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Middle Klamath River Floodplain Habitat Enhancement and Mine Tailing Remediation

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Cover photo: Floodplain mine tailings and channel vegetation encroachment in Reach 45 between Lime Gulch and Cayuse Creek (RM 170.2).

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1 INTRODUCTION

1.1 Purpose and Objectives

The Middle Klamath River Floodplain Habitat Enhancement and Mine Tailing Remediation Project (Project) is a broad-scale, collaborative effort by the Mid Klamath Watershed Council (MKWC), Karuk Tribe, and Klamath National Forest to reconnect floodplains, restore floodplain and off-channel fisheries habitat, and remediate mine tailings within a 71.3-mile reach of the Klamath River extending from the Shasta River to Elk Creek in Siskiyou County (Figure 1-1). Project objectives include: (1) restoring, enhancing, and reconnecting floodplain and off-channel features to the main channel to improve critical winter rearing habitat and refuge for juvenile salmonids, (2) protecting and expanding summer thermal refuge and reducing summer water temperatures in these areas, and (3) restoring riparian vegetation. The Project identifies opportunities and constraints to restoring and enhancing degraded floodplains, prioritizes floodplain and off-channel areas for potential restoration and enhancement, and develops conceptual engineering designs for restoring priority sites. The analyses and products of this Project will facilitate programmatic permitting and environment compliance, as well as future site-specific project design implementation.

The Project is a critical component in the recovery of salmon, steelhead, other anadromous fish populations in the Klamath Basin; including Southern Oregon/Northern California Coast (SONCC) coho salmon (*Oncorhynchus kisutch*), Upper Klamath-Trinity Rivers (UKTR) fall- and spring-run Chinook salmon (*O. tshawytscha*), Klamath Mountains Province (KMP) steelhead (*O. mykiss irideus*), Pacific lamprey (*Entosphenus tridentatus*), and green sturgeon (*Acipenser medirostris*). Mainstem and off-channel habitats within the Middle Klamath River corridor are critical to the survival and growth of juvenile salmon emigrating from tributaries (e.g., the Scott River and Shasta River). These juvenile rearing habitats promote rapid growth during seasonal windows with suitable hydraulic and temperature conditions and abundant food supplies. Juvenile rearing habitat in the Middle Klamath River is limited during the winter by lack of low velocity refuge habitat and during the summer by high water temperatures. During these periods with high flows or warm water temperatures, juvenile salmonids rely on limited refuge habitats associated with non-natal tributaries, floodplains, and off-channel features along the mainstem corridor. The Middle Klamath River corridor lacks extensive, low-lying valley bottom floodplains and off-channel habitats that are connected to the mainstem channel and accessible to juvenile fish during critical rearing periods. The wider, more alluvial reaches with historically more extensive and ecologically important floodplain habitats were typically those most impacted by placer mining and related development, resulting in a disproportionately large loss of low-velocity winter rearing habitat.

Figure 1-1. Project area.

Historical placer mining is one of the most important anthropogenic factors leading to the decline and continued low abundance of anadromous salmonids in the Middle Klamath River. Large scale placer mining between 1850 and the 1930s using hydraulic and dredging practices in combination with construction of wing dams led to profound and enduring changes to the Klamath River channel and floodplains. The Project area encompasses the reach of the Klamath River most degraded by historic mining activities (i.e., Shasta River confluence to approximately Happy Camp). Placer mining in this reach denuded floodplains and adjacent river terraces and hillslopes, delivered enormous quantities of sediment to the mainstem river channel, and completely rearranged the pre-settlement river channel morphology. The legacy of historical placer mining profoundly affects today's channel structure and floodplain habitat conditions throughout the mainstem and larger tributary reaches. Aggradation caused by mined sediment widened and shallowed alluvial reaches, filled pools, reduced the complexity and connectivity of floodplain habitats, and led to coarsening of the channel bed. Floodplain mine tailings limit flow inundation by channelizing mainstem flow and altering the connectivity of secondary flow paths. Mine tailings, denuded floodplains, and stored coarse sediment deposits prevent riparian vegetation establishment and contribute to elevated summer water temperatures by exposing large areas of the river corridor to direct solar radiation. Legacy impacts to the channel and floodplain inhibit natural recovery and require mechanical intervention to recover within human and salmon population time scales.

The impacts of placer mining were compounded by approximately 70 years of intensive timber harvest from the 1950s through the 1980s. Extensive logging accelerated erosion throughout the basin, changed the natural fire regime, created a network of legacy roads, and in combination with fire suppression, reduced the amount of large wood in tributary stream channels. These impacts have further reduced the amount and quality of rearing and overwintering habitat on floodplains and in off-channel areas and have reduced the amount of thermally suitable summer habitat.

Flow, sediment transport, channel morphology, and stream temperatures in the Project area are also affected by five upstream dams constructed on the mainstem Klamath River between 1903 and 1965 (Keno Dam, Copco No. 1, Copco No. 2 Dam, J.C. Boyle Dam, and Iron Gate Dam), Dwinell Dam built on the mainstem Shasta River in 1928, and numerous other smaller tributary dams and water diversions. The effects of these dams and diversions on reducing sediment supply and transport and in reducing peak flow magnitudes and durations necessary for maintaining dynamic alluvial channel morphology within the Project area is most pronounced from the Shasta River confluence to the Scott River confluence. The channel in this reach lacks dynamic fluvial processes; and historical floodplain and off-channel habitats are disconnected by a lack of high flow, encroachment of riparian vegetation onto channel banks and bars, and associated geomorphic adjustments (e.g., sediment levees).

The objectives and intended outcomes of the Project align with the priorities identified in the SONCC Recovery Plan for the Middle Klamath populations, including creating and enhancing winter and summer rearing habitat for juvenile salmonids and improving the connectivity of floodplain and off-channel habitats with the mainstem channel. Implementation of individual restoration projects will also improve riparian functions, increase hydraulic complexity and hyporheic/groundwater exchange, and reduce the effects of solar radiation on water temperature. The Project will ultimately help increase the long-term resiliency of Klamath River salmon and steelhead populations to the anticipated effects of climate change (Beechie et al. 2012).

1.2 Approach

The Project approach involved developing a conceptual model that incorporates information about the life-histories of target salmonid species, riverine habitat types, and use of these floodplain and off-channel habitats by juvenile salmonids in the Middle Klamath River corridor. The conceptual model also considers variability in channel morphology and placer mining disturbance with respect to juvenile salmonid use of riverine habitats in the mainstem river corridor, including tributary confluences and the lower alluvial reaches of larger tributaries. Reaches were delineated based on channel morphology and fluvial processes; floodplain morphology and flow inundation; tributary inputs of flow, sediment, and cold water; large-scale disturbance from historical placer mining and other land uses; and existing aquatic and riparian habitat conditions.

A Design Team with expertise in Klamath River salmonid ecology and experience in habitat restoration guided conceptual model development, prioritization of reaches for restoration and enhancement, selection of design sites, and development of conceptual design plans. Table 1-1 lists Design Team members and their affiliations.

Table 1-1. Design team and their affiliations.

Design team member	Affiliation
Will Harling	MidKlamath Watershed Council
Mitzi Wickman	MidKlamath Watershed Council
Charles Wickman	MidKlamath Watershed Council
Toz Soto	Karuk Tribe Department of Natural Resources, Fisheries Program
Jon Grunbaum	Klamath National Forest
Rocco Fiori	Fiori Geosciences
Jay Stallman	Stillwater Sciences
Joel Monschke	Stillwater Sciences
Dylan Caldwell	Stillwater Sciences

A hydrologic analysis using existing long-term gaging records was conducted to characterize flows important to design objectives within the Project area. 2010 Light Detection and Ranging (LiDAR) data was used to create a current conditions DTM that, along with an air photo time series, provided the basis for characterizing inundation and mapping floodplain features over the range of flows relevant to salmonid rearing and refuge habitat. Floodplain and off-channel habitat features (e.g., existing ponds, tributary channels, side channel); important geomorphic features (e.g., bedrock channel and riffle crest hydraulic controls; floodplains and secondary flow paths, mine-excavated areas and mine tailings); and infrastructure were identified within the 100-year floodplain. Cold-water tributaries and sources were assessed based on existing thermal infrared imagery (TIR). Supplemental field investigations were conducted to augment and validate existing information, where necessary and appropriate.

The available information and analysis results were then compiled for the Project area, and all reaches were prioritized for potential restoration and enhancement based on (1) a subjective expert opinion rating by Design Team members and (2) an objective rank developed from physical criteria (e.g., channel gradient, valley width, and extent of low-lying floodplain area). Reaches with a high objective rank and corresponding high expert opinion rating were investigated in the field by the Design Team. Design sites were then selected based on the expert opinion rating, objective ranking, results from field investigations, and additional information related to parcel ownership and the potential willingness of landowners to participate.

Lastly, conceptual engineering design plans were developed for fifteen design sites within the highest priority reaches. The design process began with a Design Team workshop to identify habitat restoration and design criteria and potential treatments within design sites. Conceptual designs were then developed in CAD, including planform maps and profiles of proposed design features; existing and proposed access routes, staging and spoil areas; preliminary estimates of material quantities; and a planning-level construction cost estimate. Conceptual designs were refined during field assessments by the Design Team and based on the anticipated ecological benefits relative to feasibility and the initial planning-level construction cost estimate.

2 JUVENILE SALMONID USE OF HABITATS WITHIIN THE MIDDLE KLAMATH RIVER CORRIDOR

2.1 Overview of Salmonid Life Histories

The middle Klamath River corridor is utilized to varying degrees by coho salmon, Chinook salmon, and steelhead for adult migration, spawning, juvenile rearing, and juvenile outmigration. The following sections provide an overview of the life histories of these species and their timing of use in the Middle Klamath River Project area, focusing on the juvenile life stages that are the primary target of planned floodplain and off-channel habitat enhancements. Understanding the diversity in juvenile life history strategies and timing of use of these species is fundamental for identifying reach specific habitat enhancement potential, selecting sites, and designing habitat enhancements that maximize survival, growth, and population response.

During their year-long freshwater residency, coho salmon are particularly reliant on the low-velocity habitat associated with off-channel and floodplain habitat enhancements and therefore, their life history and habitat use in the mainstem Klamath River corridor are described in more detail than other species.

2.1.1 Coho salmon

Adult coho salmon typically migrate from the ocean to their natal stream during the fall of their third year (Sandercock 1991) and enter the Klamath River between September and mid-December, with peak upstream migration occurring between late-October and mid-November (Maurer 2002, NRC 2004) (Table 2-1). Most adult coho salmon enter the Scott River in late November (Maurer 2002) and the Shasta River from mid-October to mid-December (Chesney and Knechtle 2011, 2017). Most spawning occurs in tributaries or in mainstem side channel habitats (Lestelle 2007). Spawning in the Klamath River generally occurs within a few weeks after migration ceases, peaking in early to mid-December (Maurer 2002, Magneson and Gough 2006).

Coho salmon fry begin to emerge from redds in late February, with peak emergence in March and April (NRC 2004). After emergence, fry seek out low-velocity rearing habitats along the stream margin or in off-channel habitats, a habitat preference that they maintain throughout their freshwater residency (Nickelson et al. 1992, Soto et al. 2016). Some individuals remain in their natal tributary streams and some move downstream to the mainstem Klamath River in search of suitable low-velocity habitats. Coho salmon typically rear in freshwater for one year prior to out-migrating to the ocean in the spring; although in some populations, a fraction of individuals may spend two years in freshwater (e.g., Bell and Duffy 2007).

During their time in freshwater, juvenile coho salmon in the Middle Klamath River display a wide range of movement and habitat use patterns, which are largely driven by stream flow and temperature patterns occurring in both natal tributaries and the mainstem Klamath River (Lestelle 2007, Soto et al. 2016). The generalized movement patterns exhibited by juvenile coho salmon in the Klamath River are summarized as follows based on Soto et al. (2016). Fry that disperse from (rather than rear in) natal tributaries, such as the Shasta and Scott rivers, enter the mainstem during the spring snow-melt run-off. Some of these juveniles redistribute in early summer in search of thermally suitable habitat (e.g., cold water seeps in the mainstem, off-channel ponds, or in the lower reaches of cool water tributaries) as water temperatures rise. Relatively little movement occurs for the remainder of the summer. Another more extensive redistribution occurs in fall and early winter as flows increase and juveniles search for low-velocity overwintering habitats. At this time, fish have been documented moving into both off-channel habitats adjacent to the mainstem and into tributary habitats, sometimes moving great distances (>200 miles) from their oversummering habitat (Soto et al. 2016). Some juvenile coho that oversummer in natal tributaries redistribution to the mainstem Klamath River in Fall or early winter (Soto et al. 2016). Following fall redistribution, most individuals cease large-scale movements until smolt outmigration in the spring, which occurs from March through early June, peaking in April and May (Scheiff et al. 2001, Cheseney and Yokel 2003, Soto et al. 2016). Once in the mainstem, smolts appear to quickly move downstream; Wallace (2004) reported that numbers of coho salmon smolts in the Klamath River estuary peaked in May, the same month as peak outmigration from the tributaries. Wallace (2004) also observed a significant decrease in estuary presence by June and July, suggesting that smolts spend a relatively brief period in the estuary prior to entering the ocean.

Table 2-1. Life-history timing of coho salmon in the Klamath River.[1]

Life stage	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Adult migration																	■	■	■	■	■	■	■	
Spawning	■	■																			■	■	■	■
Incubation & emergence	■	■	■	■	■	■	■	■	■	■											■	■	■	■
Rearing	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Juvenile redistribution											■	■	■						■	■	■	■	■	
Juvenile outmigration					■	■	■	■	■	■	■													

[1] References for listed life history timing for each life stage are provided in text.

2.1.2 Chinook salmon

In the Klamath River Basin, Chinook salmon can be broadly divided into two runs based on life history timing: the fall-run and the spring-run. Fall-run Chinook salmon, which typically enter freshwater in late-summer and early fall as sexually mature adults, are the predominant Chinook population currently present in the Middle Klamath River and its tributaries. Spring-run Chinook salmon, which enter freshwater in the spring as sexually immature adults and hold through the summer prior to fall spawning, are considered extirpated or in very low numbers in the Klamath River basin upstream of the Salmon River. In light of recent evidence that spring-run Chinook salmon populations have regions of the genome associated with premature migration that are distinct from fall-run Chinook salmon and irreplaceable (Prince et al. 2017, Thompson et al. 2018), the Klamath and Trinity River populations have been petitioned for listing as a separate Evolutionary Significant Unit that is threatened or endangered under the Endangered Species Act (Karuk Tribe and Salmon River Restoration Council 2017). Along with the forthcoming removal of mainstem Klamath River dams, there are plans to reintroduce spring-run Chinook salmon into the upper Klamath Basin. Accordingly, the life histories of both Chinook salmon runs are summarized here.

2.1.2.1 Fall-run Chinook salmon

Adult fall-run Chinook salmon generally enter the lower Klamath River from August through October, with peak migration typically occurring in September (NRC 2004, Strange 2012, Hearsey and Kinziger 2015) (Table 2-2). Fall-run Chinook salmon adults typically reach spawning grounds two to four weeks following river entry (NRC 2004, Strange 2012).

Fall-run Chinook salmon spawning in the Klamath River typically peaks in late October and substantially declines by the end of November (Shaw et al. 1997, Gough et al. 2018). Although there is evidence of spawning as late as early December in some years (Magneson 2006). Based on spawning timing and capture of fry in outmigrant traps, eggs and alevins are typically in the gravel from October through February, and fry emerge from early February through mid-April (David et al. 2016). Fall-run Chinook salmon fry are typically captured leaving the Shasta and Scott River in March, April, and May (Chesney and Yokel 2003). Age-0+ juveniles are also typically captured in the estuary beginning in April and May (Wallace 2004).

Fall-run Chinook salmon can exhibit a diversity of juvenile life history strategies (Bouret et al 2016) and there appear to be three primary types in the Klamath River basin (Sullivan 1989):

- Type I (smolts enter ocean within a few months of emergence in early spring)
- Type II (smolts enter ocean in autumn or early winter)
- Type III (smolts enter ocean in spring at age-1+)

Scale analysis of returning adults conducted in the 1980s indicated that juvenile fall-run Chinook salmon in the Klamath River basin primarily exhibited the Type I or Type II life history, with <4% exhibiting Type III (Sullivan 1989). The majority of juvenile fall Chinook salmon in the Klamath River migrate to the estuary or ocean by mid-summer (Sullivan 1989, Scheiff et al. 2001, David et al. 2016). A comparison of fry outmigration timing in the upper Middle Klamath and the Shasta and Scott rivers to smolt outmigration timing indicates juveniles likely rear for several months in the mainstem before smolting. Fry generally emerge from redd gravels in the upper Middle Klamath (David et al. 2016) and tributaries (Chesney and Yokel 2003) from February through April, but peak fall Chinook outmigration at the Big Bar trap near Orleans occurs in June and July, with very few individuals captured prior to June (Scheiff et al. 2001).

Scale analysis of fall-run adult Chinook salmon returning to the Scott and Shasta Rivers in 1986 indicates that a considerable number individuals remain in freshwater as juveniles until fall or winter (Sullivan 1989). The authors speculate that these individuals either remained in their natal tributaries until fall rains or reared in the mainstem or estuary until ocean entry. Sullivan (1989) also documented that a small fraction of the adults returning to the Scott and Shasta Rivers (mostly four-year olds) had remained in freshwater for approximately one year and out-migrated in the spring as yearlings.

Table 2-2. Life-history timing of fall-run Chinook salmon in the Klamath River basin.[1]

Life stage		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Adult migration																■	■	■	■	■	■				
Spawning																				■	■	■	■	■	
Incubation & emergence		■	■	■	■	■	■	■												■	■	■	■	■	■
Type I	Rearing				■	■	■	■	■	■	■	■	■	■	■										
	Juvenile outmigration					■	■	■	■	■	■	■	■	■	■										
Type II	Rearing					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	Juvenile outmigration																	■	■	■	■	■	■		
Type III	Rearing	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile outmigration			■	■	■	■	■	■																

[1] References for listed life history timing for each life stage are provided in text.

2.1.2.2 Spring-run Chinook salmon

Historically, spring-run Chinook salmon was the dominant run in the Klamath Basin (Barnhart 1994). Currently, spring-run Chinook salmon are distributed mostly in the Salmon and South Fork Trinity rivers and in the mainstem Klamath River downstream from these tributaries during migratory periods. The generalized spring-run Chinook life history described here is based primarily on Salmon River observations, which is the closest extant population to the Project area. In the event spring-run Chinook are successfully reintroduced upstream of the Project area, additional variation in adult and juvenile life history timing and habitat use may occur.

Spring-run Chinook salmon generally enter freshwater and migrate upstream during the receding limb of the snow melt hydrograph, from early spring through early summer (Barnhart 1994) (Table 2-3). Adult spring-run Chinook salmon begin entering the Klamath River as early as February (Tuss et al. 1990, as cited in Olson 1996), and continue freshwater entry for the duration of the spring season (NRC 2004, Barnhart 1994). Adults entering the Klamath River hold in pre-spawning holding pools for the spring (NRC 2004). It appears that fish start to hold in the South Fork Trinity and Salmon rivers by May and June, respectively (Dean 1995, Olson 1996). Adults spawn in the Salmon River from mid-September to late-October (Sartori 2006). Spawning in the South Fork Trinity River occurs from September through early November (Dean 1995).

Incubation of spring-run Chinook salmon eggs occurs primarily from September to mid-January, based on estimated 50 percent hatch timing from Olson (1996). Emergence from redd gravels is occurs from March through May, with a peak in April (Olson 1996). Age-0 juveniles rearing in the Salmon River emigrate at various times of the year, with one peak outmigration occurring in April through May (Type I life history) and a second peak migration occurring in mid-October (Type II life history) (Olson 1996). Scale analyses of spawners in the upper South Fork Salmon River indicated that the majority of returning adults have a Type II life history (Olson 1996). It is unclear how much time outmigrating age-0 juveniles spend in the mainstem Klamath River and estuary before entering the ocean. There is little data to inform outmigration timing of Type III spring-run Chinook salmon in the Klamath River Basin, but based on capture of age-1 fish during trapping at Big Bar in the mainstem, outmigration is expected to occur primarily from March through May (Scheiff et al. 2001). This timing is generally consistent with outmigration timing of yearling spring-run Chinook salmon observed in other river systems (Healey 1991, Lindley et al. 2004).

Table 2-3. Life-history timing of spring-run Chinook salmon in the Klamath River basin.[1]

Life stage		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult migration													
Adult holding													
Spawning													
Incubation & emergence													
Type I	Rearing												
	Juvenile outmigration												
Type II	Rearing												
	Juvenile outmigration												
Type III	Rearing												
	Juvenile outmigration												

[1] References for listed life history timing for each life stage are provided in text.

2.1.3 Steelhead

Steelhead in the Klamath River Basin can be broadly divided into three adult runs based on adult migration timing: the summer-run, fall-run, and winter-run. Summer-run steelhead enter freshwater as sexually mature adults in spring and early summer, generally migrating upstream during the snow melt period and holding until spawning the following winter or spring (Barnhart 1994, Hopelain 1998, Papa et al. 2007). Summer steelhead primarily hold and spawn in cooler tributaries to the Klamath River such as Indian Creek, Elk Creek, Dillon Creek, Clear Creek, and the Salmon River (McEwan and Jackson 1996, USFWS 1998). Fall-run steelhead generally enter the Klamath River from July through October and spawn in the winter (Hopelain 1998). Winter-run steelhead enter freshwater as sexually mature adults from November through March (Hopelain 1998). Winter-run and fall-run steelhead primarily spawn in tributaries, with peak spawning timing in February and March (ranging from January to April) (NRC 2004). Unlike salmon, a portion of the steelhead population is iteroparous. That is, instead of dying, after soon spawning they return to the ocean and undergo one or more spawning runs in subsequent years. Based on scale analysis, Hopelain (1998) reported that the incidence of repeat spawning was 31 percent for the winter run and ranged from 40 percent to 64 percent for the summer run and 18 percent to 48 percent for the fall-run.

After emerging from redd gravels in the spring, most Klamath River juvenile steelhead rear in freshwater for two years before migrating to the ocean (Hopelain 1998) (Table 2-4). During this time, juveniles display a variety of life history and movement patterns, utilizing habitats in spawning tributaries, the mainstem Klamath River, and the estuary (Hopelain 1998, Scheiff et al. 2001, Chesney and Yokel 2003, Wallace 2004). Outmigrant trapping conducted in the middle mainstem Klamath River (at a site just upstream of the Scott River) captured age-0 steelhead from mid-April through late-June and age-1 and older steelhead are captured throughout the spring trapping period (late-February to late-June) (David et al. 2016, 2017), indicating that both age classes utilize this reach of the mainstem in the summer. Outmigrant trapping in the Shasta and Scott Rivers indicated similar movement patterns for these age classes and suggest some individuals leave these systems to rear in the middle Klamath River (Chesney and Yokel 2003). Juvenile steelhead were captured in the Klamath River estuary from early spring through early fall (the entire period sampled) (Wallace 2004). In the Klamath River and tributaries, smolt outmigration to the ocean generally occurs from late winter through spring, peaking in April and May (Scheiff et al. 2001, Chesney and Yokel 2003).

Klamath River steelhead display the "half-pounder" life-history pattern, where some individuals return to freshwater in the fall after only two to four months in the ocean, spend the fall and winter feeding in the river, then emigrate back to the ocean again the following spring (Busby et al. 1994, Hodge et al. 2014). Based on scale analysis, Hopelain (1998) found that between 87 percent and 100 percent of adults returning to tributaries to the Klamath River upstream of the Salmon River had displayed the half-pounder life history.

Table 2-4. Life-history timing of steelhead in the Klamath River basin.[1]

Life stage		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Summer-run	Adult migration					X	X	X	X	X	X	X	X												
	Holding													X	X	X	X	X	X	X	X	X	X		
	Spawning	X	X	X	X	X	X																	X	X
Fall-run	Adult migration														X	X	X	X	X	X	X	X	X		
	Spawning	X	X	X	X	X	X	X	X	X															
Winter-run	Adult migration	X	X	X	X	X	X																	X	X
	Spawning	X	X	X	X	X	X	X	X	X															
Incubation & emergence		X	X	X	X	X	X	X	X	X	X	X	X												
Rearing		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Juvenile outmigration						X	X	X	X	X	X	X	X												
Half-pounder residence		X	X	X	X	X	X										X	X	X	X	X	X	X	X	X

[1] References for listed life history timing for each life stage are provided in text.

2.2 Riverine Habitat

This section briefly introduces the general habitat types used by juvenile salmonids within the mainstem Middle Klamath River corridor. The classification system described here is modified from Lestelle et al. (2005), where habitat types are defined based on channel reach type and geomorphic unit. Channel reaches consist of repeating sequences of specific types of geomorphic units across which morphology can be linked to fluvial processes and habitat characteristics, typically over a scale of 10 to 20 channel widths in length (Montgomery and Buffngton 1997, Bisson et al. 2017). Geomorphic units are physical features within a channel reach that have relatively homogenous depth, velocity, and substrate characteristics.

Riverine habitats are divided into in-channel (i.e., main channel) and off-channel (i.e., floodplain) types (Figure 2-1). These two general channel types are further subdivided into geomorphic units that form key salmonid habitats.

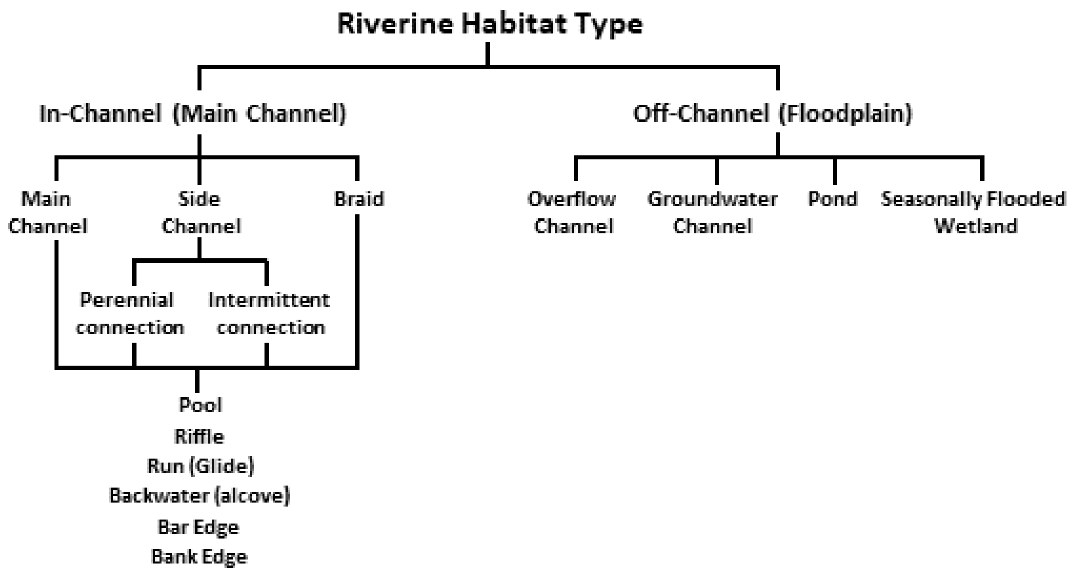

Figure 2-1. Classification of riverine habitat types used by juvenile salmonids in the Middle Klamath River (modified from Lestelle et al. 2005).

2.2.1 Main channel habitat types

In-channel habitats include the main channel, side channels, and braids (Figure 2-2). Side channels and braids are connected to the main channel at both upstream and downstream ends. A side channel is a single channel separated from the main channel by a stable, vegetated island. Side channels convey surface flow from inlet to outlet at less than bankfull discharge and may be perennially or intermittently connected to the main channel at the upstream end at low flows. A braided channel typically has multiple branches separated by transient alluvial bars that tend to be unvegetated and submerged at bankfull flow. In-channel mesohabitat types relevant to juvenile rearing include pools, bank and bar edges, and backwater units. Backwater units, also referred to as alcoves, commonly form at the confluence of the main river channel and a secondary channel type (e.g., side channel, overflow channel, or groundwater channel).

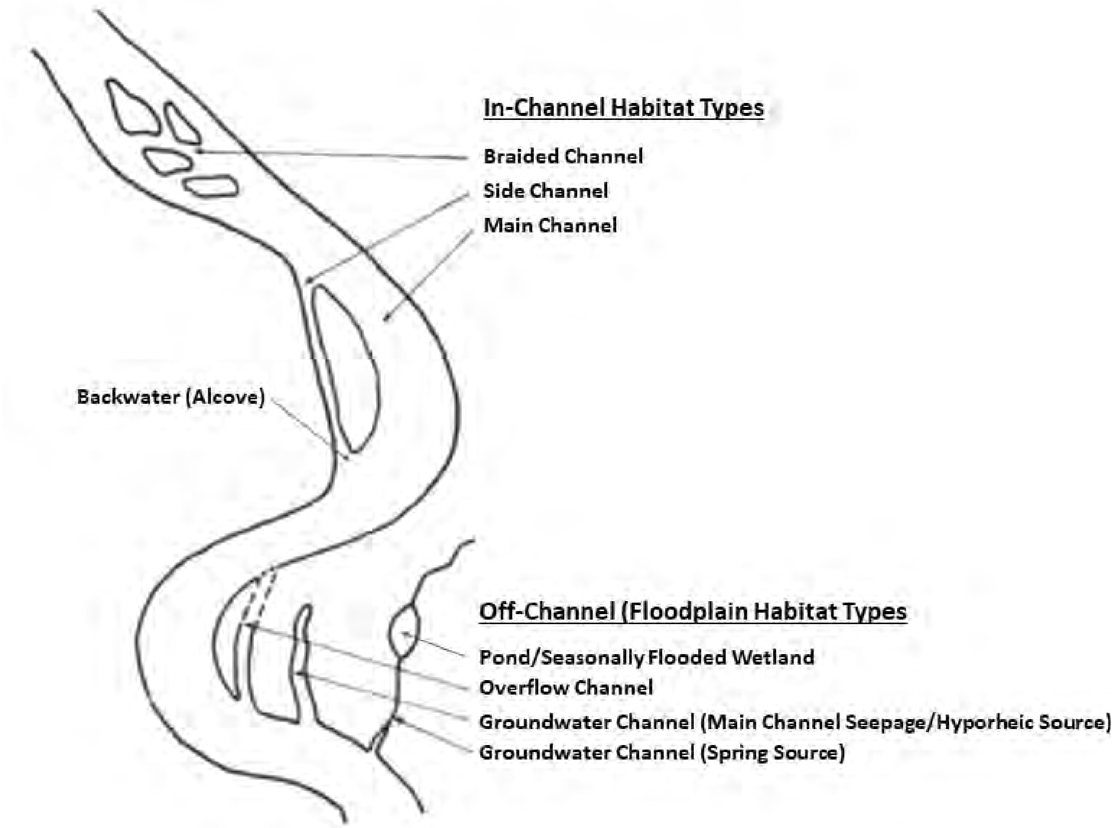

Figure 2-2. Typical planform representation of riverine habitat types used by juvenile salmonids in the Middle Klamath River (modified from Lestelle et al. 2005).

2.2.2 Floodplain and off-channel habitat types

Non-natal, off-channel habitats are particularly important for survival, growth, high flow refuge, and overall life history diversity of anadromous salmonids in the Project area. Off-channel habitat types typically occur as a continuum of features formed by channel migration and floodplain development and are commonly associated with the inside of meander bends (Figure 2-2). Off-channel habitat types are fed by groundwater, nearby tributary surface runoff, and seepage from the mainstem channel when flows are less than bankfull (i.e., these habitat types have no direct surface water connection to the main river when flows are less than bankfull). Off-channel habitats can be broadly subdivided into overflow channels, groundwater channels, ponds, and seasonally flooded wetlands. Overflow channels are secondary flow paths, often relict mainstem channels, that are connected to the main river at their upstream end when flows exceed bankfull. Groundwater channels are typically relict mainstem or overflow channels fed by subsurface flow. They include several subtypes: (1) channels originating from the seepage of main channel surface water, (2) channels fed by the larger floodplain hyporheic zone, and (3) channels fed by tributaries or springs emerging from adjacent slopes. In practice, it is often difficult to distinguish groundwater channel subtypes without seasonal monitoring of mainstem and off-channel surface water and shallow groundwater levels.

2.2.3 Summer thermal refuge

Juvenile salmonids require cool water temperatures to grow and survive. While each species can withstand periods of exposure to higher temperatures (particularly when sufficient food resources are available), juvenile coho salmon generally require maximum weekly average water temperatures (MWAT) below 17°C, juvenile Chinook salmon below 19°C, and juvenile steelhead below 22°C (North Coast Regional Water Quality Control Board 2010, Appendix 4).

The Klamath River is listed as impaired for excessive water temperatures (North Coast Regional Water Quality Control Board 2010), and under current conditions, summer temperatures throughout most of the Middle Klamath River are unsuitable for juvenile salmonids except in highly localized areas with cooler water. These thermal refuges typically occur in mainstem reaches near the confluences of tributaries that supply cold surface water, areas associated with seeps and springs, and areas associated with emergent hyporheic flow. The magnitude and spatial distribution of these thermal refuges can vary over daily and seasonal time scales, exerting important controls on salmonid rearing, migration, and pre-spawn holding. The spatial distribution of thermally suitable summer habitats is therefore an important consideration in identifying and prioritizing floodplain habitat restoration opportunities within the Middle Klamath River Project area.

Thermal infrared (TIR) imaging data acquired for the mainstem Klamath River corridor during two of the warmest summer periods in 2003 (July 27 at 735 cfs and August 9 at 996 cfs [flow at Iron Gate]) indicate that daily median water temperatures in the mainstem channel can exceed 25°C in late July and 22.5°C in early August throughout the Project area (Figure 2-3) (Watershed Sciences 2004). Late July temperatures exceeded 28°C near the downstream end of the Project area, and early August temperatures approached 25°C at both the upstream and downstream ends. The TIR data indicate that many tributaries in the Project area have substantially cooler water temperatures compared with those measured in the adjacent mainstem Klamath River. These data highlight the importance of considering tributary influence and connectivity when planning restoration of sites that permit summer rearing of juvenile salmonids.

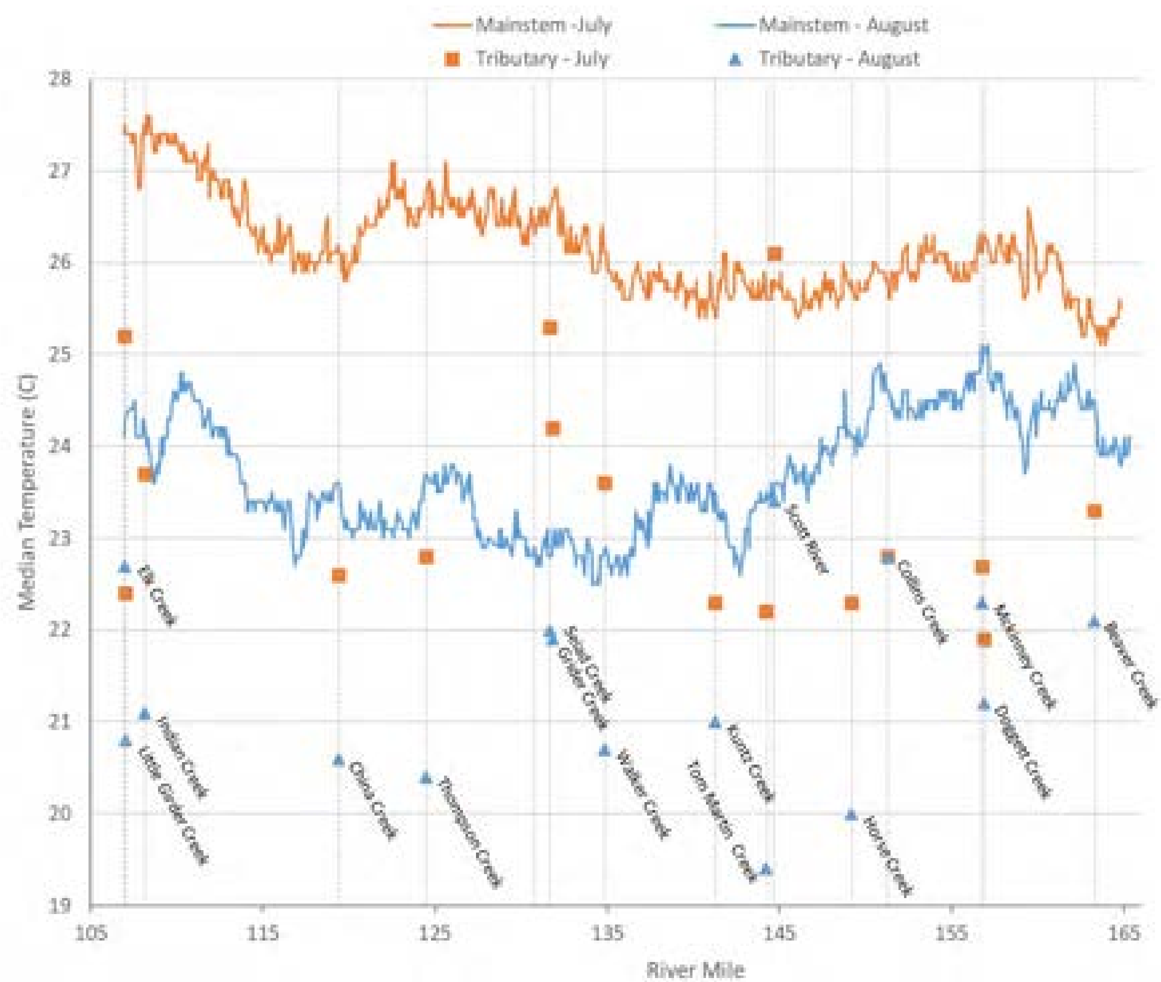

Figure 2-3. Median TIR temperatures for the mainstem and major tributaries within Project area in July and August of 2003.

2.3 Seasonal Habitat Use

Empirical information about the seasonal use of riverine habitats by juvenile salmonids is critical for informing appropriate selection and design of restoration and enhancement sites. On-going research indicates the value of the mainstem Klamath River corridor for providing seasonal rearing habitat for juvenile coho salmon, both for natal individuals and for non-natal individuals emigrating through the corridor from important spawning streams such as the Scott and Shasta Rivers (Hillemeier et al. 2009, Soto et al. 2016). Because a large percentage of the coho salmon population must past through the corridor during some point in their life and because summer and winter rearing habitats in many spawning streams are degraded, habitats in the mainstem Klamath River corridor are expected to be important for maintaining population productivity, life history diversity, and resiliency. During periods when the mainstem Klamath River is inhospitable to juvenile salmonids due to excessively high water temperatures or high flows, they seek out summer and winter refuge habitats that are typically associated with the lower portions of tributaries, floodplains and associated groundwater channels, and other off-channel features along the mainstem corridor such as alcoves and ponds. Soto et al. (2016) provides a comprehensive synthesis of use of the mainstem Klamath River corridor by coho salmon based on over four years of PIT tag detection data from fish tagged at numerous sites across the watershed. They found that juvenile coho salmon redistribute from natal spawning streams within the main Klamath River corridor throughout the year, but that the movements are most prevalent in spring, early summer, fall, and early winter. This section relies heavily on information in Soto et al. (2016) to summarize general patterns in summer and winter use of these important in Middle Klamath River corridor habitats by salmonids, with a focus on coho salmon.

Within a few months of emerging from redd gravels in the spring and early summer, substantial numbers of age-0 coho salmon move into the mainstem Klamath River from spawning streams (Soto et al. 2016). After entering the Klamath River corridor, these individuals generally move downstream, seeking out shallow, low-velocity habitats associated with backwaters, floodplain channels, ponds, or small, low-gradient tributaries (Soto et al. 2016). As water temperatures increase in the early summer, some individuals redistribute to low-velocity habitats with suitable water temperatures. Such thermal refugia exist at cold water seeps in the mainstem Klamath River or in the lower reaches of colder tributaries. This early summer movement of age-0 fish from their natal tributaries appears to be typically less than 30 miles in length, but fish tagged in the Shasta River fish have been found to move nearly 200 miles downstream to sites near the Klamath River estuary during this period (Soto et al. 2016).

After finding thermally suitable summer rearing habitat, there is little movement until the first fall rains, when a second, more extensive redistribution occurs. At this time, age-0 coho salmon, both non-natal and natal individuals, are seeking out low-velocity overwinter habitats that are well protected from high flow events. These habitats generally occur in floodplain channels with ponded habitat or off-channel ponds that are connected to the Klamath River by egress channels. During this fall redistribution, fish may move relatively short distances or over 100 miles within the Klamath River mainstem corridor before finding a suitable site for overwintering until the spring smolt outmigration period.

3 CHANNEL REACHES

3.1 Geology and Geomorphology

The Klamath River traverses approximately 260 river miles, originating in Upper Klamath Lake in southern Oregon and cutting southwest through the Klamath Mountains and northern California Coast Range to the Pacific Ocean near Requa. Over this course, the river flows through several distinct geomorphic provinces, each uniquely influencing hydrology; channel morphology; and tributary supply of water, sediment, nutrients, and wood.

The Upper Klamath Subbasin, located upstream of Iron Gate Dam, drains the High Lava Plains, Modoc Plateau, and Cascade Range geomorphic provinces composed predominantly of Miocene age basalts and andesitic volcanic rocks of Cenozoic age (CGS 2002). The permeable volcanic rocks and subdued relief in the Upper Klamath Subbasin results in low drainage density, low stream gradients, and internally drained areas that are typically filled with volcaniclastic sediment, alluvial fan deposits, and lake sediment (e.g., Upper Klamath, Lower Klamath, and Tule lakes). The Upper Klamath Subbasin also lies in the rain shadow of the Klamath and Cascade mountain ranges, and streamflow is largely from relatively steady groundwater flow. Low channel gradients, limited surface runoff, and internal drainage contribute to a muted hydrologic response to storm events and low sediment yield to the Klamath River.

The Middle Klamath Subbasin extends from approximately Iron Gate Dam downstream to the Trinity River confluence near Weitchpec. The Middle Klamath Subbasin occurs predominantly within the Klamath Mountains geomorphic province and is underlain by a series of geologic terranes comprised of oceanic lithosphere, volcanic arcs, and mélange that were successively accreted to the convergent margin of western North America through a series of tectonic episodes (Irwin 1994). Widespread metamorphism, folding, and faulting occurred in both the continental and accreted rocks during each episode. The complex geologic and geomorphic character of the Klamath Mountains reflects this tectonostratigraphic growth and subsequent plutonic intrusive, metamorphic, and volcanic activity that has occurred since the early Devonian (Irwin 1994).

The steep, mountainous terrain in the Middle Klamath Subbasin results in more peaked storm runoff and more prevalent mass wasting processes compared to the upper basin, leading to more dynamic fluvial processes (i.e., sediment supply, transport, and storage) in the mainstem channel and tributaries. The Middle Klamath River is generally a coarse-grained, bedrock-controlled channel with short alluvial reaches and relatively little floodplain development (Ayres Associates 1999). Degree of confinement, channel morphology, and bed grain size distribution are locally controlled by bedrock, Quaternary fans and terraces, and tributary flow and sediment inputs.

The regulated flow and coarse sediment deficit resulting from upstream dams and diversions have coarsening the channel bed and reduced bed mobility, leading to vegetation encroachment, channel entrenchment, and less floodplain inundation. These effects of regulated flow and reservoir sediment trapping are most apparent in the reach between J.C. Boyle Reservoir and the Scott River. Reduced coarse sediment delivery and lower peak flows in this reach, combined with the associated changes in channel morphology, have reduced the amount and quality of spawning habitat and the occurrence and availability of floodplain and off-channel rearing habitats (Buer 1981, PacifiCorp 2004).

The following sections describe reach scale channel morphology in the Project area between the Shasta River and Elk Creek confluences.

3.1.1 Shasta River to Scott River

The Klamath River channel between the Shasta River and Scott River confluences is mostly meandering and single thread, with valley width ranging from 300 feet (ft) to almost 1,200 ft. Wider valley sections typically promote a lower gradient channel, more frequent alluvial features, and more extensive floodplains. Unvegetated point bars at the inside of channel bends, mid-channel bars, and side channel complexes are prevalent in this reach. Alluvial features are largest in the areas immediately downstream of major tributary confluences and do not exceed about 17 acres/mile until after the Scott River confluence near RM 143. Terraces have been extensively mined throughout the reach, with tailings piles occurring in many floodplain areas. Humbug Creek, Beaver Creek, and Horse Creek are the largest tributaries in this reach.

From the Shasta river confluence (RM 177.7) to the Badger Creek confluence (RM 175.4), the Klamath River flows within a confined valley. The muted hydrograph and low sediment supply resulting from upstream impoundment and diversion results in a relatively static channel and widespread vegetation encroachment. Between the Badger Creek and Humbug Creek confluences (RM 172.3), the valley widens but the river channel is mostly still confined within terraces that are occupied by numerous residential structures. The valley widens substantially downstream of Humbug Creek, with secondary flow paths bisecting broad, low-lying floodplain surfaces. The river valley becomes more confined from Dutch Creek (RM 167.4) to Beaver Creek (RM 161.7).

From Beaver Creek (RM 161.7) to Horse Creek (near RM 147), the river valley broadens and includes terraces and gravel bars. A narrower section between RM 154 and RM 150 is confined by bedrock and by the Kohl Creek alluvial fan. From RM 150 to Horse Creek, the river valley widens and has been extensively placer mined, resulting in mine tailings and other floodplain disturbance, primarily at Cherry Flat (RM 149).

From Horse Creek to Scott River (RM 143), the river valley narrows and is confined by bedrock. Terraces and bars are restricted to the insides of meander bends. Several small tributaries enter in this reach, forming steep alluvial fans at the confluence with the Klamath River. Channel morphology is single thread with few small and unvegetated mid-channel bars and point bars.

3.1.2 Scott River to Elk Creek

The Scott River is a major source of gravel and finer sediment to the Klamath River (Ayres Associates 1999). The prevalence, size, and height of unvegetated gravel bars increases downstream of the Scott River confluence in response to this increased sediment supply, with discontinuous narrow alluvial terraces forming along the canyon margins.

At Seiad Valley, large alluvial fans from Seiad Creek, Little Grider Creek, and Grider Creek form a wider alluvial valley in which terraces are cut on the front edges of the fans and the increased tributary sediment supply results in large bars and riffles. Extensive placer mining has occurred on floodplains and terraces within the Seiad Valley area. Grider Creek enters from the left bank at the downstream end of Seiad Valley.

From Grider Creek (RM 130.1) to China Point (RM 118), the Klamath River flows through a bedrock canyon with unvegetated bars located on the insides of meander bends. Valley terraces and bars with bedrock at shallow depth are prevalent in this reach. From RM 121.5 to China Point, the canyon narrows as it enters bedrock of the Jurassic Galice Formation. Bedrock benches form along the channel margins. At China Point, an extensive, unvegetated gravel bar lies on the inside of the bend along with a higher alluvial terrace. Tributaries that contribute flow and sediment to the river in this reach include Thompson, Fort Goff, Portuguese, Grider, Walker, O'Neil, and Macks creeks.

From China Point to Elk Creek (RM 118-105.5), the channel alternates between wider and narrower reaches with numerous valley terraces that have been extensively mined. Well-developed bars and riffles occur at tributary confluences and meander bends. The lowest portion of this reach contains large unvegetated bars formed by large sediment inputs from Elk and Indian creeks and channel constrictions downstream of RM 104.

3.2 Floodplain Morphology and Flow Inundation

To characterize floodplain morphology and relative flow inundation potential within the Project area, we analyzed the height of valley bottom landforms (e.g., bars, floodplains, levees, and terraces) above a reference surface defined by thalweg elevations at prominent riffle crests throughout the Project area (n=172). Riffle crest thalweg elevations were extracted from a digital terrain model (DTM) derived from LiDAR point cloud data collected in 2010 (USBR 2012). Riffle crest thalweg points (position and elevation) mapped from aerial photography and LiDAR data were used to create a digital slope model for an area within 1,000 ft of the channel centerline. The slope model was constructed by projecting orthogonal 3-D breaklines from each riffle crest to the 1,000-foot buffer. The slope model created from the riffle crest thalweg points was subtracted from the original LiDAR DTM. The resulting differences between the two surfaces indicate the height of geomorphic features above the riffle crest thalweg datum (Figure 3-1, Appendix B). The process is equivalent to removing the overall trend in down valley slope from the topography (commonly referred to as surface detrending). The detrended surface is a simplified method of assessing floodplain morphology, inundation potential, and secondary flow paths within the lateral extent of the 100-year floodplain. The method is particularly useful where developing a hydraulic model is infeasible or cost-prohibitive due to insufficient data, the overall length of channel being assessed, or other factors. Hydraulic modeling was used in a subsequent step of this Project to inform conceptual design elevations of features within design sites (refer to Section 5.3.2).

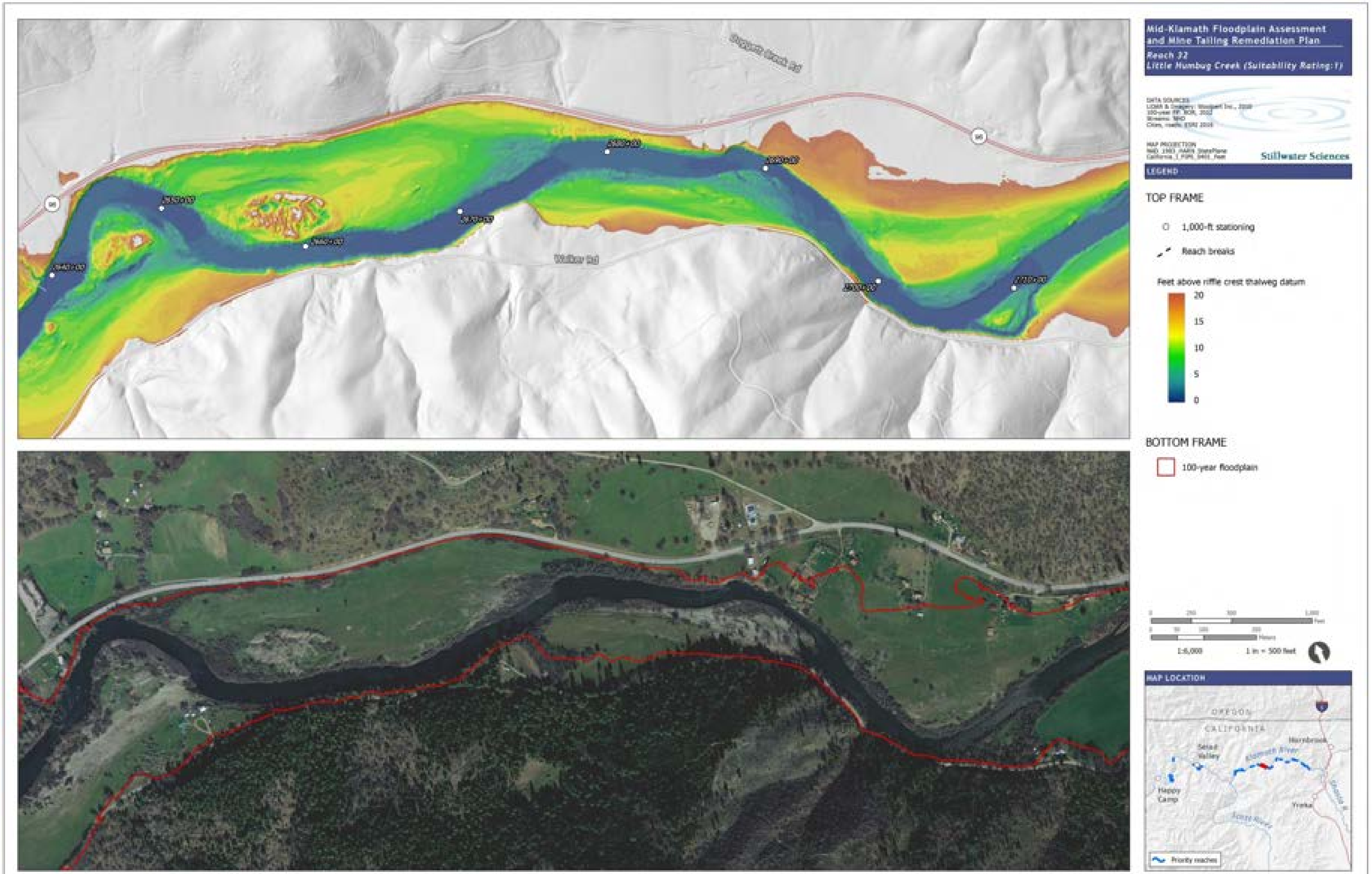

Figure 3-1. Height of geomorphic features above the riffle crest thalweg within the 100-year floodplain at Reach 32 (Little Humbug Creek).

3.3 Reach Delineation

A total of 49 channel reaches were delineated within the Project area based on geomorphic characteristics, such as channel gradient, valley width, and the height of geomorphic features above the riffle crest thalweg (described above) (Figure 3-2, Table 3-1, Appendix A). These data were used in conjunction with review of other spatial data, including a LiDAR-derived hillshade, aerial imagery, and coarse scale geomorphic mapping. To support the reach delineation, a longitudinal profile of the mainstem Klamath River channel through the Project area (Figure 3-3) was created using a LiDAR-derived channel centerline and US Geological Survey (USGS) geospatial data sources. Channel elevations were sampled at 100-foot station intervals across the 71.3-mile Project area channel length. Channel slope was calculated from the longitudinal profile using a 2,200-foot moving average (Figure 3-3). Because riffle crests are a primary control on channel slope, the average riffle crest spacing throughout the Project area was used as the basis for the 2,200-foot moving average distance. The 100-year floodplain inundation extent modeled by the U.S. Bureau of Reclamation (USBR 2012) was used as a proxy for valley width. Individual valley width measurements were taken orthogonal to the valley centerline at 500-foot station intervals (Figure 3-3).

Reach delineation was also informed by coarse-scale mapping of geomorphic features (e.g., the channel, vegetated and unvegetated bars, floodplain, alluvial and strath terraces, and alluvial fans) within the mainstem river corridor from Iron Gate Dam to the Klamath River estuary obtained from the USBR (Appendix H in USBR 2012). The USBR digitized existing geomorphic mapping by Ayres Associates (1999).

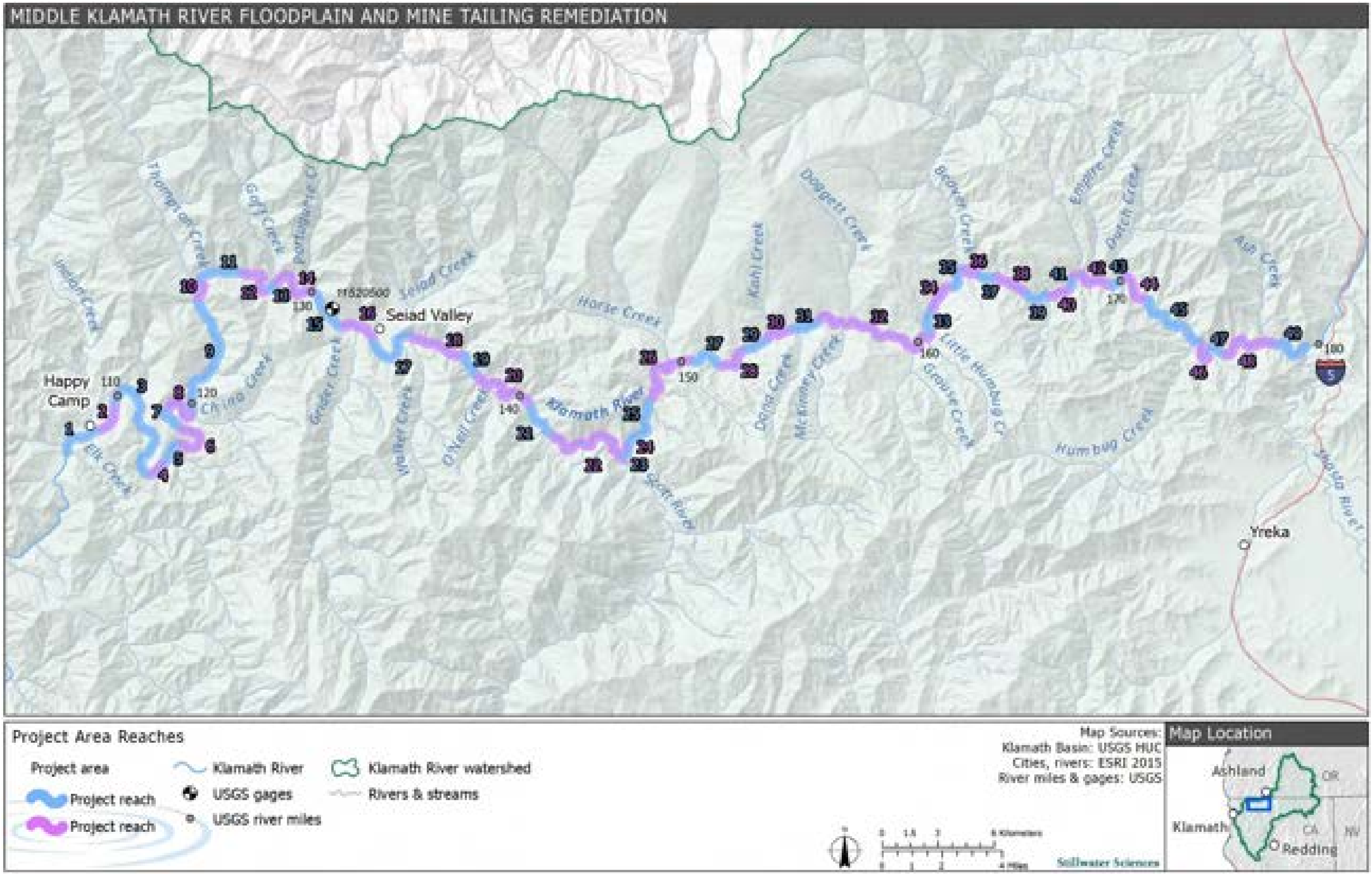

Figure 3-2. Channel reaches in the Project area.

Table 3-1. Channel reaches in the Project area.

Reach no.	Reach name[1]	Downstream RM	Upstream RM	Length (mi)
1	Indian Creek	105.5	106.8	1.30
2	Happy Camp	106.8	108.2	1.41
3	Cade Creek	108.2	112.7	4.45
4	Below Fryingpan Creek	112.7	113.4	0.67
5	Fryingpan Creek	113.4	114.2	0.79
6	Little Horse Creek	114.2	116.0	1.78
7	Below China Creek	116.0	116.9	0.91
8	China Creek	116.9	118.3	1.32
9	Joe Miles Creek	118.3	122.6	4.30
10	Thompson Creek	122.6	123.3	0.72
11	Tims Creek	123.3	124.8	1.44
12	Ladds Creek	124.8	126.3	1.53
13	Below Fort Goff	126.4	126.7	0.34
14	Fort Goff	126.7	128.6	1.91
15	Below Seiad Valley	128.6	130.1	1.44
16	Seiad Valley	130.1	131.4	1.27
17	Walker Creek	131.4	133.6	2.19
18	Walker Gulch	133.6	135.5	1.86
19	Below O'Neil Creek	135.5	136.3	0.83
20	O'Neil Creek	136.3	138.9	2.60
21	Kuntz Gulch	138.9	140.2	1.25
22	Below Scott River	140.2	143.6	3.41
23	Above Scott River	143.6	143.9	0.30
24	Below Kinsman Creek	144.0	144.1	0.16
25	Kinsman Creek	144.1	146.1	1.95
26	Horse Creek	146.1	148.8	2.71
27	Cherry Flat	148.8	150.1	1.29
28	Lime Gulch	150.1	151.4	1.27
29	Above Lime Gulch	151.4	152.3	0.85
30	Kohl Creek	152.3	153.3	0.96
31	Dona Creek	153.3	154.3	1.01
32	Little Humbug Creek	154.3	159.1	4.80
33	Smith Gulch	159.1	159.9	0.73
34	Quigleys Cove	159.9	161.0	1.16
35	Beaver Creek	161.1	161.8	0.77
36	Miller Gulch	161.8	162.5	0.65
37	Cougar Gulch	162.5	163.1	0.60
38	Above Cougar Gulch	163.1	164.3	1.16
39	Vesa Creek	164.3	165.2	0.91
40	Above Vesa Creek	165.2	166.1	0.84
41	China Gulch	166.1	166.4	0.33
42	Gottsville	166.4	168.0	1.53
43	Below Swiss Bar	168.0	168.6	0.59
44	Swiss Bar	168.6	169.9	1.27
45	Humbug Creek	169.9	172.6	2.75
46	Garvey Gulch	172.6	173.6	1.00
47	Woodrat Bar	173.7	174.2	0.53
48	Ash Creek	174.2	176.2	1.97
49	Below Shasta River	176.2	177.7	1.48

[1] Reach names are based on nearby place names (e.g., tributaries, river bars, and towns).

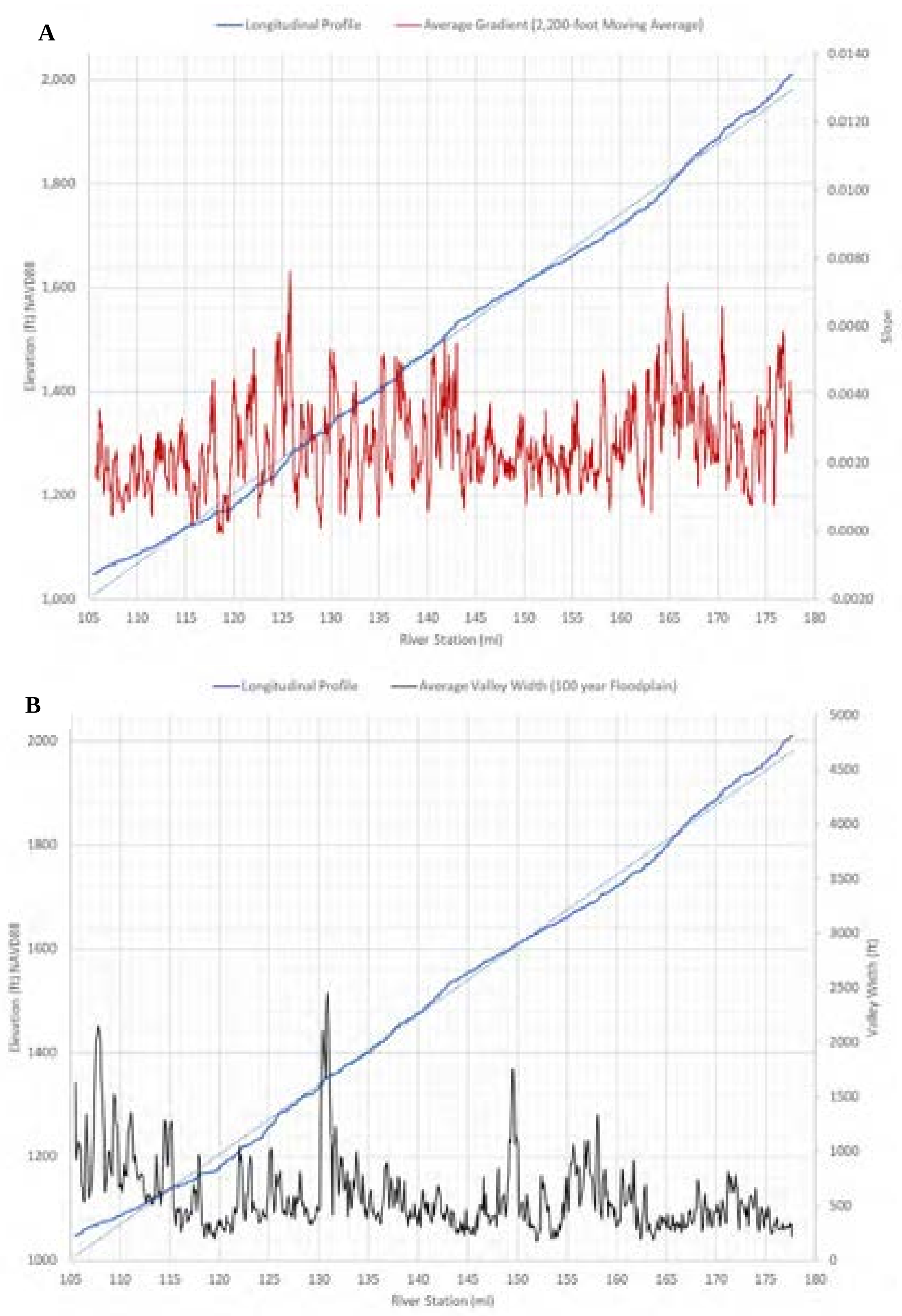

Figure 3-3. Channel gradient (A) and valley width (B) in the Project area.

3.4 Placer Mining in the Middle Klamath River Corridor

Placer mining occurred extensively within the mainstem Middle Klamath River and in tributaries from the time gold was discovered at New Orleans Bar (Orleans) in 1850 through about the 1940s. At the beginning of this period, near-surface placer deposits on exposed gravel bars and floodplains were mined by hand (e.g., with pan, rocker, long tom, and sluice) and with drift mines (i.e., tunnels dug into the deposits) during the dry season. By the mid-1850s, miners were using wing dams, a type of timber coffer dam typically extending across most of the channel (200–300 ft), to expose large areas of the mainstem river bed for excavation (Stumpf 1979). Mining the channel bed with the support of wing dams, like hand methods, occurred during the dry season when mainstem river flows were low. In the 1870s, miners began using hydraulic sluicing techniques involving high-pressure monitors to deeply mine thick placer deposits on higher floodplains and river terraces. Hydraulicing often completely rearranged river bars, floodplains, and terraces near tributary confluences. From the 1870's through the 1880's, increasingly larger scale cooperative hydraulic mining required more labor, capital and water; as well as professional engineering to develop the water delivery systems that diverted tributary flow to the mines (Stumpf 1979, USDA Forest Service 2003). Most hydraulic mining claims operated only during the wet season when tributaries provided water, and most mines incurred repeated flood damage during operation.

The primary mining districts in the Project area during this period of gold production included Humbug Creek, Gottville, Oak Bar, Hamburg Bar, Seiad, Nolton and Happy Camp (Indian Creek) (Stumpf 1979). Each of these mining districts contained many hydraulic, ground sluicing, and drift mines. The mainstem Klamath River corridor between Humbug Creek and the Scott River (the Gottville and Oak Bar Districts) was the most extensively mined. Nearly every alluvial bar and floodplain area along the mainstem channel and lower reaches of the larger tributaries in this reach of the river was excavated (especially at Humbug Creek; McConnell, Masonic, Skeahan, and Kanaka bars in the mainstem Klamath River; and in Lumgrey, Empire, Dutch and Vesa creeks).

The 1884 decision in the case of Woodruff vs. the North Bloomfield Gravel Mining Company described the damage to the Yuba River caused by hydraulic mining and prohibited the mining company from discharging mining sediment into watercourses. The ruling, although applicable only to the Sierra Nevada at the time, effectively ended the era of large-scale hydraulic-mining in much of California. Hydraulic mining resumed on a much smaller scale after 1893 when the United States Congress passed the Camminetti Act, which allowed hydraulic mining to occur if detention structures were constructed to trap mining debris. Placer mining for gold in the Klamath Basin boomed again during the early1930s with the increase in gold prices. During this time, bucket-line and dragline dredging largely replaced hydraulic mining practices in the Middle Klamath River and some if its major tributaries. Substantial bucket-line and dragline dredging in Seiad Valley and Cherry Flat disrupted large areas of the mainstem Klamath River corridor, where the enduring effects persist today as vast tailings piles and mine pits. Local gold production sharply declined during World War II, due in part to the War Production Order L-208 in 1942, and in 1943, Senate Bill No. 380 amended California Fish and Game Code Section 482 to prohibit mining operations in the Klamath River between July 1 and November 30.

Mining activity substantially impacted the mainstem river and tributaries, establishing the present-day physical template in many alluvial reaches. Hundreds of acres of floodplain and stream terrace deposits were processed down to bedrock (typically 30–50 ft), and most of the tailings (alluvial sand, gravel, cobble and boulders) were delivered to the Klamath River (USDA

Forest Service 2003). Although mining activity in the Middle Klamath River corridor fluctuated considerably during the period from 1850 to 1943, it delivered millions of cubic yards (cu yds) of sediment to the river annually during peak production years (USDA Forest Service 2003). Many tributary channels were realigned and altered at their confluence with the Klamath River due to mining activities. Periodic floods during this period (e.g., 1852, 1861, 1864, 1875 and 1880) mobilized large quantities of unconsolidated sediment disturbed by mining and reportedly scoured all mining improvements from the river corridor (Wells 1881, as cited in USDA Forest Service 2003). Aquatic and riparian habitats in the Klamath River corridor were substantially disturbed, simplified, or lost entirely due to placer mining during this period. Channel conditions created barriers to salmon and steelhead migration, pools were filled due to excessive sediment, and habitat conditions in many tributaries were unsuitable for spawning and rearing. The effect of these impacts on salmon and steelhead populations was likely significance and enduring, although difficult to estimate without information about the historical run sizes prior to mining (USDA Forest Service 2003).

Large floods in the Klamath River (e.g., 1955, 1964, 1997) likely transported and redistributed large volumes of mining debris, aggrading the channel and established persistent long-wavelength barforms, as has been described in the Trinity River following the 1955 flood (Krause et al. 2010). The long-term residence time of mining debris moved into the mainstem river channel from floodplain tailings and other sources during large floods is unknown.

Flow, sediment transport, and channel morphology in the Project area has also been affected by upstream dams and diversions. The effects of these dams and diversions on reducing sediment supply and transport and in reducing peak flow magnitudes and durations necessary for maintaining dynamic alluvial channel morphology within the Project area is most pronounced from the Shasta River confluence to the Scott River confluence. The channel in this reach lacks dynamic fluvial processes; and relict floodplain and off-channel habitat features are disconnected by a lack of high flow, encroachment of riparian vegetation onto channel banks and bars, and associated geomorphic adjustments (e.g., sediment levees). These changes in river hydrology, hydraulics, sediment supply and transport, and morphology have likely increased the residence time of mining debris introduced into the river channel during mining operations and subsequent infrequent large flood events. Downstream of the Scott River confluence, tributary flow accretion and sediment supply begin to promote more dynamic fluvial processes and channel morphology.

3.4.1 Mapping mining-impacted areas

To help identify opportunities and constraints to restoration and enhancement of floodplain habitat for juvenile rearing salmonids in the Middle Klamath River corridor, areas with obvious disturbance from historical hydraulic and dredger placer mining were mapped throughout the Project area. Three mining-impacted disturbance types were identified: tailings, pits, and undifferentiated areas of disturbance. Tailings are identified by piles of mining spoils, typically above the existing floodplain elevation. Pits are identified as excavations, typically below the existing floodplain elevation. Undifferentiated areas are broadly defined areas of disturbance other than tailings and pits, including other types of relatively large disturbance features that are obviously composed of fill (e.g., spoils sites, construction pads, and levees unrelated to mining) and that significantly obstruct floodplain flow paths and/or inundation. Features within the 100-year floodplain of the mainstem Klamath River were mapped from aerial imagery, LiDAR topography, and the height above the riffle crest thalweg datum. Mapping also included some large disturbed areas in the downstream extent of large tributary valley bottoms where they coalesce with the 100-year floodplain of the mainstem Klamath River.

Mining disturbance is most continuously prevalent within the mainstem river corridor from Humbug Creek to approximately Vesa Creek. The three largest areas of mine tailings occur in the Humbug Creek, Cherry Flat (Figure 3-5), and Seiad Valley reaches (including the Walker Creek reach located at the upstream end of Seiad Valley). These reaches cumulatively represent 94 percent of the mine tailings mapped in the Project area (Table 3-2, Figure 3-4, Appendix B). These three reaches also contain the largest existing mining pits that maintain ponded water throughout the year.

Table 3-2. Mining impacted areas in the Project area.

Reach	Name	Disturbed Area, Ac		
		Pits	Tailings	Undifferentiated
2	Happy Camp	0.0	0.5	7.3
3	Cade Creek	0.0	0.0	1.4
6	Little Horse Creek	0.0	0.1	1.5
16	Seid Valley	6.7	45.2	4.8
17	Walker Creek	1.4	23.9	0.1
25	Kinsman Creek	0.0	0.0	3.9
26	Horse Creek	0.1	0.2	0.0
27	Cherry Flat	15.4	41.1	13.4
30	Kohl Creek	0.0	0.0	2.6
32	Little Humbug Creek	0.1	5.2	4.1
34	Quigleys Cove	0.0	0.0	1.5
35	Beaver Creek	0.0	0.0	0.1
36	Miller Gulch	0.0	0.0	0.3
39	Vesa Creek	0.0	1.9	0.0
40	Above Vesa Creek	0.0	0.5	0.0
41	China Gulch	0.3	1.4	0.4
42	Gottsville	0.1	2.0	2.3
43	Below Swiss Bar	0.0	0.4	1.2
44	Swiss Bar	0.0	0.3	0.0
45	Humbug Creek	2.6	17.3	13.2
46	Garvey Gulch	0.5	0.3	0.0
47	Woodrat Bar	0.8	0.2	0.0
48	Ash Creek	0.0	1.7	0.1
49	Below Shasta River	0.0	0.4	0.0
Total		**27.9**	**142.7**	**58.3**

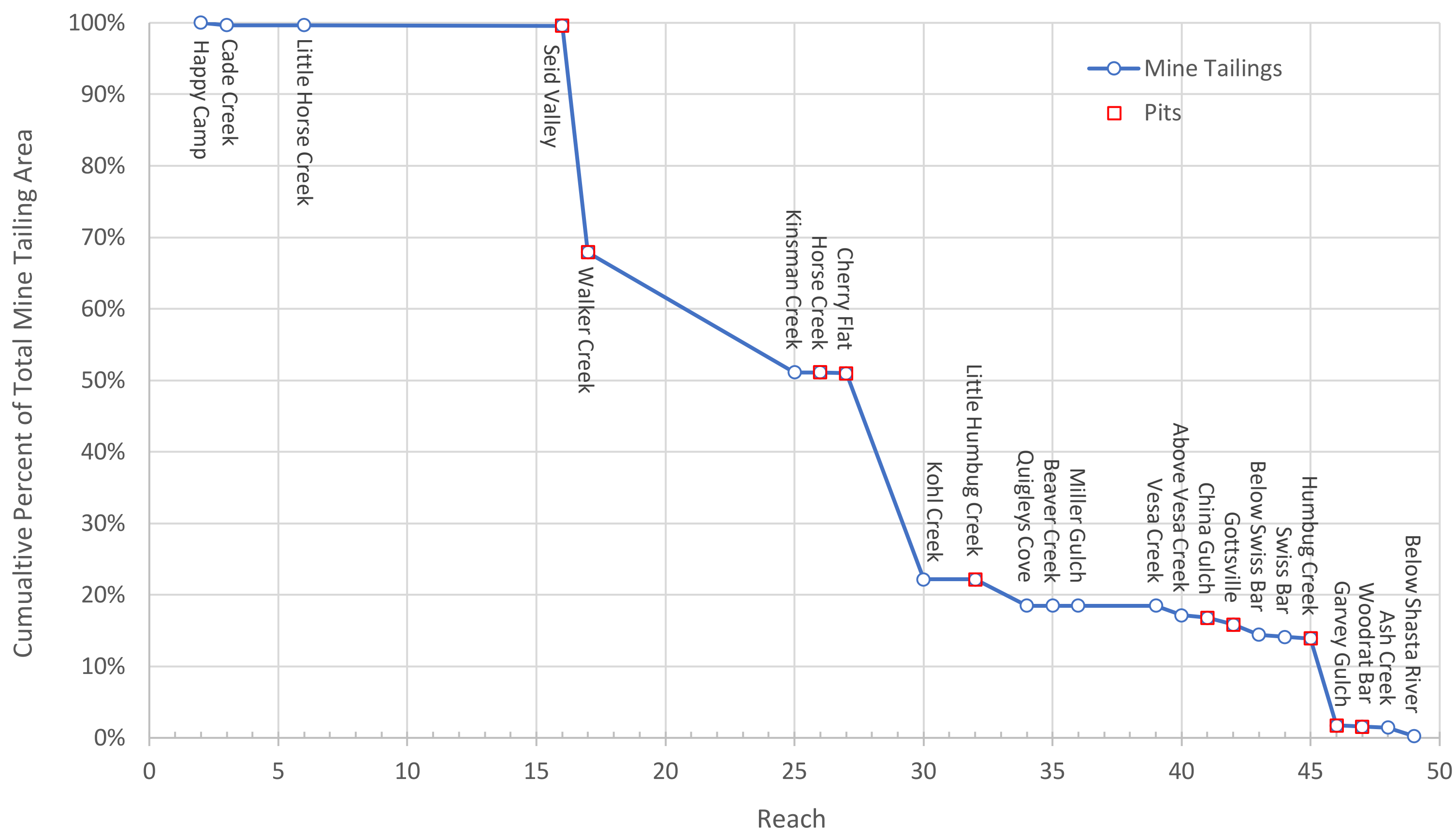

Figure 3-4. Mine tailings and pits in the Project area

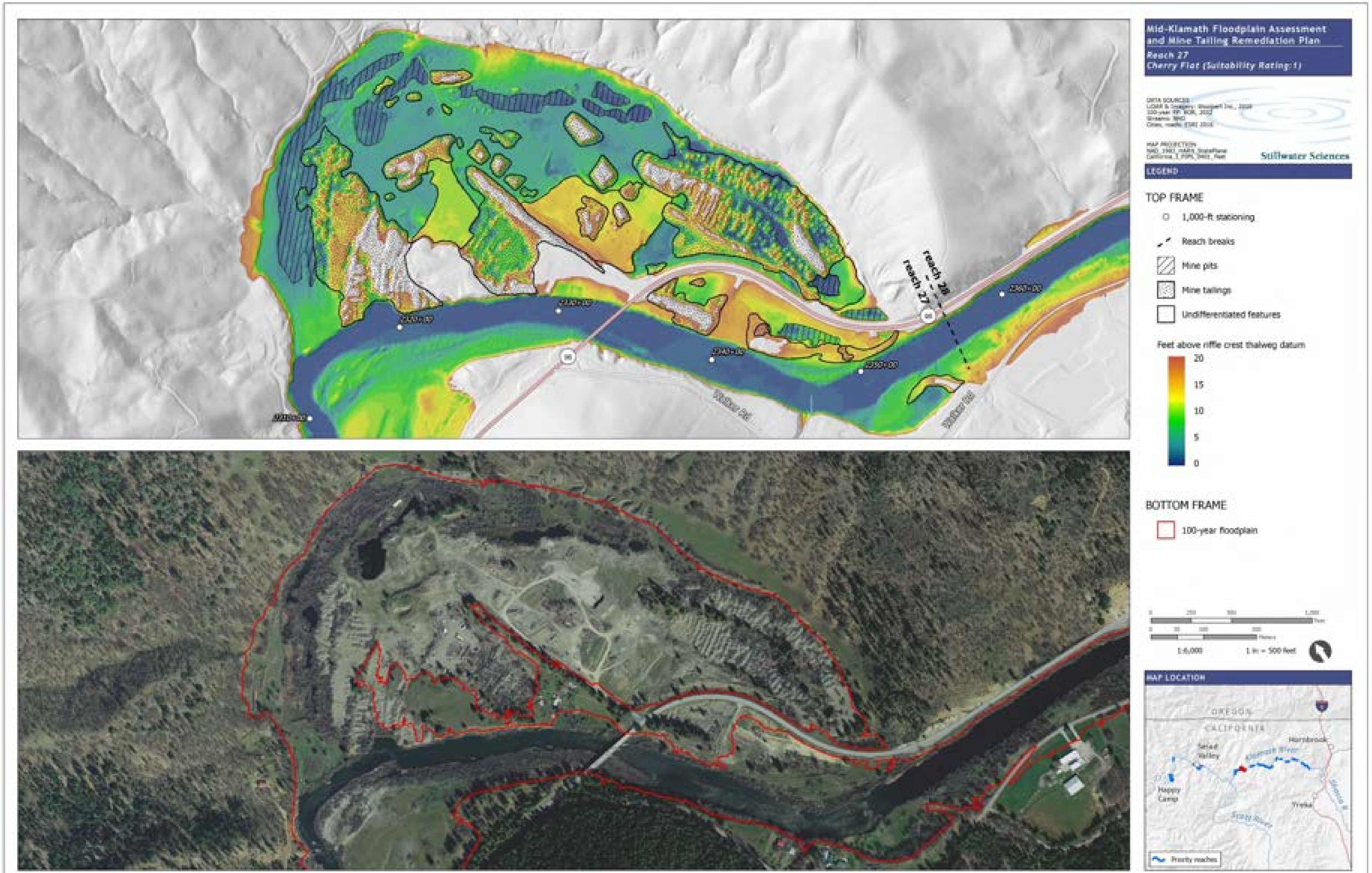

Figure 3-5. Impacts from historical placer mining at Cherry Flat illustrated by the height of geomorphic features above the riffle crest thalweg and aerial imagery.

4 FLOODPLAIN HABITAT ENHANCEMENT POTENTIAL

4.1 Reach Enhancement Potential

The potential for restoration and enhancement of floodplain and off-channel rearing habitats for juvenile salmonids within Project reaches was assessed based on compilation of existing information, a subjective suitability rating based on the expert opinion of Design Team members, an objective ranking based on physical criteria, and field observations by the Design Team and others.

4.1.1 Enhancement suitability rating based on expert opinion

Channel reaches were initially rated (1=high to 4=low) according to their relative suitability (i.e., relative potential) for restoration and enhancement of floodplain and off-channel rearing habitats for juvenile salmonids (Table 4-1, Appendix A). The initial suitability rating for restoration and enhancement represents the professional opinion of Design Team members following review of available physical and biological information and a workshop focused on discussing restoration suitability criteria and their application to Project reaches. The Design Team considered a reach to have higher restoration suitability if it contained shallower channel gradient, less confined valley width, more alluvial floodplain area with potential for frequent inundation, and more complex off-channel (floodplain) morphology. The type and severity of disturbance relative to the known or inferred pre-disturbance channel and floodplain topography, as well as the presence and quality of summer thermal refuges were additional important factors in rating the restoration suitability of channel reaches. The Design Team considered a reach to have lower restoration suitability if it contained steeper channel gradient, more confined valley width, limited potential for floodplain inundation, and/or more bedrock or large boulder control within and adjacent to the active channel. The presence of large infrastructure (e.g., major roads and bridges) and lack of summer thermal refuge were also considered in rating the restoration suitability of channel reaches. The Design Team members' professional opinion of restoration suitability reflects local experience with the existing habitat; documented utilization of those habitats by juvenile salmonids; disturbance history; and other physical, biological, and land use characteristics of each reach.

Table 4-1. Reach enhancement suitability rating (based on expert opinion) and composite rank (based on physical criteria).

Reach no.	Reach name	Suitability rating	Composite rank[1]
1	Indian Creek	2	2
2	Happy Camp	3	20
3	Cade Creek	2	7
4	Below Fryingpan Creek	4	14
5	Fryingpan Creek	3	10
6	Little Horse Creek	1	3
7	Below China Creek	4	30
8	China Creek	2	11
9	Joe Miles Creek	4	42
10	Thompson Creek	1	19
11	Tims Creek	4	34
12	Ladds Creek	2	17
13	Below Fort Goff	4	30

Reach no.	Reach name	Suitability rating	Composite rank[1]
14	Fort Goff	2	24
15	Below Seiad Valley	4	34
16	Seiad Valley	1	4
17	Walker Creek	1	5
18	Walker Gulch	3	22
19	Below O'Neil Creek	4	29
20	O'Neil Creek	2	25
21	Kuntz Gulch	4	36
22	Below Scott River	2	32
23	Above Scott River	4	43
24	Below Kinsman Creek	2	41
25	Kinsman Creek	4	43
26	Horse Creek	1	18
27	Cherry Flat	1	1
28	Lime Gulch	2	21
29	Above Lime Gulch	4	45
30	Kohl Creek	2	9
31	Dona Creek	4	40
32	Little Humbug Creek	1	6
33	Smith Gulch	2	15
34	Quigleys Cove	3	26
35	Beaver Creek	1	12
36	Miller Gulch	3	27
37	Cougar Gulch	2	27
38	Above Cougar Gulch	4	49
39	Vesa Creek	2	45
40	Above Vesa Creek	3	47
41	China Gulch	2	39
42	Gottsville	2	38
43	Below Swiss Bar	2	13
44	Swiss Bar	2	33
45	Humbug Creek	1	8
46	Garvey Gulch	3	16
47	Woodrat Bar	2	23
48	Ash Creek	3	37
49	Below Shasta River	4	48

[1] The sum of the individual component rankings (i.e., reach gradient, valley width, and extent of low-lying floodplain area) was used to calculate a composite ranking for each reach.

4.1.2 Rank based on physical criteria

In addition to the enhancement suitability rating based on expert opinion, we developed an objective ranking approach that incorporates quantitative information about key physical criteria within the Project area. These physical criteria included: (1) channel gradient, (2) valley width, and (3) extent of low-lying floodplain area (Appendix A, Table A-1 and Table A-2). Ranks were assigned for individual criterion based on inferences regarding how each physical parameter contributes to the suitability and feasibility of implementing actions to restore and enhance floodplain and off-channel rearing habitat for juvenile salmonids within a reach. The sum of the individual component rankings for each physical criterion was used to calculate a composite ranking for each reach.

4.1.2.1 Rank based on channel gradient

The channel gradient ranking is based on the departure in reach average channel gradient from the average channel gradient over the Project length (0.0026) (Appendix A, Table A-2). Reaches with lower channel gradient typically have lower flow velocities and finer bed materials comprising more dynamic alluvial bedforms and floodplain features, all factors that contribute to higher quality juvenile rearing habitat for salmonids. Negative departures indicate reach gradients less than the average gradient over the Project length. Positive departures indicate reach gradients greater than the average gradient over the Project length. The reach with the most negative departure (i.e., lowest gradient) received the highest rank (i.e., rank=1) (Figure 4-1).

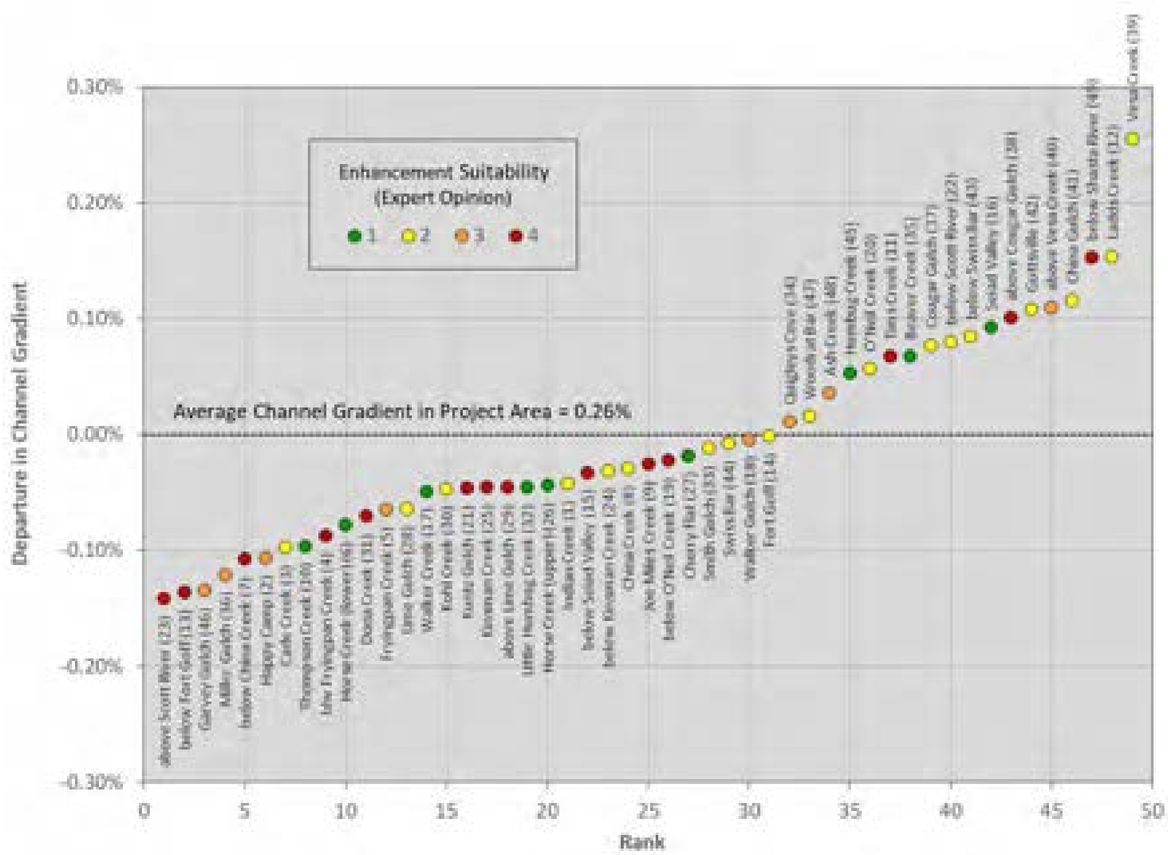

Figure 4-1. Rank based on departure in reach average channel gradient from average channel gradient over the Project length (0.0026). Reaches are color-coded by the enhancement suitability rating for comparison with the rank based on gradient.

4.1.2.2 Rank based on valley width

The valley width ranking is based on the departure in reach average valley width from the average valley width over the Project length (549 ft) (Appendix A, Table A-2). Wider valleys typically have more space for channel migration and the formation and maintenance of alluvial floodplains and off-channel features important to juvenile salmonid rearing habitat. Valley width is defined as the 100-year floodplain (USBR 2012). Positive departures indicate reach valley widths greater than the average valley width over the Project length. Negative departures indicate reach valley widths less than the average valley width over the Project length. The reach with the largest departure (i.e., largest valley width) received the highest rank (i.e., rank=1) (Figure 4-2).

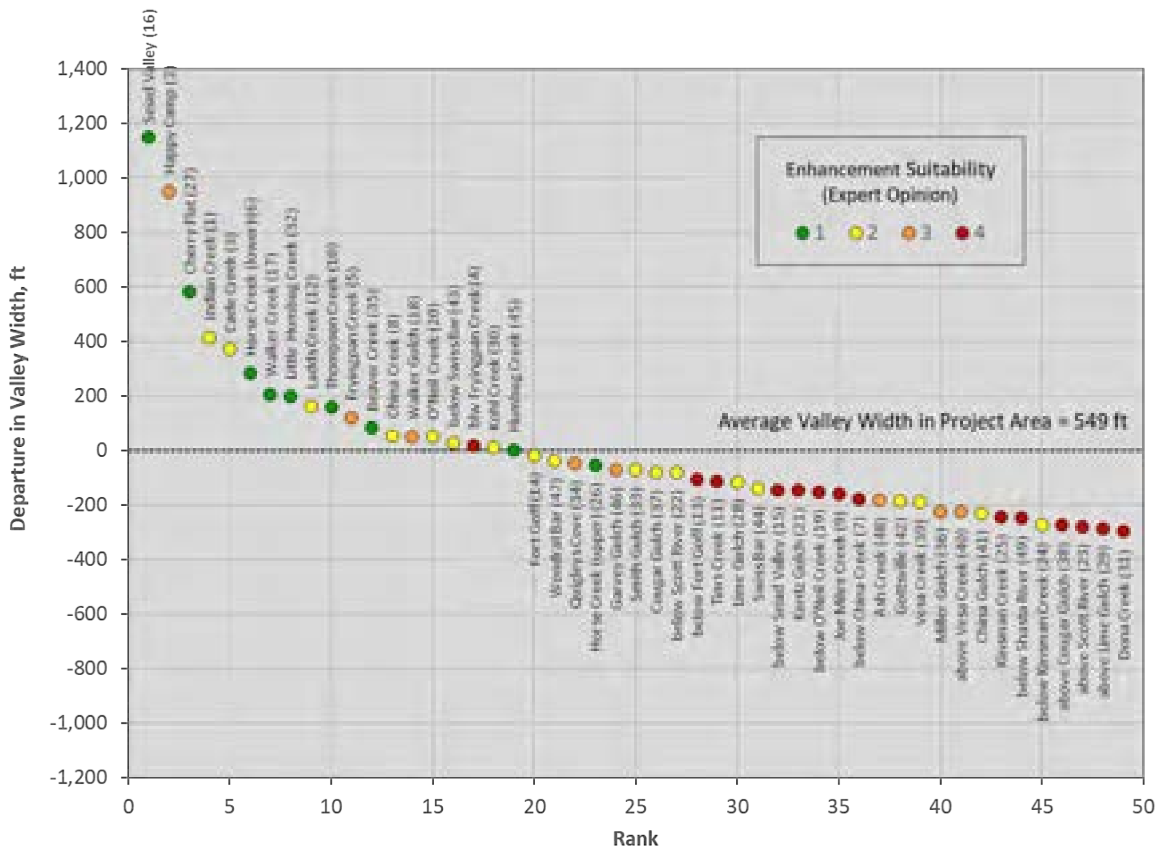

Figure 4-2. Rank based on departure in reach average valley width from average valley width over the entire Project length (592 ft). Reaches are color-coded by the enhancement suitability rating for comparison with the rank based on valley width. Valley width is defined by the 100-year floodplain (USBR 2012).

4.1.2.3 Rank based on extent of low-lying floodplain area

Low-lying floodplain areas that inundate more frequently and for longer duration typically offer more opportunities for restoring and enhancing rearing habitat for juvenile salmonids. Low-lying floodplain areas require less earthwork to create functional off-channel rearing habitats, and their proximity to groundwater provides more opportunity for establishing riparian vegetation important as cover, structure, and food resources. Low-lying floodplain areas were assessed based on the cumulative unit area (ft^2/ft) where valley bottom elevations occur within a specified range above a reference surface defined by the riffle crest thalweg datum (Appendix A, Table A-2). Refer to Section 3.2 for a description of how elevations above the riffle crest thalweg are determined. Cumulative unit area was calculated by dividing the total area within the specified elevation range by the reach length. The reach with the largest floodplain area received the highest rank (i.e., rank=1). Ranking systems were developed for two different floodplain elevation ranges: less than 5 ft above the riffle crest thalweg datum (Figure 4-3) and 5 to 10 ft above the riffle crest thalweg datum (Figure 4-4).

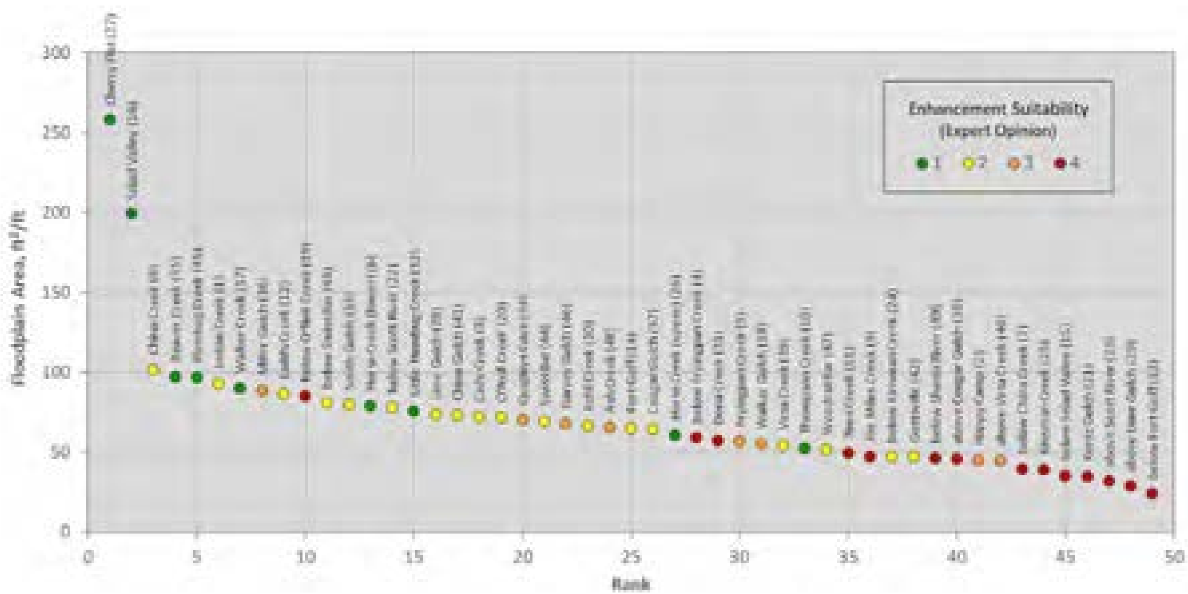

Figure 4-3. Rank based on the extent of low-lying floodplain area less than 5 ft above the riffle crest thalweg datum. Reaches are color-coded by the enhancement suitability rating for comparison with the rank based on low-lying floodplain area.

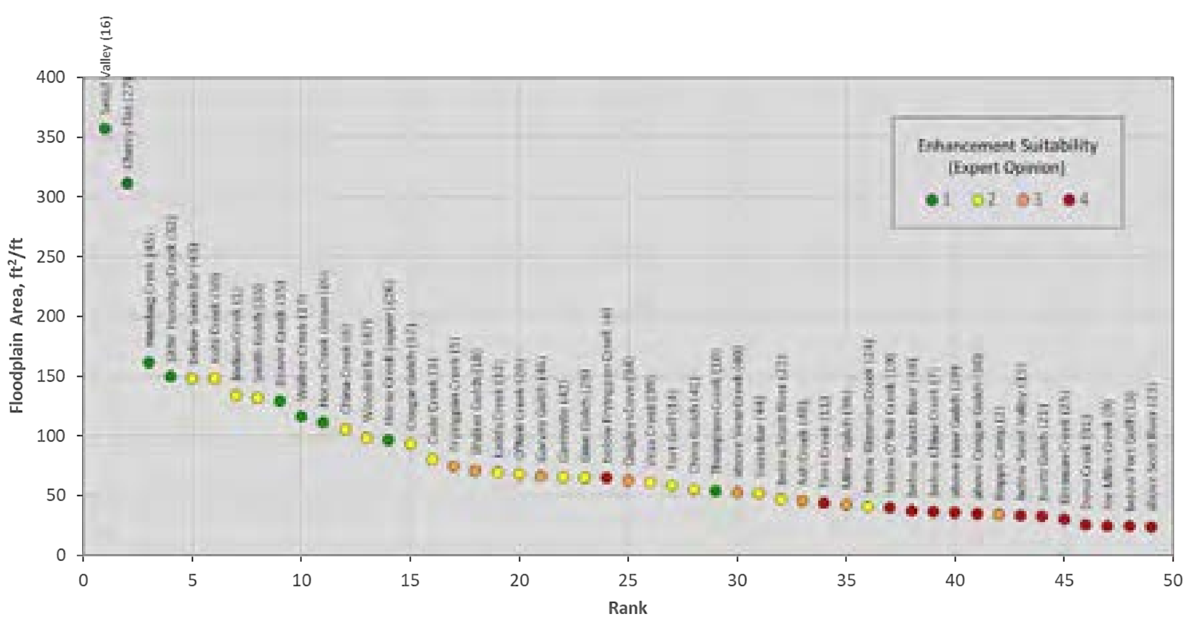

Figure 4-4. Rank based on the extent of low-lying floodplain area 5 to 10 ft above the riffle crest thalweg datum. Reaches are color-coded by the enhancement suitability rating for comparison with the rank based on low-lying floodplain area.

Floodplain and off-channel rearing habitats for juvenile salmonids in the Middle Klamath River Project area and other analogous large alluvial rivers most often occur or have the potential to occur where there is a coincidence of low channel gradient and low-lying, more frequently inundated topography. Figure 4-5 depicts this relationship between channel gradient and floodplain area within Project reaches in terms of four domains. Domain A includes reaches with relatively low channel gradient and a large amount of low-lying floodplain topography. Reaches that fall within this domain theoretically have the highest potential for restoration and enhancement of rearing habitat. Domain B includes reaches with relatively steep channel gradient and a large amount of low-lying floodplain topography. Reaches that fall within this domain theoretically have a more dynamic mainstem channel with less potential rearing habitat due to high velocities but likely offer off-channel habitat enhancement opportunities. Domain C includes reaches with relatively steep channel gradient and little floodplain area due to channel and/or valley confinement. Reaches that fall within this domain theoretically have the least potential for restoration and enhancement of rearing habitat. Domain D includes reaches with relatively low channel gradient and little floodplain area. Reaches that fall within this domain theoretically provide rearing habitat opportunities in the mainstem channel but little opportunity for restoring and enhancing rearing habitat in off-channel areas.

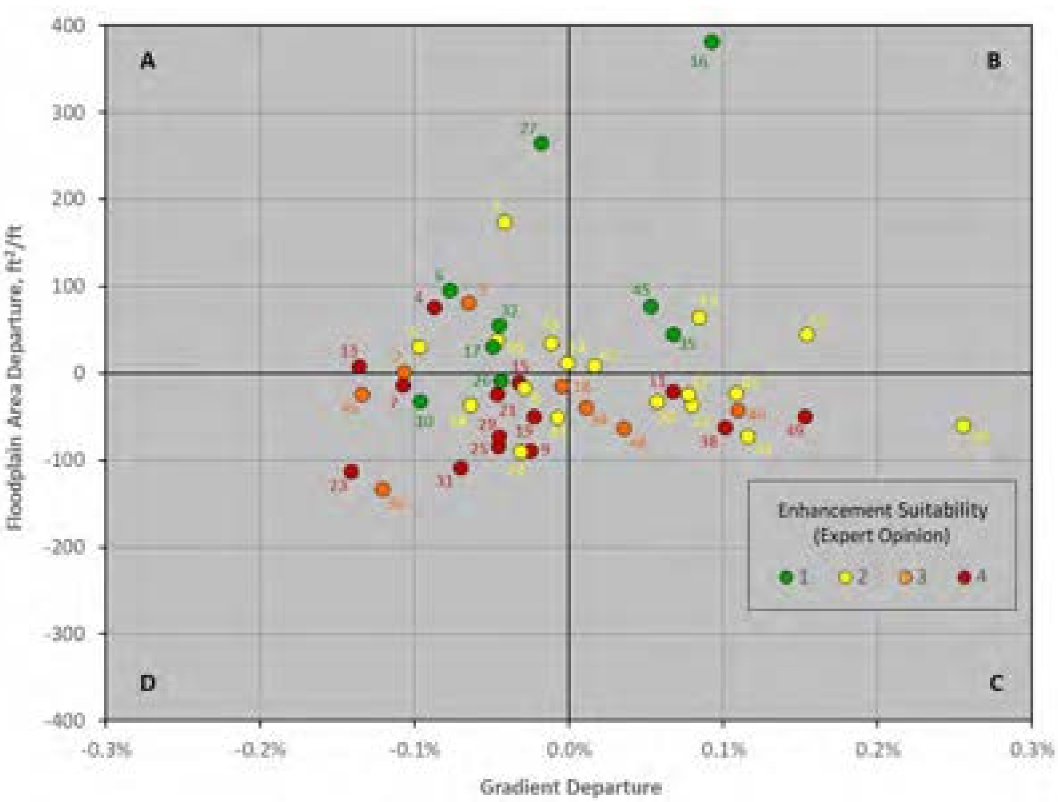

Figure 4-5. Enhancement domains defined by departures from average channel gradient and average floodplain area (<10 ft above the riffle crest thalweg datum). Reaches are color-coded by the enhancement suitability rating for comparison. Numbers next to data points indicate reach numbers (refer to Figure 3-2 and Table 3-1 for reach names, numbers, and locations).

The sum of the individual component rankings for each physical criterion was used to calculate a composite ranking for each reach (Appendix A, Table A-2). A composite score was first determined by summing component rankings for gradient, valley width, and low-lying floodplain area. The composite score was then transformed into an ordered rank, with the lowest score receiving the highest composite rank (i.e., rank of 1 indicating the reach with the highest potential for restoring and enhancing floodplain and off-channel rearing habitat for salmonids) (Table 4-1). Most reaches that ranked high based on objective physical criteria also had a high suitability rating (i.e., 1 or 2) based on expert opinion (Figure 4-6).

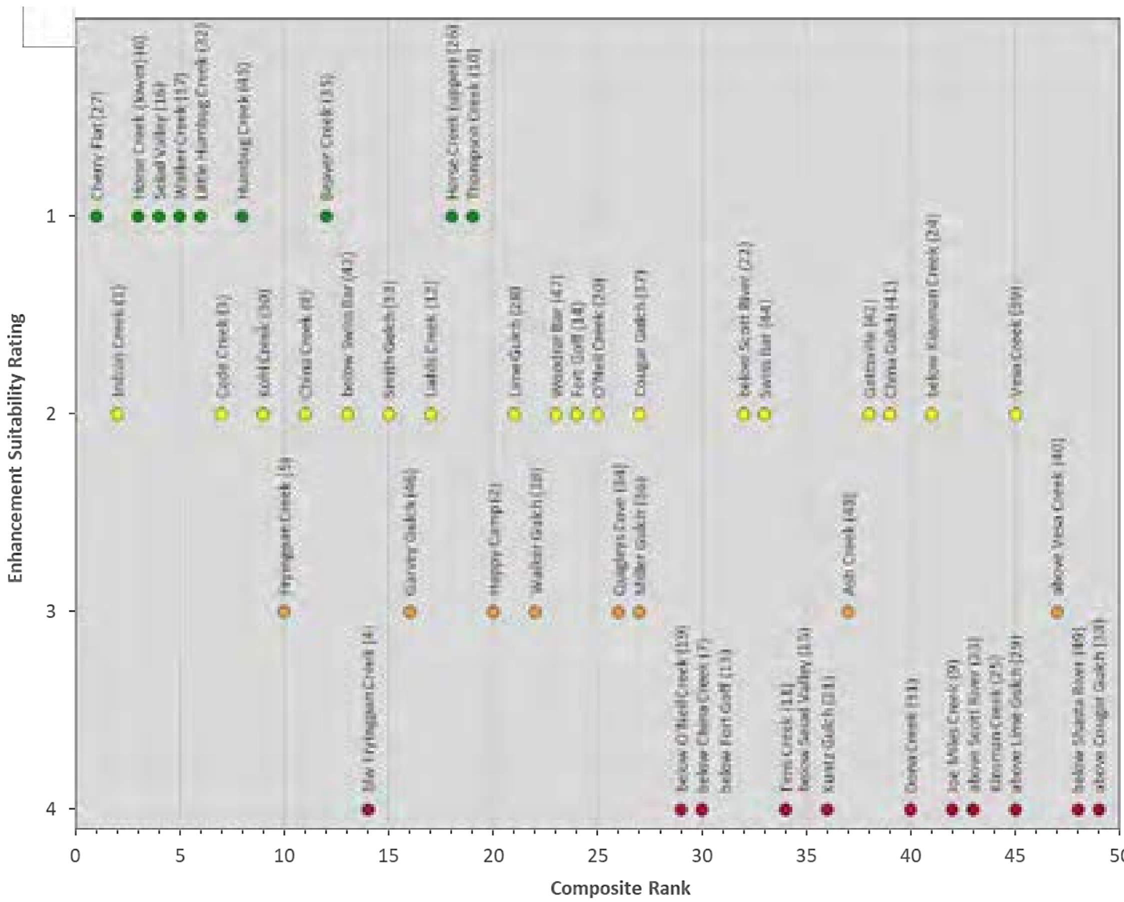

Figure 4-6. Comparison of composite rank based on physical criteria and enhancement suitability rating based on expert opinion. A high composite rank (i.e., rank of 1) indicates the reach with the highest potential for restoring and enhancing floodplain and off-channel rearing habitat for salmonids.

5 CONCEPTUAL SITE DESIGN

The following sections describe design site selection, the basis for developing conceptual designs, and the conceptual design plans for each priority site that include a description of the site, the proposed habitat enhancement activities in planform and profile, and a planning-level construction cost estimate.

5.1 Design Site Selection

Priority design sites were selected by the Design Team by considering the correspondence between the composite rank based on physical criteria and the enhancement suitability rating based on expert opinion; as well as information about sources of cold water from tributaries and springs that create or could support thermal refuge within the mainstem river corridor; the type and magnitude of historical disturbance to the channel and floodplain areas, existing rearing habitat conditions, and existing land uses and ownership.

All of the Project reaches that ranked or were rated high during the preliminary analyses were investigated by the Design Team during a field effort that occurred on May 21 and 22, 2018. The Design Team investigated more than 35 potential design sites encompassing most of the Project reaches.

The Design Team subsequently convened for a design workshop where preliminary site-specific design concepts identified in the field were discussed and refined. The Design Team also selected the fifteen priority design sites for further development of conceptual engineering design plans and planning-level construction cost estimates (Figure 5-1 and Table 5-1). Design sites were selected based on correspondence between the suitability rating and objective ranking, as well as information regarding past and present habitat values, disturbance, land uses, and other factors related to property boundaries and ownership.

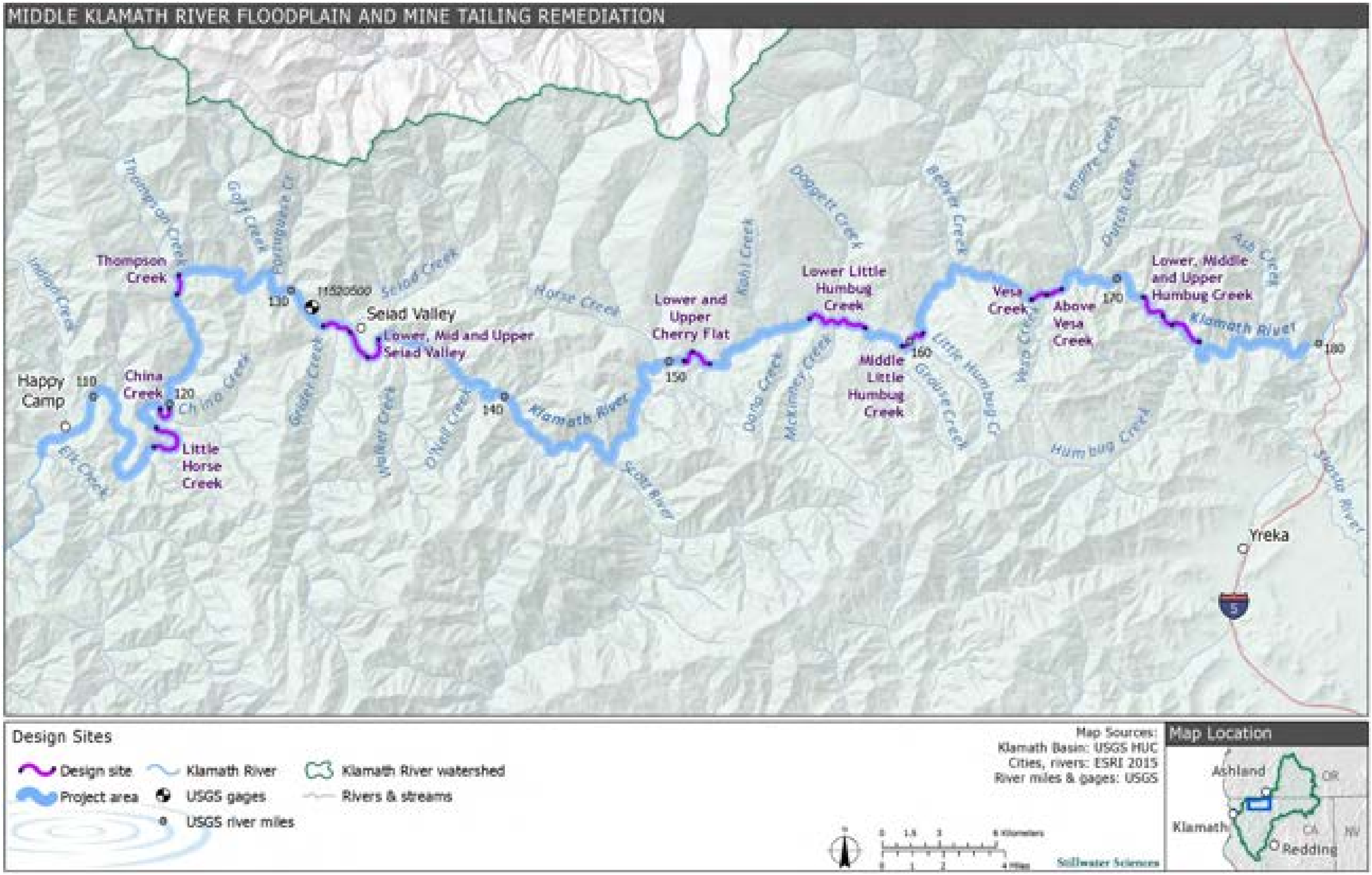

Figure 5-1. Priority Design sites.

Table 5-1. Priority design site characteristics.

Design site ID	Design site Name	Upstream RM	downstream RM	Suitability rating	Composite rank	Tributaries	Mining disturbance, ac: Tailings	Mining disturbance, ac: Total	Design approach
6	Little Horse Creek	114.2	115.6	1	3	Little Horse	1.6	1.6	Backwater (alcove) habitat enhancement, coarse sediment additions, modify riffle crest hydraulic controls to raise water surface and increase floodplain inundation, grade mine tailings to restore floodplain elevations.
8	China Creek	117.7	118.1	2	8	China	0.0	0.0	Improve fish passage and thermal refuge at China Creek confluence, modify riffle crest hydraulic controls to raise water surface and increase floodplain inundation, side channel enhancement.
10	Thompson Creek	123.0	123.3	1	21	Thompson	0.0	0.0	Add structure to Thompson Creek on fan to split flow into existing secondary channels, route cold tributary flow into upstream mainstem eddy, increase riparian vegetation cover by planting and providing more secondary flow for irrigation.
16A	Lower Seiad Valley	130.0	130.9	1	4	Grider, West Grider, Schoolhouse, Seiad	33.5	42.2	Tributary flow enhancement, improve cold water refuge at tributary confluence, side channel enhancement with large wood and BDAs, modify riffle crest hydraulic controls to raise water surface and increase floodplain inundation, create/enhance off-channel ponds.
16B	Mid Seiad Valley	131.5	132.0	1	4	Caroline	35.7	40.1	Construct alcoves and off-channel ponds, coarse sediment augmentation, grade mine tailings to restore floodplain elevations, modify riffle crest hydraulic controls to raise water surface and increase floodplain inundation.
16C	Upper Seiad Valley	132.0	132.8	1	4	Gard			Side channel enhancement with large wood structures, riparian planting, and bar apex jam at channel inlet. Lower side channel bed to increase inundation frequency and duration.
27A	Lower Cherry Flat	149.0	149.7	1	1		0.0	1.2	Construct stage zero channels in left bank floodplain, modify riffle crest hydraulic controls to raise water surface and increase floodplain inundation.
27B	Cherry Flat	149.2	150.0	1	1	Collins	41.1	68.2	Construct connected alcoves and ponds, construct infiltration gallery to promote subsurface flow and cool surface water inputs to downstream ponds and alcoves, grade mine tailings to restore floodplain elevations.
32A	Lower Little Humbug Creek	154.3	156.3	1	6	McKinney, Doggett	5.2	5.2	Modify riffle crest hydraulic controls to raise water surface elevations and increase floodplain inundation, improve cold water refuge at tributary confluences, add structure to tributary channels across fans to split flow into existing secondary channels, construct alcoves and off-channel ponds, construct side channel, modify riffle crest hydraulic controls to raise water surface and increase floodplain inundation.
32B	Middle Little Humbug Creek	158.1	158.3	1	6	Grouse/Barkhouse, Little Humbug	0.0	0.6	Improve side channel complexity, enhance spawning habitat by trapping and sorting spawning gravel, enhance tributary streamflow through conservation measures.
39	Vesa Creek	164.8	165.1	2	45	Vesa	1.9	1.9	Side channel construction/enhancement, floodplain lowering, modify riffle crest hydraulic controls to raise water surface and increase floodplain inundation, potentially realign tributary confluence.
40	Above Vesa Creek	165.4	165.6	3	47	Horse Trough Spring	0.5	0.5	Modify riffle crest hydraulic controls to raise water surface and increase floodplain inundation, side channel construction/enhancement, remove and grade mine tailings to restore floodplain elevations.
45A	Lower Humbug Creek	169.9	170.7	1	9	Lime Gulch	5.8	10.7	Coarse sediment augmentation through direct injection of mine tailings during high flow, modify riffle crest hydraulic controls to raise water surface and increase floodplain inundation, remove and grade mine tailings to restore floodplain elevations, construct alcoves and off-channel pond.
45B	Middle Humbug Creek	170.8	171.3	1	9		7.1	7.8	Coarse sediment augmentation through direct injection of mine tailings during high flow, modify riffle crest hydraulic controls to raise water surface and increase floodplain inundation, construct/enhance side channel, remove and grade mine tailings to restore floodplain elevations.
45C	Upper Humbug Creek	171.3	172.3	1	9	Humbug, Skunk	4.5	14.6	Create stage zero channel network across highly disturbed floodplain, construct ELJs to promote flow splits, coarse sediment augmentation through direct injection of mine tailings during high flow, improve fish passage at tributary confluence.

5.2 Topography

Digital terrain data and aerial imagery of the Project area were obtained from the USBR. The USBR digital terrain model (DEM) combined LiDAR data, bathymetry data, and interpolated channel toe lines (USBR 2012). The LiDAR data and aerial imagery of the mainstem Klamath River corridor from Link Dam to Happy Camp, CA were flown in February and March of 2010. The Bathymetry data was collected by the USBR and USGS in October 2009 using two boats equipped with multibeam Acoustic Doppler Current Profilers (ADCP's) (USBR 2012). Channel toe lines were created by digitized bank toe lines and interpolated bathymetry data. The combined DEM, created in ArcGIS from the USBR's LiDAR and bathymetric data, was clipped into sections for use in hydraulic modeling and conceptual design within the Middle Klamath River design sites.

5.3 Hydrology and Hydraulics

Flow hydraulics were modeled within priority design sites to inform design decisions. At the current conceptual design level, one-dimensional hydraulic modeling was conducted for existing conditions.

5.3.1 Hydrology

Flows important to the design objectives were defined as follows:

- The 80 percent exceedance flow represents the typical summer base flow;
- The 50 percent exceedance was important for model validation;
- The 20 percent exceedance flow represents the typical winter base flow;
- The 2-year, 5-year, and 10-year recurrence interval peak flows were important for floodplain inundation and design of off-channel habitat features.

An area-based-proration method using two Klamath River gages was used to predict Klamath River design flows within design sites. Tributary flows were predicted using a similar proration method and the USGS StreamStats website (http://water.usgs.gov/osw/streamstats/california.html). These methods are described in the sections below.

Daily average exceedance flows were evaluated at both gages using average daily flow data throughout the periods of record. Annual peak flow magnitudes and frequencies were evaluated at both gages using Log Pearson Type III (LPIII) probabilistic analysis consistent with USGS Bulletin 17B (USGS 1982). The resulting design flows at the gage locations (presented in Table 5-2) were used to predict the design flows within priority design sites.

Table 5-2. Exceedance discharge and flood frequency at Klamath River gages.

Gage	Drainage area (mi^2)[1]	Exceedance flow (cfs)[2]			Peak flow (cfs)[3]		
		80 percent	50 percent	20 percent	2-year	5-year	10-year
Klamath River near Seiad Valley	6,940	1,440	2,530	5,330	16,238	34,804	53,300
Klamath River downstream from Iron Gate Dam	4,630	969	1,340	2,900	5,856	10,795	14,854

[1] Drainage areas exclude Lost River, Butte Creek and Lower Klamath Lake Basins
[2] Exceedance flows calculated using standard flow duration analysis
[3] Peak flows predicted using Log-Pearson Type III distribution

5.3.1.1 Klamath River reaches

Flow within the 70-mile Project area is influenced by spatially variable geology and climate and is variously impacted by upstream dams and diversions. The permeable volcanic rocks and subdued relief in the geomorphic provinces upstream of the Project area result in low drainage density, low stream gradients, and large internally drained areas (e.g., Upper Klamath, Lower Klamath, and Tule lakes). Low channel gradients, limited surface runoff, and internal drainage contribute to low discharge per unit drainage area. The mountainous tributaries located west of Cottonwood Creek and the Shasta River basins drain the Klamath Mountains Province and are underlain by a series of geologic terranes that are more resistant to weathering, form high-relief terrain with prominent ridge and valley topography, and have high discharge per unit drainage area. Refer to Section 3.1 for more a more detailed description of the geology and geomorphic terrains in the Project area.

To account for flow accretion from within the upstream and downstream portions of the Project area with different watershed characteristics, total flow accretion between the gages below Iron Gate and near Seiad Valley was normalized by drainage area (cfs/mi^2). The design flows at a design site (Table 5-3) were then calculated using the following formula:

$$Q_{Site} = \frac{(Q_{Seiad} - Q_{Iron\ Gate})}{(DA_{Seiad} - DA_{Iron\ Gate})} * (DA_{Site} - DA_{Iron\ Gate}) + Q_{Iron\ Gate})$$

Where:

Q_{Site} = Flow at downstream end of design site (cfs)
Q_{Seiad} = Flow at Seiad gage (cfs)
$Q_{Iron\ Gate}$ = Flow at Iron Gate gage (cfs)
DA_{Site} = Drainage area at downstream end of design site (mi^2)
$DA_{Iron\ Gate}$ = Klamath River drainage area at Iron Gate gage (mi^2)
DA_{Seiad} = Klamath River drainage area at Seiad gage (mi^2)

Table 5-3. Modeled exceedance discharge and flood frequency estimates for design sites.

Design sites[1]	Drainage area[2] (mi^2)	Exceedance flow (cfs)[3]			Peak flow[3]		
		80 percent	50 percent	20 percent	2-year	5-year	10-year
6	7,038.2	1,460	2,581	5,433	16,679	35,825	54,934
8	7,032.4	1,459	2,578	5,427	16,653	35,764	54,838
10	7,012.8	1,455	2,568	5,407	16,565	35,561	54,512
16A, 16B, 16C	6,943.7	1,441	2,532	5,334	16,255	34,842	53,362
27A, 27B	5,933.3	1,235	2,011	4,271	11,714	24,341	36,545
32A, 32B	5,910.9	1,230	2,000	4,247	11,613	24,108	36,172
39, 40[4]	5,736.0	1,195	1,910	4,063	10,827	22,291	33,261
45A, 45B, 45C	5,699.1	1,187	1,891	4,025	10,661	21,907	32,647

Notes:
1 Estimates are for the downstream end of each site.
2 Drainage areas exclude Lost River, Butte Creek and Lower Klamath Lake Basins
3 Prorated from USGS gages, based on accretion drainage area below Iron Gate gage
4 Site 39 and Site 40 were modeled together. Information is reported for the downstream end of Site 39.

While other proration approaches were explored during the hydrologic analysis, the methods described above best predicted flows based on minimizing the variance between estimated and measured flows at the USGS gage sites.

5.3.1.2 Tributaries

There are no long-term gage records for unregulated tributaries in the Project area; and the characteristics of nearby gaged watersheds with long-term records differs substantially from those in the Project area. For this reason, recurrence interval flows in tributaries were obtained from the interactive USGS StreamStats website. The website uses a geographic information system (GIS) and flow regression equations to calculate storm discharges at any point along gaged and ungaged watercourses (Gotvald et al. 2012). For ungaged streams, StreamStats provides peak flow estimates for 2-, 5-, 10-, 25-, 50-, and 100-year flood events. StreamStats results for the tributaries are provided in Table 5-4.

Tributary exceedance flows were calculated using a proration method similar to that used for the Klamath River reaches. Tributary exceedance flows (Table 5-3) were calculated using the following equation:

$$Q_{Trib} = (Q_{Seiad} - Q_{Iron\ Gate}) * \frac{(DA_{Trib})}{(DA_{Seiad} - DA_{Iron\ Gate})}$$

Where:

Q_{Trib} = Tributary design flow (cfs)
Q_{Seiad} = Flow at Seiad gage (cfs)
$Q_{Iron\ Gate}$ = Flow at Iron Gate gage (cfs)
DA_{Trib} = Tributary drainage area (mi^2)
$DA_{Iron\ Gate}$ = Klamath River drainage area at Iron Gate gage (mi^2)
DA_{Seiad} = Klamath River drainage area at Seiad gage (mi^2)

Table 5-4. Modeled exceedance discharge and flood frequency estimates for tributaries within design sites.

Tributary	Drainage area (mi^2)	Exceedance Flow (cfs) [2]			Peak Flow (cfs) [1]		
		80 percent	50 percent	20 percent	2-year	5-year	10-year
Little Horse Creek	3.98	1	2	4	348	642	851
China Creek	9.72	2	5	10	839	1,500	1,960
Thompson Creek	36.33	7	19	38	2,870	4,980	6,440
Seiad Creek	29.30	6	15	31	1,870	3,420	4,510
Grider Creek	43.18	9	22	45	3,860	6,470	8,270
West Grider Creek	3.01	1	2	3	287	524	693
Carroline Creek	0.18	<1	<1	<1	17	35	48
McKinney Creek	11.40	2	6	12	117	236	350
Doggett	12.14	2	6	13	143	289	429
Grouse/Barkhouse Creek	15.93	3	8	17	151	305	451
Little Humbug Creek	9.69	2	5	10	103	209	309
Vesa Creek	4.93	3	8	17	66	134	198
Humbug Creek	36.96	2	5	10	229	461	683
Skunk Creek	0.50	<1	<1	1	7	15	22

Notes:
[1] Peak flow estimate directly from StreamStats
[2] Exceedance flows calculated using Prorated from USGS gage differences, based on tributary drainage area

5.3.2 Hydraulic modeling

One-dimensional hydraulic models of the design sites were developed in HEC-RAS 5.0. The Klamath River channel alignment was clipped to individual design sites, maintaining the original channel stationing for the Project area. Contoured surfaces were created from the clipped DEM's, and tributary alignments were developed from the contours. Cross sections were placed about every 200 ft up the tributaries, adapting and supplementing the USBR cross sections where appropriate. Additional cross sections were established to improve resolution in areas important to design development.

All design flows were modeled as steady flow. In reaches with significant tributaries, the flow above a tributary was approximated by subtracting the tributary flow from the downstream flow. All Manning's n values were set to 0.045 in channel and 0.055 for overbank areas (consistent with calibration done by the USBR for their model). The 1-D model assumes uniform flow direction and constant velocity distribution within the channel and floodplain portion of each cross section. The DEM's of the modeled water surface elevations were imported from HEC-RAS to AutoCAD and used to inform design development.

Daily flow data from the USGS gages corresponding to the LiDAR flight dates were used to determine the relative flow magnitude during the time period of the data collection—approximately 50 percent exceedance. The 50 percent exceedance flows were calculated for all Project reaches and tributaries using the methods described in the hydrology section. The 50 percent exceedance flows were modeled, and the resulting inundation boundary was compared to the edge of water in aerial imagery taken during the LiDAR flight. The modeled and observed water edges were qualitatively similar in areas visible on aerial photos.

5.4 Habitat Enhancement Actions and Activity Areas

Proposed actions within design sites may include the following types of restoration and enhancement activities intended to reconnect the river's floodplain with the main channel, establish or expand side-channel and off-channel habitats, and enhance the bed and banks of the mainstem Klamath River and major tributaries.

- Recontouring (e.g., grading and/or adding structure) and revegetating degraded floodplains and mine tailings to promote development of functional riparian habitat, increase riparian shading, reduce heating, and improve hyporheic exchange. These activities would include grading to create and enhance topographic features but with no net change in the volume of earthen material within the activity areas.
- Constructing or lowering floodplain surfaces to improve hydrologic function and processes, primarily by expanding the surface area of the channel inundated at specific flows and by increasing flow connectivity (e.g., frequency and duration of inundation) and hyporheic exchange (i.e., interaction between shallow groundwater and surface flows) between the winter baseflow channel, secondary channels, and other off-channel areas. Newly inundated surfaces would provide rearing and low velocity habitat for juvenile salmonids and other native anadromous fish. These treatment areas would rely on a combination of natural recruitment of native riparian vegetation and riparian planting to establish a diverse assemblage of native vegetation.
- Modifying historical side channels or constructing new side channels to reconnect the Klamath River to its floodplain at targeted flows.
- Excavating alcoves to specific design elevations at the downstream end of side channels and other appropriate locations to provide continuous, year-round juvenile fish habitat.
- Creating, enhancing, and connecting off-channel ponds and wetlands to improve rearing habitat.
- Adding structural complexity (e.g., large wood structures) to secondary channels and other off-channel areas to promote hydraulic complexity and pool depth, increase the amount and quality of low-velocity rearing habitat, and sort spawning gravel.
- Protecting and expanding cold water refuges at summer baseflow within the mainstem channel, in off-channel areas, and in the lower reaches of major tributaries to improve holding and summer rearing habitat conditions.
- Restoring vegetation to degraded riparian areas and terraces by manual or mechanical planting.

One or more of the actions listed above could be implemented within a design site.

Actions are organized into six discrete types of activity areas: In-Channel Activity Areas (IC), Riverine Activity Areas (R), Upland Activity Areas (U), Staging Areas (C), Roads (M=existing, N=new), and Temporary Crossing (X). Each action is assigned a unique label comprised of the activity area symbol followed by the number for the action followed by a letter code identifying the design site. For example, the first action in a riverine area of Site 6 (Little Horse Creek

[LHC]) would be labeled R-1-LHC. The following sections provide a brief description of each type of activity area.

In-Channel Activity Areas (IC)

In-channel (IC) activity areas are intended to reestablish dynamic fluvial processes and geomorphology. A variety of construction techniques could be used to modify channel gradient, add coarse sediment, and diversify the type and location of alluvial features.

Riverine Activity Areas (R)

Riverine (R) activities would require removal of vegetation and excavation of alluvial material from the bed and banks of the Klamath River and/or tributaries; including alcoves, side channels, and overflow channels. Modifications at strategic locations would promote the river processes necessary for the restoration and maintenance of rearing habitat for juvenile salmonids and other native aquatic organisms over a range of flows.

Upland Activity Areas (U)

Upland (U) activity areas are locations for disposing excavated material (i.e., sand, gravel, cobble, and cleared vegetation, primarily from the riverine areas), stockpiling of coarse sediment for instream additions, and reestablishing native upland vegetation. Activities may also include measures to enhance upland and riparian habitat, while inhibiting the introduction and spread of noxious and invasive vegetation.

Staging Areas (C)

Staging areas are required for construction activities, including gravel processing, storage of equipment and materials, and temporary placement of topsoil. Additionally, these areas may be used for the processing and storage of coarse sediment.

Roads (M, N)

Existing roads and access routes (M) in the Project vicinity would be evaluated and upgraded as necessary to provide the necessary access. Project activities may include construction of new temporary roads and access routes (N) to and between staging areas and activity areas. Any new roads and access routes would be constructed to the standard necessary to limit impacts from erosion and runoff. New roads would be decommissioned at project completion when requested.

Temporary Crossings (X)

Some activities and treatments may require construction of temporary stream crossings (X) over tributaries to provide access for vehicles and construction equipment. All temporary stream crossings would incorporate design specifications appropriate to address resource impacts.

This approach to identifying and describing actions and activity areas generally follows the approach used by the Trinity River Restoration Program in planning, designing, and permitting analogous channel rehabilitation projects on the mainstem Trinity River (TRRP 2009).

5.5 Mine Tailing Remediation

Historical placer mining has had large and enduring impacts on floodplain and off-channel habitat within the Middle Klamath River Project area, establishing the present-day physical template in many alluvial reaches. Hydraulic excavation of floodplain and terrace deposits delivered millions of cubic yards of sediment to the river annually, many tributary channels were realigned and altered at their confluence with the Klamath River, and aquatic and riparian habitats were simplified or destroyed entirely. Natural recovery from these impacts has been limited in many areas.

Restoration and enhancement within the Project area focuses, to a large degree, on accelerating recovery where floodplain, off-channel, and riparian habitats have been most impacted by hydraulic and dredger mining. The following treatments types, if applied within the priority design sites and other locations where mining impacts persist in the Project area (e.g., large tailing piles, excavated pits, aggraded channels, disconnected floodplains, altered tributary and secondary flow paths, and deforested valley bottom areas), would effectively remediation historical mining impacts to floodplain and off-channel aquatic habitats and riparian vegetation communities.

Mechanical manipulation to recover floodplain elevations and width

This set of actions would involve removing and/or regrading large tailings piles that prohibit floodplain inundation and riparian vegetation establishment and restoring floodplain functions and off-channel habitat features within reaches where historical mining operations aggraded floodplains and channels with coarse sediment. In most cases, extensive earthwork would be required to reestablish elevations that permit flow inundation; facilitate hyporheic exchange between floodplain, off-channel, and in-channel features; and allow riparian vegetation to access the summer phreatic zone. Much of the tailings material could be sorted, and the appropriate size classes used as coarse sediment additions to modify gradient and create dynamic alluvial features in the mainstem river channel. Where feasible, the remaining fractions of tailings material that are unsuitable for instream use could be crushed into merchantable aggregate or be used to fill mining pits. The large costs of excavating, processing, and hauling the enormous volume of existing floodplain tailings to suitable nearby disposal sites or other end users will require a long-term strategy that is phased over decades.

Replacing soil and organics

Tailings and other coarse sediment deposits resulting from hydraulic and dredger placer mining in the Middle Klamath River are typically devoid of organic soil (including macronutrients [N, P, K], bacteria, and fungi) and finer sediment (e.g., sand, silt, and clay) required for cation exchange, soil moisture retention, and plant growth. In addition, the large void spaces in coarse-grained tailings leads to low water-holding capacity, and combined with a lack of existing vegetative cover, creates a hot and dry environment for plant establishment and growth. Hydraulic mine tailings often have inverted stratigraphy within which finer sediments formerly near the surface are now positioned at the base of the deposit, and coarse sediments formerly near the base now overlying these finer materials. Where finer sediments exist within the profile, this material can be sorted and stockpiled for future top dressing after earthwork is completed. Mechanical manipulation of the mine tailings and aggraded channel and floodplain areas will also require application of materials to amend the substrate and reconstruct the soil ecosystem to provide an environment conducive to plant growth. One strategy for restoring the soil ecosystem within some design sites in the Project area is to lower floodplains in strategic locations that will function as depositional zones when removal of the Klamath River dams releases reservoir sediments to downstream reaches. Further investigation is required to determine if mine tailings in the Project area contain mercury and/or other toxic heavy metals.

Revegetating native plant species

Revegetating areas disturbed by mine tailings and aggraded coarse sediment deposits with native plant species is one of the most difficult components of placer mining remediation. As previously indicated, these environments usually lack the soil, groundwater, and microclimate conditions conducive to herbaceous and woody riparian plant establishment and growth. Successful revegetation requires developing a planting plan with native species adapted to the environment and that will ultimately achieve the desired ecological objectives; establishing the topographic, stratigraphic, and soil conditions conducive to plant establishment and growth; propagating and/or acquiring the necessary plant materials and storing these materials where they remain in good condition; designing and implementing a cost effective and resilient irrigation plan; controlling invasive plant species, and employing a monitoring program to inform adaptive management of the revegetation site over time.

The fifteen priority design sites encompass the majority of the areas in the Middle Klamath River corridor where extensive hydraulic and dredger mining disturbances persist within low-lying floodplain areas that have potential for restoration and enhancement of off-channel salmonid rearing habitat. The mine tailing remediation treatments discussed above are key components of the conceptual design plans discussed below.

5.6 Conceptual Design Plans

The following sections summarize the conceptual designs for the fifteen priority design sites; including a site description, conceptual design plan and profiles, a discussion of the proposed habitat enhancement activities, and a planning-level construction cost estimate based on estimated material quantities and unit costs for a standardized set of line items.

5.6.1 Site 6 – Little Horse Creek (LHC)

5.6.1.1 Site description

Site 6 (Little Horse Creek) is located between RM 114.2 and RM 115.6 (Sta 450+00 to Sta 550+00) at a prominent meander bend. Channel gradient through the site is approximately 0.0018 and average valley width is 830 ft. The valley bottom consists of a meandering, predominantly alluvial channel with a large right bank gravel- and cobble-dominated point bar complex (Appendix B, Figures B-1 and B-2). The right bank point bar in the middle of the reach is cut by overflow channels; and the channel at the backedge of this bar is fed by a seasonal tributary draining the adjacent terrace. Opposite the point bar apex, a weakly developed left bank side channel terminates in a vegetated backwater feature at approximately Sta 492+00. The steep mainstem channel gradient and relatively high associated velocities likely limit fish movement in and out of the existing backwater feature.

The main feature in the downstream half of the reach is a long (approximately 1,400 ft) overflow or groundwater channel located along the backedge of an expansive right bank alluvial bar. This overflow channel was the main channel before the planform through this portion of the reach adjusted to the left bank after 1944. The low-lying topography and presence of dense young riparian vegetation in this feature suggest a shallow summer groundwater table, but further investigation is required during future design phases to determine seasonal groundwater levels and surface water inputs to the feature.

Mine tailings at the upstream end and central portions of the site provide a potential source of material for coarse sediment additions to the mainstem channel. Little Horse Creek enters the site from the left bank near RM 114.4 (Sta 470+00), the confluence of which creates a summer thermal refuge. The MidKlamath Watershed Council is implementing a habitat enhancement project in Little Horse Creek upstream of the China Grade Road crossing.

5.6.1.2 Proposed habitat enhancement activities

Proposed enhancement activities at Site 6 include coarse sediment additions, reestablishing floodplain width and elevations by removing mine tailings, and constructing and expanding backwater alcoves to provide rearing habitat during winter and summer baseflows (i.e., 20 percent exceedance and 80 percent exceedance, respectively). (Figure 5-2, Figure 5-3, Table 5-5).

Coarse sediment additions are designed to modify riffle crest hydraulic controls by locally raising the water surface elevation and increasing the frequency and duration of inundation in upstream side channel, backwater, and floodplain areas across a wide range of flow conditions. Fluvial processes resulting from coarse sediment additions are expected to promote more dynamic sinuous morphology and increase complex aquatic and riparian habitat.

The smaller left bank backwater feature at 490+00 (R-1 LHC) would increase winter and summer rearing habitat by taking advantage of existing topographic shade and cold-water inputs from the adjacent hillslope. The existing swale would be enlarged and lowered to improve connectivity at summer flows and provide more inundation for longer periods of time during the winter. This existing feature and adjacent upstream, mostly unvegetated floodplains and terraces are within a state wildlife area.

The overall size and depth of excavation in the larger right bank backwater feature (R-2 LHC) would depend on the depth to groundwater and presence of cold-water inputs available to support summer rearing habitat. There may be potential to design this backwater feature as an overflow channel by lowering the topography at the head to improve surface flow connectivity with the main channel, but the high topography at the upstream end would likely require substantial excavation (greater than 15 ft). Riparian vegetation would be established along the southern margin of this backwater feature to create more shade over summer rearing habitat.

The left bank is accessible via a secondary road off China Grade Road that passes through a property owned by the State, and the right bank is accessible via a private road off Gordon's Ferry Road. Both sides of the river have large areas suitable for staging and spoils.

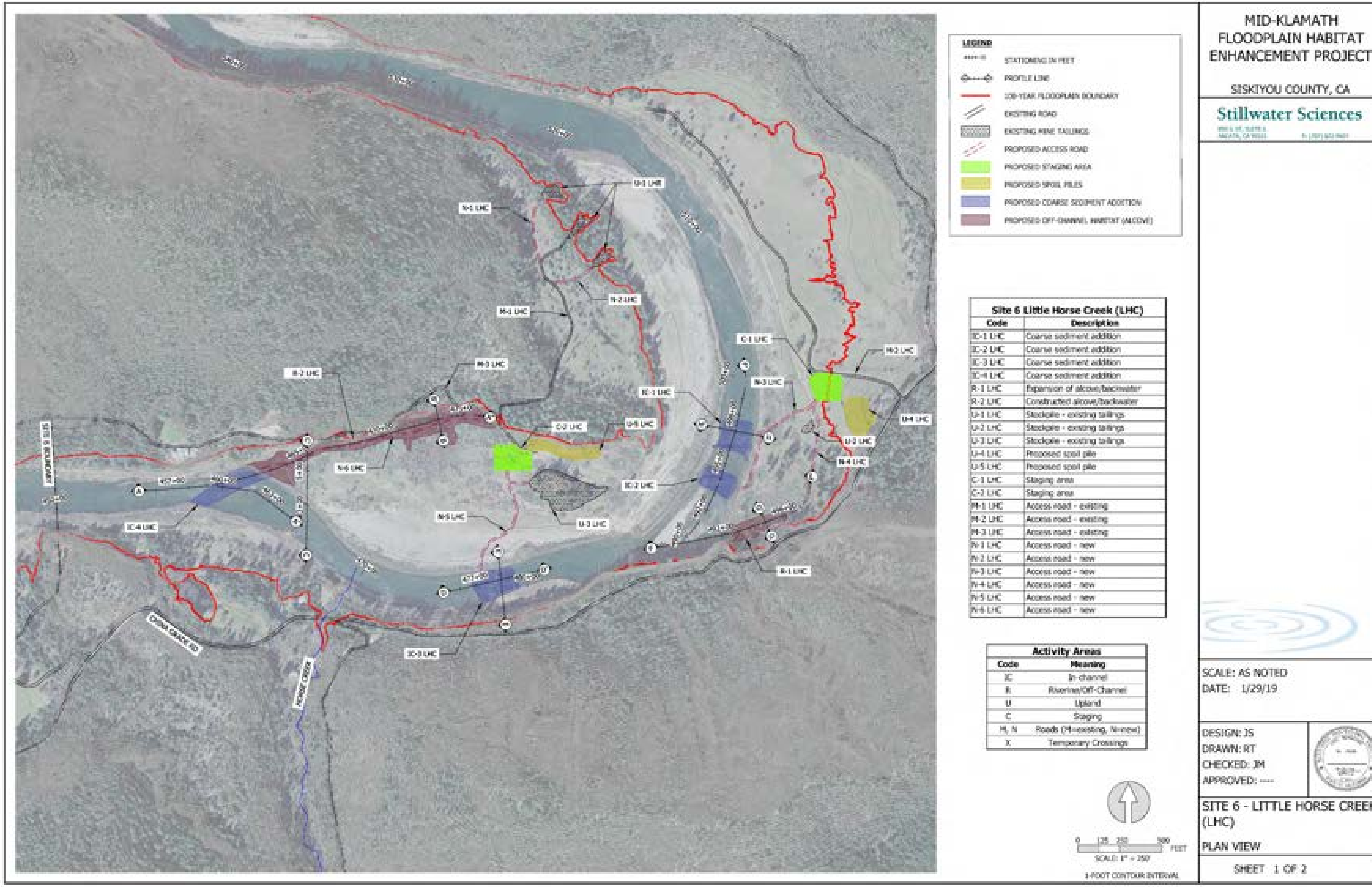

Figure 5-2. Design plan for Site 6 (Little Horse Creek)

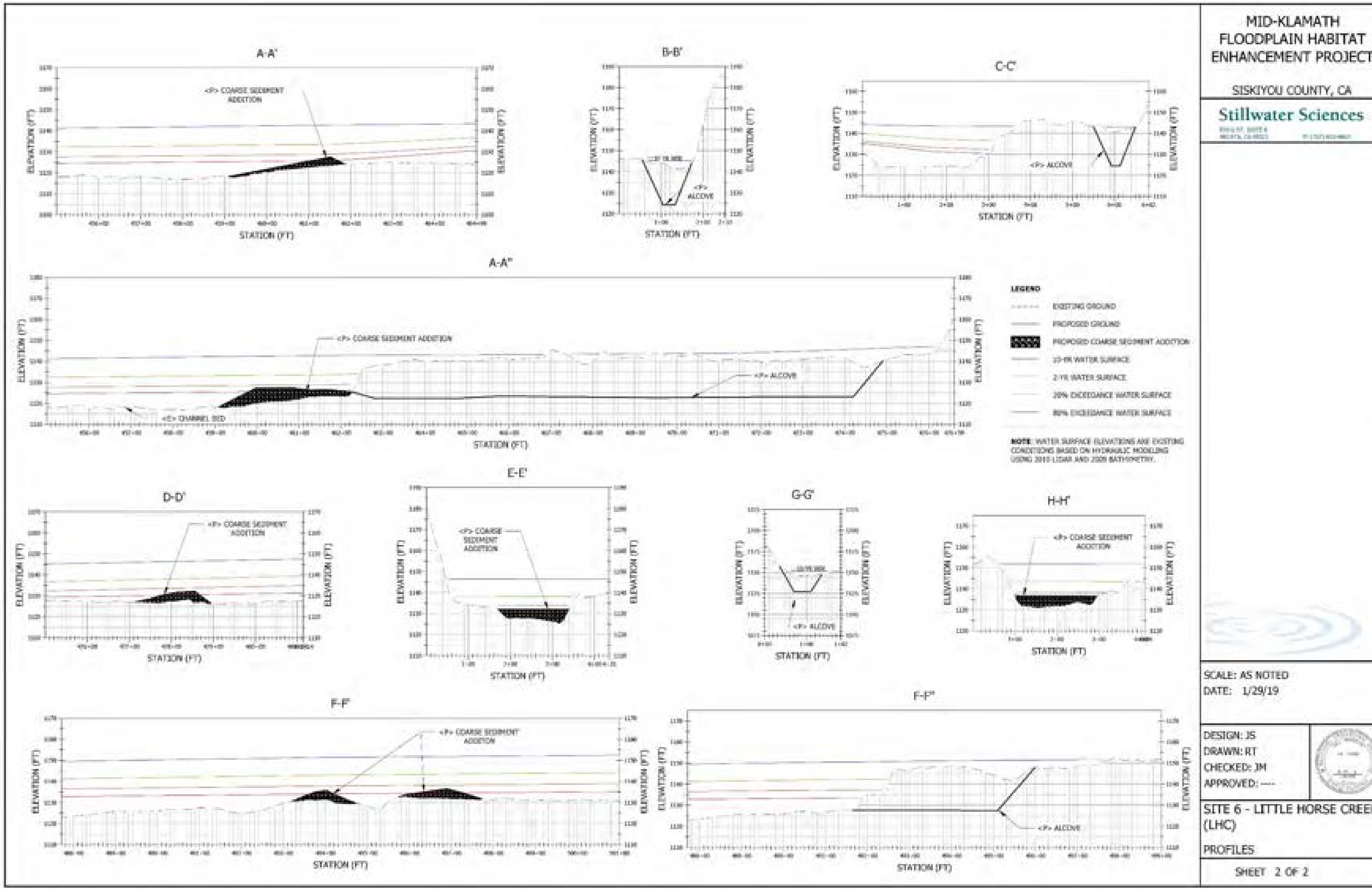

Figure 5-3. Design profiles for Site 6 (Little Horse Creek).

Table 5-5. Little Horse Creek activity areas.

Code	Description
IC-1 LHC	Coarse sediment addition
IC-2 LHC	Coarse sediment addition
IC-3 LHC	Coarse sediment addition
IC-4 LHC	Coarse sediment addition
R-1 LHC	Expansion of alcove/backwater
R-2 LHC	Constructed alcove/backwater
U-1 LHC	Stockpile – existing tailings
U-2 LHC	Stockpile – existing tailings
U-3 LHC	Stockpile – existing tailings
U-4 LHC	Proposed spoil pile
U-5 LHC	Proposed spoil pile
C-1 LHC	Staging area
C-2 LHC	Staging area
M-1 LHC	Access road – existing
M-2 LHC	Access road – existing
M-3 LHC	Access road – existing
N-1 LHC	Access road – new
N-2 LHC	Access road – new
N-3 LHC	Access road – new
N-4 LHC	Access road – new
N-5 LHC	Access road – new
N-6 LHC	Access road – new

5.6.1.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 6 is shown in Table 5-6. The largest cost associated with this site is excavation of backwater feature R2-LHC. It is recommended that the design for this proposed feature be refined through a cost-benefit analyses in future design phases to optimize the habitat benefits and minimize the grading volume.

Table 5-6. Planning-level construction cost estimate for Site 6 (Little Horse Creek).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$30,000	1	LS	$30,000
2	Temporary access, clearing and grubbing	$7,000	1	LS	$7,000
3	Dewatering and/or turbidity management	$25,000	1	LS	$25,000
4	Grading (cut) balanced on site	$15	63,000	CY	$945,000
5	Grading (fill) balanced on site	$25	13,000	CY	$325,000
6	Large wood structures—placed and anchored	$1,500	0	each	$0
7	Boulders—placed and anchored	$150	0	Tons	$0
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	0	SF	$0
10	Seeding/mulch/planting	$25,000	1	LS	$25,000
11	Other	$0	1	LS	$0
Total					**$1,357,000**

5.6.2 Site 8 – China Creek (CC)

5.6.2.1 Site description

Site 8 (China Creek) is located between RM 117.7 and RM 118.1 (Sta 633+00 and 672+00). Channel gradient through the site is approximately 0.0023 and average valley width is 603 ft. China Creek enters from the left bank at the upstream end of the site near a large bedrock outcrop and alcove. China Creek provides habitat for natal and non-natal coho salmon. Thermal infrared imagery indicates that China Creek is one of the cooler tributaries in the Project area (Figure 2-3) and provides an important summer thermal refuge at the confluence with the mainstem Klamath River. The Mid Klamath Watershed Council has implemented wood loading projects in upstream reaches of China Creek.

Large, partially vegetated bars and floodplain surfaces occur on river right across and upstream of the China Creek confluence, and on river left downstream of the confluence (Appendix B, Figure B-3). The bar deposits and floodplain on the left bank at the apex of the bend downstream of the confluence are cut by a well-defined, intermittently connected side channel along the back edge. Riparian vegetation is established throughout the length of the side channel, and the side channel contains intermittent large wood pieces and small jams. The side channel outlet occurs in an alcove at a slope break in the mainstem where the channel steepens through a riffle, creating relatively high velocity conditions.

The site occurs adjacent to a relict meander bend, a terrace that was abandoned by mainstem incision likely during the late Quaternary Period. Alluvial deposits within the relict meander were extensively hydraulically mined down to the underlying bedrock.

5.6.2.2 Proposed habitat enhancement activities

Proposed enhancement activities at Site 8 include coarse sediment addition, increasing floodplain inundation, improving fish passage and thermal refuge at the China Creek confluence, and side-channel enhancement (Figure 5-4, Figure 5-5, Table 5-7).

Fish passage improvements in lower China Creek would include large wood structures designed to maintain a consistent channel gradient at the confluence. Coarse sediment additions in the downstream riffle would also raise the water surface and help improve access into lower China Creek. One alternative would involve re-aligning the confluence along a longer flow path routes cold water from China Creek directly into the downstream bedrock alcove, which would further lower the channel gradient and enhance an important existing cold-water refuge.

A number of enhancements would be implemented to improve flow and habitat conditions in the left bank side channel between 660+00 and 650+00. A large bar apex jam (IC-2 CC) would be constructed to split flow and sort bed material at the entrance, and in combination with the adjacent coarse sediment addition (IC-1 CC), would locally raise the water surface elevation and increase side channel inundation across a wider range of flow conditions. The side channel would be modified to created beaded channel morphology and a number of features would be constructed to improve both winter and summer rearing habitat, including large wood structures, beaver dam analogues, a pond, and an alcove. At the downstream end of the side-channel, large boulders would be placed along the eddy line to help locally reduce entrance velocities.

Private roads off China Creek Road provide access to the left bank where most of the enhancement work would be conducted. A private road off Highway 96 also provides access to the right bank within the site. Spoils and staging areas are located at the site on the large bar and floodplain deposits and within the relic meander.

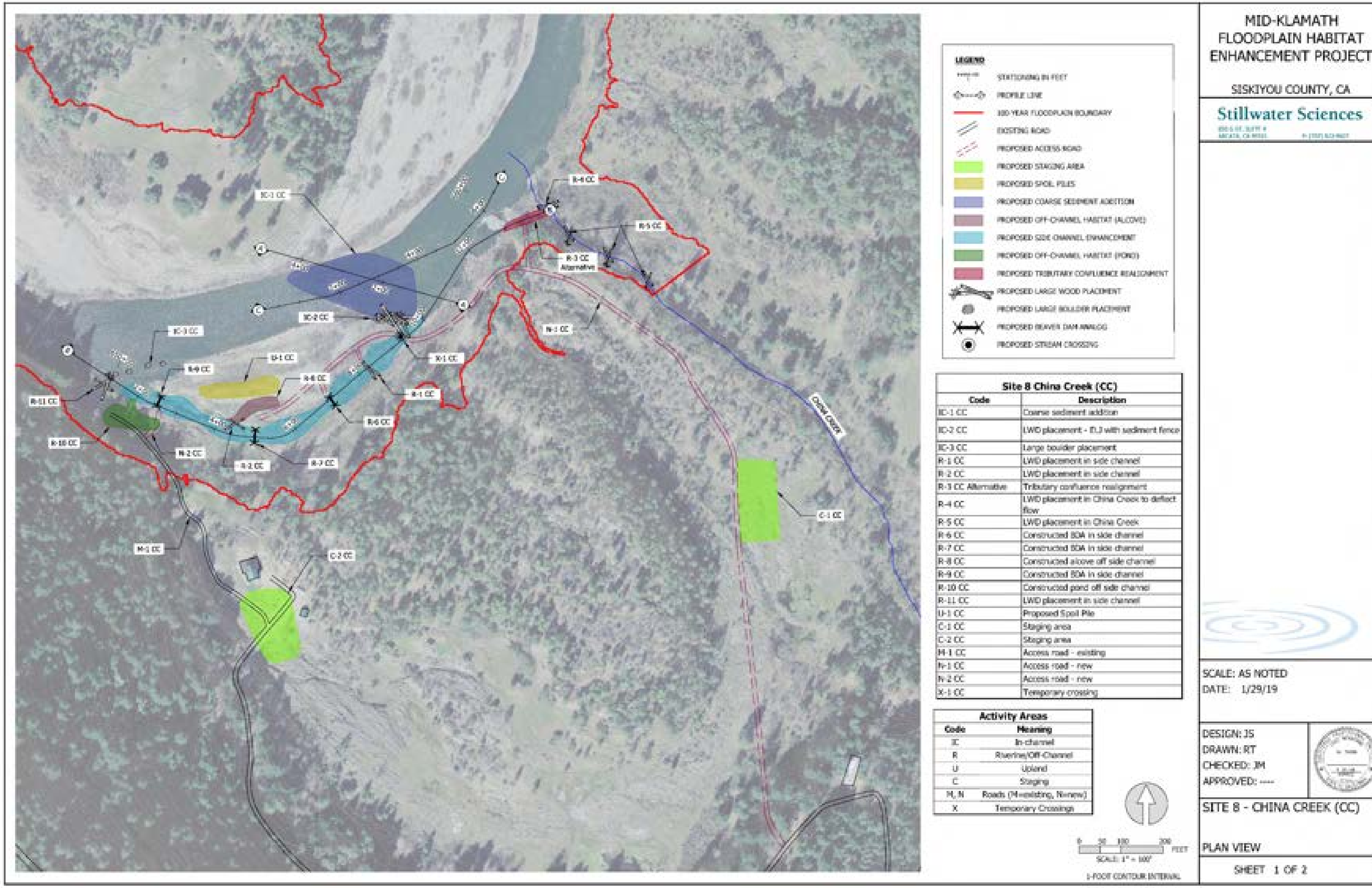

Figure 5-4. Design plan for Site 8 (China Creek).

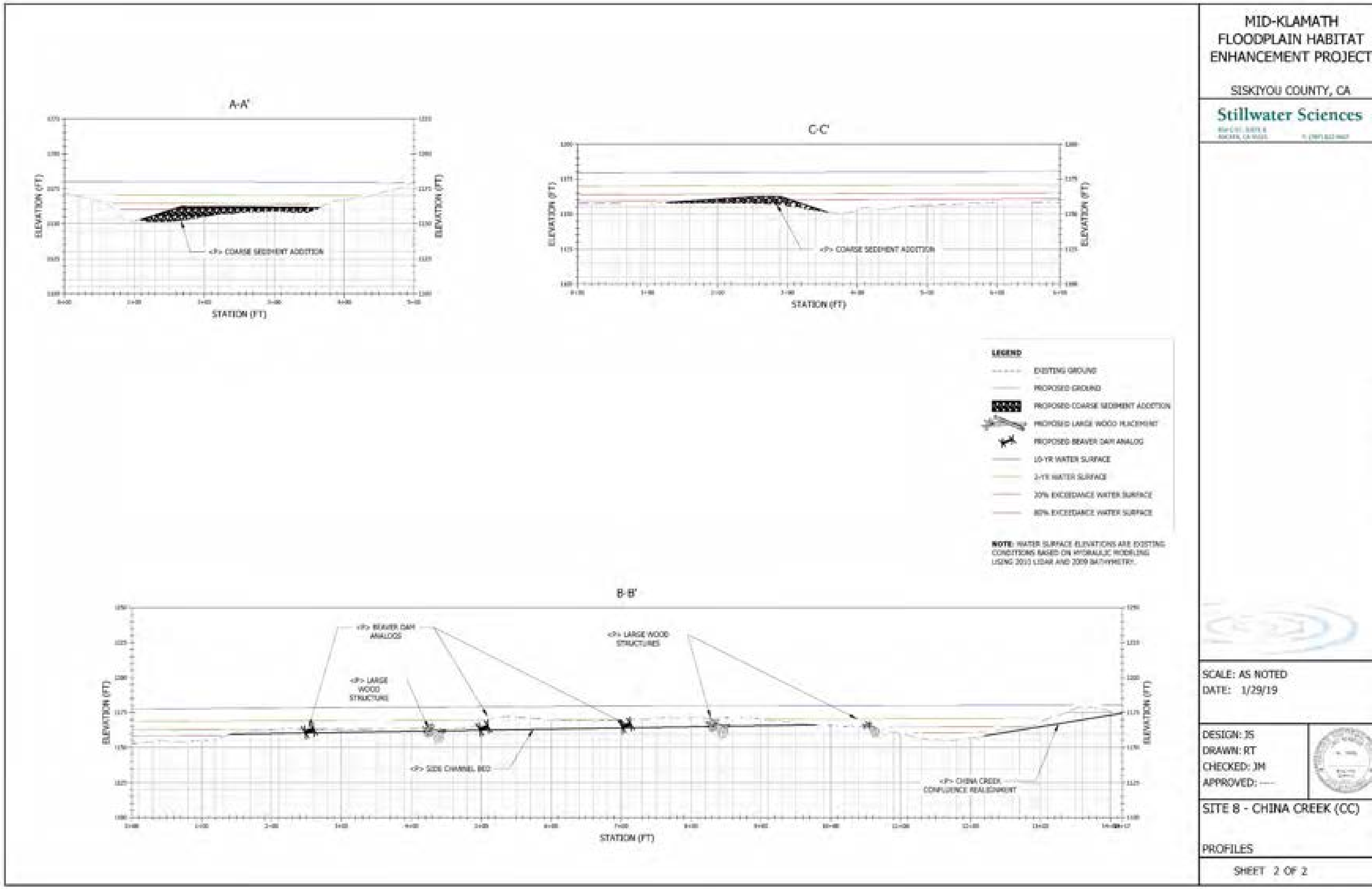

Figure 5-5. Design profiles for Site 8 (China Creek).

Table 5-7. China Creek activity areas.

Code	Description
IC-1 CC	Coarse sediment addition
IC-2 CC	LWD placement – ELJ with sediment fence
IC-3 CC	Large boulder placement
R-1 CC	LWD placement in side channel
R-2 CC	LWD placement in side channel
R-3 CC Alternative	Tributary confluence realignment
R-4 CC	LWD placement in China Creek to deflect flow
R-5 CC	LWD placement in China Creek
R-6 CC	Constructed BDA in side channel
R-7 CC	Constructed BDA in side channel
R-8 CC	Constructed alcove off side channel
R-9 CC	Constructed BDA in side channel
R-10 CC	Constructed pond off side channel
R-11 CC	LWD placement in side channel
U-1 CC	Proposed Spoil Pile
C-1 CC	Staging area
C-2 CC	Staging area
M-1 CC	Access road – existing
N-1 CC	Access road – new
N-2 CC	Access road – new

5.6.2.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 8 is shown in Table 5-8. This project has the potential to be relatively cost effective, however uncertainties associated with the costs include complicated construction access to the upstream extent of the site, as well as the source and transport of the coarse sediment for instream placement.

Table 5-8. Planning-level construction cost estimate for Site 8 (China Creek).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$11,000	1	LS	$11,000
2	Temporary access, clearing and grubbing	$25,000	1	LS	$25,000
3	Dewatering and/or turbidity management	$10,000	1	LS	$10,000
4	Grading (cut) balanced on site	$15	2,000	CY	$30,000
5	Grading (fill) balanced on site	$25	3,000	CY	$75,000
6	Large wood structures—placed and anchored	$1,500	29	each	$43,500
7	Boulders—placed and anchored	$150	18	Tons	$2,700
8	Beaver dam analogues	$5,000	3	LS	$15,000
9	Riparian planting	$1	0	SF	$0
10	Seeding/mulch/planting	$15,000	1	LS	$15,000
11	Other	$0	1	LS	$0
Total					**$227,200**

5.6.3 Site 10 – Thompson Creek (TC)

5.6.3.1 Site description

Site 10 (Thompson Creek) is located between RM 123.0 and RM 123.3 (Sta 905+00 and 942+00). Channel gradient through the site is approximately 0.0016 and average valley width is 706 ft. The valley is confined by steep hillslopes on river left and a tributary debris fan at the Thompson Creek confluence on river right (Appendix B, Figure B-4). A large eddy and associated backwater occurs where Klamath River flow impinges on the upstream margin of the Thompson Creek fan. Thompson Creek is connected to the backwater by high flow distributaries. Thompson Creek is a relatively large tributary with cool, perennial flow (Figure 2-3).

The January1997 storm event triggered widespread mass wasting in the Thompson Creek watershed (De la Fuente and Elder 1998), and the associated flood in Thompson Creek delivered a large volume of sediment to the fan, scouring riparian vegetation from the confluence and downstream right bank. The flood reset channel morphology in this area, establishing multiple flow paths across the fan between the Highway 96 crossing and the Klamath River (approximately 600 ft). The flood had less of an effect on riparian vegetation and channel conditions on the portion of the fan upstream of the confluence. Channel conditions across the fan have been dynamic over the last 30 years. Currently, most of the winter base flow is conveyed across the fan in a relatively straight and steep, single thread channel. The portion of the fan upstream of the confluence continues to support an older, more dense woody riparian forest while riparian vegetation in the downstream portion of the fan occurs as linear bands associated with high flow distributary channels of Thompson Creek and Klamath River shorelines.

A previous MKWC project involved enhancing thermal refuge habitat by modifying the existing upstream-most distributary channel of Thompson Creek to route more cold summer low flow into the Klamath River eddy and associated backwater upstream of the confluence.

5.6.3.2 Proposed habitat enhancement activities

Proposed enhancement at Site 10 include adding large wood and boulder structures in the main Thompson Creek channel to sort bed material, split flow, and increase channel complexity across the fan (Figure 5-6, Figure 5-7, Table 5-9). Large wood structures would be placed to route additional flow into the upstream distributary channel (R-1 TC) and down a newly constructed high flow side channel along the southern portion of the fan (R-6 TC). An alcove (R-2 TC) would be constructed to provide winter velocity refuge and summer thermal refuge in the upstream distributary channel. Riparian planting islands (R7-TC) would be installed along the newly constructed high flow side channel along the southern portion of the fan to seed expansion of the riparian forest in this area. Riparian plantings would provide cover and be irrigated by hyporheic flow from Thompson Creek.

The Thompson Creek debris fan is a dynamic landscape in terms of hydraulic and geomorphic processes and riparian vegetation response. The proposed treatments are accordingly process based, with the more permanent investments in habitat enhancement occurring in the more stable areas of the fan upstream of the confluence (e.g., the modified channel R-1 TC and R-2 TC alcove). Long term success of this site will depend in part on work in upstream reaches of Thompson Creek to retain and meter sediment.

Highway 96 is adjacent to the site and a spur road provides direct access. Adequate staging areas are located on both sides of the Thompson Creek confluence.

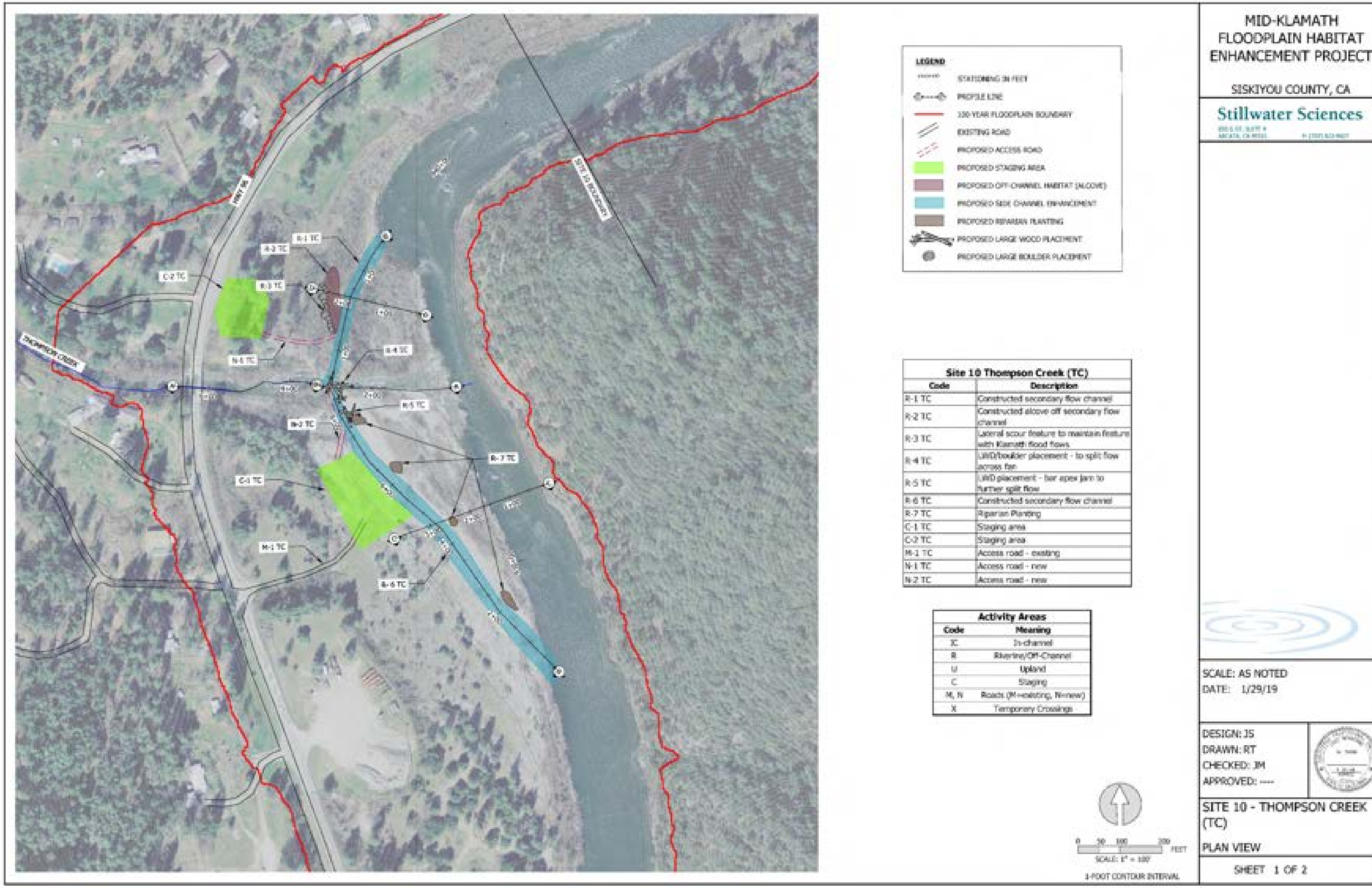

Figure 5-6. Design plan for Site 10 (Thompson Creek).

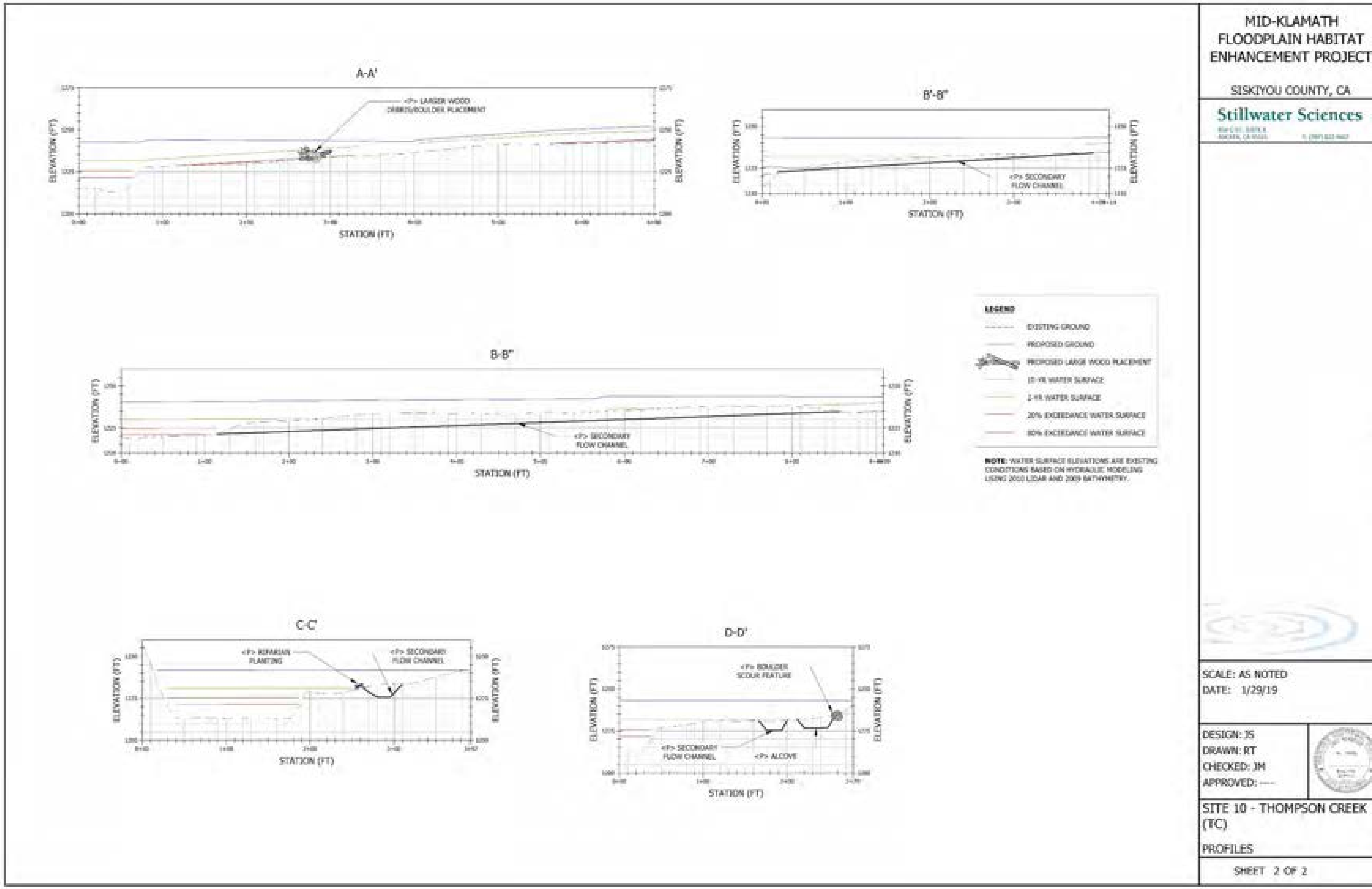

Figure 5-7. Design profiles for Site 10 (Thompson Creek).

Table 5-9. Thompson Creek activity areas.

Code	Description
R-1 TC	Constructed secondary flow channel
R-2 TC	Constructed alcove off secondary flow channel
R-3 TC	Lateral scour feature to maintain feature with Klamath flood flows
R-4 TC	LWD/boulder placement to split flow across fan
R-5 TC	Constructed LWD apex jam to further split flow
R-6 TC	Constructed secondary flow channel
R-7 TC	Riparian Planting
C-1 TC	Staging area
C-2 TC	Staging area
M-1 TC	Access road – existing
N-1 TC	Access road – new
N-2 TC	Access road – new

5.6.3.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 10 is shown in Table 5-10. This project has the potential to be relatively cost effective. It's uncertain, however, if there is a suitable nearby location for placing excavated spoils.

Table 5-10. Planning-level construction cost estimate for Site 10 (Thompson Creek).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$6,000	1	LS	$6,000
2	Temporary access, clearing and grubbing	$5,000	1	LS	$5,000
3	Dewatering and/or turbidity management	$0	1	LS	$0
4	Grading (cut) balanced on site	$15	6,000	CY	$90,000
5	Grading (fill) balanced on site	$25	0	CY	$0
6	Large wood structures—placed and anchored	$1,500	7	each	$10,500
7	Boulders—placed and anchored	$150	20	Tons	$3,000
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	2,500	SF	$2,500
10	Seeding/mulch/planting	$15,000	1	LS	$15,000
11	Other	$0	1	LS	$0
Total					**$132,000**

5.6.4 Site 16A – Lower Seiad Valley (SVA)

5.6.4.1 Site description

Site 16A (Lower Seiad Valley) is located between RM 130 and RM 130.9 (Sta 1300+00 and 1340+00). Channel gradient through the site is 0.0035 and average valley width is 1,700 ft. Seiad Creek flows under Highway 96 and into a former channel of Klamath River, remaining within the former channel for approximately 3,000 ft before reaching the mainstem Klamath River near RM 130.3. Extensive mine tailings separate the mainstem Klamath River from the lower Seiad Creek channel and floodplain over much of its length. The Seiad Creek channel and floodplain within the mainstem Klamath River corridor were extensively disturbed by hydraulic and dredger mining activity. Despite historical placer mining disturbance, Seiad Creek remains a source of abundant cold summer water (Figure 2-3) and provides important summer thermal refugia for juvenile salmonids. Large areas of the broad floodplain adjacent to lower Seiad Creek are low-lying (Appendix B, Figure B-5) and have a shallow groundwater table conducive to enhancing off-channel summer and winter rearing habitat. The Mid Klamath Watershed Council has successfully implemented several projects in lower Seiad Creek where off-channel ponds were constructed ponds were constructed to provide winter rearing habitat and summer thermal refuge.

Grider Creek and West Grider Creek enter the mainstem Klamath River on the left bank in the downstream portion of Site 16A. Flow in West Grider Creek originates from both the West Grider Creek watershed, as well as a distributary of Grider Creek that bifurcates from the mainstem near the head of a dynamic alluvial fan over which Grider Creek and its distributaries have historically migrated. The January 1997 flood event delivered large volumes of sediment from the Grider Creek basin and resulted in significant channel migration and other geomorphic changes to the Grider Creek channel and its confluence with the Klamath River (De la Fuente and Elder 1998). Aggradation at the confluence emplaced a large delta and lateral bar along the left bank of the mainstem Klamath River, shifting the mainstem channel flow to the right bank; conditions that persistent today.

5.6.4.2 Proposed Habitat Enhancement Activities

Proposed enhancement activities at the site include coarse sediment additions, installing large wood and boulder structures, constructing BDA's and off-channel ponds, and riparian plantings (Figure 5-8, Figure 5-9, Table 5-11). Construction of a large off-channel pond (R-7 SVA) is proposed on the left bank of lower Seiad Creek a short distance downstream of the Highway 96 crossing where Seiad Creek makes a sharp bend and enters the former Klamath River channel. This large pond would be designed to provide winter and summer rearing habitat, with a relatively deep center and wide, shallow littoral zone around the margins. Engineered log jams would be constructed at the inlets of the mainstem Klamath River side-channel upstream of the Grider Creek confluence to sort bed material and split flow. BDA's and off-channel ponds would be constructed along Grider Creek and West Grider Creek to retain spawning gravels, reduce flow velocity, increase surface and groundwater storage, and provide rearing habitat. Further field investigation is needed to evaluate the potential risk of Grider Creek avulsing into the proposed off-channel pond (R5-SVS) during a large flood event. Riparian islands would be planted within the Grider Creek delta to establish riparian shade and help steer flow. The mine tailings provide an onsite source of coarse sediment for gravel augmentation. Coarse sediment additions would promote lateral scour along the right bank of the mainstem channel, further recruiting coarse sediment from the tailing pile.

China Grade Road provides access to the site on river left and spur roads off of Highway 96 provides access on river right. There are suitable staging areas on both sides of the river.

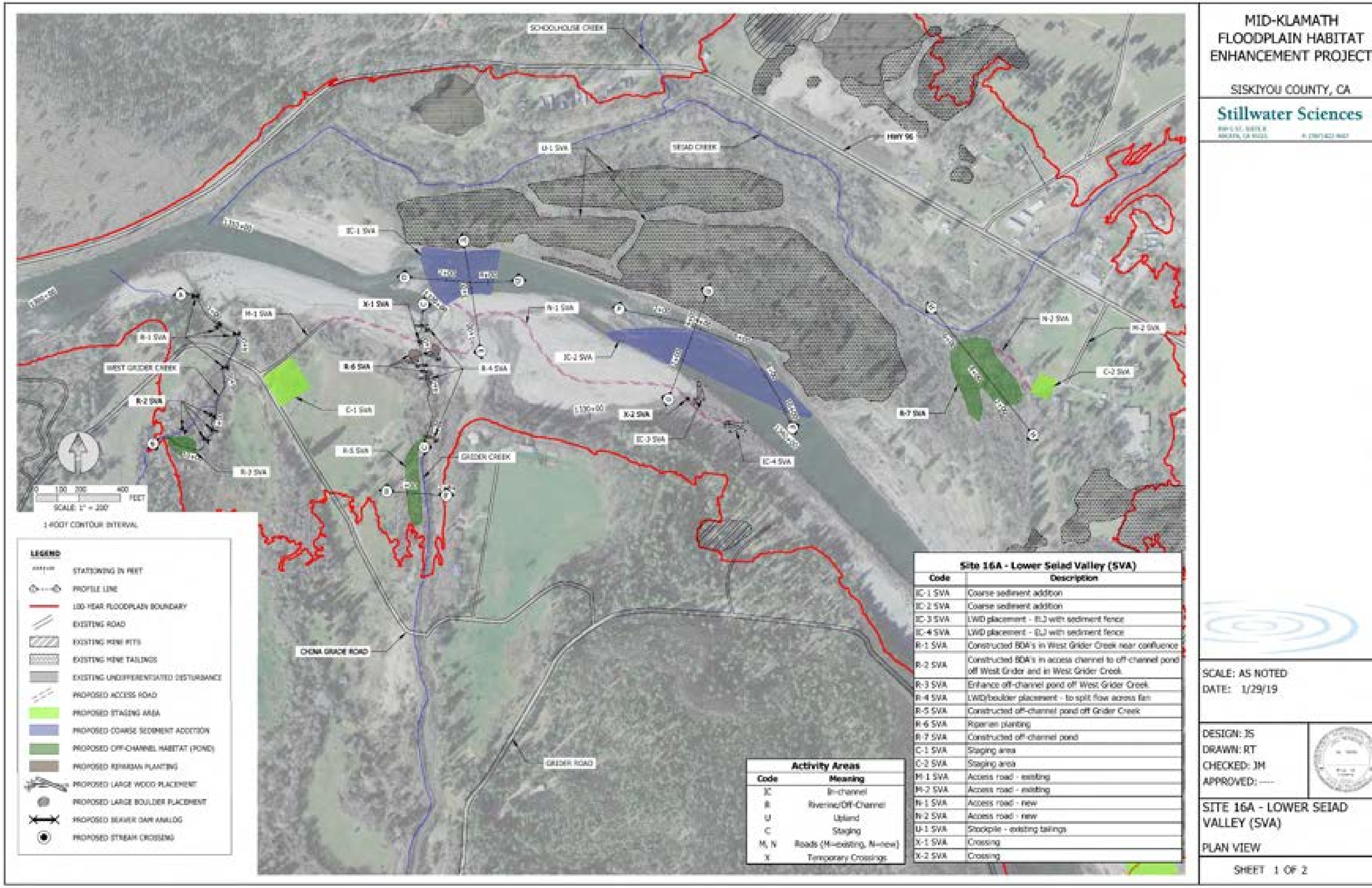

Figure 5-8. Design plan for Site 16A (Lower Seiad Valley).

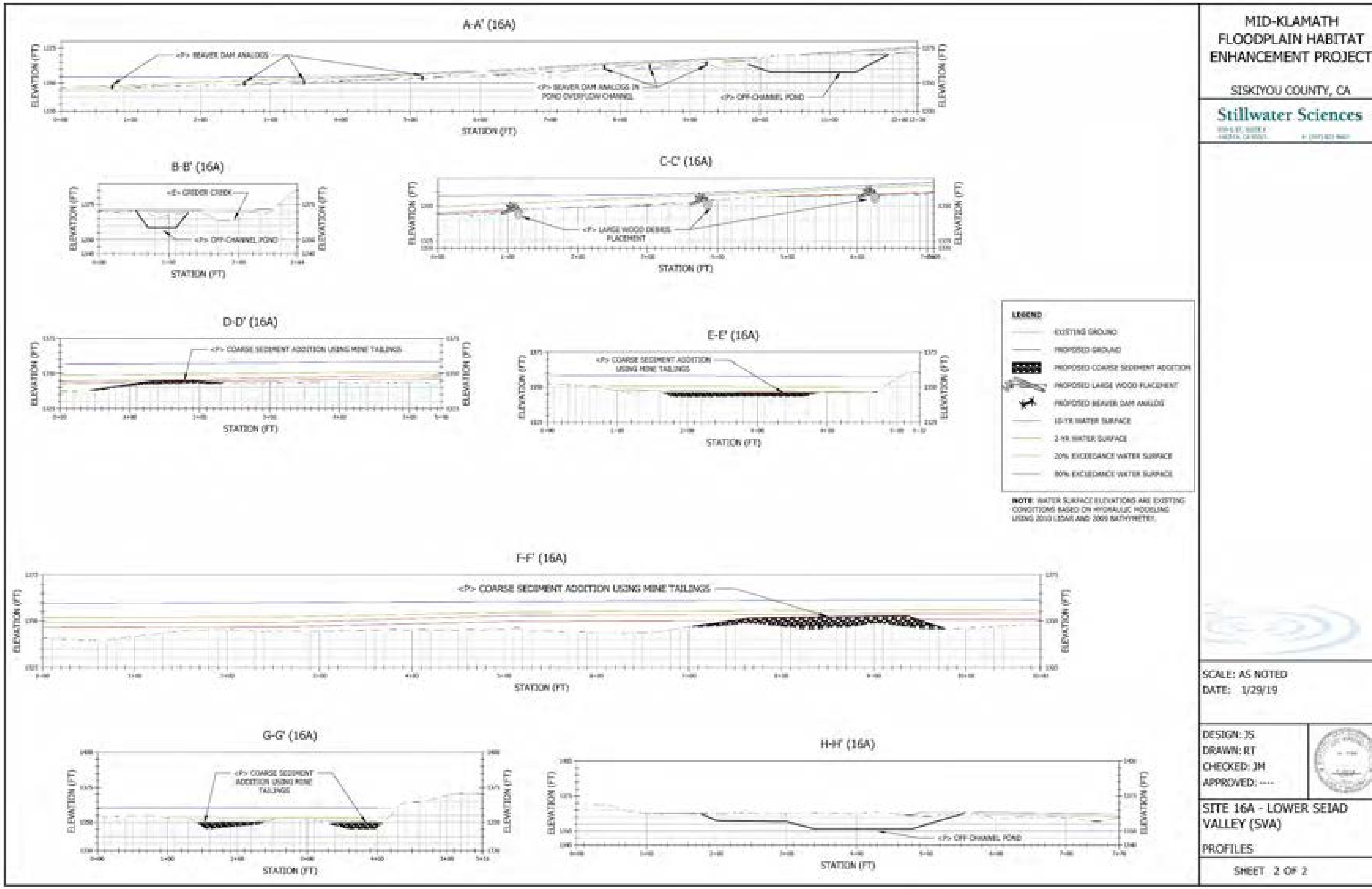

Figure 5-9. Design profiles for Site 16A (Lower Seiad Valley).

Table 5-11. Lower Seiad Valley activity areas.

Code	Description
IC-1 SVA	Coarse sediment addition
IC-2 SVA	Coarse sediment addition
IC-3 SVA	LWD placement – ELJ with sediment fence
IC-4 SVA	LWD placement – ELJ with sediment fence
R-1 SVA	Constructed BDA's in West Grider Creek near confluence
R-2 SVA	Constructed BDA's in access channel to off-channel pond off West Grider and in West Grider Creek
R-3 SVA	Enhance off-channel pond off West Grider Creek
R-4 SVA	LWD/boulder placement to split flow across fan
R-5 SVA	Constructed off-channel pond off Grider Creek
R-6 SVA	Constructed off-channel pond off Seiad Creek
R-7 SVA	Riparian planting
C-1 SVA	Staging area
C-2 SVA	Staging area
M-1 SVA	Access road – existing
M-2 SVA	Access road – existing
N-1 SVA	Access road – new
N-2 SVA	Access road – new
U-1 SVA	Stockpile – existing tailings
X-1 SVA	Crossing
X-2 SVA	Crossing

5.6.4.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 16A is shown in Table 5-12. This project has many different components. In future design phases, MKWC may want to consider further dividing the large project into a number of discrete smaller projects with phased implementation. For example, one relatively inexpensive project could involve constructing the proposed features in Grider and West Grider Creeks, and a second project could involve placing the coarse sediment in the Klamath River and constructing the off-channel pond along Seiad Creek. During future design phases, larger project features should be refined through a cost-benefit analyses.

Table 5-12. Planning-level construction cost estimate for Site 16A (Lower Seiad Valley).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$27,000	1	LS	$27,000
2	Temporary access, clearing and grubbing	$5,000	1	LS	$5,000
3	Dewatering and/or turbidity management	$10,000	1	LS	$10,000
4	Grading (cut) balanced on site	$15	9,000	CY	$135,000
5	Grading (fill) balanced on site	$25	12,000	CY	$300,000
6	Large wood structures—placed and anchored	$1,500	21	each	$31,500
7	Boulders—placed and anchored	$150	0	Tons	$0
8	Beaver dam analogues	$5,000	8	LS	$40,000
9	Riparian planting	$1	4,500	SF	$4,500
10	Seeding/mulch/planting	$5,000	1	LS	$5,000
11	Other	$0	1	LS	$0
Total					**$558,000**

5.6.5 Site 16B – Middle Seiad Valley (SVB)

5.6.5.1 Site description

Site 16B (Middle Seiad Valley) is located between RM 131.5 and RM 132.0 (Sta 1350+00 and 1403+00). Channel gradient is 0.0035 and average valley width is 1,700 ft. The predominantly alluvial river channel through the reach has riffle pool morphology and is bound by steep hillslopes on its left bank. Caroline Creek enters the upstream extent of the site on river left. The floodplain on river right has been extensively modified by historical hydraulic and dredger placer mining, resulting in vast tailing piles that artificially confine the river to a relatively narrow width (300–350 ft) (Appendix B, Figure B-6). These tailings piles, the largest concentrated area of tailings in the Project area, occupy 400 to 450 ft of the former Klamath River floodplain width and extend over 3,800 ft of channel length. Portions of these tailing at the downstream end of the site have been graded and are occupied by structures and other land uses (e.g., log landing and agriculture). Riparian encroachment and tailing piles have significantly diminished floodplain inundation and limit dynamic fluvial processes. Multiple mining pits occur 2–4 ft above the riffle crest thalweg but are isolated from the river by tailing piles.

5.6.5.2 Proposed habitat enhancement activities

The focus of habitat enhancement work at Site 16B is primarily mine tailing remediation with the long-term objective of increasing floodplain inundation and complexity. Proposed enhancement activities at the site include grading mine tailings, creating off-channel habitat by connecting and enhancing alcoves and ponds and adding coarse sediment to the mainstem channel (Figure 5-10. Figure 5-11, Table 5-13). Mine tailings would be sorted for use as coarse sediment augmentation and graded to reestablish functional floodplain elevations and widths. Three existing depressions within the mine tailing area would be excavated and connected to the mainstem river channel to create backwaters (alcoves) that provide winter and summer rearing habitat. Coarse sediment additions are designed to modify riffle crest hydraulic controls by locally raising the water surface elevation and increasing alcove and pond inundation across a wider range of flow conditions.

Multiple private roads off Highway 96 provide access throughout the site. There are several large potential staging areas across the site.

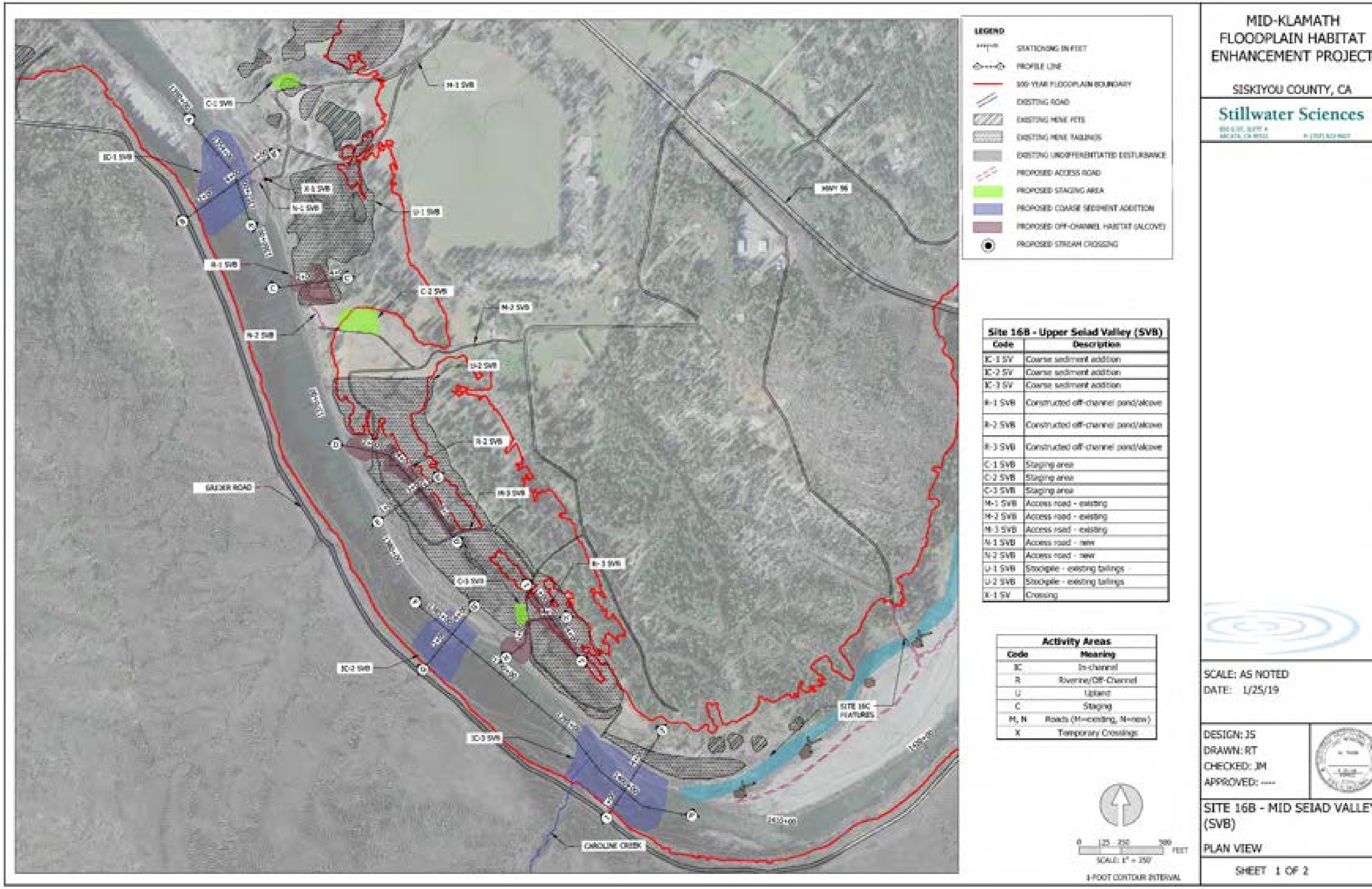

Figure 5-10. Design plan for Site 16B (Middle Seiad Valley).

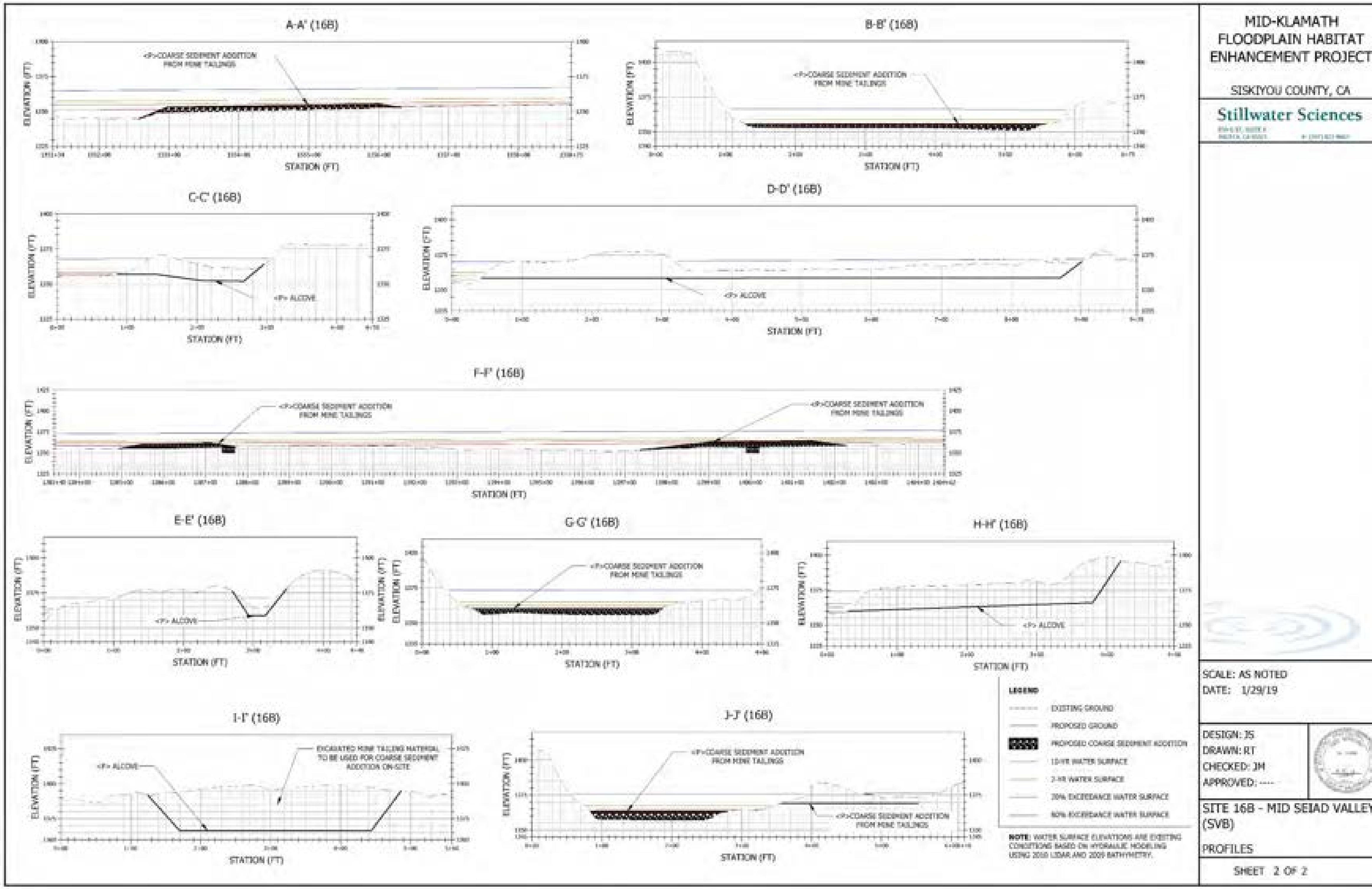

Figure 5-11. Design profiles for Site 16B (Middle Seiad Valley).

Table 5-13. Middle Seiad Valley activity areas.

Code	Description
IC-1 SVB	Coarse sediment addition
IC-2 SVB	Coarse sediment addition
IC-3 SVB	Coarse sediment addition
R-1 SVB	Constructed off-channel pond/alcove
R-2 SVB	Constructed off-channel pond/alcove
R-3 SVB	Constructed off-channel pond/alcove
C-1 SVB	Staging area
C-2 SVB	Staging area
C-3 SVB	Staging area
M-1 SVB	Access road – existing
M-2 SVB	Access road – existing
M-3 SVB	Access road – existing
N-1 SVB	Access road – new
N-2 SVB	Access road – new
U-1 SVB	Stockpile – existing tailings
U-2 SVB	Stockpile – existing tailings
X-1 SVB	Crossing

5.6.5.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 16B is shown in Table 5-14. Based on the current design and planning-level cost analyses, the large quantity of proposed earthwork (cut and fill) amounts to a large expense. It is possible, however, that the unit costs for grading could be significantly reduced for this site due to cut and fill areas located near each other and a broad work area to facilitate efficient earthwork with large heavy equipment. These options and the effect on cost should be evaluating during future design phases.

Table 5-14. Planning-level construction cost estimate for Site 16B (Middle Seiad Valley).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$30,000	1	LS	$30,000
2	Temporary access, clearing and grubbing	$5,000	1	LS	$5,000
3	Dewatering and/or turbidity management	$20,000	1	LS	$20,000
4	Grading (cut) balanced on site	$15	56,000	CY	$840,000
5	Grading (fill) balanced on site	$25	53,000	CY	$1,325,000
6	Large wood structures—placed and anchored	$1,500	0	each	$0
7	Boulders—placed and anchored	$150	0	Tons	$0
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	0	SF	$0
10	Seeding/mulch/planting	$20,000	1	LS	$20,000
11	Other	$0	1	LS	$0
Total					**$2,240,000**

5.6.6 Site 16C – Upper Seiad Valley (SVC)

5.6.6.1 Site description

Site 16C is located along a prominent meander in the river between RM 132.0 and RM 132.8 (Sta 1403+00 and 1440+00) (Appendix B, Figure B-7). Average channel gradient is 0.0021 and average valley width is 755 ft. The reach encompasses a large point bar on river right and an elevated strath terrace that has been dissected by historical mining activity. An existing overflow channel along the back edge of the point bar is relatively low with respect to the riffle crest thalweg elevation, however modeling suggests it only inundates during large flows (i.e., above a 2- to 10-year flow event). The extent to which this overflow channel may be fed by groundwater or cool tributary surface flow is unknown. Gard Creek enters the upstream extent of the site on river left.

5.6.6.2 Proposed Habitat Enhancement Activities

Proposed enhancement activities at this site include side channel excavation (R1-SVC) and enhancement with large wood structures, riparian plantings, and a bar apex jam at the channel inlet (Figure 5-12, Figure 5-13, Table 5-15). Lowering the side channel bed would increase inundation frequency and duration. Riparian planting islands would be established along the left bank of the side channel to provide shade and cover. The apex jam would help maintain hydraulic control for flow entering the side channel and sort bed material to improve potential spawning habitat near the bar head where the valley width expands. The coarse sediment addition at the upstream end of Site 16B (IC-3 SVB) would help to backwater the side channel outlet. Spoils from the side channel excavation, if comprised of suitable size material, could be used for this coarse sediment addition.

Diamond Road off Highway 96 provides access to the right bank in the central portion of the site, and several smaller private roads that branch from Diamond Road provide access to the right bank in the southern portion of the site.

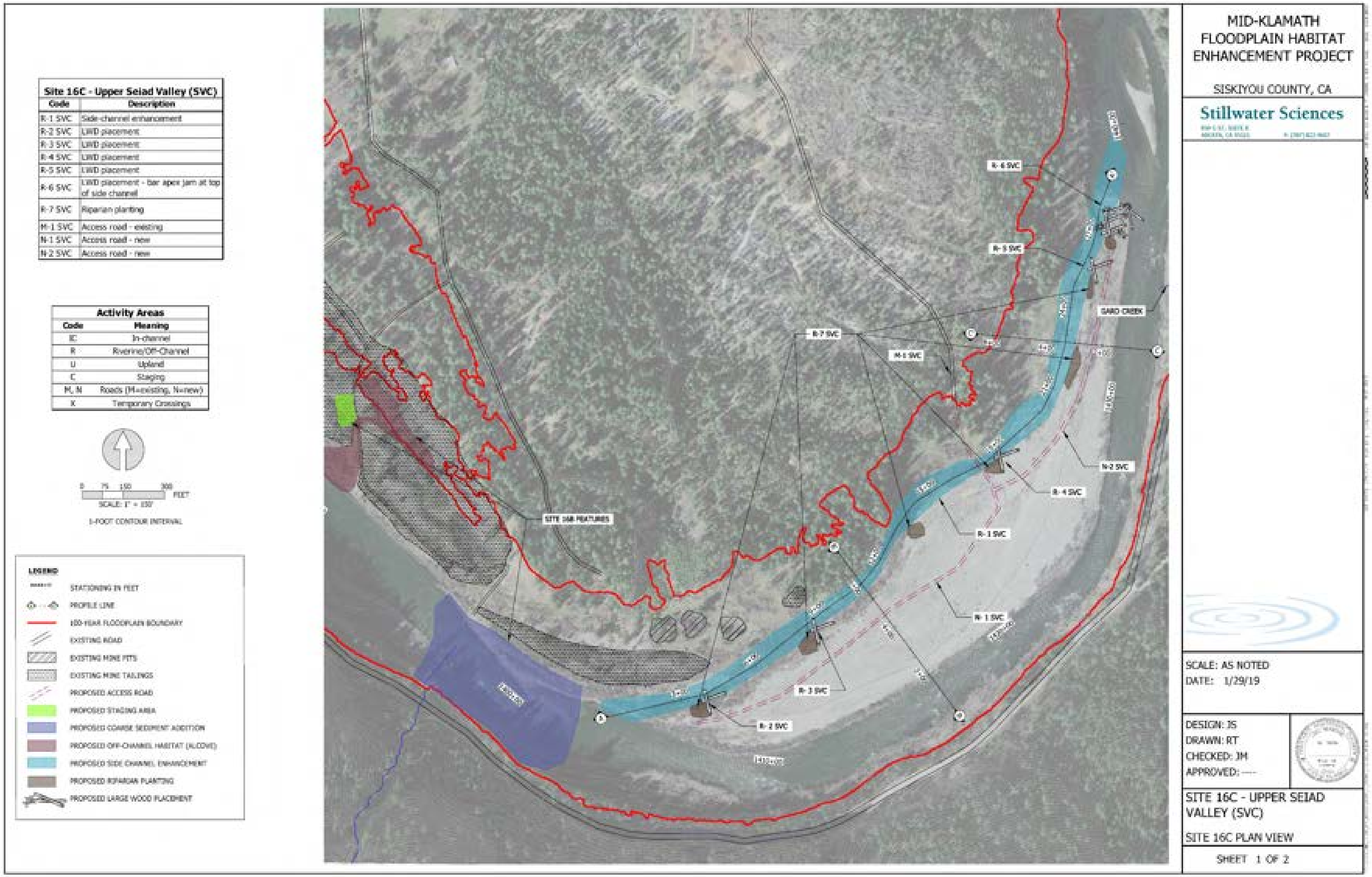

Figure 5-12. Design plan for Site 16C (Upper Seiad Valley).

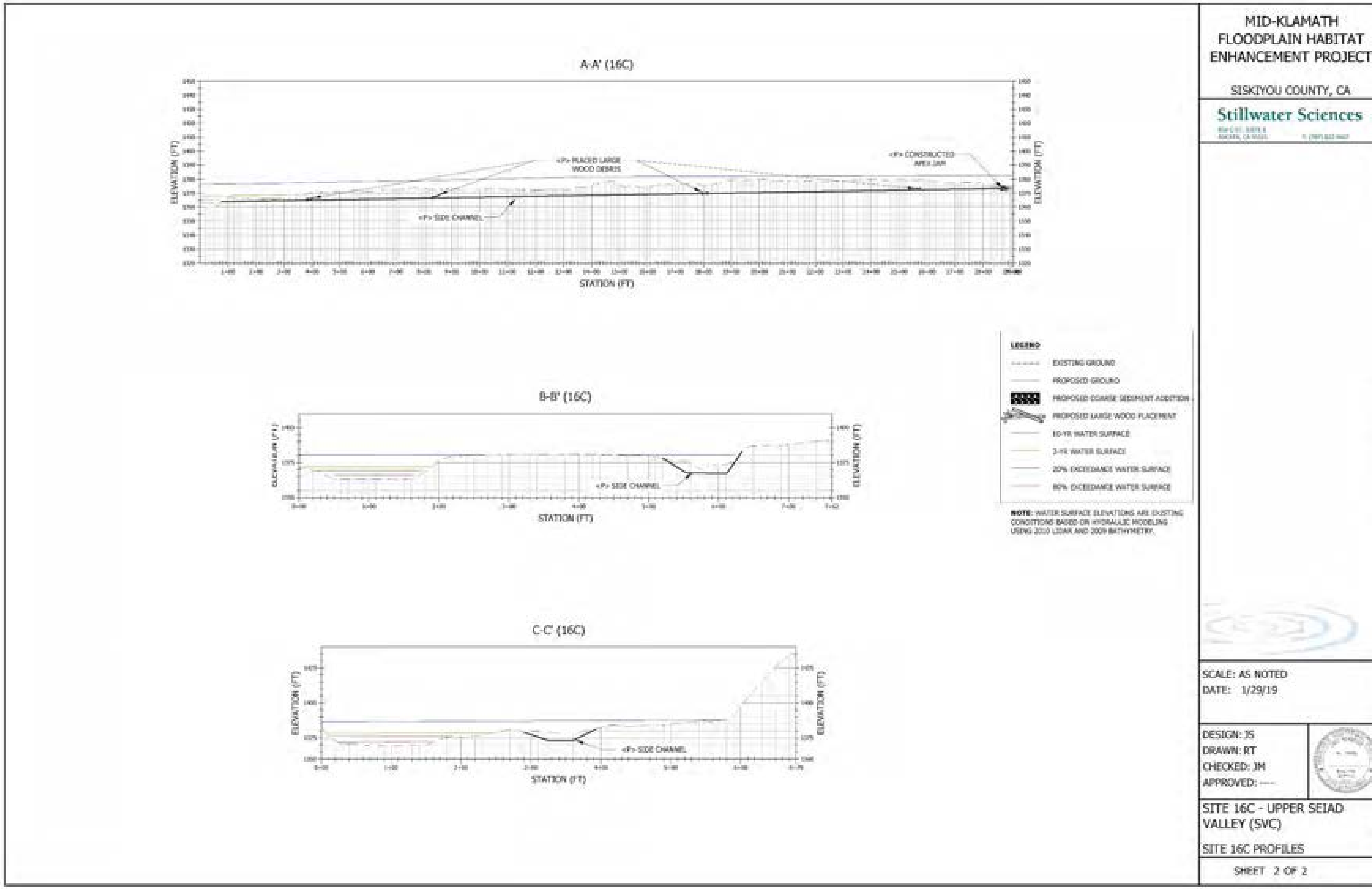

Figure 5-13. Design profiles for Site 16C (Upper Seiad Valley).

Table 5-15. Upper Seiad Valley activity areas.

Code	Description
R-1 SVC	Side-channel enhancement
R-2 SVC	LWD placement
R-3 SVC	LWD placement
R-4 SVC	LWD placement
R-5 SVC	LWD placement
R-6 SVC	Constructed bar apex jam at top of side channel
R-7 SVC	Riparian planting
M-1 SVC	Access road – existing
N-1 SVC	Access road – new
N-2 SVC	Access road – new

5.6.6.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 16C is shown in Table 5-16. The largest cost associated with this site is excavation of side channel feature R-1 SVC. It is recommended that this proposed feature be refined through a cost-benefit analyses in future design phases to optimize habitat benefits and minimize the grading volume. The unit cost for earthwork would also be reduced if spoils could be placed nearby.

Table 5-16. Planning-level construction cost estimate for Site 16C (Upper Seiad Valley).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$23,000	1	LS	$23,000
2	Temporary access, clearing and grubbing	$5,000	1	LS	$5,000
3	Dewatering and/or turbidity management	$8,000	1	LS	$8,000
4	Grading (cut) balanced on site	$15	25,000	CY	$375,000
5	Grading (fill) balanced on site	$25	0	CY	$0
6	Large wood structures—placed and anchored	$1,500	20	each	$30,000
7	Boulders—placed and anchored	$150	10	Tons	$1,500
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	18,100	SF	$18,100
10	Seeding/mulch/planting	$15,000	1	LS	$15,000
11	Other	$0	1	LS	$0
Total					**$475,600**

5.6.7 Site 27A – Lower Cherry Flat (CFA)

5.6.7.1 Site description

Site 27A (Lower Cherry Flat) is located along a prominent meander in the river between RM 149.0 and RM 149.7 (Sta 2288+00 and 2326+00). Average channel gradient is 0.0024 and average valley width is 580 ft. The site has an expansive floodplain surface on river left that contains multiple defined high-flow paths (Appendix B, Figures B-9 and B-10) Portions of the floodplain are relatively low above the riffle crest thalweg elevation, however modeling suggests they only inundate during large flows (i.e., above a 2- to 10-year flow event).

5.6.7.2 Proposed habitat enhancement activities

Proposed enhancement activities at Site 27A include coarse sediment additions, constructing a broad and complex inundation surface (R-1 CFA) by lowering the floodplain, enhancing side channels with wood structures and excavation to increase inundation frequency and duration, and constructing an engineered log jam at the side channel inlet (Figure 5-14, Figure 5-15, Table 5-17). The constructed inundation surface (R-1 CFA) is in a strategic location to test the strategy of restoring the soil ecosystem by lowering floodplains where they will function as a depositional zone when removal of the Klamath River dams releases reservoir sediments to downstream reaches. Large wood and boulder structures built on the upstream side of the side channel outlets will help maintain connectivity to the mainstem and provide alcove habitat. Excavated material from the constructed side channel and inundation surface will provide coarse sediment for gravel augmentation. Abundant mining tailings are also located across the river at the Upper Cherry Flat site. Coarse sediment additions are designed to modify riffle crest hydraulic controls by locally raising the water surface elevation and increasing floodplain and side channel inundation across a wider range of flow conditions. Fluvial processes resulting from coarse sediment additions are expected to promote more dynamic sinuous morphology and increase complex aquatic and riparian habitat.

The site is adjacent to Highway 96 and an existing spur road provides access. There is a large staging area at the downstream extent of the site adjacent to Highway 96.

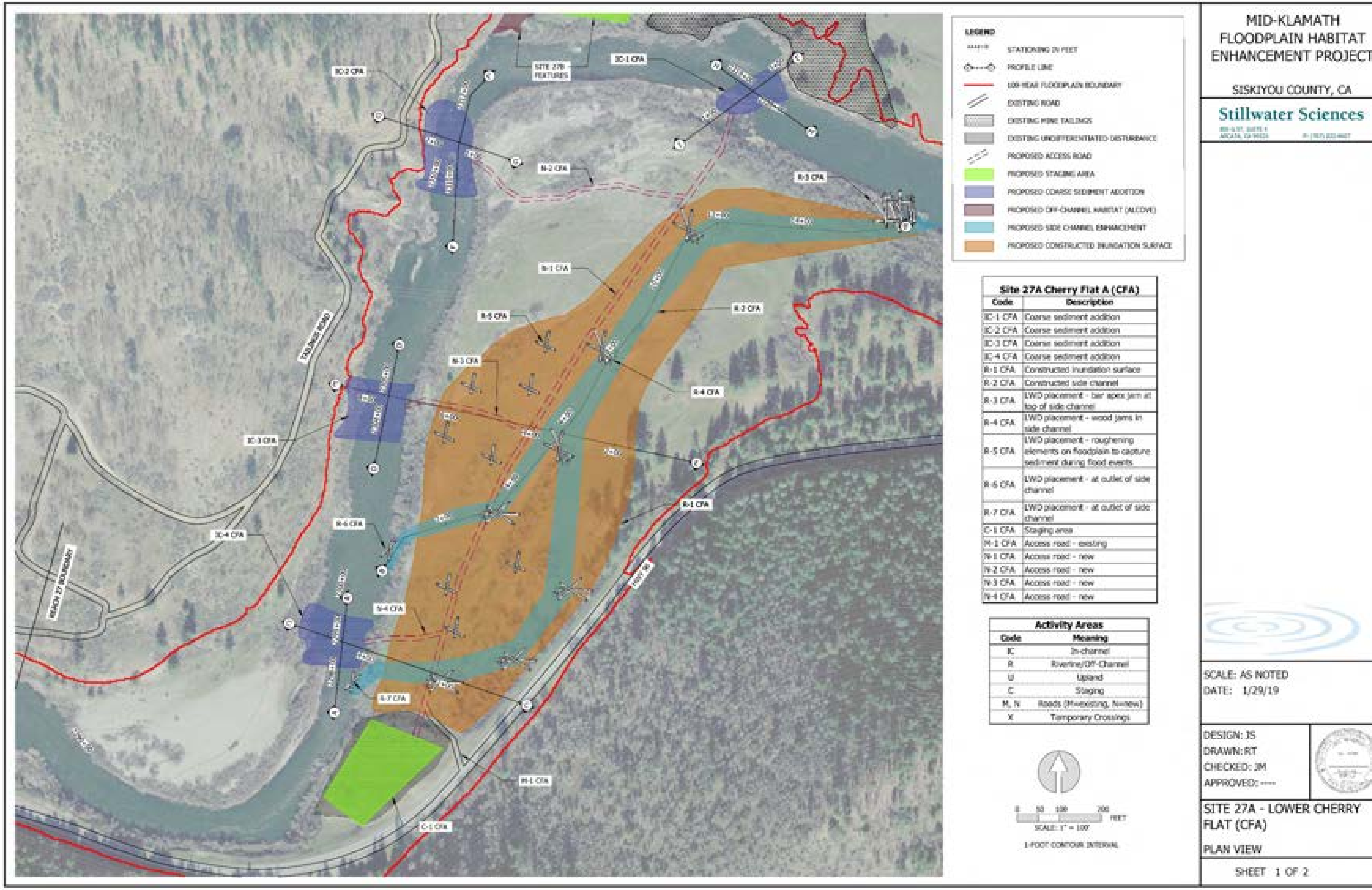

Figure 5-14. Design plan for Site 27A (Lower Cherry Creek).

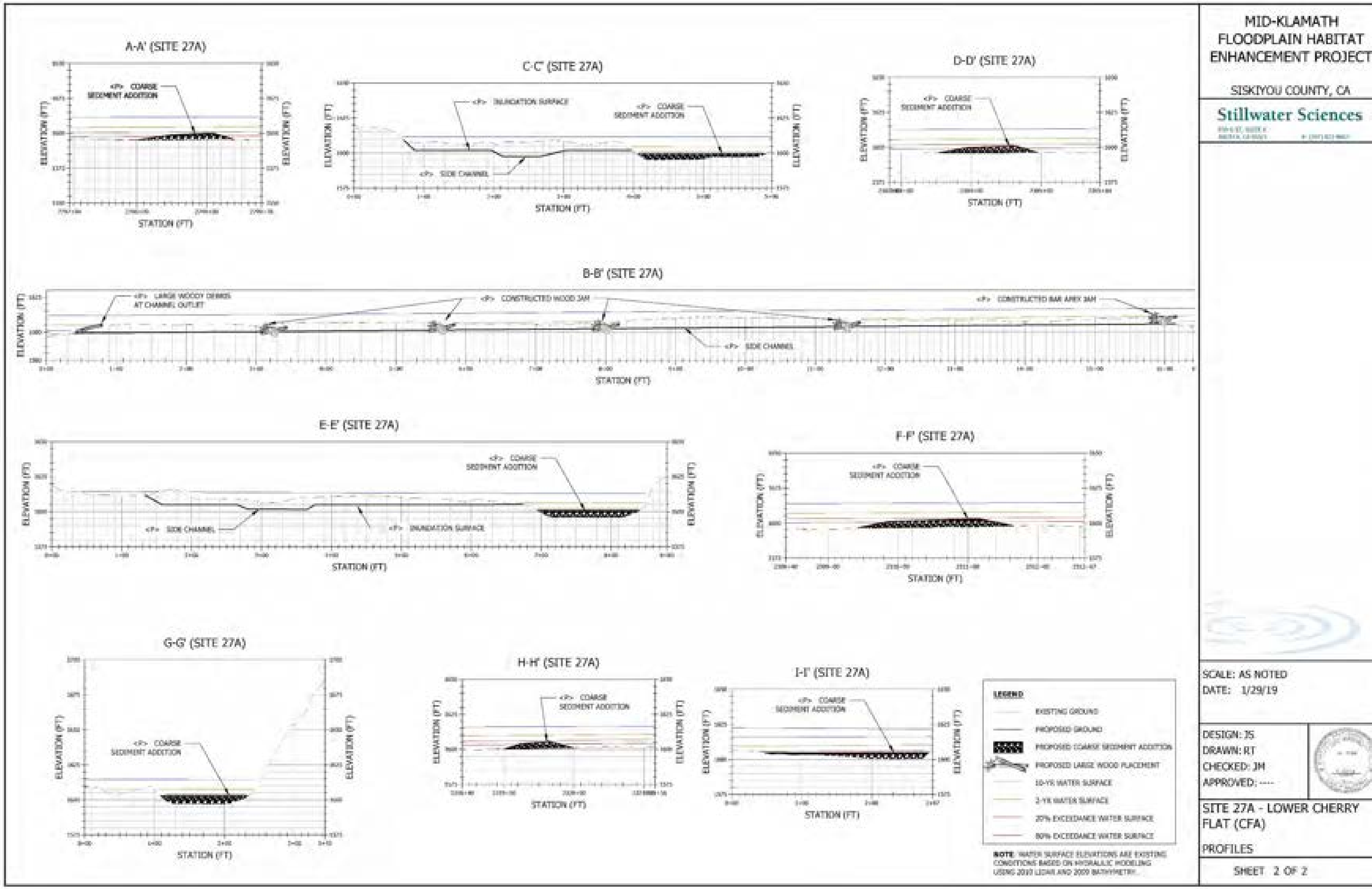

Figure 5-15. Design profiles for Site 27A (Lower Cherry Creek).

Table 5-17. Lower Cherry Flat activity areas.

Code	Description
IC-1 CFA	Coarse sediment addition
IC-2 CFA	Coarse sediment addition
IC-3 CFA	Coarse sediment addition
IC-4 CFA	Coarse sediment addition
R-1 CFA	Constructed inundation surface
R-2 CFA	Constructed side channel
R-3 CFA	Constructed bar apex jam at top of side channel
R-4 CFA	Constructed wood jams in side channel
R-5 CFA	Constructed roughening elements on floodplain to capture sediment during flood events
R-6 CFA	Large wood debris placement at outlet of side channel
R-7 CFA	Large wood debris placement at outlet of side channel
C-1 CFA	Staging area
M-1 CFA	Access road – existing
N-1 CFA	Access road – new
N-2 CFA	Access road – new
N-3 CFA	Access road – new
N-4 CFA	Access road – new

5.6.7.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 27A is shown in Table 5-18. Based on the current design and planning-level cost analyses, the large quantities of earthwork (cut) proposed for enhancement of the floodplain and side channel amount to a large expense. Although the broad potential benefit of the project may warrant high construction costs, project features should be refined through a cost-benefit analyses during future design phases.

Table 5-18. Planning-level construction cost estimate for Site 27A (Lower Cherry Flat).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$30,000	1	LS	$30,000
2	Temporary access, clearing and grubbing	$5,000	1	LS	$5,000
3	Dewatering and/or turbidity management	$20,000	1	LS	$20,000
4	Grading (cut) balanced on site	$15	80,000	CY	$1,200,000
5	Grading (fill) balanced on site	$25	8,000	CY	$200,000
6	Large wood structures—placed and anchored	$1,500	55	each	$82,500
7	Boulders—placed and anchored	$150	0	Tons	$0
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	0	SF	$0
10	Seeding/mulch/planting	$35,000	1	LS	$35,000
11	Other	$0	1	LS	$0
Total					**$1,572,500**

5.6.8 Site 27B – Upper Cherry Flat (CFB)

5.6.8.1 Site Description

Site 27B is located between RM 149.2 and RM 150.0 (Sta 2310+00 and 2355+00). Average channel gradient is 0.0024 and average valley width is 580 ft. The site occupies a relic meander cutoff of the Klamath River (Appendix B, Figure B-10). This is the most expansively placer mined site within the Project area, historically mined using wing dam, hydraulic, and dredge techniques. Gravel harvesting operations continue at the site. Mining impacts include numerous pits connected by surface water and/or groundwater, extensive tailing piles, and multiple large laydown and staging areas. Most of the mining pits occupy the relic river channel and are at the same elevation as the mainstem riffle crest thalweg datum. Construction of Highway 96, riparian encroachment, and mine tailing deposits prohibit Klamath River flow from occupying the relic channel.

5.6.8.2 Proposed habitat enhancement activities

Proposed enhancement activities at the site are divided into two phases. The initial phase would involve enhancing mining pits as off-channel ponds, constructing connection channels between the ponds, and constructing an alcove and entrance channel at the downstream extent of the relic channel (Figure 5-16, Figure 5-17, Table 5-19). The Mid Klamath Watershed Council has been monitoring shallow groundwater in this portion of the project site to inform the design process.

The second phase would involve installing connecting infrastructure (culvert, bottomless arch, or bridge) underneath Highway 96 that would connect the mainstem Klamath River and the upstream extent of the relic channel. The connection would provide a through-flow hydrologic input to the enhanced pond sequence along the relic channel. The tailing piles at the upstream end of the relic channel would be graded to create a large infiltration gallery that would enhance groundwater storage and sustain base-flows through the pond sequence. Phase two enhancements would ideally be designed and implemented in coordination with improvements that the California Department of Transportation is considering for Highway 96 through the Cherry Flat site.

The mine tailings provide an onsite source of coarse sediment for gravel augmentation. Highway 96 and a private road provide access to the site. There are suitable staging areas across the site.

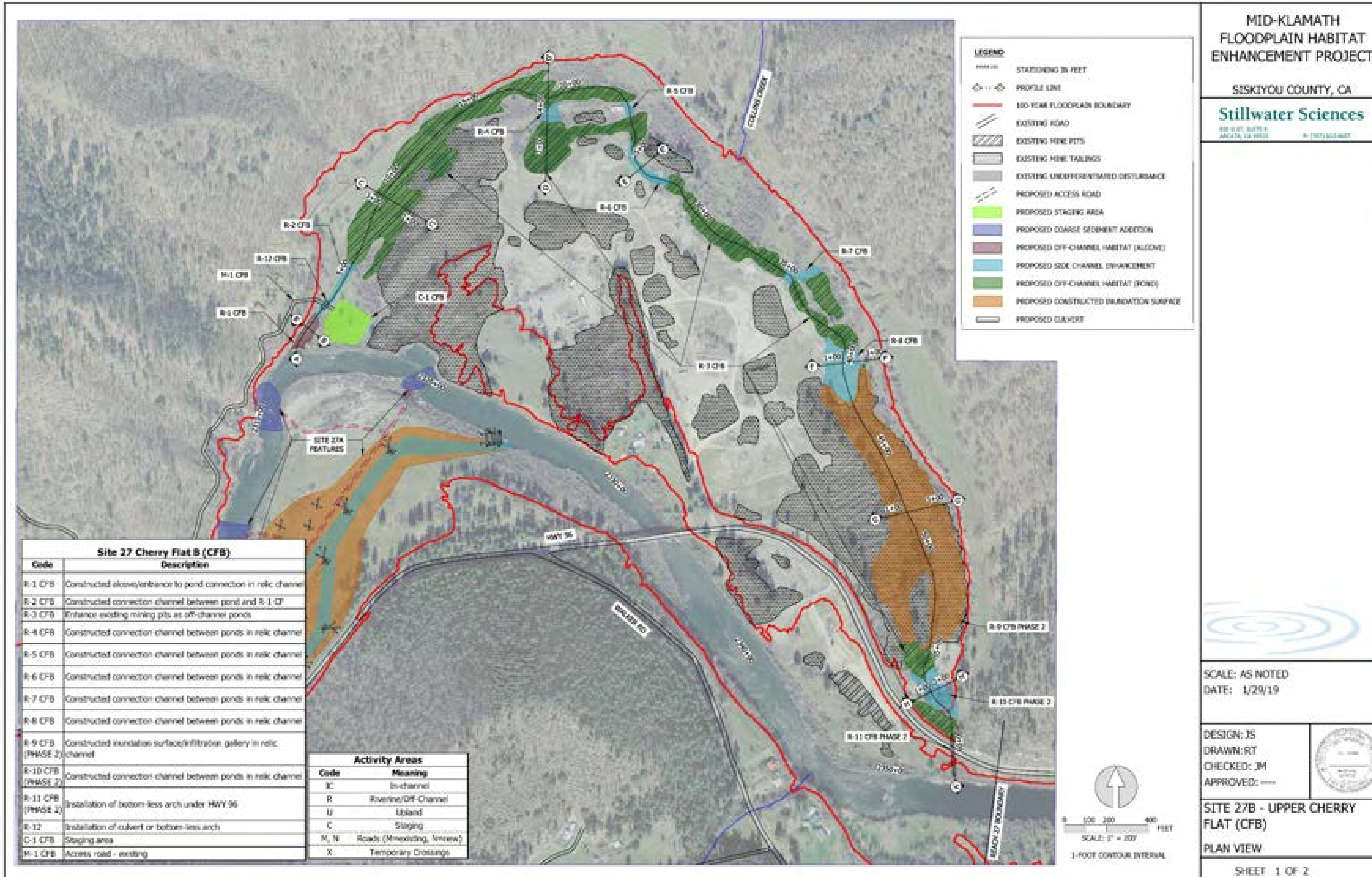

Figure 5-16. Design plan for Site 27B (Upper Cherry Flat).

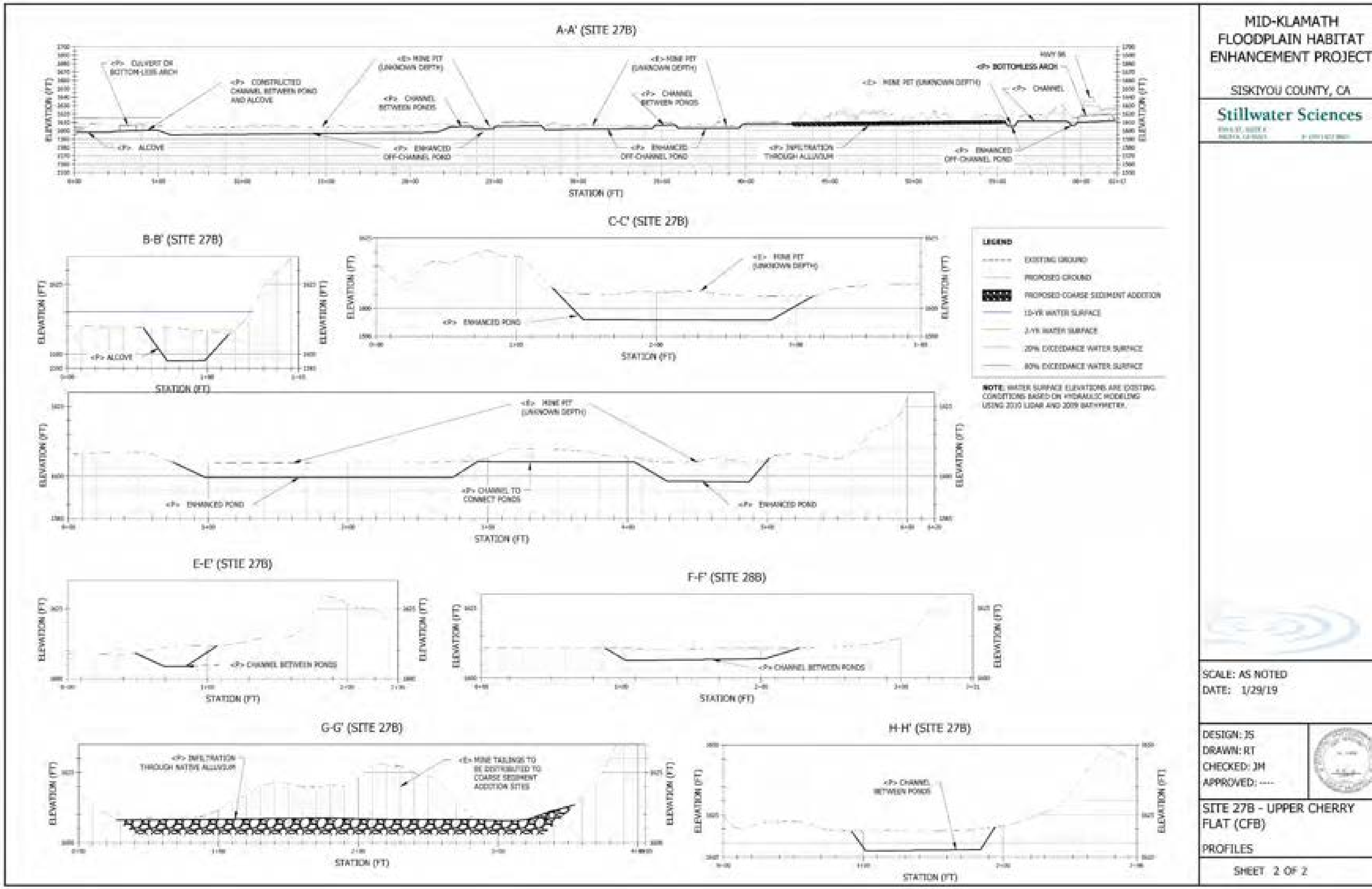

Figure 5-17. Design profiles for Site 27B (Upper Cherry Flat).

Table 5-19. Upper Cherry Flat activity areas.

Code	Description
R-1 CFB	Constructed alcove/entrance to pond connection in relic channel
R-2 CFB	Constructed connection channel between pond and R-1 CF
R-3 CFB	Enhance existing mining pits as off-channel ponds
R-4 CFB	Constructed connection channel between ponds in relic channel
R-5 CFB	Constructed connection channel between ponds in relic channel
R-6 CFB	Constructed connection channel between ponds in relic channel
R-7 CFB	Constructed connection channel between ponds in relic channel
R-8 CFB	Constructed connection channel between ponds in relic channel
R-9 CFB (PHASE 2)	Constructed inundation surface/infiltration gallery in relic channel
R-10 CFB (PHASE 2)	Constructed connection channel between ponds in relic channel
R-11 CFB (PHASE 2)	Installation of bottomless arch under HWY 96
R-12	Installation of culvert or bottom-less arch
C-1 CFB	Staging area
M-1 CFB	Access road – existing

5.6.8.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 27A is shown in Table 5-20. Based on the current design and planning-level cost analyses, the large quantities of earthwork (cut) associated with the proposed side channel habitat enhancement amount to a large expense. As previously described, this project is likely to be constructed in a phased approach with an initial relatively inexpensive Phase I project connecting the downstream extent of the side channel to the Klamath River. The larger Phase II project has numerous uncertainties associated with the project scope and resulting cost that will need to be revisited and further developed during future design phases.

Table 5-20. Planning-level construction cost estimate for Site 27B (Upper Cherry Flat).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$30,000	1	LS	$30,000
2	Temporary access, clearing and grubbing	$20,000	1	LS	$20,000
3	Dewatering and/or turbidity management	$5,000	1	LS	$5,000
4	Grading (cut) balanced on site	$15	169,000	CY	$2,535,000
5	Grading (fill) balanced on site	$25	0	CY	$0
6	Large wood structures—placed and anchored	$1,500	0	each	$0
7	Boulders—placed and anchored	$150	0	Tons	$0
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	0	SF	$0
10	Seeding/mulch/planting	$40,000	1	LS	$40,000
11	Other (culverts—pipes and installation)	$80,000	1	LS	$80,000
Total					**$2,710,000**

5.6.9 Site 32A – Lower Little Humbug Creek (LHA)

5.6.9.1 Site description

Site 32A (Lower Little Humbug Creek) is located between RM 154.3 and RM 156.3 (Sta 2572+00 and 2688+00). Average channel gradient is 0.0021 and average valley width is 750 ft. This long site (11,600 ft) encompasses alternating meanders with large bar and floodplain surfaces that include formerly function off-channel features (e.g., side channels and backwaters, overflow channels, and groundwater channels) that have been abandoned and are currently inundated only during large, infrequent flows (Appendix B, Figure B-12 and B-13). Attenuated peak flows and reduced sediment supply and transport resulting from flow regulation and sediment trapping by upstream dams, in combination with riparian encroachment and local mine tailing deposits, have confined mainstem flow, limited bed mobilization and dynamic channel forming processes, and reduced floodplain inundation at this site and in other reaches upstream of the Scott River. Much of the floodplains on both sides of the river are relatively low (less than 10 ft above the riffle crest thalweg elevation), however, hydraulic modeling indicates they are inundated infrequently (greater than a 2- to 10-year flow event). Residential structures and agricultural land uses occur intermittently within former floodplain areas throughout the site. Doggett and McKinney creeks enter from opposing banks near the middle to the site. Both streams can provide summer thermal refuge at their confluence during wetter water years.

5.6.9.2 Proposed habitat enhancement activities

Proposed enhancement activities at this site include coarse sediment additions, constructing a side channel and off-channel pond (L-7 LHA), constructing and enhancing two alcoves, large wood and boulder installations, and a culvert upgrade to improve fish passage on McKinney Creek (Figure 5-18, Figure 5-19, Table 5-21). The inlet of the proposed side channel at the upstream end of the site (R-1 LHA) would include an engineered log jam with a sediment fence to reduce fine sediment transport into the side channel. Coarse sediment additions are designed to modify riffle crest hydraulic controls by locally raising the water surface elevation and increasing floodplain and side channel inundation across a wider range of flow conditions. Replacing the undersized culvert on lower McKinney Creek will improve fish passage and stream function, and the off-channel pond at the creek confluence is designed to expand a cold-water refuge. An enhanced backwater (alcove) (R-8 LHA) and coarse sediment addition (IC-3 LHA) at the downstream end of the site would provide winter rearing habitat.

The mine tailings provide an onsite source of coarse sediment for gravel augmentation. Highway 96 and Walker Road provide multiple access points on both sides of the river. There are multiple suitable staging and spoil areas onsite.

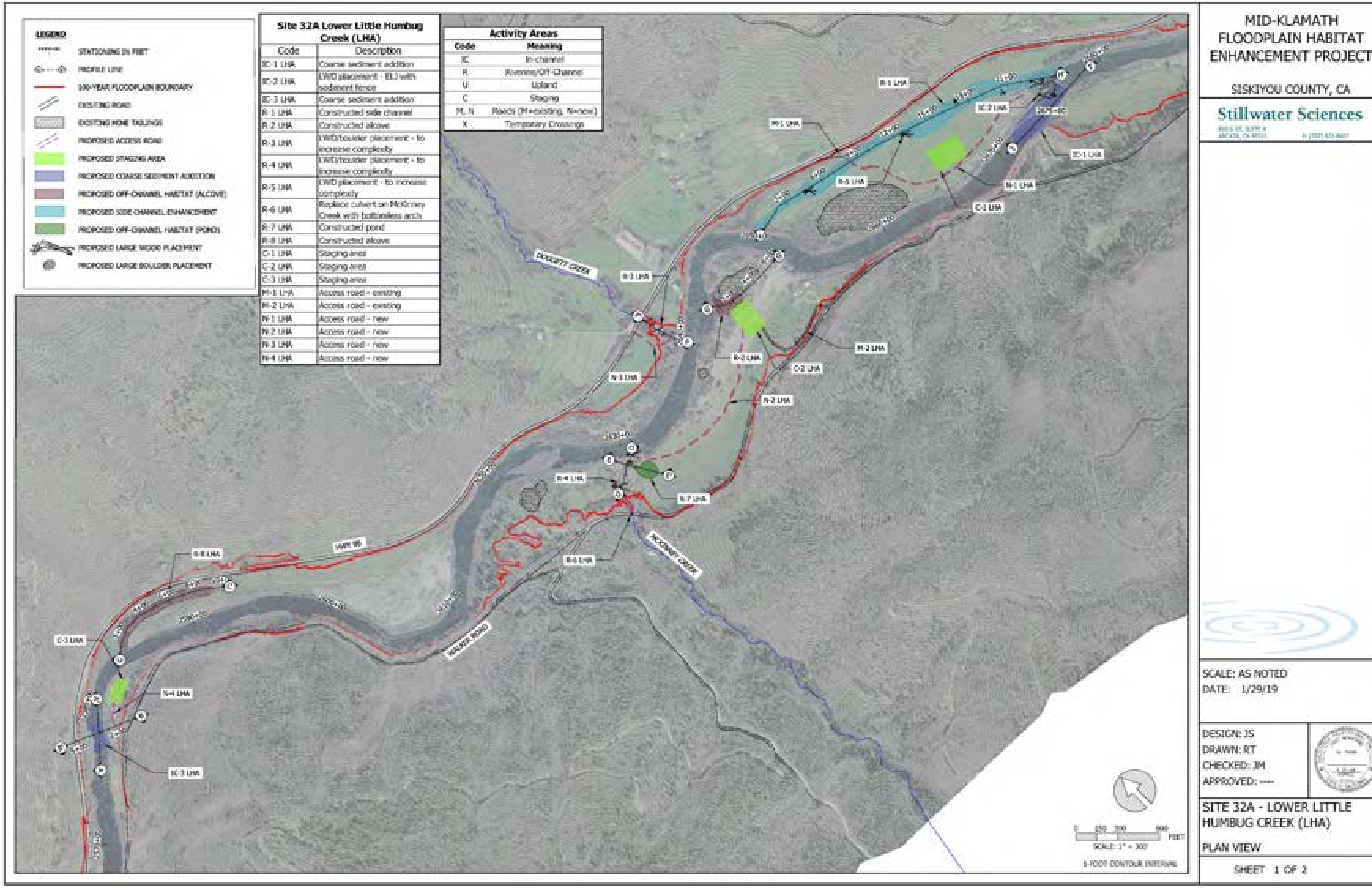

Figure 5-18. Design plan for Site 32A (Lower Little Humbug Creek).

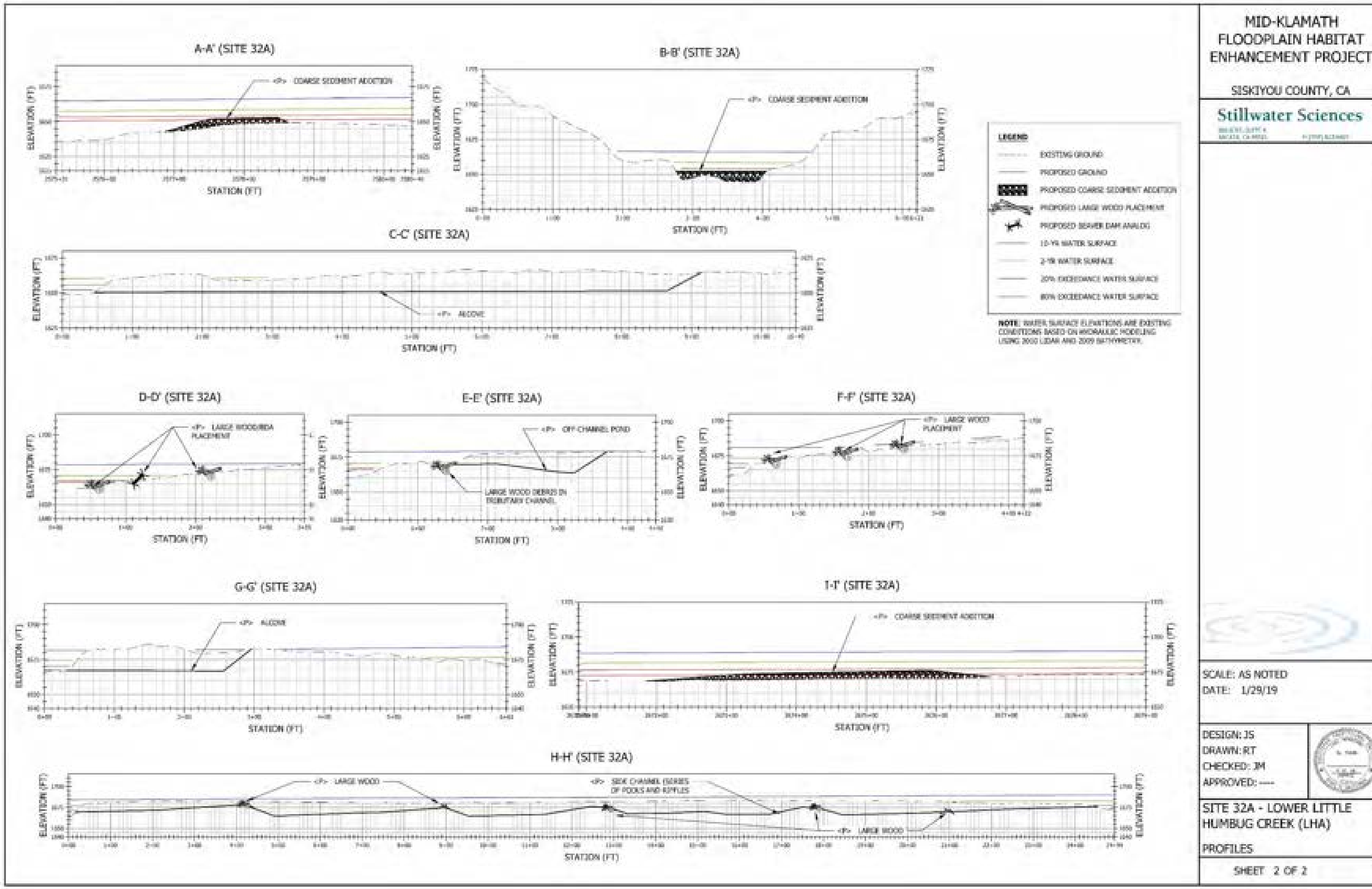

Figure 5-19. Design profiles for Site 32A (Lower Little Humbug Creek).

Table 5-21. Lower Little Humbug Creek activity areas.

Code	Description
IC-1 LHA	Coarse sediment addition
IC-2 LHA	LWD placement – ELJ with sediment fence
IC-3 LHA	Coarse sediment addition
R-1 LHA	Constructed side channel
R-2 LHA	Constructed alcove
R-3 LHA	LWD/boulder placement to increase complexity
R-4 LHA	LWD/boulder placement to increase complexity
R-5 LHA	LWD placement to increase complexity
R-6 LHA	Replace culvert on McKinney Creek with bottomless arch
R-7 LHA	Constructed pond
R-8 LHA	Constructed alcove
C-1 LHA	Staging area
C-2 LHA	Staging area
C-3 LHA	Staging area
M-1 LHA	Access road – existing
M-2 LHA	Access road – existing
N-1 LHA	Access road – new
N-2 LHA	Access road – new
N-3 LHA	Access road – new
N-4 LHA	Access road – new

5.6.9.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 32A is shown in Table 5-22. This project has many different components that MKWC will likely want to further divide into smaller implementation projects. The first project should include the less expensive treatments on Dogget and Mckinney Creeks, potentially combined with enhancement of the smaller alcove on the Klamath River. The second project should include construction of the larger-scale side channel enhancements, alcove, and coarse sediment additions that require significant cut and fill. These features will need a more detailed cost-benefit analyses in future design phases.

Table 5-22. Planning-level construction cost estimate for Site 32A (Lower Little Humbug).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$30,000	1	LS	$30,000
2	Temporary access, clearing and grubbing	$18,000	1	LS	$18,000
3	Dewatering and/or turbidity Management	$20,000	1	LS	$20,000
4	Grading (cut) balanced on site	$15	89,000	CY	$1,335,000
5	Grading (fill) balanced on site	$25	11,000	CY	$275,000
6	Large wood structures—placed and anchored	$1,500	32	each	$48,000
7	Boulders—placed and anchored	$150	8	Tons	$1,200
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	0	SF	$0
10	Seeding/mulch/planting	$30,000	1	LS	$30,000
11	Other (culvert replacement with bottomless arch)	$60,000	1	LS	$60,000
Total					**$1,817,200**

5.6.10 Site 32B – Middle Little Humbug Creek (LHB)

5.6.10.1 Site description

Site 32B is located between RM 158.1 and RM 158.3 (Sta 2770+00 and 2790+00). The river at this site has a split channel (Appendix B, Figure B-15). The right channel (main flow path) is straight and relatively steep, whereas the left channel is low gradient and occupies a cutoff meander. The left bank channel conveys a large fraction of Klamath River flow during the summer and is recognized as an important spawning and rearing habitat for coho Salmon and other salmonids. Grouse Creek enters the river-left channel near its downstream extent, just before re-connecting with the other split channel. Little Humbug Creek enters just upstream of the site (upstream of the channel split).

5.6.10.2 Proposed habitat enhancement activities

Proposed enhancement activities at this site include coarse sediment additions, riparian plantings, constructing a bar apex jam, enhancing the river-left split channel with large wood and boulder structures and a sequence of BDA's (Figure 5-20, Figure 5-21, Table 5-23). Coarse sediment additions are designed to modify riffle crest hydraulic controls by locally raising the water surface elevation and increasing split channel flow across a wider range of flow conditions. Large wood and boulder structures are designed to sort spawning gravels, increase habitat complexity, and promote dynamic fluvial processes. BDA's are designed retain spawning gravels, reduce flow velocity, and increase surface and groundwater storage.

Walker Road provides access to the site, and there is a large staging area just off the road.

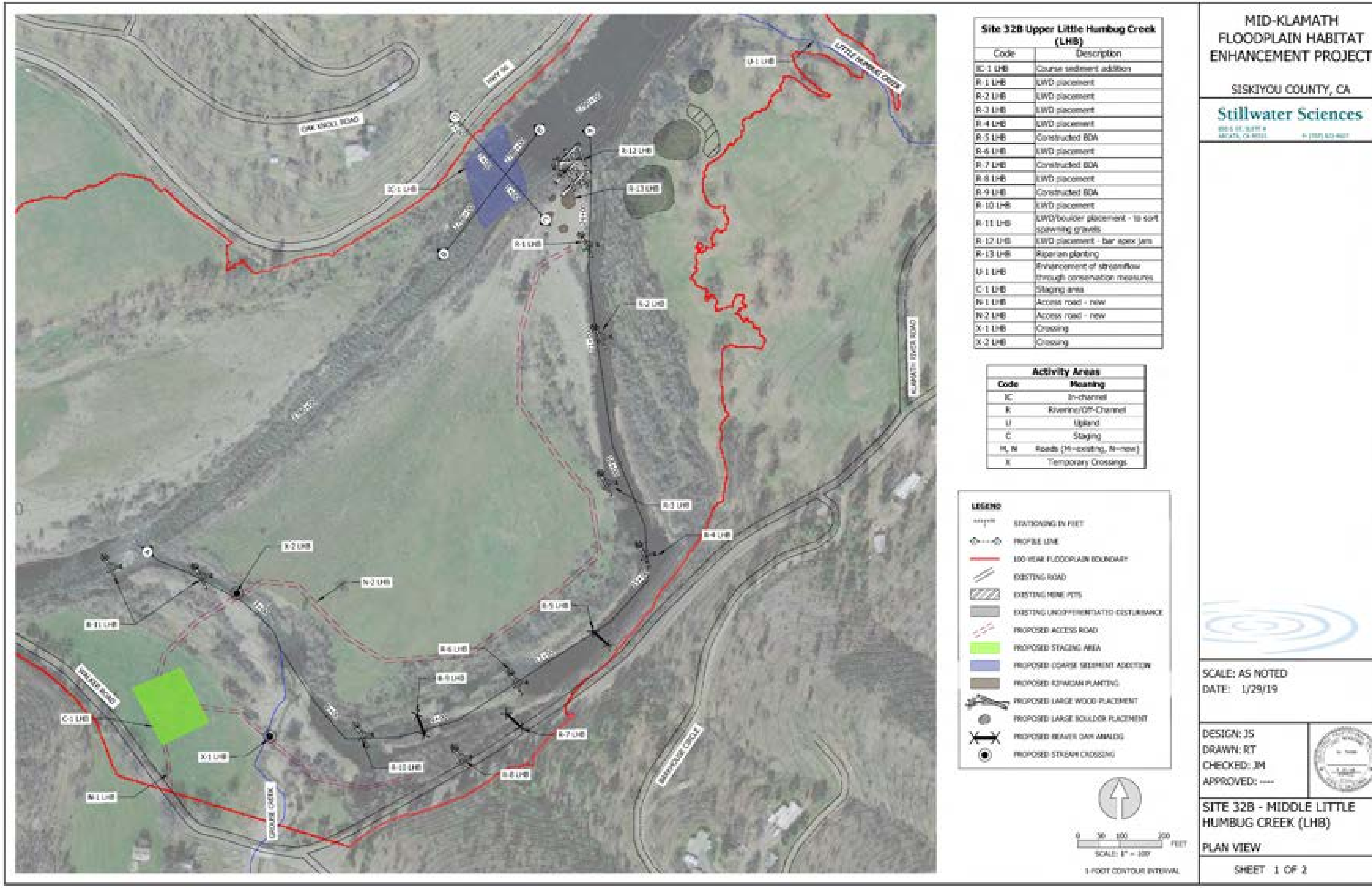

Figure 5-20. Design plan for Site 32B (Middle Little Humbug Creek).

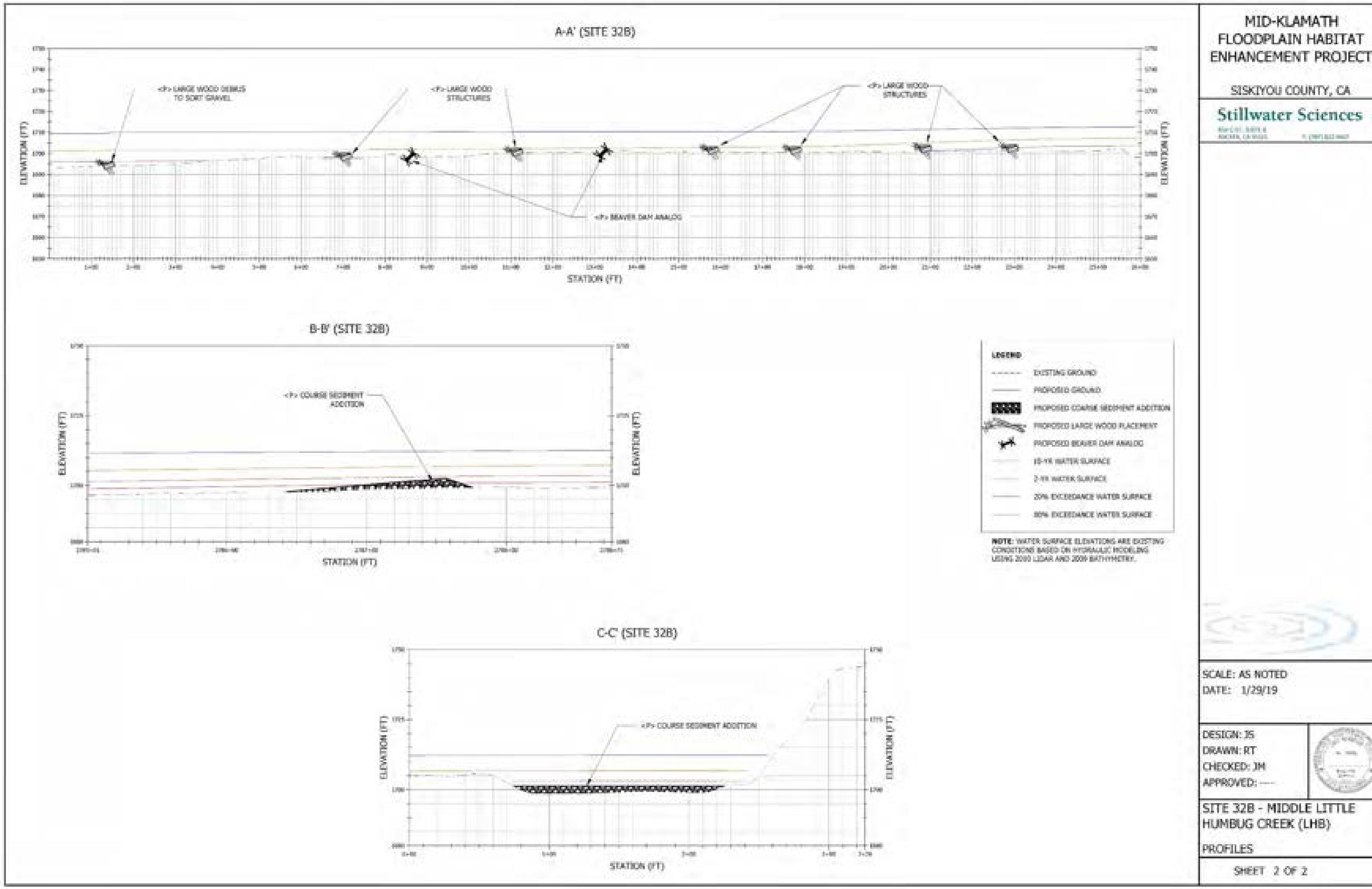

Figure 5-21. Design profiles for Site 32B (Middle Little Humbug Creek).

Table 5-23. Middle Little Humbug Creek activity areas.

Code	Description
IC-1 LHB	Course sediment addition
R-1 LHB	LWD placement
R-2 LHB	LWD placement
R-3 LHB	LWD placement
R-4 LHB	LWD placement
R-5 LHB	Constructed BDA
R-6 LHB	LWD placement
R-7 LHB	Constructed BDA
R-8 LHB	LWD placement
R-9 LHB	Constructed BDA
R-10 LHB	LWD placement
R-11 LHB	LWD and boulder placement to sort spawning gravels
R-12 LHB	Constructed apex bar jam
R-13 LHB	Riparian planting
U-1 LHB	Enhancement of streamflow through conservation measures
C-1 LHB	Staging area
N-1 LHB	Access road - new
N-2 LHB	Access road - new
X-1 LHB	Crossing
X-2 LHB	Crossing

5.6.10.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 32B is shown in Table 5-24. This project has the potential to be relatively cost effective, although there are uncertainties associated with the source for the proposed coarse sediment addition. The unit cost would likely increase if this material must be trucked in from off-site.

Table 5-24. Planning-level construction cost estimate for Site 32B (Middle Little Humbug).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$7,000	1	LS	$7,000
2	Temporary access, clearing and grubbing	$15,000	1	LS	$15,000
3	Dewatering and/or turbidity management	$20,000	1	LS	$20,000
4	Grading (cut) balanced on site	$15	0	CY	$0
5	Grading (fill) balanced on site	$25	1,000	CY	$25,000
6	Large wood structures—placed and anchored	$1,500	42	each	$63,000
7	Boulders—placed and anchored	$150	15	Tons	$2,250
8	Beaver dam analogues	$5,000	3	LS	$15,000
9	Riparian planting	$1	1,600	SF	$1,600
10	Seeding/mulch/planting	$5,000	0	LS	$0
11	Other	$0	0	LS	$0
Total					**$148,850**

5.6.11 Site 39 – Vesa Creek (VC)

5.6.11.1 Site description

Site 39 (Vesa Creek) is located between RM 164.8 and RM 165.1 (Sta 3130+00 and 3145+00). Average channel gradient is relatively steep at 0.0052 and the average valley width is 360 ft. Although the valley bottom is relatively confined at the Vesa Creek confluence, channel width increases immediately downstream and the left bank floodplain includes mining ponds and other side channel and off-channel features (Appendix B, Figure B-18). Modeling suggests the side channel only inundates at above a 2- to 10-year flow event. Riparian encroachment, mine tailing deposits, and bedrock exposure limit dynamic channel evolution and extensive floodplain inundation.

5.6.11.2 Proposed habitat enhancement activities

Proposed enhancement activities at this site include removing mine tailings and enhancing the side channel by excavating it to increase inundation frequency and duration (Figure 22, Figure 23, Table 25). An alternative enhancement action is to realign the Vesa Creek confluence by routing it into the enhanced side channel, which would increase the channel length receiving cold tributary flow. Injecting coarse sediment locally sourced from the mine tailings could also be implemented to promote more dynamic sinuous morphology and increase complex aquatic and riparian habitat.

Abundant mine tailings provide a source of coarse sediment for gravel augmentation at this site and others. Klamath River Road provides direct access and there are suitable staging areas onsite.

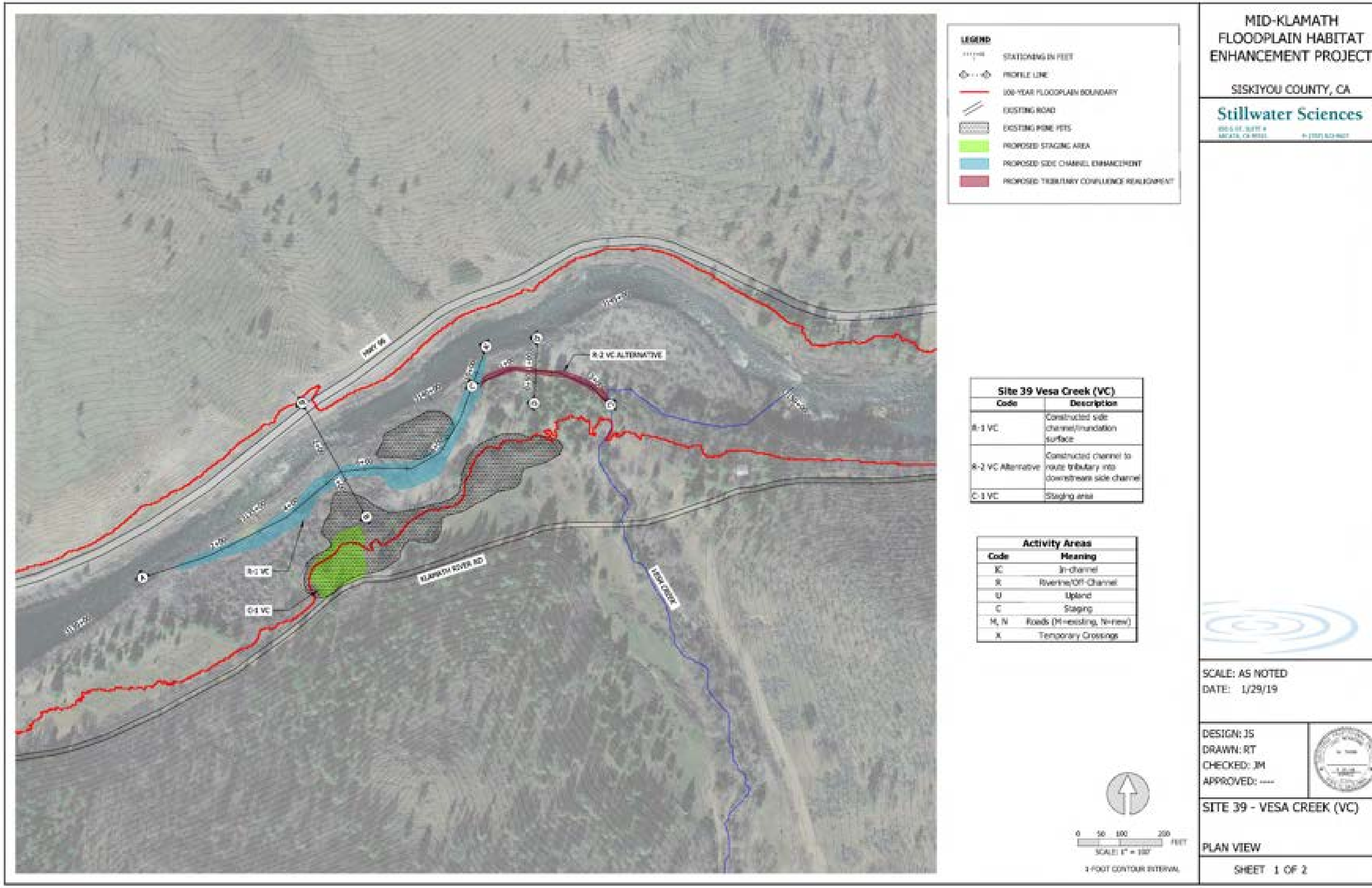

Figure 5-22. Design plan for Site 39 (Vesa Creek).

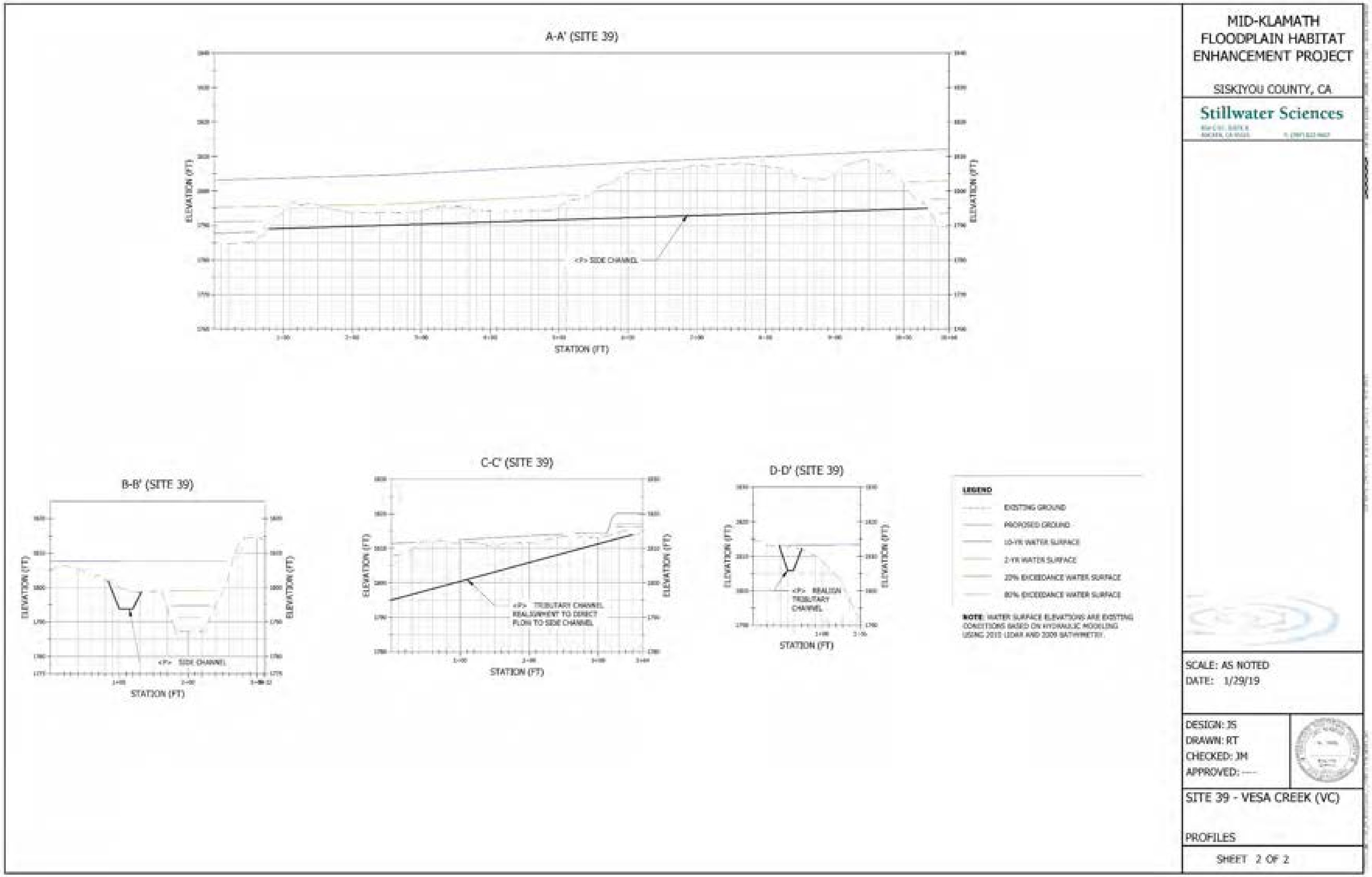

Figure 5-23. Design profiles for Site 39 (Vesa Creek).

Table 5-25. Vesa Creek activity areas.

Code	Description
R-1 VC	Constructed side channel/inundation surface
R-2 VC Alternative	Constructed channel to route tributary into downstream side channel
C-1 VC	Staging area

5.6.11.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 39 is shown in Table 5-26. There is less overall uncertainty in the planning level construction cost estimate for this site, since the project includes only two features requiring earthwork.

Table 5-26. Planning-level construction cost estimate for Site 39 (Vesa Creek).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$7,000	1	LS	$7,000
2	Temporary access, clearing and grubbing	$5,000	1	LS	$5,000
3	Dewatering and/or turbidity management	$0	1	LS	$0
4	Grading (cut) balanced on site	$15	7,000	CY	$105,000
5	Grading (fill) balanced on site	$25	0	CY	$0
6	Large wood structures—placed and anchored	$1,500	0	each	$0
7	Boulders—placed and anchored	$150	0	Tons	$0
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	0	SF	$0
10	Seeding/mulch/planting	$15,000	1	LS	$15,000
11	Other	$0	1	LS	$0
Total					**$132,000**

5.6.12 Site 40 – Above Vesa Creek (AVC)

5.6.12.1 Site description

Site 40 (Above Vesa Creek) is located between RM 165.4 and RM 165.6 (Sta 3165+00 and 3175+00). Average gradient through the site is 0.0037 and average valley width is 320 ft. Although relatively confined, there are two prominent alternating floodplain surfaces (Appendix B, Figure B-18). Riparian encroachment and mine tailing deposits limit dynamic fluvial processes. Portions of the floodplain on river left are relatively low above the riffle crest thalweg elevation, however modeling indicates they only inundate at above a 10-year flow event. The mine tailings provide an onsite source of coarse sediment for gravel augmentation. Horse Trough Springs discharges cold water into a channel along the southern margin of the floodplain at the downstream end of the site.

5.6.12.2 Proposed habitat enhancement activities

Proposed enhancement activities at this site include coarse sediment additions, removing mine tailings, lowering floodplain surfaces, constructing side channels with alcoves at the inlet and outlet, and constructing an engineered log jam at the side channel inlet with a sediment fence to reduce fine sediment transport into the side channel (Figure 24, Figure 5-25, Table 5-27). Coarse sediment additions are designed to modify riffle crest hydraulic controls by locally raising the water surface elevation and increasing floodplain and side channel inundation across a wider range of flow conditions. Fluvial processes resulting from coarse sediment additions are expected to promote more dynamic sinuous morphology and increase complex aquatic and riparian habitat. Relatively cold water from Horse Trough Springs provides opportunity to enhance and expand cold water refuge habitat within the proposed left bank side channel and downstream alcove.

River Road and the Gottville River Access provide access to the site on the left and right banks, respectively. There are limited staging and spoil areas onsite.

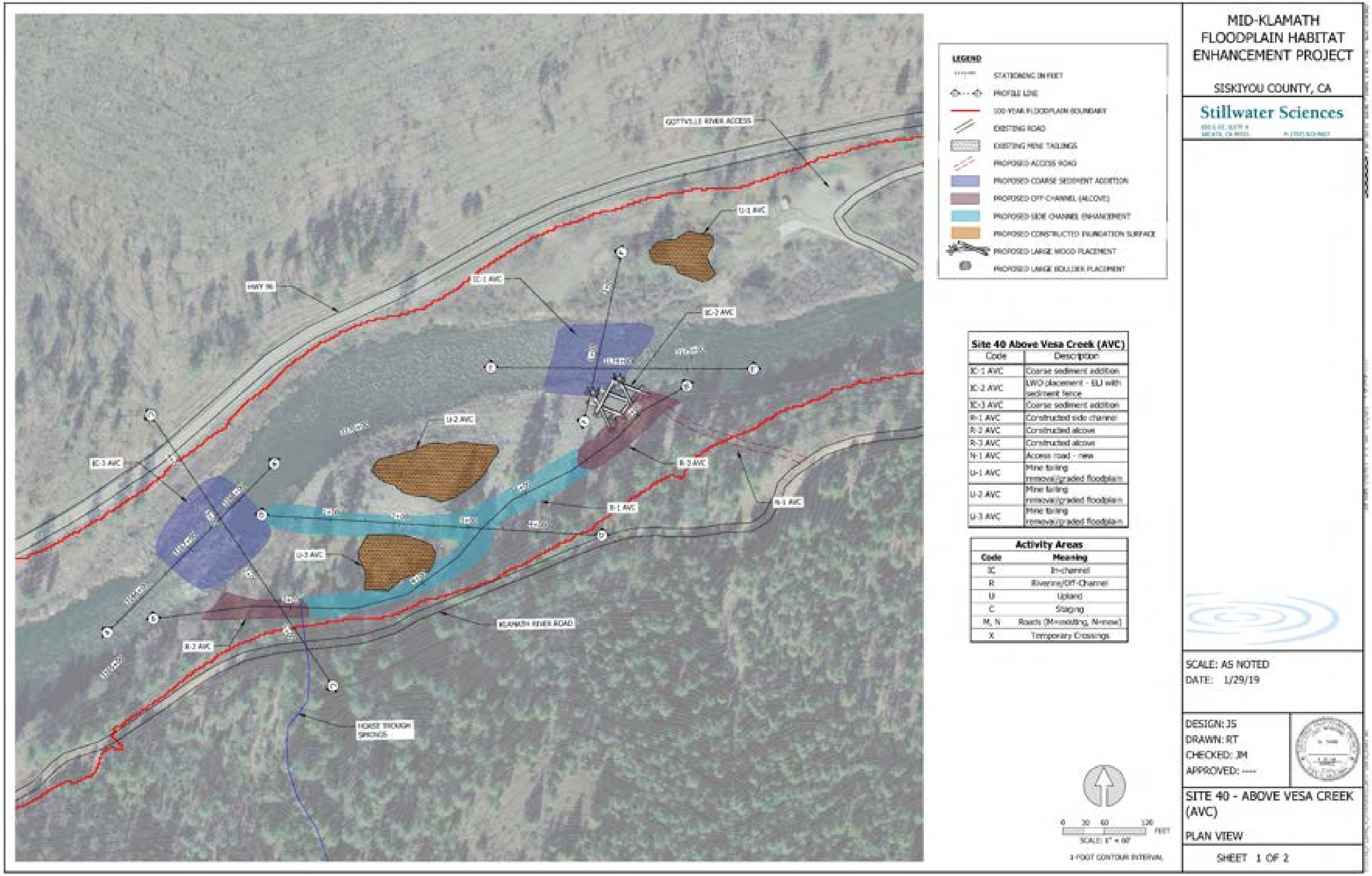

Figure 5-24. Design plan for Site 40 (Above Vesa Creek).

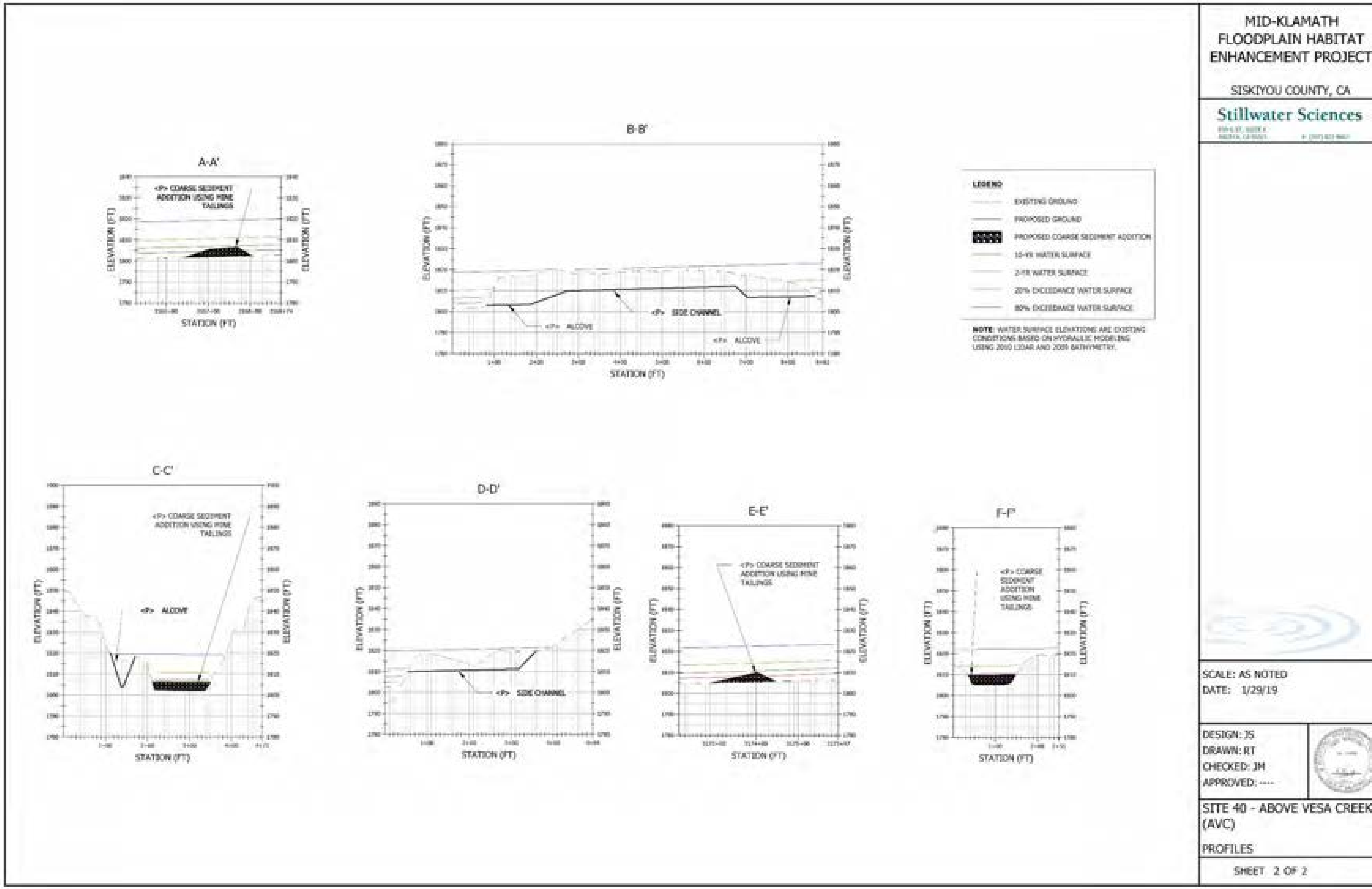

Figure 5-25. Design profiles for Site 40 (Above Vesa Creek).

Table 5-27. Above Vesa Creek activity areas.

Code	Description
IC-1 AVC	Coarse sediment addition
IC-2 AVC	LWD placement - ELJ with sediment fence
IC-3 AVC	Coarse sediment addition
R-1 AVC	Constructed side channel
R-2 AVC	Constructed alcove
R-3 AVC	Constructed alcove
N-1 AVC	Access road - new
U-1 AVC	Mine tailing removal/graded floodplain
U-2 AVC	Mine tailing removal/graded floodplain
U-3 AVC	Mine tailing removal/graded floodplain

5.6.12.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 40 is shown in Table 5-28. This site has the potential to be a relatively cost-effective project that tests many of the restoration approaches at one relatively small and contained site. One uncertainty associated with the cost estimate is finding a suitable nearby location for placing excavated spoils.

Table 5-28. Planning-level construction cost estimate for Site 40 (Upper Vesa Creek).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$11,000	1	LS	$11,000
2	Temporary access, clearing and grubbing	$10,000	1	LS	$10,000
3	Dewatering and/or turbidity management	$20,000	1	LS	$20,000
4	Grading (cut) balanced on site	$15	7,000	CY	$105,000
5	Grading (fill) balanced on site	$25	2,000	CY	$50,000
6	Large wood structures—placed and anchored	$1,500	14	each	$21,000
7	Boulders—placed and anchored	$150	15	Tons	$2,250
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	0	SF	$0
10	Seeding/mulch/planting	$10,000	1	LS	$10,000
11	Other	$0	1	LS	$0
Total					**$229,250**

5.6.13 Site 45A – Lower Humbug Creek (HCA)

5.6.13.1 Site Description

Site 45A (Lower Humbug Creek) is located between RM 169.9 and RM 170.7 (Sta 3390+00 and 3448+00). Average gradient through the site is 0.0031and average valley width is 550 ft. This site encompasses alternating meanders with bar and floodplain surfaces (Appendix B, Figure B-20). The Klamath River corridor in this reach between Humbug Creek and Vesa Creek was extensively mined between 1850 and 1930, and nearly every alluvial bar and floodplain area along the mainstem channel and lower reaches of the larger tributaries was excavated. Riparian encroachment and extensive mine tailing deposits limit dynamic channel forming processes and floodplain inundation. An historical mining pit on the right bank floodplain near Sta 3400+00 appears to hold water year-round but is not connected to the mainstem river except during large floods. Existing water level fluctuations and water quality conditions within the pond are unknown. Lime Gulch enters from the right bank near the upstream end of the site, and Cayuse Creek enters from the right bank just downstream of the site.

5.6.13.2 Proposed habitat enhancement activities

Proposed enhancement activities at this site include coarse sediment additions, removing mine tailings, lowering floodplain surfaces, large wood installations, and constructing alcoves and an off-channel pond (Figure 5-26, Figure 5-27, Table 5-29). A primary objective of the enhancement activities at Site 45A is to create complex off-channel winter rearing habitats by reestablishing floodplain elevations and width within the area current occupied by extensive mine tailing from Sta 3405+00 to 3420+00 (R-3 HCA). The mine tailings provide an onsite source of material for coarse sediment addition. Coarse sediment additions are designed to modify riffle crest hydraulic controls by locally raising the water surface elevation and increasing inundation frequency and duration within the restored right bank floodplain and side channel features. Fluvial processes resulting from coarse sediment additions are also expected to promote more dynamic sinuous channel morphology and increase complex aquatic and riparian habitat. Alcoves are designed to provide off-channel rearing habitats by expanding and enhancing the downstream extent of existing overflow/groundwater channels. The pond is designed to provide off-channel rearing habitats by expanding and enhancing the existing mining pit and by connecting this historical feature to the mainstem river channel during winter and summer base flows.

Klamath River Road and Highway 96 provide access to the site on both sides of the river. There is a large staging area at the downstream end of the site.

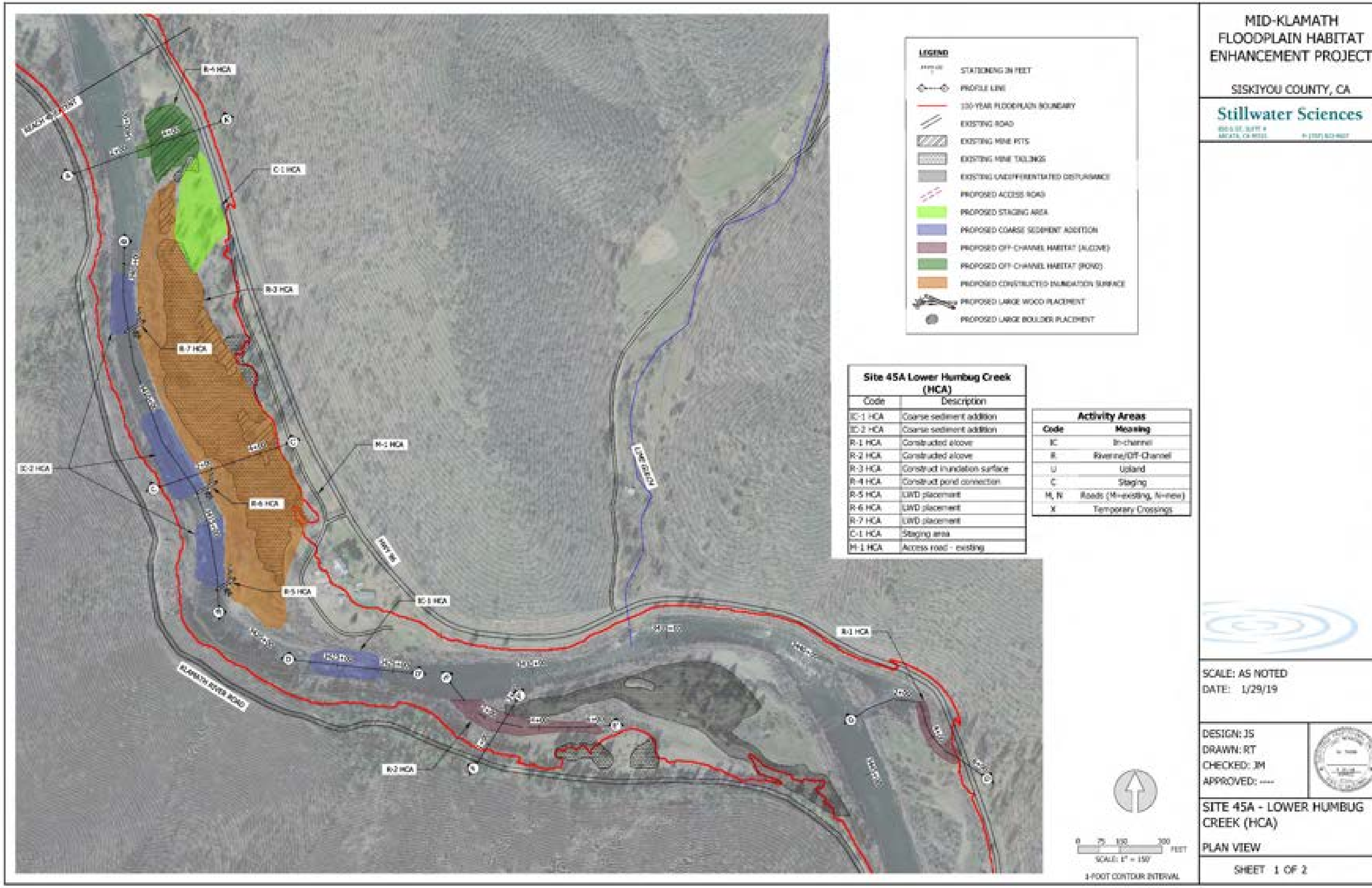

Figure 5-26. Design plan for Site 45A (Lower Humbug Creek).

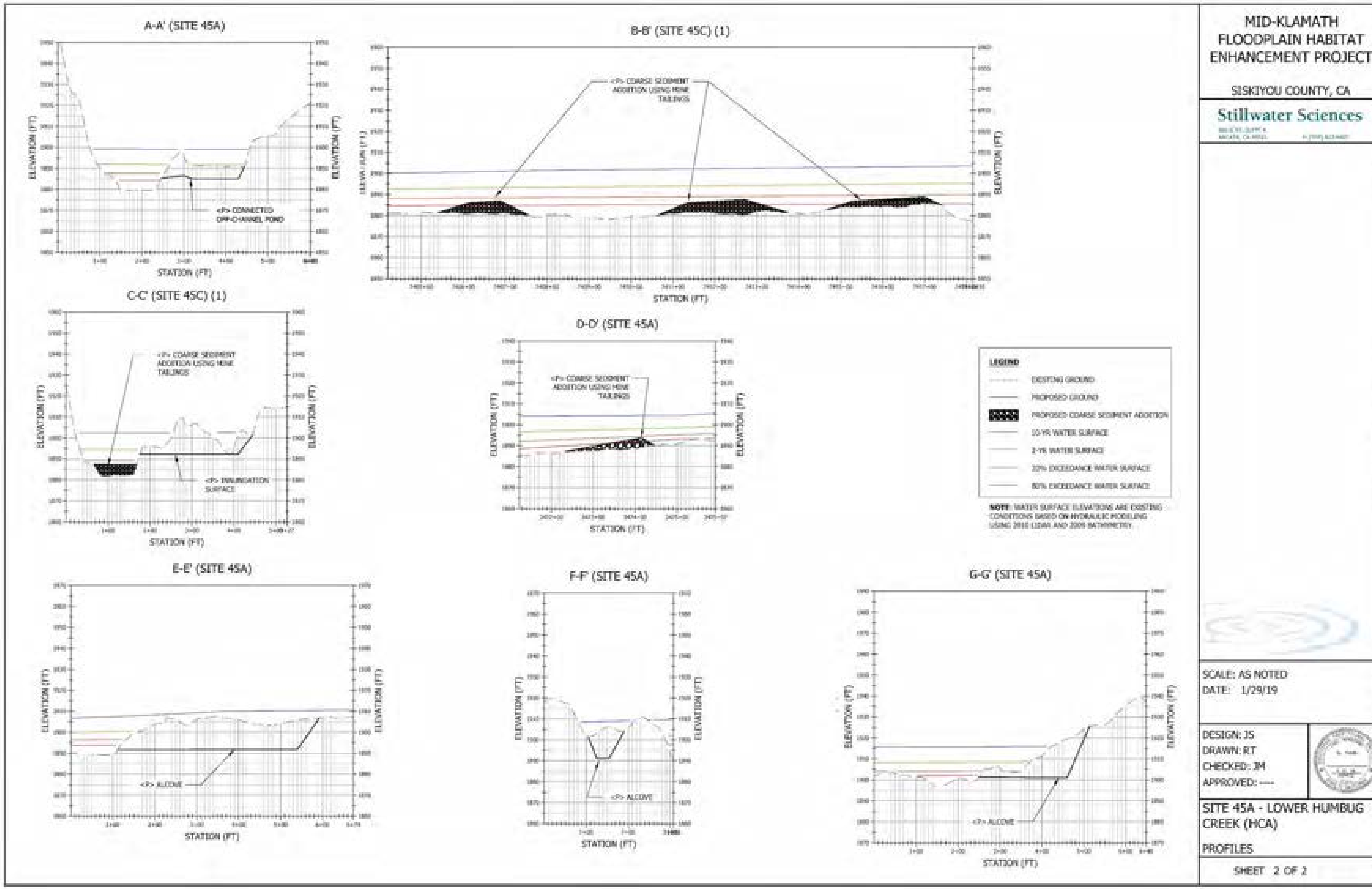

Figure 5-27. Design profiles for Site 45A (Lower Humbug Creek).

Table 5-29. Lower Humbug Creek activity areas.

Code	Description
IC-1 HCA	Coarse sediment addition
IC-2 HCA	Coarse sediment addition
R-1 HCA	Constructed alcove
R-2 HCA	Constructed alcove
R-3 HCA	Construct inundation surface
R-4 HCA	Construct pond connection
R-5 HCA	LWD placement
R-6 HCA	LWD placement
R-7 HCA	LWD placement
C-1 HCA	Staging area
M-1 HCA	Access road – existing

5.6.13.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 45A is shown in Table 5-30. Based on the current design and planning-level cost analyses, the large quantities of proposed earthwork (cut) amount to a large expense. The planning level construction cost estimate assumed that cut material will be placed directly into the river as coarse sediment addition, so there is no "grading fill" line item in the budget table. Like previously described sites with large construction costs, it will be important to refine the project through a cost-benefit analyses during future design phases.

Table 5-30. Planning-level construction cost estimate for Site 45A (Lower Humbug Creek).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$30,000	1	LS	$30,000
2	Temporary access, clearing and grubbing	$5,000	1	LS	$5,000
3	Dewatering and/or turbidity management	$20,000	1	LS	$20,000
4	Grading (cut) balanced on site	$15	89,000	CY	$1,335,000
5	Grading (fill) balanced on site	$25	0	CY	$0
6	Large wood structures—placed and anchored	$1,500	6	each	$9,000
7	Boulders—placed and anchored	$150	0	Tons	$0
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	0	SF	$0
10	Seeding/mulch/planting	$25,000	1	LS	$25,000
11	Other	$0	1	LS	$0
Total					**$1,424,000**

5.6.14 Site 45B – Middle Humbug Creek (HCB)

5.6.14.1 Site description

Site 45B is located between RM 170.8 and RM 171.3 (Sta 3448+00 and 3473+00). Average gradient through the site is 0.0031and average valley width is 550 ft. This site has large bar and floodplain surfaces (Appendix B, Figure B-20). Site 45B includes the downstream extent of McConnell Bar. The Klamath River corridor in this reach between Humbug Creek and Vesa Creek was extensively mined between 1850 and 1930, and nearly every alluvial bar and floodplain area along the mainstem channel and lower reaches of the larger tributaries was excavated. The site was the locus of multiple hydraulic and dredger mining operations during the late 1800s and early 1900s.

Riparian encroachment and extensive mine tailing deposits limit dynamic channel forming processes and floodplain inundation. Two historical mining pits occur on the right bank floodplain between Sta 3460+00 and 3465+00. The ponds appear to hold water year-round but are not connected to the mainstem river except during large floods. Existing water level fluctuations and water quality conditions within the ponds are unknown. Skunk Gulch enters from the left bank at the top of the site, although the channel is not well-developed across McConnell Bar. Brushy Gulch enters from the right bank just upstream of the reach. These small tributaries are ephemeral and do not appear to offer summer thermal refuge near the confluences with the Klamath River. Residential structures and land uses occur at the outer/higher extents of McConnel Bar

5.6.14.2 Proposed habitat enhancement activities

Proposed enhancement activities at this site include coarse sediment additions, removing mine tailings, and side-channel and off-channel pond enhancement (Figure 5-28, Figure 5-29, Table 5-31). Coarse sediment additions are designed to modify riffle crest hydraulic controls by locally raising the water surface elevation and increasing floodplain and side channel inundation across a wider range of flow conditions. Fluvial processes resulting from coarse sediment additions are expected to promote more dynamic sinuous morphology and increase complex aquatic and riparian habitat. Ponds are designed to provide off-channel rearing habitats by expanding and enhancing existing mining pits and by connecting these features to the mainstem river channel during winter and summer base flows.

The mine tailings provide an onsite source of coarse sediment for gravel augmentation. Klamath River Road provides access to the site and there is a large staging area near the downstream end of the site.

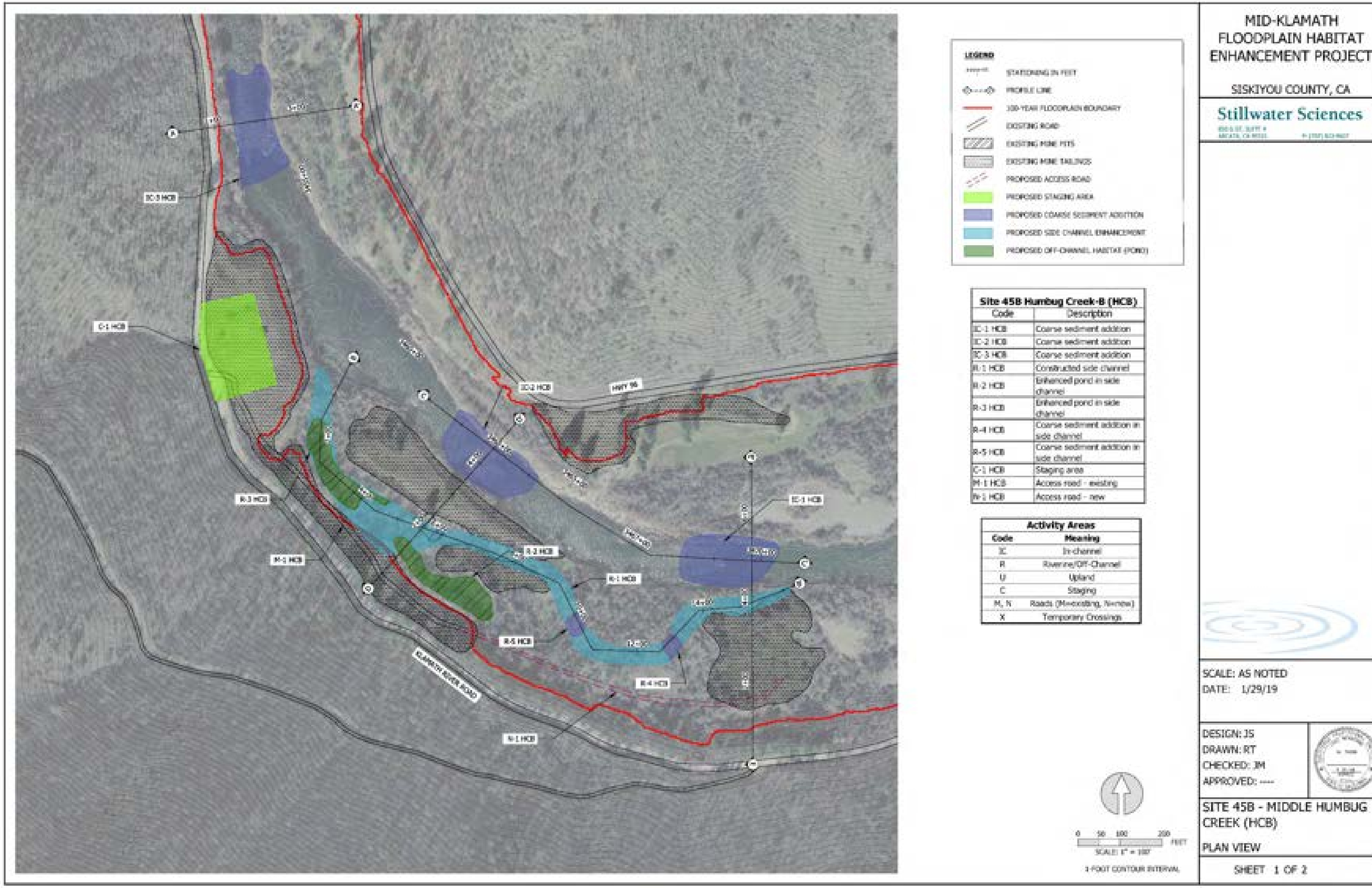

Figure 5-28. Design plan for Site 45B (Middle Humbug Creek).

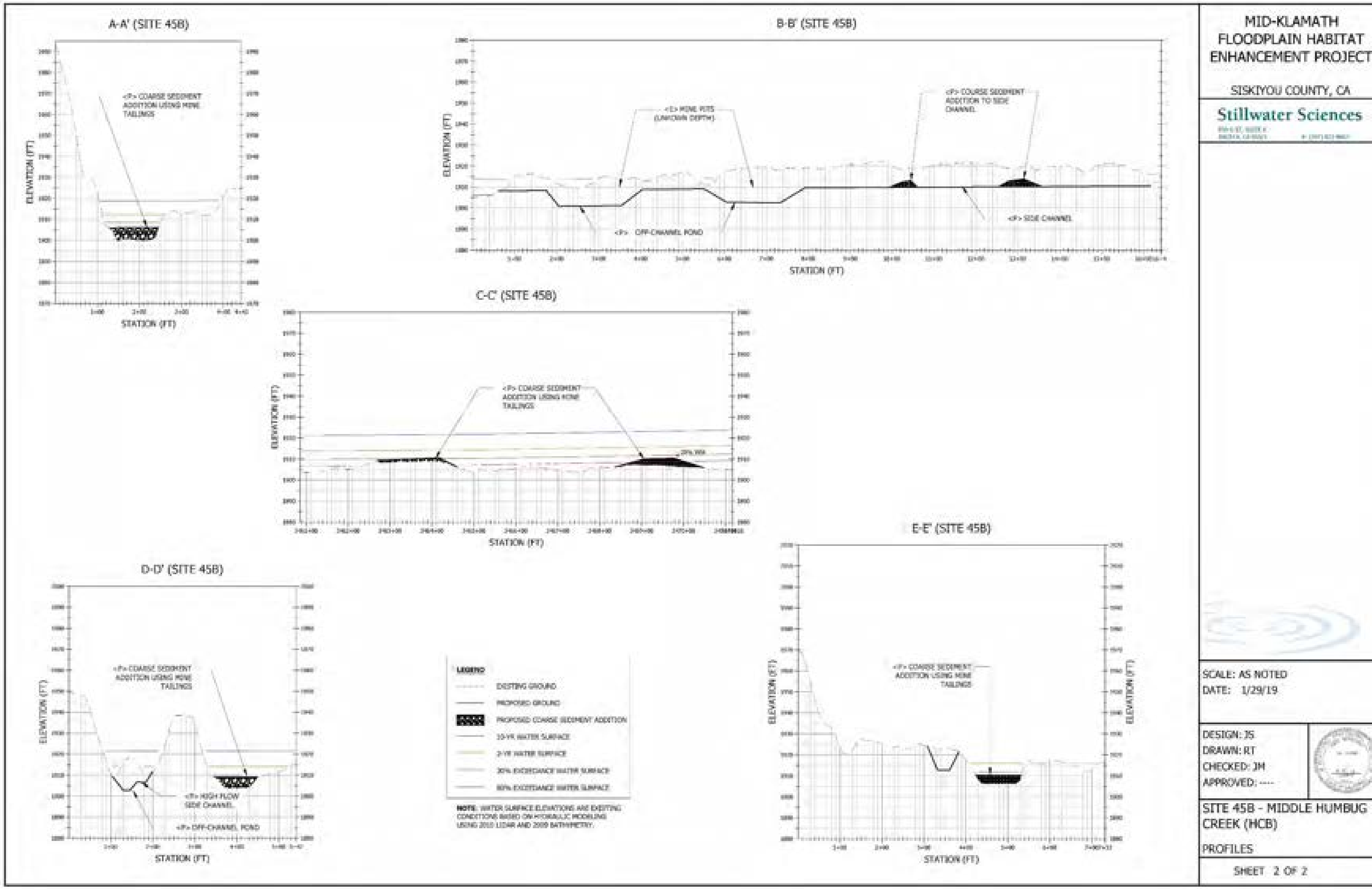

Figure 5-29. Design profiles for Site 45B (Middle Humbug Creek).

Table 5-31. Middle Humbug Creek activity areas.

Code	Description
IC-1 HCB	Coarse sediment addition
IC-2 HCB	Coarse sediment addition
IC-3 HCB	Coarse sediment addition
R-1 HCB	Constructed side channel
R-2 HCB	Enhanced pond in side channel
R-3 HCB	Enhanced pond in side channel
R-4 HCB	Coarse sediment addition in side channel
R-5 HCB	Coarse sediment addition in side channel
C-1 HCB	Staging area
M-1 HCB	Access road – existing
N-1 HCB	Access road – new

5.6.14.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 45B is shown in Table 5-32. Based on the current design and planning-level cost analyses, this project has the potential to be relatively cost effective based on the significant off-channel habitat enhancement proposed and moderate construction cost. Project features should be refined, and their costs and benefits reevaluated during future design phases.

Table 5-32. Planning-level construction cost estimate for Site 45B (Middle Humbug Creek).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$19,000	1	LS	$19,000
2	Temporary access, clearing and grubbing	$10,000	1	LS	$10,000
3	Dewatering and/or turbidity management	$20,000	1	LS	$20,000
4	Grading (cut) balanced on site	$15	14,000	CY	$210,000
5	Grading (fill) balanced on site	$25	5,000	CY	$125,000
6	Large wood structures—placed and anchored	$1,500	0	each	$0
7	Boulders—placed and anchored	$150	0	Tons	$0
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	0	SF	$0
10	Seeding/mulch/planting	$20,000	1	LS	$20,000
11	Other	$0	1	LS	$0
Total					**$404,000**

5.6.15 Site 45C – Upper Humbug Creek (HCC)

5.6.15.1 Site description

Site 45 C is located between RM 171.3 and RM 172.3 (Sta 3473+00 and 3537+00). Average gradient through the site is 0.0031and average valley width is 550 ft. Humbug Creek enters from the left bank at the upstream end of the site, and Skunk Creek enters the right back at the downstream end of the site. The site encompasses McConnel Bar, a large bar and floodplain complex located along the left bank throughout the site (Appendix B, Figure B-21). McConnell Bar was the locus of multiple hydraulic and dredger mining operations during the late 1800s and early 1900s (including Northern California Mining Company, McConnel Bar Placer Mine, Austin and Cambell Placer Mine, Gold Nugget Placer Mine, and Klamath River Gold (dredge), among others). In 1912, five placer claims operated within the site (Eddy 1912). During this time, a clam-shell bucket dredge was used to excavate two alluvial channels over 4,000 ft long extending up the left bank floodplain from below Brushy Gulch to the Humbug Creek confluence. Eddy (1912) describes the excavation:

> *"These channels have an average depth of 45 ft. and maximum of 70 ft. The length of the cut described by excavation is about 1,800 ft., average width is about 150 ft. It is the purpose to turn the stream into the excavated channel; and to prospect the bed of the present live stream …"*

Bedrock underlying McConnell Bar was also excavated during this period. The pervasive mining disturbance obliterated all floodplain and off-channel features for over 4,000 ft of mainstem channel length. Wild fire burned through the left bank floodplain at the site in 2016, destroying most riparian vegetation within the site. The site presently has little aquatic or riparian habitat value.

Extensive areas of the left bank floodplain are low-lying, have evidence of anastomosing secondary flow paths that are active during high flow events in the mainstem Klamath River, and has excellent potential for aquatic and riparian habitat restoration. However, hydraulic modeling indicates these areas currently experience only infrequent inundation by Klamath River flows. Infrequent inundation is due in large part to flow regulation by upstream dams, and by the presence of a boulder level located along the left bank of the mainstem Klamath River channel. The secondary flow paths across the left bank floodplain may also be activated by and connected to Humbug Creek during high flow events in that tributary.

5.6.15.2 Proposed habitat enhancement activities

Many enhancement activities are proposed at this site to provide short-term habitat benefits, as well as to initiate a dynamic processed-based flow and sediment transport regime that will create a stage zero channel network across a more complex floodplain surface. Site 45C is another ideal location to test the design concept of restoring the soil ecosystem by strategically designing low-lying floodplains to function as depositional zones when removal of the Klamath River dams releases reservoir sediments to downstream reaches. Specific enhancement activities include coarse sediment additions, removing mine tailings, constructing and enhancing side-channels and off-channel ponds, riparian plantings, large wood and boulder installations, boulder levee removal, and fish passage improvements (Figure 5-30, Figure 5-31, Table 5-33). Coarse sediment additions are designed to modify riffle crest hydraulic controls by locally raising the water surface elevation and increasing floodplain and side channel inundation across a wider range of flow conditions. Fluvial processes resulting from coarse sediment additions and large wood structures are expected to promote more dynamic sinuous morphology and increase complex aquatic and riparian habitat. Ponds are designed to provide off-channel rearing habitats.

The mine tailings provide an onsite source of coarse sediment for gravel augmentation. Klamath River Road provides multiple access points to the site and there are multiple staging areas onsite as well.

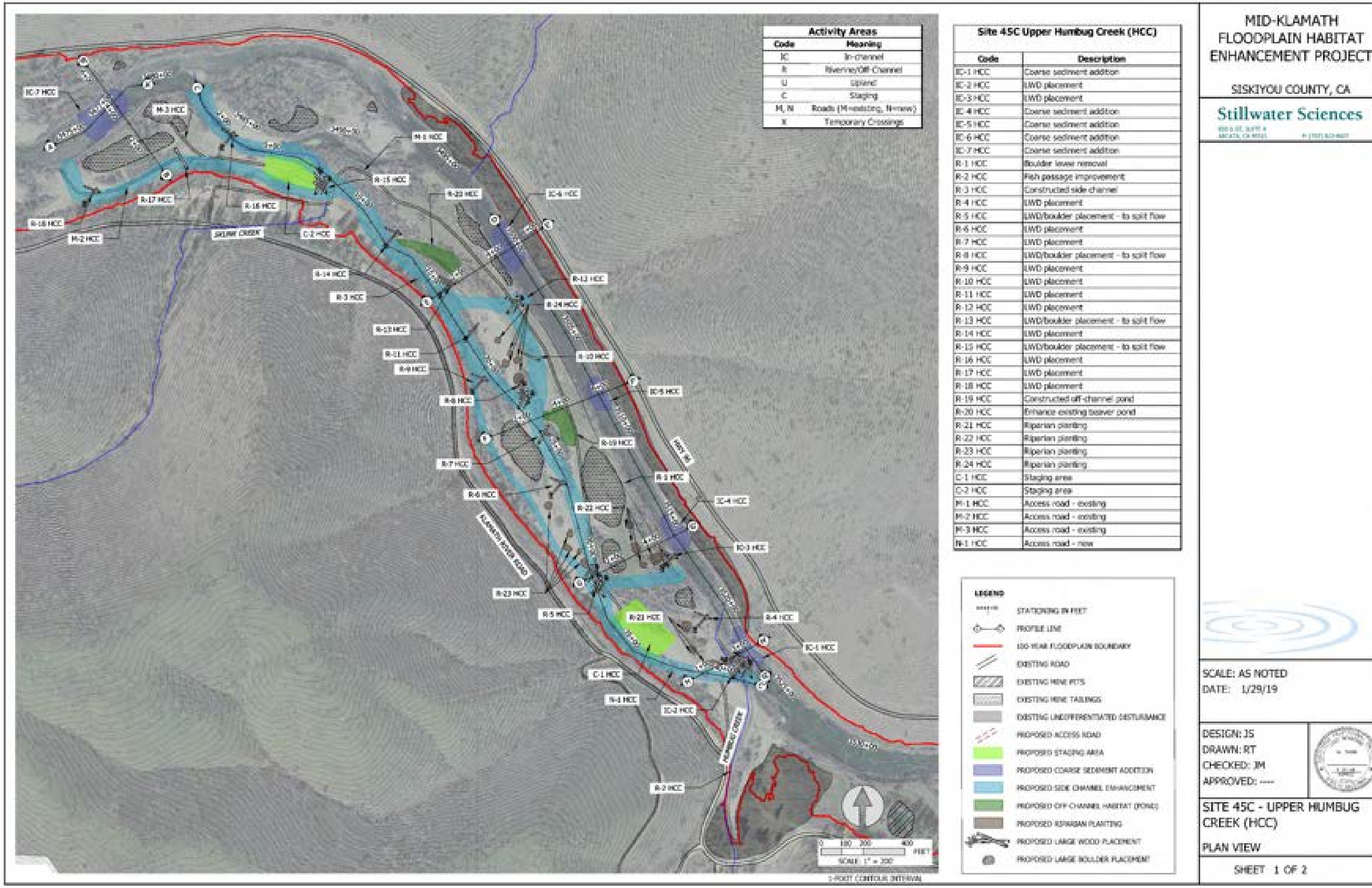

Figure 5-30. Design plan for Site 45C (Upper Humbug Creek).

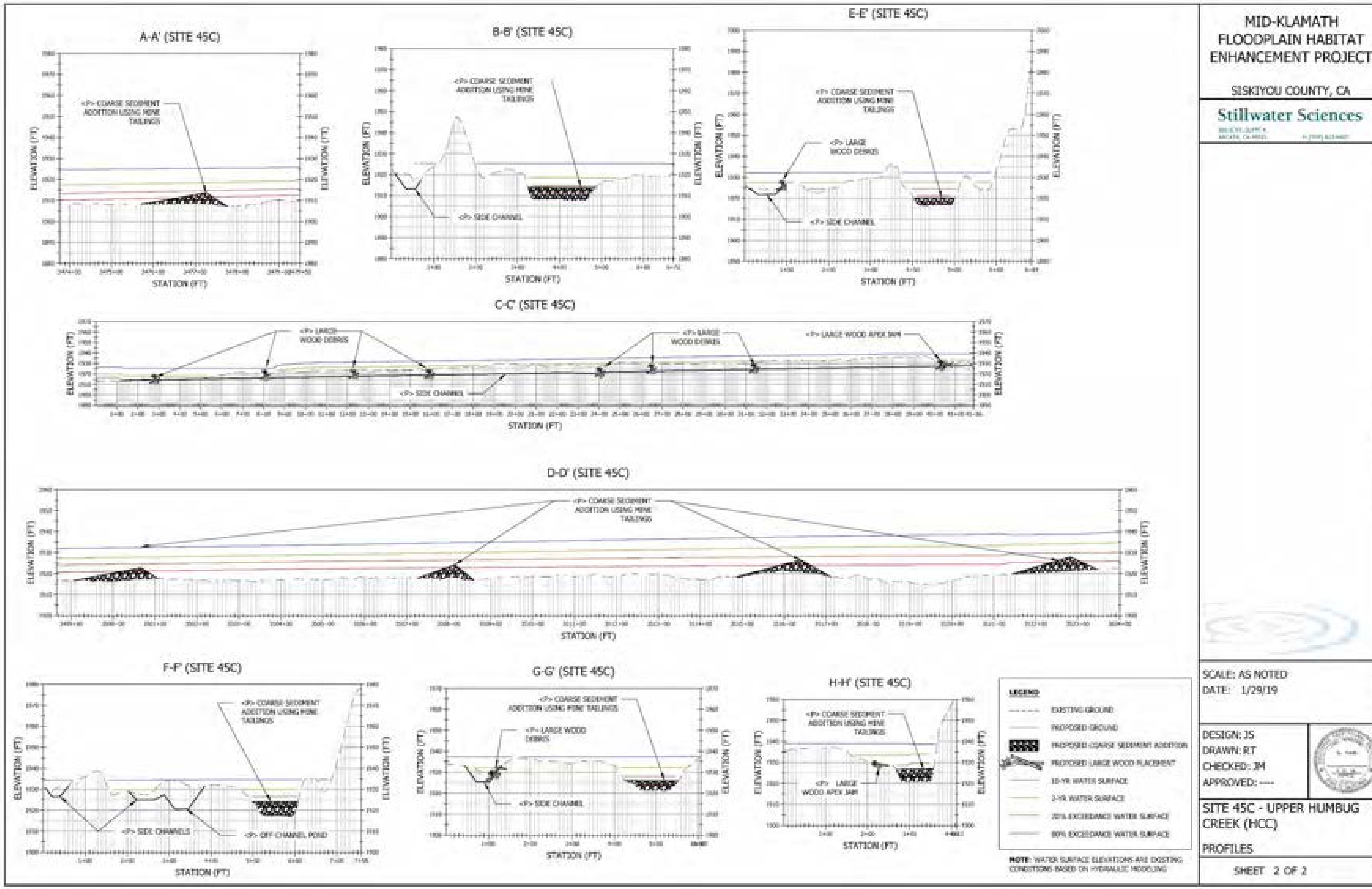

Figure 5-31. Design profiles for Site 45C (Upper Humbug Creek).

Table 5-33. Upper Humbug Creek activity areas.

Code	Description
IC-1 HCC	Coarse sediment addition
IC-2 HCC	LWD placement
IC-3 HCC	LWD placement
IC-4 HCC	Coarse sediment addition
IC-5 HCC	Coarse sediment addition
IC-6 HCC	Coarse sediment addition
IC-7 HCC	Coarse sediment addition
R-1 HCC	Boulder levee removal
R-2 HCC	Fish passage improvement
R-3 HCC	Constructed Side Channel
R-4 HCC	LWD placement
R-5 HCC	LWD/boulder placement to split flow
R-6 HCC	LWD placement
R-7 HCC	LWD placement
R-8 HCC	LWD/boulder placement to split flow
R-9 HCC	LWD placement
R-10 HCC	LWD placement
R-11 HCC	LWD placement
R-12 HCC	LWD placement
R-13 HCC	LWD/boulder placement to split flow
R-14 HCC	LWD placement
R-15 HCC	LWD/boulder placement to split flow
R-16 HCC	LWD placement
R-17 HCC	LWD placement
R-18 HCC	LWD placement
R-19 HCC	Constructed off-channel pond
R-20 HCC	Enhance existing beaver pond
R-21 HCC	Riparian planting
R-22 HCC	Riparian planting
R-23 HCC	Riparian planting
R-24 HCC	Riparian planting
C-1 HCC	Staging area
C-2 HCC	Staging area
M-1 HCC	Access road – existing
M-2 HCC	Access road – existing
M-3 HCC	Access road – existing
N-1 HCC	Access road – new

5.6.15.3 Planning-level construction cost estimate

The planning-level construction cost estimate for Site 45C is shown in Table 5-34. Based on the current design and planning-level cost analyses, the large quantity of earthwork (cut) that is proposed for enhancement of the floodplain and side channels amounts to a large expense. However, the high potential for significant habitat improvements over a large area may warrant higher construction costs. Project features should be refined through a cost-benefit analyses during future design phases.

Table 5-34. Planning-level construction cost estimate for Site 45C (Upper Humbug Creek).

No.	Item	Unit cost	Quantity	Units	Total cost
1	Mobilization	$30,000	1	LS	$30,000
2	Temporary access, clearing and grubbing	$5,000	1	LS	$5,000
3	Dewatering and/or turbidity management	$10,000	1	LS	$10,000
4	Grading (cut) balanced on site	$15	56,000	CY	$840,000
5	Grading (fill) balanced on site	$25	8,000	CY	$200,000
6	Large wood structures—placed and anchored	$1,500	65	each	$97,500
7	Boulders—placed and anchored	$150	50	Tons	$7,500
8	Beaver dam analogues	$5,000	0	LS	$0
9	Riparian planting	$1	19,800	SF	$19,800
10	Seeding/mulch/planting	$40,000	1	LS	$40,000
11	Other (fish passage improvement)	$20,000	1	LS	$20,000
Total					**$1,249,800**

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Appendices

Appendix A

Reach Characteristics, Enhancement Suitability, and Composite Rank

Table A-1. Summary of Project reach characteristics, enhancement suitability based on expert opinion, and composite rank based on physical criteria.

Reach no.	Reach name[1]	Length (mi)	Suitability rating (expert opinion)[2]	Composite rank (physical criteria)[3]	Thermal refuge				Historical placer mining disturbance, ac			
					Tributaries with 2003 TIR data reported	2003 TIR temp Δ[4], °C: July	2003 TIR temp Δ[4], °C: August	Tributaries without 2003 TIR data reported	Tailings	Excavation	Undiff	Total
1	Indian Creek	1.30	2	2	Elk, Little Grider, Indian	-2.2, -5.0, -3.7	-1.4, -3.5, -3.2	Curley Jack				
2	Happy Camp	1.41	3	20					0.5		7.3	7.8
3	Cade Creek	4.45	2	7				Woods, Cade			1.4	1.4
4	Below Fryingpan Creek	0.67	4	14								
5	Fryingpan Creek	0.79	3	10				Fryingpan				
6	Little Horse Creek	1.78	1	3				Horse	0.1		1.5	1.6
7	Below China Creek	0.91	4	30								
8	China Creek	1.32	2	11	China	-3.5	-3					
9	Joe Miles Creek	4.30	4	42				Joe Miles, Shinar, Oak Hollow, Seattle				
10	Thompson Creek	0.72	1	19	Thompson	-4	-3.3					
11	Tims Creek	1.44	4	34				Tims				
12	Ladds Creek	1.53	2	17				Ladds				
13	Below Fort Goff	0.34	4	30								
14	Fort Goff	1.91	2	24				Fort Goff, Bittenbender, Portuguese				
15	Below Seiad Valley	1.44	4	34								
16	Seiad Valley	1.27	1	4	Seiad, Grider	-1.3, -2.5	-0.80, -1.1	West Grider	45.2	6.7	4.8	56.8
17	Walker Creek	2.19	1	5	Walker	-2.5	-2.2	Gard, Caroline	23.9	1.4	0.1	25.4
18	Walker Gulch	1.86	3	22								
19	Below O'Neil Creek	0.83	4	29								
20	O'Neil Creek	2.60	2	25				Louie, Negro, O'Neil				
21	Kuntz Gulch	1.25	4	36				Kuntz				
22	Below Scott River	3.41	2	32	Tom Martin, Scott	-3.4, 0.30	-4.0, -0.20	Jim, Macks, Mill, Mitchell				
23	Above Scott River	0.30	4	43								
24	below Kinsman Creek	0.16	2	41								
25	Kinsman Creek	1.95	4	43				Kinsman			3.9	3.9
26	Horse Creek (upper)	2.71	1	18	Horse	-3.5	-4.1	Everill	0.2	0.1		0.3
27	Cherry Flat	1.29	1	1	Collins	-3	-1.8		41.1	15.4	13.4	69.9
28	Lime Gulch	1.27	2	21								
29	Above Lime Gulch	0.85	4	45								
30	Kohl Creek	0.96	2	9				Kohl			2.6	2.6
31	Dona Creek	1.01	4	40				Dona				
32	Little Humbug Creek	4.80	1	6	McKinney, Doggett	-3.4, -4.4	-2.8, -3.9	Little Humbug	5.2	0.1	4.1	9.4

Reach no.	Reach name[1]	Length (mi)	Suitability rating (expert opinion)[2]	Composite rank (physical criteria)[3]	Thermal refuge				Historical placer mining disturbance, ac			
					Tributaries with 2003 TIR data reported	2003 TIR temp Δ[4], °C		Tributaries without 2003 TIR data reported	Tailings	Excavation	Undiff	Total
						July	August					
33	Smith Gulch	0.73	2	15								
34	Quigleys Cove	1.16	3	26							1.5	1.5
35	Beaver Creek	0.77	1	12	Beaver	-2	-2.4				0.1	0.1
36	Miller Gulch	0.65	3	27							0.3	0.3
37	Cougar Gulch	0.60	2	27								
38	Above Cougar Gulch	1.16	4	49								
39	Vesa Creek	0.91	2	45				Vesa	1.9			1.9
40	Above Vesa Creek	0.84	3	47					0.5			0.5
41	China Gulch	0.33	2	39					1.4	0.3	0.4	2.1
42	Gottsville	1.53	2	38				Empire, Lumgrey, Dutch	2.0	0.1	2.3	4.4
43	Below Swiss Bar	0.59	2	13					0.4		1.2	1.6
44	Swiss Bar	1.27	2	33					0.3			0.3
45	Humbug Creek	2.75	1	8				Humbug, Skunk	17.3	2.6	13.2	33.1
46	Garvey Gulch	1.00	3	16					0.3	0.5		0.8
47	Woodrat Bar	0.53	2	23					0.2	0.8		0.9
48	Ash Creek	1.97	3	37				Badger, Ash	1.7		0.1	1.8
49	Below Shasta River	1.48	4	48				Shasta River	0.4			0.4

[1] Reach names are based on nearby place names (e.g., tributaries, river bars, and towns).
[2] Suitability rating (1=high to 4=low) of Project reaches for restoration and enhancement of floodplain and off-channel habitats based on the professional opinion of Design Team members.
[3] Ranking of Project reaches for restoration and enhancement of floodplain and off-channel habitats based on physical criteria (e.g., reach gradient, valley width, and extent of low-lying floodplain area).
[4] Difference in TIR temperatures between the mainstem Klamath River and the tributary at its confluence with the Klamath River.

Table A-2. Ranking of Project reaches for restoration and enhancement of floodplain and off-channel habitats based on physical criteria.

Reach no.	Reach name	Composite[1] rank		Gradient rank[2]			Valley width rank[3]			Floodplain area rank[4]						Gradient – floodplain function rank[5]		
										≤ 1 ft abv RCT		1 ≥ 5 ft abv RCT		5 ≥ 10 ft abv RCT				
		Score	Rank	Gradient	Departure	Rank	Width, ft	Departure	Rank	Area, ft^2/ft	Rank	Area, ft^2/ft	Rank	Area, ft^2/ft	Rank	Predicted	Departure, ft^2/ft	Rank
1	Indian Creek	41	2	0.22%	-0.04%	21	964	415	4	287	1	93	6	134	7	313	109	3
2	Happy Camp	108	20	0.15%	-0.11%	6	1497	947	2	215	8	45	41	34	42	305	-56	17
3	Cade Creek	57	7	0.16%	-0.10%	7	919	370	5	198	12	72	18	81	16	306	-27	11
4	below Fryingpan Creek	84	14	0.17%	-0.09%	9	568	19	17	258	3	59	28	65	24	307	16	6
5	Fryingpan Creek	75	10	0.20%	-0.06%	12	669	120	11	254	4	57	30	75	17	310	19	5
6	Little Horse Creek	44	3	0.18%	-0.08%	10	832	283	6	232	5	79	13	111	11	308	35	4
7	below China Creek	143	30	0.15%	-0.11%	5	371	-178	36	197	13	40	43	37	39	304	-71	20
8	China Creek	76	11	0.23%	-0.03%	24	603	54	13	124	44	102	3	106	12	314	-84	24
9	Joe Miles Creek	186	42	0.24%	-0.02%	25	388	-161	35	134	40	47	36	25	47	315	-156	43
10	Thompson Creek	107	19	0.16%	-0.10%	8	706	157	10	161	22	52	33	54	29	306	-91	27
11	Tims Creek	164	34	0.33%	0.07%	37	435	-114	29	183	15	49	35	44	34	326	-100	29
12	Ladds Creek	100	17	0.41%	0.15%	48	711	161	9	223	7	86	9	70	19	337	-45	15
13	below Fort Goff	143	30	0.12%	-0.14%	2	441	-109	28	231	6	24	49	25	48	301	-46	16
14	Fort Goff	121	24	0.26%	0.00%	31	529	-20	20	201	11	65	25	59	27	318	-58	18
15	below Seiad Valley	164	34	0.23%	-0.03%	22	403	-146	32	203	9	35	45	34	43	314	-77	22
16	Seiad Valley	47	4	0.35%	0.09%	42	1698	1148	1	272	2	199	2	357	1	330	300	1
17	Walker Creek	50	5	0.21%	-0.05%	14	755	206	7	162	21	90	7	117	10	312	-33	12
18	Walker Gulch	118	22	0.26%	0.00%	30	600	50	14	162	20	55	31	71	18	317	-85	25
19	below O'Neil Creek	142	29	0.24%	-0.02%	26	397	-153	34	157	27	85	10	40	37	315	-118	35
20	O'Neil Creek	122	25	0.32%	0.06%	36	598	49	15	147	32	72	19	68	20	325	-110	32
21	Kuntz Gulch	165	36	0.21%	-0.05%	16	401	-148	33	190	14	35	46	33	44	312	-89	26
22	below Scott River	147	32	0.34%	0.08%	40	467	-82	27	164	16	78	14	47	32	328	-117	34
23	above Scott River	191	43	0.12%	-0.14%	1	269	-280	47	111	48	32	47	24	49	300	-165	47
24	below Kinsman Creek	185	41	0.23%	-0.03%	23	275	-275	45	116	46	47	37	41	36	314	-157	44
25	Kinsman Creek	191	43	0.21%	-0.05%	17	303	-247	43	133	41	39	44	30	45	312	-149	42
26	Horse Creek (upper)	105	18	0.22%	-0.04%	20	496	-53	23	143	36	60	27	97	14	312	-73	21
27	Cherry Flat	35	1	0.24%	-0.02%	27	1132	583	3	202	10	258	1	311	2	316	197	2
28	Lime Gulch	110	21	0.20%	-0.06%	13	432	-117	30	145	33	74	16	65	23	310	-99	28
29	above Lime Gulch	192	45	0.21%	-0.05%	18	263	-286	48	138	38	29	48	36	40	312	-137	38
30	Kohl Creek	72	9	0.21%	-0.05%	15	560	10	18	137	39	66	23	148	6	312	-27	10
31	Dona Creek	183	40	0.19%	-0.07%	11	251	-298	49	114	47	58	29	26	46	309	-170	48
32	Little Humbug Creek	54	6	0.21%	-0.05%	19	747	198	8	153	28	76	15	150	4	312	-10	8
33	Smith Gulch	86	15	0.25%	-0.01%	28	479	-70	25	151	30	80	12	132	8	317	-34	13
34	Quigleys Cove	132	26	0.27%	0.01%	32	502	-48	22	145	34	70	20	62	25	319	-112	33
35	Beaver Creek	77	12	0.33%	0.07%	38	632	83	12	163	18	97	4	129	9	326	-34	14
36	Miller Gulch	136	27	0.14%	-0.12%	4	325	-225	40	71	49	89	8	43	35	303	-189	49
37	Cougar Gulch	136	27	0.34%	0.08%	39	468	-81	26	130	42	65	26	93	15	328	-104	30
38	above Cougar Gulch	211	49	0.36%	0.10%	43	275	-275	46	150	31	46	40	35	41	331	-145	41
39	Vesa Creek	192	45	0.52%	0.26%	49	360	-189	39	126	43	55	32	61	26	350	-162	46
40	above Vesa Creek	195	47	0.37%	0.11%	45	324	-226	41	152	29	45	42	53	30	332	-127	37
41	China Gulch	178	39	0.38%	0.12%	46	318	-231	42	119	45	73	17	55	28	333	-158	45
42	Gottsville	173	38	0.37%	0.11%	44	364	-186	38	159	24	47	38	66	22	332	-107	31
43	below Swiss Bar	82	13	0.34%	0.08%	41	577	27	16	164	17	81	11	148	5	329	-17	9
44	Swiss Bar	148	33	0.25%	-0.01%	29	408	-141	31	144	35	69	21	52	31	317	-120	36
45	Humbug Creek	69	8	0.31%	0.05%	35	550	1	19	163	19	97	5	162	3	325	0	7

Reach no.	Reach name	Composite[1] rank		Gradient rank[2]			Valley width rank[3]			Floodplain area rank[4]						Gradient – floodplain function rank[5]		
										≤ 1 ft abv RCT		1 ≥ 5 ft abv RCT		5 ≥ 10 ft abv RCT				
		Score	Rank	Gradient	Departure	Rank	Width, ft	Departure	Rank	Area, ft^2/ft	Rank	Area, ft^2/ft	Rank	Area, ft^2/ft	Rank	Predicted	Departure, ft^2/ft	Rank
46	Garvey Gulch	93	16	0.13%	-0.13%	3	480	-70	24	157	26	68	22	66	21	301	-78	23
47	Woodrat Bar	120	23	0.28%	0.02%	33	511	-38	21	157	25	51	34	99	13	320	-64	19
48	Ash Creek	167	37	0.30%	0.04%	34	367	-182	37	138	37	65	24	46	33	322	-138	39
49	below Shasta River	208	48	0.41%	0.15%	47	300	-250	44	160	23	46	39	38	38	337	-140	40

[1] A composite score was determined by summing component rankings for gradient, valley width, floodplain area, and the gradient- floodplain function. The composite score was then transformed into an ordered rank, with the lowest score receiving the highest composite rank (i.e., rank=1).

[2] The gradient ranking is based on the departure in reach average gradient from the average gradient over the Project length (0.0026). Negative departures indicate reach gradients less than the average gradient over the Project length. Positive departures indicate reach gradients greater than the average gradient over the Project length. The reach with the most negative departure (i.e., lowest gradient) received the highest rank (i.e., rank=1).

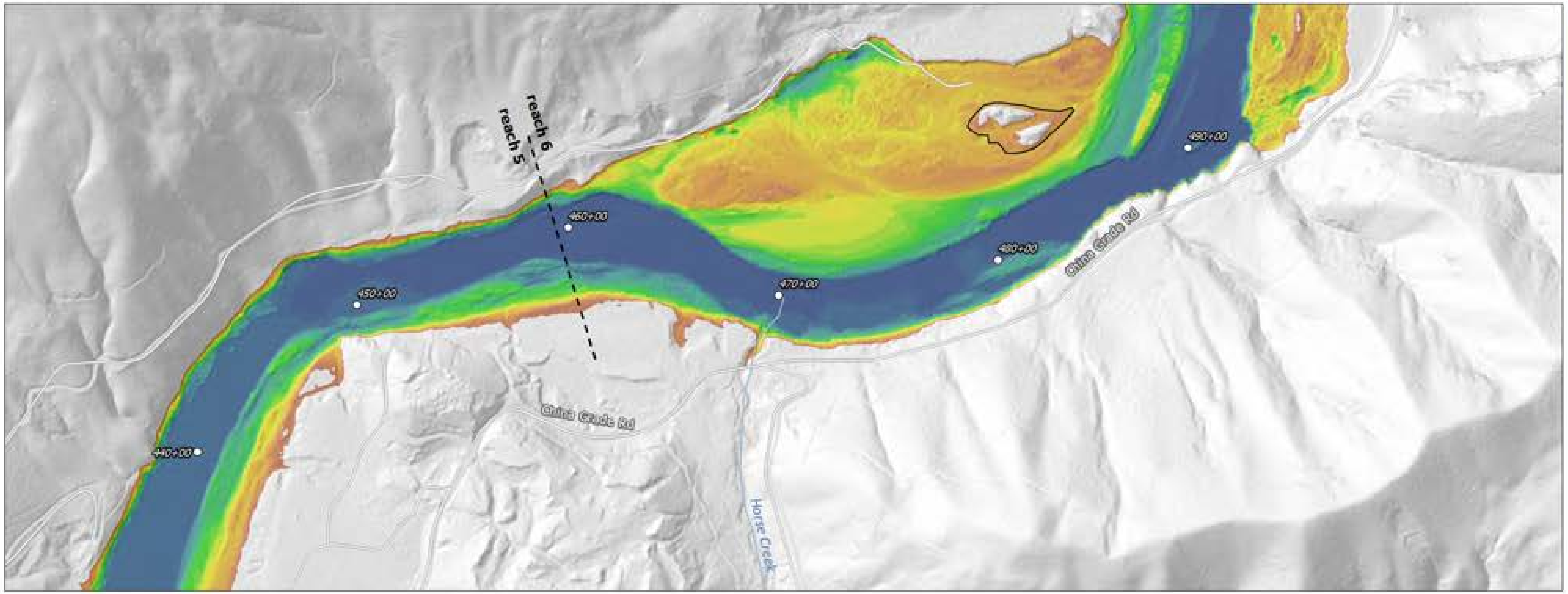
[3] The valley width ranking is based on the departure in reach average valley width from the average valley width over the Project length (549 ft). Valley width is defined by the 100-year floodplain mapped by USBR (2012). Positive departures indicate reach valley widths greater than the average valley width over the Project length. Negative departures indicate reach valley widths less than the average valley width over the Project length. The reach with the largest departure (i.e., largest valley width) received the highest rank.

[4] Cumulative unit area (ft^2/ft) where valley bottom elevations occur within the specified range above a reference surface defined by the riffle crest thalweg (RCT) profile. Refer to Section 3.2 for a description of how elevations above the riffle crest thalweg are determined. Cumulative unit area was calculated by dividing the total area within the specified elevation range by the reach length. The reach with the largest floodplain area received the highest rank (i.e., rank=1).

[5] The gradient-unit area function is defined by a linear regression model relating reach average gradient and cumulative floodplain (i.e., where elevations are within 10 ft of the riffle crest thalweg profile). Reaches are ranked based on the departure in the observed floodplain area from the floodplain area predicted from the regression model. Larger departures indicate more extensive floodplain area for a give gradient. The reach with the largest departure received the highest rank (i.e., rank=1)

Appendix B

Height Above the Riffle Crest Thalweg Datum, Aerial Photography, and Areas Disturbed by historical Placer Mining Within Potential Enhancement Reaches



Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 6 (tile 1 of 2)
Little Horse Creek (Suitability Rating: 1)

DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

BOTTOM FRAME

- 100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters

1:6,000 1 in = 500 feet

MAP LOCATION

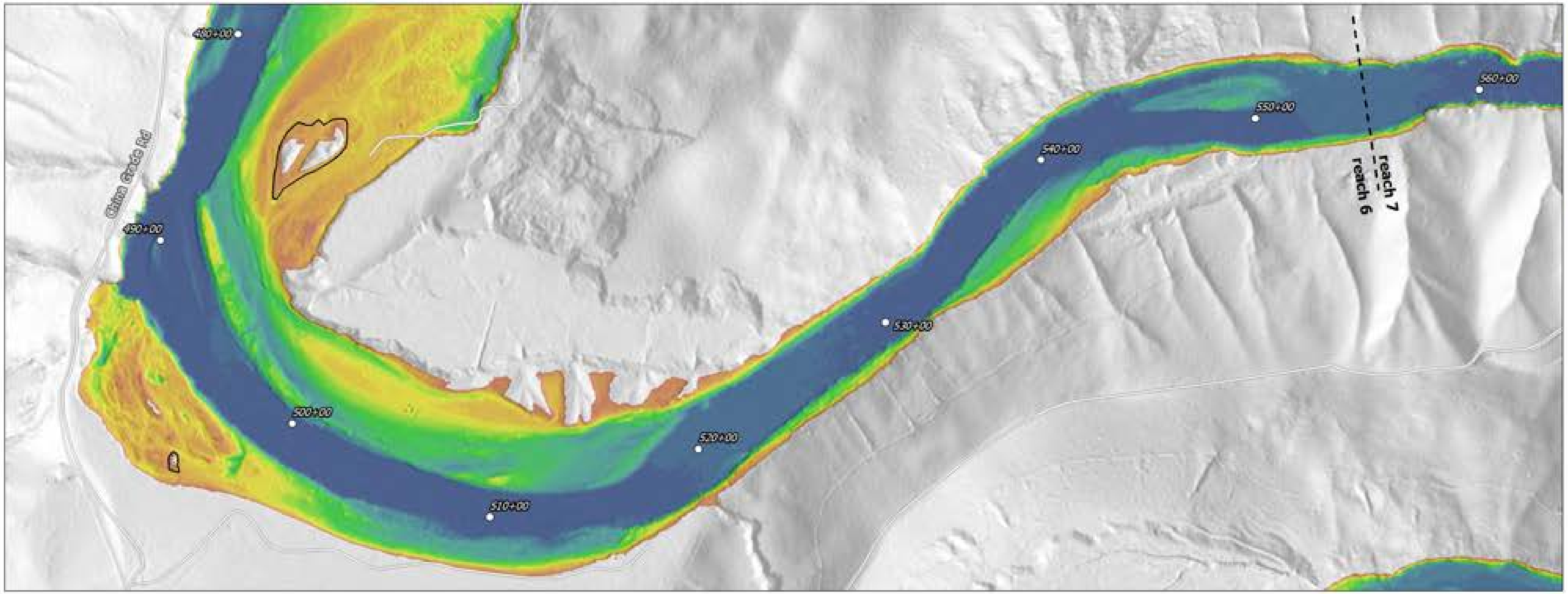
Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 6 (tile 2 of 2)
Little Horse Creek (Suitability Rating:1)

DATA SOURCES
LiDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences



LEGEND

TOP FRAME

1,000-ft stationing
Reach breaks
Mine pits
Mine tailings
Undifferentiated features

Feet above riffle crest thalweg datum
20
15
10
5
0

BOTTOM FRAME

100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters
1:6,000
1 in = 500 feet

MAP LOCATION

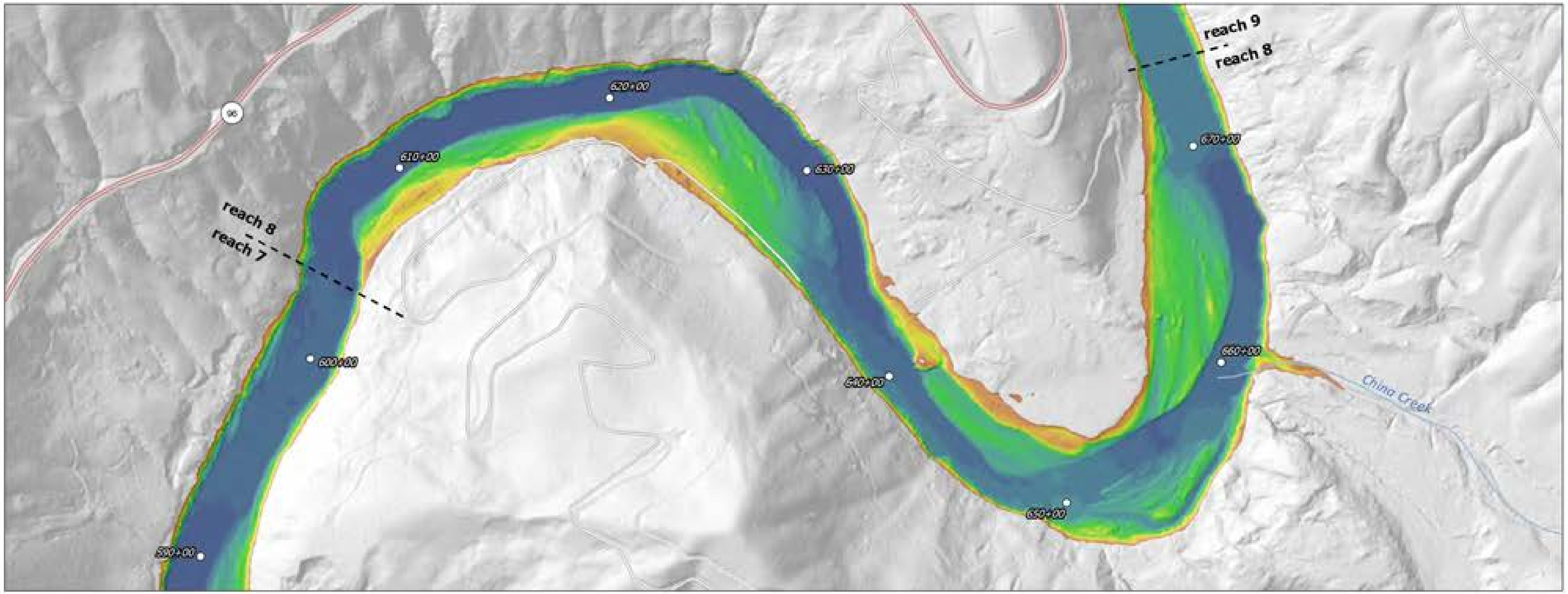
Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 8 (tile 1 of 1)
China Creek (Suitability Rating:2)

DATA SOURCES
LiDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences



LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum: 20, 15, 10, 5, 0

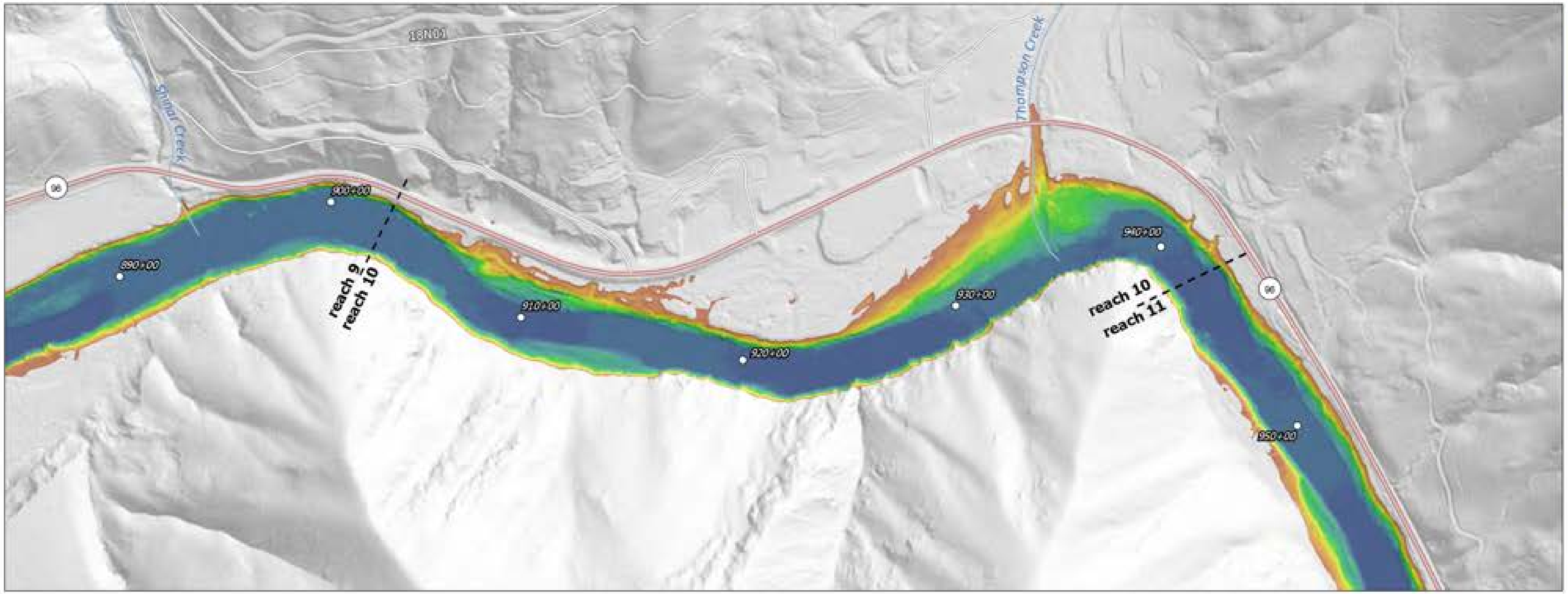
BOTTOM FRAME

- 100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters

1:6,000 1 in = 500 feet

MAP LOCATION



Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 10 (tile 1 of 1)
Thompson Creek (Suitability Rating:1)

DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

1,000-ft stationing
Reach breaks
Mine pits
Mine tailings
Undifferentiated features

Feet above riffle crest thalweg datum
20
15
10
5
0

BOTTOM FRAME

100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters
1:6,000 1 in = 500 feet

MAP LOCATION

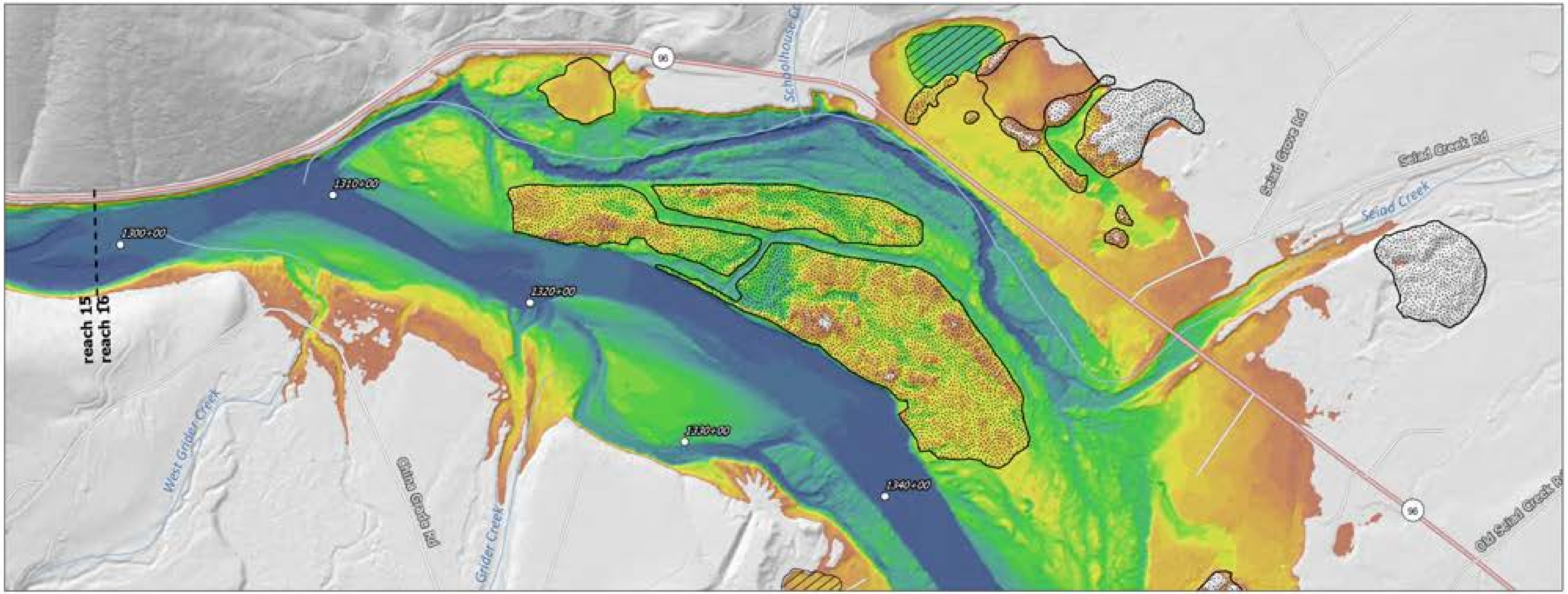
Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 16 (tile 1 of 2)
Seiad Valley (Suitability Rating:1)

DATA SOURCES
LiDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences



LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum: 20, 15, 10, 5, 0

BOTTOM FRAME

- 100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters
1:6,000 1 in = 500 feet

MAP LOCATION *pg 5 of 21*

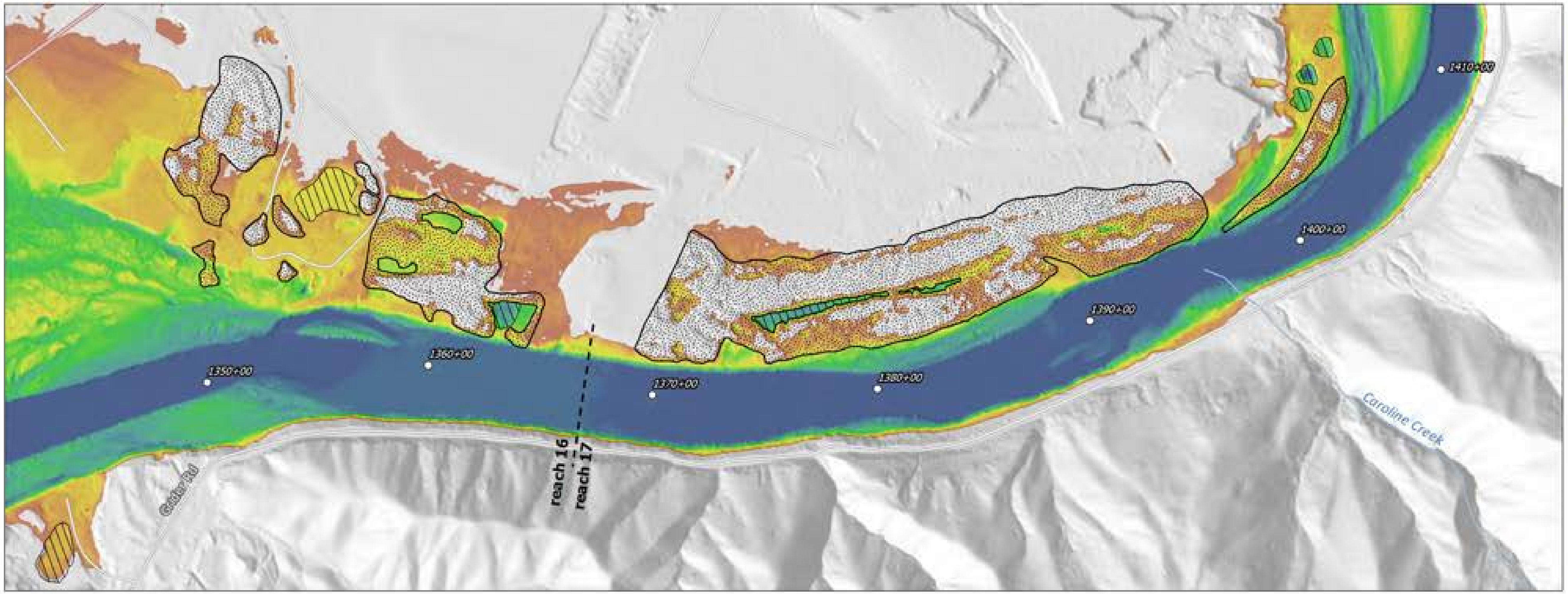
Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 16 (tile 2 of 2)
Seiad Valley (Suitability Rating:1)
Reach 17 (tile 1 of 2)
Walker Creek (Suitability Rating: 1)

DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences



LEGEND

TOP FRAME

1,000-ft stationing
Reach breaks
Mine pits
Mine tailings
Undifferentiated features

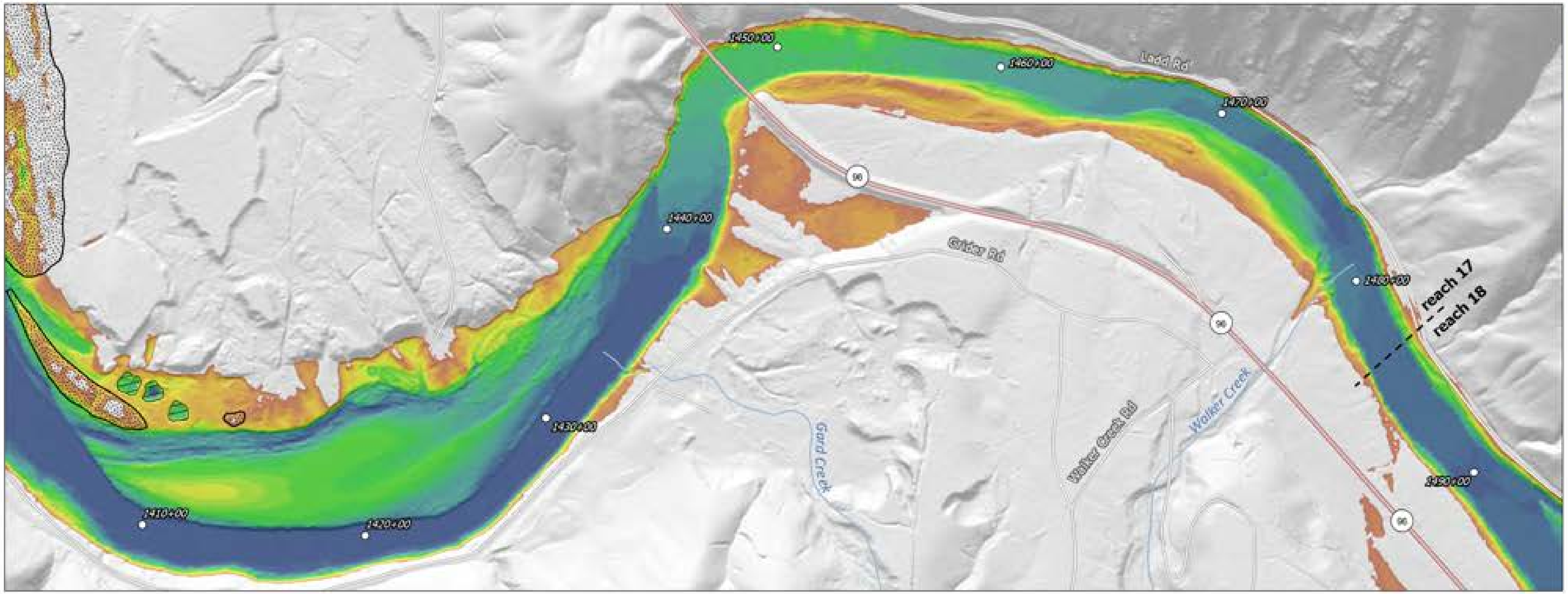
Feet above riffle crest thalweg datum
20
15
10
5
0

BOTTOM FRAME

100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters
1:6,000
1 in = 500 feet

MAP LOCATION



Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 17 (tile 2 of 2)
Walker Creek (Suitability Rating:1)

DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

1,000-ft stationing

Reach breaks

Mine pits

Mine tailings

Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

BOTTOM FRAME

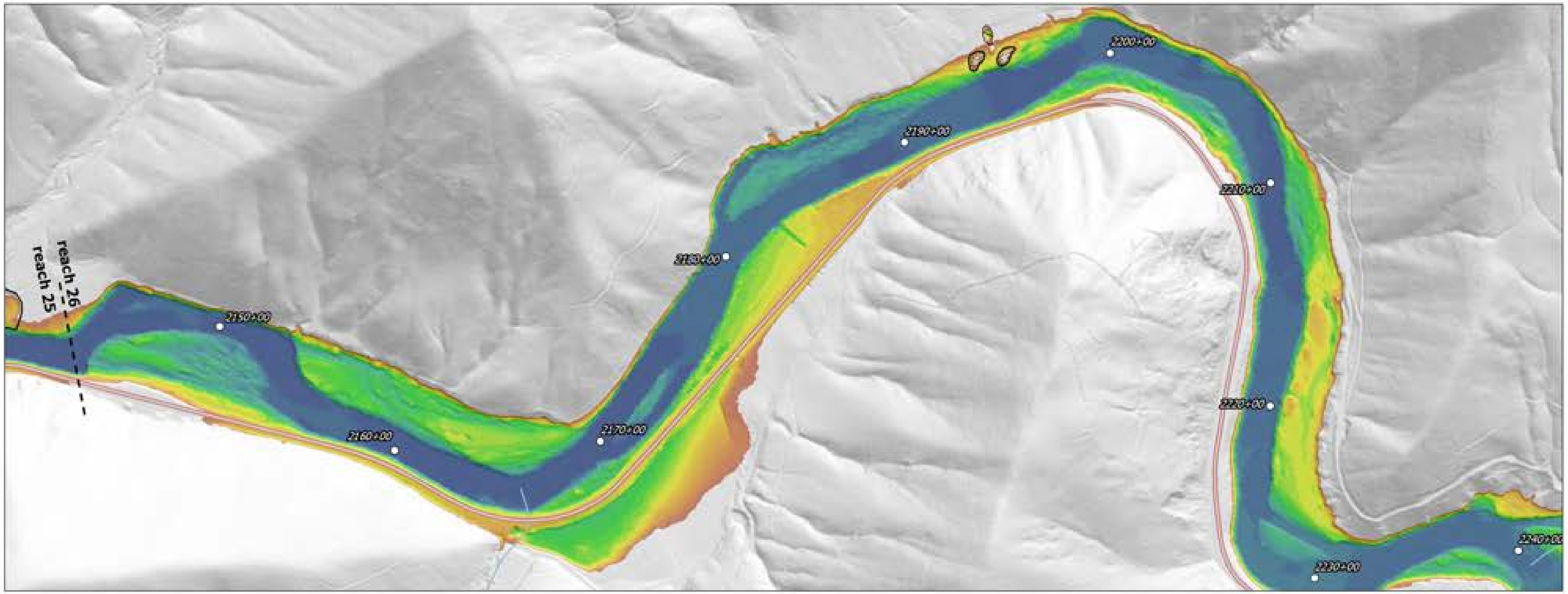
100-year floodplain

0 250 500 1,000 Feet

0 50 100 200 Meters

1:6,000 1 in = 500 feet

MAP LOCATION



Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 26 (tile 1 of 2)
Horse Creek (Suitability Rating:1)

DATA SOURCES
LiDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

BOTTOM FRAME

- 100-year floodplain

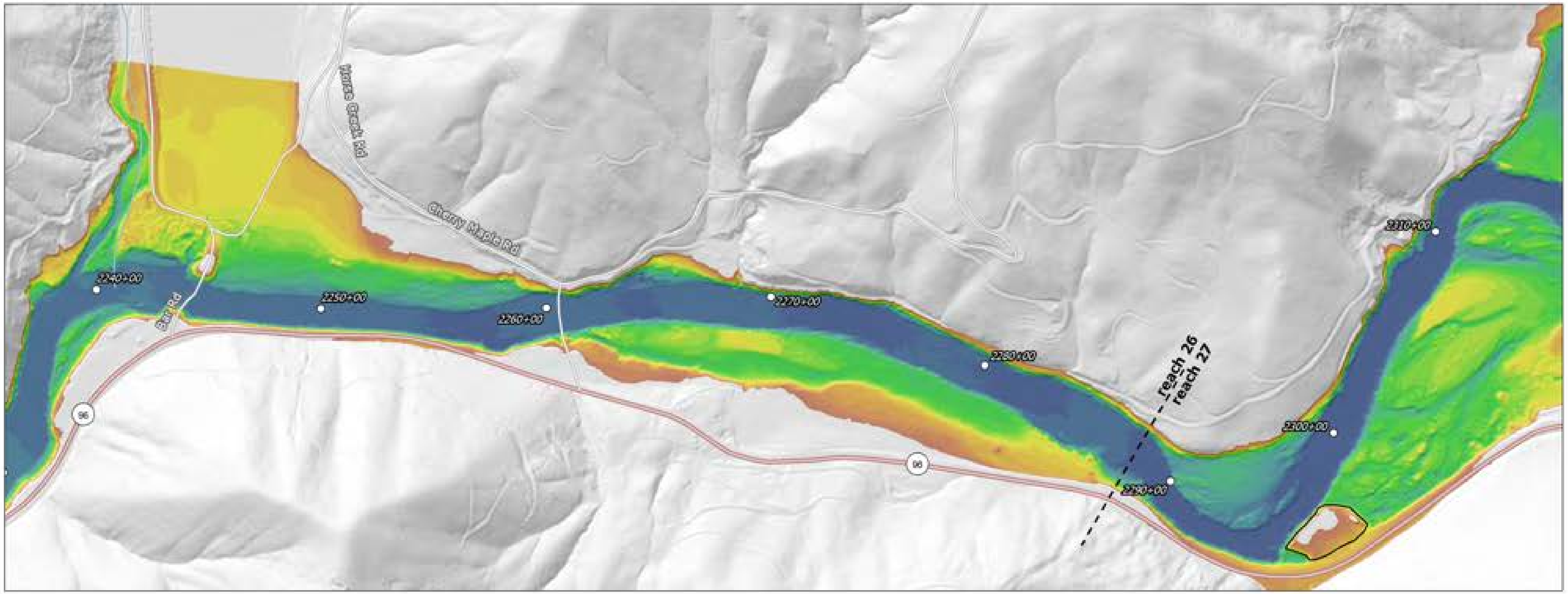
0 250 500 1,000 Feet
0 50 100 200 Meters

1:6,000 1 in = 500 feet

MAP LOCATION

Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 26 (tile 2 of 2)
Horse Creek (Suitability Rating:1)
Reach 27 (tile 1 of 2)
Cherry Flat (Suitability Rating: 1)



DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

BOTTOM FRAME

- 100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters

1:6,000 1 in = 500 feet

MAP LOCATION ***pg 9 of 21***

Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 27 (tile 2 of 2)
Cherry Flat (Suitability Rating:1)

DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

BOTTOM FRAME

- 100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters
1:6,000 1 in = 500 feet

MAP LOCATION *pg 10 of 21*

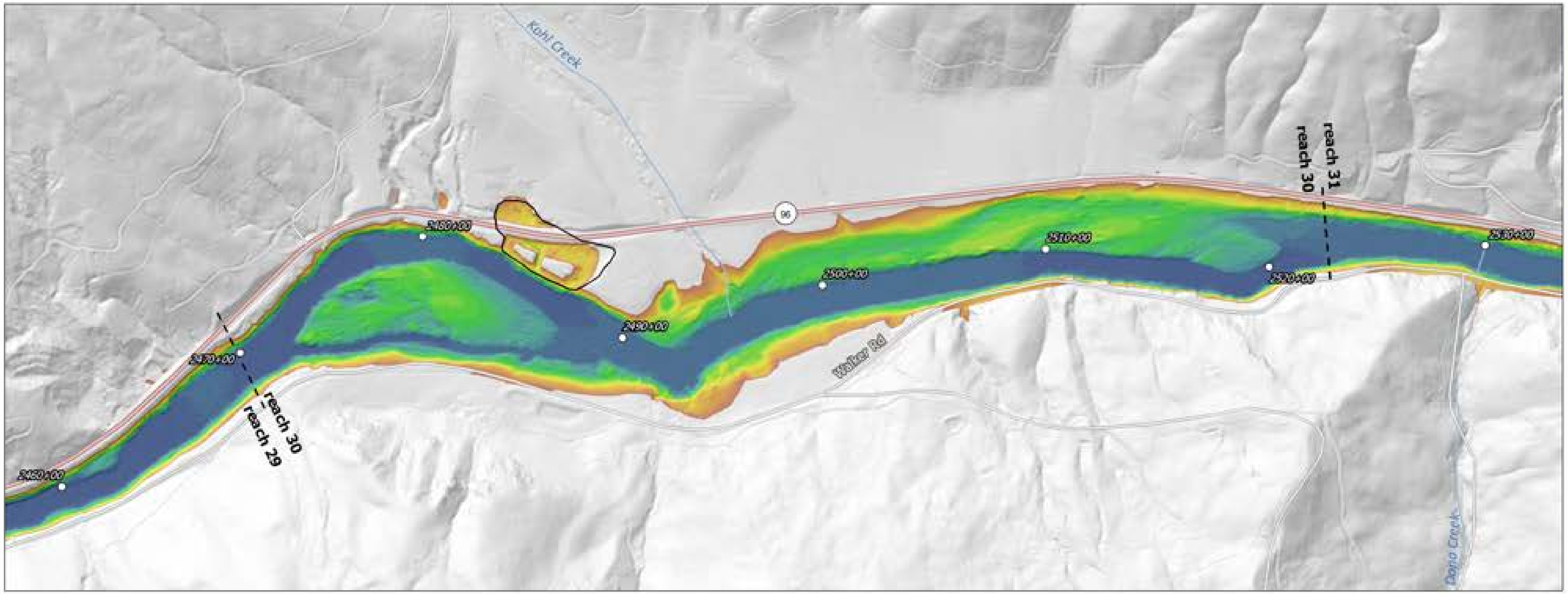
Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 30 (tile 1 of 1)
Kohl Creek (Suitability Rating:2)

DATA SOURCES
LiDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences



LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

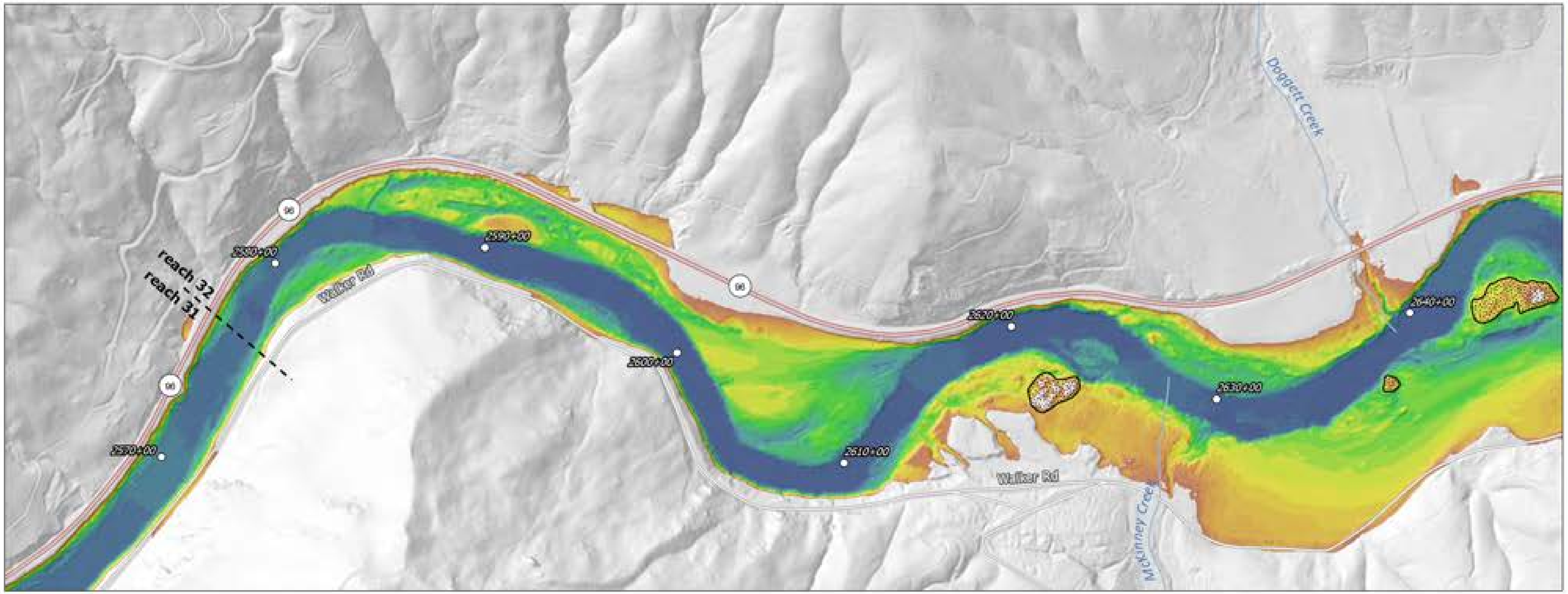
BOTTOM FRAME

- 100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters

1:6,000 1 in = 500 feet

MAP LOCATION



Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 32 (tile 1 of 4)
Little Humbug Creek (Suitability Rating:1)

DATA SOURCES
LiDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

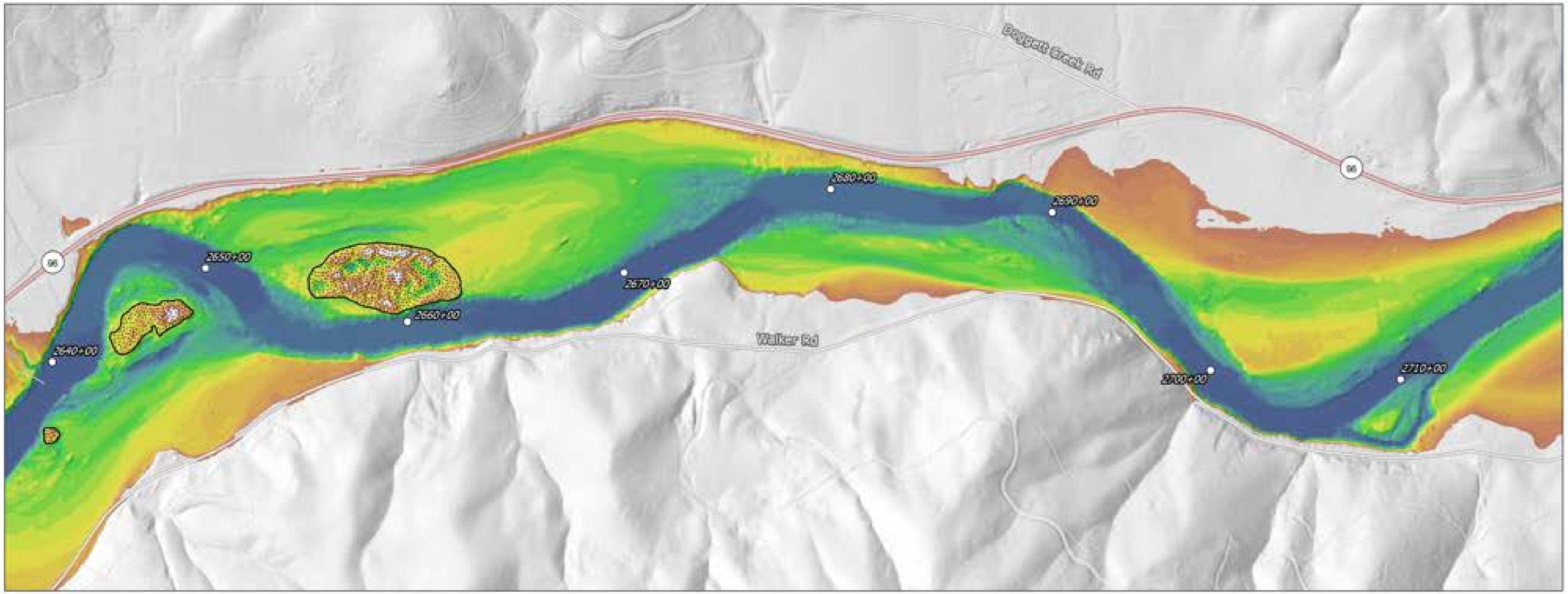
BOTTOM FRAME

- 100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters

1:6,000 1 in = 500 feet

MAP LOCATION



Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 32 (tile 2 of 4)
Little Humbug Creek (Suitability Rating:1)

DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum
20
15
10
5
0

BOTTOM FRAME

- 100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters
1:6,000 1 in = 500 feet

MAP LOCATION

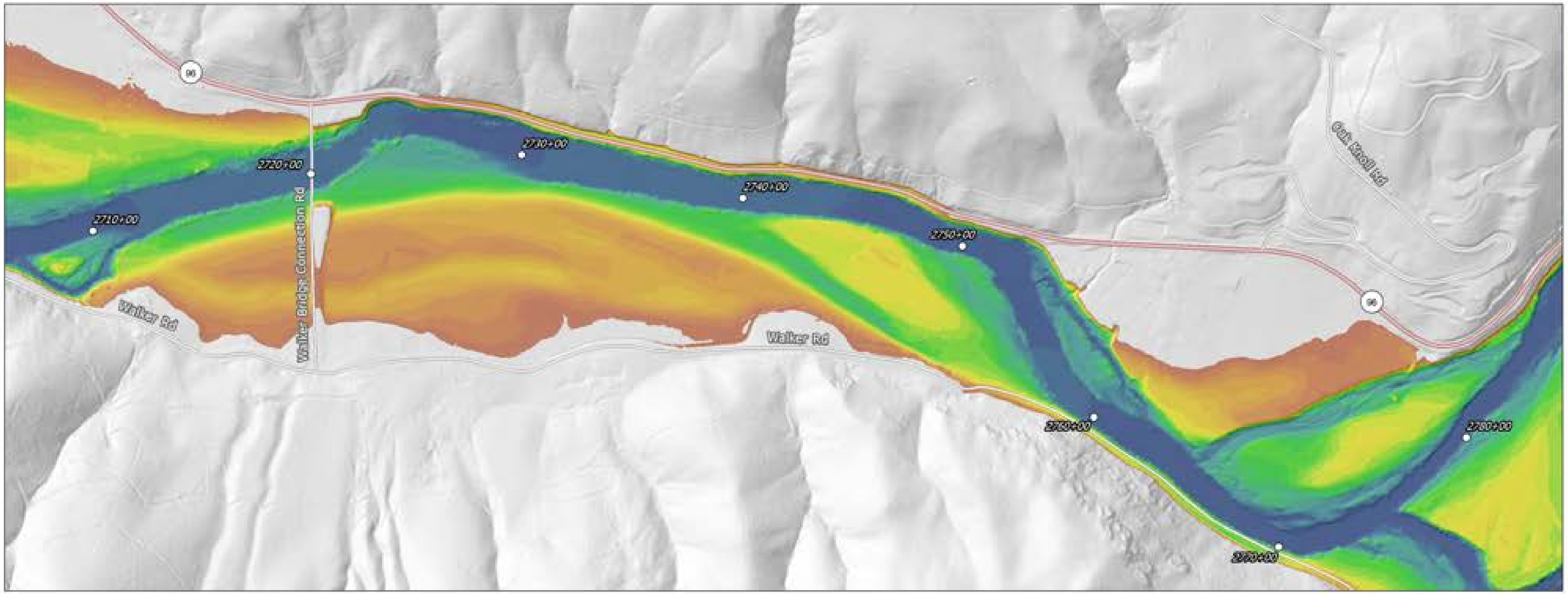
Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 32 (tile 3 of 4)
Little Humbug Creek (Suitability Rating:1)

DATA SOURCES
LiDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences



LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

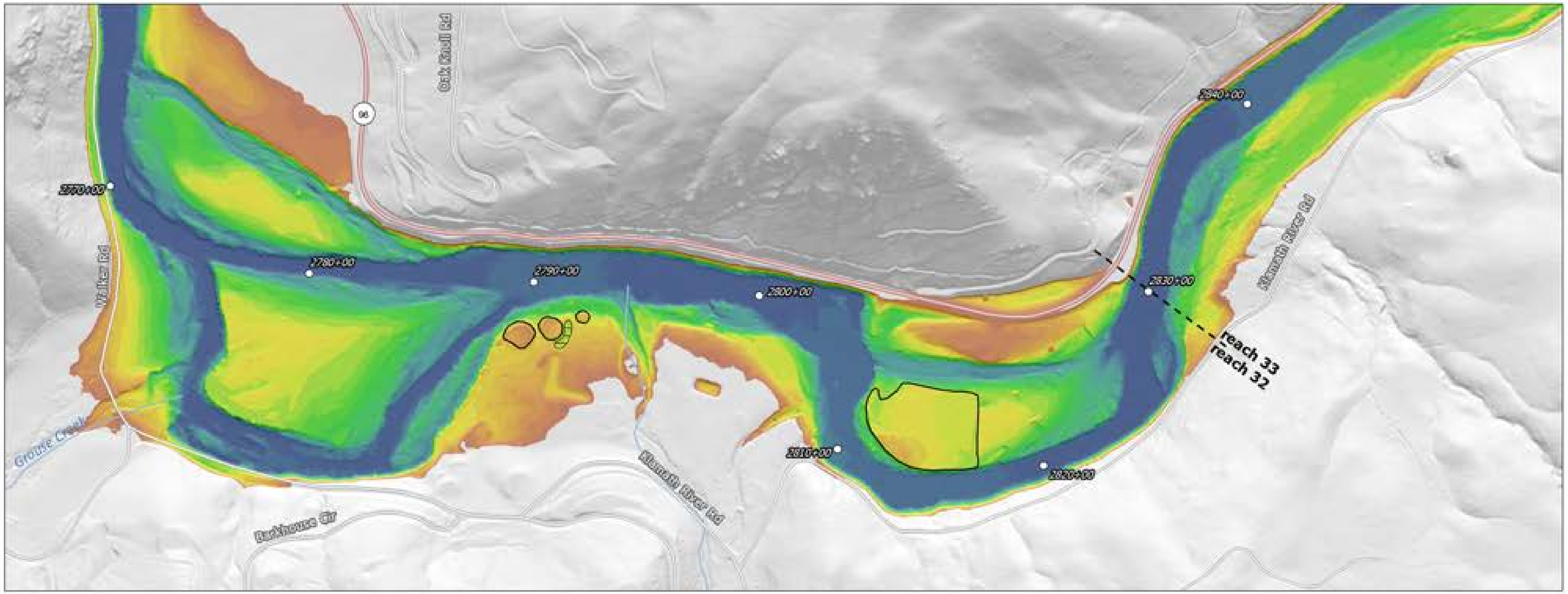
BOTTOM FRAME

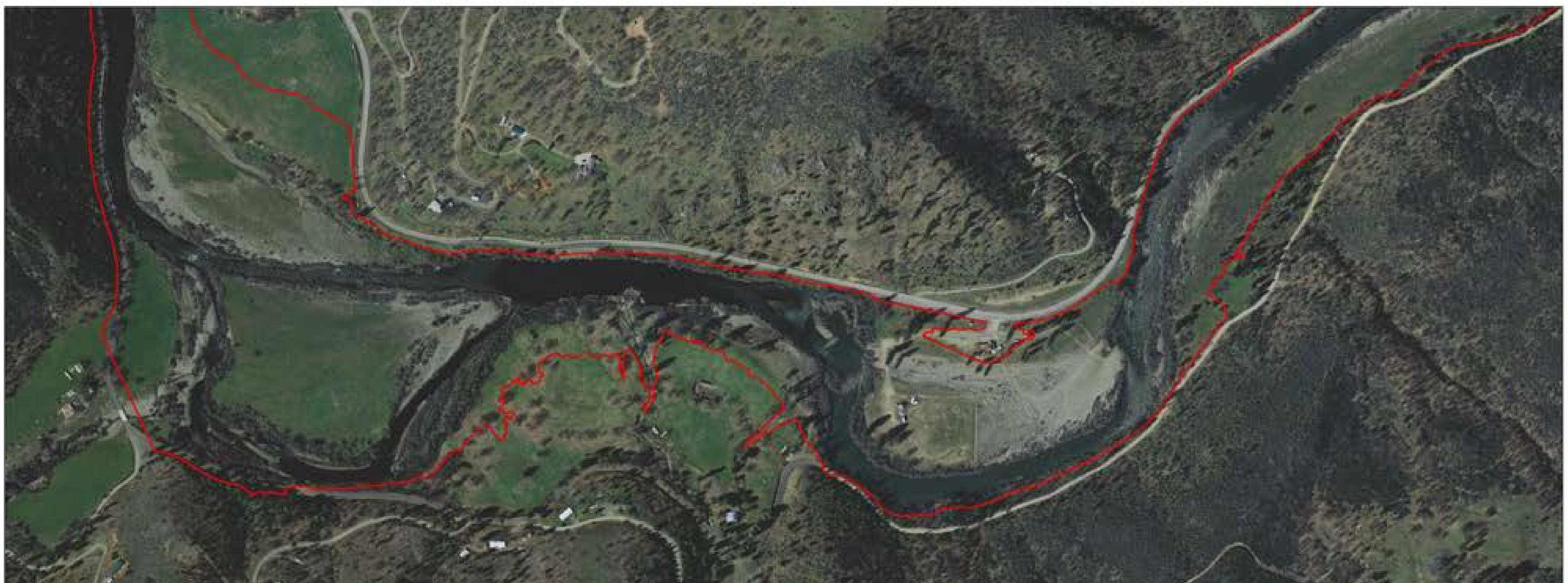
- 100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters

1:6,000 1 in = 500 feet

MAP LOCATION pg 14 of 21





Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 32 (tile 4 of 4)
Little Humbug Creek (Suitability Rating:1)

DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

1,000-ft stationing
Reach breaks
Mine pits
Mine tailings
Undifferentiated features

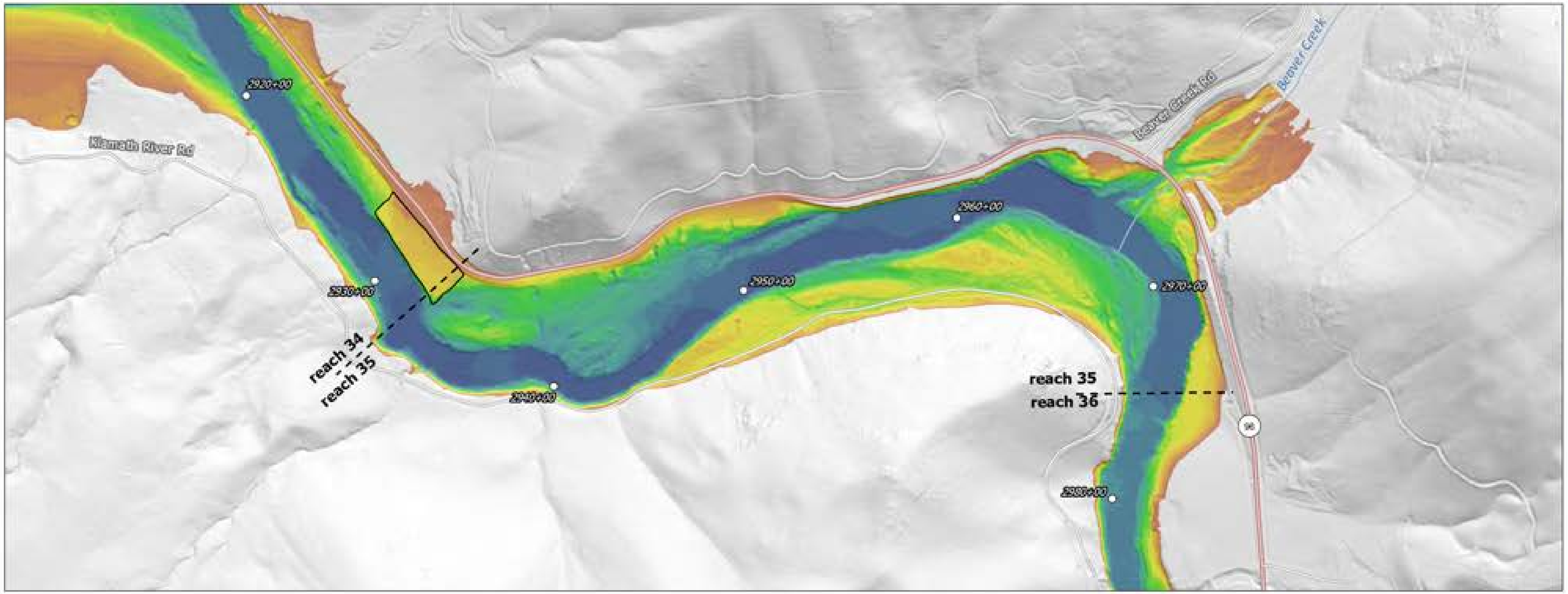
Feet above riffle crest thalweg datum
20
15
10
5
0

BOTTOM FRAME

100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters
1:6,000
1 in = 500 feet

MAP LOCATION *pg 15 of 21*



Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 35 (tile 1 of 1)
Beaver Creek (Suitability Rating:1)

DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

1,000-ft stationing
Reach breaks
Mine pits
Mine tailings
Undifferentiated features

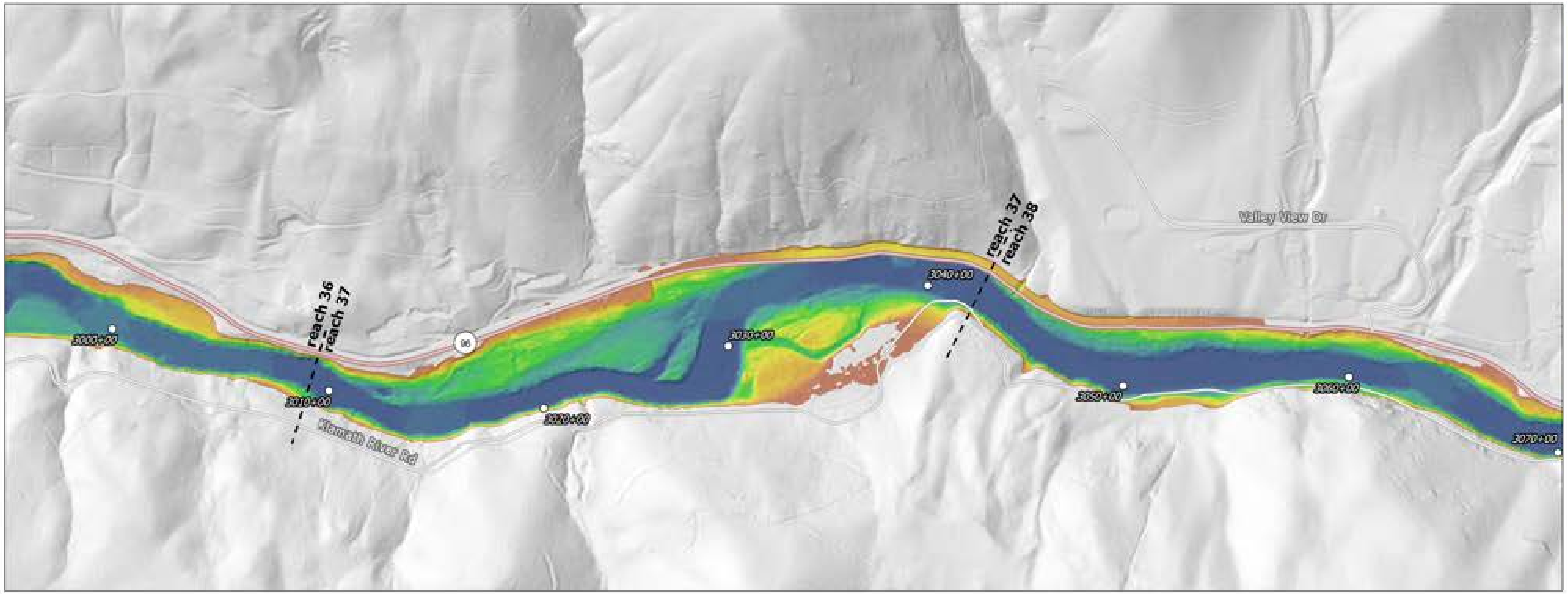
Feet above riffle crest thalweg datum
20
15
10
5
0

BOTTOM FRAME

100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters
1:6,000 1 in = 500 feet

MAP LOCATION



Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 37 (tile 1 of 1)
Cougar Gulch (Suitability Rating:2)

DATA SOURCES
LiDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

1,000-ft stationing

Reach breaks

Mine pits

Mine tailings

Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

BOTTOM FRAME

100-year floodplain

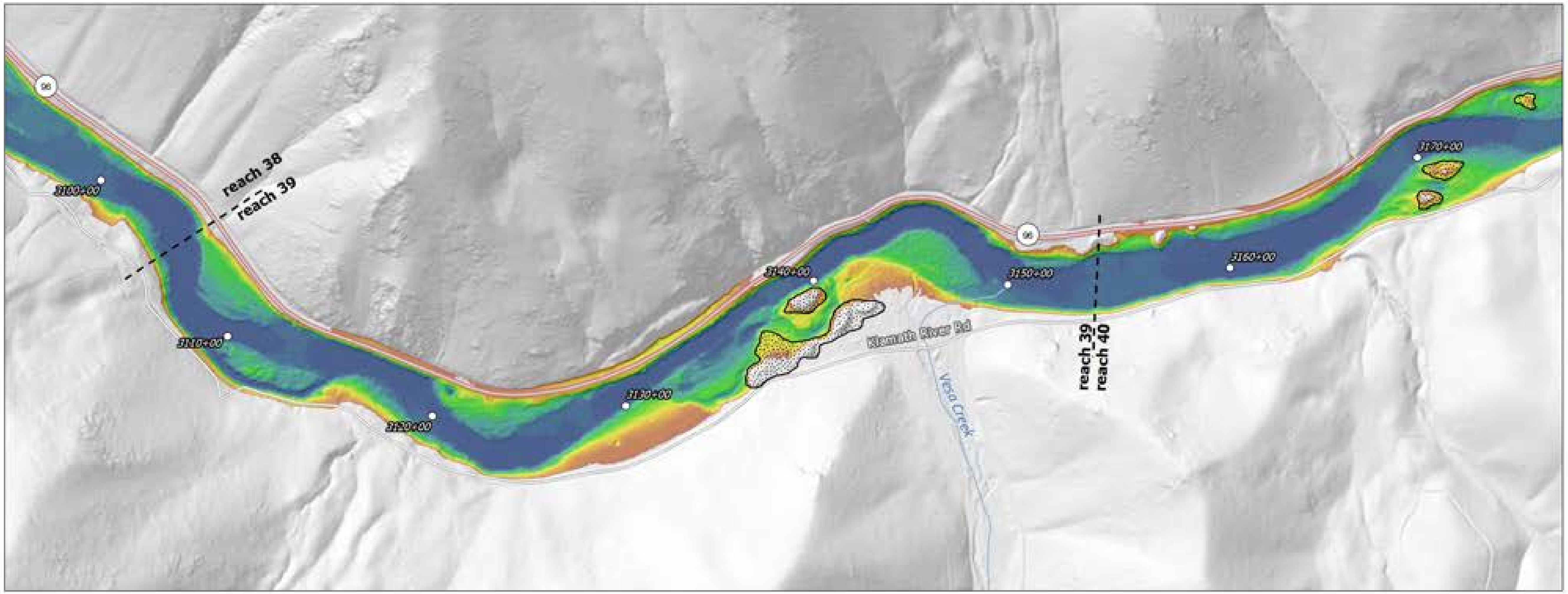
0 250 500 1,000 Feet

0 50 100 200 Meters

1:6,000

1 in = 500 feet

MAP LOCATION *pg 17 of 21*



Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 39 (tile 1 of 1)
Vesa Creek (Suitability Rating:2)

DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

1,000-ft stationing
Reach breaks
Mine pits
Mine tailings
Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

BOTTOM FRAME

100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters

1:6,000 1 in = 500 feet

MAP LOCATION

Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 42 (tile 1 of 1)
Gottsville (Suitability Rating:2)

DATA SOURCES
LiDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences

LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

BOTTOM FRAME

- 100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters

1:6,000 1 in = 500 feet

MAP LOCATION *pg 19 of 21*

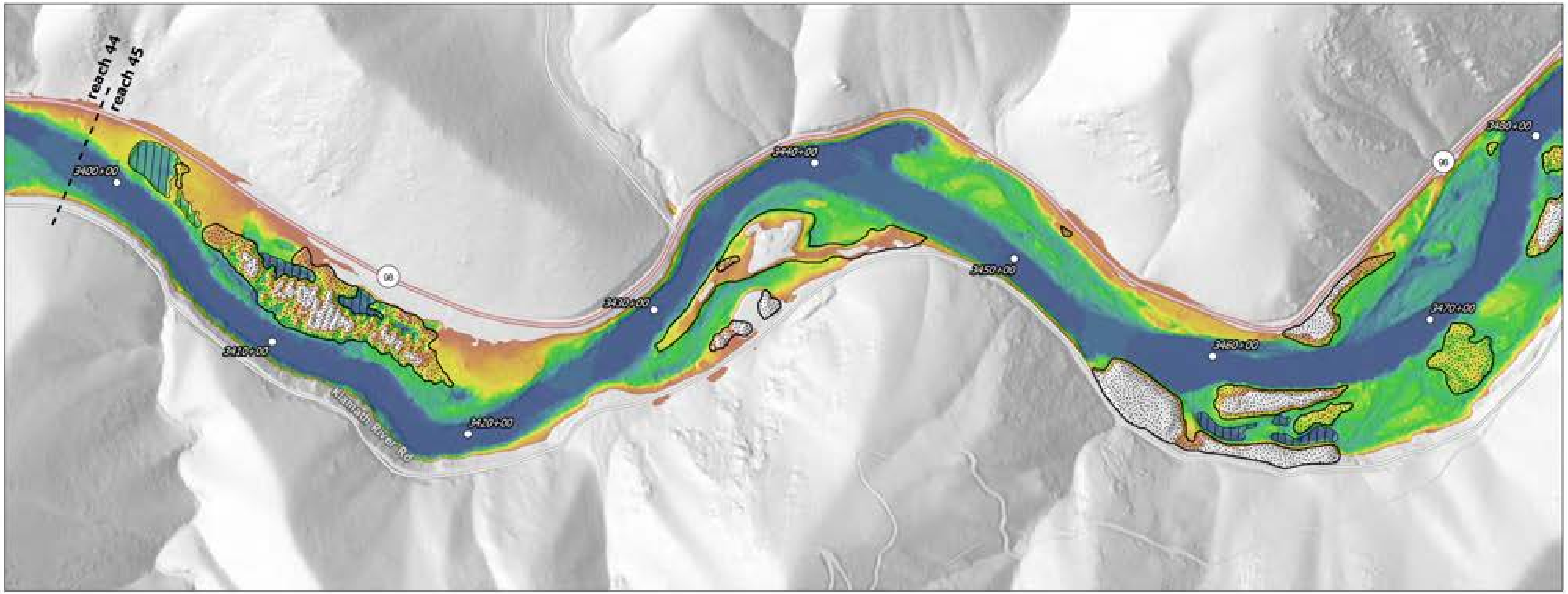
Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 45 (tile 1 of 2)
Humbug Creek (Suitability Rating:1)

DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

MAP PROJECTION
NAD_1983_HARN_StatePlane
California_I_FIPS_0401_Feet

Stillwater Sciences



LEGEND

TOP FRAME

- 1,000-ft stationing
- Reach breaks
- Mine pits
- Mine tailings
- Undifferentiated features

Feet above riffle crest thalweg datum

20
15
10
5
0

BOTTOM FRAME

- 100-year floodplain

0 250 500 1,000 Feet
0 50 100 200 Meters

1:6,000   1 in = 500 feet

MAP LOCATION   pg 20 of 21

Mid-Klamath Floodplain Assessment and Mine Tailing Remediation Plan

Reach 45 (tile 2 of 2)
Humbug Creek (Suitability Rating:1)

DATA SOURCES
LIDAR & Imagery: Woolpert Inc., 2010
100-year FP: BOR, 2012
Streams: NHD
Cities, roads: ESRI 2016

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MAP LOCATION pg 21 of 21