Indian Creek Connectivity and Restoration Project
Draft 90% Design

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Contents

1 PROJECT OVERVIEW

This proposed project is located on Indian Creek, which is a tributary to the Trinity River within the Klamath Basin. The project reach is located in a relatively wide alluvial valley bottom, much of which is highly disturbed by past land use practices and has undergone significant aggradation in the last century. This degraded watershed is in response to aggressive historic mining activities and more recent upslope logging practices. Currently the major issue for this reach is Indian Creek's low flow goes subsurface through a section of this stream impairing development of riparian forest, and causing a barrier to anadromous fish migration and disconnection from upstream habitats.

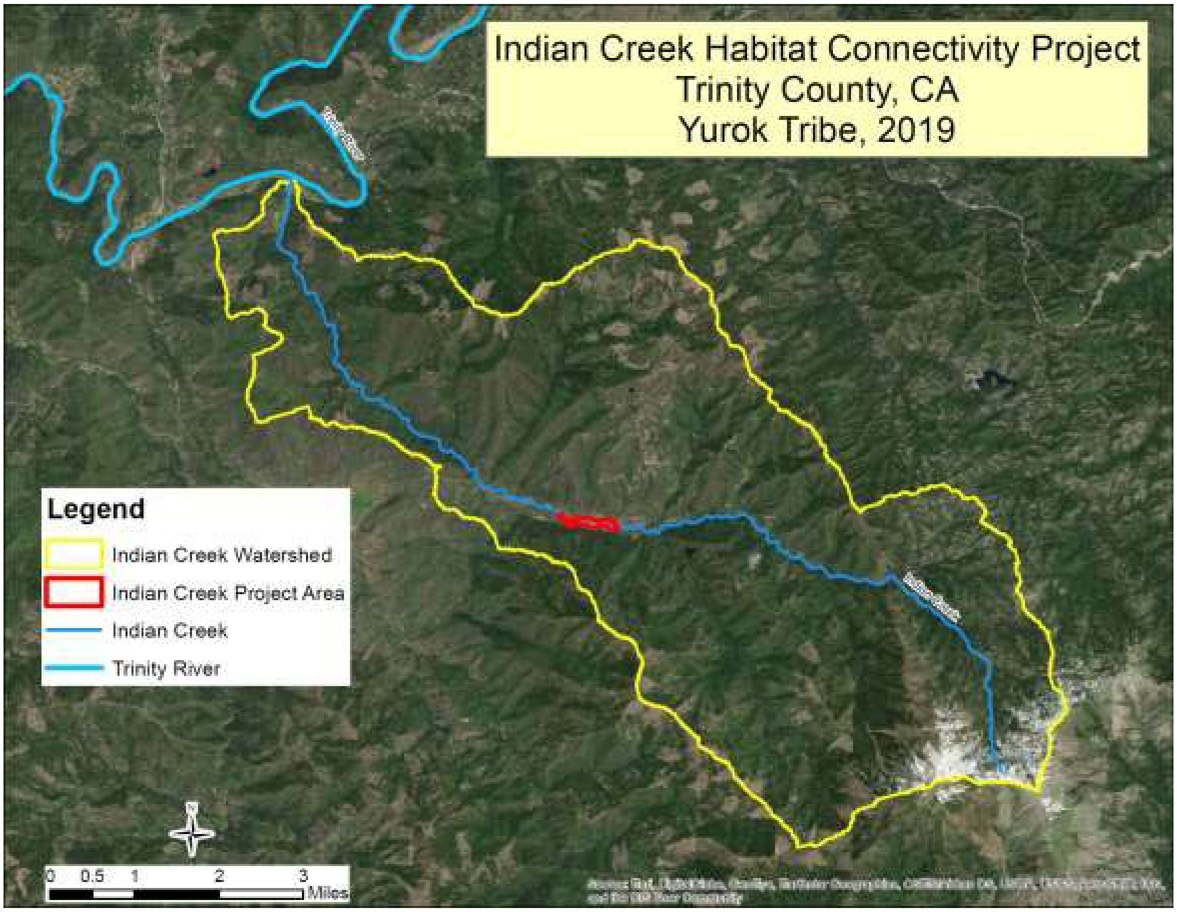

Figure 1. The Indian Creek watershed (yellow) and project location (red).

Indian Creek has an approximately 34 square mile watershed that is Southern exposed and located within Trinity County, California (Figure 1). The Indian Creek project reach is set in the uppermost portion of the low gradient alluvial valley approximately at the mid-point of the watershed. Rehabilitation work proposed along a 3,300-ft-long reach encompasses public lands, managed by the Bureau of Land Management (BLM), and portions of two private parcels. The Indian Creek watershed is a documented source of fine sediment and is on the State of California's Clean Water Act section 303(d) list of impaired waterways for sediment; a total maximum daily load (TMDL) for fine sediment has been established for the watershed (US Environmental Protection Agency [EPA], 2001). The project is designed to meet the following goals and objectives, in accordance with the goals of the funding solicitations that it was awarded, CVIP (2016) and U.S. Bureau Reclamation (2017):

- Means Objective: Restore/improve surface water connectivity by raising groundwater elevation within the 3,300 ft project reach to reduce temporal fluvial barrier for anadromous fish migration:

• Goal 1: Restore/Enhance Indian Creek habitats and habitat connectivity within the project reach for all freshwater life stages of native anadromous fish.

• Goal 2: Restore and Enhance Indian Creek geomorphic processes within the project reach by increasing floodplain connectivity; increase surface water / groundwater exchange and sediment sorting and residency time.

• Goal 3: Restore and Enhance Indian Creek water quality within the project reach by increasing riparian corridor vegetation establishment and ground water retention.

• Goal 4: Provide proof of concept for future in-river restoration throughout additional reaches and other watersheds; perform research oriented implementation actions to determine most efficient and cost-effective techniques to raise groundwater within a degraded losing stream corridor.

Since proposals submission to secure funding of this project, the Yurok design team has worked closely with a group of restoration practitioners from the U.S. Forest Service, Region 6, who have developed and successfully implemented a valley scale restoration strategy. This strategy restores ecological function by raising groundwater in incised stream valleys. This strategy, commonly referred to as "stage 0", has been influential in the development of this draft design. Fiori Geosciences and the Technical Service Center, of the U.S. Bureau of Reclamation, have also provided critical feedback and input on design development and monitoring efforts.

2 PROJECT SITE EXISTING CONDITIONS

2.1 Location and Land Ownership

The Indian Creek project site is located adjacent to Indian Creek Road in Section 25 of Township 32 N, Range 9 in western Trinity County. The downstream end of the project's Environmental Study Limits (ESL) is located about 200 ft northwest of where Indian Creek Road Bridge 5C-046 crosses Indian Creek. From there, the ESL extends upstream for a distance of about 4,000 ft (Figure 2.). The downstream (west) half of the ESL is located entirely on BLM land, whereas the upstream half is approximately evenly split between BLM land and portions of two private parcels. Of the 29.25 acres within the ESL, BLM owns 22.55 acres and 6.7 acres are private property.

2.2 Physical Setting

The Indian Creek watershed drains about 34 square miles on the northeast side of Bully Choop Mountain, which rises to 6977 ft on the divide between Trinity and Shasta Counties in northern California. From the divide, the creek flows about 12.5 miles toward the northeast where it discharges into the Trinity River at Douglas City, CA. Most of the watershed is underlain by Abrams mica schist and Salmon hornblende schist of the Central Metamorphic Terrain [Fraticelli et al. 1987] (Figure 3). A small headwater portion of the watershed drains the Shasta Bally batholith, which weathers to produce copious amounts of sandy sediment referred to as decomposed granite. The Indian Creek project site is located in the middle of the watershed, 6.25 miles upstream from the confluence with the Trinity River.

The area in which work is planned occupies a relatively wide, flat valley bounded by a bedrock escarpment on the north and to the south by terraces composed of hydraulic mining outwash and occasional bedrock knobs (Figure 4A). The valley slope through the work area is fairly constant with an average value of 0.0214 and a standard deviation of 0.0062. Hydraulic mining scars and sluices cut into the bedrock farther upslope on both sides of the valley attest to severe disturbance of the site by historical mining activities. Vast quantities of sediment were washed off the surrounding hillsides and appear to have buried the pre-settlement valley. The creek later incised into the valley fill, leaving outwash terrace scarps as much as 35 ft high in places.

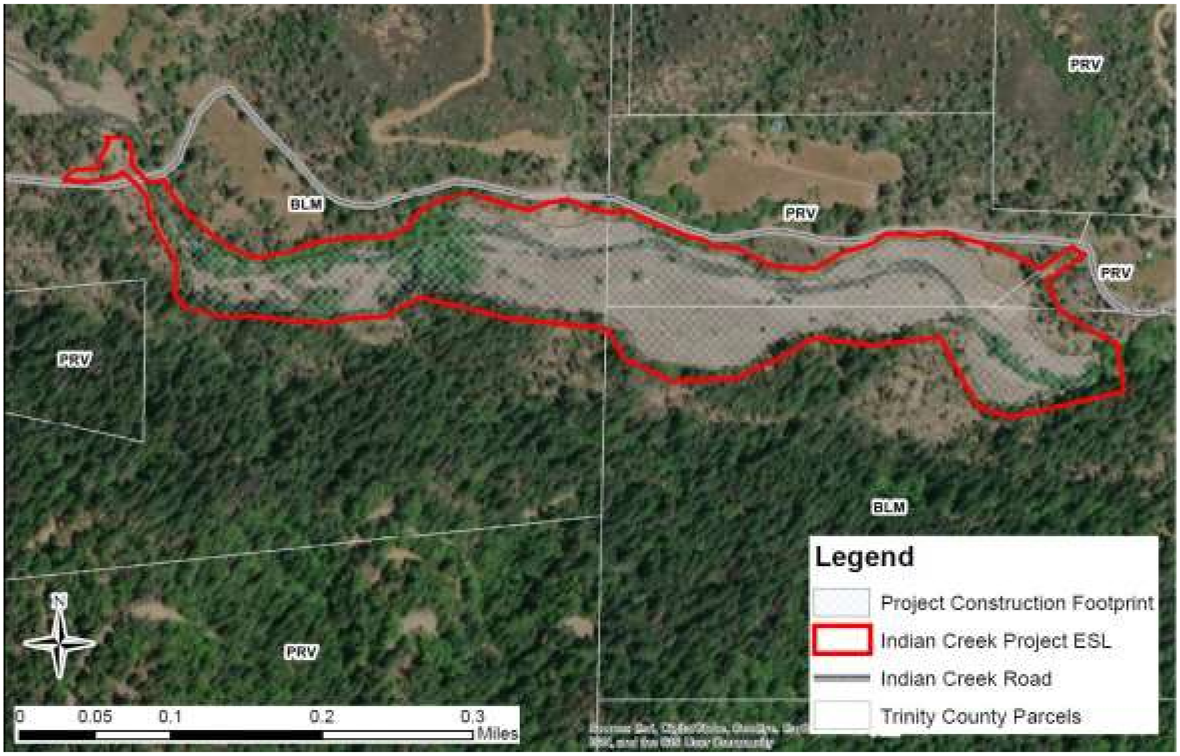

Figure 2. Project Environmental Study Limits and land ownership. The creek flows from right to left.

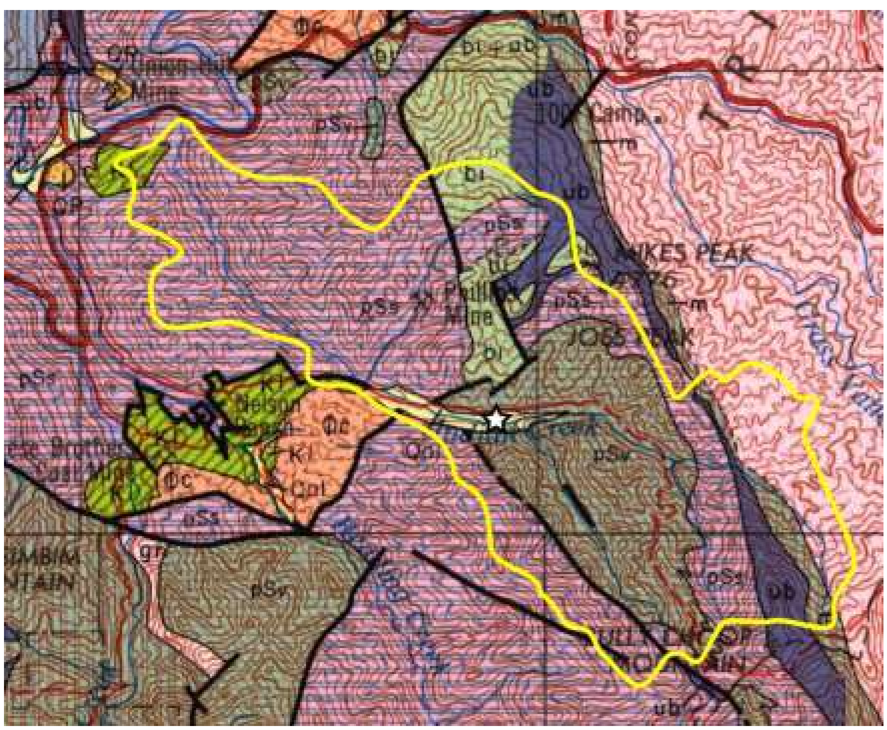

Figure 3. Geology of the Indian Creek watershed. The white star indicates the project location and the watershed boundary is shown in yellow. The confluence with the Trinity River is near the upper left corner of the figure. pSs = Abrams mica schist; pSv = Salmon hornblende schist; Shasta Bally batholith is the lighter pink area on the far right side of the map.

The upstream limit of construction activities is at approximately station 4000 where a narrow canyon transitions to the broader valley. The valley makes a sharp turn to the left between a bedrock knob to the south and an alluvial fan formed by an unnamed ephemeral tributary to the north (Figure 4). One of two planned access routes to the work area is adjacent to that tributary. Between the bend to the left and station 1700 the valley reaches a maximum width of about 420 ft and is almost entirely devoid of vegetation. Frietas Creek, an intermittent tributary, enters this portion of the valley from the north. Indian Creek itself goes dry in this part of the project area during the summer and fall of many years.

A riparian forest appears on the valley bottom and perennial surface water in the stream reappears at approximately station 1700. In addition to the water in the stream channel, water was also observed emerging from a spring about 160 ft south of the creek channel in the spring of 2019. The appearance of water and riparian vegetation downstream from station 1700 is accompanied by the appearance of several bedrock outcrops along the southern valley margin between stations 1600 and 1350 and a reduction in valley width to about 135 ft at station 1450. This morphology coupled with the re-emergence of water suggests the presence of shallow bedrock beneath the alluvium that blocks the subsurface transmission of groundwater somewhere nearby.

Downstream from the point of maximum constriction in valley width, the riparian vegetation becomes patchy and the valley narrows. The narrowing is primarily due to a lateral levee that originates at the south valley wall near station 700 and progressively restricts the width of the functional valley to about 40 ft where it passes under the Indian Creek Road Bridge. Current rehabilitation plans anticipate no work in the stretch of stream adjacent to that levee. Impacts to that area will be limited to use of the levee crest as an access road to the downstream half of the project area.

LiDAR data exist for the project reach from a 2014 effort led by Trinity County Resource Conservation District (TCRCD; Watershed Sciences 2015). The Yurok design team has also flown orthophotography using drone base cameras and used structure from motion to create a digital terrain map from the summer and fall of 2018. This will allow for the use of 2-D hydrodynamic modeling to assess later stages of project design.

Longitudinal profiles of channel bed elevations and the valley grade line are plotted in Figure 5. The bed profile was created by projecting elevations extracted from LiDAR topography onto the valley station line. The significance of the valley grade line is discussed more thoroughly in later sections of this report, and details regarding its development are presented in Appendix A. For the time being it suffices to explain that the valley grade line is a statistically smoothed representation of the mean elevation across the valley floor as a function of longitudinal position. It maintains a nearly constant slope through the project site, as demonstrated by application of ordinary least squares regression, which yields a coefficient of determination of 0.999. The streambed elevations, however, display a more stepped profile. A particularly large step occurs at station 2330, where the bed elevation drops more than 4 ft over a horizontal distance of 20 ft. This distinct knick point in the bed elevation profile likely originated some distance downstream and propagated upstream to its present position. The time scale over which the knick point propagation may have occurred is uncertain.

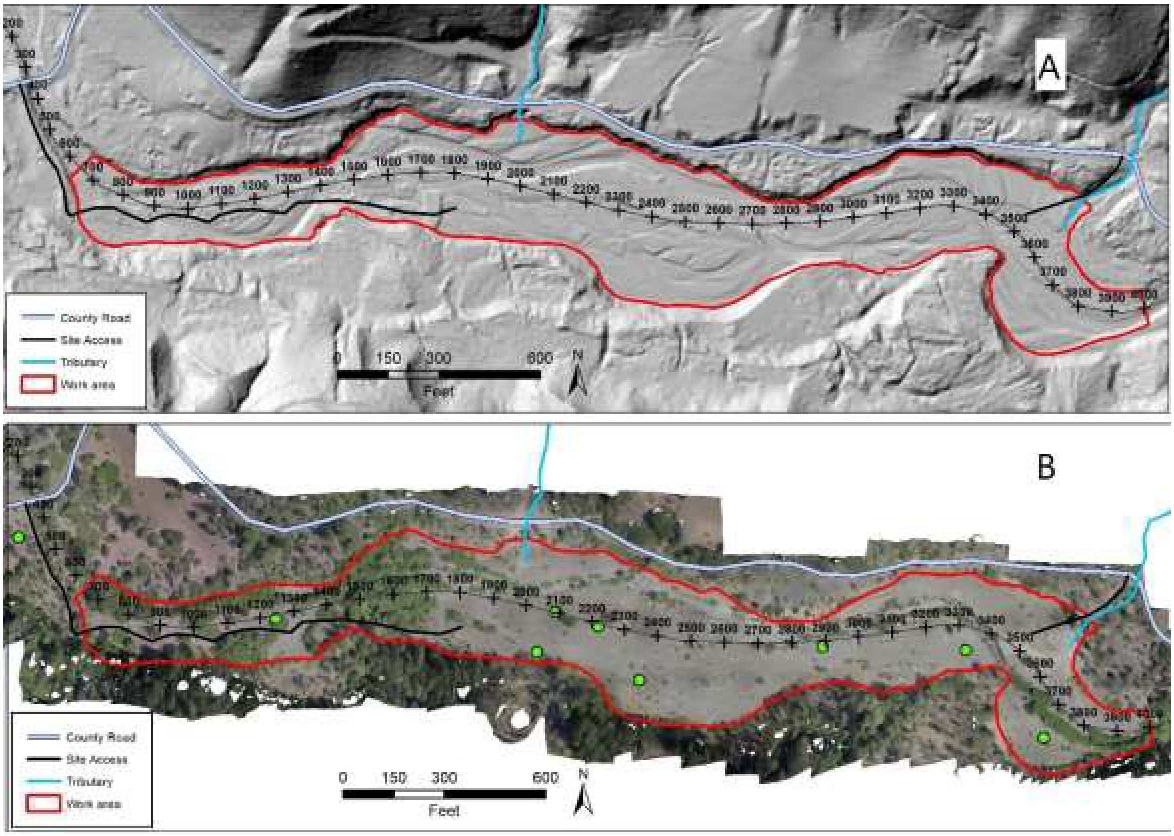

Figure 4. Valley stationing, access routes, and the extents of the valley bottom work area on maps showing A) hillshade relief and B) aerial photography. Green dots on B indicate the locations of test pits described in the text. The creek flows from right to left.

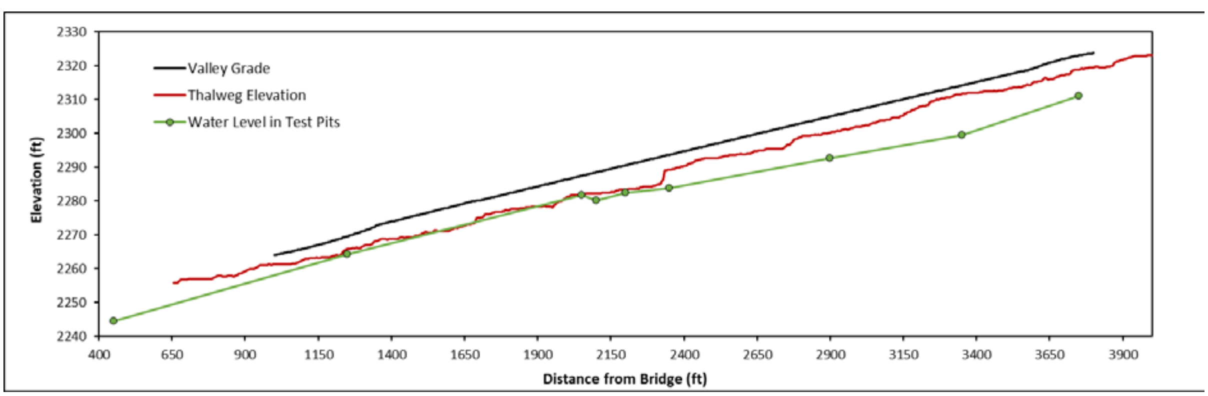

Figure 5. Longitudinal profiles of the channel bed elevation, the valley grade line, and water levels observed in test pits in spring 2019.

In addition to the history of mining impacts, current conditions at the project site also reflect the effects of previous rehabilitation actions. There is a long history of unsuccessful attempts to improve instream habitat within this reach and the valley downstream of Indian Creek Road dating back to the 1970's. In 1989 BLM fish biologists attempted to increase available habitat by stabilizing the channel in the lower mile of the valley segment downstream of Indian Creek road using heavy equipment and bank stabilizing structures. Main and side channel pools were created to increase summer rearing habitat. Success was minimal due to high bedload movement throughout the zone during high winter flows (WA 1996). A 1996 restoration attempt by TCRCD and Watershed Associates (WA), in which the stream was confined to a relatively narrow portion of the valley bottom, involved excavation of a mildly sinuous channel within a relatively narrow inset floodplain (Figure 6). The design included at least three rock revetments, built to prevent lateral channel migration. Material from the floodplain excavation filled other portions of the valley. That project was destroyed within weeks of its completion by the New Year's flood of 1997, but the additional flow confinement associated with the valley fill and floodplain excavation could be partially responsible for the incised condition currently observed at the site. A subsequent effort to do restoration in the project reach in 2011, led by Phillip Williams & Associates, Ltd (PWA), and managed by the TCRCD yielded significant findings about the existing conditions of the project reach and established four ground water wells or piezometers, which the Yurok design team has since reoccupied. However, the actual work done was limited to minor excavation and the construction of several willow baffles (PWA 2011), which experienced 100% mortality.

Geological investigations were performed within the project ESL in late March and early April of 2019. March of 2019 was a wet month that included several significant storm events. Flow in Indian Creek at the time was relatively high (around 100 cfs) and lateral inflow from ephemeral hillslope sources was observed. The investigation included excavation of nine test pits upstream from the Indian Creek Road Bridge and installation of piezometers to monitor groundwater levels throughout the upcoming dry season. For current purposes, the test pits are designated according to their approximate valley stations, as plotted on Figure 4B.

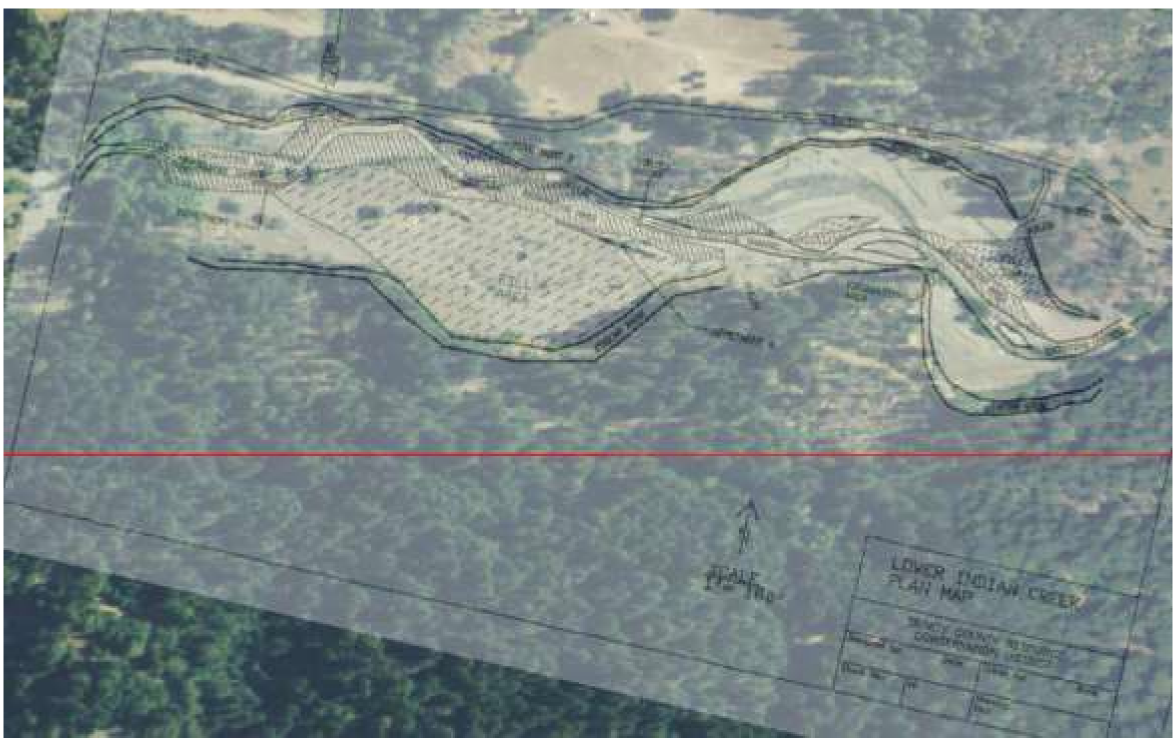

Figure 6. Sketch map of the 1996 Indian Creek rehabilitation project design. Image adapted from PWA (2011). The creek flows from right to left.

While the different pits showed some differences in detail, the stratigraphy exposed in the pits was remarkably consistent throughout the site. In general, the pits revealed an upper layer of poorly sorted sand, gravel, and cobble. This upper layer was typically greyish in color and ranged from 2 to 5 ft in thickness, with a fabric ranging from weakly bedded with signs of imbrication to almost entirely unstructured. Despite a high sand content, the deposits were fully clast supported. We interpreted this layer as valley alluvium that had been reworked by relatively recent flood events. Most pits showed a rather sharp break between the upper greyish layer and a deeper layer of similar material that differed by its inclusion of a significant fraction of boulder-sized material and by its reddish color. The boulders in this deeper layer were generally in the small to medium boulder range, but several large boulders were also observed. For example, three boulders with intermediate axes of 2 ft or more were extracted from the pit at station 3350, and the maximum dimension of one of them exceeded 4 ft.

The thickness of this coarser reddish layer is uncertain due to the presence of water at depth in most of the test pits, but it was in some cases at least 7 ft thick. We interpret this layer as older alluvium that accumulated iron oxide under oxidizing conditions. However, this layer is also relatively young, as evidenced by large pieces of wood found at depths of 12 ft or more near the bottom of pits at stations 3750 and 2100. The wood appeared to be well preserved, presumably due to consistently dry conditions in the well-drained alluvium. In two instances (stations 2350 and 2200), the reddish layer was restricted to thicknesses of 2 ft and 4.6 ft respectively, and overlays another layer of greyish material. In those instances, the return to a grey color at depth could indicate frequent groundwater saturation and reducing conditions. The transition back to a greyish color at station 2350 occurred just 0.6 ft above the level of water observed in the pit, whereas at station 2200 the change occurred 3.4 ft above the observed water level.

In general, the boulder content of the deeper alluvium increases with depth. In particular, pits at stations 2350, 1250, and 450 had a distinct layer of boulders immediately above where bedrock was encountered at depths between 8.3 and 10.3 ft. Bedrock was also encountered in pits at stations 3750, 3350, 2900, and 2100 at depths of ranging from 13 to 13.8 ft. The pit at station 450 was unique in that the material extracted from the pit was much finer than in any other locations. The upper part of that pit consisted of 2.5 ft of clast supported sandy gravel similar to the material in the other pits, but a layer of well-sort sand 2 ft thick was observed below that. About 1.5 ft of sandy gravel was visible beneath the sand layer above water level in the pit, which prevented deeper observation of the pit wall. Material extracted from beneath the water surface consisted of abundant boulders, but also considerable quantities of silt and clay. These finest fractions were almost entirely absent from the other pits.

In addition to water surface elevations in the test pits, water surface elevations in the stream channel adjacent to each pit were collected on the days the pits were open. A comparison between the two water surface profiles provides a snapshot of groundwater-surface water dynamics at the site during a wet period with abundant rainfall. Despite the wet conditions, groundwater levels were as much as 10 ft below the adjacent creek levels in the upstream half of the project site (Figure 5). At the more upstream pits, water was encountered only at the interface between the bedrock floor and the boulder-dominated alluvium immediately above it. Water flowing on the surface apparently infiltrates directly down to that highly conductive layer with almost no lateral migration into the valley sediments. The groundwater level, however, rises above the bedrock floor as the region with riparian vegetation is approached, and by station 2050 is within 1.6 ft of the water level in the channel. At station 1250, which is immediately downstream of the greatest valley constriction, the two water levels are virtually indistinguishable. The gradual decrease in the separation between the two water surface profiles downstream from station 3350 is consistent with the hypothesis that a bedrock sill that functions as a sort of subsurface dam exists somewhere near station 1250.

Groundwater levels observed in the test pits are also plotted on Figure 5 for comparison with the channel bed elevation profile. Groundwater levels in the spring of 2019 were nearly coincident with the elevation of the adjacent channel bed from station 1250 through station 2350. This near equality in water levels is expected, because stream channels are efficient drains that capture any groundwater that may be available above bed level and quickly transmits it downstream. As the channels incises, it taps more deeply into the groundwater and drains it to a lower level. Thus, existence of the distinct knick point at station 2330 draws the groundwater at that location down lower than would be the case in the absence of a knick point. The lower groundwater elevation at the knick point can then propagate upstream due to decreased potential for backwater control on upstream groundwater flow rates. Consequently, water levels observed in test pits at stations 2900 and 3350 are most likely also lower than they would be in the absence of the knick point at station 2330.

Groundwater levels appear to once again fall below surface water elevations downstream from station 1250 (Figure 7). Although it is likely that the falling groundwater level is at least partially due to the presence of highly conductive alluvium at depth, we suspect that channel incision farther downstream exacerbates the groundwater loss in this portion of the project site.

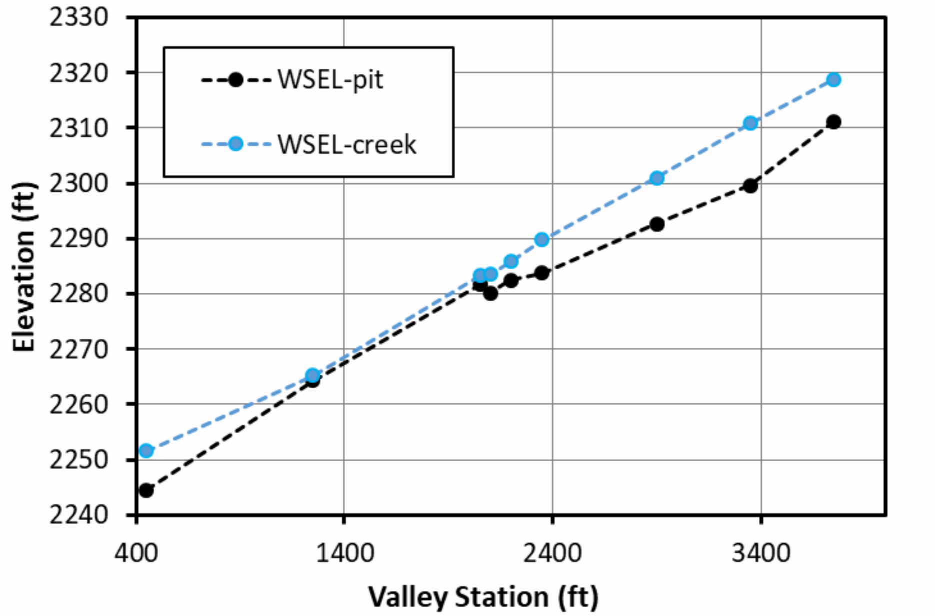

Figure 7. Profiles of water surface elevations in test pits and in the adjacent Indian Creek channel in the spring of 2019

2.3 Hydrologic Setting

The hydrology of Indian Creek, and the Trinity River Basin, is driven by a Mediterranean climate of hot, dry summers and cool, wet winters. Most precipitation occurs October through May as rain at lower elevations and snow at higher elevations (>4,000 feet). Extended high, snowmelt-driven flows occur April through June for most years, and the end of the snowmelt recessional limb leads to the start of summer baseflow typically, in July or August. Baseflow continues from August through October. In November, flow increases with the onset of the wet season as rainfall recharges groundwater and snow is stored in the upper watershed. Baseflows begin to increase as a result, and continue to increase due to seasonal rain-driven floods from November through January. These rain driven floods coincide with the spawning and migration timing of several anadromous fish species. Rainfall and snowmelt-driven flows typically commence in February and last until flows are dominate by snowmelt in April. The February to April elevated and variable flows that occur coincide with the early rearing period for juvenile salmonids.

The U.S. Geological Survey (USGS) has operated and maintained a stream gage, USGS 11525670 INDIAN C NR DOUGLAS CITY CA, from October of 2004 until present. This gage is located at the lower end of Indian Creek near its confluence with the Trinity River. The general patterns described above are reflective by the average monthly flows over the period of record (Table 1). Looking at the probability of exceedance flows from the summer and winter time periods further describes the annual drought/flood cycle that is typical of watersheds in Mediterranean climates.

Table 1. Average monthly and yearly flows were calculated from daily averaged flows recorded at USGS 11525670 INDIAN C NR DOUGLAS CITY CA. Months highlighted in green are periods in the record where some level of surface water disconnection in the project reach could be expected.

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	**Average Monthly**
January		59.52	127.22	12.88	39.10	9.58	78.11	39.64	14.59	28.23	2.89	20.20	99.23	104.43	10.69	70.20	47.77
February		77.73	91.80	37.31	53.98	39.44	119.62	30.02	15.44	21.40	7.35	92.32	53.96	227.60	8.57	148.47	68.33
March		116.57	107.43	34.12	44.54	132.50	73.31	109.62	53.51	24.70	22.21	21.34	163.00	103.14	17.41	139.06	77.50
April		69.17	238.16	20.71	35.57	38.55	102.28	112.83	89.36	29.80	16.05	13.67	48.72	98.73	27.79	120.10	70.76
May		147.19	145.54	14.93	55.19	42.65	90.66	77.79	35.88	13.00	5.89	8.57	24.11	57.29	9.34	97.26	55.02
June		61.04	57.20	7.05	23.92	15.99	82.21	69.18	13.16	6.75	2.34	4.30	11.28	22.36	4.25		27.22
July		21.26	19.81	3.51	8.20	6.19	24.91	24.31	6.31	2.90	0.77	2.20	4.48	8.88	1.60		9.67
August		8.38	9.41	2.13	4.00	3.38	9.07	9.54	2.91	1.81	0.27	1.24	1.74	4.22	0.52		4.19
September		6.19	7.02	1.87	2.93	2.49	6.31	5.92	2.24	1.64	0.68	1.12	1.58	2.90	0.54		3.10
October	7.37	6.48	7.69	5.52	4.59	8.12	10.53	8.28	2.98	3.05	3.10	1.96	10.00	4.10	2.23		5.73
November	9.67	9.80	10.48	5.98	11.70	6.46	13.13	9.04	17.17	4.02	4.85	2.84	20.31	8.83	6.00		9.35
December	44.67	124.88	18.39	11.30	7.11	10.91	50.45	7.64	56.78	3.37	75.11	13.94	52.20	6.16	9.97		32.86
Average yearly	59.02	70.01	13.11	24.24	26.36	55.05	41.98	25.86	11.72	11.79	15.31	40.88	54.05	39.65			

Table 2. Exceedance flows for several probabilities, calculated from USGS 11525670 INDIAN C NR DOUGLAS CITY CA gage data, are presented for the entire year as well as the summer and winter periods. Also presented is the minimum and maximum daily average flows for those periods.

Exceedance Probability	10%	25%	50%	75%	90%	Min CFS	Max CFS
CFS (Daily Average)	92.9	41.2	11.6	5.1	2.3	0.1	956.4
CFS Summer (July/Aug/Sept)	12.7	7.0	3.2	1.7	0.7	0.1	49.3
CFS Winter (Jan/Feb/Mar)	148.7	82.6	38.3	17.8	9.0	2.6	876.6

After initial site visits during the latter half of 2018, the Yurok design team established several gaging stations in the project reach, during the winter and spring of 2019, to monitor stage and discharge at various points in the valley. One of these sites re-occupied a gaging station established by the North Coast Regional Water Quality Control Board (NCRWQCB), as part of a 2016 and 2017 effort to look at instream flows and water use in tributaries to the Trinity River (NCRWQCB 2019). These stations are being monitored using continuous temperature and water level data loggers, Onset® HOBO® Water Level (30’) Data Logger, and calibrated with instantaneous measurements of discharge using, Sontek® Flow Tracker® 2. Ground water wells established in 2011 by PWA were re-occupied during the summer of 2018 and the same continuous temperature and water level loggers described above were installed in the winter of 2019. All of the ground water wells established during the 2019 geological investigation (Figure 4B) are also being monitored using the same continuous data loggers, installed in May of 2019. Subsurface flows were observed in September of 2019 while the USGS gage was reading 4.52 cfs. The upstream extent was near valley station 2300 and the downstream extent was near valley station 1800 on 9/6/2019. This information was used to generate expected subsurface flows for the historic record (Table 1).

Table 3. *Preliminary gaging data from established transects within the project reach compared to data from USGS 11525670 INDIAN C NR DOUGLAS CITY CA.*

	Discharges (CFS)						
Date; Time	Top of main Valley (Station 3600)	Main Valley (Station 2600)	Upstream of vegetation (Station 1700)	At Indian Creek Road Crossing (Station 350)	Below Indian Creek Road Crossing (Station 0)	USGS Gauge 11525670 CFS (Indian Creek)	Time
12/18/2018; 12:00	9.3	N/A	9.4	6.8	N/A	12.1	1200
12/28/2018; 10:00	9.9	N/A	N/A	N/A	N/A	13.0	1000
1/2/2019; 12:00	N/A	N/A	N/A	4.1	3.5	8.4	1200
1/9/2019; 11:30	122.1	N/A	110.2	107.2	122.8	130.0	1130
2/7/2019; 13:45	N/A	N/A	N/A	N/A	74.9	86.6	1345
2/12/2019; 13:45	N/A	N/A	N/A	N/A	46.4	53.2	1345
5/24/2019; 12:00	91.9	78.5	103.2	94.3	N/A	92.3	1200
6/6/2019; 13:30	57.4	49.2	54.2	50.1	N/A	52.1	1330

2.4 Biologic Setting

The Indian Creek watershed supports a diverse array of fish and wildlife species normally found throughout the Trinity River watershed. The following section details the species and their known status. Project level mitigation measures have been included in the project design to minimize or negate anticipated project level impacts on the biological resources of Indian Creek within and downstream of the project area.

2.4.1 Fish Resources

Indian Creek is known to support four anadromous and six resident fish species. The anadromous fish species utilizing the Indian Creek Watershed include fall Chinook Salmon (Oncorhynchus tshawyscha), Coho salmon (O. kisutch), Steelhead (O. mykiss), and Pacific Lamprey (Entosphenus tridentatus). Summer-run steelhead and spring-run Chinook salmon are not believed to occur in Indian Creek due to a lack of large pools and cold water. The resident fish species known to utilize Indian Creek are brown trout (Salmo Trutta), rainbow trout (O. mykiss), speckled dace (Rhincthys osculus), three-spined stickleback (Gasterosteus aculeatus), Klamath smallscale sucker (Catostomus rimiculus), and sculpin (Cottus sp.).

There are several barriers to migration within the Indian Creek watershed, which limit the temporal and spatial variability of fish movement (Figure 8). The most downstream barrier has been documented in the project reach and extending downstream for approximately 1.2 miles to the Spring Gulch confluence (DPA 1991). This is considered a temporal barrier as subsurface flows that occur in the project reach between July and the onset of fall rains block fish movement during this time. The next known barrier to fish migration is located approximately 1.1 miles upstream of the project area in South Fork Indian Creek. This barrier is listed in the California Department of Fish and Wildlife (CDFW) Passage Assessment Database (PAD) as a 9 foot waterfall. The South Fork Indian Creek barrier is considered a total barrier to all fish species and only resident fish are believed to occur upstream of here. The last known barrier to fish migration is located on the mainstem of Indian Creek approximately 2.25 miles upstream of the project reach. This barrier is listed as a set of falls in a bedrock chute. This mainstem Indian Creek barrier is considered a total barrier to all fish species and only resident fish are believed to occur upstream of this point.

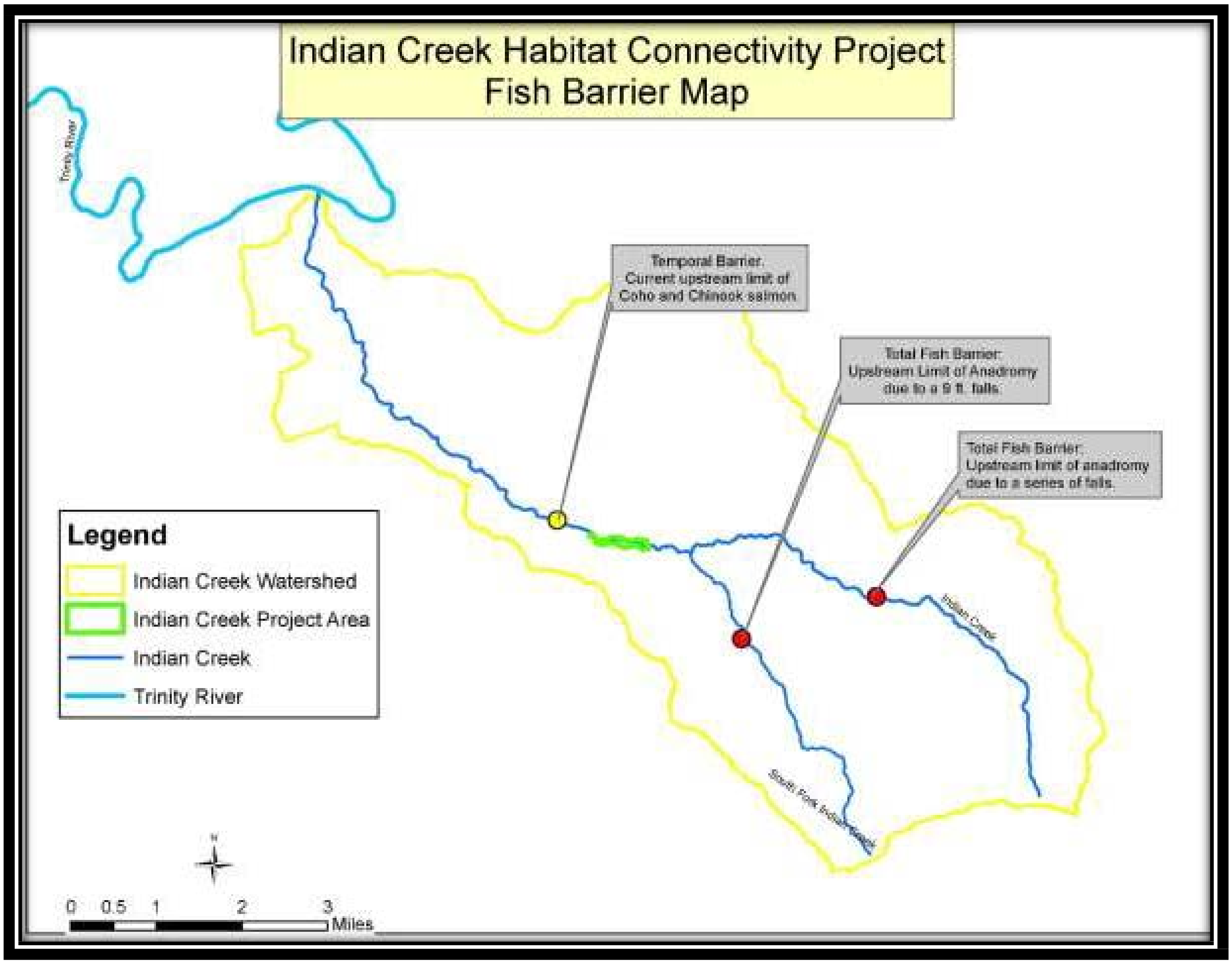

Figure 8. Indian Creek sub-watershed with physical barriers to anadromy indicated by red circles and temporal barrier indicated by yellow circle.

Fall Chinook Salmon

Chinook salmon found in Indian Creek are part of the Upper Klamath/Trinity River (UKTR) Chinook Salmon Evolutionarily Significant Unit (ESU). Currently there is no distinction made between fall-run Chinook Salmon and spring-run Chinook Salmon within this ESU. However, this ESU is currently undergoing a status review to determine if listing of spring-run Chinook Salmon is warranted under the Endangered Species Act (ESA).

Adult UKTR fall Chinook Salmon enter the Klamath system, from the ocean, in August to begin their upstream migration to the spawning grounds. Fall Chinook Salmon spawning typically occurs between October and December. Adult fall Chinook Salmon have been documented utilizing the mainstem of Indian Creek for spawning. CDFW (formerly CDFG) tributary spawning surveys conducted in the lower 1.5-mile reach of lower Indian Creek between 1990 and 1995 documented a total of seven live Chinook Salmon during this time, with five of those fish occurring in 1995. (CDFG 1991-1995). The upper extent of Chinook Salmon spawning for Indian Creek is thought to be near the Spring Gulch confluence (DPA 1991) and approximately 1.2 miles downstream of the project. DPA personnel observed adult fall Chinook Salmon attempting to migrate through the project reach with “great difficulty”.

Coho Salmon

Coho Salmon found in Indian Creek are part of the Southern Oregon Northern California Coast (SONCC) ESU. This ESU was listed as threatened under the ESA in 1997. A subsequent Critical Habitat (CH) designation was added in 1999 for this species.

Adult SONCC Coho Salmon enter the Klamath system, from the ocean, in September to begin their upstream migration to the spawning grounds. SONCC Coho Salmon spawning typically occurs between October and December. CDFW tributary spawning surveys conducted in the lower 1.5-mile reach of lower Indian Creek between 1990 and 1995 documented a total of two live Coho Salmon during this time (CDFG 1991-1995). The upper extent of Coho Salmon spawning for Indian Creek is likely near the Spring Gulch confluence, which is approximately 1.2 miles downstream of the project.

Steelhead

Steelhead found in Indian Creek are part of the Klamath Mountain Province (KMP) Distinct Population Segment (DPS). This DPS is currently not listed under the ESA. This DPS comprises fall-, winter-, spring-, and summer-run steelhead. Because of these overlapping runs of steelhead, discussion of steelhead stocks is complex. All runs of steelhead into the Trinity River will be grouped together to simplify discussion of Indian Creek utilization by steelhead. Adult steelhead enter Indian Creek during high winter flows and commence spawning from January thru March. BLM fish surveys and CDF&G reports indicate juvenile steelhead presence throughout the watershed. However, the upper limits of steelhead vs. resident trout habitat in the headwaters is unclear. BLM fish surveys from 1978-81 document steelhead/resident trout present in the major headwater tributaries which include the South Fork, Canonball Creek, and Corral Creek. The only documentation of steelhead presence in any of the downstream tributaries is a BLM fish survey of Spring Gulch in 1981. However, steelhead are considered the most numerous and prevalent anadromous fish in the Indian Creek watershed.

Pacific Lamprey

The spawning run of anadromous adult lamprey occurs from May thru September. The adults will remain in the system until spawning commences the following spring. There is little current data on adult lamprey or juvenile (ammocoetes) distribution and abundance in Indian Creek.

Resident Fish

Resident salmonids present in Indian Creek are Brown Trout (Salmo trutta) and Rainbow Trout (Oncorhynchus mykiss). BLM fish spawner survey field notes from 1979-1980 report adult Brown Trout spawning in lower Indian Creek from the confluence with Trinity River to Goods Gulch.

Resident Rainbow Trout are present throughout the watershed, but are referred to as Rainbow Trout (vs. steelhead) only in the headwater tributaries. Rainbow Trout occurrence above presumed natural barriers in the South Fork and in the high gradient reach of the North Fork, including Canonball and Corral Creeks, are classified resident and non- anadromous here.

Non-salmonid species present in the watershed include Speckled Dace (Rhinicthys osculus), Three Spine Stickleback (Gasterosteus aculeatus), Klamath Small Scale Sucker (Catostomus rimiculus), and sculpin (Cottus sp.). Distribution and abundance of the resident fish of Indian Creek is relatively unknown, however they are widespread throughout the watershed.

2.4.2 Herpetofauna

The following species of aquatic dependent animals are also found in Indian Creek, including the project reach; Foothill Yellow-legged Frog (FYLF, Rana boylii), Pacific Chorus Frog (Pseudacris regilla), Garter Snake (genus Thamnophis), Western Pond Turtles (Actinemys marmorata), and Western Toad (Anaxyrus boreas).

Foothill Yellow-legged Frogs (FYLF, Rana boylii) were recently accepted as a candidate species for listing under California's Endangered Species Act. In contrast, FYLF are common and abundant throughout the Indian Creek watershed, including the project reach. FYLF breeding and egg oviposition occurs from early April to early June, tadpole development occurs from mid-May to early September, and sub-adult development occurs from mid-July through late September.

2.4.3 Wildlife

The following species that require special management considerations are known to occur in the Indian Creek watershed; Northern Spotted Owl (Strix occidentalis caurina), Bald Eagle (Haliaeetus leucocephalus), Pacific Fisher (Pekania pennant), Balcktail Deer (Odocoileus hemionus), and Roosevelt Elk (Cervus canadensis roosevelti).

3 PROPOSED DESIGN

3.1 Design Approach

The primary objective of the proposed Indian Creek Connectivity design is to increase the extent and duration of groundwater-surface connectivity within the project area. As described in existing conditions sections, the creek loses sufficient water into the subsurface in the upstream half of the project area. Water lost to the subsurface near station 3300 at the upstream end of the site re-emerges as surface flow near station 1700, but the intervening stream reach is frequently dry and that stretch of valley is nearly devoid of riparian vegetation. The data evidence indicates this situation is partly due to unusually large hydraulic conductivity of the valley alluvium, particularly near the interface between the alluvium and underlying bedrock. However, it is also partly due the incised condition of the stream channel, which represents an efficient groundwater drain.

We propose to increase groundwater residence times and groundwater elevations by implementing a "stage 0" restoration approach. First described by Cluer and Thorne (2013), the stage-0 concept has been applied to restoration of ground water connectivity in impaired alluvial valleys with incised channels at multiple sites around the region (Powers et al. 2019). We believe a stage-0 approach will increase the lateral habitat connectivity of the valley bottom during the wet season and the duration of surface flows during the annual dry period at the Indian Creek Connectivity and Restoration project site. We also expect this approach to facilitate the revegetation of the valley bottom, providing allochthonous inputs to the aquatic ecosystem and improving wildlife habitat connectivity.

Stage-0 design is the best available science for restoring an alluvial reach with disconnected floodplains and groundwater due to channel incision, and involves excavation of high portions of the valley floor and filling in low areas to create a valley grade surface that approximates the average longitudinal profile of the valley floor. The development of the valley grade surface for the Indian Creek Stream Connectivity and Restoration Project is detailed in Appendix A of this document. This valley grade surface has zero slope perpendicular to the valley axis, but slopes at a roughly constant rate parallel to the valley axis. Although valley grade surfaces are defined by sloping planes at the large scale, as constructed they incorporate micro-topography and roughness elements such as vegetation and wood that slow flow and promote hydraulic diversity. Roughness elements are applied at a 50% higher rate on fill surfaces compared to cut surfaces to prevent the channel from reoccupying its previous course, over less consolidated material. As initially constructed, valley grade surfaces lack a defined low-flow channel and so are perpetually in a state of flood. Water spreads out over a wide area, providing abundant salmonid rearing habitat and efficiently recharging groundwater supplies. In time, we expect a multi-thread network of anastomosing channels with easily overtopped banks to develop. Because even minor floods can spread widely across the valley floor, stream power and sediment transport capacities are limited. Consequently, the potential for erosion that could re-incise the channel decreases, whereas the potential for sediment deposition, which promotes dynamic processes such as channel migration and avulsion that maintain habitat diversity, increases.

3.2 Design Features

The project work area covers a total of 21.4 acres. Total cut and fill quantities are nearly balanced, with approximately 32,700 yd^3 of fill required to reach design grade. The design cut is slightly less at about 28,200 yd^3, but additional areas for harvesting material to meet the fill requirements are identified. See section 3.4 for a detailed accounting of cut and fill quantities. The specific elements that comprise the present design are described below and illustrated in Figure 9.

<u>VG-1 Valley Grade Surface</u>

VG-1 is the main valley grade surface that approximates the average longitudinal profile of the valley floor through most of the upper two-thirds of the project site. This portion of the project site is where groundwater connectivity is most impaired and the primary target of the proposed restoration design. Subtracting the valley grade surface from the existing surface yields a cut/fill surface indicating the depth of fill to be placed in existing depressions and the depth of excavation required in elevated parts of the valley. The methods used to develop the valley grade surface are intended to result in an approximate balance between cut and fill quantities. Those methods are discussed in a later section on design development. As currently graded, VG-1 covers 14.45 acres and requires 21,570 yd^3 of cut and 24,960 yd^3 of fill, for a net fill of 3,390 yd^3.

<u>SG-1 Selective Valley Grade</u>

SG-1 is a modified valley grade surface in which portions of the SG-1 area are selectively excluded from grading. The SG-1 grade surface and cut/fill surface is similar to the VG-1, but it differs in that the design grading will applied selectively. Some areas will be left lower than the valley grade and other areas will be left higher. We expect to identify small-scale deviations from the design grade in the field prior to or during construction, but a few larger deviations that have already been identified are presented as independent design elements below. Although a perennial connection between the stream and groundwater currently exists in SG-1, grading in the area is nonetheless needed to address the incised condition of the existing channel as well as to reduce the potential for future incision. Filling the incised channel in the SG-1 area is analogous to plugging a drain that draws down the local groundwater pool and removes backwater control on the subsurface flow of groundwater farther upstream. A small local plug with a steep downstream slope, however, would be likely to initiate headward migration of a new knick point that extends a new cycle of channel incision well upstream from SG-1. Thus, it is important for the plug to extend well downstream at a mild slope. In the current design, SG-1 covers 3.33 acres and requires 6,380 yd^3 of cut and 6,570 yd^3 of fill, for a net fill of 190 yd^3.

<u>FT-1, FT-2 Fill Tapering</u>

FT-1 and FT-2 are regions in which the valley grade surfaces described above transition back to existing ground. In FT-1, the grading was developed by matching the valley grade surface at the downstream end of SG-1 and extending that surface downstream at a constant slope of 0.027 until the surface meets the channel bed elevation at station 720. We chose that station for blending the transition surface into the existing ground because the local channel gradient is relatively low at that point. In FT-2, the grading was developed by extending the valley grade elevation at the upstream end of VG-1 upstream until it meets the channel bed. In both FT-1 and FT-2, the fill portions of the cut/fill surfaces are implemented whereas most surfaces above the valley grade elevation will be left at existing grade. Together, FT-1 and FT-2 cover 1.6 acres and require 1,170 yd^3 of fill.

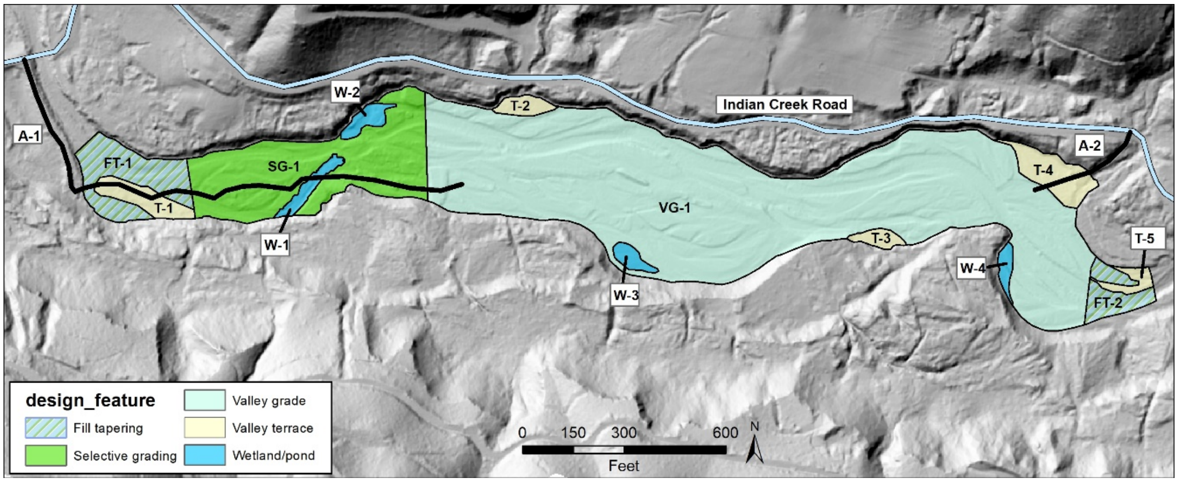

Figure 9. Design features comprising the proposed Indian Creek Connectivity project. The creek flows from right to left.

T-1, T-2, T-3, T-4, T-5 Valley Terraces
These units are relatively high, barren areas within the valley that can be excavated to harvest additional fill material as needed to balance cut and fill throughout the site. T-1 and T-5 are high portions of the valley bottom adjacent to the FT-1 and FT-2 fill tapering areas at the upstream and downstream ends of the site. T-2, T-3, and T-4 are alluvial fan terraces along the valley margins in the central part of the site. T-2 is located where Frietas Creek enters the valley bottom and T-4 is at the mouth of an unnamed tributary where access road A-2 enters the valley. T-3 is a small alluvial fan located where a mining sluice discharges into the valley from the south. Final grade at these locations will likely be somewhat higher than the adjacent valley grade surface, but their final elevations will depend on the volume of additional fill material needed to complete nearby surfaces. Together, these areas cover 1.44 acres and contain up to about 7,800 yd^3 of material that can be harvested if needed.

W-1, W-2 Wetland/Ponds
These features are relatively large areas within SG-1 that will not be graded. W-1 is an existing high-flow channel that is 1 to 2 ft lower than the design valley grade surface. It will remain at its existing elevation and will likely function as the baseflow stream channel after project completion. W-2 occupies a portion of the existing Indian Creek channel that includes a relatively deep pool. That area will remain at its existing elevation and will function as an off-channel pond and wetland after project completion. Together, these features cover 0.37 acres.

W-3, W-4 Wetland/Ponds
These features identify excavated depressions in the valley grade surface. W-3 will be excavated to about 1.5 ft below the adjacent valley grade to form a small wetland (0.13 acres) near the south valley margin at the center of the site. W-4 will be excavated to as much as 4 ft below the adjacent valley grade to create a small pond (0.12 acres) at the base of bedrock knob near the upstream end of the site. Cut associated with these features is included in the grading given for the VG-1.

A-1, A-2 Access Roads
The A-1 access road is an existing track on top of a lateral levee at the downstream end of the project site. It terminates about 800 ft upstream from the Indian Creek Road Bridge. Upstream from the levee, A-1 occupies patches of open ground and largely avoids existing vegetation before reaching the upper two-thirds of the site, which is almost completely barren of vegetation. The A-2 access road accesses the upstream end of the site and occupies a route used for a 2012 project implemented by the TCRCD.

3.3 Existing Vegetation and Revegetation

Much of the Indian Creek project site is currently devoid of vegetation. Patches of continuous riparian vegetation are mostly limited to the upstream half of SG-1 and to narrow strips along portions of the existing stream channel. Higher parts of the valley are typically barren or support only a sparse scattering of small shrubs. Because most of the existing vegetation at the site lies at the lower elevations, it is located in areas where grading plans call for fill or where the depth of cut needed to reach design grade is negligible. In most cases beyond the existing channel bed, less than 3 ft of fill is required to reach design grade (Figure 10). As riparian vegetation is adapted to the dynamic scour and fill processes that characterize the riverine environment, we believe that the vast majority of the woody riparian vegetation in fill areas will survive. Those fill or zero-cut areas where survival of the existing vegetation is expected span 11.45 acres, or 54% of the total work area (Figure 11). We have also identified additional patches of vegetation outside of the zero-cut area for preservation. Although those patches are in areas where excavation is planned, the depth of the cut is such that it will be possible to leave desirable vegetation on low pedestals a foot or two above the general valley grade. An added benefit of this preservation strategy, which saves an additional 0.55 acres of existing vegetation, is that the patches of slightly higher ground and the plants they support also serve as ready-made floodplain roughness elements. Beyond the regions of zero-cut and patches of selectively preserved vegetation, almost all of the remaining work area (9.15 acres) consists of essentially barren upland. Canopy removal is anticipated in just one small area along the southern edge of the valley where excavation to widen the valley requires the removal of about a dozen medium-sized conifers. That area, outlined in red on Figure 11 covers 0.25 acres. We will utilize any trees removed from that area in large wood structures or other floodplain roughness elements.

Revegetation efforts will be limited to excavated wetland features (W-3 and W-4), and areas of fill. Wetland areas will be planted with container stock of emergent herbaceous plants and willow cuttings or clumps will be used to provide roughness within the fill sections of VG-1, SG-1, FT-1 and FT-2. All other valley grade surfaces will be expected to exhibit natural recruitment of vegetation on surfaces, which will self-select for proper speciation as the new anastomosed channel and adjacent floodplains take shape and adjust after construction. Seeding and mulching with native grasses will occur at access points A-1 and A-2.

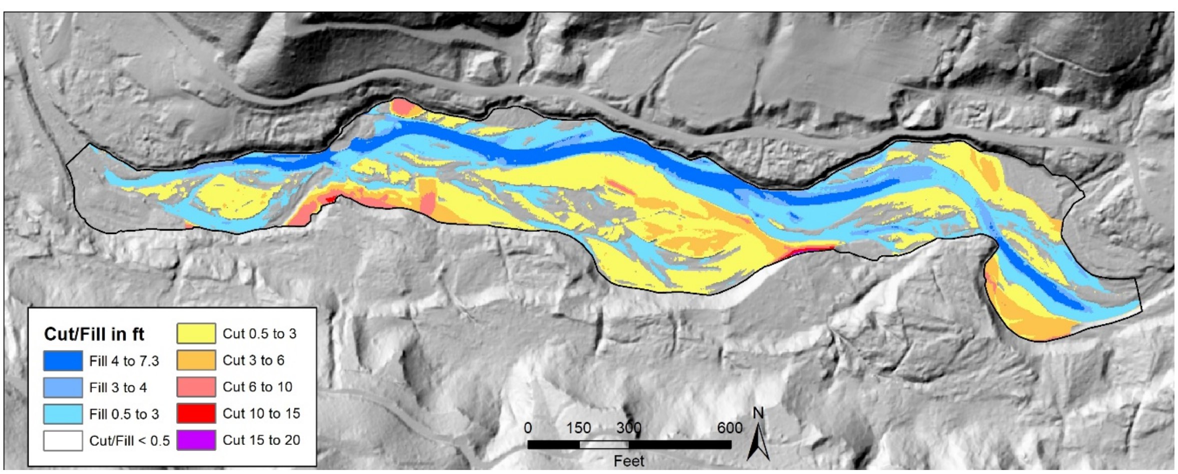

Figure 10. Cut and fill depths within the project work area. The creek flows from right to left.

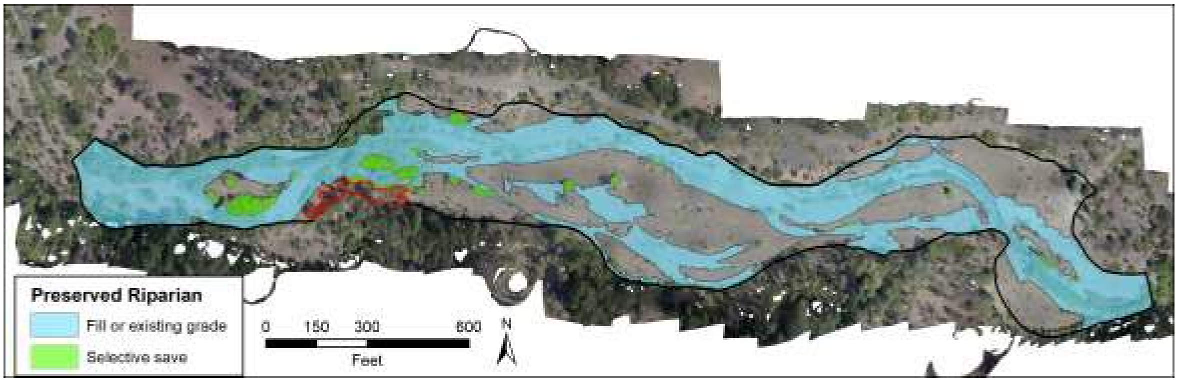

Figure 11. Existing vegetation will be preserved almost everywhere it exists at the project site. The current design requires the removal of existing canopy only in the area outlined in red. The creek flows from right to left.

3.4 Quantities

The total fill quantity needed to meet design grade is about 32,700 yd^3 (Table 4). This exceeds the total cut required to meet design grade by about 4,500. We therefore identify five fill harvesting areas, denoted T-1 through T-5, that will be excavated as needed to supply the necessary fill material. Those areas consist of unvegetated valley terraces or alluvial fan terraces that together have the potential to yield an estimated 7,800 yd^3 of fill while remaining at or above the adjacent valley grade surfaces. The actual quantity of fill harvested from each of these terrace surfaces will likely be smaller than the harvest potential listed in Table 4, depending on proximity to the locations where additional fill is needed during construction.

Table 4. Cut and fill quantities by grading area. All volumes in yd^3.

Grading Area	Cut	Fill	Net	Harvest Potential
FT-1	160	420	Fill 260	
SG-1	6,385	6,570	Fill 190	
VG-1	21,570	24,960	Fill 3390	
FT-2	70	750	Fill 680	
Totals	28,185	32,700	Fill 4,500	
T-1				3,370
T-2				900
T-3				550
T-4				2,500
T-5				480
Total				7,800

4 SUMMARY

The proposed Indian Creek connectivity and restoration project employs a "Stage-0" rehabilitation approach to raise groundwater elevations and improve surface water connectivity through a 3,300 ft reach of Indian Creek. This reach of stream was severely impacted by historical gold mining that buried the valley in mining debris and altered the hydraulic properties of the valley substrate. Consequently, the central portion of the project reach runs dry during the late summer and early fall of most years. The restoration design is expected to shorten the period when low flows present a barrier to anadromous fish passage and will improve ecologic and geomorphic conditions by promoting the establishment of riparian vegetation and increasing the residence time of water and sediment in the reach.

The stage-0 restoration strategy proposed for this project involves re-grading the valley bottom to create a laterally-flat valley bottom that slopes downstream at a nearly constant gradient. Although the constructed valley surface will lack a defined channel, it will incorporate complex microtopography and hydraulic roughness elements generate hydraulic and ecological diversity. Due to the absence of a continuous channel that rapidly conveys water through the reach, surface water and groundwater are retained within the reach for extended periods. Rather than flowing rapidly downstream and drawing down the groundwater table, surface flow is spread over a large portion of the valley bottom where it can recharge the alluvial aquifer. In addition to increasing aquatic habitat availability during low-flow periods, spreading the flow over a large portion of the valley bottom spreads the erosive energy of floods over a wide area, thereby discouraging channel incision.

Creating the geomorphic grade surface proposed herein will require approximately 32,700 yd^3 of fill and an equal volume of cut. The vast majority of the excavated material will be sourced in close proximity to the location where it is used as fill, so material handling and transportation costs will be minimized.

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APPENDIX A. STAGE-0 VALLEY GRADE DEVELOPMENT

Valley grade surfaces utilized for this design were developed following a "stage-0" conceptual model in which valley grade lines are statistically fit to the existing valley topography. The first step in this development is to define the region considered to be the "valley." This is an important step, in that the inclusion (or exclusion) of higher terrain along the valley margins will increase (or decrease) the elevation of the final valley grade surface. Once the extent of the valley has been defined, the topographic data within that extent (aerial LiDAR in this case) can be extracted.

The existing topography is then projected onto the valley centerline. Each station on the centerline profile is then assigned the mean elevation of all topographic points that project to that station. The result is a longitudinal profile of mean valley elevations.

If it is reasonably straight, a valley profile can be statistically fit with a line that defines the valley grade line, or a valley profile that displays constant curvature can be fit with a quadratic equation. A long valley profile, however, may not maintain a constant slope or constant curvature. In the case of the Indian Creek project site, slight undulations in the valley profile create numerous inflection points that would require a polynomial of high order to fit. A reasonably close fit, however, is desirable because it minimizes the cut and fill volumes required to reach design grade as well as the net cut/fill. We therefore chose to divide the Indian Creek valley profile into four sections plus the fill tapering segments at each end, and fit each section independently (Figure B-1). The area of selective grading downstream from station 1700 was split into two sections (SG-1a and SG-1b) that were fit separately. Likewise, the main valley grade upstream from station 1700 was split into a long section with relatively constant slope (VG-1) and a short upper section that displays convexity near the upstream boundary of the project area (VG-1 upper).

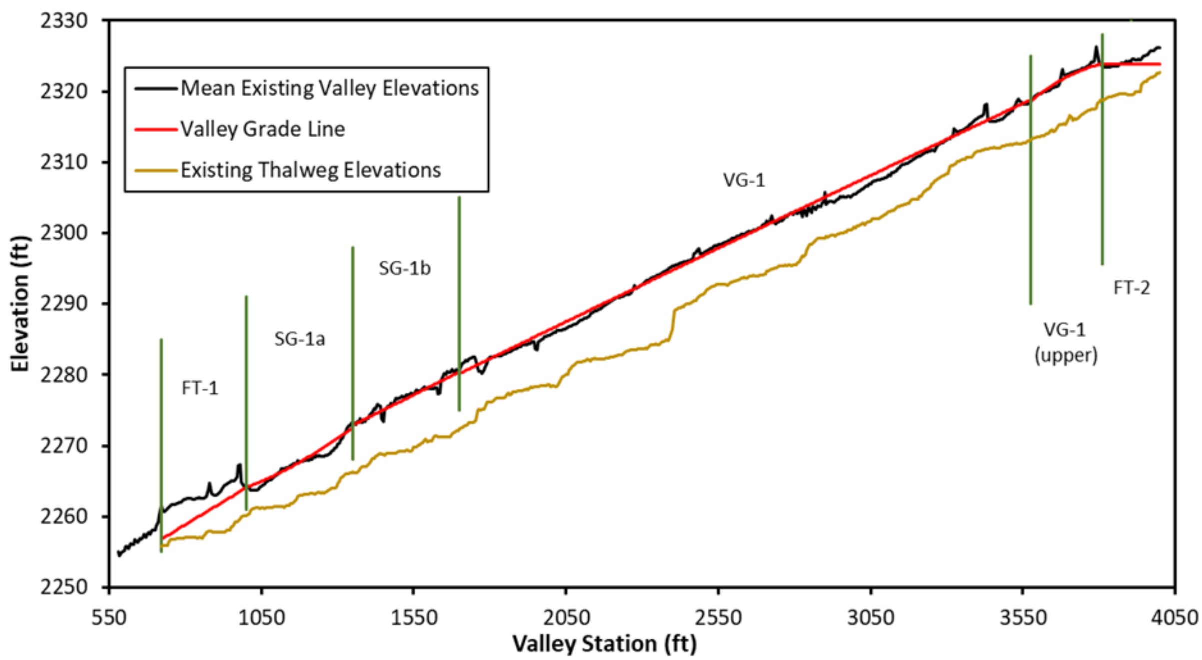

Figure B- 1. The valley grade line fit to six sections of the mean valley profile developed from LiDAR data. The fitted valley grade line is shown in red, boundaries of valley sections 1 through 6 are indicated in green.

Transitions from the ends of the valley grade surfaces to the existing ground in FT-1 and FT-2 were accomplish by extending the fill components of the valley grades surfaces upstream and downstream while ignoring any cut implied by the grade surfaces. As explained in the feature descriptions, the elevation at the downstream end of FT-2 was carried upstream with zero slope until it blended into the existing channel bed (Figure B-1). Similarly, the elevation at the upstream end of FT-1 was carried downstream at a slightly larger slope than the channel bed until it blended into the bed at a location where the local channel slope begins to flatten.

Each section of the valley grade line was fit to the corresponding subsection by optimizing an n-degree polynomial via least squares. Depending on the complexity of the valley section, a linear or quadratic polynomial was used. In some cases, the polynomial parameters were adjusted slightly from the best statistical fit in order to match elevations where one section ends and the next begins. The fitted valley grade lines for the six valley sections are as follows:

FT-1: $Y = 0.0261X + 2238$

SG-1a: $Y = 2.25E{-}05X^2 - 2.85E{-}2X + 2270.1$

SG-1b: $Y = 2.15E{-}2X + 2243.9$

VG-1: $Y = -2.10E{-}07X^2 + 2.17E{-}2X + 2243.9$

VG-1(upper): $Y = -5.21E{-}05X^2 + 0.407X + 1530$

FT-2: $Y = 2323.9$

where Y is the elevation of the valley grade line and X is the distance upstream from the profile origin. The valley grade elevations produced by these equations were then transferred to a valley surface grid.