North Fork Salmon River Red Bank Off-Channel Fisheries and Riparian Habitat Enhancement Project

Final Basis of Design Report

May 2017

Prepared for:
Salmon River Restoration Council
PO Box 1089
25631 Sawyers Bar Road
Sawyers Bar, CA 96027

California Department of Fish and Wildlife
Fisheries Restoration Grants Program (P1410524)

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Cover Photo: Salmon spawning in the NF Salmon River at Red Bank Bar (October 22, 2016)

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1 INTRODUCTION

1.1 Project Location and Need

The Red Bank project area is located along the North Fork Salmon River (NF Salmon River) approximately nine river miles upstream of its confluence with the South Fork Salmon River near Forks of Salmon, California (Figure 1-1). The project area includes a wide overbank bar complex on river left (as looking downriver) that contains a frequently inundated Primary Side Channel and multiple high-flow side channels. The lower end of the Primary Side Channel contains several groundwater-fed perennial pools where salmonids have been observed rearing during the dry season (Figure 1-2). The entire project area is located on United States Forest Service (USFS) lands, within the Klamath National Forest.

The Salmon River is one of the most biologically intact sub-basins of the Klamath River and has been identified by the Klamath National Forest as the watershed with the best anadromous fisheries habitat in the Forest. The Salmon River hosts all the native anadromous fish runs present in the Klamath River basin, including coho, spring and fall-run Chinook, summer and winter steelhead, Pacific lamprey, and green sturgeon; yet they face a risk of extinction. These salmonids are either protected under California and/or Federal Endangered Species Act or listed by the State and Federal government as a sensitive species that is "of concern" and "at-risk of extinction."

Problems facing salmonids and other aquatic species on the Salmon River include invasive species, barriers to fish passage, depleted large woody debris, high sediment loads from the extensive road system, timber harvesting and hydraulic mining impacts, along with large wildfires, limited riparian function, unstable spawning gravels, and temperature impairment (NMFS, 2014). Remnant mine tailings and riparian disturbance continue to affect coho salmon habitat in the Salmon River and mined-over floodplains and terraces have remained poorly vegetated many decades after large-scale mining has ended.

The NMFS Southern Oregon/ Northern California Coast (SONCC) Coho Salmon Recovery Plan (NMFS, 2014) states that summertime water temperatures and lack of winter rearing habitat are the greatest stressors for juvenile coho in the Salmon River. The highest priority for recovery of coho on the Salmon River was identified to be improving the quality and extent of rearing habitat and refugia, including improving connectivity to existing off-channel habitat, constructing new off-channel habitat, increasing large woody debris, and protecting or enhancing potential cold-water refugia areas.

1.2 Importance of Off-Channel Habitat for Rearing Coho Salmon

Studies have shown the importance of channel margins and groundwater-fed off-channel and side-channel habitats for fry and rearing juvenile coho salmon, which prefer slower water velocities than steelhead or Chinook salmon (Lestelle, 2007; Roni et al., 2006; and Blackwell, et al., 1999; among many). Off-channel habitats may provide both summer and winter rearing habitat. Seasonally groundwater-fed off channel habitat, particularly channels and ponds with cooler temperatures in the summer and warmer temperature in the winter have been called "hotspots of production" for aquatic species (Stanford and Ward, 1993). It has been observed by Lestelle (2007) that SONCC coho salmon utilize groundwater channels more than any other salmonid species in the summer months due to their particularly low velocity and cooler water temperatures in the summer. Studies have shown that when water temperatures are elevated, juvenile coho salmonids find refuge in deep pools and areas with dense shade and large wood cover (NMFS, 2014; Brown et al. 1994).

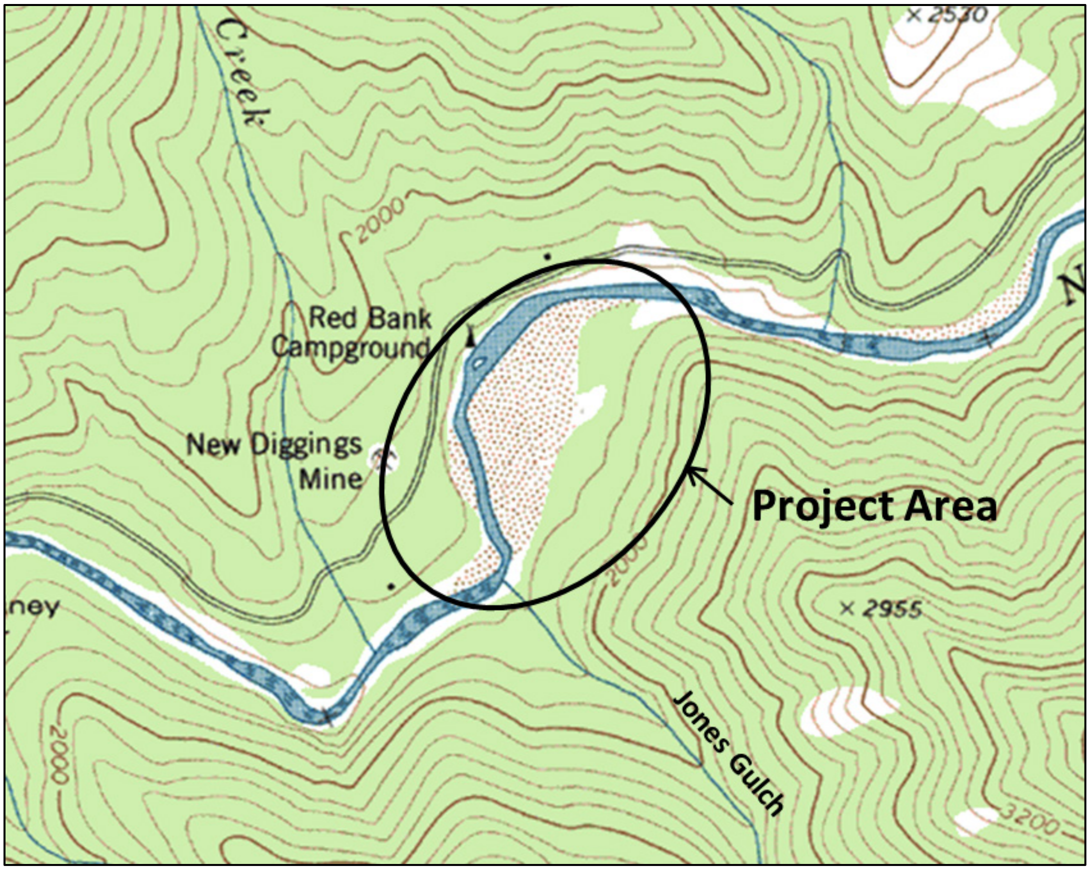


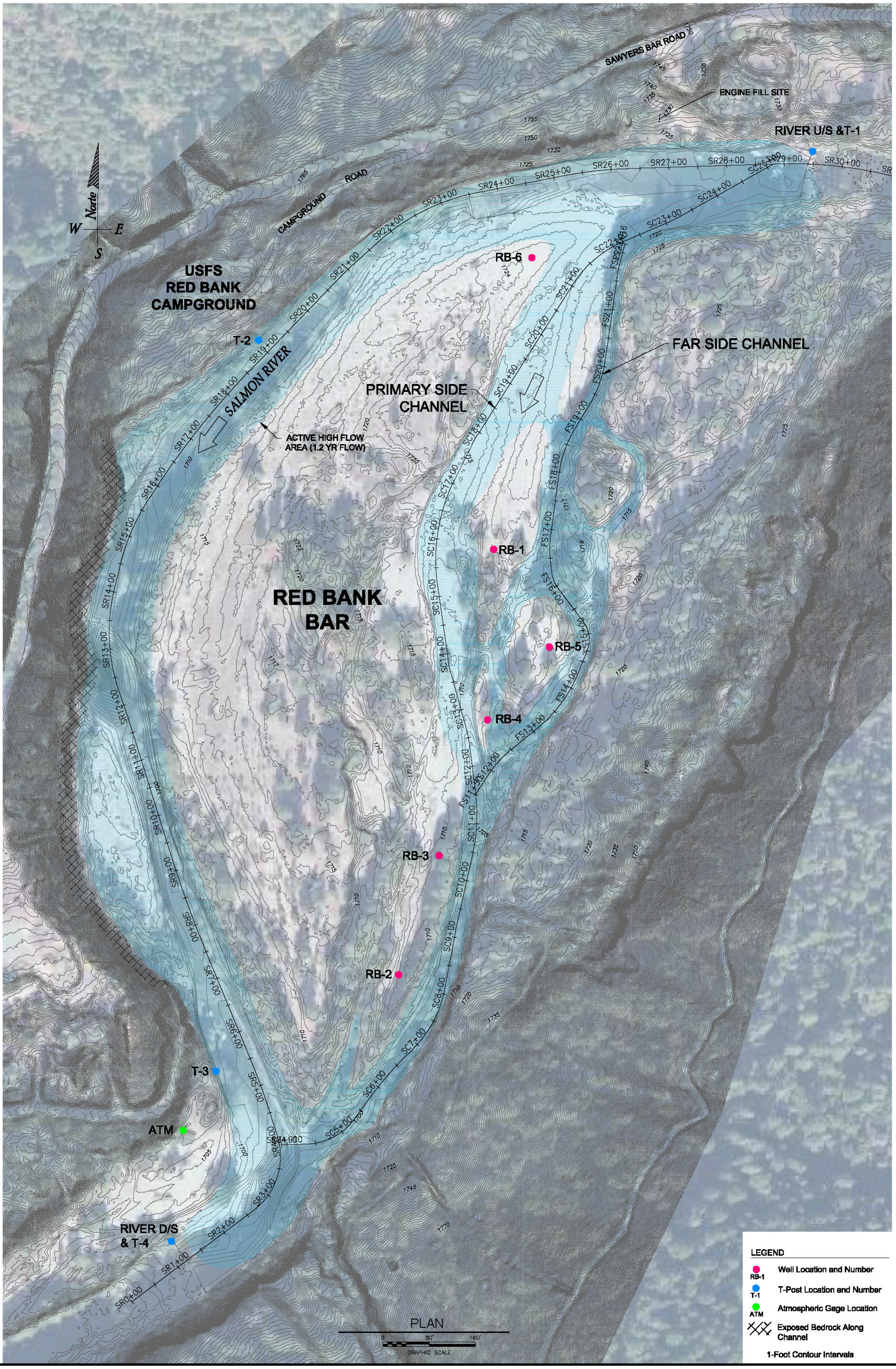
Figure 1-1. Location of the Red Bank Bar project area on the NF Salmon River upstream of Forks of Salmon in Siskiyou County, California (USGS Sawyers Bar Quadrangle).

During winter high flows, coho have been found to move into and overwinter in river margin features such as backwater alcoves and groundwater-fed off-channel habitat features, which are often warmer than the main river, and provide refugia from the higher velocities of the main channel during elevated flows. Juvenile coho that over-winter in these areas commonly experience survival rates substantially greater than those that rear in main channel habitats due to less energy expenditure and warmer water temperatures, as summarized in Lestelle (2007). This survival difference can have a tremendous influence on whether a population, either in its entirety or some of its components, is sustainable under prevailing environmental conditions.

Coho salmon also prefer the presence of complex wood more than other salmonid species. Due to their poorer swimming capability, they have been found to favor the slow water in the scour pools and the cover provided by large wood that reduces predation (Lestelle, 2007).

1.3 Background

The Salmon River Restoration Council (SRRC) fisheries program coordinates the bulk of monitoring, assessment and restoration in the Salmon River for anadromous fisheries. In 2008, the SRRC received a grant to conduct an assessment that evaluated riparian conditions and fisheries habitat throughout the Salmon River, and to develop conceptual designs for sites prioritized for restoration.



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Salmon River Restoration Council
RED BANK OFF-CHANNEL
FISHERIES AND RIPARIAN HABITAT DESIGN

MAP OF PROJECT AREA AND
LOCATIONS OF MONITORING STATIONS

VERIFY SCALE

THIS BAR IS
ONE INCH LONG
AT FULL SCALE

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SRRC contracted Pacific Watershed Associates (PWA) to develop conceptual designs for restoration of riparian conditions and salmonid habitat at two high priority sites on a key reach of the NF Salmon River. One of these sites was the Red Bank project area (PWA, 2012). Their recommendations included regrading the Primary Side Channel on the bar to create a self-maintaining perennial side channel with fish habitat and hydraulic structures; creation of a large alcove in the central part of the bar off the Primary Side Channel; and modifying the floodplain on the eastern part of the bar between the Primary Side Channel and a side channel to the east.

SRRC obtained funding through the California Department of Fish and Wildlife (CDFW) Fisheries Restoration Grant Program (FRGP Agreement No. P1410524) to prepare preliminary through final (100%) engineering plans for constructing salmonid rearing habitat improvements on Red Bank Bar. SRRC retained Michael Love & Associates, Inc. (MLA) and PWA to perform the field investigations and prepare the engineering designs for the project. This report summarizes the results of the field investigations, alternatives evaluation, and basis of design for the proposed project.

Design plans for the project are in Appendix A.

1.4 Project Goals and Objectives

Goals for the Red Bank Bar project are to increase the abundance of complex off-channel rearing habitat with high intrinsic potential for year-round rearing of juvenile salmonids by providing both high-flow and thermal refugia. Specific project objectives include:

- Enhance and increase the area of perennial groundwater-fed pools in the lower portion of the Primary Side Channel for thermal refugia
- Increase in-channel bed complexity using large wood features to maintain pool habitat that supports thermal refugia and provides high-flow velocity refugia
- Create self-sustaining alcoves for high-flow off-channel refugia
- Create large wood complexity in off-channel habitats
- Minimize removal of large riparian vegetation
- Use native and salvaged materials

1.5 Project Approach

The project approach involved developing an understanding of the physical opportunities and limitations of the project area by conducting topographic surveys and characterizing the geologic, geomorphic, hydrologic, hydraulic, and water quality conditions at the Red Bank Bar and adjacent river. This data was then used to identify suitable areas where summer thermal refugia, and/or high-flow velocity refugia for rearing salmonids could be created or expanded. Based on the findings, concept design plans were then prepared, which were then developed into final designs for the project after review by SRRC, CDFW, USFS, and others.

This report presents the results of the project area investigations and designs for the project area.

1.6 Project Description

This project focuses on enhancing and expanding portions of the Lower Side Channel and Far Side Channel of Red Bank Bar on the North Fork of the Salmon River. The objectives of the project are to enhance and expand areas of thermal and high-flow refugia for rearing salmonids.

The presence of perennial groundwater pools and suitable water quality conditions in the Lower Side Channel creates highly suitable, but spatially limited thermal refugia rearing habitat for salmonids. During higher flows in the river, velocities in the Lower Side Channel remain relatively low compared to other reaches of the side channels, but still higher than desired due to lack of complexity. The restoration focus in the Lower Side Chanel is to increase the amount of forcing features to break up the plane-bedded nature of the channel and expand the extent and depth of the groundwater-fed pools used for thermal refugia. The forcing features will also increase the complexity of the channel bed, creating a diversity in velocities and flow patterns that can be used by salmonids for high-flow refugia.

The lower reaches of the Far Side Channel were identified are a focus area to increase high-flow refugia habitat for rearing salmonids. The multiple channels provide numerous areas for habitat enhancement and generally have lower velocities than the Primary Side Channel. The habitat enhancements in this area focus on increasing the complexity of the channel bed and banks to provide high flow velocity refugia.

For the project, a total of 48 multi-log large wood structures, using a total of 200 30-foot logs will be installed within the project area, including Root Wad Cover Structures, Bank Logs, Root Wad Alcoves, Apex Jams, Abutment Jams A total of 6 groups of Random Boulder clusters will be installed.

Additionally, nine off-channel Backwater/Alcove features will be excavated to provide high-flow refugia for rearing juveniles for flows ranging in magnitude from winter baseflow to the 25-year flood event. Eight of the Backwater/Alcove features will be located on the side channels on Red Bank Bar, and one Backwater feature will be located on the river. A total of 31,120 square feet (0.73 acres) of backwater habitat will be created with the proposed Backwater/Alcove Features. To provide channel bank stability and shade, a total of 600 linear feet of brush baffles will be installed. The project will include approximately 4,150 cy of excavation, which will be spoiled on site.

1.7 Technical Advisory Review Meetings

1.7.1 30% Design Review Meeting

A 30% design review meeting was held on February 16, 2017. The meeting was held via conference call. A list of meting attendees is shown in Appendix B. The intent of the meeting was for MLA to present the project findings and conceptual design approach to the advisory group, and to receive verbal and written comments for incorporation into the 65% design plans.

It was decided during the meeting that the construction access for the project should be only from the Engine Fill Site at the upstream end of Red Bank Bar. A low-water crossing was identified to be more cost effective and better for fish passage than a bridge. CDFW was going to check whether a temporary low-water crossing could be permitted and identify time constraints relative to fish passage. SRRC directed MLA to show a low-water crossing on the design plans.

Dr. Josh Strange expressed concern that the project may not provide high-flow refugia during extreme flow events, which may sweep juvenile salmonids out of the system. He suggested that juveniles would seek out off-channel backwater features during high-flow events for refugia. After the meeting, he provided a sketch map of several potential areas where simple backwater alcoves could be excavated into areas on the bar that are less frequently inundated by elevated flows. SRRC also provided comments on Dr. Strange's recommendations, and made suggestions for a few additional potential backwater feature sites. Based on these recommendations, MLA developed hydraulic modeling and concept plans for a total of eight backwater refugia areas for the 65% design submittal. The Backwater features provide high-flow refugia during a range of flows from the winter baseflow up to a 25-year flow event. Further discussion of the Backwater Feature design is presented in Section 6.2.1.

Other comments from the 30% design review meeting did not result in substantial changes to the design. A summary of written comments from the 30% design, with MLA's responses is presented in Appendix B.

1.7.2 65% Design Review Meeting

A 65% design review meeting was held on April 2, 2017. The meeting consisted of a brief presentation of the revised design plans, followed by a field-walk of the project area. A list of meting attendees is shown in Appendix B. The intent of the meeting was for MLA to present changes to the design plans, review the project in the field with the advisory group, and to receive verbal and written comments for incorporation into the 90% design plans.

Toz Soto indicated that his observations of juveniles in the Salmon River indicate that they typically do not move around during the winter months, and may not find the backwaters if they only become active during high flow events. Based on Toz's comments, SRRC directed MLA to expand the widths of the pond areas in Backwaters 4 through 8 and include large wood habitat structures within the features. These changes are shown on the 90% design plans.

After observing changes at the confluence of the side channel with the river, SRRC also directed MLA to incorporate notes onto the design plans to allow minor grading and installation of large wood structures in this area to enhance the alcove feature forming at the confluence. These enhancements will be field-fit depending on the confluence geometry at the time of construction.

Other comments from the 65% design review meeting did not result in substantial changes to the design. A summary of written comments from the 65% design, with MLA's responses is presented in Appendix B.

2 SITE TOPOGRAPHY AND HYDROLOGY

2.1 Topographic Survey

LiDAR-based topography (flown March & April 2014) produced for SRRC was used for the base-mapping of the project area. The horizontal control for the LiDAR survey is North American Datum 1983 (NAD83) California State Plane, Zone 1, in feet and vertical control is North American Vertical Datum of 1988 (NAVD88) in feet. GMA Hydrology provided the survey control for the project area to correspond with the LiDAR datums.

The LiDAR topography did not contain details of the river channel due to the presence of flow in the channel when the LiDAR survey was completed. To supplement the LiDAR survey, MLA performed a field-run survey of the active channel of the river in October, 2015 using a total station. The survey included nearly 3,000 feet of the river, extending approximately 500 feet upstream and downstream of Red Bank Bar. The survey included a thalweg survey, left and right edges of water, lower streambanks, bedrock outcrops, and the locations of water level monitoring stations. Most of the side channels on the bar were not surveyed because they were dry at the time the LiDAR was flown. However, thalweg and water levels in the isolated pools in the downstream part of the side channel on Red Bank Bar were surveyed.

MLA merged the field-run topography survey with the LiDAR topography to create a digital terrain model and base-map of the project area with 1-foot contours, as shown on Figure 1-2. A 2015 aerial photograph was overlain with the base-map for use in delineation of vegetated areas and to show the location of Sawyers Bar Road.

2.2 Hydrology

The drainage area to the river at Red Bank Bar is 186 square miles. Annual precipitation for the project area ranges between 40 and 50 inches per year (Prism, 2010) and falls as both rain and snow. The lower elevations along the river corridor receive most of their precipitation in the form of rainfall. The higher elevations within the North Fork Salmon River watershed receive precipitation primarily in the form snowfall. However, warmer precipitation events during the wet season can result in rainfall throughout nearly the entire river basin, often leading to the highest flow events during the year. In the late spring and early summer, snowmelt generally creates sustained elevated flows in the river. During late summer and early falls river flows become extremely low due to a lack of precipitation during this period.

2.2.1 Peak Flows

Flows at the project site are not gaged; however, there are two USGS stream gaging stations on the Salmon River. The South Fork of the Salmon River near Forks gage (USGS Station No. 11522300) was active between 1953 and 1977 and has a drainage area of 252 square miles. The Salmon River at Somes Bar gage (USGS Station No. 11522500), has been active since 1911, and has a drainage area of 751 square miles.

A Log Pearson Type III (LPIII) probabilistic analysis (USGS, 1982) was prepared using annual peak flow data from both stream gages to predict peak flow magnitude and frequencies. Peak flows were then normalized to flow per square mile (cfs/mi^2) for both gages. Normalized peak flows from the two gages were averaged and scaled to the drainage area of the river at Red Bank Bar to estimate peak flow magnitudes and associated return periods, as summarized in Table 2-1.

Table 2-1. Estimated return period of peak flows for the North Fork Salmon River at Red Bank Bar.

North Fork Salmon River at Red Bank							
Drainage Area	Return Period of Peak Flow						
	1.2-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
186 sq. miles	2,598 cfs	5,082 cfs	9,003 cfs	12,139 cfs	16,698 cfs	20,517 cfs	24,694 cfs

The LPIII analysis of the Somes Bar gage identified five flood events with return periods greater than 20-years between 1944 and present. These include the 1964 flood which had an approximately 90-year return period, the 1955 flood which had a 44-year return period, and three 20-30-year return period events in 1974, 1997 and 2005.

Appendix C provides the peak flow hydrologic analyses.

2.2.2 Daily Flow Duration

Daily flow duration analyses were prepared using daily average flow records from the two USGS Salmon River gaging stations for the period that they were concurrently operational; water years 1958 through 1965. Daily flows for both gages were normalized to the drainage area of the NF Salmon River at Red Bank Bar. Annual exceedance flows for the project were based on averaging the normalized results from both gages, producing the flow duration curve shown in Figure 2-1.

Appendix C provides the flow duration analyses.

2.2.3 Estimating Real-Time NF Salmon River Discharge at Red Bank Bar

NF Salmon River flows during the project monitoring period were estimated using on the USGS Salmon River at Somes Bar 15-minute real-time flow data. This data was scaled to the drainage area of the river at the project site. Subsequent hydraulic analyses suggested this approach provided relatively accurate estimates of flows at Red Bank Bar, as presented in Section 4 of this report.

2.2.4 Monthly Flows During Project Monitoring

The flows in the Salmon River at Somes Bar during the project monitoring period were compared with historical flows (1911-2016) to place observations into a long-term context. The monthly average flows during water year (WY) 2015/2016 are shown in Table 2-2. Provisional flow data was used to compute the average monthly flow for May through October, 2016. As evident in the table, mean monthly flows in the Salmon River in fall of 2015 were less than 50% of average. Between December and April, flows were above average. From May through September, flows dropped to below average. October 2016 (beginning of WY 2017) was extremely wet, with flows being 404% of average.

Appendix C provides the monthly mean flow data.

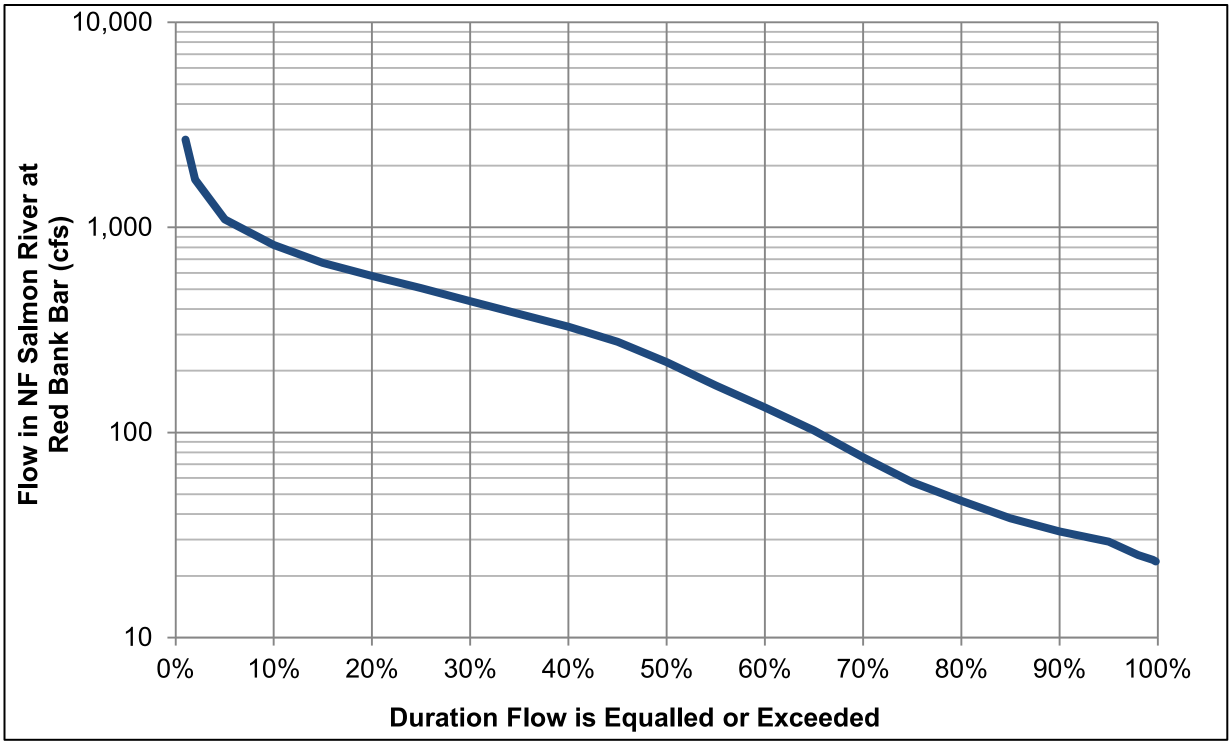


Figure 2-1. Constructed flow duration curve for NF Salmon River at Red Bank Bar constructed using USGS daily average flows scaled by drainage area averaged from the South Fork of the Salmon River near Forks gage (11522300) and Salmon River at Somes Bar gage (11522500).

Table 2-2. Historical mean monthly flows on the Salmon River at Somes Bar (USGS Station No. 11522500) for a 104-year period of record, compared to monthly mean flows during water year (WY) 2015/16 and the first month of WY 2017.

Data Record	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.
Historical Mean Monthly Flow (cfs)	339	1,030	2,230	2,950	2,910	2,920	2,990	3,080	1,880	616	260	199
2015/16 WY Mean Monthly Flow (cfs)	122/ 1,370[1,2]	253	2,798	5,658	3,814	6,819[1]	3,821[1]	2,211[1]	920[1]	349[1]	188[1]	150[1]
WY 2015/16 Percent of Historical Mean	36%/ 404%[2]	25%	125%	192%	131%	234%	128%	72%	49%	57%	72%	75%

[1] *computed using average daily provisional data*
[2] *WY 2017*

3 GEOLOGIC AND GEOMORPHIC ASSESSMENTS

3.1 Geologic Investigation

PWA performed geologic investigations of the project area and surroundings (Appendix D, PWA, 2016, and PWA, 2012). The investigation included a description of the geologic and geomorphic setting, characterization of the subsurface stratigraphy of Red Bank Bar, installation of six shallow groundwater wells, and recommendations regarding stable side slopes, suitability of materials for reuse, water management, sediment control and site stabilization.

The PWA reports indicate the project area is in the Klamath Mountain physiographic province. The river valley walls consist of poorly consolidated and sheared metamorphic rocks as well as deeply weathered granitic rocks that are particularly susceptible to erosion and mass wasting events during periods of heavy rainfall. The alluvial bar is crossed by multiple active side channels. The bar and river appear to have been reworked by placer mining activities and channel dredging within the last 150 years. The hillside on the eastern side of the bar was hydraulically mined and tailing piles are overlying alluvial deposits.

The subsurface investigation indicated that the materials comprising Red Bank Bar are fairly consistent and mostly made up of heterogeneously mixed unconsolidated, non-cohesive coarse-grained alluvial materials ranging in size from sands to boulders. The report characterized the materials as having a high intrinsic permeability, allowing for a rapid response in groundwater conditions with river fluctuations.

PWA recommended that the maximum side-slopes for excavated areas not exceed 3H:1V.

3.2 Geomorphic Assessment

To characterize the existing geomorphology of the project area and to understand the extents that the river alignment can be expected to change over time, a geomorphic assessment was conducted for the project area. The assessment included interpretation of historical aerial photos and a field-based geomorphic assessment.

3.2.1 Historical Aerial Photograph Interpretation

The 2014 LiDAR topography and historical aerial photographs were used to evaluate the geomorphic history of the project area. Historical aerial photographs of the project area were available for select years from 1944 through 2015 (1944-1995 Salmon River Restoration Council, 2015 Google Earth) and are shown in Appendix E. All aerial photographs were taken in August/September, except for the 2015 Google Earth photograph, which was taken in July. Only the 2015 aerial photo was ortho-rectified upon receipt. To overlay photographs, each aerial was digitally 'rubber sheeted' to match as closely as possible landmarks visible on both the subject aerial photo and the 2015 image.

Figure 3-1 shows topography, the 2015 aerial photograph, tracings of current flow extents during a 1.2-year flow event (see Section 5), and tracings of the 1944, 1965 and 1975 historic channel and side channel alignments. The Red Bank Bar site is located at a wide location in the river valley where the river makes an abrupt 90-degree bend, with the broad Red Bank Bar located on the inside of the bend. Both upstream and downstream of Red Bank Bar, the river flows through a narrow and confined gorge. Red Bank Bar is located on the river-right inside bend (east side) of the river where it is flowing to the south.

Inspection of the topography and scars on the landscape in the aerial photographs shows evidence of extensive mining activities on both hillslopes adjacent to Red Bank Bar and also upstream and downstream of the bar. Vertical embankments, linearly shaped gullies, and "tongue"-shaped tailing features indicate that hydraulic mining was occurring on the valley slopes and terraces surrounding the area. On the bar itself, hummocky mounds and occasional pits on the bar surface indicate that mining was occurring on the bar. As indicated by the geologic report, mining actives are more recent than 150 years old, but appear to be pre-1944 due to the vegetation coverage in the 1944 aerial photo.

1944 and 1955 Air Photos

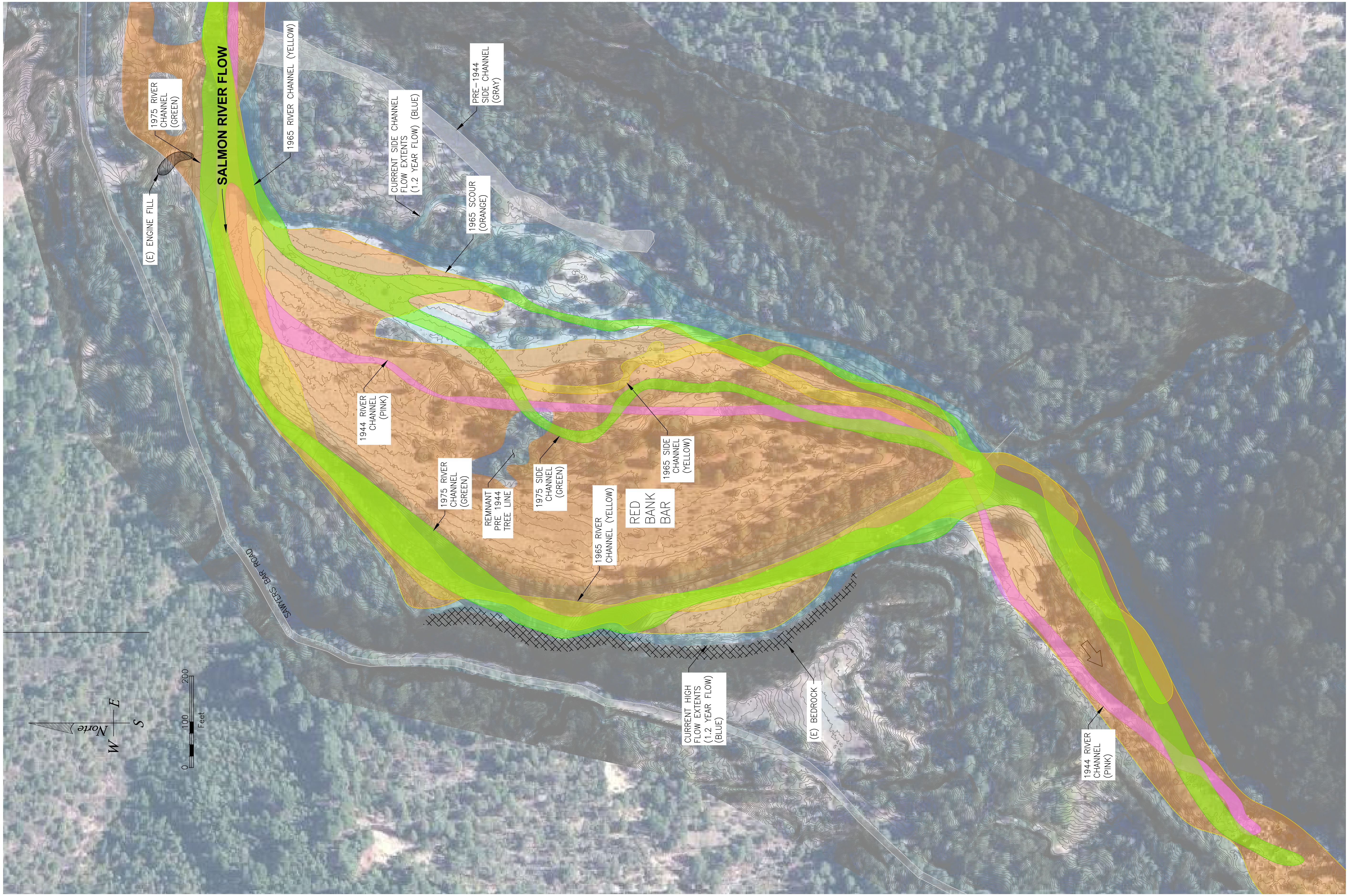
As shown in Figure 3-1 and in Appendix E, before the 1965 photograph, the river channel flowed through the central part of Red Bank Bar and did not appear to undergo significant changes between 1944 and 1955. The 1944 and 1955 photographs show that most of the bar and area to the west of the channel appears to be covered with forest vegetation, and only the main river channel and traces of a side channel network to the east are visible due to thinner vegetation. Mining activities are apparent along the hillslopes on both sides of the river, but appear to have become revegetated on the bar. A stereo-pair inspection of the 1955 aerial photographs shows that there may have been a side channel or abandoned channel on the west side of the 1944 and 1955 river alignments, in the location of the current-day river channel.

Observed Changes in 1965 Air Photo

Between 1955 and 1965, the main river channel at Red Bank Bar shifted nearly 500 feet to the west, to its current-day alignment. Data from the Somes Bar Gage (Section 2.2) indicates that two large flow events occurred between when 1944 and 1965 photos were taken, including a flood event in December 1955 that had an approximately 44-year return period, and the December 1964 flood, which had an approximately 90-year return period. The avulsion of the river almost certainly occurred during one of these events, though it is unknown during which event. The 1965 photo indicates that the river had avulsed into its current-day alignment, and most of the Red Bank Bar had been scoured of vegetation, except in one area in the center part of the bar where large trees persist to the present. A side channel remained in parts of the pre-1965 river alignment. The extent of scour on the 1965 photograph did not extend to the east side of the bar to the pre-1944 side channel network, where channels and large trees persist in this area to the present.

1975 Air Photo

The 1975 aerial photograph shows that vegetation is beginning to recover on the bar. In addition to the main river channel, there is a distinct and active side channel flowing through the central part of the bar. This side-channel network could be a result of a larger than 15-year flow event that occurred on January 16, 1974 or a remnant of an earlier event. The 1975 side channel was a multiple-threaded channel with a meander corridor that reworked portions of both the 1944 and 1955 river channels across an extensive portion of the central part of the bar. At the downstream confluence with the river, the eastern thread of the 1975 side channel followed the alignments of the 1944/55 river channel. The western thread of the 1975 side channel follows the alignment of the current-day Primary Side Channel. In the 1975 photograph, the side channel was still flowing when the photograph was taken in in late August, indicating that the side channel remained active, even during lower flows during late-summer.



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VERIFY SCALE
THIS BAR IS ONE INCH LONG AT FULL SCALE

Salmon River Restoration Council
RED BANK OFF-CHANNEL
FISHERIES AND RIPARIAN HABITAT DESIGN

Red Bank Current and Historic Channel Alignments

DATE
JAN. 2017
SUBMITTAL

DESIGN
RS

DRAWN
NN

FIGURE
3-1

Q:\Red Bank\5_CAD_FIGURES\Historic Air Photos.dwg

2012 Air Photo

Between 1965 and 2012, vegetation continued to increase on the bar and the alignment of the main river channel underwent only minor changes, despite a 30-year flow event in 1997 and a 22-year flow event in 2005. The side channel on the bar appears to persist roughly in the same channel corridor occupied by the 1944/55 river channels and the west branch of the 1975 side channel. The pre-1944 side-channel network on the east side of the bar has also remained active. Other than indications of active flow in the river and in the main side channel, the central part of the bar appears to have remained undisturbed since the 1965 aerial photograph was taken.

3.2.2 Geomorphic Assessment

The geomorphic assessment of the project area consisted of evaluating the river and bar topography, planform and profile, sketching existing flow patterns, conducting pebble counts, and interpreting overall geomorphic function of the river and adjacent floodplains. Figure 3-2 presents a low-elevation aerial photography of the project taken in February, 2016. Figure 3-3 presents a geomorphic sketch map of the project area, and Figure 3-4 and Figure 3-5 present thalweg profiles of the river and side channel, respectively. Pebble count results are provided in Appendix F.

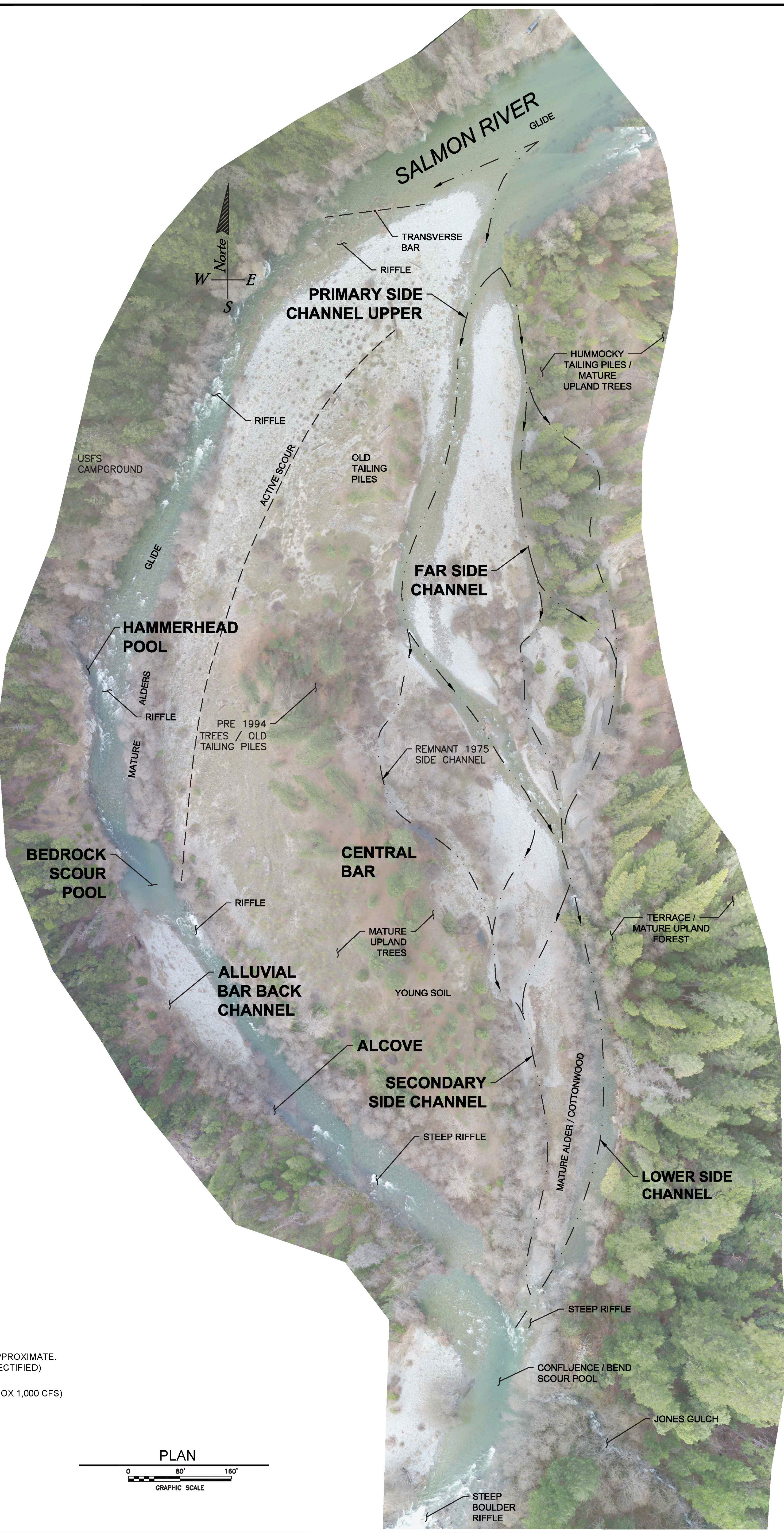
River Channel

The river channel at Red Bank Bar is a semi-alluvial river with a 100 to 150-foot wide active channel width. Upstream and downstream of the bar, the river is confined by narrow valleys comprised of intact and decomposing bedrock. At Red Bank Bar, the river bends 90-degrees southwards, and the valley opens up to a width of approximately 900 feet wide at its widest point. Red Bank Bar is located on the inside (east side) of the river bend. A bedrock outcrop is present along a substantial part of the western river valley wall that prevents the river from migrating further westward. Except at Red Bank Bar, the planform of the valley controls the planform of the river. Both sides of the river valley have been heavily mined, in addition to the bar (See Section 3.2.1), as shown Figure 3-1 and Figure 3-3.

The overall slope of the river channel at Red Bank Bar ranges from 0.9% to 1.18%, with localized areas of steeper riffles, gentler glides, and deep pools, as shown in Figure 3-4. Upstream and downstream of Red Bank Bar, where the river is confined by a narrow valley, the river bed is composed of steeply-sloped riffles comprised of boulders up to 10-feet in diameter. The thalweg of the river channel adjacent to the bar consists of alternating riffles and pools predominantly forced by bedrock and boulders. A pebble count in the glide near the upstream end of the bar indicated that the median grain size is 35 mm gravel, with the largest particle sizes of 500 mm (Appendix F).

The Red Bank USFS Campground is located on the northwest side of the river on a terrace with large mature fir trees. The bedrock outcrop comprising the western river bank is located downstream of the campground. The low-elevation aerial photograph in Figure 3-2 shows that river flows impinging perpendicularly on the bedrock outcrop form a “hammerhead pool” on the western bank of the river (river right) near river station 16+00, as shown on Figure 3-2 and Figure 3-3.

Further downstream, near river station 9+00, there is a recess in the bedrock wall on the western (river right) side of the channel. An approximately 10-foot deep scour pool has formed adjacent to the bedrock, and a large cobble bar has formed upstream of the pool. A back-channel is present on the bar that receives flow during an approximately 1-year flow. An alcove bounded by bedrock on the western side is located at the downstream side of the back-channel. During the field investigations in October, 2015, this alcove was very shallow and filled with muck and decomposing organic matter. However, in February, 2016, when the low-elevation aerial photo was taken, the alcove appeared to be scoured out and a deeper pool present, as show in Figure 3-2.



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DATE JAN. 2017 SUBMITTAL DESIGN RS DRAWN NN FIGURE 3-2	Salmon River Restoration Council RED BANK OFF-CHANNEL FISHERIES AND RIPARIAN HABITAT DESIGN Red Bank Current and Historic Channel Alignments	VERIFY SCALE THIS BAR IS ONE INCH LONG AT FULL SCALE	Michael Love & Associates, Inc. PO Box 4477 • Arcata, CA 95518 • (707) 822-2411 Salmon River Restoration Council PO BOX 1089 • 25631 Sawyers Bar RD, Sawyers Bar CA 96027 530-462-4665 Fax 530-462-4664

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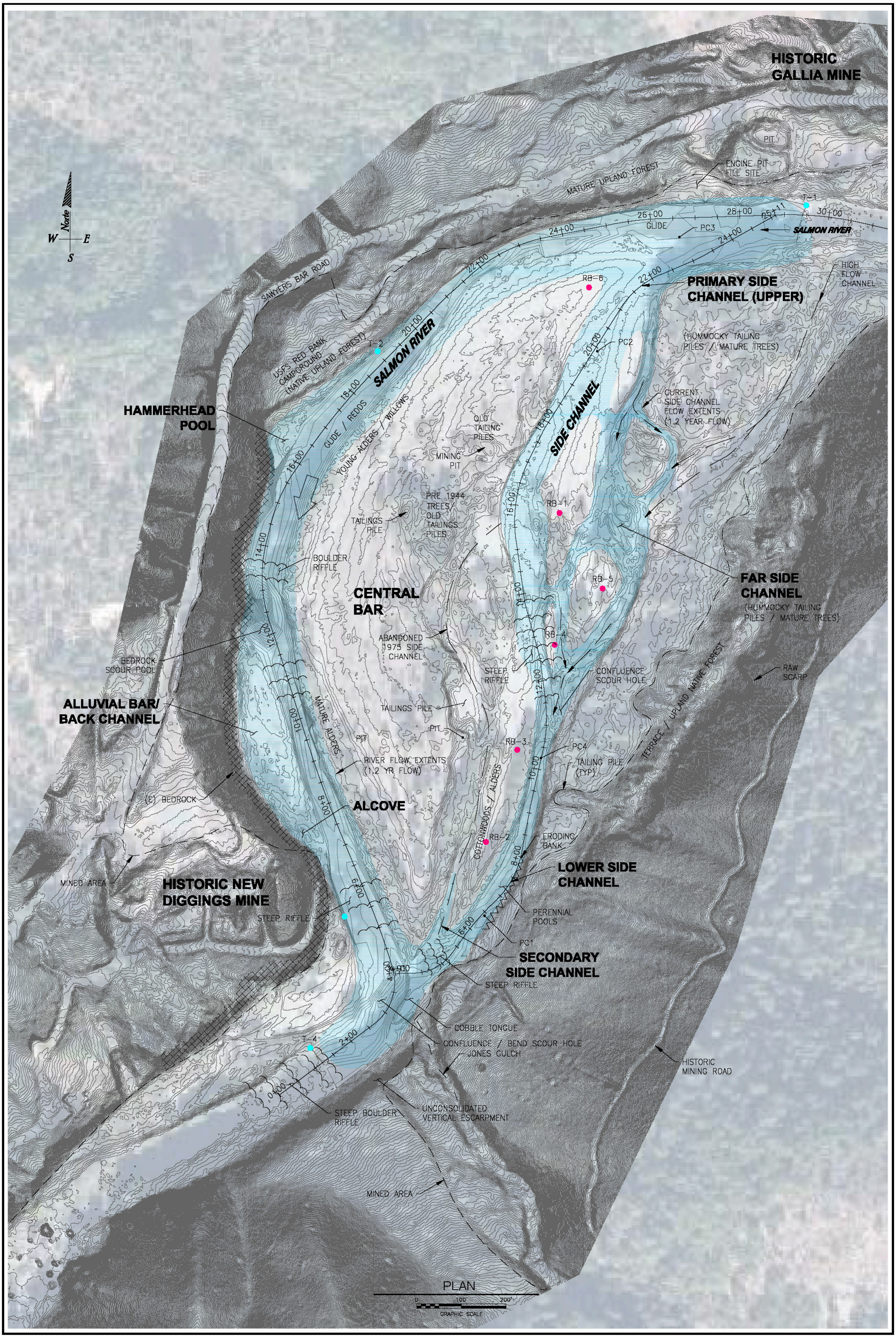

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FIGURE	3-3

Salmon River Restoration Council
RED BANK OFF-CHANNEL
FISHERIES AND RIPARIAN HABITAT DESIGN

GEOMORPHIC SKETCH MAP

VERIFY SCALE
THIS BAR IS ONE INCH LONG AT FULL SCALE

Michael Love & Associates, Inc.
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Salmon River Restoration Council
PO BOX 1089 • 25631 Sawyers Bar RD, Sawyers Bar CA 96027
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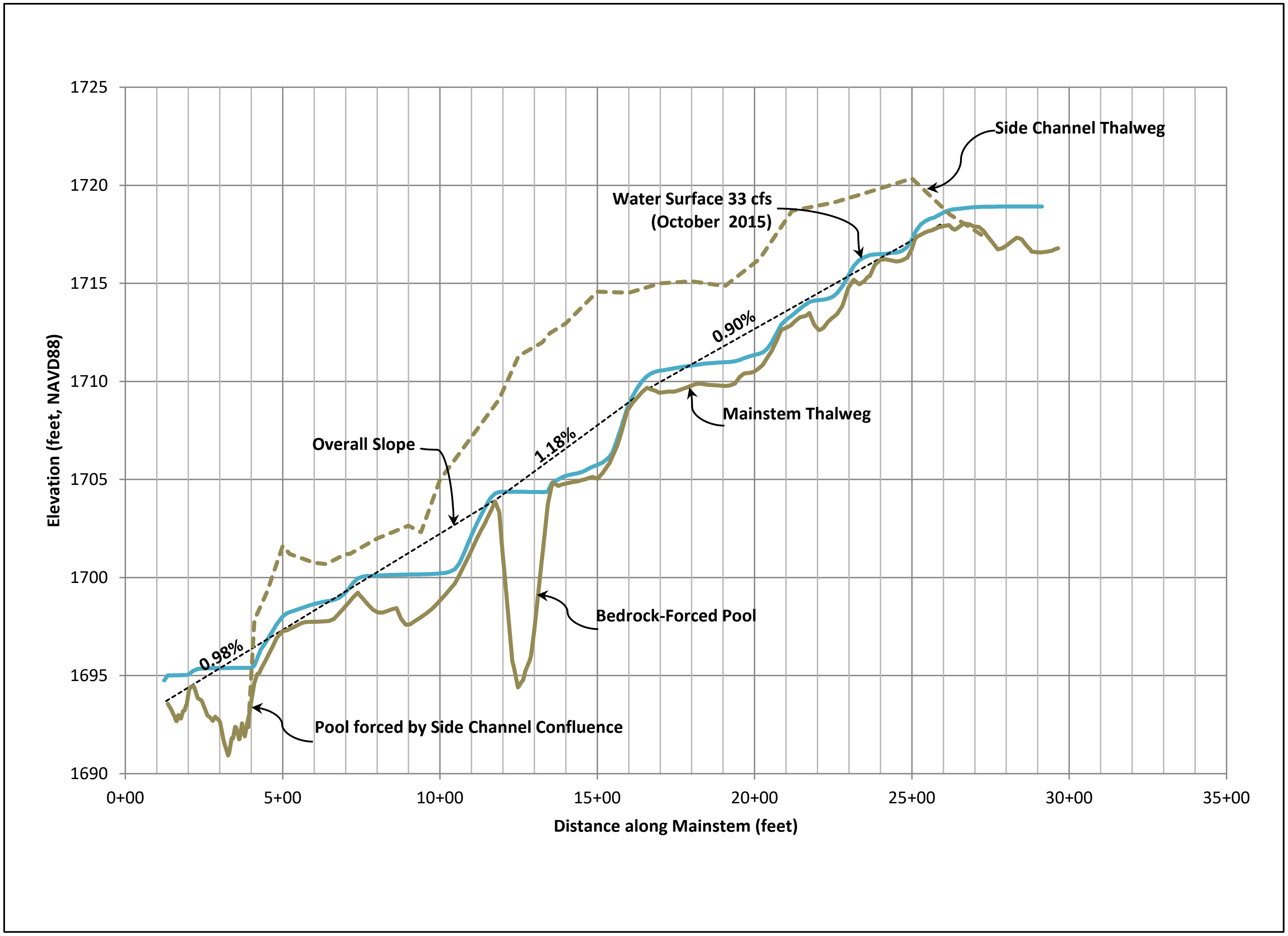


Figure 3-4. Existing thalweg profile of the NF Salmon River at the Red Bank Bar project area. The side-channel thalweg is projected onto the river profile perpendicularly to the river valley alignment.

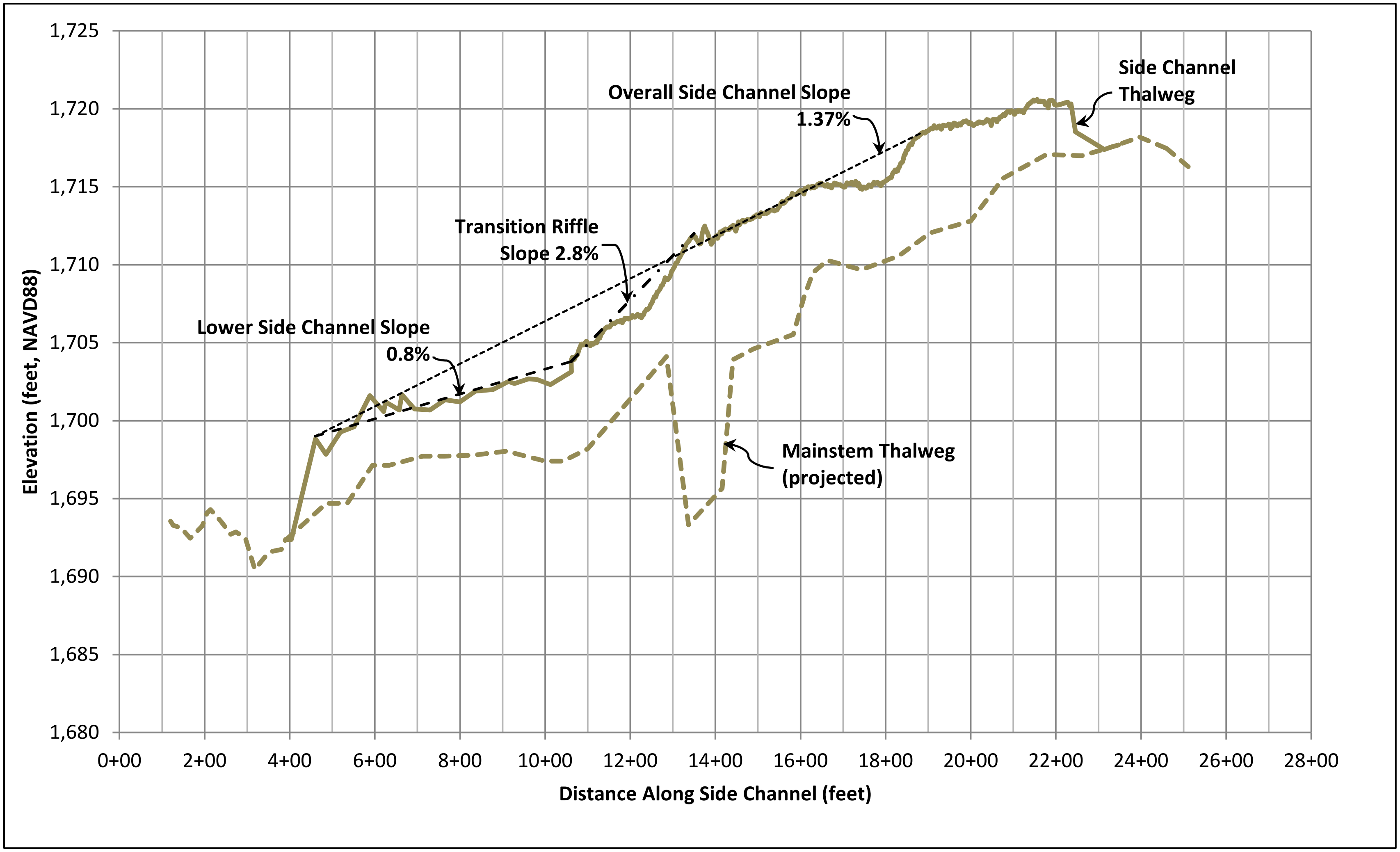


Figure 3-5. Existing thalweg profile of the Primary Side Channel at the Red Bank Bar project area. The main river channel thalweg is projected onto the side-channel profile perpendicularly to the river valley alignment.

Red Bank Bar

The Red Bank Bar is an alluvial bar complex that forms a broad and active floodplain on the inside (east side) of a tight meander bend in the river, as shown on Figure 3-2 and Figure 3-3. The bar ranges in width from approximately 100 feet wide at its downstream end to nearly 800-feet wide at its mid-point. The surface of the bar was broken into different regions shown, as on the figures and discussed in detail below:

1. Central Bar
2. Primary Side Channel (Upper and Lower)
3. Far Side Channel
4. Secondary Side Channel

The eastern side of the bar is bounded by a terrace 10 to 20 feet higher than the surface of the bar. This area is covered with a riparian area consisting of large, mature Sitka spruce, ponderosa pine, and a mature understory. Numerous large tailing piles are located along the terrace associated with intensive historical hydraulic mining of the hillslope to the east of the bar.

<u>Central Bar</u>

The central bar portion of Red Bank Bar is a crescent-shaped area of higher ground running north to south between the river and the side channel, as shown on Figure 3-2 and Figure 3-3. A photograph of the central bar is shown in Figure 3-6. The eastern side of the central bar is a defined by a sharp scarp that delineates the remnants of the 1944 and 1955 river channels and 1975 side channel.

Mining pits and tailing piles are scattered throughout the central bar. This part of the bar is covered with fine grained materials and a weakly developed soil horizon/organic layer. A mature riparian area covers most of the central bar and includes large pine trees, upland trees such as oak, maples, and madrone. The hydraulic modeling indicates that this area is only shallowly inundated during flows greater than a 50-year flood event. There are no defined channels on the Central Bar and review of the historical aerial photographs indicate the neither the main river channel nor the side channels flowed through this area since 1944, though it was completely inundated between the 1955 and 1965 air photos, when it was mostly stripped of vegetation.

<u>Primary Side Channel</u>

The Primary Side Channel flows from north to south through Red Bank Bar to the east of the Central Bar. As show in in Figure 3-5, the Primary Side Channel is approximately 1,800 feet long and has an overall slope of 1.37%. The Primary Side Channel is about 400 feet shorter than the river mainstem, giving it a higher slope than the river; and is approximately 5 feet higher in elevation to the river channel. The locations of steep riffles and more gently sloped reaches in the side channel are coincident with the river thalweg profile, though unlike the river channel, no bedrock controls are present along the Primary Side Channel.

The results of the geologic investigations (PWA, 2016, Appendix D) and three pebble counts of surface materials along the Primary Side Channel indicate that the material comprising the bar ranges in size from sands to boulders, with a median grain size of 40-110 mm gravels and cobbles, and the largest particle sizes consisting of 500 mm boulders.


(a)

(b)

Figure 3-6. Photographs of the higher and rarely inundated Central Bar with (a) upland trees and young soil and (b) remnant tailing piles.

Field observations and the results of the hydraulic modeling indicate that the Primary Side Channel receives flows during most of the winter and spring months, when river flows exceed about 350 cfs, which is a flow exceeded approximately 36% of the time (131 days) in an average year.

The Primary Side Channel can be split into an Upper Side Channel and Lower Side Channel, with the demarcation between the two areas at the downstream end of a nearly 300-foot long transitional riffle with a 2.8% slope.

Upper Side Channel: The upper 860 feet of the Primary Side Channel originates from a glide in the river at the head of Red Bank Bar. Figure 3-7 shows the upper portion of the side channel both flowing and dry.

The Upper Side Channel is a broad, highly active, featureless plane-bedded channel mostly devoid of vegetation. Plane bedded channels typically lack bed forms, resulting in relatively featureless beds that are less suitable for fish habitat. Complexity in channel bedforms are formed by forcing features such a flow obstructions (boulders, large wood) and channel planform geometry (Montgomery and Buffington, 1997).

Evaluation of the historical aerial photographs indicates that the portion of the bar where the Upper Side Channel is located underwent substantial changes between the period of 1944 and 1975. During this period, the features from the 1944 and 1955 river channels were reworked by the multi-threaded 1975 side channels, which that had a wider meander corridor that spanned both the 1944 and 1955 river channel. The reworking of the bar resulted in a complex array of superimposed channels that become inundated during a range of flow larger than a 3-year event. The reworking of the channels and the broad meander corridor of the 1975 side channel is likely why the Upper Side Channel is broad and contains few mature trees.

Lower Side Channel: The lower portion of the Primary Side Channel begins downstream of the 2.8% slope riffle (Figure 3-5) and extends approximately 500 feet downstream to the confluence with the river, as shown in Figure 3-2 and Figure 3-3. The Lower Side Channel has an overall slope of 0.8% and flows along the base of a terrace on the eastern side of the river valley.

Unlike the upper portion of the Primary Side Channel, the Lower Side Channel is bounded by a riparian area of mature cottonwoods and alders on the west side and mature upland forest on the terrace to the east. Evaluation of the aerial photographs indicates that this portion of the bar was not substantially reworked by migrating side channels. Instead, it appears that only two channel alignments have persisted in this area, with a riparian corridor between the two alignments. The eastern alignment, which forms the Primary Side Channel, appears to have been formed by the eastern thread of the 1975 side channel.

Figure 3-8 presents typical conditions in the Lower Side Channel when receiving flow from the river and during the dry-season period. The Lower Side Channel is a typical plane-bedded channel that relies on localized forcing features to create diversity in the channel bed. Forcing features in the Lower Side Channel include occasional large boulders, tree roots, and downed trees that have created some channel diversity by creating pools. However, many of these features are transitory, limiting the development of more permanent bed diversity.

When the side channel is not receiving surface flow from the river, shallow groundwater-fed perennial pools persist where juvenile salmonids have been observed year-round. These pools are interspersed by a plane-bed cobble and boulder channel. The groundwater seeps that feed the pools appear to originate along the eastern bank of the Lower Side Channel. Additional water could be originating as hyporheic flow from the upstream channels.

The Lower Side Channel transitions to the main river channel through a steep riffle. A large tongue-shaped bar of gravel and boulders has formed at the mouth. The size of material comprising this bar indicates the grain size that is transported through the side channel. As shown in Appendix F, the larger sizes of these material range from 130 to 450 mm.

Far Side Channel

The Far Side Channel appears to be a series of side channels that developed prior to the 1944 aerial photograph and remained active since that time. Figure 3-9 shows a typical area of the Far Side Channel. The overall slope of the upper reaches of the Far Side Channel is about 1.02%, as shown in Figure 3-10. The channel is broad, plane-bedded, and open with little vegetation on the banks (Figure 3-9a). Further downstream, the lower portions of the Far Side Channel becomes more wooded and the slope steepens to 1.82%. The lower reaches of the Far Side Chanel contain several 10 to 20-foot wide channels that wind through the low hummocks formed by historical mine tailing piles, as shown in (Figure 3-9b). The channels in this area are also plane-bedded, but contains some shallow pools forced by tree roots, meander bends and confluence scour. The large size of the tailings has limited the development pools. A mature forest of conifers has developed on the tailing piles between the channels and young alders grow along the edges of the channel.

The Far Side Channel also receives surface flow from the river when flows in the river exceed 650 cfs (16% exceedance flow). Flows in this area split into multiple side channels in this complex, depending on the amount of flow received.


(a)


(b)

Figure 3-7. TheUpper Side Channel looking downstream (a) on 5-13-16 at an approximate river discharge of 630 cfs (Photo by SRRC) and (b) same location on 9-8-16 when the side channel is dry.


(a)


(b)

Figure 3-8. The Lower Side Channel (a) on 2-22-16 (Photo SRRC) and (b) looking upstream on 10-21-16 showing isolated groundwater pools in a plane bed channel.


(a)


(b)

Figure 3-9. The Far Side Channel (a) upper reaches on 5/17/16 at a river flow of approximately 550 cfs and (b) lower reach when dry.

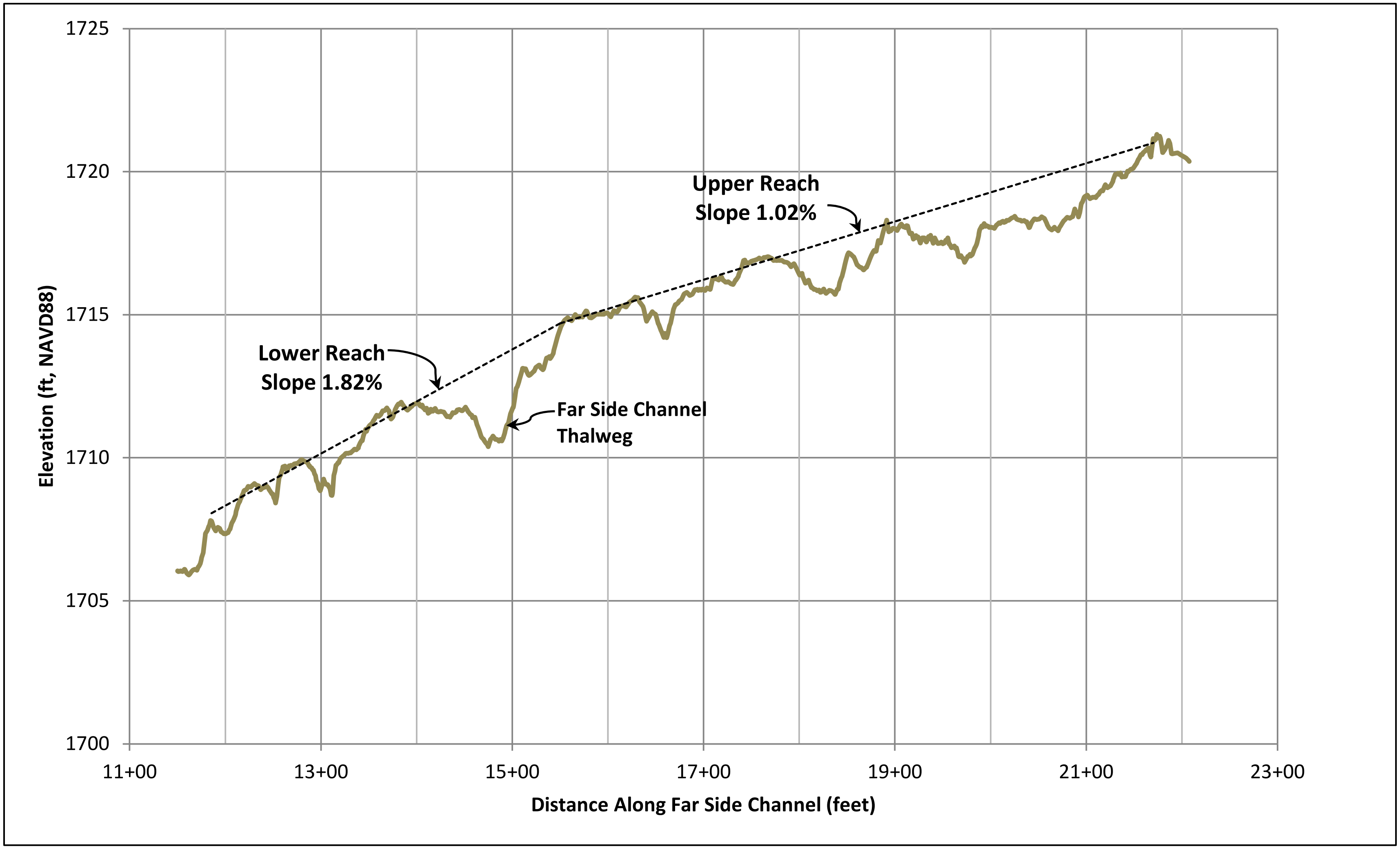


Figure 3-10. Existing thalweg profile of the Far Side Channel.

Secondary Side Channel

The Secondary Side Channel, which flows parallel to the Lower Side Channel on its west side (Figure 3-3), appears to be a remnant of the 1944/1955 main river channel channels and the western branch of the 1975 side channel. The Secondary Side Channel currently begins to receive flows from both the Upper and Lower Side Channels during 1.5-year and larger flow events. The Secondary Side Channel is slightly higher in elevation than the Primary Side Channel and is dry when not receiving surface flow.

Like the Primary Side Channel, the Secondary Side Channel is a plane-bedded channel with few forcing features to create channel bed complexity and flow diversity. Boulders sculpted by flowing water are present in the Secondary Channel (Figure 3-11), indicating that it conveyed sufficient flows for a duration of time to sculpt the boulders.

Figure 3-11. Photograph of Secondary Side Channel. Large sculpted boulders are present in the channel.

3.2.3 Long-Term Channel Stability

The geomorphic investigation indicates that Red Bank Bar lies within a moderately dynamic river reach, having historically undergone substantial channel alignment changes in response to flow events on the order of 50 to 100-year return periods, but no substantial changes during more frequent flow events. Since 1964, only minor changes to the river alignment and the bar at Red Bank have occurred despite a 30-year flow event in 1997.

The Red Bank Bar can be classified as a confined vertical accretion floodplain, based on a 2-year stream power of about 400 watts/m^2 (Nanson & Croke, 1992). These types of floodplains are typically found in confined valleys with laterally stable channels and floodplains. The floodplains are shaped by extreme events and experience fine-grained vertical accretion and revegetation between extreme flow events. Floodplain surfaces are characterized by back-channels and scour holes. Only extreme flow events have the power to reshape them, allowing the bars to persist over long periods of time between extreme flow events. Vegetation also has a substantial role in stabilizing the floodplain (Burge, 2006).

Prior to the 1965 aerial photograph, the river channel flowed through what is now the Primary Side Channel on Red Bank Bar. The river avulsed to its present alignment, mostly likely during the large flow events of December 1955 or December 1964. However, in the 1955 aerial photograph, taken prior to these floods, a channel trace in the current-day river alignment is visible. This suggests that the river may have avulsed at some earlier point to flow across the bar, and there is a chance that it may avulse back earlier alignment in the future.

Generally, rivers avulse when meander bends become excessively tight, when the new alignment has a substantial slope advantage over the current alignment, or when sediment or debris jams force the flows into another alignment (Slingerland, 2003, Leddy et al, 1993). Qualitatively, the present Salmon River alignment at Red Bank Bar appears to meet criteria for a stable planform geometry substantially better than the pre-1965 alignment. To avulse into the present side channel (pre-1965 alignment) would necessitate the river turning abruptly at the downstream end of a steep, long riffle upstream of the bar. This turn would require a large change in the momentum and direction of the flows. Given that there is no forcing feature such as a hillslope, overcoming the present linear momentum would be unlikely. Additionally, as visible in Figure 3-4, the profile of the existing river contains a steep riffle in its profile just downstream of the flow-split to the side channel, providing it with a substantial localized slope advantage over the profile of the side channel. A large debris jam or sediment plug could form in the main river channel forcing flows across the bar; however, the jam or bar would need to be of substantial size to span the channel and adjacent low sloping bar, to not be entrained by the steep riffle in the river.

It is possible that the pre-1965 river alignment was influenced by the mining activities. Both the river valley and the hillslopes adjacent to the river have been heavily mined using both hydraulic and placer mining techniques. Substantial sediment loading and debris delivered to the river from mining activities could have created a flow blockage of sufficient size to cause the river to avulse onto the bar. The river planform may also have been anthropogenically manipulated to facilitate mining activities. However, the present day planform and profile of the river do not appear to lend themselves to a high chance of avulsion.

4 WATER LEVEL AND WATER QUALITY MONITORING

Water surface elevations (WSE) in the river along the project area were monitored by SRRC to identify seasonal water surface elevations in the river, correlate them to groundwater levels along Red Bank Bar, and for use in calibrating the hydraulic models developed for the project. Water temperature and dissolved oxygen (DO) were also monitored in the river and in groundwater wells on the bar to establish the need for and suitability of various locations for summer rearing habitat. The monitoring period extended from October, 2015 through October 2016.

4.1 Water Level and Water Quality Monitoring Methods

In September 2014 six (RB-1 through RB-6) approximately 10-foot deep groundwater monitoring wells were installed on the bar adjacent to the Primary Side Channel, as shown in Figure 1-2. Additionally, two stilling wells (River U/S and River D/S) were installed in the river at the upstream and downstream limits of the project area. Elevations of the well rims and adjacent ground were surveyed. Hobo water level (pressure transducer) and temperature data loggers were installed on the river at River U/S, River D/S, and at monitoring wells RB-2, RB-5, and RB-6. Hobo data was collected at 15-minute intervals. On a monthly basis, SRRC downloaded the Hobo data and also manually measured water levels, dissolved oxygen, and water temperatures in all wells throughout the monitoring period. A total of 12 sets of direct measurements were made in addition to the continuously collected water level and temperate data. Water depth, water temperature and dissolved oxygen were also collected in the Primary Side Channel adjacent to RB-1, RB-2 and RB-6 when the side channel contained surface flow.

In addition to obtaining 15-minute data of river water levels, water level measurements were made at four T-posts (T-1 through T-4) installed along the length of the river adjacent to the bar, as shown in Figure 1-2. These T-posts served as stage plates for measuring water levels. A total of 12 sets of measurements were made at the T-posts concurrent with direct measurements and Hobo measurements of well water levels. Photographs of river conditions and a written description of field-observations were also logged during each monitoring event.

Direct measurements of well and T-post data were collected for river flows ranging from 34 cfs to 1,573 cfs. High flows and velocities in the river precluded data collection due to safety issues. Scaled data from the Somes Bar gage indicates that peak flows during the monitoring period reached about 7,800 cfs, which has a return period of approximately 3.5 years.

Rating curves of stage versus flow in the river were prepared for each well using scaled flows from the USGS Somes Bar gage. Figure 4-1 presents the stage-flow rating curve and resulting regression equations for the River D/S gage. All logged water level data showed some hysteresis with rising and receding flows, which is not unusual given the large amount of flow storage on Red Bank Bar. To average out the hysteresis, the stage and flow data was interpolated with regression curves to directly correlate the average gage stage with river flow. The regression curves were used to obtain river and side-channel water levels for specific flows to evaluate flow conditions at the project site for other flows of interest. The calibrated rating curve for the River D/S gage was extrapolated to the 100-year flow using a normal depth computation module in the hydraulic model (Chapter 5).

Appendix G presents the results of the water level monitoring for each well.

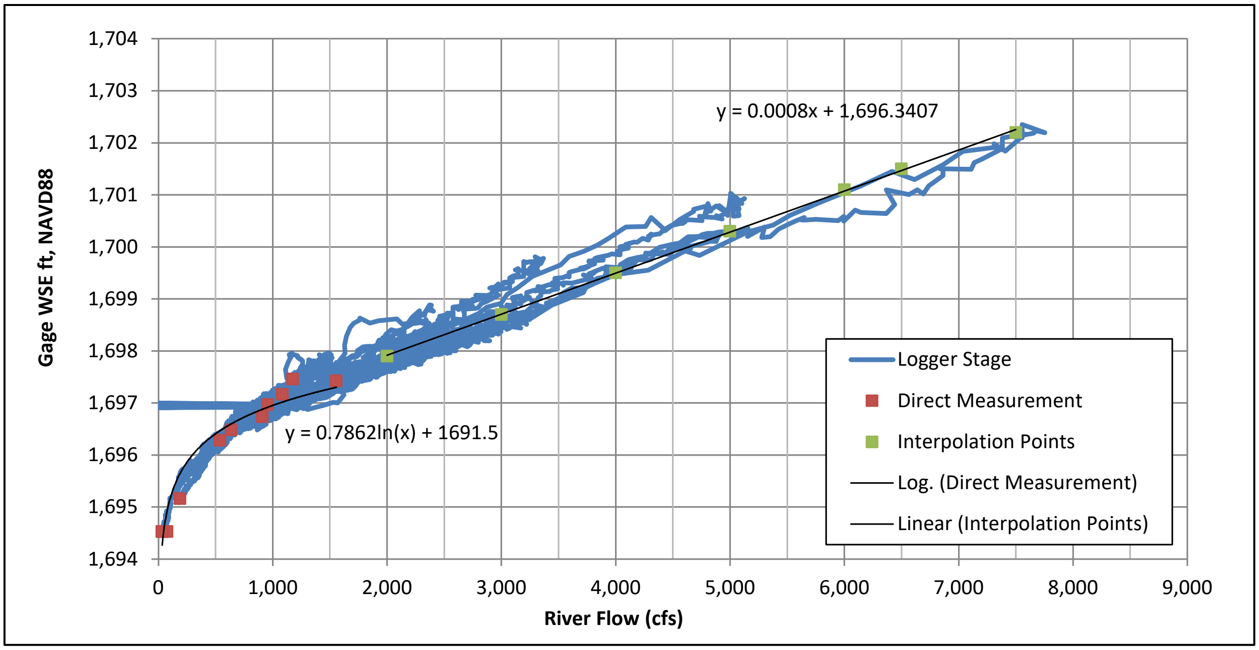


Figure 4-1. Rating curve for River D/S gage showing gaged water levels and the corresponding river flow scaled from the Somes Bar USGS gage. The data was fitted with regression lines to directly correlate stage and flow.

4.2 Water Level Monitoring Results

The water level monitoring indicated that river maintained perennial flow, but all wells except RB-2 and RB-3 went dry in June, 2016 and remained dry through the end of the monitoring period in October 2016. Measurements of flow depth in the Primary Side Channel indicated that the side channel went dry in early June, except for the lower reach of the side channel adjacent to RB-2 and RB-3, where flows remained perennial. The depth to groundwater on the bar during the dry season was not obtained due to the shallow nature of the wells.

All Results

Figure 4-2 presents the results of the ground and surface-water monitoring for three of the monitoring events, reflecting the conditions during monitored river flows of 193 cfs (55% daily exceedance flow), 627 cfs (16% daily exceedance flow), and 6,924 cfs (approximately 3-year flow event). Water surface profiles derived from the calibrated hydraulic modeling (See Chapter 5) are also shown on the profiles. The profiles in Figure 4-2 show the thalweg and river WSE, with the side channel thalweg and WSE projected perpendicularly across the valley onto the river stationing. For the 6,924 cfs event no direct measurements were made at T-posts or wells and only data derived from the stage-flow rating curves for each well are shown. Similar plots for the other monitoring events and flows are presented in Appendix G.

As shown in Figure 4-2 and Appendix G, model-predicted flows were generally within 0.5 feet of measured water levels, with exceptions as discussed below. The similarity between measured and model-predicted flow provided confidence in the results for modeling of flows during which direct measurements were not taken.

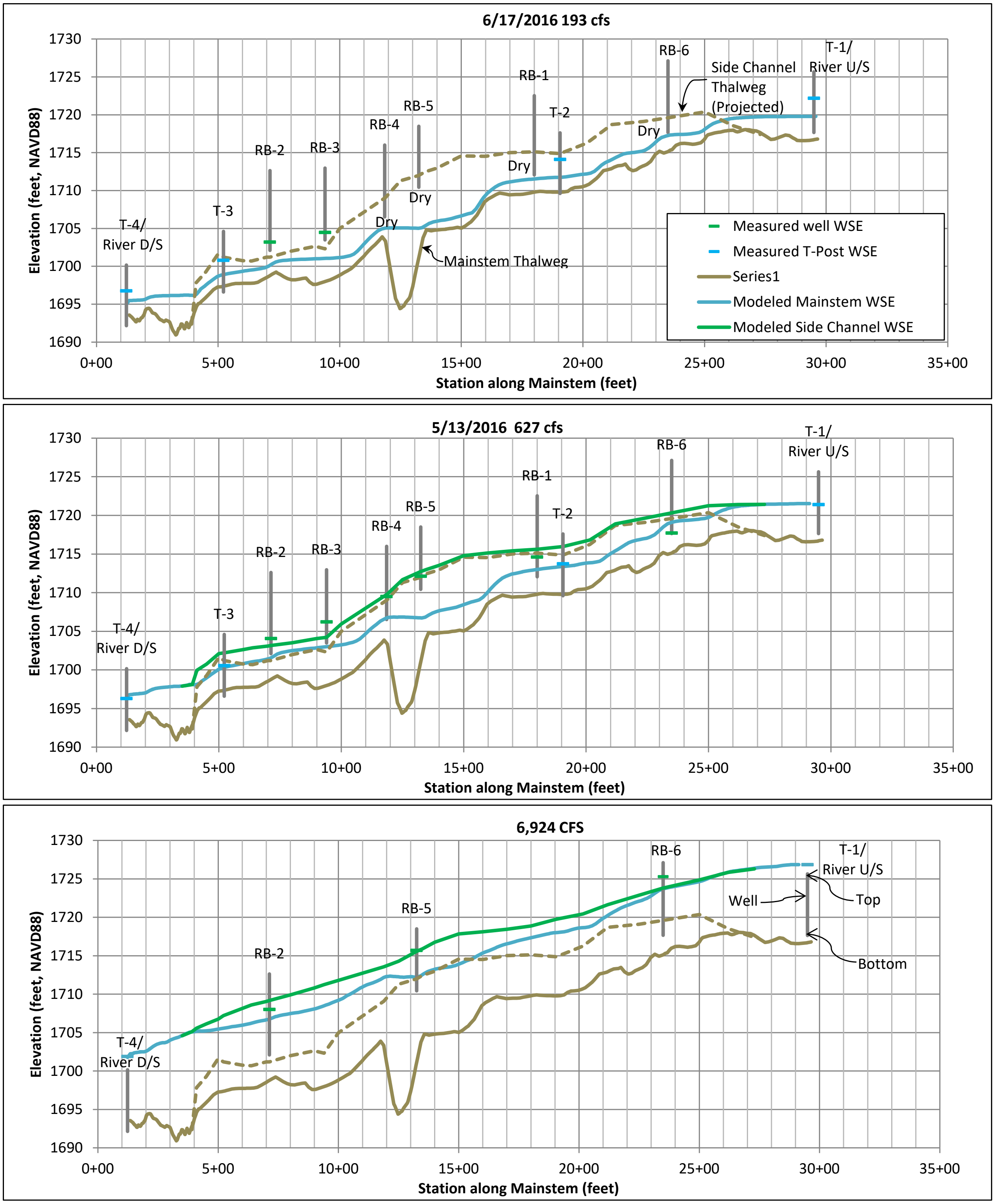


Figure 4-2. Measured groundwater and surface water elevations at wells and T-posts along the NF Salmon River and main side channel on Red Bank Bar. The side channel profiles are projected onto the river stationing. "Dry" indicates well was dry at time of direct measurement.

Flows begin to inundate the Primary Side Channel at approximately 350 cfs. Recorded water levels in the wells, except RB-6, RB-2 and RB-3, generally tracked water levels in the side channel (RB-1, RB-4, and RB-5) when flows were present in the side channel. This tracking substantiates that the subsurface materials in the bar have a high intrinsic permeability, as characterized by the project geologist (Section 3.1). This h allows rapid response of groundwater levels to changes in river and side channel water levels.

Monitoring Well RB-6

Though RB-6 showed a response to changing flows in the river, unlike the other wells, the water levels in RB-6 showed poor correlation with water levels in the river or side channel, as shown in Appendix G. During lower flows, water levels in the well generally remained lower than the river or side channel water levels. At flows over approximately 2,500 cfs, water levels in RB-6 tended to be higher than the adjacent river or side channel. The geologic log of RB-6 indicates that it is similar material than the other wells. It is unknown if the logged water levels are a result of an aquiclude that delayed the response of the well, or if the well was malfunctioning. Therefore, the water level results from RB-6 were not used for any further analysis.

Lower Side Channel (RB-2 and RB-3)

Measured water levels in RB-2 and RB-3 remained consistently higher than modeled flow elevations in the lower reach of the side channel adjacent to the wells, except for flow events greater than river flows of about 1,000 cfs.

During flows less than about 1,000 cfs, field measurements indicated water levels in the side channel generally corresponded with well WSE's. Field observations indicated that surface-flow persisted in the Lower Side Channel throughout the monitoring period, even when the upstream side channel and wells were dry. A water depth of 1 foot was measured in the Lower Side Channel adjacent to RB-2 in October 2016.

Inspection of the plots in Figure 4-2 and Appendix G suggest that the hydraulic gradient from the river and Primary Side Channel upstream of RB-2 and RB-3 and the narrowing of the overall valley width from upstream to downstream may be driving hyporheic flow and maintaining the observed perennial flow in the lower part of the side channel adjacent RB-2 and RB-3. The perennial flow is also supported by springs emerging along the eastern bank of the side channel, close to the adjacent hillslope.

During flows higher than about 1,000 cfs, water levels in RB-2 (RB-3 did not have a continuous data logger) are lower than the water surface in the adjacent side channel but higher than the river level. This may suggest that at high flows the Lower Side Channel is a "losing reach." Alternatively, the well could be less responsive to rapid changes in surface flows than at other monitoring wells due to localized subsurface conditions that delay the response of the well.

Far Side Channel

Figure 4-3 presents a profile of the Far Side Channel with the limited amount of groundwater elevation data collected. Note that some observations are missing, rather than the wells being dry.

Field observations indicated the Far Side Channel receives subsurface flows from the Primary Side Channel, causing it to contain flow for most of the winter and spring months, though these pools dried out in mid-May, 2016, when river flows were about 550 cfs. The Far Side Channel also receives surface flow from the river when flows in the river exceed 650 cfs (16% exceedance flow). Frequent scouring flows and the depth to groundwater in the upper portion of the Far Side Channel

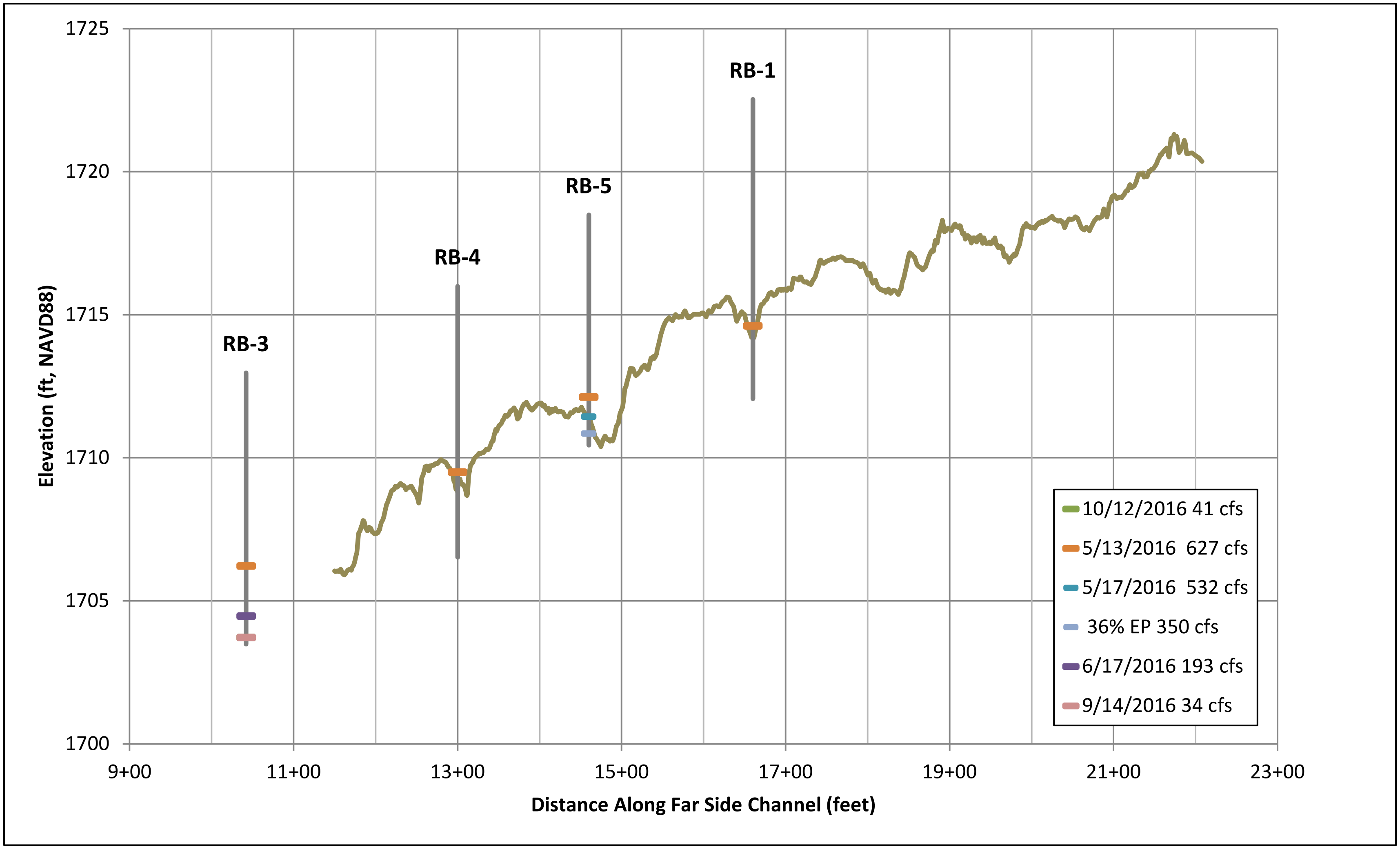


Figure 4-3. Thalweg profile of the Far Side Channel showing groundwater elevations for various flows in the river. Missing data indicates that well was dry. Data was not collected at RB-1 and RB-4 on 5/17/16. Data was not collected at RB-1 RB-3 and RB-4 on during the 350 cfs flow event.

during the drier season (193 cfs and 37 cfs) are likely the reason that little vegetation is growing on the upper portion of the Far Side Channel. Groundwater levels in the lower portion of the Far Side Channel appear to be closer to the ground surface, which is supported by the observations of isolated pools in this area in the late spring.

4.2.1 Water Quality Monitoring Results

Figure 4-4 presents the results of the water quality monitoring in the river, wells, and side channel. All data by monitoring event is provided in Appendix H. River flows are shown for reference.

Water Temperature

Optimum water temperatures for growth of coho range from 14 to 18° C (Sullivan, et al., 2000). Based on findings from a multi-year study to assess key aspects of the seasonal life-history patterns of juvenile coho salmon within the Klamath River, coho begin to seek thermal refugia when water levels reach 19° C (Hillemeier, et al., 2009). When water temperatures reach 22 to 24° C, coho become stressed (Hillemeier, et al., 2009 and Eaton et al., 1995), and lethal temperatures range from 20 to 30° C, (McCullough, 1999). The findings also indicate steelhead are able to tolerate slightly warmer temperatures than coho. For this study, it was assumed that salmonids would begin seeking off-channel refugia from warm water when river temperatures exceed 19° C.

During the monitoring period, peak river water temperatures exceeded 19° C beginning in late June (Figure 4-4a), and rose above 22 ° C in late July. Water temperatures dropped below 22 ° C in late August, but had not drop below 19° C before the data loggers were removed on October 12, 2016. The river temperature monitoring indicates salmonids will likely seek thermal refugia beginning as early as June and utilize thermal refugia into the fall due to the elevated river water temperatures.

At Red Bank Bar, all water temperatures measured in the wells and side channel during the course of monitoring were suitable for salmonids. Generally, groundwater temperatures in the wells and side channel remained lower than river temperatures through the late summer, and remained warmer than the river as it cooled in the winter (Figure 4-4a), which is the optimum pattern for off-channel coho rearing (Lestelle, 2007).

Water temperatures measured in the open water of the Lower Side Channel near RB-2 and RB-3 were cooler than water temperatures in the adjacent wells, and substantially cooler than the river. The observed low temperatures in the Lower Side Channel indicate that water in the side channel is being substantially cooled by hyporheic flows or is receiving spring flow from the adjacent hillslope, or both.

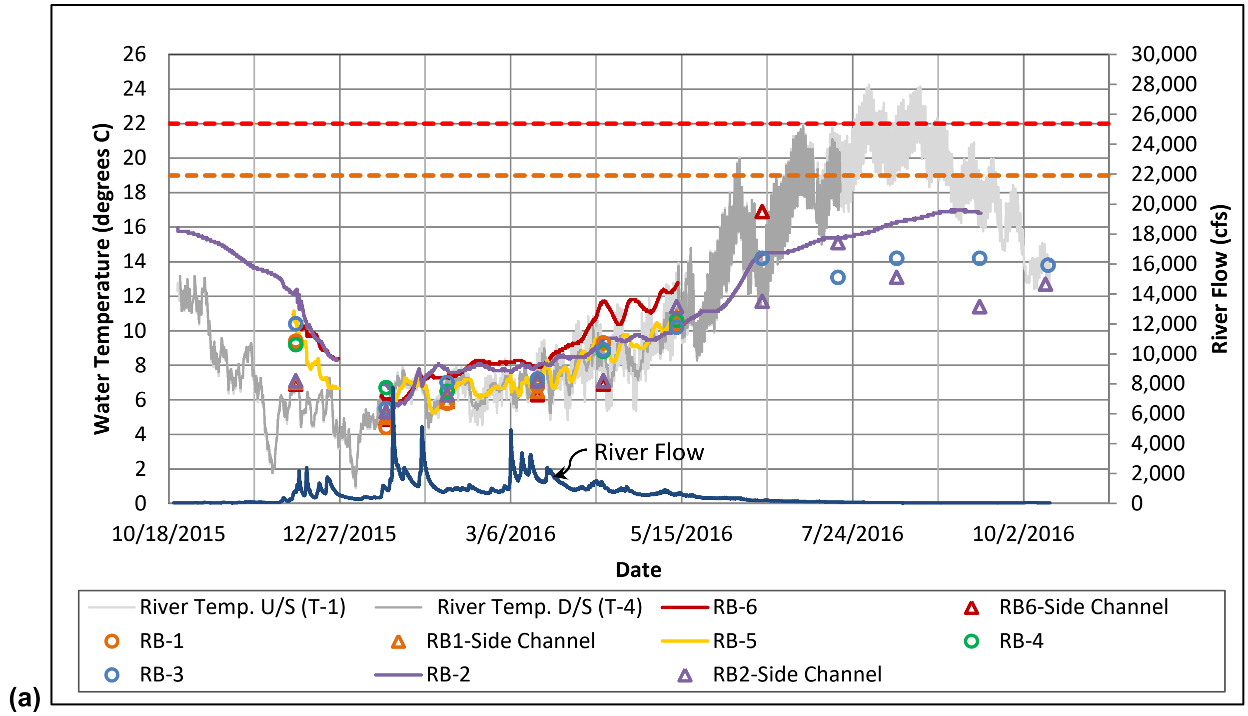
Dissolved Oxygen

Juvenile salmonids are frequently found thriving in waters with dissolved oxygen (DO) concentrations as low as 5 to 6 mg/l (Michael Wallace, CDFW, Personal Communication). Habitat with even lower DO concentrations can still be of value if water temperature is suitable. For example, coho have recently been found consistently utilizing off-channel habitat with DO as low as 1 mg/l in the lower Klamath River basin, but water temperatures were generally 15° C or less (Beesley and Fiori, 2014).

Figure 4-4b indicates that DO levels remain suitable for salmonid habitat in both the river and side channel through the duration of monitoring. Even when the river was near lethal temperatures, DO levels remained suitable in the river. DO levels in the side channel were substantially higher than in the wells during the monitoring period. The lowest measured DO values of round 2 mg/l were observed at RB-2 starting in June, and dropping to 1.6 mg/l on October 12, 2016.

As shown in Figure 4-4b, dissolved oxygen in the wells decreased in the downstream direction from RB-6 to RB-2. It has been observed by numerous studies that that dissolved oxygen levels in the hyporheic zone decrease with the amount of time that flows are in the hyporheic zone, which is typically related to the distance of flow travel (Findlay, 1995, among many). The decrease in DO is a production of biological oxygen demand due to decomposition of organic matter, microbial action, invertebrates, and changes in water chemistry. DO levels increase upon flow emergence to the surface, where it mixes with atmospheric oxygen.

During the winter months, when the side channels were receiving flows from the river, DO levels in the side channels where higher than wells. During the summer months, DO levels in the side channel adjacent to RB-2 were higher than measured in the adjacent wells, suggesting the mixing is occurring as the hyporheic/spring flows emerge and are exposed to the open atmosphere.



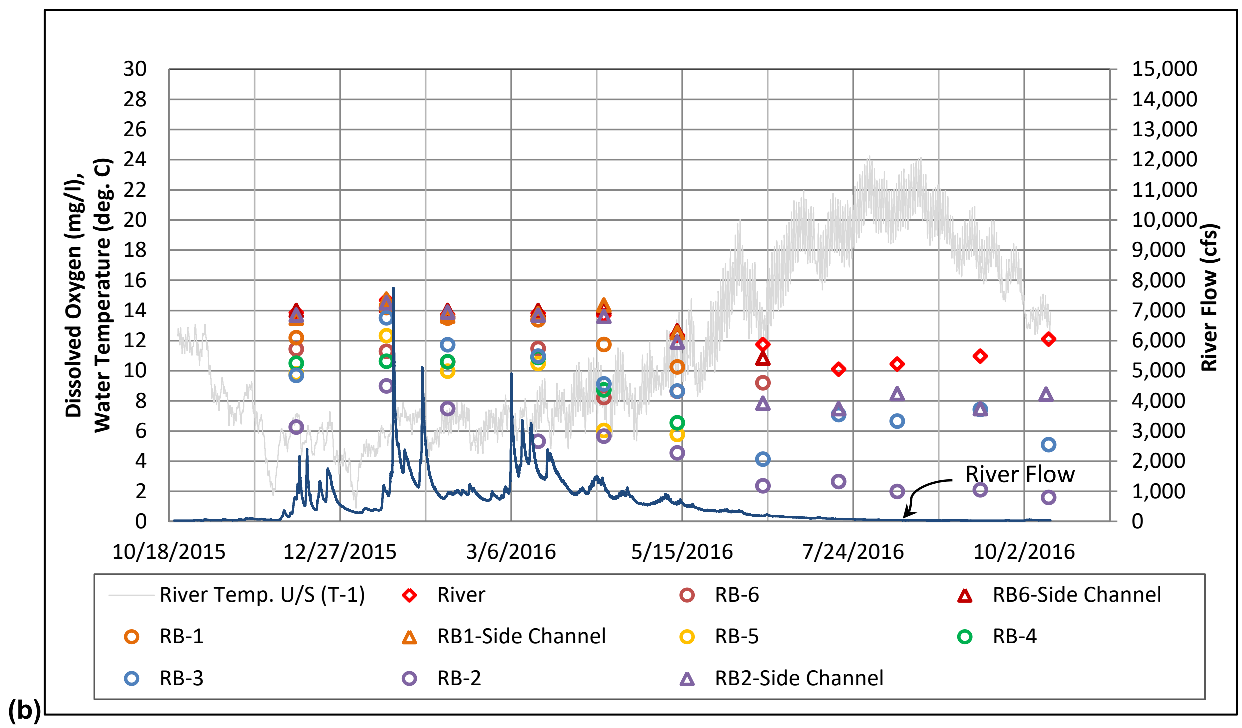


Figure 4-4. Results of (a) water temperature (b) and dissolved oxygen in the river and groundwater monitoring wells at the Red Bank Bar project area. Continuous lines represent continuous measurements and symbols represent discrete measurements. The dashed lines indicate 19° C (orange) threshold for when coho salmon may seek thermal refugia, and 22° C (red) threshold for when they become stressed. Data from dry wells not shown.

5 EXISTING CONDITION HYDRAULICS

Hydraulic conditions for the project were assessed using the SRH-2D numerical model (Bureau of Reclamation, 2008). SRH-2D is a two-dimensional hydraulic model suitable for evaluating the complexity and variably of flow directions and velocities in the river and multiple side channels comprising the project area at Red Bank Bar. The SRH-2D model (2D Model) was selected for the hydraulic analysis due to its suitability for the hydraulic conditions being assessed and its overall stability. The 2D model does not simulate groundwater conditions.

After calibrating the 2D model with known water levels, the model was used to evaluate water surface elevations, flow patterns, inundation depth, and frequency, water velocity, and sediment transport competence for a range of flows.

5.1 SRH-2D Model Setup

SRH-2D is a grid-based model that solves the standard St. Venants equations for gradually varying flow using finite-volume methods. The grid elements are a combination of rectangular elements within channels and triangular elements on floodplains and adjacent valley walls. A 2-dimensional (2-D) model was prepared for the 3,000 feet of surveyed channel that encompasses the project area. The model extended on both sides of the river channel and up the valley walls. The main river channel was modeled with rectangular elements 5 feet width and approximately 15 feet in length, oriented with the long axis parallel to the flow direction. Floodplain modeling used triangular elements with 5-foot sides. Valley wall modeling used triangular elements with 10-foot sides. The elevations of the grid were derived from the project's digital terrain model (DTM) derived by merging the LiDAR and topographic survey DTMs.

The 2D model was prepared in steady flow for each simulated flow event. Flow events evaluated ranged from 34 cfs (83% exceedance flow) to the 100-year flow (19,353 cfs). A stage-flow rating curve derived from flow gaging (Chapter 4) was used as the downstream boundary condition for all model simulations. For flows greater than the 7,300 cfs, the maximum flow that occurred during the monitoring period, flow were derived from a calibrated normal-depth rating curve developed in SRH-2D. The upstream boundary conditions consisted of inflows from the river at the upstream end of the model domain. Inflows were distributed across available conveyance areas at the upstream boundary condition using a flow conveyance boundary. The model was started with the elements dry and executed with 2-second time steps until flow conditions stabilized.

5.2 Model Calibration

Water surface elevations for a given flow event predicted by the 2D model were calibrated using the water level data collected during 16 of the flow events that occurred during the monitoring period. During 11 of these events, water levels in the wells, stream gages, and at the T-posts were used for the model calibration (Chapter 4). During larger flows, water levels in the wells and in the river collected by the continuous data loggers were used to verify the model calibration. A flow event captured by the LiDAR surface showing the edge of the wetted channel was also used to assess model calibration.

Water level measured were compared to the model-predicted water surface. More weight was assigned to WSE elevations measured at the T-posts and wells RB-1, RB-5 and RB-4. Less weight was assigned to wells RB-6, RB-3 and RB-2, which did not appear to have a direct hydraulic connection to the adjacent side channels, as discussed in Section 4.2. Flows at the project area were scaled from the real-time reported flows at the USGS gage at Somes Bar for the sampling period (Section 3.2).

To calibrate the 2D model, roughness values associated with each grid element were adjusted so that the model-predicted water surface elevations (WSE) matched the observed water surfaces within a few tenths of feet, where possible. SRH-2D does not use contraction and expansion coefficients as part of the computations. Therefore, contraction and expansion losses need to be incorporated into roughness values. A total of six roughness values were used to calibrate the model, as shown in Table 5-1. These roughness values are typical of major channels with irregular and rough cross sections (Chow 1959).

Model-predicted WSE compared to the river WSE at the T-posts for select flow events are shown on Figure 4-2, and results for the other flow events are presented in Appendix G. For flows less than 350 cfs, the model-predicted flows showed a weaker calibration to the gaged water levels than the larger flows. This is understandable because at lower flows, relative protrusion of the channel material and Manning's roughness values are higher than at higher flows (Limerinos, 1970). Flows lower than approximately 350 cfs are summertime flows and were not a large focus of the project. Therefore, additionally model calibration on these flows was not performed.

Table 5-1. Manning's roughness coefficient used for 2D modeling of the Red Bank Bar project area.

Feature	Manning's Roughness Coefficient
Steep Boulder Riffles	0.075
Glides, Pools	0.065
Dense Riparian Areas	0.100
Unvegetated Floodplain, Side Channels	0.065
Vegetated Floodplain Side Channels	0.075
Deep Scour Pools	0.070

5.3 Model Results

Figure 5-1 and Figure 5-2 present results from the 2D modelling for two flow events. Additional modeling results for other flow events are presented in Appendix I.

The 2-D model results indicate that flows remain within the main channel of the river until approximately 350 cfs, when flows inundate the Primary Side Channel. As flows increase, additional side channels on the bar are activated, including the Far Side Channel at flows greater than about 630 cfs (16% exceedance flow), and the Secondary Channel during about a 1.5-year flow. The pre-1944 side channel on the eastern-most side of the bar starts to become active around a 3-year event. During a 10-year flow event, all side channels on the bar are active. During a 50-year flow event, most areas of the bar are inundated except the lower portion of the Central Bar and two areas of mine tailings (Figure 3-2 and Figure 3-3). During a 100-year event, the lower central portion of the bar becomes shallowly inundated, and only the two mine tailing piles remain exposed.

Stable, self-maintaining side channels receive flows frequently enough to scour out fine sediments to maintain an open channel, and are stabilized with the presence of vegetation and/or low bed mobility during overtopping flow events (Burge, 2006). Side channels can carry up to 20% of total flow during bankfull events, which preserves sediment transport continuity in the mainstem but maintains the side channel (Miori, et al., 2006). Table 5-2 summarizes model-predicted flows in the river mainstem and side channels during a range of flow events. The side channels carry less than 1% of channel flow when they begin to become inundated at 350 cfs. As flows increase, the side channels carry 20% of flow during a 1.2-year event (approx. bankfull event), which increases to 27% of flow during a 5-year event. Above a 5-year event flows begin to expand out of the side channels and onto the adjoining floodplain surfaces of the bar.

Table 5-2. Existing condition model-estimated proportion of total flow conveyed through side channel networks on Red Bank Bar. Percentages indicate the amount of flow in the side channel network relative to the total river flow. "EP" is the daily exceedance.

Location	Daily Exceedance of Event		Return Period of Event				
	16% Exceedance	4% Exceedance	1.2 Years	1.5 Years	2 Years	3 Years	5 Years
Total Flow Event	646 cfs	1240 cfs	2,598 cfs	3785 cfs	5082 cfs	6924 cfs	9003 cfs
Flow in River	618 cfs	1,084 cfs	2,012 cfs	2,754 cfs	3,525 cfs	4,578 cfs	5,701 cfs
Flow in Side Channels	28 cfs	157 cfs	586 cfs	1,032 cfs	1,557 cfs	2,344 cfs	3,301 cfs
Percent of Flow in Side Channels	4%	13%	23%	27%	31%	34%	37%

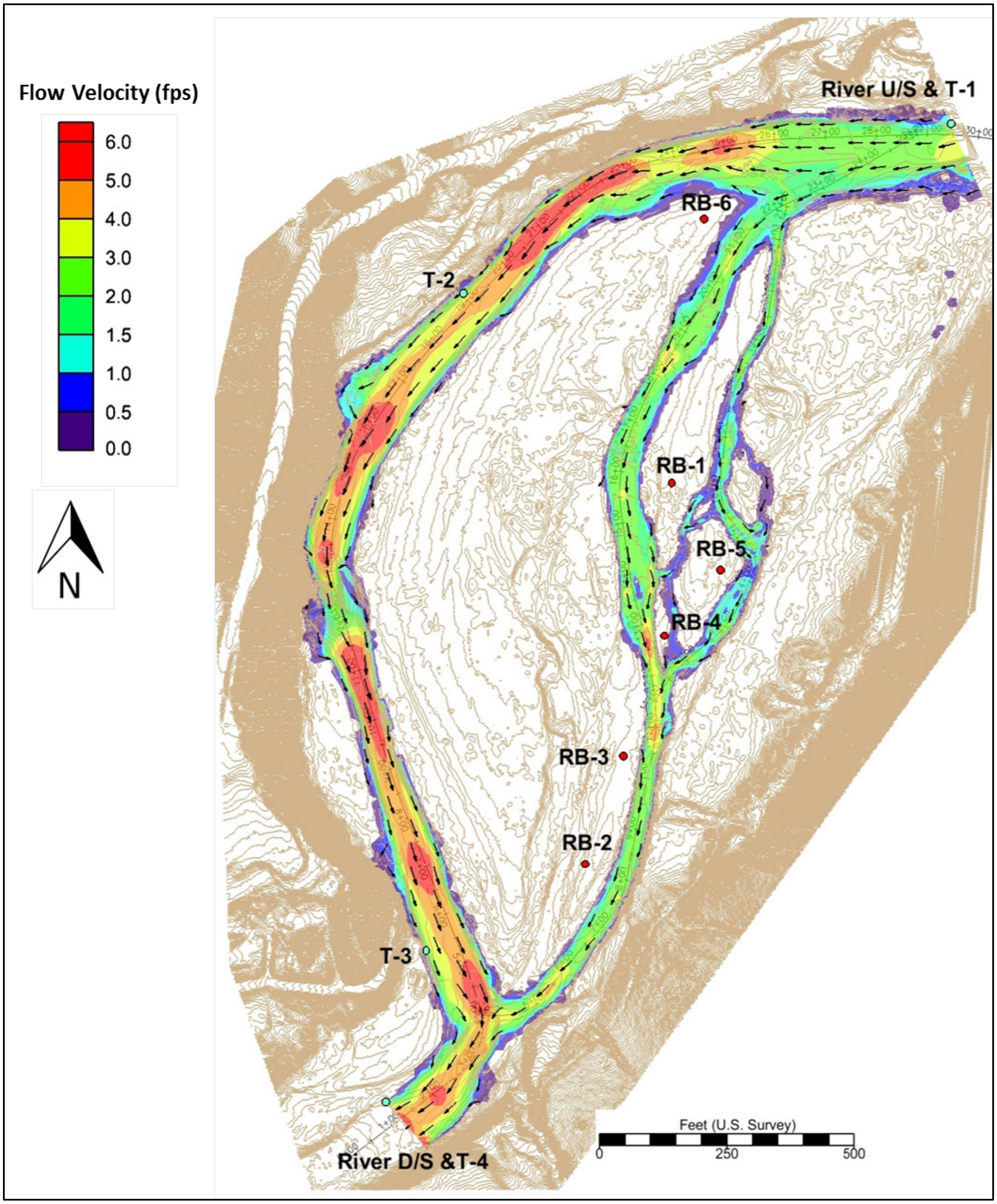


Figure 5-1.SRH-2D predicted water velocities (fps) and inundation extents during a 1,240 cfs (4% Exceedance) flow event in the NF Salmon River at Red Bank Bar. The arrows represent water velocities, with the larger arrows indicating higher velocities. Flow velocities greater than 6 fps are show as red.

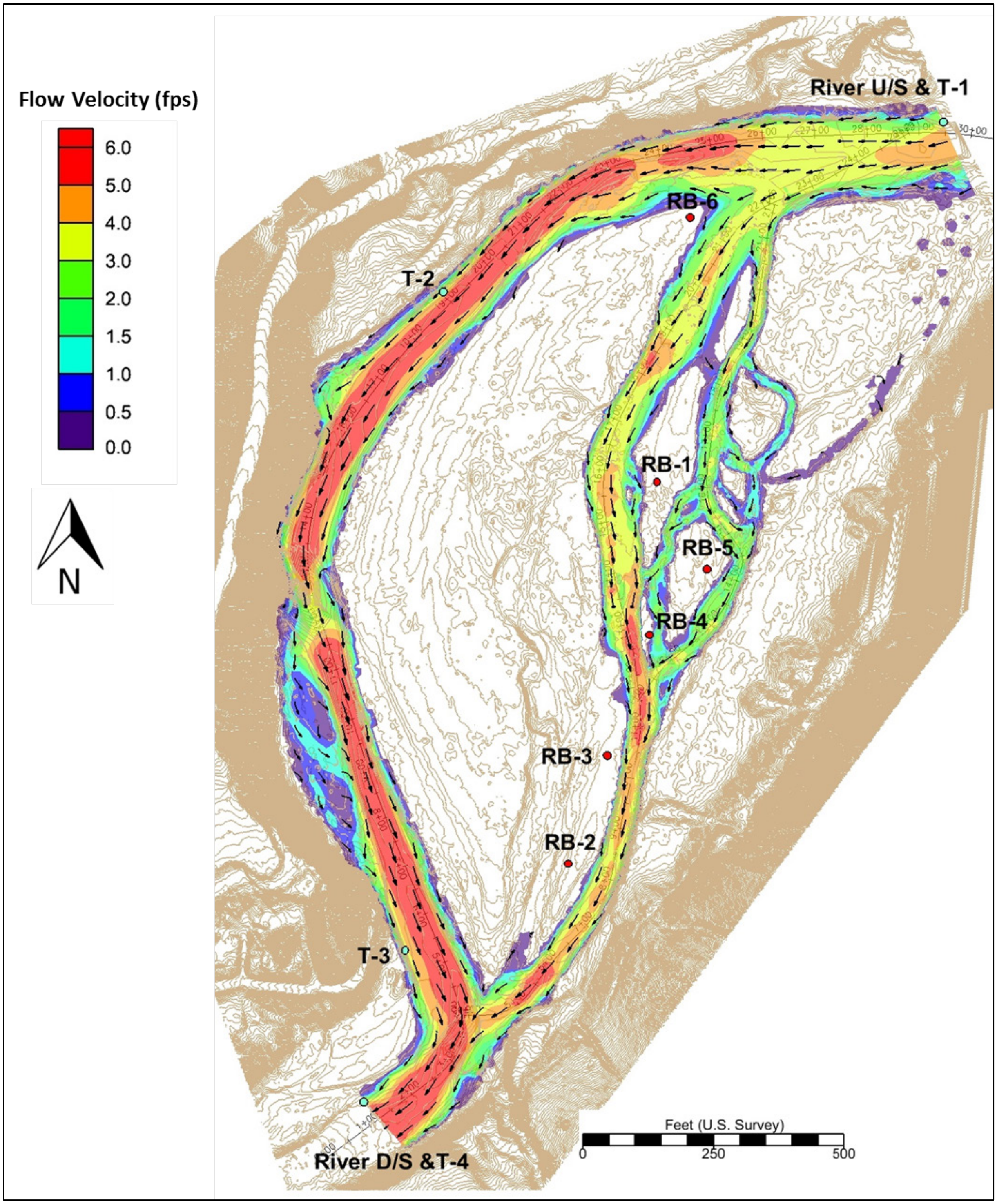


Figure 5-2.SRH-2D predicted flow velocities (fps) and inundation extents during a 2,598 cfs (1.2-year) flow event in the NF Salmon River at Red Bank Bar. The arrows represent water velocities, with the larger arrows indicating higher velocities. Flow velocities greater than 6 fps are show as red.

5.4 Evaluation of Rearing Habitat for High-Flow Refugia

The 2-D model results were used in tandem with field observations to identify locations that presently provide areas of low velocity and adequate depth to provide high-flow refugia. These results also aided in identifying areas where high-flow refugia habitat could be created or expanded. Habitat suitability was evaluated for a range of flows up to a 25-year flow event.

Suitable areas of high-flow refugia located by identifying areas where depth exceeds 0.5 feet and flow velocities are less than 1 fps. The hydraulic analysis considered only the river geometry and flows and did not consider the effects of localized features such as large boulders and log jams.

Figure 5-3 shows the results of the high-flow refugia assessment for 532 cfs, which is the 23% daily exceedance flow and is expected to be exceeded about 84 days per year. Figure 5-4 shows the results of the high-flow refugia assessment for 1,240 cfs, which has is the 4% daily exceedance flow and is expected to be exceeded about 15 days per year. Figure 5-5 shows the results of the high-flow refugia assessment for 2,598 fs cfs, which has a 1% daily exceedance flow and has a 1.1-year return period, and Figure 5-6 shows the results of the high-flow refugia assessment for 16,998 cfs, which has a 25-year return period. Modeling results for other flows are shown in Appendix J. Note that the hydraulic modeling does not capture localized roughness features, such as downed wood, that may create localized habitat.

5.4.1 River

Figure 5-3 through Figure 5-5, and other modeling results in Appendix J s that velocities in the main river channel are excessive for winter rearing and persist even along the channel margins during more frequent high flow events. During 5-year and greater flow events, lower velocity regions are present on Red Bank Bar adjacent to the river channel, but in most areas, flow depths are less than 0.5 feet deep.

The modeling results indicate there are three locations where high-flow refugia may be available in the river. These are at the entrance to the Primary Side Channel near river station 27+00, the hammerhead pool at river station 16+00 and at the alluvial bar/back channel and alcove on the western bank near river station 9+00.

Entrance to Primary Side Channel (River Station 27+00)

The entrance to the Primary Side Channel is located in a glide on the main river, and the side channel itself is a higher elevation than the river bed at this location (Figure 3-4). In the glide, water pools upstream of the side channel entrance before either flowing down the side channel or river. At flows less than 543 cfs, when little flow is entering the side channel, velocities in this pool are suitable for juvenile salmonids. However, as the side channel begins to convey more flow, velocities in this area increase and are not suitable as high-flow refugia.

Hammerhead Pool (River Station 16+00)

In the hammerhead pool, the hydraulic modeling indicates velocities during lower flows (1,240 cfs and less) are less than 1 fps, though the edges of the pool are less than 1-foot deep. The low-elevation aerial photograph in Figure 3-2, taken when river flows were approximately 1,000 cfs, shows that the velocities in the pool appear to be relatively slow adjacent to the more turbulent riffle. As flows increases above 1,240 cfs, velocities also increase, but some lower velocities appear to persist on the edges of the pool. During 2-year and large flow events, velocities within the Hammerhead become unsuitable for high-flow refugia.

Alluvial Bar Alcove (River Station 9+00)

During lower flows, up to 1,240 cfs, velocities in the alcove at the downstream end of the alluvial bar are suitable to provide high-flow refugia. The hydraulic modeling indicates flow depths are less than 0.5 feet during lower flows, however this area was not surveyed, and the flow depths may not be accurately simulated in the model. During the field investigations in October, 2015 (river flow of 34 cfs), this alcove was shallow and filled with decomposing organic matter. However, in February 2016, when river flows were about 1,000 cfs, the alcove appeared to be scoured out and a deeper pool present, as seen in Figure 3-2. As flows increase to 2,598 cfs, the back-channel on the alluvial bar becomes active, and there appears to be some lower-velocity areas of sufficient flow depth to provide high-flow refugia. As flows increase, velocities in the back-channel become unsuitable for high-flow refugia and velocities in the alcove begin to increase and become unsuitable for rearing.

5.4.2 Primary Side Channel and Far Side Channel

The hydraulic modeling indicated that the Primary Side Channel receives flow when river flows are near 350 cfs (36% daily exceedance flow), indicating that the side channel contains flows during most of the winter and spring months. At a flow of 532 cfs, only the Primary Side Channel is flooded, and none of the other side channels receive flow. During a flow of 532 cfs, flow depths in the Upper Side Channel are less than 0.5 feet. Depths are greater than 0.5 feet in most of the Lower Side Channel, and a large portion of the Lower Side Channel has velocities less than 1 fps. Generally, velocities rarely exceeded 1.3 fps elsewhere in the Lower Side Channel.

As flows increase in the side channel to about 650 cfs, the Far Side Channel becomes active. At a flow of 1,240 cfs, except within the transition riffle between the upper and Lower Side Channel, flow depths along the Primary Side Channel are suitable for rearing, and velocities range from 2 to 3 fps. Flow velocities in the Primary Side Channel tend to be uniform across the channel, and there is little diversity in flow direction or velocities across the channel.

Flow velocities are generally lower in the Far Side Channel than the Primary Side Channel. In the Far Side Channel, a variation of flow velocities and direction are generated by the planforms, flow splits and confluences of the multiple side channels. Flow depths are suitable along the upstream portions of the Far Side Channel, but become shallower as channel splits into multiple channels.

At 2,598 cfs, additional channels become active in the Far Side Channel. Flow depth in both the Primary Side Channel and Far Side Channel are suitable for rearing. Flow velocities in the main side channel exceed 4 fps and have little diversity in direction in velocity. Flow velocities in the Far Side Channel are slower than the Primary Side Channel, and continue to show a range of diversity in velocity and direction. As flows increase in the side channels, additional peripheral side channels become wetted. However, flow depths are atypically too shallow or velocities too high for rearing.

Fish seeking high-flow refugia off the main river can access the Primary Side Channel and Far Side Channel on the upstream side of the bar, or by navigating the steep riffle present at the downstream confluence of the Primary Side Channel and river. At flows less than 532 cfs, flows depths at both the entrance and exit of the side channel are less than 0.5 feet deep and access may not be possible. As flows increase, swim-in access from the upstream entrance of the side channel will be possible.

During flows less than about 1,500 cfs, flows in the river do not backwater the downstream confluence of the side channel (Appendix J), and fish accessing the side channel will need to navigate higher velocities on the steep riffle at the confluence. At flows when the river backwaters the confluence, flows in the side channel are nearly 5 fps, which may make swim-in access for small salmonids difficult. Therefore, fish access to the side channel is likely predominately from upstream.

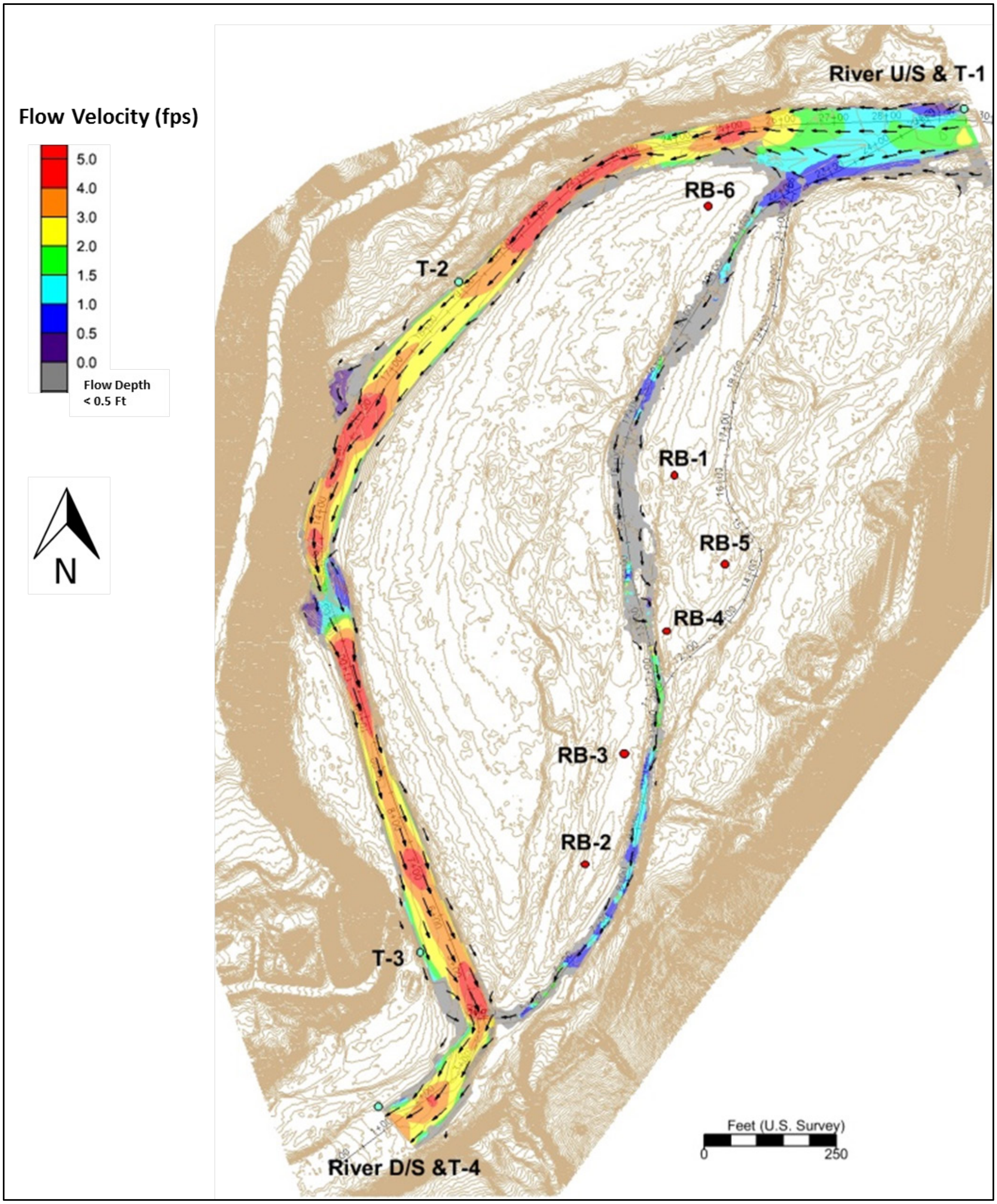


Figure 5-3. Hydraulic analysis to identify existing-condition high-flow refugia at 532 cfs event (23% daily exceedance flow). Flow depths less than 0.5 feet are shown in grey. Flow velocities greater than 5 fps are show as red.

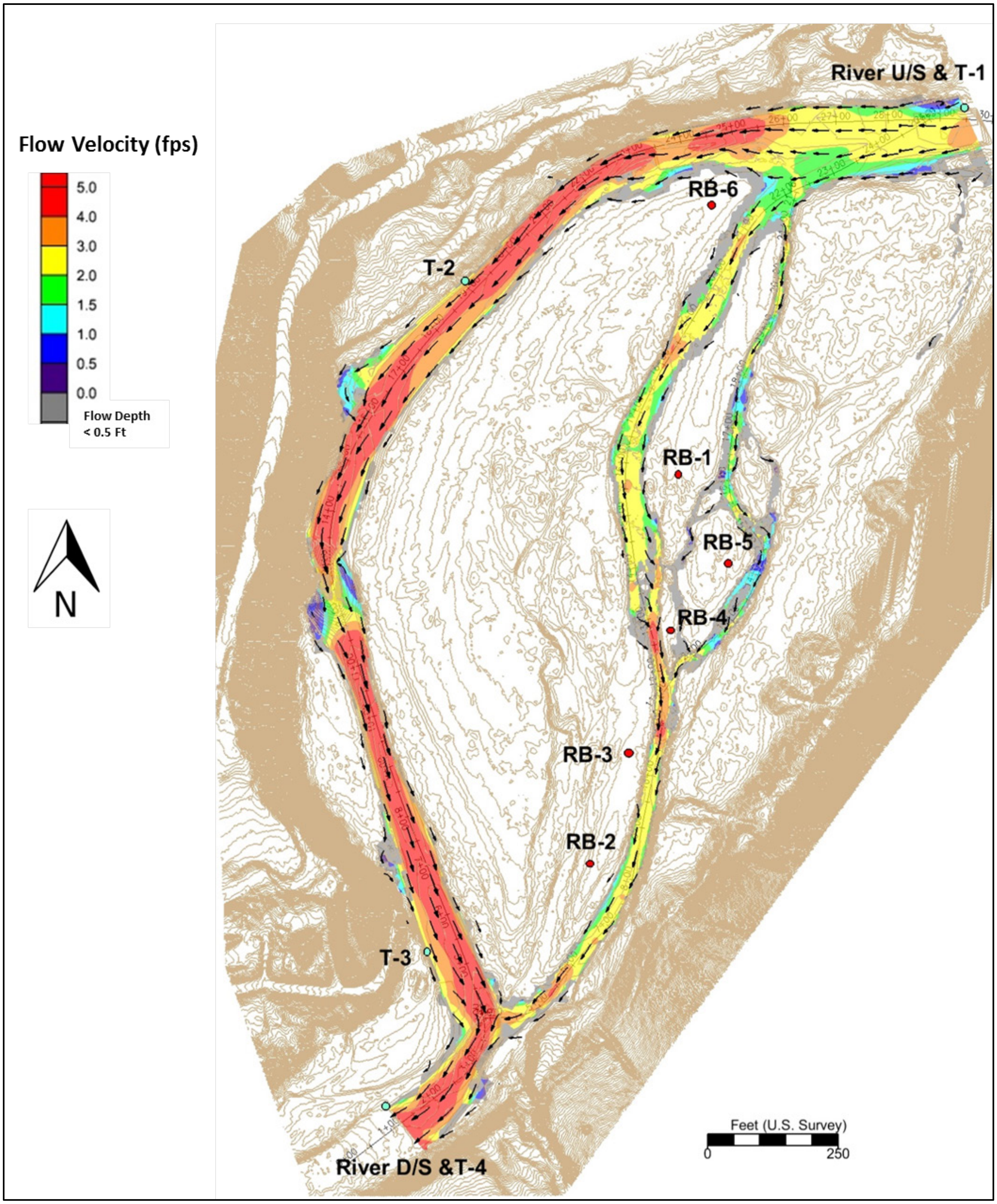


Figure 5-4. Hydraulic analysis to identify existing-condition high-flow refugia at 1,240 cfs (4% daily exceedance flow). Flow depths less than 0.5 feet are shown in grey. Flow velocities greater than 5 fps are show as red.

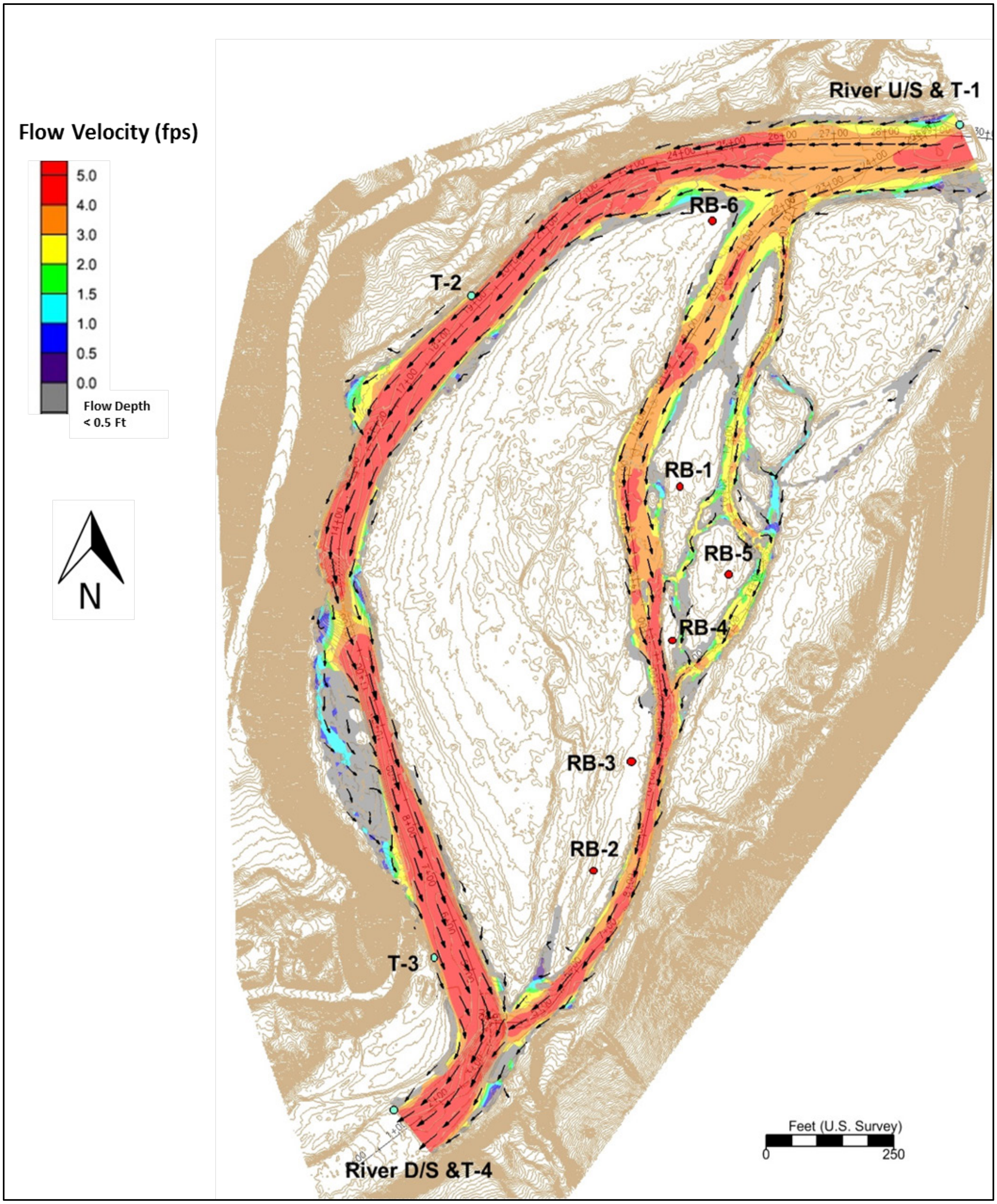


Figure 5-5. Hydraulic analysis to identify existing-condition high-flow refugia at 2,598 cfs flow (1% daily exceedance flow, 1.1-year flow event). Flow depths less than 0.5 feet are shown in grey. Flow velocities greater than 5 fps are show as red.

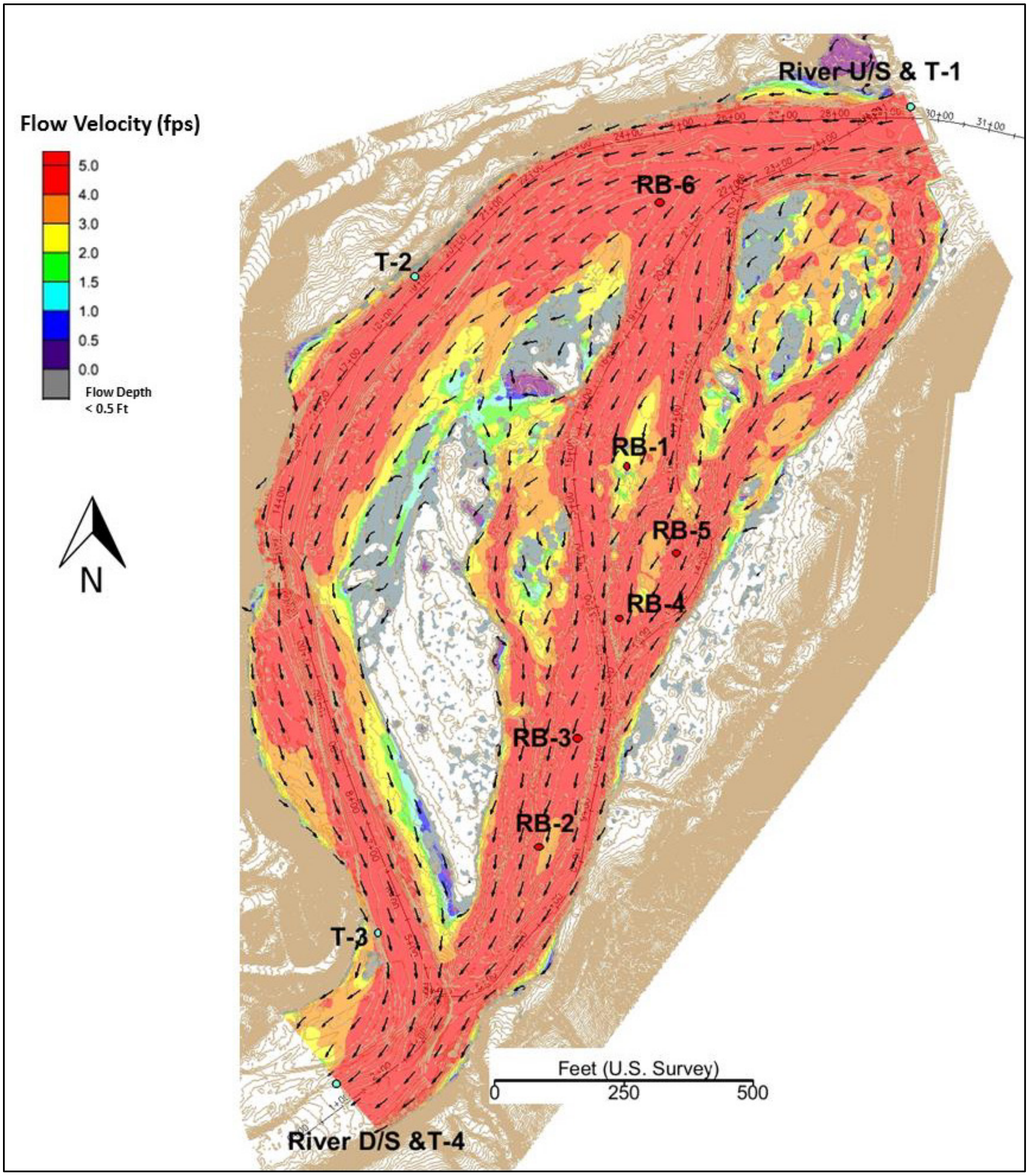


Figure 5-6. Hydraulic analysis to identify existing-condition high-flow refugia during a 25-year flow event. Flow depths less than 0.5 feet are shown in grey. Flow velocities greater than 5 fps are show as red.

6 DESIGN OF SALMONID HABITAT IMPROVEMENTS

6.1 Identification of Habitat Restoration Focus Areas

The results of the water quality and water level monitoring, geomorphic assessment, and hydraulic analysis found that the most suitable locations to improve or create high-flow velocity refugia and warm-season thermal refugia habitat for salmonids are at two locations on Red Bank Bar, totaling about 1,100 feet of side channel. Focusing habitat restoration in these two areas would be most cost-effective because habitat restoration techniques to create or enhance thermal refugia are often the same techniques necessary to create high-velocity refugia.

Project recommendations focused on the need for providing summer and winter rearing habitat for salmonids at Red Bank Bar. Existing conditions analysis showed a lack of high-flow refugia and thermal conditions unsuitable for salmonids during low-flow periods in the summer.

Section 6.3 presents a discussion of areas where habitat restoration was considered but was not pursued for a variety of reasons.

6.1.1 Lower Side Channel

The Lower Side Channel appears to be suitable for enhancing and expanding areas for thermal refugia, but is also an appropriate area to provide high flow refugia. The presence of perennial groundwater pools and suitable water quality conditions measured during the course of monitoring indicated that the Lower Side Channel creates highly suitable, but limited thermal refugia rearing habitat for salmonids. During higher flows in the river, velocities in the Lower Side Channel remain relatively low compared to other reaches of the side channels, but still higher than desired due to lack of complexity.

The restoration focus in the Lower Side Chanel is to increase the amount of forcing features to break up the plane-bedded nature of the channel. Forcing features will expand the size and depth of the groundwater-fed pools used for thermal refugia. The forcing features will also increase the complexity of the channel bed, creating a diversity in velocities and flow patterns that can be used by salmonids for high-flow refugia.

It is expected that fish will access this area primarily from upstream, finding the top of the side channel as they are moving downriver. Access from the downstream end of the side channel is unlikely due to the steep riffle and high velocities at the confluence with the river.

6.1.2 Far Side Channel

The lower reaches of the Far Side Channel were identified are a focus area to increase high-flow refugia habitat. The multiple channels provide numerous areas for habitat enhancement and generally have lower flow velocities than the Primary Side Channel. Fish could access the Far Side Channel from the River on the upstream end and Primary Side Channel on the downstream end.

The habitat enhancement focus in this area is to increase the complexity of the channel bed and banks to provide high flow velocity refugia. Due to the size of the material comprising the bed, it will be necessary to specifically excavate pools rather than allow them to self-scour. However, it is not expected that the pools will fill in.

Insufficient information is available on the groundwater elevations in this area to identify if increasing the depth and area of pools in this area would provide rearing area for thermal refugia, but based on observations of existing pools in this area, it is unlikely.

Additionally, consideration was given to improving the Far Side Channel to provide spawning habitat. Studies on Oregon coastal streams found that coho fry emergence takes place between March and July, with peak emergence in March and May (Groot & Margolis, 1991). The pools in the Far Side Channel were observed to dry out in mid-May, which could potentially dry out any late-hatching eggs. Therefore, this area will likely be unsuitable for spawning habitat, except during years with wet springs.

6.2 Habitat Enhancement Approach and Techniques

The approach for enhancing the off-channel habitat at Red Bank Bar was based on the premise that persistent and sustainable salmonid rearing habit can be created by substantially increasing the number and stability of forcing features within the side channels that create scour pools and flow diversity. The few existing forcing features within the lower Primary Side Channel create the limited amount of rearing habitat present in the otherwise plane-bed channels. Additional forcing features will expand the amount of rearing habitat.

Rather than large-scale side channel and alcove excavation, or installation of large structures to redirect flows; the restoration approach at Red Bank Bar will use several localized techniques to force the break-up of the plane-bedded nature of the side channels. Each of the proposed habitat enhancement techniques is described below. These techniques become effective at providing high-flow refugia in different locations at differing flows. Hydraulic modeling was used to evaluate the performance of most of the proposed structures.

Design plans for the project are shown in Appendix A. The modeling results for each structure are presented in the following descriptions. The locations of each habitat enhancement technique are shown where they are feasible and their benefit will be optimized. The exact location of each feature will be adjusted in the field during construction to work within the existing site constraints. Anticipated scour depth and structure anchoring computations will be provided as part of final design.

Based on the recommendations from the project geologist, all graded slopes will be no steeper than 3H:1V.

6.2.1 Alcoves and Backwater Features

Alcoves

Two different techniques to create small alcoves are recommended; channel-edge alcoves and off-channel alcoves. Both of these alcoves will provide perennial groundwater-fed pools that can be used for thermal refugia. Both also create quiet, low-velocity habitat. Neither of these techniques creates a more traditional in-line alcove. In-line alcoves are located centrally in a channel and receive high flows from the upstream channel that scour and maintain the alcove. In-line alcoves were not considered for the Red Bank Bar project due to space constraints and sediment transport concerns, as discussed in Section 6.3.

Channel-edge alcoves are similar to in-line alcoves, in that they rely partly on upstream flows to scour and maintain the alcove pool. Instead, they are small alcoves located at the edges of the channel where sediment transport is substantially lower than in the center of the channel, reducing the chance for sedimentation within the alcove pool.

Off-channel alcoves are located completely off the channel, with only a narrow channel connection between the alcove and the main channel. Off-channel alcoves receive flows primarily by groundwater or backwatering from the adjacent channel. Frequent inflows that could carry sediment into the alcove are undesirable.

Selection of the technique to construct an alcove at Red Bank Bar was based on the amount of space available for excavation on the floodplain. The materials comprising the subgrade at Red Bank Bar consist of non-cohesive, unconsolidated materials that cannot maintain a side-slope steeper than a 3H:1V. Up to 10-feet of excavation will be necessary in places to create an alcove pool that will provide sufficient depth below the summer groundwater elevation. Large excavation areas are limited at Red Bank Bar due to multiple side channels flowing adjacent to each other, large trees that would be beneficial to retain, or high, steep hillslopes. Therefore, the alcove-creation techniques recommended for Red Bank Bar use a combination of excavation and large wood structures to create the alcoves.

Root Wad Alcove (Channel-Edge Alcove): Root Wad Alcoves are channel-edge alcoves that are recommended where there is little space to excavate an alcove completely into the adjacent floodplain. Root Wad Alcoves are small "pocket" alcoves constructed by partially excavating the streambank and partially relying on a wood structure to create and maintain the alcove.

Design drawings for a Root Wad Alcove are show in Figure 6-1. A pool will be excavated at the side of the channel bed and into the streambank as feasible. The pool will be constructed to provide about 2-feet of depth below the summer groundwater elevation. Tree trunks with root wads will be placed upstream of the pool to direct flow around the structure, creating a low-velocity flow area along the streambanks. The pool in the alcove will be maintained by both flow scour around the root wads and plunging flow over the tree trunks during larger flow events. A root wad placed in the pool will provide edge complexity and cover in the pool.

Root Wad Alcoves are similar to Root Wad Cover Structures (see below), but project further into the stream channel to exploit the plunging flows to maintain the alcove pool. The large wood comprising the Root Wad Alcove will be stabilized by partially burying the tree trunks and using pinning logs.

The hydraulic performance of a Root Wad Alcove was evaluated with the 2-dimensional hydraulic model to verify flow velocities and expected pool scour depth and location. The results of the modeling were used to refine the concept design and are shown for a flow of 1,240 cfs (4% daily exceedance flow) in Figure 6-2. The modeling verifies the flow accelerations around the edges of the root wad that will create a scour pool, and the high velocity plunging flow that will occur over the tops of the tree boles that will create a scour pool downstream of the trees. A low-velocity zone is also present adjacent to the streambanks upstream and downstream of the log structure at this flow.

Alcove with Abutment Jams: An Alcove defined by an Abutment Jam on the channelward side will be constructed midway along the Lower Side Channel where space is available on the floodplain to excavate an alcove. The Alcove will be located completely off-channel and rely solely on groundwater and backwater from the channel to maintain the pool depth. This off-channel feature will provide thermal refugia in the groundwater–fed pool and high-flow refugia when flow velocities are elevated within the side channel.

Designs for an Alcove with Abutment Jam are shown in Figure 6-3. The Abutment Jam will be oriented in a flow-parallel direction so it does not project into the flow area. The alcove pool will be excavated in the floodplain behind the Abutment Jam. The size, depth, and shape of the pool will be constrained by the space available and preservation of large trees. On the channelward side of the

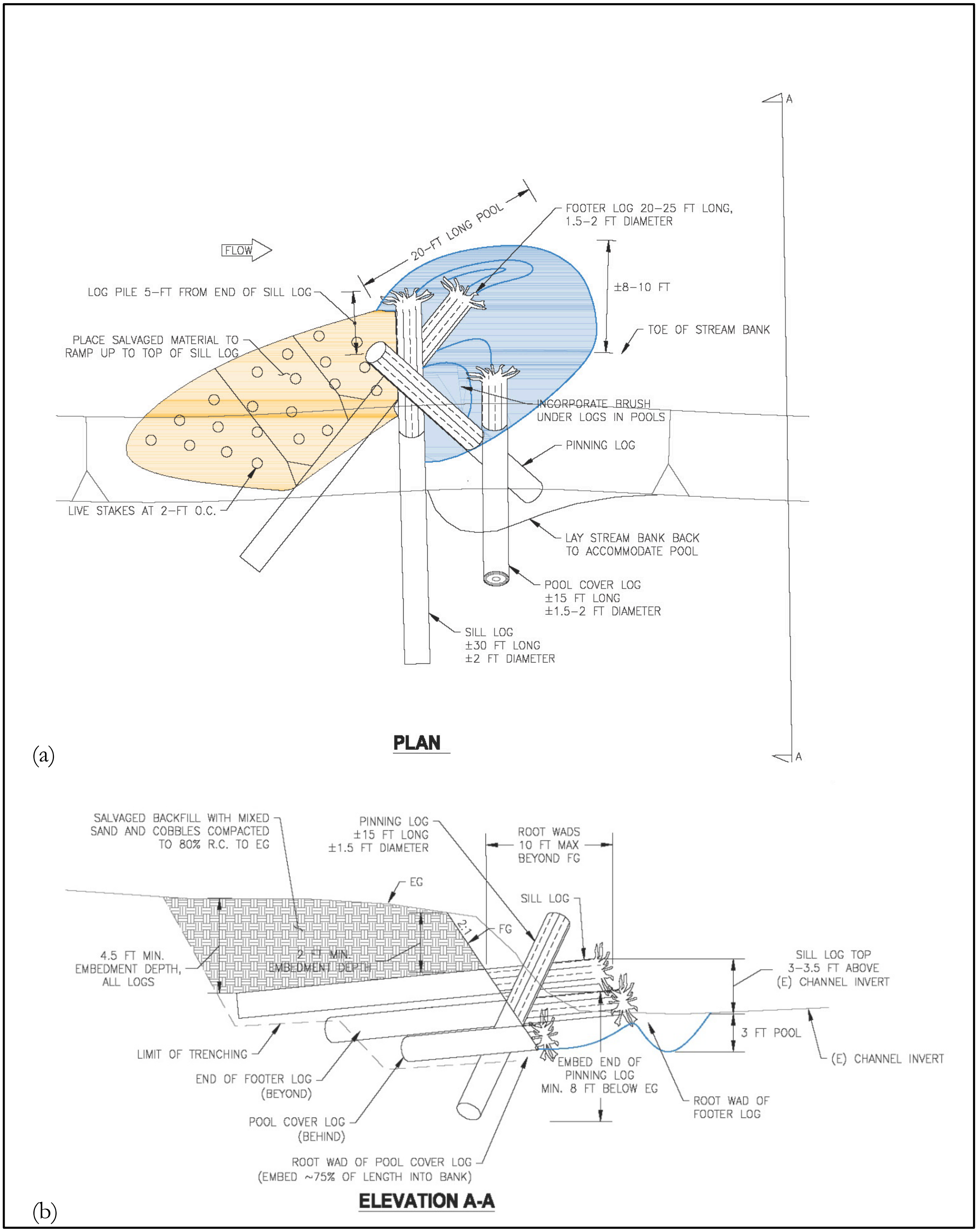
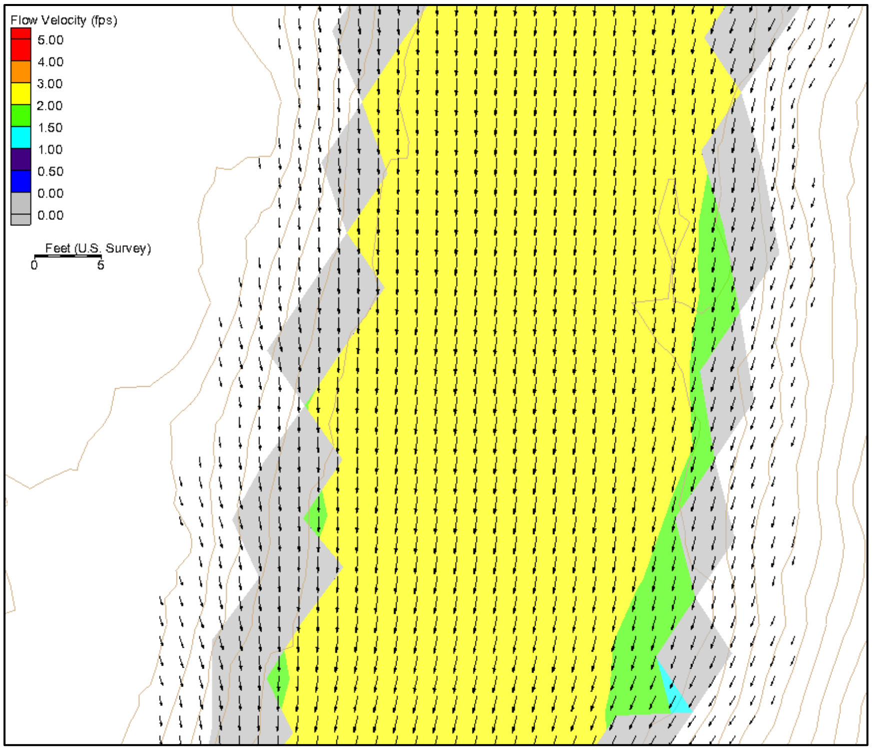


Figure 6-1. Design drawings for a Root Wad Alcove in (a) plan and (b) section.

a.


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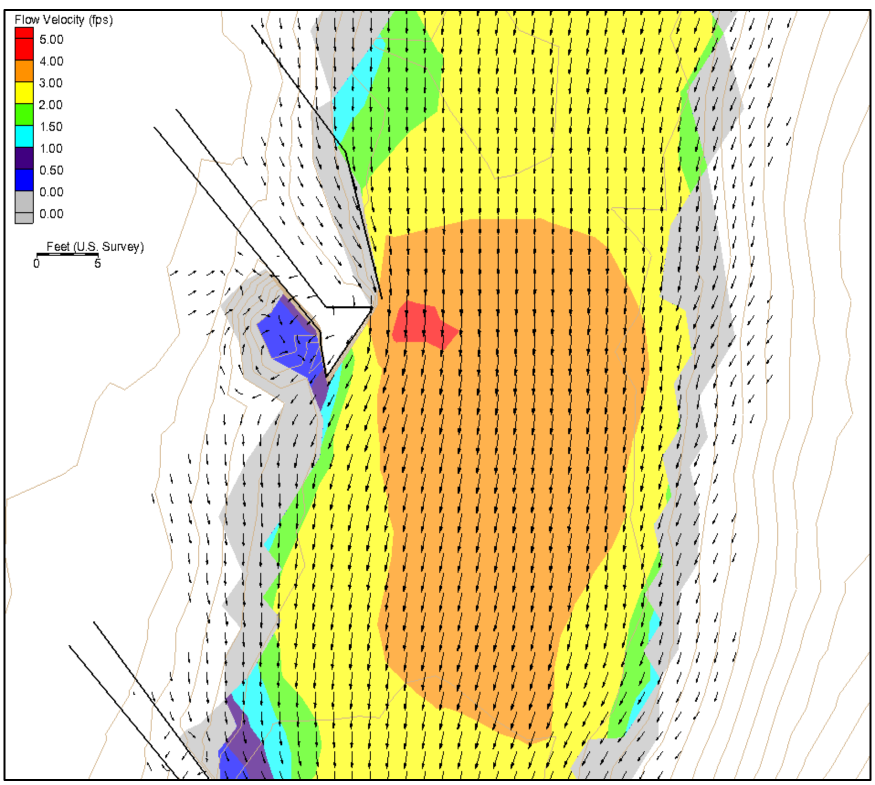


Figure 6-2. Two-dimensional hydraulic modeling of channel velocities for (a) existing conditions and (b) Root Wad Alcove on the Lower Side Channel at 1,240 cfs (4% exceedance). Flows less than 0.5-feet deep are shown in grey.

Figure 6-3. Design drawings for an Alcove with Abutment Jam in plan view.

alcove, an Alcove Abutment Jam will be used to create a peninsula-shaped feature that will define both the inside edge of the alcove and the channel bank. The Alcove Abutment Jam will be narrower and not project into the flow area like a larger independent Abutment Jam (see below). Root wads located on both the alcove and channel-side of the Alcove Abutment Jam will provide cover and create flow complexity.

The intent of the Alcove Abutment Jam is to create a feature that separates the main channel from the alcove and does not require a lot of space. It is not intended to create a large scour pool like an independent Abutment Jam. Also, unlike an independent Abutment Jam, the Alcove Abutment Jam will be constructed so that it projects only minimally beyond the existing streambank. If it were constructed to project beyond the streambank, there is the potential for deposition to occur at the downstream end of the jam which could close off the mouth of the channel entering the alcove.

An aquatic bench constructed in the alcove below the groundwater elevation may be feasible, depending on space constraints and proximity of large trees. The location, width and elevation of an aquatic bench will be field-fit during constriction. Root Wad Cover Structure and Cantilever Logs can be installed within the alcove to increase edge complexity and create cover.

Backwater Features

MLA designed a total of eight backwater features for the project, with support from SRRC, Toz Soto of the Karuk Tribe, and Josh Strange of Sweet River Sciences. The primary objective for the backwater features is to provide off-channel high-flow refugia where rearing salmonids will temporarily take refuge during high-flow events.

The backwater features will be excavated into higher elevation areas of Red Bank Bar adjacent to the river and side channels so they become backwatered during flow events as low as winter baseflow, but will not receive overland flow until during extreme flow events. The rationale for constructing features in these higher-elevation areas is that they will not be flow-through features except for extreme events, thus will provide low velocity zones during larger flow events and be less prone to sedimentation.

The original intent of the backwater features was to provide areas of quiet water during elevated flows, with no habitat features that would encourage fish to linger in the features. Thus, the preliminary design of the backwater features consisted of simple trapezoidal features with at 5-foot bottom width and positive drainage towards the receiving channel. After review of the concept designs for the backwater features, Toz Soto said that observed juveniles in the Salmon River typically redistribute into new habitats in the fall and do not move around during the winter months. Therefore, they may not find the backwaters during high flows. Additionally, Mr. Soto requested that the mouths of the backwaters be flared at their confluence with the receiving channel to make it easier for fish to find the features. Based on Toz's comments, SRRC directed MLA to change the shape of the Backwater 4 through 8, expand the widths of the pond areas, and include large wood habitat structure within these features.

Aerial photographs were used to refine the locations and shapes of the backwater features where the least number of large trees would be affected by the excavation of each feature. For Backwaters 4, 5, 7, and 8, the grading extents of each backwater were determined using a 15-foot wide mouth, 5-foot wide throat, and 15-foot wide pond area, with 3H:1V side slopes. The grading for Backwaters 1,2 and 6 used only a 5-foot bottom width due to site constraints. The longitudinal profiles of the backwaters generally meet the invert elevation of the channel to which they are adjacent. Site constraints limited the depth of excavation for Backwater 2, as described below.

To prevent fish stranding, the backwaters were designed to slope towards the receiving channel, with the exception of Backwater 6, which will contain a seasonal groundwater-fed pool. Backwater 4 through 8 will contain Root Wad Cover structures to enhance fisheries habitat. Additionally, a large wood structure or random boulders will be installed in the receiving channel at the mouth of most of the backwaters to maintain sediment transport across the mouth to prevent aggradation and potential mouth closure of the feature.

Material excavated from the Backwater features will be placed on the upstream side of the excavated feature to divert floodplain flows around the feature for flows up to a 25-year event. In general, spoil placement will not exceed approximately 2 to 3 feet in height. The berms will prevent flows into the features from the floodplain to ensure that water velocities in the backwatered features remain less than 1 fps. Additionally, the berms will minimize the potential for sedimentation within the backwaters.

Where groundwater is in closer proximity to the grounds surface, Brush Baffles, rather than spoil piles, will be placed on the upstream side of each alcove to divert flow around the mouths of the Backwater to minimize sedimentation. During construction, the actual placement and extent of the grading and placement for each feature will be field-adjusted to minimize impacts to large trees.

Figure 6-4 shows 2-D hydraulic modeling results of 5-year flow velocities for the preliminary design of the backwater features. Additional figures of modeled flow depths and velocities for a range of flow events are shown in Appendix K. Note that as part of final design, the shape of some of the backwater features changed, and Backwater 2 was moved slightly upstream.

Following is a brief description of each backwater feature:

Backwater 1 will be located adjacent to the lower portion of the Secondary Side Channel. The invert elevation of the mouth of Backwater 1 will be the same as the invert elevation of the Secondary Side Channel. This feature will start to activate during a 1.1-year flow event, when the side channel is backwatered by the river. As flows increase, a greater area of the Backwater feature will be activated. The depth of this backwater was limited primarily by the presence of large trees at its mouth and on the bar surface. To minimize the extents of grading at the mouth, it may be necessary to stack salvaged boulders on one or both sides of the channel within the riparian area.

Consideration was given to excavate the bottom of Backwater 1 to an approximately elevation of 1696 feet to create an additional off-channel area with a groundwater-fed perennial pool. However, it was determined that the extents of excavation would be large and result in substantial impact to large riparian trees.

Backwater 2 will be located adjacent to the Salmon River near Station SR10+00. This feature will become active become during flows as low as 1,100 cfs (5.5% Annual Exceedance). The mouth of Backwater 1 was placed within the alder and willow riparian area adjacent to the river. To minimize the extents of grading at the mouth, it may be necessary to stack boulders on one of both sides of the channel within the riparian area.

Backwater 3 will be located adjacent to the Secondary Side Channel. This feature will become active during 2 -year flow and larger flow events when the side channel is active. Backwater 3 will be a "passive backwater" in the sense that it will not be excavated. It will be created by placing spoils to block floodplain flows into a historic mining pit adjacent to the Secondary Side Channel, effectively creating a backwater area. Spoil material from the excavation of the other Backwater features will be used for the spoil placement at Backwater 3. The higher area upstream of the pit where spoils will be placed is a large flat area comprised of mining tailings.

Backwater 4 will be located adjacent to the Far Side Channel near station FS 20+50. This feature will become active during flows as low as 1,100 cfs (5.5% Annual Exceedance). The invert elevation of the mouth of Backwater 4 will be the same as the invert elevation of the Far Side Channel, allowing fish access into the backwater feature when flows are present in the Far Side Channel.

Backwater 5 will be located adjacent to the Primary Side Channel near station SC17+50. This feature will become active during flows as low as 1,100 cfs (5.5% Annual Exceedance). The invert elevation of the mouth of Backwater 5 will be the same as the invert elevation of the Side Channel, allowing fish access into the feature when flows are present in the Primary Side Channel.

Backwater 6 will be located adjacent to the Far Side Channel. This feature will become active during flows as low as 1,100 cfs (5.5% Annual Exceedance). The invert elevation of the mouth of Backwater 6 will be the same as the invert elevation of the Far Side Channel, allowing fish access into the feature when flows are present in the Side Channel.

Backwater 6 is expected to have a seasonal groundwater elevation similar to the Far Side Channel, where groundwater-fed pools are present through the spring. Therefore, Backwater 6 will be constructed to maintain a residual pool. It is expected that the pool within Backwater 6 will dry out during the summer months and there is a chance of fish stranding in the pool. However, the pool in the backwater will be similar in elevation to the naturally formed pools in the adjacent side channel, thus will provide no greater risk of stranding than the natural pools.

Backwaters 7 and 8 will be located adjacent to a tributary that flows into the Far Side Channel on its north side. Hydraulic modeling indicated that the channel to which these features are connected will become active during a 2 to 5-year flow event. However, this channel was active during a field visit in March, 2017, indicating that localized sediment patterns may affect the activity of this channel. The invert elevations of the feature's mouths will be the same as the invert elevation of the adjacent channel, allowing fish access into the backwater feature when flows are present in the channel.

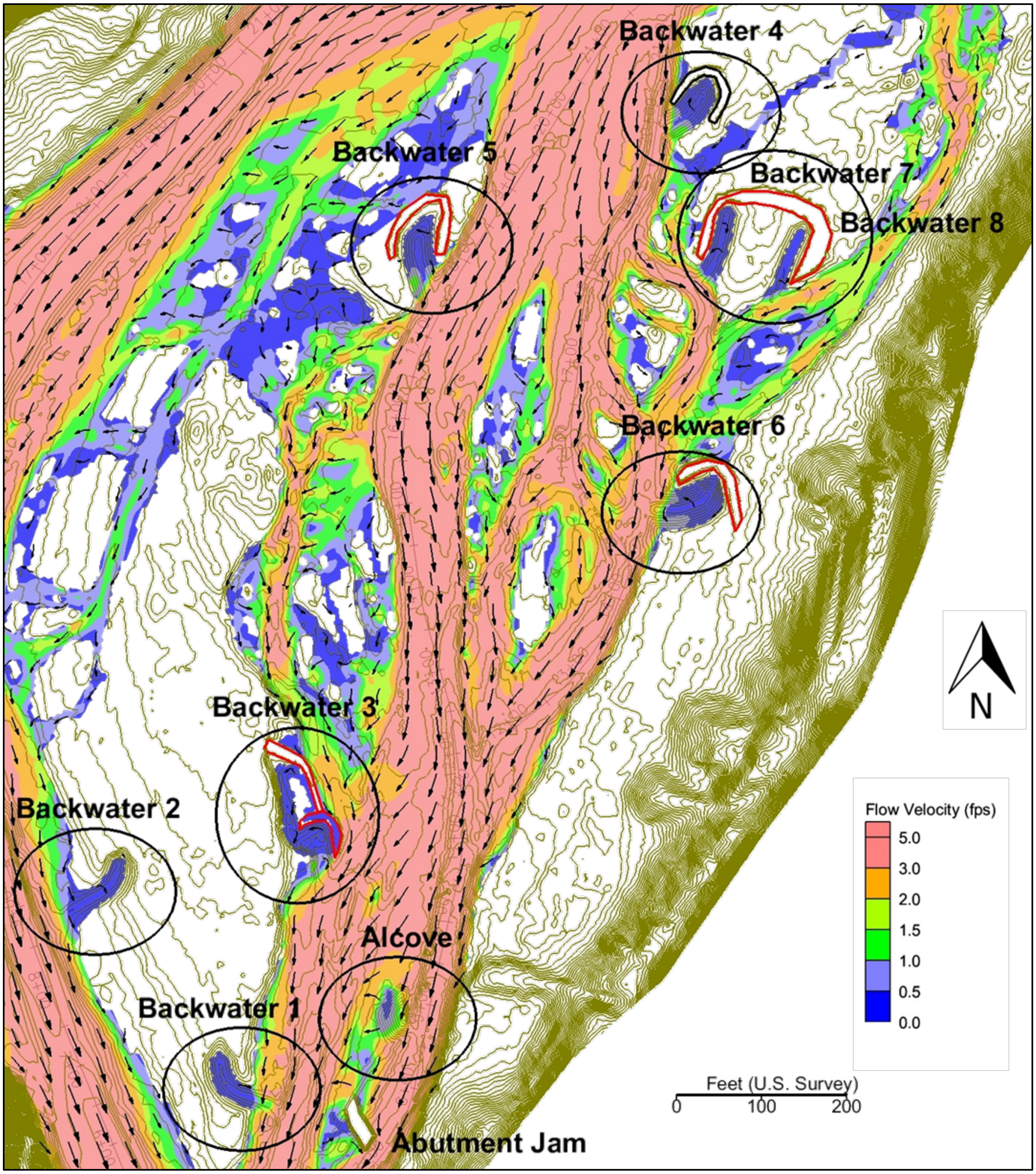


Figure 6-4. Two-dimensional hydraulic modeling results of 5-year flow velocities from preliminary Backwater feature design. The features differ slightly in the final design.

6.2.2 Root Wad Cover Structures

Root Wad Cover Structures imitate fallen trees that project into the flow area of a channel, constricting flows and creating a scour pool. The roots in the root wad create complex edge habitat that creates cover and slow velocities.

Figure 6-5 presents the design of a Root Wad Cover Structure. The structure will consist of one to two logs buried into the streambank such that the root fans project into the stream flow. An approximately 2-foot deep scour pool will be constructed downstream of the root fans. Additional brush will be incorporate into the trench to increase the complexity of cover in the scour pool. The structure will be stabilized by partially burying the tree trunks and using pinning logs as necessary.

The hydraulic performance of a Root Wad Cover Structure was evaluated with the 2-dimensional hydraulic model to verify flow velocities and expected pool scour depth and location. The results of the modeling were used to refine the concept design and are shown for a flow of 1,240 cfs (4% exceedance flow) in Figure 6-6. The modeling indicates that the projection of the root wad into the stream channel will create a broad low-velocity zone adjacent to the streambank. Additionally, the concentration of flow around the root wads will create a high velocity flow jet at the end of the root wad and downstream that will create and maintain a scour pool.

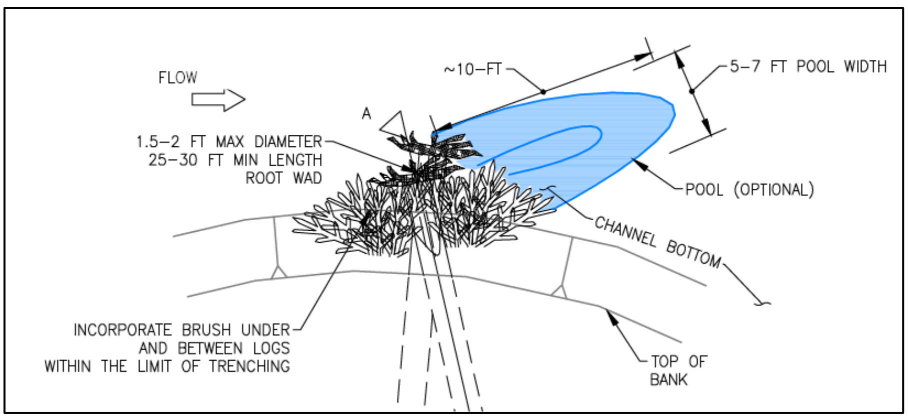
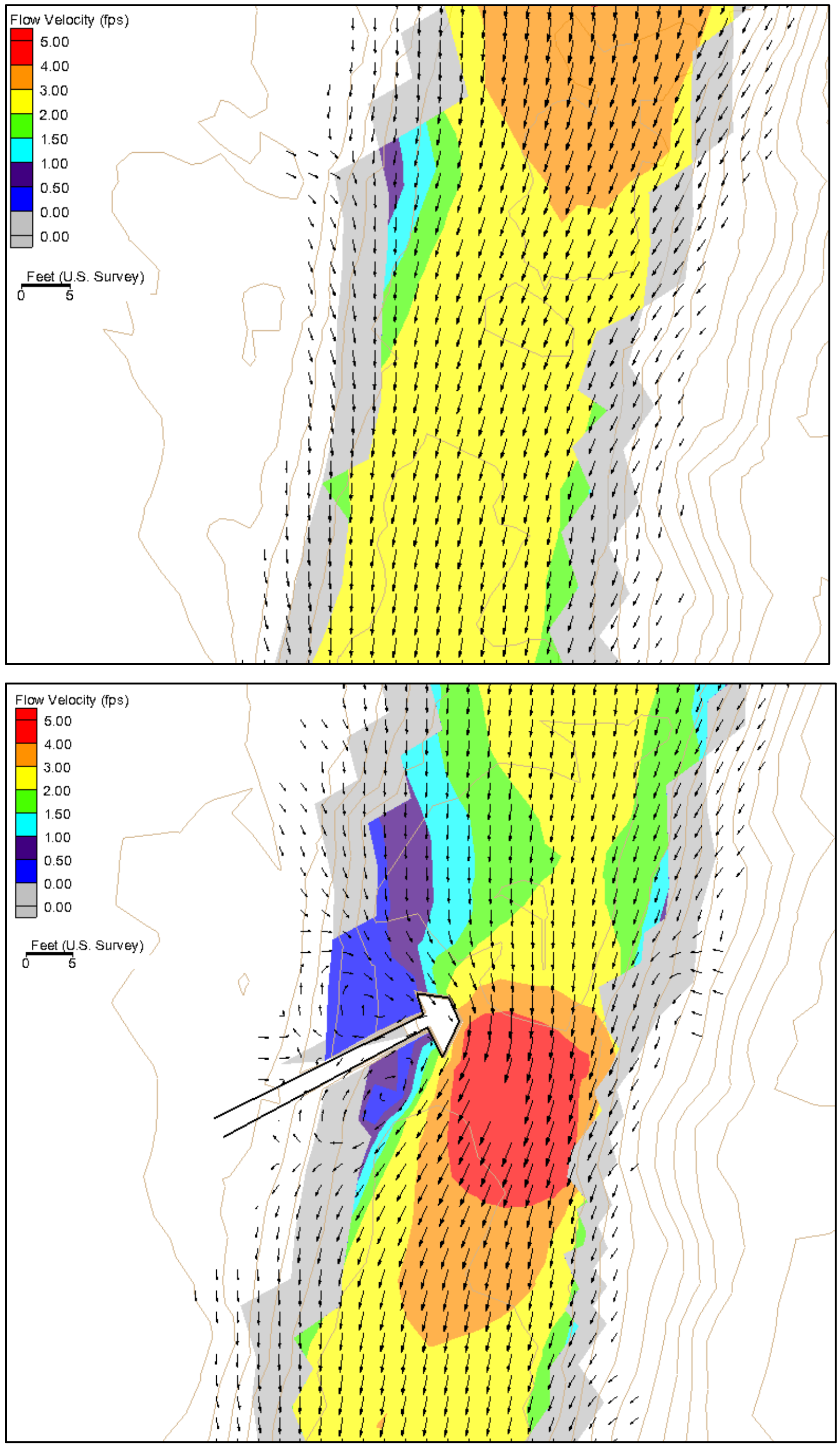


Figure 6-5. Design drawing of a Root Wad Cover Structure.



a.

b.

Figure 6-6. Two-dimensional hydraulic modeling of channel velocities for (a) existing conditions and (b) Root Wad Cover Structure at a 1,240 cfs flow (4% exceedance). Flows less than 0.5-feet deep are shown in grey.

6.2.3 Bank Logs

Trees with root fans partially obstructing flow, or that have fallen and laying on the streambank often cause localized constrictions and accelerations in flow velocities that result in the development of a scour pool around the tree roots. A photograph of a tree adjacent to the Lower Side Channel with scour around its roots is shown in Figure 6-7. An approximately 1.5 to 2-foot deep scour pool had formed around the roots of this tree and was filled with groundwater, providing thermal refugia with complex cover. Salmonids were present in this pool in October, 2015.

Figure 6-8 presents a design drawing of Bank Log Structures. These structures are used similarly to Root Wad Cover Structures, but are used in areas where trenching to install a structure is not feasible, such as steep or tall slopes, or unstable slopes.

The Bank Log Structure will consist of a large tree placed on the surface of the adjacent hillslope such that its root wad projects into the flow area. An approximately 2-foot deep scour pool will be constructed adjacent to and downstream of the root fan. The structure would be stabilized by lodging the trunk of the bank log between several trees on the slope to prevent rotation. It may also be necessary to install pinning logs to restrain uplift and prevent rotation. A root wad on the pinning log can be used to create a larger flow obstruction that will create a larger pool and low-velocity area adjacent to the streambank.

The hydraulic performance of a Bank Log Structure is expected to be similar to a Root Wad Cover Structure.

Figure 6-7. Scour hole that developed adjacent to exposed tree roots in the Lower Side Channel. Water filling the hole is groundwater and salmonids were present in October, 2016.

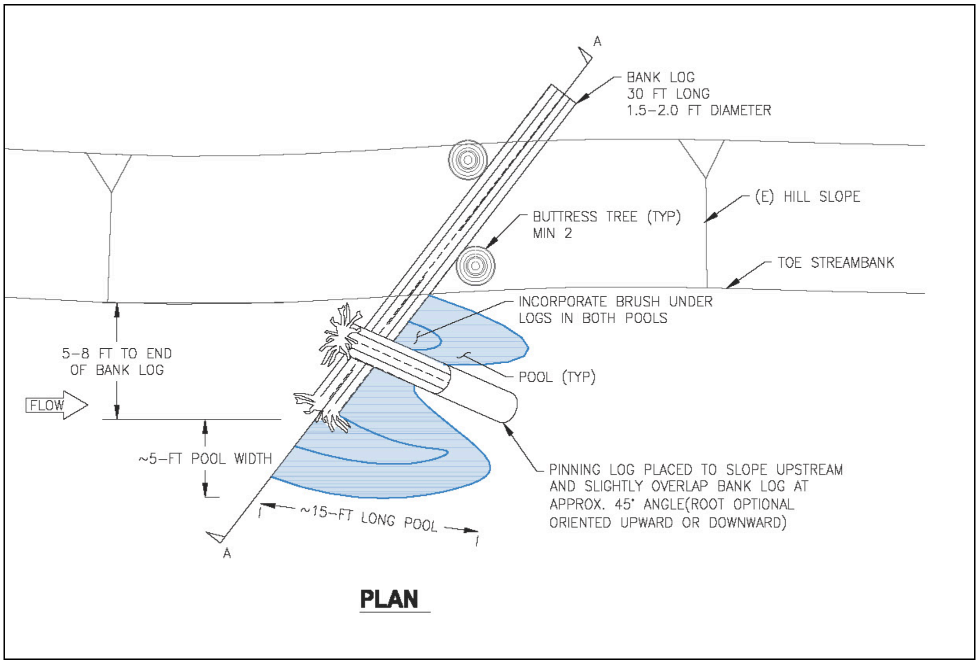


Figure 6-8. Design drawing for Bank Logs (plan view).

6.2.4 Abutment Jam

Abutment Jams simulate areas of the channel where a large quantity of logs and brush has accumulated, projecting into the stream channel and creating a large scour pool and broad low-velocity zone adjacent to the streambank. This accumulation often starts as a small structure like a root wad, but increases in size and height. Abutment Jams are used in areas of a channel where a large scour pool and broad low-velocity zone adjacent to the banks are desired.

Design drawings for an Abutment Jam are shown in Figure 6-9. An Abutment Jam will be similar to an Alcove Abutment Jam as shown in Figure 6-3, but will be larger and project into the stream channel, unlike the Abutment Jam associated with the Alcove. The projection of the Abutment Jam into the stream channel is expected to form a broad and long scour pool. The structure consists of Racking Members and Key Members stacked to form a box-line structure with the tree trunks in the center of the structure. Between each layer of trees, boulder and cobble ballast will be contained within brush "baskets" to prevent flotation of the structure and control porosity/piping. Log piles will also be used primarily to hold together the stacked logs, but will also act to prevent resist sliding and rotation of the structure. To contribute to structure stability, the top of the structure will extend about 2- feet above the adjacent floodplain elevation.

The hydraulic performance of an Abutment Jam in the Lower Side Channel was evaluated with the 2-dimensional hydraulic model to verify flow velocities and expected pool scour depth and location. The results of the modeling were used to refine the concept design and are shown for a flow of 2,598 cfs (1.2-Year flow exceedance flow) in Figure 6-10. The modeling indicates that the projection of the Abutment Jam into the stream channel will create a broad low-velocity zone adjacent to the streambank. Additionally, the concentration of flow around the root wads will create a high velocity flow jet at the edge of the Abutment Jam that is expected to create and maintain a scour pool extending across most of the channel width.

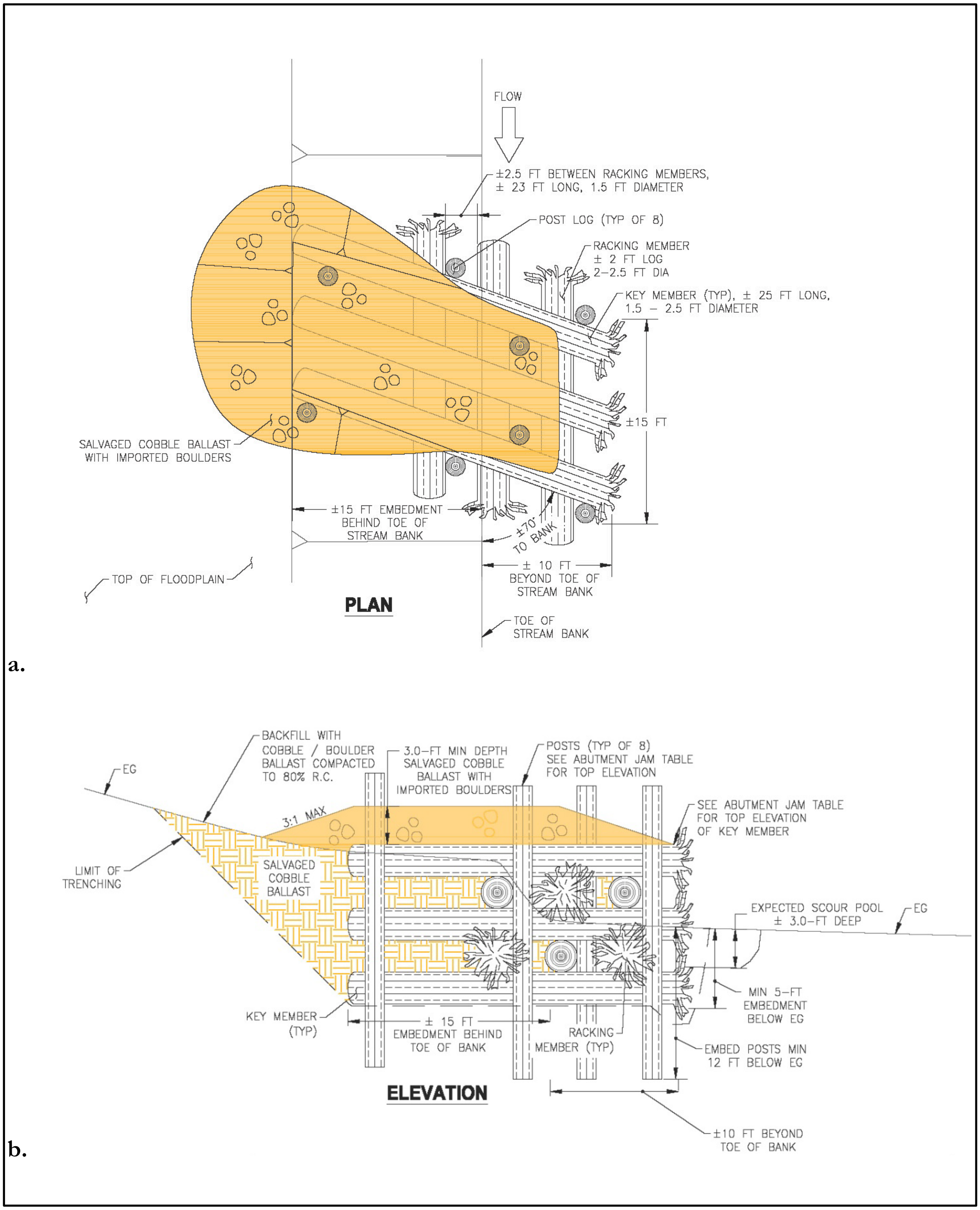
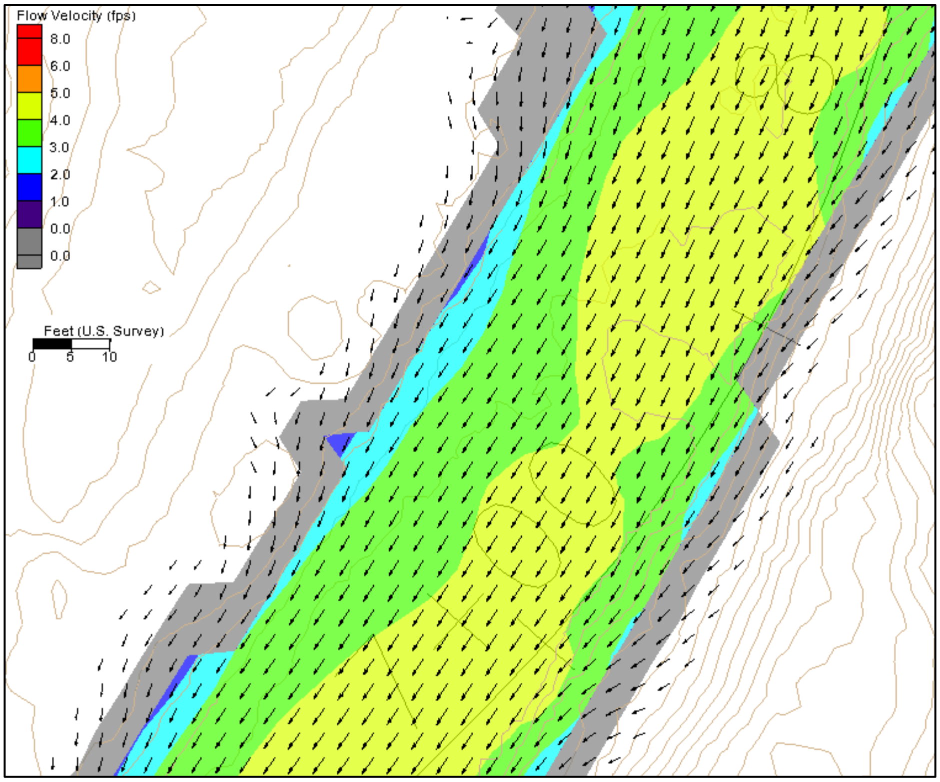
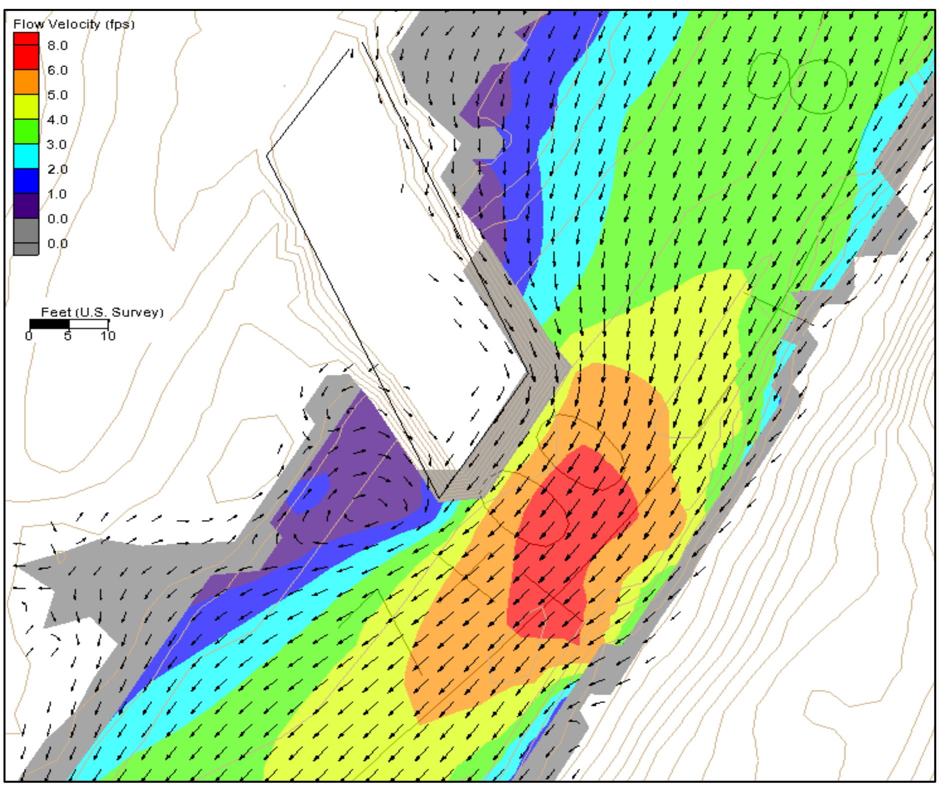


Figure 6-9. Design drawings for an Abutment Jam in (a) plan and (b) section.



a.



b.

Figure 6-10. Two-dimensional hydraulic modeling of channel velocities for (a) existing conditions and (b) Abutment Jam on the Lower Side Channel at a 2,598 cfs flow (1.2-year event). Flows less than 0.5-feet deep are shown in grey.

6.2.5 Apex Jams

Apex jams (Abbe and Montgomery, 1996) consist of single or multiple root wads lying flow-parallel in the channel with the root-fan facing upstream. The root fan of an Apex Jam causes flow accelerations around the root fan, resulting in the development of a crescent-shaped scour pool upstream of the root fan that would create a perineal pool that provides salmonids thermal refugia area. Flow eddies (reverse currents) develop downstream of the root-fan, creating a lower velocity zone downstream of the root fan that would be used by salmonids as high-flow refugia.

A photograph of a downed tree forming an Apex Jam in the Lower Side Channel at Red Bank Bar is shown in Figure 6-11. At Red Bank Bar, an approximately 3-foot deep scour pool had formed around the root fan and was filled with groundwater, providing optimal thermal refugia with complex cover. Because the downed tree forming the Apex Jam at Red Bank Bar was not anchored in place, it has floated away since it was initially observed. However, with suitable anchoring, Apex Jams can be used to create persistent high-flow refugia and pools that provide thermal refugia.

Figure 6-12 presents a design drawing of an Apex Jam structure. The main root wad forming the Apex Jam will be pinned in-place using two root wads or tree trunks. Additionally, the structure will be ballasted using salvaged cobbles and boulders.

The hydraulic performance of an Apex Bar Jam was evaluated with the 2-dimensional hydraulic model to verify flow velocities and expected pool scour depths. The results of the modeling for a flow of 1,240 cfs (4% daily exceedance flow) are presented in Figure 6-13. The crescent shaped low-velocity flow shadow that will be created downstream of the root fan of the Apex Jam is evident.


(a)

(b)

Figure 6-11. Photographs of an Apex Jam in Lower Side Channel at Red Bank Bar (a) looking downstream and (b) looking across the channel. Note the crescent-shaped groundwater fed pool around the root fan.

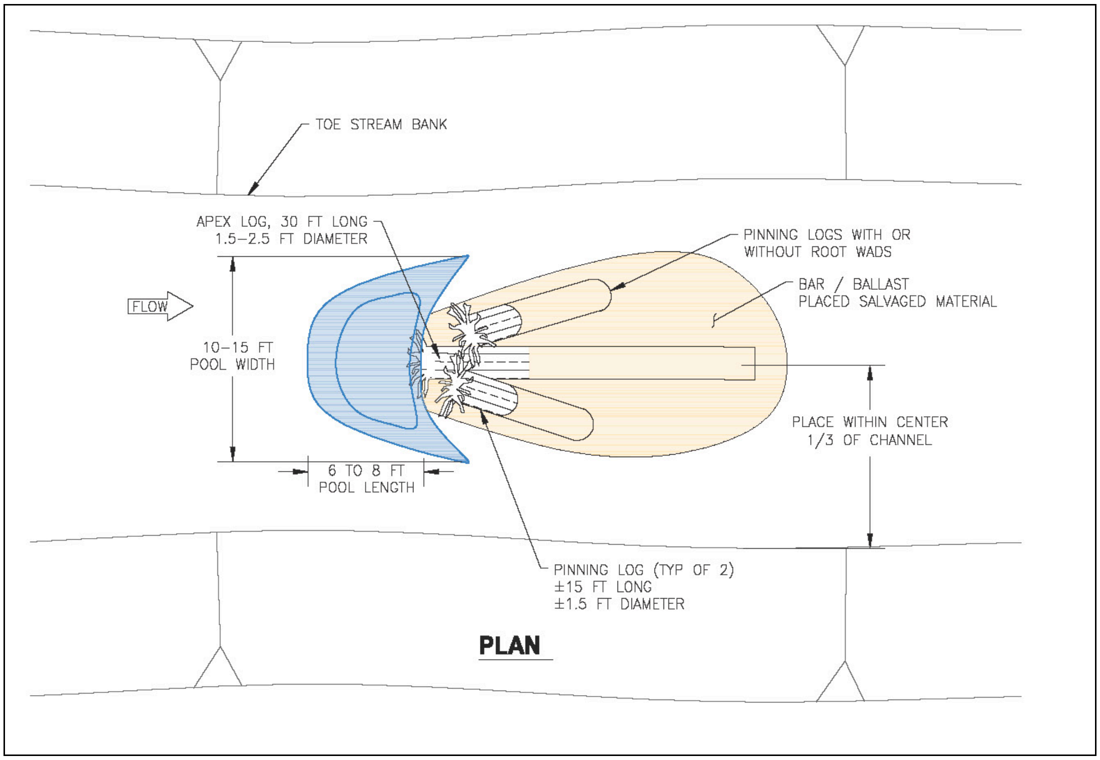


Figure 6-12. Design drawing of an Apex Jam with anchoring.

6.2.6 Random Boulders

Random Boulders are large boulders placed in the channel that obstruct flow, creating a scour pool on the upstream and sides of the boulder and a low-velocity zone downstream of the boulder. Random Bounders function similarly to Apex Jams, but due to their lower profile, they are more effective at lower flows. As an example, Figure 6-14 shows a photograph of a large boulder in the Far Side Channel. A crescent-shaped scour pool has developed upstream of the boulder.

Figure 6-15 shows design drawings for placement of random boulders. A series of three 4-foot boulders (i.e. 3-ton rocks) will be placed in a triangular pattern and a 2-foot deep pool constructed around the edges of the boulders.

The hydraulic performance of the Random Boulders configuration was evaluated with the 2-dimensional hydraulic model to verify flow velocities and expected pool scour depth and location. The results of the modeling were used to refine the concept design and are shown for a flow of 545 cfs (4% exceedance flow) In Figure 6-16. The modeling indicates that the triangular pattern of the placed boulders creates a long scour pool around the edges of the boulders and lower velocities downstream of each boulder. A secondary pool between the two downstream boulders will be maintained by higher flow velocities contracting between the two downstream boulders.

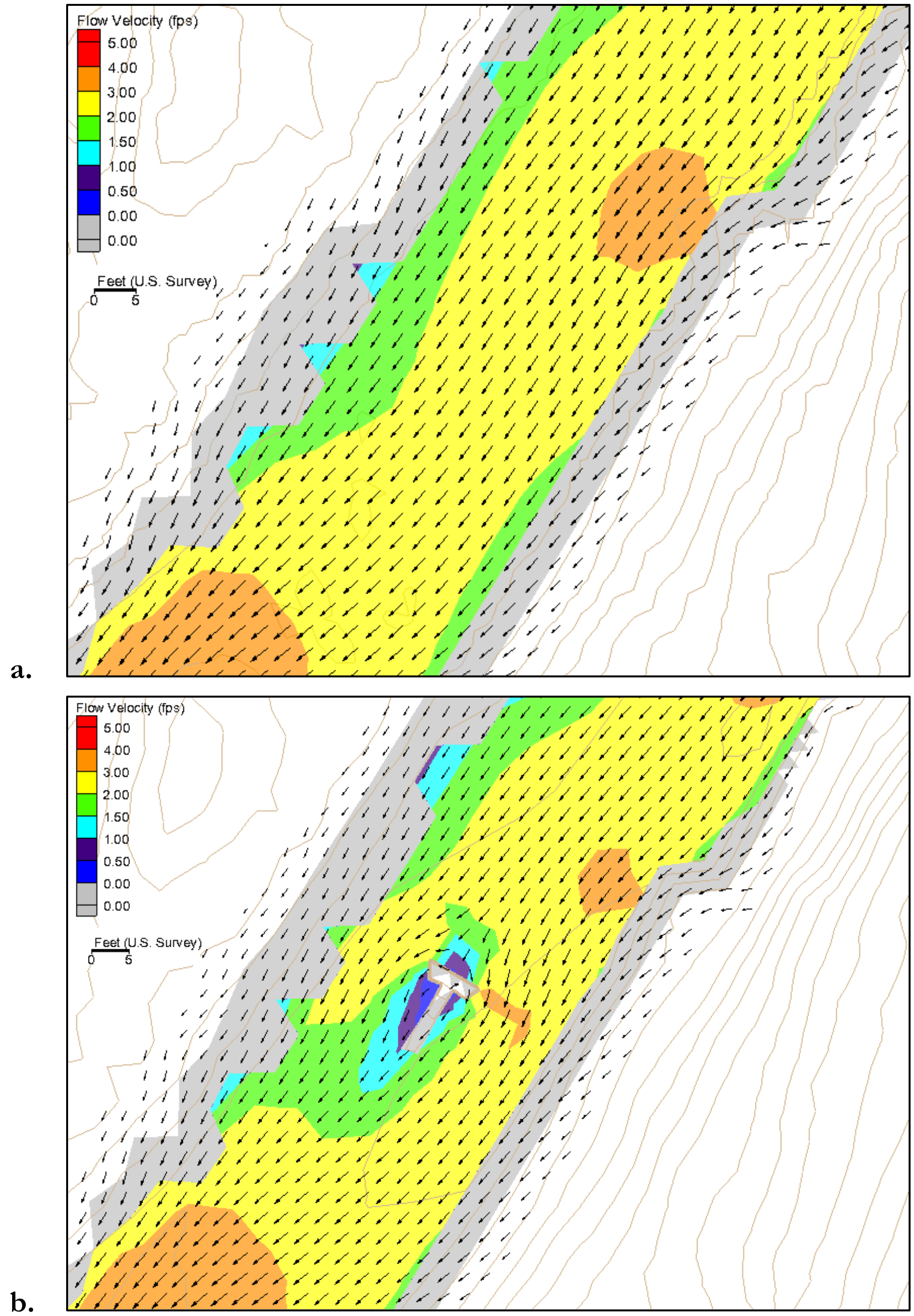


Figure 6-13. Two-dimensional hydraulic modeling of channel velocities for (a) existing conditions and (b) Apex Jam on the Lower Side Channel at a 1,240 cfs flow (4% daily exceedance flow). Flows less than 0.5-feet deep are shown in grey.

Figure 6-14. Large boulder in one of the Red Bank Bar side channels (looking downstream). Note the crescent shaped scour pool around the upstream side of the boulder and scour pool on the downstream side of the boulder.

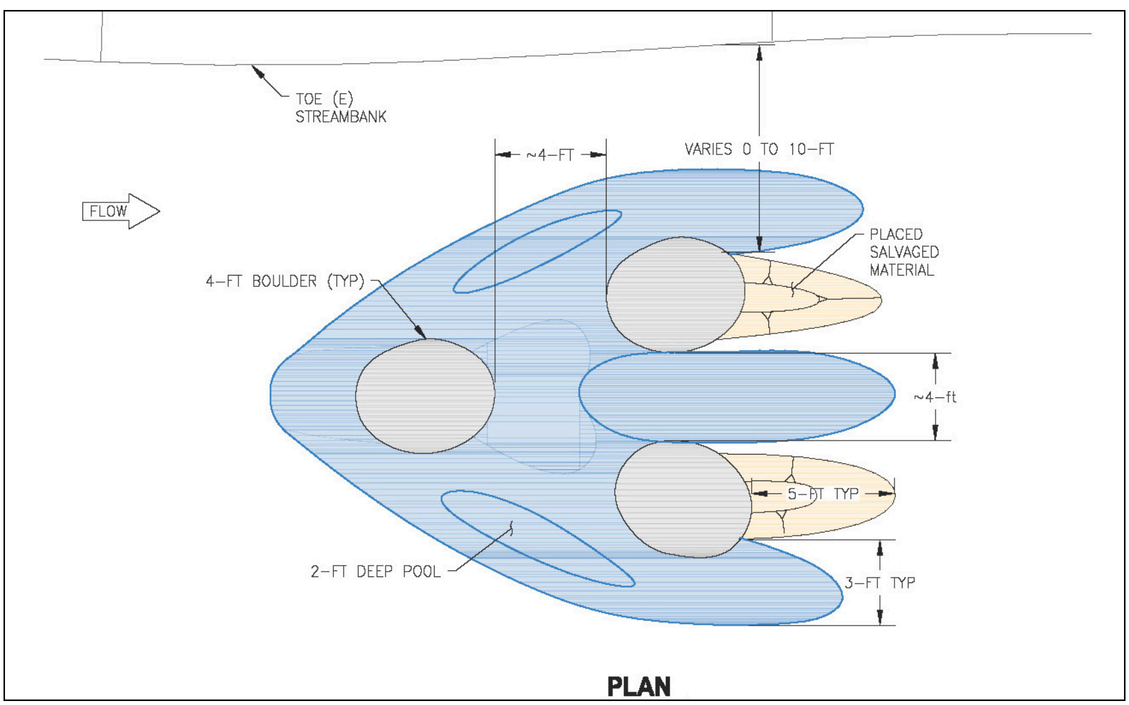
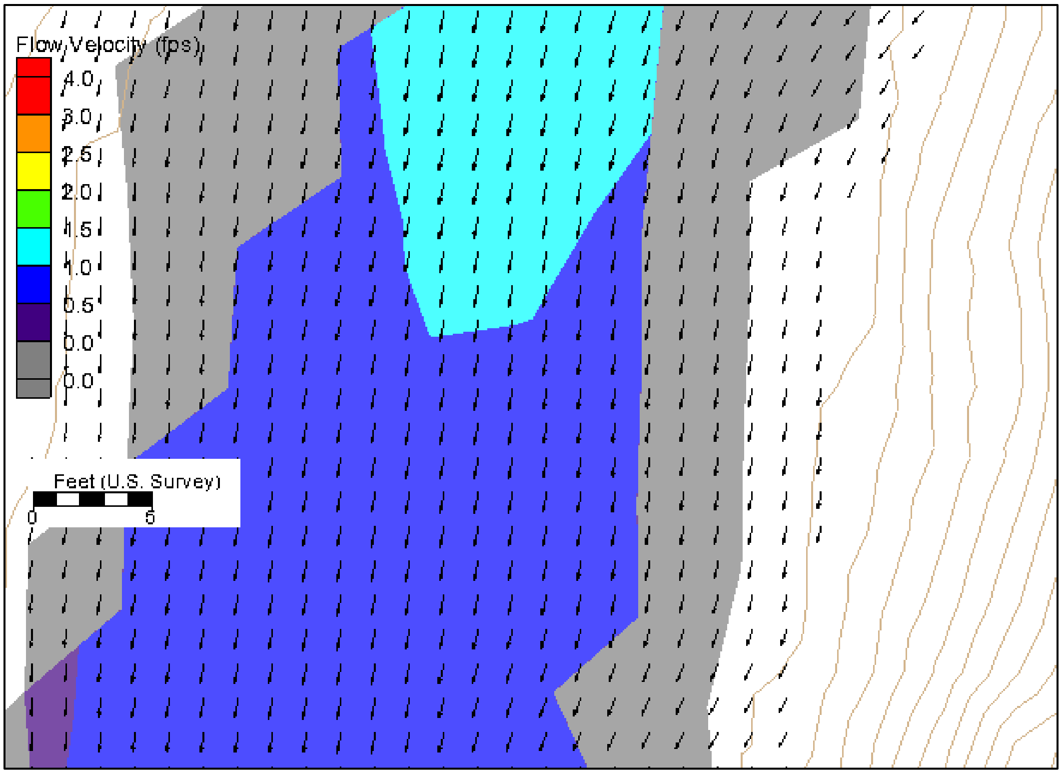


Figure 6-15. Design drawing plan view for Random Boulder placement.

a.



b.

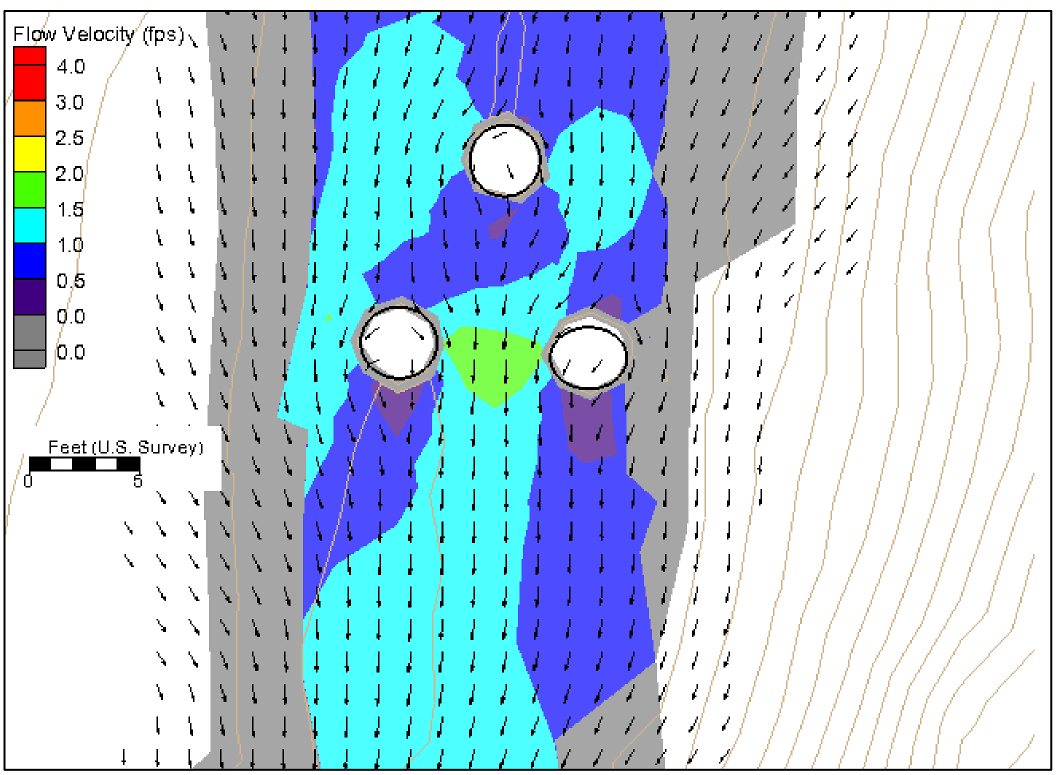


Figure 6-16. Two-dimensional hydraulic modeling of channel velocities for (a) existing conditions and (b) Random Bounders on the Lower Side Channel at a 545 cfs flow (4% exceedance). Flows less than 0.5-feet deep are shown in grey.

6.2.7 Revegetation

The revegetation shown in the proposed design focuses on vegetation installed as bioengineering that will achieve geomorphic stability and function of the stream channel and habitat features. Two different bioengineering methods are proposed for the project: Brush Baffles and Live Stakes. A detailed riparian restoration plan will be prepared by SRRC under separate cover.

Brush Baffles

Brush Baffles, also known as siltation baffles, consist of a "wall" of live brush installed to intersect or divert stream flows, slow flow velocities, and cause sediment deposition. The baffles consist of a live brush comprised of species that can develop roots, such as willows and cottonwoods. Often, dead brush is imported into the baffles to increase the stem density. The brush is installed vertically in an excavated trench that intersects the groundwater table to ensure that the live materials have a water supply. Chunks of large wood or wood chips are often installed at the bottom of the trench to act as a "sponge" for water, providing a water supply if groundwater levels drop below the level of the bottom of the trench.

It is expected that at the Red Bank Bar project area, the brush baffles would be comprised of willow, cottonwood, and slash. It is unknown if there is sufficient material for harvesting on site.

It was assumed that the maximum available length for the live brush cuttings would not exceed 10 feet. Therefore, brush baffles are only proposed in areas where the summer groundwater elevation is within 8-feet of finished grade.

Live Stakes

Live stakes provide a fairly inexpensive method to increase channel bank stability and begin the development of riparian areas. Live stakes consist of live cuttings of species installed so the bottom of the stake intersects the summer groundwater table, and consist of woody plant materials that can develop roots, such as willow and cottonwood. Live stakes will be incorporated into placed material in Abutment Jams, around the perimeters of Backwaters 4-8, and in backfilled areas as stabilization. Similar to the brush baffles, it was assumed that the maximum available length for the live stakes would not exceed 10 feet. Therefore, live stakes are only proposed in areas where the summer groundwater elevation is within 8-feet of finished grade.

6.3 Alternatives Considered but Not Further Developed

This section presents other habitat restoration techniques and areas at Red Bank Bar that were evaluated to improve salmonid rearing habitat, but were not further considered for the reasons provided.

6.3.1 Salmon River

Summer refugia may be present in in the deep scour pools on the main channel such as the hammerhead pool near river station 16+00, the bedrock scour pool near river station 12+00, and the confluence/bend scour pool near river station 5+00 where the side channel meets the mainstem of the river. These pools are already deeply scoured by the river, and there is little that can be done to increase the depth or size of these pools to increase thermal refugia. Therefore, no habitat improvements are recommended in these areas.

The hydraulic analysis prepared to identify existing or potential locations that provide high-flow refugia (Section 5.4) found low velocity areas uncommon on the mainstem of the river. Three areas on the river were identified where high-flow rearing habitat may currently exist and could be enhanced. These areas included the entrance to the Primary Side Channel near river station 27+00, the hammerhead pool at river station 16+00, and at the alluvial bar/back channel and alcove on the western bank near river station 9+00.

Hammerhead Pool

In the hammerhead pool, high-flow refugia may be provided at lower flows, especially around the edges of the pool. But as flows increase, it is likely that impingement of the river flows at the hammerhead pool could be creating higher velocity 3-dimensional eddies that are not predicted by the 2-dimensional modeling, and that could make high-flow refugia unsuitable in this area. This area should be visually evaluated at higher flows to evaluate flow turbulence and rearing habitat suitability. At this time, it is not recommended that a large-wood structure be installed in this area to improve habitat. The presence of the bedrock and multi-directional high velocities flows will make it very difficult to anchor. Therefore, measures to improve rearing habit in this area were not pursued.

Alluvial Bar/Back Chanel and Alcove

High-flow refugia is present in the alcove at the downstream end of the alluvial bar. The back-channel starts to become inundated and begins to deliver flows to the alcove around 2,598 cfs. During the field investigations in October, 2015, this alcove was very shallow and filled with silt and decomposing organic matter and did not appear to receive the scouring forces to maintain an alcove usable for summer or high-flow rearing habitat.

Consideration was given to increase the flow frequency to the back channel to further scour the alcove, creating an off-channel high flow velocity refugia. However, evaluation of the February, 2016 low-elevation aerial photo showed alcove scoured out and a deeper pool present. This pool is likely not fed by groundwater at low river stages, thus not providing thermal refugia.

To enhance this pool as high-flow refugia would require a separate bridge to cross the river to access the alluvial bar for construction. Given that the alcove appears to be functioning it was deemed that the merit of further increasing flows to the alcove would not justify the construction costs.

6.3.2 Primary Side Channel

Side Channel Entrance

The hydraulic analysis showed that the entrance to the Primary Side Channel provide a low-velocity refugia area during lower flow events when the side channel is conveying little to no flow. As the side channel begins to accept additional flow, velocities in this area become unsuitable for high-flow refugia. Because it is within the main conveyance area of the river and subject large hydraulic forces, placement of structures to enhance high-flow refugia in this area would be difficult. Therefore, measures to improve rearing habit in this area were not pursued.

Upper Side Channel

The Upper Side Channel receives flows during most of the winter and spring months. When water levels drop below 350 cfs, the upper reaches of the side channel become dry and groundwater levels drop substantially below the channel thalweg. Because the channel is dry and groundwater is deep during the time when thermal refugia is desired, it is not a suitable location.

Field observation and the hydraulic analysis identified that the Upper Side Channel is a broad, featureless, high energy channel with little vegetation. Evaluation of the aerial photographs and geomorphic investigation of this area indicates that the area continues to remain unstable due to the past migration patterns of the river side channels. The Upper Side Channel area may be suitable for providing high-flow refugia, and fish can access the area from the river channel upstream. However, construction of any in-stream features to provide velocity refugia could further destabilize the channel and could themselves be difficult to stabilize due to the channel instability. Additionally, because the channel is so broad, future shifting of the Upper Side Channel could result in abandonment of any constructed in-stream features from the channel shifting away from them.

6.3.3 In-Line Alcoves

In-line alcoves are constructed within the main flow path of a channel. The pool in the alcove is maintained by the scouring forces of flows in the channel. Flow-through alcoves were considered at two locations: the confluence of the Primary Side Channel with the river, and in the Secondary Channel.

The confluence of the Primary Side Channel and the river is located on a steep depositional riffle. There is also a depositional "tongue" of large cobble and small boulders (Figure 3-3). The riffle and the depositional area indicate that a large amount of sediment is transported through the Primary Side Channel, and deposited at the downstream confluence with the river. Because the confluence is in a depositional area, a self-maintaining alcove would not be suitable in this location.

An in-line alcove was also considered at the confluence of the Secondary Side Channel and Primary Side Channel. This alcove could have been used to maintain a groundwater-fed pool that would provide thermal refugia. The Secondary Channel currently begins to receive flows from both the upper and Lower Side Channels during 1.5-year and larger flow events. The design intent was to use these flows to scour and maintain the alcove. However, hydraulic modeling indicated that the alcove would be backwatered by the river at this flow. Therefore, the high-velocity flows necessary to maintain the alcove will not be present, and the alcove would be expected to fill in with sediment. A deep scour pool at this location is not present now, which confirms the results of the hydraulic modeling.

6.3.4 Removal of Historic Mine Tailings on Bar

Mine tailings have been observed at locations throughout the Salmon River to obstruct natural geomorphic processes by blocking or redirecting flow, being immobile due to the size and location of the material, and preventing channel bed and bar development. There are several areas of Red Bank Bar with tailing mounds within the floodplain, including the Central Bar and the Far Side Channel.

Hydraulic modeling of the project area has indicated that on the Central Bar the mine tailings have only a small role in affecting flows, and affect flows only during extreme flow events, such as the 50- and 100-year flow events. There are several mining pits on the Central Bar that appear to hold water transmitted though the bar when the river is elevated, but are dry during the dry season. These pits are not located in close proximity to side channels receiving frequent flow and are dry most of the year. Therefore, it did not appear cost effective to connect these pits to the side channels to create alcoves. Because surface flows only infrequently reach these pits, there is little chance that salmonids will become stranded in them. However, the presence of these pits should be evaluated by others to determine their effects on more upland ecological processes.

The Far Side Channel has developed a complex flow path through several hummocky tailing piles. Large trees on the tailing piles provide bank strength, bank structure and shade to the channels. Some of the material forming the tailing piles and adjacent channels is quite large and immobile. The complex channels winding through the Far Side Channel were identified as an area that provides limited high flow refugia off the main river and Primary Side Channel. Removal of the tailing piles would necessitate removal of the large trees that provide a substantial benefit to the area.

7 ENGINEERING DESIGN OF LARGE WOOD FEATURES

Several types of large wood structures are proposed for the project, including Root Wad Cover Structures, Root Wad Alcoves, Bank Logs, Apex Jams, and Abutment Jams. This section describes the computations prepared to assess the stability of each structure type.

Computations are provided in Appendix L for each type of structure. Computations were only prepared for the end-range of dimensions for each structure type, typically including the longest and shortest log lengths with a maximum log diameter of 2.5 feet. Assumptions are included in the computations for each structure, and as described in the following sections.

7.1 Log Structure Components

The proposed structures will be constructed using 20 to 30 foot long, 1.5 to 2.5-foot diameter Douglas fir. Site conditions limit the feasibility of specific log sizes for some structures, thus specific log sizes are specified for each type of structure. Root wads on the logs are preferable, but may be limited in supply due to constraints in harvesting the material. If trees with root wads are not available for construction, "pseudo" root wads will be constructed by incorporating brush into each structure so that it projects into the flow column similar to a root wad.

Hardware anchoring will not be used on the structures. Instead, the structures will be anchored by burial in the ground, placement of salvaged streambed and rock ballast, use of adjacent trees as buttress against horizontal movement, and use of pinning logs (piles, posts) to prevent horizontal and vertical movement.

7.2 Risk Assessment and Structure Design Flow

Risks of the placed large-wood features to public safety, property, infrastructure, and channel erosion was assessed using methods presented in Knutson & Fealko (2014). The wood features that will be constructed will simulate naturally-occurring large wood features along the river and side channels. Even under existing conditions, the Primary Side Channel contains downed trees that span the channel. Therefore, the placed features are expected to create no more of a public safety risk than the existing wood features.

Large wood of the size that will be used for the construction of the large wood features at Red Bank is commonly conveyed by the NF of the Salmon River. The river width at elevated flows is over 100 feet wide. If one or several of the placed log structures were to fail, the logs from the structure would comprise a small portion of the large wood transported naturally within the system. Additionally, there is little infrastructure on the NF of the Salmon River, and given the river width and the apparently opening areas of the bridge crossings on the river, there is little risk that large wood from the constructed features would increase the potential for a jam to form at a bridge crossing.

Therefore, the large wood feature placement at Red Bank project area can be considered low-risk. Knutson and Fealko (2014) recommend that large wood features constructed in low-risk areas be designed to remain stable under 10 to 25-year flow events. As recommended by CDFW (2017 FRPG PSN), the wood structures at Red Bank were designed to remain stable for a minimum flow return period of 25 years. However, where feasible, 100-year flow conditions were applied to the stability analyses. Each structure was designed to achieve a minimum Factor of Safety of 1.5.

7.3 Structure Design Methods

7.3.1 Moment-Based Analyses

Several different computational methods were used to evaluate the stability of the large wood features. For Root Wad Cover Structures, Root Wad Alcoves, Bank Logs, and Apex Jams, computation methods and a spreadsheet developed by Rafferty (2016) was used. This spreadsheet computes vertical forces on a structure including buoyancy, lift, and ballast, and horizontal forces including drag, passive soil pressure, and frictional resistance. Factors of safety are computed for both vertical and horizontal forces, and using a moment-based analysis for the resultant of the combined horizontal and vertical forces.

Pinning log (pile, post) stability was evaluated for both lateral and horizontal stability using methods in Knutson and Fealko (2014). Resultant forces in both the horizontal and vertical directions were applied for net drag forces and anchoring forces. Notes on the forces applied are included in the "Driving" force section for both the horizontal and vertical pile stability computations. The pile embedment necessary to resist buoyant and anchoring forces governed the necessary depth of pile embedment (L_e). The same embedment was used for the horizontal analyses of the pile.

For the analyses, the density of air-dried coastal Douglass fir was used. The streambank and ballasting material into which the structure will be embedded was loose gravel, and the streambed over which frictional forces were computed had a median particle diameter of 45 mm, which was derived from pebble counts at the site. The 100-year flow depth, velocity, and channel area were used in the computations. Flow hydraulics were obtained from the 100-year SRH-2D hydraulic model. The computations were prepared assuming the structures will be fully submerged.

It is anticipated that subsurface conditions at Red Bank Bar will prevent piles from being driven. Therefore, it was assumed that piles will be installed by excavation and backfill. Thus, only 25%, of the coefficient of lateral earth pressure for driven piles used, as recommended by Knutson and Fealko (2014). Additionally, because excavation will be needed to install the piles, a maximum pile embedment of 10 feet was assumed for constructability.

7.3.2 Abutment Jam Computations

The abutment jams will be constructed using both racking and key members with salvaged cobbles and gravels as ballast on the internal tiers of the structures. The top racking members will be ballasted with salvaged cobbles, boulders and large imported boulders that will remain in place during large flow events. Vertical piles (posts) will maintain the key and racking members in their placed locations, but will not bear any vertical loading from the structure. The top elevations of the piles were set above the 25-year water surface elevation to keep key and racking members from floating up and over the top of the piles if they become buoyant. The top key members will be placed at an elevation higher than the adjacent floodplain, as recommended by Abbe (Draft NRCS Document), to reduced shear stresses on the top of the structure.

The stability of abutment jams were computed using force-based computations that considered vertical forces including buoyancy, lift, and ballast, and horizontal forces including drag, passive soil pressure, and frictional resistance. The computations were prepared assuming the abutment jams will be fully submerged.

The expected scour depth due to the abutment jam projection into the active flow of the channel was computed using the Larsen live-bed contraction-scour equations in HEC-18 (FHWA, 2012). Flow in the Primary Side Channel, where the abutment jams will be located, rather than the entire river flow were used for the computations. Flow hydraulics were obtained from the 100-year SRH-2D hydraulic model. An average scour depth of approximately 3 feet is predicted for an abutment jam that projects 10 feet into the approximately 50-foot wide side channel.

The piles (posts) that will be used to retain the key and racking members in place were assessed for vertically stability to determine the minimum embedment depth necessary to resist buoyant forces. Because the piles will not be mechanically attached to the logs within the Abutment Jams, there will be no vertical driving forces on the piles other than buoyancy. Computations indicate that the ballast weight on the structure will be sufficient to prevent horizontal sliding of the structure. Therefore, no substantial horizontal forces are expected to be applied to the piles.

The proposed abutment jams were also assessed for overturning potential using methods in Knutson & Fealko (2014). Only drag forces and the ballast weight of the structure were used in the computations. Lift and the vertical resistance from piles were not included in the computations. Passive soil pressure was also not considered in the computations in the event that channel bed scour removes the material that could provide passive resistance.

8 CONSTRUCTION LOGISTICS, COSTS AND NEXT STEPS

8.1 Earthwork

Excavation for the project will include excavation of the eight backwater features and the alcove on the lower Primary Side channel. There will also be incidental excavation for placement of log structures and for construction access.

Table 8-1 presents a summary of the major earthwork components of the project. Because of site constraints, and need for spoils to construct Backwater 3 and the large wood features, it was not feasible to balance excavation/backfill locally at each backwater feature, and trucking of materials to other locations on Red Bank Bar will be necessary.

As shown in Table 8-1, there will be an excess of approximately 1,650 cy of excavated material. It is anticipated that this material can be disposed of with minor field-adjusted enlargements of the spoil areas, for restoration of construction access areas, and spreading materials within the dry areas of the bar that are devoid of vegetation.

Table 8-1. Summary of major excavation and backfill items for the Red Bank Bar project.

Location	Excavation Volume	Spoil/Ballast Placement Volume
Backwater 1	250 CY	200 CY
Backwater 2	350 CY	200 CY
Backwater 3	-	200 CY
Backwater 4	600 CY	200 CY
Backwater 5	600 CY	150 CY
Backwater 6	600 CY	150 CY
Backwater 7	350 CY	400 CY
Backwater 8	400 CY	(Part of 7)
Alcove	1,000 CY	-
Abutment Jam Ballast (2 structures)	-	200 CY
Apex Jam Ballast (8)	-	800 CY
TOTAL	**4,150 CY**	**2,500 CY**
Excess Excavated Material to be Spoiled		**1,650 CY**

8.2 Construction Access

Construction access to the project area to the project area will be from Engine Fill Site, as shown on the design plans in Appendix A. The Engine Fill Site has some flatter areas near the river that can be used as stockpile areas, and additional area adjacent to Sawyers Bar Road.

Access to Red Bank Bar will be via a temporary low-water crossing constructed using salvaged materials from the bar. The crossing would be constructed so that water can flow over its top, but will be shallow enough to allow passage of construction equipment. The crossing would be constructed in a shallow glide that was about 80 feet wide when surveyed in October, 2016.

Construction access from the Engine Fill Site would necessitate the use of haul roads across an active part of the bar. The contractor will be required to submit a plan for how they propose to access the project areas and restore the access roads upon completion of the work.

8.3 Water Management and Fish Removal

Construction of the project is expected to occur during the dry season when river levels are lowest. However, the areas selected for restoration contain groundwater seeps and receive hyporheic flows. Therefore, water can be expected to be present during excavation and dewatering may be necessary. Dewatering of the work area and treatment of the sediment-laden water from the dewatering process can be expected. Water from the dewatering operations can be pumped to a flat area away from the work area and allowed to infiltrate into the ground.

None of the proposed restoration techniques will be performed in or adjacent to the river channel, therefore, a clearwater diversion of a portion of the river is not anticipated, except for the installation of the temporary low-water crossing on the river.

Salmonids are anticipated to be present in the groundwater-fed pools in the Lower Side Channel, where much of the construction is proposed. Additionally, adult salmonids were observed in October, 2016 spawning in the river near where the low-water crossing would be located. Therefore, fish exclusion screens and fish removal by a qualified biologist will be necessary as part of the project. It may be feasible to construct a temporary deep groundwater-fed pool in the Lower Side Channel outside of the work area to provide a location to relocate fish from this area during construction.

8.4 Opinion of Probable Construction Cost

An opinion of probable construction cost (OPCC) is presented in Appendix M.

Costs were based on quantities measured from the design construction drawings (Appendix A), equipment and labor costs using prevailing wages, and productivity rates appropriate to the site. The OPCC assumes that all wood for the log features will need to be purchased. At the direction of SRRC, cost of $800 for a 30-foot long log delivered to the site was assumed, due to the long distance of the hauling and double handling of materials SRRC is experiencing with other large-wood enhancement projects. Similarly, costs for furnishing rock are also higher than typical, given the long haul distance to the project area.

Excavation unit costs in the OPCC assume that the excess material excavated from the project area will be used as part of the log-structure construction or can be spoiled on site. SRRC research has identified that the focus areas for restoration are located on several different mining claims presently owned by the same owner (Appendix N).

The cost estimates exclude permitting and environmental documentation, and construction management and oversight. The cost estimates were prepared with a 15% contingency for unidentified site conditions that maybe discovered during construction. Equipment and labor costs were determined assuming a 2% cost escalation over 2 years.

The total opinion of probable construction cost for the project is $828,000.

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Appendix A

Design Plans

SALMON RIVER RESTORATION COUNCIL

PLANS FOR CONSTRUCTION OF

RED BANK OFF-CHANNEL FISHERIES AND RIPARIAN HABITAT DESIGN

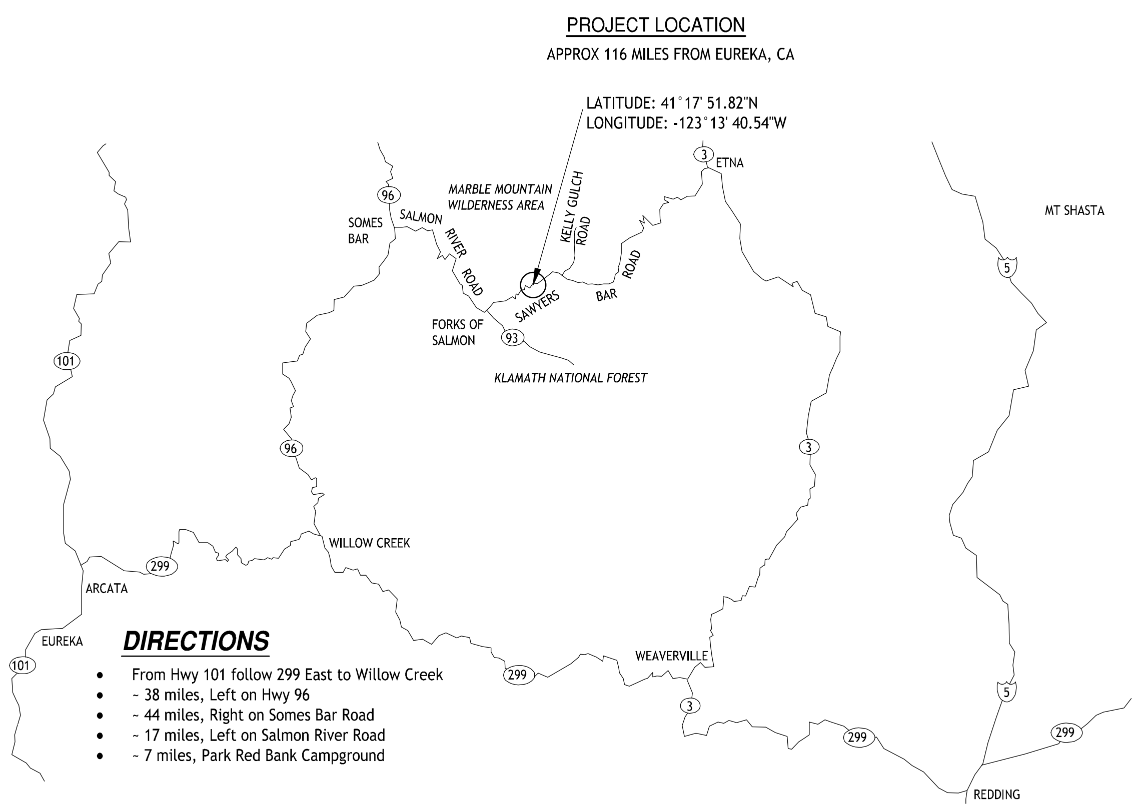
June, 2017

Final Design

Prepared For:

- **SALMON RIVER RESTORATION COUNCIL**
- **CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE, FISHERIES RESTORATION GRANTS PROGRAM (AGREEMENT No. P1310303)**
- **KLAMATH NATIONAL FOREST**

VICINITY MAP
NOT TO SCALE



DIRECTIONS

- From Hwy 101 follow 299 East to Willow Creek
- ~ 38 miles, Left on Hwy 96
- ~ 44 miles, Right on Somes Bar Road
- ~ 17 miles, Left on Salmon River Road
- ~ 7 miles, Park Red Bank Campground

LOCATION MAP
NOT TO SCALE

SHEET LIST TABLE	
Sheet No.	Sheet Title
1	TITLE
2	LEGEND ABBREVIATIONS AND NOTES
3	WATER MANAGEMENT
4	EXISTING CONDITIONS
5	LAYOUT AND CONSTRUCTION ACCESS
6	UPPER SIDE CHANNEL AND FAR SIDE CHANNEL PLAN
7	MID SIDE CHANNEL PLAN
8	LOWER SIDE CHANNEL PLAN
9	DETAIL SHEET 1
10	DETAIL SHEET 2
11	DETAIL SHEET 3
12	DETAIL SHEET 4
13	BACKWATER PROFILES AND SECTIONS

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Salmon River Restoration Council
PO BOX 1089 • 25631 Sawyers Bar RD, Sawyers Bar CA 96027
530-462-4665 Fax 530-462-4664

REGISTERED PROFESSIONAL ENGINEER MICHAEL A. LOVE CIVIL STATE OF CALIFORNIA

VERIFY SCALE — THIS BAR IS ONE INCH LONG AT FULL SCALE

Salmon River Restoration Council
RED BANK OFF-CHANNEL FISHERIES AND RIPARIAN HABITAT DESIGN

TITLE

DATE	JUN. 2017
SUBMITTAL	Final Design
DESIGN	RS / ML
DRAWN	RS / NN
SHEET	1 of 13

LEGEND AND SYMBOLS

EXISTING

FENCE LINE

EXISTING CONTOUR AND ELEVATION (95)

SPOT ELEVATION (99.0)

CHANNEL THALWEG OR DRAINAGE

CONTROL POINT/TEMPORARY BENCH MARK

FLOW DIRECTION

BEDROCK

NEW

SURVEY CONTROL POINT

SPOT ELEVATION (16)

STATIONING ALONG ALIGNMENT (FEET) (1+00)

SLOPE LINE

LOG/LARGE WOOD STRUCTURE

WATER SURFACE

SPOIL PLACEMENT AREAS

BRUSH BAFFLES

ABBREVIATIONS

APPROX, ~	APPROXIMATELY	NFSR	NORTH FORK SALMON RIVER
CA	CALIFORNIA	NTS	NOT TO SCALE
CL	CENTERLINE	OZ	OUNCE
CP	SURVEY CONTROL POINT	O.C.	ON CENTER
CFS	CUBIC FEET PER SECOND	RD	ROAD
DIA	DIAMETER	R.C	RELATIVE COMPACTION
EG	EXISTING GROUND	STA	STATION
EL	ELEVATION	SY	SQUARE YARDS
(E)	EXISTING	TBM	TEMPORARY BENCHMARK
EP	AVERAGE DAILY EXCEEDANCE PROBABILITY	TYP	TYPICAL
FG	FINISHED GROUND	W/	WITH
FT, '	FOOT OR FEET	WSE	WATER SURFACE ELEVATION
LOD	LIMIT OF DISTURBANCE	YR	YEAR
MAX/MIN	MAXIMUM/MINIMUM	(1.5:1)	(HORIZONTAL:VERTICAL) SLOPE
(N)	NEW	%	PERCENT

SECTION DETAIL OR TYPICAL NAME

SHEET NUMBER ON WHICH SECTION, DETAIL OR TYPICAL APPEARS

GENERAL NOTES

1. The term "Contract Owner (CO)" is defined as Salmon River Restoration Council (SRRC). The term Contract Owners Representative (COR) is defined as authorized qualified professional(s) designated by SRCC. All improvements shall be accomplished under the approval, inspection and to the satisfaction of the COR. The landowner is the U.S. Forest Service.
2. In the event cultural resources (i.e., historical, archaeological, paleontological, and human remains) are discovered during grading or other construction activities, work shall be halted within a 100 foot radius of the find. The U.S. Forest Service shall be consulted for an on-site evaluation. If human burials or human remains are encountered, the Contractor shall also notify the county coroner.
3. If hazardous materials or what appear to be hazardous materials are encountered, stop work in the affected area immediately and contact 911 or the appropriate agency for further instruction.
4. Contractor is responsible for complying with all project permits. Copies of all permits shall be maintained on site by the contractor.
5. A set of signed working drawings shall be kept on site at all times.
6. Contractor agrees to assume sole and complete responsibility for the work area during the course of construction, including safety of all persons and property. This requirement shall apply continuously and shall not be limited to normal working hours.
7. Contractor shall defend, indemnify and hold CO and its representatives, and the U.S. Forest Service harmless from any liability, real and or alleged, in conjunction with the performance of this project.
8. Placed materials not conforming to specifications shall be removed and replaced as directed by the COR at no additional cost to the CO.
9. Traffic control shall conform to California Manual of Uniform Traffic Control Devices (2012).
10. Contractor shall be responsible for providing their own water and power for operations, irrigation and dust control. Water shall not be pumped from the creek/river for these uses.
11. Noted dimensions take precedence over scale.

SURVEY AND STAKEOUT NOTES

1. Channel topography was surveyed by Michael Love & Associates in October 2015. Overbank topography derived from LiDAR surveys.
2. Horizontal Datum: North American Datum 1983 (NAD83), California State Plane Zone 1, in feet.

   Vertical Datum: North American Vertical Datum 1988 (NAVD88), in vertical feet.
3. Construction stakeout will be provided by the CO. Stakeout will consist of the following:
   a. Establishment of temporary monuments for elevation control (minimum of 2 per project area).
   b. Offset stakes of the Backwater centerlines at 10 to 25-foot-foot intervals.
   c. Reference stations of log structures.
4. It shall be the responsibility of the Contractor to maintain temporary monuments for elevation control and staking and to provide any additional staking necessary to perform the specified work.
5. It shall be the responsibility of the Contractor to construct the project to the lines and grades specified in the construction documents.

CONSTRUCTION ACCESS AND PROJECT AREA RESTORATION NOTES

1. Contractor shall submit a plan for construction access, indicating locations of access areas and temporary river and stream crossings, for approval by COR prior to mobilization.
2. There shall be no clearing beyond approved construction access areas and the Limit of Grading shown on the plans.
3. Upon completion of all construction activities, construction access areas are to be restored to a condition equal to or better than found prior to undertaking the work and to the satisfaction of the COR. Construction access areas shall be ripped to a minimum depth of 6" inches and stabilized as specified.

CLEARING, GRUBBING, AND WOODY MATERIAL SALVAGE NOTES

1. The extent of clearing shall be minimized to the extent possible within construction access areas to allow maneuverability of equipment.
2. Grubbing shall be minimized except where it conflicts with finished grade.
3. Vegetation trimming along the edges of construction access areas, using standard arborist equipment, can be performed with the permission of the COR.
4. Small woody material removed within approved construction access areas and the Limit of Grading shall be retained in as large pieces as feasible (15 to 20' foot lengths), including the root wad and brush, and stockpiled for incorporation into log structures as brush. Brush consists of small trees, shrubs, and branches. Woody material remaining after construction shall be chipped and/or dispersed at the direction of the COR.

EXCAVATION NOTES

1. The geologic report prepared by Pacific Watershed Associates is available upon request. No side slopes shall be graded steeper than 3:1 unless directed by COR.
2. Excavated materials shall be segregated and stockpiled in 3 stockpile areas, including (1) Cobble materials from the surface, (2) Sandy materials, (3) Mixed Sand/Cobbles from the subgrade. Segregation will be directed by COR. No screening of materials will be required.
3. Backfill shall consist of materials, as specified, from the segregated stockpile areas. All Backfill shall be placed in 6-inch lifts and track or bucket-compacted to 80% R.C. or to the satisfaction of the COR.
4. Excavation shall include excavation and handling of saturated soils. Contractor shall be prepared to dewater and /or transport saturated soil in a manner that prevents excess discharge or spillage of soils or water within the construction access area or on adjacent properties or roadways. Should any discharge occur, the Contractor shall be responsible for immediate and complete cleanup. Multiple handling of material may be necessary.
5. Unsuitable material shall become the property of the Contractor and shall be removed from the site by the Contractor for disposal in an approved location. Unsuitable material includes concrete, grouted riprap, pipes, and other manmade materials within work areas.
6. All typical sections are looking up station (upstream).
7. Grading shall be at the direction of COR and may change to fit with existing natural features and vegetation. Unless otherwise specified, tolerance for finished grade shall be a rough surface within ± 0.3 feet of finished grade. The tolerance for horizontal locations shall be ± 1.0 feet unless otherwise directed by COR.
8. Excess excavated material shall be transported to the designed Spoil Placement Areas and placed as specified. Material shall be sloped to create positive drainage, and have a finished surface of ± 0.2 feet to prevent localized ponding. Spoil shall be placed at direction of COR to avoid trees.
9. Shoring and Trench Safety: Attention is directed to Labor Code Section 6705 of the State of California relating to lateral and subjacent support, and the Contractor shall comply with this law.

UTILITY NOTES

1. All utilities shown (if any) were located from above ground visual structures. No utility research was conducted for the site. Notify Underground Service Alert (DigAlert) at least two days prior to any grading or excavation within the site by calling 811 or 1-800-227-2600.
2. Contractor is responsible for any damage to utilities, features and structures located in the project area and construction access routes. Contractor shall avoid disruption of any utilities unless previously arranged with the CO.
3. Construction may take place in the vicinity of overhead utility lines. It is the Contractor's responsibility to be aware of and observe the minimum clearances for workers and equipment operating near high voltage, and comply with the Safety Orders of the California Division of Industrial Safety as well as other applicable safety regulations.

SEQUENCE OF CONSTRUCTION

Work phasing shall occur as follows, unless otherwise approved by Owner in writing. All fish removals will be conducted by CO.

1. Mobilization.
2. Installation of temporary Erosion and Sediment Control measures, as necessary.
3. Clearing for access to the temporary Low Water Crossing at River.
4. Installation of temporary Exclusion measures and fish removal.
5. Installation of temporary Low Water Crossing across River.
6. Clearing for access.
7. Excavate alcoves and backwaters, install log structures and brush baffles.
8. Restore construction access areas and install stabilization measures.
9. Removal of temporary Waterway Crossing and Fish Exclusion measures.
10. Demobilization.

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REGISTERED PROFESSIONAL ENGINEER
MICHAEL A. LOVE
CIVIL
STATE OF CALIFORNIA

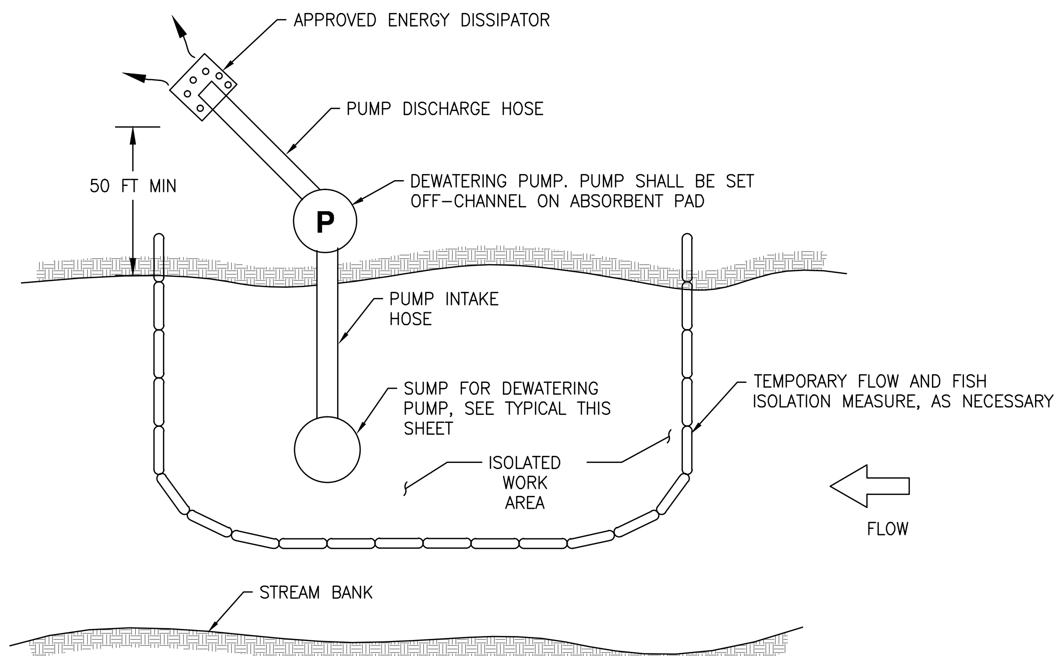
VERIFY SCALE
THIS BAR IS ONE INCH LONG AT FULL SCALE

Salmon River Restoration Council
RED BANK OFF-CHANNEL
FISHERIES AND RIPARIAN HABITAT DESIGN

LEGEND ABBREVIATIONS AND NOTES

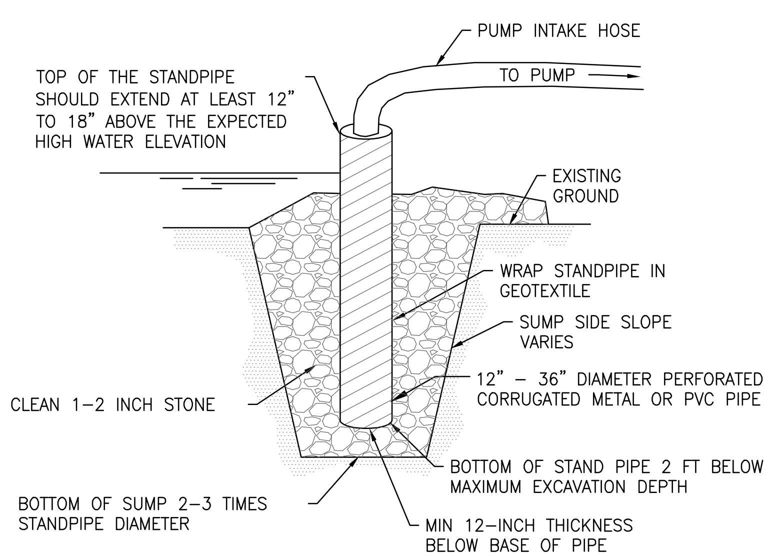
DATE: JUN. 2017
SUBMITTAL: Final Design
DESIGN: RS / ML
DRAWN: RS / NN
SHEET: 2 of 13

Q:\Red Bank\5_CAD\SHEETS\1_TITLE.dwg



TEMPORARY WORK AREA ISOLATION AND DEWATERING MEASURES

PLAN **(NTS)**



SUMP PIT

SECTION **(NTS)**

WATER POLLUTION CONTROL SPECIFICATIONS

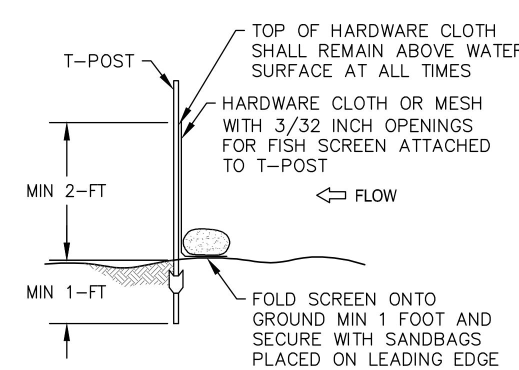
1. At minimum the Contractor shall employ the following Best Management Practices (BMPs) as applicable, as described in the current California Stormwater BMP Handbook for Construction (BMP Handbook) (www.casqa.org) including:

EC-1 Scheduling	NS-4 Temporary Stream Crossing
EC-2 Preservation of Existing Vegetation	NS-5 Clear Water Diversion
EC-6 Straw Mulch	NS-9 Vehicle Equipment and Fueling
EC-8 Wood Mulching	NS-10 Vehicle and Equipment Maintenance
EC-10 Velocity Dissipation Devices	SE-7 Street Sweeping and Vacuuming
WE-1 Wind Erosion Control	WM-2 Material Use
WM-3 Stockpile Management	WM-4 Spill Prevention and Control
WM-5 Solid Waste Management	WM-9 Sanitary/Septic Waste Management

2. Not all necessary erosion and sediment control BMP's are designated in the contract documents. The Contractor, as necessary, shall implement other BMP's as specified in the BMP Handbook dictated by site conditions or as directed by the COR. Contractor shall be responsible for all fines and cleanup resulting from a stormwater pollution violation.
3. It is the responsibility of the Contractor to minimize erosion and prevent the transport of sediment to sensitive areas.
4. All erosion and sediment control measures shall be maintained in accordance to their respective BMP Fact Sheet until disturbed areas are stabilized.
5. Sufficient Erosion Control Supplies shall be available on-site at all times to deal with areas susceptible to erosion during rain events. Contractor must ensure that the construction site is prepared prior to the onset of any storm.
6. Contractor shall keep project areas generating dust well-watered during the term of the contract in accordance with WE-1.
7. The Contractor shall have spill containment materials located at the site with operators trained in spill control procedures.
8. The Contractor shall provide bear-proof receptacles for common solid waste at convenient locations on the job site and provide regular collection of wastes.
9. Covered and secured storage areas for potentially toxic materials shall be provided. All hazardous material containers shall be placed in secondary containment.
10. Vehicle and equipment maintenance shall be performed off-site whenever practical.
11. All sediment deposits on paved surfaces shall be swept at the end of each working day, as necessary or as directed by the COR. A stabilized construction entrance may be required to prevent sediment from being deposited on paved roads.
12. It will be at the responsibility of the Contractor to fix any deficiencies indicated by the COR to prevent erosion and control sediment.

WATER MANAGEMENT NOTES

1. Contractor shall submit a Water Management Plan for approval by the CO prior to construction. The Plan shall include materials, methods, and approximate locations of water management devices, as well as a contingency plan for addressing unforeseen water management issues, such as storm events, groundwater etc.
2. Water Management shall be performed in accordance with Water Pollution Control Specifications and as specified in the contract documents.
3. The need for a clearwater diversion is not anticipated, though isolation and dewatering of the work areas may be necessary.
4. Approximate locations of temporary Fish Exclusion measures are shown on the plans.
5. CO will provide a qualified Biologist for fish removal.
6. Contractor shall be prepared to implement isolation, and dewatering operations such that they occur in a timely manner and do not impact the work schedule.
7. Contractor shall be responsible for providing pumps and pipes with adequate capacity to maintain suitable dewatered working conditions within the work area.
8. Any gas powered pumps used on-site shall be placed on absorbent pads out of the stream channel.
9. Dikes, cofferdams, or other suitable measures shall be used to isolate areas requiring dewatering. Additional control measures in isolated areas where dewatering is not required shall include turbidity curtains, filter fabric isolation, or other suitable methods.
10. The outlet of the dewatering pump shall be directed onto a flat area able to receive water and allow it to percolate into the soils such that it does not return to work area. An approved Energy Dissipater Device shall be used to prevent surface erosion.



FISH EXCLUSION MEASURE

TYPICAL SECTION **(NTS)**

(A) **WATER MANAGEMENT**

TYPICAL

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530-462-4665 Fax 530-462-4664

REGISTERED PROFESSIONAL ENGINEER MICHAEL A. LOVE No. 71681 CIVIL STATE OF CALIFORNIA

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FISHERIES AND RIPARIAN HABITAT DESIGN

WATER MANAGEMENT

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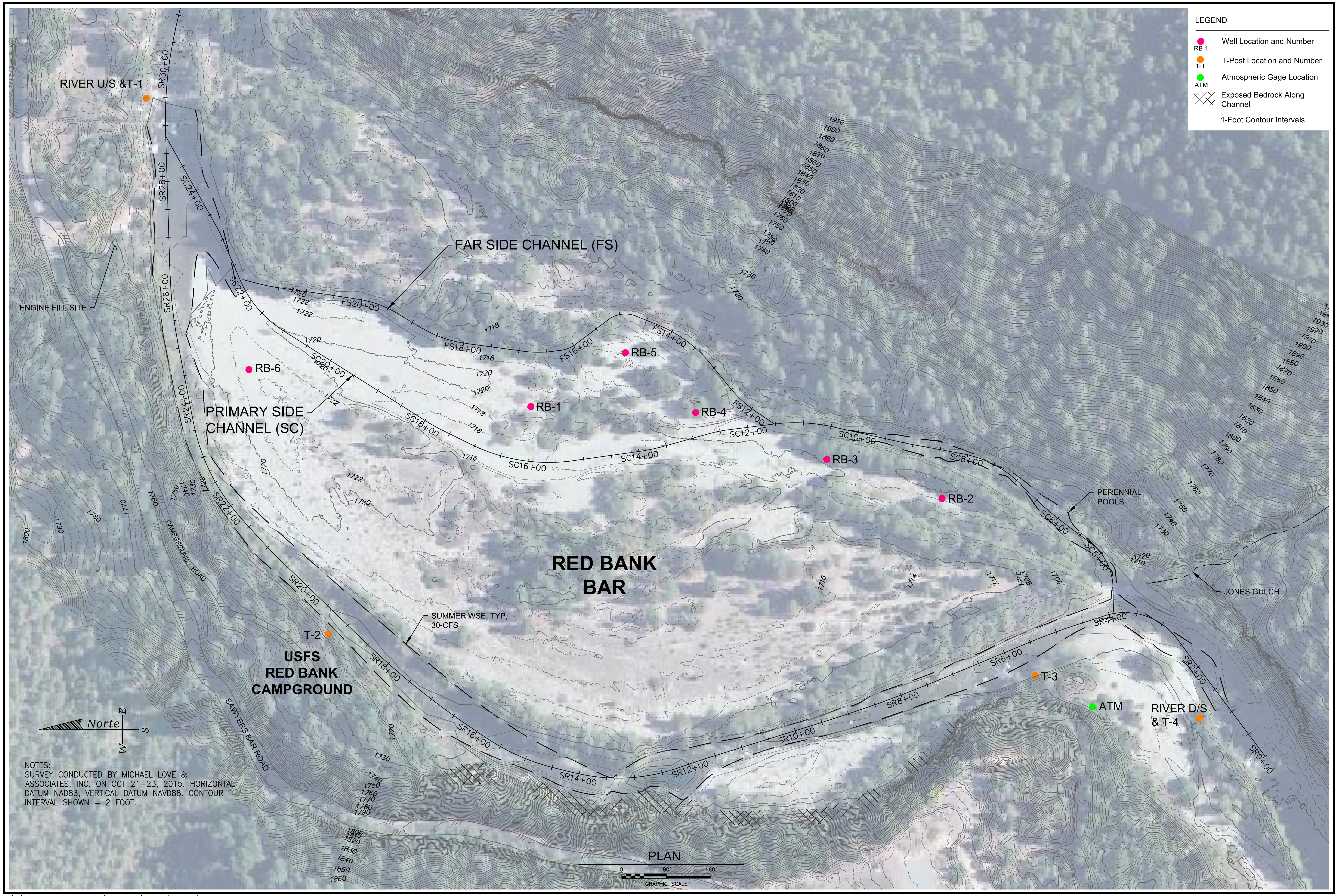
DRAWN	RS / NN
SHEET	3 of 13



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EXISTING CONDITIONS

DATE	JUN. 2017
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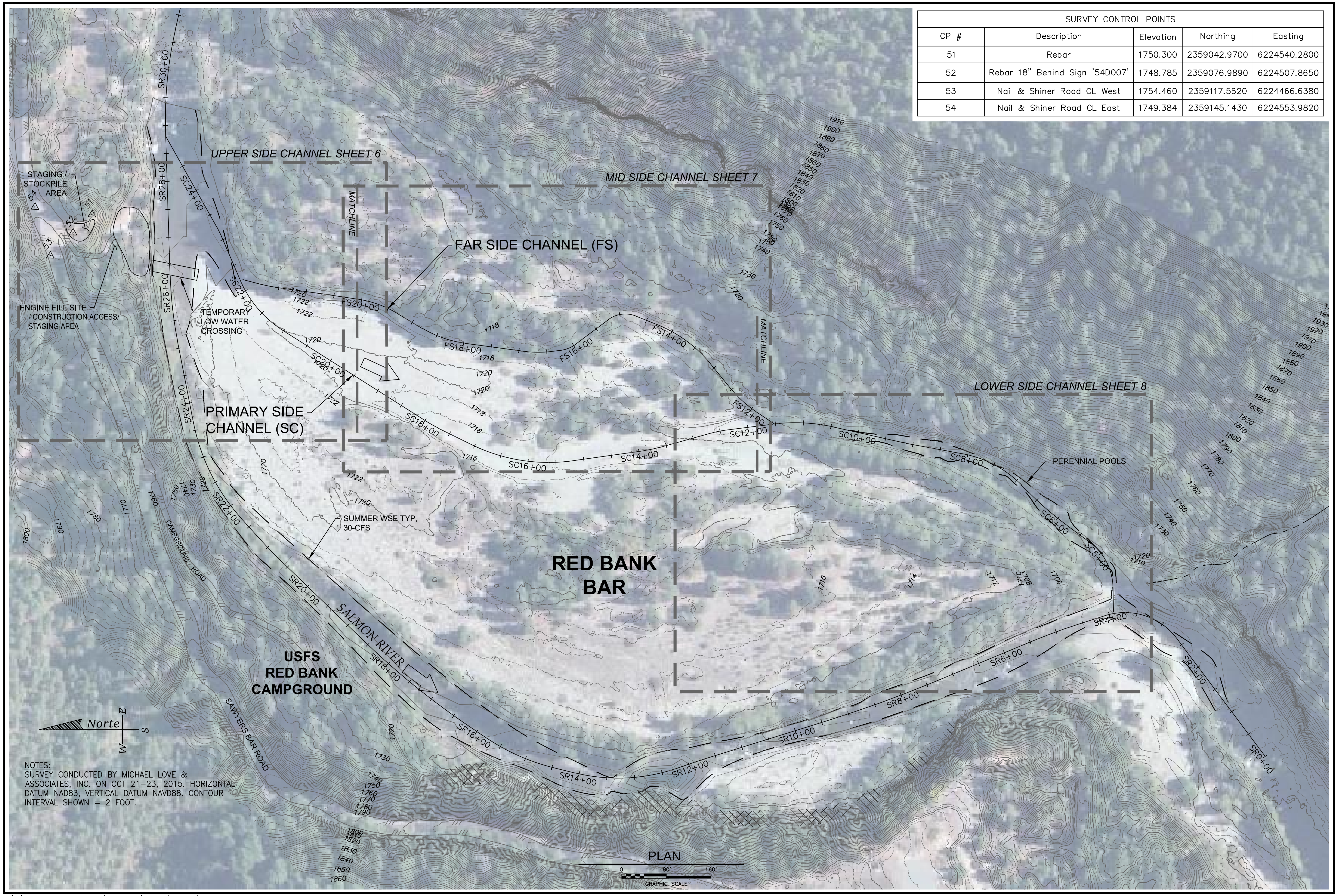
SHEET	4 of 13



SURVEY CONTROL POINTS				
CP #	Description	Elevation	Northing	Easting
51	Rebar	1750.300	2359042.9700	6224540.2800
52	Rebar 18" Behind Sign '54D007'	1748.785	2359076.9890	6224507.8650
53	Nail & Shiner Road CL West	1754.460	2359117.5620	6224466.6380
54	Nail & Shiner Road CL East	1749.384	2359145.1430	6224553.9820

NOTES:
SURVEY CONDUCTED BY MICHAEL LOVE & ASSOCIATES, INC. ON OCT 21-23, 2015. HORIZONTAL DATUM NAD83, VERTICAL DATUM NAVD88. CONTOUR INTERVAL SHOWN = 2 FOOT.

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LAYOUT AND CONSTRUCTION ACCESS

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SHEET 5 of 13

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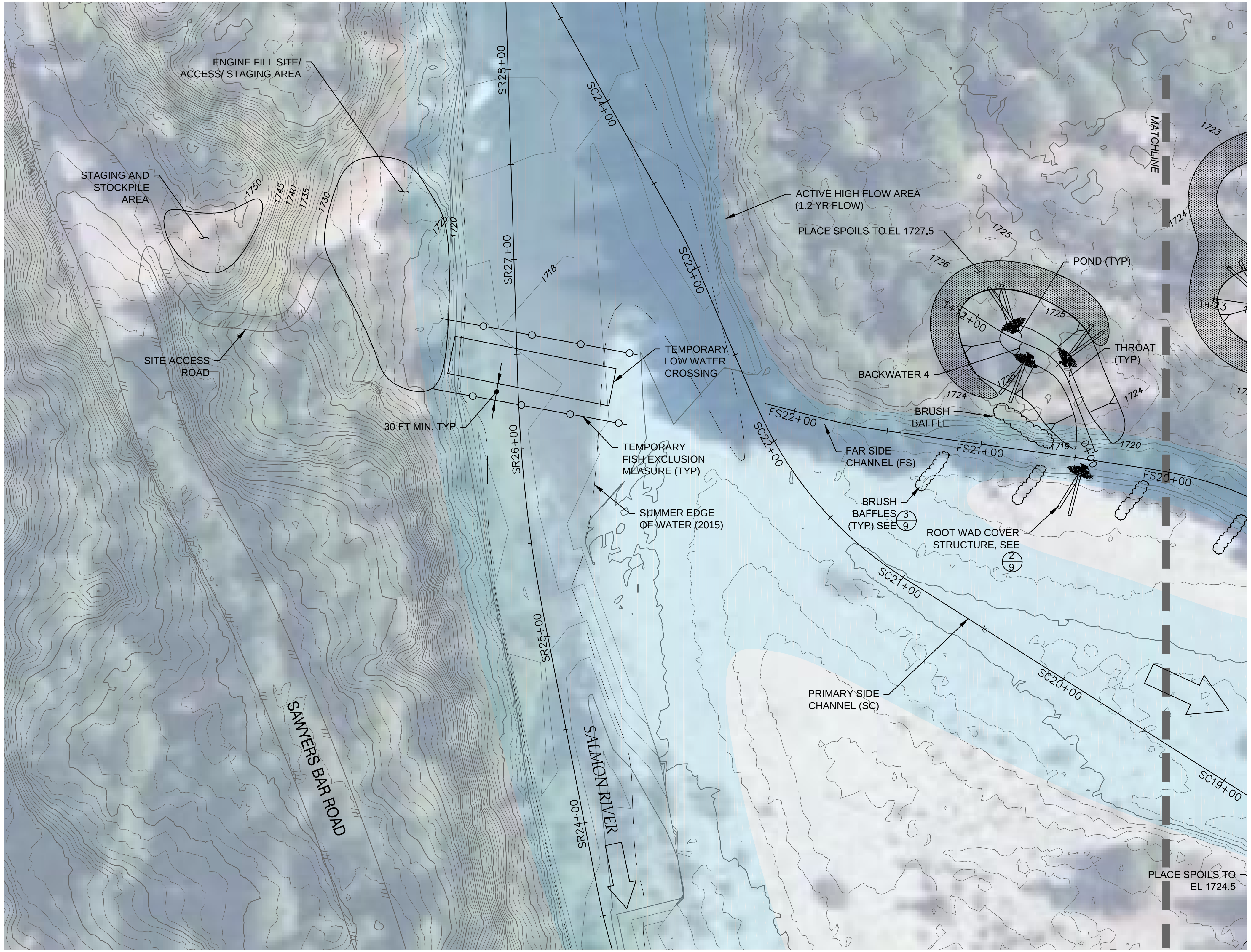

PLAN

0 30' 60'
GRAPHIC SCALE

North

NOTES:

1. LOCATIONS OF HABITAT IMPROVEMENT FEATURES APPROXIMATE. FINAL LOCATIONS TO BE DETERMINED BY COR IN FIELD.
2. FOR BACKWATERS, SEE SECTION AND PROFILES SHEET 13.

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UPPER SIDE CHANNEL AND FAR SIDE CHANNEL PLAN

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SUBMITTAL	Final Design
DESIGN	RS / ML
DRAWN	RS / NN
SHEET	6 of 13

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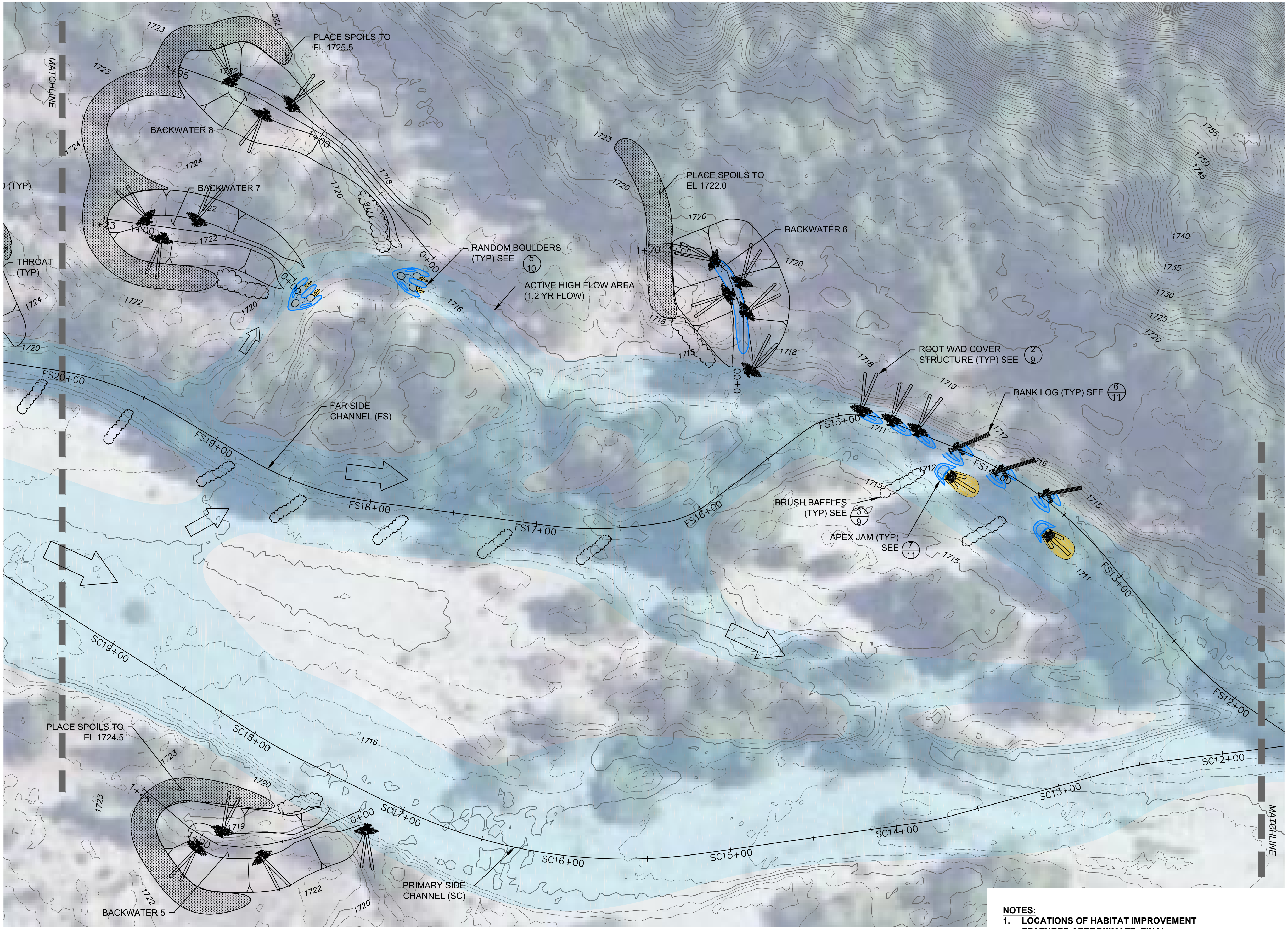

PLAN

0 30' 60'
GRAPHIC SCALE

North

NOTES:

1. **LOCATIONS OF HABITAT IMPROVEMENT FEATURES APPROXIMATE. FINAL LOCATIONS TO BE DETERMINED BY COR IN FIELD.**
2. **FOR BACKWATERS, SEE SECTION AND PROFILES SHEET 13.**

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MID SIDE CHANNEL PLAN

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RS / NN
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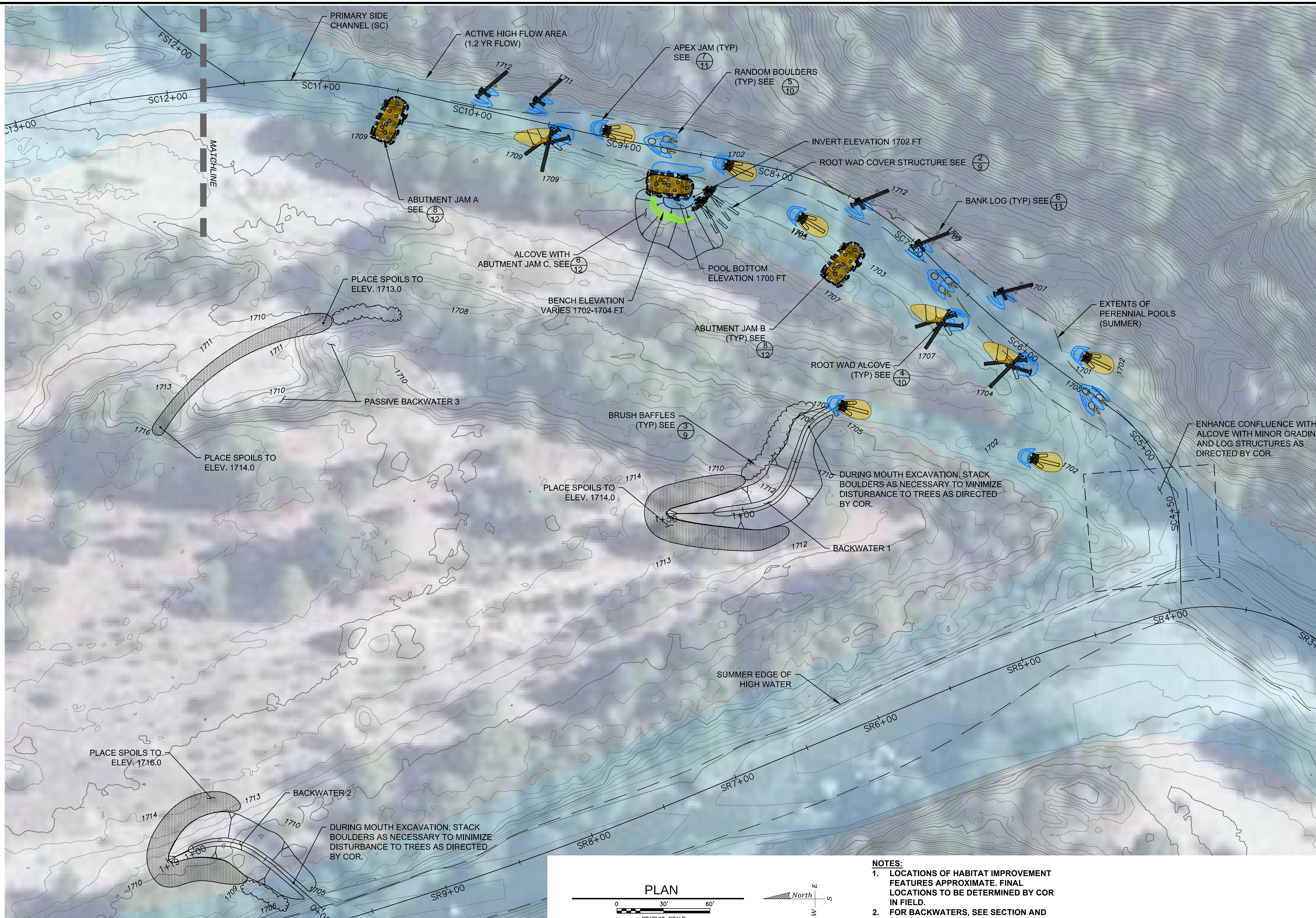

NOTES:

1. LOCATIONS OF HABITAT IMPROVEMENT FEATURES APPROXIMATE. FINAL LOCATIONS TO BE DETERMINED BY COR IN FIELD.
2. FOR BACKWATERS, SEE SECTION AND PROFILES SHEET 13.

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LOWER SIDE CHANNEL PLAN

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SHEET	8 of 13

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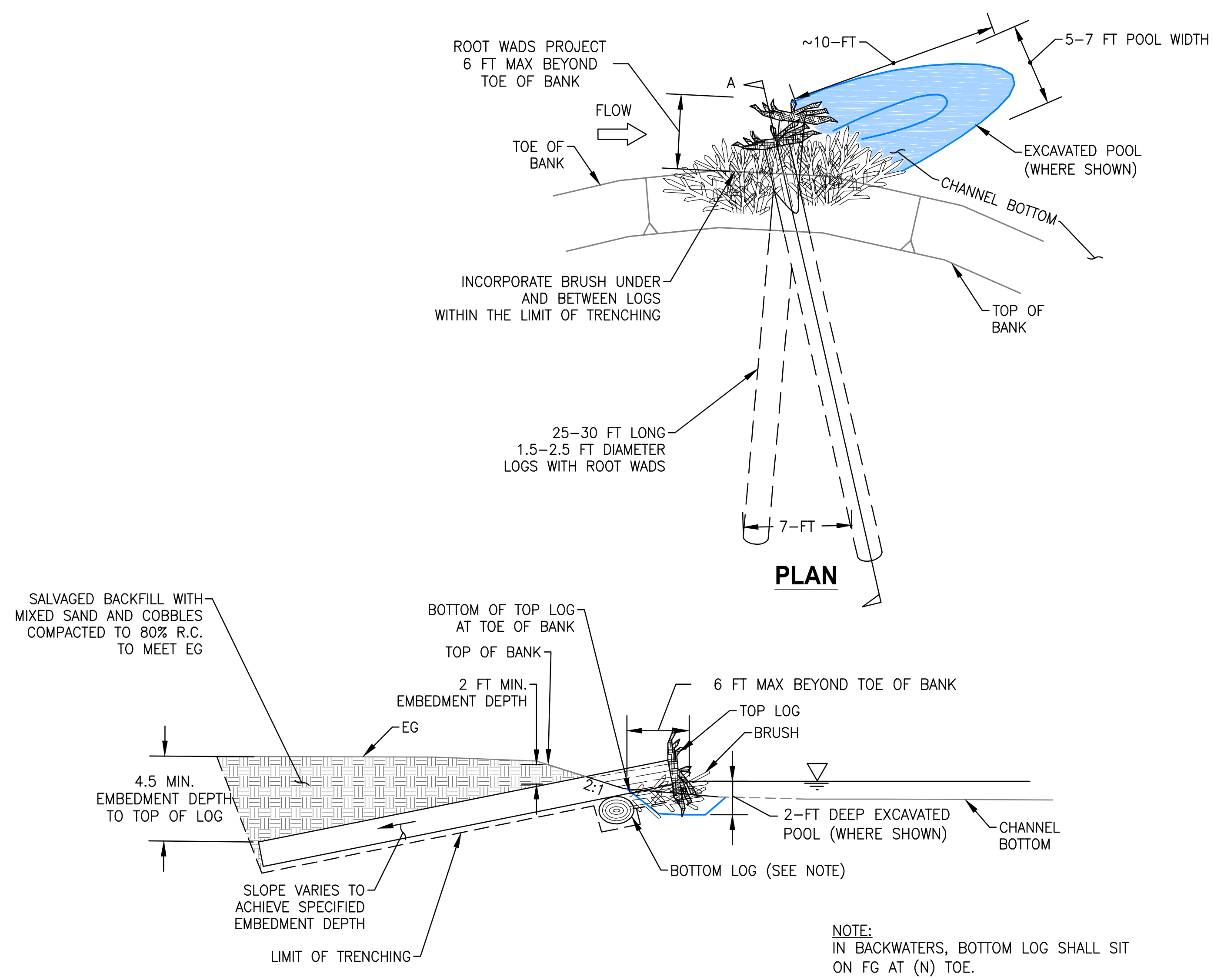
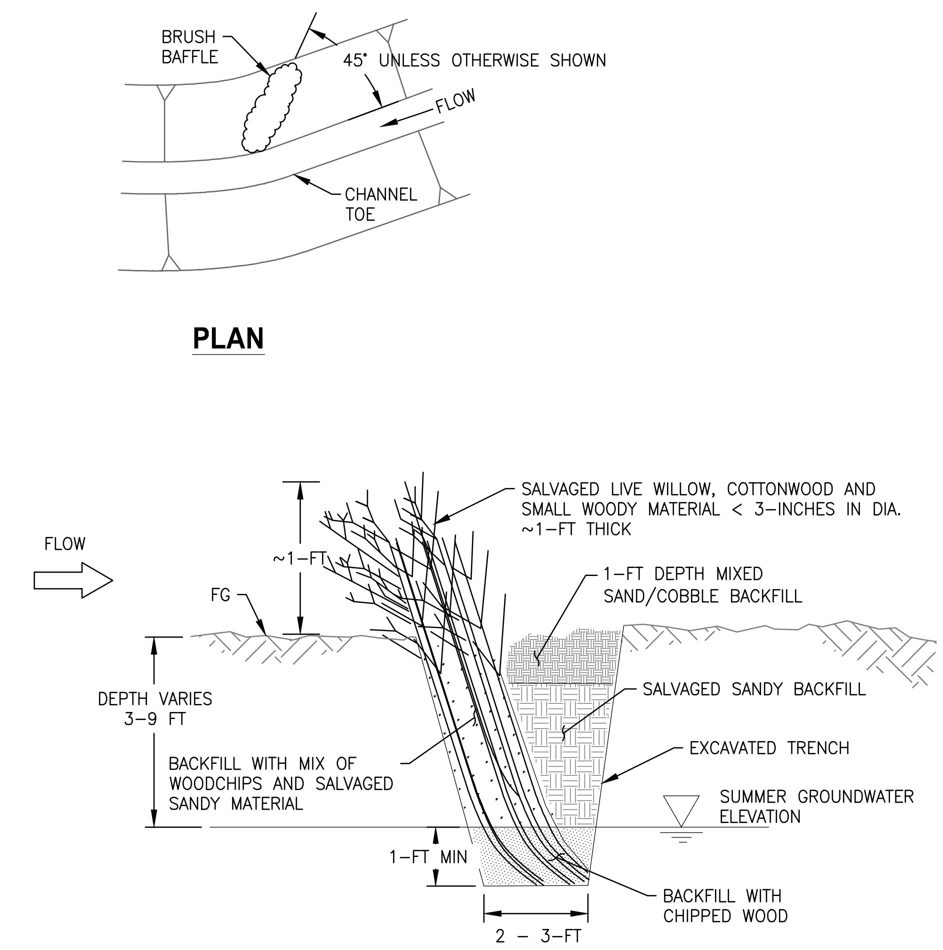


SECTION A

2 ROOT WAD COVER STRUCTURE

TYPICALS **NTS**



SECTION

3 BRUSH BAFFLES

TYPICALS **NTS**

SPECIFICATIONS FOR LOG STRUCTURES (INCLUDING BRUSH)

Materials

1. CO will provide all logs. Cutting of logs shall not be performed without permission of COR.
2. Logs shall meet the dimensions shown on the contract documents. Log diameter shall be the average (midpoint) diameter of the specified length log. Pile Logs shall have bark removed.
3. Log lengths shall not be accomplished by joining multiple logs, unless approved by owner.
4. Backfill material and rock shall be as specified on the design plans.
5. Salvaged brush shall be material stockpiled during Clearing and Grubbing Operations or provided by the CO.

Execution

1. Log structures shall be installed as specified on the Contract Documents and at the direction of the COR.
2. Excavate trench to the minimum depth for the entire structure.
3. Install logs to the line and grade specified. Tolerance for finished grade shall be ± 0.3 feet vertically and ± 1.0 feet horizontally
4. Pile logs shall be driven or installed via excavation. If necessary, cut point on pile tip to facilitate installation. An augured pilot hole may be used to facilitate driving of Pile Logs. Pilot hole shall be at least 8 inches smaller than the Pile Log diameter to ensure adequate skin friction is obtained. After installation, cut top of pile to specified height.
5. Backfill and compact trench.

SPECIFICATIONS FOR BRUSH BAFFLES AND WILLOW STAKES

Materials

1. Live willow and cottonwood shall be salvaged from site or provided by the CO.
2. Material shall be relatively straight, a minimum of ½-inch in diameter, and the specified length.
3. Material shall be live and freshly cut. Materials not installed within 2 hours of cutting shall be covered and thoroughly sprayed with water once per hour until installation. Material shall not be stored more than 48 hours before installation.
4. Small woody material shall consist of salvaged woody material or material provided by CO. Material shall be less than 3-inches in diameter and of similar length as the live plant material.
5. Chipped wood shall be from salvaged wood on-site. Wood pieces a minimum of 6-inches in diameter and 1-foot long are acceptable substitutes for chipped wood.
6. Backfill shall be as specified.

Execution

1. Materials shall be installed to the summer groundwater elevation, see planting plan under separate cover.
2. Create pilot holes or trenches the entire depth of the material installation.
3. Install material with leaf buds facing up using methods that minimize crushing or splitting.
4. Trim plant material such that material extends approximately 1-foot above ground level.

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FISHERIES AND RIPARIAN HABITAT DESIGN

DETAIL SHEET 1

DATE	JUN. 2017
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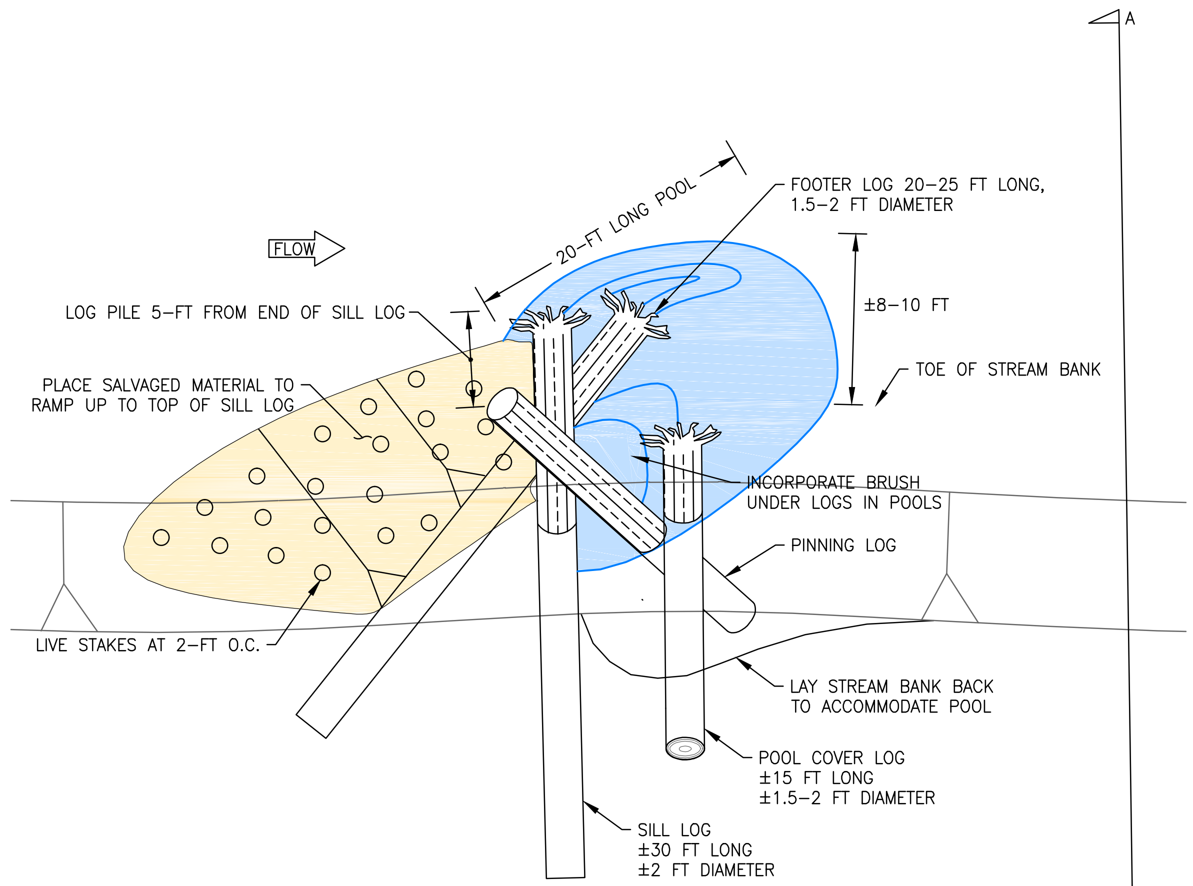
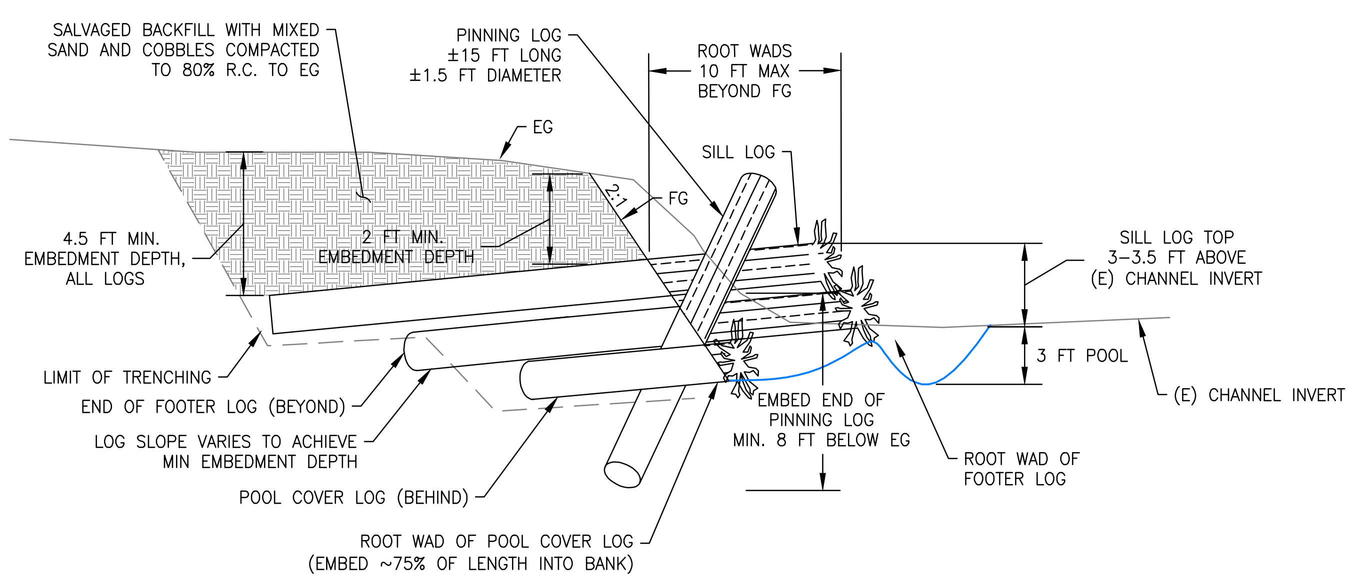
SHEET	9 of 13



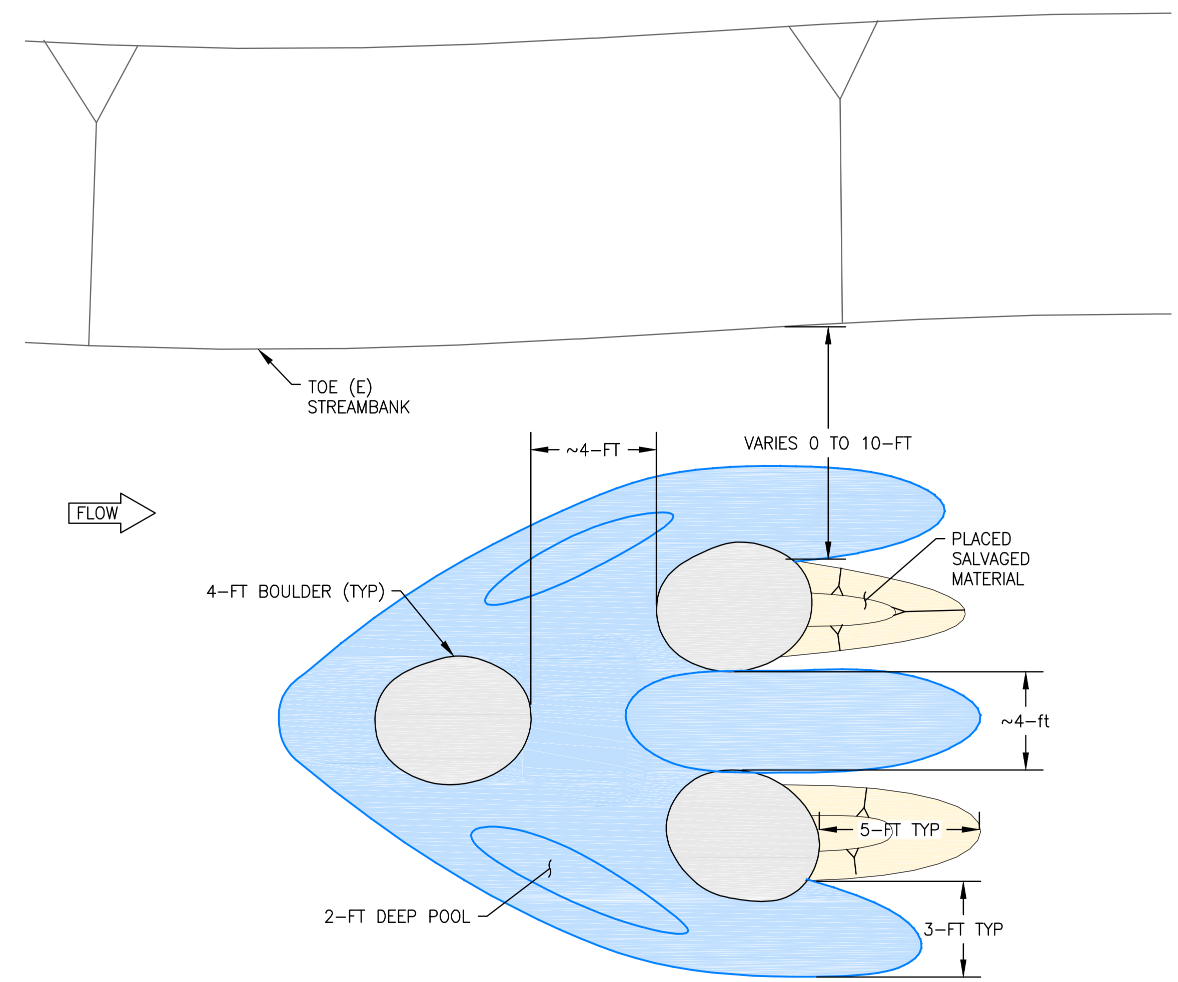
PLAN



ELEVATION A-A

4 ROOT WAD ALCOVE

TYPICALS NTS



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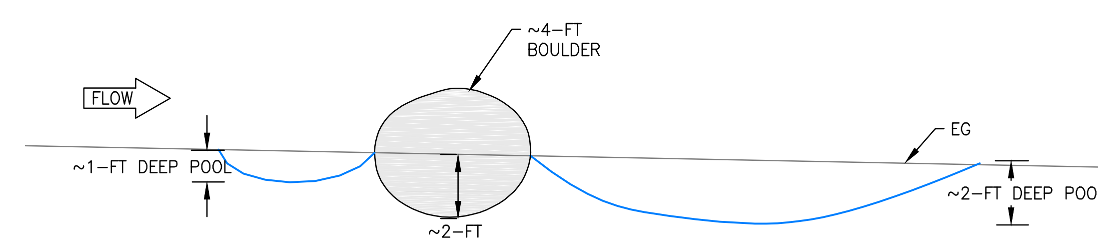

PROFILE

5 RANDOM BOULDERS

TYPICALS NTS

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DETAIL SHEET 2

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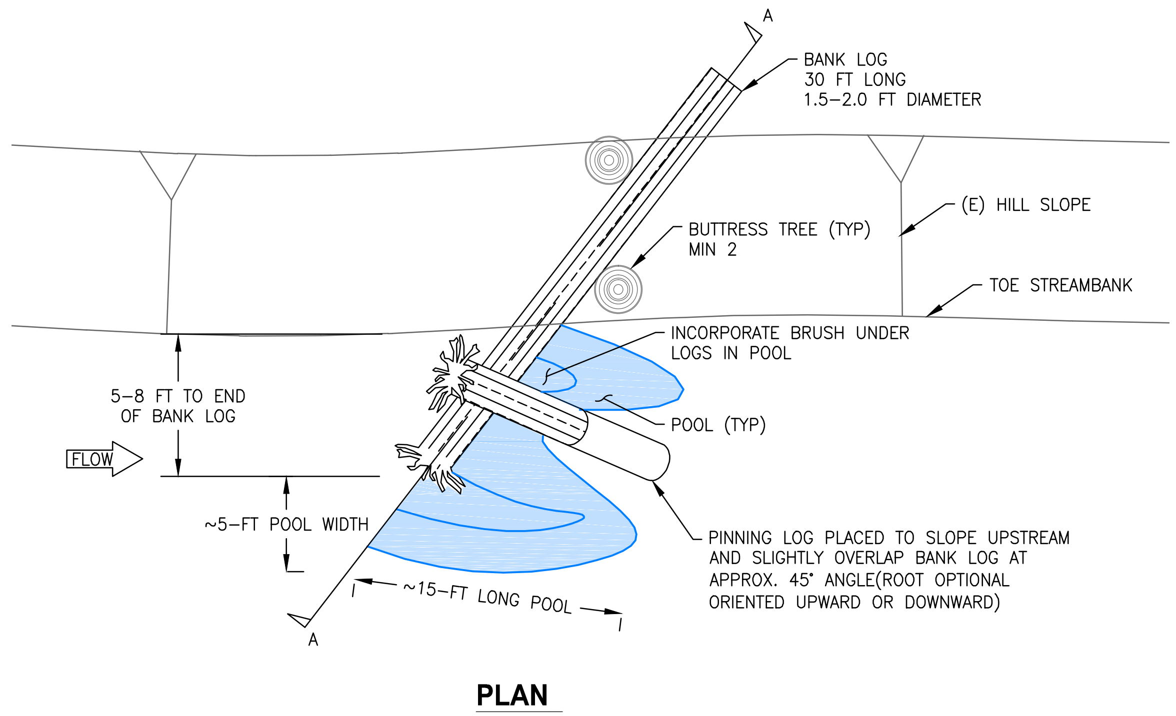
SHEET: 10 of 13



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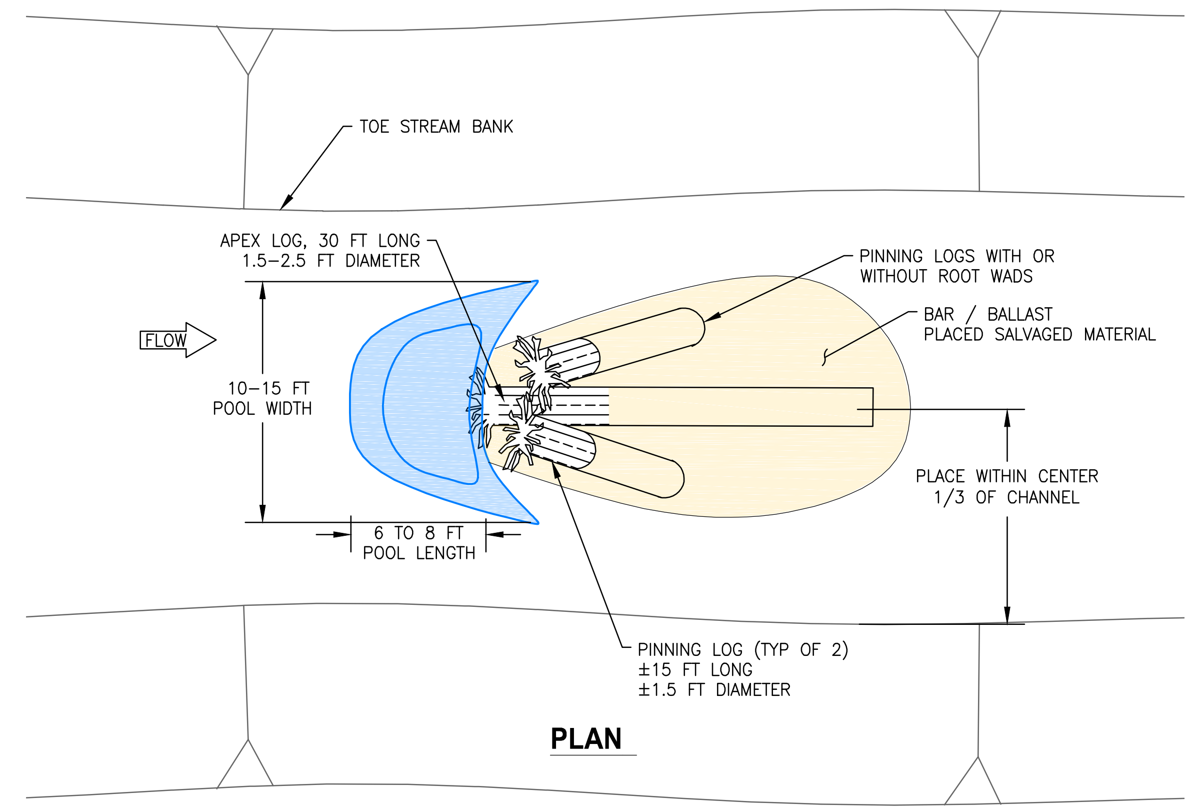

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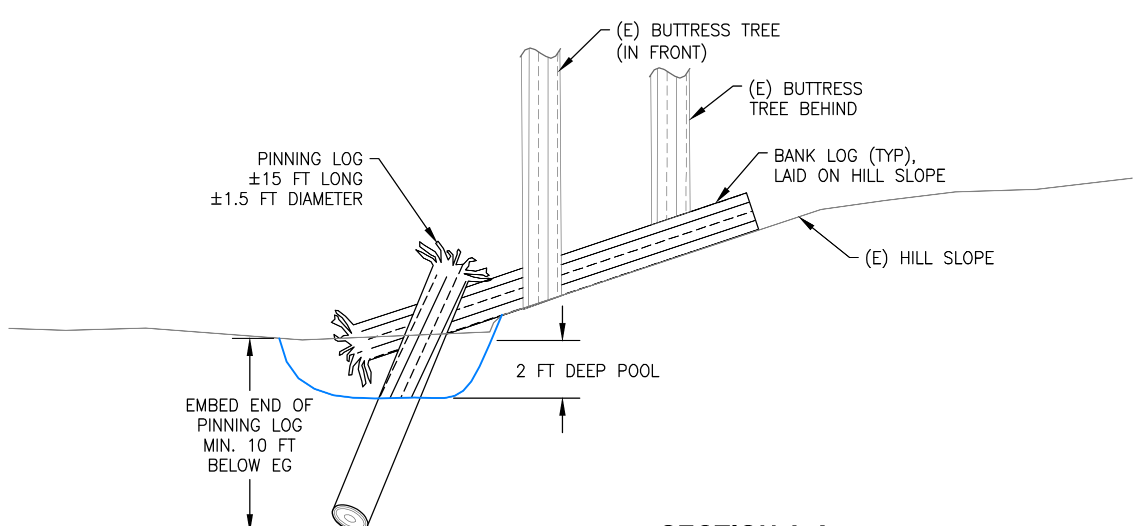
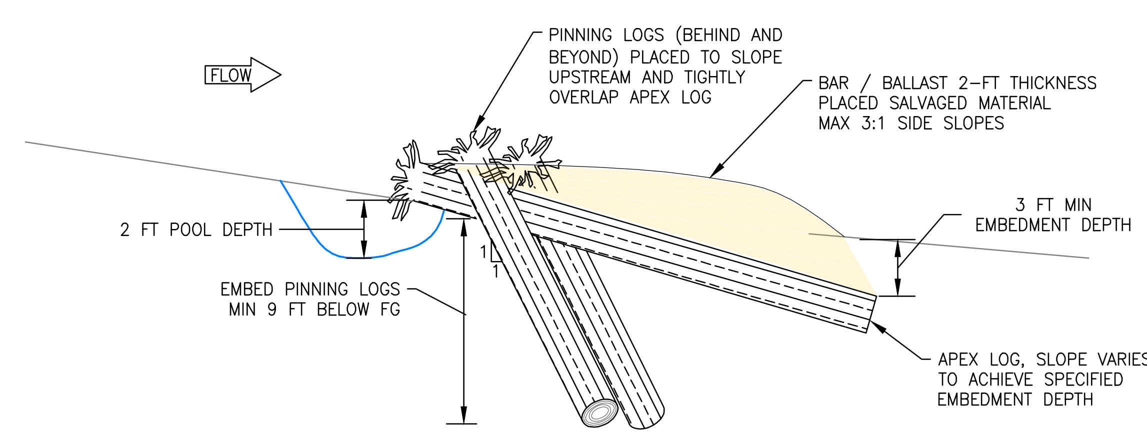


SECTION A-A



PROFILE

6 BANK LOG
TYPICALS NTS

7 APEX JAM
TYPICALS NTS

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DETAIL SHEET 3

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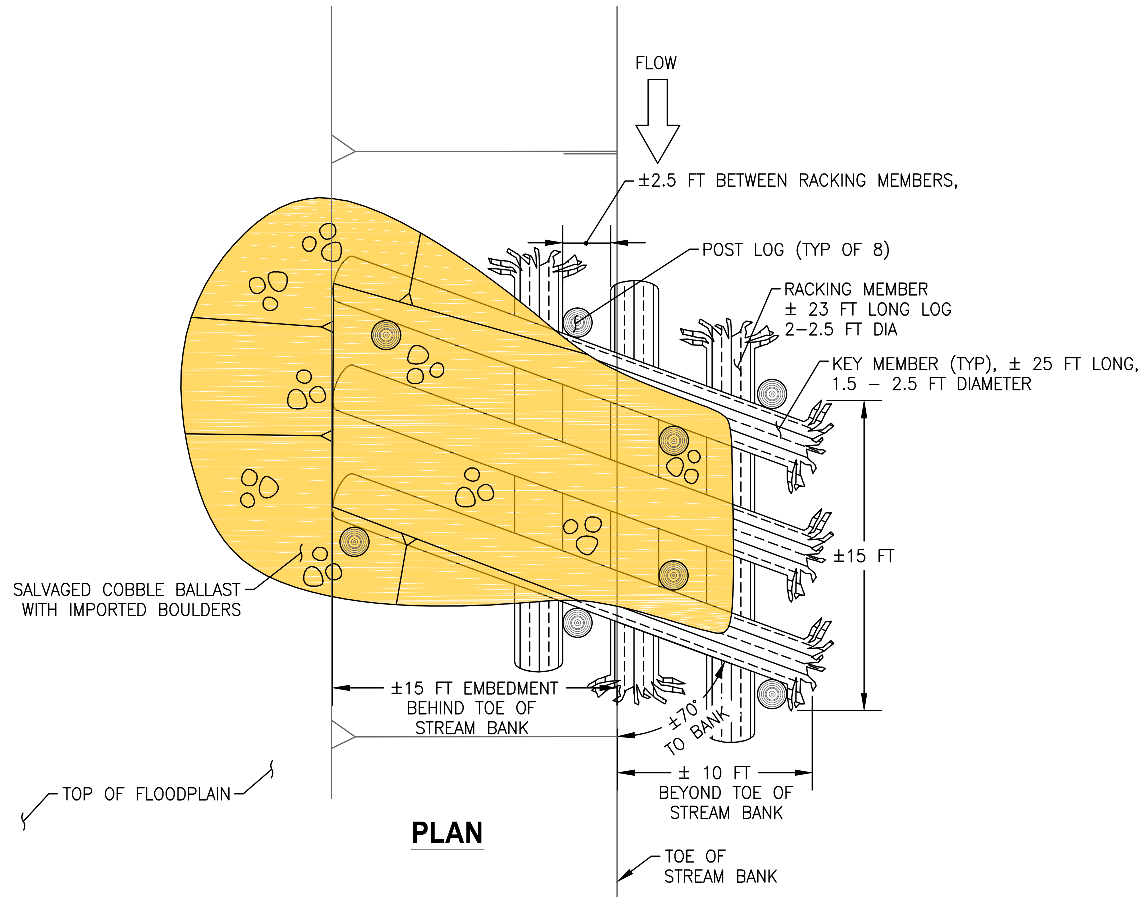

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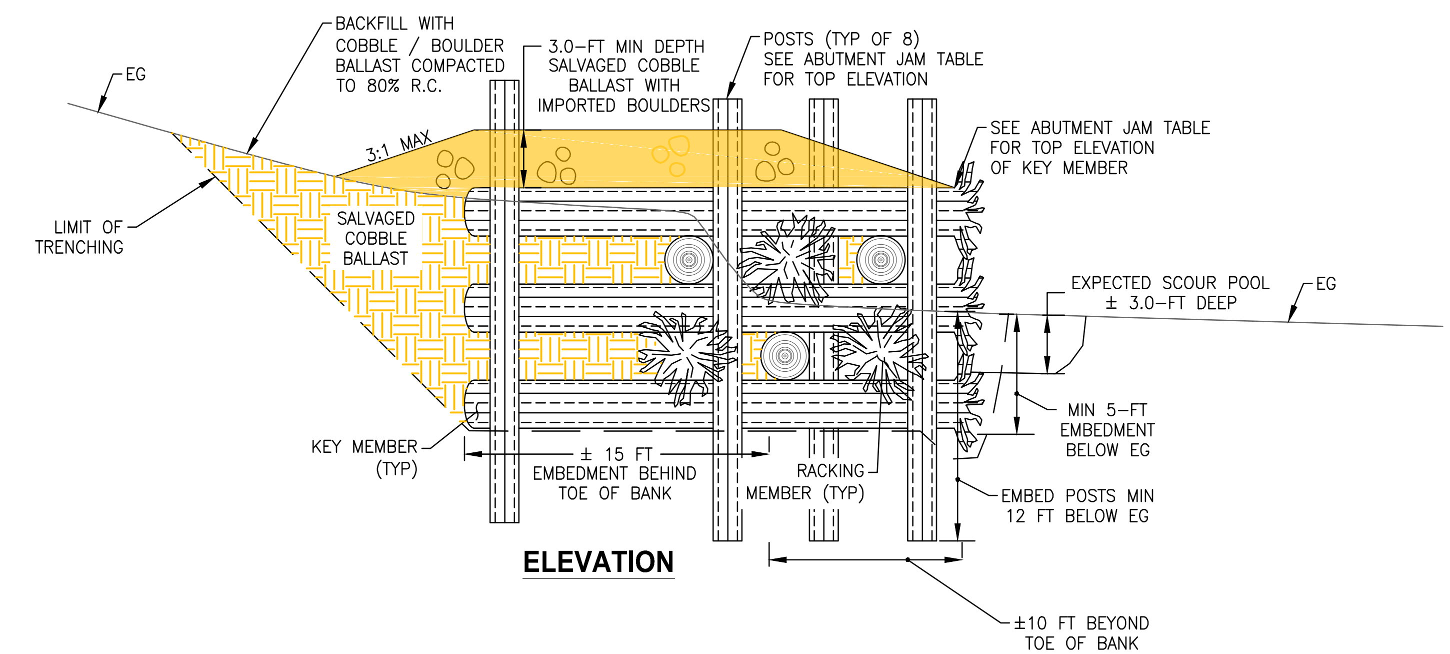

ELEVATION

ABUTMENT JAM TABLE

JAM	STATION	APPROX EG INVERT ELEVATION	ELEVATION TOP OF KEY MEMBER	ELEV TOP OF POST	LENGTH OF JAM (PERPENDICULAR TO FLOW)
A	± 10+50	± 1702.5	± 1711.5	1714.0	20 Ft
B	± 8+50	± 1706.0	± 1711.0	1712.0	20 Ft
C	± 7+25	± 1702.0	± 1711.0	1713.0	15 Ft

NOTES:
1. SPECIFIC NUMBER OF KEY AND RACKING MEMBER LAYERS WILL VARY WITH LOG SIZE AND TOP RACKING ELEVATION.
2. TOP TIER OF LOGS SHALL BE KEY MEMBERS.
3. PLACE 0.5 FT OF DENSELY CRISS–CROSSED BRUSH ON TOP OF EACH KEY AND RACKING LAYER TO RETAIN BALLAST.
4. INCORPORATE LIVE STAKES INTO BRUSH LAYERS FOR LAYERS WITHIN 3 FT OF THE CHANNEL INVERT. INSTALL A MINIMUM OF 3 LIVE STAKES ADJACENT TO EACH POST SUCH THAT THE BOTTOM OF EACH STAKE IS EQUAL TO OR LOWER THAN THE CHANNEL INVERT.
5. EACH STRUCTURE SHALL CONTAIN A TOTAL OF ± 100 CY SALVAGED COBBLE BALLAST WITH MIN 6.5 TONS IMPORTED 2–3 FT DIAMETER BOULDERS ON TOP OF STRUCTURE.

8 **ABUTMENT JAM**
TYPICALS NTS

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DETAIL SHEET 4

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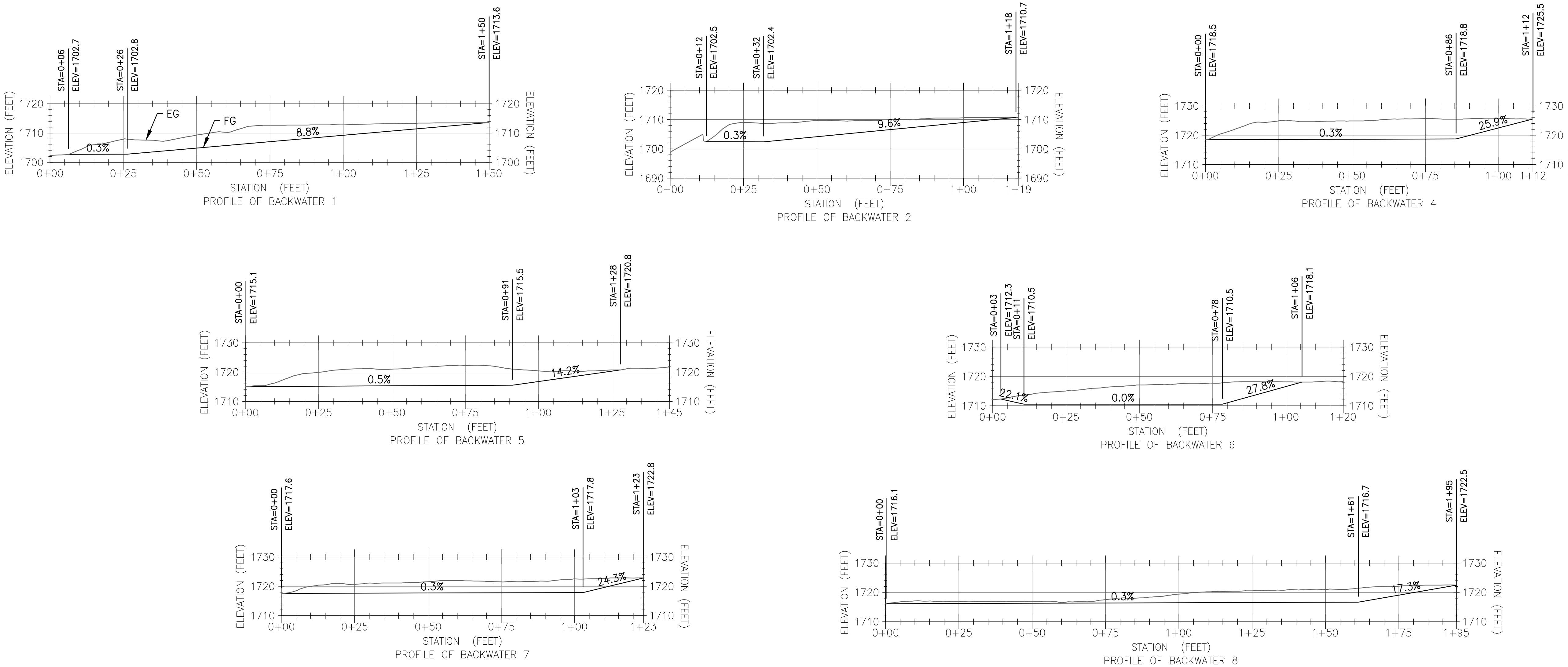
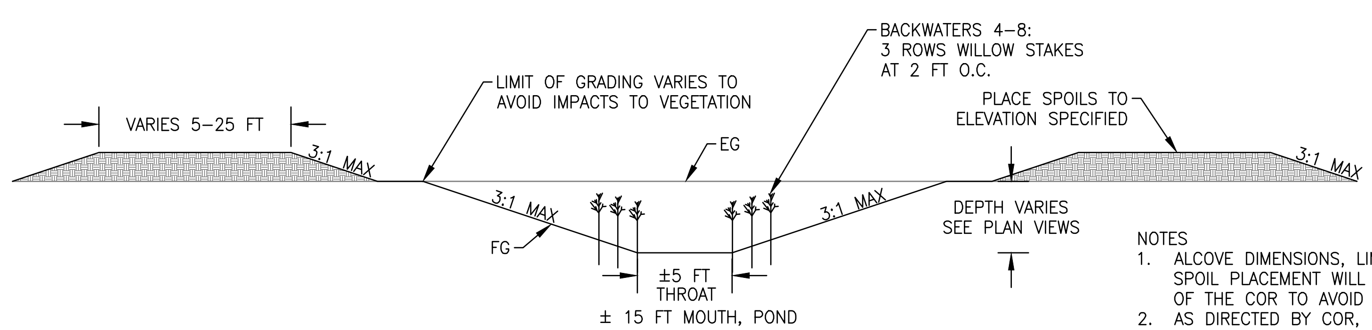


- BACKWATER PONDS
PROFILES

0 20 40
HORIZONTAL AND VERTICAL GRAPHIC SCALE



9 BACKWATER
TYPICAL CROSS SECTION NTS

NOTES
1. ALCOVE DIMENSIONS, LIMIT OF GRADING, AND SPOIL PLACEMENT WILL BE AT THE DIRECTION OF THE COR TO AVOID IMPACTS TO TREES.
2. AS DIRECTED BY COR, BACKWATER SIDE SLOPES STEEPER THAN 3:1 CAN BE CREATED BY STACKING BOULDERS OR INSTALLING LARGE WOOD.

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BACKWATER PROFILES AND SECTIONS

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SHEET 13 of 13

Appendix B
Comments and Responses on Submittals

Michael Love & Associates
Hydrologic Solutions

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March 25, 2017

Ms. Melissa Van Scoyoc
Habitat Restoration Coordinator
Salmon River Restoration Council
PO Box 1089
Sawyers Bar, CA 96027

Re: 65% Design Submittal for the Red Bank Bar Off-Channel Fisheries and Riparian Habitat Design on the North Fork of the Salmon River (Electronic Submittal)

Dear Mel,

Michael Love & Associates, Inc. (MLA) is pleased to provide you with the 65% design submittal for the Red Bank Bar Off-Channel Fisheries and Riparian Habitat Design on the North Fork of the Salmon River (**Attachment 1**). Electronic version of the design plans can be downloaded at:

http://www.h2odesigns.com/Red_Bank_Bar

This submittal is composed of the 65% construction plan set. As we discussed, the final Basis of Design Report will be submitted with the 90% submittal after the field meeting and receipt of review comments.

The next submittal for this project under the current contract will be the 90% design plans on Tuesday May 23, 2017.

Changes to the Design Plans

1. Plans were updated to the 65% design level, and include general notes, and water management notes and details.
2. Details for the large wood features were updated to the 65% level and specifications for construction of the wood features were added.
3. Construction access was updated to be only from the Engine Fill Site and include a low-water crossing.
4. A total of eight potential backwater features were added to the design plans in response to comments on the 30% design plans (See **Attachment 3** for more detail).

Detailed responses to comments on the 30% submittal are provided in **Attachment 2**.

A summary of the proposed backwater feature design method, description of each feature, and results of hydraulic modeling of the features are presented in **Attachment 3**. During the 65% field meeting, MLA would like to evaluate each of the proposed backwater feature sites with SRRC, the USFS, and CDFW to identify the available footprint for construction and number of trees that could be removed. MLA will also like to evaluate with the group the merits of construction feature OP1, recommended by Dr. Josh Strange.

A summary of the design methods and computations for the large wood structures is presented in **Attachment 4.**

A finalized Basis of Design Report will be provided with the 90% submittal. The report will include a section on the design of the backwater features and computations supporting the large wood feature designs.

The implementation cost estimate for the project will be updated as part of the 90% submittal, after the backwater features.

Please feel free to call with any questions or comments.

Sincerely,

Rachel Shea P.E., M.S.
Engineering Geomorphologist
Michael Love & Associates, Inc.
(707) 822-2411 x 3 / shea@h2odesigns.com

Attachments:

- *Attachment 1: 65% Design Plans*
- *Attachment 2: Response to 30% Comments*
- *Attachment 3: Backwater Design*
- *Attachment 4: Large Wood Stability Computations*

Attachment 1

65% Design Plans

(See Separate pdf file)

Attachment 2

Response to Comments

Salmon River Restoration Council (Comments received 3/4/17) (i*n Italics*)

Full text of comments are provided at back of this Attachment.

1. Habitat Enhancement Approach and Techniques (Report Section 6.2)

Given that the individual structures will be field fit, could the BOD include more information on this process?

The proposed structures are shown roughly where they are anticipated to be placed in the field. The "field fit" term in the report indicates that they may be slightly adjusted to fit the existing topography and minimize impacts to adjacent trees. If, during construction, excavation for one type of structure would be deemed to affect more adjacent trees that is desirable, a different structure may be selected that would not require as much excavation, such as a Bank Log.

It would be interesting to see the hydraulics of how these structures are affecting each other during various flows, along with the existing modeling of individual structures at various flows. This would help to visualize the overall habitat available at varying flows within the project site and their proximity to one another.

Due to the level of effort it would take, a hydraulic model of all the structures was not prepared. Instead, hydraulic modeling was performed for each structure independently. This modeling was used to determine the extent of hydraulic influence of each structure, including the extents of scour pools expected to form. Based on the results of the modeling, the structures were placed such that their areas of influence do not substantially overlap. This was done to avoid unforeseen flow patterns that could result in excessive scour and potential failure of a structure.

Was a range of structures evaluated (e.g., all possible locations, some middle number of structures, and the bare minimum to make a difference)? It would be helpful to know if the plans represent all feasible structures, an assessment of the best balance of structures to reach habitat goals, and whether some of these structures need to be implemented in series to get the desired effect.

The number and placement of the structures was based on the extent of influence for each structure, effectively optimizing the number and placement of the structures. There are a few locations where an additional feature may be feasible. Thus the project budget was developed assuming that one extra of each structure (except the Abutment Jams) may be determined to be feasible in the field, ensuring that there is sufficient budget to construct them.

There are no structures that require being in series to achieve the desired effect, though construction of a series of Bank Logs or Root Wad Cover structures would result in a longer continuous pool rather individual pools.

The side channels where the log structures will be placed are classified as "plane-bedded channels," in which bedforms rely on forcing features to generate diversity such as riffles and pools (Montgomery and Buffington, 1997). The forcing features within the side channels consist of occasional large boulders and fallen trees. Both the number and location of these feature are relatively random, thus there is no "optimal" number of features.

2. In-Line Alcoves (Report Section 6.3.3)

…It would be great to evaluate other areas of the bar for winter high flow pool refugia (i.e. on or off channel pools that would maintain larger areas of quiet water during high flow events). We are thinking that we would want to look for pool locations that would be engaged in 5 year events and provide habitat up to at least 10 year events.

See **Attachment 3** for design method and description of each of eight proposed backwater features.

3. Construction Access (Report Section 7.1)

SRRC would like to pursue a low water crossing at the engine fill for site access. We will work with CDFW and FS on this. Spawning typically begins around September 30th at Red Bank. Assuming the work window begins on 7/9, construction could be completed before spawning occurs in the area.

At the request of SRRC, construction access for the project area will be from the Engine Fill Station. Rather than a bridge, construction access will consist of a wet low-water crossing constructed of river-run gravel. During construction, fish would be excluded from the low-water crossing using temporary fish exclusion devices.

4. Jones Gulch

Will you be including evaluating enhancement opportunities at the mouth of Jones Creek in the 65%? Unfortunately, we didn't get the field visit for the 30%, so you won't be able to look at it before the 65% submittal.

Our evaluation of the Jones Creek confluence suggested it was not suitable for an alcove. It is on the outside of an abrupt bend in the river, exposed to high velocities and scouring forces, and dominated by shallow bedrock. At the upcoming site visit the group can verify these observations and consider if there are any enhancements appropriate for this site.

Existing Condition 2-D Modeling results (Appendix H)

Please add the corresponding Salmon River gaged flow (CFS) to the model results pages. We all think in terms of the gaged flow around here, so this will help us put the modeled flow into perspective with what we are seeing at the site given specific flow event recorded at the gage.

Flows at the gage in addition to the flows at the site will be added to the report and appendices for the Final report submittal.

NOAA Restoration Center (Bob Pagliuco) (Comments received 2/27/17) (i*n Italics*)

Full comment text is provided at back of Attachment.

1. *I encourage you to include live willow stakes that have their root zone in contact with the summer groundwater table to each of the larger jam features to encourage forested islands.*

   Willow stakes are proposed to be incorporated into Brush Baffles and Abutment Jams to provide long term stability. The plans specify that the willow stakes be installed below the summer groundwater table. A profile or map of summer groundwater elevations will be included in the design plans after McBain Associates prepare a detrended analysis of groundwater depths as part of their development of a riparian restoration plan for the Bar.

2. *Page 31 – The DO readings are very high for groundwater in the summertime. The RB3 well in June had the lowest reading of ~4 mg/l. This leads me to believe that this is not true groundwater, but the wells are showing that these sites have a good connection to the river.*

   MLA will revise the text in the Basis of Design report to suggest that the source of the water in the wells is likely a combination of both river water and groundwater.

3. *Page 47 – Will splitting the low flow channel into two separate pools with an alcove abutment jam reduce the water quality? Would a single pool rather than a peninsula pool be better for summer rearing?*

   The alcove abutment jam is intended to provide high-flow refugia. It will likely be fed by groundwater in the summer and provide good summer rearing habitat. Even if the Alcove does not, the other wood placed throughout the side channel is intended to create pools for primarily summer rearing.

4. *Page 58 – Given the difficulty of planting riparian species on the Salmon River, any designs of willow baffles should include small wood "nurse logs" buried at the toe of the baffle to provide moisture as the willows are becoming established.*

   The detail for the Brush Baffles specifies that both woodchips and wood chunks be installed in the baffle trench to provide a moisture sources.

5. *Appendix G – Page 2 – Missing the "n" in "water Quality Mo**n**itoring" in the header. RB – 2 shows DO concentrations in the well dip down to 2 mg/l in June 2016 and continue through October, but the graph showing DO concentrations on pg 31 of the BOD doesn't show any readings below ~4mg/l. Please check these numbers for errors.*

   These values will be checked and corrected as necessary in the final Basis of Design Report.

Red Bank Off-Channel Fisheries and Riparian Habitat Design - 30% Review

Comments: SRRC (Bonnie Bennett, Lyra Cressey, Karuna Greenberg, Kristen Sellmer, Melissa Van Scoyoc)

3/4//2017

Page (e-page)	Section	Comment
47(43)	6.2 Habitat Enhancement Approach and Techniques	The design of the habitat features are good. We like the complexity, current locations, and techniques in the current plans. We are very happy with the current design of this project. The BOD states "These techniques become effective at providing highflow refugia in different locations at differing flows. Hydraulic modeling was used to evaluate the performance of most of the proposed structures… The locations of each habitat enhancement technique are shown where they are feasible and their benefit will be optimized. The exact location of each feature will be adjusted in the field during construction to work within the existing site constraints." Given that the individual structures will be field fit, could the BOD include more information on this process? -It would be interesting to see the hydraulics of how these structures are affecting each other during various flows, along with the existing modeling of individual structures at various flows. This would help to visualize the overall habitat available at varying flows within the project site and their proximity to one another. -Was a range of structures evaluated (e.g., all possible locations, some middle number of structures, and the bare minimum to make a difference)? It would be helpful to know if the plans represent all feasible structures, an assessment of the best balance of structures to reach habitat goals, and whether some of these structures need to be implemented in series to get the desired effect. -We are aiming to maximize fish habitat and increase habitat diversity through a range of flows throughout the year, while still keeping the project feasible. Including an evaluation of how we decide to maximize habitat will help us justify the project in the future.
64(60)	6.3.3 In-Line Alcoves	An in-line alcove/groundwater–fed pool option was analyzed at the confluence of the secondary and primary side channels. -Though this area was considered for a ground-water fed pool, it would be great to evaluate other areas of the bar for winter high flow pool refugia (i.e. on or off channel pools that would maintain larger areas of quiet water during high flow events). The combination of the current designs and a few high flow pools could really develop the bar so that it

		provides fish refugia for a full range of flows, giving juvenile fish maximum ability to utilize habitat features and stay within the project area throughout the year. -We are thinking that we would want to look for pool locations that would be engaged in 5 year events and provide habitat up to at least 10 year events. Engaging at lower flow events would be great if feasible, but it seems like the proposed structures would provide decent habitat during lower flow events. -This would result in Red Bank being a very high quality site where fish can have up to a two-year residence time, something greatly lacking on the Salmon River. Given the lack of high water refugia on the Salmon River, the more opportunities that we can provide to weather the storms, the more likely we are to have juveniles overwinter in the river and not be flushed out of the system. Additionally, these still water pools may increase juvenile recruitment to the project area during high flow events. -Red Bank is a great place to figure out how to create a functional high flow pool. We are thinking of this project as a pilot project and are willing to test techniques to see what works, so that the methods can be replicated and/or adjusted for future projects. -We are willing to try something that may need maintenance in 5 years or is just an ephemeral feature. -Using Red Bank as model for how to create functional high flow pools, especially among mine tailings if possible, can provide us with valuable insights on how to restore historic flood plain areas in the Salmon River that are currently overwhelmed with tailings. How do we reconstruct and stabilize those piles to provide fish habitat? This project can be used to test methods for this type of process. - We have more to discuss on this topic and are looking forward to the upcoming call to discuss potential for including pools in the design.
65(61)	7.1 Construction Access	SRRC would like to pursue a low water crossing at the engine fill for site access. We will work with CDFW and FS on this. -Spawning typically begins around September 30th at Red Bank. -Assuming the work window begins on 7/9, construction could be completed before spawning occurs in the area. -A temporary bridge could block spring Chinook from migrating upstream. -Using spawning sized gravel to fill the ford area would be less of an impact than fish getting blocked by the temporary bridge. -Restoration of any impacts from the low water crossing area would be pretty simple. -The north fork spring Chinook population is limited compared to other reaches of the Salmon River so it will be especially important that the migration corridor for these fish is not compromised.
NA		Will you be including evaluating enhancement opportunities at the mouth of Jones Creek in the 65%? Unfortunately, we didn't get the field visit for the 30%, so you won't be able to look at it before the 65% submittal.
150(NA)	Appendix H	Please add the corresponding Salmon River gaged flow (CFS) to the model results pages. We all think in terms of the gaged flow around here,

	Existing Condition 2-D Modeling results	so this will help us put the modeled flow into perspective with what we are seeing at the site given specific flow event recorded at the gage.
NA		We look forward to working with you and a revegetation specialist contractor to develop a comprehensive revegetation/planting plan.

NOAA Restoration Center's Comments and Questions on the North Fork Salmon River Red Bank Off-Channel Fisheries and Riparian Habitat Enhancement Project

February 27, 2017 - Bob Pagliuco

General Comments: The design approach is sound and well thought out. Incorporating whole tree materials into the structures will add the complexity needed for juvenile rearing and will provide an effective structure to rack LWD and SWD in the future. I encourage you to include live willow stakes that have their root zone in contact with the summer groundwater table to each of the larger jam features to encourage forested islands.

Page 31 – The DO readings are very high for groundwater in the summertime. The RB3 well in June had the lowest reading of ~4 mg/l. This leads me to believe that this is not true groundwater, but the wells are showing that these sites have a good connection to the river.

Page 47 – Will splitting the low flow channel into two separate pools with an alcove abutment jam reduce the water quality? Would a single pool rather than a peninsula pool be better for summer rearing?

Page 58 – Given the difficulty of planting riparian species on the Salmon River, any designs of willow baffles should include small wood "nurse logs" buried at the toe of the baffle to provide moisture as the willows are becoming established.

Appendix G – Page 2 – Missing the "n" in "water Quality Mo**n**itoring" in the header. RB – 2 shows DO concentrations in the well dip down to 2 mg/l in June 2016 and continue through October, but the graph showing DO concentrations on pg 31 of the BOD doesn't show any readings below ~4mg/l. Please check these numbers for errors.

Subject: Re: Fwd: Red Bank 30% comments
From: Rachel <shea@h2odesigns.com>
Date: 3/3/2017 3:06 PM
To: Melissa Van Scoyoc <habitat@srrc.org>, Mike Love <mlove@h2odesigns.com>

Mel,

Thanks for the comments. I know that they got the wells as deep as they could, but dont know the details for each well.

Thanks for staying on Margie for comments.

I have been remiss in responding to your email regarding the pond. We are looking forward to the pond concept, though we have about another week before we really need to get into it. We are happy to have an conference call with whoever you would like. We would like some time to evaluate what Josh is proposing before the call though.

Have a good weekend,

Rachel

On 3/3/2017 11:34 AM, Melissa Van Scoyoc wrote:

> Here are Margie's comments.
>
> I'll have to look at why RB-5 didn't end up deeper, I know it was as deep as we could get it. I believe it was because the hole was collapsing. Do either of your remember off-hand?
>
> Margie did not comment on the crossing. I asked if she and Mark had discussed it yet, and sent her SRRC's comments on the subject.
>
> I will get you SRRC's comments today. I am waiting on final review from Karuna before I send them to you.
>
> Melissa Van Scoyoc
> Habitat Restoration Coordinator
> Salmon River Restoration Council
> PO BOX 1089
> 25631 Sawyers Bar Road
> Sawyers Bar, CA 96027
> 530.462.4665
> srrc.org
>
> ---------- Forwarded message ----------

From: **Caisley, Marjorie@Wildlife** <Marjorie.Caisley@wildlife.ca.gov>
Date: Thu, Mar 2, 2017 at 3:43 PM
Subject: RE: Red Bank 30% comments
To: Melissa Van Scoyoc <habitat@srrc.org>

Hi Melissa,

I don't have many comments on the design features. They all look thoughtfully considered to me. I'm interested in discussing the addition of a pond. There seem to be trade-offs involved, such as apparent vegetation in the lower 1975 side channel. This area would probably have nice groundwater levels in it though. The other area that come to mind is in the far side channel from station 14+00 to 17+00. Again, mature trees appear to be an issue and some regrading of the channel bed would likely be necessary to connect to the primary side channel. It's too bad that Well RB-5 did not go deeper. The bottom of that well is at the same elevation as the bed in the pool in the far side channel adjacent to the well.

Thanks,

Margie

From: Melissa Van Scoyoc [mailto:habitat@srrc.org]
Sent: Wednesday, March 01, 2017 3:59 PM
To: Caisley, Marjorie@Wildlife
Subject: Red Bank 30% comments

Hey Margie- Can you get us comments on the Red Bank 30% Designs/BOD pretty soon? If not, can you let me know when you think you'll be able to provide comments?

Thanks so much-Mel

Melissa Van Scoyoc

Habitat Restoration Coordinator

Subject: Re: Fwd: Red Bank Off-Channel Fisheries and Riparian Habitat Design Project - 30% Design Plan Review
From: Rachel <shea@h2odesigns.com>
Date: 2/27/2017 1:03 PM
To: Melissa Van Scoyoc <habitat@srrc.org>, Mike Love <mlove@h2odesigns.com>

Hi Mel,

We have not gotten any other comments. I am hoping to hear from CDFW about the timing window for construction access limitations. Can you give everyone a nudge?

Thanks,

Rachel

On 2/25/2017 6:48 PM, Melissa Van Scoyoc wrote:

> I thought maybe I would get more comments from Maija, Friday, but I did not.
>
> So far, these are the only comments I have received. Did you folks get comments Friday?
>
> I am organizing SRRC's comments since we have 5 people reviewing this and will get you SRRC's comments Monday.
>
> Melissa Van Scoyoc
> Habitat Restoration Coordinator
> Salmon River Restoration Council
> PO BOX 1089
> 25631 Sawyers Bar Road
> Sawyers Bar, CA 96027
> 530.462.4665
> srrc.org
>
> ---------- Forwarded message ----------
> From: **Meneks, Maija -FS** <mmeneks@fs.fed.us>
> Date: Mon, Jan 23, 2017 at 9:10 AM
> Subject: RE: Red Bank Off-Channel Fisheries and Riparian Habitat Design Project - 30% Design Plan Review
> To: Melissa Van Scoyoc <habitat@srrc.org>
>
> Mel,

I looked over the report and plans. Good information! I don't have much to add as far as a review because I have yet to be involved in (to completion) a large-river restoration project and see, afterwards, how the various structures function under varying conditions. Given the power of the Salmon River system, and seeing how past structures have poorly faired, my only caution is to allow for, and expect, that these things are likely to move…perhaps radically so. However, I'm not seeing much in the way for cable and rebar in the plans, so it looks like things are supposed to be a bit more organic than the structures of the past. Therefore, I'll leave the substantial comments to those with a bit more experience in river restoration engineering.

Maija Meneks
District Fish Biologist

Forest Service

Klamath National Forest, Salmon-Scott Ranger District

p: 530-468-1272
mmeneks@fs.fed.us

11263 N. State Hwy 3
Fort Jones, CA 96032
www.fs.fed.us

Caring for the land and serving people

From: Melissa Van Scoyoc [mailto:habitat@srrc.org]
Sent: Thursday, January 19, 2017 6:06 PM
To: sprice@karuk.us; Bob Pagliuco - NOAA Affiliate <Bob.Pagliuco@noaa.gov>; Bull, Jennifer@Wildlife <Jennifer.Bull@wildlife.ca.gov>; Caisley, Marjorie@Wildlife <Marjorie.Caisley@wildlife.ca.gov>; Ester, Christopher - FS <cester@fs.fed.us>; Donald.Flickinger@noaa.gov; Dr Joshua Strange <joshua@sweetriversciences.com>; Elfgen, Mark@Wildlife <Mark.Elfgen@wildlife.ca.gov>; Forest@Waterboards Fortescue <Forest.Fortescue@waterboards.ca.gov>; Laurie, Gregory -FS <glaurie@fs.fed.us>; Jacob J.@Waterboards Shannon <Jacob.Shannon@waterboards.ca.gov>; Jay Stallman <Jay@stillwatersci.com>; Jennifer Silveira <jsmvfriends@gmail.com>; Karuna Greenberg <karuna@srrc.org>; Kristen Sellmer <fisheries@srrc.org>; Lyra Cressey <lyra@srrc.org>; Meneks, Maija -FS <mmeneks@fs.fed.us>; Miller, Bobbie -FS <bdimontemiller@fs.fed.us>; nathanielpennington@hotmail.com; Ryan Fogerty <ryan_fogerty@fws.gov>; Toz Soto <tsoto@karuk.us>; Will Harling <will@mkwc.org>
Cc: Mike Love <mlove@h2odesigns.com>; Rachel Shea <shea@h2odesigns.com>
Subject: Red Bank Off-Channel Fisheries and Riparian Habitat Design Project - 30% Design Plan Review

Hello All- Below is a link for the 30% Design Plans for the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project. Please review these plans and provide me comments by Friday, February 24th.

http://www.h2odesigns.com/Red_Bank_Bar/Red%20Bank_30_Submittal_1_17_17.zip

This project is on a bit of an accelerated schedule, though less so than those of you who reviewed Kelly bar last year. We need to complete the design prior to June 30, preferably by May 30. Because we are a little behind schedule, the attached plans are more developed than traditional 30% Plans, in the hope of expediting later submittals. The 65% Plans will include any changes resulting from comments on the 30% submittal, specifications, more developed construction access, and water management plans. The final Basis of Design Report will include log structure stability computations for each structure.

Additionally, complete this **Doodle Poll** for your availability for a meeting at SRRC in Sawyers Bar to discuss the plans and provide input/comments/mitigation. The discussion at this meeting will be summarized and shared with the team prior to reviews being due.

We will have a 1 hour meeting, followed by a quick lunch at the office and then, depending on the weather and river flows, proceed to the project site. We have to cross the North Fork Salmon River to access the project site. We will provide a guided boat for folks to cross the river.

It is winter out here, so wear waders and rain gear, bring warm clothes, hot beverages, and a lunch. Be prepared for winter driving conditions. We will cancel this meeting if the driving conditions are at all dangerous.

Cheers! Mel

Melissa Van Scoyoc

Habitat Restoration Coordinator

Salmon River Restoration Council

PO BOX 1089
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Appendix C
Hydrology

Estimated Peak Flows on the NF Salmon River at Red Bank using (USGS, 1982).

NF Salmon Drainage Area at Red Bank 186.04 square miles

Return Period	Flow/mi^2	NF Salmon at Red Bank
Years	**cfs/mi^2**	**cfs**
1.2	14	2,548
1.5	20	3,747
1.8	25	4,590
2	27	5,058
2.33	31	5,715
2.4	31	5,859
2.6	34	6,244
2.8	35	6,594
3	37	6,913
3.5	41	7,598
4	44	8,156
5	48	9,007
10	65	12,145
25	90	16,673
50	110	20,438
100	132	24,530

Data is based on averaged results of LPIII analyses of the Salmon River at Somes Bar (USGS Gage No. 11522500) and the South Fork of the Salmon River Near Forks (USGS Gage No. 11522300).

Flood Frequency based on Annual Maximum Series

USGS 11522500 SALMON R A SOMES BAR CA

Drainage area **751** mi^2

Annual Maxima Series

WY	Date of Peak	Discharge (cfs)	RANK	Recurrence Interval (years)	Discharge (cfs)	Discharge (cms)	Log-discharge (cfs)
	12/22/1964	**133,000**	1	89.00	133,000	3,766	5.12
	12/22/1955	**84,000**	2	44.50	84,000	2,379	4.92
	1/1/1997	**70,800**	3	29.67	70,800	2,005	4.85
	12/30/2005	**67,500**	4	22.25	67,500	1,911	4.83
	1/16/1974	**63,500**	5	17.80	63,500	1,798	4.80
	3/2/1972	**56,900**	6	14.83	56,900	1,611	4.76
	1/18/1971	**51,700**	7	12.71	51,700	1,464	4.71
	1927-02-00	**49,000**	8	11.13	49,000	1,388	4.69
	1/18/1953	**45,900**	9	9.89	45,900	1,300	4.66
	1/22/1970	**42,600**	10	8.90	42,600	1,206	4.63
	12/19/1981	**41,300**	11	8.09	41,300	1,169	4.62
	2/18/1986	**39,100**	12	7.42	39,100	1,107	4.59
	12/2/1962	**37,100**	13	6.85	37,100	1,051	4.57
	3/23/1998	**34,700**	14	6.36	34,700	983	4.54
	1/29/1958	**34,400**	15	5.93	34,400	974	4.54
	12/28/1945	**33,000**	16	5.56	33,000	934	4.52
	1/7/1948	**32,500**	17	5.24	32,500	920	4.51
	2/23/1968	**32,100**	18	4.94	32,100	909	4.51
	1/31/1995	**32,000**	19	4.68	32,000	906	4.51
	12/14/1977	**31,700**	20	4.45	31,700	898	4.50
	1/12/1980	**30,600**	21	4.24	30,600	867	4.49
	12/11/1937	**27,000**	22	4.05	27,000	765	4.43
	12/2/2012	**26,300**	23	3.87	26,300	745	4.42
	2/8/1960	**25,900**	24	3.71	25,900	733	4.41
	12/16/1982	**25,700**	25	3.56	25,700	728	4.41
	2/5/1951	**25,500**	26	3.42	25,500	722	4.41
	11/22/1988	**24,400**	27	3.30	24,400	691	4.39
	2/17/1912	**23,800**	28	3.18	23,800	674	4.38
	12/28/2002	**23,700**	29	3.07	23,700	671	4.37
	1/6/1966	**23,600**	30	2.97	23,600	668	4.37
	12/31/1913	**23,500**	31	2.87	23,500	665	4.37
	2/26/1957	**22,700**	32	2.78	22,700	643	4.36
	2/2/1952	**22,500**	33	2.70	22,500	637	4.35
	12/27/1942	**22,400**	34	2.62	22,400	634	4.35
	1/21/1969	**21,700**	35	2.54	21,700	614	4.34
	1/14/1936	**21,600**	36	2.47	21,600	612	4.33
	3/30/2012	**21,600**	37	2.41	21,600	612	4.33
	3/26/1928	**21,200**	38	2.34	21,200	600	4.33
	2/28/1940	**21,200**	39	2.28	21,200	600	4.33
	12/2/1941	**21,100**	40	2.23	21,100	597	4.32
	1/12/1959	**21,000**	41	2.17	21,000	595	4.32
	1/29/1967	**21,000**	42	2.12	21,000	595	4.32
	3/17/1993	**20,800**	43	2.07	20,800	589	4.32
	1/8/1990	**20,600**	44	2.02	20,600	583	4.31
	3/18/1975	**20,400**	45	1.98	20,400	578	4.31

Generalized Skew=	**-0.3**	A=	-0.32380
Station Skewness (log Q)=	-0.08	B=	0.91986
Station Mean (log Q)=	4.27	MSE (station skew) =	0.06418
Station Std Dev (log Q)=	0.31		
Weighted Skewness (G_W)=	**-0.12**		

Log Pearson Type III Distribution

Return Period (years)	**Exceedence Probability**	**Log-Pearson K**	**Predicicted Discharge (cfs)**	**Discharge/Mi^2 (cfs/mi^2)**
1.2	0.833	-0.98804	9,294	12
1.5	0.667	-0.41831	13,921	19
1.8	0.556	-0.12195	17,177	23
2.0	0.500	0.01936	18,988	25
2.33	0.429	0.19600	21,522	29
2.4	0.417	0.23154	22,072	29
2.6	0.385	0.32255	23,543	31
2.8	0.357	0.40055	24,882	33
3	0.333	0.46815	26,104	35
3.5	0.286	0.60336	28,731	38
4	0.250	0.70476	30,874	41
5.0	0.200	0.84673	34,144	45
10	0.100	1.26837	46,045	61
25	0.040	1.70990	62,977	84
50	0.020	1.99071	76,855	102
100	0.010	2.24036	91,742	122

Values From K-Table for Linear interpolation

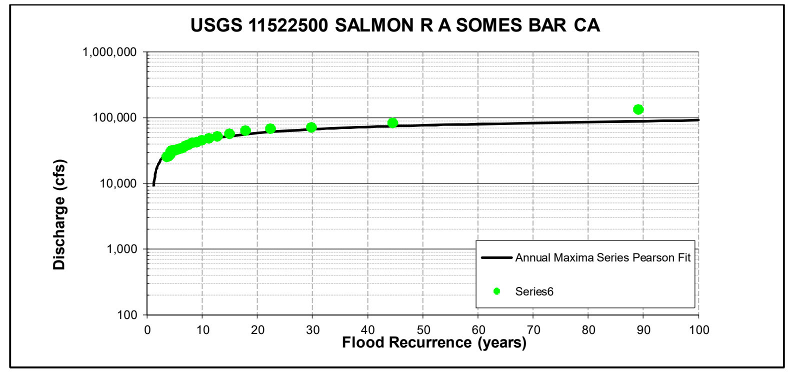
Weighted Skewness =	-0.20	-0.10	-0.12	
P	K	K	K	Return Period (Years)
0.9	-1.30105	-1.29178	-1.29331	1.1
0.8	-0.83044	-0.83639	-0.83541	1.3
0.7	-0.49927	-0.51207	-0.50996	1.4
0.6	-0.22168	-0.23763	-0.23500	1.7
0.500	0.03325	0.01662	0.01936	2.0
0.429	0.20925	0.19339	0.19600	2.3
0.200	0.84986	0.84611	0.84673	5.0
0.100	1.25824	1.27037	1.26837	10.0
0.040	1.67999	1.71580	1.70990	25.0
0.020	1.94499	1.99973	1.99071	50.0
0.010	2.17840	2.25258	2.24036	100.0

Flood Frequency based on Annual Maximum Series
USGS 11522500 SALMON R A SOMES BAR CA

Drainage area **751** mi^2

Annual Maxima Series

WY	Date of Peak	Discharge (cfs)	RANK	Recurrence Interval (years)	Discharge (cfs)	Discharge (cms)	Log-discharge (cfs)	
	12/10/1987	**20,200**	46	1.93	20,200	572	4.31	
	11/24/1953	**19,500**	47	1.89	19,500	552	4.29	
	4/13/1937	**19,400**	48	1.85	19,400	549	4.29	
	3/19/1932	**19,300**	49	1.82	19,300	547	4.29	
	1/20/1964	**19,300**	50	1.78	19,300	547	4.29	
	12/30/1995	**19,300**	51	1.75	19,300	547	4.29	
	2/17/2004	**18,800**	52	1.71	18,800	532	4.27	
	12/14/1983	**17,600**	53	1.68	17,600	498	4.25	
	2/1/1915	**17,400**	54	1.65	17,400	493	4.24	
	2/11/1961	**16,700**	55	1.62	16,700	473	4.22	
	12/13/2006	**16,000**	56	1.59	16,000	453	4.20	
	2/13/1945	**15,700**	57	1.56	15,700	445	4.20	
	11/21/1998	**15,300**	58	1.53	15,300	433	4.18	
	6/4/2010	**15,100**	59	1.51	15,100	428	4.18	
	1/11/1979	**14,700**	60	1.48	14,700	416	4.17	
	11/12/1984	**14,600**	61	1.46	14,600	413	4.16	
	12/9/2004	**13,700**	62	1.44	13,700	388	4.14	
	1/6/2002	**13,200**	63	1.41	13,200	374	4.12	
	12/19/1961	**13,100**	64	1.39	13,100	371	4.12	
	12/2/1980	**12,900**	65	1.37	12,900	365	4.11	
	3/17/1950	**12,300**	66	1.35	12,300	348	4.09	
	3/16/2011	**12,200**	67	1.33	12,200	345	4.09	
	1/13/1973	**10,900**	68	1.31	10,900	309	4.04	
	2/14/2000	**10,900**	69	1.29	10,900	309	4.04	
	5/5/2009	**10,900**	70	1.27	10,900	309	4.04	
	10/19/2007	**10,800**	71	1.25	10,800	306	4.03	
	3/28/1934	**10,600**	72	1.24	10,600	300	4.03	
	11/15/1975	**10,500**	73	1.22	10,500	297	4.02	
	4/17/1992	**8,660**	74	1.20	8,660	245	3.94	
	11/19/1946	**8,120**	75	1.19	8,120	230	3.91	
	12/21/1940	**8,100**	76	1.17	8,100	229	3.91	
	6/10/1933	**7,750**	77	1.16	7,750	219	3.89	
	3/13/1939	**7,660**	78	1.14	7,660	217	3.88	
	3/12/1987	**7,560**	79	1.13	7,560	214	3.88	
	12/31/1954	**7,500**	80	1.11	7,500	212	3.88	
	3/18/1931	**7,250**	81	1.10	7,250	205	3.86	
	2/22/1949	**6,730**	82	1.09	6,730	191	3.83	
	4/29/1935	**5,880**	83	1.07	5,880	167	3.77	
	3/4/1991	**5,830**	84	1.06	5,830	165	3.77	
	3/10/1944	**4,420**	85	1.05	4,420	125	3.65	
	5/15/2001	**4,180**	86	1.03	4,180	118	3.62	
	5/21/1929	**3,770**	87	1.02	3,770	107	3.58	
	12/8/1993	**3,210**	88	1.01	3,210	91	3.51	
	9/29/1977	**1,810**	89	1.00	1,810	51	3.26	Outlier discarded



Sample Size, n =	**88**		
Skewness =	2.78	2.78	-0.08
Mean=	23979	679	4.27
Std Dev=	19495	552	0.308
Outliers			
Kn=	**2.973**		
Q-low =	**2274 cfs**		
Q-high =	**154,251 cfs**		

Flood Frequency based on Annual Maximum Series

USGS 11522300 SF SALMON R NR FORKS OF SALMON CA

Drainage area **252** mi^2

Annual Maxima Series WY	Date of Peak	Discharge (cfs)	RANK	Recurrence Interval (years)	Discharge (cfs)	Discharge (cms)	Log-discharge (cfs)	
	12/22/1964	**31400**	1	26.00	31,400	889.15	4.50	
	12/22/1955	**24200**	2	13.00	24,200	685.27	4.38	
	1/16/1974	**18400**	3	8.67	18,400	521.03	4.26	
	3/2/1972	**13100**	4	6.50	13,100	370.95	4.12	
	1/22/1970	**12700**	5	5.20	12,700	359.63	4.10	
	1/17/1971	**12500**	6	4.33	12,500	353.96	4.10	
	12/2/1962	**10600**	7	3.71	10,600	300.16	4.03	
	2/23/1968	**9290**	8	3.25	9,290	263.06	3.97	
	1/20/1964	**8110**	9	2.89	8,110	229.65	3.91	
	1/29/1958	**7970**	10	2.60	7,970	225.69	3.90	
	3/18/1975	**7750**	11	2.36	7,750	219.46	3.89	
	1/12/1959	**7690**	12	2.17	7,690	217.76	3.89	
	1/4/1966	**7590**	13	2.00	7,590	214.93	3.88	
	1/29/1967	**7360**	14	1.86	7,360	208.41	3.87	
	2/8/1960	**7330**	15	1.73	7,330	207.56	3.87	
	2/11/1961	**5630**	16	1.63	5,630	159.42	3.75	
	11/24/1953	**5400**	17	1.53	5,400	152.91	3.73	
	1/20/1969	**4840**	18	1.44	4,840	137.05	3.68	
	11/15/1975	**4420**	19	1.37	4,420	125.16	3.65	
	1/13/1973	**3470**	20	1.30	3,470	98.26	3.54	
	12/19/1961	**3230**	21	1.24	3,230	91.46	3.51	
	12/31/1954	**2800**	22	1.18	2,800	79.29	3.45	
	12/14/1977	**2630**	23	1.13	2,630	74.47	3.42	
	2/26/1957	**2600**	24	1.08	2,600	73.62	3.41	
	5/26/1977	**360**	25	1.04	360	10.19	2.56	Outlier dis

	(cfs)	(cms)	Log
Sample Size, n =	**25**		
Skewness =	1.89	1.89	0.27
Mean=	9209	261	4
Std Dev=	6992	198	0.292
Outliers			
Kn=	**2.486**		
Q-low =	**1382 cfs**		
Q-high =	**39,152 cfs**		

Generalized Skew=	**-0.3**	A=	-0.30838
Station Skewness (log Q)=	0.27	B=	0.86975
Station Mean (log Q)=	3.87	MSE (station skew) =	0.22157
Station Std Dev (log Q)=	0.29		
Weighted Skewness (G_W)=	**0.03**		

Log Pearson Type III Distribution

Return Period (years)	**Exceedence Probability**	**Log-Pearson K**	**Predicicted Discharge (cfs)**	**Discharge/Mi^2 (cfs/mi^2)**
1.2	0.833	-0.98805	3,785	15
1.5	0.667	-0.43782	5,480	22
1.8	0.556	-0.14537	6,671	26
2.0	0.500	-0.00480	7,332	29
2.33	0.429	0.17264	8,262	33
2.4	0.417	0.20910	8,467	34
2.6	0.385	0.30244	9,015	36
2.8	0.357	0.38245	9,514	38
3	0.333	0.45179	9,968	40
3.5	0.286	0.59048	10,942	43
4	0.250	0.69449	11,735	47
5.0	0.200	0.84011	12,943	51
10	0.100	1.28451	17,451	69
25	0.040	1.76050	24,036	95
50	0.020	2.06913	29,580	117
100	0.010	2.34752	35,671	142

Values From K-Table for Linear interpolation

Weighted Skewness =	0.00	0.10	0.03	
P	K	K	K	Return Period (Years)
0.9	-1.28155	-1.27037	-1.27832	1.1
0.8	-0.84162	-0.84611	-0.84292	1.3
0.7	-0.52440	-0.53624	-0.52782	1.4
0.6	-0.25335	-0.26882	-0.25782	1.7
0.500	0.00000	-0.01662	-0.00480	2.0
0.429	0.17733	0.16111	0.17264	2.3
0.200	0.84162	0.83639	0.84011	5.0
0.100	1.28155	1.29178	1.28451	10.0
0.040	1.75069	1.78462	1.76050	25.0
0.020	2.05375	2.10697	2.06913	50.0
0.010	2.32635	2.39961	2.34752	100.0

Exceedence flows for North Fork of the Salmon River at Red Bank Bar based on the averaged results from Salmon River Near Forks of Salmon CA (11522300) and Salmon River at Somes Bar CA (11522500)	
Percent Time Flow is Equalled or Exceeded	**Annual Exceedance Flow cfs**
1%	2683.1
2%	1714.7
5%	1091.7
10%	821.0
15%	672.2
20%	578.7
25%	506.4
30%	436.2
35%	377.9
40%	327.8
45%	276.5
50%	220.4
55%	169.6
60%	132.3
65%	102.1
70%	75.5
75%	57.1
80%	46.4
85%	38.2
90%	33.0
95%	29.4
98%	25.2
99.5%	23.9
99.8%	23.5

Exceedence flows for North Fork of the Salmon River at Red Bank Bar based on USGS Gaging data from Salmon River Near Forks of Salmon CA (11522300)	
Percent Time Flow is Equalled or Exceeded	**NF Salmon River at Red Bank**
	Annual Exceedance Flows
	cfs
1%	2932.2
2%	1780.0
5%	1121.5
10%	826.7
15%	668.7
20%	575.0
25%	496.4
30%	426.0
35%	367.5
40%	315.9
45%	265.7
50%	216.6
55%	169.8
60%	133.6
65%	104.8
70%	78.2
75%	57.6
80%	45.0
85%	36.2
90%	31.0
95%	27.3
98%	22.1
99.5%	21.4
99.8%	20.7

Exceedence flows for North Fork of the Salmon River at Red Bank Bar based on USGS Gaging data from Salmon River at Somes Bar CA (11522500)	
Percent Time Flow is Equalled or Exceeded	**NF Salmon River at Red Bank Annual Exceedance Flows cfs**
1%	2433.9
2%	1649.4
5%	1062.0
10%	815.4
15%	675.6
20%	582.4
25%	516.4
30%	446.5
35%	388.3
40%	339.7
45%	287.3
50%	224.2
55%	169.5
60%	131.1
65%	99.4
70%	72.9
75%	56.7
80%	47.8
85%	40.2
90%	34.9
95%	31.5
98%	28.3
99.5%	26.4
99.8%	26.4

USGS 11522500 SALMON R A SOMES BAR CA												
	00060, Discharge, cubic feet per second,											
YEAR	Monthly mean in ft³/s (Calculation Period: 1911-10-01 -> 2015-03-31)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1911										217.3	298.7	289.9
1912	3,590	3,942	1,539	1,608	4,994	3,223	765.4	341.6	403.8	298.2	2,203	1,583
1913	1,977	2,002	1,737	3,209	4,346	2,400	843.4	350.9	276.8	351.3	1,100	1,499
1914	6,834	4,000	4,500	4,500	4,500	3,500	900	328	227.5	1,170	900	1,100
1915	1,753	4,754	3,740	5,236	4,377	3,610	1,152	352.5	210.1			
1927										240	1,300	928.3
1928	1,600	1,850	3,380	4,127	3,000	966.7	355	177.7	166.6	211.5	488.2	791.1
1929	936.1	790.5	1,050	1,447	2,256	1,300	300	142.5	113.1	150	150	2,800
1930	1,000	2,500	2,300	1,707	1,162	583.3	206.4	118.3	116.4	132.9	296.7	373.2
1931	788.5	767.6	1,982	1,681	1,083	433.1	146	81.6	83.1	274.9	499	869.1
1932	1,389	1,116	3,769	2,667	3,739	2,090	510.5	196.9	120.6	138.7	391.2	509.7
1933	671.5	820	2,315	3,015	3,106	4,214	1,091	299.8	211.5	212.6	232.9	886.2
1934	2,061	1,137	1,878	1,482	877.1	426.9	189.6	117.7	106.9	312.3	1,745	1,436
1935	1,665	2,418	1,745	3,538	3,573	1,663	451.5	205.7	155	208.4	293	603.8
1936	4,727	2,536	2,566	2,947	2,771	1,442	490.1	196.7	139.4	117.6	129.9	175.5
1937	190.2	542.4	1,842	4,590	4,535	3,001	729.1	229.2	153.3	291.1	3,051	3,782
1938	3,021	4,105	5,668	5,741	6,174	3,750	1,046	321.5	192	269.4	679.5	1,266
1939	813	1,227	2,950	2,518	1,599	737	270.2	129.5	113.7	141.7	139.3	1,332
1940	2,374	4,504	4,872	3,706	2,445	1,014	339.9	164.7	197	309.5	537.3	1,829
1941	2,482	2,560	2,482	2,969	4,161	2,140	916.6	360.8	267.5	213.3	559.1	4,165
1942	2,928	3,661	1,473	1,878	3,162	2,646	823.4	296.2	193.8	187.5	2,185	5,290
1943	5,440	3,569	2,857	3,626	2,662	1,810	650	312.8	217.4	386.9	639.7	510
1944	838.3	1,083	1,535	1,426	2,155	1,161	393.5	199.5	144.1	159.9	1,005	1,149
1945	1,725	4,098	1,955	2,826	3,622	1,565	475.9	217.7	161.3	253.8	1,622	4,402
1946	3,982	2,072	2,885	3,287	3,777	1,831	650.4	230.3	178	229.8	1,108	956.2
1947	642.8	1,912	2,645	2,342	1,525	901.5	294.1	172.1	133.2	757.5	622.4	477.9
1948	3,899	1,637	1,540	3,224	3,757	3,198	821.6	302.1	239.6	286.6	609.2	1,516
1949	738.5	1,552	2,493	3,383	3,305	1,308	380.3	186.1	141.7	190.6	390.8	375.6
1950	2,254	2,293	4,026	3,511	3,603	1,960	589.6	227.1	180	1,846	3,043	5,525
1951	3,782	5,791	2,219	3,432	2,546	1,155	382.2	194.1	155.4	388.2	1,325	3,904
1952	1,979	5,494	3,093	5,429	5,477	3,382	1,331	406.2	239.4	195.4	233.7	1,228
1953	8,041	3,604	2,138	3,173	4,223	4,354	1,906	565.4	312.6	362.8	2,033	2,139
1954	3,788	5,059	3,817	4,142	2,935	1,417	571.6	272.5	232.1	223.3	500.1	753.7
1955	897.6	836.5	878.5	1,242	2,489	1,294	334.3	157	144.1	174.7	949	8,465
1956	8,090	3,238	3,008	3,909	4,338	2,559	902.7	289	189.8	507.3	783.2	1,234
1957	747	2,804	5,035	3,029	3,189	1,480	469.3	212.4	196.6	871.3	1,961	3,033
1958	4,832	11,190	3,215	3,666	5,106	2,695	839.8	355.5	240.4	206.4	578	548.8
1959	3,296	2,576	2,369	3,260	2,021	1,127	347.5	179.3	189.5	183.7	160	197.8
1960	391.7	2,595	3,034	2,756	3,254	2,316	452	214.3	160.9	174.7	945	1,543
1961	766.1	3,991	3,475	3,089	3,045	2,298	472.2	226.4	169.5	237.9	599.7	1,661
1962	951.4	2,305	1,978	3,471	2,265	1,554	454.7	320	180	2,297	2,025	3,980
1963	979.4	4,923	1,782	5,115	4,730	1,680	598.7	297.6	218.4	414.3	2,483	1,303
1964	3,045	2,564	1,695	2,187	2,337	1,708	504.2	238	167.7	157.5	686.9	10,480
1965	5,813	3,114	1,897	3,522	2,808	1,406	447.6	269	190.9	186.4	520.8	579.9
1966	3,029	1,227	2,932	4,321	3,379	1,285	478.3	223.3	185.2	167.8	877.2	2,397
1967	2,836	2,405	2,059	1,681	4,333	2,755	836.4	303.7	213.6	300.8	352.2	698.7
1968	2,100	5,137	2,461	1,572	1,559	852	315.1	250.9	178.9	315	1,249	2,110
1969	4,833	2,652	2,259	3,972	6,081	2,778	698.1	281.6	200.5	296.6	362.5	2,854
1970	11,260	3,021	2,787	1,328	2,370	1,268	387.5	209.5	151.3	182.1	4,388	3,875
1971	9,489	2,902	5,631	3,786	4,907	3,498	1,247	381.7	293.7	342.2	1,212	1,800
1972	5,164	3,266	9,615	2,940	2,826	1,760	537.5	290.1	204.6	204	367.9	1,983
1973	2,751	1,829	1,666	2,193	2,557	898.9	325.7	168.9	237.8	768.2	5,961	6,806
1974	9,036	3,268	5,323	4,925	4,005	3,304	1,024	355.9	207.7	181.5	274.5	717.6
1975	1,643	3,379	4,838	3,233	5,077	4,032	1,260	399.1	223.6	620.5	1,725	2,025
1976	1,645	1,843	2,259	1,956	2,321	1,077	421.6	426.9	227.6	190.5	218.7	186.6
1977	218.2	254.9	448.3	710	786.3	603	152.2	97.5	205.8	270.7	1,747	4,566
1978	3,743	2,971	2,688	2,558	2,357	1,759	754.4	281.8	498.9	206	256.3	571
1979	1,180	1,331	2,466	1,884	3,046	940.3	380.5	205.5	190.2	745.9	1,722	2,001
1980	5,409	3,211	2,896	2,707	2,397	1,376	621.1	236.8	192.3	206.5	374.9	2,320

USGS 11522500 SALMON R A SOMES BAR CA												
	00060, Discharge, cubic feet per second,											
YEAR	**Monthly mean in ft³/s (Calculation Period: 1911-10-01 -> 2015-03-31)**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1981	1,223	2,602	1,681	1,676	1,260	704.8	272.6	151.3	149.1	457.3	3,519	7,686
1982	3,452	7,840	3,369	4,544	4,294	2,356	875.6	336.7	234.3	606.2	1,185	4,505
1983	3,465	5,905	6,065	4,211	5,298	4,280	1,777	838.6	527.8	322.4	3,270	6,921
1984	3,091	2,916	3,839	2,971	3,893	2,023	678.9	309.2	236.9	414.1	3,550	1,727
1985	968.8	1,853	1,258	3,271	1,926	1,167	344.6	198	216.5	341.3	463.1	944
1986	2,561	9,140	5,458	2,174	2,070	1,156	371.6	188.6	323.6	412.3	521.4	631.1
1987	1,349	2,163	2,492	2,334	1,709	570.2	249.6	144.6	126.3	117.3	198.5	2,412
1988	2,222	1,489	1,206	1,232	1,468	1,704	444.2	219.8	156.2	152.6	1,894	1,304
1989	1,799	1,761	5,241	3,998	2,117	1,242	449.4	259.8	231.3	436.1	375.8	555.6
1990	1,825	1,245	2,313	1,730	1,734	1,974	454.3	260	206.1	204	252.4	331.3
1991	733.8	940.5	1,420	1,437	1,566	869.8	332.6	173.7	139.3	153.8	328.2	557.2
1992	539.5	1,450	1,119	2,312	990.4	401.6	246.6	116.2	102.5	172.3	640	1,002
1993	2,246	2,041	4,695	4,474	5,296	3,808	931.3	404.4	241.4	237.4	214.7	585.3
1994	1,119	891.3	1,253	1,209	1,351	508.5	212.6	121.8	103.6	123.6	372.4	905
1995	5,283	5,675	6,053	4,374	4,308	3,159	1,296	407.5	245.5	208.5	273.8	3,562
1996	4,122	6,113	3,882	4,057	4,056	1,787	695.3	306.2	253	338.2	1,491	7,662
1997	8,139	2,639	1,979	2,429	1,866	969.6	471.8	265.6	260.1	433.2	870.9	1,253
1998	6,066	4,955	6,508	3,930	4,141	4,105	1,576	445.9	247.7	256.6	2,178	2,717
1999	3,219	4,286	3,807	3,297	4,201	2,976	883.5	376.5	228.5	239	624.6	848.7
2000	2,685	3,068	2,759	2,996	2,552	1,466	453.5	217.9	184.2	212.1	290	389.6
2001	361.9	434.3	1,071	1,074	1,282	408	186.3	91.7	80.2	102.4	736.9	2,143
2002	3,453	2,509	1,966	3,010	2,027	1,127	359.2	171	124.8	122.3	408.1	3,085
2003	5,294	2,553	3,471	3,594	3,954	2,247	608.6	300.1	194.6	163.5	294.7	1,658
2004	2,352	3,627	3,618	3,133	2,743	1,444	543.4	252.8	165.5	321	317.2	1,768
2005	1,652	1,352	1,688	2,845	4,345	1,942	763.6	296.4	192.8	214.5	1,093	8,663
2006	9,539	5,791	2,877	3,662	4,665	2,304	767.8	334.7	203.1	189.7	1,051	3,784
2007	2,375	1,978	3,896	2,443	2,204	860.9	352.3	183.5	141.6	738.5	698.3	1,451
2008	2,209	2,480	2,806	2,558	4,140	1,768	521.2	231	149.9	209.1	747.8	924.5
2009	1,835	1,578	2,782	2,205	2,891	985.2	347.6	181.1	126.6	246	404.4	708.7
2010	2,363	1,837	2,042	3,470	3,567	4,339	1,114	367.2	269.6	661.1	1,273	4,122
2011	3,148	1,630	4,147	4,656	3,713	4,051	1,603	457.9	232.6	379.5	469.3	576.5
2012	2,260	1,434	3,944	5,317	3,423	1,490	572.6	259.9	175.9	223.4	869.9	3,649
2013	1,693	1,373	1,775	2,578	1,387	635.7	279.8	177.5	313.7	318.9	266.3	268.2
2014	315.2	2,398	3,461	1,526	892.8	388.2	206.7	133.5	133	550.6	1,005	3,177
2015	1,638	4,529	1,329	1,015	664.9	395.8	232.4	140.1	126	122.7	253.3	2,798
2016	5,658	3,814	*6,819*	*3,828*	*2,200*	*901*	*371*	*188*	*150*	*1,370*	-	-
Mean of monthly Discharge	2,950	2,910	2,920	2,990	3,080	1,880	616	260	199	339	1,030	2,230
Min. Monthly Dischage	190	255	448	710	665	388	146	82	80	102	130	176
Max. Monthly Dischage	11,260	11,190	9,615	5,741	6,174	4,354	1,906	839	528	2,297	5,961	10,480
2015-2016 WY % of Historical Mean	192%	131%	234%	128%	71%	48%	60%	72%	75%	36%	25%	125%

** Italicized values computed by MLA from average daily provisional data*

Appendix D
Geologic Report

Date: December 8, 2016

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Salmon River Restoration Council
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From: William Randy Lew, Professional Geologist (#7872)
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Subject: Geologic Investigation Technical Memorandum for the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project

Introduction and Background

The *Red Bank Off-Channel Fisheries and Riparian Habitat Design Project* is located within the North Fork Salmon River watershed, approximately 5.1 miles west of Sawyers Bar, in northern California (Map 1). The project area is located within the USGS Sawyers Bar 7.5-minute quadrangle in Township 40N Range 12W Section 28, Siskiyou County, California. The Cal Watershed HUC 8 is 18010210.

All 4 species of anadromous salmonids, as well as the Pacific lamprey and green sturgeon, are present in the Salmon River watershed. Currently the fluvial system is significantly modified from its natural configuration in large part because of historic land management activities. Modifications resulted in floodplain/side channel disconnection due to placer mining along the alluvial channel corridor as well as accelerated channel sedimentation caused by hydraulic placer mining and forest management practices. Whereas salmonid populations have evolved and flourished with the natural processes of rainfall and erosion in the area, the impact of anthropogenically induced habitat fragmentation and watershed erosion (e.g., mining, timber production and road construction) has resulted in the degradation of salmonid habitat, loss of riparian function and accelerated sediment delivery to streams in this important watershed.

In part because of the observable decline in anadromous fish populations, the California Department of Fish and Wildlife (CDFW) and U.S. Fish and Wildlife Service (USFWS), among others, have funded numerous watershed and fisheries restoration projects throughout northern California over the last several decades. These efforts have included instream habitat restoration projects, many of which have been focused on providing improved rearing habitat in these watershed systems. Increasing the available rearing habitat for juvenile salmonids is of great importance for the future of coho salmon in the Salmon River watershed. Because coho salmon require slow water refugia and summer cold water temperatures for rearing habitat, increasing side channel habitat and riparian forest canopy are especially beneficial to the future health of these important species.

The *Red Bank Off-Channel Fisheries and Riparian Habitat Design Project (RBFDP)* is intended to provide winter and/or summer off-channel habitat for juvenile salmonids where they can find velocity or thermal refuge and more effectively mature and prepare for their oceanic life stage. The project area is located along a floodplain/bar complex approximately 9 river miles up the North Fork Salmon River (NFSR) from its confluence with the South Fork. The *RBFDP* area consists of approximately 20 acres of mostly barren, large alluvial floodplain with several sparsely vegetated high-flow side channels and vegetated alluvial terraces. The project area is contained on the right side (facing downstream) by mainstem NFSR. On the upstream end of the alluvial bar the high-flow side channels are devoid of vegetation and largely dry throughout the late summer and fall. Lower on the alluvial bar these high-flow channels converge and riparian vegetation becomes more prolific, as surface and near surface base flow conditions become perennial. The entire *RBFDP* area is located on United States Forest Service (USFS) property, within the Klamath National Forest.

The goal of the project as stated in the project proposal is to enhance side channel habitat, increase channel complexity, connect and enhance disconnected alcoves as off-channel ponds where viable, increase riparian shading and LWD recruitment, and increase and improve coho winter rearing habitat on an important reach of the NFSR. Depending upon final design outcomes, additional project benefits may include the increase of summer cold water refugia and enhancement of associated riparian forest canopy. Using ongoing, long-term hydrologic data coupled with shorter term site specific data from the proposed restoration site, the project engineer will design a plan that allows for predictable seasonal flows into the side channel(s) and/or alcove areas. This report summarizes the subsurface geologic and geomorphic investigations that were conducted to inform the project engineer of geologic conditions and potential constraints within the proposed project area.

Scope of Work

The scope of this part of the larger *RBFDP* was limited to the installation of on-site shallow groundwater monitoring wells, characterization of the subsurface stratigraphy observed during the well installations, geomorphic mapping, and identification/characterization of potential project constraints, based largely on subsurface geologic and geomorphic conditions. Specifically, the project tasks included:

(1) Pre-field work meetings with the project engineer and Salmon River Restoration Council (SRRC) staff to review site conditions and proposed trench/well locations.

(2) Analyzing excavator exploratory pit/trenches and characterizing the subsurface stratigraphy at 6 monitoring well locations.

(3) Installation of shallow groundwater monitoring wells at 6 locations identified by the project engineer.

(4) Geomorphic mapping of the project area.

(5) Post-field work communication to discuss preliminary stratigraphic/geomorphic findings.

(6) Description and analysis of data collected at pit/well locations.

(7) Preparing a technical memorandum summary report and recommendations pertaining to the proposed restoration project.

Geologic and Geomorphic Setting

The regional geology of the Salmon River watershed is composed of diverse rock groups including several distinct metamorphic belts, intrusive granitic batholiths, alluvial terrace deposits, colluvial deposits, and recent alluvial deposits. The Salmon River watershed is part of the greater regional physiographic Klamath Mountain province. Poorly consolidated and sheared metamorphic rocks as well as deeply weathered granitic rocks that are particularly susceptible to erosion and mass wasting during periods of sustained or heavy rainfall are exposed throughout the watershed.

Published geologic mapping of the area (Ernst, 1998; Wagner and Saucedo, 1987) shows that the primary project area is underlain by Quaternary alluvium (Qal), while the adjacent hillslopes are composed of Mezozoic granitoids, and metavolcanics in addition to serpentinites from the Western Paleozoic and Triassic Belt (Map 3). A characterization of subsurface materials within the project area identified alluvial deposits consistent with these published California Division of Mines and Geology (DMG) maps. A detailed description of subsurface materials is included in Figures 1a & 1b.

The geomorphic setting of the *RBFDP* area is dominated by channel and floodplain processes along the North Fork Salmon River (NFSR), located approximately 9 river miles upstream from its (NFSR) confluence with the South Fork (Map 1). The project area consists of approximately 20 acres of mostly barren, alluvial floodplain/bar with several sparsely vegetated high-flow side channels and vegetated alluvial terraces; it is contained on the right side (facing downstream) by mainstem NFSR. Much of the alluvial surface appears to have been reworked by historic placer mining activities as well as channel dredging. On the upstream end of the alluvial bar the high-flow side channels are devoid of vegetation and largely dry throughout the late summer and fall. These high-flow side channels contained within the active floodplain are inundated annually to semi-annually. However, the lower portions of the main side channel retains perennial flow, likely through groundwater input or by hyporheic exchange (Map 2).

Methods

Our geologic investigation consisted of four parts: (1) excavating exploratory trenches/pits at 6 locations to log and characterize subsurface stratigraphic conditions that will be encountered at well sites within the project area; (2) installing groundwater monitoring wells according to the typical specification illustrated in Figure 2 at locations identified by the project engineer; (3) conducting a field-based reconnaissance to characterize and map the project-scale geomorphic conditions; and (4) analyzing and reporting on the results. The exploratory trenches/pits were excavated using an excavator that first forded the NFSR, then track-walked along the dry alluvial bar to reach the well locations. Once the excavation trenches were completed to the desired depth, detailed logs of the subsurface stratigraphy were compiled, then the well casings were backfilled with alluvial materials removed during the excavation. Field classification method ASTM D 2488-00 (Visual-Manual Procedure) was used to describe and identify the soils and alluvial materials logged during the exploratory trenches. Soil descriptions were classified according to the Unified Soil Classification System (Figures 1a & 1b).

Discussion

Characterization of subsurface stratigraphy

The subsurface stratigraphy in all of the trenches was fairly consistent. In general, subsurface materials consisted entirely of course-grained alluvium from sand to boulder sized particles (Figures 1a & 1b). All trenches contained either a mixture of sand, gravel, cobble and boulder (RB-1, RB-2, RB-4 & RB-6), or a mixture of sand, gravel and cobble (RB-3 & RB-5). Most columns (RB-1, RB-2, RB-5 & RB-6) exhibited no obvious or apparent sedimentary structures but rather a heterogeneous mix of particles throughout. The remaining trench columns exhibited a varying degree of discernable sedimentary structures including clast imbrication and alternating beds with partially defined bedding and lamination planes. All of the materials observed were unconsolidated and are considered to be cohesionless alluvial soils (Figures 1a and 1b).

Interpretation of subsurface stratigraphy

Geomorphic and geologic observations indicate the stratigraphy within the project area is consistent with channel, bar and floodplain deposits typical of high-energy fluvial environments. However, anthropogenic activities (i.e., placer mining, road construction, channel dredging) have likely redistributed upper unit materials in places along the *RBFDP* area over time. This is specifically evident along the eastern portions of the project area, where hillslopes have been hydraulically mined and tailing pile deposits are overlying alluvial terrace deposits (Map 2). There is no age control on the deposition (natural and anthropogenic) of these sediments so the actual timing of deposition is equivocal. However, giving the geomorphic nature of the active *RBFDP* area channel/bar/floodplain complex, it is likely the deposits observed in the exploratory trenches are of recent and historic (< 200 years) origin.

The intrinsic permeability of the substrate encountered during the subsurface investigation is relatively high given the coarse nature of materials encountered throughout the exploratory trenches. The sands, gravels, cobbles and boulders encountered during the subsurface exploration are typical of high-energy channel, bar and floodplain deposits found along the NFSR. These deposits are likely to allow for the rapid lateral movement of groundwater from the side channel(s) to NFSR and conversely, depending on river flow levels and seasonal groundwater fluctuations. Depending upon side channel excavation depths, these high permeability units could pose the most significant challenge to managing groundwater during construction. Because the exploration trenches terminated at relatively shallow depths, the extent or thickness of these alluvial units, and their connectivity to groundwater or hyporheic sources, is undetermined.

Potential project constraints and recommendations

1) **North Fork Salmon River Lateral Channel Migration:** Sequential analysis of historic aerial photos conducted during previous studies suggest that the NFSR channel thalweg has undergone periodic lateral migration or avulsion within the project reach (PWA, 2012). In the 1944 and 1955 photo sets the mainstem NFSR is located to the east of its current configuration. After the 1965 photo set, the channel migrated several hundred feet westward to its current configuration where it is confined by the steep right bank/native hillslope. Additionally, the alluvial bar and side channels along the unconfined left bank have evolved significantly over time. The 1944 and 1955 photo sets show the alluvial bar mostly covered in uniform age riparian vegetation with faintly visible side channels proximate to their current location. In the 1965 photos the alluvial bar has been stripped and is largely denuded of vegetation, with a small cluster of trees on the middle of the bar remaining. The side channel alignments became more prominent. These side channels mostly follow their current configuration. A stereoscopic photo pair was not available

for 1975, however surface flows are visible in the side channel in early August for the one photo that is available. In the 1980 photos the side channel has evidence of surface flows in late summer but these flows appear to become less persistent by 1995. By 1980 the riparian vegetation has reoccupied the channel margins and sparse vegetation on the alluvial bar. In the 1995 photos the riparian vegetation appears to be well established, albeit sparse. The riparian vegetation is predominantly occupying the lower half of the alluvial bar and the channel margins.

Based upon historical aerial photo evidence, the NFSR channel thalweg appears now to be in relative equilibrium within the project reach, having attained that condition in the 1970s. However, historical evidence also suggests the potential for major periodic shifts in channel location as a result of periodic floods or mass wasting events typical within the watershed.

Recommendation:

- Engineering design considerations should account for possibility of significant lateral channel shifts or migration during the design life of the project.

2) **Soil and Groundwater Constraints during Construction:** The proposed restoration project calls to excavate new channels, alcoves and/or depressions that will reconnect to NFSR during design flow events. During side channel/alcove excavation and construction, saturated soils and groundwater piping are likely to be encountered. Excavation of saturated materials is likely to cause significant turbidity; therefore, preventing sediment discharge to NFSR will require special care. In the upper portions of the side channel(s) excavation column, cohesionless strata consisting of relatively dry sands, gravels, cobbles and boulders are likely to be encountered (Figures 1a & 1b). However, in the lower portions of the excavation column, a saturated mix of sands, gravels, cobbles and boulders may be locally encountered (Figures 1a & 1b). These materials may be subject to slumping and calving during construction, particularly as groundwater sapping occurs during initial drawdown.

Recommendations:

- During side channel/alcove excavation and construction, hydraulic pumps, sumps and/or coffer dams may need to be utilized for water and sediment control.
- An erosion and sediment control plan should be developed by a qualified professional prior to the beginning of construction. Among other things, the plan should specifically address the disposal and/or treatment of turbid water and liquefied fine sediment.
- The project engineer, in consultation with the project geologist when deemed necessary, should evaluate exposed excavated materials in determining final as-built slope grades. In general, final slope grades in the excavated side channel banks should be no steeper than 3:1 (H:V), and perhaps less depending upon design and modeling considerations.

3) **Placement of Spoils:** The excavation and removal of alluvial materials for the construction of the side channel(s) and alcove(s) will likely generate excess spoil material that will need to be disposed of or reused in the construction of designed landforms. Excess spoil material should be

suitable for even distribution along the adjacent floodplain areas, away from any watercourses or wetland areas that are not part of designed landforms. Depending on its water content, the spoils may require some soil conditioning to allow for sufficient drying prior to the final regrading of the materials. Based on our subsurface investigation, it is likely that only minor amounts of organic debris will be excavated during the channel excavations.

Recommendations:

- Organic debris should not be buried or distributed within the fill material being spread throughout the project area or where spoils may be stockpiled. However, organic debris can be used as a final surface treatment on top of finish grade slopes or for in-channel habitat benefits; when and where agency permits allow.
- The final graded spoil material should be mulched, seeded and planted as necessary to prevent surface erosion and any potential for sediment delivery.

4) **Suitability of Excavated/Dredge Materials for Structural Fills:** If structural fills or embankments are incorporated into the final project design, special care should be taken in the use of excavated/dredge materials. Some of the excavated materials generated on-site may be suitable for structural fills. However, some portion of the excavated materials will be unsuitable for structural fill construction because of their composition, grain size, grain shape and/or moisture content. Excavated materials that are composed of, or incorporate, organic debris or other deleterious materials are unsuitable for construction. Additionally, materials that are saturated may require soil conditioning if they are to be used for construction. Some alluvial materials may not be suitable for achieving typical, required rates of compaction.

Recommendations:

- Use only excavated/dredge materials that are largely free from organic debris or other deleterious materials, and of proper soil moisture, to construct structural fills.
- Prior to construction, develop relative compaction and optimum moisture content standards based on site specific soils and project design criteria.
- Import additional engineered fill material as necessary to construct structural fills.
- Condition (spread and air dry) saturated soils to specified moisture content standard prior to use in structural fills.

5) **Additional General Recommendations:**

- Grazing livestock should be excluded from any proposed channel(s) or pond excavation areas as they can and will browse stabilizing riparian vegetation, destabilize channel banks, produce turbidity, increase erosion rates, and accelerate infilling of the ponds.
- Prior to construction, develop a revegetation plan that incorporates native aquatic and terrestrial plants suitable to the project area and implement the plan following construction. Planting with willows and/or other fast growing, deep-rooted native plants should be incorporated into the revegetation plan for areas with near surface summer groundwater or soil moisture. However, given the seasonally dry nature of the soils

within the project area, irrigation may need to be incorporated into parts of the project area for several years.

References

Ernst, W.G., 1998, DMG Map Sheet 47, Geology of the Sawyers Bar area, Klamath Mountains, Northern California, scale 1:48,000.

Wagner, D.L. and Saucedo, G.J., 1987, DMG Map NO. 4A, Geologic Map of the Weed Quadrangle, California, scale 1:250,000.

Pacific Watershed Associates (PWA), 2012, Salmon River Riparian Assessment Pilot Planning Project and Conceptual Design for Fisheries and Riparian Vegetation Enhancement, Prepared for Salmon River Restoration Council, Sawyers Bar, California.

Certification and Limitations

This report, entitled *Geologic Investigation Technical Memorandum for the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project* was prepared by or under the direction of a licensed professional geologist at Pacific Watershed Associates Inc. (PWA), and all information herein is based on data and information collected by PWA staff. The subsurface investigation analysis for the project, as well as engineering design recommendations, were similarly conducted by, or under the responsible charge of, a California licensed professional geologist at PWA.

The interpretations and recommendations presented in this report are based on a study of inherently limited scope. Observations are qualitative, or semi-quantitative, and confined to surface expressions of limited extent and shallow borings of subsurface materials. Interpretations of problematic geologic and geomorphic constraints and erosion processes are based on the information available at the time of the study, and on the nature, distribution and exposure of existing features.

The recommendations contained in this report are professional opinions derived in accordance with current standards of professional practice, and are valid as of the submittal date. No other warranty, expressed or implied, is made. PWA is not responsible for changes in the conditions of the property with the passage of time, whether due to natural processes or to the works of man, or changing conditions on adjacent areas. Furthermore, to be consistent with existing conditions, information contained in this report should be re-evaluated after a period of no more than three years. It is the responsibility of the project engineer and project proponent to ensure that all recommendations in this report are reviewed and implemented according to the conditions existing at the time of construction. Also, PWA, including the licensed professionals, are not responsible for recommendations implemented outside of their professional oversight. Finally, PWA is not responsible for changes in applicable or appropriate standards beyond our control, such as those arising from changes in legislation or the broadening of knowledge, which may invalidate any of our findings.

Certified by:

William R. Lew, California PG #7872
Associate Geologist
Pacific Watershed Associates Inc.

Attachments:

Map 1. Location map for the geologic investigation of the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project, Siskiyou County, California

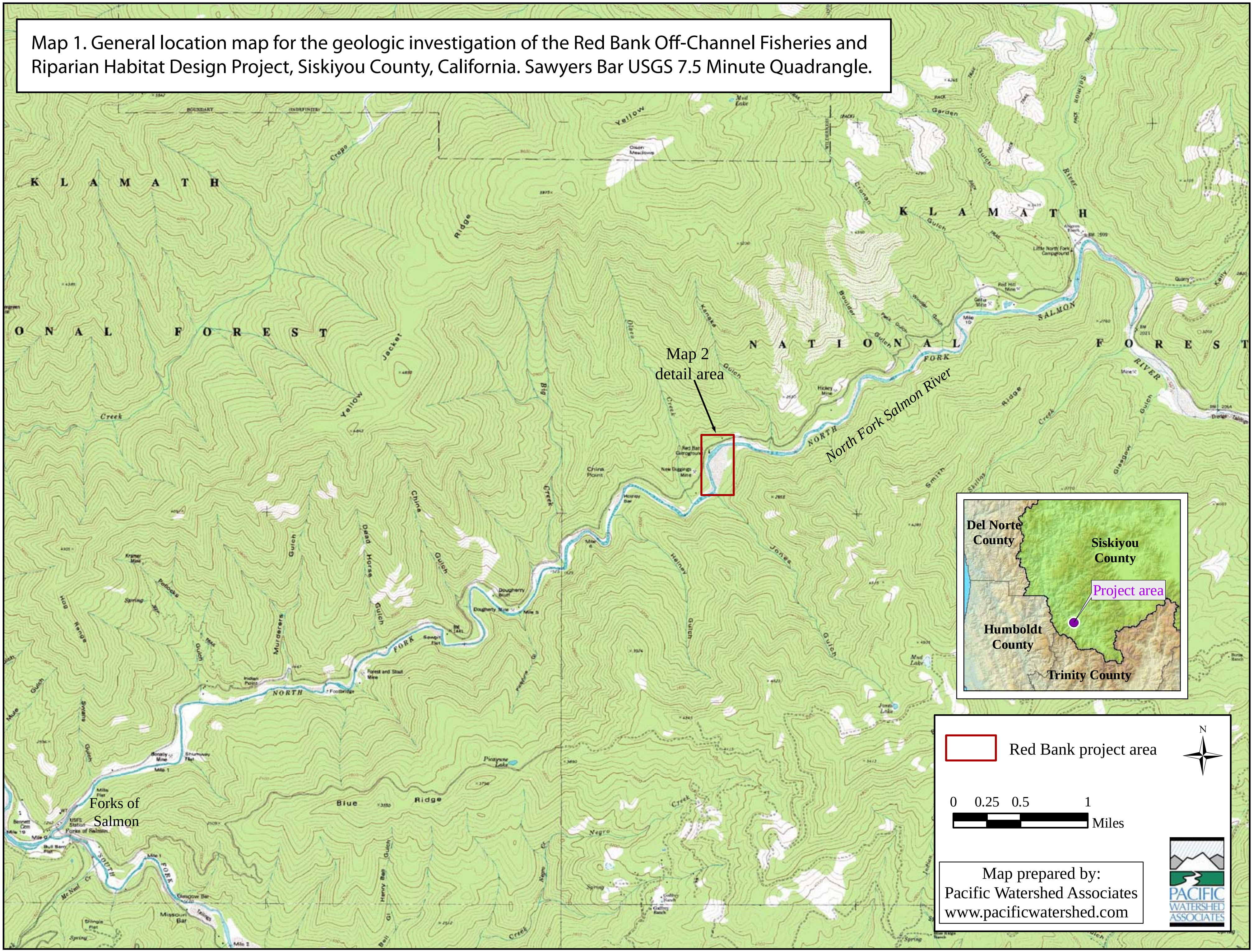
Map 2. Geomorphic features and trench log locations for the geologic investigation of the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project, Siskiyou County, California

Map 3. Geologic Map of the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project, Siskiyou County, California

Figure 1a. Core logs RB-1 through RB-4 for the geologic investigation of the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project, Siskiyou County, California

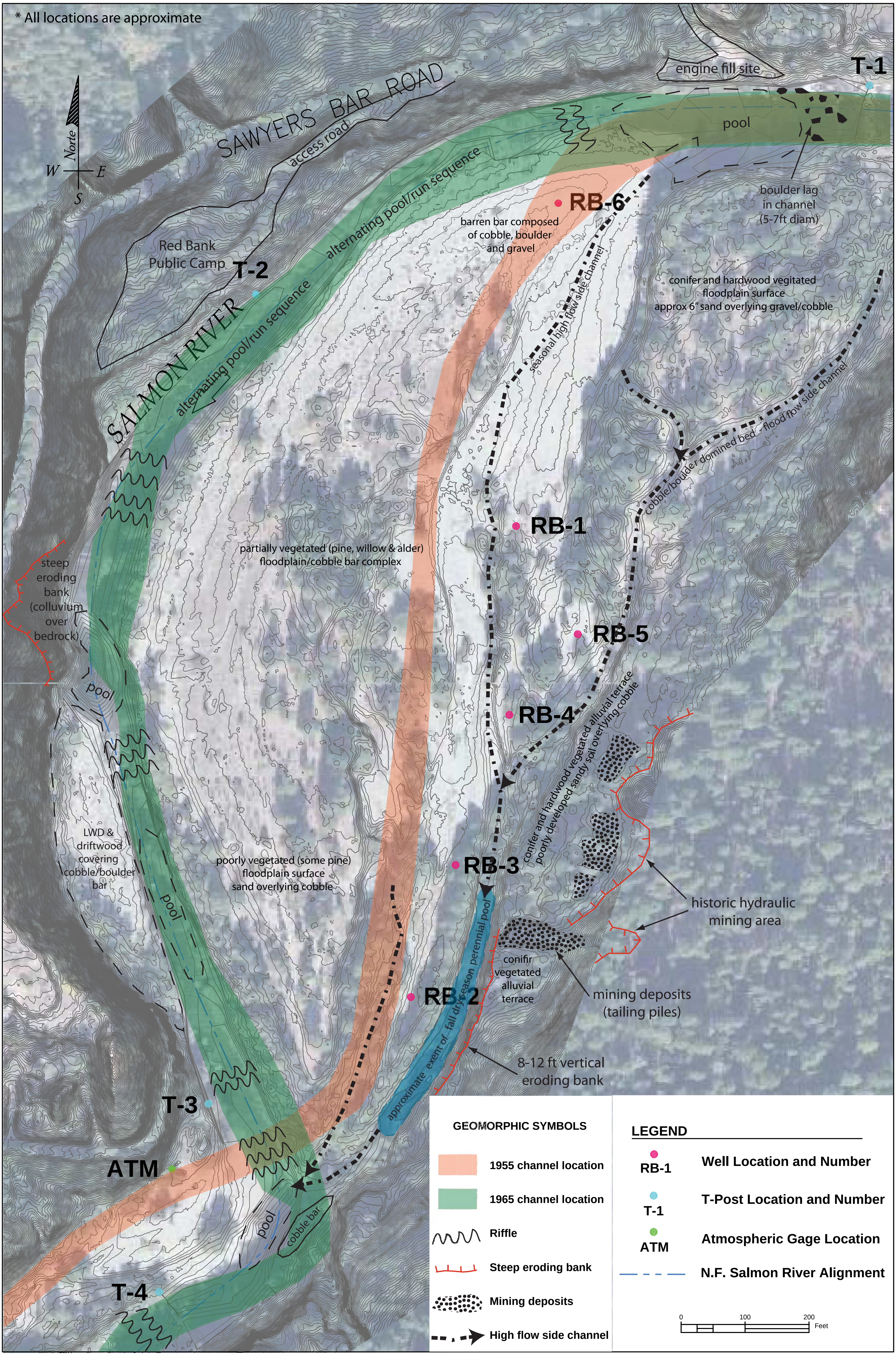
Figure 1b. Core logs RB-5 through RB-6 for the geologic investigation of Red Bank Off-Channel Fisheries and Riparian Habitat Design Project, Siskiyou County, California

Figure 2. Groundwater monitoring well typical design used for the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project, Siskiyou County, California

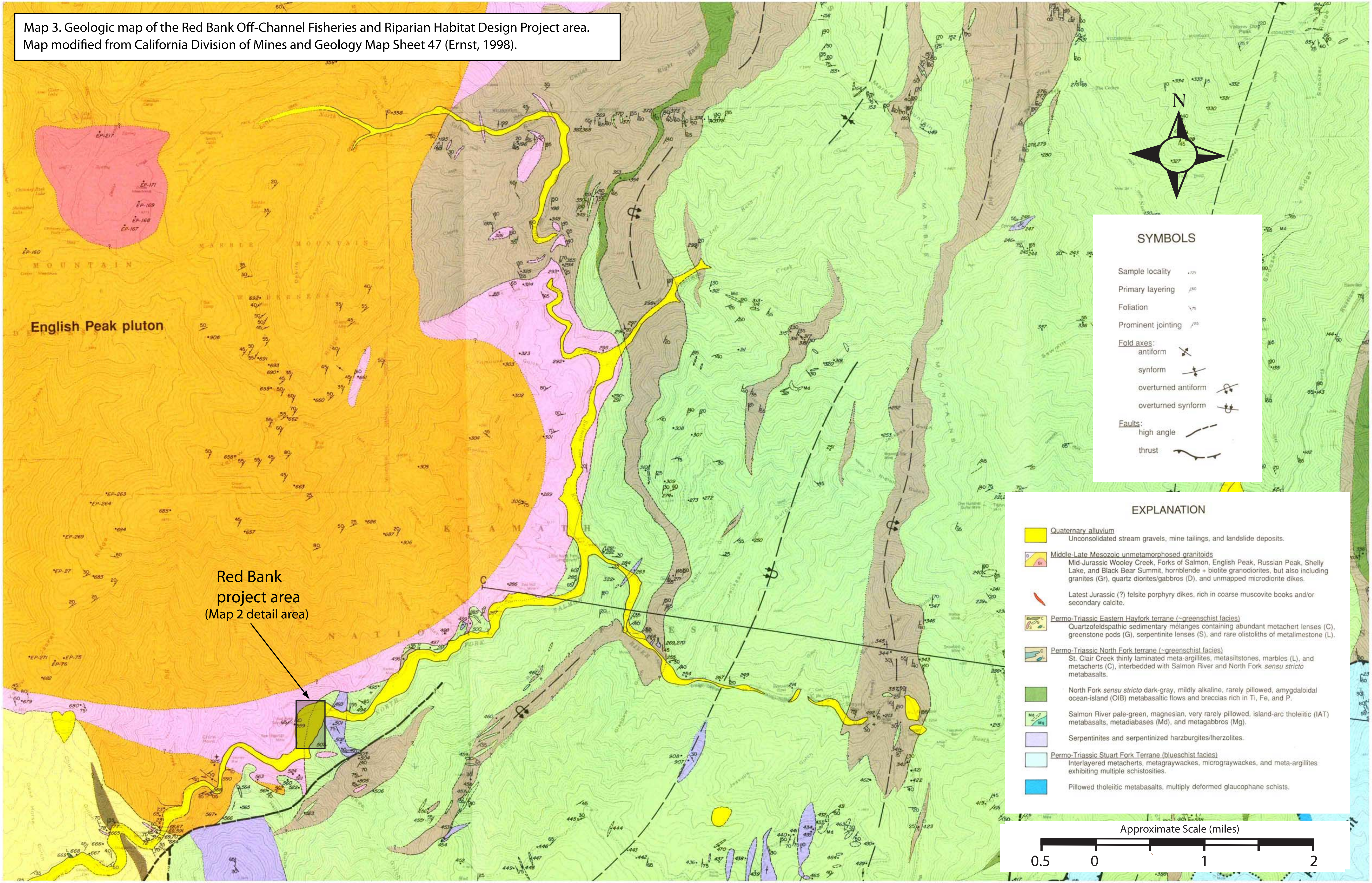


Map 1. General location map for the geologic investigation of the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project, Siskiyou County, California. Sawyers Bar USGS 7.5 Minute Quadrangle.

Map 2. Geomorphic features and trench log locations for the geologic investigation of the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project, Siskiyou County California. Base mapping provided by Michael Love and Associates, 2015.



Map 3. Geologic map of the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project area. Map modified from California Division of Mines and Geology Map Sheet 47 (Ernst, 1998).



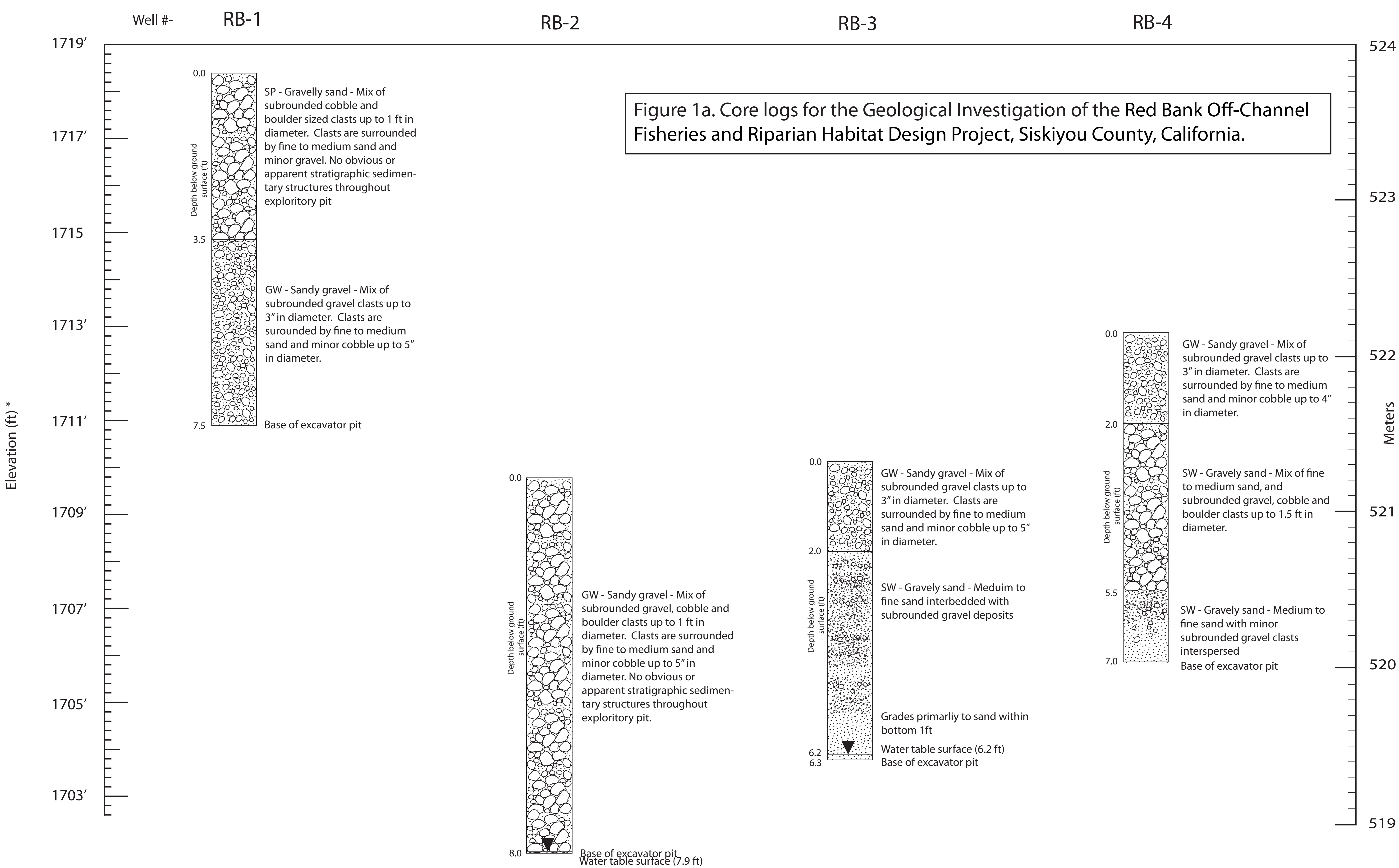


Figure 1a. Core logs for the Geological Investigation of the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project, Siskiyou County, California.

*Elevation in feet (NADV 1988) based on survey conducted by Michael Love and Associates, 2015

Note: Soil cores described using field classification method ASTM D 2488-00 (Visual-Manual Proceedure)

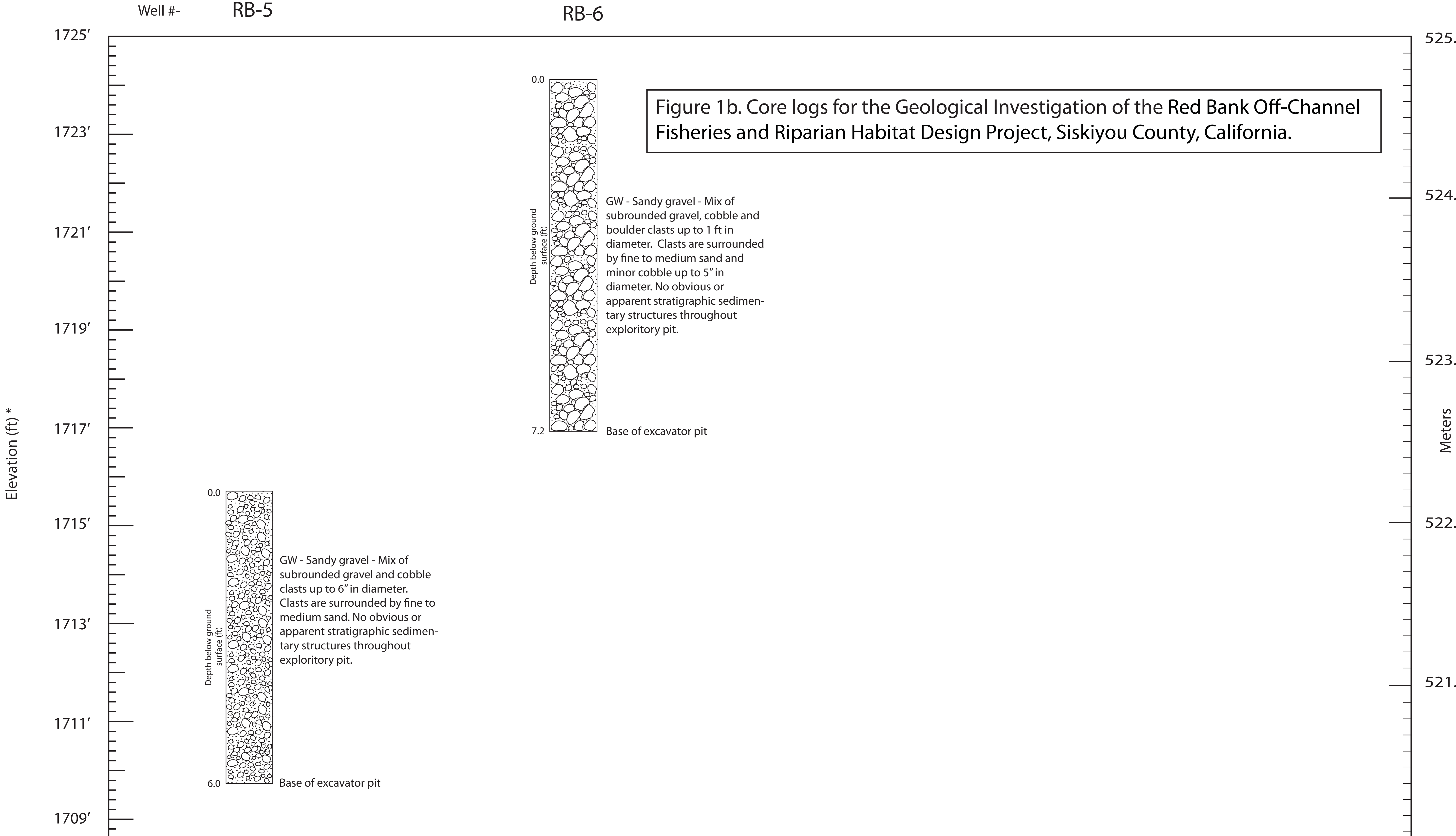
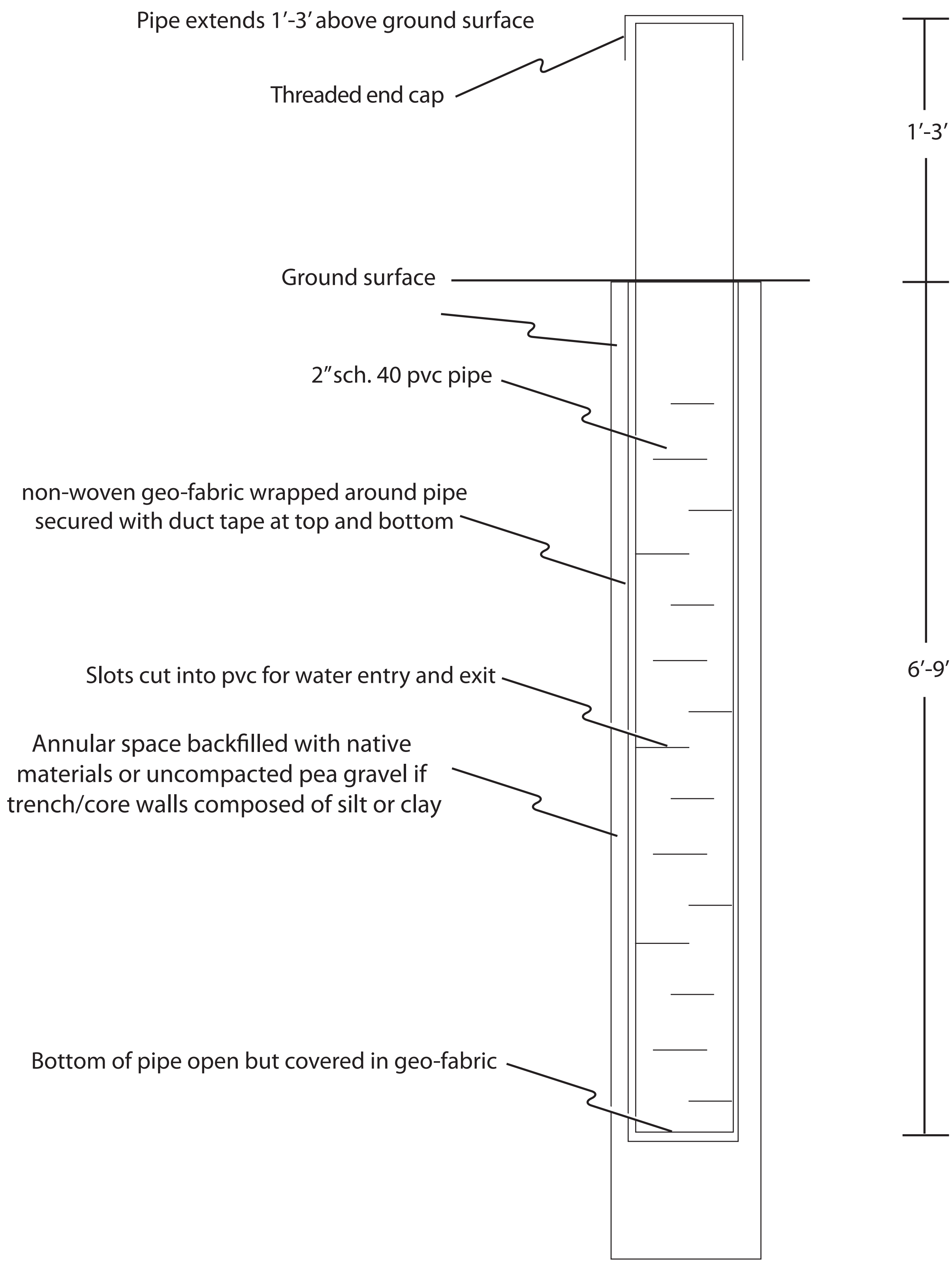


Figure 1b. Core logs for the Geological Investigation of the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project, Siskiyou County, California.

*Elevation in feet (NADV 1988) based on survey conducted by Michael Love and Associates, 2015

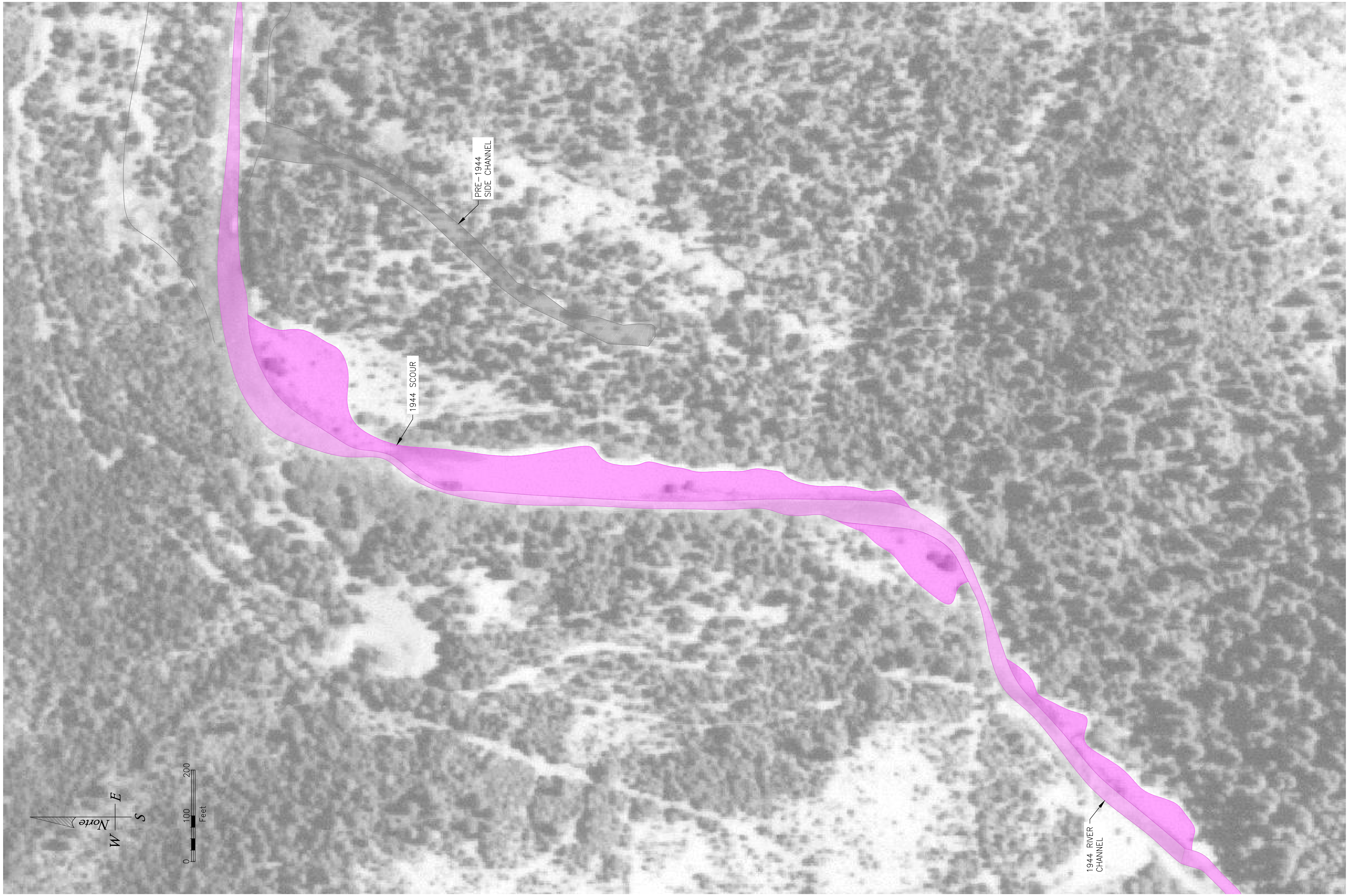
Note: Soil cores described using field classification method ASTM D 2488-00 (Visual-Manual Proceedure)

Figure 2. Groundwater monitoring well typical design used in the Red Bank Off-Channel Fisheries and Riparian Habitat Design Project, Siskiyou County, CA



Drawing not to scale

Appendix E
Historical Aerial Photographs



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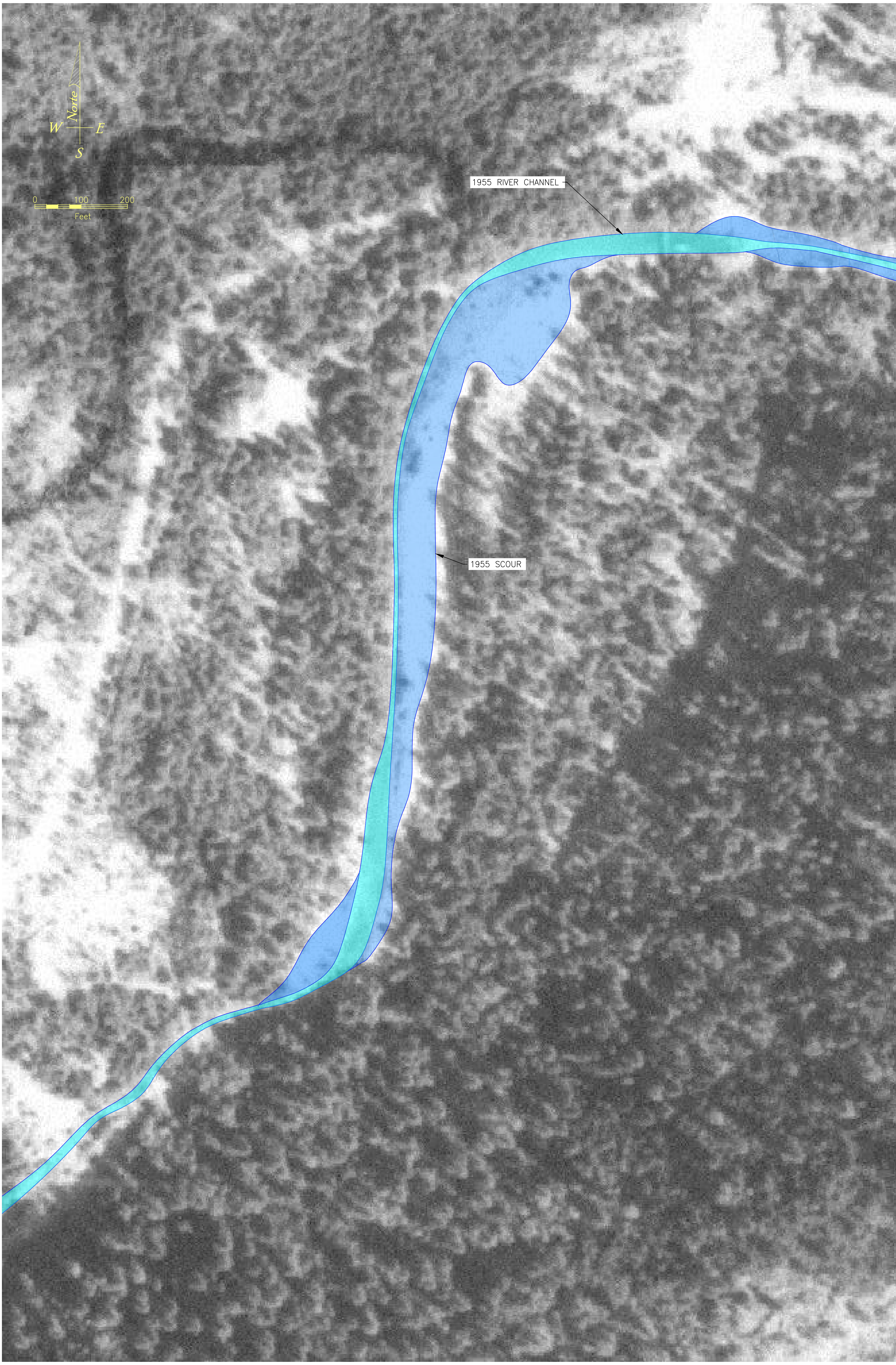
530-462-4665 Fax 530-462-4664

VERIFY SCALE
THIS BAR IS ONE INCH LONG AT FULL SCALE

Salmon River Restoration Council
RED BANK OFF-CHANNEL
FISHERIES AND RIPARIAN HABITAT DESIGN

Red Bank 1944

DATE	JAN. 2017
SUBMITTAL	
DESIGN	RS
DRAWN	NN
FIGURE	1



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DATE	JAN. 2017
SUBMITTAL	
DESIGN	RS
DRAWN	NN
FIGURE	2

Salmon River Restoration Council
RED BANK OFF-CHANNEL
FISHERIES AND RIPARIAN HABITAT DESIGN

Red Bank 1955

VERIFY SCALE
THIS BAR IS ONE INCH LONG AT FULL SCALE

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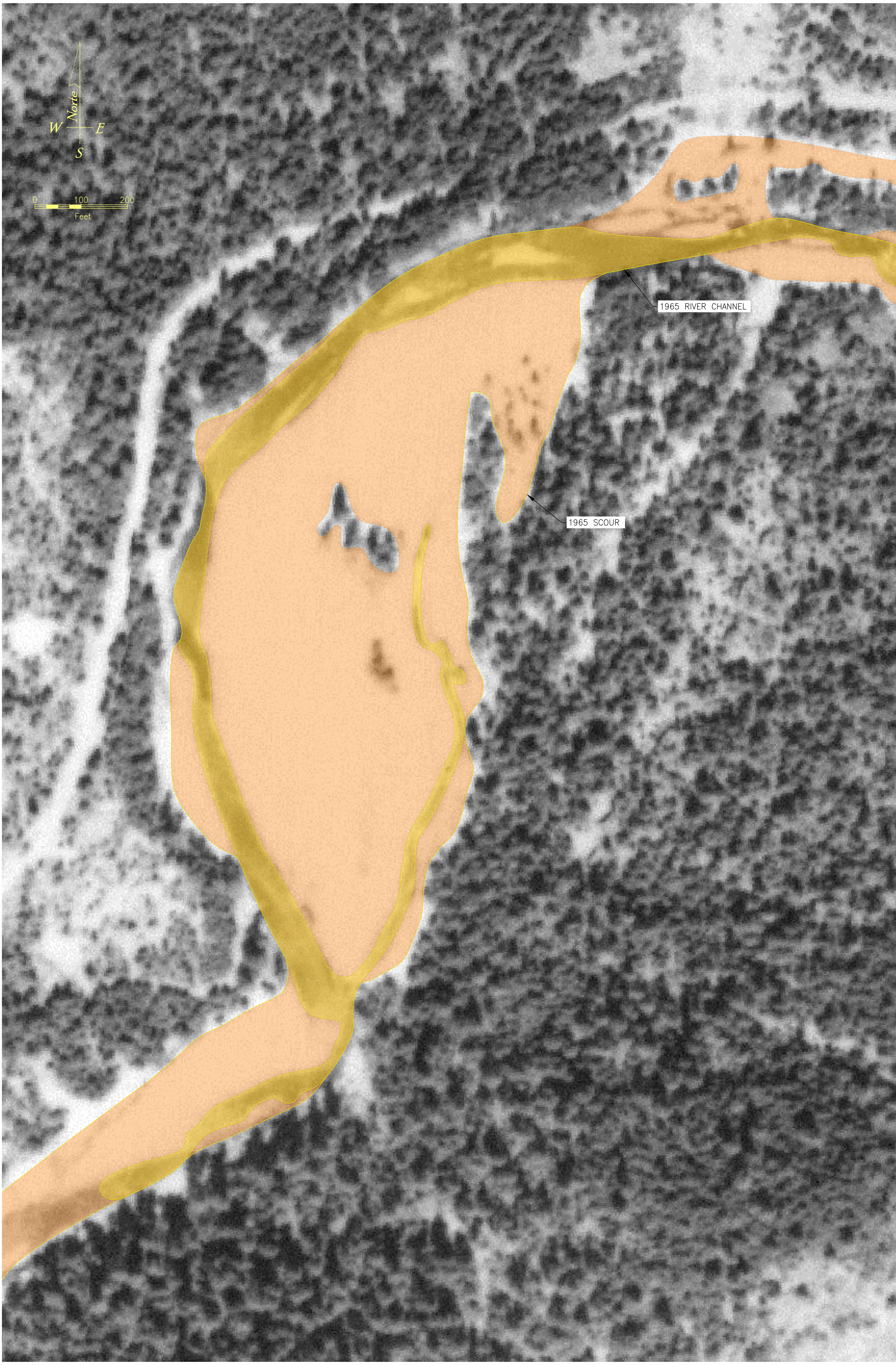
PO BOX 1089 • 25631 Sawyers Bar RD, Sawyers Bar CA 96027
530-462-4665 Fax 530-462-4664



Salmon River Restoration Council
RED BANK OFF-CHANNEL
FISHERIES AND RIPARIAN HABITAT DESIGN

Red Bank 1965

VERIFY SCALE
THIS BAR IS ONE INCH LONG AT FULL SCALE

Michael Love & Associates, Inc.
PO Box 4477 • Arcata, CA 95518 • (707) 822-2411

Salmon River Restoration Council
PO BOX 1089 • 25631 Sawyers Bar RD, Sawyers Bar CA 96027
530-462-4665 Fax 530-462-4664

DATE JAN. 2017
SUBMITTAL
DESIGN RS
DRAWN NN
FIGURE 3

Michael Love & Associates, Inc.
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VERIFY SCALE
THIS BAR IS ONE INCH LONG AT FULL SCALE

Salmon River Restoration Council
RED BANK OFF-CHANNEL
FISHERIES AND RIPARIAN HABITAT DESIGN

Red Bank 1975

DATE
JAN. 2017
SUBMITTAL

DESIGN
RS
DRAWN
NN
FIGURE
4

Q:\Red Bank\5_CAD_FIGURES\Historic Air Photos.dwg

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VERIFY SCALE
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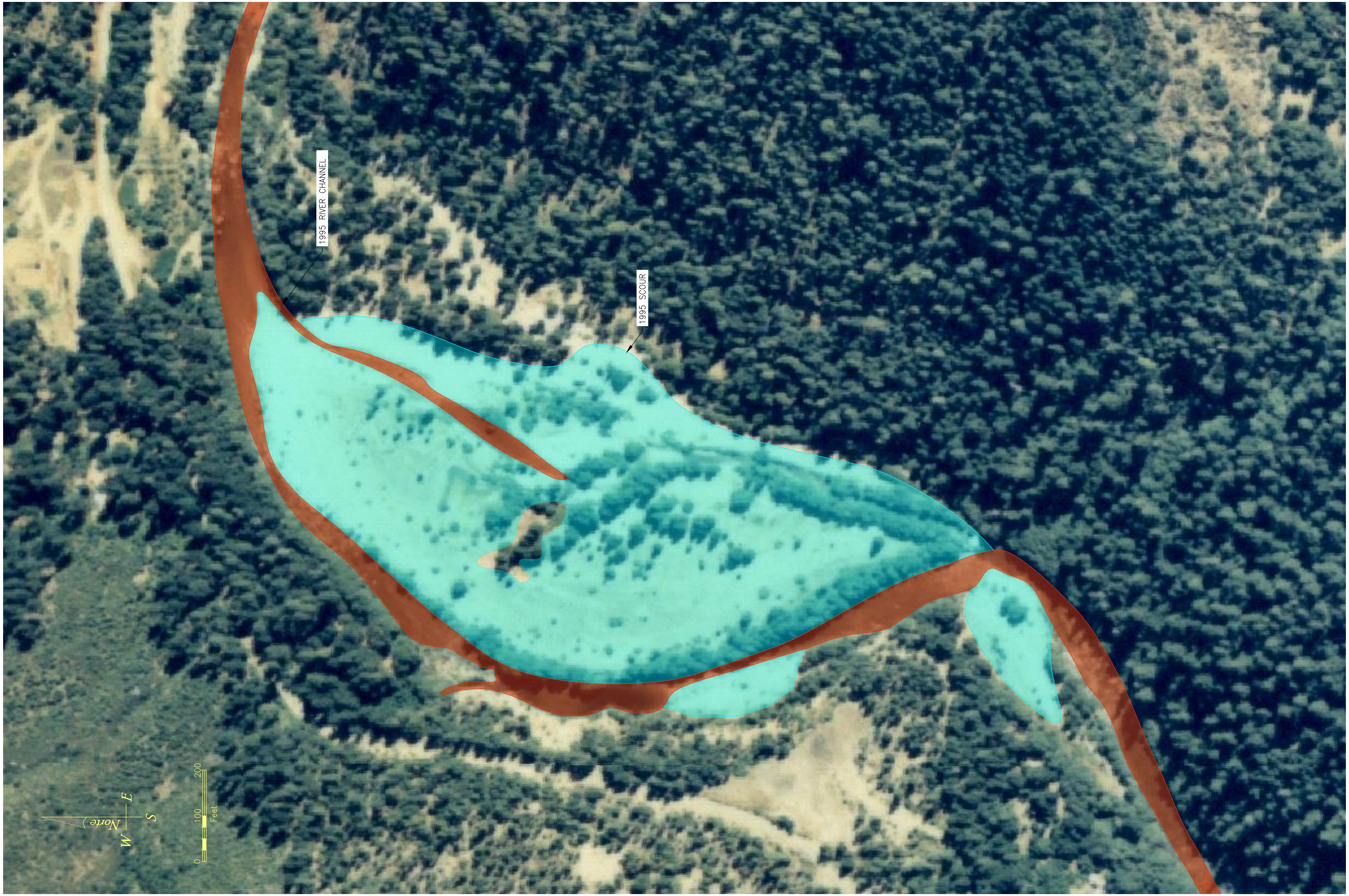
Salmon River Restoration Council
RED BANK OFF-CHANNEL
FISHERIES AND RIPARIAN HABITAT DESIGN

Red Bank 1980

DATE	JAN. 2017
SUBMITTAL	
DESIGN	RS
DRAWN	NN
FIGURE	5



Michael Love & Associates, Inc.
PO Box 4477 • Arcata, CA 95518 • (707) 822-2411

Salmon River Restoration Council
PO BOX 1089 • 25631 Sawyers Bar RD, Sawyers Bar CA 96027
530-462-4665 Fax 530-462-4664

VERIFY SCALE
THIS BAR IS ONE INCH LONG AT FULL SCALE

Salmon River Restoration Council
RED BANK OFF-CHANNEL
FISHERIES AND RIPARIAN HABITAT DESIGN

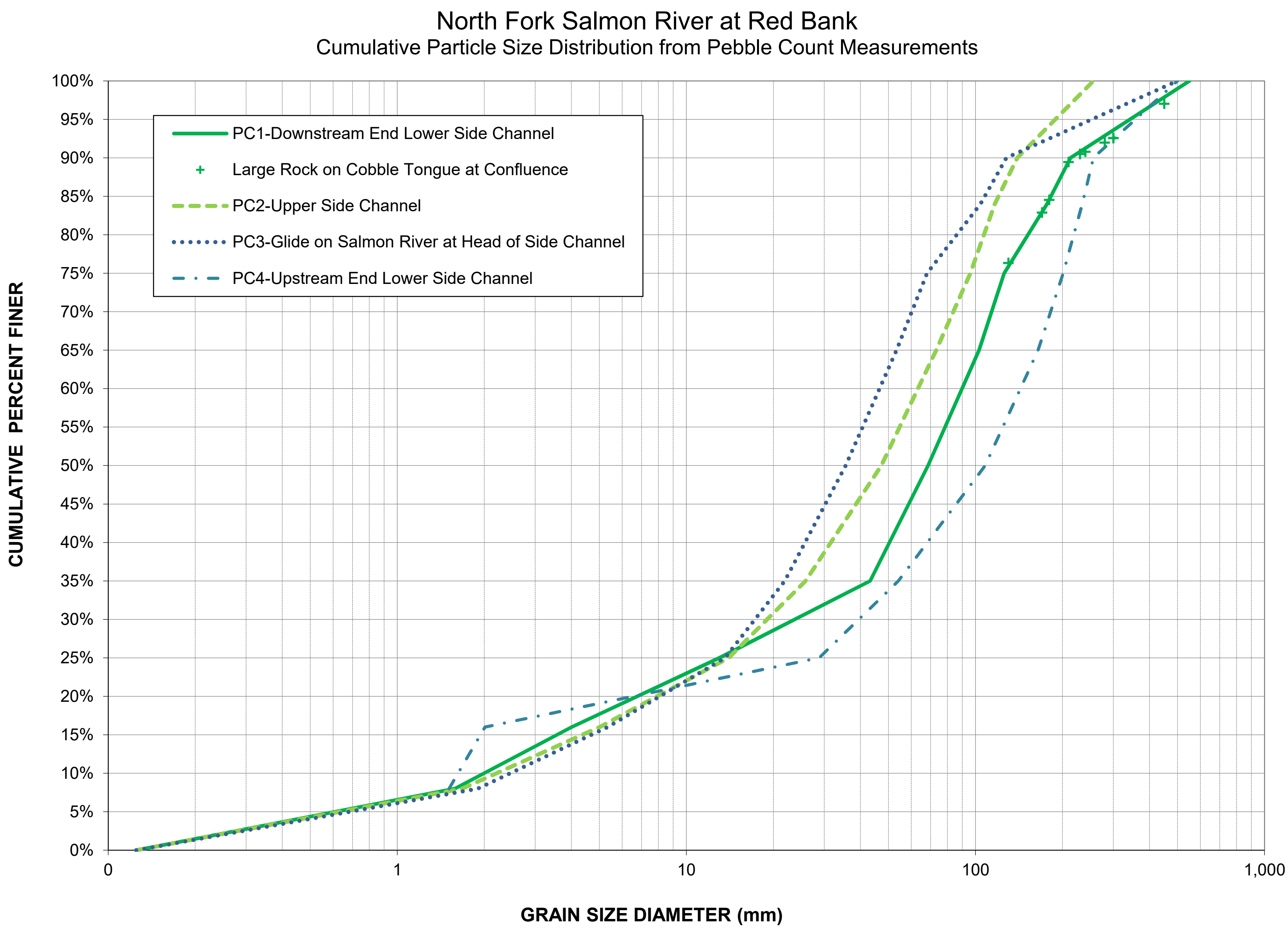
Red Bank 1995

DATE
JAN. 2017
SUBMITTAL

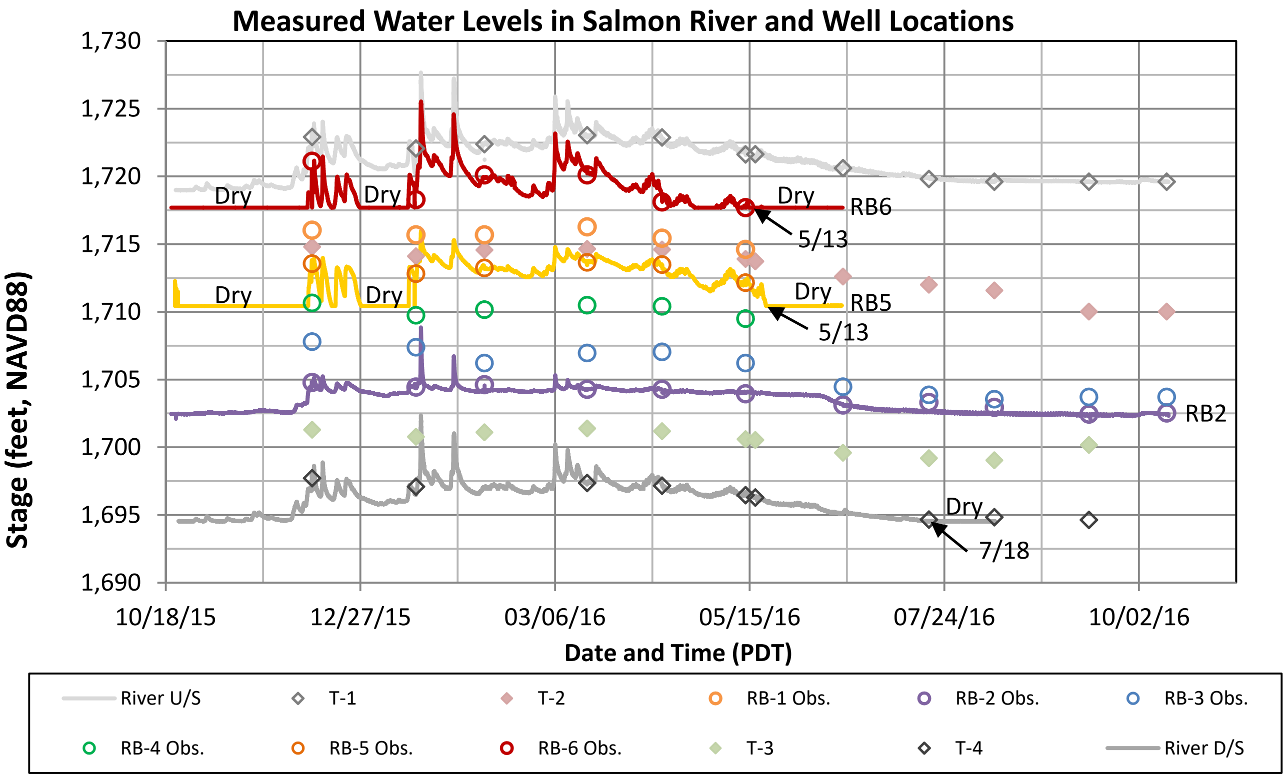
DESIGN
RS
DRAWN
NN
FIGURE
6

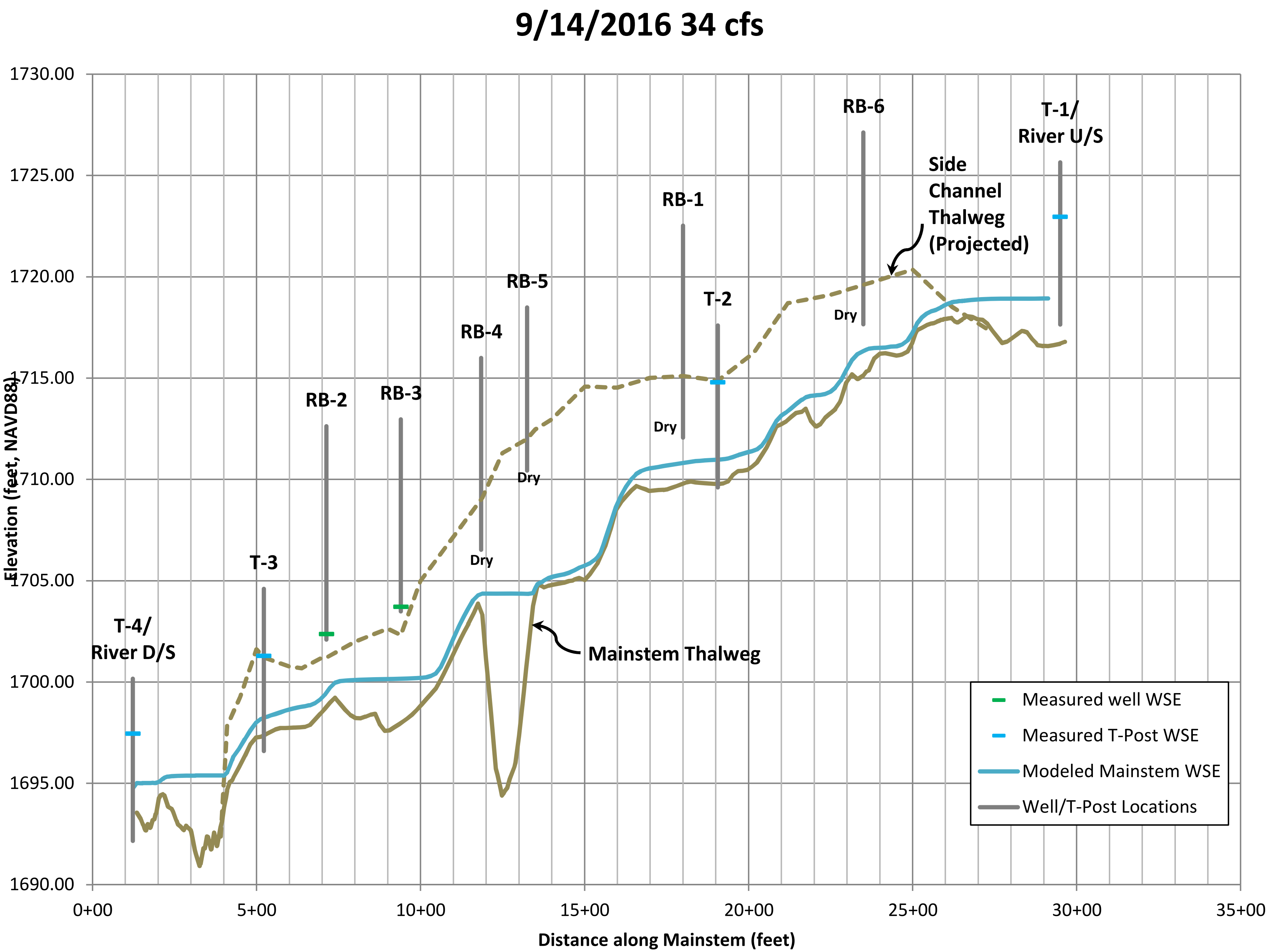
Q:\Red Bank\5_CAD_FIGURES\Historic Air Photos.dwg

Appendix F
Pebble Count Data

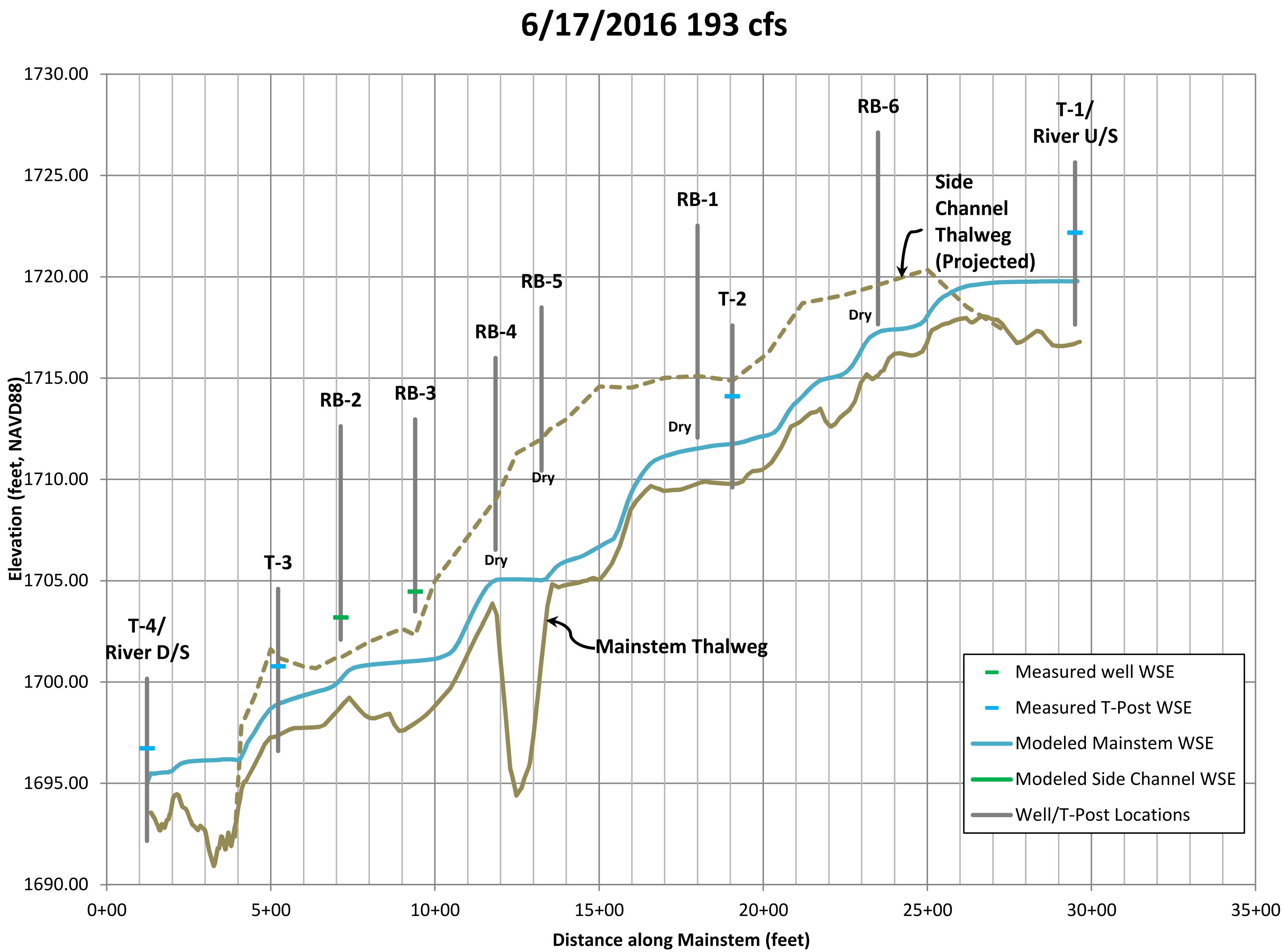

North Fork Salmon River at Red Bank
Cumulative Particle Size Distribution from Pebble Count Measurements
PC1-Downstream End Lower Side Channel
Large Rock on Cobble Tongue at Confluence
PC2-Upper Side Channel
PC3-Glide on Salmon River at Head of Side Channel
PC4-Upstream End Lower Side Channel
CUMULATIVE PERCENT FINER
100%
95%
90%
85%
80%
75%
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
1
10
100
1,000
GRAIN SIZE DIAMETER (mm)

Appendix G
Water Level Monitoring

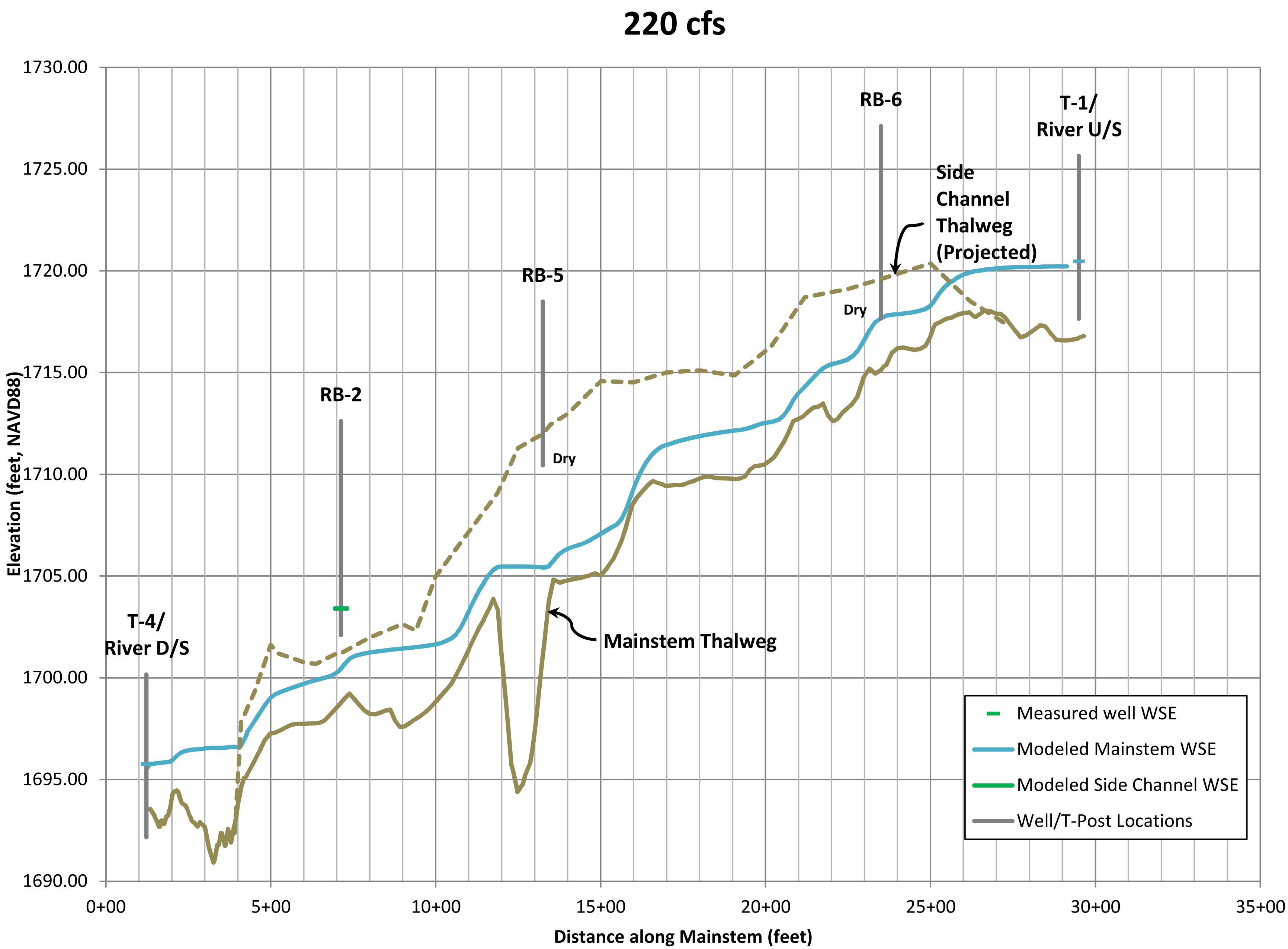

Measured Water Levels in Salmon River and Well Locations
1,730
1,725
1,720
1,715
1,710
1,705
1,700
1,695
1,690
Stage (feet, NAVD88)
10/18/15
12/27/15
03/06/16
05/15/16
07/24/16
10/02/16
Date and Time (PDT)
Dry
Dry
Dry
RB6
5/13
Dry
Dry
Dry
RB5
5/13
RB2
Dry
7/18
River U/S
T-1
T-2
RB-1 Obs.
RB-2 Obs.
RB-3 Obs.
RB-4 Obs.
RB-5 Obs.
RB-6 Obs.
T-3
T-4
River D/S

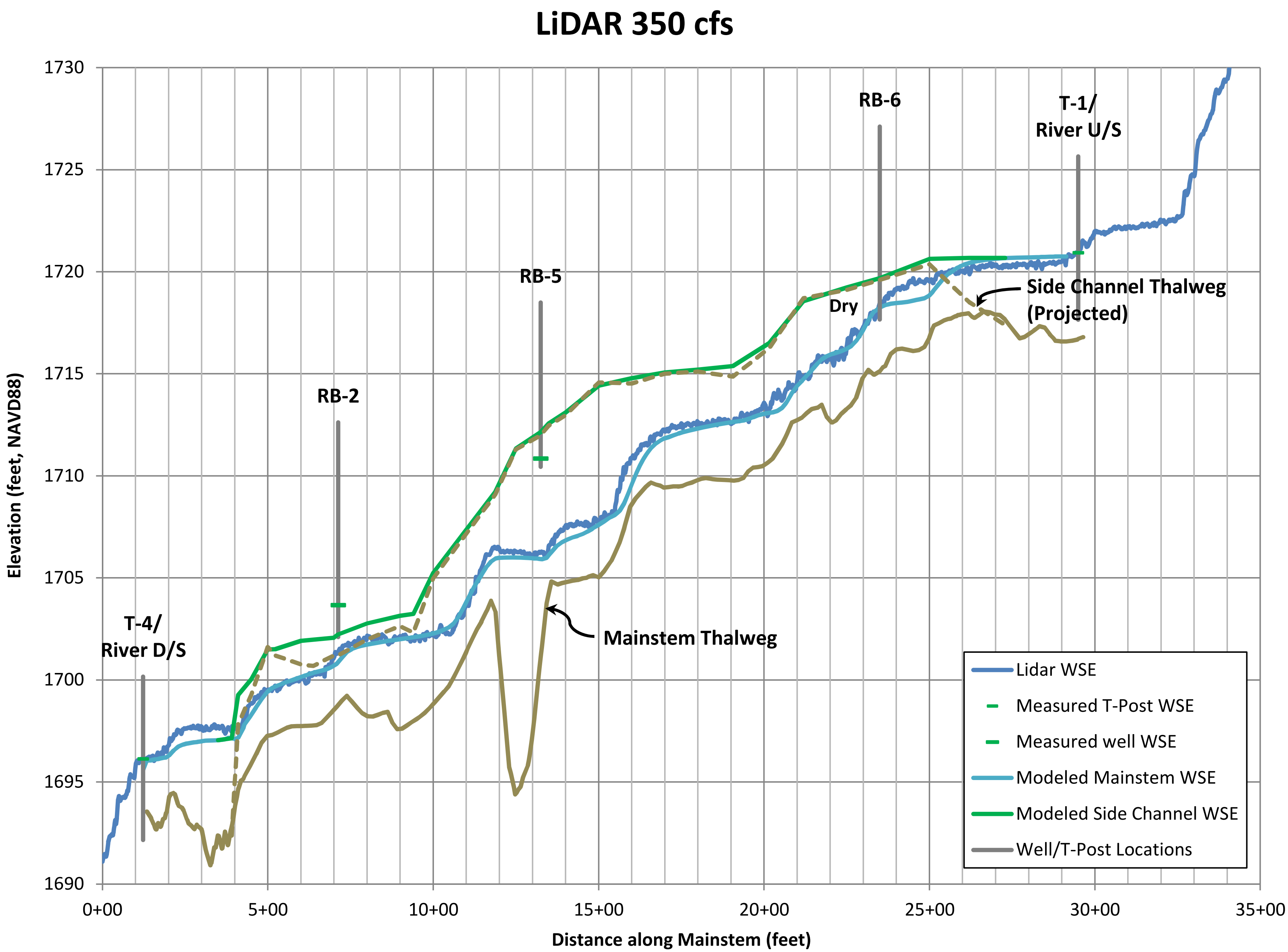


9/14/2016 34 cfs
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
T-3
RB-2
RB-3
RB-4
Dry
RB-5
Dry
RB-1
Dry
T-2
RB-6
Dry
Side
Channel
Thalweg
(Projected)
T-1/
River U/S
Mainstem Thalweg
Measured well WSE
Measured T-Post WSE
Modeled Mainstem WSE
Well/T-Post Locations

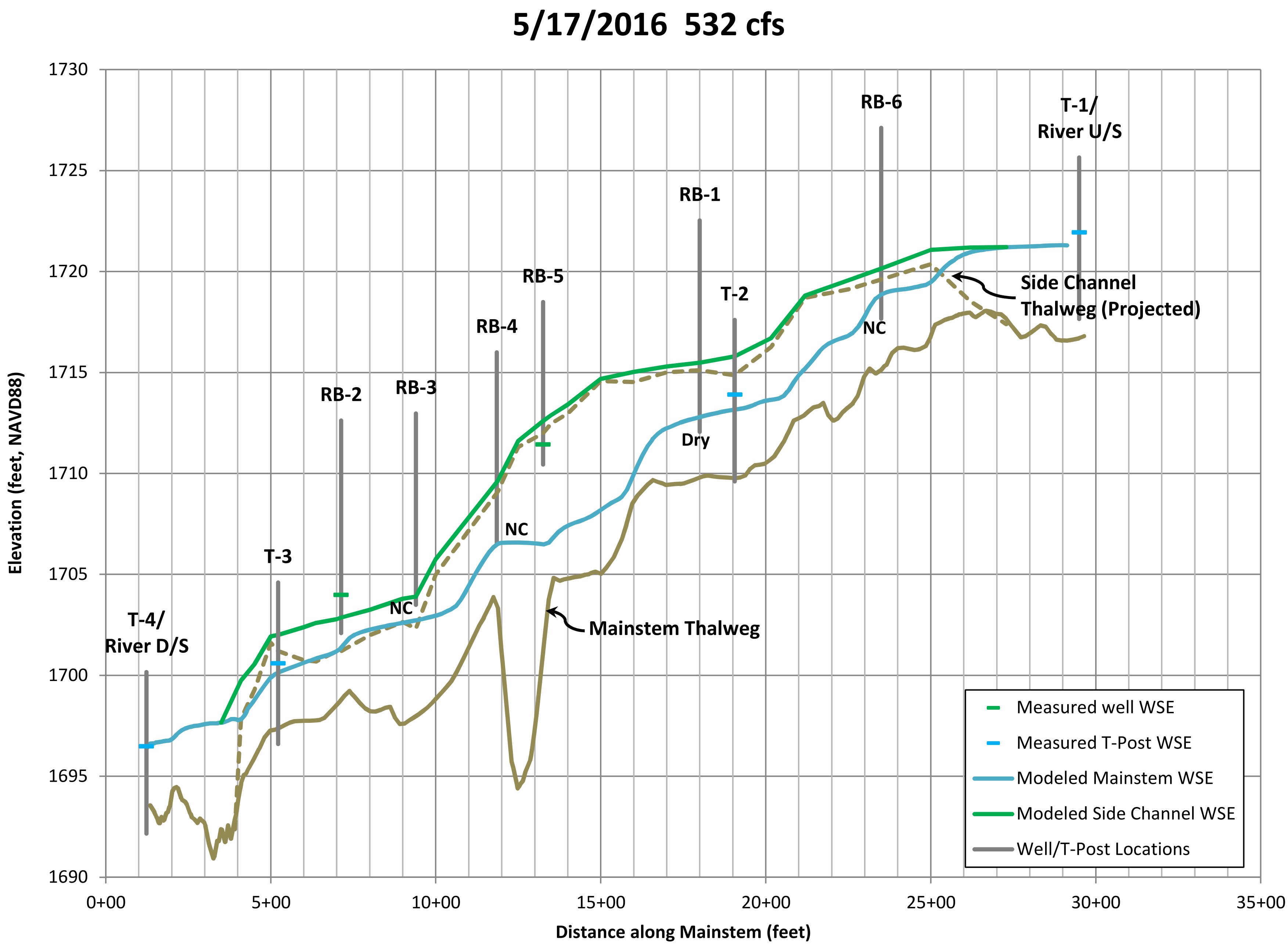


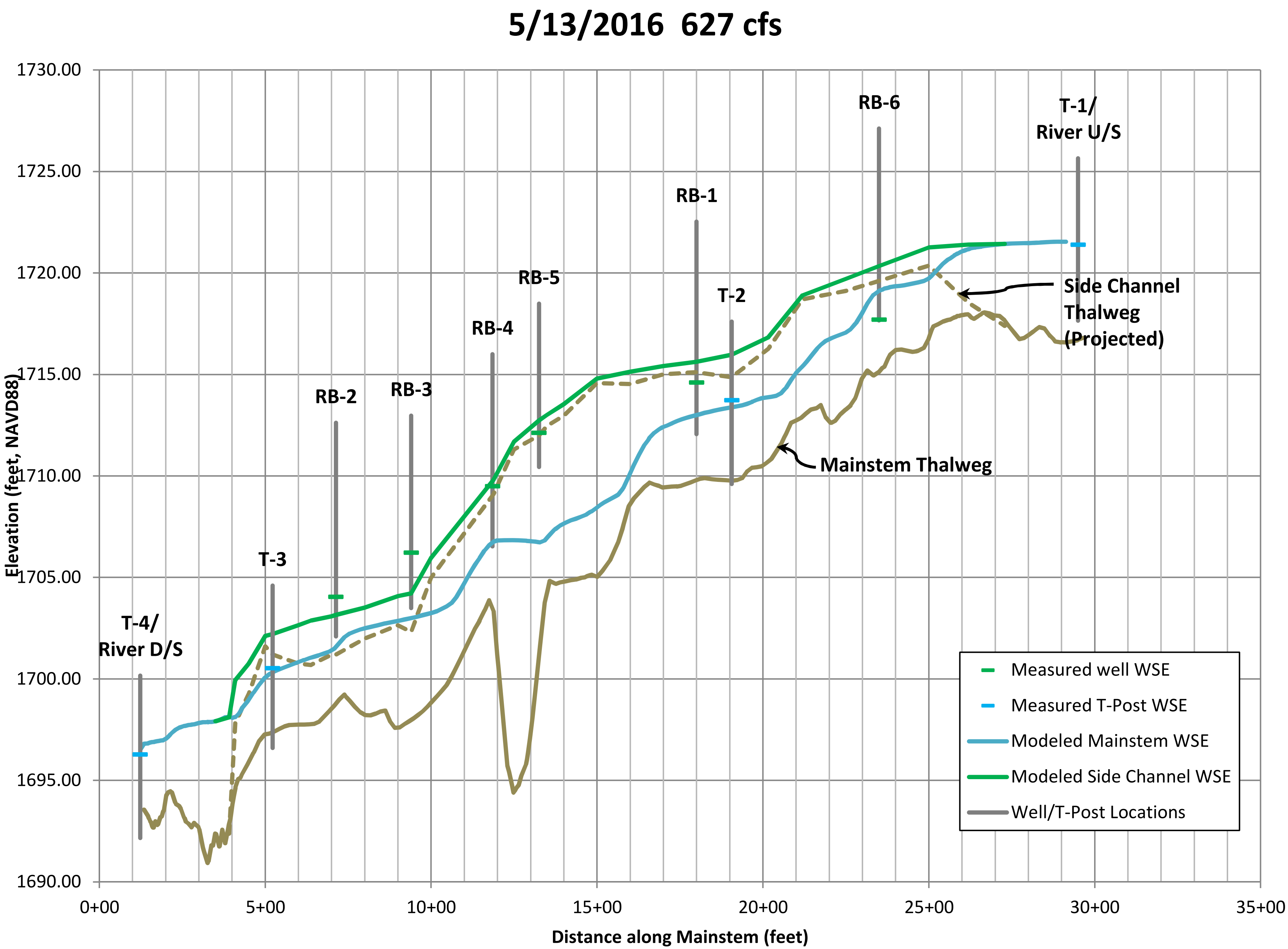
6/17/2016 193 cfs
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
T-3
RB-2
RB-3
RB-4
Dry
RB-5
Dry
RB-1
Dry
T-2
RB-6
Dry
T-1/
River U/S
Side
Channel
Thalweg
(Projected)
Mainstem Thalweg
Measured well WSE
Measured T-Post WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations

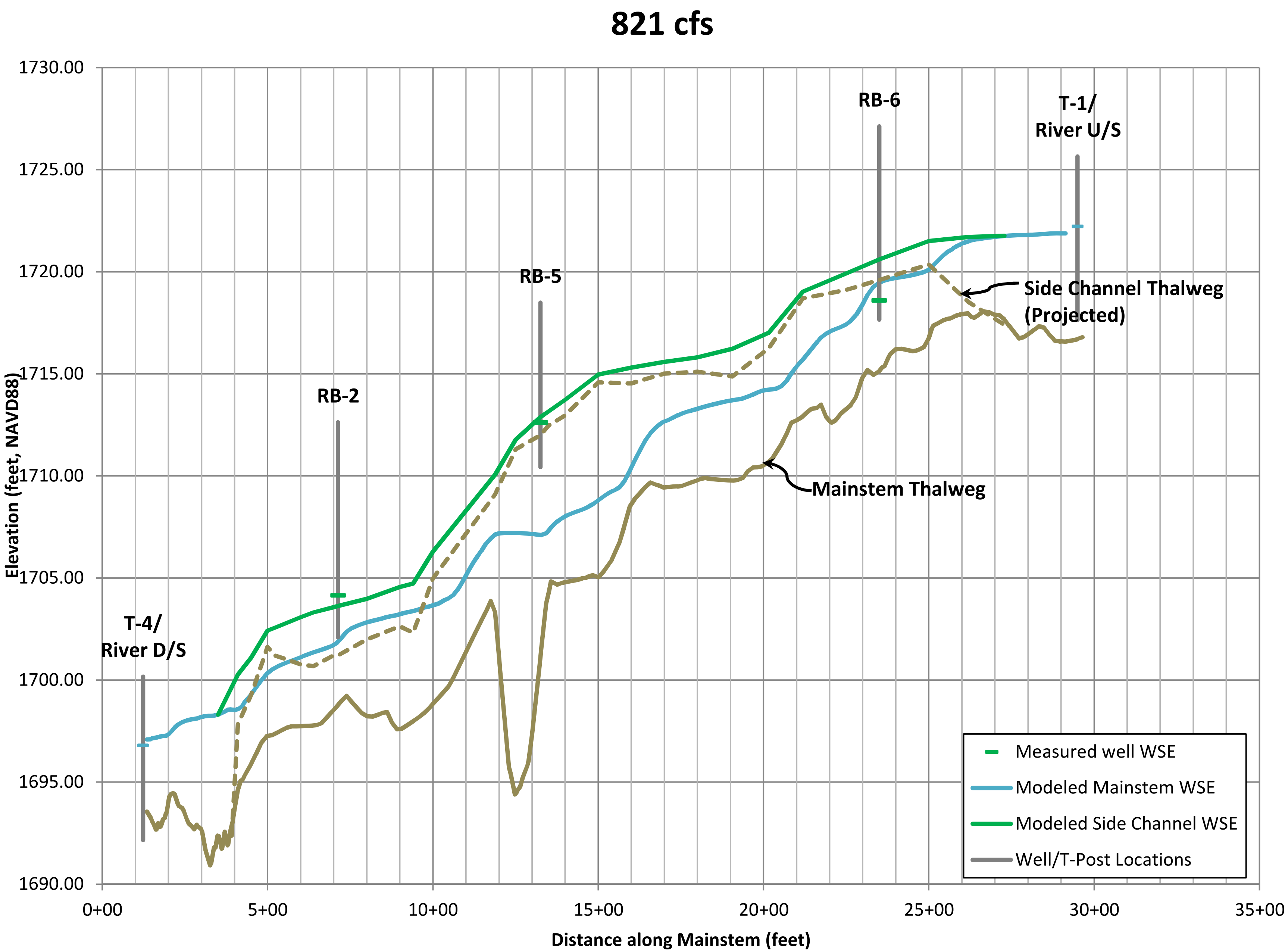

220 cfs
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
RB-2
RB-5
Dry
RB-6
Dry
Side
Channel
Thalweg
(Projected)
T-1/
River U/S
Mainstem Thalweg
Measured well WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations

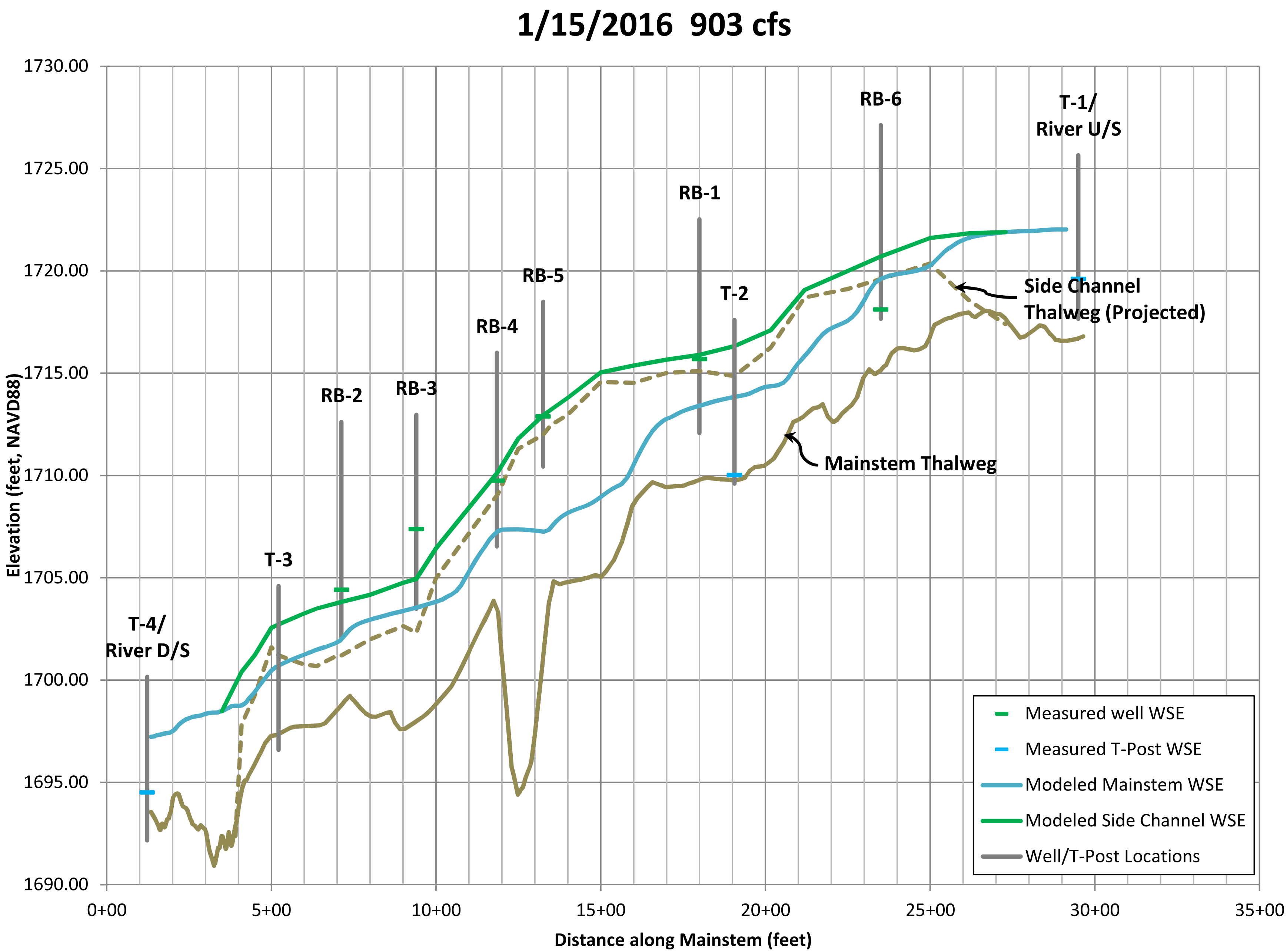


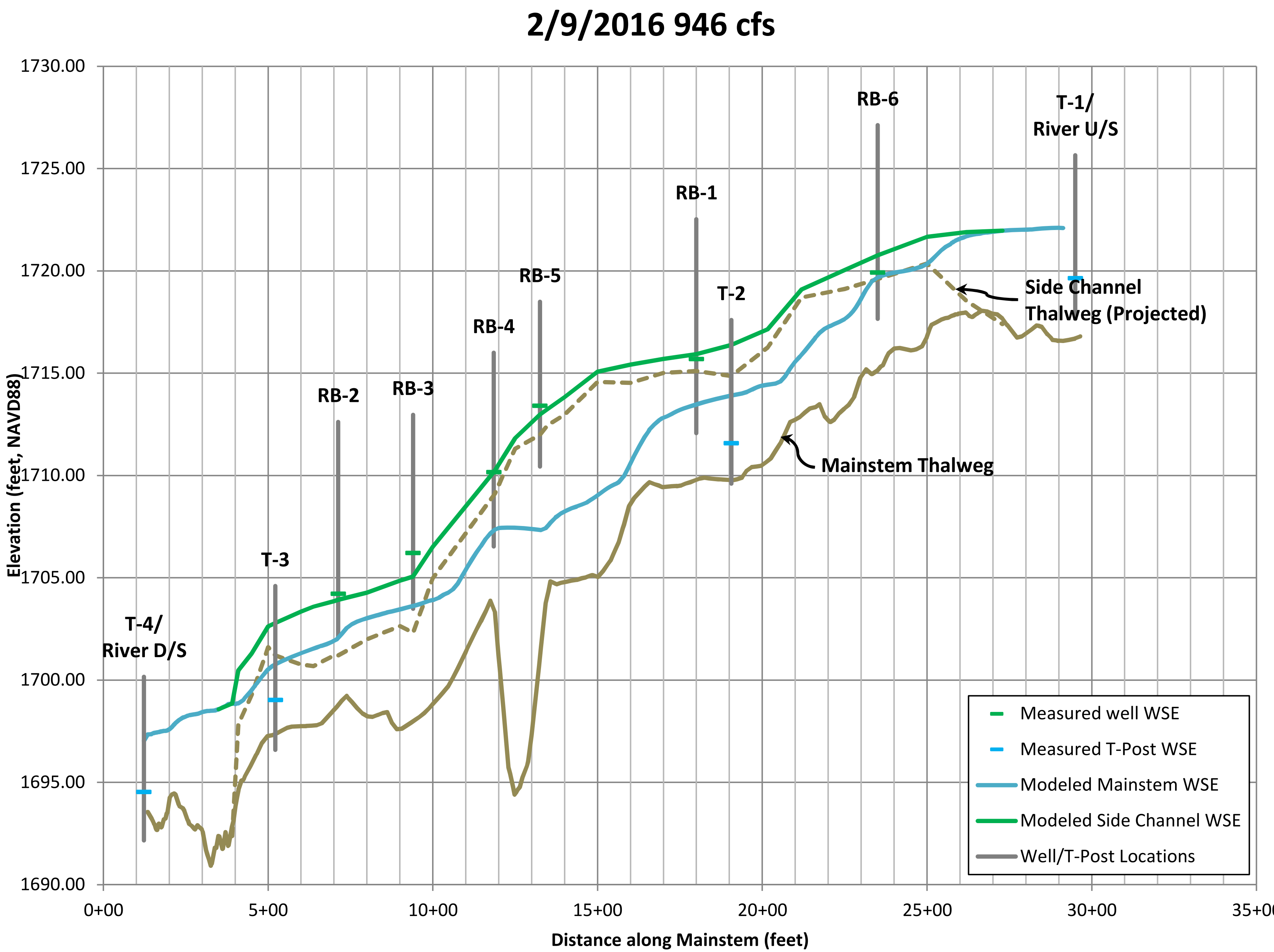
LiDAR 350 cfs
Elevation (feet, NAVD88)
Distance along Mainstem (feet)
1730
1725
1720
1715
1710
1705
1700
1695
1690
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
T-4/
River D/S
RB-2
RB-5
RB-6
Dry
T-1/
River U/S
Side Channel Thalweg
(Projected)
Mainstem Thalweg
Lidar WSE
Measured T-Post WSE
Measured well WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations

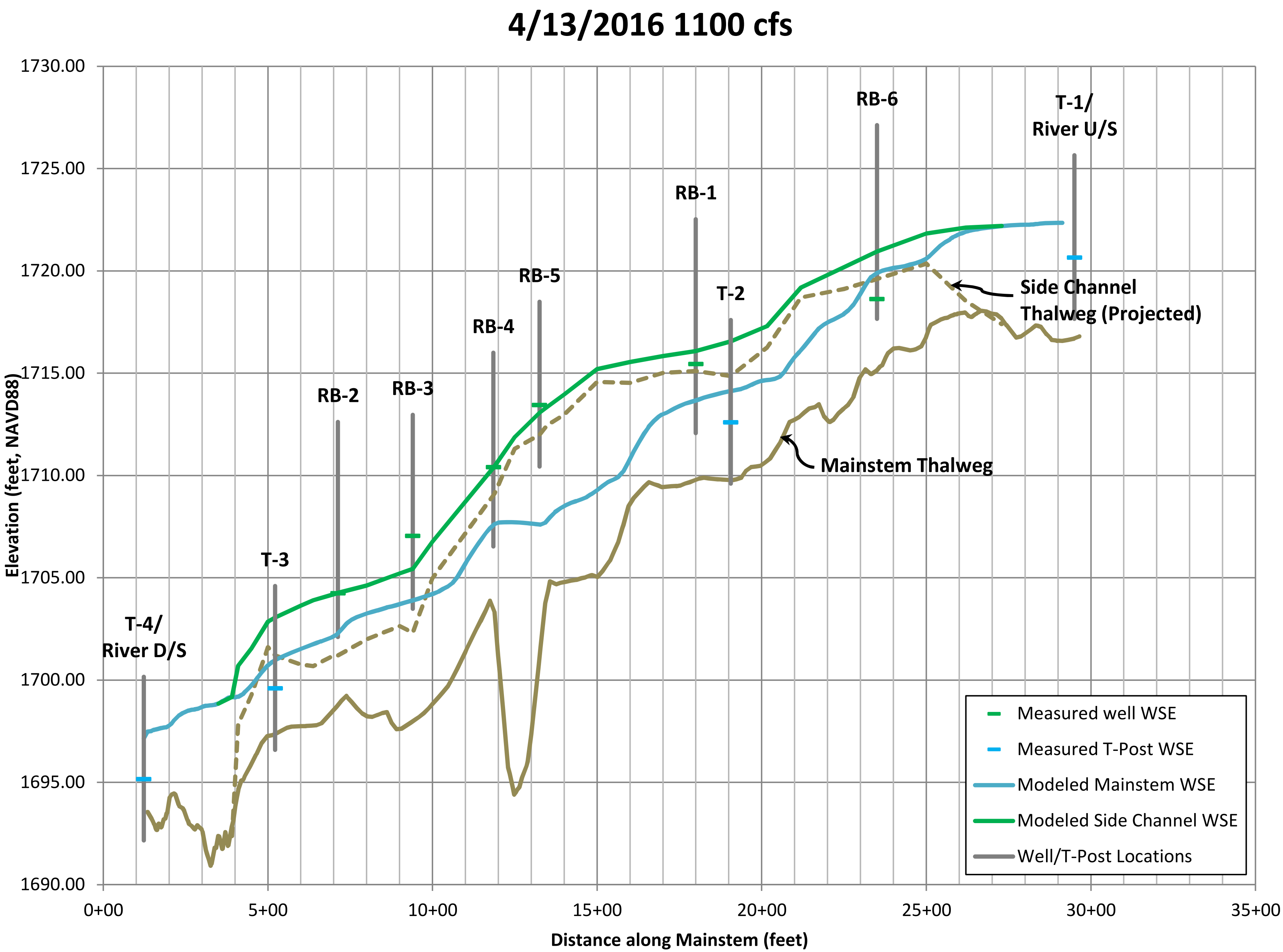

5/17/2016 532 cfs
Elevation (feet, NAVD88)
1730
1725
1720
1715
1710
1705
1700
1695
1690
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
T-3
RB-2
RB-3
NC
RB-4
NC
RB-5
Mainstem Thalweg
RB-1
Dry
T-2
RB-6
NC
T-1/
River U/S
Side Channel
Thalweg (Projected)
Measured well WSE
Measured T-Post WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations

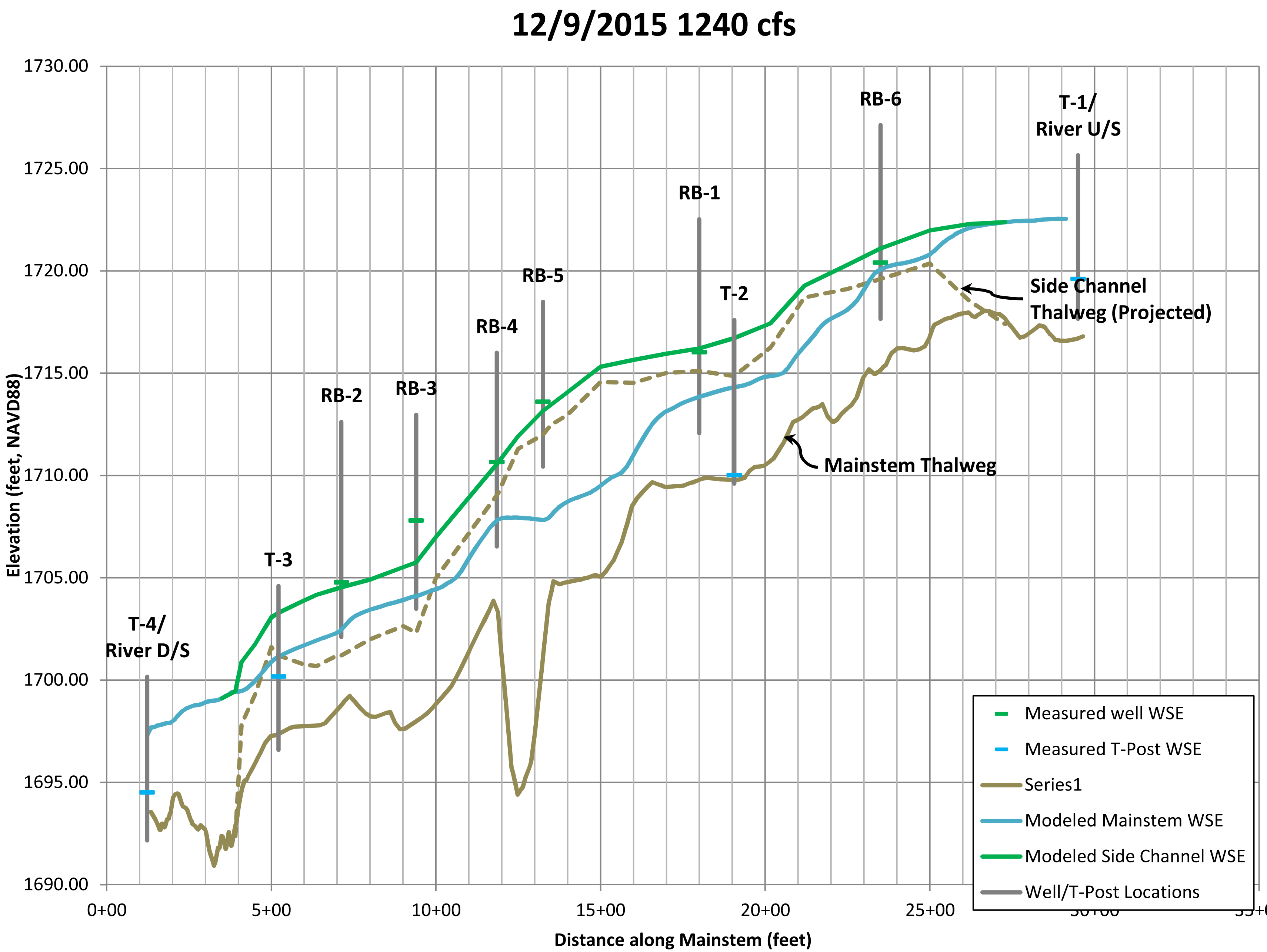

5/13/2016 627 cfs
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
T-3
RB-2
RB-3
RB-4
RB-5
RB-1
T-2
RB-6
T-1/
River U/S
Side Channel
Thalweg
(Projected)
Mainstem Thalweg
Measured well WSE
Measured T-Post WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations

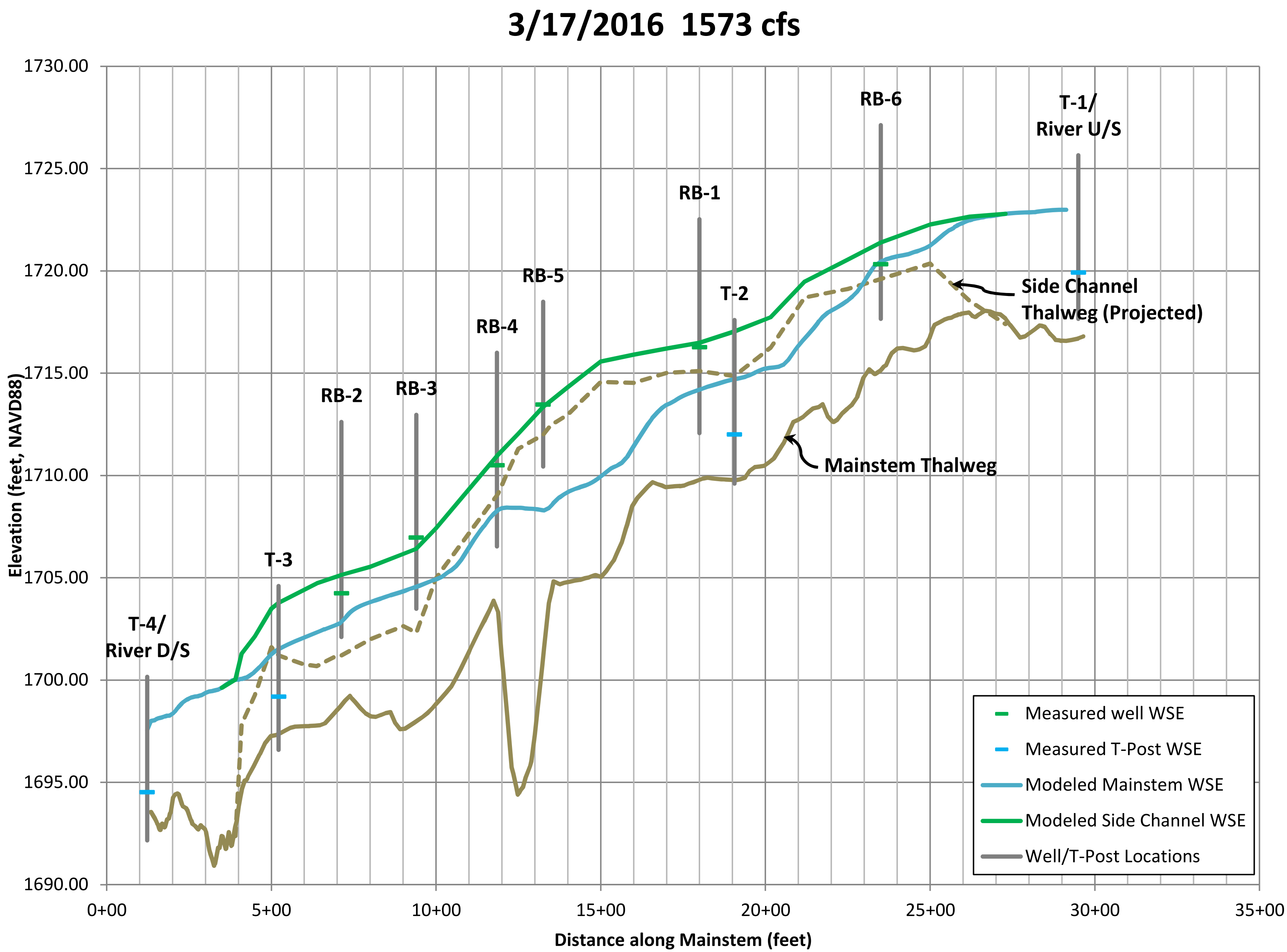

821 cfs
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
RB-2
RB-5
RB-6
T-1/
River U/S
Side Channel Thalweg
(Projected)
Mainstem Thalweg
Measured well WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations

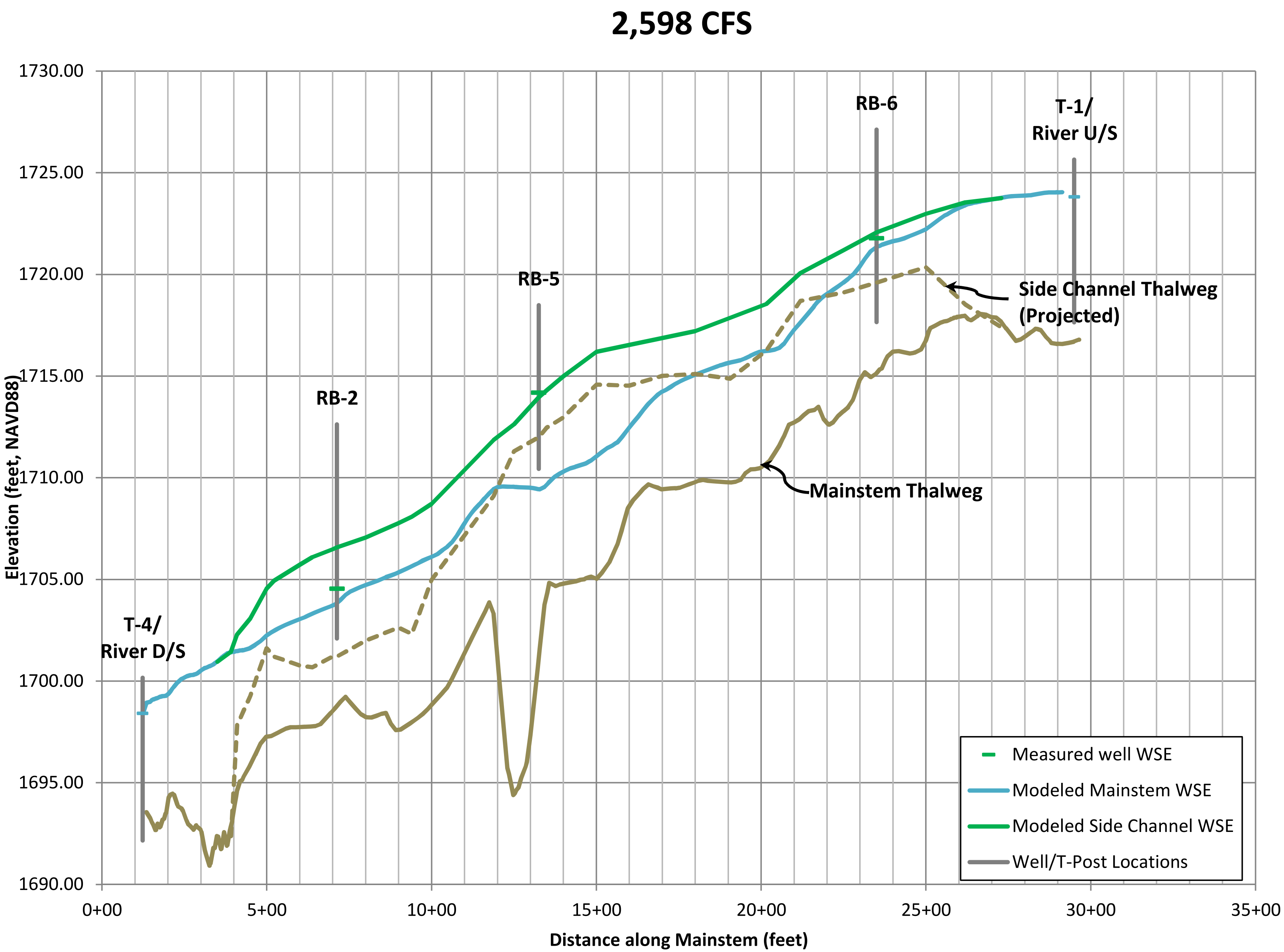

1/15/2016 903 cfs
Elevation (feet, NAVD88)
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
T-3
RB-2
RB-3
RB-4
RB-5
RB-1
T-2
RB-6
T-1/
River U/S
Side Channel
Thalweg (Projected)
Mainstem Thalweg
Measured well WSE
Measured T-Post WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations


2/9/2016 946 cfs
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
T-3
RB-2
RB-3
RB-4
RB-5
RB-1
T-2
RB-6
T-1/
River U/S
Side Channel
Thalweg (Projected)
Mainstem Thalweg
Measured well WSE
Measured T-Post WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations

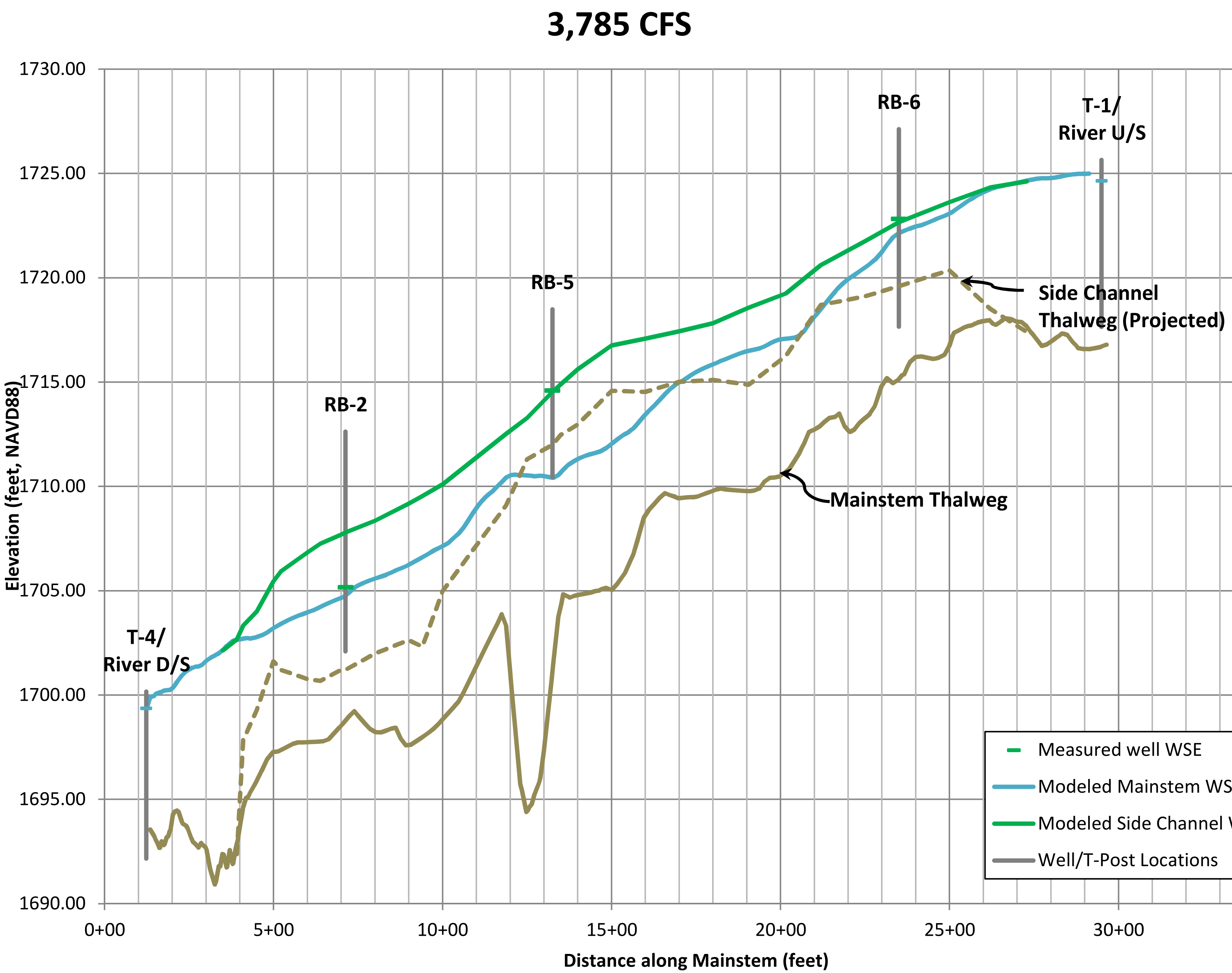

4/13/2016 1100 cfs
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
T-3
RB-2
RB-3
RB-4
RB-5
RB-1
T-2
RB-6
T-1/
River U/S
Side Channel
Thalweg (Projected)
Mainstem Thalweg
Measured well WSE
Measured T-Post WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations

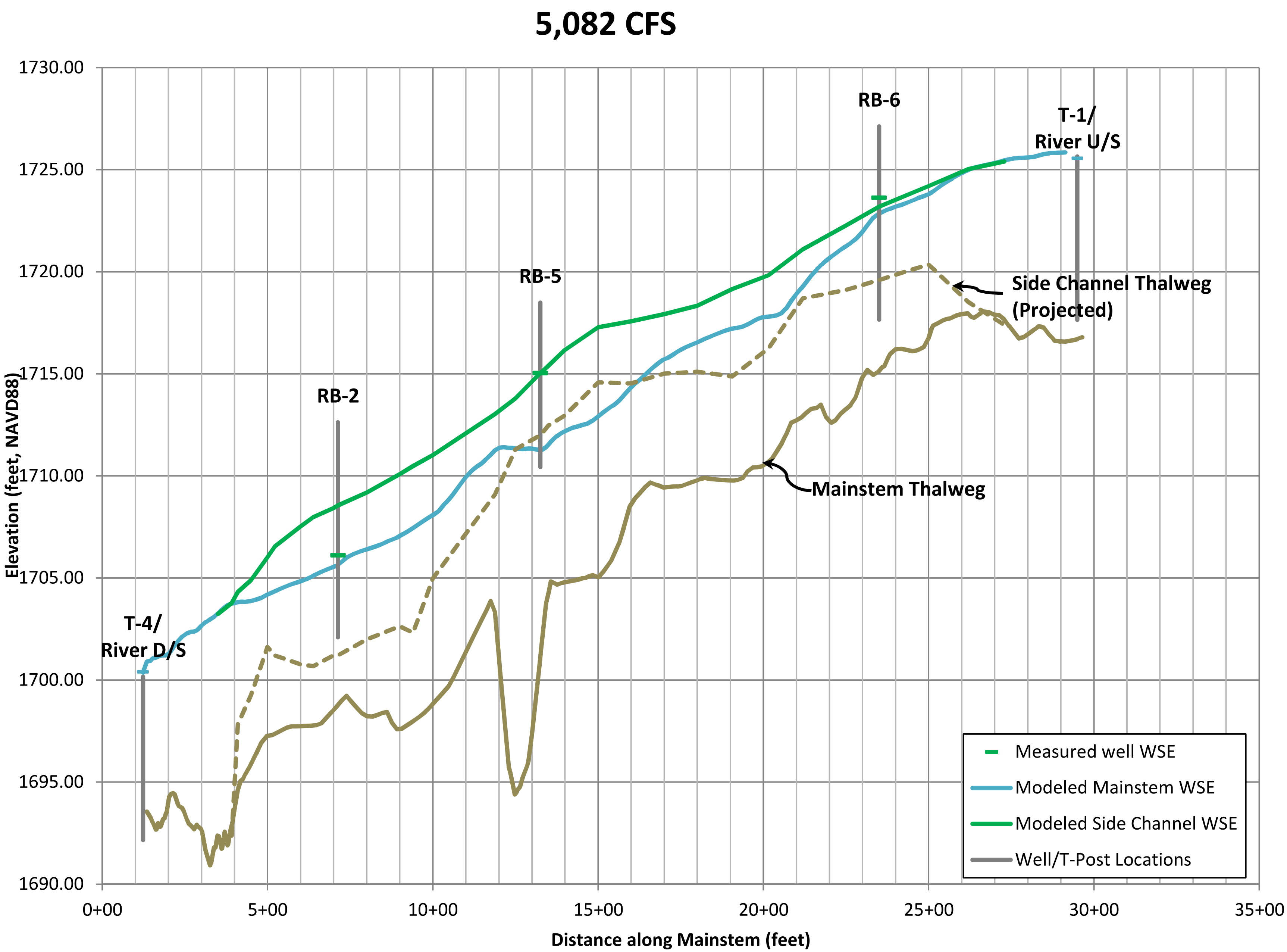

12/9/2015 1240 cfs
Elevation (feet, NAVD88)
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
T-3
RB-2
RB-3
RB-4
RB-5
RB-1
T-2
RB-6
T-1/
River U/S
Side Channel
Thalweg (Projected)
Mainstem Thalweg
Measured well WSE
Measured T-Post WSE
Series1
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations

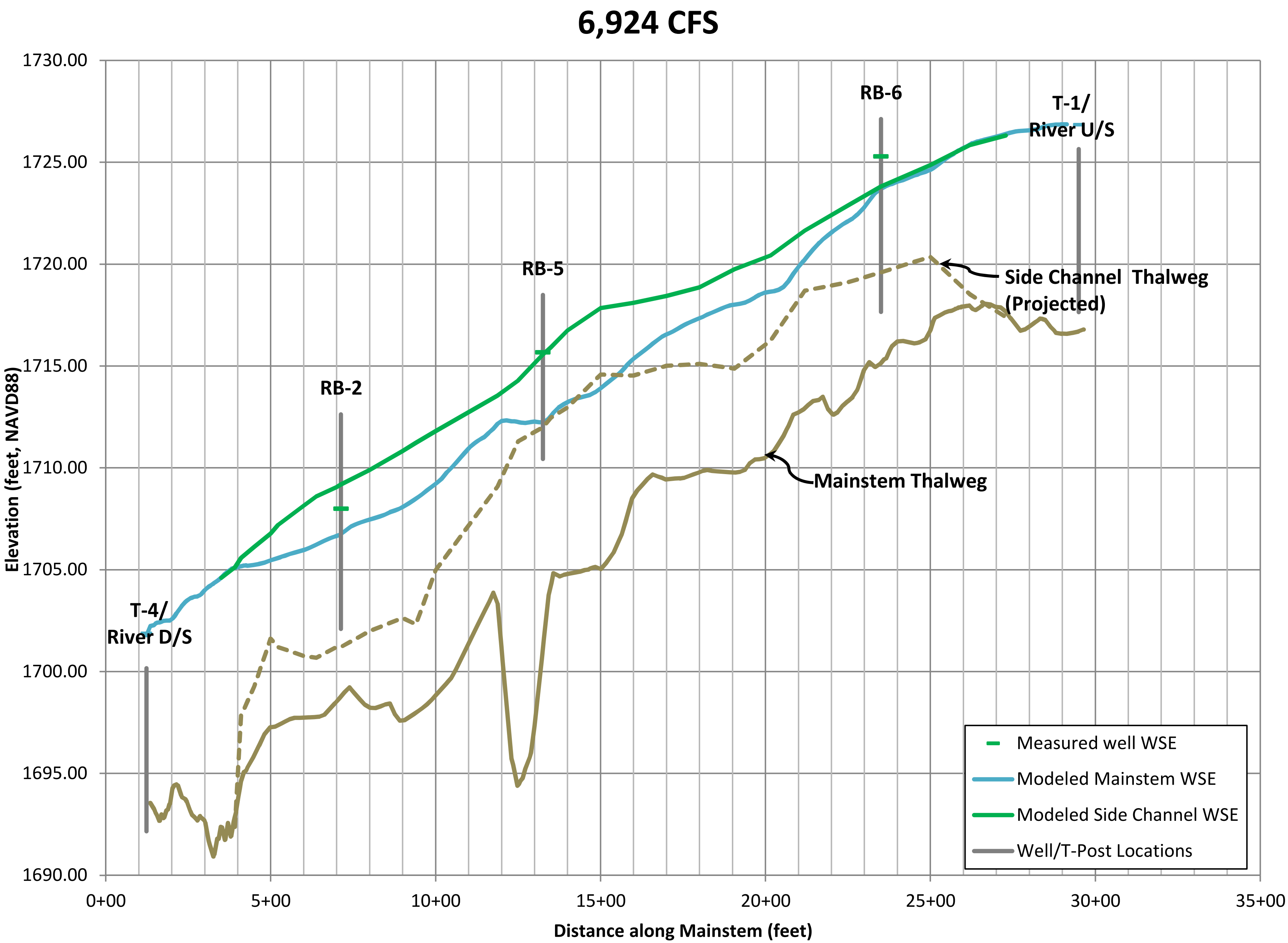

3/17/2016 1573 cfs
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
T-3
RB-2
RB-3
RB-4
RB-5
RB-1
T-2
RB-6
T-1/
River U/S
Side Channel
Thalweg (Projected)
Mainstem Thalweg
Measured well WSE
Measured T-Post WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations

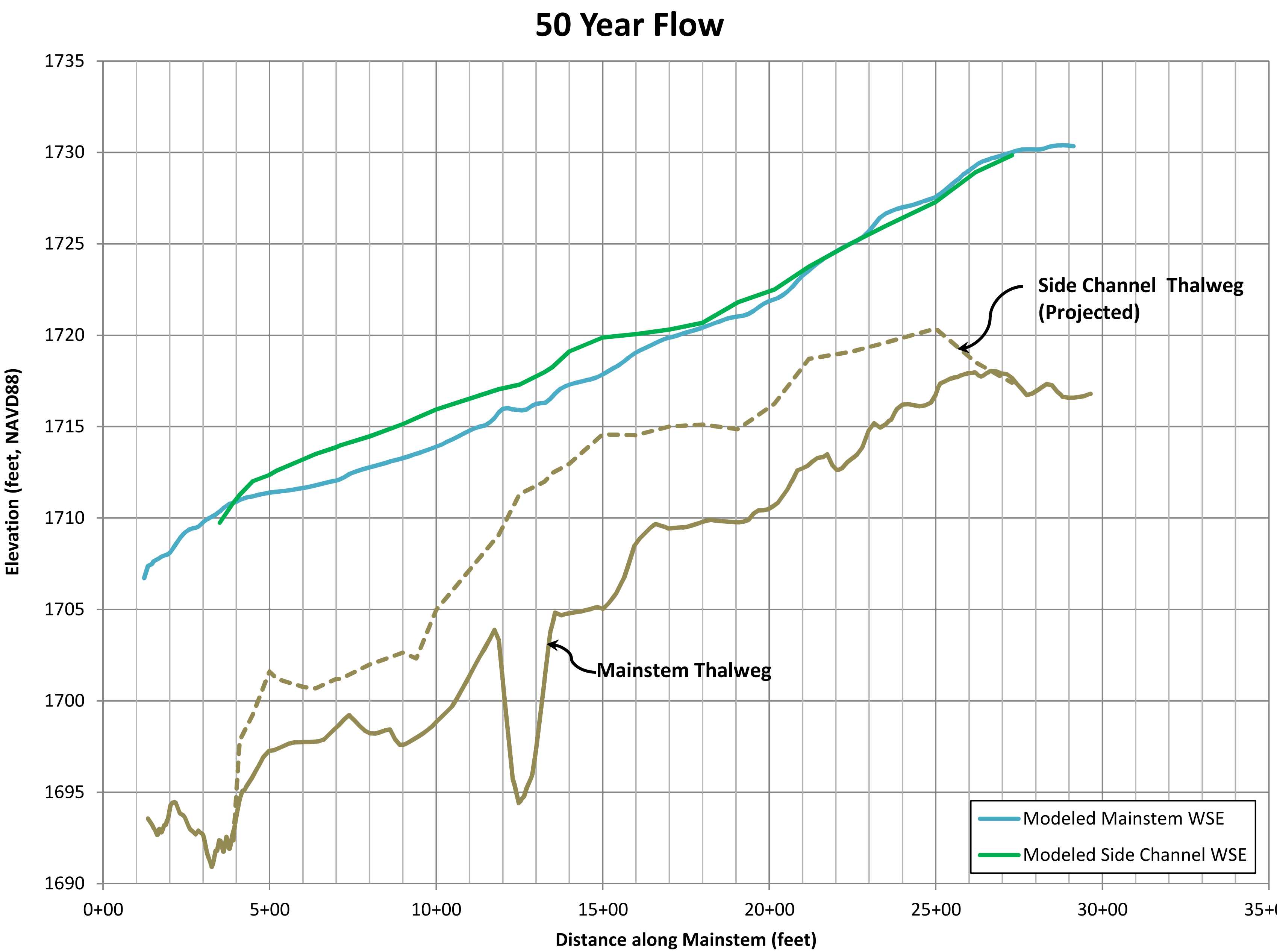


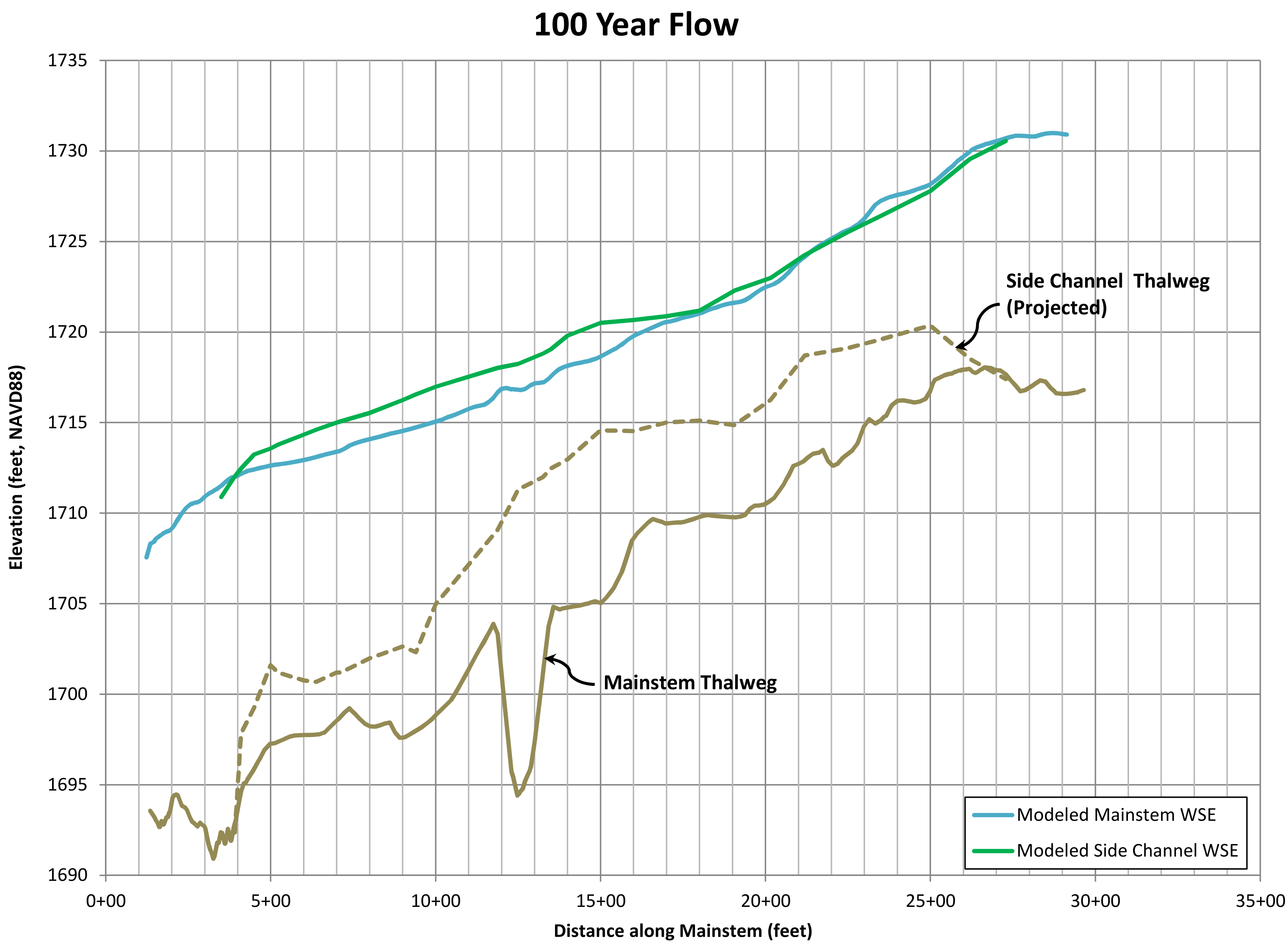
2,598 CFS
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
RB-2
RB-5
RB-6
T-1/
River U/S
Side Channel Thalweg
(Projected)
Mainstem Thalweg
Measured well WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations


3,785 CFS
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
RB-2
RB-5
RB-6
T-1/
River U/S
Side Channel
Thalweg (Projected)
Mainstem Thalweg
Measured well WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations


5,082 CFS
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
RB-2
RB-5
RB-6
T-1/
River U/S
Side Channel Thalweg
(Projected)
Mainstem Thalweg
Measured well WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations


6,924 CFS
1730.00
1725.00
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
T-4/
River D/S
RB-2
RB-5
RB-6
T-1/
River U/S
Side Channel Thalweg
(Projected)
Mainstem Thalweg
Measured well WSE
Modeled Mainstem WSE
Modeled Side Channel WSE
Well/T-Post Locations


50 Year Flow
1735
1730
1725
1720
1715
1710
1705
1700
1695
1690
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
Side Channel Thalweg (Projected)
Mainstem Thalweg
Modeled Mainstem WSE
Modeled Side Channel WSE



100 Year Flow
1735
1730
1725
1720
1715
1710
1705
1700
1695
1690
Elevation (feet, NAVD88)
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
Distance along Mainstem (feet)
Side Channel Thalweg (Projected)
Mainstem Thalweg
Modeled Mainstem WSE
Modeled Side Channel WSE

RB-1

Well Rim, Elev = 1722.53 ft

Note: time change on 11/01/15

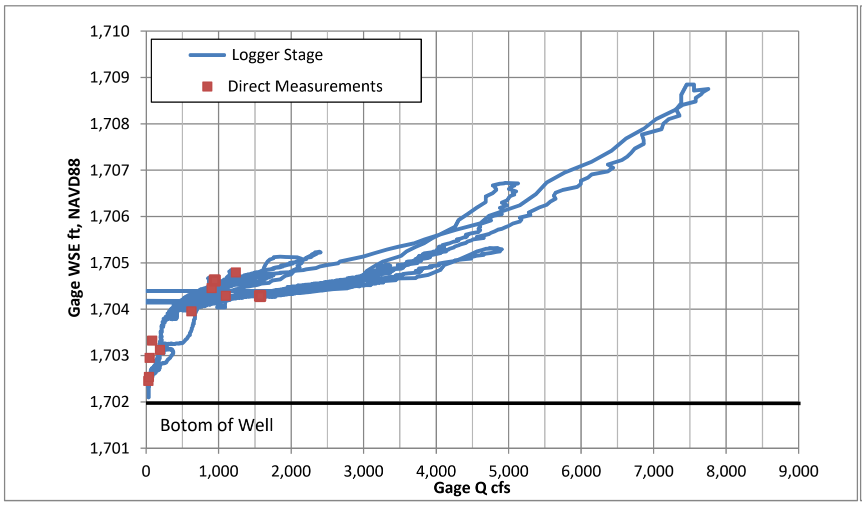
Date and Time (PST)	Date and Time (PDT)	Dist from Rim	WSEL	Notes
12/9/15 15:00	12/9/15 16:00	**6.50**	1716.03	
1/15/16 11:36	1/15/16 12:36	**6.83**	1715.69	
2/9/16 11:10	2/9/16 12:10	**6.83**	1715.69	
3/17/16 10:53	3/17/16 11:53	**6.25**	1716.28	
4/13/16 10:25	4/13/16 11:25	**7.08**	1715.44	
5/13/16 10:50	5/13/16 11:50	**7.92**	1714.61	
5/17/16 10:24	5/17/16 11:24			no data collected
6/17/16 12:06	6/17/16 13:06			DRY
7/18/16 11:00	7/18/16 12:00			Dry
8/11/16 9:45	8/11/16 10:45			Dry
9/14/16 10:20	9/14/16 11:20			Dry
10/12/16 15:00	10/12/16 16:00			Dry

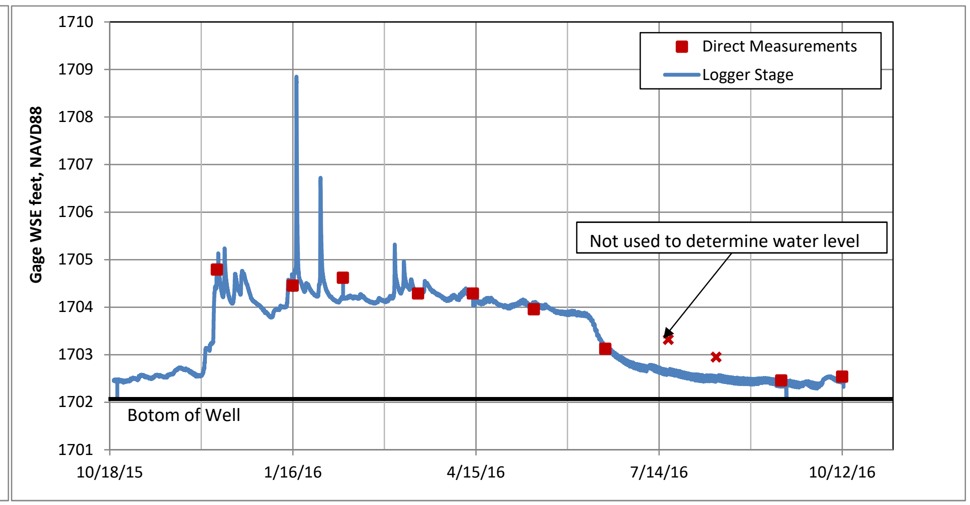
RB-2

Well Rim, Elev = 1712.62 ft

Note: data logger in PDT

Date and Time (PST)	Date and Time (PDT)	Dist from Rim	WSEL	Downloaded	Notes
12/9/15 15:00	12/9/15 16:00	7.83	1704.79	N	Difficult to see water
1/15/16 12:15	1/15/16 13:15	8.17	1704.45	Y	
2/9/16 12:11	2/9/16 13:11	8.00	1704.62	Y	reading appears to be off based on rest of hobo data
3/17/16 11:52	3/17/16 12:52	8.33	1704.29	Y	
4/13/16 11:10	4/13/16 12:10	8.33	1704.29	Y	
5/13/16 11:35	5/13/16 12:35	8.67	1703.95	Y	
5/17/16 10:24	5/17/16 11:24			N	
6/17/16 12:06	6/17/16 13:06	9.50	1703.12	Y	
7/18/16 11:00	7/18/16 12:00	9.30	1703.32	Y	
8/11/16 10:20	8/11/16 11:20	9.67	1702.95	Y	
9/14/16 11:25	9/14/16 12:25	10.17	1702.45	Y	
10/12/16 14:15	10/12/16 15:15	10.08	1702.54	Y	





RB-3

Well Rim, Elev = 1712.97 ft

Note: time change on 11/01/15

Date and Time (PST)	Date and Time (PDT)	Dist from Rim	WSEL	Notes
12/9/15 15:00	12/9/15 16:00	**5.17**	1707.80	
1/15/16 12:08	1/15/16 13:08	**5.58**	1707.38	
2/9/16 12:00	2/9/16 13:00	**6.75**	1706.22	
3/17/16 11:39	3/17/16 12:39	**6.00**	1706.97	
4/13/16 11:01	4/13/16 12:01	**5.92**	1707.05	
5/13/16 11:27	5/13/16 12:27	**6.75**	1706.22	
5/17/16 12:00	5/17/16 13:00			no data collected
6/17/16 13:00	6/17/16 14:00	**8.50**	1704.47	
7/18/16 11:00	7/18/16 12:00	**9.10**	1703.87	
8/11/16 10:05	8/11/16 11:05	9.42	1703.55	
9/14/16 11:15	9/14/16 12:15	9.25	1703.72	
10/12/16 16:00	10/12/16 17:00	9.25	1703.72	

RB-4

Well Rim, Elev = 1716.00 ft

Note: time change on 11/01/15

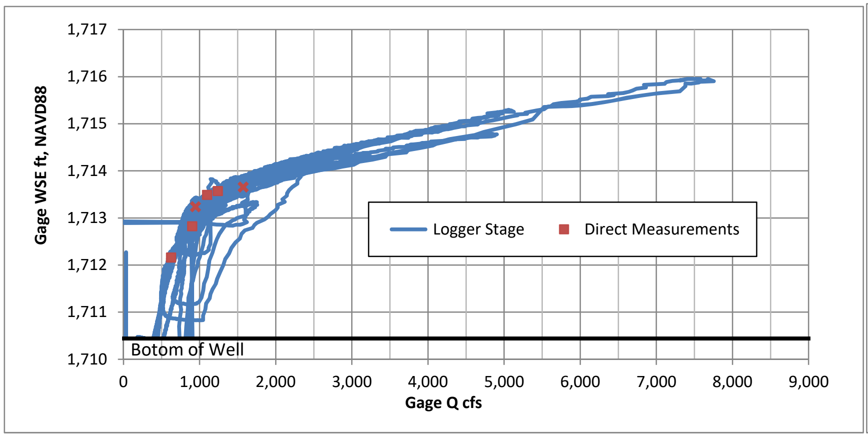
Date and Time (PST)	Date and Time (PDT)	Dist from Rim	WSEL	Notes
12/9/15 15:00	12/9/15 16:00	**5.33**	1710.66	
1/15/16 11:51	1/15/16 12:51	**6.25**	1709.75	
2/9/16 11:45	2/9/16 12:45	**5.83**	1710.16	
3/16/16 23:24	3/17/16 0:24	**5.50**	1710.50	
4/13/16 10:40	4/13/16 11:40	**5.58**	1710.41	
5/13/16 11:15	5/13/16 12:15	**6.50**	1709.50	
5/17/16 10:24	5/17/16 11:24			no data collected
6/17/16 11:53	6/17/16 12:53			DRY
7/18/16 11:00	7/18/16 12:00			Dry
8/11/16 10:00	8/11/16 11:00			Dry
9/14/16 11:10	9/14/16 12:10			Dry
10/12/16 15:00	10/12/16 16:00			Dry

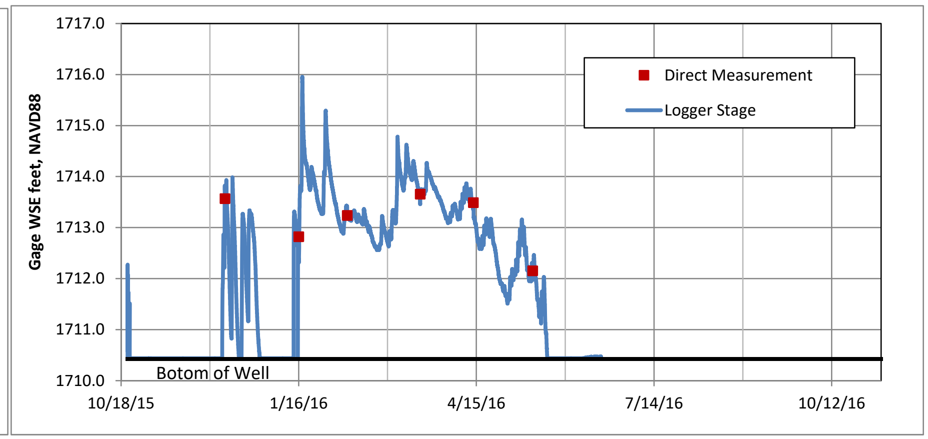
RB-5

Well Rim, Elev = 1718.49 ft

Note: data logger in PDT

Date and Time (PST)	Date and Time (PDT)	Dist from Rim	WSEL	Downloaded	Notes
12/9/15 15:00	12/9/15 16:00	4.92	1713.57	N	
1/15/16 11:43	1/15/16 12:43	5.67	1712.82	Y	
2/9/16 11:43	2/9/16 12:43	5.25	1713.24	N (ATTEMPT)	Attempted to dowload, but shuttle didn't work. Data Series parsed in two sets due to download on 2/20 (no stage data recorded at download).
3/17/16 11:09	3/17/16 12:09	4.83	1713.66	Y	
4/13/16 10:40	4/13/16 11:40	5.00	1713.49	Y	
5/13/16 11:10	5/13/16 12:10	6.33	1712.16	Y	
5/17/16 10:24	5/17/16 11:24			N	no data collected
6/17/16 11:47	6/17/16 12:47			Y	DRY - ATM data was collected on 5/17/2016 without filling out a data form, since the well is dry it cannot be calibrated from this end of the data.
7/18/16 11:00	7/18/16 12:00			Y	Dry
8/11/16 9:50	8/11/16 10:50			Y	Dry
9/14/16 11:05	9/14/16 12:05			Y	Dry
10/12/16 15:00	10/12/16 16:00			y	Dry



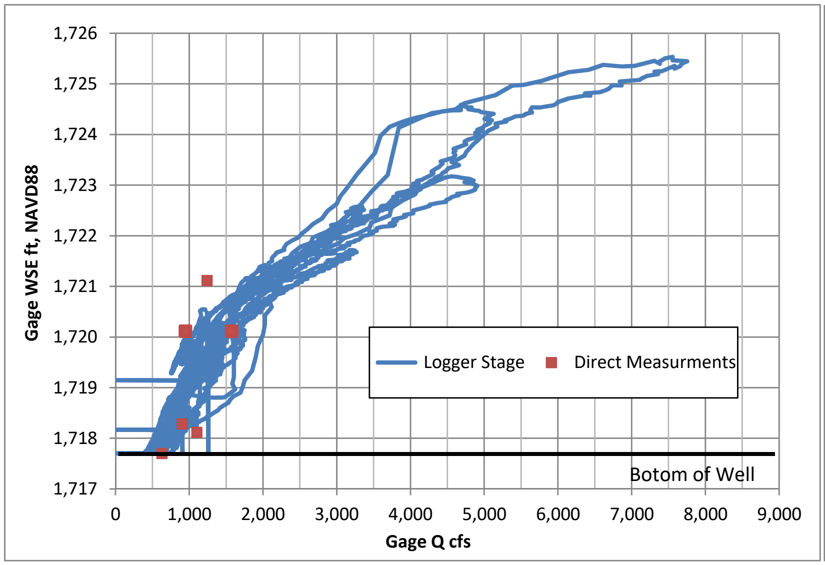


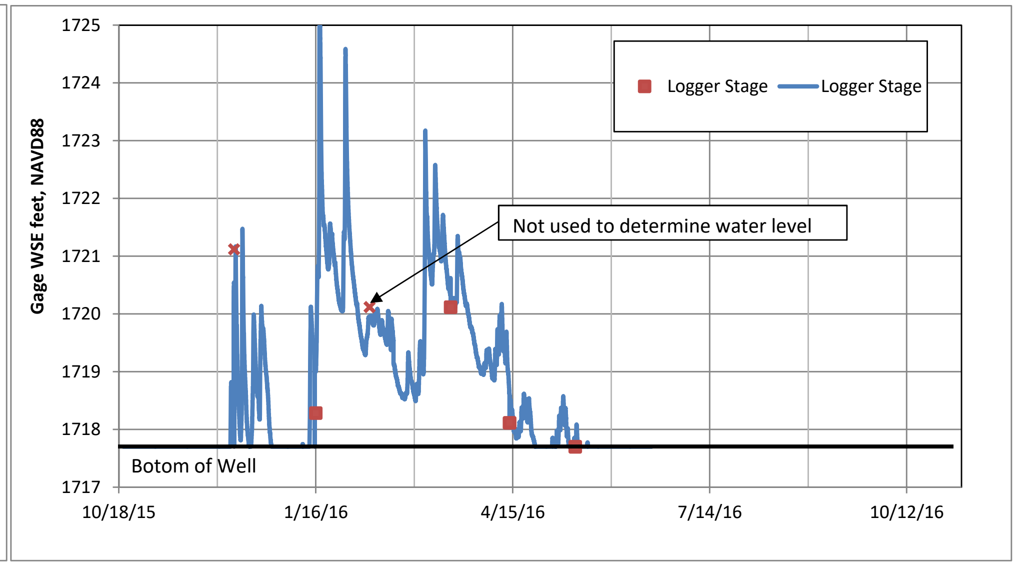
RB-6

Well Rim, Elev = 1727.12 ft

Note: data logger in PDT

Date and Time (PST)	Date and Time (PDT)	Dist from Rim	WSEL	Downloaded	Notes
12/9/15 15:00	12/9/15 16:00	6.00	1721.12	N	6 ft, Could not see water
1/15/16 11:00	1/15/16 12:00	8.83	1718.28	Y	could not see water
2/9/16 10:38	2/9/16 11:38	7.00	1720.12	N	7 ft, Approximate depth - PVC Bent a little bit, Data Series parsed in two sets due to download on 9/20 (no stage data recorded at download) data not used
3/17/16 10:23	3/17/16 11:23	7.00	1720.12	Y	7 feet, Best Guess "very hard to know"
4/13/16 9:52	4/13/16 10:52	9.00	1718.12	Y	
5/13/16 10:30	5/13/16 11:30	9.42	1717.70	Y	
5/17/16 10:24	5/17/16 11:24				no data collected
6/17/16 10:48	6/17/16 11:48			Y	DRY - Maybe 1" water. Called it dry 5/17 ATM data calibrated with WSE from previous data set and not an actual field measurement.
7/18/16 11:00	7/18/16 12:00			Y	Dry
8/11/16 9:30	8/11/16 10:30			Y	Dry
9/14/16 12:00	9/14/16 13:00			Y	Dry
10/11/16 23:00	10/12/16 0:00			Y	Dry



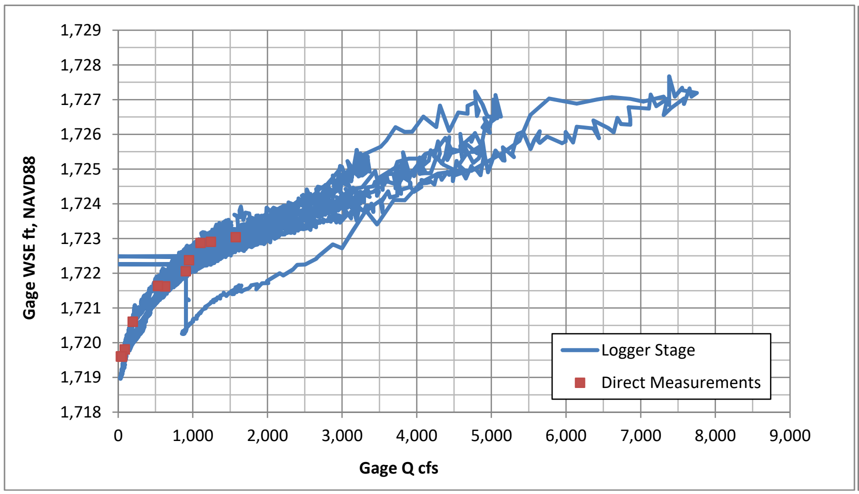


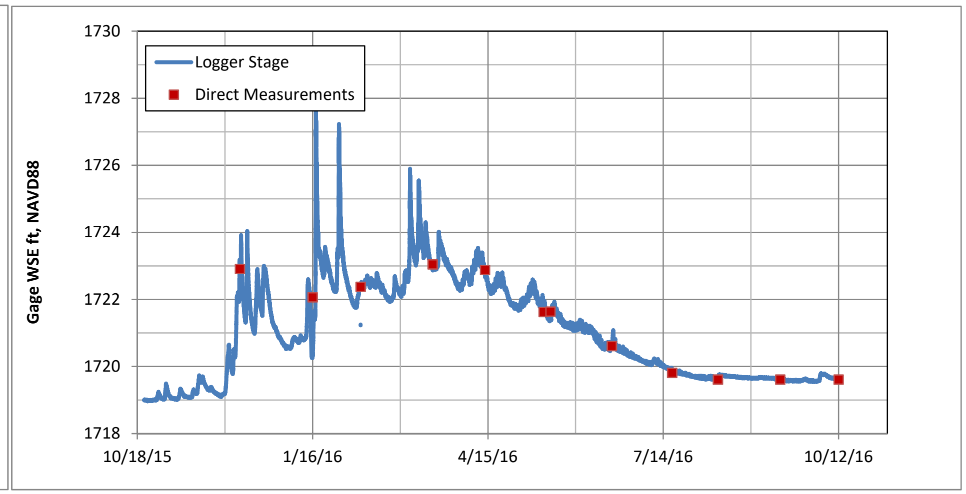
T-1/ US Hobo

Top of T-Post, Elev =	1723.21 ft	Post # 2, Elev	1720.505
		Post # 3, Elev	1719.693

Note: data logger in PDT

Date and Time (PST)	Date and Time (PDT)	Dist from T-Post Top	Obs WSE	Downloaded	Notes
12/9/15 14:32	12/9/15 15:32	0.30	1722.91	N	Collection time 02:32 to 6:02 PMLocal time
1/15/16 10:38	1/15/16 11:38	1.15	1722.06	Y	t post in water. Logger appears to have not gone to bottom of well, then slipped down at next flow peak.
2/9/16 12:25	2/9/16 13:25	0.83	1722.38	N	0.83 feeet, Data Series parsed in two sets due to download on 9/20 (no stage data recorded at download), post bent, data questionable.
3/17/16 9:45	3/17/16 10:45	0.17	1723.04	N	
4/13/16 9:20	4/13/16 10:20	0.33	1722.88	N	
5/13/16 9:30	5/13/16 10:30	1.58	1721.63	Y	
5/17/16 10:15	5/17/16 11:15	1.57	1721.64	N	No data sheet. Mike and Travis measured.
6/17/16 10:45	6/17/16 11:45	2.60	1720.61	Y	T post in water
7/18/16 11:00	7/18/16 12:00	3.40	1719.81	Y	
8/11/16 9:20	8/11/16 10:20	3.60	1719.61	Y	
9/14/16 12:45	9/14/16 13:45	3.60	1719.61	Y	
10/12/16 15:45	10/12/16 16:45	3.60	1719.61	Y	Out of water





T-2

Top of T-Post, Elev = 1717.40 ft

Note: time change on 11/01/15

Date and Time (PST)	Date and Time (PDT)	Dist from T-Post Top	Obs WSE	Notes
12/9/15 15:00	12/9/15 16:00	**2.60**	1714.80	
1/15/16 12:55	1/15/16 13:55	**3.29**	1714.11	
2/9/16 14:30	2/9/16 15:30	**2.83**	1714.57	bent
3/17/16 13:05	3/17/16 14:05	**2.75**	1714.65	
4/13/16 12:30	4/13/16 13:30	**2.80**	1714.60	
5/13/16 13:30	5/13/16 14:30	**3.50**	1713.90	
5/17/16 10:24	5/17/16 11:24	**3.67**	1713.73	ML and pT of MLA measurments, **pushed T-post upright**
6/17/16 13:00	6/17/16 14:00	**4.80**	1712.60	
7/18/16 11:00	7/18/16 12:00	**5.40**	1712.00	
8/11/16 12:25	8/11/16 13:25	5.82	1711.58	
9/20/16 16:48	9/20/16 17:48	7.38	1710.02	
10/12/16 15:30	10/12/16 16:30	7.38	1710.02	Reported not as a number, but as similar to last measurement

T-3

Top of T-Post, Elev = 1706.19 ft

Note: time change on 11/01/15

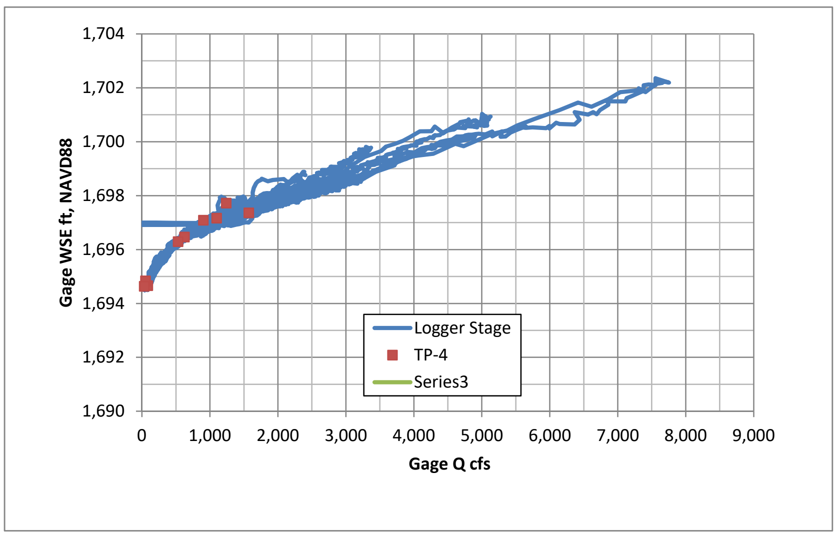
Date and Time (PST)	Date and Time (PDT)	Dist from T-Post Top	Obs WSE	Notes
12/9/15 15:00	12/9/15 16:00	4.90	1701.29	
1/15/16 9:55	1/15/16 10:55	5.42	1700.78	
2/9/16 15:10	2/9/16 16:10	5.08	1701.11	
3/17/16 13:43	3/17/16 14:43	4.80	1701.39	
4/13/16 13:00	4/13/16 14:00	5.00	1701.19	
5/13/16 13:00	5/13/16 14:00	5.60	1700.59	
5/17/16 13:04	5/17/16 14:04	5.66	1700.53	
6/17/16 13:20	6/17/16 14:20	6.60	1699.59	
7/18/16 11:00	7/18/16 12:00	7.00	1699.19	
8/12/16 11:50	8/12/16 12:50	7.16	1699.03	
9/20/16 16:30	9/20/16 17:30	6.02	1700.17	This is inconsistent with T-2, water level should not be rising yet.
10/12/16 15:00	10/12/16 16:00	6.02	1700.17	Reported not as a number, but as similar to last measurement

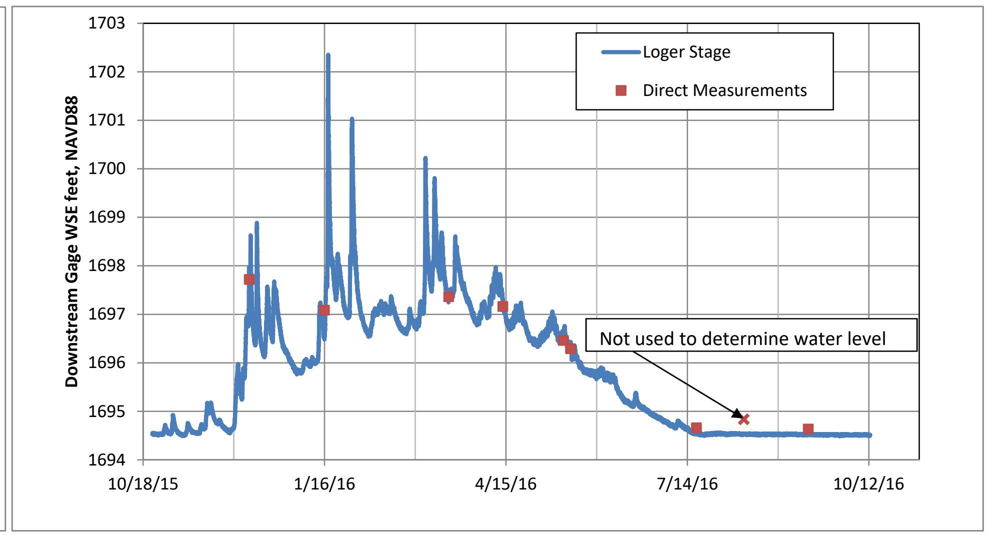
T-4/DS Hobo

Top of T-Post, Elev =	1700.42 ft	1696.4625	Top of Upper Surveyor Stake/rebar
		1694.936	Top of **LOWER** Surveyor Stake/rebar

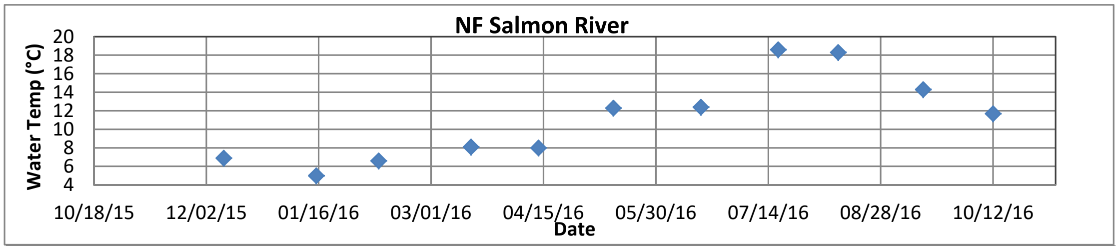
Note: data logger in PDT

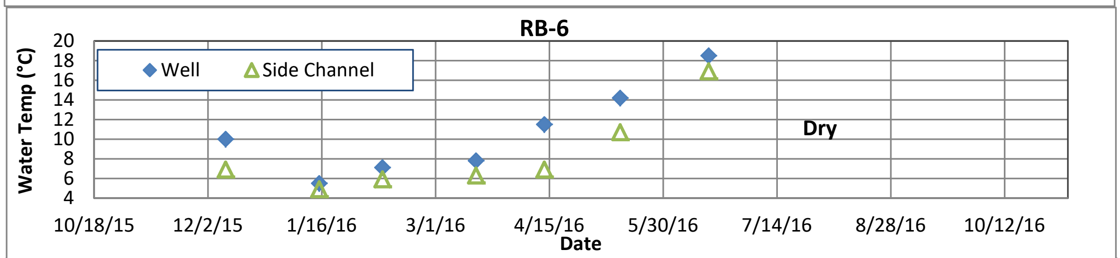
Date and Time (PST)	Date and Time (PDT)	Dist from T-Post Top	WSEL	Downloaded	Notes
12/9/15 16:02	12/9/15 17:02	2.70	1697.72	N	post in water, 2.7 feet from WSE to top of post, Collection time 14:32 to 6:02 Local time
1/15/16 9:46	1/15/16 10:46	3.33	1697.09	Y	
2/9/16 15:00	2/9/16 16:00			N-attempt to pull	T-Post Washed Away, logger stuck in sediment, attempt dislodged logger
3/17/16 13:30	3/17/16 14:30	-0.90	1697.36	N	Using Rebar Stake 1 at same location for WSE Measurements, logger stuck in sediment
4/13/16 13:12	4/13/16 14:12	-0.70	1697.16	N	measurment from stake 1, logger stuck in stediment
5/13/16 12:45	5/13/16 13:45	0.00	1696.46	N	measurment from stake 1, logger stuck in stediment
5/17/16 10:58	5/17/16 11:58	0.17	1696.29	Y	Well pulled to get sedimend and logger out. Reinstalled and elev. of logger likely changed. SURVEYED Debris line at 6.45 ft above the top of stake 1, WS in Pool 1.33 ft above stake 1, debris line at rt side pool 7.62 above stake 1, debris line at head of pool 8.04 ft above stake 1
6/17/16 13:30	6/17/16 14:30			Y	0.5 ft water depth at stake. Ground elevation unknown (not surveyed). **Point not usable**
7/18/16 11:00	7/18/16 12:00	1.80	1694.66	Y	from top of surveyors stake, Gage PVC almost out of water.
8/11/16 11:30	8/11/16 12:30	0.10	1694.84	Y	from top of LOWER rebar
9/14/16 12:00	9/14/16 13:00	0.30	1694.64	Y	
10/12/16 14:45	10/12/16 15:45			Y	"Bottom of rebar 3" out of water", comment could not be used for data calibration.

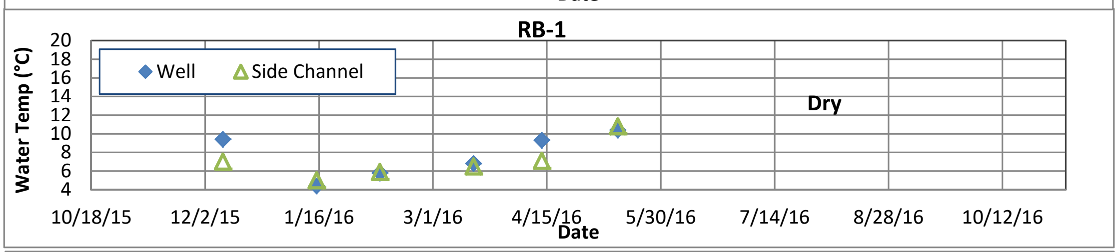


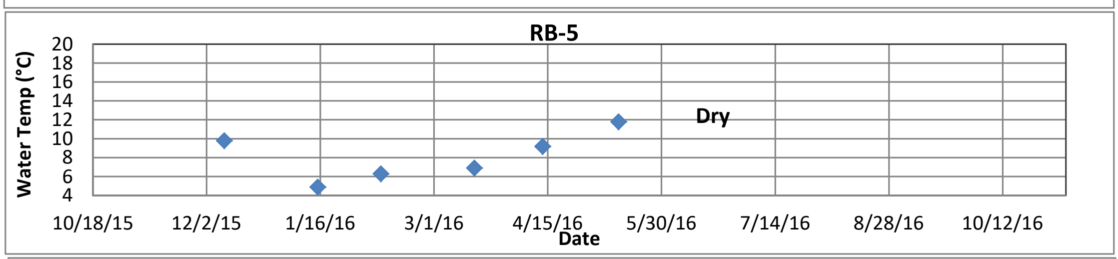


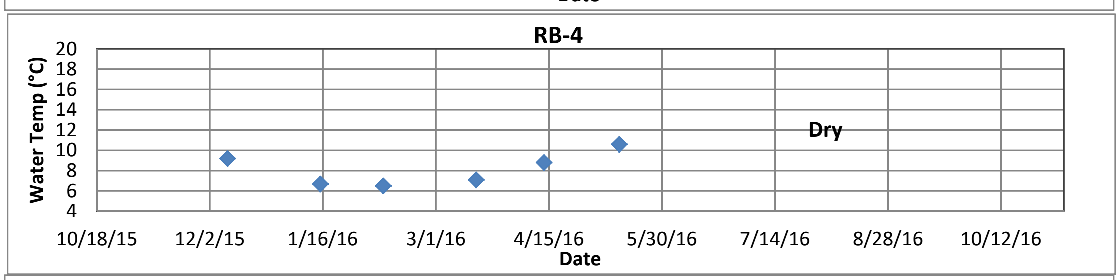
Appendix H
Water Quality Monitoring Results

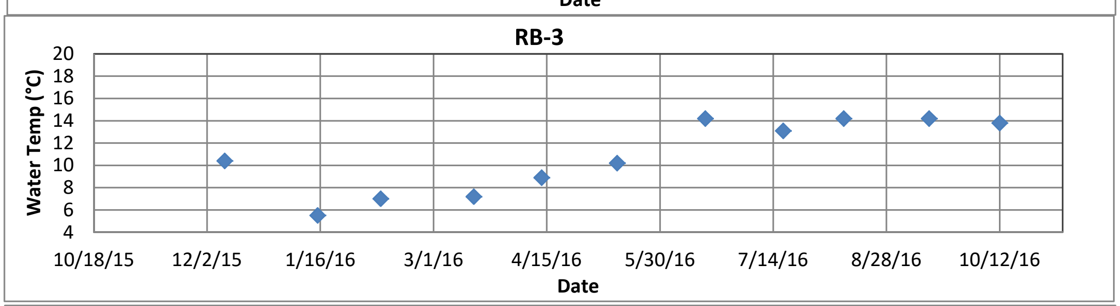

NF Salmon River
Water Temp (°C)
20 18 16 14 12 10 8 6 4
10/18/15 12/02/15 01/16/16 03/01/16 04/15/16 05/30/16 07/14/16 08/28/16 10/12/16
Date

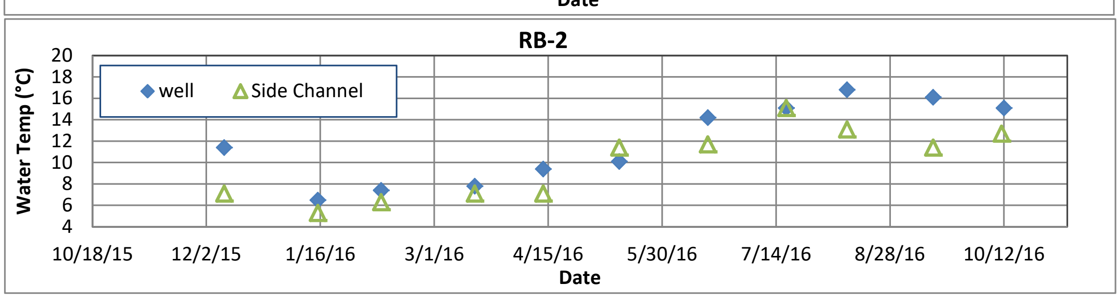

RB-6
Well
Side Channel
Water Temp (°C)
20 18 16 14 12 10 8 6 4
Dry
10/18/15 12/2/15 1/16/16 3/1/16 4/15/16 5/30/16 7/14/16 8/28/16 10/12/16
Date

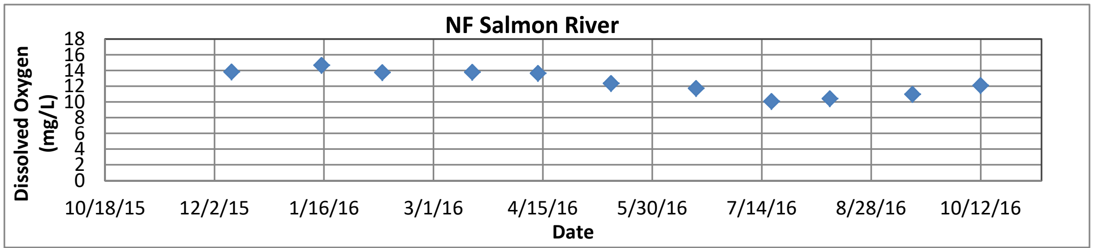

RB-1
Well
Side Channel
Water Temp (°C)
20 18 16 14 12 10 8 6 4
Dry
10/18/15 12/2/15 1/16/16 3/1/16 4/15/16 5/30/16 7/14/16 8/28/16 10/12/16
Date

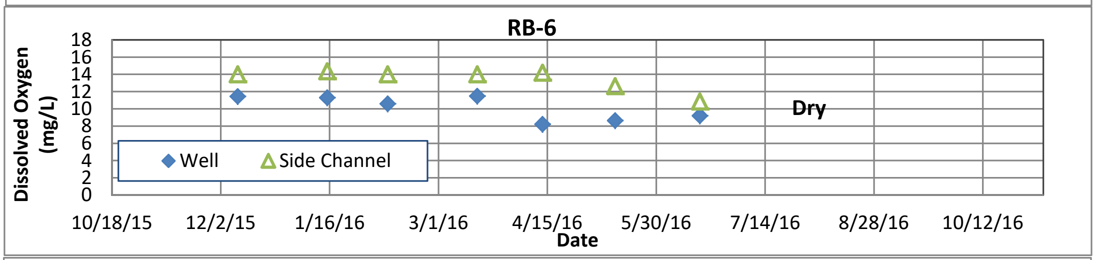

RB-5
Water Temp (°C)
20 18 16 14 12 10 8 6 4
Dry
10/18/15 12/2/15 1/16/16 3/1/16 4/15/16 5/30/16 7/14/16 8/28/16 10/12/16
Date

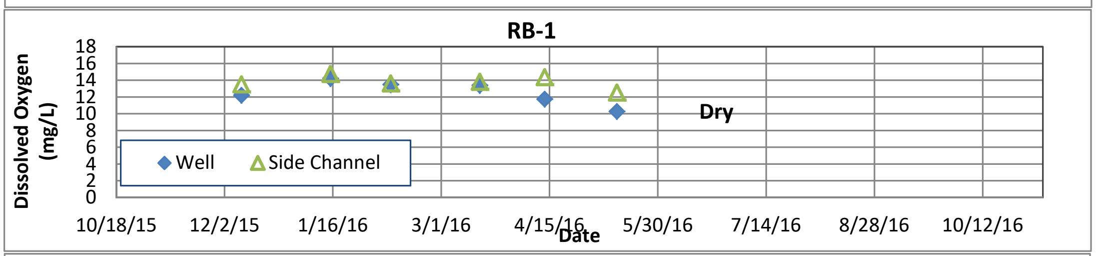

RB-4
Water Temp (°C)
20 18 16 14 12 10 8 6 4
Dry
10/18/15 12/2/15 1/16/16 3/1/16 4/15/16 5/30/16 7/14/16 8/28/16 10/12/16
Date

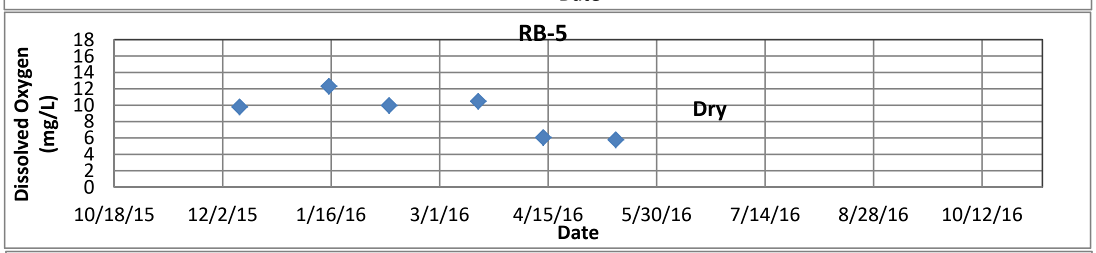

RB-3
Water Temp (°C)
20 18 16 14 12 10 8 6 4
10/18/15 12/2/15 1/16/16 3/1/16 4/15/16 5/30/16 7/14/16 8/28/16 10/12/16
Date

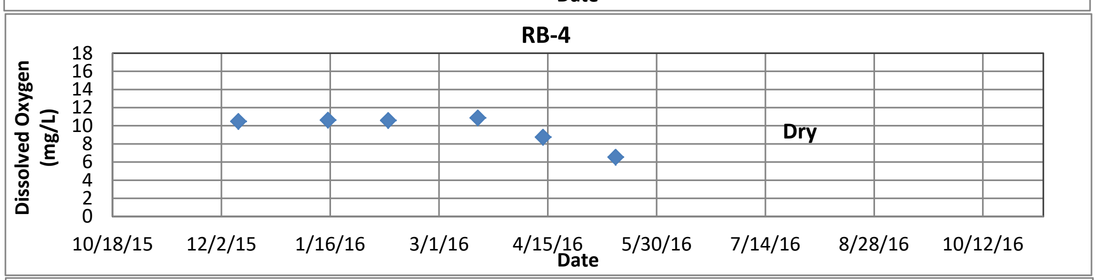

RB-2
well
Side Channel
Water Temp (°C)
20 18 16 14 12 10 8 6 4
10/18/15 12/2/15 1/16/16 3/1/16 4/15/16 5/30/16 7/14/16 8/28/16 10/12/16
Date

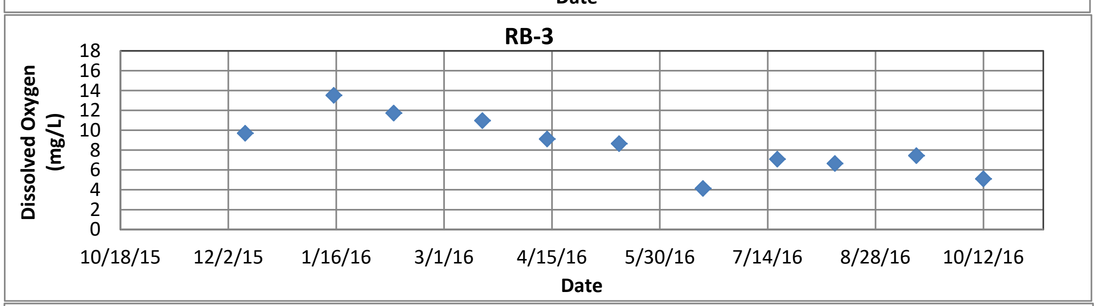

NF Salmon River
Dissolved Oxygen (mg/L)
Date

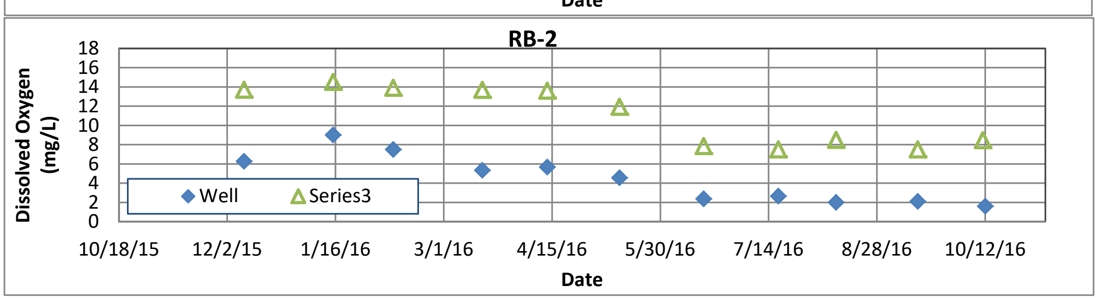

RB-6
Dissolved Oxygen (mg/L)
Well
Side Channel
Dry
Date


RB-1
Dissolved Oxygen (mg/L)
Well
Side Channel
Dry
Date


RB-5
Dissolved Oxygen (mg/L)
Dry
Date


RB-4
Dissolved Oxygen (mg/L)
Dry
Date


RB-3
Dissolved Oxygen (mg/L)
Date


RB-2
Dissolved Oxygen (mg/L)
Well
Series3
Date

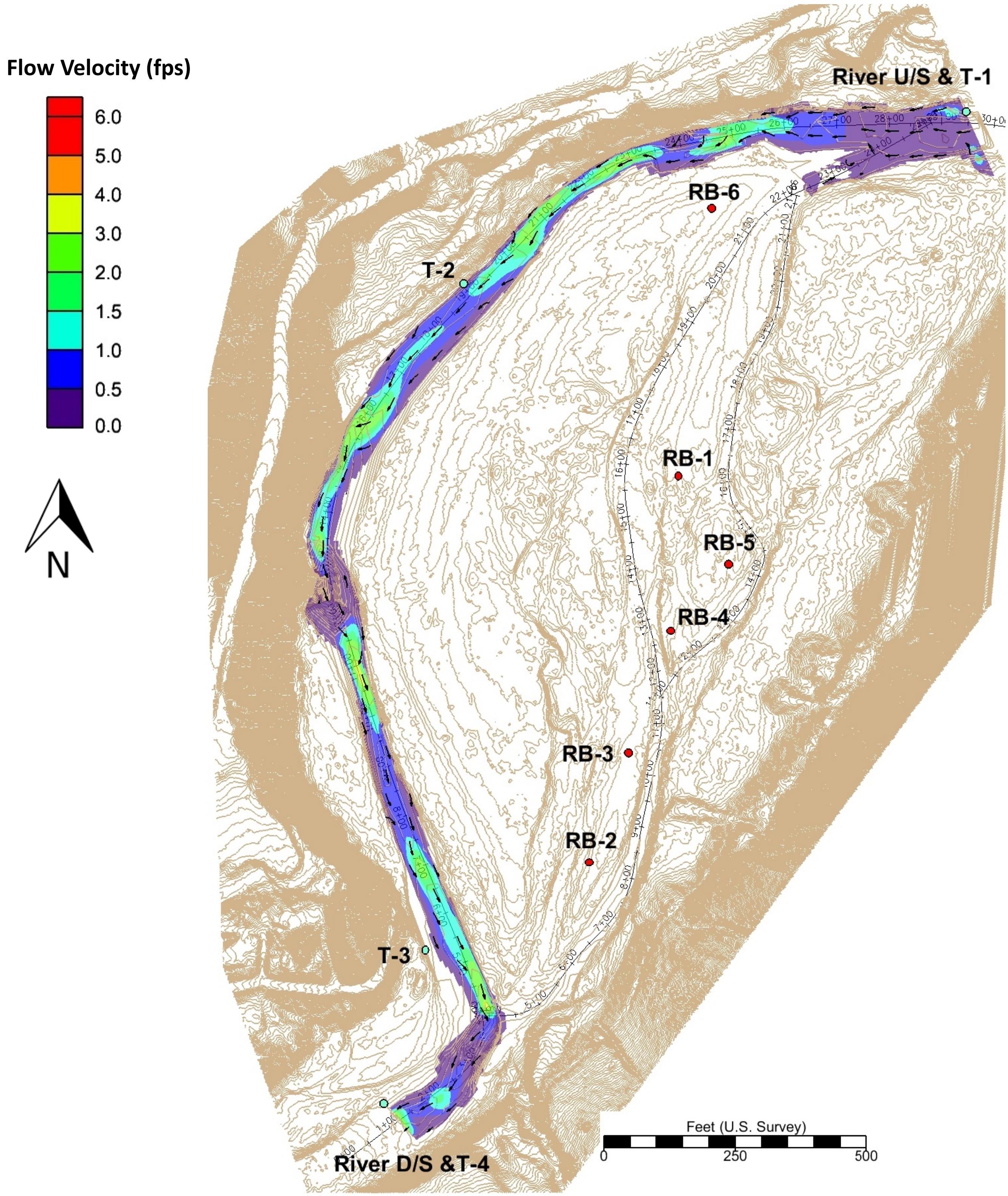
	Date	Water Temp (°C)	Dissolved Oxygen (mg/L)	Max. Depth (ft)	
RB1-Side Channel	12/9/2015	7.0	13.50	1.8	
	1/15/2016	5.0	14.75	1.1	
	2/9/2016	5.9	13.62	2.4	
	3/17/2016	6.5	13.80	2	
	4/13/2016	7.1	14.36	1.4	
	5/13/2016	10.8	12.53	1.6	
	6/17/2016			0	Dry
	7/18/2016			0	Dry
	8/11/2016			0	Dry
	9/14/2016			0	Dry
	10/12/2016			0	Dry

				Max Depth (ft)
RB2-Side Channel	12/9/2015	7.1	13.70	2.5
	1/15/2016	5.3	14.51	1.6
	2/9/2016	6.3	13.90	2.6
	3/17/2016	7.10	13.68	1.8
	4/13/2016	7.1	13.60	1.9
	5/13/2016	11.4	11.92	1.6
	6/17/2016	11.7	7.84	0.9
	7/18/2016	15.1	7.50	0.5
	8/11/2016	13.1	8.48	0.6
	9/14/2016	11.4	7.49	0.8
	10/11/2016	12.7	8.45	1

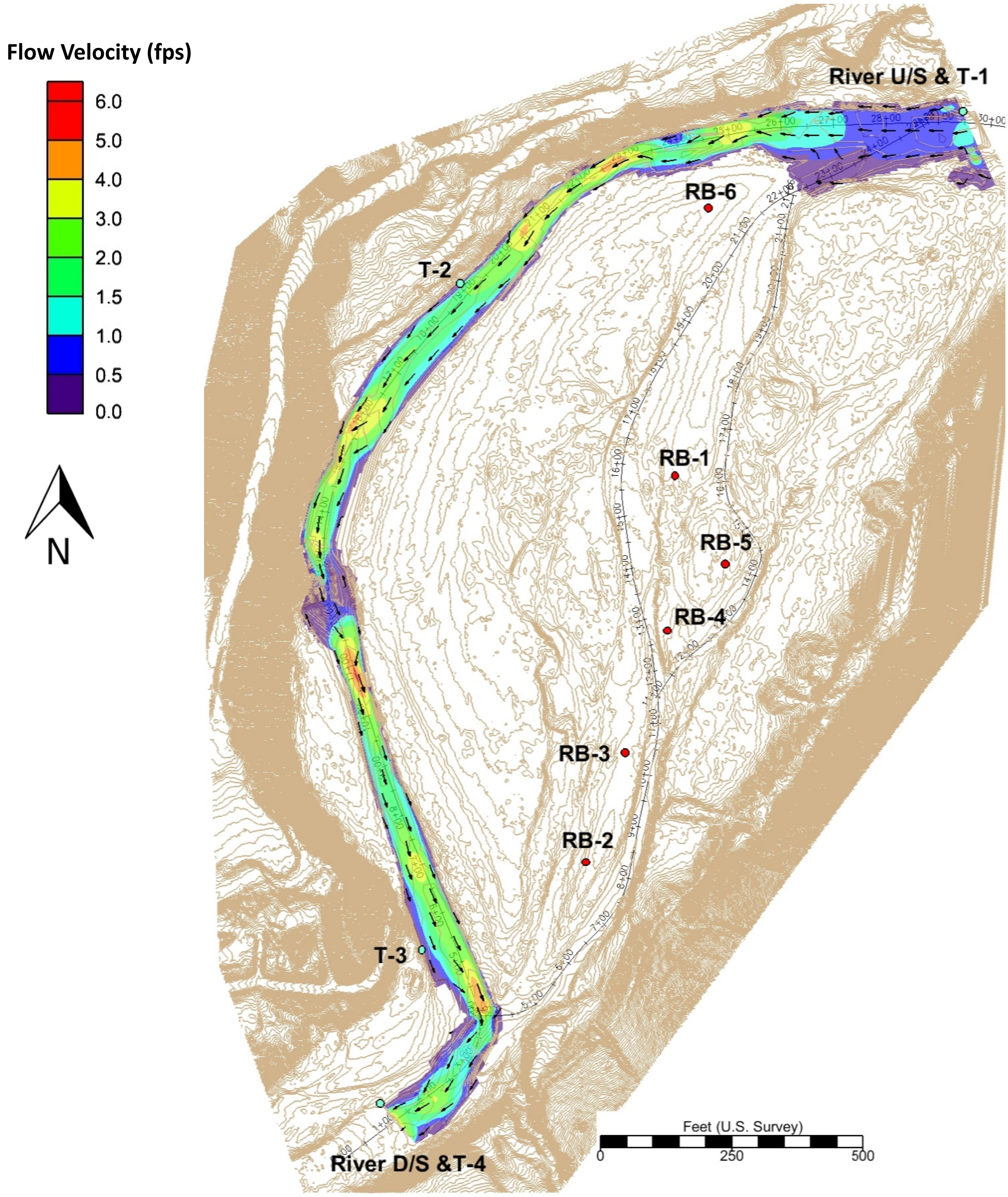
				Max Depth (ft)	
RB6-Side Channel	12/9/2015	6.9	14.00	3	
	1/15/2016	4.9	14.35	2.1	
	2/9/2016	5.90	14.00	2.6	
	3/17/2016	6.3	14.00	3	
	4/13/2016	6.90	14.20	2.5	
	5/13/2016	10.70	12.64	1.7	
	6/17/2016	16.90	10.85	0.2	
	7/18/2016			0	Dry
	8/11/2016			0	Dry
	9/14/2016			0	Dry
	10/12/2016			0	Dry

Appendix I
Existing Condition 2-D Modeling Results

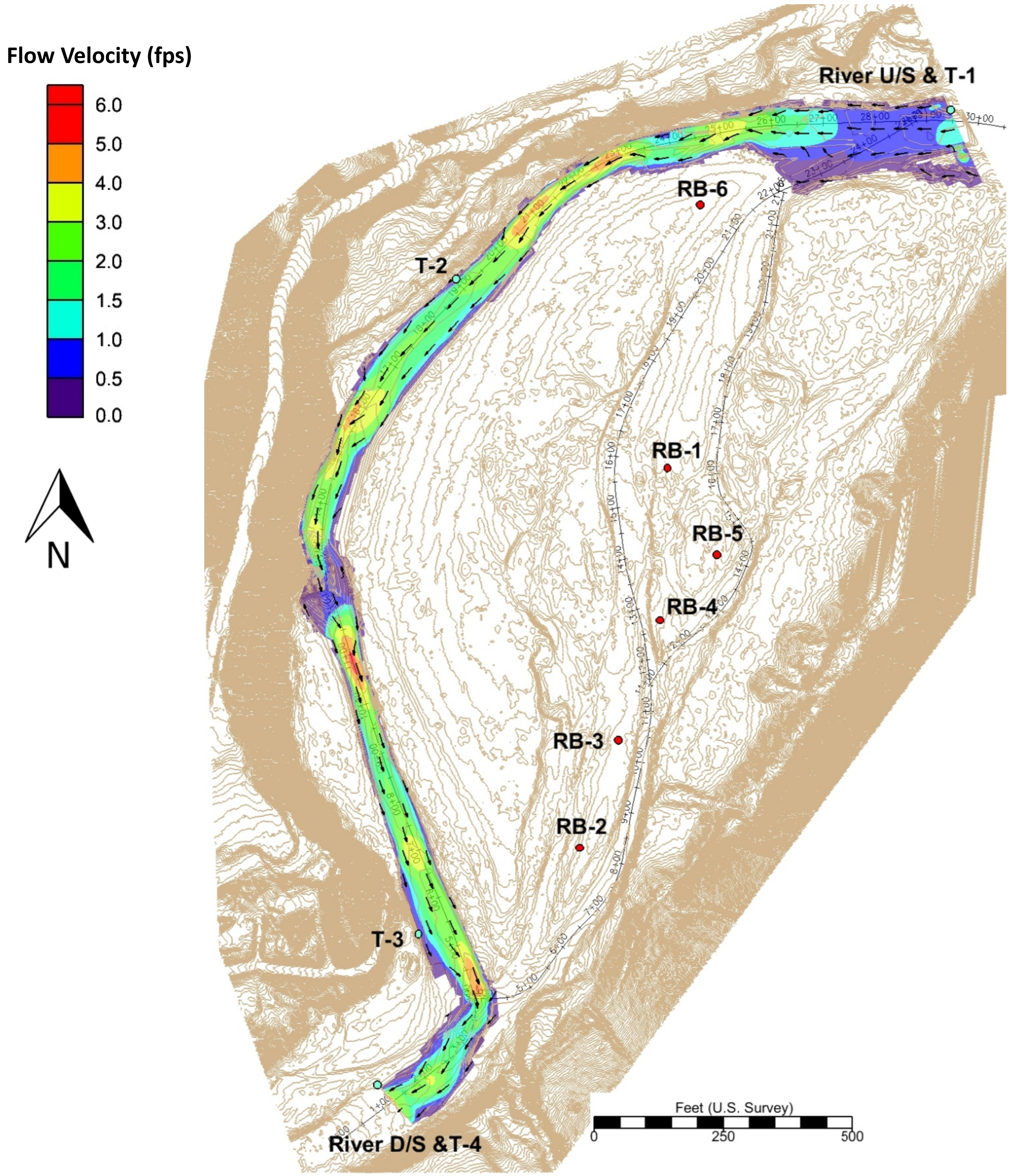
Red Bank Bar
Existing Conditions
34 cfs (83% Exceedance) (182 cfs at Somes Bar Gage)



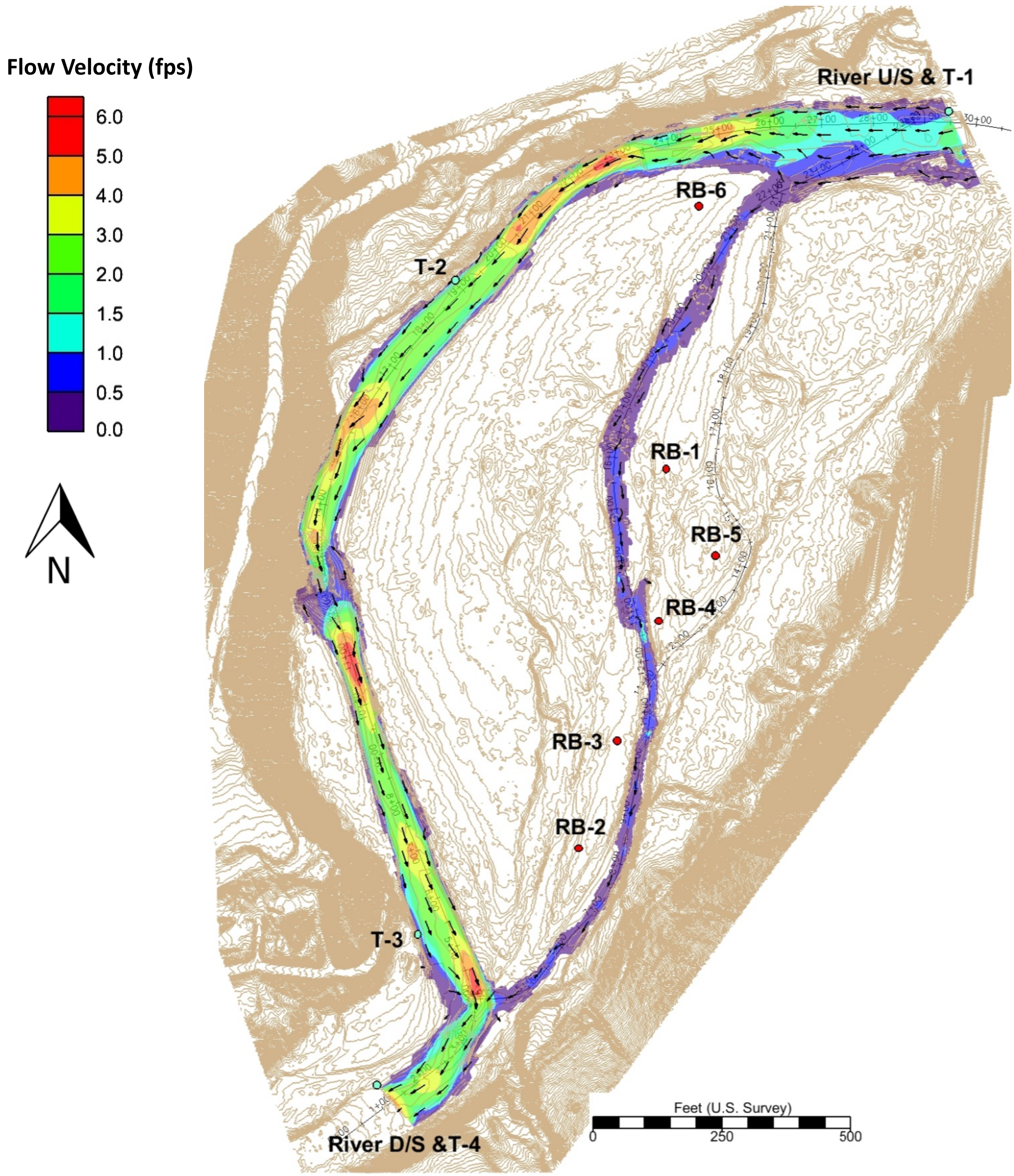
Red Bank Bar
Existing Conditions
193 cfs (55% Exceedance) (782 cfs at Somes Bar Gage)



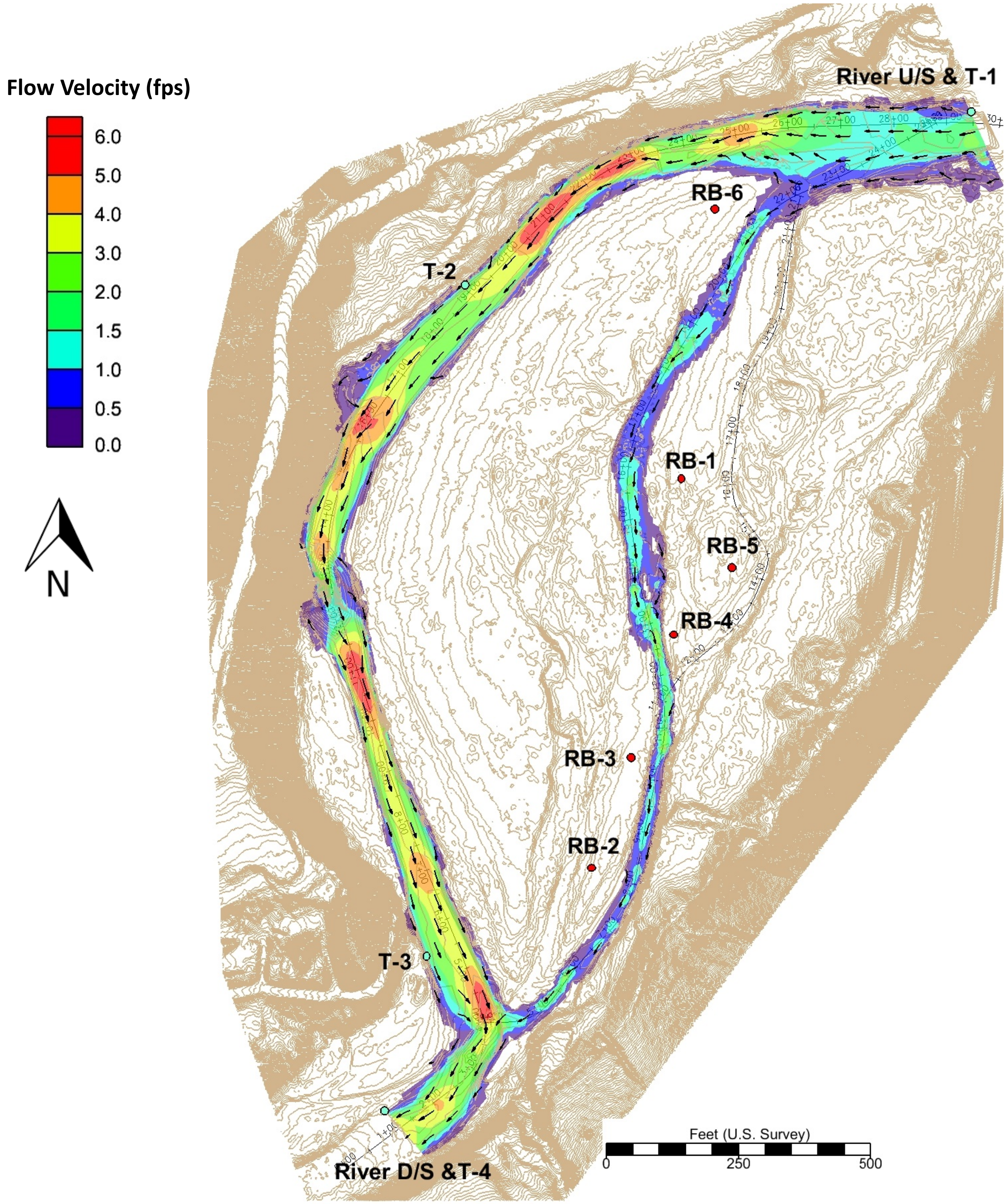
Red Bank Bar
Existing Conditions
220 cfs (50% Exceedance) (902 cfs at Somes Bar Gage)



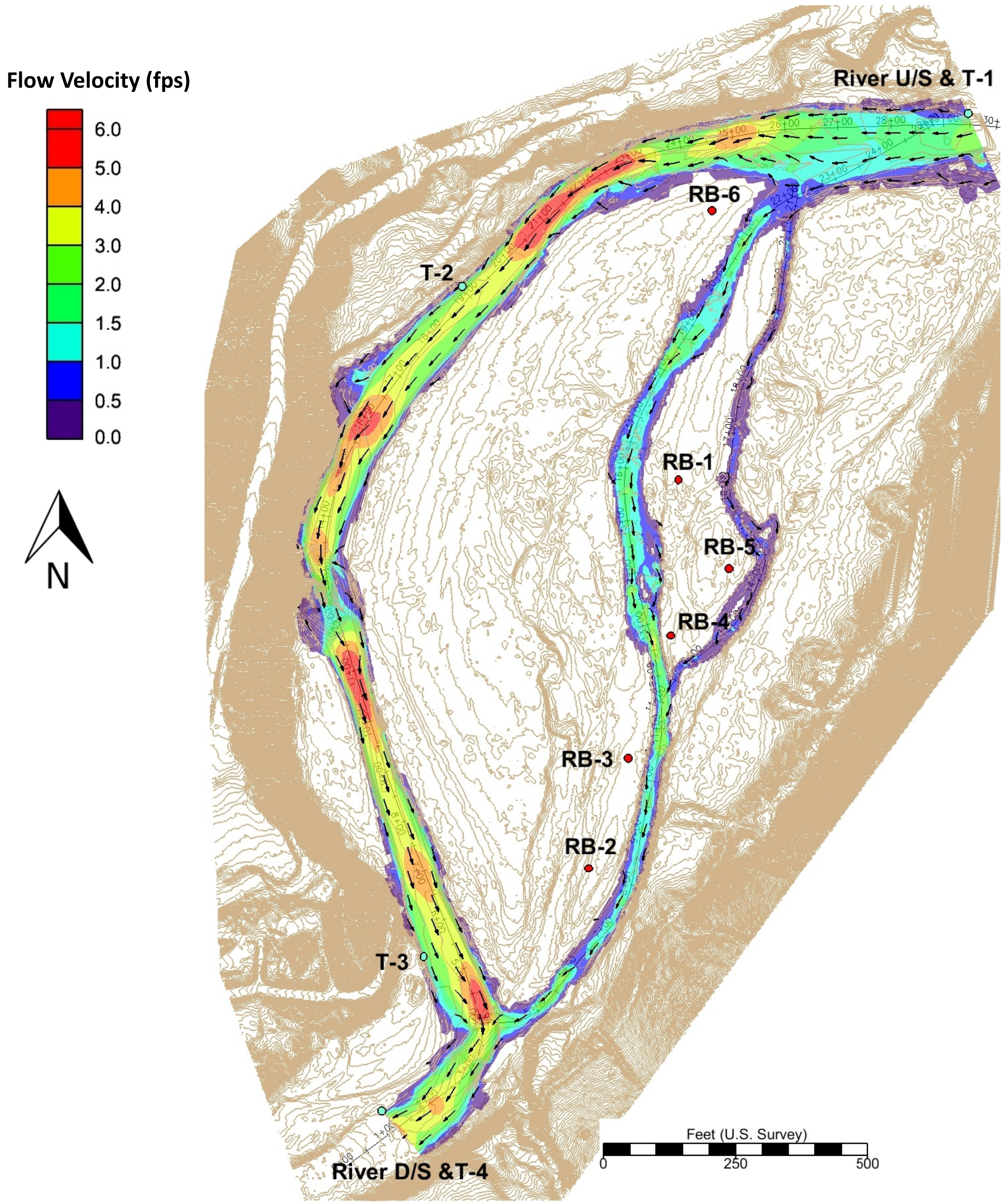
Red Bank Bar
Existing Conditions
350 cfs (36% Exceedance) (1,435 cfs at Somes Bar Gage)



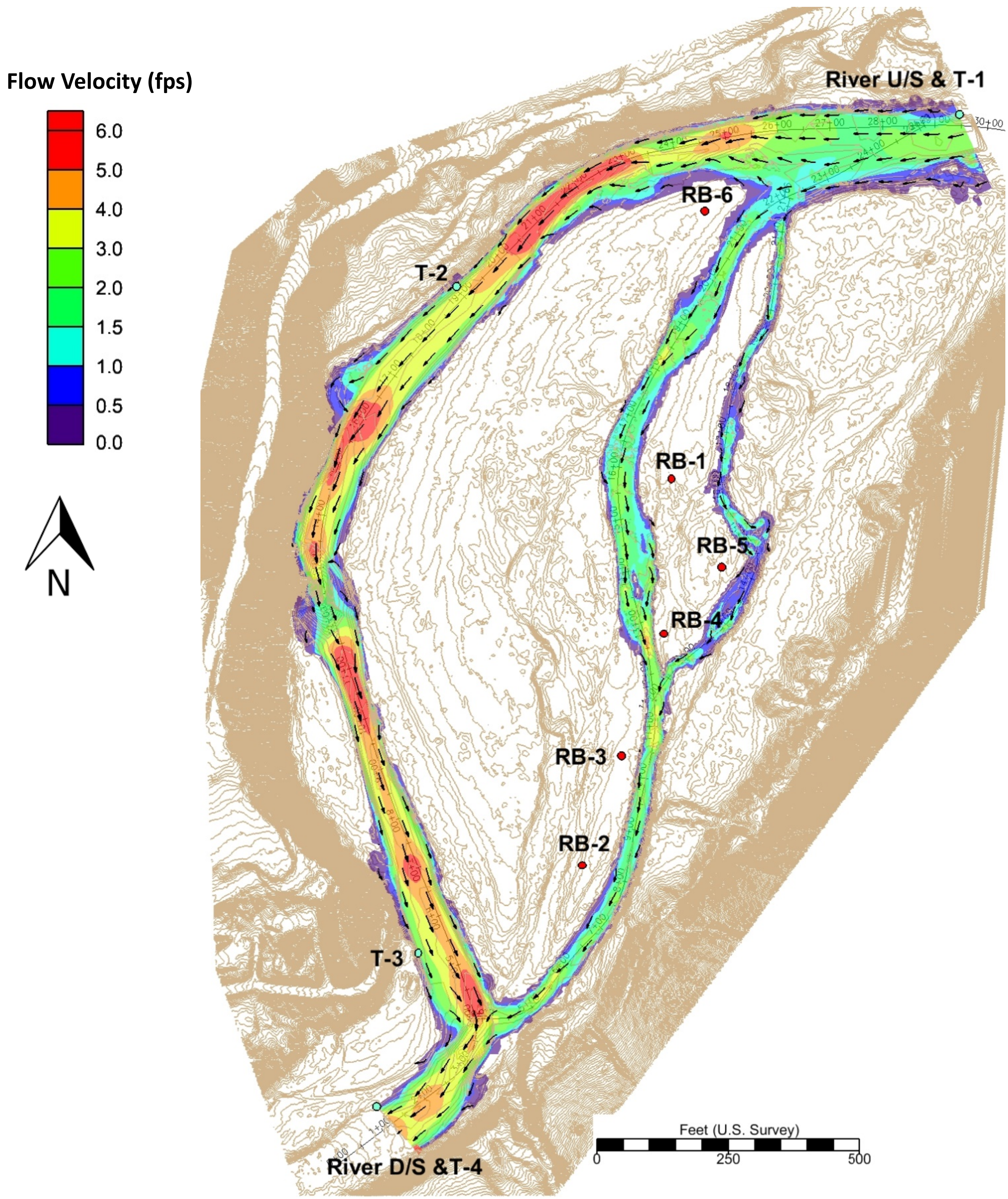
Red Bank Bar
Existing Conditions
532 cfs (23% Exceedance) (2,050 cfs at Somes Bar Gage)



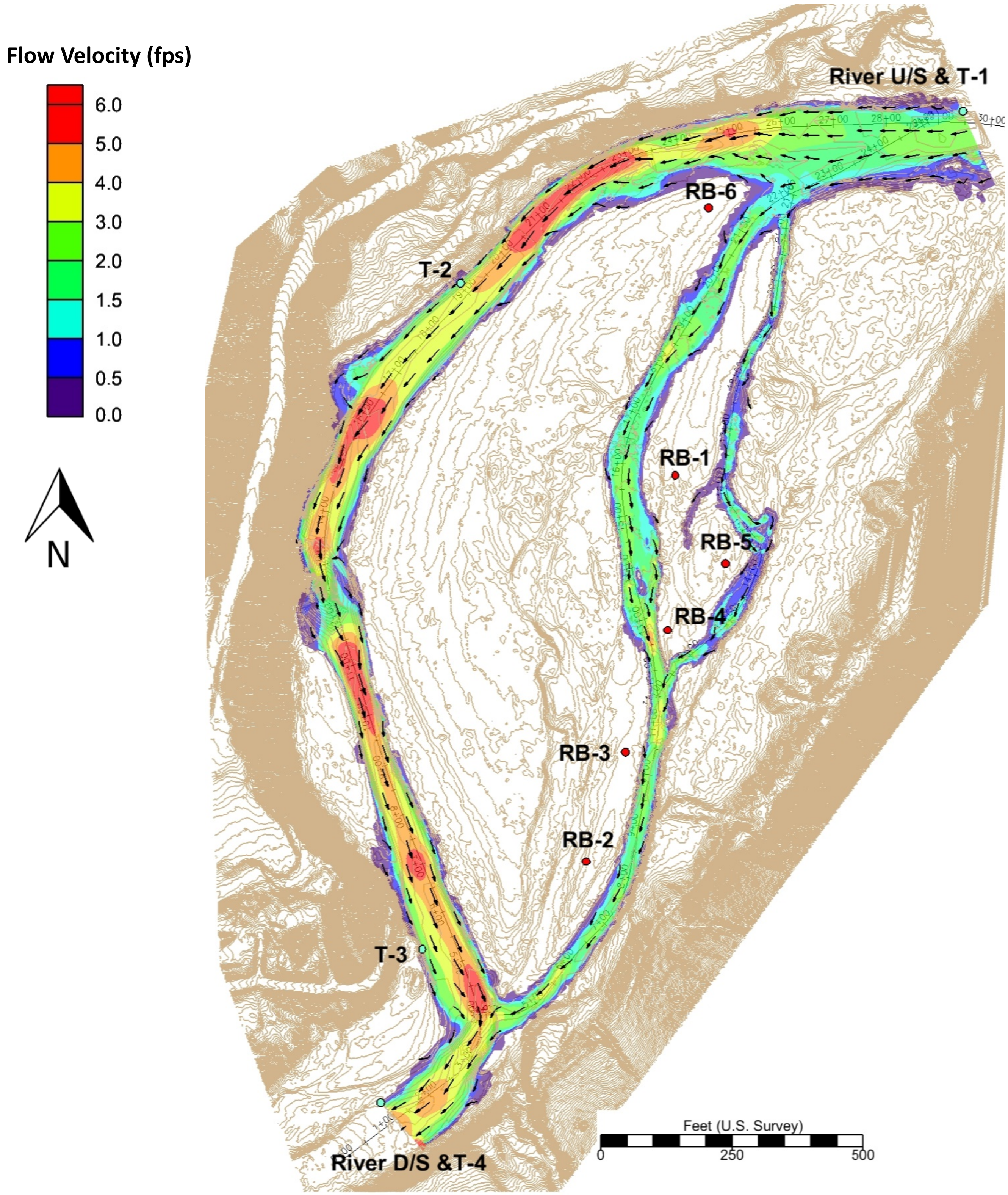
Red Bank Bar
Existing Conditions
627 cfs (16% Exceedance) (2,560 cfs at Somes Bar Gage)



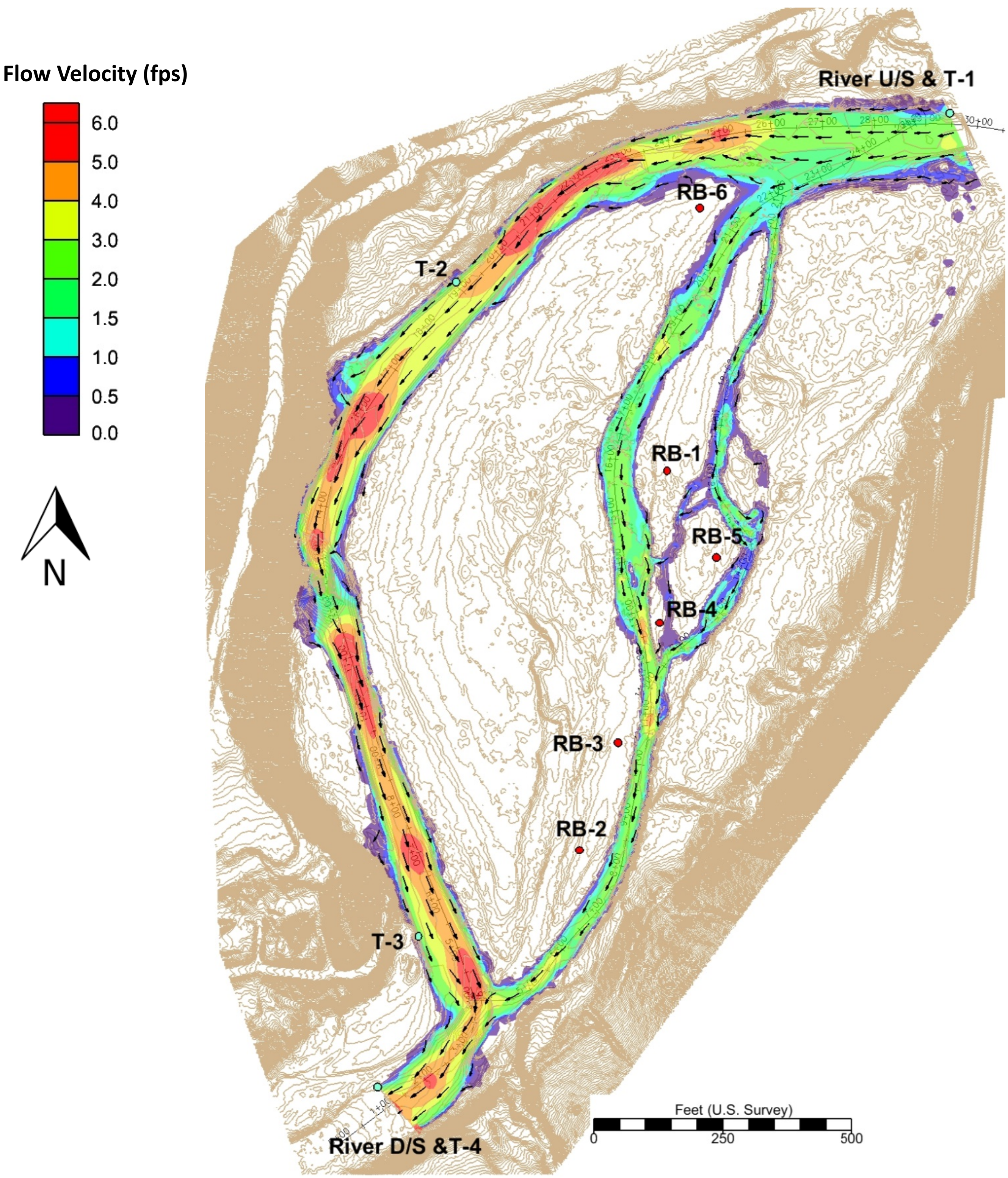
Red Bank Bar
Existing Conditions
903 cfs (8% Exceedance) (3,520 cfs at Somes Bar Gage)



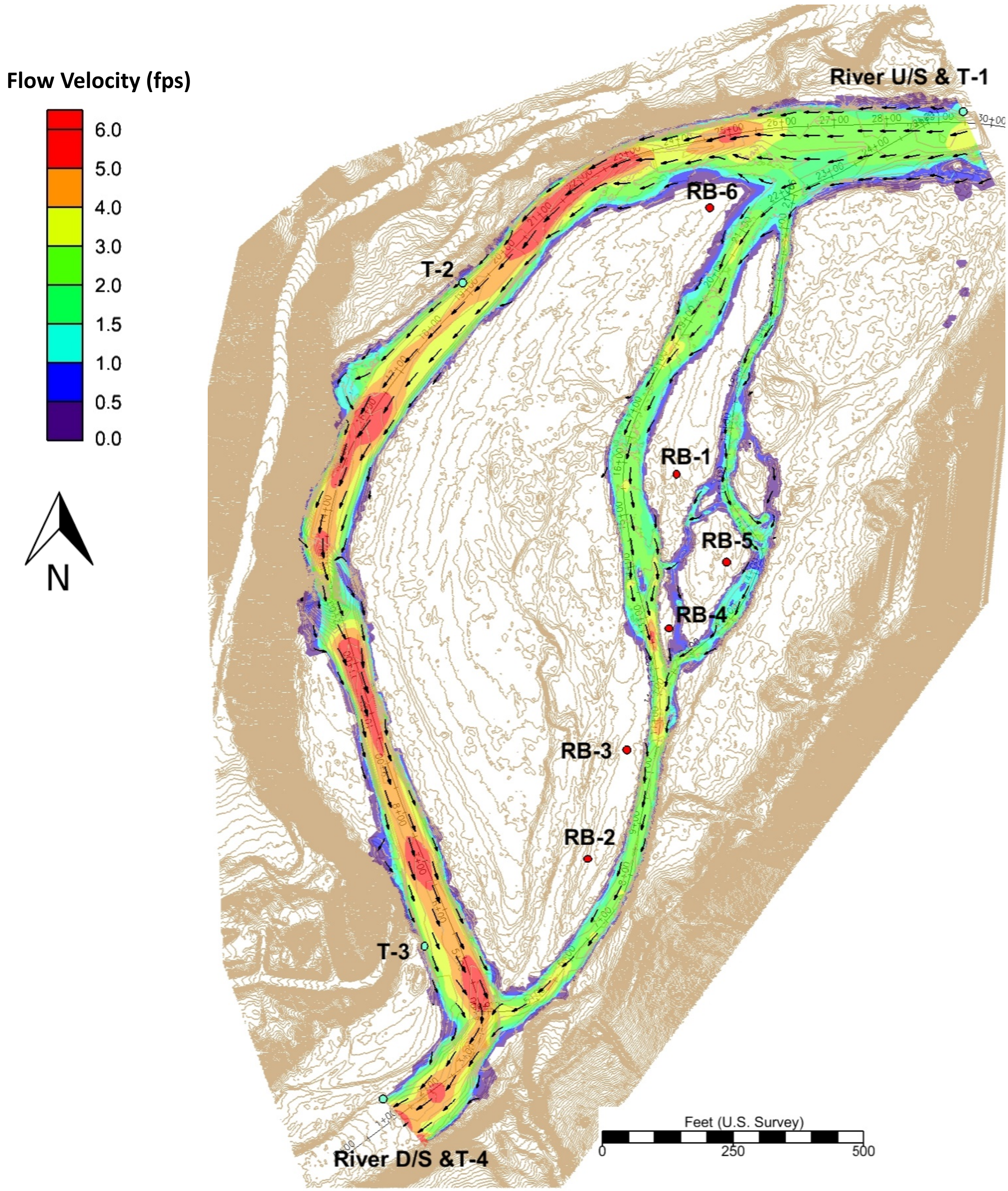
Red Bank Bar
Existing Conditions
944 cfs (8% Exceedance) (3,840 cfs at Somes Bar Gage)



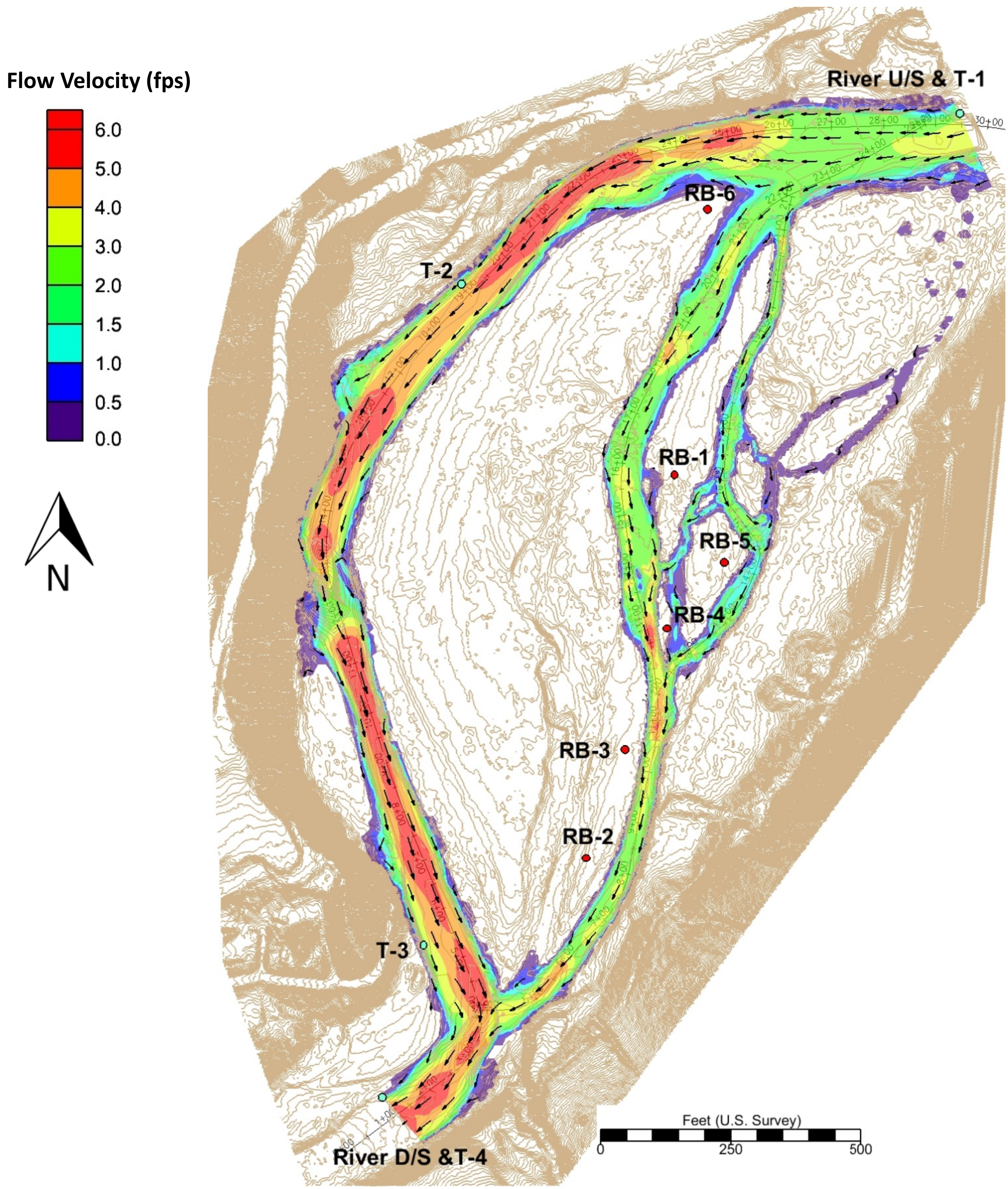
Red Bank Bar
Existing Conditions
1,100 cfs (5.5% Exceedance) (4,420 cfs at Somes Bar Gage)



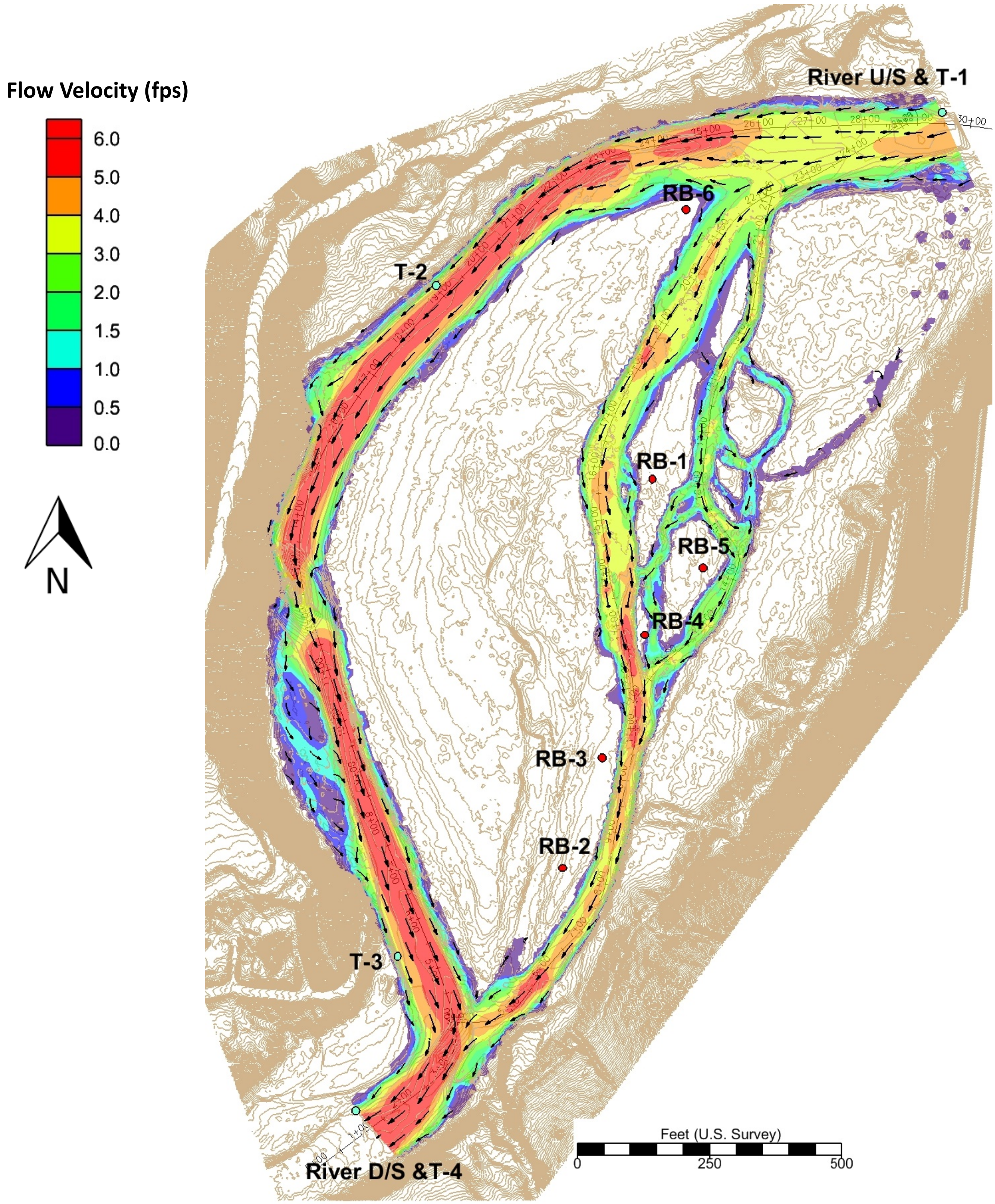
Red Bank Bar
Existing Conditions
1,240 cfs (4% Exceedance) (5,090 cfs at Somes Bar Gage)



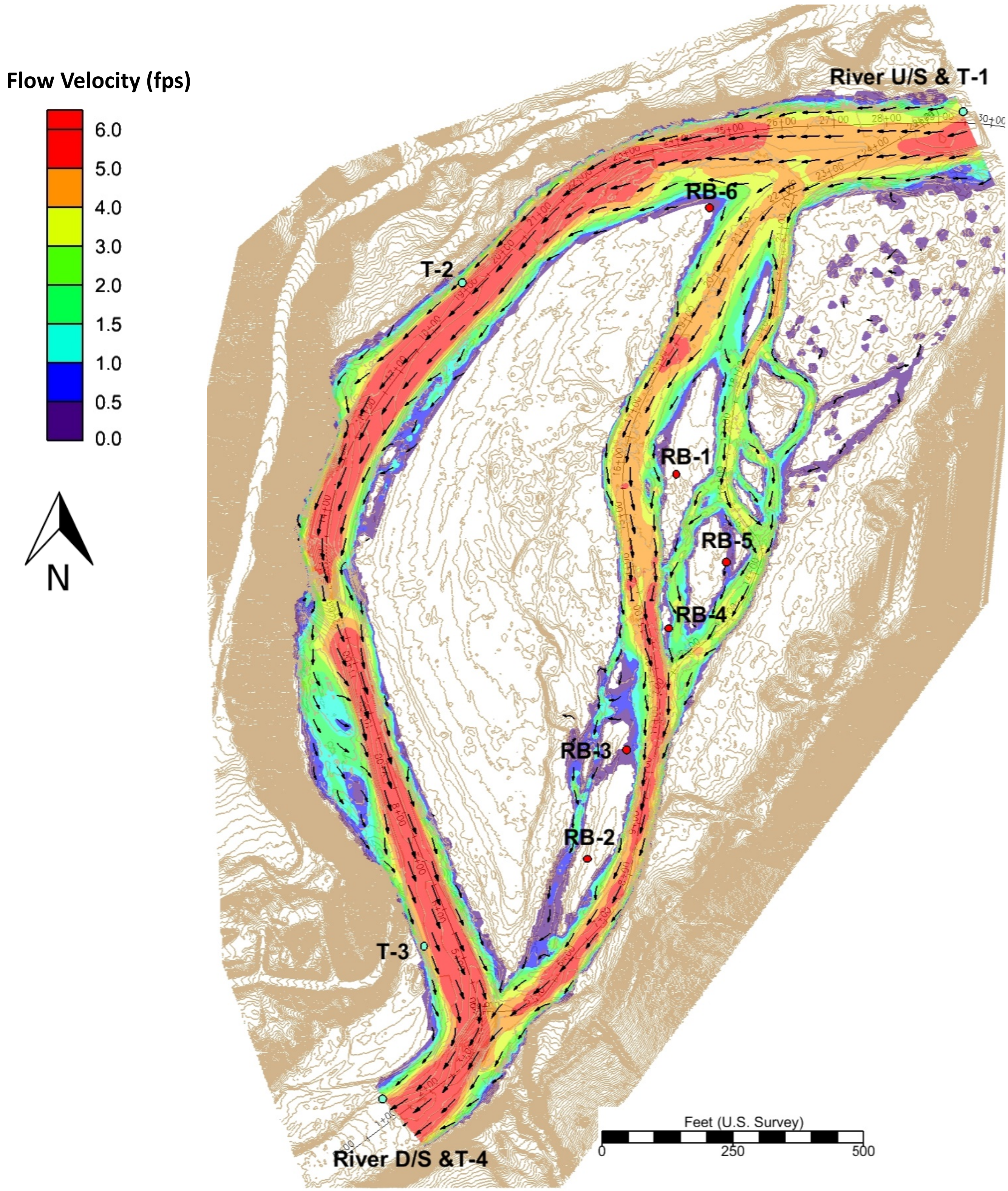
Red Bank Bar
Existing Conditions
1,573 cfs (2.5% Exceedance) (6,240 cfs at Somes Bar Gage)



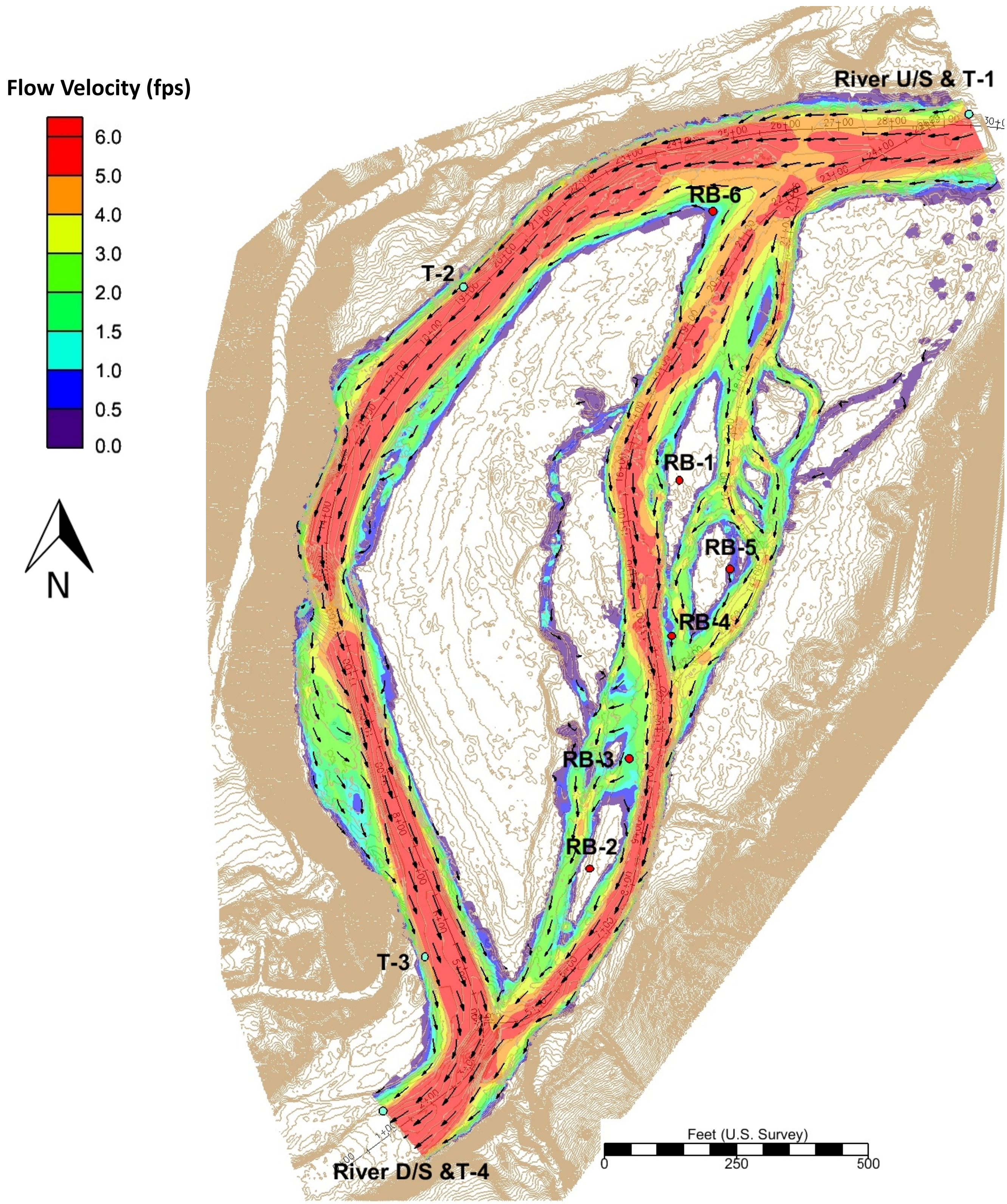
Red Bank Bar
Existing Conditions
2,598 cfs (1.2-Year) (9,294 cfs at Somes Bar Gage)



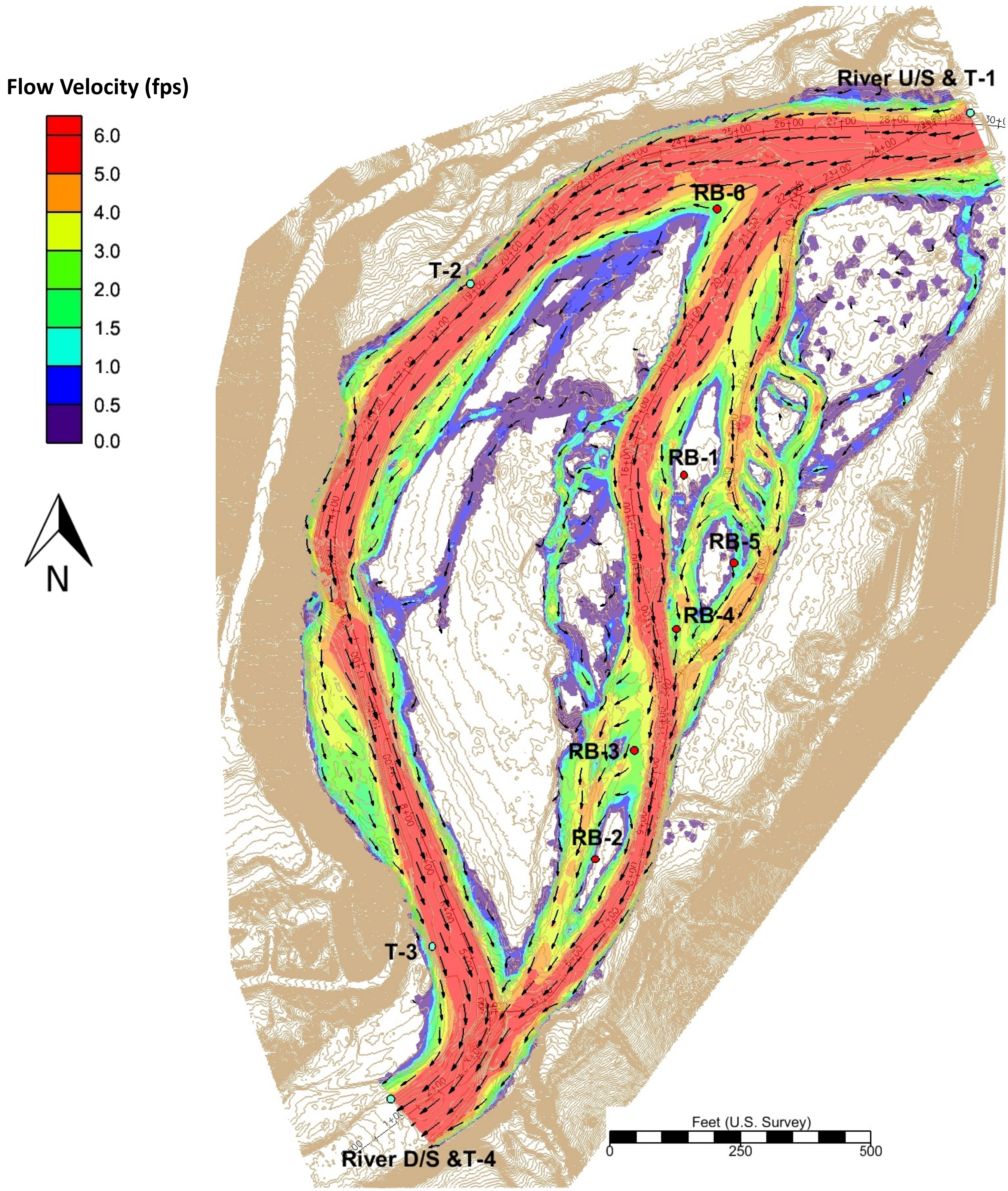
Red Bank Bar
Existing Conditions
3,785 cfs (1.5-Year) (13,921 cfs at Somes Bar Gage)



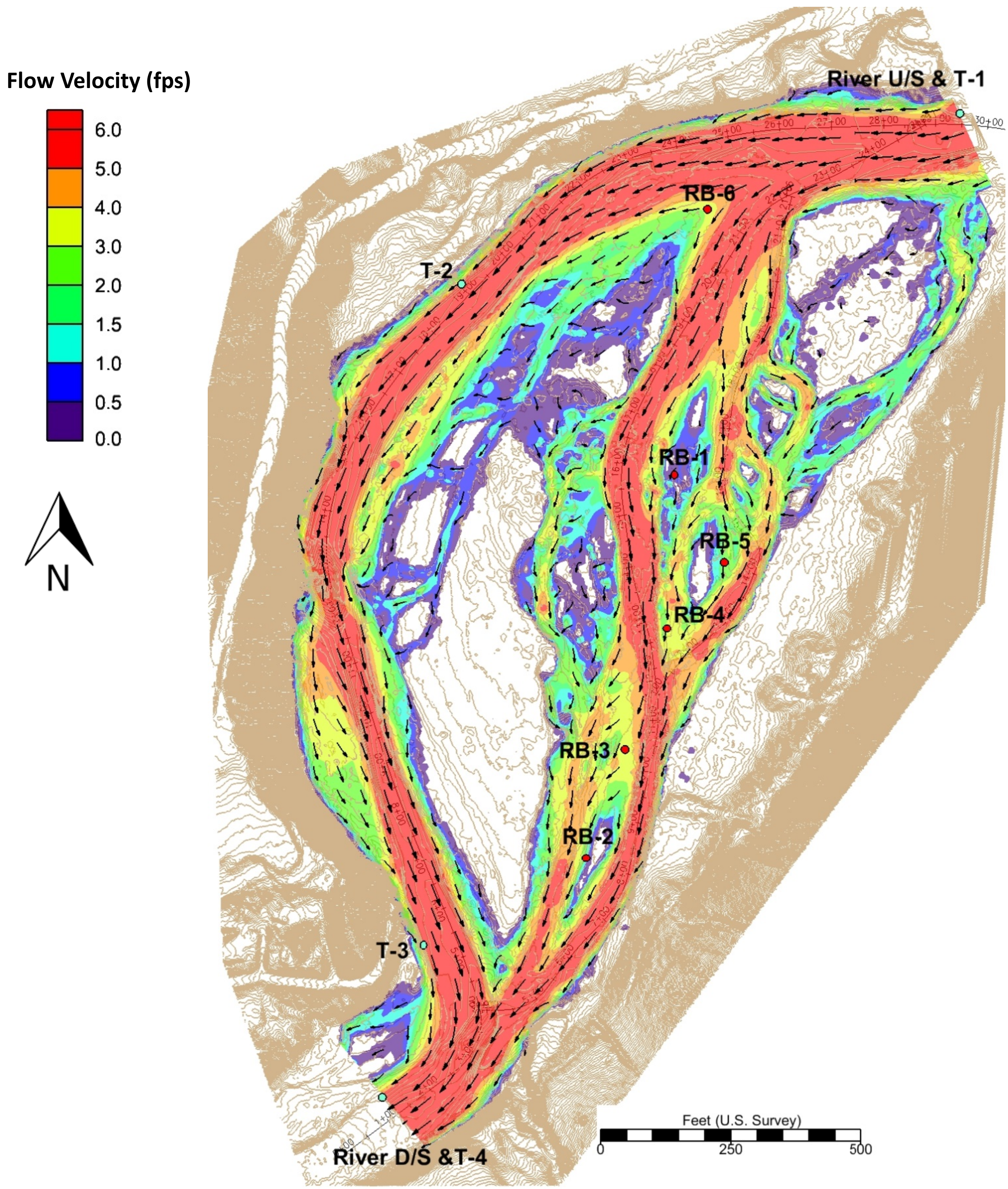
Red Bank Bar
Existing Conditions
5,082 cfs (2-Year) (18,988 cfs at Somes Bar Gage)



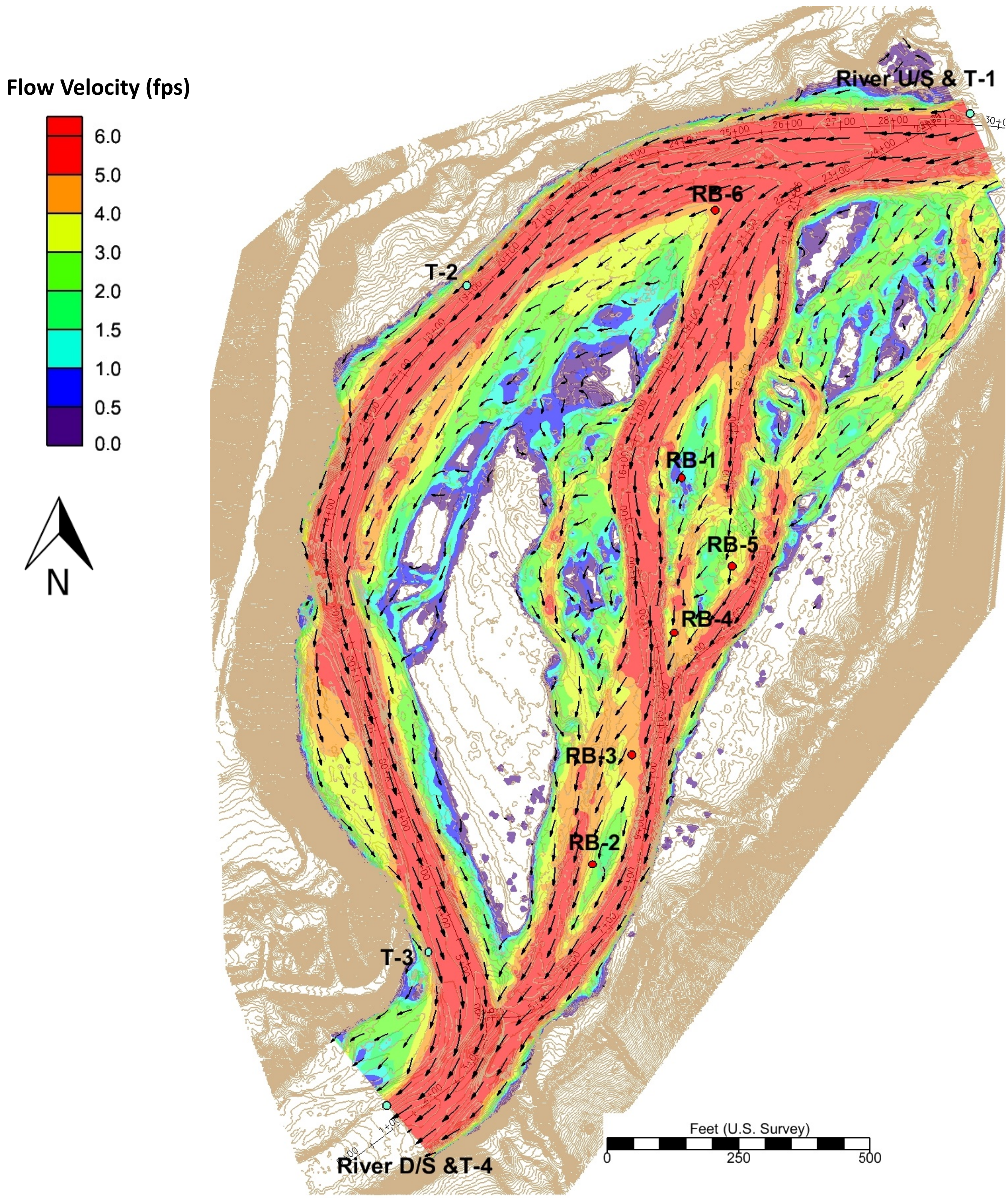
Red Bank Bar
Existing Conditions
6,924 cfs (3-Year) (26,104 cfs at Somes Bar Gage)



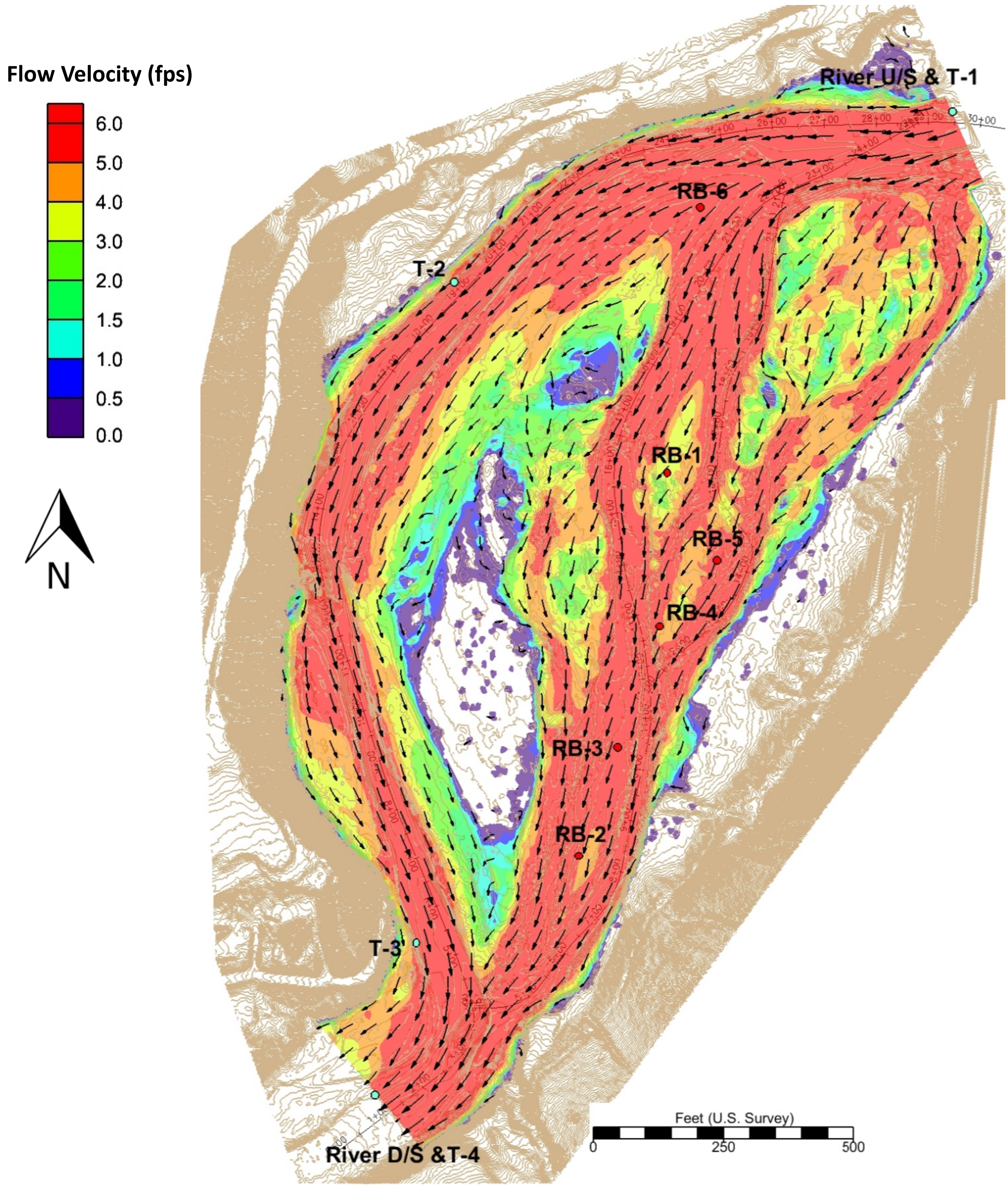
Red Bank Bar
Existing Conditions
9,003 cfs (5-Year) (34,144 cfs at Somes Bar Gage)



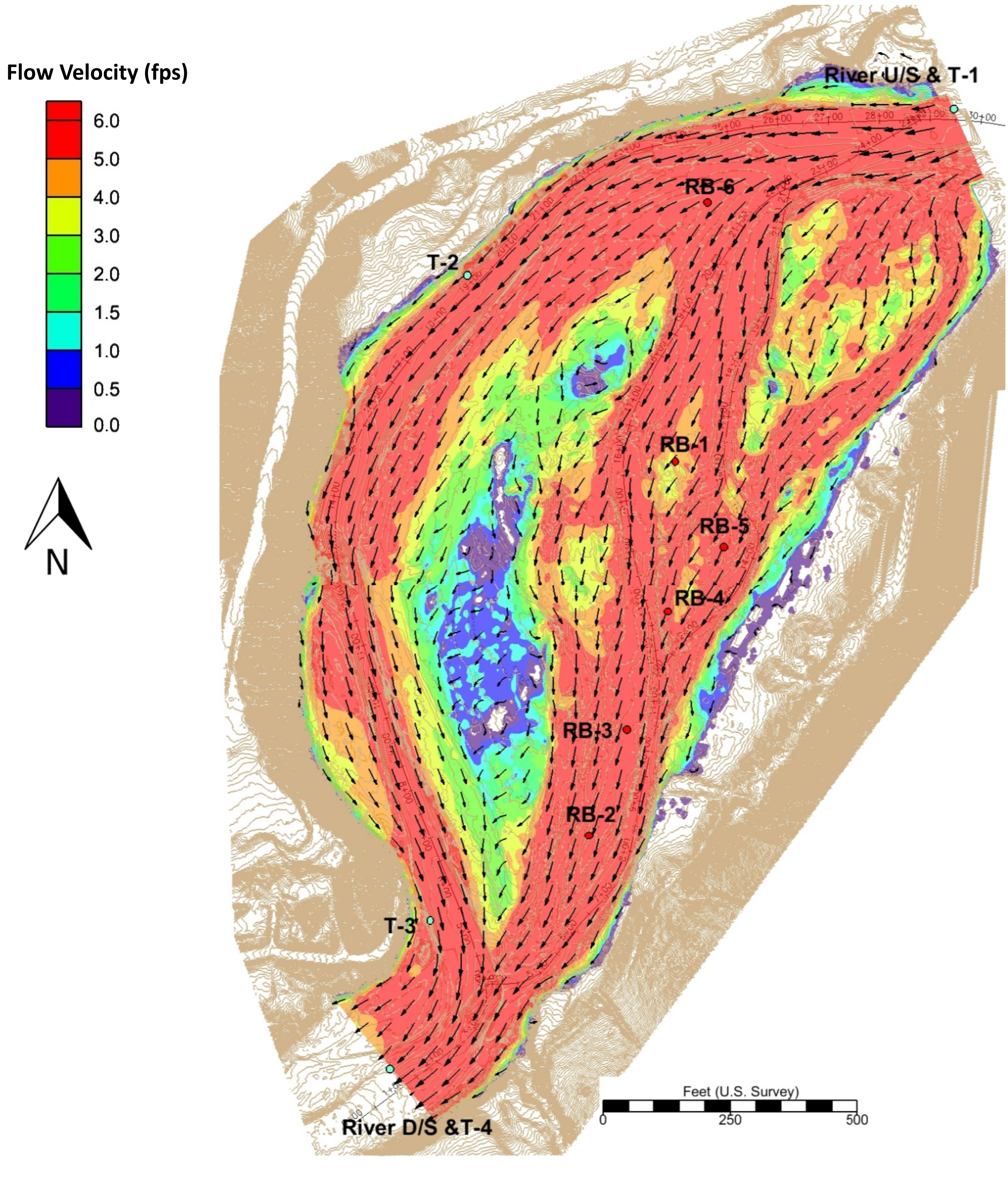
Red Bank Bar
Existing Conditions
12,139 cfs (10-Year) (46,045 cfs at Somes Bar Gage)



Red Bank Bar
Existing Conditions
20,517 cfs (50-Year) (76,855 cfs at Somes Bar Gage)

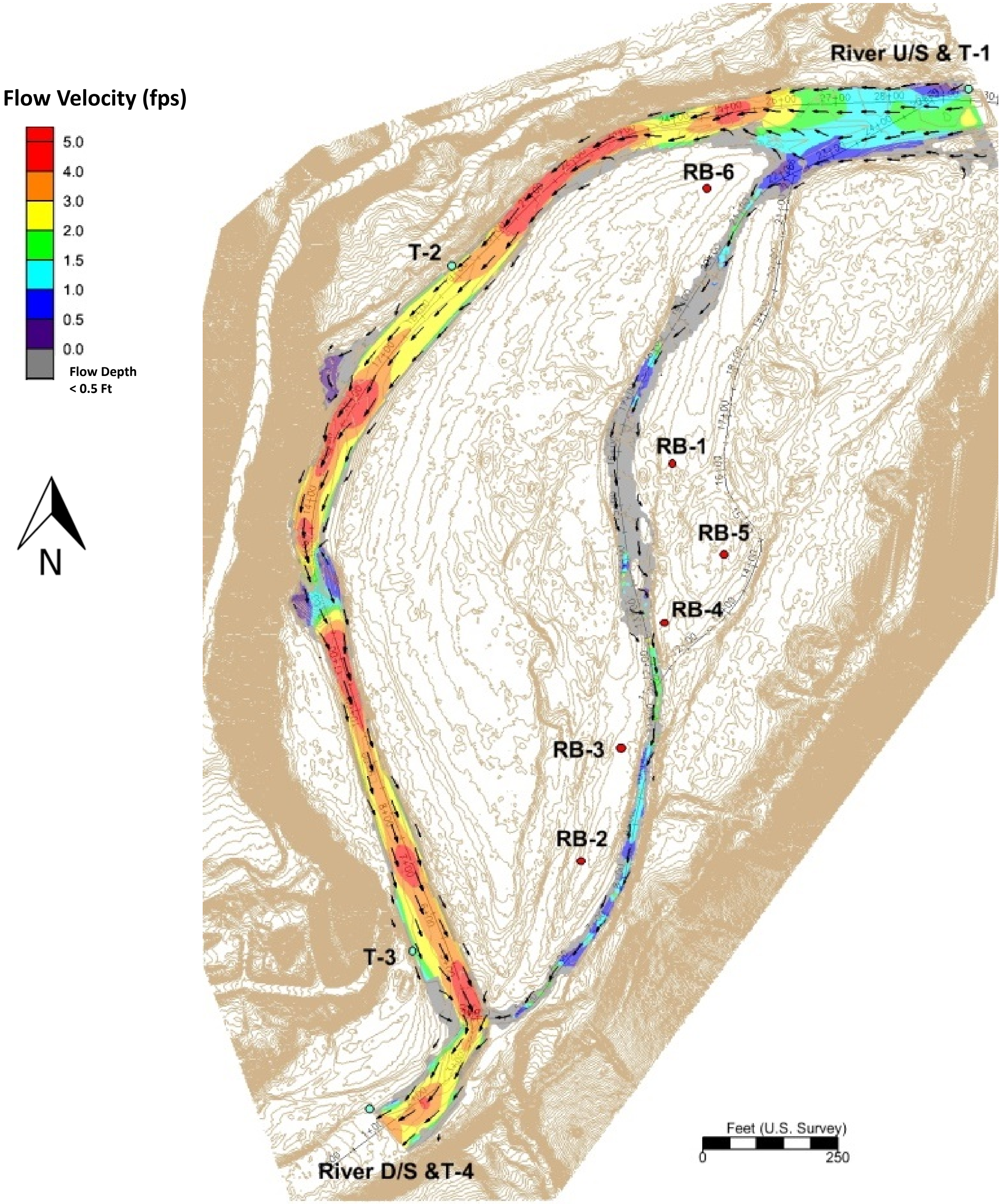


Red Bank Bar
Existing Conditions
24,694 cfs (100-Year) (91,742 cfs at Somes Bar Gage)

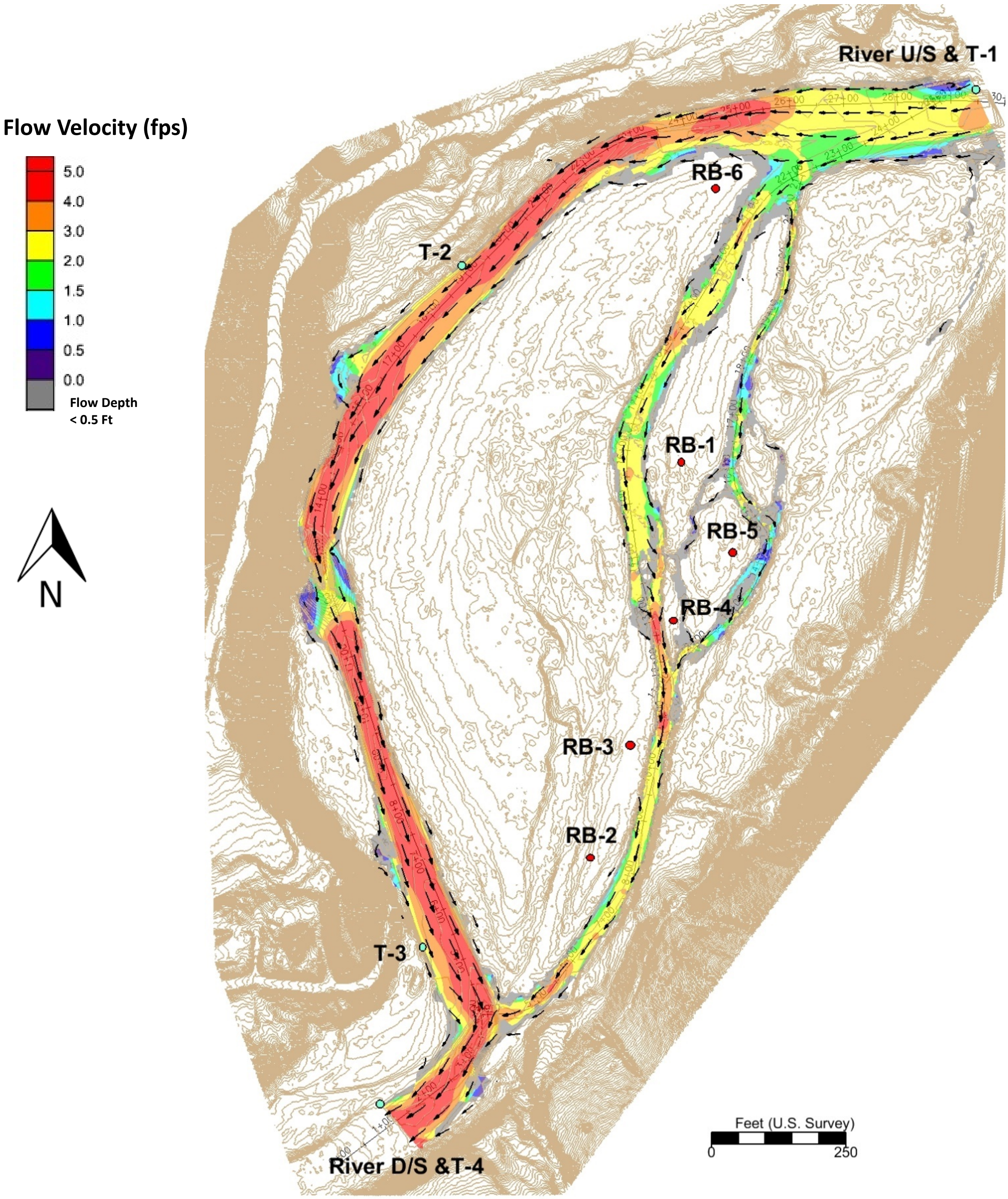


Appendix J
2-D Hydraulic Modeling Results of Potential Rearing Habitat

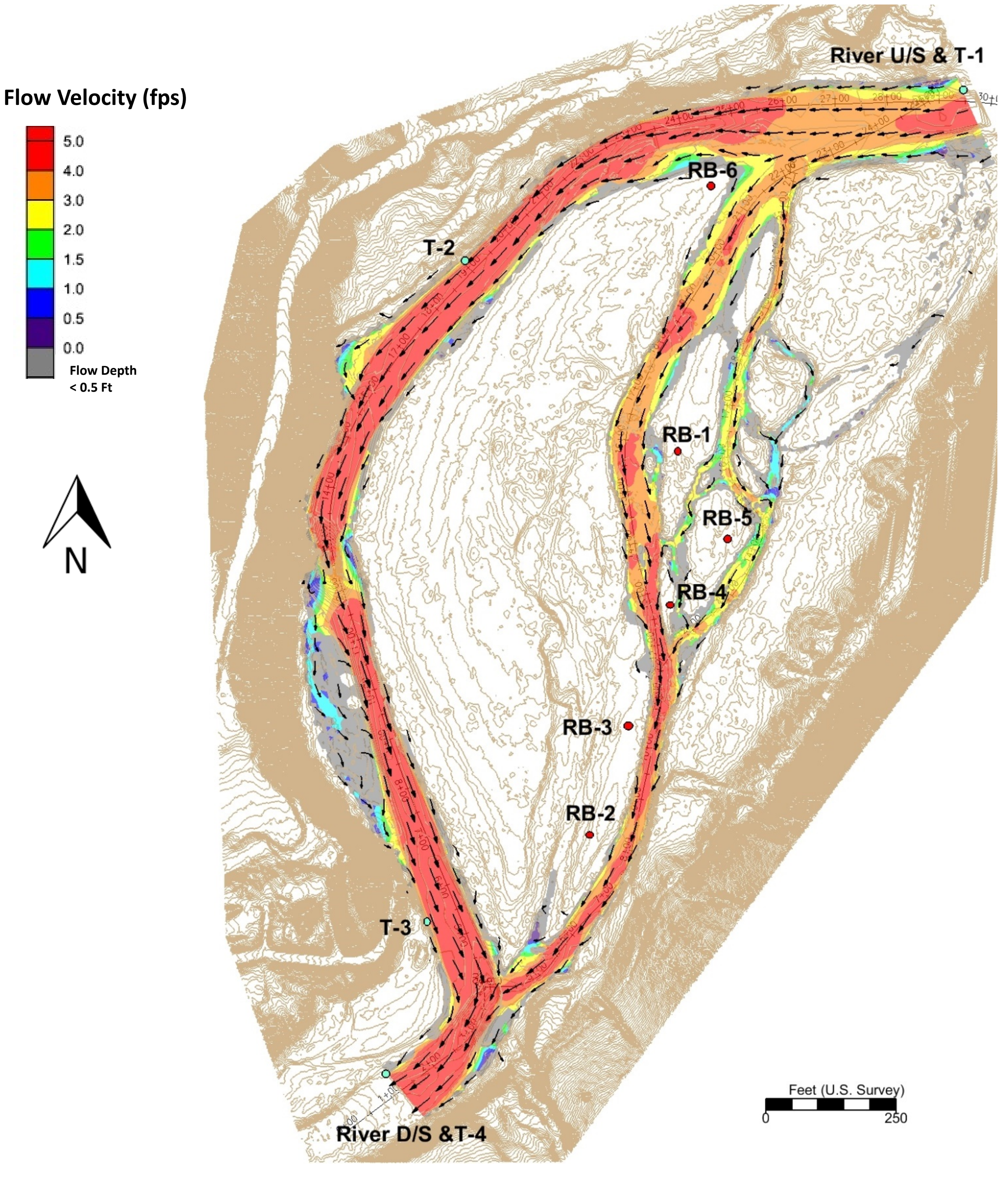
Red Bank Bar
Habitat Suitability
532 cfs (23% Exceedance) (2,050 cfs at Somes Bar Gage)



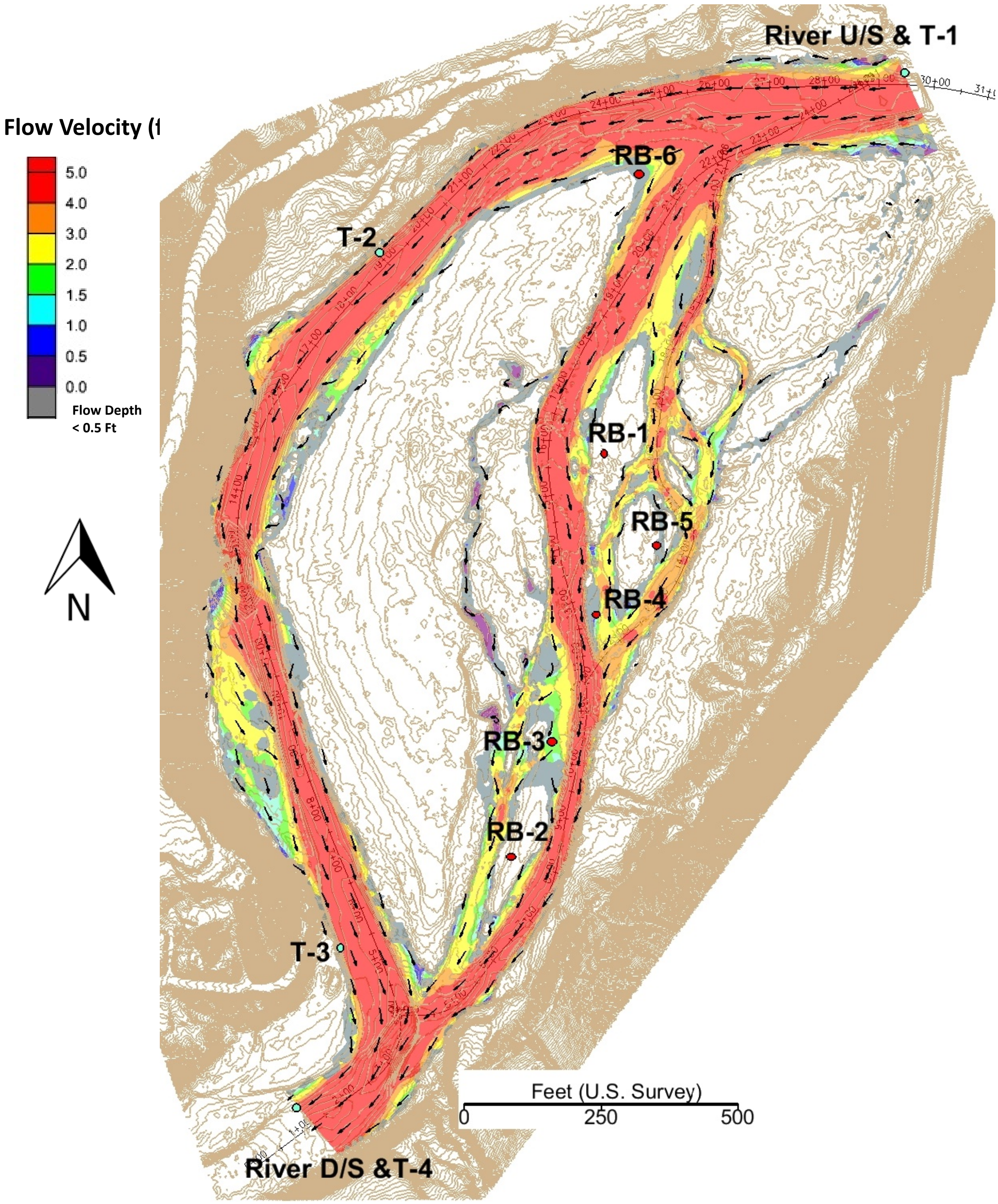
Red Bank Bar
Habitat Suitability
1,240 cfs (4% Exceedance) (5,090 cfs at Somes Bar Gage)



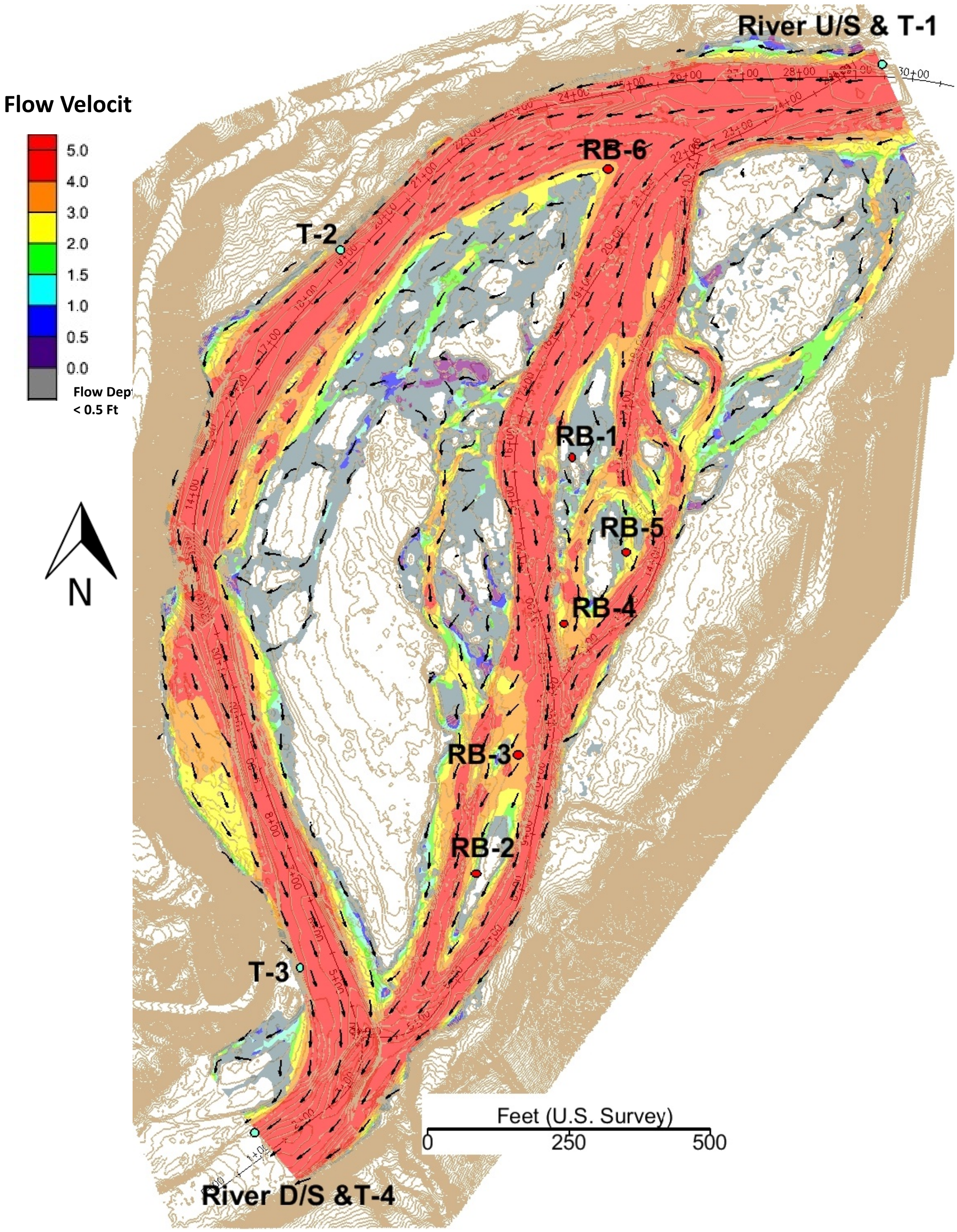
Red Bank Bar
Habitat Suitability
2,598 cfs (1.2-Year) (9,294 cfs at Somes Bar Gage)



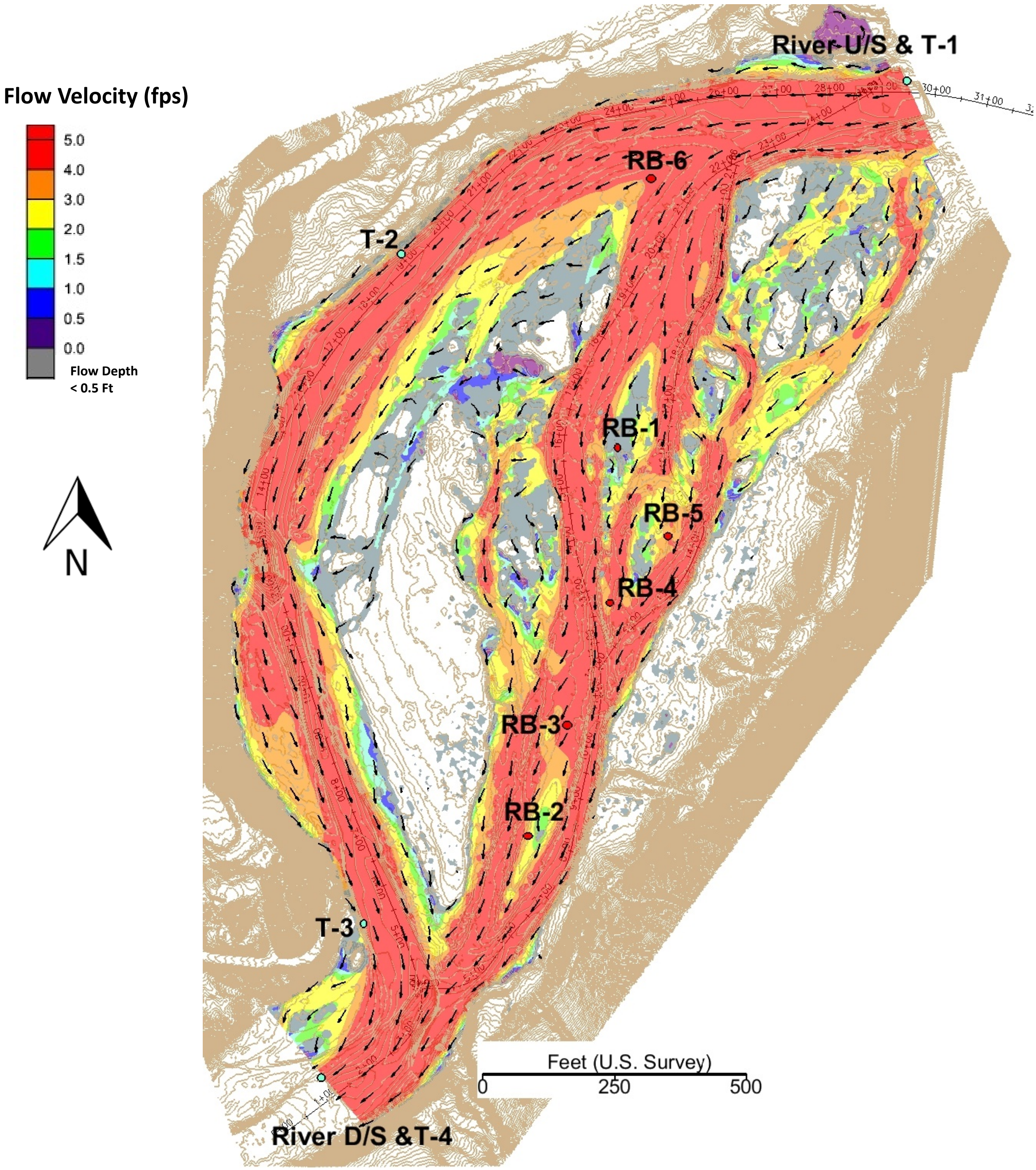
Red Bank Bar
Habitat Suitability
2-Year (5,082 cfs) (18,988 cfs at Somes Bar Gage)



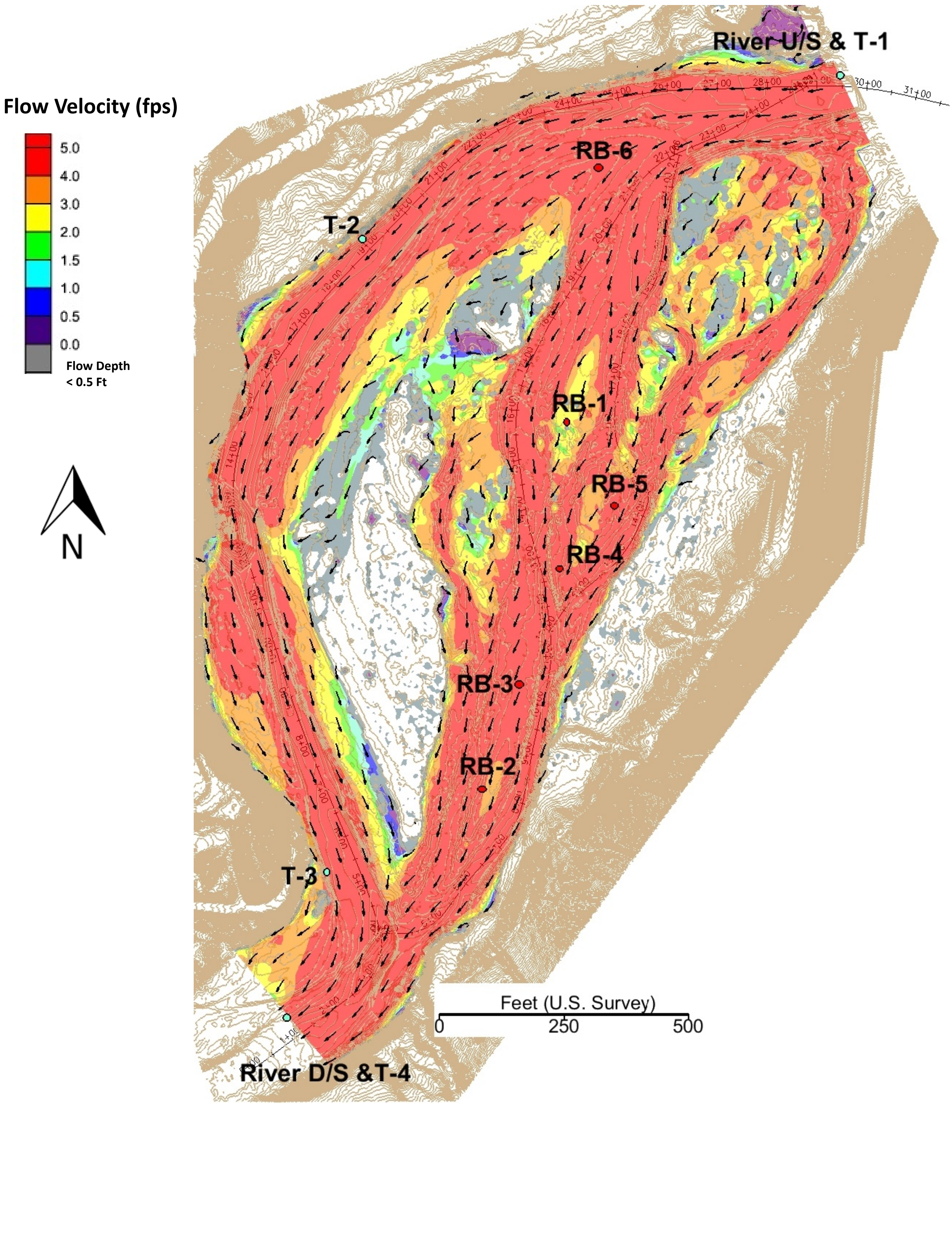
Red Bank Bar
Habitat Suitability
5-Year (9,003 cfs) (34,144 cfs at Somes Bar Gage)



Red Bank Bar
Habitat Suitability
10-Year (12,139 cfs) (46,045 cfs at Somes Bar Gage)

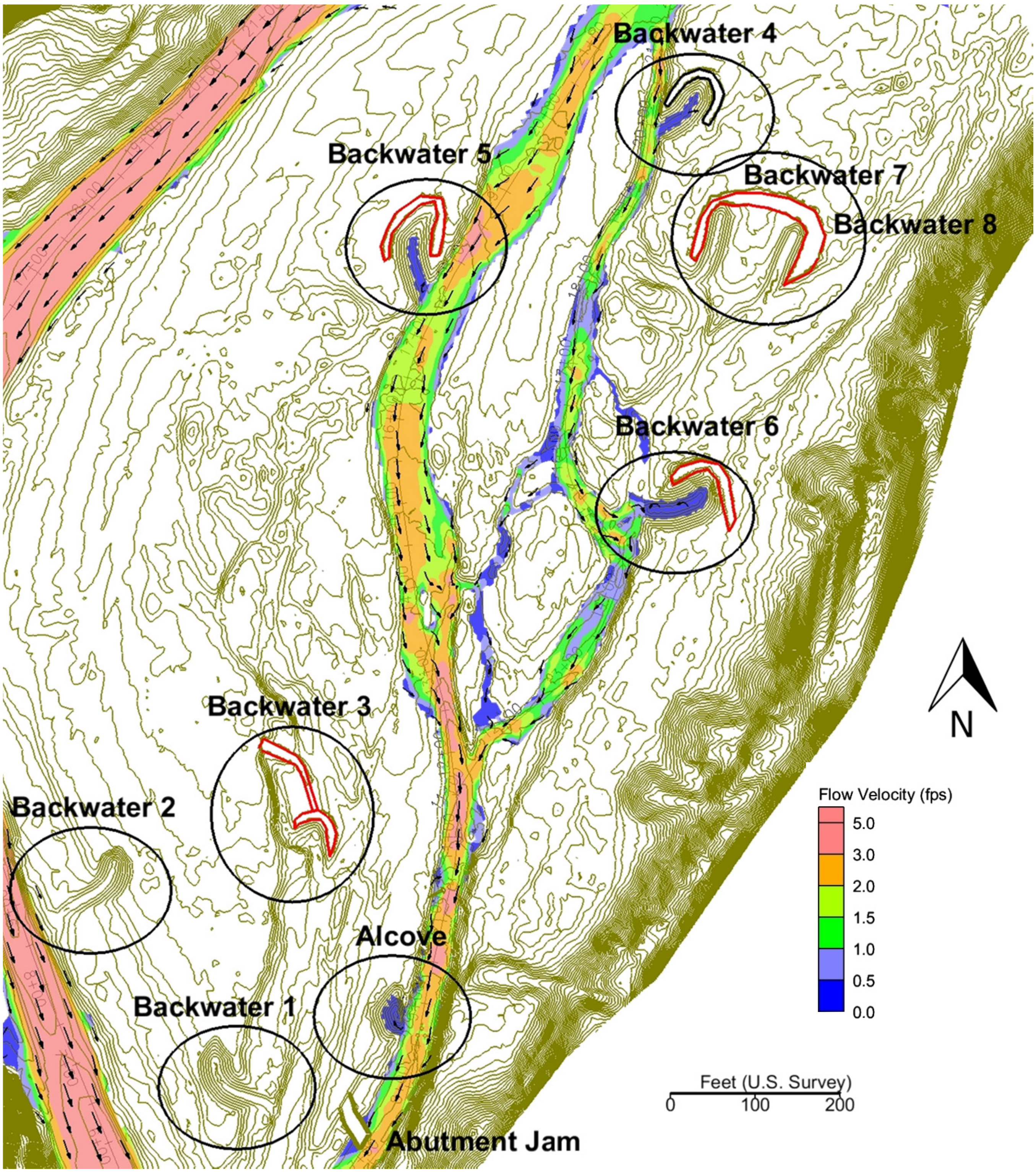


Red Bank Bar
Habitat Suitability
25-Year (16,698 cfs) (62,977 cfs at Somes Bar Gage)

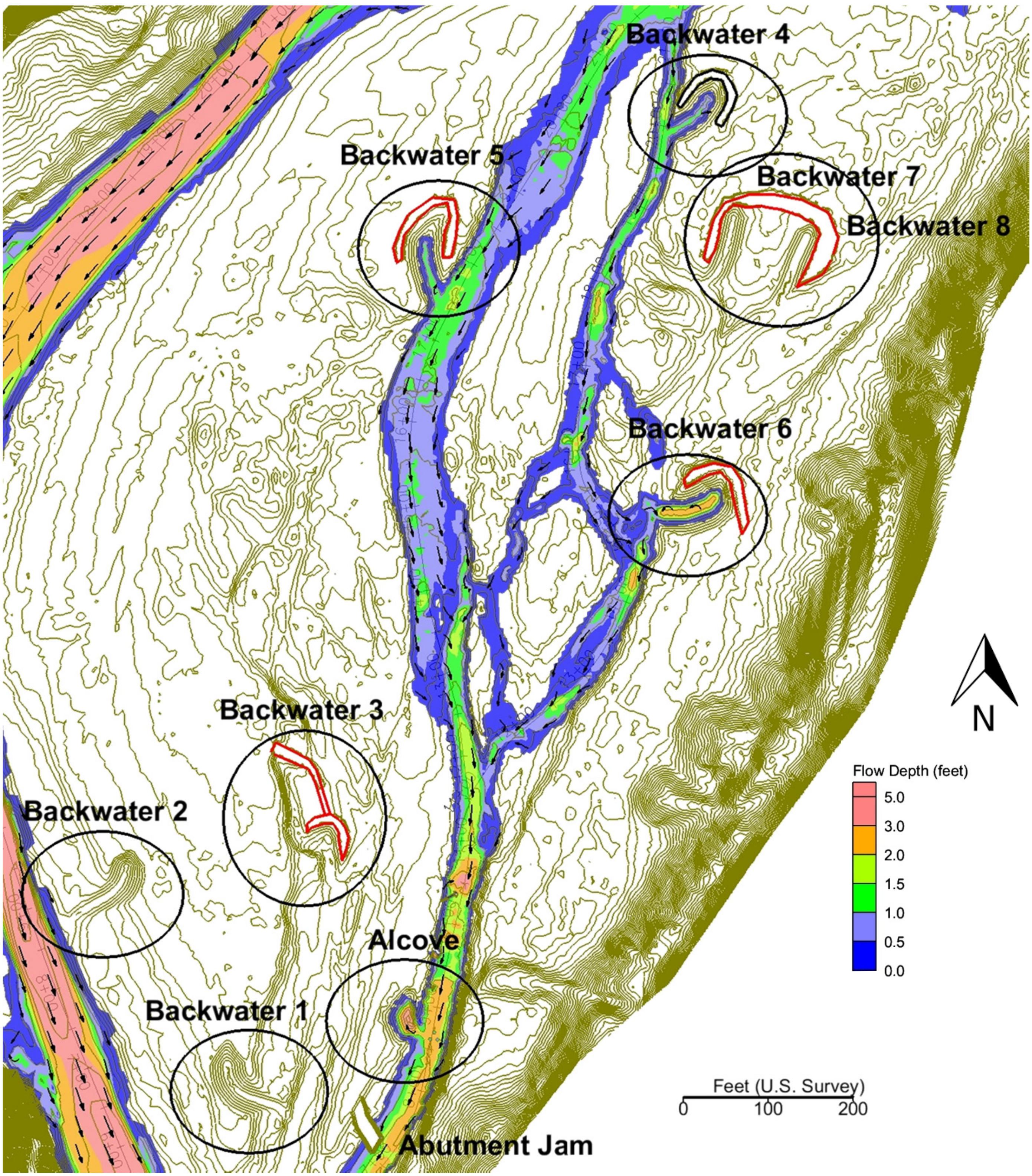


Appendix K–
2-D Hydraulic Modeling Results of Backwater Features (Preliminary Design)

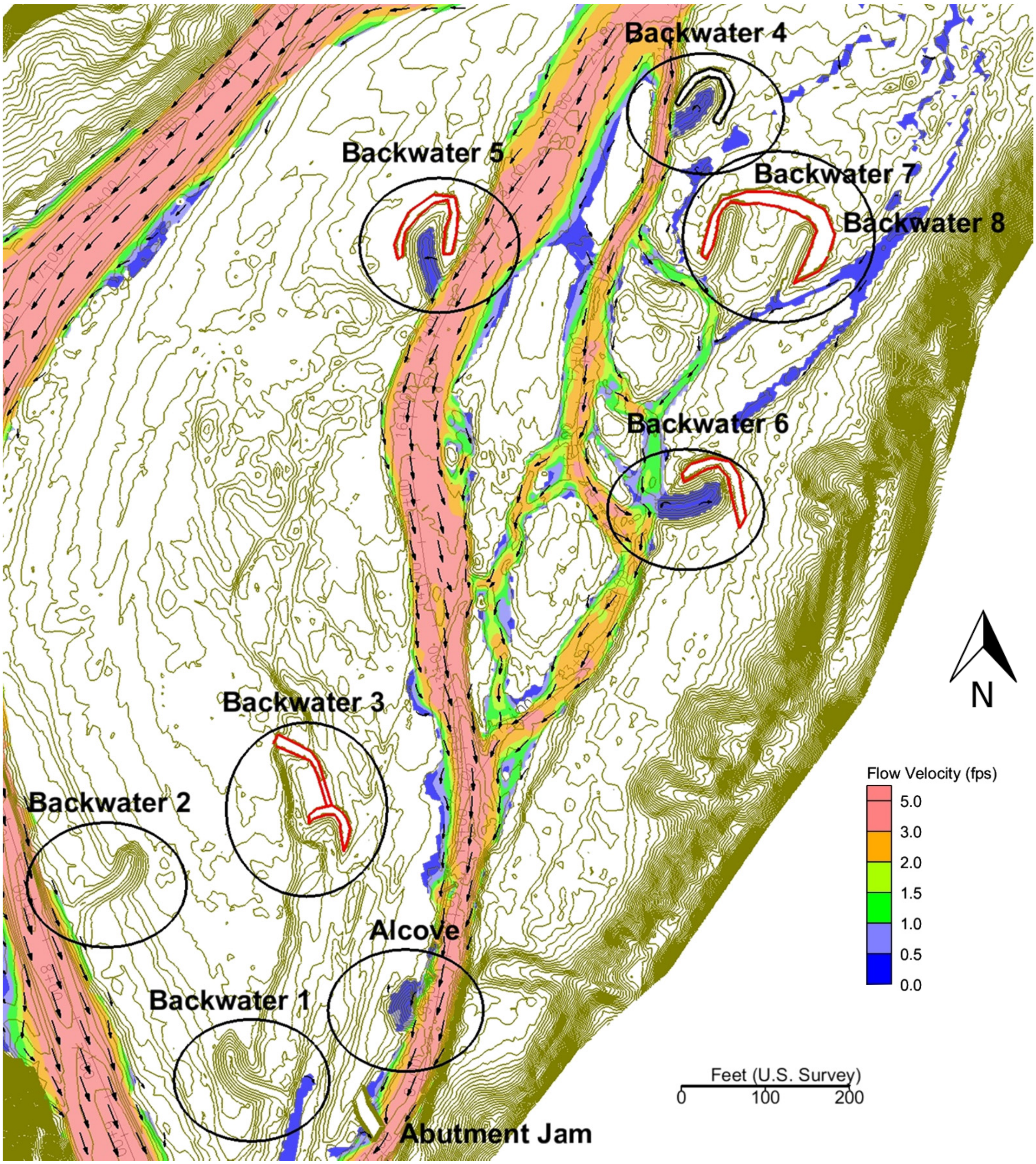
Red Bank Bar
Flow Velocities in Proposed Backwater Refugia Areas
1,100 cfs (5.5% Exceedance) (4,420 cfs at Somes Bar Gage)



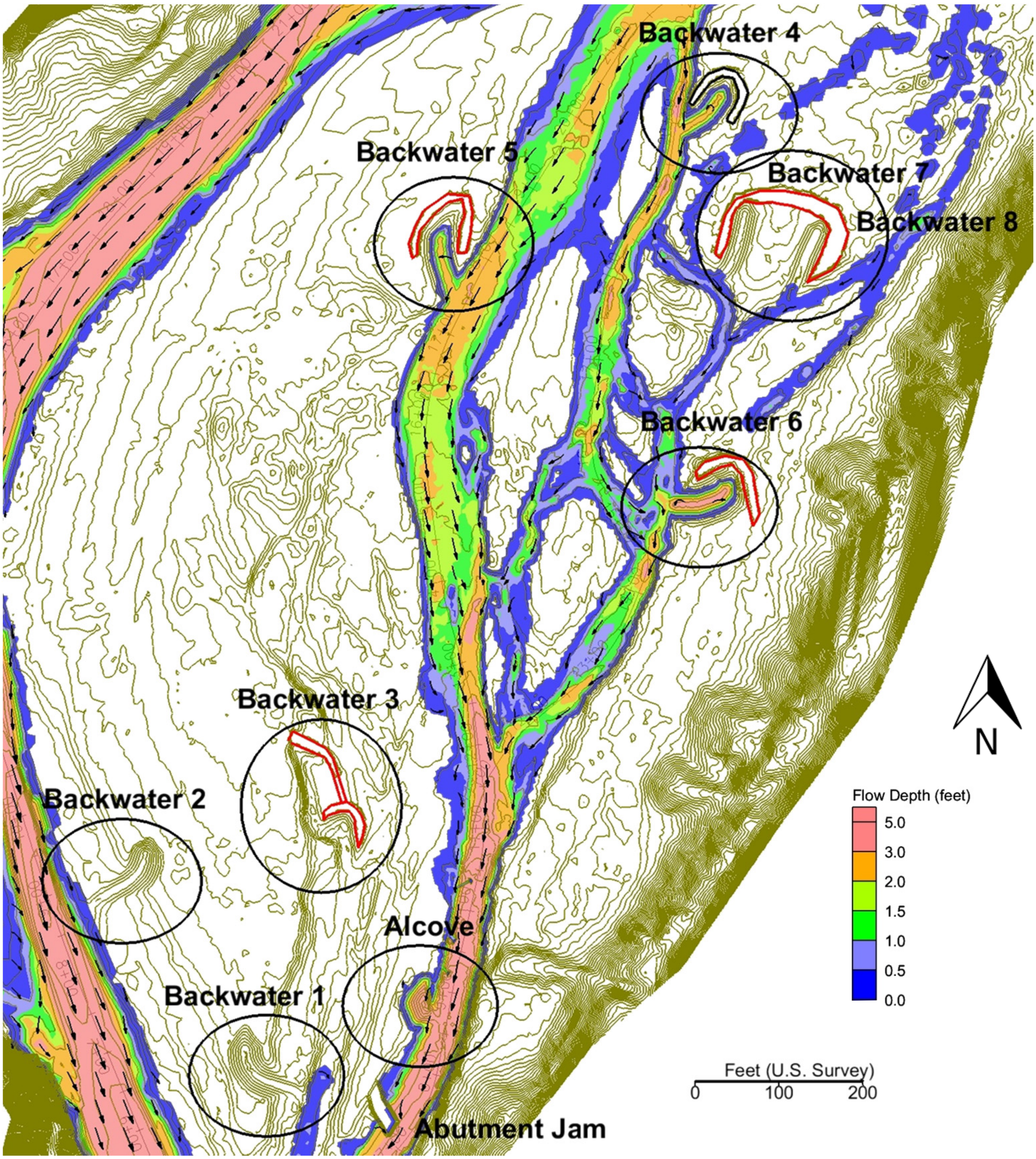
Red Bank Bar
Flow Depths in Proposed Backwater Refugia Areas
1,100 cfs (5.5% Exceedance) (4,420 cfs at Somes Bar Gage)



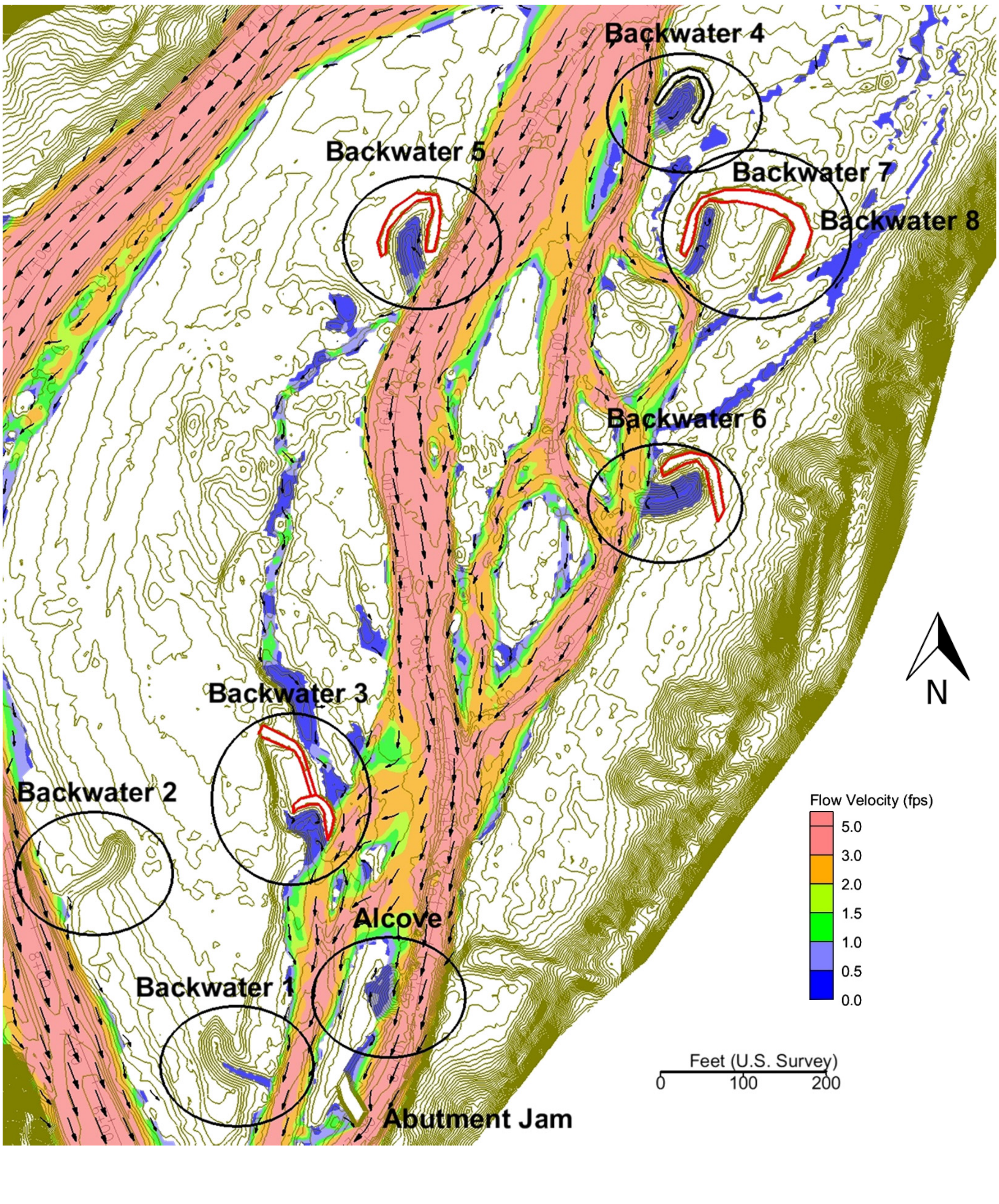
Red Bank Bar
Flow Velocities in Proposed Backwater Refugia Areas
2,598 cfs (1.2-Year Flow)) (9,294 cfs at Somes Bar Gage)



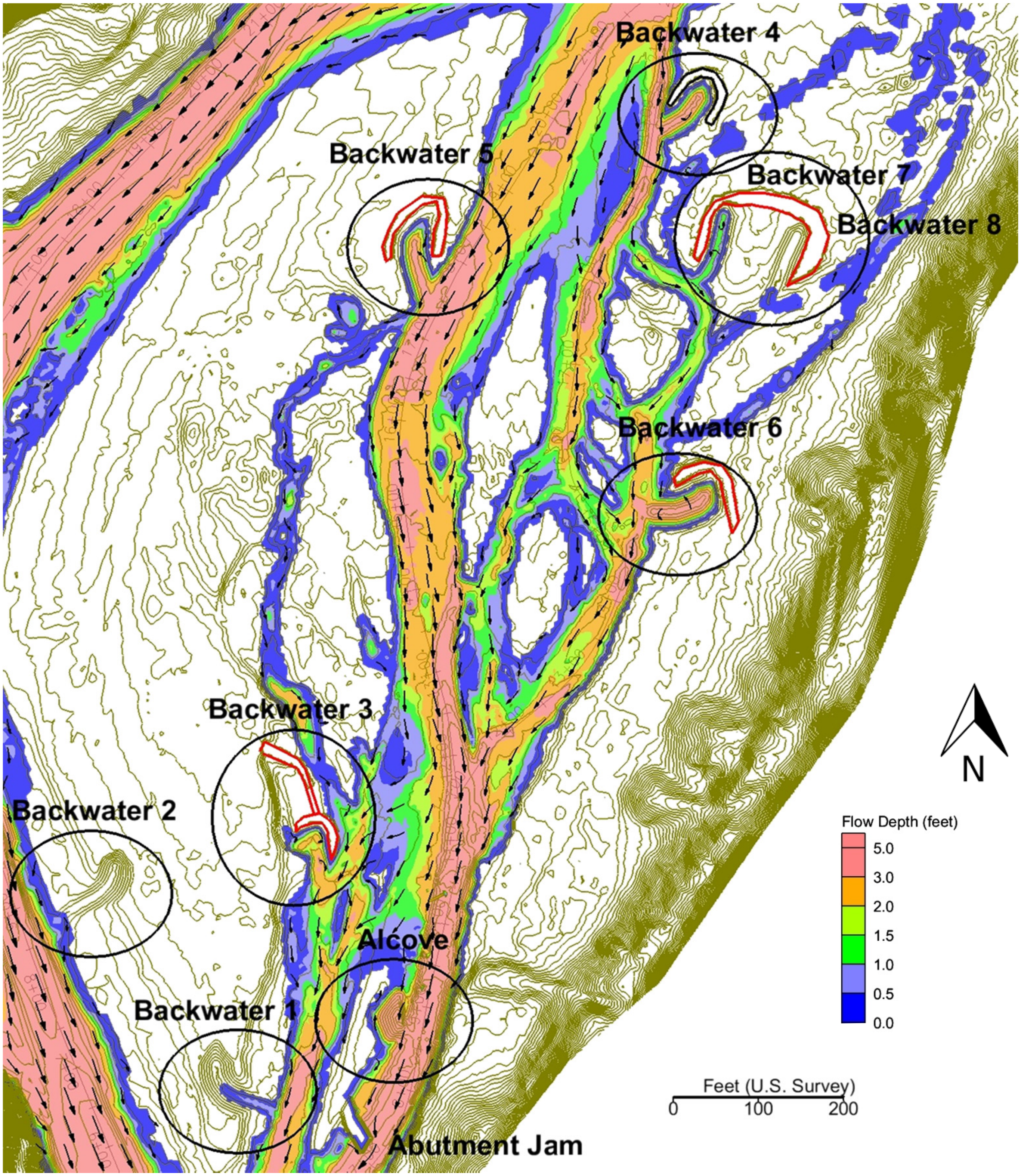
Red Bank Bar
Flow Depths in Proposed Backwater Refugia Areas
2,598 cfs (1.2-Year Flow) (9,294 cfs at Somes Bar Gage)



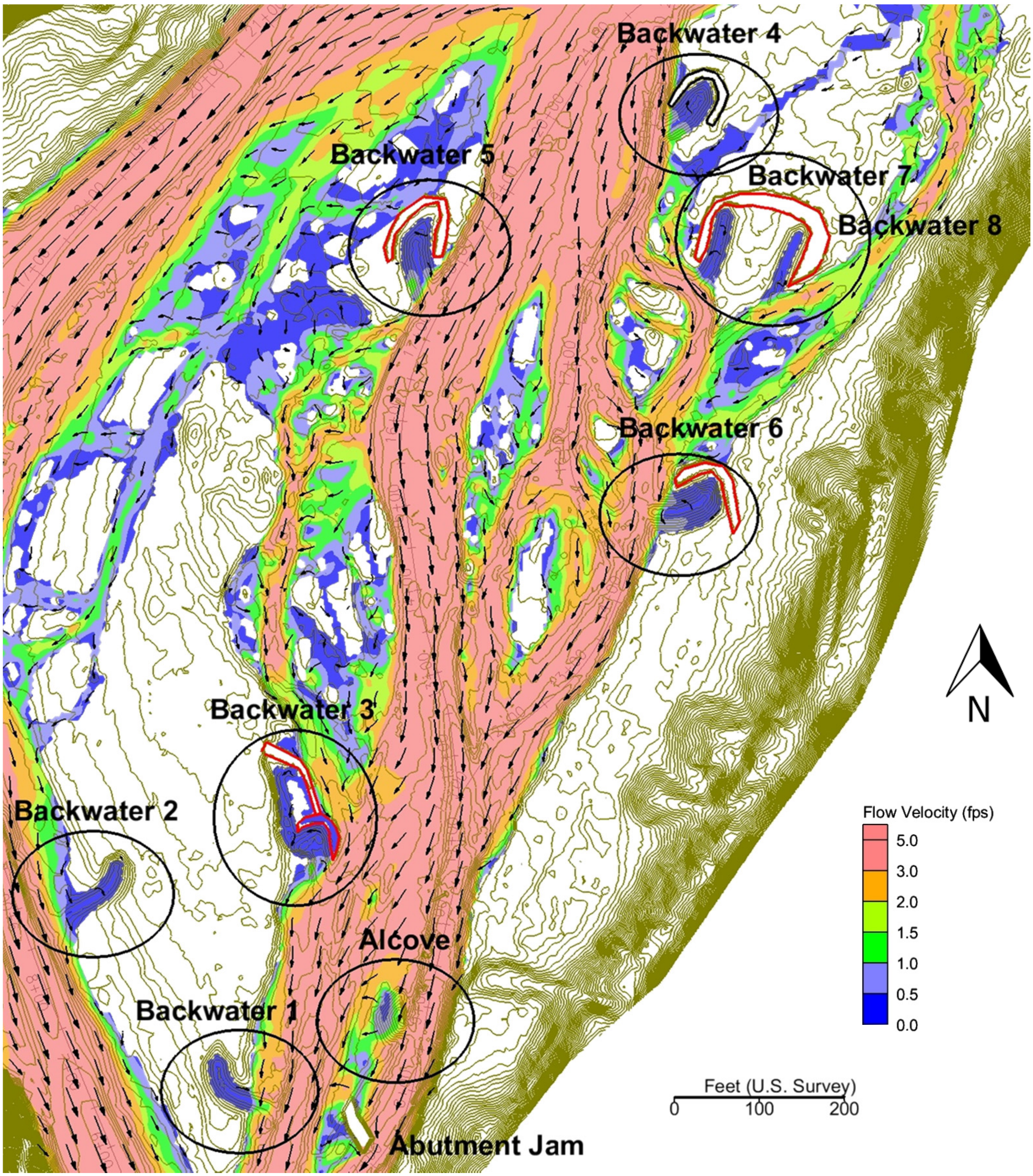
Red Bank Bar
Flow Velocities in Proposed Backwater Refugia Areas
5,082 cfs (2-Year Flow)) (18,988 cfs at Somes Bar Gage)



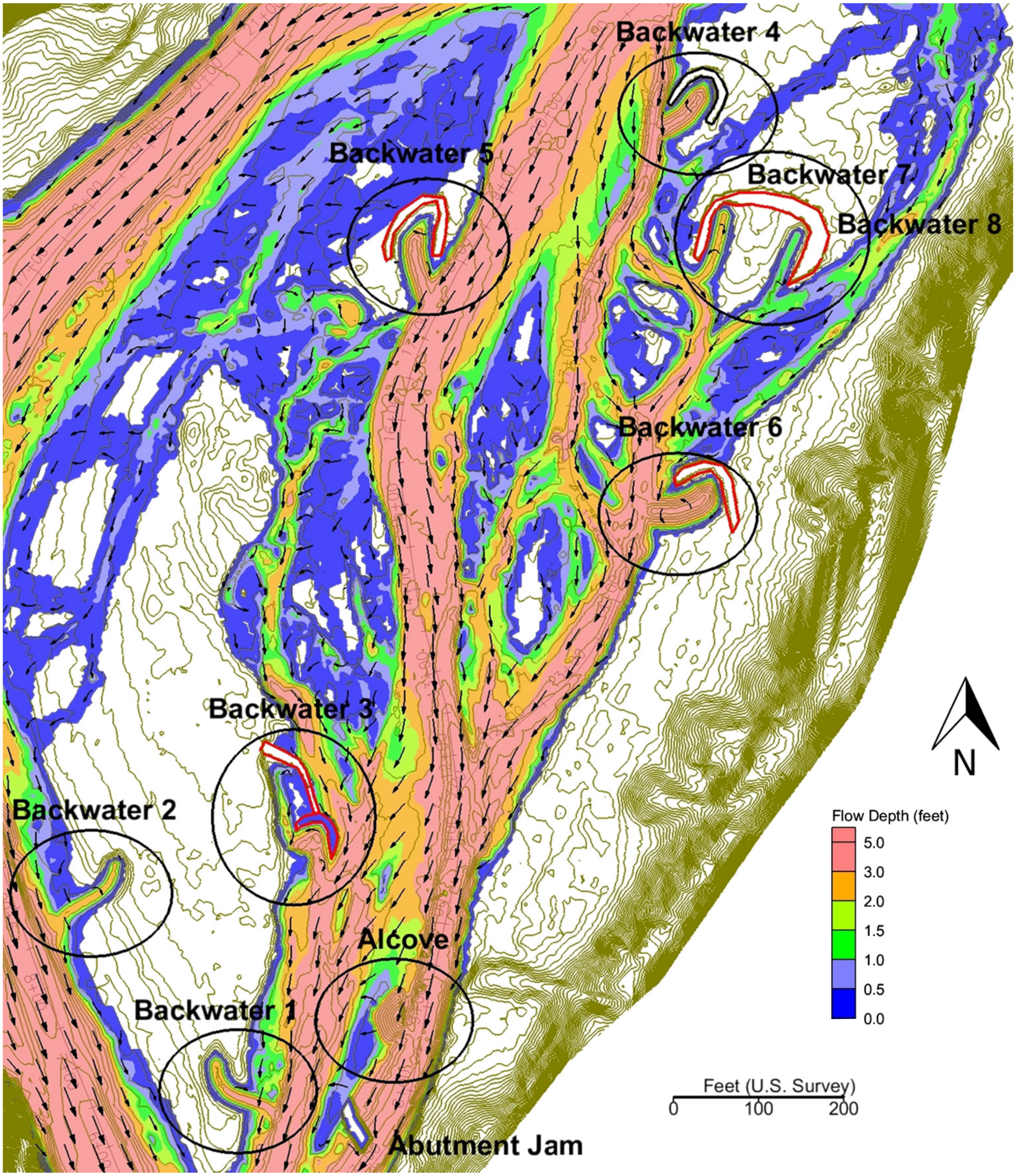
Red Bank Bar
Flow Depths in Proposed Backwater Refugia Areas
5,082 cfs (2-Year Flow) (18,988 cfs at Somes Bar Gage)



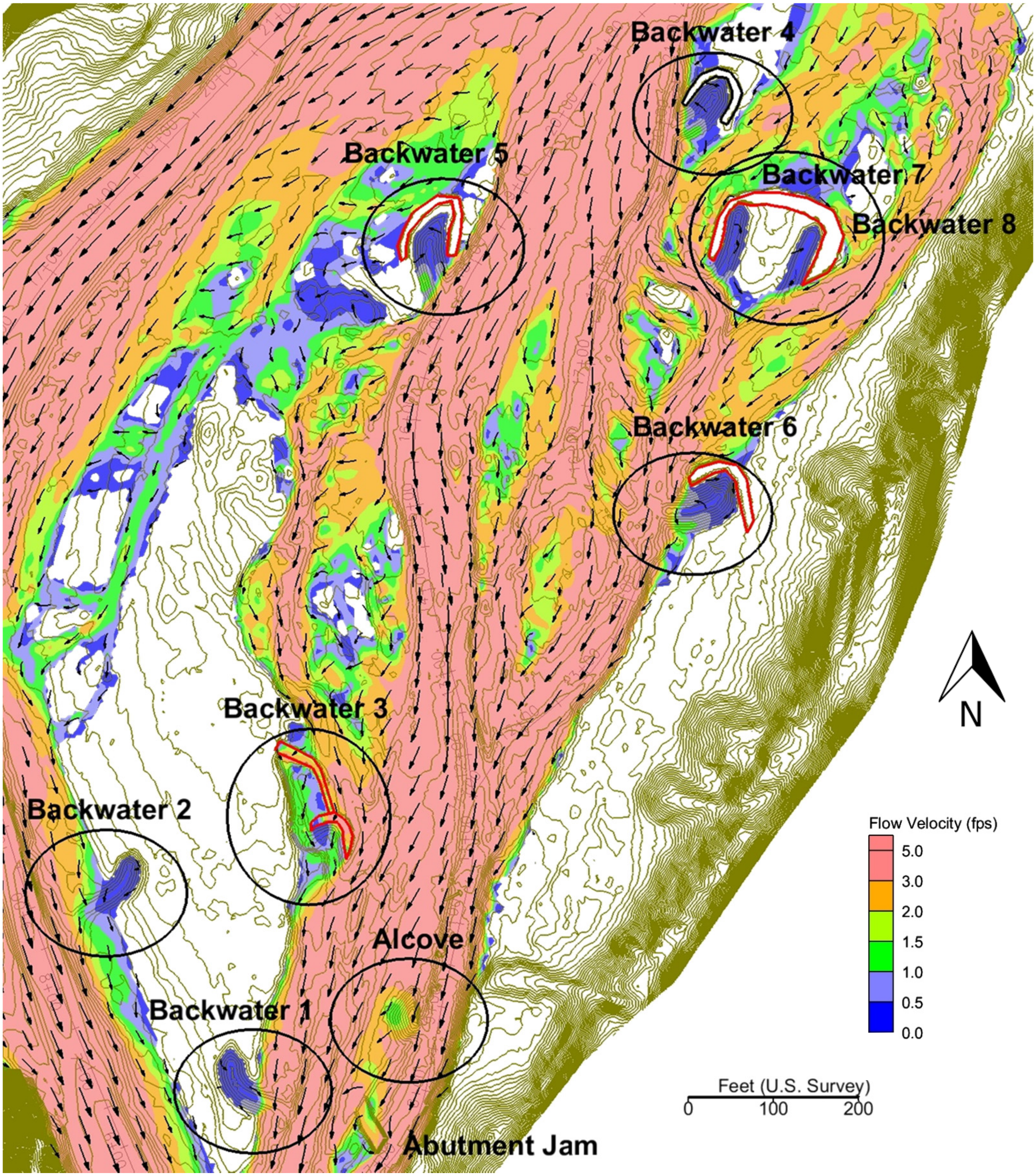
Red Bank Bar
Flow Velocities in Proposed Backwater Refugia Areas
9,003 cfs (5-Year Flow) (34,144 cfs at Somes Bar Gage)



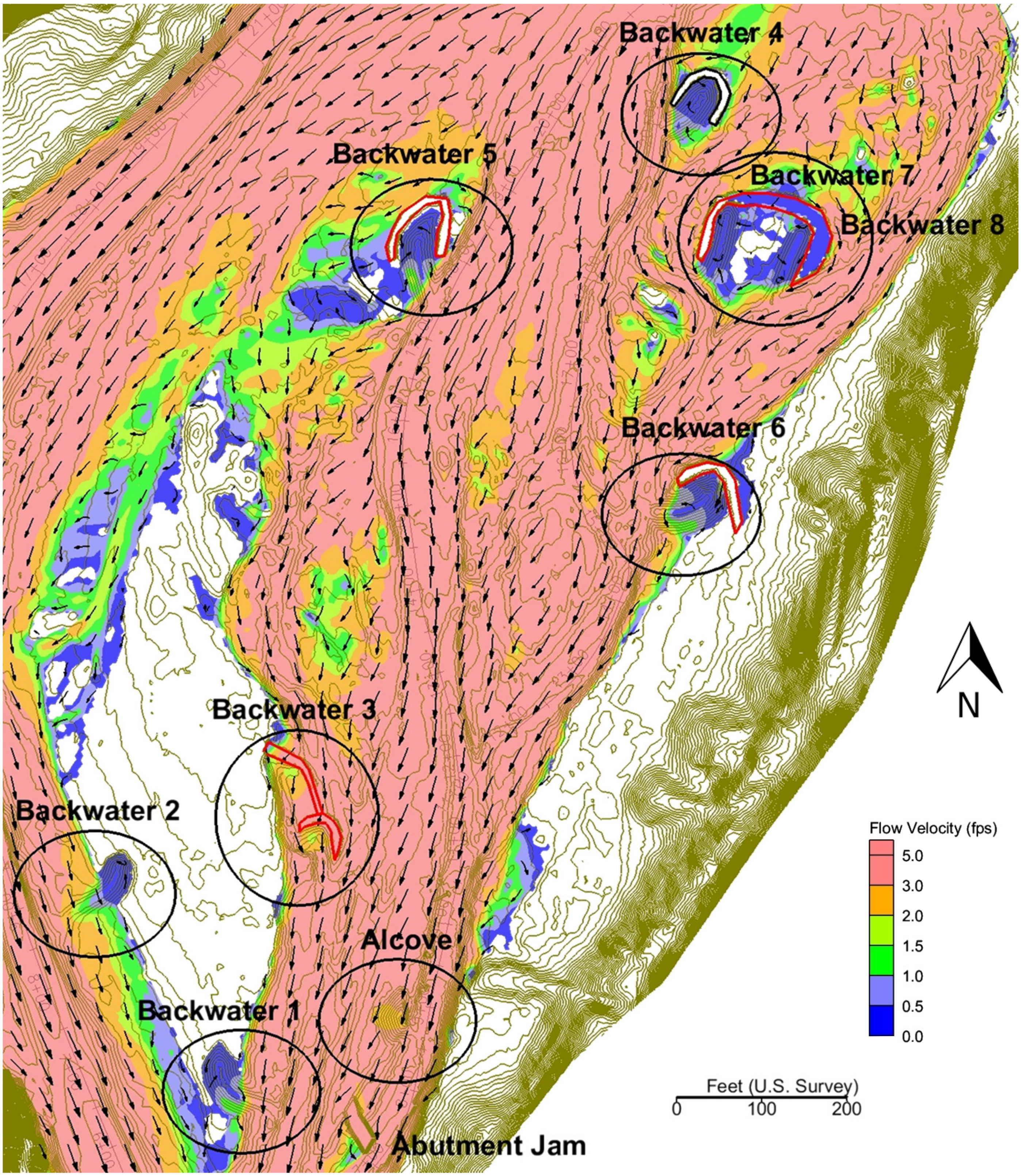
Red Bank Bar
Flow Depths in Proposed Backwater Refugia Areas
9,003 cfs (5-Year Flow) (34,144 cfs at Somes Bar Gage)



Red Bank Bar
Flow Velocities in Proposed Backwater Refugia Areas
12,139 cfs (10-Year Flow) (46,045 cfs at Somes Bar Gage)



Red Bank Bar
Flow Velocities in Proposed Backwater Refugia Areas
16,298 cfs (25-Year Flow) (62,977 cfs at Somes Bar Gage)



Appendix L
Large Wood Structure Stability Computations

Red Bank Bar on the NF Salmon River

Large Wood Structure Stability Analysis

TABLE OF CONTENTS

Date of Last Revision: January 7, 2016

Designer:
Rachel Shea, P.E.

Reviewed by:
Michael Love, P.E.

Large Wood Structure Stability Analysis Spreadsheet was developed by Michael Rafferty, P.E.
Version 1.1

Reference for Companion Paper:

Rafferty, M. 2016. *Computational Design Tool for Evaluating the Stability of Large Wood Structures.* Technical Note TN-103.1. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center. 27 p. http://www.fs.fed.us/biology/nsaec/products-tools.html

Adapted By Rachel Shea, P.E., Michael Love & Associates

Red Bank Bar on the NF Salmon River
Notation, Units, and List of Symbols

Notation

Symbol	Description	Unit
A_W	Wetted area of channel at design discharge	ft^2
A_{Tp}	Projected area of wood in plane perpendicular to flow	ft^2
c_D	Centroid of the drag force along log axis	ft
c_{Am}	Centroid of a mechanical anchor along log axis	ft
c_{Ar}	Centroid of a ballast boulder along log axis	ft
c_{Asoil}	Centroid of the added ballast soil along log axis	ft
$c_{F\&N}$	Centroid of friction and normal forces along log axis	ft
c_L	Centroid of the lift force along log axis	ft
c_P	Centroid of the passive soil force along log axis	ft
c_{soil}	Centroid of the vertical soil forces along log axis	ft
$c_{T,B}$	Centroid of the buoyancy force along log axis	ft
$c_{T,W}$	Centroid of the log volume along log axis	ft
c_{WI}	Centroid of a wood interaction force along log axis	ft
C_{Lrock}	Coefficient of lift for submerged boulder	-
C_{LT}	Effective coefficient of lift for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_D*	Effective coefficient of drag for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_W	Wave drag coefficient of submerged tree	-
$d_{b,avg}$	Average buried depth of log	ft
$d_{b,max}$	Maximum buried depth of log	ft
d_w	Maximum flow depth at design discharge in reach	ft
D_{50}	Median grain size in millimeters (SI units)	mm
D_r	Equivalent diameter of boulder	ft
D_{RW}	Assumed diameter of rootwad	ft
D_{TS}	Nominal diameter of tree stem (DBH)	ft
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-
e	Void ratio of soils	-
$F_{A,H}$	Total horizontal load capacity of anchor techniques	lbf
$F_{A,HP}$	Passive soil pressure applied to log from soil ballast	lbf
$F_{A,Hr}$	Horizontal resisting force on log from boulder	lbf
F_{Am}	Load capacity of mechanical anchor	lbf
$F_{A,V}$	Total vertical load capacity of anchor techniques	lbf
$F_{A,Vr}$	Vertical resisting force on log from boulder	lbf
$F_{A,Vsoil}$	Vertical soil loading on log from added ballast soil	lbf
F_B	Buoyant force applied to log	lbf
F_D	Drag forces applied to log	lbf
$F_{D,r}$	Drag forces applied to boulder	lbf
F_F	Friction force applied to log	lbf
F_H	Resultant horizontal force applied to log	lbf
F_L	Lift force applied to log	lbf
$F_{L,r}$	Lift force applied to boulder	lbf
F_P	Passive soil pressure force applied to log	lbf
F_{soil}	Vertical soil loading on log	lbf
$F_{W,H}$	Horizontal forces from interactions with other logs	lbf
$F_{W,V}$	Vertical forces from interactions with other logs	lbf

Notation (continued)

Symbol	Description	Unit
F_V	Resultant vertical force applied to log	lbf
Fr_L	Log Froude number	-
FS_V	Factor of Safety for Vertical Force Balance	-
FS_H	Factor of Safety for Horizontal Force Balance	-
FS_M	Factor of Safety for Moment Force Balance	-
g	Gravitational acceleration constant	ft/s^2
K_P	Coefficient of Passive Earth Pressure	-
$L_{T,em}$	Total embedded length of log	ft
L_{RW}	Assumed length of rootwad	ft
L_T	Total length of tree (including rootwad)	ft
L_{Tf}	Length of log in contact with bed or banks	ft
L_{TS}	Length of tree stem (not including rootwad)	ft
$L_{TS,ex}$	Exposed length of tree stem	ft
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-
M_d	Driving moment about embedded tip	lbf
M_r	Driving moment about embedded tip	lbf
N	Blow count of standard penetration test	-
p_o	Porosity of soil volume	-
Q_{des}	Design discharge	cfs
R	Radius	ft
R_c	Radius of curvature at channel centerline	ft
SG_r	Specific gravity of quartz particles	-
SG_T	Specific gravity of tree	-
u_{avg}	Average velocity of cross section in reach	ft/s
u_{des}	Design velocity	ft/s
u_m	Adjusted velocity at outer meander bend	ft/s
V_{dry}	Volume of soils above stage level of design flow	ft^3
V_{sat}	Volume of soils below stage level of design flow	ft^3
V_{soil}	Total volume of soils over log	ft^3
V_{RW}	Volume of rootwad	ft^3
V_S	Volume of solids in soil (void ratio calculation)	ft^3
V_T	Total volume of log	ft^3
V_{TS}	Total volume of tree	ft^3
V_V	Volume of voids in soil	ft^3
V_{Adry}	Volume of ballast above stage of design flow	ft^3
V_{Awet}	Volume of ballast below stage of design flow	ft^3
$V_{r,dry}$	Volume of boulder above stage of design flow	ft^3
$V_{r,wet}$	Volume of boulder below stage of design flow	ft^3
W_{BF}	Bankfull width at structure site	ft
W_r	Effective weight of boulder	lbf
W_T	Total log weight	lbf
x	Horizontal coordinate (distance)	ft
y	Vertical coordinate (elevation)	ft
$y_{T,max}$	Minimum elevation of log	ft
$y_{T,min}$	Maximum elevation of log	ft

Greek Symbols

Symbol	Description	Unit
β	Tilt angle from stem tip to vertical	deg
γ_{bank}	Dry specific weight of bank soils	lb/ft^3
$\gamma_{bank,sat}$	Saturated unit weight of bank soils	lb/ft^3
γ'_{bank}	Effective buoyant unit weight of bank soils	lb/ft^3
γ_{bed}	Dry specific weight of stream bed substrate	lb/ft^3
γ'_{bed}	Effective buoyant unit weight of stream bed substrate	lb/ft^3
γ_{rock}	Dry unit weight of boulders	lb/ft^3
γ_s	Dry specific weight of soil	lb/ft^3
γ'_s	Effective buoyant unit weight of soil	lb/ft^3
γ_{Td}	Air-dried unit weight of tree (12% MC basis)	lb/ft^3
γ_{Tgr}	Green unit weight of tree	lb/ft^3
γ_w	Specific weight of water at 50ºF	lb/ft^3
η	Rootwad porosity	-
θ	Rootwad (or large end of log) orientation to flow	deg
μ	Coefficient of friction	-
ν	Kinematic viscosity of water at 50ºF	ft/s^2
Σ	Sum of forces	-
ϕ_{bank}	Internal friction angle of bank soils	deg
ϕ_{bed}	Internal friction angle of stream bed substrate	deg

Units

Notation	Description
cfs	Cubic feet per second
ft	Feet
lb	Pound
lbf	Pounds force
kg	Kilograms
m	Meters
mm	Millimeters
s	Seconds
yr	Year

Abbreviations

Notation	Description
ARI	Average return interval
Avg	Average
DBH	Diameter at breast height
deg	Degrees
Dia	Diameter
Dist	Distance
D/S	Downstream
ELJ	Engineered log jam
Fldpln	Floodplain
H&H	Hydrologic and hydraulic
ID	Identification
i.e.	That is
LB	Left bank
LW	Large wood
Max	Maximum
MC	Moisture content
Min	Minimum
ML	Multi-log
SL	Single log
N/A	Not applicable
no	Number
Pt	Point
rad	Radians
RB	Right bank
RW	Rootwad
SL	Single log
Thw	Thalweg (lowest elevation in channel bed)
Typ	Typical
U.S.	United States
WS	Water surface
WSE	Water surface elevation
↑	Above
↓	Below

Red Bank Bar on the NF Salmon River
Factors of Safety and Design Constants

Symbol	Description	Value
FS_V	Factor of Safety for Vertical Force Balance	**1.50**
FS_H	Factor of Safety for Horizontal Force Balance	**1.50**
FS_M	Factor of Safety for Moment Force Balance	**1.50**

Symbol	Description	Units	Value
C_{Lrock}	Coefficient of lift for submerged boulder (D'Aoust, 2000)	-	0.17
C_{Drock}	Coefficient of drag for submerged boulder (Schultz, 1954)	-	0.85
g	Gravitational acceleration constant	ft/s^2	32.174
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-	2.00
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-	1.50
SG_{rock}	Specific gravity of quartz particles	-	2.65
γ_{rock}	Dry unit weight of boulders	lb/ft^3	165.0
γ_w	Specific weight of water at 50ºF	lb/ft^3	62.40
η	Rootwad porosity from WDFW (2012)	-	0.60
ν	Kinematic viscosity of water at 50ºF	ft/s^2	1.41E-05

Red Bank Bar on the NF Salmon River
Hydrologic and Hydraulic Inputs

Spreadsheet developed by
Michael Rafferty, P.E.

Average Return Interval (ARI) of Design Discharge: 100 yr

Site ID	Proposed Station	Design Discharge, Q_{des} (cfs)	Maximum Depth, d_w (ft)	Average Velocity, u_{avg} (ft/s)	Bankfull Width, W_{BF} (ft)	Wetted Area, A_W (ft^2)	Radius of Curvature, R_c (ft)
Red Bank	1+00	24,694	15.00	8.00	50.0	750	5,000

Red Bank Bar on the NF Salmon River
Stream Bed Substrate Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Red Bank Bar on the NF Salmon R
Bank Soil Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Stream bed D_{50} (mm)	Stream Bed Substrate Grain Size Class	Bed Soil Class	Dry Unit Weight[1], γ_{bed} (lb/ft^3)	Buoyant Unit Weight, γ'_{bed} (lb/ft^3)	Friction Angle, ϕ_{bed} (deg)	Bank Soils (from field observations)	Bank Soil Class	Dry Unit Weight, γ_{bank} (lb/ft^3)	Buoyant Unit Weight, γ'_{bank} (lb/ft^3)	Friction Angle, ϕ_{bank} (deg)
Red Bank	1+00	**45.00**	Very coarse gravel	5	130.8	81.5	40	**Gravel, loose**	5	125.7	78.3	36

Source: Compiled from Julien (2010) and Shen and Julien (1993); soil classes from NRCS Table TS14E–2 Soil classification

[1] γ_{bed} (kg/m^3) = 1,600 + 300 log D_{50} (mm) (from Julien 2010)

1 kg/m^3 = 0.062 1 lb/ft^3

Red Bank Bar on the NF Salmon River
Large Wood Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Project Location: West Coast

Timber Unit Weights			Air-dried[1] γ_{Td} (lb/ft^3)	Green[2] γ_{Tgr} (lb/ft^3)
Selected Species	**Common Name**	**Scientific Name**		
Tree Type #1:	**Douglas-fir, Coast**	Pseudotsuga menziesii var. menzi.	33.5	38.0
Tree Type #2:				
Tree Type #3:				
Tree Type #4:				
Tree Type #5:				
Tree Type #6:				
Tree Type #7:				
Tree Type #8:				
Tree Type #9:				
Tree Type #10:				

[1] **Air-dried unit weight, γ_{Td}** = Average unit weight of wood after exposure to air on a 12% moisture content volume basis. Air-dried unit weight is used in the force balance calculations for the portion of wood that is above the proposed thalweg elevation (assuming unsaturated conditions).

[2] **Green unit weight, γ_{Tgr}** = Average unit weight of freshly sawn wood when the cell walls are completely saturated with water. Green unit weight is used in the force balance calculations as a conservative estimate of the unit weight for the portion of wood that is below the proposed thalweg elevation (assuming saturated conditions). For comparison, Thevenet, Citterio, & Piegay (1998) determined wood unit weight typically increases by more than 100% after less than 24 hours exposure to water.

Source for timber unit weights:

U.S. Department of Agriculture, U.S. Forest Service. (2009) Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America. Research Note NRS-38. Table 1A.

Red Bank Bar on the NF Salmon River
Notes: 30 Ft long, 2.5 Ft diameter Cover Log (Top Log). Stability provided by embedment in streambank.

Spreadsheet developed by Michael Rafferty, P.E.

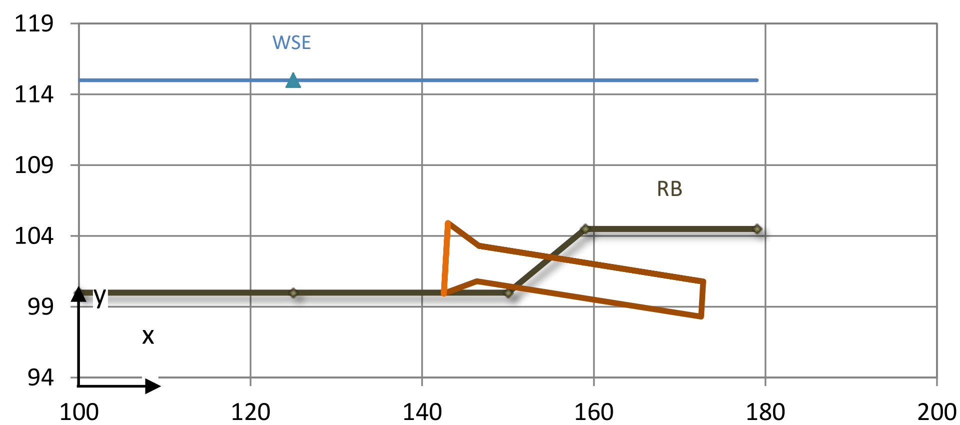
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Red Bank	Tree Revetment	Right bank	Straight	1+00	15.00	100.00	8.00

Multi-Log Structures	Layer	Log ID

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	71.00	104.50
Top LB	91.00	104.50
Toe LB	100.00	100.00
Thalweg	125.00	100.00
Toe RB	150.00	100.00
Top RB	159.00	104.50
Fldpln RB	179.00	104.50

Proposed Cross-Section and Structure Geometry (Looking D/S)

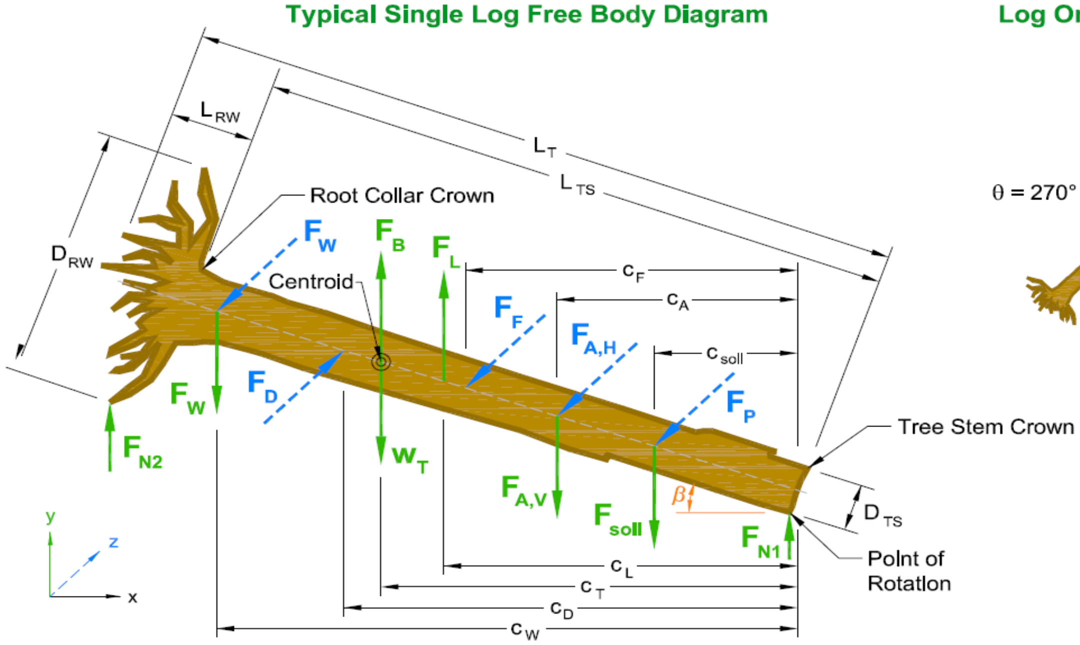


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Douglas-fir, Coast	Yes	30.0	2.50	3.75	5.00	33.5	38.0

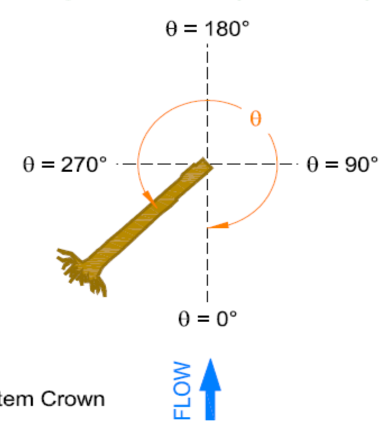
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	-5.5	Stem tip: Bottom	172.50	98.30	98.30	104.91	25.27

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Very coarse gravel	130.8	81.5	40.0	5	0.00	0.00	0.00
Bank	Gravel, loose	125.7	78.3	36.0	5	17.83	3.71	2.64

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Red Bank Tree Revetment Page 2

Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft³)	V_{RW} (ft³)	V_T (ft³)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	101.0	17.2	118.1	3,963	7,372
↓Thalweg	27.9	0.0	27.9	1,060	1,740
Total	128.9	17.2	146.0	5,023	9,113

Lift Force

C_{LT}	0.11
F_L (lbf)	178

Soil Ballast Force

Soil	V_{dry} (ft³)	V_{sat} (ft³)	V_{soil} (ft³)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	117.3	117.3	9,178
Total	0.0	117.3	117.3	9,178

Vertical Force Balance

F_B (lbf)	9,113	↑
F_L (lbf)	178	↑
W_T (lbf)	5,023	↓
F_{soil} (lbf)	9,178	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	4,911	↓
FS_V	1.53	✓

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.03	0.89	1.10	0.02	1.20	1,883

Horizontal Force Balance

F_D (lbf)	1,883	→
F_P (lbf)	17,676	←
F_F (lbf)	3,614	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	19,407	←
FS_H	11.31	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.60	0	2.00	0.84	344
Bank	3.85	17,676	21.98	0.73	3,270
Total	-	17,676	23.98	-	3,614

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
14.9	26.0	23.9	14.9	8.9	11.0	11.8

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	184,541
M_r (lbf)	455,842
FS_M	2.47 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft³)	V_{Awet} (ft³)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft³)	$V_{r,wet}$ (ft³)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Red Bank Bar on the NF Salmon River
Notes: 25 Ft long, 2.5 Ft diameter Cover Log (Top Log). Stability provided by embedment in streambank.

Spreadsheet developed by
Michael Rafferty, P.E.

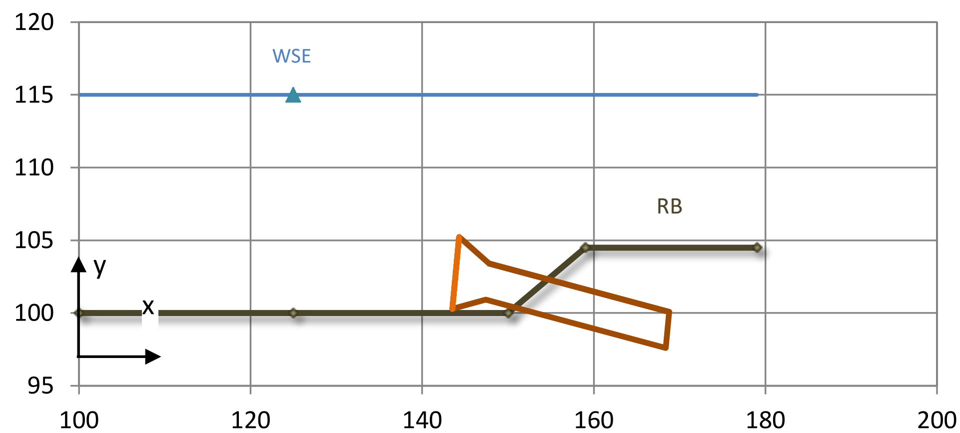
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Red Bank	Tree Revetment	Right bank	Straight	1+00	15.00	100.00	8.00

Multi-Log Structures	Layer	Log ID

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	71.00	104.50
Top LB	91.00	104.50
Toe LB	100.00	100.00
Thalweg	125.00	100.00
Toe RB	150.00	100.00
Top RB	159.00	104.50
Fldpln RB	179.00	104.50

Proposed Cross-Section and Structure Geometry (Looking D/S)

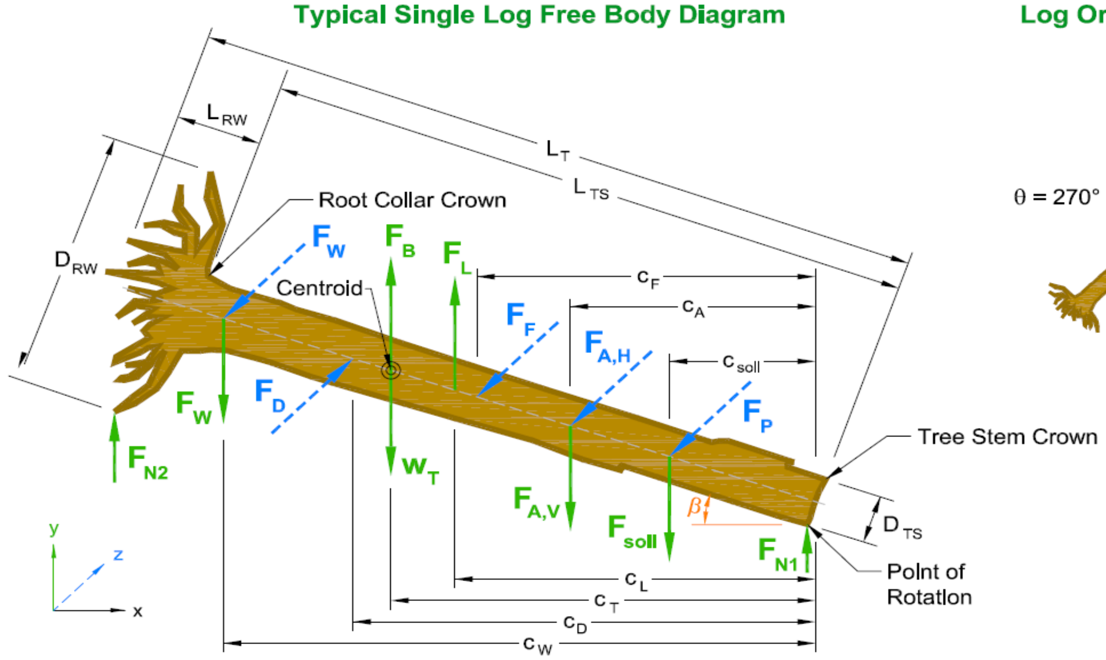


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Douglas-fir, Coast	Yes	25.0	2.50	3.75	5.00	33.5	38.0

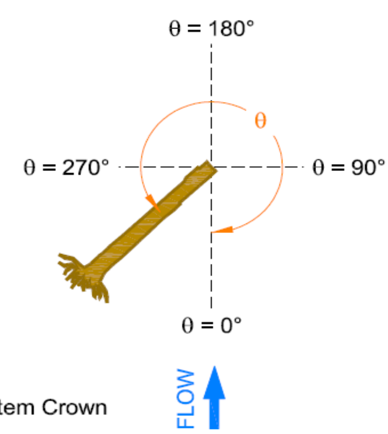
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	-9.0	Stem tip: Bottom	168.40	97.60	97.60	105.21	22.28

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Very coarse gravel	130.8	81.5	40.0	5	0.00	0.00	0.00
Bank	Gravel, loose	125.7	78.3	36.0	5	14.34	4.43	2.98

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Red Bank Tree Revetment Page 2

Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	67.7	17.2	84.9	2,849	5,299
↓Thalweg	36.6	0.0	36.6	1,390	2,282
Total	104.3	17.2	121.5	4,238	7,581

Lift Force

C_{LT}	0.08
F_L (lbf)	104

Vertical Force Balance

F_B (lbf)	7,581	↑
F_L (lbf)	104	↑
W_T (lbf)	4,238	↓
F_{soil} (lbf)	8,338	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	4,892	↓
FS_V	1.64	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	106.5	106.5	8,338
Total	0.0	106.5	106.5	8,338

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.03	0.89	1.10	0.02	1.19	1,647

Horizontal Force Balance

F_D (lbf)	1,647	→
F_P (lbf)	16,059	←
F_F (lbf)	3,609	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	18,020	←
FS_H	11.94	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.60	0	2.00	0.84	407
Bank	3.85	16,059	18.19	0.73	3,202
Total	-	16,059	20.19	-	3,609

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
12.4	20.8	19.7	12.4	7.1	9.1	9.5

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	126,849
M_r (lbf)	337,265
FS_M	2.66 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Red Bank Bar on the NF Salmon River

Notes: 30 Ft long 2.5 Ft diameter Apex Log. Computations prepared neglecting ballast weight of placed materials. Pinning Log anchoring provides vertical stability.

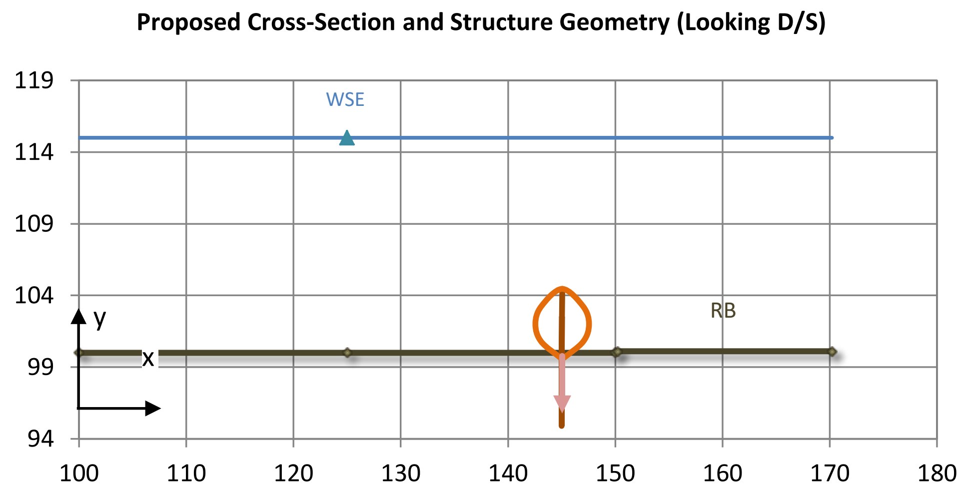
Spreadsheet developed by Michael Rafferty, P.E.

Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Red Bank	Mid-Channel	Right bank	Straight	1+00	15.00	100.00	8.00

Multi-Log Structures	Layer	Log ID

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	79.80	100.10
Top LB	99.80	100.10
Toe LB	100.00	100.00
Thalweg	125.00	100.00
Toe RB	150.00	100.00
Top RB	150.20	100.10
Fldpln RB	170.20	100.10

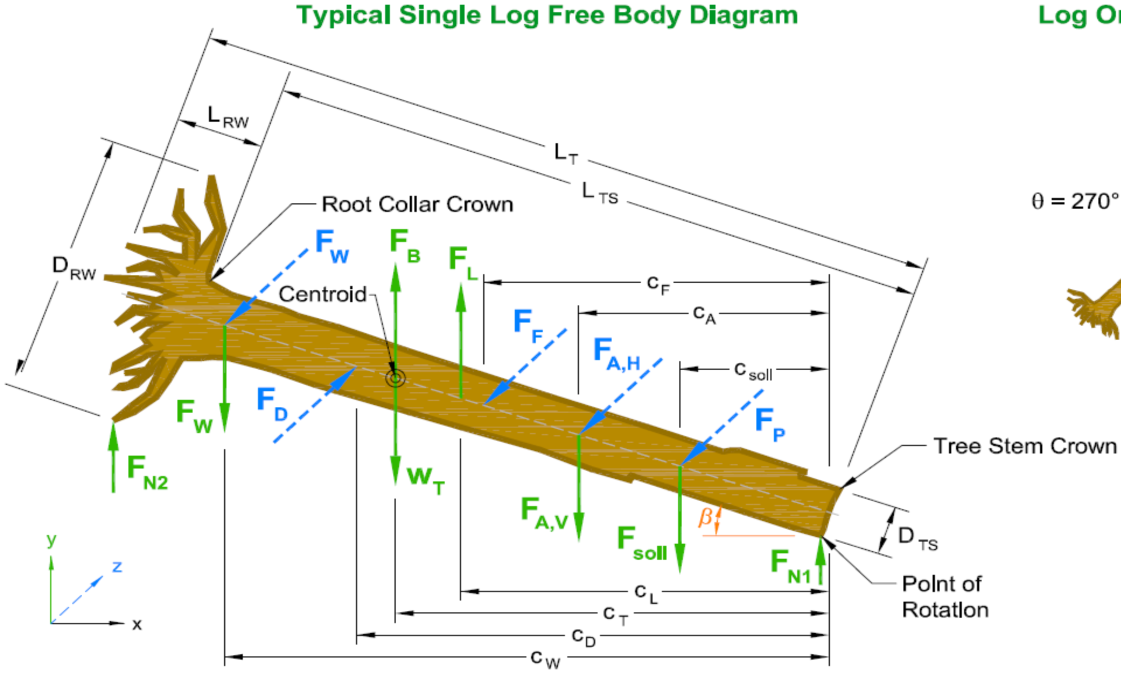


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Douglas-fir, Coast	Yes	30.0	2.50	3.75	5.00	33.5	38.0

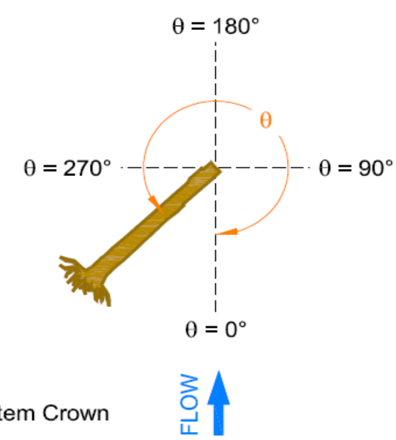
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	0.1	-11.3	Stem tip: Bottom	145.00	94.90	94.90	104.46	18.81

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Very coarse gravel	130.8	81.5	40.0	5	13.52	2.65	1.33
Bank	Gravel, loose	125.7	78.3	36.0	5	0.00	0.00	0.00

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	31.8	16.7	48.5	1,629	3,029
↓Thalweg	97.1	0.4	97.5	3,704	6,083
Total	128.9	17.2	146.0	5,333	9,113

Lift Force

C_{LT}	0.08
F_L (lbf)	88

Vertical Force Balance

F_B (lbf)	9,113	↑
F_L (lbf)	88	↑
W_T (lbf)	5,333	↓
F_{soil} (lbf)	3,646	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	4,822	↓
Σ F_V (lbf)	4,600	↓
FS_V	1.50	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	44.7	44.7	3,646
Bank	0.0	0.0	0.0	0
Total	0.0	44.7	44.7	3,646

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_W	C_D*	F_D (lbf)
0.03	0.89	1.20	0.02	1.28	1,492

Horizontal Force Balance

F_D (lbf)	1,492	→
F_P (lbf)	8,383	←
F_F (lbf)	3,860	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	178	←
Σ F_H (lbf)	10,929	←
FS_H	8.33	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.60	8,383	28.02	0.84	3,860
Bank	3.85	0	0.00	0.73	0
Total	-	8,383	28.02	-	3,860

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
14.8	28.1	21.8	14.8	6.8	13.0	9.0

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	166,554
M_r (lbf)	405,711
FS_M	2.44 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
Custom#1	25.00	Bed	5,000
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Red Bank Bar on the NF Salmon River — Vertical Pile Stability Analysis

Notes: 30 Ft long 2.5 Ft diameter Apex Log. Computations prepared neglecting ballast weight of placed materials. Pinning Log anchoring provides vertical stability.
Prepared by Michael Love & Associates, Inc.

From Knutson & Fealko, 2014. Large Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

$$F_{piles-v} = N_{piles} * \pi * d_{piles} * L_{piles}(k_s * \tan\frac{2}{3}\emptyset * \sigma' + \frac{d_{piles}}{4} * (\gamma_{wood} - \gamma_w))$$

Equation 15

N_{piles} = number of piles
d_{piles} = diameter of piles
L_{piles} = embedded length of piles
k_s = coefficient of lateral earth pressure (0.5 to 1.5 depending on soil and density)
ϕ = internal angle of friction of soils

$$\sigma' = L_{piles} * (\gamma_{sat} - \gamma_w)$$

Equation 16

Note: Error in equation. N, π, and d_{piles} should be outside parentheses encompassing remainder of equation. L_{pile} should be L_e- length of embedded pile. Buoyancy component of equation computed separately.

	Variables	
N_{piles}	2	Number Piles
d_{pile}	1.5	Pile diameter (ft)
L_e	7.2	**Length pile embedded below scour depth (feet)**
L_{pile}	15.0	Total Length Pile
ϕ	36.00	Soil Internal Friction angle, degrees
ϕ	0.63	Soil angle repose, radians
K_s	0.40	Coefficient of Lateral Earth Pressure (0.5 to 1.5, 25% Ks if excavated)
γ_{wood}	33.5	Dry unit weight wood , lbs/ft^3
γ	78.3	Effective unit weight soil (γ_e-γ_w), lbs/ft^3
σ'	563.60	L_{emb} x γ_e

Resisting Force (F_{pile-v})	**3,406**	F pile (lbs) Uplift (Resisting) Force Indivdidual Pile can withstand (Buoyant Force Not Applied)
Driving Forces	1,020	Buoyant Force of Individual Pile (F_b) (lbs) (L_{pile} x π x d_{pile} x σ') (half force because pile at 45 degree angle)
	1,250	Anchoring Force on Individual Pinning log (half force because pile at 45 degree angle)
	2,270	**Total Driving Force Upward Force Per Pile (lbs)**
	1.50	**FS per Pile**

Red Bank Bar on the NF Salmon River — Horizontal Pile Stability Analysis

Notes: 30 Ft long 2.5 Ft diameter Apex Log. Computations prepared neglecting ballast weight of placed materials. Pinning Log anchoring provides vertical stability.
Prepared by Michael Love & Associates, Inc.

From Knutson & Fealko, 2014. Large Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

$$F_{piles-h} = -N_{piles} * \frac{L_{pile}^{3} * \frac{1}{2} * \gamma_e * d_{pile} * K_p}{h_{load} + L_{pile}}$$

Equation 36

Note: Error in Equation 36. L_{pile} should be L_e

	Variables	
γ	**78.3**	Effective unit weight soil (γ_e-γ_w), lbs/ft^3
ϕ	**36**	Soil angle repose degrees
ϕ	**0.6**	Soil angle repose, radians
K_p	**3.9**	$K_p = (1+\sin\phi)/(1-\sin\phi)$
L_{pile}	**15**	Total Pile Height, ft
h_{load}	**5**	Height above potential scour depth load applied, feet
d_{pile}	**1.5**	Pile diameter (ft)
L_e	**7.2**	**Length pile embedded below scour depth (feet)**
N_{piles}	**2**	
Resisting Force (F_{pile-h})	6,920	F pile group (lbs) Lateral Force Pile group can Withstand
Driving Forces	2,500	Anchoring Force on Pinning log (half force because pile at 45 degree angle
	1,020	Buoyant Force of Pile (F_b) (lbs) (L_{pile} x π x d_{pile} x σ') (half force because pile at 45 degree angle)
	3,520	**Total Horizontal Driving Force (lbs) per Pile**
	1.97	**FS per Pile**

Red Bank Bar on the NF Salmon River
Notes: 25 Ft long, 2.5 Ft diameter Apex Log. Computations prepared neglecting ballast weight of placed materials. Pinning Log anchoring provides vertical stability.

Spreadsheet developed by Michael Rafferty, P.E.

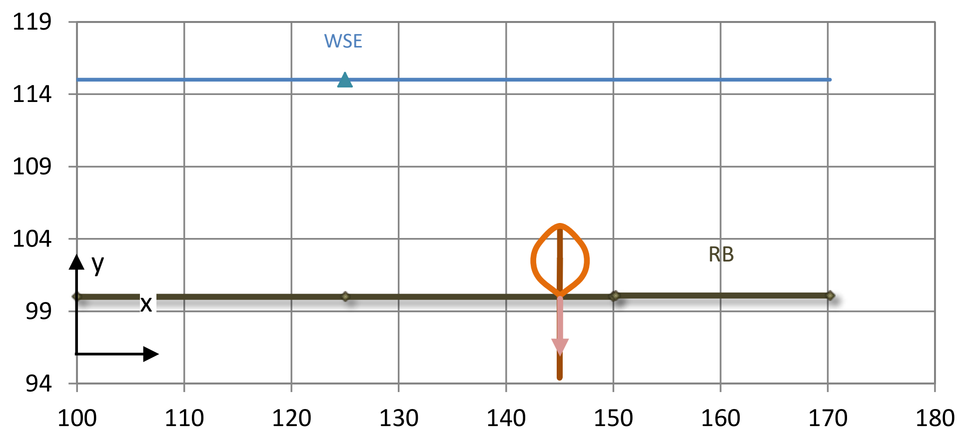
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Red Bank	Mid-Channel	Right bank	Straight	1+00	15.00	100.00	8.00

Multi-Log Structures	Layer	Log ID

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	79.80	100.10
Top LB	99.80	100.10
Toe LB	100.00	100.00
Thalweg	125.00	100.00
Toe RB	150.00	100.00
Top RB	150.20	100.10
Fldpln RB	170.20	100.10

Proposed Cross-Section and Structure Geometry (Looking D/S)

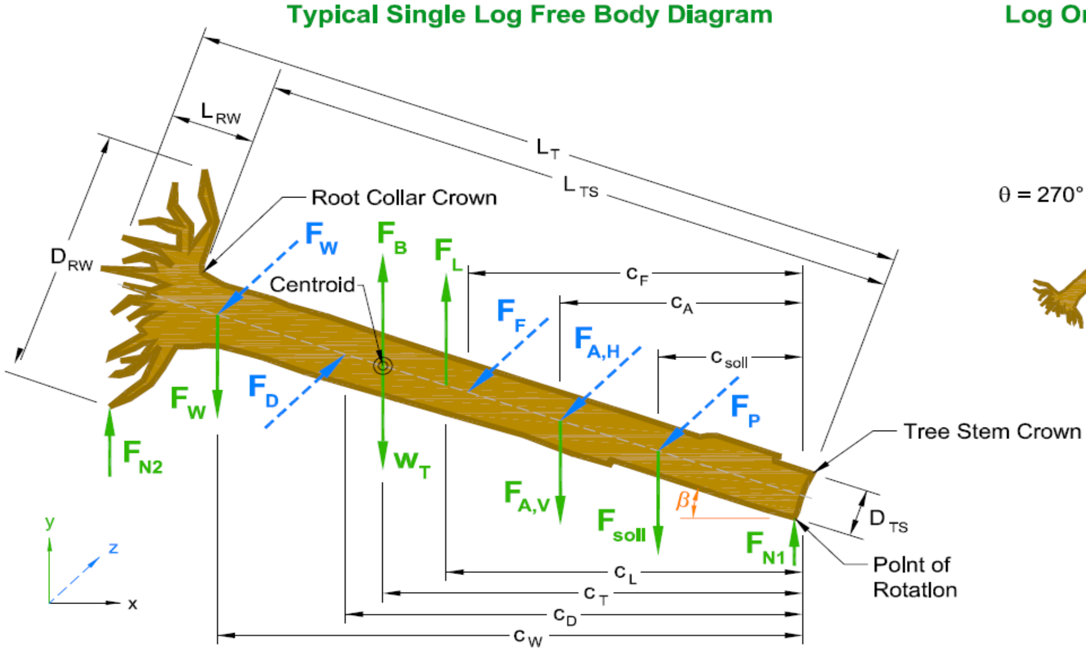


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Douglas-fir, Coast	Yes	25.0	2.50	3.75	5.00	33.5	38.0

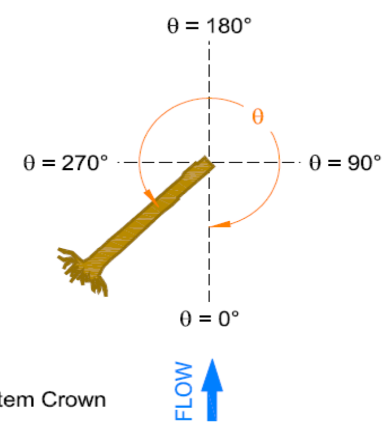
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	0.1	-16.0	Stem tip: Bottom	145.00	94.40	94.40	104.90	19.68

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	φ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Very coarse gravel	130.8	81.5	40.0	5	11.60	3.20	1.61
Bank	Gravel, loose	125.7	78.3	36.0	5	0.00	0.00	0.00

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Red Bank Mid-Channel

Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft³)	V_{RW} (ft³)	V_T (ft³)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	26.0	17.2	43.2	1,448	2,693
↓Thalweg	78.3	0.0	78.3	2,977	4,888
Total	104.3	17.2	121.5	4,424	7,581

Lift Force

C_{LT}	0.08
F_L (lbf)	92

Vertical Force Balance

F_B (lbf)	7,581	↑
F_L (lbf)	92	↑
W_T (lbf)	4,424	↓
F_{soil} (lbf)	3,776	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	3,310	↓
Σ F_V (lbf)	3,837	↓
FS_V	1.50	✓

Soil Ballast Force

Soil	V_{dry} (ft³)	V_{sat} (ft³)	V_{soil} (ft³)	F_{soil} (lbf)
Bed	0.0	46.3	46.3	3,776
Bank	0.0	0.0	0.0	0
Total	0.0	46.3	46.3	3,776

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.03	0.89	1.20	0.02	1.28	1,565

Horizontal Force Balance

F_D (lbf)	1,565	→
F_P (lbf)	8,683	←
F_F (lbf)	3,219	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	240	←
Σ F_H (lbf)	10,577	←
FS_H	7.76	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.60	8,683	22.31	0.84	3,219
Bank	3.85	0	0.00	0.73	0
Total	-	8,683	22.31	-	3,219

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
12.3	22.6	18.3	12.3	5.8	10.1	7.7

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	119,233	↻
M_r (lbf)	274,121	↺
FS_M	2.30	✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft³)	V_{Awet} (ft³)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
Custom#1	20.00	Bed	3,550
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft³)	$V_{r,wet}$ (ft³)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Red Bank Bar on the NF Salmon River **Vertical Pile Stability Analysis**

Notes: 25 Ft long, 2.5 Ft diameter Apex Log. Computations prepared neglecting ballast weight of placed materials. Pinning Log anchoring provides vertical stability.
Prepared by Michael Love & Associates, Inc.

From Knutson & Fealko, 2014. Large Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

$$F_{piles-v} = N_{piles} * \pi * d_{piles} * L_{piles}(k_s * \tan\frac{2}{3}\emptyset * \sigma' + \frac{d_{piles}}{4} * (\gamma_{wood} - \gamma_w))$$

Equation 15

N_{piles} = number of piles
d_{piles} = diameter of piles
L_{piles} = embedded length of piles
k_s = coefficient of lateral earth pressure (0.5 to 1.5 depending on soil and density)
ϕ = internal angle of friction of soils

$$\sigma' = L_{piles} * (\gamma_{sat} - \gamma_w)$$

Equation 16

Note: Error in equation. N, π, and d_{piles} should be outside parentheses encompassing remainder of equation. L_{pile} should be L_e-length of embedded pile. Buoyancy component of equation computed separately.

	Variables	
N_{piles}	2	Number Piles
d_{pile}	1.5	Pile diameter (ft)
L_e	6.6	**Length pile embedded below scour depth (feet)**
L_{pile}	15.0	Total Length Pile
ϕ	36.00	Soil Internal Friction angle, degrees
ϕ	0.63	Soil angle repose, radians
K_s	0.40	Coefficient of Lateral Earth Pressure (0.5 to 1.5, 25% Ks if excavated)
γ_{wood}	33.5	Dry unit weight wood , lbs/ft^3
γ	78.3	Effective unit weight soil (γ_e-γ_w), lbs/ft^3
σ'	516.60	L_{emb} x γ_e

Resisting Force (F_{pile-v})	**2,862**	F pile (lbs) Uplift (Resisting) Force Indivdidual Pile can withstand (Buoyant Force Not Applied)
Driving Forces	1,020	Buoyant Force of Individual Pile (F_b) (lbs) (L_{pile} x π x d_{pile} x σ') (half force because pile at 45 degree angle)
	888	Anchoring Force on Individual Pinning log (half force because pile at 45 degree angle)
	1,907	**Total Driving Force Upward Force Per Pile (lbs)**
	1.50	**FS per Pile**

Red Bank Bar on the NF Salmon River — Horizontal Pile Stability Analysis

Notes: 25 Ft long, 2.5 Ft diameter Apex Log. Computations prepared neglecting ballast weight of placed materials. Pinning Log anchoring provides vertical stability.
Prepared by Michael Love & Associates, Inc.

From Knutson & Fealko, 2014. Large Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

$$F_{piles-h} = -N_{piles} * \frac{L_{pile}^3 * \frac{1}{2} * \gamma_e * d_{pile} * K_p}{h_{load} + L_{pile}}$$

Equation 36

Note: Error in Equation 36. L_{pile} should be L_e

	Variables	
γ	**78.3**	Effective unit weight soil (γ_e-γ_w), lbs/ft^3
ϕ	**36**	Soil angle repose degrees
ϕ	**0.6**	Soil angle repose, radians
K_p	**3.9**	$K_p = (1+\sin\phi)/(1-\sin\phi)$
L_{pile}	**15**	Total Pile Height, ft
h_{load}	**5**	Height above potential scour depth load applied, feet
d_{pile}	**1.5**	Pile diameter (ft)
L_e	**6.6**	**Length pile embedded below scour depth (feet)**

N_{piles}	**2**	
Resisting Force (F_{pile-h})	5,605	F pile group (lbs) Lateral Force Pile group can Withstand
Driving Forces	1,020	Buoyant Force of Individual Pile (F_b) (lbs) (L_{pile} x π x d_{pile} x σ') (half force because pile at 45 degree angle)
	888	Anchoring Force on Individual Pinning log (half force because pile at 45 degree angle)
	1,907	**Total Horizontal Driving Force (lbs) per Pile**
	2.94	**FS per Pile**

Red Bank Bar on the NF Salmon River

Notes: 30 ft, 2.0 Dia. Bank Log. Stability dependent on buttress trees for horizontal and vertical stabity, and pinning log anchoring for vetical stability in the channel.

Spreadsheet developed by
Michael Rafferty, P.E.

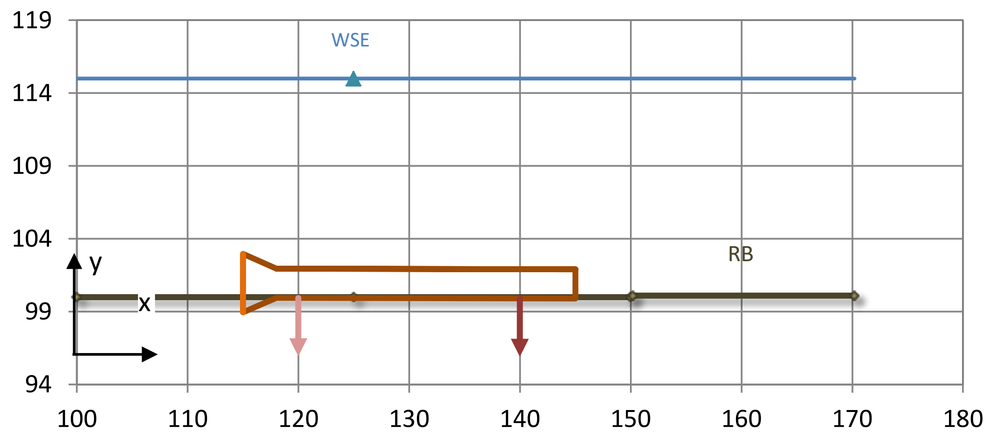
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Red Bank	Rootwad	Right bank	Straight	1+00	15.00	100.00	8.00

Multi-Log Structures	Layer	Log ID

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	79.80	100.10
Top LB	99.80	100.10
Toe LB	100.00	100.00
Thalweg	125.00	100.00
Toe RB	150.00	100.00
Top RB	150.20	100.10
Fldpln RB	170.20	100.10

Proposed Cross-Section and Structure Geometry (Looking D/S)

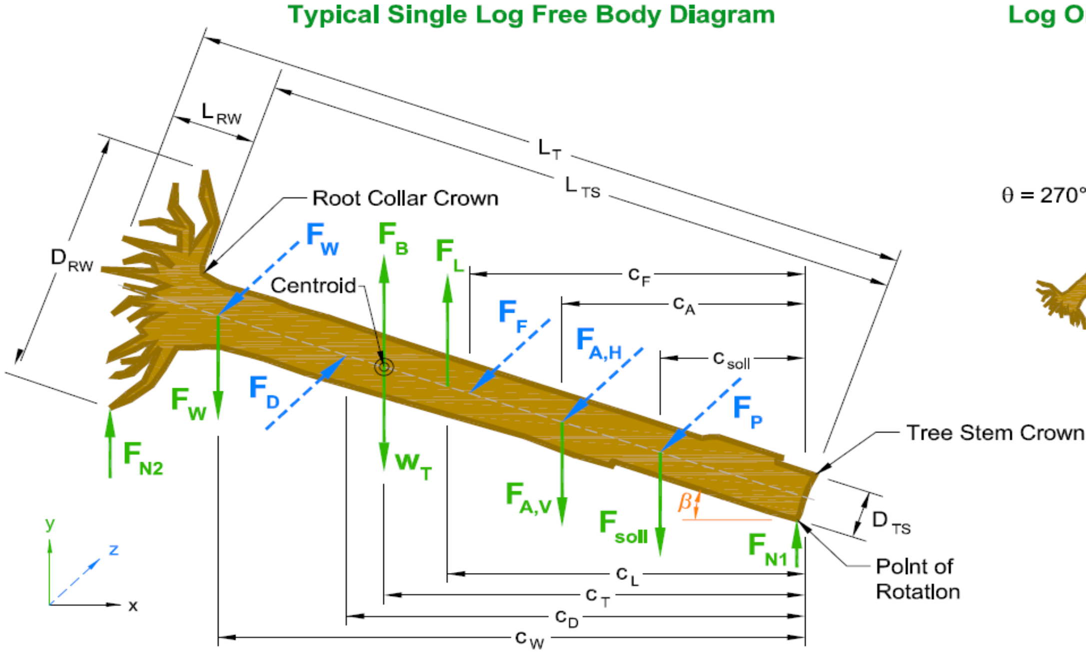


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Douglas-fir, Coast	Yes	30.0	2.00	3.00	4.00	33.5	38.0

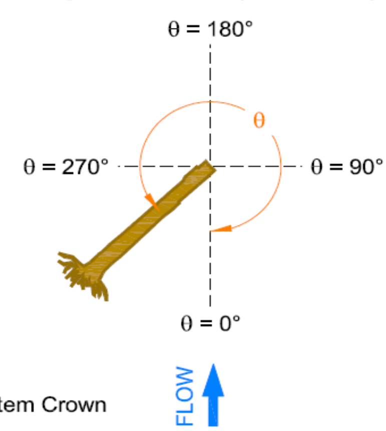
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	-0.1	Stem tip: Bottom	145.00	99.90	98.95	102.95	57.79

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Very coarse gravel	130.8	81.5	40.0	5	0.00	0.00	0.00
Bank	Gravel, loose	125.7	78.3	36.0	5	0.00	0.00	0.00

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	83.8	7.6	91.3	3,063	5,698
↓Thalweg	1.1	1.2	2.3	87	144
Total	84.8	8.8	93.6	3,151	5,842

Lift Force

C_{LT}	0.00
F_L (lbf)	0

Vertical Force Balance

F_B (lbf)	5,842 ↑
F_L (lbf)	0
W_T (lbf)	3,151 ↓
F_{soil} (lbf)	0
$F_{W,V}$ (lbf)	0
$F_{A,V}$ (lbf)	5,612 ↓
ΣF_V (lbf)	2,921 ↓
FS_V	1.50 ✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	0.0	0.0	0
Total	0.0	0.0	0.0	0

Horizontal Force Analysis
(Neglected-Buttress Trees and bank log strength resist horizontal rotation)

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.08	1.00	1.10	0.01	1.30	0

Horizontal Force Balance

F_D (lbf)	0	
F_P (lbf)	0	
F_F (lbf)	0	
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	Neglected
ΣF_H (lbf)	8,588 ←	
FS_H	0.00 ✗	

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.60	0	32.00	0.84	2,451
Bank	3.85	0	0.00	0.73	0
Total	-	0	32.00	-	0

Moment Force Balance (Vertical Only)

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
15.0	0.0	0.0	15.0	0.0	0.0	0.0

*Distances are from the stem tip

Point of Rotation: Rootwad

Moment Force Balance

M_d (lbf)	87,866
M_r (lbf)	348,010
FS_M	3.96 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors*

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
Custom#1	25.00	Bed	7,100
Custom#2	5.00	Bed	7,100

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

*NOTE: Custom Anchor 2 simulates horizontal resistance from butress trees, and vertical resistance from friction between bank log and buttress trees.

Red Bank Bar on the NF Salmon River **Vertical Pile Stability Analysis**

Notes: 30 ft, 2.0 Dia. Bank Log. Stability dependent on buttress trees for horizontal and vertical stabity, and pinning log anchoring for vetical stability in the channel.
Prepared by Michael Love & Associates, Inc.

From Knutson & Fealko, 2014. Large Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

$$F_{piles-v} = N_{piles} * \pi * d_{piles} * L_{piles}(k_s * \tan\frac{2}{3}\emptyset * \sigma' + \frac{d_{piles}}{4} * (\gamma_{wood} - \gamma_w))$$

Equation 15

N_{piles} = number of piles
d_{piles} = diameter of piles
L_{piles} = embedded length of piles
k_s = coefficient of lateral earth pressure (0.5 to 1.5 depending on soil and density)
ϕ = internal angle of friction of soils

$$\sigma' = L_{piles} * (\gamma_{sat} - \gamma_w)$$

Equation 16

Note: Error in equation. N, π, and d_{piles} should be outside parentheses encompassing remainder of equation. L_{pile} should be L_e-length of embedded pile. Buoyancy component of equation computed separately.

	1 **Variables**	
$\mathbf{N_{piles}}$	1	Number Piles
$\mathbf{d_{pile}}$	1.5	Pile diameter (ft)
$\mathbf{L_e}$	10.2	**Length pile embedded below scour depth (feet)**
$\mathbf{L_{pile}}$	15.0	Total Length Pile
ϕ	36.00	Soil Internal Friction angle, degrees
ϕ	0.63	Soil angle repose, radians
$\mathbf{K_s}$	0.40	Coefficient of Lateral Earth Pressure (0.5 to 1.5, 25% Ks if excavated)
γ_{wood}	33.5	Dry unit weight wood , lbs/ft^3
γ	78.3	Effective unit weight soil (γ_e-γ_w), lbs/ft^3
σ'	801.67	L_{emb} x γ_e

Resisting Force (F_{pile-v})	**6,891**	F pile (lbs) Uplift (Resisting) Force Indivdidual Pile can withstand (Buoyant Force Not Applied)
Driving Forces	1,020	Buoyant Force of Individual Pile (F_b) (lbs) (L_{pile} x π x d_{pile} x σ') (half force because pile at 45 degree angle)
	3,550	Anchoring Force on Individual Pinning log (half force because pile at 45 degree angle)
	4,570	**Total Driving Force Upward Force Per Pile (lbs)**
	1.5	**FS per Pile**

Red Bank Bar on the NF Salmon River — Horizontal Pile Stability Analysis

Notes: 30 ft, 2.0 Dia. Bank Log. Stability dependent on buttress trees for horizontal and vertical stabity, and pinning log anchoring for vetical stability in the channel.
Prepared by Michael Love & Associates, Inc.

From Knutson & Fealko, 2014. Large Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

$$F_{piles-h} = -N_{piles} * \frac{L_{pile}^3 * \frac{1}{2} * \gamma_e * d_{pile} * K_p}{h_{load} + L_{pile}}$$

Equation 36

Note: Error in Equation 36. L_{pile} should be L_e

	Variables	
γ	**78.3**	Effective unit weight soil (γ_e-γ_w), lbs/ft^3
ϕ	**36**	Soil angle repose degrees
ϕ	**0.6**	Soil angle repose, radians
K_p	**3.9**	$K_p = (1+\sin\phi)/(1-\sin\phi)$
L_{pile}	**15**	Total Pile Height, ft
h_{load}	**5**	Height above potential scour depth load applied, feet
d_{pile}	**1.5**	Pile diameter (ft)
L_e	**10.2**	**Length pile embedded below scour depth (feet)**

N_{piles}	**1**	
Resisting Force (F_{pile-h})	15,940	F pile group (lbs) Lateral Force Pile group can Withstand
Driving Forces	1,020	Buoyant Force of Individual Pile (F_b) (lbs) (L_{pile} x π x d_{pile} x σ') (half force because pile at 45 degree angle)
	3,550	Anchoring Force on Individual Pinning log (half force because pile at 45 degree angle)
	4,570	**Total Horizontal Driving Force (lbs) per Pile**
	3.49	**FS per Pile**

Red Bank Bar on the NF Salmon River

Spreadsheet developed by
Michael Rafferty, P.E.

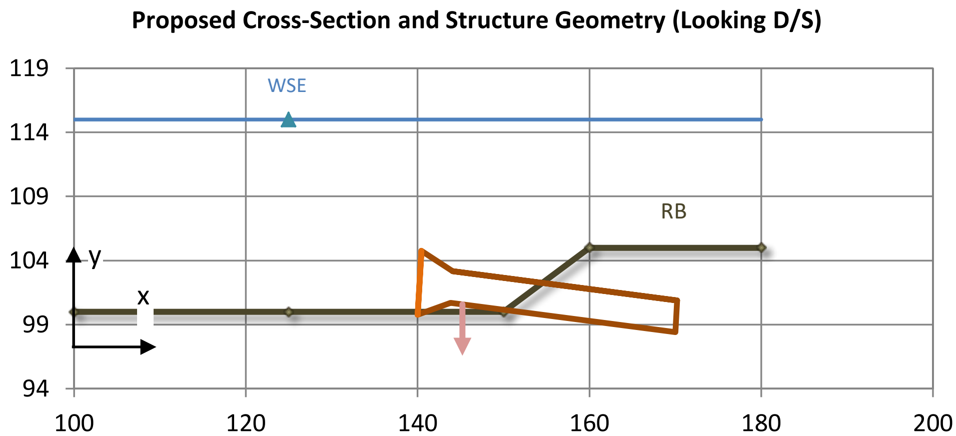
Notes: 30 Ft long, 2.5 Ft diameter Root Wad Alcove (Top Log). Stability provided by embedment in streambank and pinning log as anchor.

Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
Red Bank	Tree Revetment	Right bank	Straight	1+00	15.00	100.00	8.00

Multi-Log Structures	Layer	Log ID

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	70.00	105.00
Top LB	90.00	105.00
Toe LB	100.00	100.00
Thalweg	125.00	100.00
Toe RB	150.00	100.00
Top RB	160.00	105.00
Fldpln RB	180.00	105.00

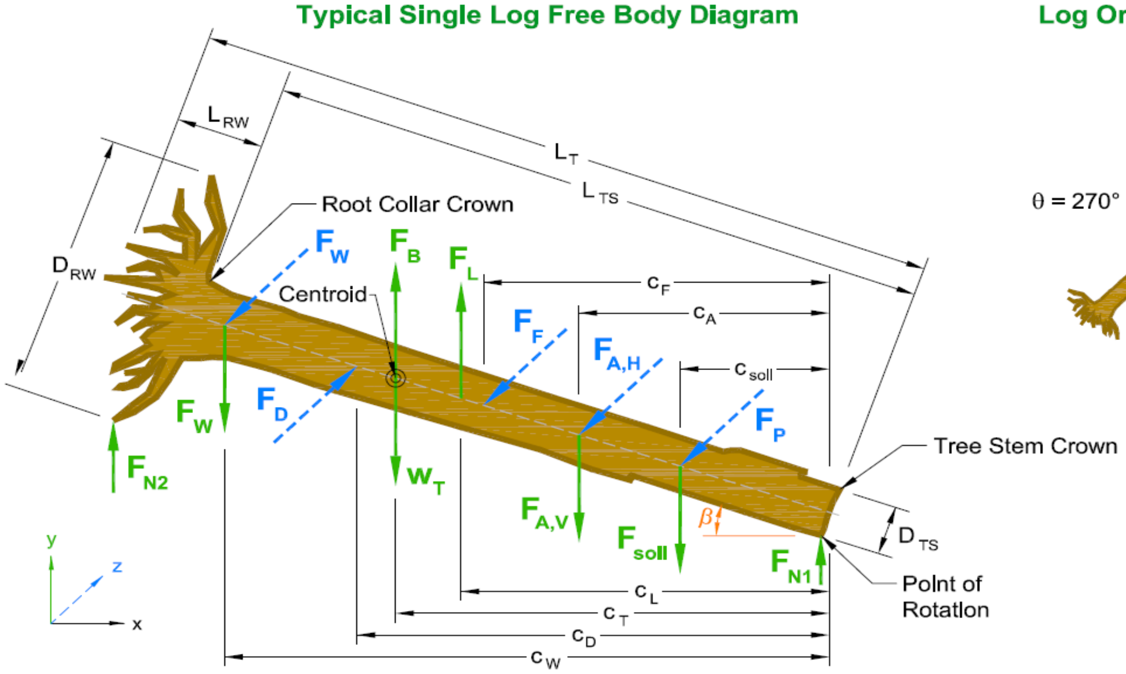


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Douglas-fir, Coast	Yes	30.0	2.50	3.75	5.00	33.5	38.0

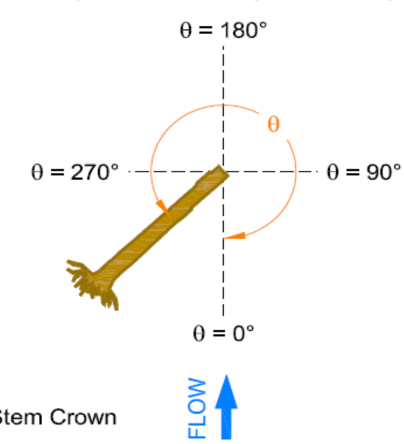
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	270.1	-5.0	Stem tip: Bottom	170.00	98.40	98.40	104.75	30.32

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Very coarse gravel	130.8	81.5	40.0	5	0.00	0.00	0.00
Bank	Gravel, loose	125.7	78.3	36.0	5	15.75	4.11	2.94

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft³)	V_{RW} (ft³)	V_T (ft³)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	102.2	17.1	119.3	4,003	7,445
↓Thalweg	26.7	0.0	26.7	1,015	1,667
Total	128.9	17.2	146.0	5,018	9,113

Lift Force

C_{LT}	0.17
F_L (lbf)	319

Vertical Force Balance

F_B (lbf)	9,113	↑
F_L (lbf)	319	↑
W_T (lbf)	5,018	↓
F_{soil} (lbf)	9,079	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	51	↓
Σ F_V (lbf)	4,716	↓
FS_V	1.50	✓

Soil Ballast Force

Soil	V_{dry} (ft³)	V_{sat} (ft³)	V_{soil} (ft³)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	116.0	116.0	9,079
Total	0.0	116.0	116.0	9,079

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_W	C_D*	F_D (lbf)
0.04	0.89	1.10	0.02	1.22	2,290

Horizontal Force Balance

F_D (lbf)	2,290	→
F_P (lbf)	17,485	←
F_F (lbf)	3,475	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	449	←
Σ F_H (lbf)	19,118	←
FS_H	9.35	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.60	0	2.00	0.84	359
Bank	3.85	17,485	20.03	0.73	3,115
Total	-	17,485	22.03	-	3,475

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
14.9	25.1	23.0	14.9	7.9	10.0	10.5

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	195,545
M_r (lbf)	422,411
FS_M	2.16 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft³)	V_{Awet} (ft³)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
Custom#1	25.00	Bed	500

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft³)	$V_{r,wet}$ (ft³)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Red Bank Bar on the NF Salmon River **Vertical Pile Stability Analysis**

Notes: 30 ft, 2.0 Dia. Bank Log. Stability dependent on buttress trees for horizontal and vertical stabity, and pinning log anchoring for vetical stability in the channel.
Prepared by Michael Love & Associates, Inc.

From Knutson & Fealko, 2014. Large Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

$$F_{piles-v} = N_{piles} * \pi * d_{piles} * L_{piles}(k_s * \tan\frac{2}{3}\emptyset * \sigma' + \frac{d_{piles}}{4} * (\gamma_{wood} - \gamma_w))$$

Equation 15

N_{piles} = number of piles
d_{piles} = diameter of piles
L_{piles} = embedded length of piles
k_s = coefficient of lateral earth pressure (0.5 to 1.5 depending on soil and density)
ϕ = internal angle of friction of soils

$$\sigma' = L_{piles} * (\gamma_{sat} - \gamma_w)$$

Equation 16

Note: Error in equation. N, π, and d_{piles} should be outside parentheses encompassing remainder of equation. L_{pile} should be L_e-length of embedded pile. Buoyancy component of equation computed separately.

1

	Variables	
N_{piles}	1	Number Piles
d_{pile}	1.5	Pile diameter (ft)
L_e	5.4	**Length pile embedded below scour depth (feet)**
L_{pile}	15.0	Total Length Pile
ϕ	36.00	Soil Internal Friction angle, degrees
ϕ	0.63	Soil angle repose, radians
K_s	0.40	Coefficient of Lateral Earth Pressure (0.5 to 1.5, 25% Ks if excavated)
γ_{wood}	33.5	Dry unit weight wood , lbs/ft^3
γ	78.3	Effective unit weight soil (γ_e-γ_w), lbs/ft^3
σ'	421.49	L_{emb} x γ_e

Resisting Force (F_{pile-v})	**1,905**	F pile (lbs) Uplift (Resisting) Force Indivdidual Pile can withstand (Buoyant Force Not Applied) ↓
Driving Forces	1,020	Buoyant Force of Individual Pile (F_b) (lbs) (L_{pile} x π x d_{pile} x σ') (half force because pile at 45 degree angle) ↑
	250	Anchoring Force on Individual Pinning log (half force because pile at 45 degree angle)
	1,270	**Total Driving Force Upward Force Per Pile (lbs)**
	1.50	**FS per Pile**

Red Bank Bar on the NF Salmon River — Horizontal Pile Stability Analysis

Notes: 30 ft, 2.0 Dia. Bank Log. Stability dependent on buttress trees for horizontal and vertical stabity, and pinning log anchoring for vetical stability in the channel.

Prepared by Michael Love & Associates, Inc.

From Knutson & Fealko, 2014. Large Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

$$F_{piles-h} = -N_{piles} * \frac{L_{pile}^3 * \frac{1}{2} * \gamma_e * d_{pile} * K_p}{h_{load} + L_{pile}}$$

Equation 36

Note: Error in Equation 36. L_{pile} should be L_e

	Variables	
γ	**78.3**	Effective unit weight soil (γ_e-γ_w), lbs/ft^3
ϕ	**36**	Soil angle repose degrees
ϕ	**0.6**	Soil angle repose, radians
K_p	**3.9**	K_p = (1+sinϕ)/(1-sinϕ)
L_{pile}	**15**	Total Pile Height, ft
h_{load}	**5**	Height above potential scour depth load applied, feet
d_{pile}	**1.5**	Pile diameter (ft)
L_e	**5.4**	**Length pile embedded below scour depth (feet)**

N_{piles}	**1**	
Resisting Force (F_{pile-h})	3,400	F pile group (lbs) Lateral Force Pile group can Withstand
Driving Forces	1,020	Buoyant Force of Individual Pile (F_b) (lbs) (L_{pile} x π x d_{pile} x σ') (half force because pile at 45 degree angle)
	250	Anchoring Force on Individual Pinning log (half force because pile at 45 degree angle)
	1,270	**Total Horizontal Driving Force (lbs) per Pile**
	2.68	**FS per Pile**

Red Bank Bar

Large Wood Abutment Jam Stability Analysis

Prepared 4/19/17

TABLE OF CONTENTS

Designer:
Rachel Shea, P.E.

Reviewed by:
Michael Love, P.E.

Engineered Log Jam Calculations, Spreadsheets developed by Scott Wright, P.E.
Adapted By Rachel Shea, P.E., Michael Love & Associates, Inc.

Supporting data from Rafferty, M. 2016. Computational Design Tool for Evaluating the Stability of Large Wood Structures. Technical Note TN-103.1. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center. 27 p. Version 1.1. January 7, 2016. http://www.fs.fed.us/biology/nsaec/products-tools.html

Red Bank Bar
Factors of Safety and Design Constants

Spreadsheet developed by
Michael Rafferty, P.E.

Symbol	Description	Units	Value
C_D	Drag Coefficeient	-	1.5
g	Gravitational acceleration constant	ft/s^2	32.174
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-	2.00
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-	1.50
SG_{rock}	Specific gravity of Rock	-	2.65
γ_{rock}	Dry unit weight of boulders	lb/ft^3	165.0
γ_w	Specific weight of water at 50ºF	lb/ft^3	62.40
η	Rootwad porosity from WDFW (2012)	-	0.60
K_s	Coefficient of Lateral Earth Pressure (0.5 to 1.5, 25% Ks if excavated)		0.4

Values from Knutson & Fealko, 2014. Large Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

Red Bank Bar
Hydrologic and Hydraulic Inputs

Spreadsheet developed by
Michael Rafferty, P.E.

Average Return Interval (ARI) of Design Discharge: 100 yr

Analysis for Flows in Side Channel Only

Site ID	Proposed Station	Design Discharge, Q_{des} (cfs)	Maximum Depth, d_w (ft)	Average Velocity, u_{avg} (ft/s)	Bankfull Width, W_{BF} (ft)	Wetted Area, A_W (ft^2)
RED BANK	1+00	24,694	15.00	8.00	50.0	750

Red Bank Bar
Stream Bed Substrate Properties

Spreadsheet developed by Michael Rafferty, P.E.

Red Bank Bar
Bank Soil Properties

Spreadsheet developed by Michael Rafferty, P.E.

Site ID	Proposed Station	Stream bed D_{50} (mm)	Stream Bed Substrate Grain Size Class	Bed Soil Class	Dry Unit Weight[1], γ_{bed} (lb/ft^3)	Buoyant Unit Weight, γ'_{bed} (lb/ft^3)	Friction Angle, ϕ_{bed} (deg)	Bank Soils (from field observations)	Bank Soil Class	Dry Unit Weight, γ_{bank} (lb/ft^3)	Buoyant Unit Weight, γ'_{bank} (lb/ft^3)	Friction Angle, ϕ_{bank} (deg)
RED BANK	1+00	45.00	Very coarse gravel	5	130.8	81.5	40	Gravel, loose	5	125.7	78.3	36

Source: Compiled from Julien (2010) and Shen and Julien (1993); soil classes from NRCS Table TS14E–2 Soil classification

[1] γ_{bed} (kg/m^3) = 1,600 + 300 log D_{50} (mm) (from Julien 2010)

1 kg/m^3 = 0.062 1 lb/ft^3

Red Bank Bar

Spreadsheet developed by Michael Rafferty, P.E.

Large Wood Properties

Project Location: **West Coast**

Timber Unit Weights			Air-dried[1] γ_{Td} (lb/ft^3)	Green[2] γ_{Tgr} (lb/ft^3)
Selected Species	**Common Name**	**Scientific Name**		
Tree Type #1:	**Douglas-fir, Coast**	Pseudotsuga menziesii var. menzi.	33.5	38.0
Tree Type #2:				
Tree Type #3:				
Tree Type #4:				
Tree Type #5:				
Tree Type #6:				
Tree Type #7:				
Tree Type #8:				
Tree Type #9:				
Tree Type #10:				

[1] **Air-dried unit weight,** γ_{Td} = Average unit weight of wood after exposure to air on a 12% moisture content volume basis. Air-dried unit weight is used in the force balance calculations for the portion of wood that is above the proposed thalweg elevation (assuming unsaturated conditions).

[2] **Green unit weight,** γ_{Tgr} = Average unit weight of freshly sawn wood when the cell walls are completely saturated with water. Green unit weight is used in the force balance calculations as a conservative estimate of the unit weight for the portion of wood that is below the proposed thalweg elevation (assuming saturated conditions). For comparison, Thevenet, Citterio, & Piegay (1998) determined wood unit weight typically increases by more than 100% after less than 24 hours exposure to water.

Source for timber unit weights:

U.S. Department of Agriculture, U.S. Forest Service. (2009) Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America. Research Note NRS-38. Table 1A.

Red Bank Bar **4/20/2017**
Contraction Scour Analysis Prepared by: RS

From: FHWA. 2012. Evaluating Scour at Bridges, Fifth Edition. Hydraulic Engineering Circular No. 18. U.S. Department of Transportation, Federal Highway Administration. Publication FHWA-HIF-12-003. Checked by: ML

Live Bed Scour (Laursen, 1960 modified by HEC-18)

ABJ Projection into Channel (L_e) 10 feet

	2 Year Event	**5-Year Event**	**10-Year Event**	**25-Year Event**	**100-Year Event**
	5082 cfs	**9003 cfs**	**12,139 cfs**	**16,198 cfs**	**24, 694 cfs**
Flow in Upstream Channel transporting sediment (Q_1) cfs	1557	3301	4929	7609	11952
Flow in the Contracted Channel (Q_2) cfs	1557.0	3301.0	4929.0	7609	11952
Bottom width of the upstream channel transporting sediment (W_1) cfs	**50.0**	**50.0**	**50.0**	**50.0**	**50.0**
Bottom width of the contracted channel (W_2) cfs	40.0	40.0	40.0	40.0	40.0
K_1 Value	**0.59**	**0.59**	**0.59**	**0.59**	**0.59**
Average Depth in the Upstream Channel (y_1)(ft)	**7.5**	**8.8**	**9.7**	**12.4**	**13.7**
Average Depth in the Contracted Channel before Scour (y_o) (ft)	7.5	8.8	9.7	12.4	13.7
Average Depth in Contraction Section (y_2) ft	8.56	10.04	11.06	14.14	15.63
Drop in Contracted Channel Elev, feet (Ys)	**1.06**	**1.24**	**1.36**	**1.74**	**1.93**

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1} \quad (6.2)$$

$$y_s = y_2 - y_o = \text{(average contraction scour depth)} \quad (6.3)$$

where:

y_1 = Average depth in the upstream main channel, ft (m)
y_2 = Average depth in the contracted section, ft (m)
y_o = Existing depth in the contracted section before scour, ft (m) (see Note 7)
Q_1 = Flow in the upstream channel transporting sediment, ft^3/s (m^3/s)
Q_2 = Flow in the contracted channel, ft^3/s (m^3/s)
W_1 = Bottom width of the upstream main channel that is transporting bed material, ft (m)
W_2 = Bottom width of main channel in contracted section less pier width(s), ft (m)
k_1 = Exponent determined below

V_*/T	k_1	Mode of Bed Material Transport
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

V_* = $(\tau_o/\rho)^{1/2} = (g y_1 S_1)^{1/2}$, shear velocity in the upstream section, ft/s (m/s)
T = Fall velocity of bed material based on the D_{50}, m/s (Figure 6.8)
For fall velocity in English units (ft/s) multiply T in m/s by 3.28
g = Acceleration of gravity (32.2 ft/s^2) (9.81 m/s^2)
S_1 = Slope of energy grade line of main channel, ft/ft (m/m)
τ_o = Shear stress on the bed, (lb/ft^2) (Pa (N/m^2))
ρ = Density of water (1.94 $slugs/ft^3$) (1000 kg/m^3)

Red Bank Bar, NF Salmon River-Internal Racking and Key Member Tiers

Abutment Jam Vertical Stability Computations

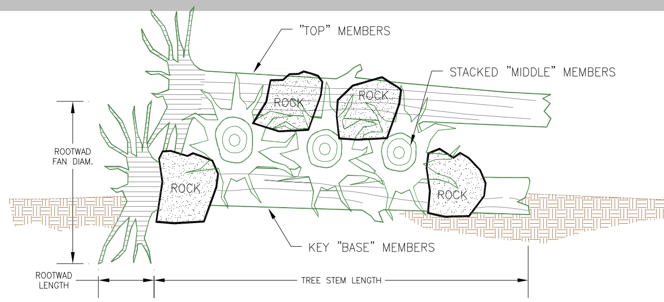
Spreadsheet developed by Scott Wright, P.E. - revision 1.4 (Adapted by MLA)

Modified by Rachel Shea, P.E. Michael Love & Associates. Corrected labeling for effective boulder weights. Updated Soil computations to reference soil data from separate tab. Method does not include lift or moments.

Methodology based on a standard force balance approach and information adapted from D'aoust & Millar (2000).
The ELJ should act as a fully connected structure and all Soil Ballast should be designed against predicted scour forces.

Analysis for single cycle of key and racking members. Each cycle designed to independently maintain a vertical FS > 1.5

Definition Sketch



Structure Dimenions

Length (flow-parallel)	18
Width (Perpindicular to Flow)	25

Key Members (No Root Wads)

Number of Logs with Rootwads	N_L =	3	
	S_L =	0.54	specific gravity
Average Rootwad Fan Diameter	D_{RW} =	0	feet
Average Rootwad Length	L_{RW} =	0	feet
Proportion of Voids in Rootwad	p =	0.60	decimal %
Tree Stem Average Diameter	D_{TS} =	2.5	feet
Tree Stem Average Length	L_{TS} =	25	feet

Wood Volume = 120 cubic feet per member

$$F_{BL} = \left(\frac{\pi D_{TS}^2 L_{TS}}{4} + \frac{\pi D_{RW}^2 L_{RW}}{4} \cdot (1-p) \right) \cdot \rho_w g (1-S_L) \cdot N_L$$

F_{BL1} = **10369** Bouyant Force, lbs

Racking MEMBERS (Root Wads)

Number of Logs with Rootwads	N_L =	3	
Specific Gravity of Large Wood	S_L =	0.54	
Average Rootwad Fan Diameter	D_{RW} =	4.94	feet
Average Rootwad Length	L_{RW} =	3.705	feet
Proportion of Voids in Rootwad	p =	0.60	decimal %
Tree Stem Average Diameter	D_{TS} =	2.5	feet
Tree Stem Average Length	L_{TS} =	20	feet

Wood Volume = 124 cubic feet per member

$$F_{BL} = \left(\frac{\pi D_{TS}^2 L_{TS}}{4} + \frac{\pi D_{RW}^2 L_{RW}}{4} \cdot (1-p) \right) \cdot \rho_w g (1-S_L) \cdot N_L$$

F_{BL2} = **10754** Bouyant Force, lbs

BOULDER BALLAST

Specific Gravity of Boulders	S_S =	2.65	
equivalent Diameter of Boulder	D_B =	2.0	feet
Number of Boulders Submerged	N_B =	0	
Number of Boulders above water level	N_{BU} =	0	

$$W' = \frac{\pi D_B^3}{6} \cdot \rho_w g (S_S - 1)$$

W' = **431** (lbs effective submerged weight per each boulder

W = **693** (lbs) Dry weight per each boulder

Total Effective Weight for all Boulders (W_b) = **0** lbs

SOIL BALLAST (Assumes all ballast submerged)

Buoyant Unit Weight of Soil Backfill	γ'_b	78.27	lbs/ft^3
Volume Wet Soil (Wood volume excluded)	A_{BF}=	617.91	ft^3
Depth of Soil Backfill Submerged	Z_B =	3	feet

Total Effective Weight for all Soil Lifts W_s = **48,362** lbs

Number of Key/Racking Layer Cycles: 3.00

FACTOR OF SAFETY: BUOYANCY

A simplified approach is used to estimate buoyancy where the logs and ballast boulders in the log jam are fully submerged. In addition, the log jam and boulders act as a

Total F_{BL} (Driving Forces)	63,370 lbs
Total Ballast (Resisting Forces) (W_b + W_s)	145,085 lbs

$FS_B = (W_b + W_s)/F_{BL}$ **FS_B = 2.3**

Red Bank Bar, NF Salmon River

Abutment Jam Vertical Stability Computations-Top Tiers

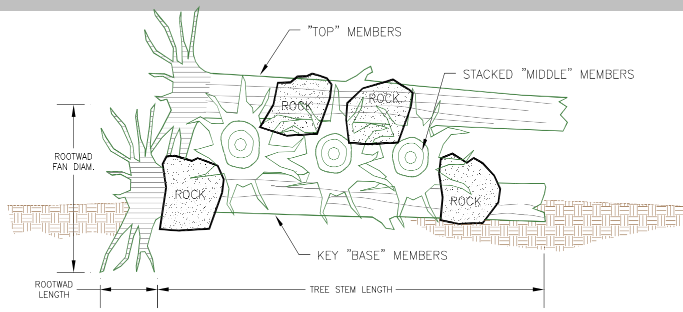
Spreadsheet developed by Scott Wright, P.E. - revision 1.4 (Adapted by MLA)

Modified by Rachel Shea, P.E. Michael Love & Associates. Corrected labeling for effective boulder weights. Updated Soil computations to reference soil data from separate tab. Method does not include lift or moments.

Methodology based on a standard force balance approach and information adapted from D'aoust & Millar (2000).
The ELJ should act as a fully connected structure and all Soil Ballast should be designed against predicted scour forces.

Analysis for single cycle of key and racking members. Each cycle designed to independently maintain a vertical FS > 1.5

Definition Sketch



Structure Dimenions

Length (flow-parallel)	18
Width (Perpindular to Flow)	25

Key Members (No Root Wads)

Number of Logs with Rootwads	N_L =	3	
	S_L =	0.54	specific gravity
Average Rootwad Fan Diameter	D_{RW} =	0	feet
Average Rootwad Length	L_{RW} =	0	feet
Proportion of Voids in Rootwad	p =	0.60	decimal %
Tree Stem Average Diameter	D_{TS} =	2.5	feet
Tree Stem Average Length	L_{TS} =	25	feet

Wood Volume = 123 cubic feet per member

$$F_{BL}=\left(\frac{\pi D_{TS}^2 L_{TS}}{4}+\frac{\pi D_{RW}^2 L_{RW}}{4}\cdot(1-p)\right)\cdot\rho_w g(1-S_L)\cdot N_L$$

F_{BL1} = **10623** Bouyant Force, lbs

Racking MEMBERS (Root Wads)

Number of Logs with Rootwads	N_L =	3	
Specific Gravity of Large Wood	S_L =	0.54	
Average Rootwad Fan Diameter	D_{RW} =	5	feet
Average Rootwad Length	L_{RW} =	3.75	feet
Proportion of Voids in Rootwad	p =	0.60	decimal %
Tree Stem Average Diameter	D_{TS} =	2.5	feet
Tree Stem Average Length	L_{TS} =	20	feet

Wood Volume = 128 cubic feet per member

$$F_{BL}=\left(\frac{\pi D_{TS}^2 L_{TS}}{4}+\frac{\pi D_{RW}^2 L_{RW}}{4}\cdot(1-p)\right)\cdot\rho_w g(1-S_L)\cdot N_L$$

F_{BL2} = **11048** Bouyant Force, lbs

BOULDER BALLAST

Specific Gravity of Boulders	S_S =	2.65	
equivalent Diameter of Boulder	D_B =	2.0	feet
Number of Boulders Submerged	N_B =	18	
Number of Boulders above water level	N_{BU} =		

$$W'=\frac{\pi D_B^3}{6}\cdot\rho_w g(S_S-1)$$

W' = 431 (lbs effective submerged weight per each boulder)
W = 693 (lbs) Dry weight per each boulder
Total Effective Weight for all Soil Lifts W_s = **7,765** lbs

SOIL BALLAST (Assumes all ballast submerged)

Buoyant Unit Weight of Soil Backfill	γ'_b	78.27	lbs/ft^3
Volume Wet Soil (Wood volume excluded)	A_{BF}=	598.96	ft^3
Depth of Soil Backfill Submerged	Z_B =	3	feet

Total Effective Weight for all Soil Lifts = **46,878** lbs

Number of Key/Racking Layer Cycles: 1.00

FACTOR OF SAFETY: BUOYANCY

Total F_{BL} (Driving Forces)	21,670 lbs
Total Ballast (Resisting forces) (W_b + W_s)	54,644 lbs

$FS_B = (W_b + W_s)/F_{BL}$ **FS_B = 2.52**

Red Bank Bar, NF Salmon River

Sliding Calculations for Engineered Log Jams Ballasted by Boulders (Entire Structure)

Spreadsheet developed by Scott Wright, P.E. - revision 1.0 (Adapted by MLA)

Modified by Rachel Shea, P.E. Michael Love & Associates. Effective Drag removed and single value of drag coefficient used. Updated F_f to include both boulder and soil forces.

Calculations make several simplifying assumptions including 1) no resistance from burial of ELJ elements, 2) ELJ is a solid structure, 3) frictional resistance is based on streambed material and normal force, and 4) ELJ is fully submerged.

Cross Sectional Area (Side Channel Only)	A =	**750**	sq. ft.
Height of Structure above channel bottom	Yu	**6**	
Depth to point of rotation on structure below scour line, ft	dbury	**5**	
Width of Exposed Structure blocking flow area	Width	**25**	feet
Effective waterway area obstructed by ELJ (10 feet tall, 15 feet wide)	A_{ELJ} =	**110**	sq. ft.
Drag Coeff.	C_D =	**1.5**	
Max Stream Velocity at ELJ (100-Year SRH-2D)	V =	**8.00**	fps
	Φ =	**36**	

Horizontal Drag Force on ELJ

$$F_D = C_D^{app} \cdot A_{ELJ} \cdot \frac{V^2}{2} \cdot \rho_w$$

F_D = **10,240** Total Drag Force, lbs

Horizontal Streambed Friction Resistance on ELJ (From Soil and Rock Ballast Effective Weights)

Friction Factor of Logs on streambed f = 0.73 *tangent of internal angle of streambed material*

63,370 F_{bl} Internal Tiers, lbs
21,670 F_{bl} Top Tier, lbs
85,040 Total Bouyant Force, lbs

145,085 $W_B + W_S$ Internal Tiers, lbs
54,644 $W_B + W_S$ Top Tiers, lbs
199,729 Total Ballast Force, lbs

114,688 Net Vertical Force, lbs Downward

F_F = f(Net Vertical Force) = **83,326** Total Frictional Resistance, lbs

Horizontal Resistance from Piles (See Pile Horizontal Stability Analysis)

0 pounds NOT USED

FACTOR OF SAFETY: SLIDING

$FS_s = F_f/F_d$ **FS_S = 8.1** $FS_s = F_f/F_d$

Red Bank Bar on the NF Salmon River **Vertical Pile Stability Analysis**

Minimum Pile Embedment to Counteract Buoyancy of Single Pile (No Vertical Load on Piles) in Abutment Jam

Does not consider resistance on piles from material in Abutment Jam.
Prepared k Prepared k Prepared k Prepared by Michael Prepared by Michael Love & Associates, Inc. Prepared b

From Knutson & Fealko, 2014. Large Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

$$F_{piles-v} = N_{piles} * \pi * d_{piles} * L_{piles}(k_s * \tan\tfrac{2}{3}\emptyset * \sigma' + \frac{d_{piles}}{4} * (\gamma_{wood} - \gamma_w))$$

Equation 15

N_{piles} = number of piles
d_{piles} = diameter of piles
L_{piles} = embedded length of piles
k_s = coefficient of lateral earth pressure (0.5 to 1.5 depending on soil and density)
ϕ = internal angle of friction of soils

$$\sigma' = L_{piles} * (\gamma_{sat} - \gamma_w)$$

Equation 16

Note: Error in equation. N, π, and d_{piles} should be outside parentheses encompassing remainder of equation. L_{pile} should be L_e- length of embedded pile. Buoyancy component of equation computed separately.

	Variables	
N_{piles}	1	Number Piles
d_{pile}	1.5	Pile diameter (ft)
L_e	8.7	**Length pile embedded below scour depth (feet)**
L_{pile}	23.0	Total Length Pile
ϕ	36.00	Soil Internal Friction angle, degrees
ϕ	0.63	Soil angle repose, radians
K_s	0.38	Coefficient of Lateral Earth Pressure (0.5 to 1.5, 25% Ks if excavated)
γ_{wood}	33.5	Dry unit weight wood , lbs/ft^3
γ_e	78.3	Effective unit weight soil (γ_e-γ_w), lbs/ft^3
σ'	683.11	L_{emb} x γ_e

Resisting Force (F_{pile-v})	**4,691**	F pile (lbs) Uplift (Resisting) Force Indivdidual Pile can withstand (Buoyant Force Not Applied)
Driving Forces	3,127	Buoyant Force of Individual Pile (F_b) (lbs) (L_{pile} x π x d_{pile} x σ')
	3,127	**Total Driving Force Upward Force Per Pile (lbs)**
	1.50	**FS per Pile**

Red Bank Bar on the NF Salmon River **Horizontal Pile Stability Analysis**

Lateral Resistance of Pile Group in Abutment Jam
Prepared by Michael Love & Associates, Inc.

From Knutson & Fealko, 2014. Large Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

$$F_{piles-h} = -N_{piles} * \frac{L_{pile}^3 * \frac{1}{2} * \gamma_e * d_{pile} * K_p}{h_{load} + L_{pile}}$$

Equation 36

Note: Error in Equation 36. L_{pile} should be L_e

	Variables	
γ_e	**78.3**	Effective unit weight soil (γ_e-γ_w), lbs/ft^3
ϕ	**36**	Soil angle repose degrees
ϕ	**0.6**	Soil angle repose, radians
K_p	**3.9**	$K_p = (1+\sin\phi)/(1-\sin\phi)$
L_{pile}	**23**	Total Pile Height, ft
h_{load}	**5**	Height above potential scour depth load applied, feet
d_{pile}	**1.5**	Pile diameter (ft)
L_e	**8.7**	**Length pile embedded below scour depth (feet)**
N_{piles}	**8**	
Resisting Force (F_{pile-h})	10,951	F pile group (lbs) Lateral Force Pile group can Withstand ←
Driving Forces	10,240	Horizontal Drag force (neglecting Frictional Resistance) →
	1,707	**Total Horizontal Driving Force (lbs) per Pile**
	6.42	**FS per Pile**

Red Bank Bar, NF Salmon River

Abutment Jam Overturning Analysis (Entire Structure)
Prepared by Michael Love & Associates, Inc.
From Knutson & Fealko, 2014. Larve Woody Material-Risk Based Design Guidelines. Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services.

$$MD_{overturn} = F_i * (Y_u + d_{bury}) + F_d * \left(\frac{Y_u}{2} + d_{bury}\right) + F_{hu} * \left(\frac{Y_u}{3} + du_{bury}\right) + |F_L| * L_s$$

Equation 46

du_{bury} = *depth at the upstream side of the structure from channel bottom to point of rotation measured perpendicular to flow*
Ls = *length of structure measured parallel to flow*

$$MR_{overturn} = |F_{hd}| * \left(\frac{Y_d}{2} + dd_{bury}\right) + |F_{passive}| * (dd_{bury}) + (F_b - F_L - F_{piles-v}) * \frac{L_S}{2} + \sum_i^n F_{pile-v_i} * Lpv_i$$

Equation 47

$$F_{pile-v_i} = \frac{F_{piles-v}}{N_{piles}}$$

Equation 48

L_{pvi} = *distance from pile 'i' to the point of rotation measured parallel to flow*

$$FOS_{overturn} = \frac{MR_{overturn}}{MD_{overturn}}$$

Equation 49

Computations neglect F_i, Fh_u,F_l, F_{hd},$F_{passive}$,$F_{piles-v}$,$F_{piles-vi}$

	Variables	
Yu	6	Height of Structure above channel bottom and below water line (Use water depth if structure not fully submerged)
d_{bury}	5	Depth to point of rotation on structure below scour line, ft
Ls	15	Length of structure parallel to flow, ft

Driving Forces	85,040	Bouyancy, lbs
	10,240	Drag Force, lbs
	95,281	**Total Driving Forces, lbs**
Driving Moment	**762,246**	ft-lbs

Resisting Force	199,729	Net force Rock and Ballast, lbs
	199,729	**Total Resisting Forces, lbs**
Resisting Moment	1,497,966	ft-lbs
	1.97	**FS**

Appendix M
Opinion of Probable Construction Costs

Opinion of Probable Construction Cost for 90% Design Submittal

Michael Love & Associates
Hydrologic Solutions
PO Box 4477 • Arcata, CA 95518 • (707) 822 -2411

North Fork Salmon River Red Bank Off-Channel Fisheries and Riparian Habitat Enhancement Project

5/25/2017

Line Item	Item Description	Unit	Quantity	Unit Cost	Total Cost
1	Mobilization/Demobilization	EA	1	53,350	$53,350
2	Clearing, Grubbing, and Construction Access	Day	5.0	$7,000	$35,000
3	Low-Water River Crossing	EA	1.0	$37,000	$37,000
4	Diversion/Dewatering	Day	45	$400	$18,000
5	Temporary Site Stabilization (Straw or wood chips)	AC	2.0	$1,500	$3,000
6	Root Wad Alcove	EA	4	$6,320	$25,280
7	Backwater Excavation/Onsite Spoil Placement	CY	4,150	$27	$112,050
8	Abutment Jams	EA	3	$50,100	$150,300
9	Root Wad Cover Structure	EA	23	$3,250	$74,750
10	Bank Log	EA	9	$3,240	$29,160
11	Apex Jam	EA	9	$5,900	$53,100
12	Random Boulder Group	EA	6	$2,200	$13,200
13	Live Willow Stakes	EA	6,500	$10	$65,000
14	Live Brush Baffles	LF	600	$85	$51,000
			Subtotal Construction		**$720,190**
			Contingency	15%	$108,000
TOTAL CONSTRUCTION COST					**$828,190**

Appendix N

Mining Claim Deeds

Run Time: 06:22 PM

Run Date: 08/20/2015

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
MINING CLAIM GEOGRAPHIC REPORT
LIST OF MINING CLAIMS BY SECTION

Serial Num	Mer Twn Rng Sec Quad	Claim Name/Number	Claimant(s)	Lead File	Casetype	Status	Loc Dt	Last Assmt
CAMC279821	21 0400N 0120W 028 NE,SE	BUM'S BET	DAHLKE GEORGIA Just upriver	CAMC279819	PLACER	ACTIVE	05/22/2002	2 0 1 5
CAMC279821	21 0400N 0120W 028 NE,SE	BUM'S BET	DAHLKE ROBERT	CAMC279819	PLACER	ACTIVE	05/22/2002	2 0 1 5
CAMC279823	21 0400N 0120W 028 NE,SE	LOW BAR	DAHLKE GEORGIA Crossing	CAMC279819	PLACER	ACTIVE	05/22/2002	2 0 1 5
CAMC279823	21 0400N 0120W 028 NE,SE	LOW BAR	DAHLKE ROBERT	CAMC279819	PLACER	ACTIVE	05/22/2002	2 0 1 5
CAMC279825	21 0400N 0120W 028 SE	ROCK PILE EXTENSION	DAHLKE GEORGIA Mid Bar	CAMC279819	PLACER	ACTIVE	05/22/2002	2 0 1 5
CAMC279825	21 0400N 0120W 028 SE	ROCK PILE EXTENSION	DAHLKE ROBERT	CAMC279819	PLACER	ACTIVE	05/22/2002	2 0 1 5
CAMC279826	21 0400N 0120W 028 SE	ROCK PILE	DAHLKE GEORGIA NO map?	CAMC279819	PLACER	ACTIVE	05/22/2002	2 0 1 5
CAMC279826	21 0400N 0120W 028 SE	ROCK PILE	DAHLKE ROBERT	CAMC279819	PLACER	ACTIVE	05/22/2002	2 0 1 5
CAMC279827	21 0400N 0120W 028 SE	JONES CREEK	DAHLKE GEORGIA No map?	CAMC279819	PLACER	ACTIVE	05/22/2002	2 0 1 5
CAMC279827	21 0400N 0120W 028 SE	JONES CREEK	DAHLKE ROBERT	CAMC279819	PLACER	ACTIVE	05/22/2002	2 0 1 5
CAMC279829	21 0400N 0120W 028 SE	NEW DIGGINS	SAGASER JOHN MARK E	CAMC279829	PLACER	ACTIVE	05/15/2002	2 0 1 5

Lost Jewel
Big Flat

033-350-220
Parcel map recorded

RECORDING REQUESTED BY:
(Mail recording to:)

Name DENNIS SMITH

Address PO BOX 1929

CLAYPOOL, AZ 85532

Siskiyou County Recorder
Contact: LEANNA DANCER
Instrument: 2002052807877
Date: 28-MAY-2002
Time: 09:58:58 A
Total Fees: $13.00
Book and Page:
Paid in Full

FOR RECORDER'S USE

PLACER MINING CLAIM LOCATION NOTICE (CALIFORNIA)

To whom it may concern, please take notice that:

1. Placer mining claim name is LOW BAR

2 Date of location (date the proper location monument was erected and location notice posted in or on it) of this placer mining claim is MAY 22, 2002
(month) (day) (year)

3. Description of the discovery monument is as follows: CAPPED 2" PVC PIPE WITH ALUMINUM DATA TAG

4. Placer mining claim IS IN an area where there is a U.S. Public Land Survey and the description of the claim by legal subdivision including aliquot part (A.P.) of section (such as E1/2NE1/4NE1/4), Section (Sec.), Township (T.), Range (R.) and Meridian (Mer.), is as follows: (FOR INFO ONLY)

A.P. ______, Sec. 28, T. 40N, R. 12W, Mer. M.D.
A.P. ______, Sec. ______, T. ____, R. ____, Mer. ______
A.P. ______, Sec. ______, T. ____, R. ____, Mer. ______
A.P. ______, Sec. ______, T. ____, R. ____, Mer. ______

. Placer mining claim IS NOT IN an area where there is a U.S. Public Land Survey, is marked by conspicuous and substantial monument at each claim corner, and is located by properly marked boundaries described below in reference to some natural object:

Natural object is (description) 5' DIAMETER ROUND ROCK, and it is by compass direction NNE, about 50 feet to the discovery monument. From the discovery monument it is by compass direction WEST, about 1150 feet to the NW corner post; from here it is by compass direction EAST, about 1500 feet to the NE corner post; from here it is by compass direction SOUTH, about 600 feet to the SE corner post; from here it is by compass direction WEST, about 1500 feet to the SW corner post; from here it is by compass direction NORTH, about 600 feet to the NW corner post.

6A. The undersigned locator(s) have defined the boundaries of the claim by erecting at each corner of the claim, or nearest accessible points thereto, a proper monument and each corner monument so erected bears or contains markings sufficient to appropriately designate the corner of the claim and the name of the claim.

6B. The date of monument erection and marking is MAY 22 2002.
(month) (day) (year)

6C. Description of each monument is as follows (4) CLAIM CORNERS MARKED WITH CAPPED 2" PVC POSTS WITH ALUMINUM DATA TAGS & A SIMILAR DISCOVERY MONUMENT.

7. Attach to this Notice an appropriate U.S. Geologic Survey topographic map showing a sketch of the outline of the placer mining claim.

8. Placer mining claim is in SISKIYOU County.

9. Placer mining claim contain(s) 20 acres.

10. If your placer mining claim is in a powersite withdrawal as determined from BLM Master Title Plat records, write "Filed under P.L. 359" on this line __________.

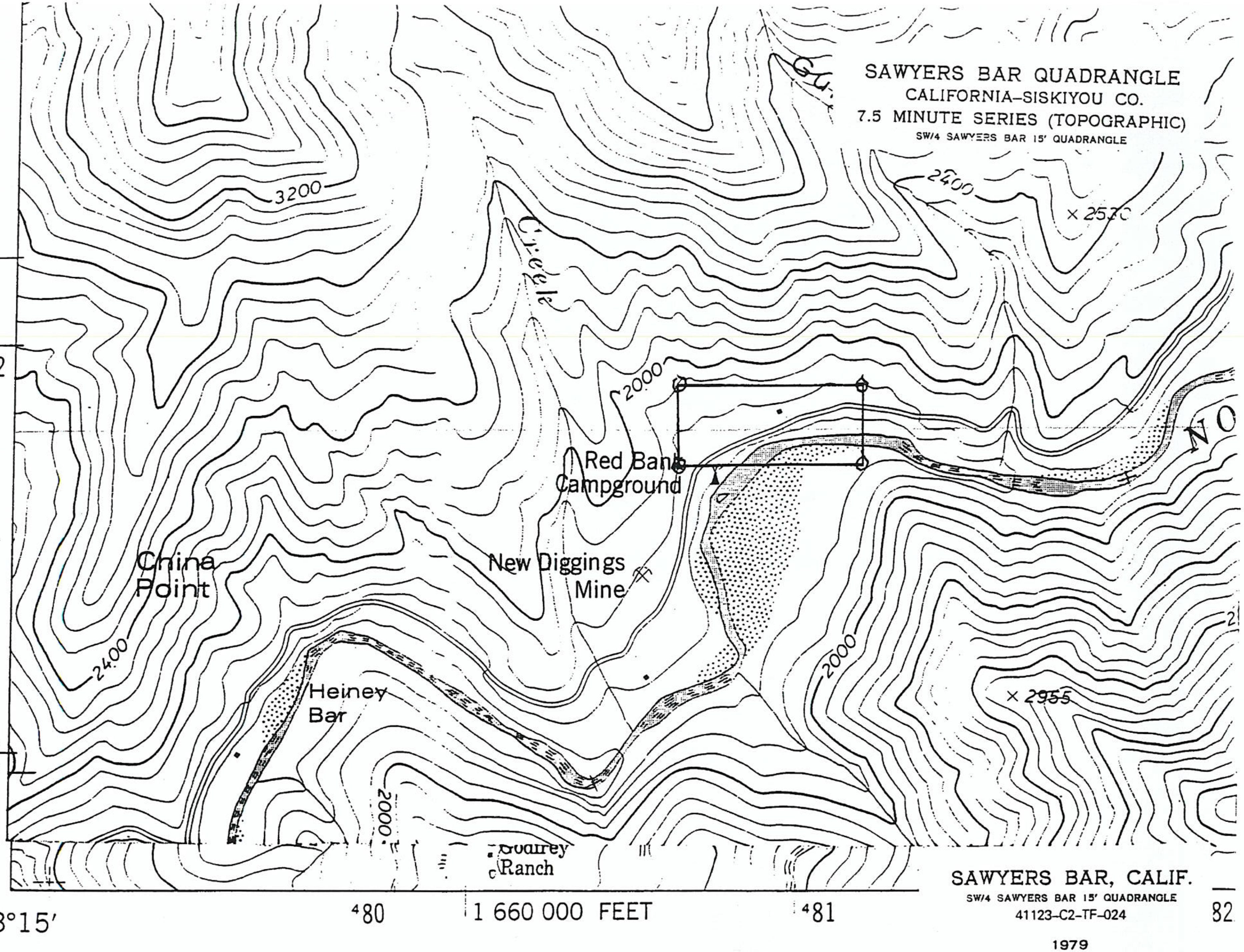
11. Locator(s) of this placer claim are: (Please Print)

Name(s)	Current Mailing or Residence Address
GEORGE W. SITES	PO BOX 277, CLAYPOOL AZ 85532
DENNIS A. SMITH	PO BOX 277, CLAYPOOL, AZ 85532

12. Signatures of locator(s):

George W. Sites	Date 5/22/02		Date
[signature]	Date 5/22/02		Date
	Date		Date
	Date		Date

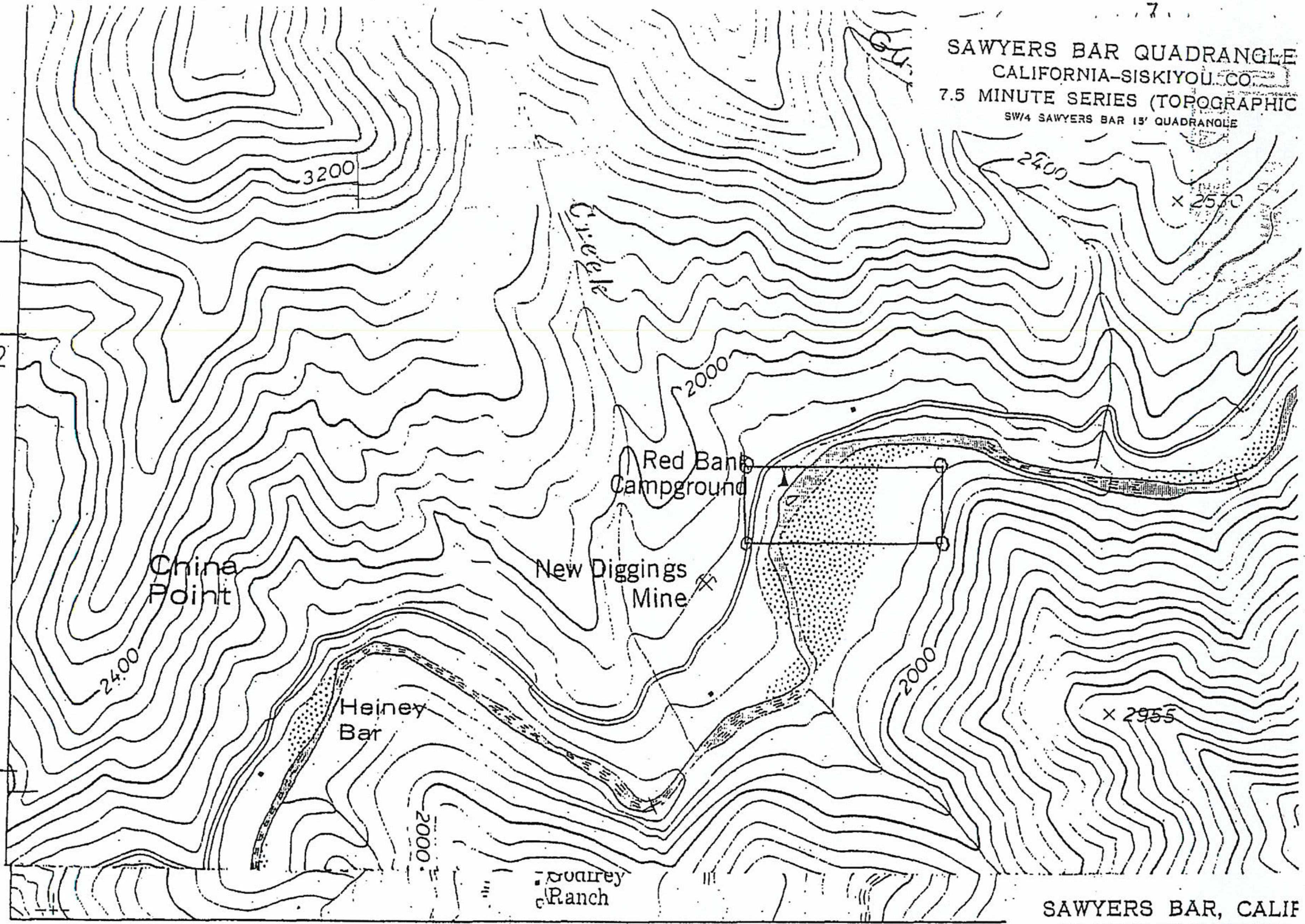
FILE THIS ORIGINAL NOTICE WITH THE APPROPRIATE COUNTY RECORDER (within 90 days of the date of location), AND FILE A DUPLICATE NOTICE (within the same 90 days) with the Bureau of Land Management, California State Office, 2800 Cottage Way Rm W1834, Sacramento, California 95825.



Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

"Low Bar"



SAWYERS BAR, CALIF
SW/4 SAWYERS BAR 15' QUADRANGLE
41123-C2-TF-024

1979

DMA 1366 I SW—SERIES V895

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"ROCK PILE EXTENSION"