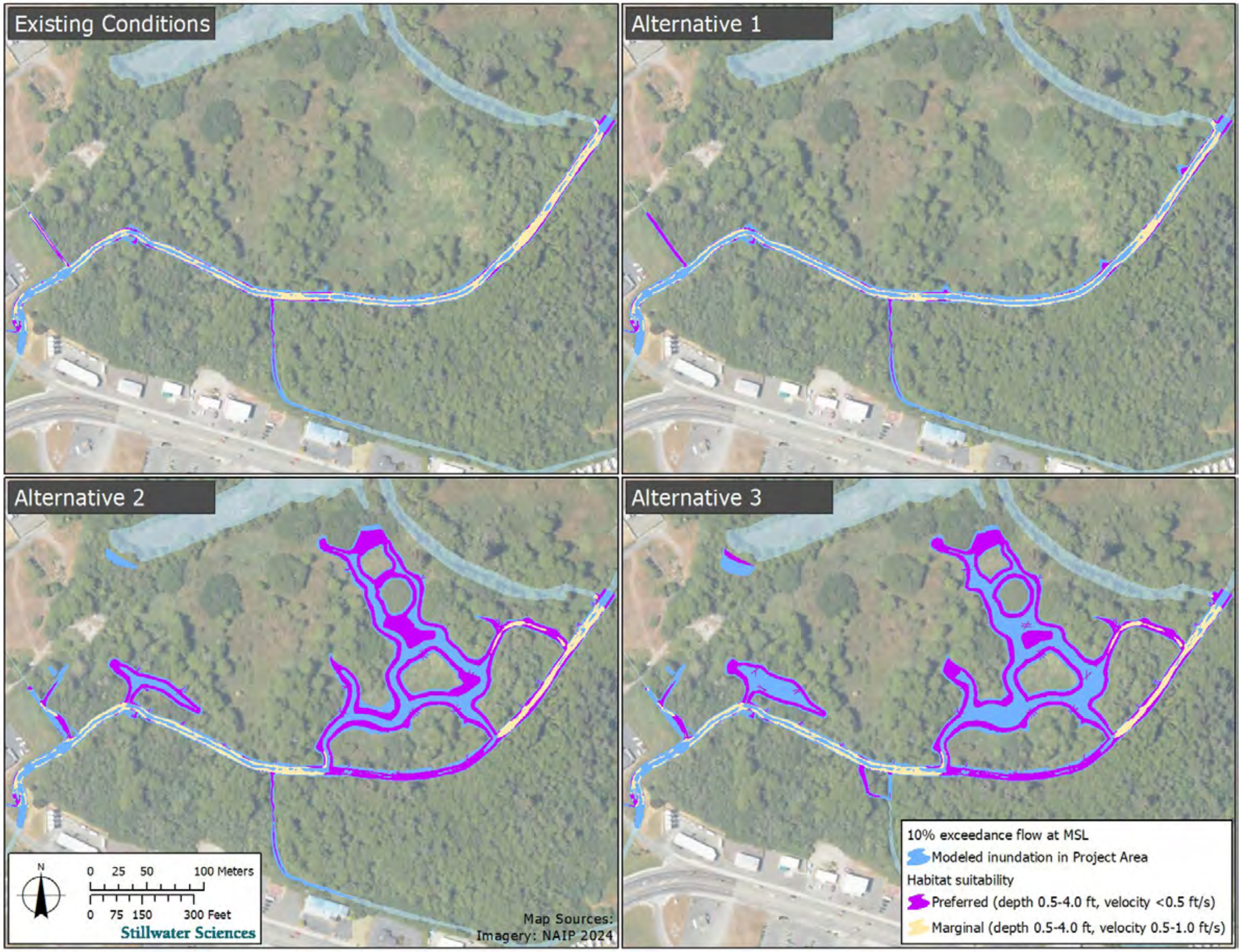

Figure 3-3. Modeled habitat suitability for design alternatives in the Project Area for the 10% exceedance flow at mean sea level.

3.4.2 Flood flows

Preliminary hydraulic modeling was conducted to evaluate flood conditions in the Project Area. The 2-year, 10-year, and 50-year flood flows were modeled with MLLW and MHHW tidal conditions, and with projected SLR. Maps of the Project Area vicinity for each flood model scenario are provided in Appendix B.

Inundation in the Elk Creek watershed during the modeled flood scenarios is widespread due to the large and very low-relief valley (see Figure 2-2). The valley bottom has an average 0% slope that extends approximately 2 miles inland from Crescent Harbor and is over half a mile wide in some locations. This large topographic basin attenuates flow velocity and results in flood inundation across a wide area, often with shallow water depths. The flood attenuation also results in very minor differences in modeled inundation between the different flood scenarios (within a ~1-foot water surface elevation range), and between the design alternatives and existing conditions (within a ~2 to 4-inch water surface elevation range). Flow velocities in the Project Area are generally low across all flood model scenarios, typically less than 3 ft/s and in most locations under 2 ft/s. The only areas exhibiting higher velocities, ranging from approximately 4 to 6 ft/s, are at the Hwy 101 culvert and its associated inlet and outlet approaches.

Contributing to widespread flood inundation across the Elk Creek valley is the topographic barrier created by the relatively high ground along the highway corridor between the Wildlife Area and Crescent Harbor. This acts as a dam holding floodwater back in the valley. The Hwy 101 culvert does not have the capacity to convey greater than approximately a 1.5- to 2-year flood without causing backwatering. Also, overland flow leaving the Wildlife Area is intercepted by the city and highway stormwater drainage networks, which convey flow to Elk Creek at and downstream of the highway. Due to the damming effect during flood events, which results in a water surface elevation of approximately 11–12 feet across the Wildlife Area-urban interface, there are only very minor differences in modeled inundation upstream of the highway under MLLW and MHHW tidal conditions, and with projected SLR.

These model results agree relatively well with the extent in the FEMA flood mapping (see Appendix B) considering the similarity in inundation at varying flood recurrence intervals.

3.5 Trail and Public Access Options

The design plans present three trail options in the Project Area. A public trail used to exist here and was built in the 1980s when the Wildlife Area was acquired by the State. The loop trail circumnavigated the central wetlands primarily along the top of the railroad and channel levees, and the trailhead was at the end of 2nd St. Over time the trail was not maintained and slowly became overgrown, with only a remnant remaining in some locations today. The trail options are presented in the design plans with a different option on each alternative; however, all trail options are compatible with each alternative.

- Trail Option A (no trail) – this option is to not have a trail in the Wildlife Area. Trails require maintenance and if CDFW is unable to secure ongoing support from other local governments or organizations, then a new trail will likely not be constructed.
- Trail Option B (out-and-back) – this option would construct a new out-and-back trail primarily along the former trail alignment. The trail would not continue along Elk Creek to connect across Floodplain Connections 2, 3, and 4 in the East Grading area. The former public access point at the end of 2nd St, which is commonly a nuisance area for dumping and camping, would be abandoned and restored. Concrete rubble would be removed and

gravel from the access road could be re-purposed as base rock for the new trail. A new trail access could be constructed at the end of 3rd St, which is a maintained paved road that provides access to critical telecommunications infrastructure on the other side of the street.

- Trail Option C (loop) – this option is for a loop trail that matches Option B but continues along Elk Creek and crosses Floodplain Connections 2, 3, and 4 with footbridges. This option also includes an improved access at the end of 3rd St and abandoning the former access point at the end of 2nd St.

A new trail could be constructed so that it is compliant with the American with Disabilities Act (ADA) using necessary widths, slopes, and surfacing requirements. The trail and footbridges could also accommodate light-duty vehicles (e.g., up to approximately 10,000 pounds) to support maintenance and emergency access. The footbridges would be constructed of corrosion-resistant aluminum designed for marine applications.

3.6 Earthwork Estimates and Spoils Management

Earthwork estimates based on conceptual design grading for each alternative are provided in Table 3-2. Alternative 1 has a relatively small net cut volume of approximately 230 cubic yards (CY), which could easily be reused onsite to construct planting hummocks (which are not drawn in the design plans) near the Floodplain Connections. Alternatives 2 and 3 have significantly larger net cut volumes of approximately 27,873 and 32,578 CY, respectively. Both alternatives have fills, which include the three large planting hummock islands, minor trail prisms, and approaches to the footbridges in Trail Option C. During later design phases additional planting hummocks will likely be included, which would reduce the net cut volumes. Alternative 2 and 3 also have approximately 7,311 CY of cut for scraping RCG from the East Grading footprint. This quantity assumes scraping the plants, rhizomes, and intermixed topsoil to an average depth of 1 foot. Estimates based on this approximate depth are reasonable considering the soil borehole logs in the Project Area and other soil investigations Stillwater has completed in RCG-infested wetlands in the Smith River and Elk River (Humboldt County) estuaries.

Spoils created from RCG scraping and tidal channel excavation will require a spoils management plan. The design plans show a potential spoils management area in the middle of the Wildlife Area, which has more upland topography and vegetation communities compared to the surrounding wetlands. Vegetation in this area is dominated by non-native grasses, Himalayan blackberry, and some RCG. Spoils management in this area could include scraping the herbaceous vegetation and topsoil out to the margins to create a wide shallow basin. RCG spoils from the East Grading area would be deposited in the bottom of the basin. Deeper soils excavated from the tidal channels would then be deposited on top of the RCG spoils. The topsoil initially scraped from the area would then be spread back over the wide low mound, which would be mulched and seeded with native species. The spoils management area shown in the design plans could accommodate approximately 15,000 CY assuming a mound height of 3 feet above existing ground elevation. Additional analysis will be required in later design phases to evaluate the potential for wetland conversion and impacts to flood hydrology with the conceptual spoils management strategy.

It is possible that an additional spoils management area will be needed if a grading plan comparable to Alternatives 2 or 3 is selected as the preferred alternative. A potential option that SRA and Stillwater are evaluating is utilizing the former McNamara & Peepe sawmill site on the west side of the Mill Pond (see Figure 1-1 and Figure 2-6). This site has documented soil contamination and a remedial action plan (RAP) developed by Environmental Forensic

Investigations, Inc. (EFI 2006). The RAP recommended an engineered soil cap among other actions to remediate the site. Spoils from the Project Area would be suitable for an engineered soil cap and this potential spoils management plan will be further evaluated in later design phases.

Table 3-2. Earthwork estimates based on conceptual design grading.

Feature	Area (SQ FT)	RCG scraping (CY)	Cut (CY)	Fill (CY)	Net (CY)
Alternative 1					
Floodplain Connection 1	978	0	21	0	-21
Floodplain Connection 2	671	0	10	0	-10
Floodplain Connection 3	2,619	0	122	0	-122
Floodplain Connection 4	1,604	0	81	4	-78
Total	**5,873**	**0**	**234**	**4**	**-230**
Alternative 2					
West Grading	81,175	0	6,081	171	-5,910
East Grading	206,567	7,311	22,900	937	-21,963
Total	**287,742**	**7,311**	**28,982**	**1,109**	**-27,873**
Alternative 3					
West Grading	82,131	0	8,145	130	-8,015
East Grading	206,562	7,311	25,548	1,012	-24,535
South Grading	3,561	0	198	8	-190
Bridge Crossings	3,700	0	2	164	162
Total	**295,954**	**7,311**	**33,893**	**1,314**	**-32,578**

3.7 Vegetation Restoration Strategy

Key objectives of the Project’s vegetation restoration actions include: (1) controlling existing invasive plant occurrences, (2) revegetating graded areas (e.g., benches and hummocks) to form resilient native plant communities that, once established, will create conditions resistant to invasive plant reinvasion, and (3) establish riparian cover and tiered structure near open channels to improve riparian functions beneficial to fish and wildlife.

3.7.1 Invasive plant control and management

In all design alternatives, the control and management of invasive plants will be key to successful restoration. Planned control and management activities for all invasive plants observed in the Project Area are presented in Table 3-3. These activities will be a crucial first step to the revegetation process. In general, invasive plant treatments will occur concurrently with initial construction activities associated with ground preparation work. Although manual removal of invasive plants outside the grading areas can occur independently.

Table 3-3. Invasive plants identified for management within the Project Area and their recommended control measures.

Species name	Growth form	Initial treatment
Hedera helix (English ivy)	woody vine	**Manual:** Whole plant removal with hand tools (e.g., weed wrench, pry bar), ensuring the entire root system and runners are removed to prevent resprouting. Removal includes cutting vining stems growing on tree trunks with handsaws and/or chainsaws. Removed plant material hauled to waste disposal facility.
Ilex aquifolium (English holly)	shrub	**Manual/Mechanical:** Whole plant removal with hand tools (e.g., weed wrench). Larger individuals may require uprooting with heavy equipment. Removed plants hauled to waste disposal facility.
Phalaris arundinacea (reed canary grass, RCG)	perennial rhizomatous grass	**Mechanical[1]:** excavation of the above and below ground material including the removal of the upper soil surface to capture amassed seedbank material, active root biomass, and living rhizomes. A prescribed burn[2] or spot burn/flaming may occur prior to mechanical excavation as it will reduce the accumulated reed canary grass aboveground litter and reduce the accrued seed bank. RCG spoils will be incorporated into a spoils management plan.
Rubus armeniacus (Himalayan blackberry)	mounding shrub	**Mechanical/Manual:** whole-plant removal using large equipment (e.g., backhoes, excavators) or manually by hand/hand tools ensuring the entire root crown is removed. Aboveground slash can be mulched on site (e.g., masticator, brush cutter, mower, mechanical chipper). When mowing or chipping is not feasible, spoils can be piled and burned or promptly hauled to a spoils location to dry prior to disposal to prevent resprouting from root and stem fragments.

[1] The extent of mechanical treatment will vary with the selected alternative. In general, RCG mechanical removal will coincide with the proposed grading footprint. Alternative 1 has the smallest treatment area, with Alternatives 2 and 3 capturing the largest extent for reed canary grass removal.

[2] Control burning activities should be conducted to occur only within a desired area by utilizing firebreaks and back burning techniques. It should be conducted with CalFire oversight to ensure success and best management practices are in use. Burning events should occur early to mid-summer or early to mid-fall to be more effective (Gedik Biological Associates 2006). Control burns require coordination with state and local authorities to ensure burn permits and regulations are followed.

3.7.2 Revegetation

Revegetation goals within the Project Area focus on the recovery of native riparian and marsh communities that are resilient to invasive weed reinvasion and restoring riparian conditions that promote natural stream function. Design Alternatives 2 and 3 include the expansion and grading of tidal networks with perennial channels bordered by low gradient marsh benches in features currently occupied by RCG (Figure 3-5). Thus, introducing two long-term controls measures for this species, brackish tidal water (i.e., salinity) and long duration inundation. In addition, the formation of planting hummocks that can be occupied by a diverse multi-story riparian forest adjacent to the expanded channel network will introduce additional RCG long-term controls, shade and competition. Shade is also a deterrent for Himalayan blackberry. Planting palette composition of the riparian hummocks will likely include a mixture of fast growing tall and midstory deciduous hardwoods (e.g., red alder, Pacific willow, coastal willow, Sitka willow), along with evergreen conifers like Sitka spruce (*Picea sitchensis*) and shore pine (*Pinus contorta* subsp. *contorta*). Plant selection will consider site hydrology, soils, aspect, and known plant associates. Marsh benches exposed to intertidal brackish waters (near Mean Higher High Water [MHHW] tidal datum) will be planted with stout perennial sedges, rushes, and bulrushes that once established will form a dense marsh network that limits bare ground exposure (Figure 3-5). The brackish marsh bench design and transition to adjacent hummocks will be informed by the anticipated tidal prism, seasonal water salinity range, and hydroperiod to promote native plant establishment while deterring potential reinvasion by invasive plants like RCG. Himalayan blackberry and naturalized grasslands that occur within upland habitats will be revegetated with native riparian and coastal scrub tree and shrub species well-adapted to site conditions.

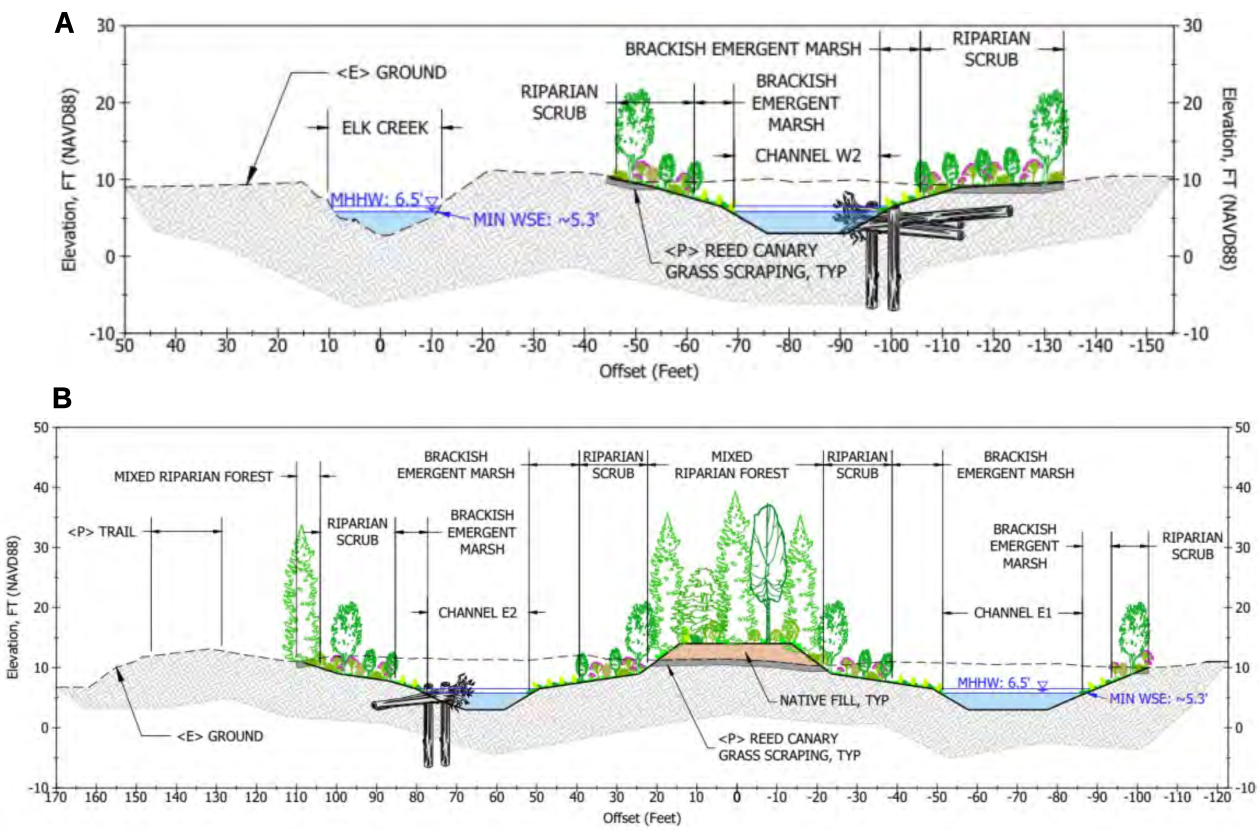

Figure 3-4. Conceptual cross sections of restoration grading and native revegetation zones in the (A) west grading and (B) east grading areas of design Alternative 2. See Conceptual Design Plans in Appendix A for additional cross sections.

4 DESIGN FEASIBILITY, RISK, AND CONSTRUCTION CONSTRAINTS

Preliminary feasibility and potential impacts were assessed to identify Project risks and construction constraints, and to support design development consistent with Project goals and appropriate risk management. The assessments described below will be further developed during later design phases. Additional assessments that may also occur during later design phases include:

- Wood stability analysis
- Updated hydraulic modeling, per design modifications
- Additional groundwater level monitoring
- Additional soil investigation
- Geotechnical soil analysis to evaluate potential settlement, and subgrade strength conditions for bridge foundations and trails

4.1 Excavation Slopes

In general, cut slopes excavated for the new tidal channels are graded at 3:1 (H:V) and no steeper than 2.5:1. These slopes are within the range of typical angles of repose for the low density alluvial sandy soils encountered in the boreholes. Some cut slopes may experience localized sloughing on the newly constructed banks. This sloughing is anticipated and allowable considering the extent and magnitude are expected to be minor. The Project Area is in a very low gradient estuary setting where flow velocities are low and channel bank erosion is uncommon, especially once vegetated. The tidal channel grading is designed using an equilibrium geometry approach that is based on the tidal prism (see Section 3.3). Therefore, the channels are not expected to substantially widen due to the hydraulic forces from daily tidal flooding and ebbing. And minor amounts of sediment sloughed from channel banks will be able to mobilize due to the transport capacity inherent in sizing the tidal channels using the equilibrium geometry approach. Site stabilization measures will be designed to provide immediate erosion prevention following construction and long-term bank stabilization will be accomplished with revegetation.

4.2 Construction Logistics and Site Access

Construction logistics related to equipment use, phasing, and site access routes will vary based on location within the Project Area and restoration actions.

Regardless of which design alternative is selected as preferred, heavy equipment will need to access the Wildlife Area, which should occur at the end of either 2nd or 3rd St. Temporary access routes will have to be established and should utilize the proposed trail corridor if that option is selected. Additional access routes may be desired by contractors, and they can be aligned through areas with invasive vegetation (Himalayan blackberry, RCG, and other nonnative grasses) to reduce impacts to native plants. Some large alder trees will have to be removed that are within the grading footprints in Alternatives 2 and 3, and to provide equipment access. These trees can be used for the proposed terrestrial wood structures. Using traditional earthworks equipment (e.g., excavator, dozer, and wheeled haul truck) should be feasible for the proposed grading, although specialized equipment (e.g., long-reach excavator, wide-track excavator, and tracked haul truck) may be advantageous to reduce ground impacts.

Excavating tidal channels should occur during the driest months of the year (i.e., August, September, and early October) when groundwater levels will be lowest. Tidal channels should be excavated prior to opening the floodplain connections into Elk Creek. Even with using this construction phasing approach, water levels in the tidal channel excavations will fluctuate daily with the tide due to permeable sandy soils across the Project Area. The tidal channels may need to be constructed in zones by installing temporary cofferdams (e.g., sheet piles and/or super sacks) and dewatering active excavations.

The former Hobbs, Wall & Co. sawmill site between 2nd and 3rd streets is an ideal contractor staging area considering it is already compacted ground with primarily gravel and grass. For invasive plant management activities on the south side of the creek, staging areas could be located in clearings on CDFW property behind businesses on Hwy 101 and just off Elk Valley Rd.

4.3 Utilities

There are no overhead utilities and no known buried utilities crossing the Project Area. Overhead and buried utilities are located around the southern and western margins of the Project Area along the urban-wildland interface. However, these utilities should not present conflicts for any of design alternatives based on their current configurations. Specifically identifying and mapping utilities will happen during later design phases.

4.4 Geologic Hazards

4.4.1 Seismicity

Potential seismic hazards in the Project Area include, but are not limited to: (1) ground rupture due to proximity of a known active fault hazard zone, (2) the anticipated magnitude and peak acceleration of a large seismic event, and (3) liquefaction.

The risk of ground rupture is negligible because the Project Area is approximately 7 to 9 miles from the nearest known active fault (i.e., offshore Saint George fault). This fault is not close enough to the Project Area to produce surface rupture. See SRA and Stillwater (2021) for further discussion of regional tectonics and pre-Quaternary faults (i.e., less likely to present a seismic hazard) in the area.

The Project Area is susceptible to strong ground motion from an earthquake either on one of the offshore thrust faults or, particularly, from a Cascadia Subduction Zone megathrust event. During a large seismic event, it is possible that steeper cut or fill slopes within the Project Area could experience localized instability (e.g., sloughing). The conceptual grading follows nature-based approaches of similar habitat types that occur throughout the north coast (i.e., tidal channels and ponds, coastal marshes, etc.), which have experienced presumably numerous large seismic events during Quaternary time, and have geomorphic forms and processes influenced by seismicity. However, it is necessary that appropriate finish slopes, compactions, and soil material properties are determined for the final plans and specifications, which will occur during later design phases. The final designs and specifications should promote slope stability during ground acceleration caused by a seismic event and the overall risks to the project are low.

Liquefaction has the potential to occur in the Project Area. Liquefaction is the loss of soil strength, resulting in fluid mobility through the soil. Liquefaction typically occurs when uniformly sized, loose, saturated sands or silts are subjected to repeated shaking in areas where the groundwater is near the ground surface. In addition to the necessary soil and groundwater conditions, the ground acceleration must be high enough and the duration of the shaking must be sufficient for liquefaction to occur. The site subsurface stratigraphy contains loose uniform sands that are susceptible to liquefaction. Other units exposed in boreholes at the site consist of more cohesive, moderately graded, and denser soils with a lower potential for liquefaction to occur. Considering the project involves habitat restoration and modification of non-essential infrastructure, the risks associated with large and infrequent seismic events are low.

Site specific seismic design criteria in accordance with ASCE/SEI 7-22, or equivalent, will be evaluated in later design phases for the bridges if they are included in a preferred alternative (ASCE 2022).

4.4.2 Tsunami

Similar to the FEMA flood hazard zone, the majority of the Elk Creek valley bottom is within the tsunami hazard area (State of California 2021). The State evaluated multiple rupture scenarios on the Cascadia Subduction Zone up to a magnitude 9.0 (M9.0) full rupture megathrust event, as well as distant source tsunamis from other subduction zone tectonic plate boundaries in the Pacific Ocean. The tsunami hazard area (see Figure 2-2) corresponds to the “worst-case” tsunami scenario, which has a 975-year average return period.

During the worst-case scenario, the entire Project Area will be inundated. During smaller magnitude tsunamis, surges flowing into the Project Area may be reduced by the bypass swales included in Alternatives 2 and 3. Although the potential impacts from a large tsunami could be significant, this risk is acceptable considering the project involves habitat restoration and modification of non-essential infrastructure.

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Appendices

Appendix A

Conceptual Design Plans

LOWER ELK CREEK WETLAND ENHANCEMENT PROJECT

DEL NORTE COUNTY, CA

30% CONCEPTUAL DESIGN DRAWINGS

MAY 2025

Sheet List	
Sheet Number	Sheet Title
1	TITLE
2	LEGEND & ABBREVIATIONS
3	EXISTING CONDITIONS
PROPOSED CONDITIONS - ALTERNATIVE 1	
4	ALTERNATIVE 1 - PLAN OVERVIEW
5	ALTERNATIVE 1 - PLAN 1 OF 2
6	ALTERNATIVE 1 - PLAN 2 OF 2
PROPOSED CONDITIONS - ALTERNATIVE 2	
7	ALTERNATIVE 2 - PLAN OVERVIEW
8	ALTERNATIVE 2 - PLAN 1 OF 2
9	ALTERNATIVE 2 - PLAN 2 OF 2
PROPOSED CONDITIONS - ALTERNATIVE 3	
10	ALTERNATIVE 3 - PLAN OVERVIEW
11	ALTERNATIVE 3 - PLAN 1 OF 3
12	ALTERNATIVE 3 - PLAN 2 OF 3
13	ALTERNATIVE 3 - PLAN 3 OF 3
PROFILES & SECTIONS	
14	PROFILES - 1 OF 2
15	PROFILES - 2 OF 2
16	SECTIONS - 1 OF 2
17	SECTIONS - 2 OF 2
DETAILS	
18	DETAILS (1)
19	DETAILS (2)

PREPARED FOR:

SMITH RIVER ALLIANCE
P.O. BOX 2129
CRESCENT CITY, CA 95531
INFO@SMITHRIVERALLIANCE.ORG

PREPARED BY:

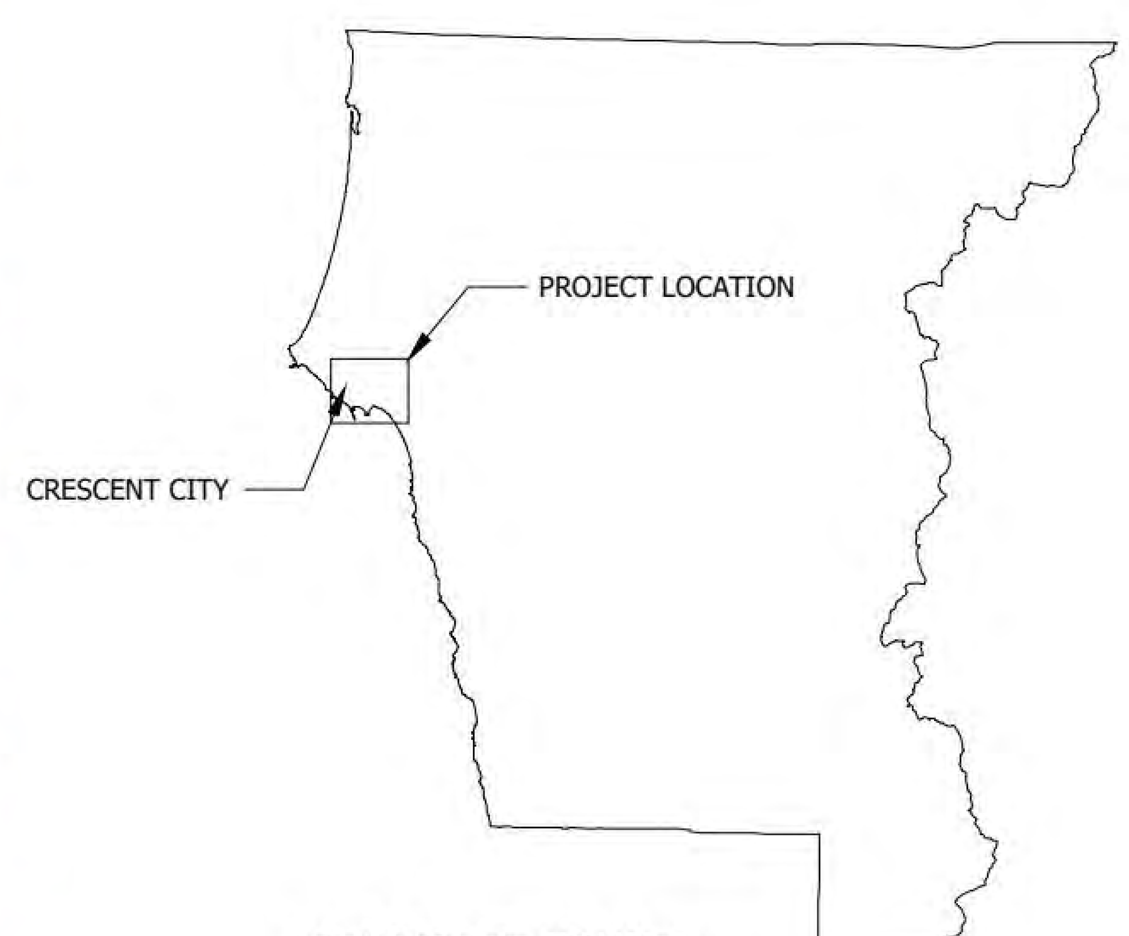
STILLWATER SCIENCES
850 G STREET SUITE K
ARCATA, CA 95521
(707) 822-9607

PROJECT FUNDED BY:

NATIONAL FISH AND WILDLIFE FOUNDATION
NATIONAL COASTAL RESILIENCE FUND

NFWF GRANT ID: 0318.23.075781

PROJECT LOCATION MAP



DEL NORTE COUNTY
NTS

CALIFORNIA
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LOWER ELK CREEK WETLAND ENHANCEMENT PROJECT

DEL NORTE COUNTY, CA

Stillwater Sciences
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REVISIONS		
NO.	DESCRIPTION	DATE

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CONCEPTUAL DESIGN DRAWINGS

NOT FOR CONSTRUCTION

PROJECT NUMBER: 836.02
SCALE: AS NOTED
DATE: 5/6/2025

DESIGN: BW/DC
DRAWN: JB/CD/CG
CHECKED: DC
APPROVED: JM

TITLE

SHEET 1 OF 19

LEGEND AND SYMBOLS

PLAN

- MAJOR CONTOUR
- MINOR CONTOUR
- THALWEG ALIGNMENT
- PARCEL BOUNDARY
- CDFW PARCEL BOUNDARY
- HISTORICAL RAILROAD ALIGNMENT
- PROJECT BOUNDARY
- DIRECTION OF FLOW
- <E> FLOWLINES
- <E> ROAD
- <E> ACCESS ROAD
- <E> BUILDINGS
- <P> LIMIT OF GRADING
- <P> POTENTIAL SPOILS MANAGEMENT LOCATION
- <P> TRAIL
- <P> FOOT BRIDGE
- <P> TERRESTRIAL LARGE WOOD STRUCTURES (NOT TO SCALE)
- <P> LARGE WOOD STRUCTURES (NOT TO SCALE)
- 3 — DETAIL # ON SHEET
- 8 — SHEET #

SECTION

- <P> NATIVE FILL
- <P> REED CANARY GRASS SCRAPING

ABBREVIATIONS:

ALT	ALTERNATIVE
APN	ASSESSOR'S PARCEL NUMBER
APPROX.	APPROXIMATE
BMP	BEST MANAGEMENT PRACTICE
CHL, CHNL	CHANNEL
CL	CENTERLINE
CYD	CUBIC YARD
DBH	DIAMETER BREAST HEIGHT
DIA	DIAMETER
DWG	DRAWING
DS	DOWNSTREAM
E	EASTING
<E>	EXISTING
EL, ELEV	ELEVATION
H, HORZ	HORIZONTAL
IE	INVERT ELEVATION
LWS	LARGE WOOD STRUCTURE
MAX	MAXIMUM
MIN	MINIMUM
MSE	MECHANICALLY STABILIZED EARTH (WALL)
N	NORTHING
NIC	NOT IN CONTRACT
NOM	NOMINAL
NTS	NOT TO SCALE
<P>	PROPOSED
PP	POWER POLE
QTY	QUANTITY
REST.	RESTORATION
R.C.	RELATIVE COMPACTION
RCG	REED CANARY GRASS
SHT	SHEET
SPEC	SPECIFICATION(S)
STA	STATION
STD	STANDARD
TBD	TO BE DETERMINED
TEMP	TEMPORARY
TOB	TOP OF BANK
TOS	TOE OF SLOPE
TYP	TYPICAL
US	UPSTREAM
V, VERT	VERTICAL
W/	WITH
W/O	WITHOUT
°	DEGREE
#	NUMBER

ASSUME ALL VALUES SHOWN ARE IN FEET (FT) UNLESS OTHERWISE INDICATED.

NOT ALL ABBREVIATIONS APPEAR IN PLANS

EARTHWORK ESTIMATES:

FEATURE	AREA (SQ FT)	RCG SCRAPE (CY)	CUT (CY)	FILL (CY)	NET (CY)
ALTERNATIVE 1					
FLOODPLAIN CONNECTION 1	978	0	21	0	-21
FLOODPLAIN CONNECTION 2	671	0	10	0	-10
FLOODPLAIN CONNECTION 3	2,619	0	122	0	-122
FLOODPLAIN CONNECTION 4	1,604	0	81	4	-78
TOTAL	5,873	0	234	4	-230
ALTERNATIVE 2					
WEST GRADING	81,175	0	6,081	171	-5,910
EAST GRADING	206,567	7,311	22,900	937	-21,963
TOTAL	287,742	7,311	28,982	1,109	-27,873
ALTERNATIVE 3					
WEST GRADING	82,131	0	8,145	130	-8,015
EAST GRADING	206,562	7,311	25,548	1,012	-24,535
SOUTH GRADING	3,561	0	198	8	-190
BRIDGE CROSSINGS	3,700	0	2	164	162
TOTAL	295,954	7,311	33,893	1,314	-32,578

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LEGEND & ABBREVIATIONS

SHEET 2 OF 19

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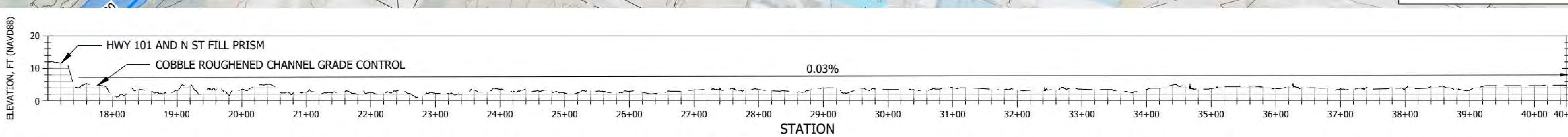
1 ELK CREEK - PLAN
Scale: 1:100



2 ELK CREEK - PROFILE
NTS

PROJECT NUMBER: 836.02
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DESIGN: BW/DC
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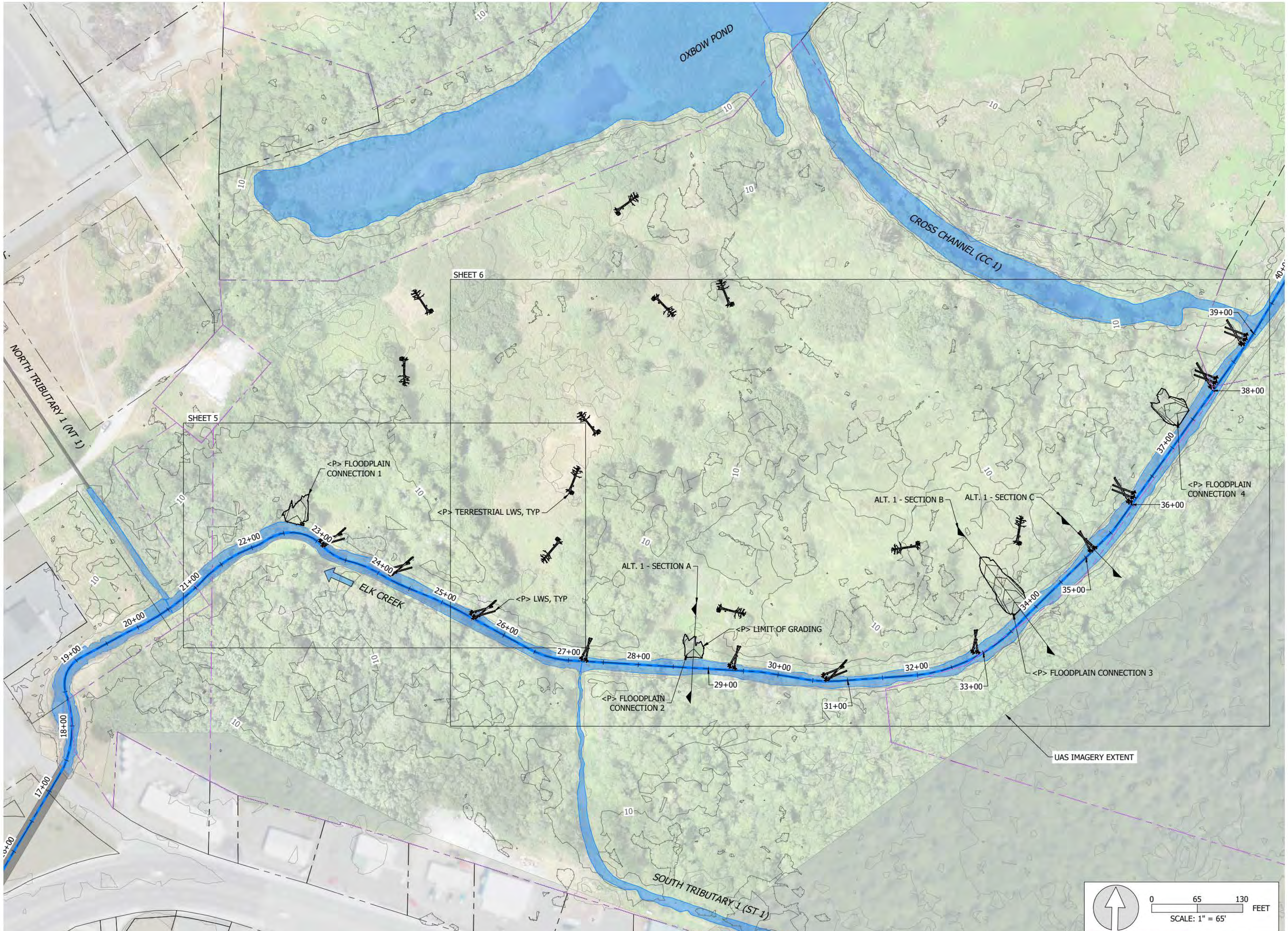
CHECKED: DC
APPROVED: JM

EXISTING CONDITIONS



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NOTE: DESIGN ALTERNATIVE 1 SHOWN WITH TRAIL OPTION A (NO TRAIL), ALTHOUGH ALL TRAIL OPTIONS ARE COMPATIBLE WITH THIS ALTERNATIVE.

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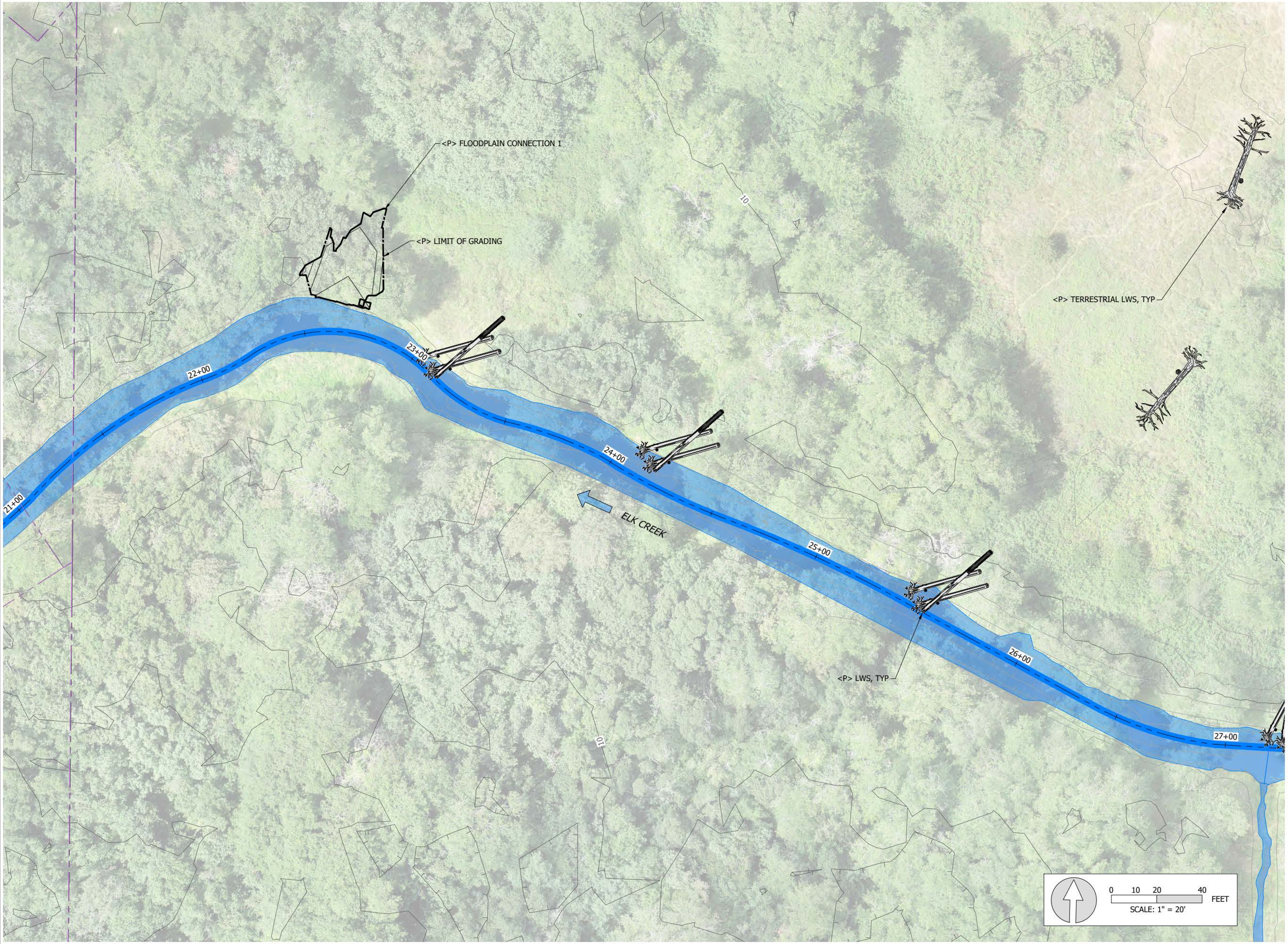
ALTERNATIVE 1 - PLAN OVERVIEW



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ALTERNATIVE 1 - PLAN 1 OF 2

SHEET 5 OF 19

IF BAR DOES NOT MEASURE 1" DRAWING IS NOT TO SCALE – ADJUST ACCORDINGLY

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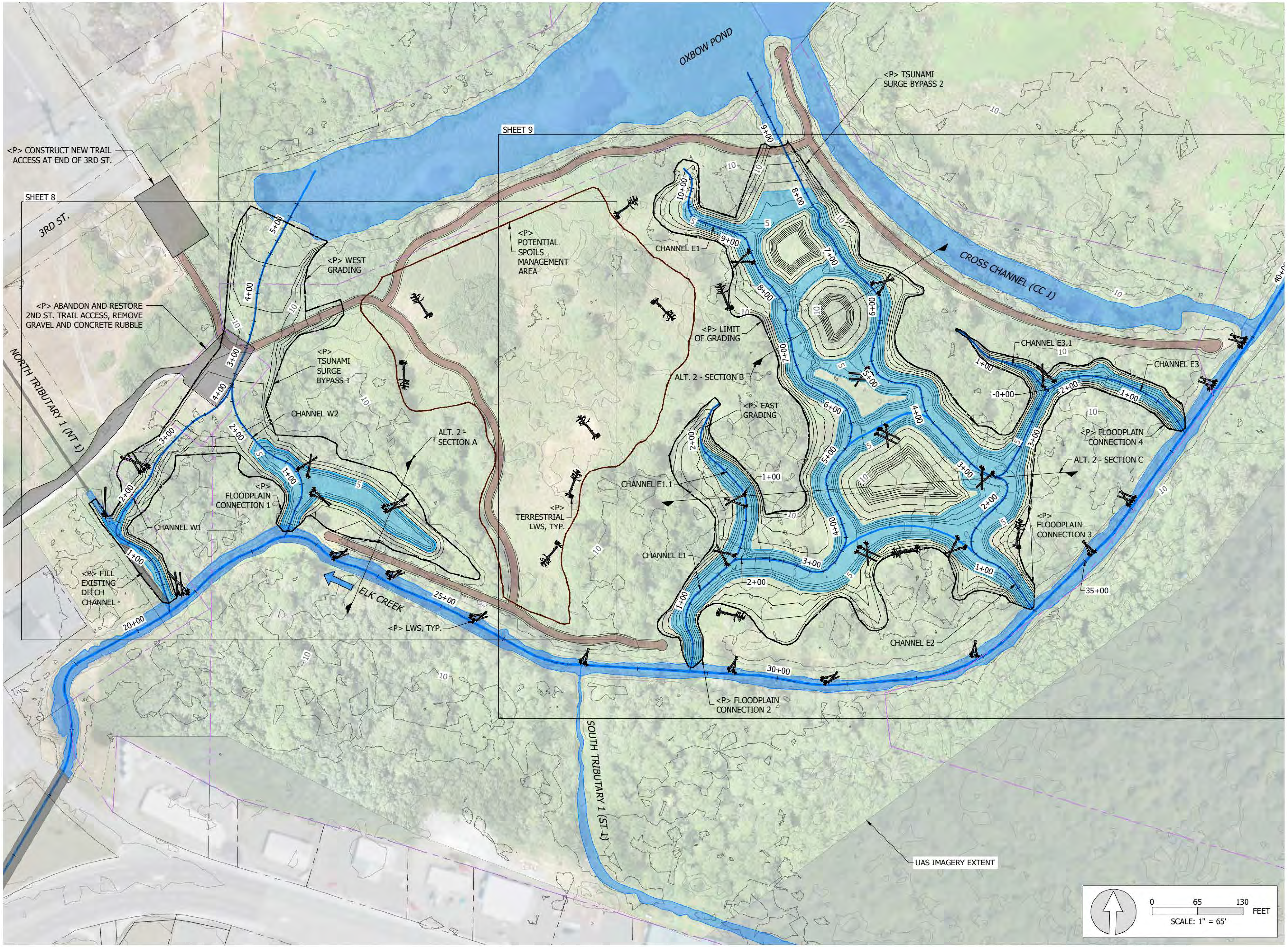
ALTERNATIVE 1 - PLAN 2 OF 2

SHEET 6 OF 19



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NOTE: DESIGN ALTERNATIVE 2 SHOWN WITH TRAIL OPTION B (OUT AND BACK), ALTHOUGH ALL TRAIL OPTIONS ARE COMPATIBLE WITH ALTERNATIVE.

CONCEPTUAL DESIGN DRAWINGS

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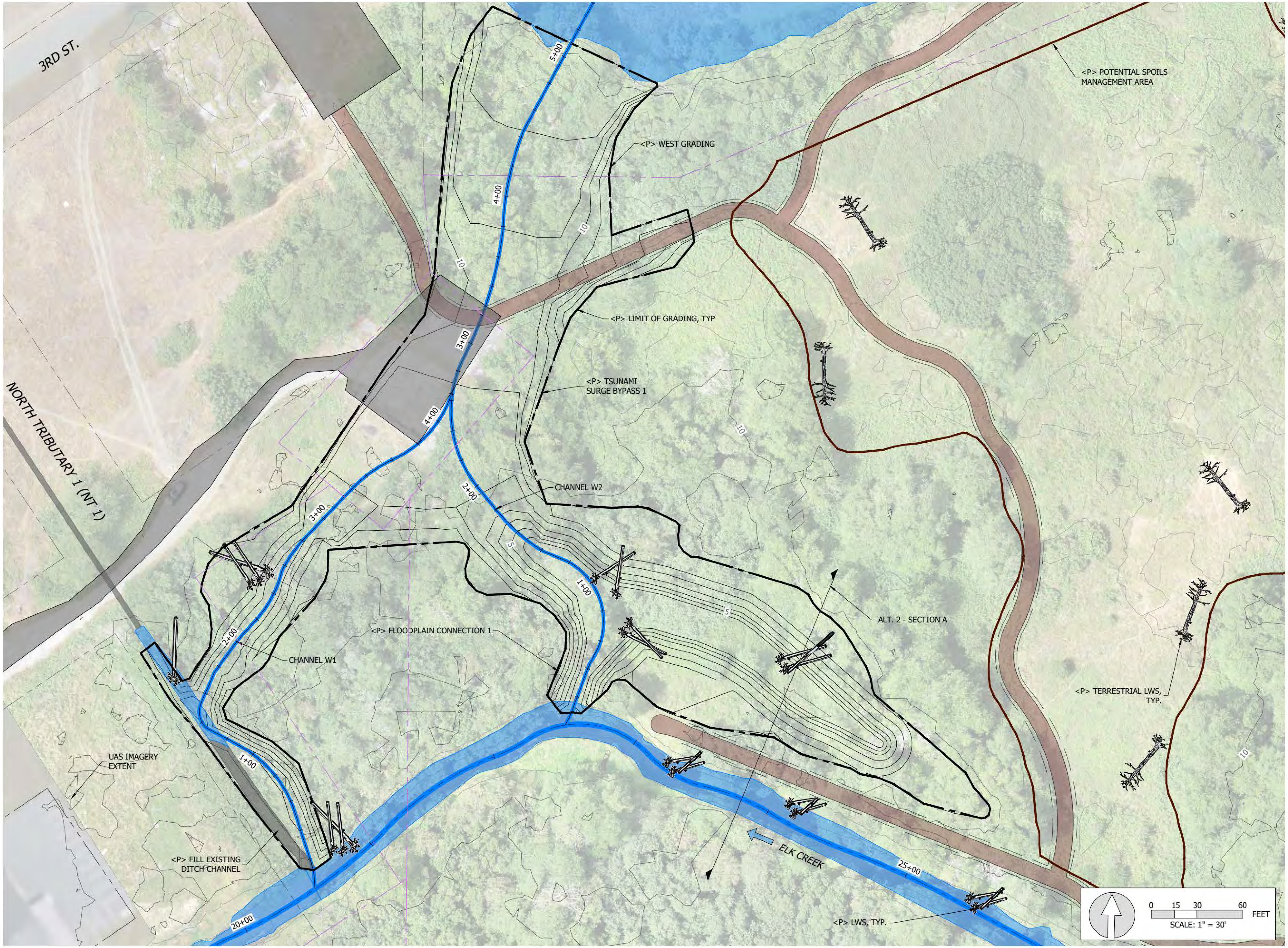
ALTERNATIVE 2 - PLAN OVERVIEW

SHEET 7 OF 19



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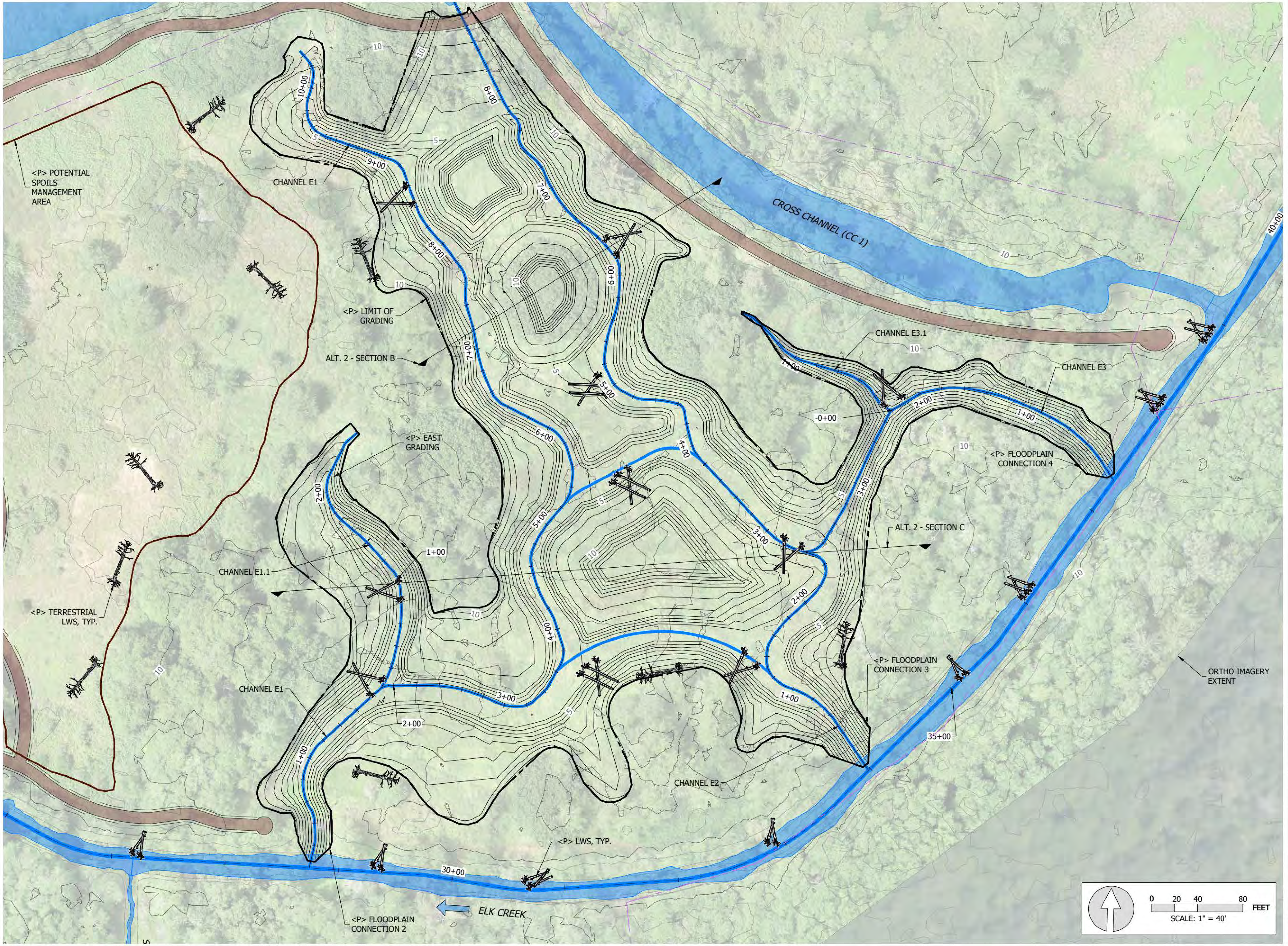
ALTERNATIVE 2 - PLAN 1 OF 2

SHEET 8 OF 19



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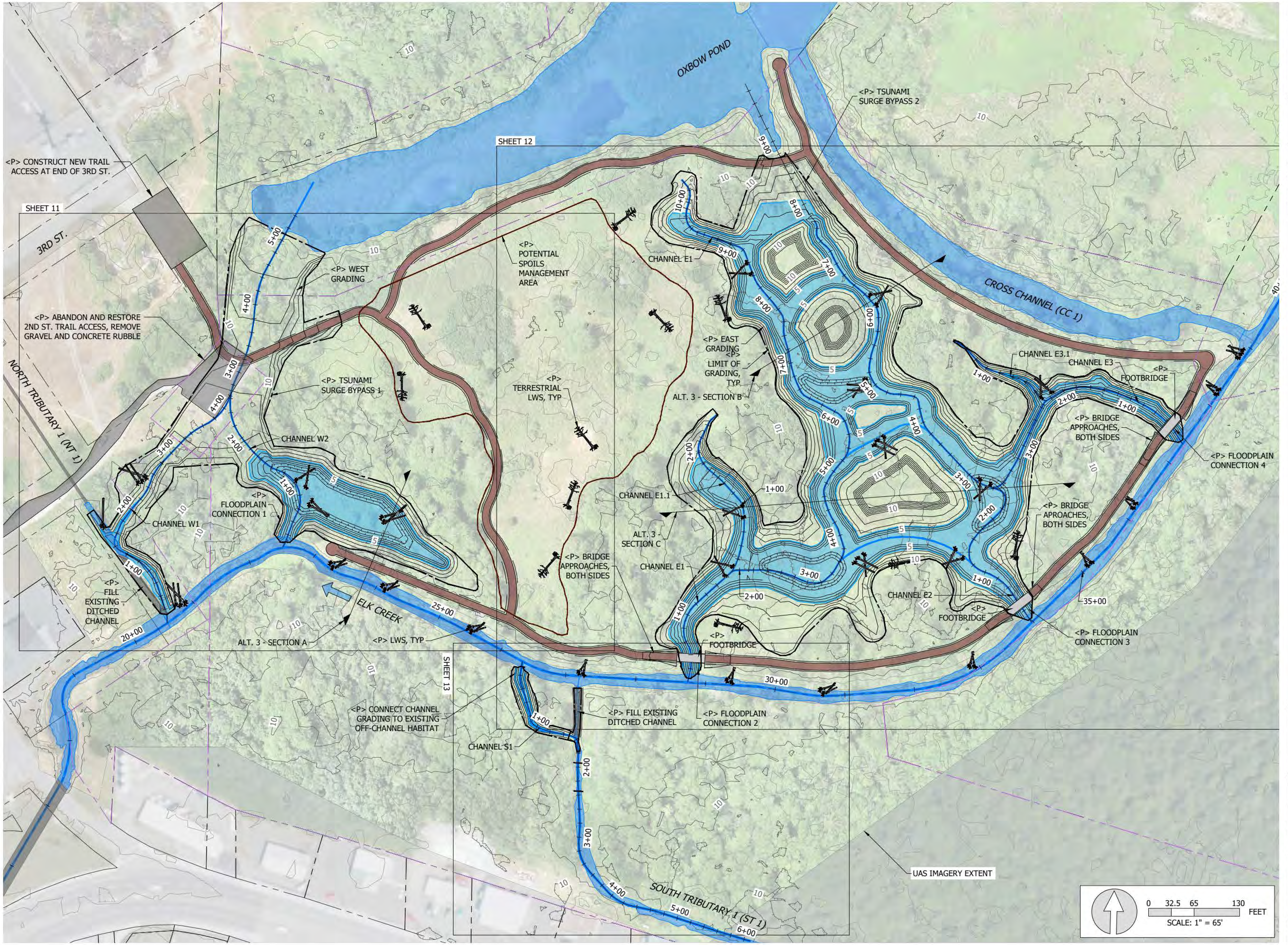
ALTERNATIVE 2 - PLAN 2 OF 2



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NOTE: DESIGN ALTERNATIVE 3 SHOWN WITH TRAIL OPTION C (LOOP TRAIL), ALTHOUGH ALL TRAIL OPTIONS ARE COMPATIBLE WITH ALTERNATIVE.

CONCEPTUAL DESIGN DRAWINGS

NOT FOR CONSTRUCTION

PROJECT NUMBER: 836.02
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DATE: 5/6/2025

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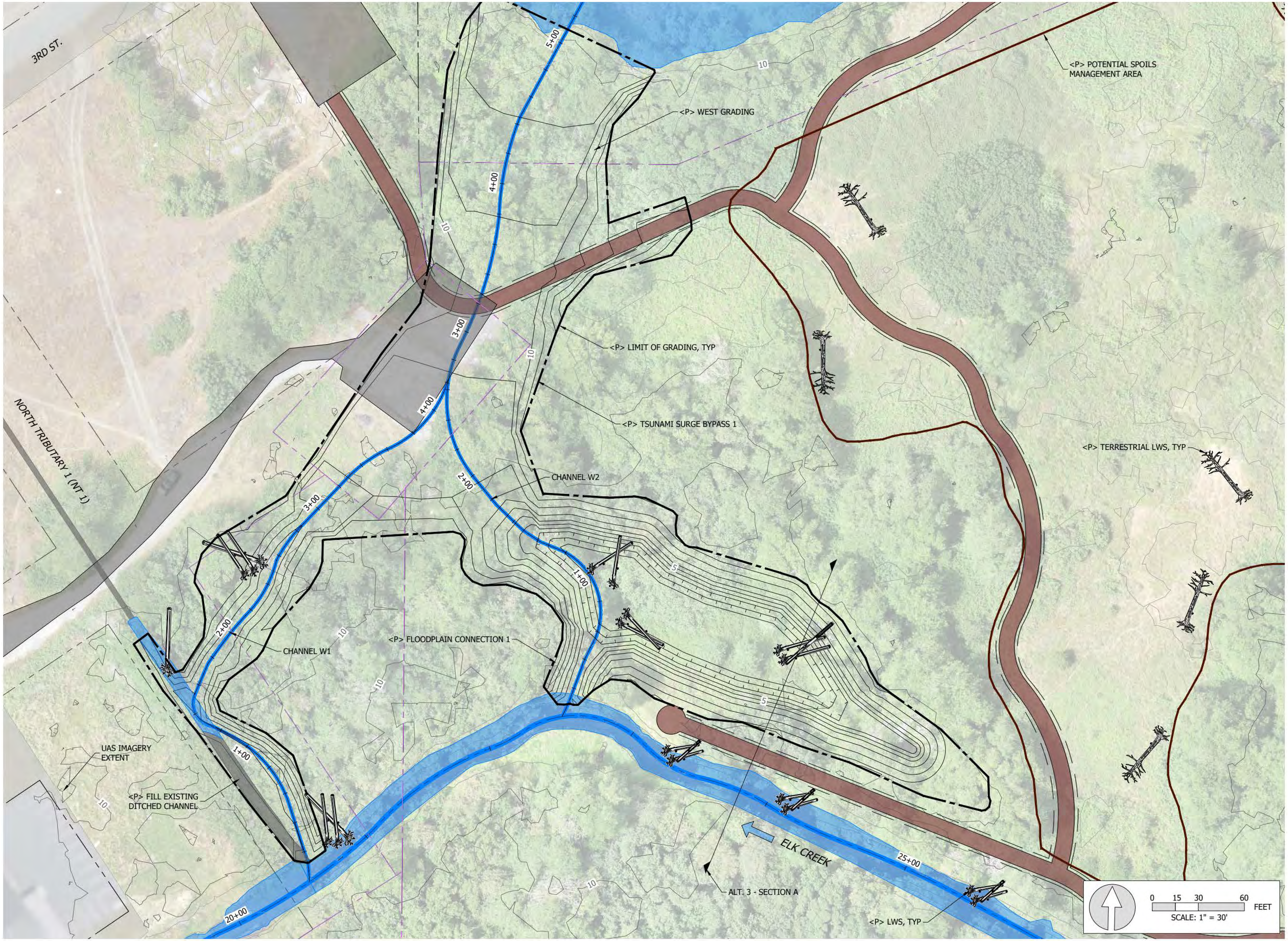
CHECKED: DC
APPROVED: JM

ALTERNATIVE 3 - PLAN OVERVIEW

SHEET 10 OF 19



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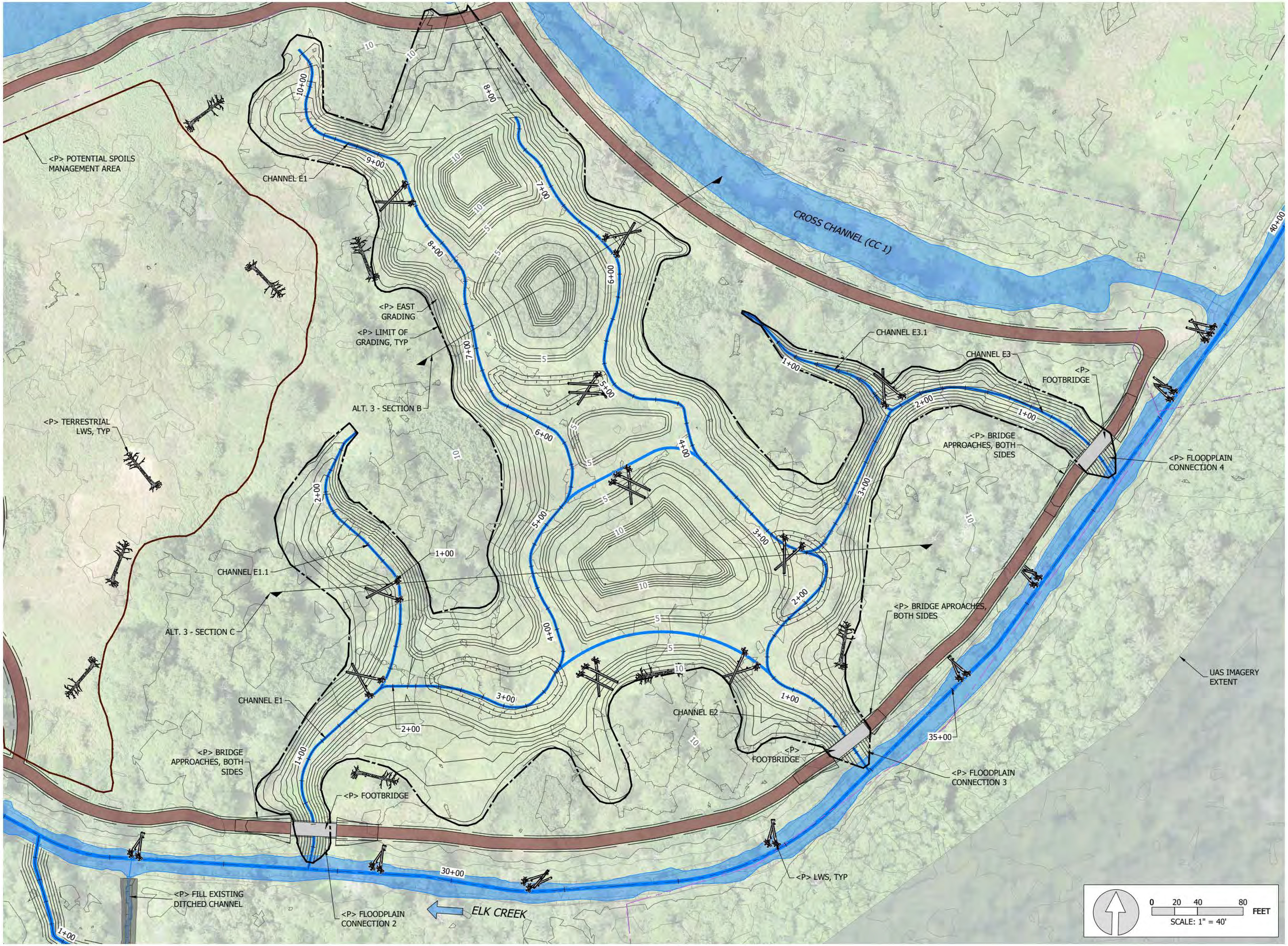
APPROVED: JM

ALTERNATIVE 3 - PLAN 1 OF 3



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ALTERNATIVE 3 - PLAN 2 OF 3

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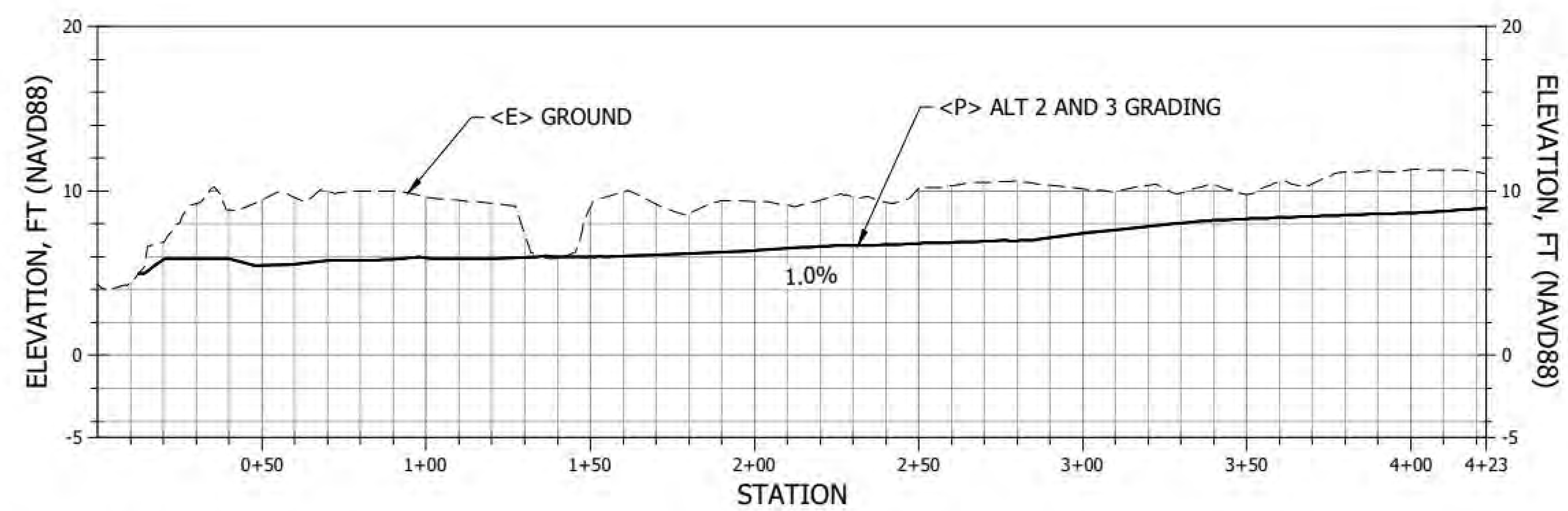
ALTERNATIVE 3 - PLAN 3 OF 3



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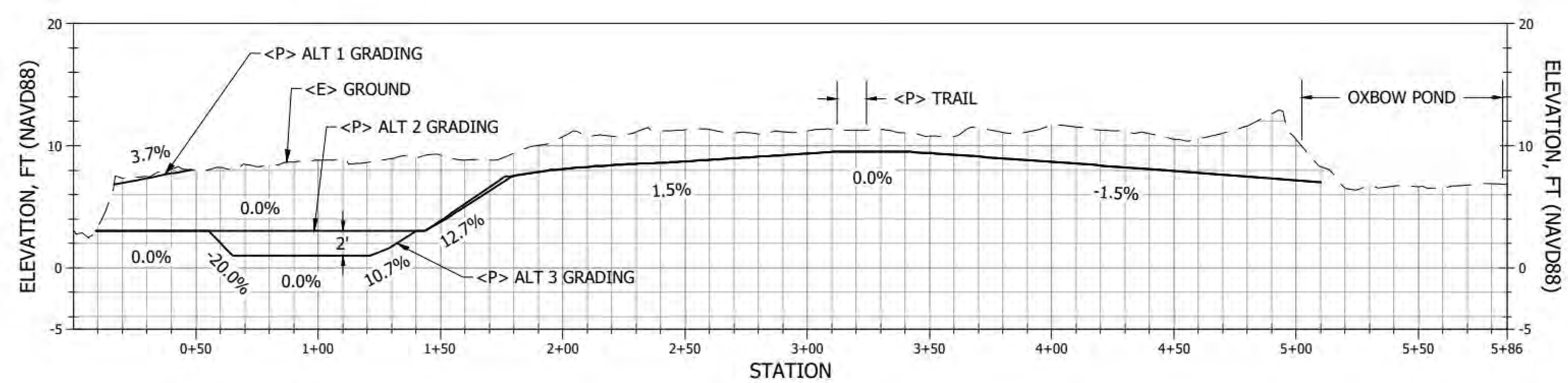

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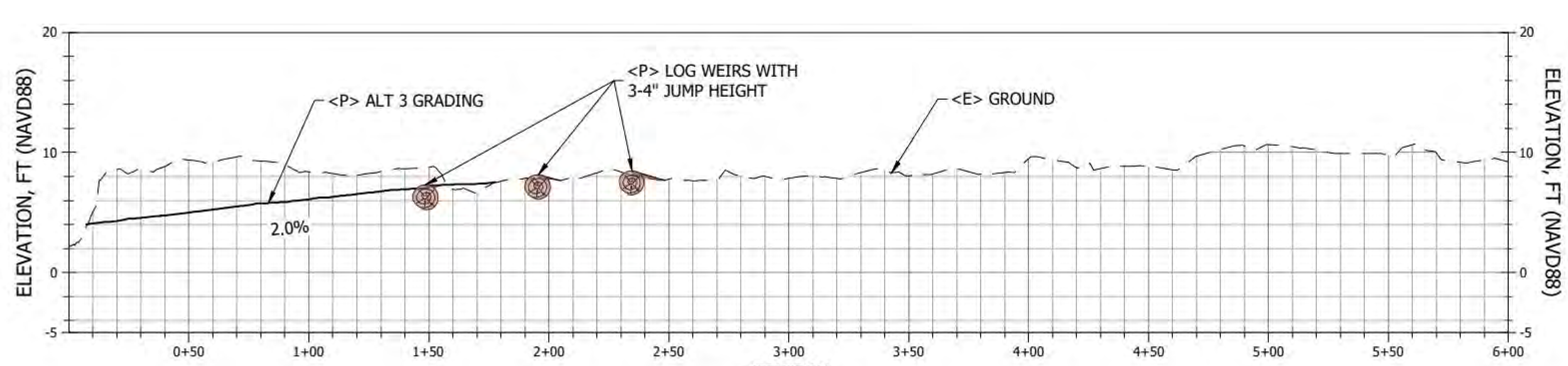

3 CHANNEL S1 (ALT 3 ONLY) - PROFILE
Scale: 1:40

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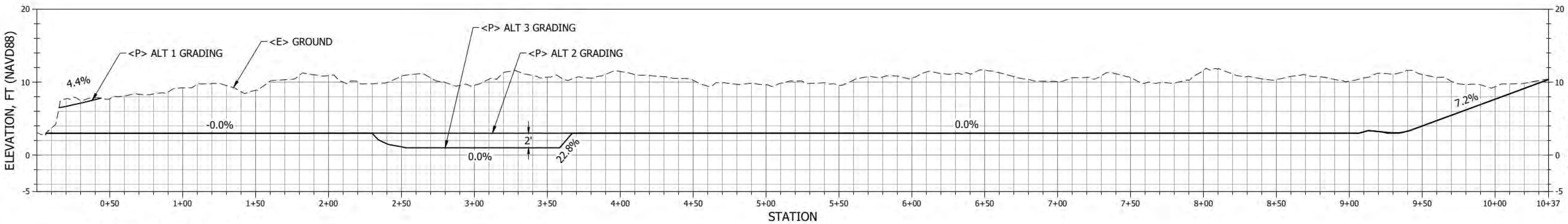
PROFILES - 1 OF 2

SHEET 14 OF 19



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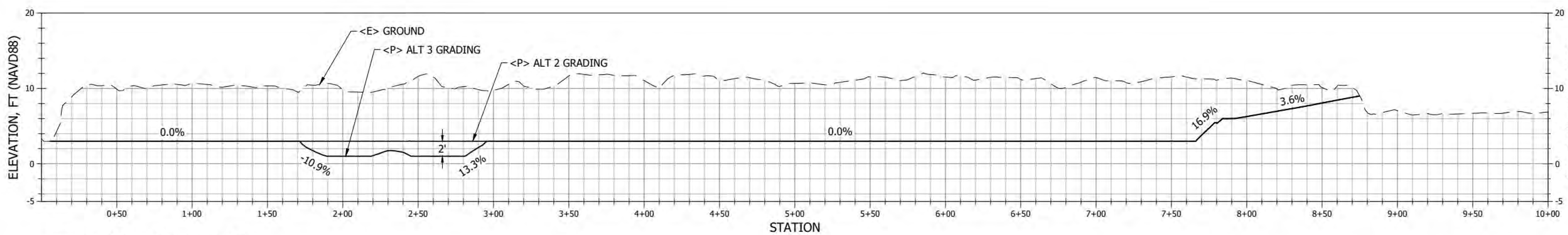

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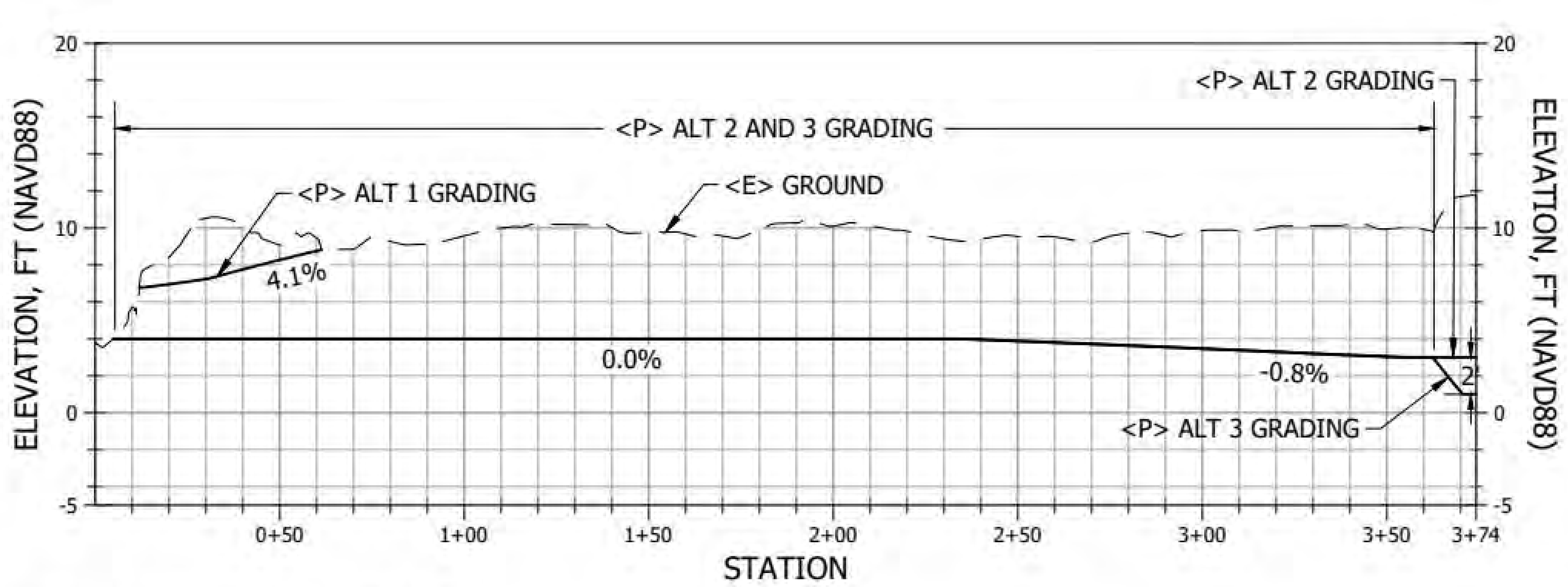

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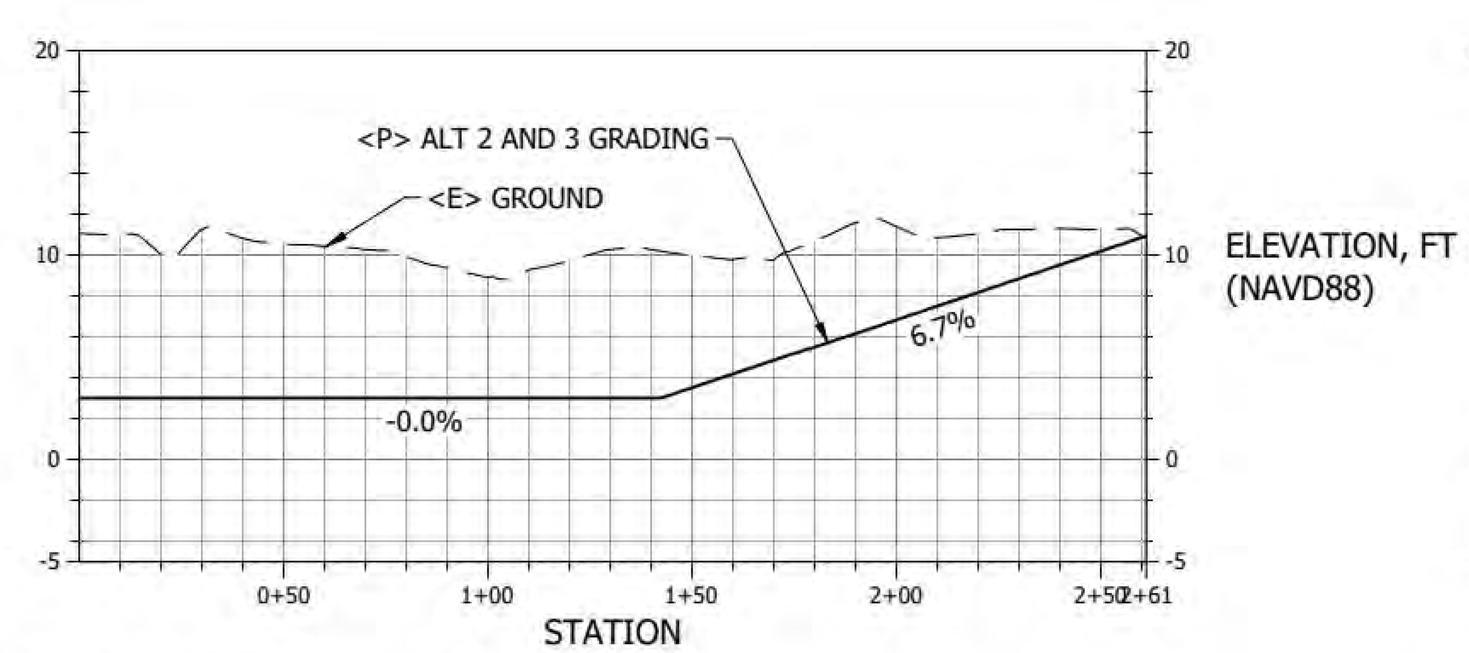

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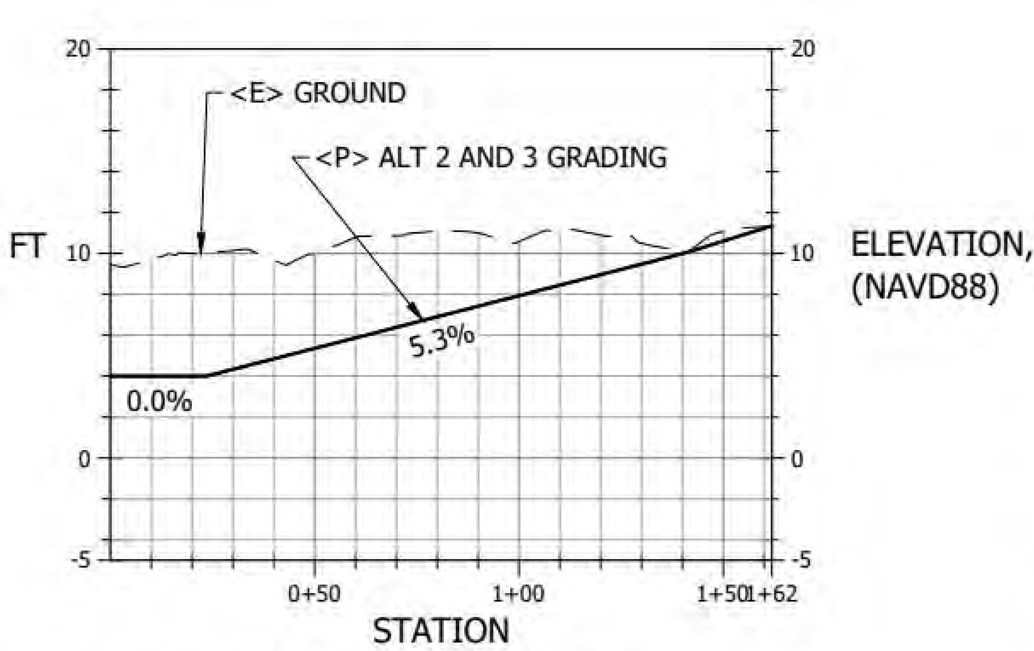

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PROFILES - 2 OF 2

SHEET 15 OF 19

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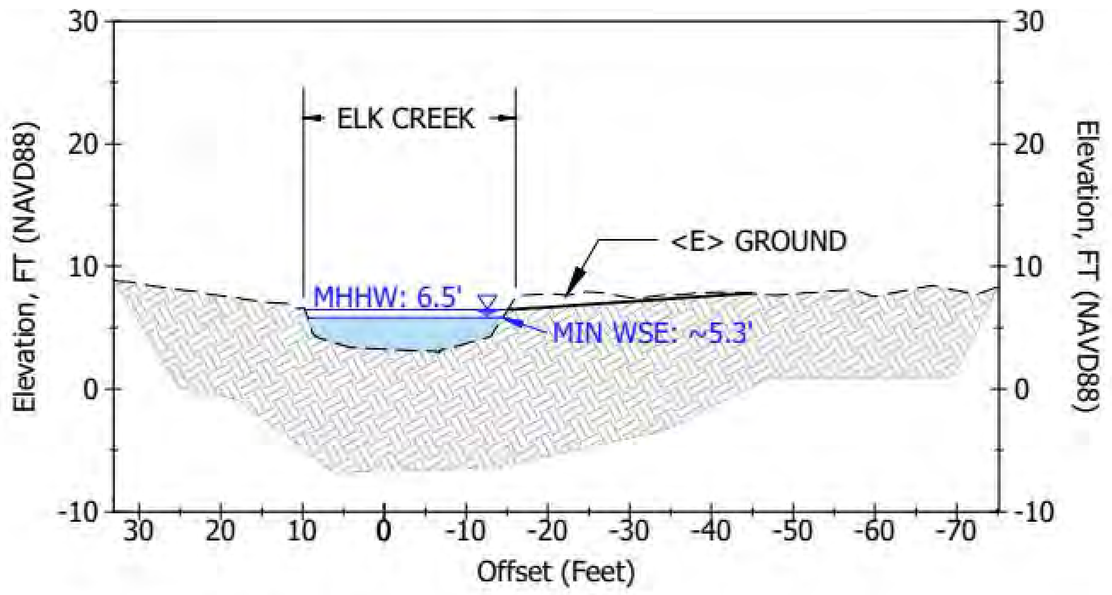

1 ALTERNATIVE 1 - SECTION A
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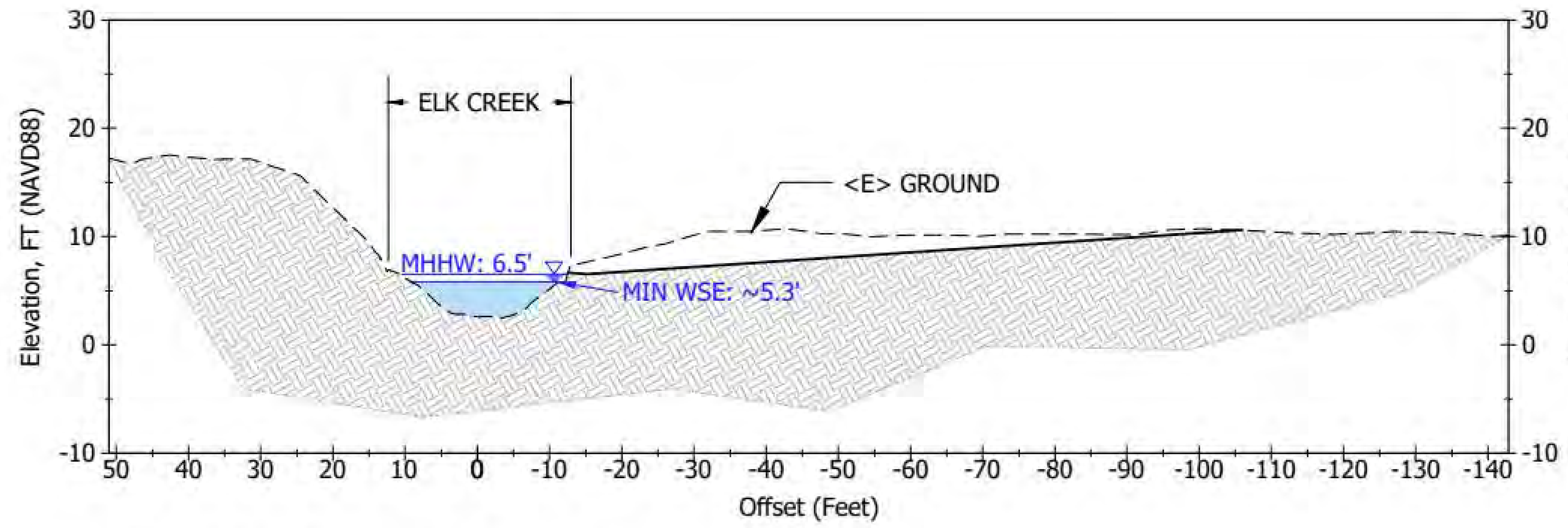

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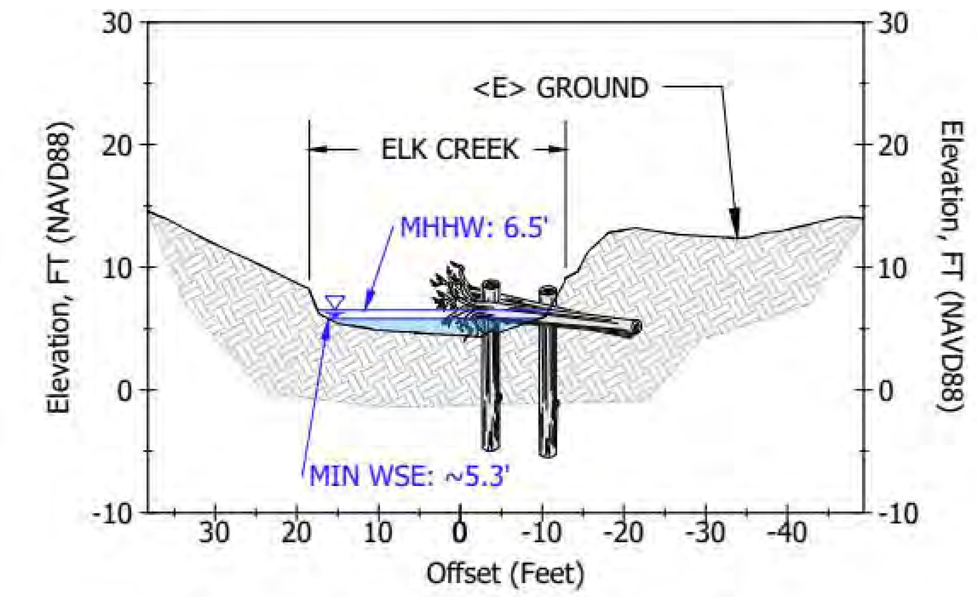
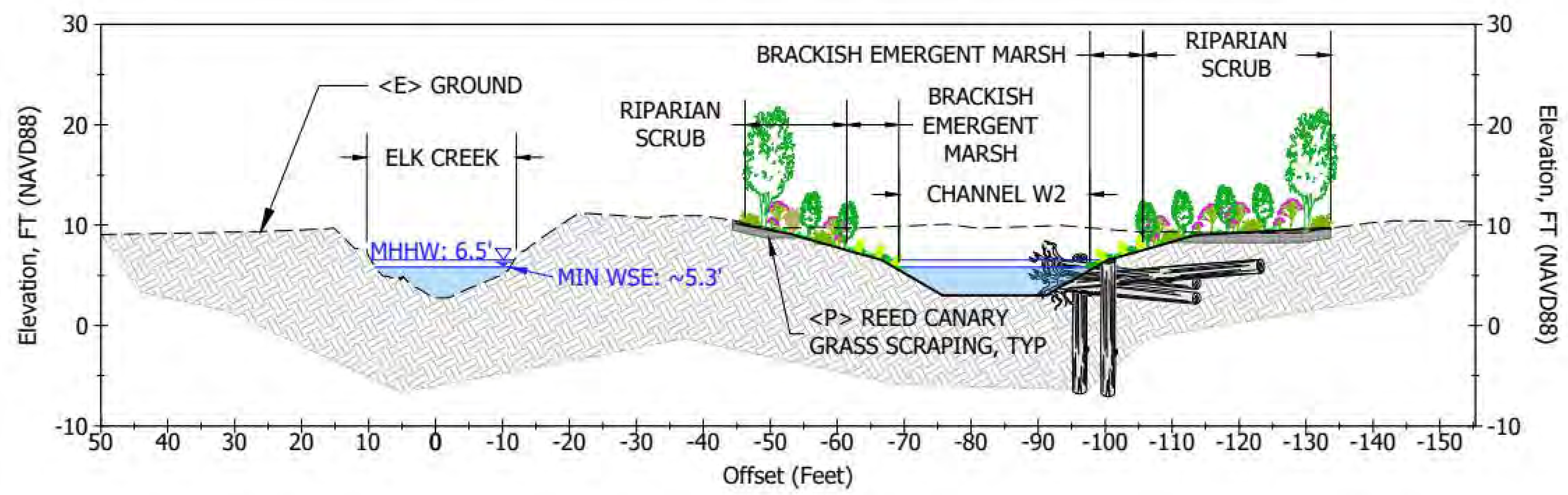


3 ALTERNATIVE 1 - SECTION C
Scale 1:20



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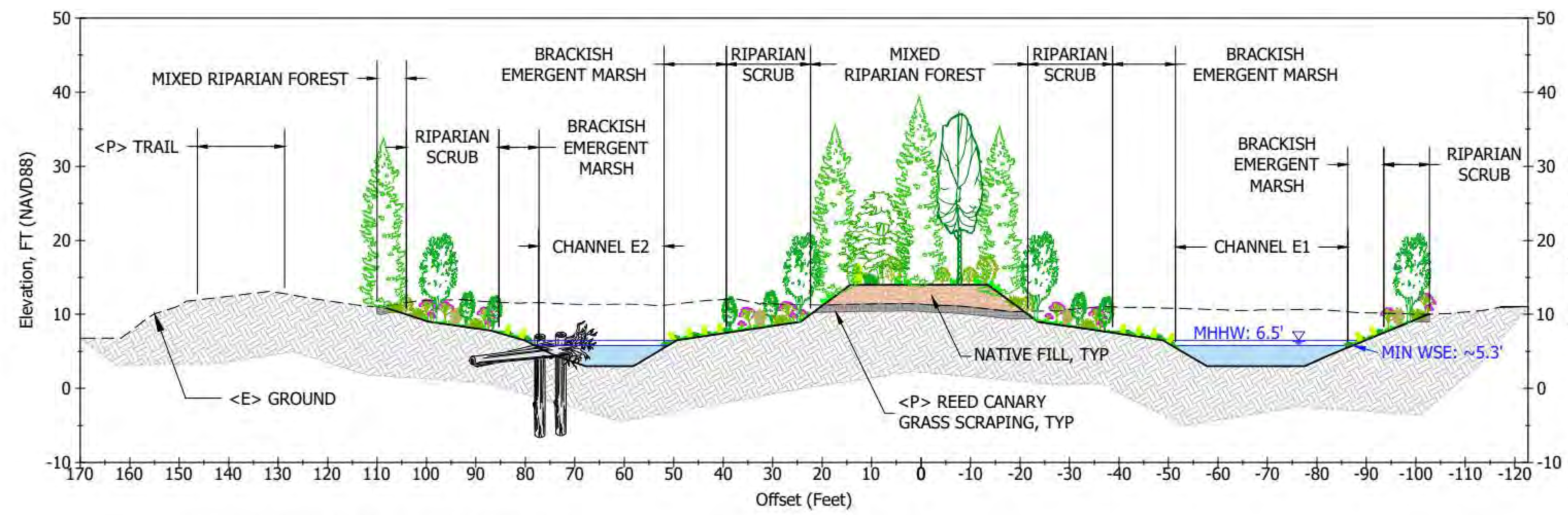
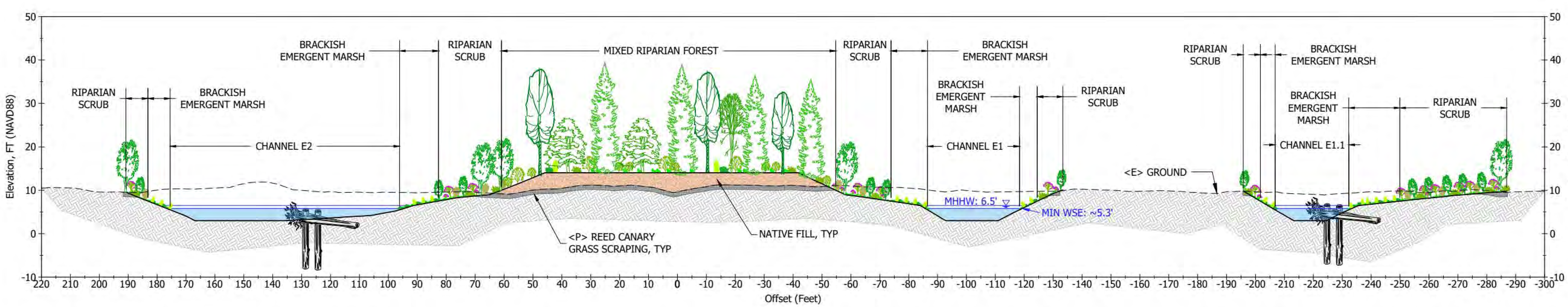


5 ALTERNATIVE 2 - SECTION B
Scale: 1:20

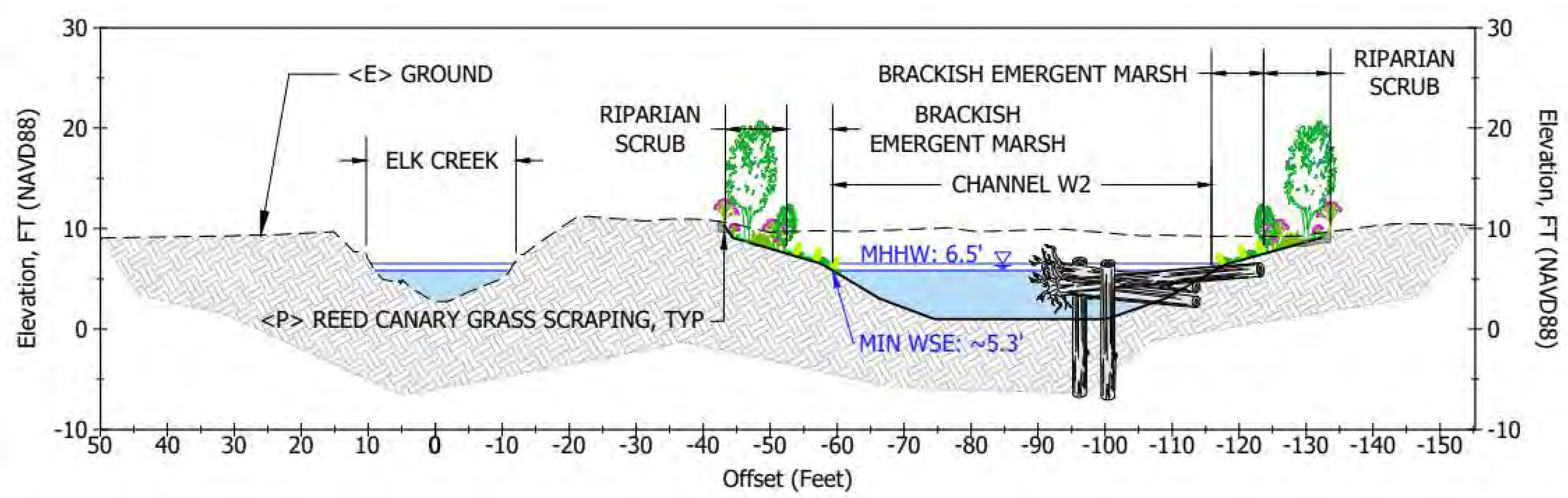


6 ALTERNATIVE 2 - SECTION C
Scale: 1:20

PROJECT NUMBER: 836.02
SCALE: AS NOTED
DATE: 5/6/2025

DESIGN: BW/DC
DRAWN: JB/CD/CG
CHECKED: DC
APPROVED: JM

SECTIONS - 1 OF 2



1 ALTERNATIVE 3 - SECTION A
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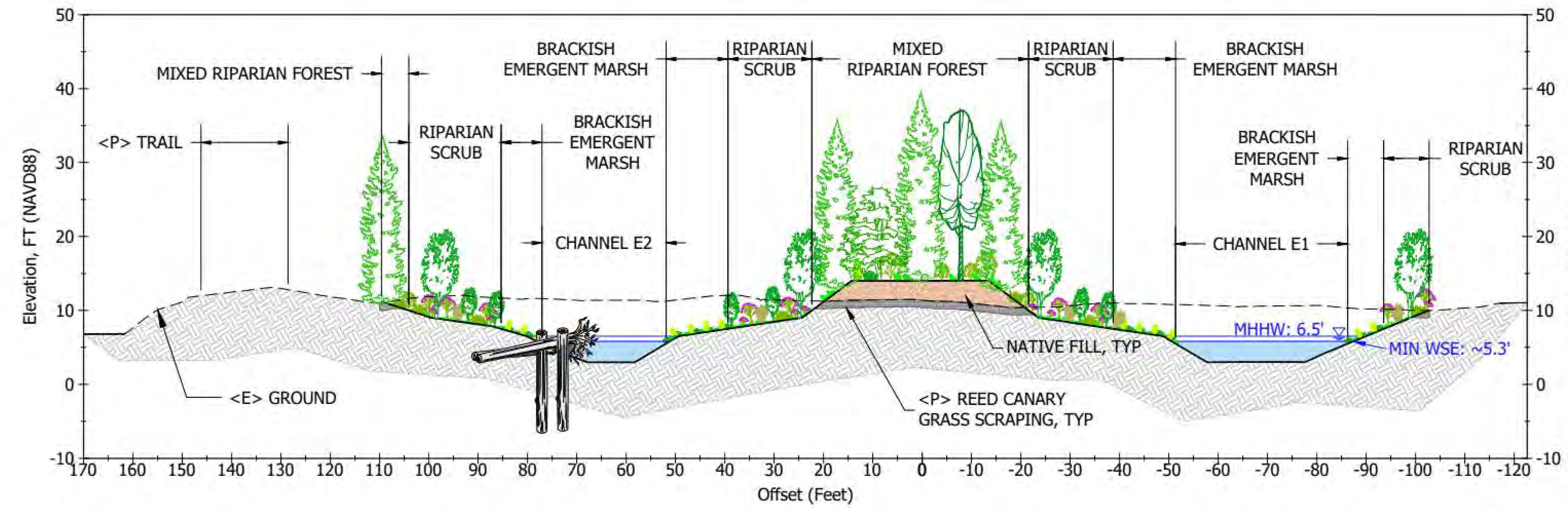
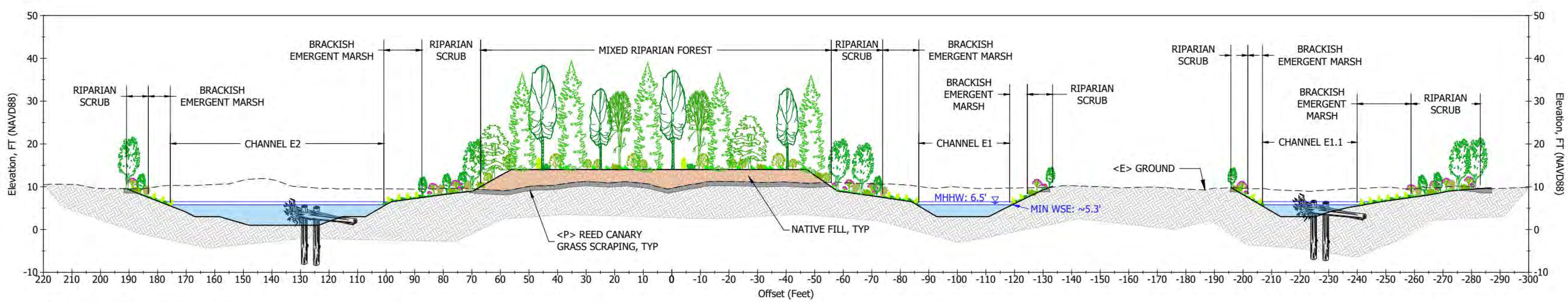


2 ALTERNATIVE 3 - SECTION B
Scale: 1:20



3 ALTERNATIVE 3 - SECTION C
Scale: 1:20

LOWER ELK CREEK WETLAND ENHANCEMENT PROJECT

DEL NORTE COUNTY, CA

Stillwater Sciences
850 G STREET SUITE K
ARCATA, CA 95521
P: (707) 822-9607

REVISIONS

NO.	DESCRIPTION	DATE

SMITH RIVER ALLIANCE

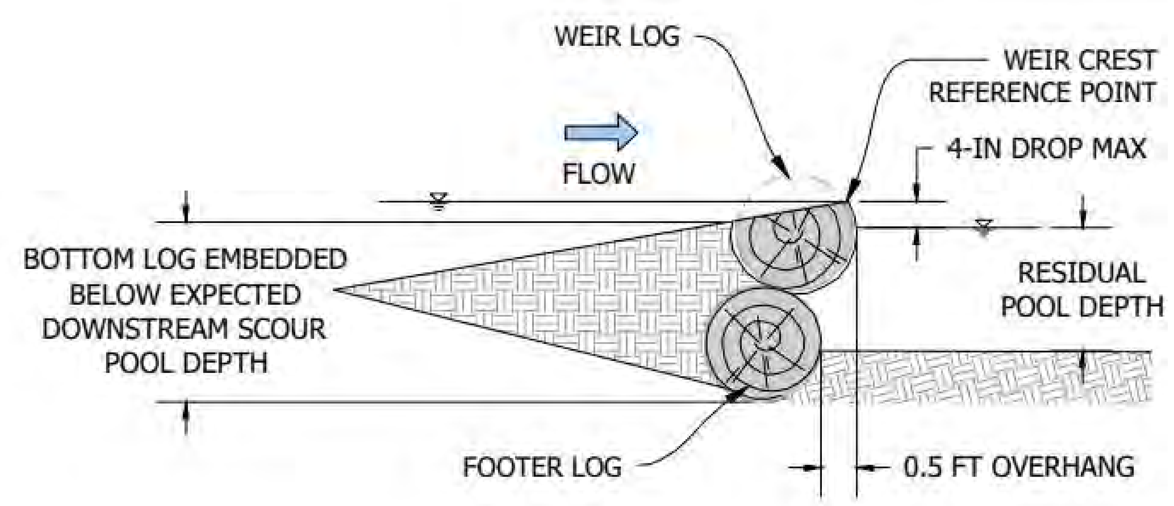
CONCEPTUAL DESIGN DRAWINGS
NOT FOR CONSTRUCTION

PROJECT NUMBER: 836.02
SCALE: AS NOTED
DATE: 5/6/2025

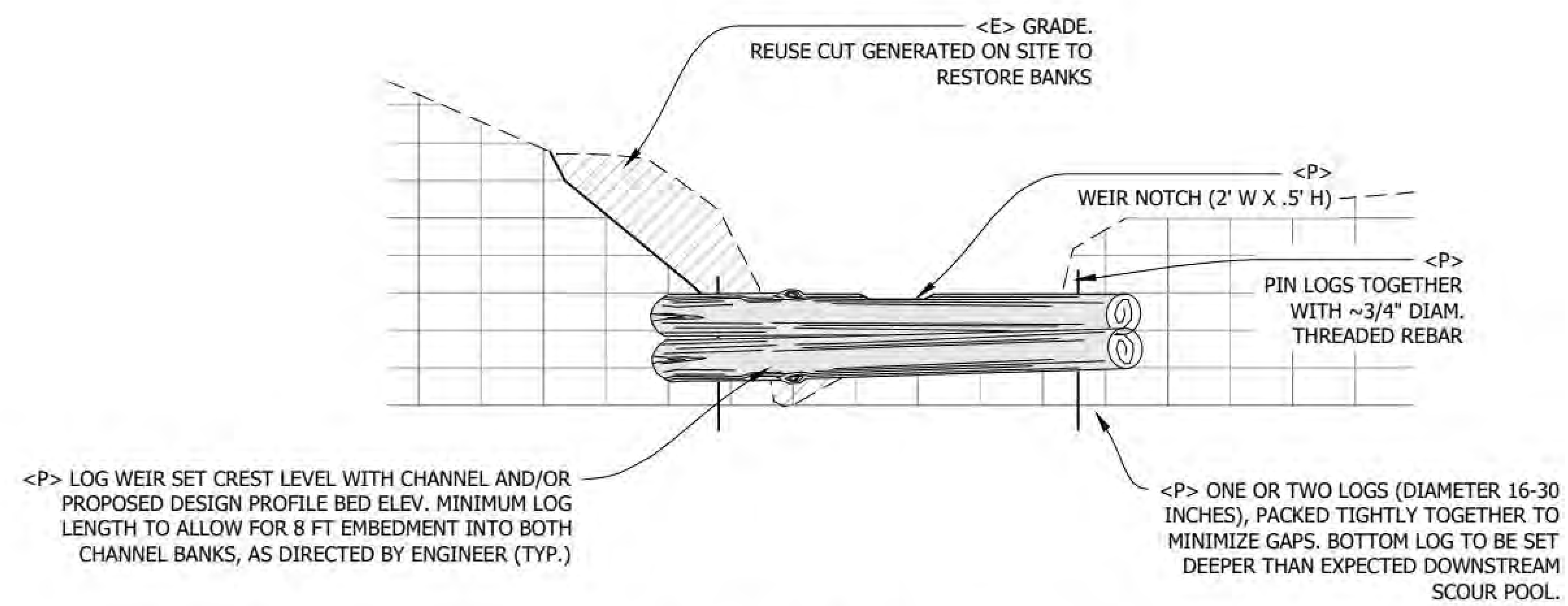
DESIGN: BW/DC
DRAWN: JB/CD/CG
CHECKED: DC
APPROVED: JM

SECTIONS - 2 OF 2

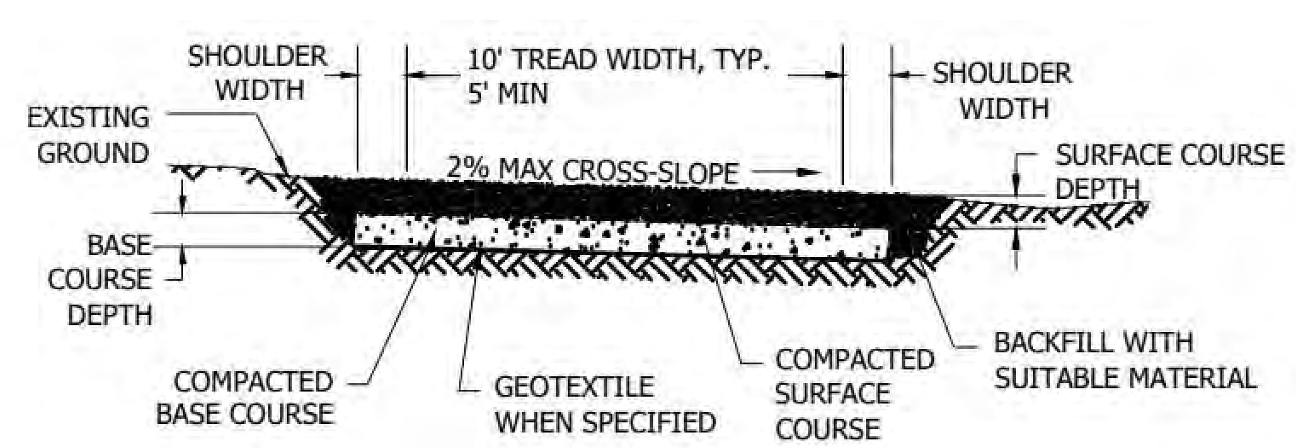
SHEET 17 OF 19



1 **BURIED CHANNEL WEIR**
PROFILE NTS



2 **BURIED CHANNEL WEIR**
SECTION NTS



NOTES:

1. REMOVE AND DISPOSE OF DUFF AND TOP ORGANIC LAYERS DOWN TO NATIVE SOIL.
2. COMPACT BACKFILL IN 6 INCH LIFTS UNTIL NO VISUAL DISPLACEMENT.
3. 5% MAX RUNNING SLOPE REQUIRED UNLESS NOTED ON PLANS.
4. MINIMUM HEADROOM OF 80" REQUIRED ALONG TRAIL ROUTE.

3 **ADA ACCESIBLE TRAIL SURFACING (TYP.) - SECTION**
NTS

LOWER ELK CREEK WETLAND ENHANCEMENT PROJECT

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REVISIONS

NO.	DESCRIPTION	DATE

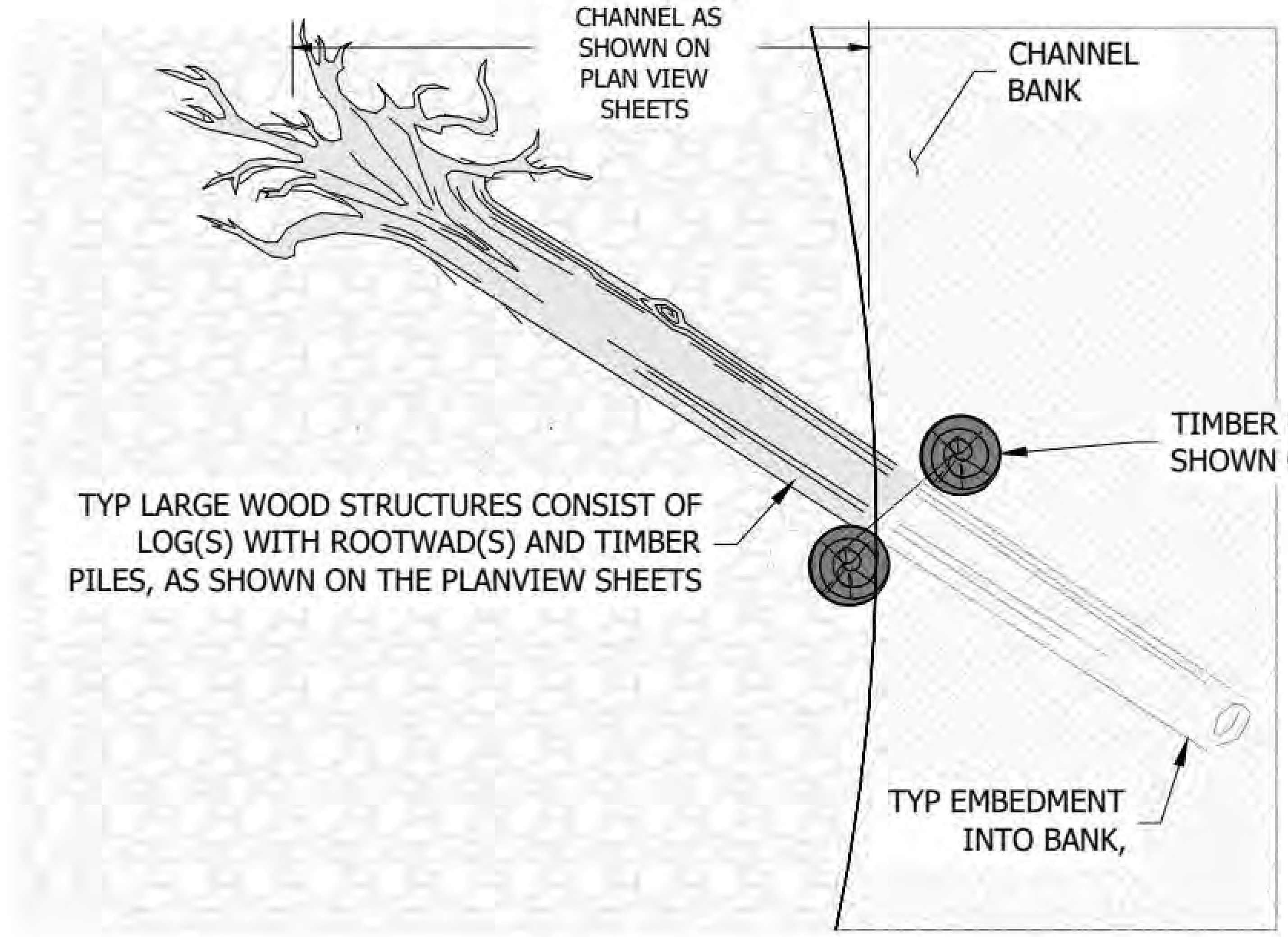
SMITH RIVER ALLIANCE

CONCEPTUAL DESIGN DRAWINGS
NOT FOR CONSTRUCTION

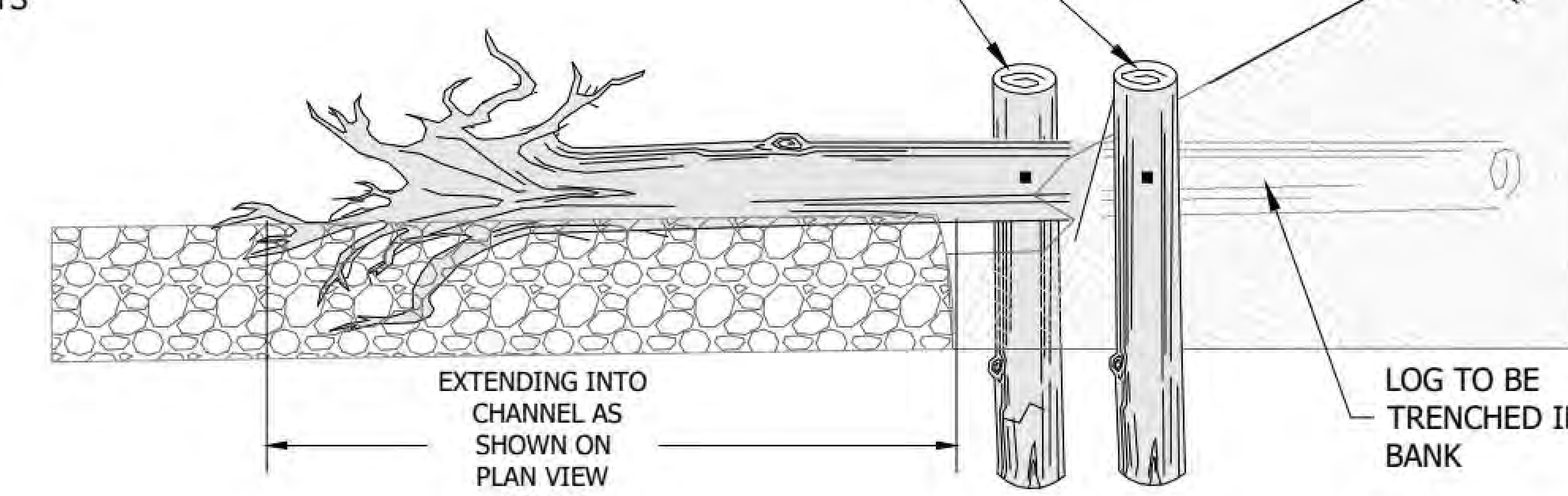
PROJECT NUMBER: 836.02
SCALE: AS NOTED
DATE: 5/6/2025

DESIGN: BW/DC
DRAWN: JB/CD/CG
CHECKED: DC
APPROVED: JM

DETAILS (1)



PLAN VIEW



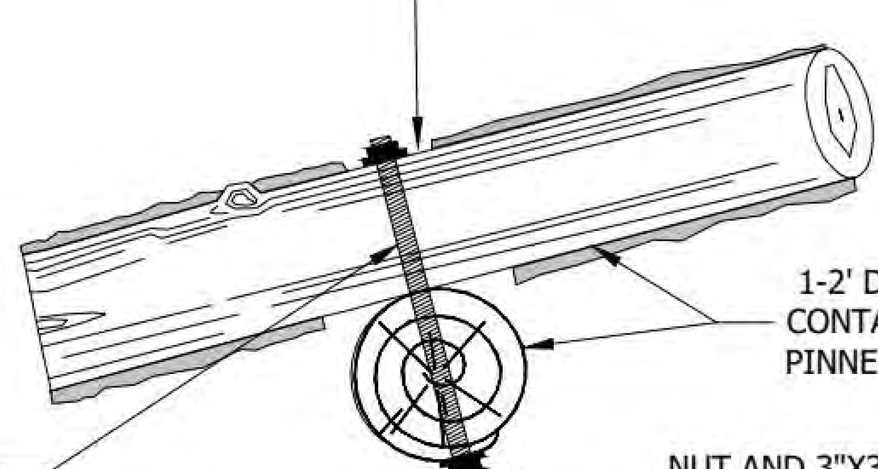
NOTES:

1. LOG STRUCTURES SHALL BE INSTALLED AS SHOWN ON PLAN VIEW SHEETS
2. LOG STRUCTURES TO BE TRENCHED INTO THE BANK TO ALLOW FOR A LOWER ANGLE AND PROVIDE MORE WOOD VOLUME IN THE ACTIVE CHANNEL
3. LOG STRUCTURE CONSTRUCTION DETAILS MAY BE MODIFIED IN THE FIELD AS APPROVED BY THE PROJECT MANAGER AND ENGINEER

SECTION VIEW

1 LOG-PILE ANCHORING

NTS

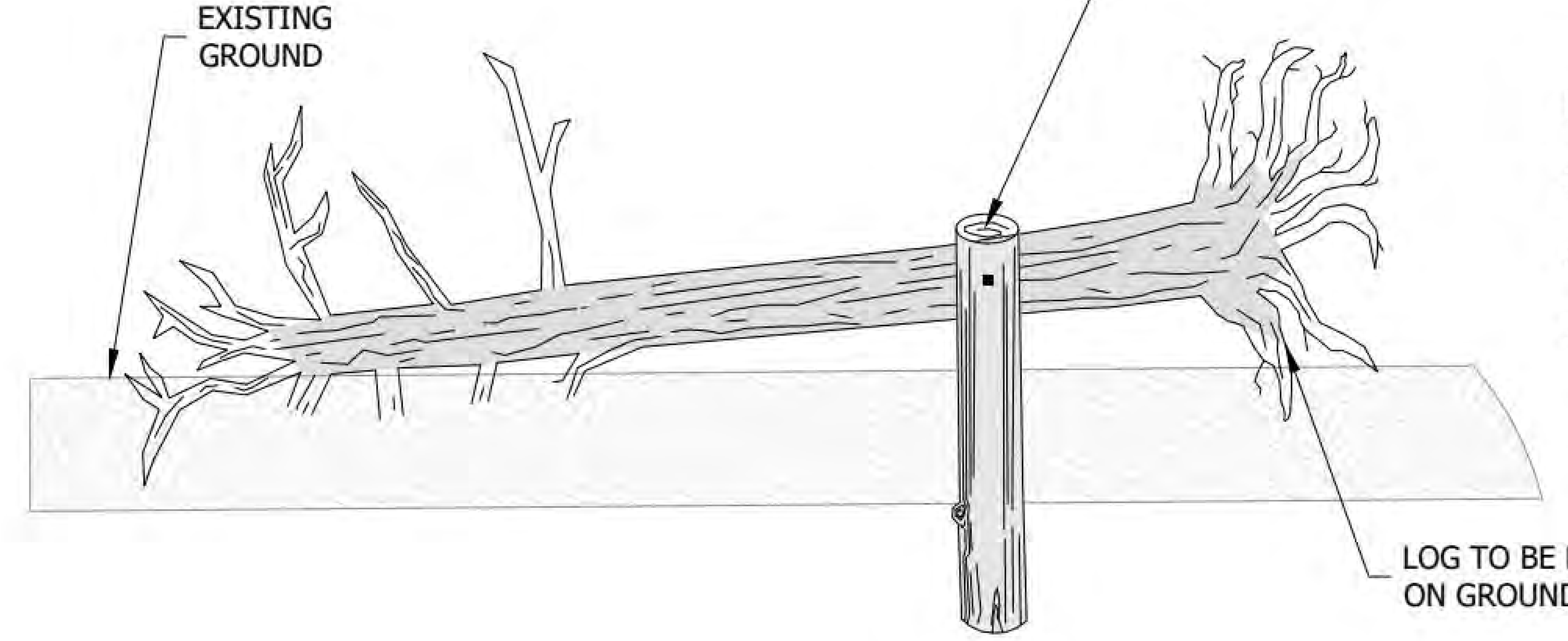


NOTES:

1. BARK REMOVAL NOT REQUIRED ON LIVE TREES TO REDUCE IMPACTS TO TREE HEALTH
2. 1 1/8" DRILL HOLES THROUGH WOOD COMPONENTS

2 LOG-LOG OR LOG-TREE ANCHORING

NTS



NOTES:

1. TERRESTRIAL LOGS SHALL BE INSTALLED AS SHOWN ON PLAN VIEW SHEETS
2. TERRESTRIAL LOGS TO BE PLACED ON GROUND SURFACE WITH MINIMUM DISTURBANCE
3. TERRESTRIAL LOG PLACEMENT DETAILS MAY BE MODIFIED IN THE FIELD AS APPROVED BY THE PROJECT MANAGER AND ENGINEER

SECTION VIEW

3 TERRESTRIAL WOOD ANCHORING

NTS

LOWER ELK CREEK WETLAND ENHANCEMENT PROJECT

DEL NORTE COUNTY, CA

Stillwater Sciences
850 G STREET SUITE K
ARCATA, CA 95521 P: (707) 822-9607

REVISIONS

NO.	DESCRIPTION	DATE

SMITH RIVER ALLIANCE

CONCEPTUAL DESIGN DRAWINGS

NOT FOR CONSTRUCTION

PROJECT NUMBER: 836.02
SCALE: AS NOTED
DATE: 5/6/2025

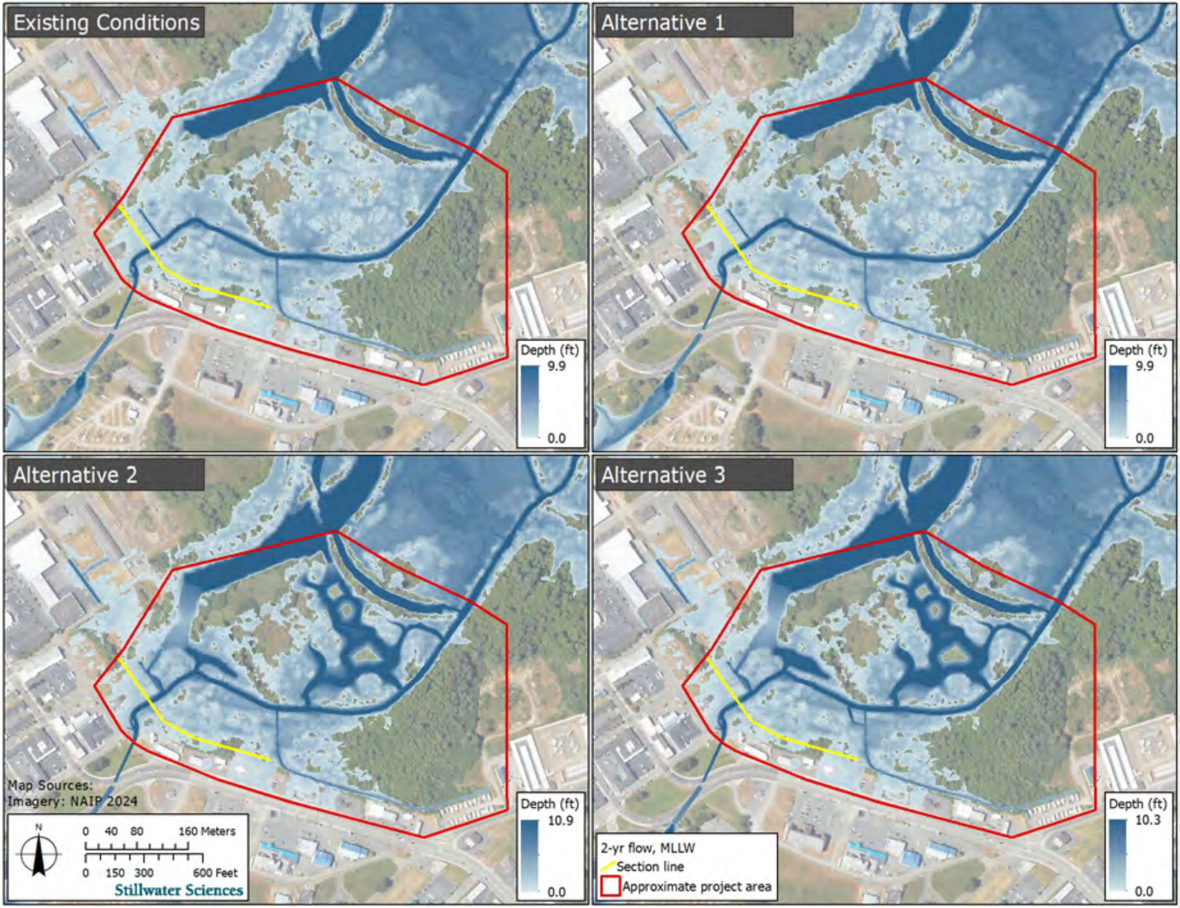
DESIGN: BW/DC
DRAWN: JB/CD/CG
CHECKED: DC
APPROVED: JM

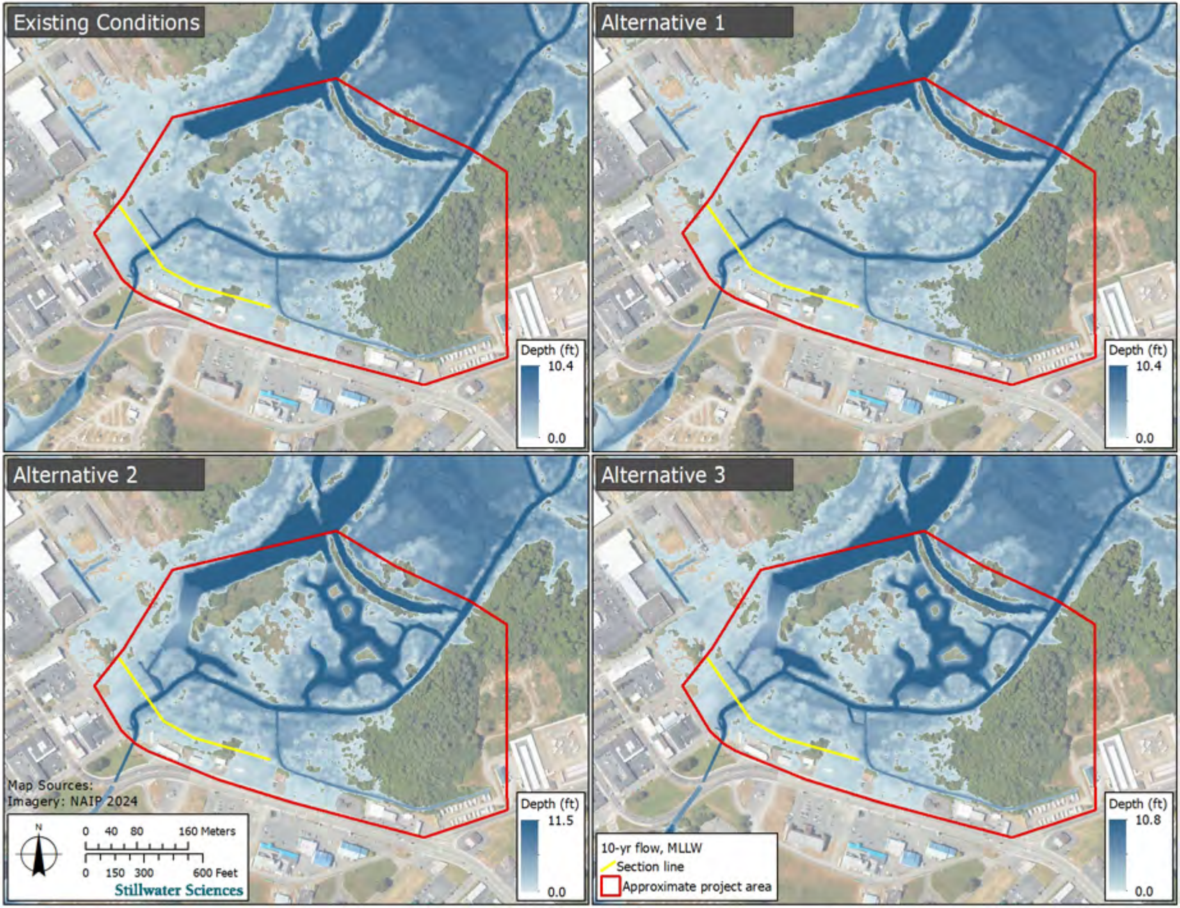
DETAILS (2)

SHEET 19 OF 19

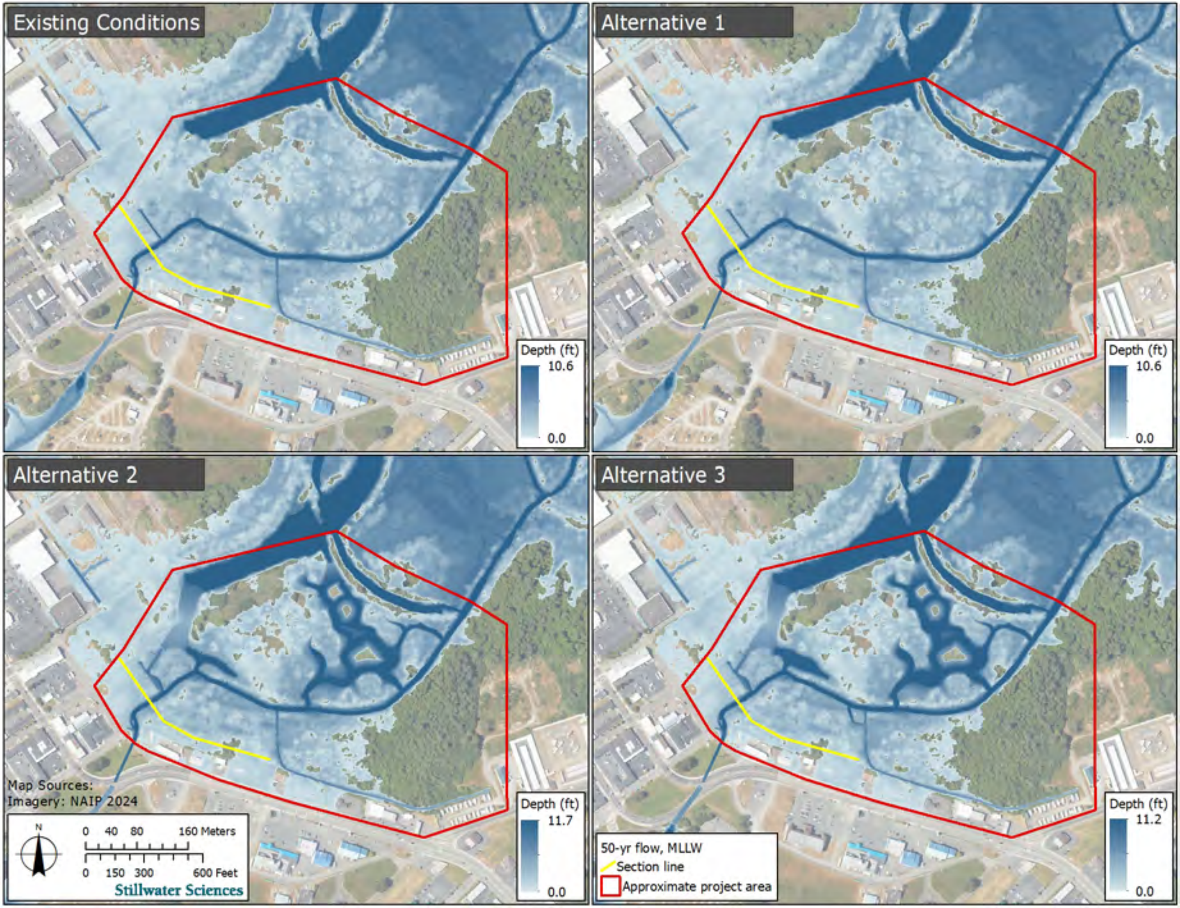
Appendix B

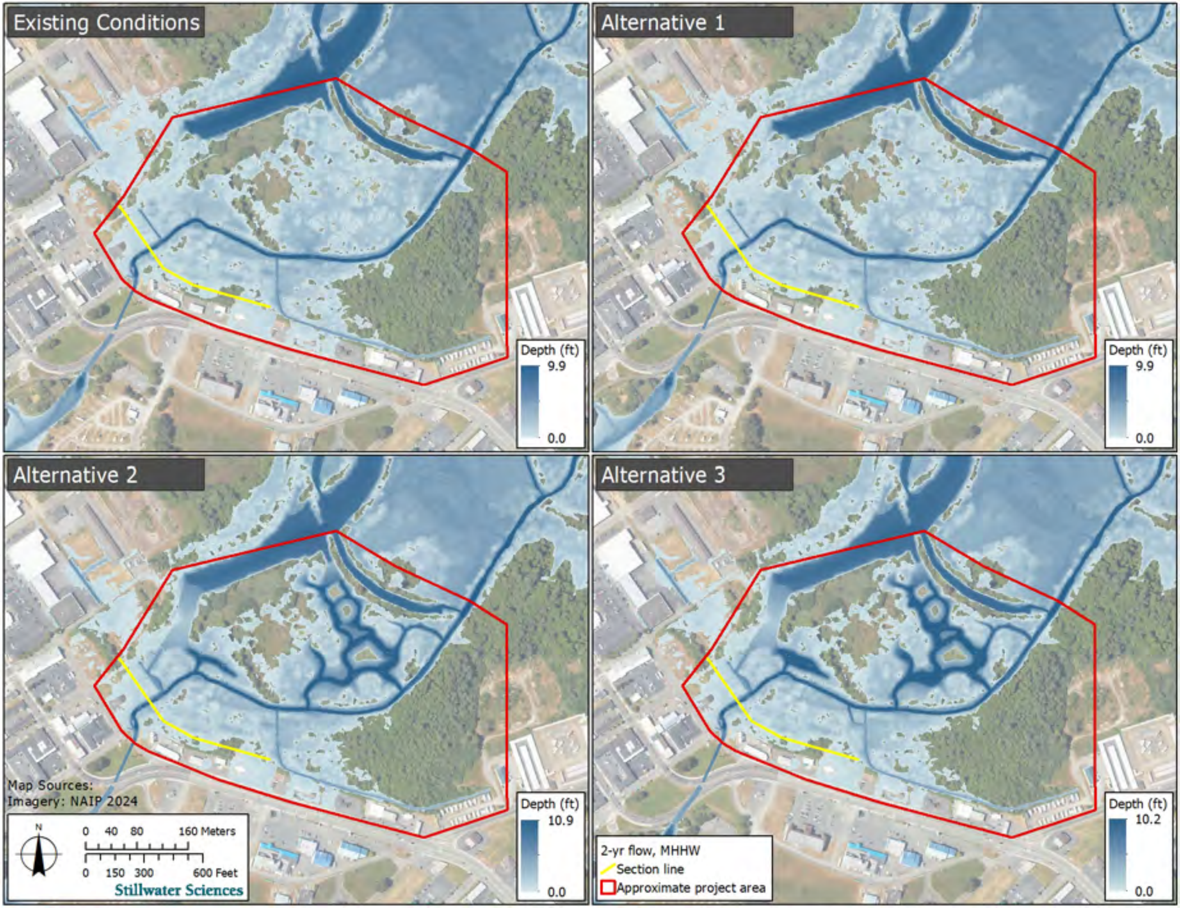
HEC-RAS Flood Model Results and FEMA Flood Mapping


Existing Conditions
Alternative 1
Alternative 2
Alternative 3
Depth (ft)
9.9
0.0
Depth (ft)
9.9
0.0
Depth (ft)
10.9
0.0
Depth (ft)
10.3
0.0
Map Sources:
Imagery: NAIP 2024
N
0 40 80 160 Meters
0 150 300 600 Feet
Stillwater Sciences
2-yr flow, MLLW
Section line
Approximate project area

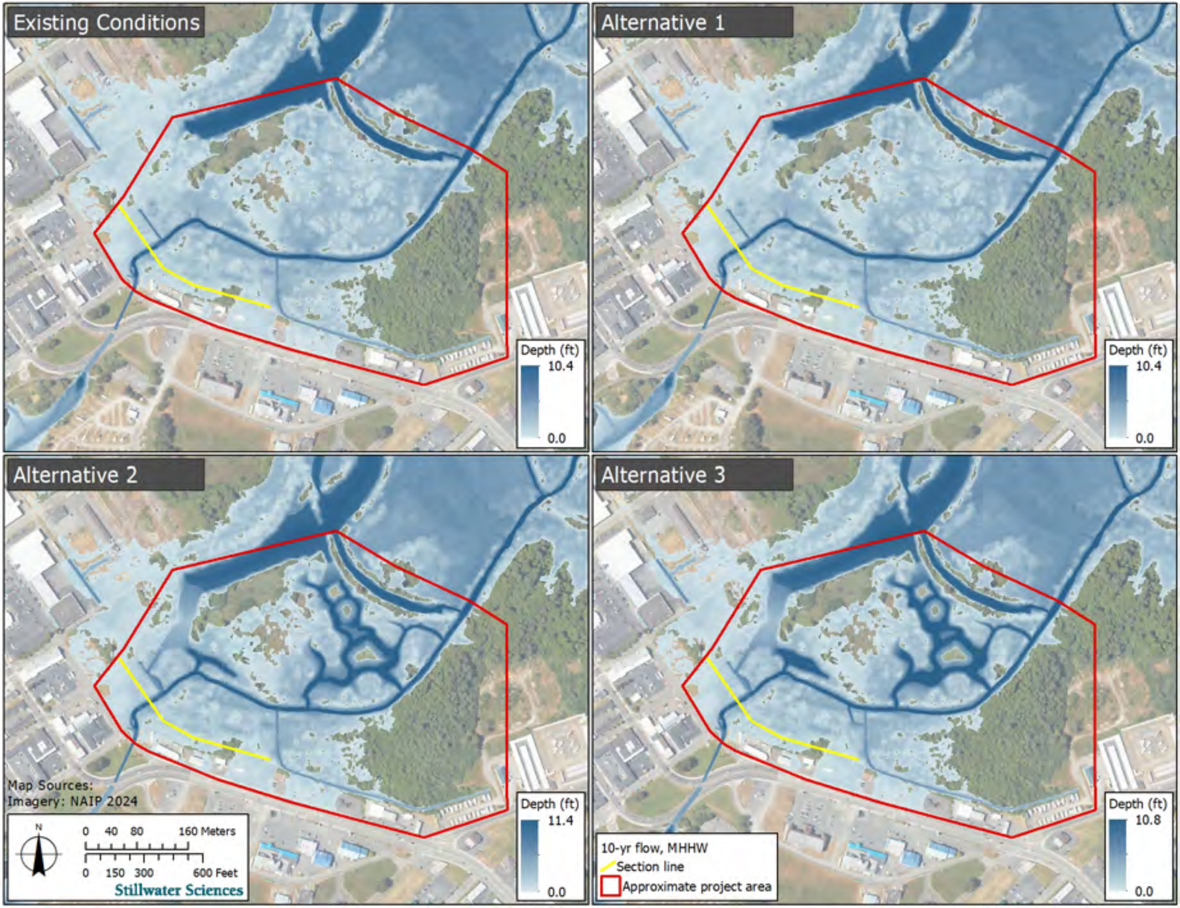


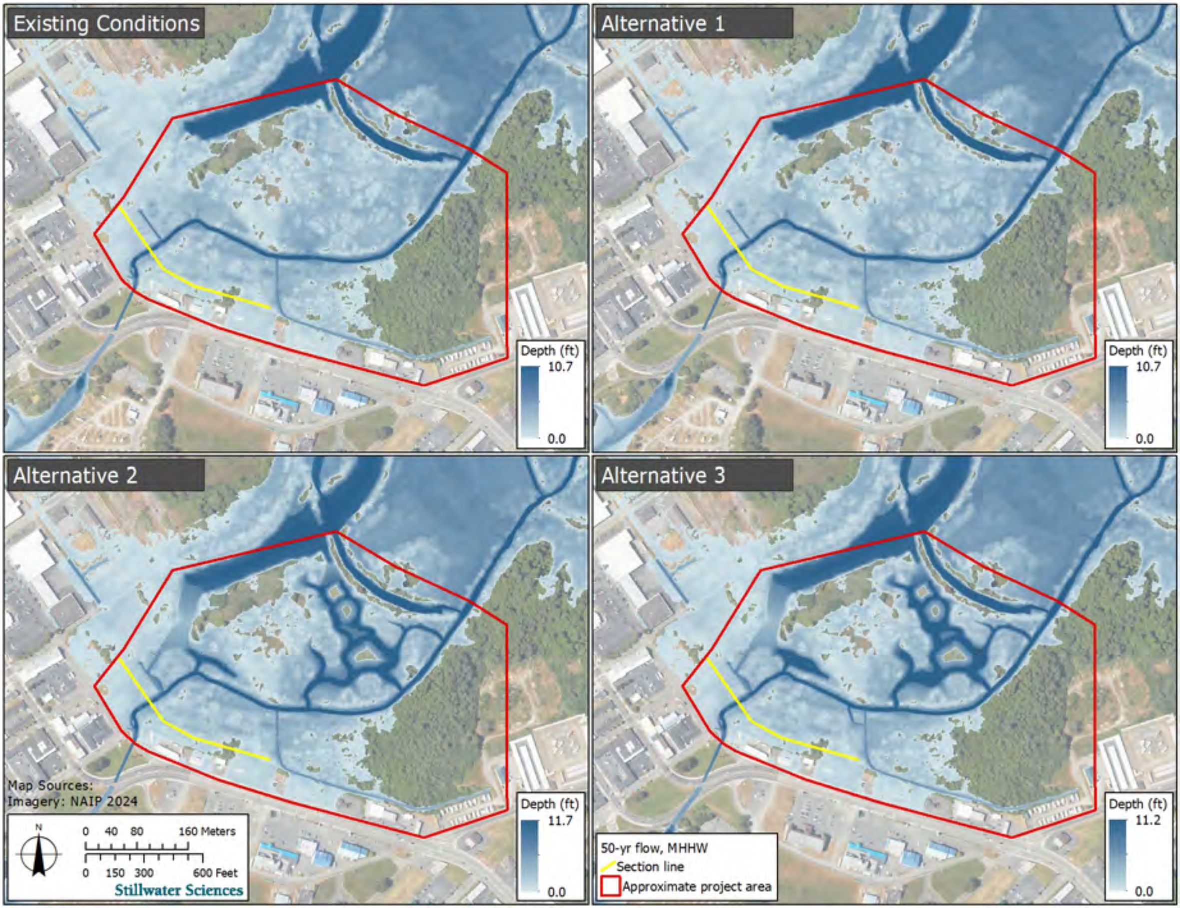
Existing Conditions
Depth (ft)
10.4
0.0
Alternative 1
Depth (ft)
10.4
0.0
Alternative 2
Depth (ft)
11.5
0.0
Alternative 3
Depth (ft)
10.8
0.0
Map Sources:
Imagery: NAIP 2024
N
0 40 80 160 Meters
0 150 300 600 Feet
Stillwater Sciences
10-yr flow, MLLW
Section line
Approximate project area


Existing Conditions
Alternative 1
Alternative 2
Alternative 3
Depth (ft)
10.6
0.0
Depth (ft)
10.6
0.0
Depth (ft)
11.7
0.0
Depth (ft)
11.2
0.0
Map Sources:
Imagery: NAIP 2024
N
0 40 80 160 Meters
0 150 300 600 Feet
Stillwater Sciences
50-yr flow, MLLW
Section line
Approximate project area

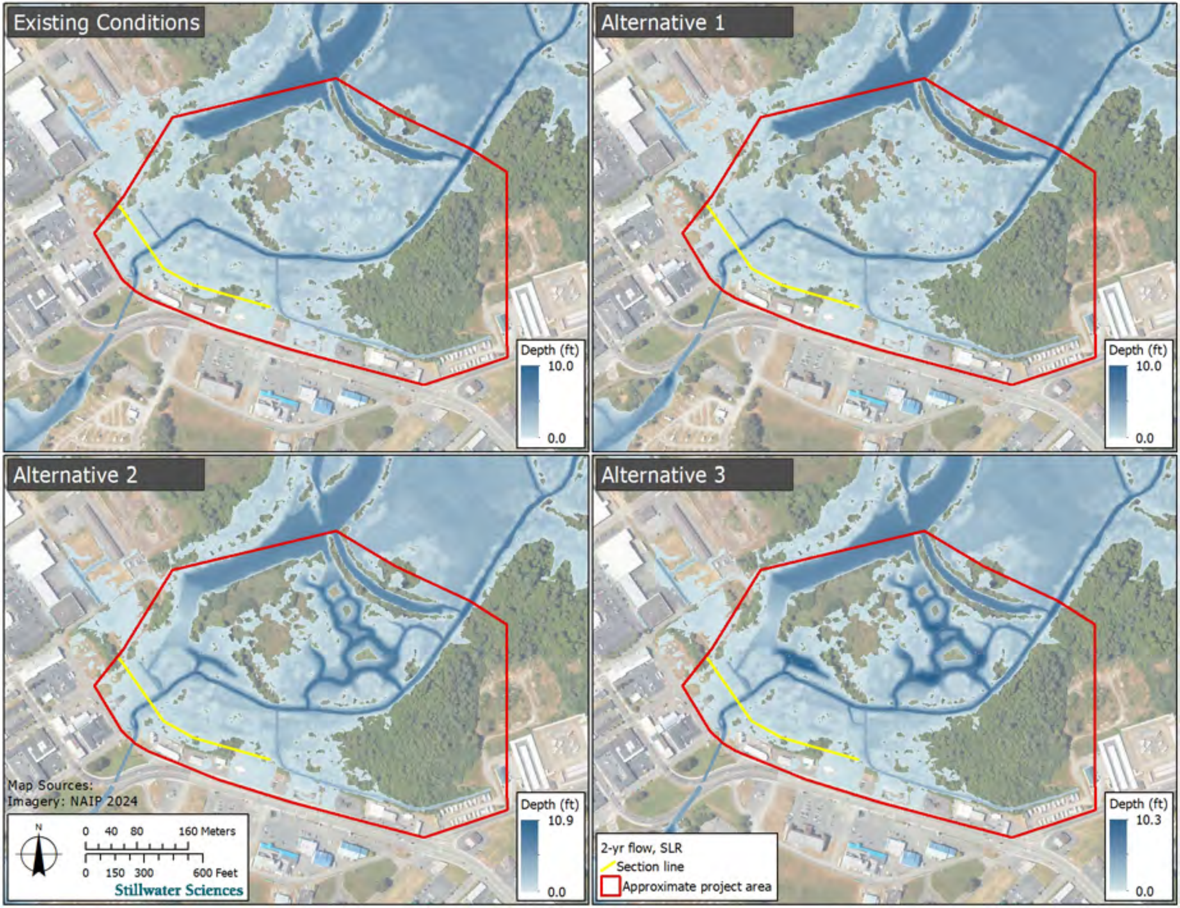


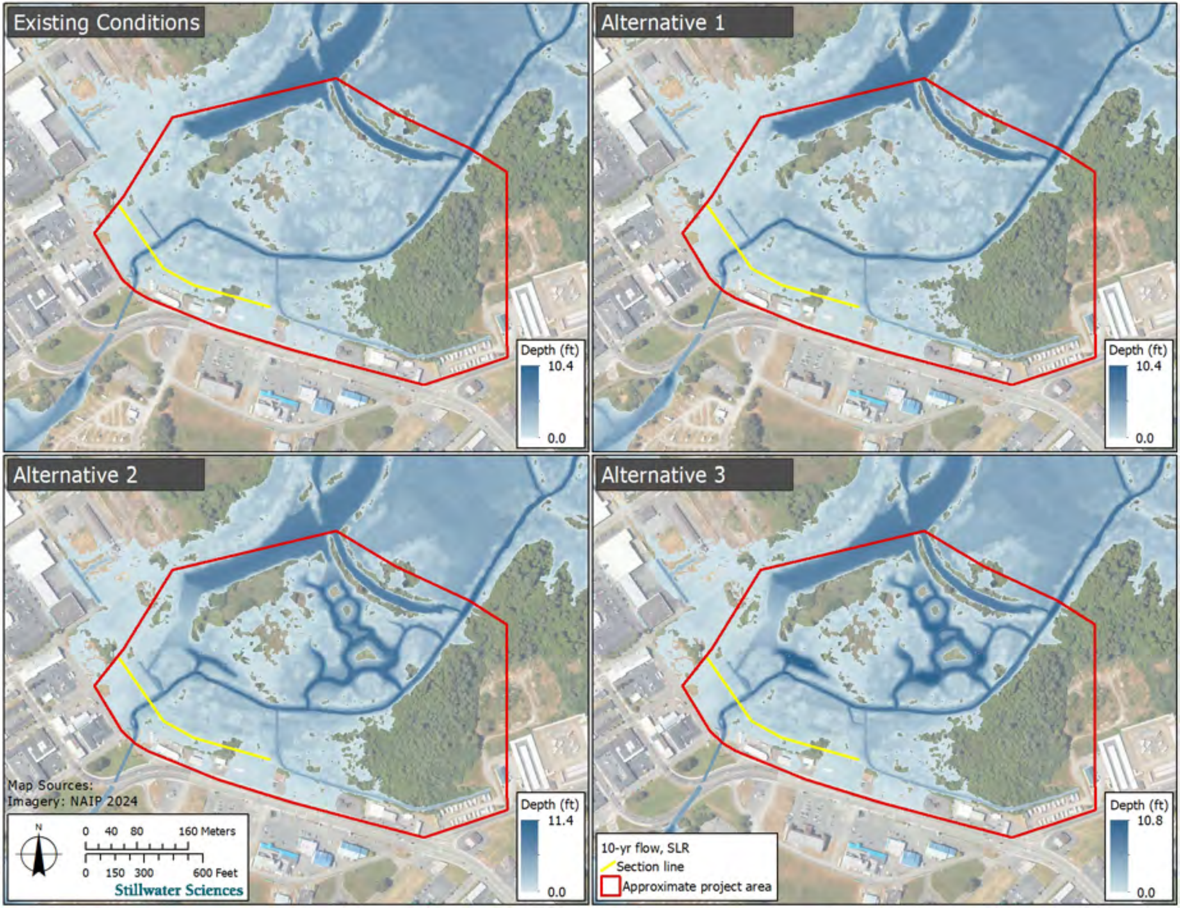
Existing Conditions
Alternative 1
Alternative 2
Alternative 3
Depth (ft)
9.9
0.0
Depth (ft)
9.9
0.0
Depth (ft)
10.9
0.0
Depth (ft)
10.2
0.0
Map Sources:
Imagery: NAIP 2024
N
0 40 80 160 Meters
0 150 300 600 Feet
Stillwater Sciences
2-yr flow, MHHW
Section line
Approximate project area

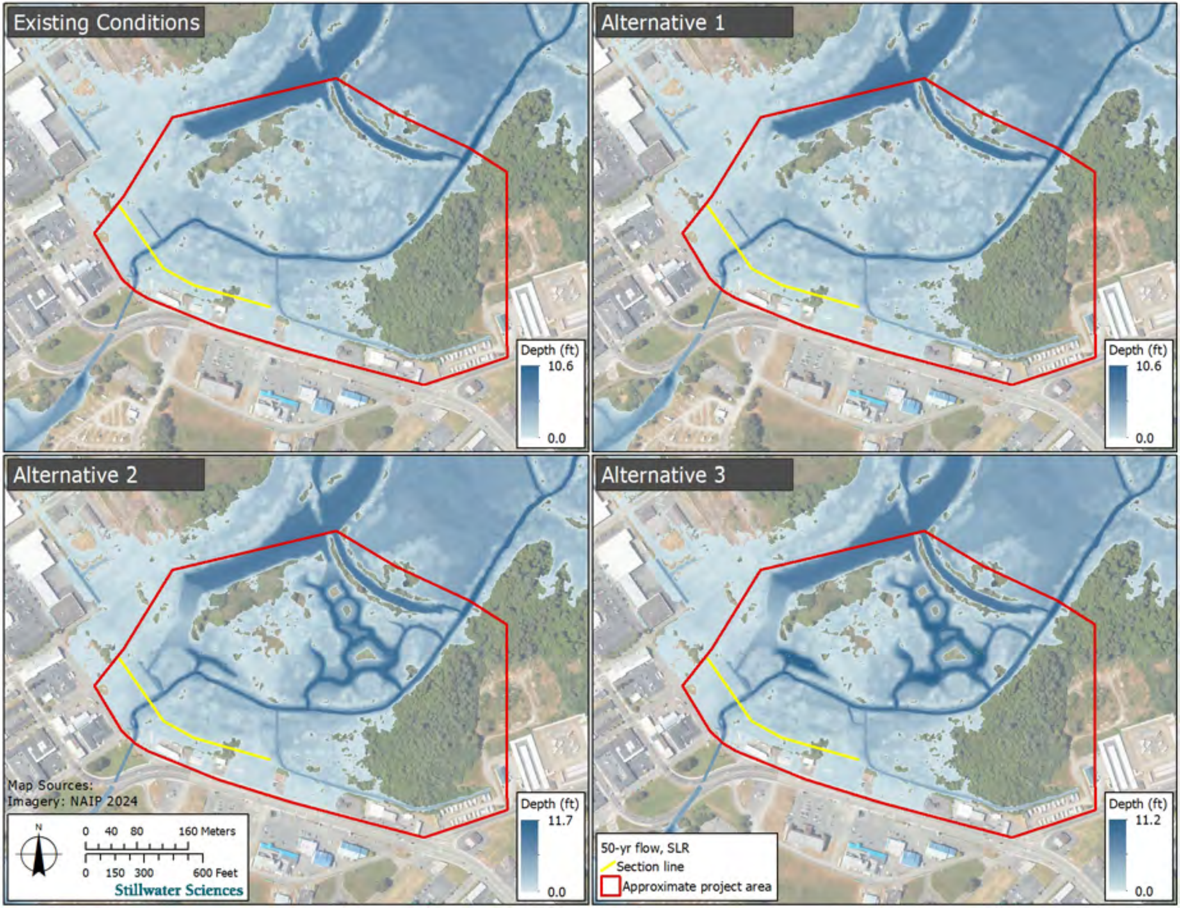

Existing Conditions
Alternative 1
Alternative 2
Alternative 3
Depth (ft)
10.4
0.0
Depth (ft)
10.4
0.0
Depth (ft)
11.4
0.0
Depth (ft)
10.8
0.0
Map Sources:
Imagery: NAIP 2024
N
0 40 80 160 Meters
0 150 300 600 Feet
Stillwater Sciences
10-yr flow, MHHW
Section line
Approximate project area



Existing Conditions
Alternative 1
Alternative 2
Alternative 3
Depth (ft)
10.7
0.0
Depth (ft)
10.7
0.0
Depth (ft)
11.7
0.0
Depth (ft)
11.2
0.0
Map Sources:
Imagery: NAIP 2024
N
0 40 80 160 Meters
0 150 300 600 Feet
Stillwater Sciences
50-yr flow, MHHW
Section line
Approximate project area


Existing Conditions
Alternative 1
Alternative 2
Alternative 3
Depth (ft)
10.0
0.0
Depth (ft)
10.0
0.0
Depth (ft)
10.9
0.0
Depth (ft)
10.3
0.0
Map Sources:
Imagery: NAIP 2024
N
0 40 80 160 Meters
0 150 300 600 Feet
Stillwater Sciences
2-yr flow, SLR
Section line
Approximate project area


Existing Conditions
Alternative 1
Alternative 2
Alternative 3
Depth (ft)
10.4
0.0
Depth (ft)
10.4
0.0
Depth (ft)
11.4
0.0
Depth (ft)
10.8
0.0
Map Sources:
Imagery: NAIP 2024
N
0 40 80 160 Meters
0 150 300 600 Feet
Stillwater Sciences
10-yr flow, SLR
Section line
Approximate project area


Existing Conditions
Alternative 1
Alternative 2
Alternative 3
Depth (ft)
10.6
0.0
Depth (ft)
10.6
0.0
Depth (ft)
11.7
0.0
Depth (ft)
11.2
0.0
Map Sources:
Imagery: NAIP 2024
N
0 40 80 160 Meters
0 150 300 600 Feet
Stillwater Sciences
50-yr flow, SLR
Section line
Approximate project area

National Flood Hazard Layer FIRMette

FEMA

124°11'35"W 41°45'31"N

124°10'58"W 41°45'4"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Basemap Imagery Source: USGS National Map 2023

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- Coastal Transect
- Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 5/8/2025 at 4:44 AM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Appendix C

Historical Aerial Photographs

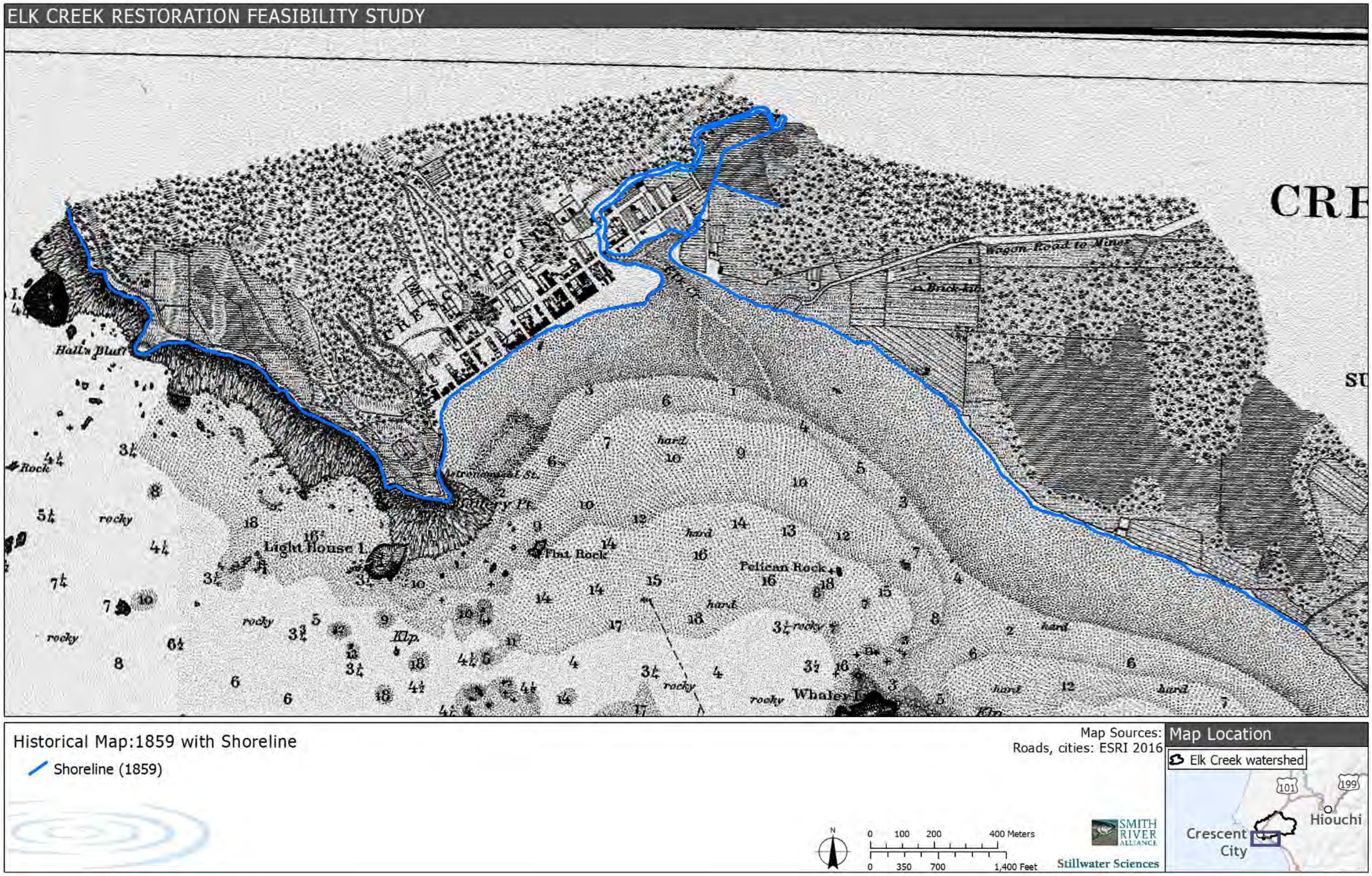


Figure C-1. U.S. Coastal Survey map of 1859 with shoreline and lower Elk Creek delineated.

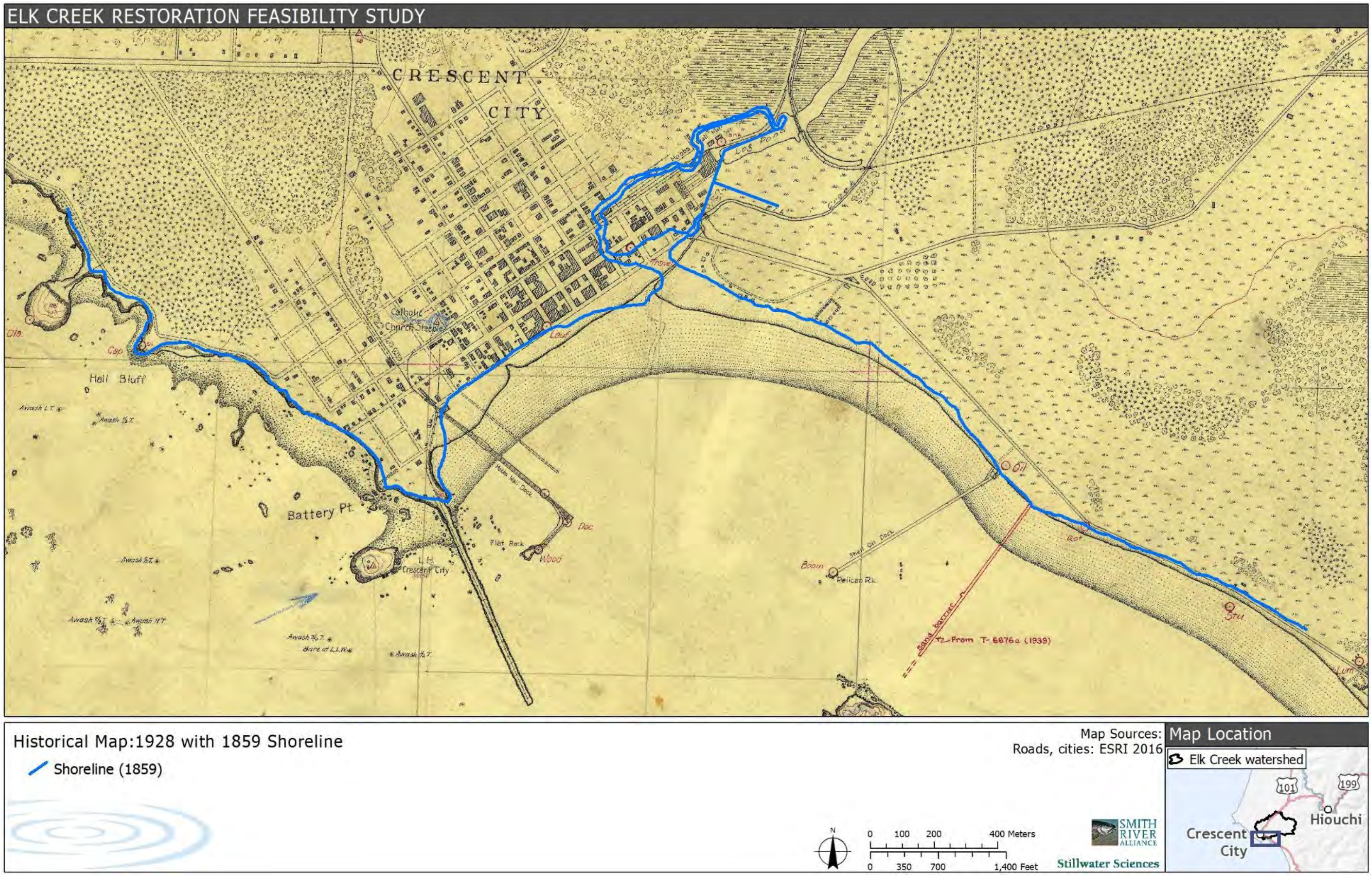


Figure C-2. U.S. Coastal Survey map of 1928 with 1859 shoreline and lower Elk Creek delineated.

Figure C-3. Aerial photograph from 1965 with 1859 shoreline and lower Elk Creek delineated.

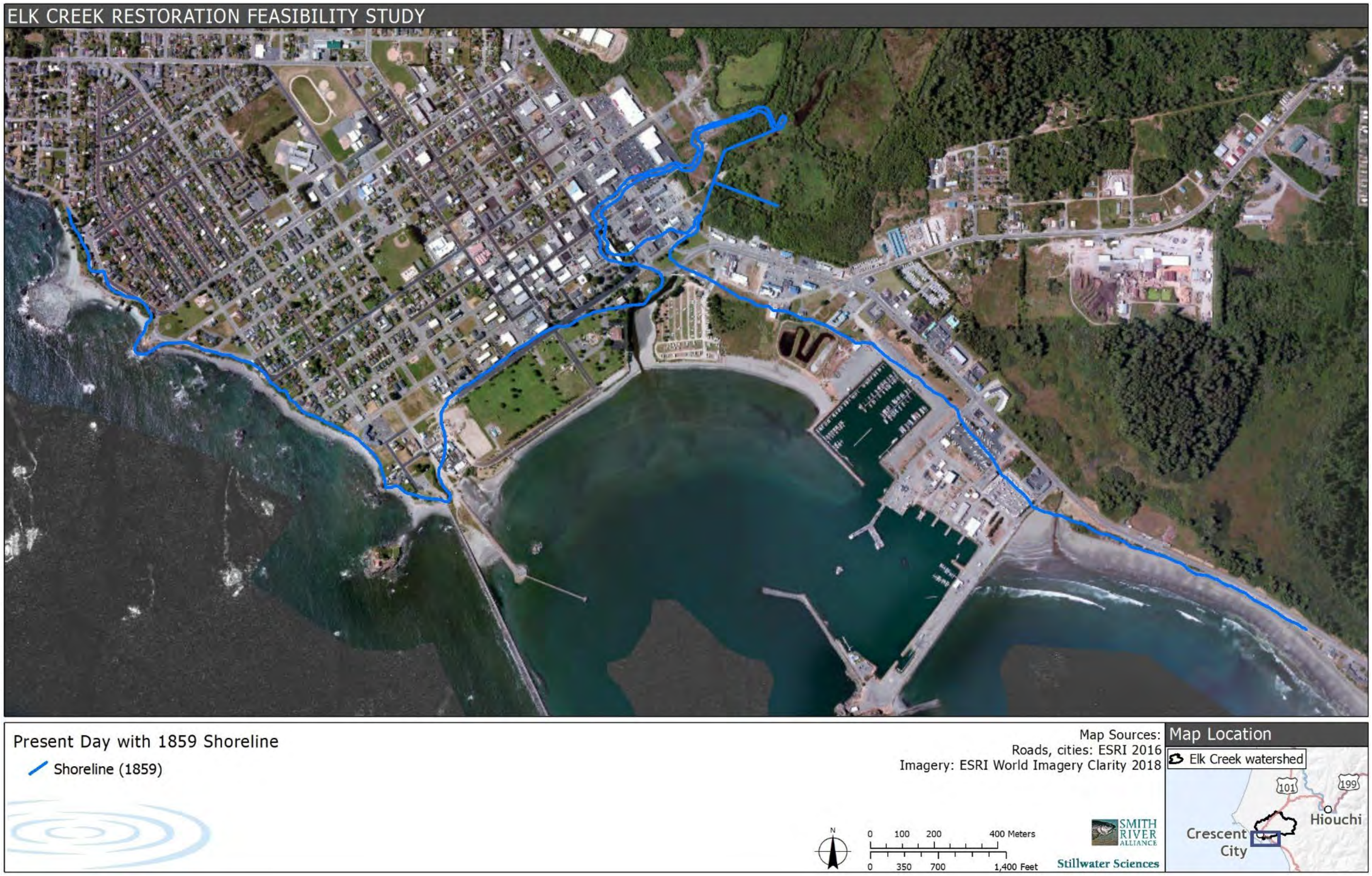


Figure C-4. Aerial photograph from 2018 with 1859 shoreline and lower Elk Creek delineated.

Appendix D

Soil Borehole Logs

Stillwater Sciences

Borehole Log

Project Name/#: Lower Elk Creek Wetland Enhancement (836.02) **Log #:** BH1

Equipment: Hand auger, 3.25" bucket **Datum:** Existing ground surface: 8.3 ft NAVD88 **Date:** 4/21/2025

Location: Near Floodplain Connection 1 **Page:** 1 of 1

Groundwater well **By:** DJC **Checked:** JDS

Well casing	Annular backfill	Groundwater	depth in feet	Unified Soil Classification System (USCS) symbol, texture, consistency, moisture, color
No GW well installed at this site		∇ (~1 ft)	0–0.4	**PT** - peat, muddy and fibrous with grass and willow roots.
			0.4–0.9	**SM -** fine sand with silt, muddy, organic, loose, moist, very dark brown.
			0.9–4	**PT** - peat, fibrous with plant fragments in silty/muddy matrix, soft, wet, very dark brown. From approximately 1.3 to 1.4 feet bgs is lens of fine sand, odiferous. Tsunami deposit? Below sand lens peat is dominated by very uniformly sized small decomposed woody material. Mill shavings?
			4–5.9	**SP -** clean fine sand, loose, wet, dark gray. Bottom of hole in same at ~5.9' BGS

Depth scale: 0 to 10 feet.

Stillwater Sciences

Borehole Log

Project Name/#:	Lower Elk Creek Wetland Enhancement (836.02)	**Log #:**	BH2
Equipment:	Hand auger, 3.25" bucket	**Datum:** Existing ground surface:	**Date:** 4/21/2025
Location:	Floodplain side of Connection 2	8.1 ft NAVD88	**Page:** 1 of 1
Groundwater well		**By:** DJC	**Checked:** JDS

Well casing	Annular backfill	Groundwater	depth in feet	Unified Soil Classification System (USCS) symbol, texture, consistency, moisture, color
No GW well installed at this site		∇	0	**PT** - peat, plant fragments with muddy fine sand, rhizomes from reed canary grass and sedges, soft, wet, very dark brown.
			1	**SM -** fine sand with muddy silt, firm/compact, wet, dominantly dark gray with some redoximorphic mottling.
			2	Some plant fragments and fine roots.
				SP - clean fine sand, loose, wet, dark gray.
			3	Some plant fragments and fine roots.
				Some plant fragments.
			4	Some plant fragments.
			5	
			6	Bottom of hole in same at ~6.0' BGS
			7	
			8	
			9	
			10	

Stillwater Sciences

Borehole Log

Project Name/#: Lower Elk Creek Wetland Enhancement (836.02) **Log #:** BH3
Equipment: Hand auger, 3.25" bucket **Datum:** Existing ground surface: 8.4 ft NAVD88 **Date:** 4/21/2025
Location: Floodplain side of Connection 3 **Page:** 1 of 1
Groundwater well **By:** DJC **Checked:** JDS

Well casing	Annular backfill	Groundwater ▽	depth in feet	Unified Soil Classification System (USCS) symbol, texture, consistency, moisture, color
No GW well installed at this site		Approx. 0.35 ft above ground surface	0 – 0.5	**PT** - peat of muddy silty reed canary grass rhizomes and decomposed plant material, very soft, wet, very dark brown.
			0.5 – 1.2	**ML** - muddy silt with peat, soft, wet, dark brown, slight plasticity. Some fine roots.
			1.2 – 2.6	**SM -** silty fine sand with trace mud, loose, wet, redoximorphic mottling (gray, brown, strong brown). Becoming denser, increase in fines producing slight plasticity, dominantly gray with faint redoximorphic mottling. Trace fine roots.
			2.6 – 3.6	**SP -** fine sand, little to no fines, yields almost no stain on the hand, very loose, wet, gray with slight redoximorphic mottling. Trace fine roots. Becomes all sand, no fines, roots, or mottling. Very dark gray.
			3.6 – 5.5	**SP -** fine sand with peat, loose, wet. Sand is very dark gray, peat is very dark brown. Peat contains fine fibrous bark, resembles redwood or cedar.
			5.5 – 6.5	**SP -** fine sand, loose, wet, very dark gray. No peat. Bottom of hole in same at ~6.5' BGS
			7	
			8	
			9	
			10	

Stillwater Sciences

Borehole Log

Project Name/#:	Lower Elk Creek Wetland Enhancement (836.02)	**Log #:**	BH4
Equipment:	Hand auger, 3.25" bucket **Datum:** Existing ground surface:	**Date:**	4/21/2025
Location:	Near eastern tsunami surge swale 10.8 ft NAVD88	**Page:**	1 of 1
Groundwater well	**By:** DJC	**Checked:**	JDS

Well casing	Annular backfill	Groundwater	depth in feet	Unified Soil Classification System (USCS) symbol, texture, consistency, moisture, color
No GW well installed at this site		∇	0	**PT -** peat, plant fragments with muddy silt, rhizomes from reed canary grass and sedges, soft, wet, very dark brown.
			1	**SM -** silty sand/sandy silt, muddy, loose, wet, redoximorphic mottling (gray, brown, strong brown), fine roots and small wood chunks.
			2	Becomes denser with slight plasticity, increase in silt content, mottling more pronounced.
				Thin alterations of sand and silt dominant, sand looser and silt firmer with slight plasticity. Still slightly muddy.
			3	No more roots.
			4	**SP -** fine sand with trace muddy fines, very slight stain on hand, loose, wet, dominantly gray with some redoximorphic mottling.
				Becomes very dark gray, mottling stops. Trace plant fragments.
			5	
			6	Trace plant fragments.
			7	Bottom of hole in same at ~7.4' BGS
			8	
			9	
			10	