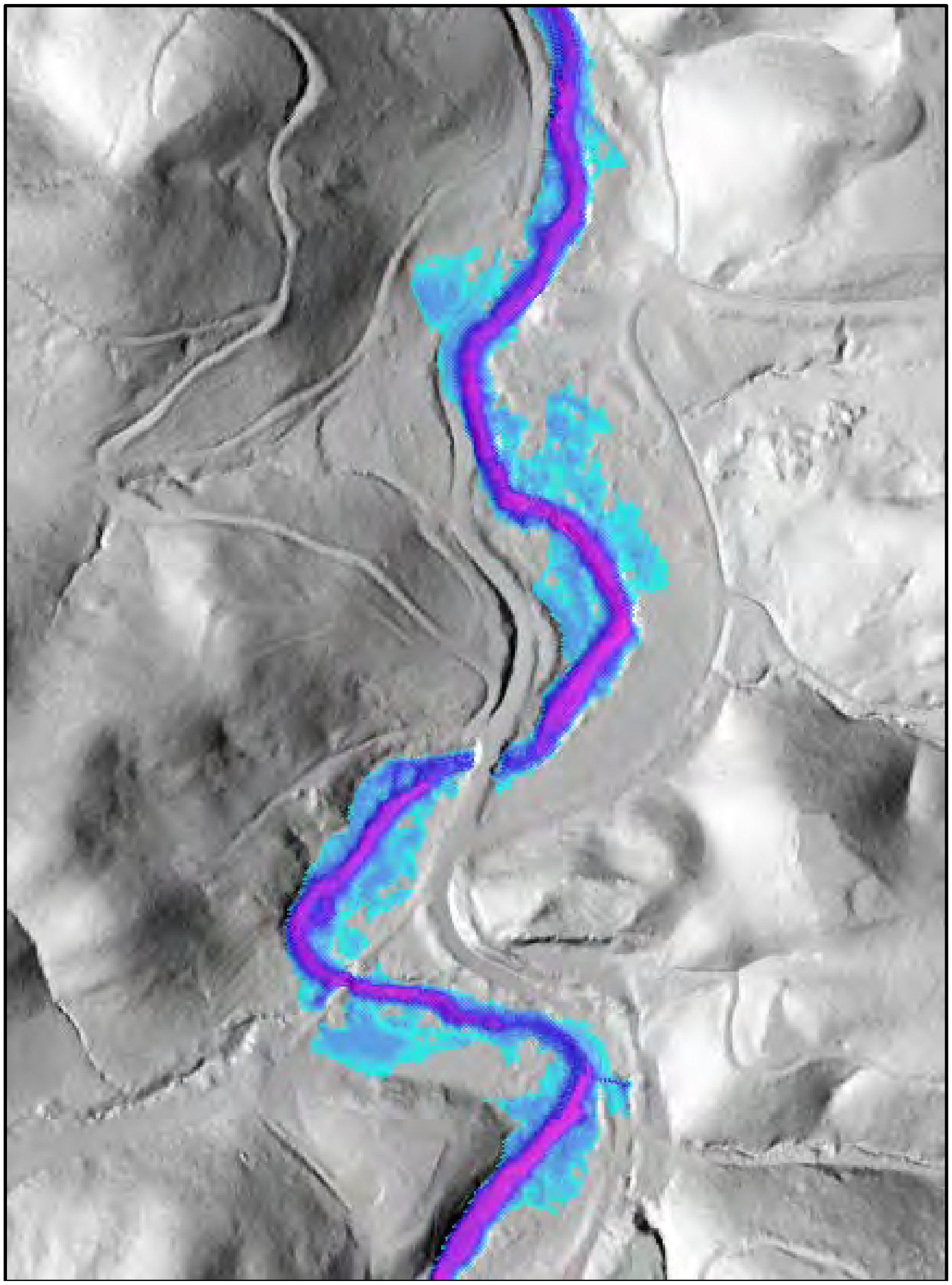
Salmonid Rearing Habitat Delineation and Restoration Prioritization:

East Austin, Pena, Mill, and Redwood Creek Watersheds, Sonoma County, California



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Chapter 1 - Introduction

The project described in this report was completed by O'Connor Environmental, Inc. (OEI) in cooperation with the Pepperwood Foundation and was funded by a Fisheries Restoration Grant from the California Department of Fish and Wildlife (CDFW Contract #P1530406).

State and Federal coho salmon (*Onchorynchus kisutch*, a listed endangered species) recovery plans for the Central Coast ESU, which includes the Russian River watershed, have identified high priority watersheds for habitat restoration and the limiting factors that restoration actions should seek to address (CDFG, 2004; NMFS, 2012). This study focuses on four tributary watersheds of the lower Russian River that are identified as high priority in the Federal coho recovery plan: Mill Creek, Pena Creek, East Austin Creek and Redwood Creek (Figure 1). All of these watersheds except Pena Creek are classified as "core areas" in the Federal plan. These watersheds also provide critical habitat for steelhead trout (*Onchorynchus mykiss,* a listed threatened species). Several factors have been identified as limiting coho survival in these watersheds including lack of high quality pool habitat, lack of winter refugia, and insufficient summer baseflows.

The goal of this project was to utilize regional high-resolution topographic data (LiDAR) and reconnaissance-level hydrologic and hydraulic analyses to quantify existing salmonid habitat conditions and identify and prioritize restoration opportunities. The primary focus of the effort was to address winter refugia as a limiting factor, however there is significant overlap between this goal and the goal of increasing/improving pool habitat, and the identified restoration project priorities are expected to improve rearing habitat in general.

The hydraulic models were used to develop water depth and velocity distributions for channel and floodplain areas over a wide range of flow conditions, and the simulation results were used in conjunction with habitat suitability indices to quantify reach-by-reach variations in availability of suitable habitat and examine the relationships between flow and habitat availability. The habitat availability maps were integrated with existing data sets provided by California Sea Grant describing observed salmonid utilization, summer low flow conditions, and pool and large wood distributions to develop reach-by-reach descriptions of available habitat conditions and recommended restoration actions.

Sites with existing side-channel features and/or frequently inundated floodplain areas were identified as priority sites for potential off-channel habitat enhancement projects. Reaches with suitable depth and velocity conditions, documented coho utilization, and perennial flow were identified as priority reaches for in-channel projects such as large woody debris (LWD) habitat structures. Candidate sites were further screened by consideration of ease of equipment access via existing roads and availability of anchoring sites (mature trees on channel banks) for LWD structures, and representative conceptual designs were developed for a variety of restoration project types.

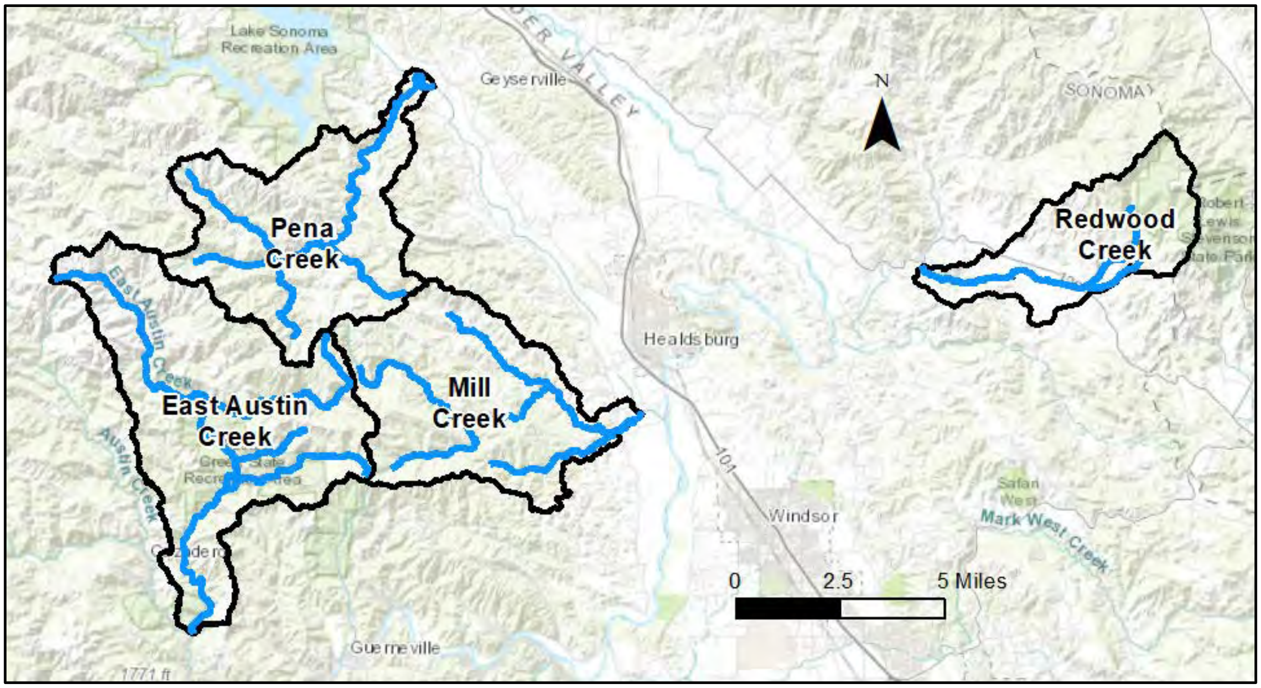


Figure 1: Locations of the watersheds and streams evaluated in this study.

Chapter 2 – Study Area and Existing Studies

In this chapter, fish habitat conditions documented in other relevant studies and on-going fisheries management efforts are summarized for each of the four watersheds in the study area.

Mill Creek

The Mill Creek watershed drains 23 square miles of the Dry Creek watershed and has 52 miles of blue line stream (Figure 2). Coho from the Russian River Coho Salmon Captive Broodstock Program have been released in Mill Creek every year since 2004 and in Palmer Creek every year since 2005 (except 2015). Coho were also released in Angel Creek in 2011. CDFG habitat surveys in 1957, 1973, 1982, and 1995 found generally good spawning habitat, elevated water temperatures, inadequate pool density and shelter, insufficient summer baseflow, and a lack of large wood. The Mill Creek Watershed Management Plan was completed by the Sonoma RCD in 2015 (SRCD, 2015) and the Mill Creek Streamflow Improvement Plan was also completed in 2015 by the Russian River Coho Water Resources Partnership (CP, 2015). These studies recommended the removal of several passage barriers (the most significant of which was removed in 2016), installation of instream habitat structures designed to enhance pool habitat, and efforts to enhance stream flow by reducing direct diversions. Numerous large wood (and wood and rock) structures have been installed in Mill, Felta, and Palmer creeks. A 2012/2013 Large Wood Assessment found that some of the older structures are decaying, however many are still functional.

Pena Creek

The Pena Creek watershed drains 22 square miles of the Dry Creek watershed and has 55 miles of blue line stream (Figure 3). Coho from the Russian River Coho Salmon Captive Broodstock Program were released in Pena Creek each year between 2011 and 2014. CDFG habitat surveys of Pena Creek were completed in 1944 and 1998, and a habitat restoration/conservation plan including Pena Creek was completed by NMFS and the Russian River Watershed Salmonid Coalition (NMFS, 2007). These studies found elevated water temperatures, good spawning conditions, low levels of riparian canopy, and inadequate pool density. Recommended habitat improvement included removal of barriers caused by debris accumulation, reduction of fine sediment inputs, and increasing large wood abundance. Numerous rock weir structures were previously installed in Pena Creek. A few of these structures are located farther up in the watershed and are still functioning, however most of them are in the lower reaches of the creek and are almost completely buried by recent sedimentation of sand and gravel.

East Austin Creek

The East Austin Creek watershed drains 32 square miles of mountainous terrain in the lower Russian River watershed and has 72 miles of blue line stream (Figure 4). Coho from the Russian River Coho Salmon Captive Broodstock Program have been released in Gray Creek every year since 2005 and in Gilliam Creek every year since 2007. Coho have also been released in Devil and Thompson Creek every year since 2010 (except 2015), in Black Rock Creek each year between 2011 and 2014, and in main-stem East Austin Creek in 2010. CDFG habitat surveys of East Austin Creek in 1947, 1962, 1968, 1977, and 1996 found good spawning habitat and low levels of riparian canopy. A watershed assessment for Austin Creek suggested reduction of fine sediment inputs and increasing instream LWD as the highest priority restoration actions (LMA, 2005). Sonoma RCD implemented the Austin Creek Sediment Source Reduction Project in 2013/2014 focused on reducing road-related erosion and sediment delivery. Sonoma RCD has also implemented LWD placement projects in Thompson and Gilliam Creeks.

Redwood Creek

Redwood Creek and its tributaries Kellogg and Yellow Jacket Creek drain 14 square miles of the Maacama Creek watershed and contain 32 miles of blue line stream (Figure 5). Unlike the other three watersheds, coho from the Russian River Coho Salmon Captive Broodstock Program have not been released in the Redwood Creek watershed. CDFG habitat surveys from 1973, 1997, and 2001 found good spawning and pool conditions but inadequate pool shelter and riparian canopy cover. A watershed assessment for Maacama Creek identified Redwood Creek and its tributaries as having the highest potential for summer rearing habitat, and suggested reduction of fine sediment inputs and improved riparian cover to improve habitat, and that low summer flows could be limiting (LMA, 2004). Several instream habitat projects have been developed in Redwood Creek throughout Knights Valley, however they have met with limited success owing to high stream velocities and unstable bed conditions.

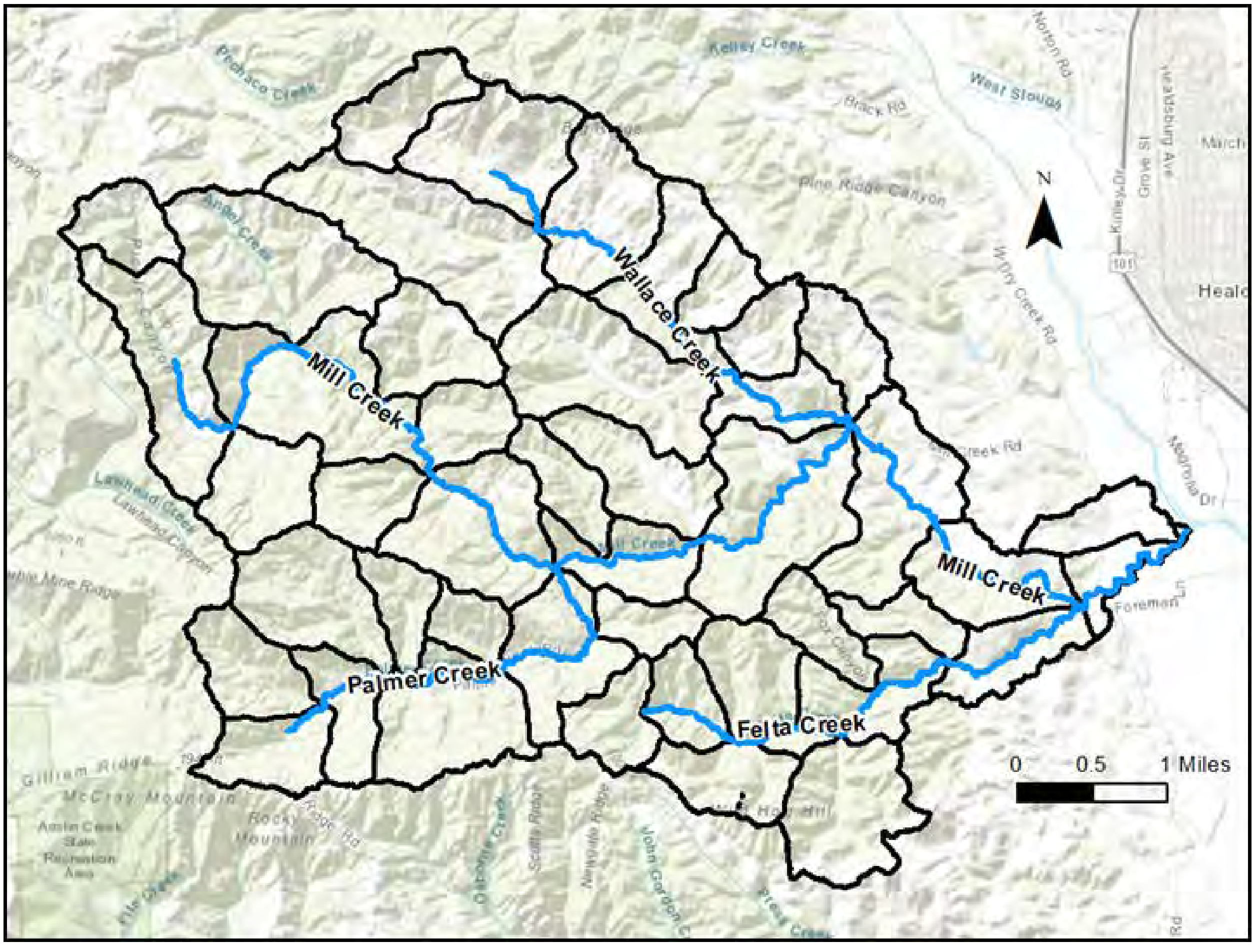


Figure 2: Sub-watersheds and stream reaches evaluated in the **Mill Creek** hydrologic and hydraulic model.

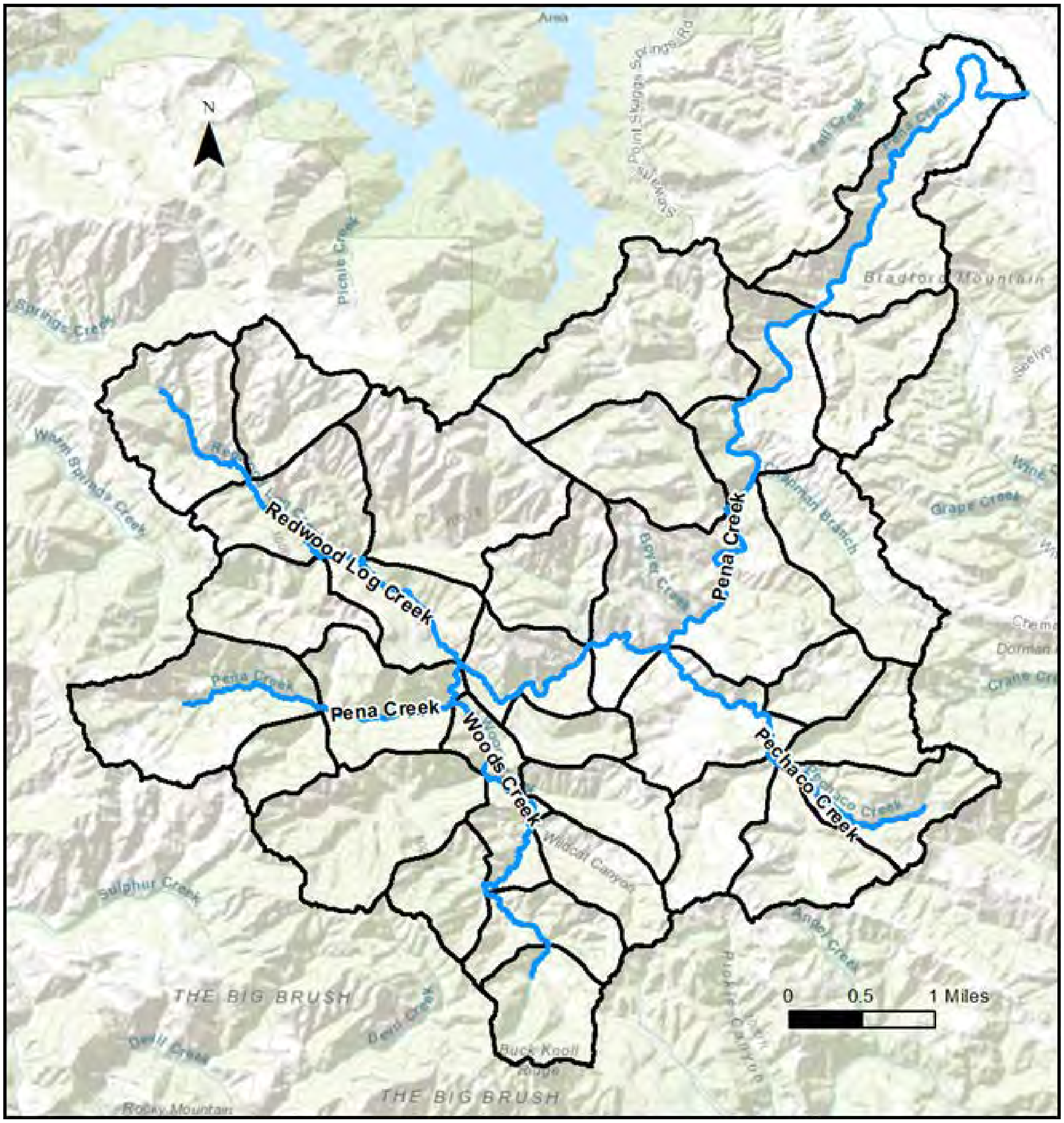


Figure 3: Sub-watersheds and stream reaches evaluated in the **<u>Pena Creek</u>** hydrologic and hydraulic model.

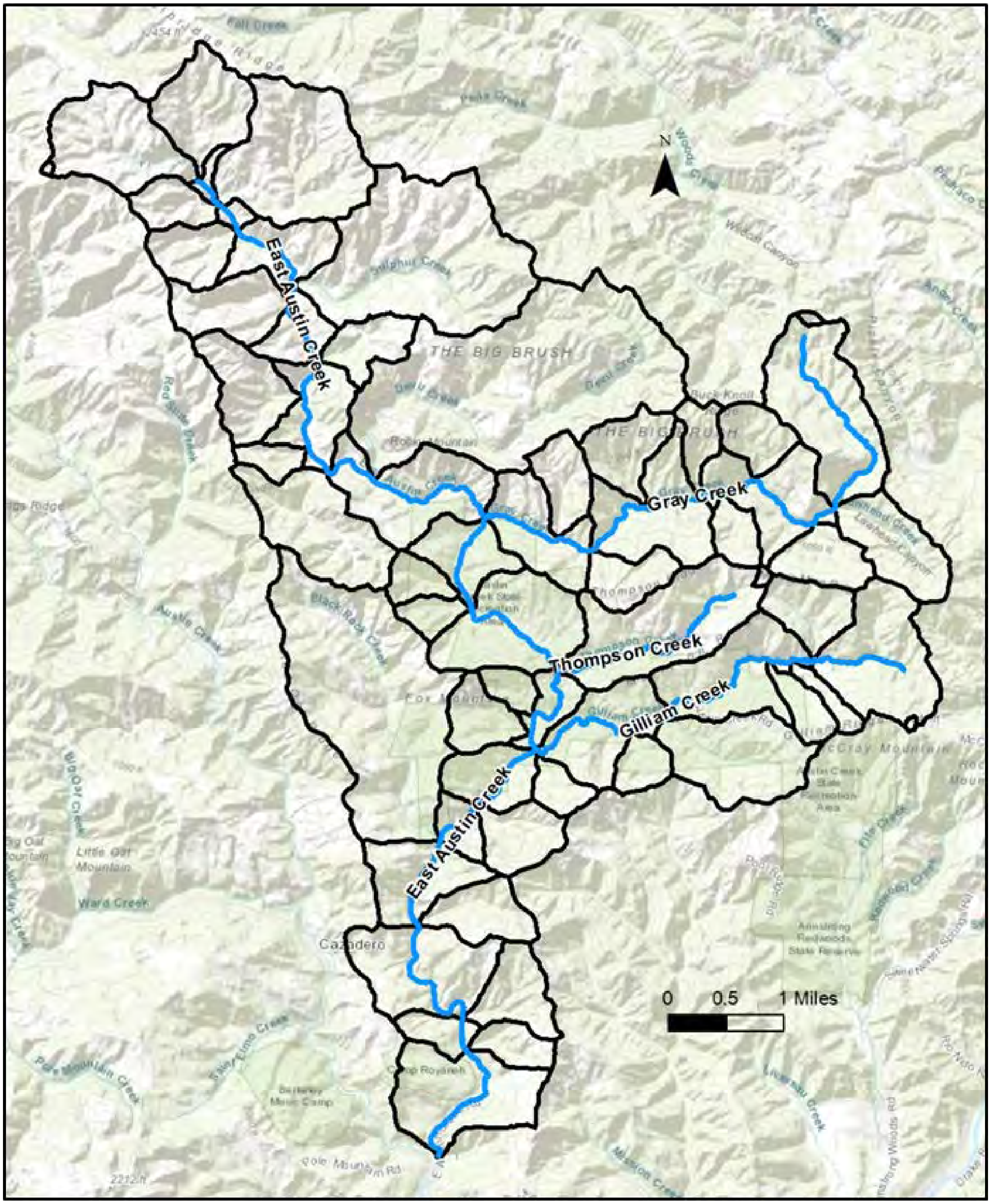


Figure 4: Sub-watersheds and stream reaches evaluated in the **East Austin Creek** hydrologic and hydraulic model.

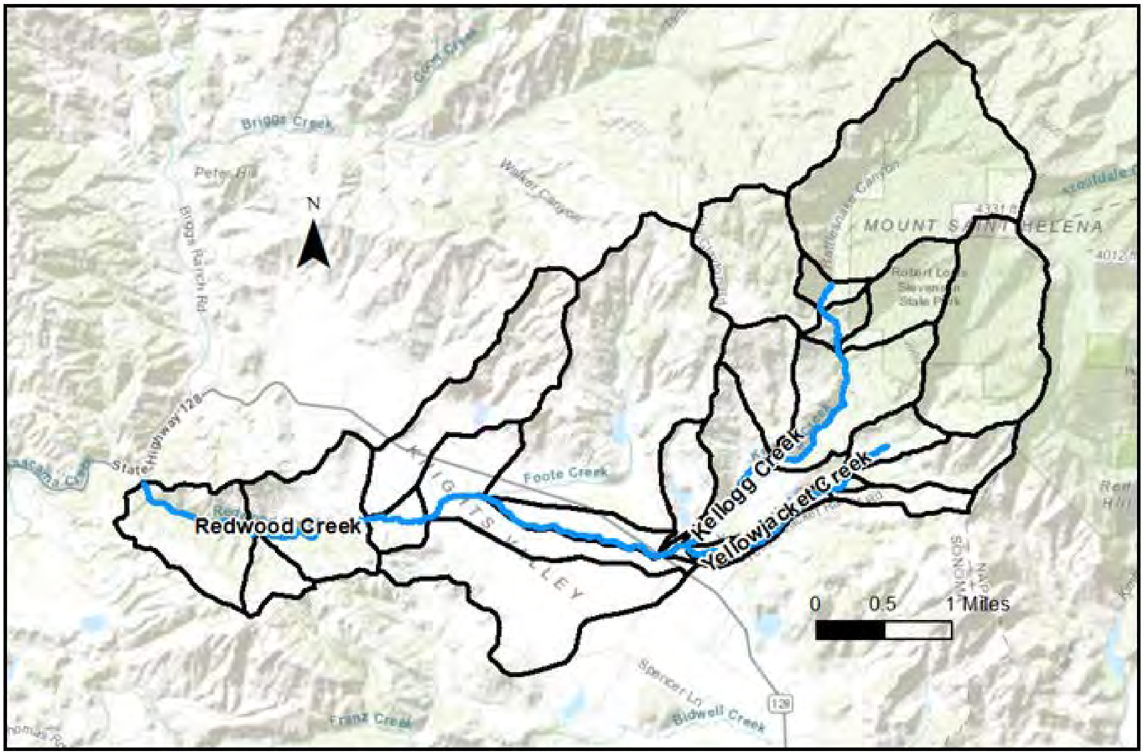


Figure 5: Sub-watersheds and stream reaches evaluated in the **Redwood Creek** hydrologic and hydraulic model.

Chapter 3 - Methodology

In this chapter we present an overview of the approach used for this study. More detailed descriptions of the methodology are presented in following chapters.

Hydrology

Hydrologic models of the four study watersheds were constructed using the NAM model (DHI, 2014). The NAM model is a deterministic, conceptual, lumped-parameter, rainfall-runoff model that continuously accounts for the water content in three inter-related linear storage reservoirs representing the land surface zone, root zone, and groundwater zone. The primary inputs for the model are precipitation and potential evapotranspiration timeseries and a series of parameters describing the storage and routing properties for the three storage reservoirs. Values for these parameters were determined primarily through calibration to measured stream flow data which is available to some degree in each of the four study watersheds. The hydrologic models were used to simulate a wide range of flow conditions from winter baseflow to a 10-yr flood event.

Hydraulics

Hydraulic models of the four study watersheds were developed using the MIKE 11 model (DHI, 2014). MIKE 11 calculates unsteady water levels and discharges using an implicit finite-difference formulation to solve the 1-dimensional St. Venant equations for open channel flow. The model is capable of simulating ephemeral stream flow conditions and backwater effects, and includes formulations for a variety of hydraulic structure types (e.g. bridges, weirs, culverts). Discharge boundary conditions were derived from the NAM hydrologic models and downstream boundary conditions were represented using water level/discharge relationships derived by solving Manning's equation for a range of expected flow conditions. Other than boundary conditions, the primary inputs for the channel flow model include channel geometry information (obtained from high resolution LiDAR topographic data) and Manning's roughness coefficients describing flow resistance.

The simulated 1-dimensional water depth and velocity results from MIKE 11 were used to produce 2-dimensional maps of these parameters. This was accomplished by distributing the results laterally across each cross section based on the conveyance distribution and interpolating between cross sections using a LiDAR-derived Digital Elevation Model (DEM). This process is sometimes referred to as quasi-2-dimensional modeling since the results are 2-dimensional but the underlying hydraulic calculations are 1-dimensional. It is important to note that while this approach can approximate the lateral and longitudinal variations in water depths and velocities, the results are not expected to be as accurate as a 2-dimensional model which can resolve and directly simulate split flows and associated depth and velocity distributions. Full 2-dimensional modeling for the study area was beyond the scope of this study but is feasible.

Habitat Suitability

The physical habitat metrics (water depth and velocity) simulated with the hydraulic models were related to habitat suitability through the use of Habitat Suitability Criteria (HSC) curves. HSC curves for northern California streams are not readily available, however curves have been developed from data collected in western Washington streams (Beecher et al., 2002). We utilized the juvenile coho salmon depth and velocity curves from the Washington study which agree broadly with the recommendations for optimal depth and velocity conditions determined locally as part of the Adaptive Management Plan for the Dry Creek Habitat Enhancement Project (Porter et al., 2014).

The suitability curves provide a simple means of transforming the model simulated water depths and velocities for each grid cell into a Habitat Suitability Index (HSI) from zero to 1 with zero being no habitat value and 1 being optimal habitat. The two individual indices for each grid cell were integrated to provide a Combined HSI as the geometric mean of the individual indices for water depth and velocity (Equation 1).

$$HSI_{Combined} = SQRT(HSI_{Depth} * HSI_{Velocity}) \qquad \text{(Equation 1)}$$

The Combined HSI was then used to generate the quantity of available habitat for each simulated flow condition using an index referred to as the Weighted Usable Area (WUA) (Equation 2) which is a commonly used metric for quantifying available habitat developed as part of the Instream Flow Incremental Methodology (IFIM) (e.g. Bovee and Milhous, 1978; Bovee et al., 1998).

$$WUA = HSI_{Combined} * Area \qquad \text{(Equation 2)}$$

Sea Grant Monitoring Data

Sea Grant operates a monitoring program in several tributaries to the Russian River as part of the Russian River Coho Salmon Captive Broodstock Program, the Coastal Monitoring Program, and an ongoing Flow and Survival Study. The monitoring data collected as part of these programs includes summer snorkel surveys to document the presence and distribution of salmonids, and late summer wetted habitat surveys to document the distribution of wet, dry, and intermittent stream flow conditions. The available snorkel survey and wetted habitat survey data for individual years between 2013 and 2017 was obtained from Sea Grant. The snorkel survey data was synthesized to produce maps of average juvenile coho abundance on stream reaches 1,000-ft in length for the portions of the study streams with available data. Reaches where coho were stocked were excluded from the analysis to obtain maps that are not biased by fish distribution data that is highly influenced by locations where fish are released by the Broodstock program. Every other pool was snorkeled during the surveys, therefore the fish counts were doubled to estimate the total number of coho in a given reach. The wetted habitat survey data was also synthesized to produce flow classification maps based on the same 1,000-ft stream segments. Three flow classes were developed: reaches with disconnected pools in most years, reaches with disconnected pools in dry years, and reaches with connected pools even in dry years. Where data was not available for either 2013 or 2014 (considered dry years for this analysis), the classification was simplified to include only two classes: reaches with disconnected pools in most years, and reaches with connected pools in most years.

Instream Project Prioritization

The prioritization of reaches for instream habitat enhancement project development was based on the concept that habitat projects should be located in reaches where background hydraulic conditions (represented by WUA) are most favorable and projects are most likely to succeed in enhancing existing suitable habitat. In addition to consideration of background hydraulic conditions and where data was available, the prioritization also emphasizes reaches with perennial flow conditions and reaches with abundant coho use.

The study streams were divided into 1,000-ft stream segments and the total WUA was calculated for each reach segment and compared to the average WUA for a given watershed. Reaches with above average WUA for two of the four flow conditions were assigned an initial priority of medium, reaches with above average WUA for three of the four flow conditions were assigned a value of high, and reaches with above average WUA for all four flow conditions were assigned an initial priority of very high. Where sufficient Sea Grant monitoring data was available, the prioritization was adjusted by removing reaches where pools become disconnected in most years and increasing the priority for reaches where pools remain connected during dry years. The prioritization was also adjusted by decreasing the priority for reaches with no documented coho use and increasing the priority for reaches with relatively abundant coho use (reaches with above average fish counts within a given watershed). An overview of the prioritization steps is provided below:

Step 1: Initial prioritization based on the number of flow conditions with WUA > watershed average WUA

Step 2: Exclude reaches with disconnected pools in most years and increase priority for reaches where pools remain connected even in dry years

Step 3: Decrease priority for reaches with no documented coho use and increase priority for reaches with fish counts > watershed average

The identified priority reaches were further subdivided based on indicators of ease of equipment access and presence/absence of large diameter trees that can provide anchoring sites for large wood structures. Reaches with relatively easy equipment access were identified by finding the priority reaches that are within 250-ft of an existing road and where slopes between the road and a point 30-ft from the top of bank are below 30%. Vegetation canopy height data was compiled from the Sonoma County Vegetation Mapping and LiDAR Program and sampled along the left and right banklines (derived from the hydraulic analysis of the 1.5-yr flood extent). Reaches with large diameter trees that can serve as anchoring sites were identified by finding the priority reaches with canopy heights greater than 50-ft along the bank where road access was identified.

Off-channel Project Prioritization

The prioritization of off-channel project sites was based on the concept that habitat projects should seek to enhance existing features rather than create new habitat features where none exist currently. The model-simulated water depths, velocities, and WUA were examined in detail to identify locations with significant existing off-channel habitat features. Four types of off-channel sites were identified: <u>side-channels</u>, <u>multi-thread side-channels</u>, <u>floodplains</u>, and <u>floodplains with alcoves</u>. All side-channels visible in model flow simulations greater than 100-ft in length and all contiguous floodplain areas (areas outside the bankfull channel and within the 10-yr floodplain) greater than 0.5-acres were included initially. In reaches with smaller watershed areas where no sites were identified in the initial pass, the criteria were relaxed to include side channels 50-ft or more in length and contiguous floodplain areas greater than 0.1-acres. Each site was classified as a side-channel, multi-thread side-channel, floodplain, or floodplain with alcove based on geomorphic feature(s) expressed by LiDAR topographic features and familiarity with characteristics of features revealed by hydraulic modeling described above. The sites were also classified based on ease of access and proximity to the high priority reaches identified as part of the onstream project prioritization as described above. Proximity to high priority reaches was used as a criterion of overall habitat quality so that proposed off-channel projects would be relatively near to portions of the watershed with high likelihood of fish use. Equipment access was evaluated using the criteria described above for the onstream project prioritization and proximity to high priority reaches was defined as reaches within 2,500-ft.

Chapter 4 – Hydrologic and Hydraulic Analyses

This chapter describes data inputs to the hydrologic and hydraulic models and model calibration.

Hydrology

Each of the four study watersheds was divided into a series of sub-watersheds to facilitate development of inflow boundary conditions for the hydraulic models. The watershed delineation included all major tributaries contributing flow to the primary streams simulated with the hydraulic models as well as the residual drainage areas not associated with a specific tributary stream. Each of the four study watersheds includes between 22 and 60 sub-watersheds (Figures 2 through 5).

Precipitation in the East Austin, Pena, and Mill Creek watersheds was represented with the Venado weather station operated by the California Department of Water Resources (CA DWR). The lower portions of the Redwood Creek watershed were represented by the Calistoga 4.6 WNW weather station operated by NOAA and the upper portions of the watershed were represented by the St. Helena 4 WSE weather station operated by NOAA. Daily precipitation data was compiled at the three stations for the 32-year period from 10/1/1984 to 9/30/2016 (Figure 6). To capture the spatial variation in precipitation across the watersheds, the ratio of the mean annual precipitation within each sub-watershed and at a given weather station location (as described by PRISM, 2010) was used to define scaling factors for precipitation in each sub-watershed. The raw station data was then multiplied by the scaling factor to develop a precipitation timeseries for each sub-watershed.

The California Irrigation Management Information System (CIMIS) station at Windsor was used to provide daily Potential Evapotranspiration (PET) inputs to the model (CIMIS, 2005). To capture the spatial variation in PET across the study area, we applied the Turc Method (Turc, 1961) to compute PET using gridded solar radiation data from the National Solar Radiation Database (NSRD, 2010) and mean monthly temperature data from PRISM (PRISM, 2010). We compared the mean annual PET predicted from the Turc Method with the mean annual PET computed from the CIMIS stations at Santa Rosa and Windsor and globally scaled the Turc Method results to conform with the CIMIS data (this provided a simple means of calibrating the Turc Method results to the available station data). The closest CIMIS station to the project watersheds is the Windsor station, therefore the data from this station was used as the basis for developing PET timeseries for each sub-watershed in the models. The ratio of the mean annual PET within each sub-watershed and at the Windsor CIMIS station was used to define scaling factors for each sub-watershed. The raw station data was then multiplied by the scaling factor to develop a PET timeseries for each sub-watershed. Data is only available at the Windsor CIMIS station beginning 10/1/1990. For the portion of the simulation period prior to this, an average daily value was computed from the available 26-years of available data (Figure 7).

Hydraulics

The hydraulic models include both the main-stem streams and the larger tributaries with documented salmonid use within each of the four study watersheds. Coho generally prefer reaches with gradients in the range of 2-3% and steelhead generally prefer reaches with gradients of 2-7% (Agrawal et al., 2005). The full lengths of the streams with gradients of less than 7% were evaluated; this is expected to include all potential coho habitat and the majority of potential steelhead habitat. In some cases, the extents of modeled reaches were further reduced due to the presence of a dam or other known barrier to fish passage. Examples include the on-stream dams in upper Mill and upper Wallace Creeks, and the natural bedrock falls in Palmer, Yellowjacket, Thompson, and Gilliam Creeks. Initial examination of the results based on these criteria revealed that the resolution of the available topographic data was insufficient to resolve hydraulic conditions in some of the smaller channels. The extent of hydraulic modeling was reduced to avoid these reaches which included the upper 9,000-ft of Pechaco Creek and the upper 3,000-ft of Redwood Log Creek in the Pena Creek watershed and the upper 8,000-ft of East Austin Creek, the upper 5,000-ft of Gray Creek, and the upper 5,000-ft of Thompson Creek in the East Austin Creek watershed.

Topographic cross sections of stream channels and floodplains were extracted from the 3-ft resolution grid from Sonoma County LiDAR at 100-ft intervals along each of the streams included in the hydraulic models for a total of 4,300 cross sections. Cross sections were reviewed, and alignments and/or locations were adjusted as needed to best represent the variations in cross section geometry along the channel. The LiDAR data was collected in late summer/early fall 2013 when stream flow in the watersheds was very low, however the LiDAR data is not expected to capture the geometry of pools since LiDAR does not penetrate through water. The accuracy of the Sonoma County LiDAR and its suitability for hydraulic modeling was evaluated through comparisons between surveyed and LiDAR-derived cross sections through previous work in nearby watersheds (OEI, 2013). The watershed scale of this analysis prohibited the development of reach-scale estimates of channel roughness. Based on field reconnaissance in the watersheds and previous modeling experience, a Manning's roughness coefficient value of 0.055 was applied globally throughout the simulated streams.

Inflow boundary conditions that link the simulated inflows from the sub-watershed hydrologic models to the hydraulic models of the primary streams were established as a series of point-source inflows (for tributaries) and distributed source inflows (for residual drainage areas). Downstream boundary conditions consisted of rating curves which were developed by solving Manning's equation for a range of discharges at the downstream-most cross sections in each of the study watersheds.

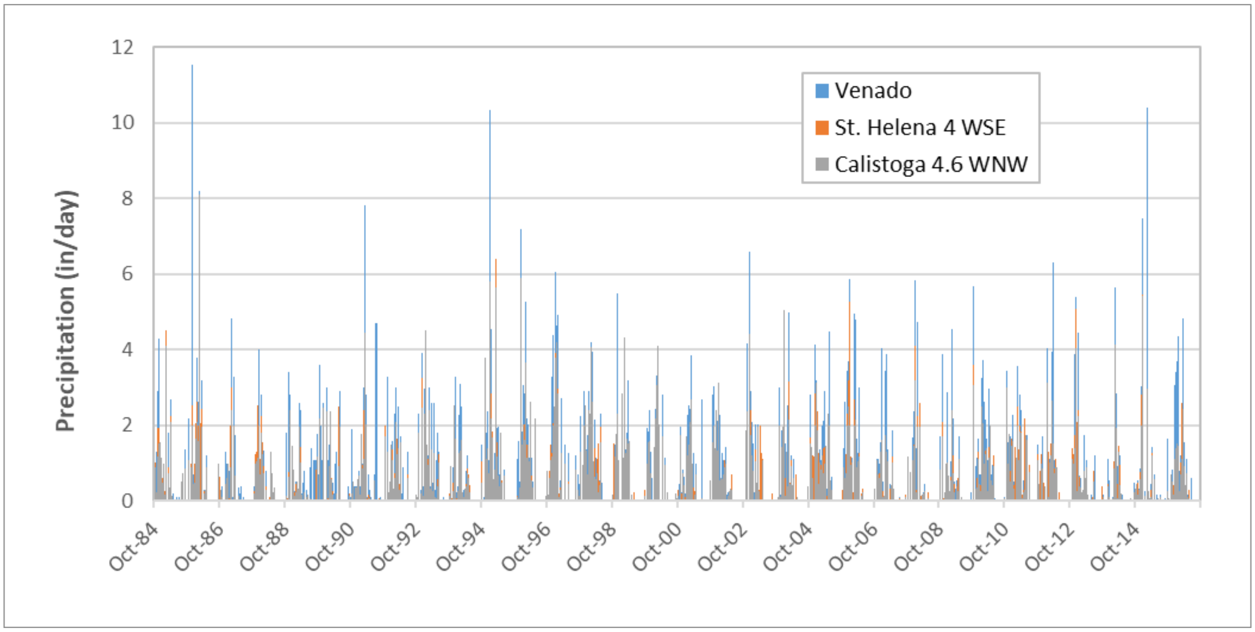


Figure 6: Rainfall data used in the hydrologic models.

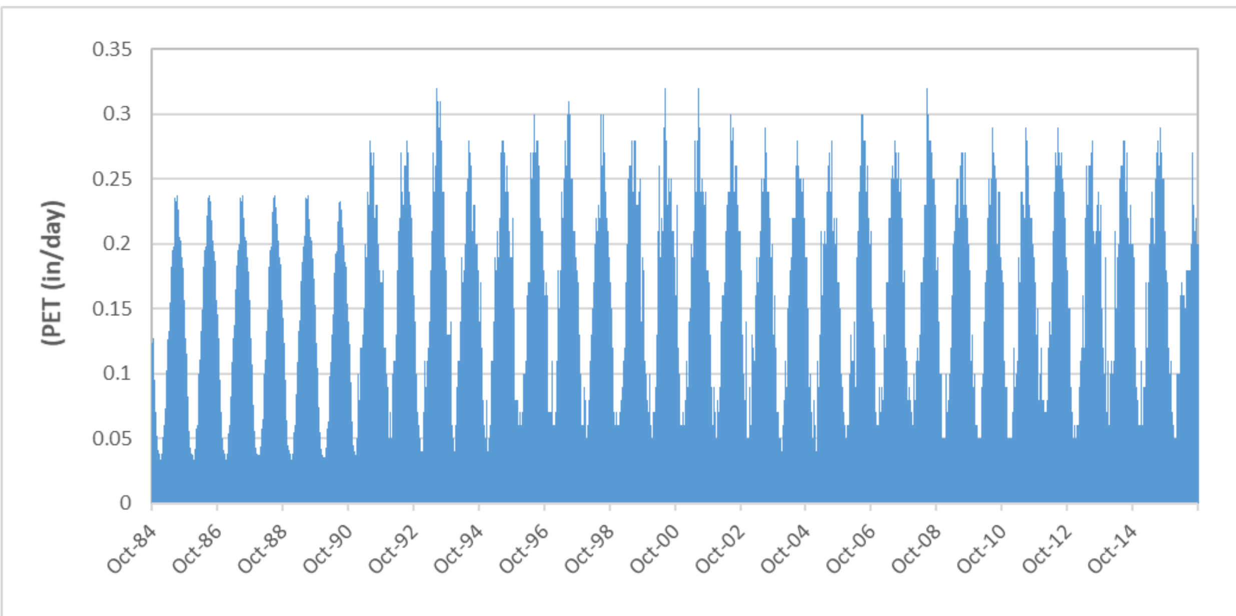


Figure 7: Potential Evapotranspiration (PET) data used in the hydrologic models.

Calibration

Several calibration statistics were used to describe the goodness-of-fit between the model simulated stream flows and stream flows measured at various stream gauges in the watersheds. These statistics include the Mean Error (ME), Root Mean Square Error (RMSE), and the Nash-Sutcliffe model efficiency coefficient (NSME). The ME and RMSE statistics provide an estimate of overall model bias or systematic error, and the NSME provides a standardized measure of the predictive capability of the model. A perfect model where all simulated values and observed values are identical has a NSME value of 1.0, a model with a NSME of zero indicates that the model predictions are as accurate as the mean of the observed data, and a NSME of less than zero indicates that the observed mean is a better predictor than the model. Models with NSME values of 0.7 or higher are generally considered to be adequately calibrated (Donigian et al., 1984).

Several stream flow gauges have been installed in the Mill Creek watershed as part of the Russian River Coho Water Resources Partnership and are currently being maintained by Trout Unlimited (TU). Development of rating curves for these sites has been focused primarily on characterizing the range of low flows (spring through autumn) and thus continuous flow records covering higher flow conditions were not readily available. To help fill this data gap, we performed a series of float measurements and estimated stream flow at one of the existing sites (located about 0.7-miles upstream of the Felta Creek confluence) during three flow events in December 2016. We used these measurements to construct a provisional high-flow rating curve and develop a continuous mean daily flow record for from the available stage data which covers the period from 12/19/2009 through 11/3/2013. The storage and routing parameters for the linear reservoirs used to represent hydrologic processes in the NAM model were adjusted to improve the fit between the observed and simulated stream flows. The final calibration had a Mean Error (ME) of -1.6 cfs, a Root Mean Square Error (RMSE) of 70.9 cfs, and a Nash-Sutcliffe model efficiency coefficient (NSME) of 0.76 (Figure 8, Table 1).

The U.S. Geological Survey (USGS) operated a stream gauge on Pena Creek near West Dry Creek Road for Water Years (WY) 1979 through 1990. Mean daily stream flow data was compiled for the portion of this period overlapping with the simulation period (WY 1985 through 1990) and compared to stream flows simulated with the Pena Creek hydrologic model. Model parameters were adjusted within a range of reasonable limits to most closely reproduce the observed stream flows. The final calibration had a Mean Error (ME) of 7.5 cfs, a Root Mean Square Error (RMSE) of 43.3 cfs and a Nash-Sutcliffe model efficiency coefficient (NSME) of 0.86 (Figure 8, Table 1).

No stream flow data is available for East Austin Creek, however the USGS operates a stream gauge on main-stem Austin Creek immediately downstream of the confluence with East Austin Creek. To facilitate calibration of the East Austin Creek hydrologic model, we expanded the model to include the full drainage area contributing flow to the gauge location. Mean daily stream flow data was compiled for a portion of the available data overlapping with the simulation period (WY 2008 through 2016) and compared to stream flows simulated with the Austin Creek hydrologic model. Model parameters were adjusted to improve the fit between the observed and simulated stream flows. The final calibration had a Mean Error (ME) of 11.5 cfs, a Root Mean Square Error (RMSE) of 195.6 cfs, and a Nash-Sutcliffe model efficiency coefficient (NSME) of 0.77 (Figure 8, Table 1).

NOAA operates a stream flow gauge in Redwood Creek just upstream of the confluence with Maacama Creek. Similar to the Mill Creek sites, development of rating curves for this gauge has been focused primarily on characterizing low flows from spring through autumn and thus continuous flow records covering high flow conditions were not readily available. Some measurements are available for moderate flow conditions as well. Due to the lack of available high flow measurements, we limited the gauge record to include only flow up to the highest gauged flow of 260 cfs and restricted the calibration to flows below this threshold. Model parameters were adjusted to improve the fit between the observed and simulated stream flows which covered the period from 10/29/11 to 8/4/2016. The final calibration had a Mean Error (ME) of -0.2 cfs, a Root Mean Square Error (RMSE) of 16.6 cfs, and a Nash-Sutcliffe model efficiency coefficient (NSME) of 0.75 (Figure 8, Table 1).

Flood Frequency Analysis

We performed a flood frequency analysis on the Pena Creek, Austin Creek, and Maacama Creek USGS gauge records using standard USGS methodology (USGS, 1981). The periods of record are relatively short (12 to 20-years) at these gauge locations, however they exceed the minimum required length of 10 years and this approach likely represents the best available means of estimating flood frequencies in the watersheds. The method produced estimates of flows for a range of recurrence intervals and the flow estimates for the 1.5-yr and 10-yr recurrence interval flows were scaled by drainage area to provide estimated flows for use in the hydraulic models (Figure 9, Table 2).

Selection of Simulation Flows

To provide an estimate of typical winter baseflow conditions in the watersheds, we compiled the 32-years of simulated mean daily flows for each sub-watershed from the calibrated hydrologic models. The median winter (November – March) discharge was calculated for each sub-watershed and used to represent typical winter baseflow conditions. Less frequent flows such as the 5, 10, and 25% exceedance flows were also calculated. Mean discharge ratios were calculated for the largest storm events in the simulation period which provided the basis for distributing the 1.5-yr and 10-yr recurrence interval flows (described above under Flood Frequency Analysis) across the various sub-watersheds. This analysis focused primarily on four flow conditions which cover a wide range of hydraulic conditions determined to be of interest for habitat evaluation and restoration planning. These flows include typical Winter Baseflow (median winter flow), the 10% Exceedance Flow, the Bankfull Flow (1.5-yr event), and the 10-yr Flood Event Flow (Table 2). Winter baseflow ranged from 7.7 cfs at the outlet of the Redwood Creek to 47.9 cfs at the outlet of the East Austin Creek. The 10-yr flood event flow ranged from 4,316 cfs at the outlet of the Pena Creek to 8,039 cfs at the outlet of the East Austin Creek (Table 2).

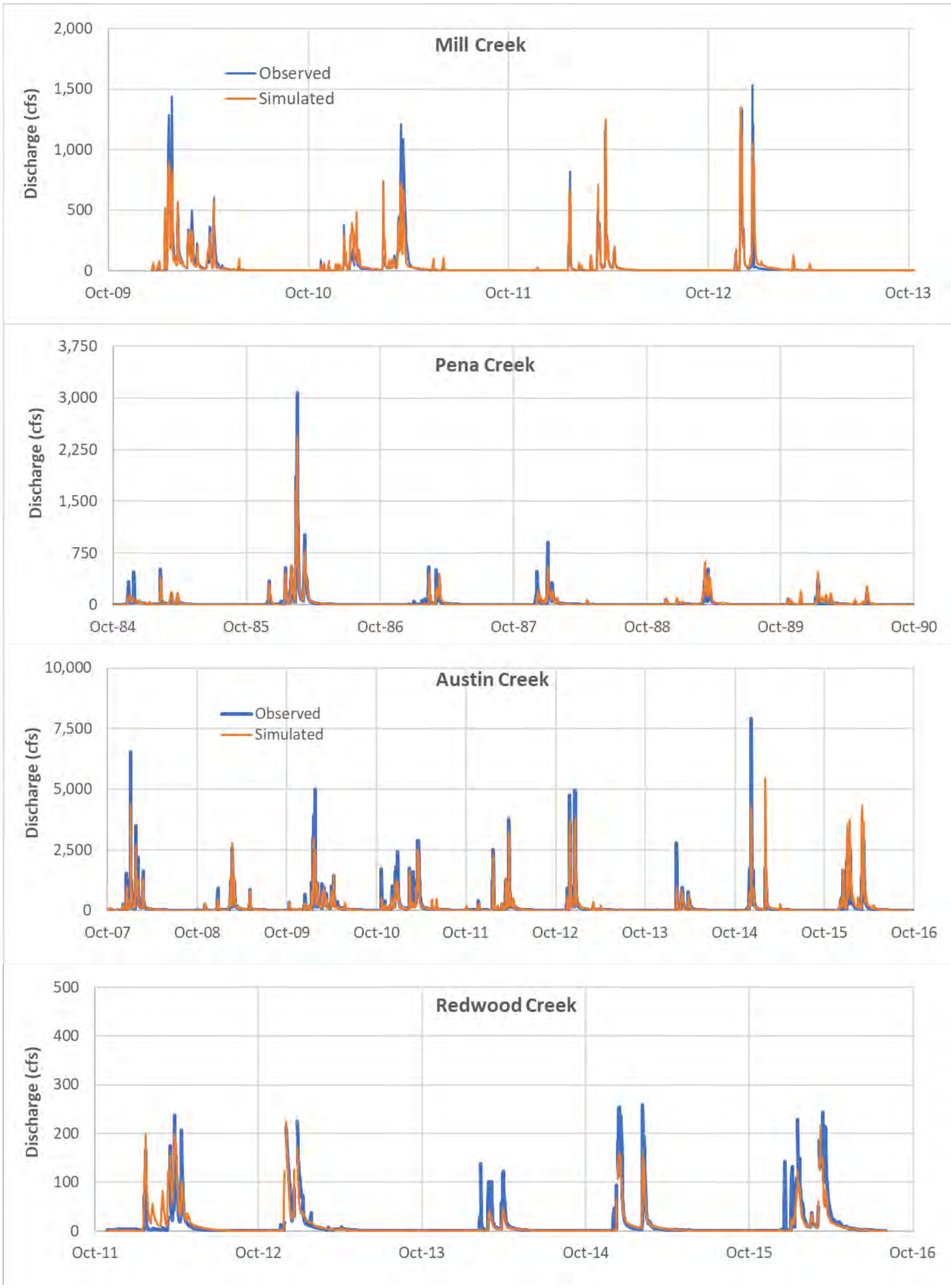


Figure 8: Comparison of model simulated and observed stream flows in the four study watersheds.

Table 1: Results of the hydrologic model calibrations for the four study watersheds.

Watershed	Calibration Period	Gauge Source	ME (cfs)	RMSE (cfs)	NSME
Mill Creek	12/09 - 11/13	TU	-1.6	70.9	0.76
Pena Creek	10/84 - 9/90	USGS	7.5	43.3	0.86
Austin Creek	10/07 - 9/16	USGS	11.5	195.6	0.77
Redwood Creek	10/11 - 8/16	NOAA	-0.2	16.6	0.75

Notes: ME – Mean Error, RMSE – Root Mean Square Error, NSME – Nash-Sutcliffe Model Efficiency Coefficient

Table 2: Flows simulated with the hydraulic models for the four study watersheds.

Watershed	Winter Baseflow (cfs)	10% Exceedance Flow (cfs)	Bankfull Flow (cfs)	10-yr Flood Flow (cfs)
Mill Creek	20.6	272	2,474	5,057
Pena Creek	13.8	225	1,461	4,316
East Austin Creek	47.9	377	3,933	8,039
Redwood Creek	7.7	123	1,024	4,657

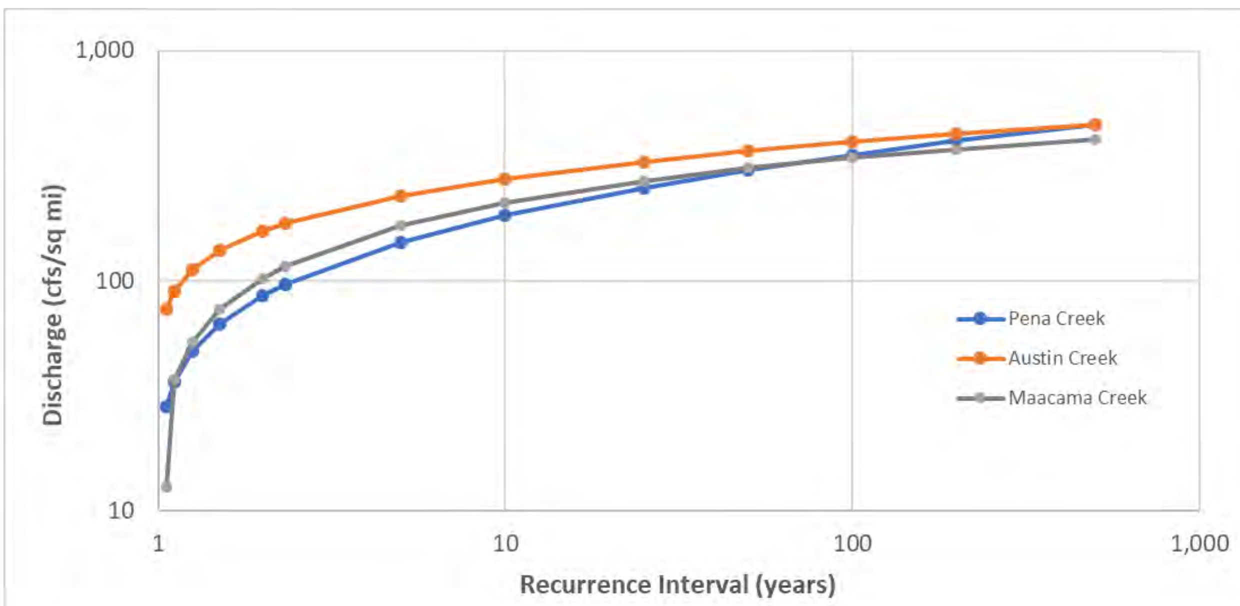


Figure 9: Results of the flood frequency analyses used to define the bankfull and 10-yr flood event flows simulated with the hydraulic models.

Chapter 5 – Results

Habitat Suitability

This chapter presents the habitat Weighted Useable Area (WUA) results derived from integrating the 2-dimensional maps of model simulated water depths, velocities, and habitat suitability indices onto 1,000-ft reaches as described in Chapter 2. Examples of the underlying maps of simulated water depths, velocities, and habitat suitability indices for the various simulated flow events are presented for select reaches in Chapter 8 (Figures 49-72). The complete data sets have been provided to CDFW in a digital format accessible on the ESRI ArcGIS platform.

<u>Mill Creek</u>

During winter baseflow, the total available area of coho rearing habitat in the Mill Creek watershed, as expressed with the metric Weighted Useable Area (WUA), is about 12 acres. WUA increases as flow increases and is about 18 acres during the 1.5-yr (bankfull) flood and about 20 acres during the 10-yr flood (Table 3).

The results indicate substantial spatial variability in the WUA and in the locations providing relatively high WUA from one flow condition to the next (Figures 10 - 13). The reaches providing consistently high WUA for most flow conditions are scattered throughout upper and lower Mill Creek, Wallace Creek, and Palmer Creek. WUA in most of lower Mill Creek and Felta Creek is relatively low compared to the other reaches.

<u>Pena Creek</u>

During winter baseflow, the total available area of coho rearing habitat in the Pena Creek watershed, as expressed with the metric Weighted Useable Area (WUA), is about 11 acres. WUA increases as flow increases and is about 17 acres during the 1.5-yr (bankfull) flood and about 22 acres during the 10-yr flood (Table 3). The results indicate substantial spatial variability in the WUA and in the locations providing relatively high WUA from one flow condition to the next (Figures 14 - 17). The reaches providing consistently high WUA for most flow conditions are scattered throughout main-stem Pena Creek below Redwood Log Creek. For higher flow conditions, WUA is relatively high in both Redwood Log Creek and Woods Creek, however WUA is consistently low throughout most of Pechaco Creek.

<u>East Austin Creek</u>

The total available area of coho rearing habitat in the East Austin Creek watershed, as expressed with the metric Weighted Useable Area (WUA), is relatively constant (ranging from 15 to 17 acres) across the range of evaluated flow conditions (Table 3). The results indicate substantial spatial variability in the WUA and in the locations providing relatively high WUA from one flow condition to the next (Figures 18 - 21). The reaches providing consistently high WUA for flows ranging from winter baseflow to the 10-yr flood are concentrated in lower East Austin Creek downstream of the confluence with Gilliam Creek. In most reaches of Gilliam, Thompson, and Gray creeks and in main-stem East Austin Creek upstream of Grey Creek, WUA is relatively low compared to the lower reaches of East Austin Creek.

Redwood Creek

During winter baseflow conditions, the total available area of coho rearing habitat in the Redwood Creek watershed, as expressed with the metric Weighted Useable Area (WUA), is about 2.5 acres. WUA increases as flow increases and is about 4 acres during the 1.5-yr (bankfull) flood and about 5 acres during the 10-yr flood (Table 3). The results indicate substantial spatial variability in the WUA and in the locations providing relatively high WUA from one flow condition to the next (Figures 22 - 25). The reaches providing consistently high WUA for flows ranging from winter baseflow to the 10-yr flood are concentrated in Redwood Creek downstream of the confluence with Foote Creek. In most reaches of Kellogg and Yellowjacket creeks, WUA is relatively low compared to the main-stem Redwood Creek.

Table 3: Summary of the total available habitat area (expressed using the Weighted Useable Area) for each simulated flow condition in the four study watersheds.

	Weighted Useable Area (acres)			
Watershed	**Winter Baseflow**	**10% Exceedance Flow**	**Bankfull Flow**	**10-yr Flood Flow**
Mill Creek	11.7	16.4	18.2	20.2
Pena Creek	11.1	15.1	16.9	22.3
East Austin Creek	16.5	17.0	15.1	16.6
Redwood Creek	2.5	2.9	4.3	5.2

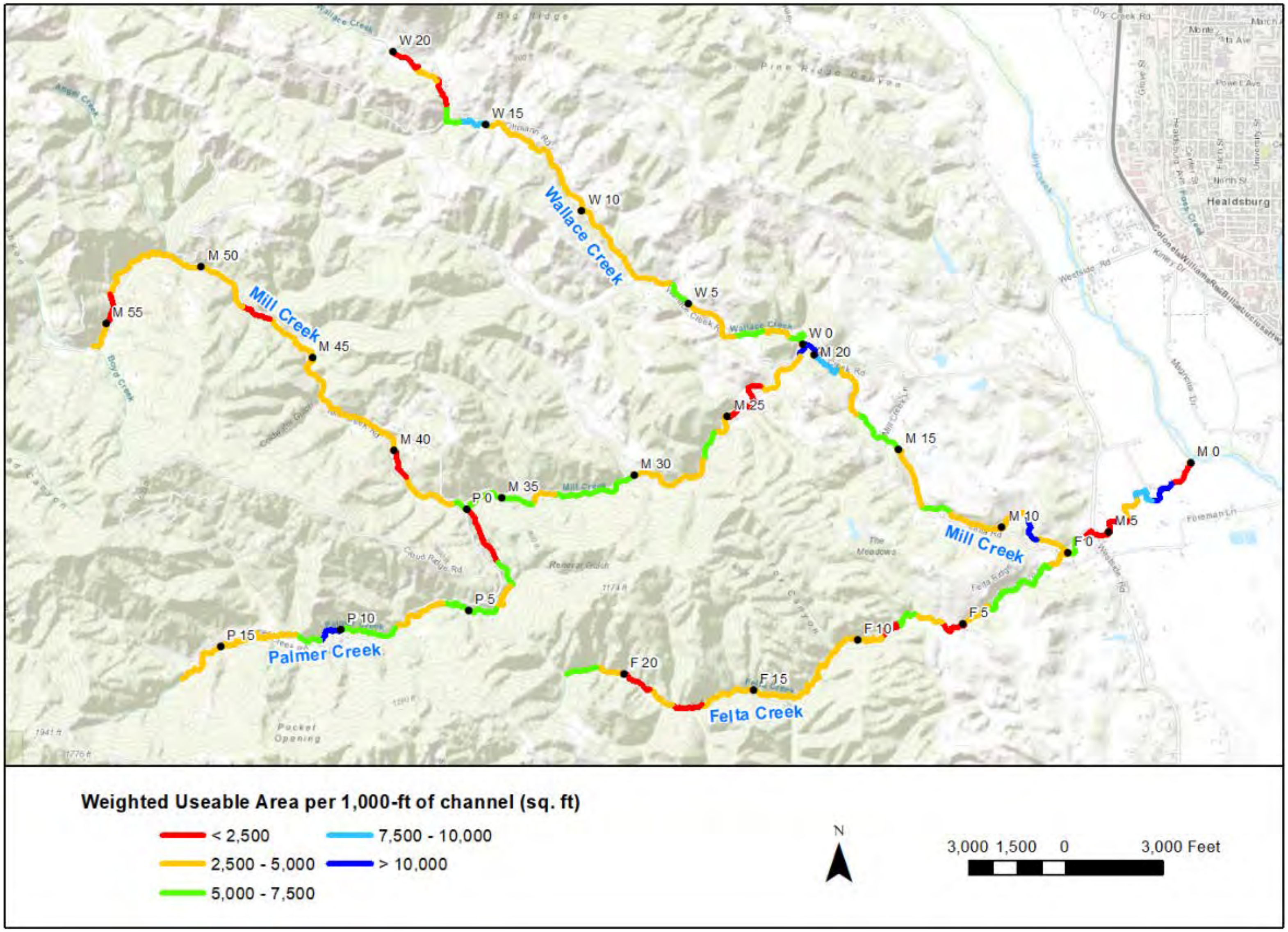


Figure 10: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **Mill Creek watershed** for **winter baseflow**.

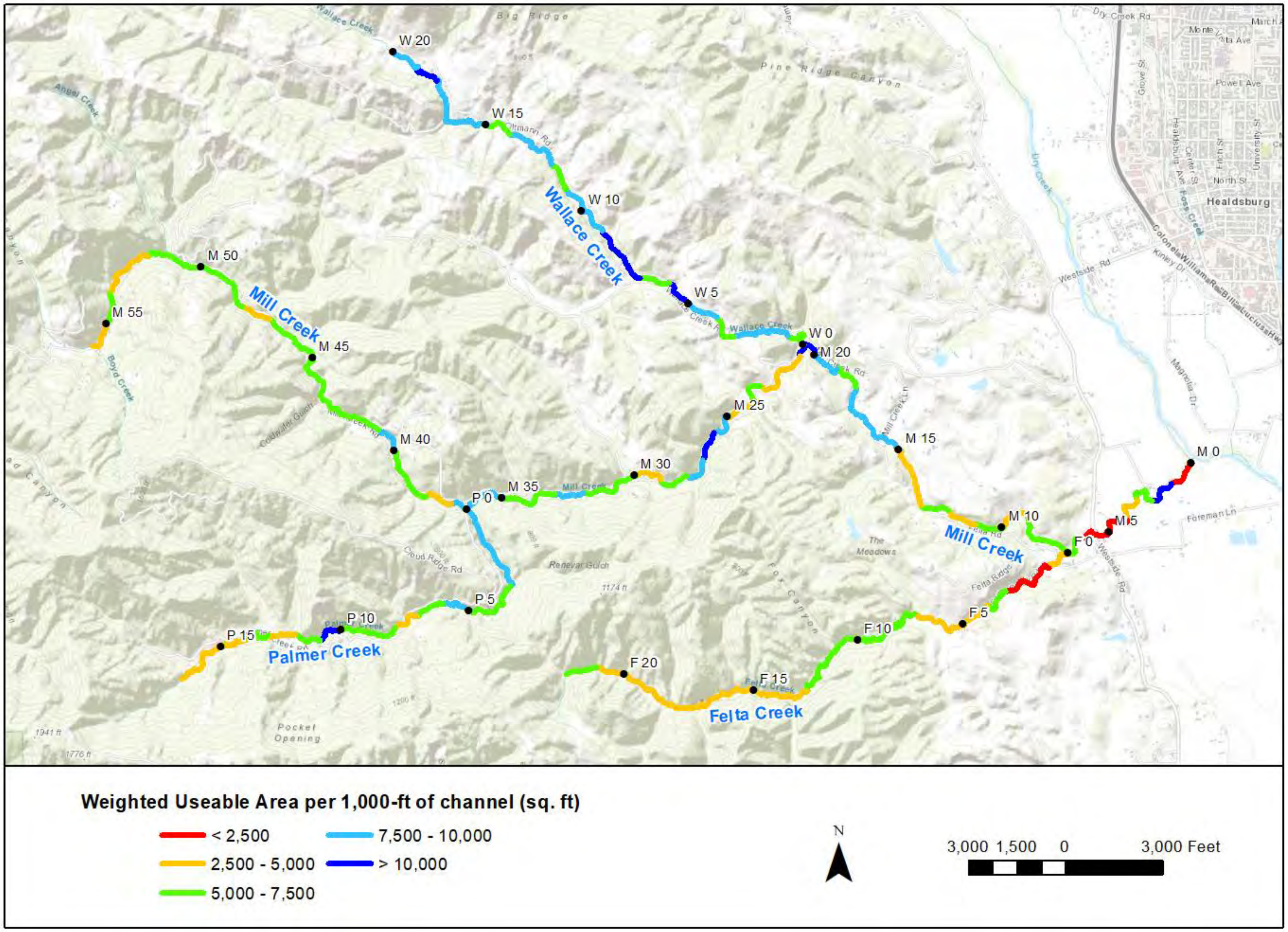


Figure 11: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **Mill Creek watershed** for the **10% exceedance flow**.

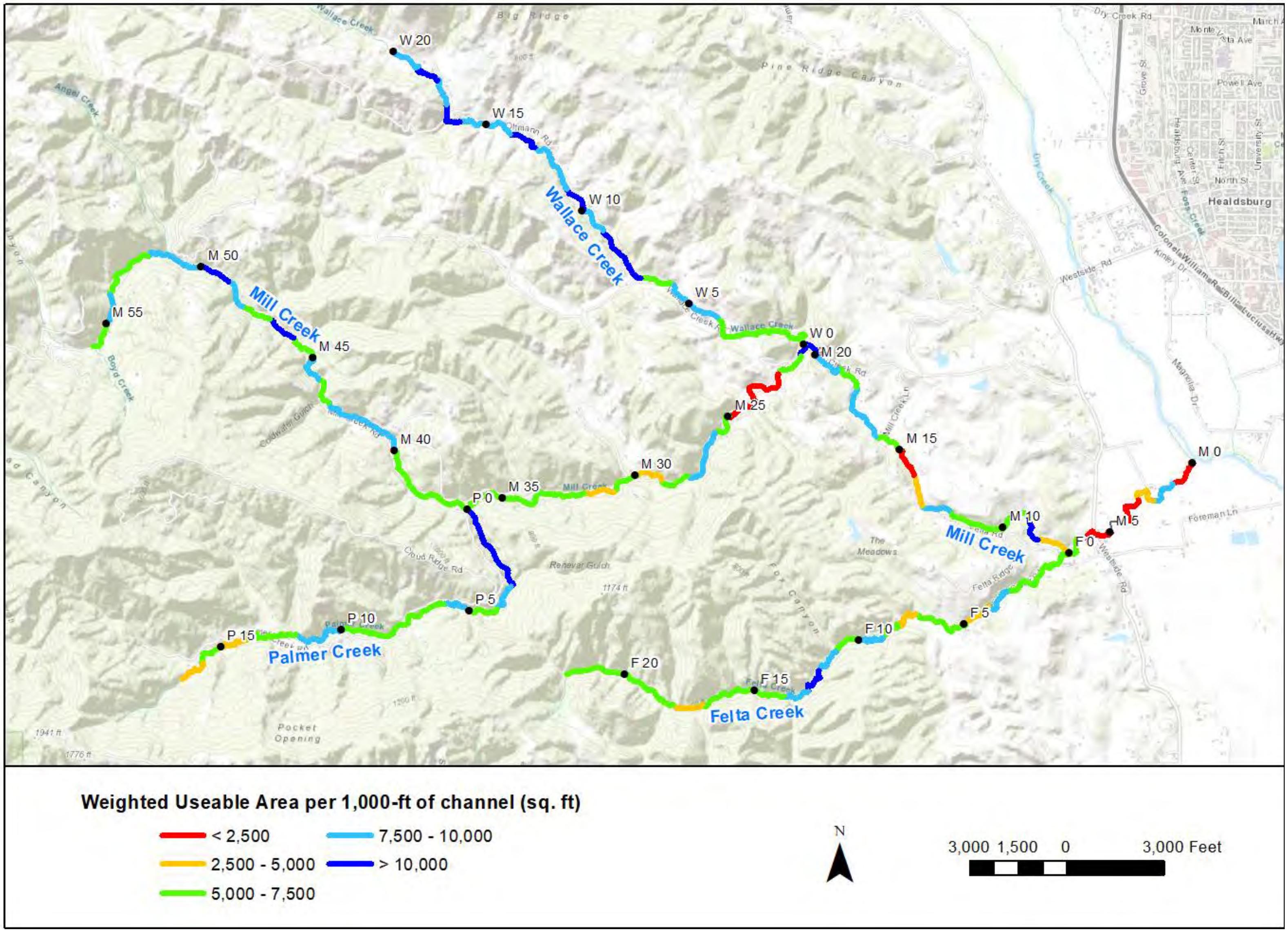


Figure 12: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **Mill Creek watershed** for the **bankfull flow**.

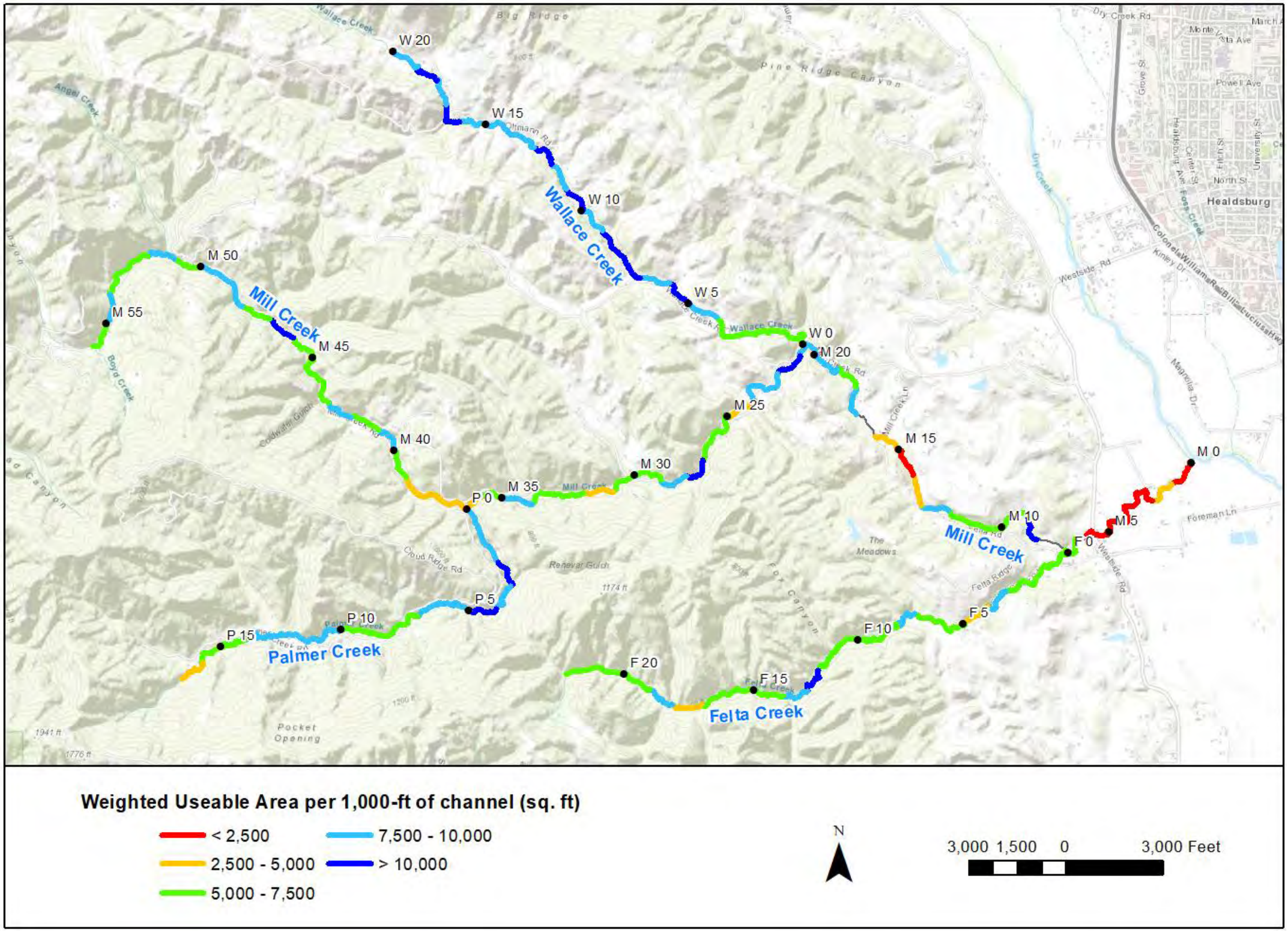


Figure 13: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **Mill Creek watershed** for the **10-yr flood flow**.

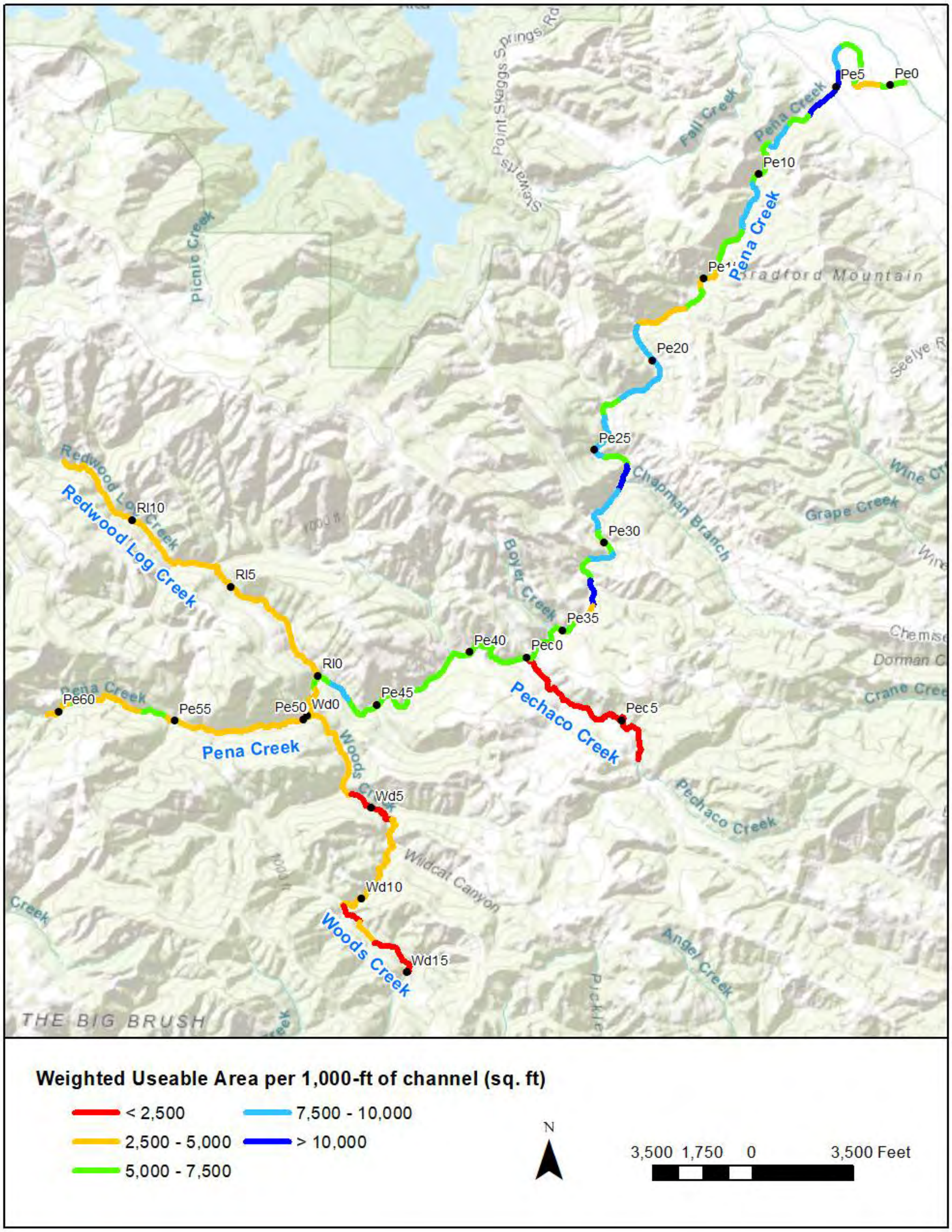


Figure 14: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **Pena Creek watershed** for **winter baseflow**.

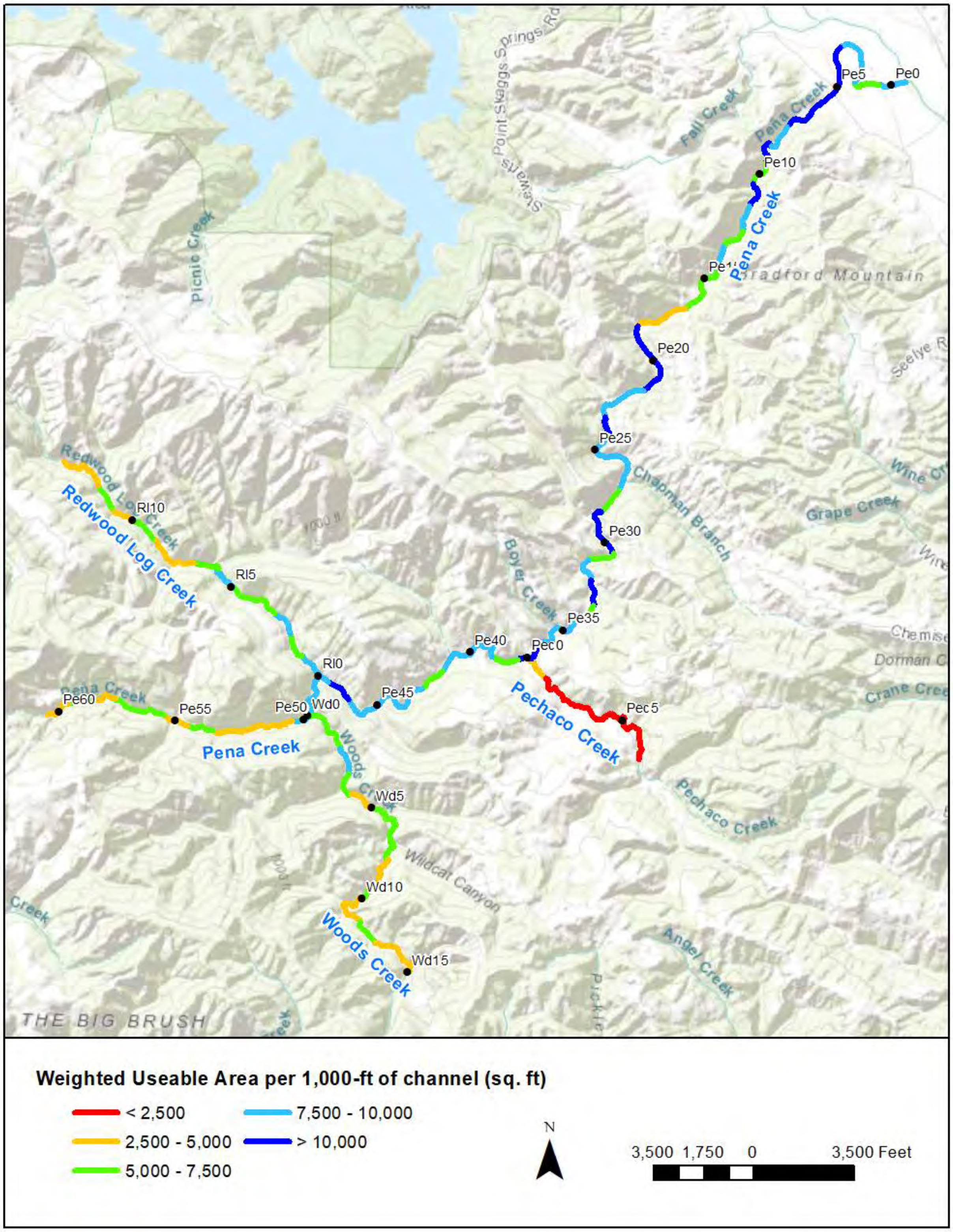


Figure 15: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **Pena Creek watershed** for the **10% exceedance flow**.

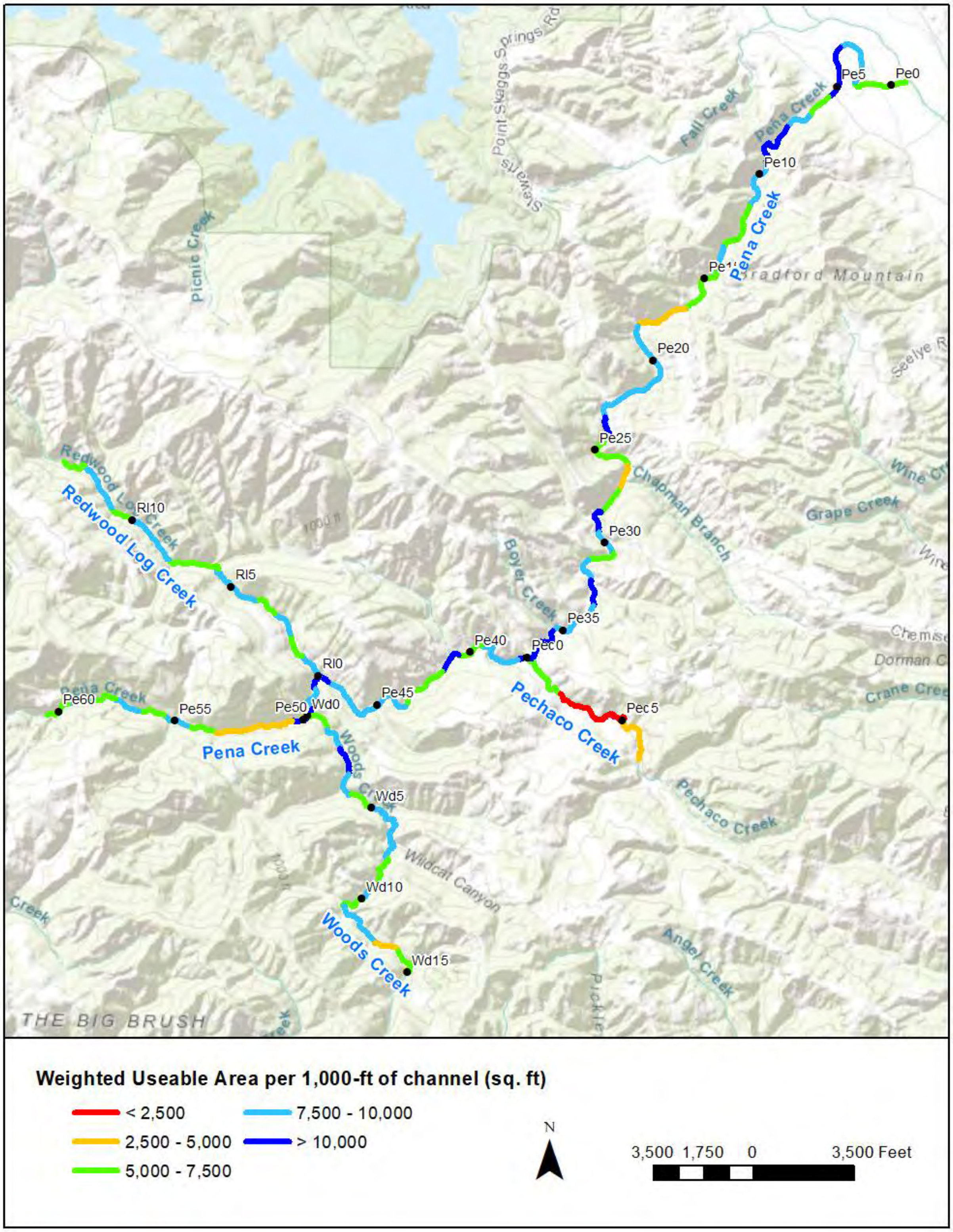


Figure 16: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **Pena Creek watershed** for the **bankfull flow**.

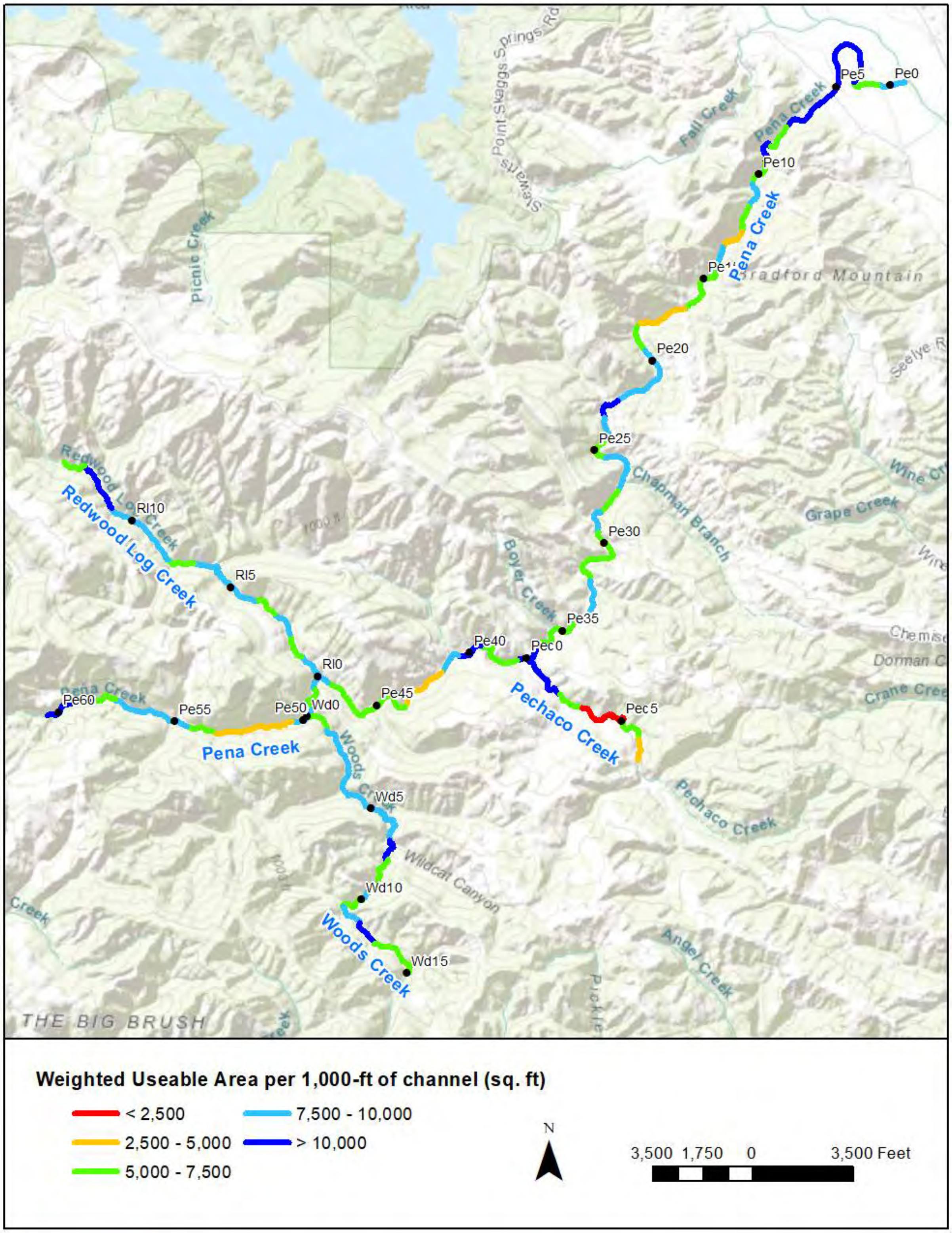


Figure 17: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **Pena Creek watershed** for the **10-yr flood flow**.

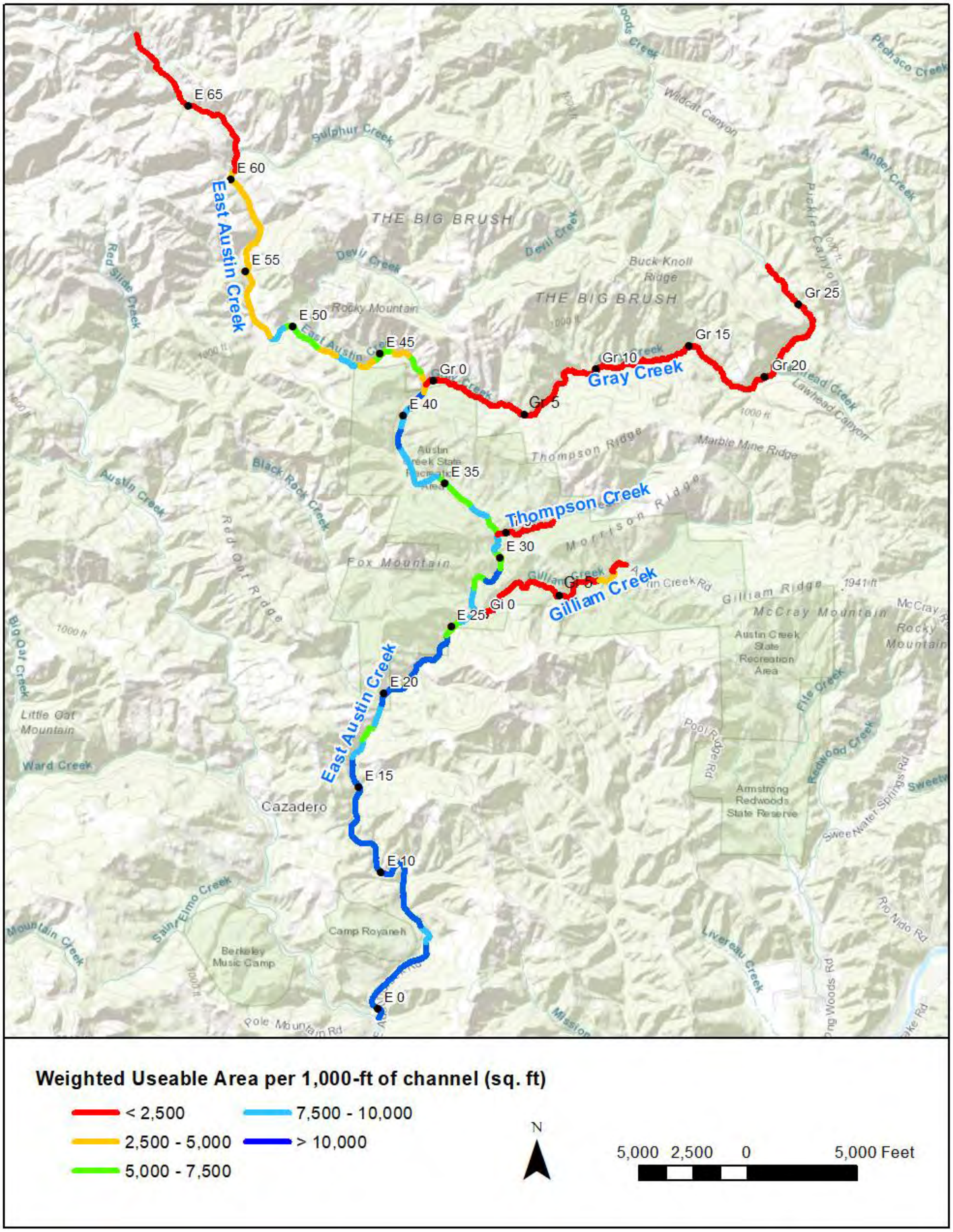


Figure 18: Distribution of total available habitat area (expressed as Weighted Useable Area) in **the East Austin Creek watershed** for **winter baseflow**.

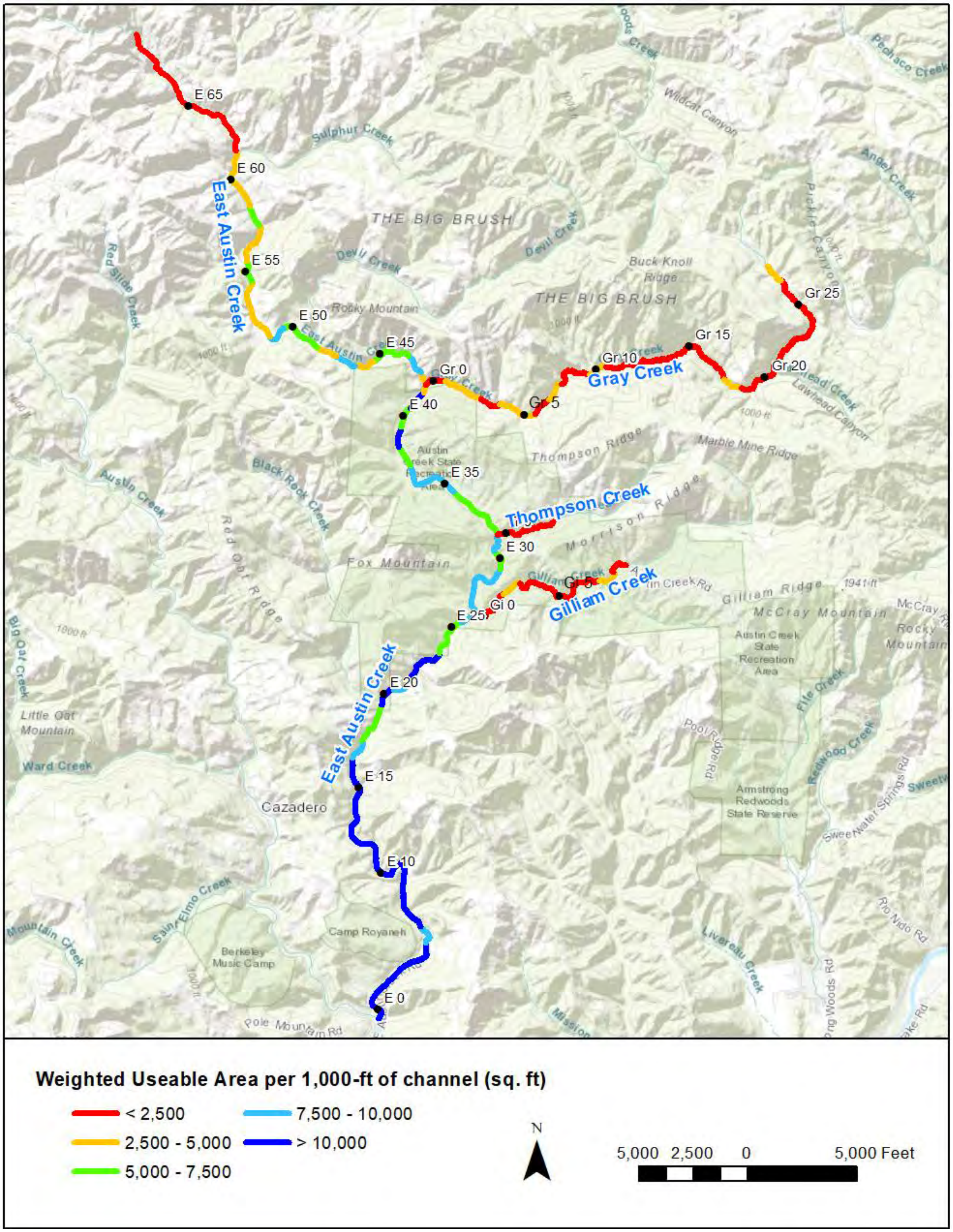


Figure 19: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **East Austin Creek watershed** for the **10% exceedance flow**.

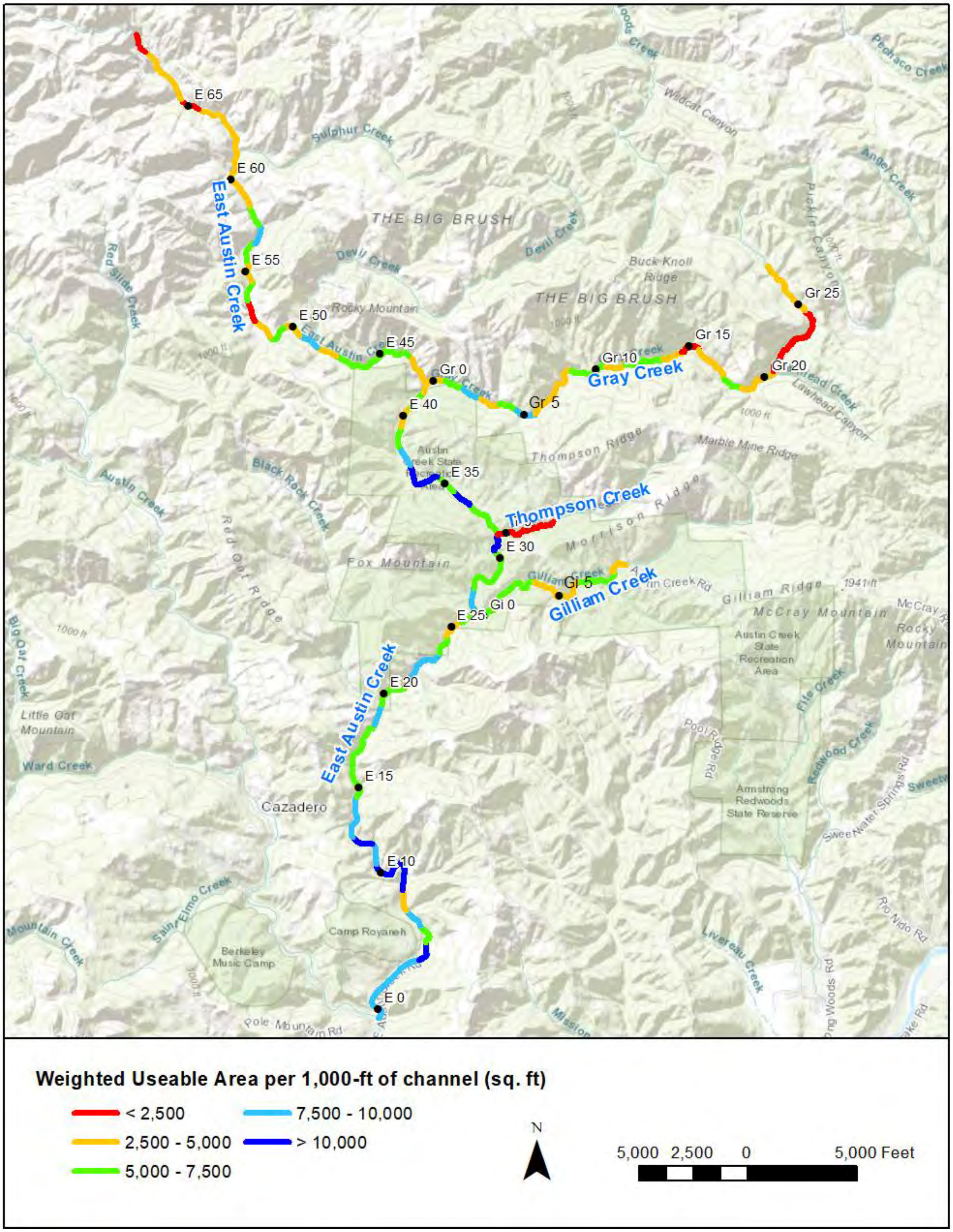


Figure 20: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **East Austin Creek watershed** for the **bankfull flow**.

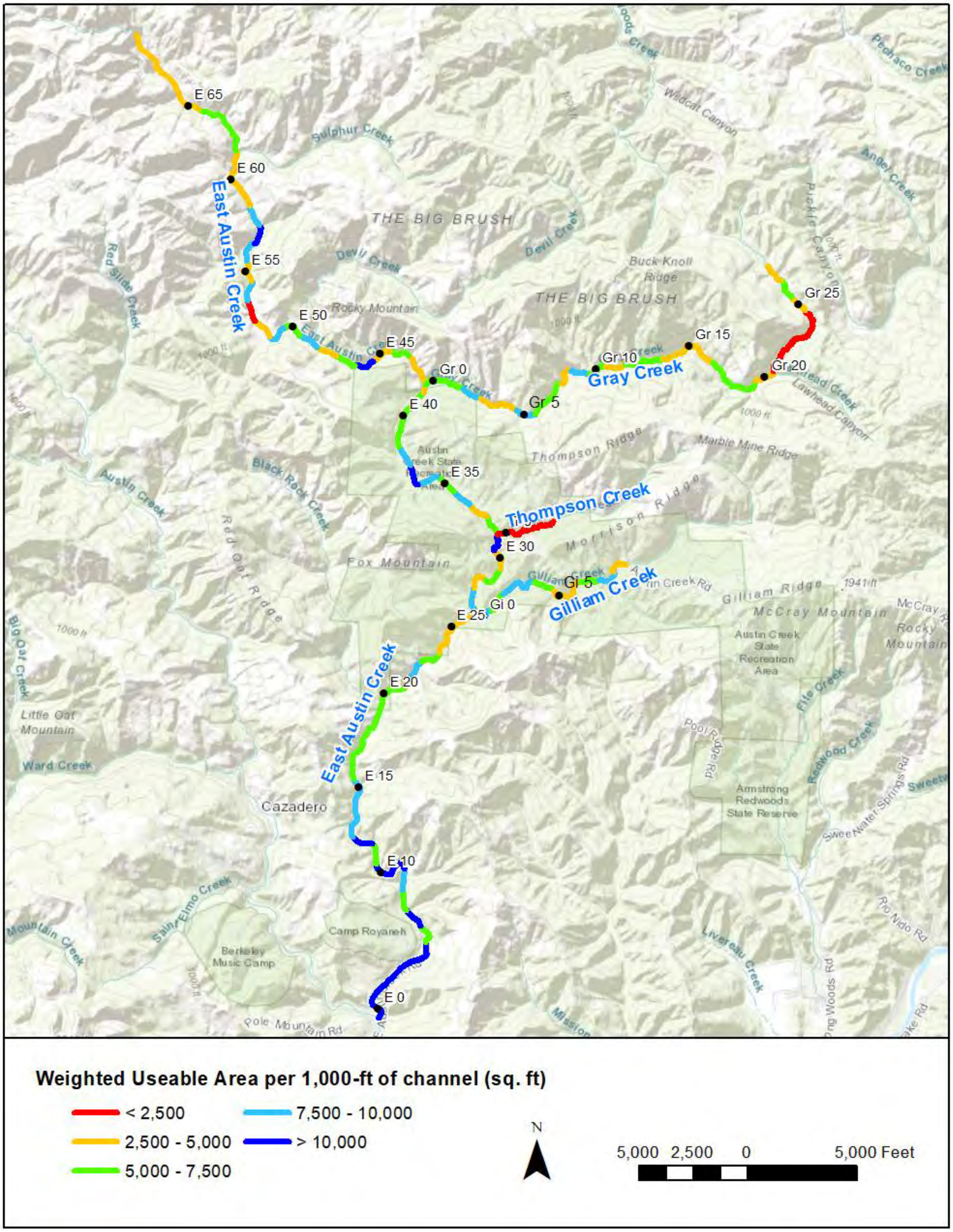


Figure 21: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **East Austin Creek watershed** for the **10-yr flood flow**.

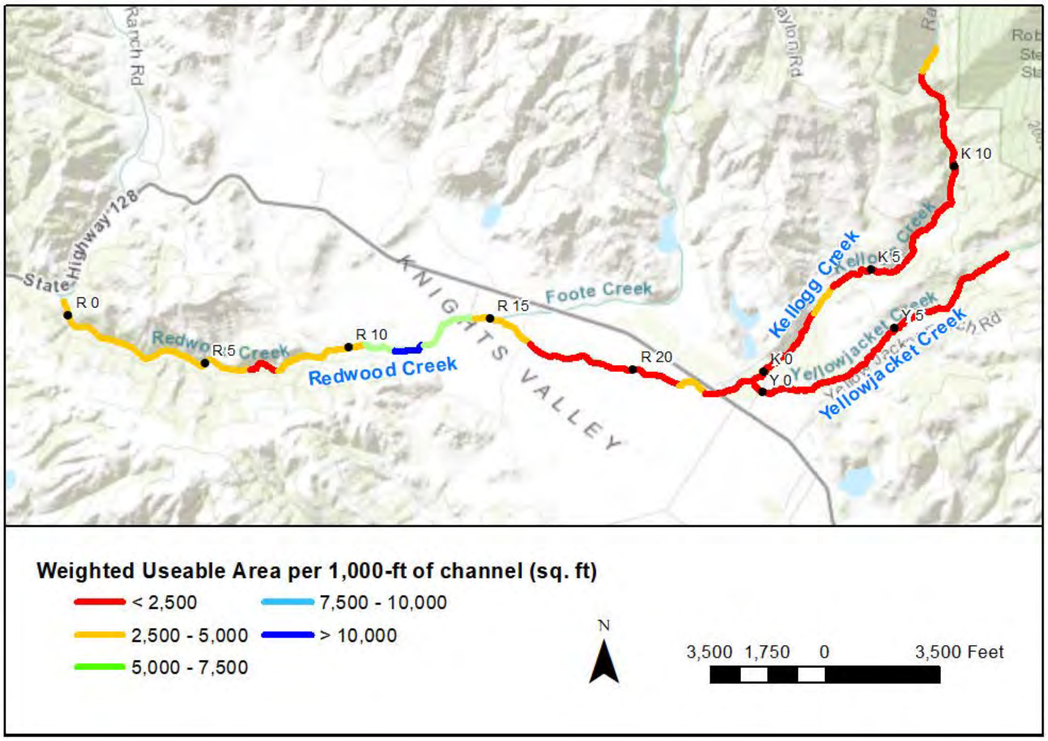


Figure 22: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **Redwood Creek watershed** for **winter baseflow**.

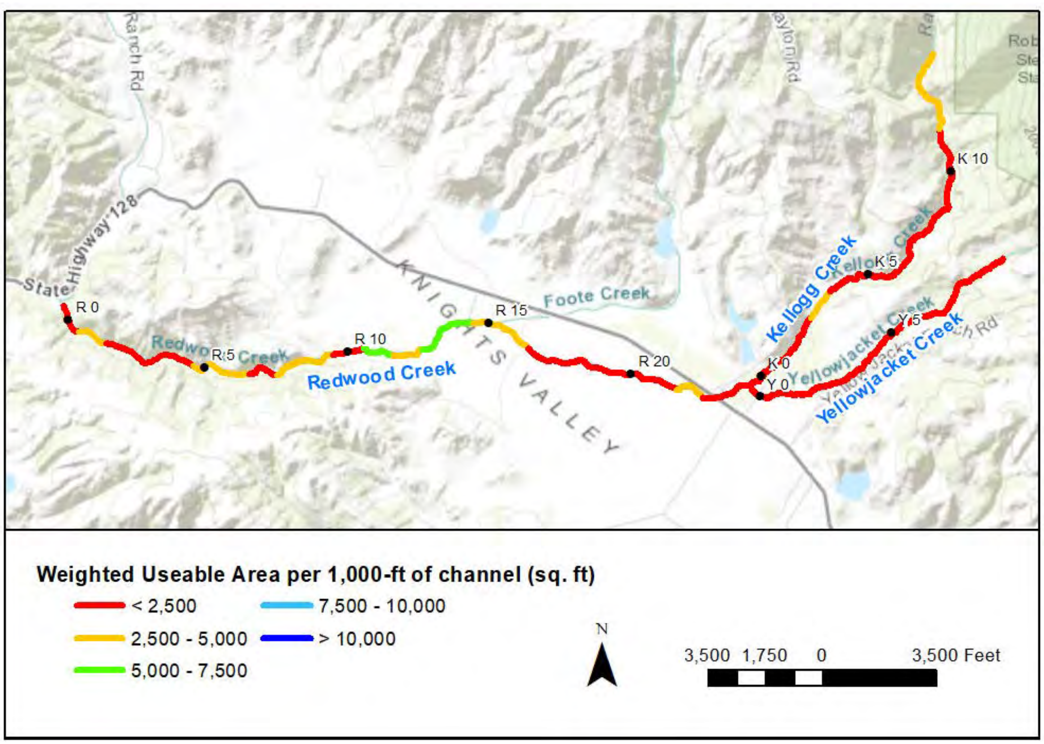


Figure 23: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **Redwood Creek watershed** for the **10% exceedance flow**.

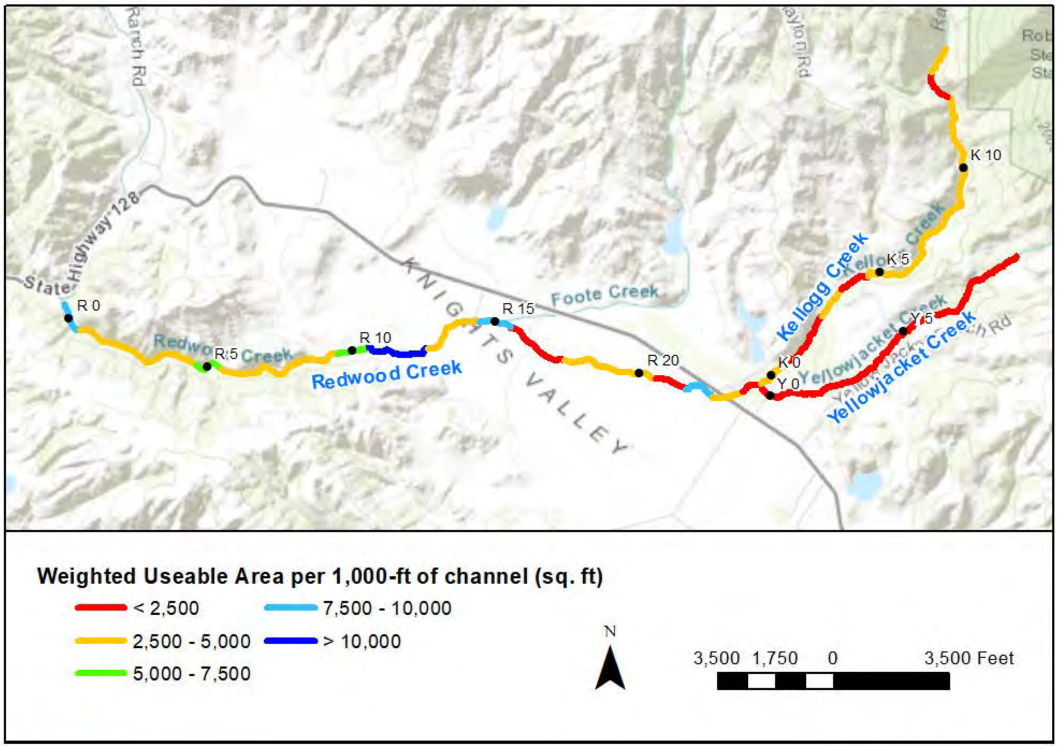


Figure 24: Distribution of total available habitat area (expressed as Weighted Useable Area) in the **Redwood Creek watershed** **for the** **bankfull flow**.

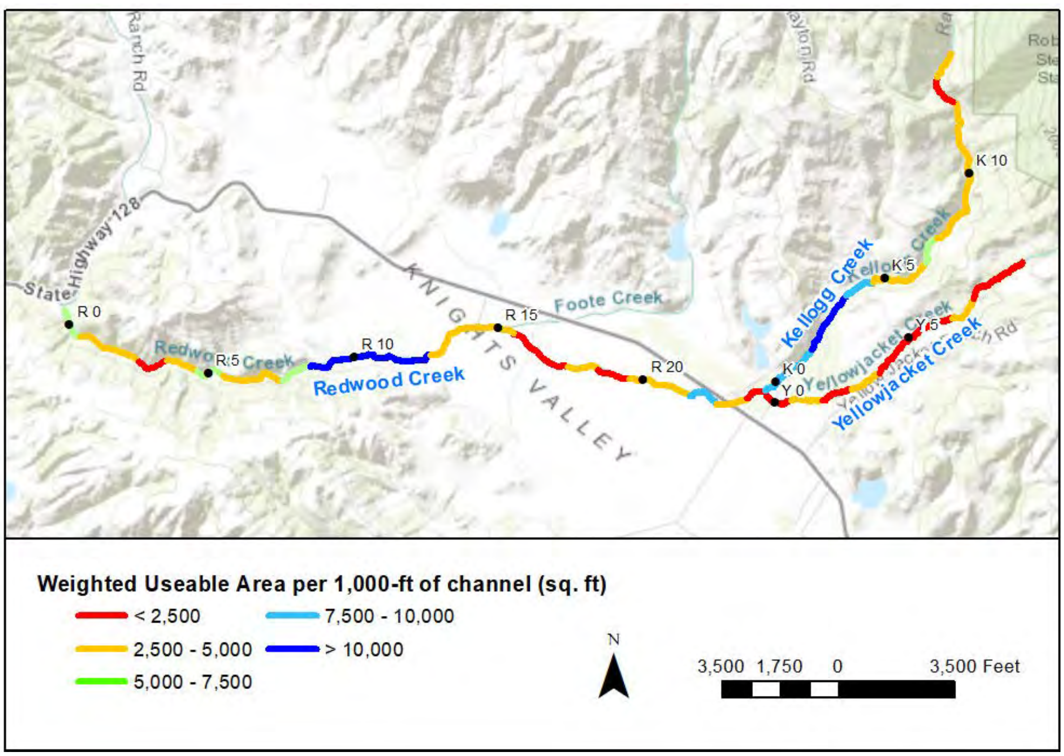


Figure 25: Distribution of total available habitat area (expressed as Weighted Useable Area) in the Redwood Creek watershed for the 10-yr flood flow.

Sea Grant Monitoring Data

Mill Creek

Sea Grant summer snorkel survey data from 2014 through 2017 indicate that there was an average of 401 juvenile coho in the sampled reaches over this period with an average density of about 5 fish per 1,000-ft of stream. The reaches with the most coho are scattered throughout main-stem Mill Creek below Palmer Creek and in Palmer Creek (Figure 26). Relatively few coho were observed in Felta, Wallace, or upper Mill Creek except for the lowest reach of Felta Creek

Sea Grant late summer mapping of wet, dry, and intermittent reaches from 2013 through 2017 indicates that during dry water years such as 2013 and 2014 pools become disconnected in most reaches (Figure 27). The only reaches maintaining surface flow throughout the drought are in upper and middle Mill Creek and middle Palmer Creek. During water years with more typical rainfall, pools remain connected throughout most of Mill and Palmer creeks, however even in average water years pools become disconnected in lower Mill Creek, Wallace Creek, and lower Felta Creek.

About 84% of the observed coho in the Mill Creek watershed are in reaches where pools became disconnected in late summer during the recent drought, and about 42% of the observed coho are located in reaches with disconnected pools even in average water years.

Sea Grant wood counts collected in 2017 indicate limited wood throughout most of the study area. Only about 10% of the sampled reaches had wood densities that meet the CDFW-recommended minimum density of 18 pieces of large wood per 1,000-ft (Figure 28). The reaches with relatively good wood density are in upper Mill Creek and upper Felta Creek. The average wood density in the study area was only 6.7 pieces of wood per 1,000-ft and 33% of the 1,000-ft reaches contained no large wood at all.

Pena Creek

Sea Grant summer snorkel survey data from 2014 through 2017 indicate that there was an average of 705 juvenile coho in the sampled reaches over this period with an average density of about 12 fish per 1,000-ft of stream. Lower Woods Creek appears to host a disproportionate number of coho, and fish counts are also relatively high in various reaches throughout middle and lower Pena Creek (Figure 29). Relatively few coho were observed in Pechaco Creek and no data is available in upper Pena Creek or Redwood Log Creek.

Sea Grant late summer mapping of wet, dry, and intermittent reaches from 2013 through 2017 indicates that during dry water years such as 2013 and 2014 pools become disconnected in almost the entire study area (Figure 30). Only 3 of the 1,000-ft reaches maintained surface flow throughout the drought. These reaches are in Pena Creek below Redwood Log Creek and a few thousand feet downstream of the Pechaco Creek confluence. Even during water years with more typical rainfall, pools disconnect in many reaches. The reaches with connected pools in average water years are concentrated in Woods Creek and middle Pena Creek between the Redwood Log Creek and Pechaco Creek confluences.

About 93% of the observed coho in the Pena Creek watershed are located in reaches where pools became disconnected in late summer during the recent drought, and about 32% of the observed coho are located in reaches with disconnected pools even in average water years.

Sea Grant wood counts collected in 2017 indicate extremely limited wood throughout most of the study area. None of the sampled reaches had wood densities that meet the CDFW-recommended minimum density of 18 pieces of large wood per 1,000-ft (Figure 31). The average wood density in the study area was only 2.6 pieces of wood per 1,000-ft and 46% of the 1,000-ft reaches contained no large wood at all. Wood densities were somewhat higher in portions of Woods Creek compared to the sampled reaches of Pena Creek but still generally well below the recommended minimum density.

East Austin Creek

Sea Grant summer snorkel survey data from 2015 through 2017 indicate that there was an average of 954 juvenile coho in the sampled reaches over this period with an average density of about 11 fish per 1,000-ft of stream. The reaches with a relatively high number of coho include the lowest 5,000-ft of East Austin Creek, several reaches of East Austin Creek from just below the confluence with Thompson Creek to just above the confluence with Gray Creek, lower Gilliam Creek, and middle Gray Creek (Figure 32). Relatively few coho were observed in Thompson Creek or the upper reaches of East Austin Creek.

The available Sea Grant late summer mapping of wet, dry, and intermittent reaches is not sufficient to allow for a comprehensive reach-by-reach characterization of summer flow regime. The available data only covers portions of Gray Creek and Gilliam Creek and is only available for 2015 through 2017. The available data indicate that pools remain connected during average water years throughout lower Gray and Gilliam Creeks but become disconnected in central Gray Creek. The extent of disconnection during dry water years is unknown.

Redwood Creek

The available Sea Grant monitoring data in Redwood Creek is much more limited than in Mill Creek or Pena Creek and is not sufficient to allow for a comprehensive reach-by-reach characterization of coho abundance or summer flow regime. Summer snorkel survey data from the lowest 12,000-ft of Redwood Creek indicate that there were no juvenile coho present during the surveys in 2014, 2015, and 2017 and only 28 coho during 2016. Survey data is also available for Yellowjacket Creek from 2017 which indicates no coho were present. The snorkel survey data from Redwood Creek indicate a very low average fish density of about 0.8 fish per 1,000-ft. Late summer mapping of wet, dry, and intermittent reaches from 2014 through 2017 indicates that during dry water years all of Redwood Creek experiences disconnected pools and that portions of the creek also experience disconnected pools during average water year conditions.

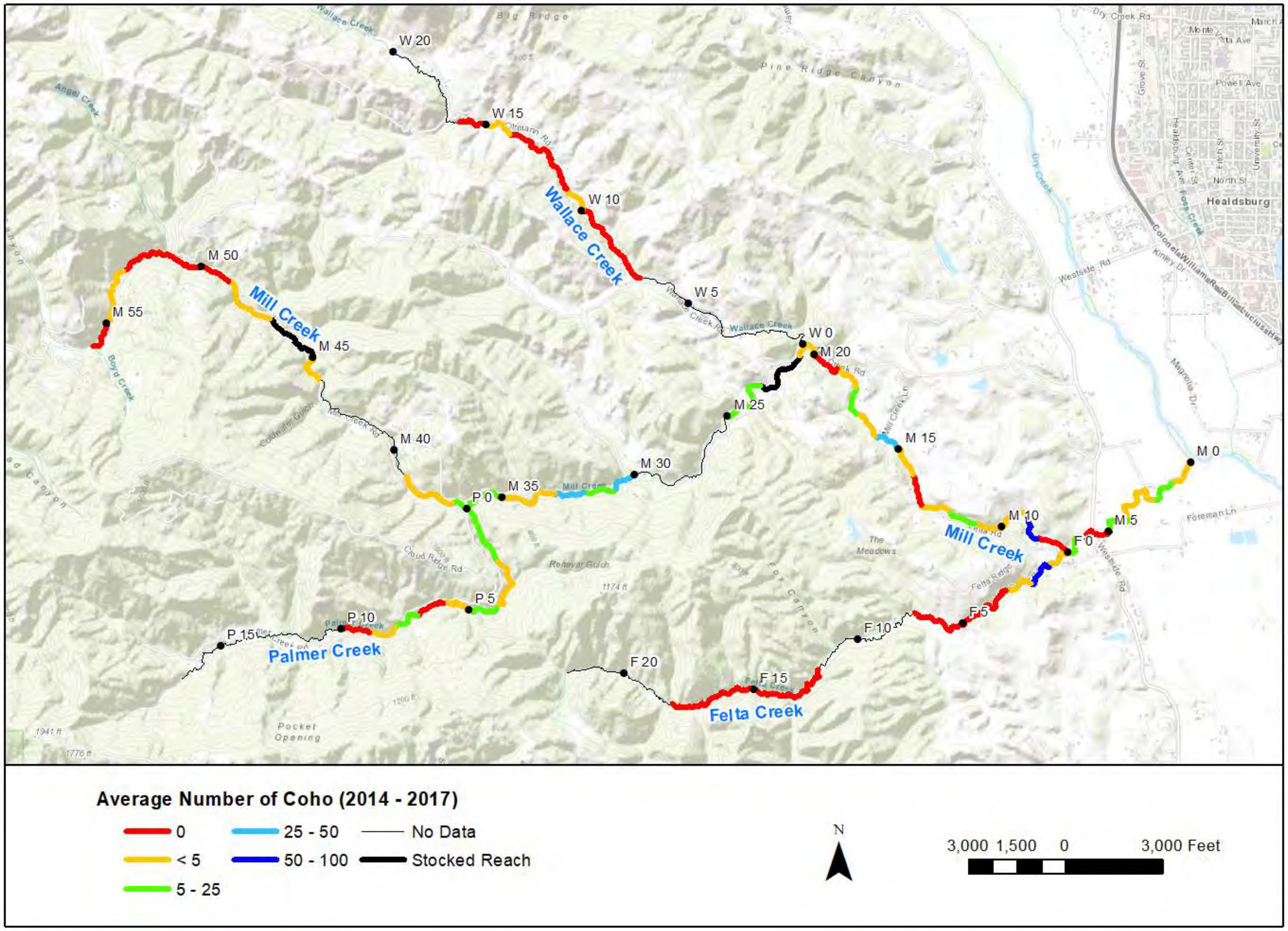


Figure 26: **__Average number of juvenile coho in the Mill Creek watershed per 1,000-ft reach__** **derived from Sea Grant summer snorkel survey data from 2014 through 2017.**

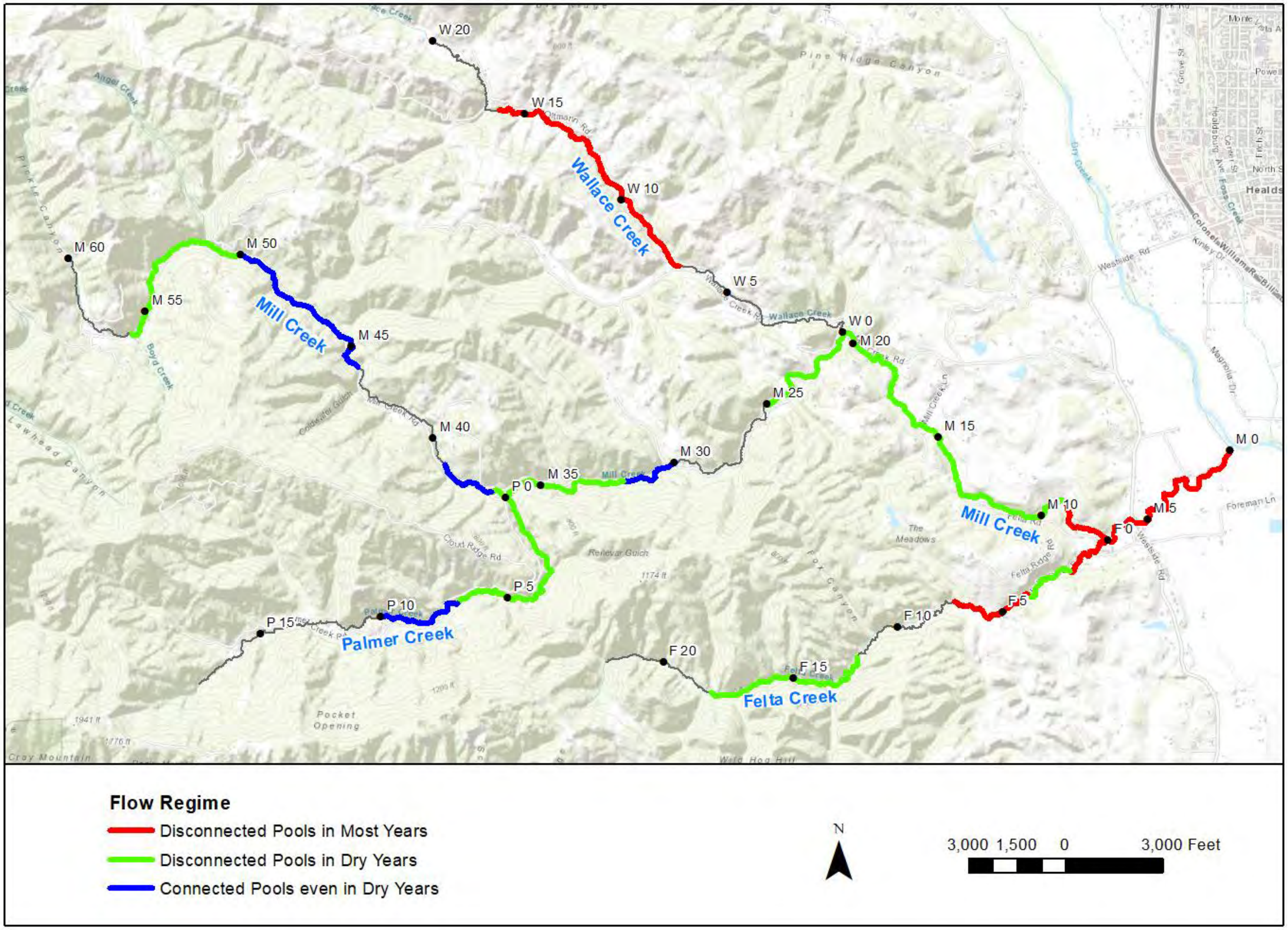


Figure 27: **Late summer flow regime in the Mill Creek watershed** derived from Sea Grant mapping of wet, dry, and intermittent reaches from 2013 through 2017.

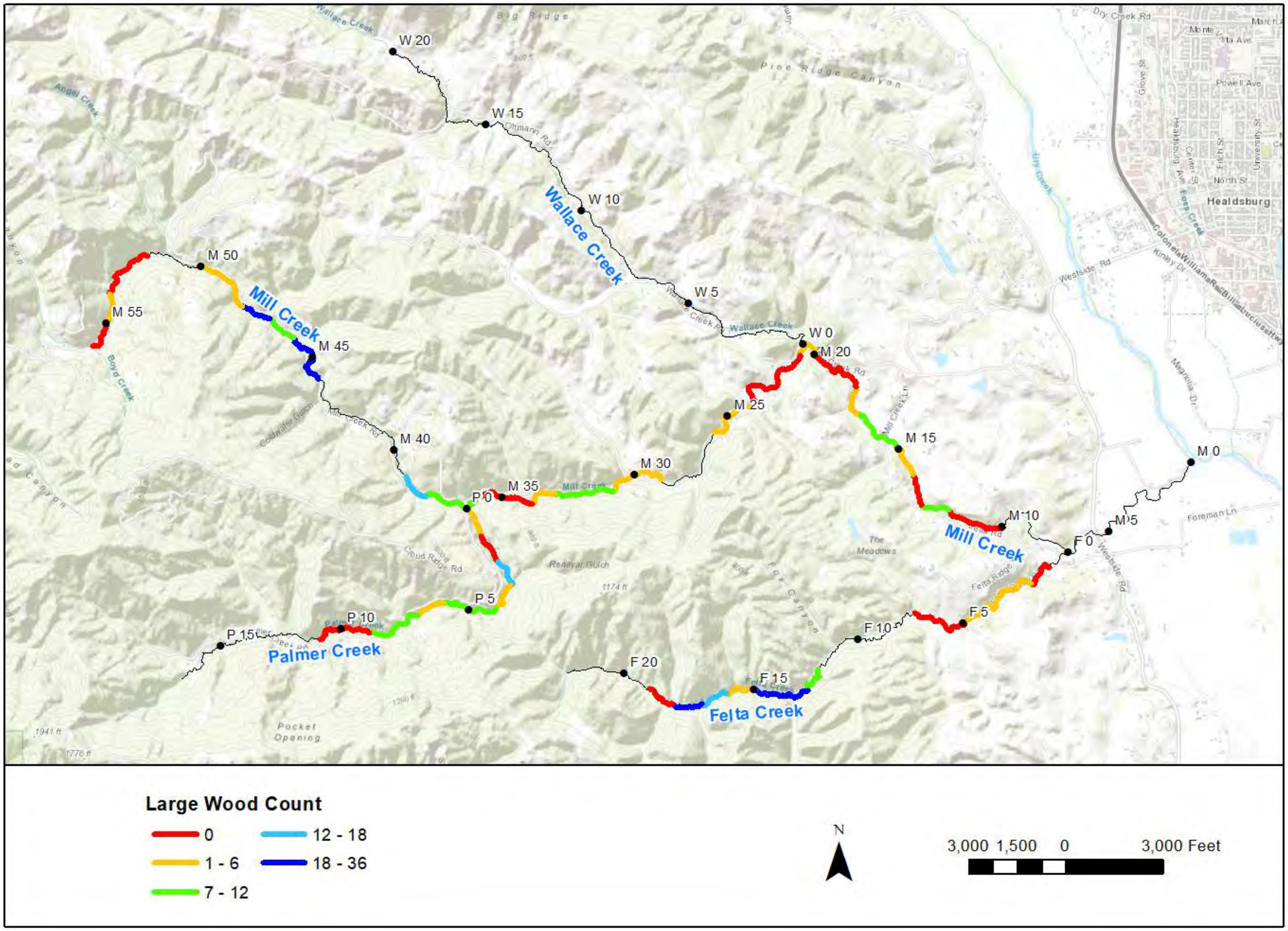


Figure 28: **Number of pieces of large wood in the Mill Creek watershed per 1,000-ft reach** derived from 2017 Sea Grant habitat mapping data.

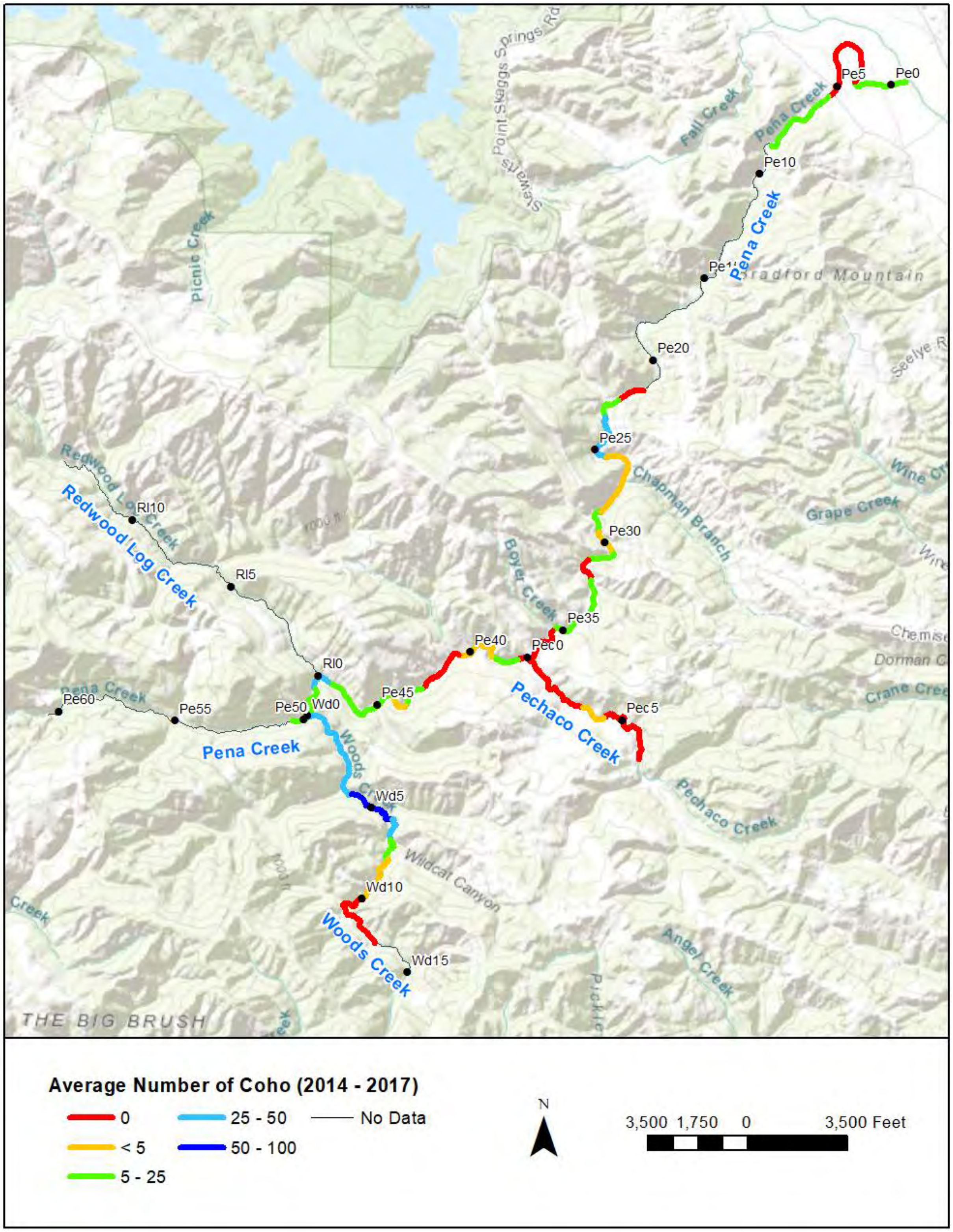


Figure 29: <u>**Average number of juvenile coho in the Pena Creek watershed per 1,000-ft reach**</u> derived from Sea Grant summer snorkel survey data from 2014 through 2017.

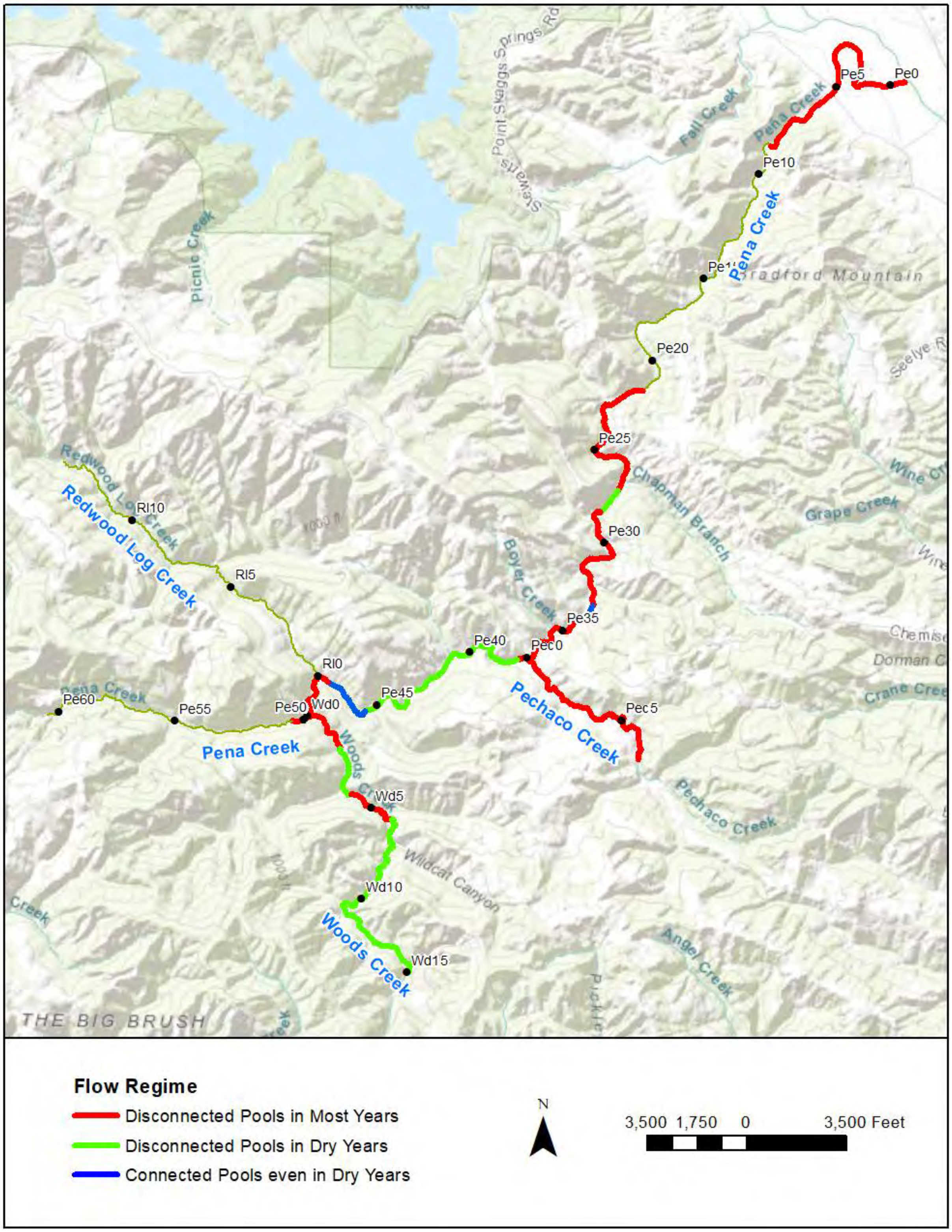


Figure 30: **Late summer flow regime in the Pena Creek watershed** derived from Sea Grant mapping of wet, dry, and intermittent reaches from 2013 through 2017.

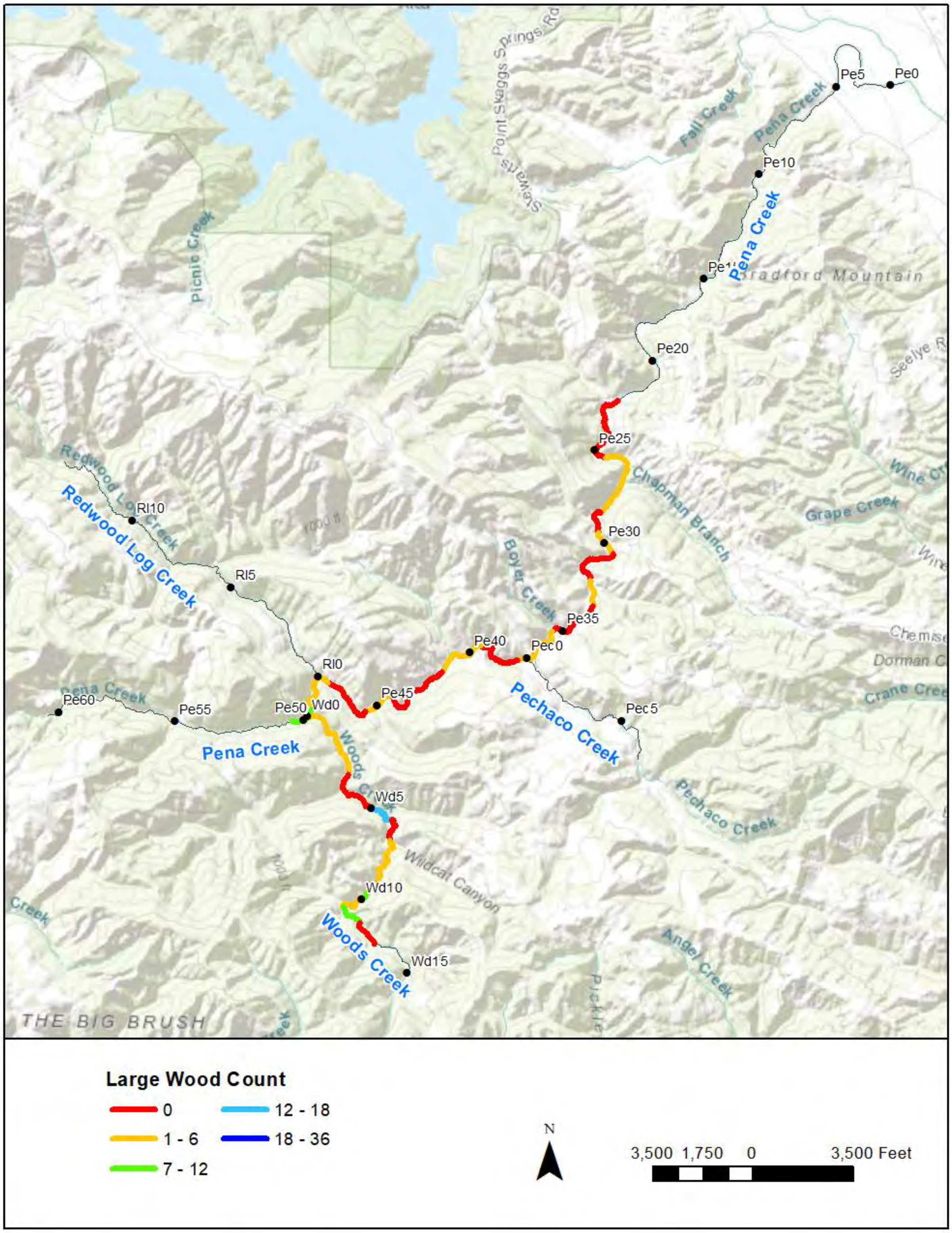


Figure 31: **Number of pieces of large wood in the Pena Creek watershed per 1,000-ft reach** derived from 2017 Sea Grant habitat mapping data.

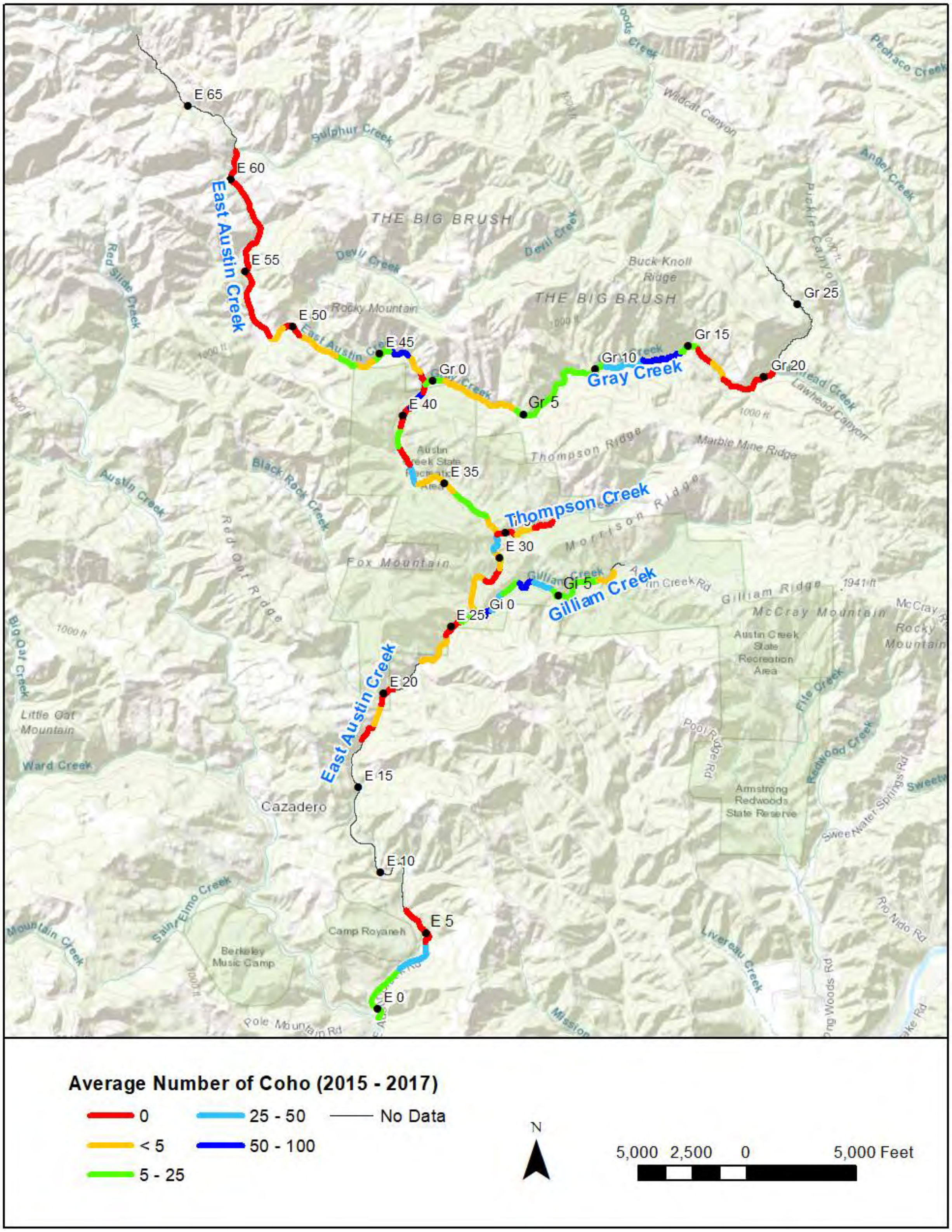


Figure 32: Average number of juvenile coho in the East Austin Creek watershed per 1,000-ft reach derived from Sea Grant summer snorkel survey data from 2015 through 2017.

Chapter 5 - Instream Project Prioritization

Mill Creek

The initial instream habitat project prioritization based solely on the total available area of coho rearing habitat, as expressed with the metric Weighted Useable Area (WUA), is shown in Figure 33. The adjusted prioritization considering flow condition and coho abundance in addition to WUA (as described in Ch. 3) is shown in Figure 34. There are twenty-four 1,000-ft reaches classified as High or Very High priority in Mill Creek, six High or Very High priority reaches in Palmer Creek, one High priority reach in Felta Creek, and none in Wallace Creek. The total stream length of High and Very High priority reaches in the watershed is about 6.6 river miles (Table 4).

We also identified four 1,000-ft reaches as the highest priority for flow augmentation projects, three in lower Mill Creek and one in lower Felta Creek (Figure 34). These reaches were identified because they have relatively high WUA and coho utilization, however pools become disconnected even during average water year conditions. If flow restoration projects can be implemented such that these reaches maintain pool connectivity during at least average water years, then instream projects would be recommended here as well.

After screening the identified priority reaches based on consideration of equipment access and presence/absence of large diameter anchoring trees (as described in Chapter 2), the extent of High or Very High priority reaches is reduced from 5.8 to 3.3 river miles including 14,600-ft in Mill Creek, 1,910-ft in Palmer Creek, and 910-ft in Felta Creek (Figure 35, Table 4).

The recommended minimum instream LWD abundance specified in the CDFW Restoration Design Manual (CDFW, 2010) is six pieces per 100-m of channel length (18 pieces per 1,000-ft). Based on wood counts performed as part of the Sea Grant monitoring program, there are an average of only 6.7 pieces of large wood per 1,000-ft in the sampled reaches of the Mill Creek watershed. Based on the CDFW guidance and the existing LWD abundance estimates, wood structures comprising approximately 295 individual logs would be required to attain the recommended minimum abundance of LWD in all 4.9 miles of Medium, High, and Very High priority reaches in the Mill Creek Watershed with reasonably easy access and good anchoring sites (Table 4).

Pena Creek

The initial instream habitat project prioritization based solely on the total available area of coho rearing habitat, as expressed with the metric Weighted Useable Area (WUA), is shown in Figure 36. The adjusted prioritization based on consideration of the flow condition and coho abundance (as described above in Ch. 3) is shown in Figure 37. There are a total of eight 1,000-ft reaches classified as High or Very High priority in Pena Creek and four in Woods Creek. The total stream length of High and Very High priority reaches in the watershed is about 2.3 river miles (Table 4). We did not include any reaches of Redwood Log Creek or Pena Creek upstream of Woods Creek because WUA values were generally low in these reaches and there are no flow observations or snorkel survey data available. It is possible that there are some perennially- flowing reaches with significant coho utilization in these areas, however additional field data is necessary to determine if instream projects are warranted in these reaches.

We also identified nine 1,000-ft reaches as the highest priority for flow augmentation projects, six in middle Pena Creek and three in lower Woods Creek (Figure 37). These reaches were identified because they have relatively high WUA and coho utilization, however pools become disconnected even during average water year conditions. If flow restoration projects can be implemented such that these reaches maintain pool connectivity during at least average water years, then instream projects would be recommended here as well.

After screening the identified priority reaches based on consideration of equipment access and presence/absence of large diameter anchoring trees (as described above in Ch. 3), the extent of High or Very High priority reaches is reduced substantially from 2.3 to 0.8 river miles including 2,760-ft in Pena Creek, and 1,410-ft in Woods Creek (Figure 38, Table 4).

The recommended minimum instream LWD abundance specified in the CDFW Restoration Design Manual (CDFG, 2010) is six pieces per 100-m of channel length (18 pieces per 1,000-ft). Based on wood counts performed as part of the Sea Grant monitoring program, there are an average of only 2.6 pieces of large wood per 1,000-ft in the sampled reaches in the Pena Creek watershed. Based on the CDFW guidance and the existing LWD abundance estimates, wood structures comprising approximately 90 individual logs would be required to attain recommended instream LWD abundance in treat all 1.1 miles of Medium, High, and Very High priority reaches in the Pena Creek Watershed with reasonably easy access and good anchoring sites (Table 4).

East Austin Creek

The initial instream project prioritization based solely on the total available area of coho rearing habitat, as expressed with the metric Weighted Useable Area (WUA), is shown in Figure 39. The adjusted final prioritization based on consideration of coho abundance (as described above under Methodology) is shown in Figure 40. There are a total of thirty-five 1,000-ft reaches classified as High or Very High priority in East Austin Creek, four High priority reaches in Gray Creek, three High priority reaches in Gilliam Creek, and none in Thompson Creek. The total stream length of High and Very High priority reaches in the watershed is about 8.0 river miles (Table 4).

After screening the identified priority reaches based on consideration of equipment access and presence/absence of large diameter anchoring trees (as described above in Ch. 3), the extent of High or Very High priority reaches is reduced substantially from 8.0 to 2.3 river miles including 8,800-ft in East Austin Creek, and 3,480-ft in Gray Creek (Figure 41, Table 4).

The recommended minimum instream LWD abundance specified in the CDFW Restoration Design Manual (CDFG, 2010) is six pieces per 100-m of channel length (18 pieces per 1,000-ft). LWD data are not available in the watershed, however based on LWD characterizations in other Russian River tributary watersheds, LWD abundance is expected to be low. Assuming LWD abundance similar to Mill Creek (6.7 pieces of large wood per 1,000-ft), suggests that approximately 175 individual logs would be required to attain recommended minimum LWD abundance in all 2.9 miles of Medium, High, and Very High priority streams in the East Austin Creek watershed with reasonably easy access and good anchoring sites (Table 4).

Redwood Creek

Given the paucity of habitat monitoring data available in the Redwood Creek watershed, the instream project prioritization is based almost entirely on the total available area of coho rearing habitat, as expressed with the metric Weighted Useable Area (WUA) (Figure 42). The only exception is in lower Redwood Creek where three reaches were adjusted from medium to high priority because coho were observed in the reaches in 2016. There are a total of fifteen 1,000-ft reaches classified as High or Very High priority all of which are located in Redwood Creek and the majority of which are located the lowest 13,000-ft of the creek. The total stream length of High and Very High priority reaches in the watershed is about 2.8 river miles.

After screening the identified priority reaches based on consideration of equipment access and presence/absence of large diameter anchoring trees (as described above under Methodology), the extent of High or Very High priority reaches is reduced substantially from 2.8 to 0.6 river miles all of which are in main-stem Redwood Creek (Figure 43, Table 4).

The recommended minimum instream LWD abundance specified in the CDFW Restoration Design Manual (CDFG, 2010) is six pieces per 100-m of channel length (18 pieces per 1,000-ft). LWD counts are not available in the watershed, however based on LWD characterizations in other Russian River tributary watersheds, LWD abundance is expected to be low. Assuming LWD abundance similar to Pena Creek (2.6 pieces of LWD per 1,000-ft), suggests that approximately 80 individual pieces of LWD would be required to attain recommended minimum LWD abundance in all 1.0 miles of Medium, High, and Very High priority streams in the Redwood Creek Watershed with reasonably easy access and good anchoring sites (Table 4).

Table 4: Summary of the identified priority reach lengths and the approximate number of logs (LWD) required to treat them in each of the four study watersheds.

Watershed	Length of Priority Reaches (miles)	Approximate Required # of Logs	Length of Priority Reaches with Good Access and Achoring Sites (miles)	Approximate Required # of Logs
Mill	8.7	520	4.9	295
Pena	3.0	245	1.1	90
East Austin	10.6	640	2.9	175
Redwood	4.3	345	1.0	80

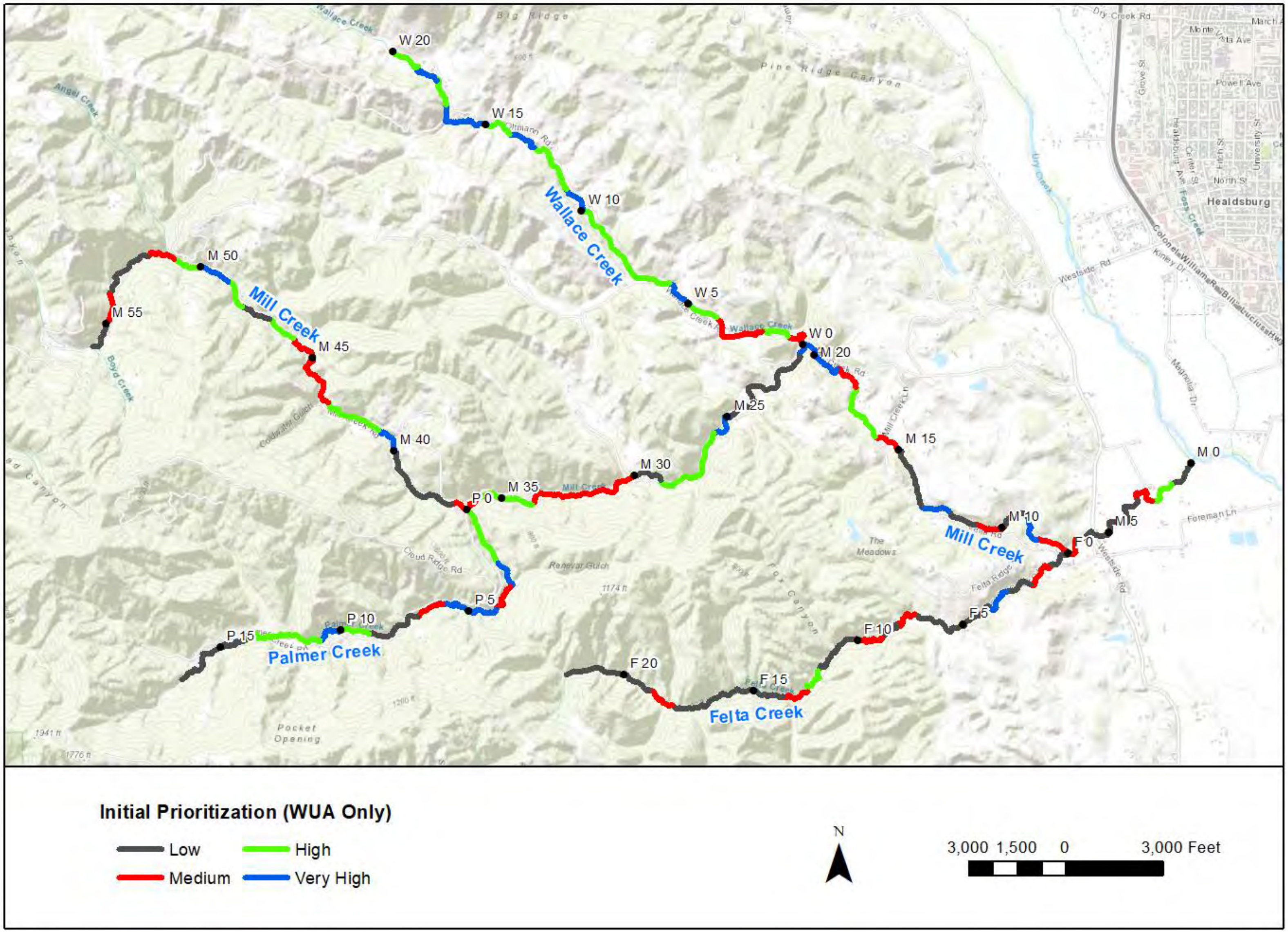


Figure 33: Initial prioritization for instream projects in the **Mill Creek watershed** based only on WUA.

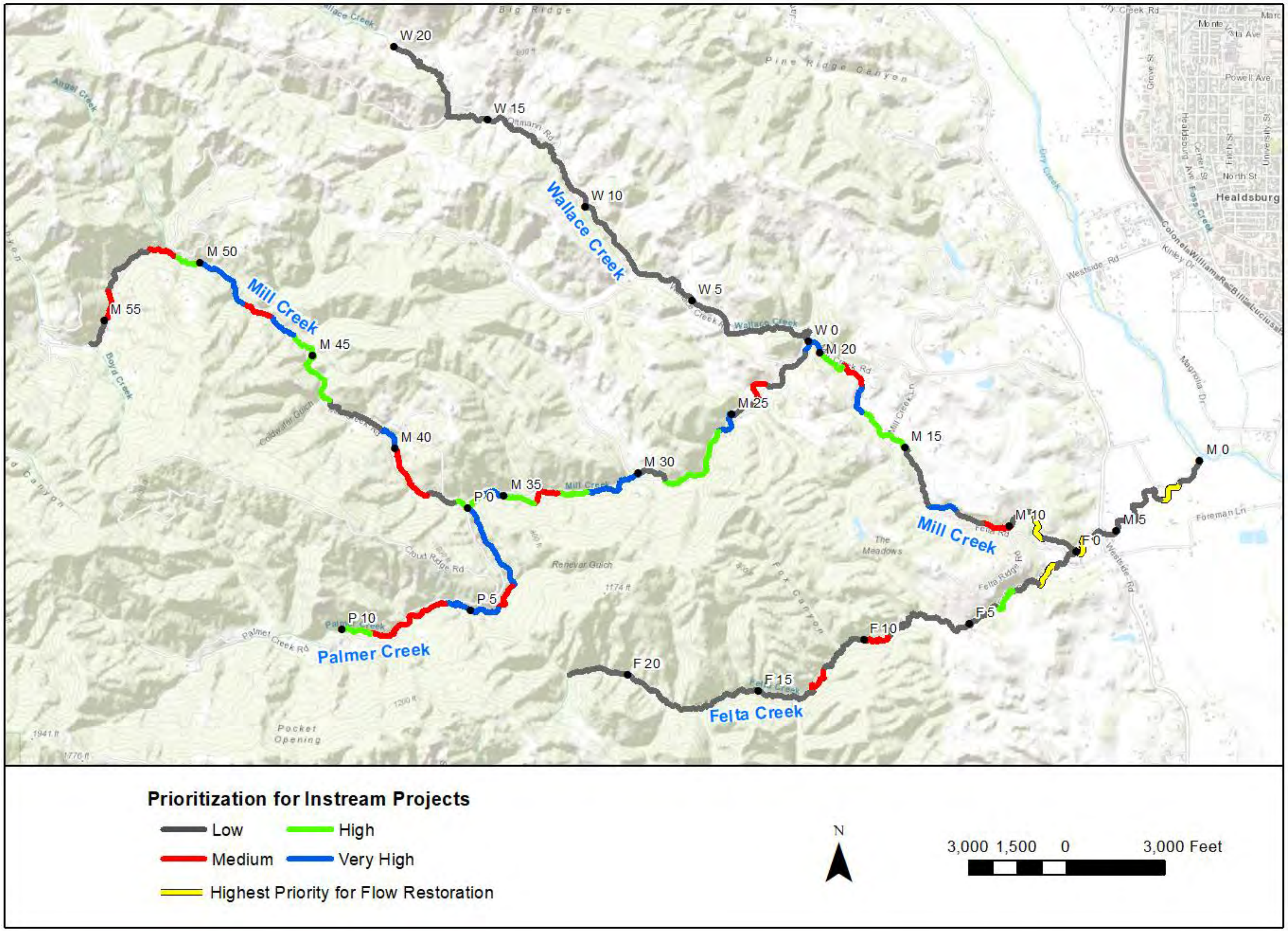


Figure 34: **<u>Prioritization for instream projects in the Mill Creek watershed</u>** based on WUA, flow condition, and coho abundance.

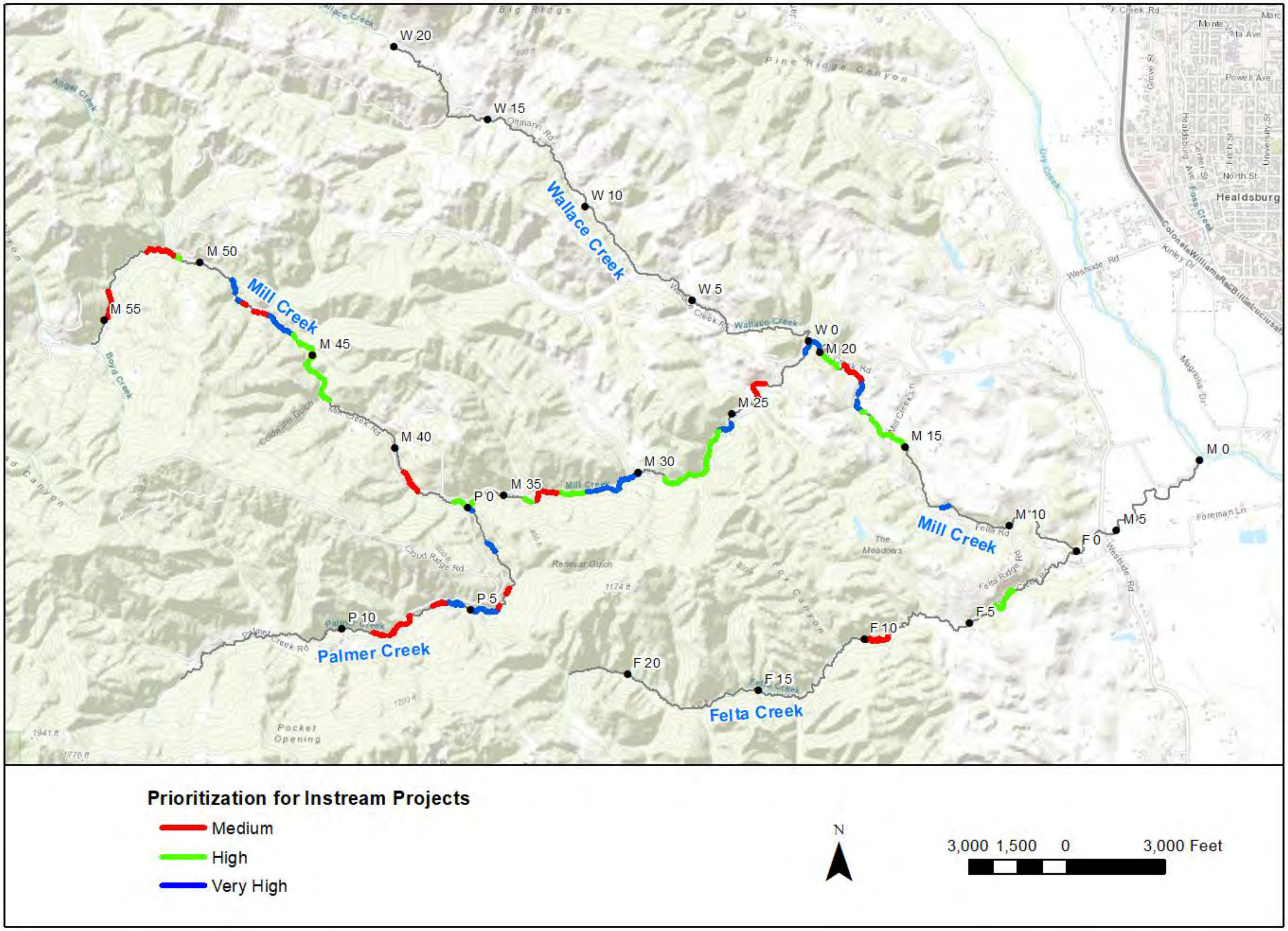


Figure 35: **<u>Final adjusted prioritization for instream projects in the Mill Creek watershed</u>** showing only the reaches with relatively good equipment access and presence of large diameter trees for anchoring sites.

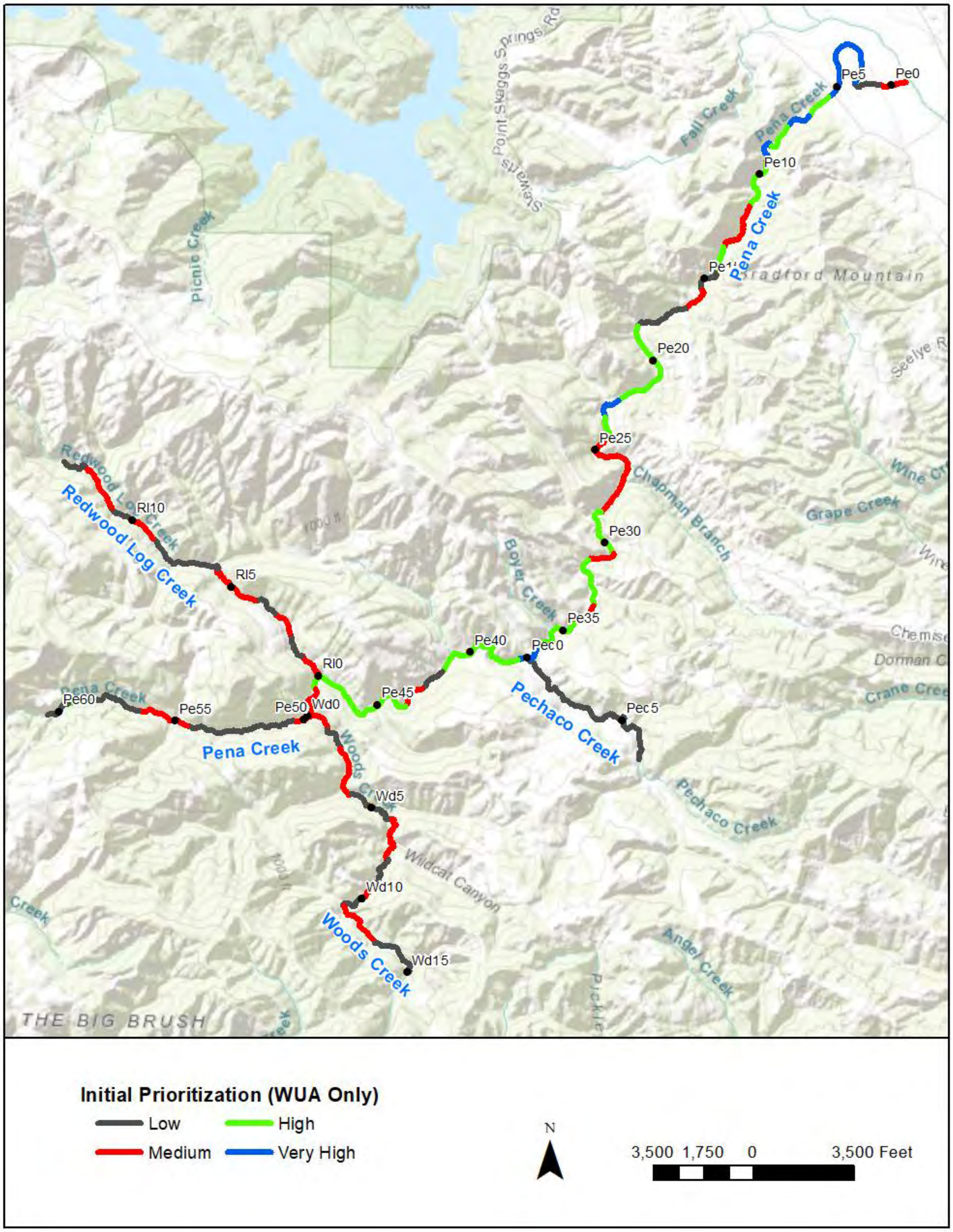


Figure 36: Initial prioritization for instream projects in the **Pena Creek watershed** based only on the WUA.

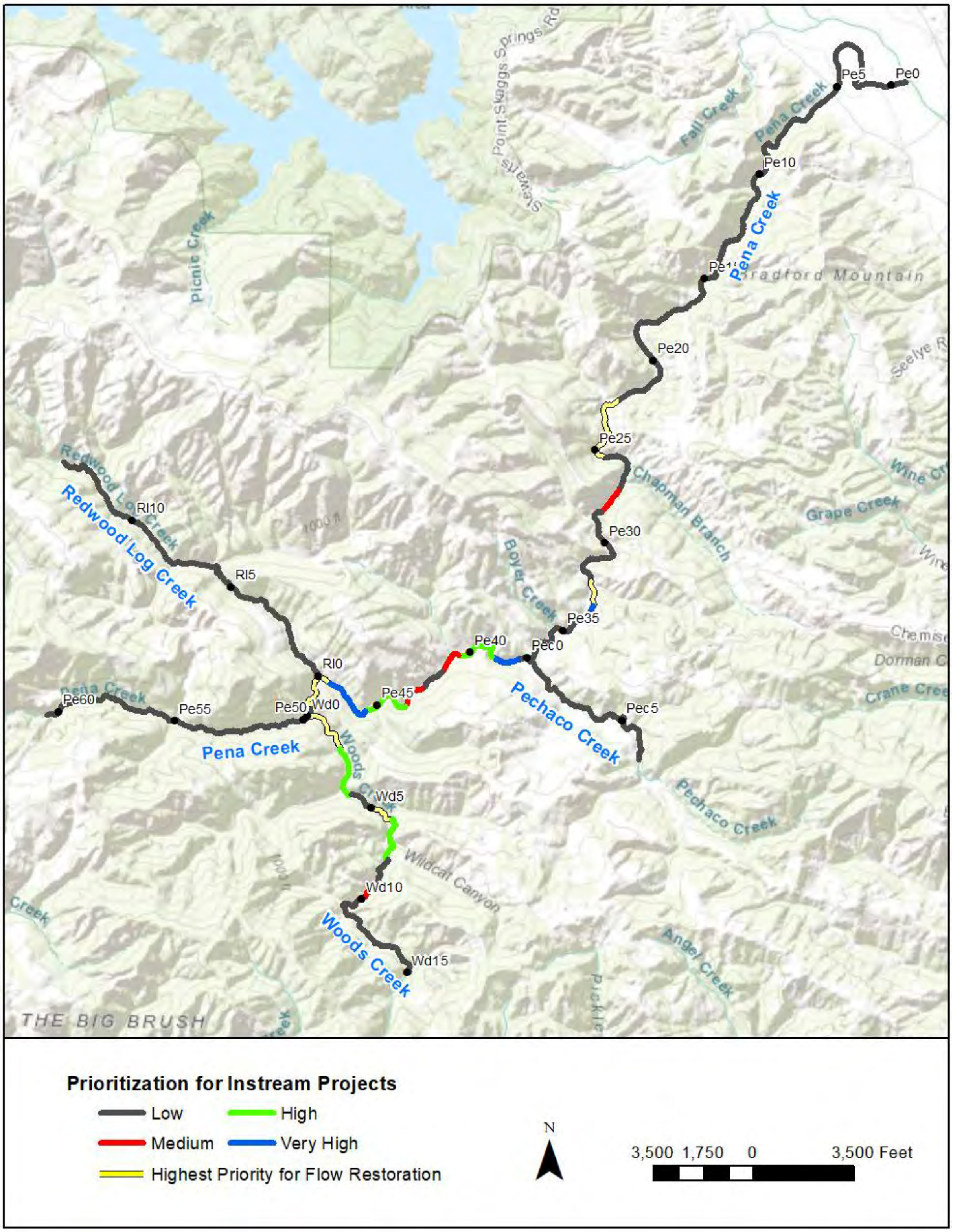


Figure 37: **Adjusted prioritization for instream projects in the Pena Creek watershed** based on WUA, flow condition, and coho abundance.

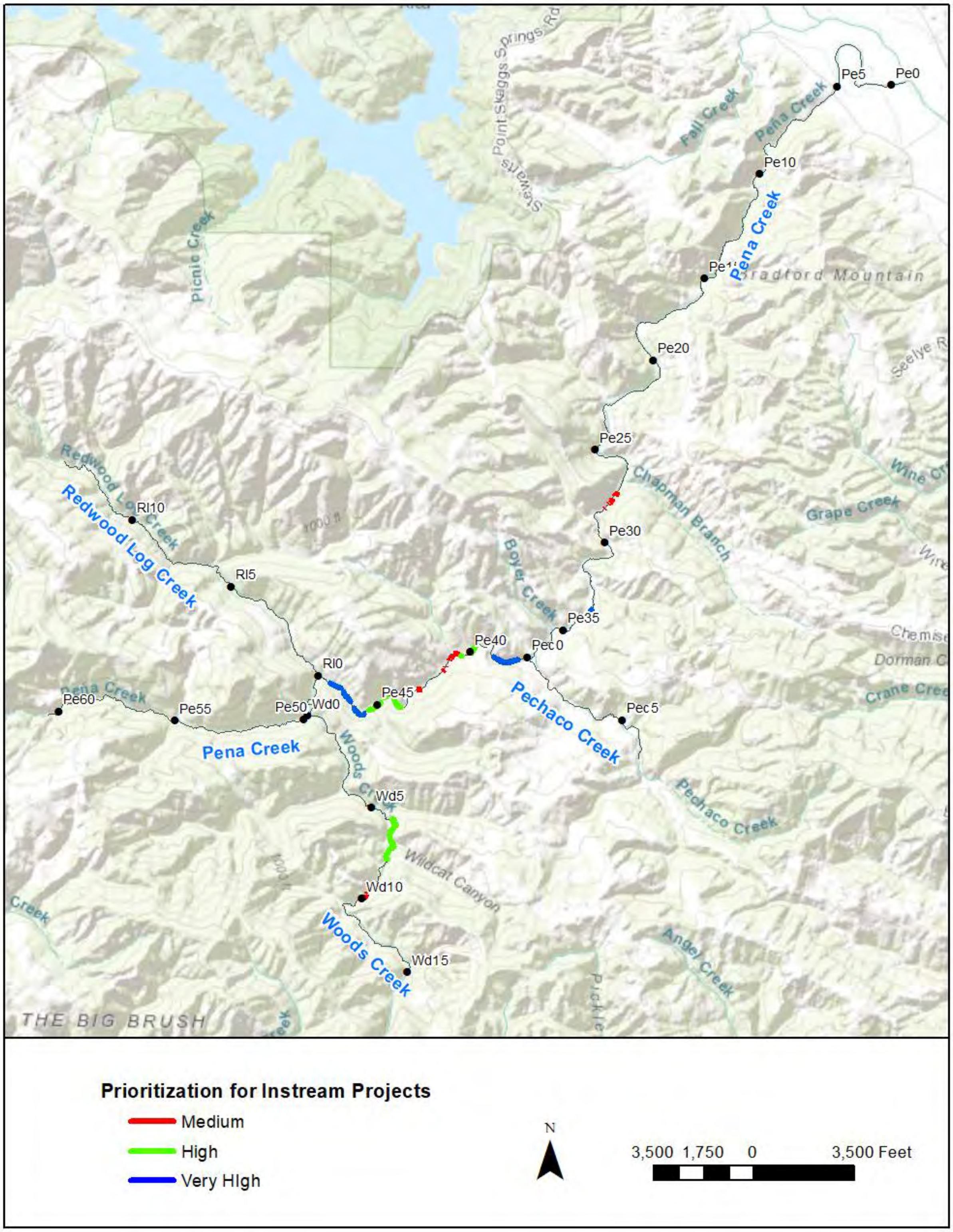


Figure 38: **Final adjusted prioritization for instream projects in the Pena Creek watershed** showing only the reaches with relatively good equipment access and presence of large diameter trees for anchoring sites.

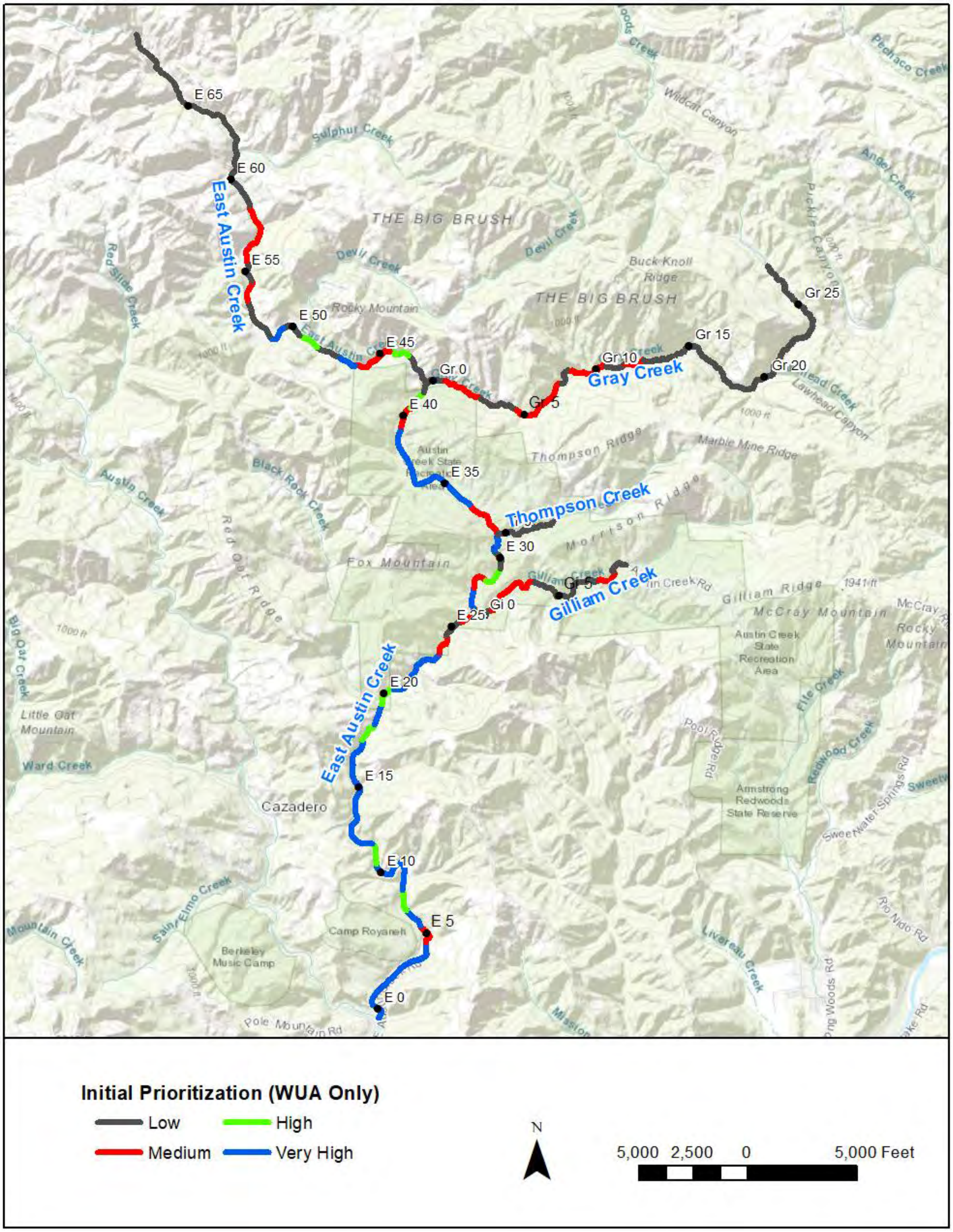


Figure 39: Initial prioritization for instream projects in the **East Austin Creek watershed** based only on the WUA.

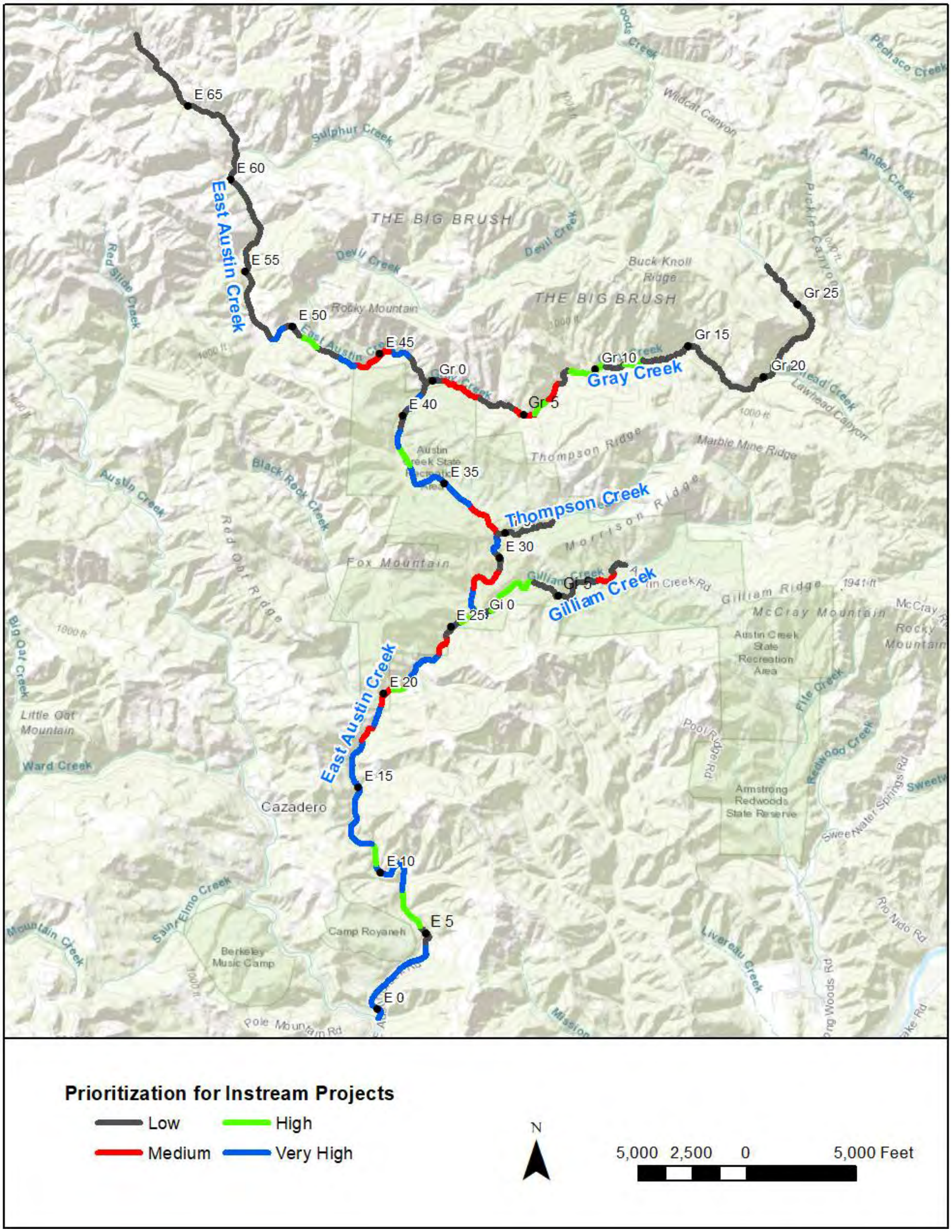


Figure 40: **<u>Adjusted prioritization for instream projects in the East Austin Creek watershed</u>** based on WUA and coho abundance.

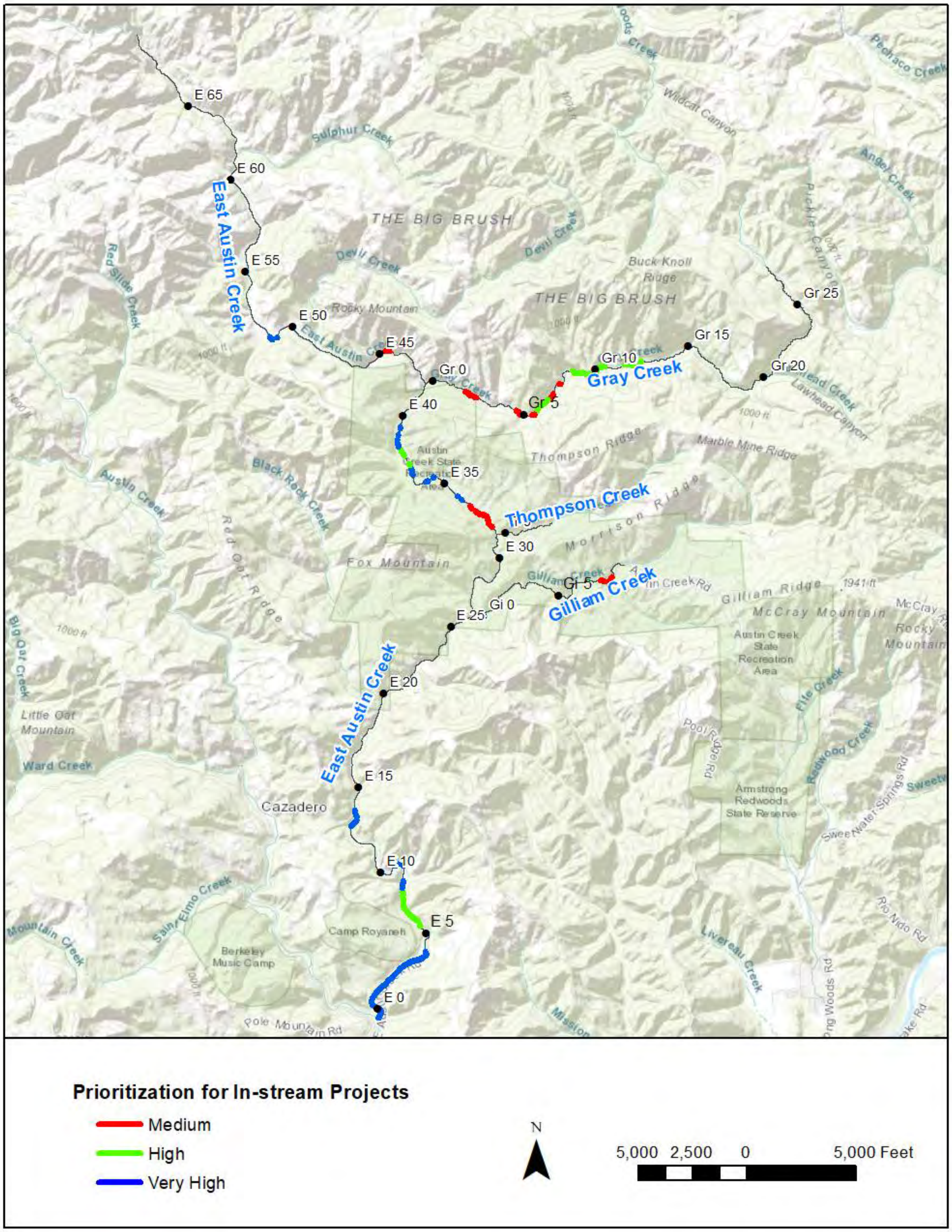


Figure 41: **Final adjusted prioritization for instream projects in the East Austin Creek watershed** showing only the reaches with relatively good equipment access and presence of large diameter trees for anchoring sites.

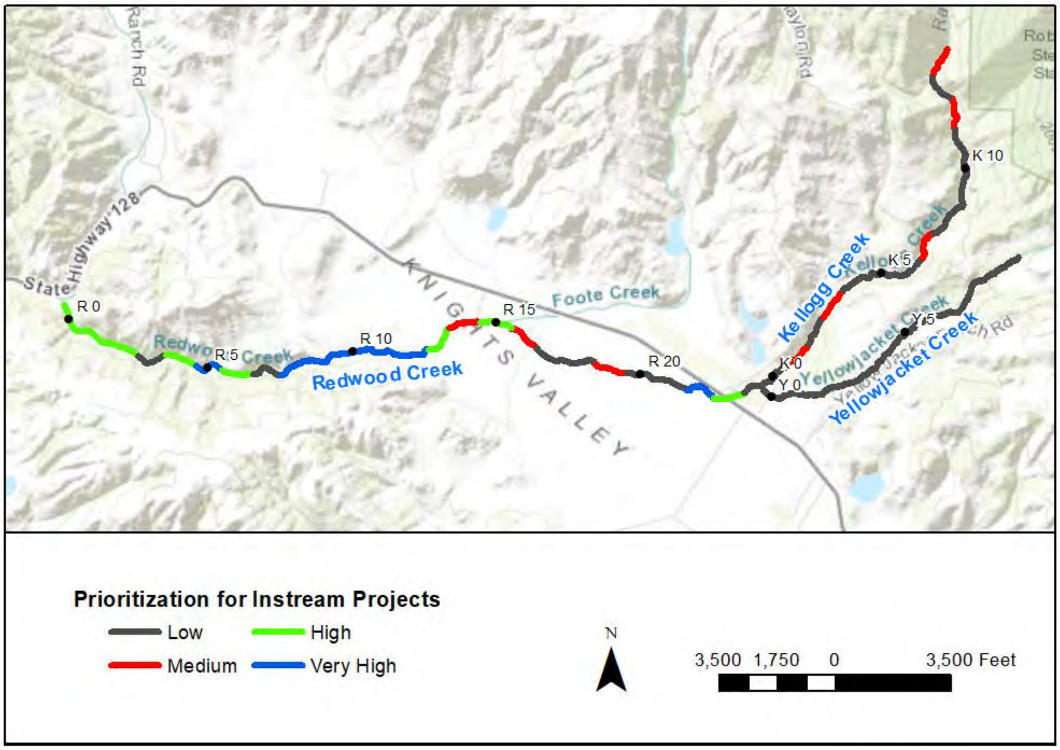


Figure 42: Prioritization for instream projects in the **Redwood Creek watershed** based on the WUA.

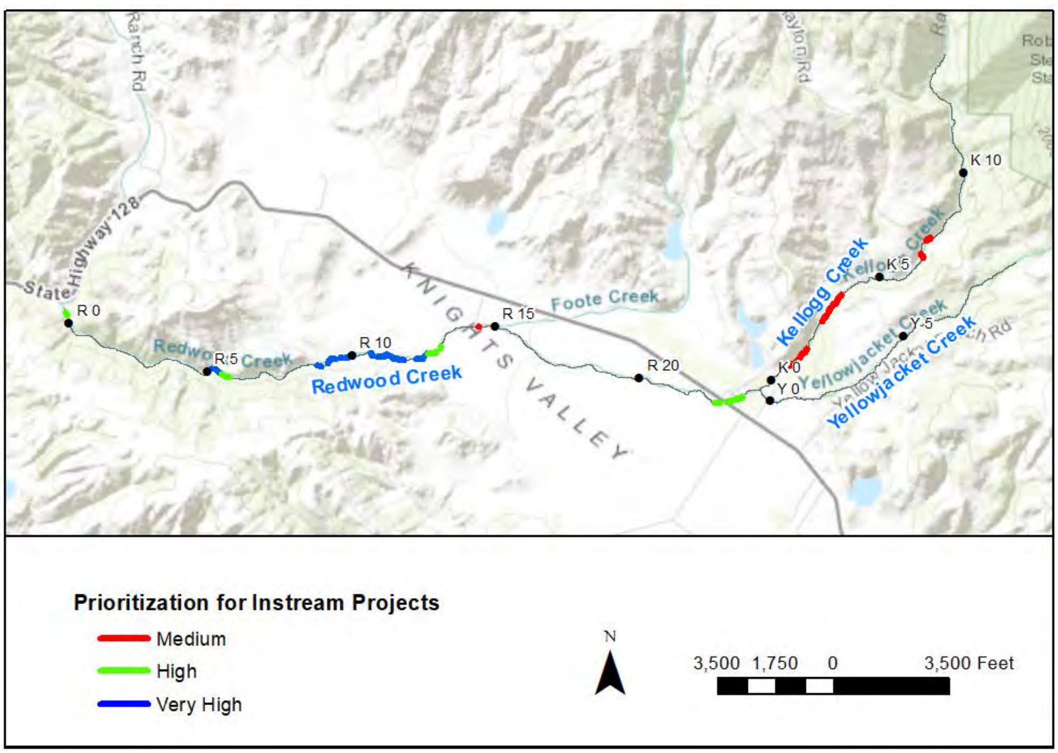


Figure 43: **Final prioritization for instream projects in the Redwood Creek watershed** showing only the reaches with relatively good equipment access and presence of large diameter trees for anchoring sites.

Chapter 6 - Off-channel Project Prioritization

Mill Creek

A total of 29 potential sites for off-channel habitat enhancement projects were identified in the Mill Creek watershed including 24 in Mill Creek, 4 in Palmer Creek, and 1 in Felta Creek (Figure 44 & Table 5). Thirteen of the 29 sites were classified as High Priority due to their proximity to high habitat value reaches and relative ease of equipment access, and 10 were classified as Very High Priority due to the factors above plus the significant scale of potential habitat enhancement work and/or location in the watershed relative to off-channel habitat needs and other habitat indicators.

The High and Very High priority sites are scattered throughout Mill Creek and Palmer Creek with a concentration of sites above and below the Wallace Creek confluence (Figure 44). The sites with the largest floodplains and longest side-channels are located in the reach between the Wallace Creek and Felta Creek confluences. These sites (M2, M4, M8, M9, M11) are classified as Very High Priority due to the larger scale of the potential habitat areas that could be created or enhanced. Although much smaller in scale the sites located in Palmer Creek and upper Mill Creek (P2, P3, P4, M23, M24) are also classified as High Priority due to the lack of existing off-channel habitat features, perennial flow conditions, and relatively high coho utilization characteristic of these reaches.

Pena Creek

A total of 23 potential sites for off-channel habitat enhancement projects were identified in the Pena Creek watershed all located on Pena Creek (Figure 45 & Table 5). Three of the 23 sites were classified as High Priority due to their proximity to high habitat value reaches and relative ease of equipment access, and 2 were classified as Very High Priority due to the factors above plus the significant scale of potential habitat enhancement work and/or location in the watershed relative to off-channel habitat needs and other habitat indicators.

The High and Very High priority sites are in a relatively short reach between the Pena Creek and Redwood Log Creek confluences (Figure 45). Many of the sites with the largest floodplains and longest side-channels are in reaches with difficult equipment access and/or in reaches several river miles downstream of high habitat value reaches with respect to other factors. Two sites (PN17, PN19) are classified as Very High Priority due to the larger scale of the potential habitat areas that could be created or enhanced.

<u>East Austin Creek</u>

A total of 23 potential sites for off-channel habitat enhancement projects were identified in the East Austin Creek watershed including 21 in East Austin Creek, and 2 in Gray Creek (Figure 46 & Table 6). Eight of the 23 sites were classified as High Priority due to their proximity to high habitat value reaches and relative ease of equipment access, and 5 were classified as Very High Priority due to the above factors plus the significant scale of potential habitat enhancement work and/or location in the watershed relative to off-channel habitat needs and other habitat indicators.

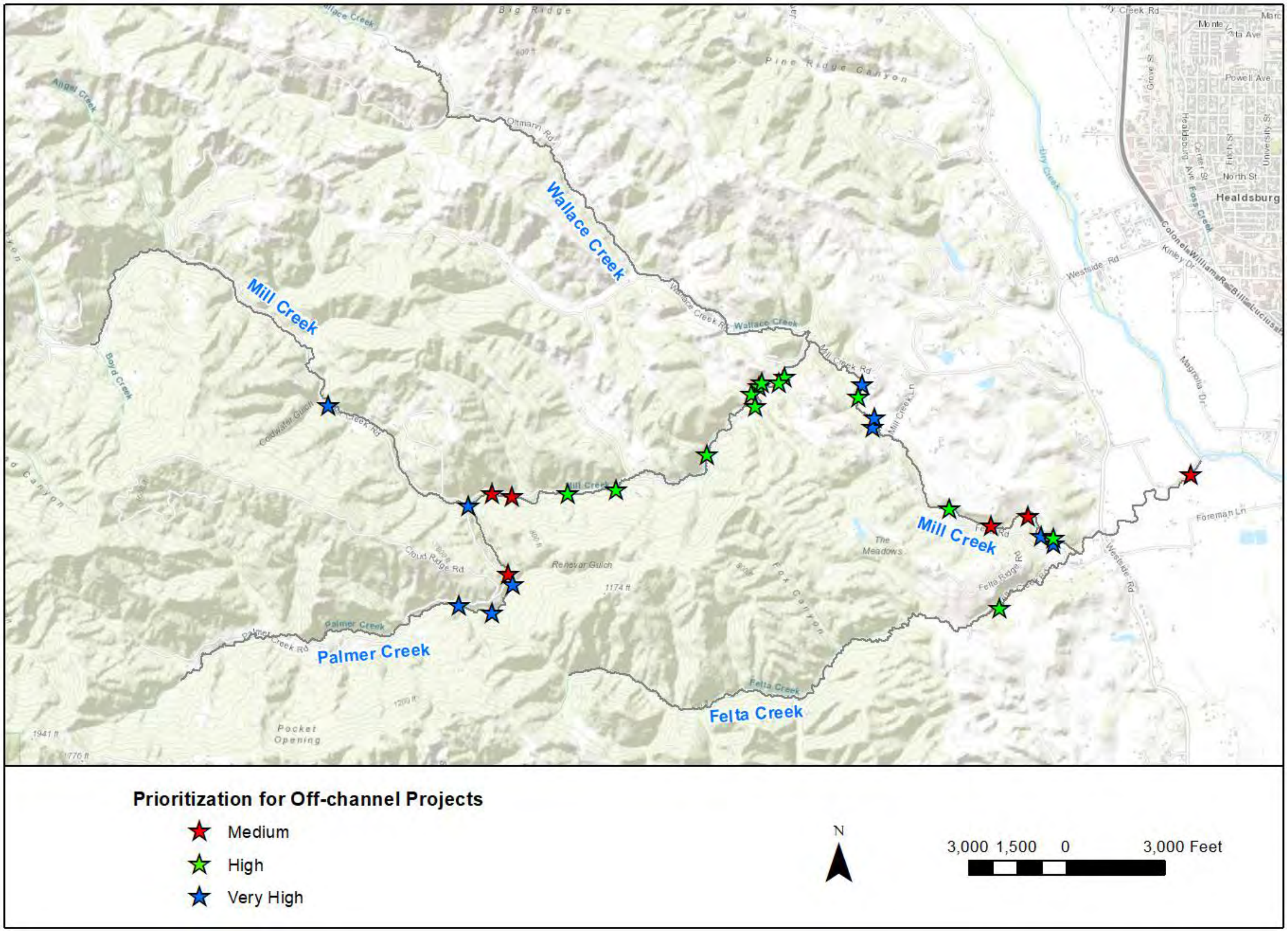


Figure 44: Locations and prioritization of potential sites identified for **off-channel habitat enhancement projects in the Mill Creek watershed**.

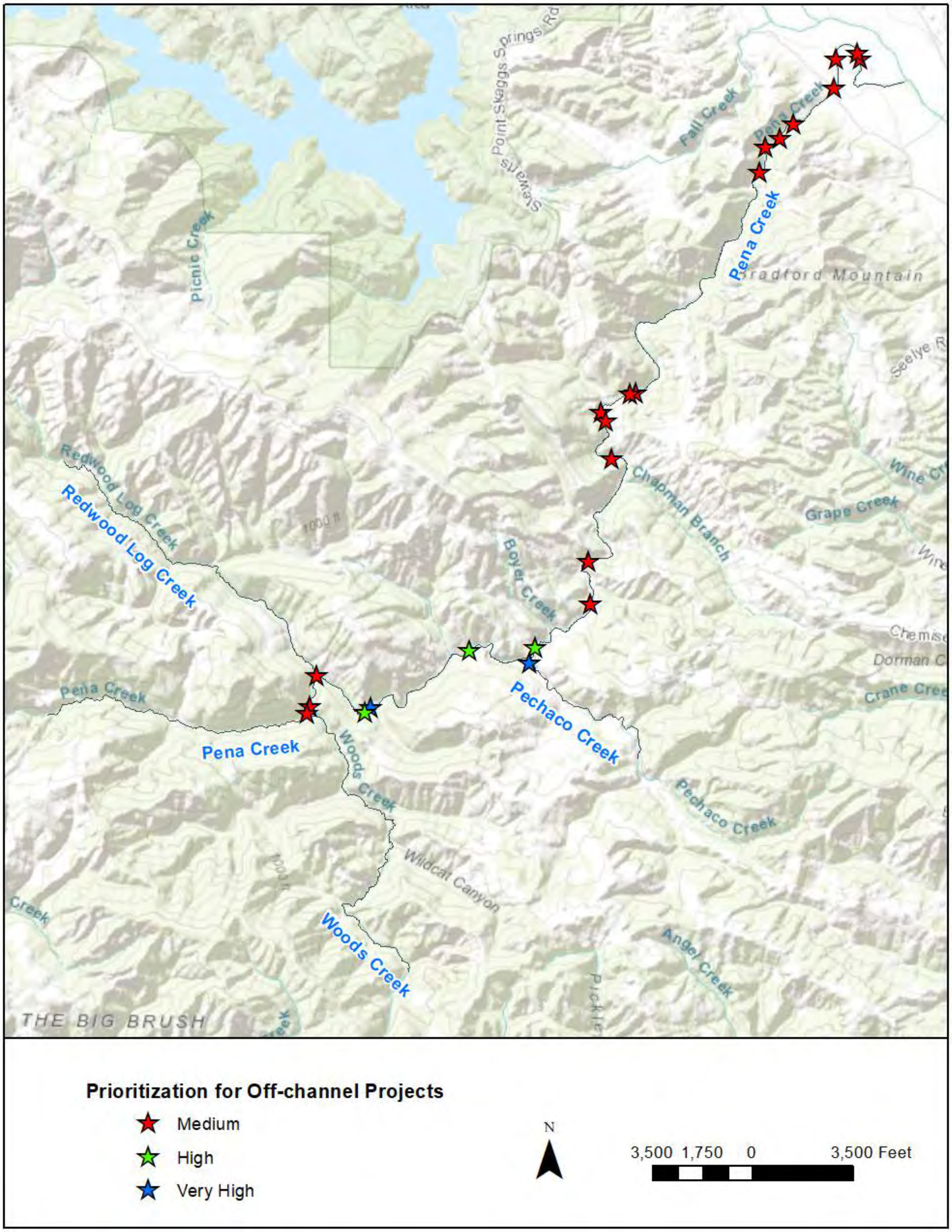


Figure 45: Locations and prioritization of potential sites identified for **<u>off-channel habitat enhancement projects in the Pena Creek watershed</u>**.

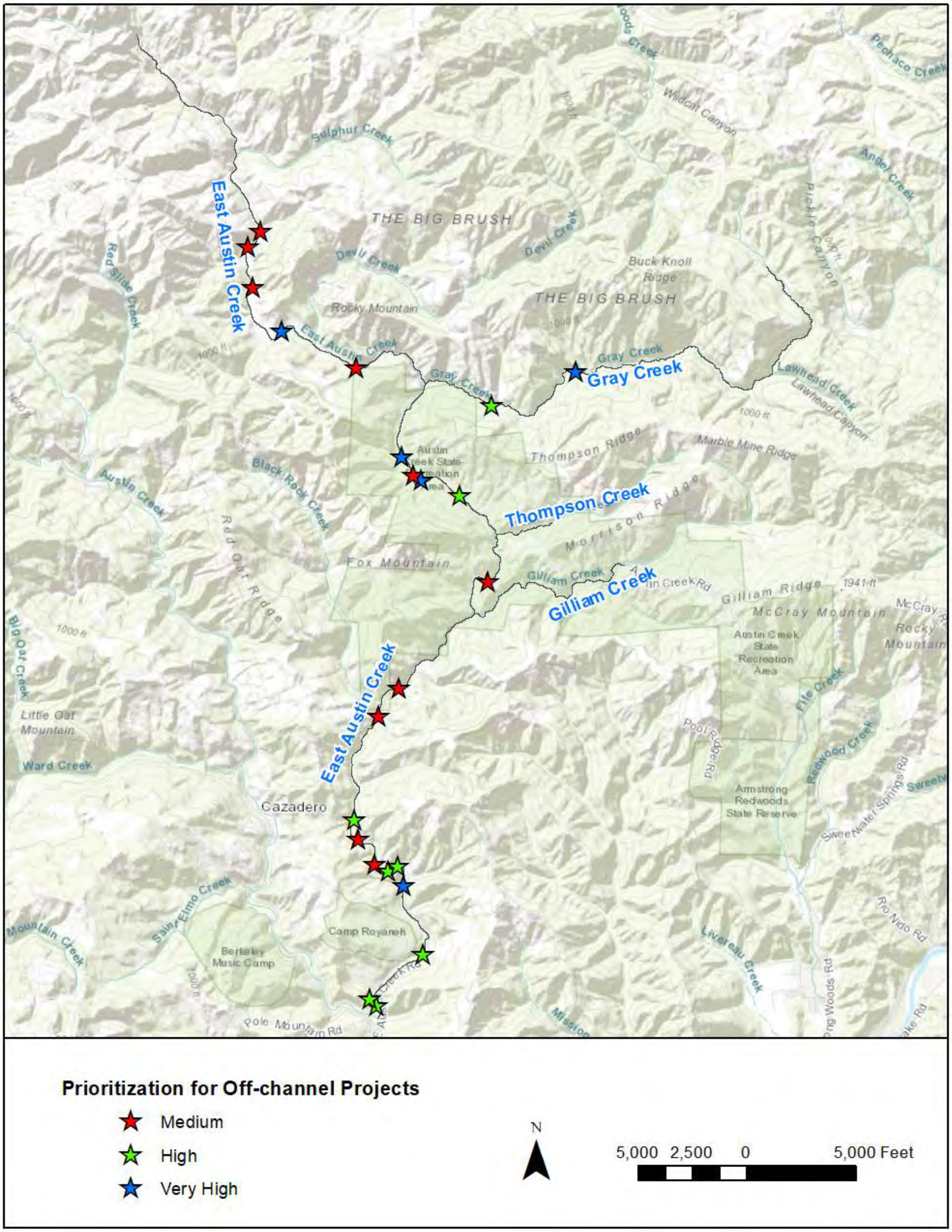


Figure 46: Locations and prioritization of potential sites identified for **off-channel habitat enhancement projects in the East Austin Creek watershed**.

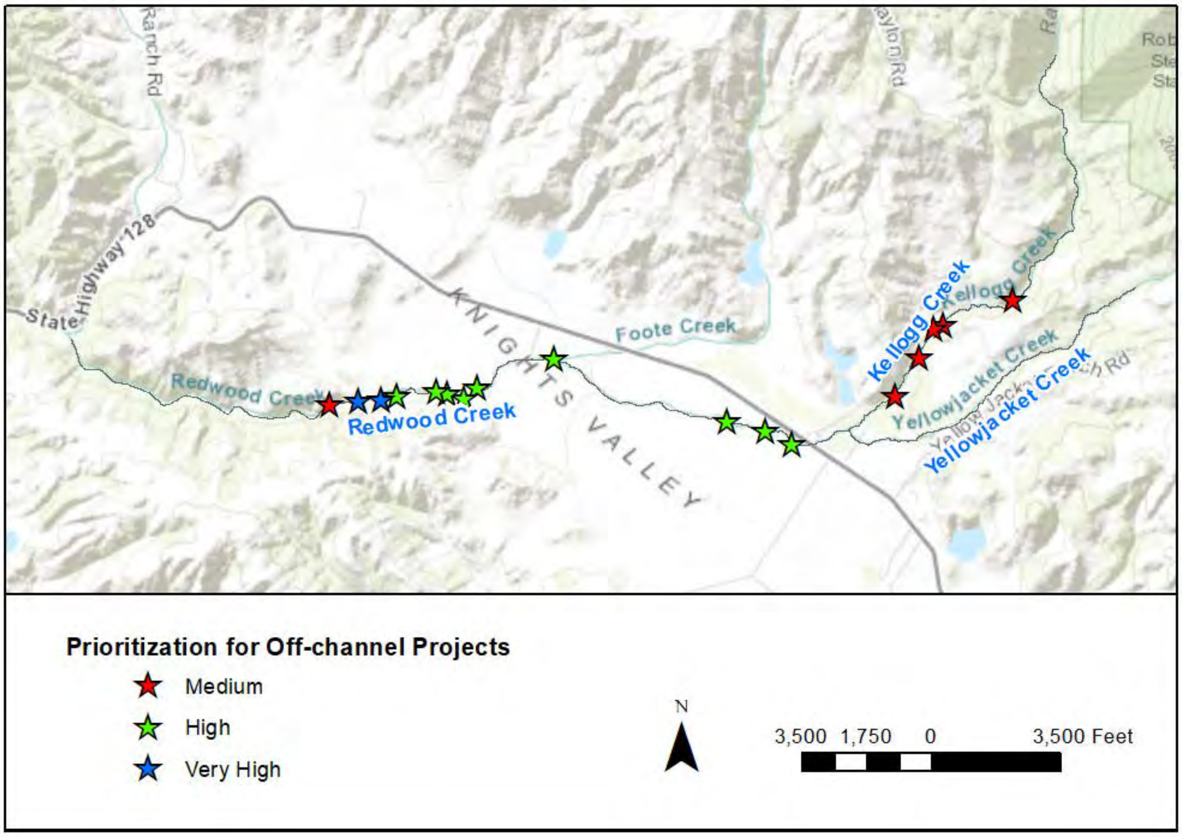


Figure 47: Locations and prioritization of potential sites identified for **off-channel habitat enhancement projects in the Redwood Creek watershed**.

The High and Very High priority sites are concentrated in the lowest 2.2 miles of East Austin Creek and in the reach between the Thompson Creek and Gray Creek confluences (Figure 46). Sites (EA4, EA14, EA16) are classified as Very High Priority due to the larger scale of the potential habitat areas that could be created or enhanced. Although much smaller in scale the site located in Gray Creek and upper East Austin Creek (GR2, EA18) are also classified as High Priority due to the lack of existing off-channel habitat features, and/or relatively high coho utilization characteristic of these reaches.

Redwood Creek

A total of 17 potential sites for off-channel habitat enhancement projects were identified in the Mill Creek watershed including 12 in Redwood Creek, and 5 in Kellogg Creek (Figure 47 & Table 6). Eleven of the 17 sites were classified as High Priority due to their proximity to high habitat value reaches and relative ease of equipment access, and 2 were classified as Very High Priority due to the factors above plus the scale of the potential habitat areas that could be created or enhanced. The High and Very High priority sites are scattered throughout Redwood Creek within Knights Valley (Figure 47). Sites (R2, R3) are classified as Very High Priority due to the larger scale of the potential habitat areas that could be created or enhanced.

Table 5: Overview of sites identified for potential off-channel habitat enhancement projects in the Mill Creek and Pena Creek watersheds. Highlighted sites indicate highest priority locations based on relatively good equipment access and proximity to high priority reaches identified as part of the instream project prioritization. Green indicates High Priority sites and Blue indicates Very High Priority sites.

ID	Type	Size	Access	Location
Mill Creek				
M1	Floodplain with alcove	0.5 acres	1	0
M2	Floodplain	2.0 acres	1	1
M3	Floodplain	1 acre	1	1
M4	Side-channel	320-ft	1	1
M5	Multi-thread Side-channel	590-ft	0	1
M6	Side-channel	120-ft	0	1
M7	Side-channel	130-ft	1	1
M8	Side-channel	530-ft	1	1
M9	Floodplain	1.4 acres	1	1
M10	Floodplain	0.3 acres	1	1
M11	Side-channel	200-ft	1	1
M12	Floodplain	0.9 acres	1	1
M13	Floodplain	0.5 acres	1	1
M14	Floodplain	0.5 acres	1	1
M15	Floodplain	0.7 acres	1	1
M16	Floodplain	0.5 acres	1	1
M17	Floodplain	0.3 acres	1	1
M18	Side-channel	130-ft	1	1
M19	Floodplain	0.2 acres	1	1
M20	Floodplain	0.2 acres	1	1
M21	Side-channel	160-ft	0	1
M22	Side-channel	100-ft	0	1
M23	Side-channel	150-ft	0	0
M24	Floodplain with alcove	0.1 acres	1	1
Palmer Creek				
P1	Floodplain	0.1 acres	0	1
P2	Floodplain	0.1 acres	1	1
P3	Floodplain	0.1 acres	1	1
P4	Floodplain	0.1 acres	1	1
Felta Creek				
F1	Side-channel	80-ft	1	1

ID	Type	Size	Access	Location
Pena Creek				
Pn1	Floodplain	1.1 acres	1	0
Pn2	Floodplain	1.2 acres	1	0
Pn3	Floodplain	0.6 acres	1	0
Pn4	Side-channel	270-ft	1	0
Pn5	Floodplain	2.4 acres	1	0
Pn6	Side-channel	240-ft	0	0
Pn7	Side-channel	230-ft	0	0
Pn8	Floodplain with alcove	0.8 acres	0	0
Pn9	Floodplain	0.6 acres	0	0
Pn10	Side-channel	130-ft	0	0
Pn11	Floodplain	1.0 acres	0	0
Pn12	Floodplain	2.1 acres	0	0
Pn13	Side-channel	380-ft	0	1
Pn14	Floodplain	0.7 acres	0	1
Pn15	Floodplain	0.6 acres	0	1
Pn16	Floodplain	0.9 acres	1	1
Pn17	Floodplain	6.0 acres	1	1
Pn18	Floodplain	1.4 acres	1	1
Pn19	Side-channel	240-ft	1	1
Pn20	Side-channel	150-ft	1	1
Pn21	Side-channel	60-ft	0	1
Pn22	Side-channel	120-ft	0	1
Pn23	SIde-channel	200-ft	0	1

Table 6: Overview of sites identified for potential **off-channel habitat enhancement projects in the East Austin Creek and Redwood Creek watersheds**. Highlighted sites indicate highest priority locations based on relatively good equipment access and proximity to high priority reaches identified as part of the instream project prioritization. Green indicates High Priority sites and Blue indicates Very High Priority sites

ID	Type	Size	Access	Location
East Austin Creek				
EA1	Floodplain	0.8 acres	1	1
EA2	Floodplain	0.8 acres	1	1
EA3	Side-channel	300-ft	1	1
EA4	Floodplain with alcove	3.7 acres	1	1
EA5	Floodplain	1.7 acres	1	1
EA6	Floodplain	1.6 acres	1	1
EA7	Side-channel	350-ft	0	1
EA8	Floodplain	3.4 acres	0	1
EA9	Floodplain	0.8 acres	1	1
EA10	Multi-thread Side-channel	830-ft	0	1
EA11	Floodplain with alcove	0.8 acres	0	1
EA12	Floodplain with alcove	0.7 acres	0	1
EA13	Floodplain with alcove	1.4 acres	1	1
EA14	Multi-thread Side-channel	1,160-ft	1	1
EA15	Floodplain with alcove	1.1 acres	0	0
EA16	Multi-thread Side-channel	870-ft	1	1
EA17	Multi-thread Side-channel	590-ft	0	1
EA18	Side-channel	330-ft	1	1
EA19	Side-channel	320-ft	1	0
EA20	Side-channel	330-ft	1	0
EA21	Side-channel	280-ft	1	0
Gray Creek				
Gr1	Side-channel	70-ft	1	1
GR2	Side-channel	220-ft	1	1

ID	Type	Size	Access	Location
Redwood Creek				
R1	Side-channel	380-ft	0	1
R2	Side-channel	420-ft	1	1
R3	Side-channel	550-ft	1	1
R4	Floodplain with alcove	1.2 acres	1	1
R5	Multi-thread Side-channel	230-ft	1	1
R6	Floodplain with alcove	1.7 acres	1	1
R7	Side-channel	280-ft	1	1
R8	Side-channel	300-ft	1	1
R9	Floodplain	1 acre	1	1
R10	Side-channel	220-ft	1	1
R11	Side-channel	280-ft	1	1
R12	Side-channel	270-ft	1	1
Kellogg Creek				
K1	Multi-thread Side-channel	2,000-ft	1	0
K2	Multi-thread Side-channel	1,310-ft	1	0
K3	Side-channel	200-ft	1	0
K4	Side-channel	520-ft	1	0
K5	Side-channel	410-ft	0	0

Chapter 7 – Basin Comparisons & Overall Restoration Considerations

A comparison of the density of existing habitat in each of the streams in the study is provided in Figure 48 & Table 7. Habitat density is expressed using the metric Weighted Useable Area per unit length of stream. Where available, a summary of the Sea Grant monitoring data is also provided. These comparisons provide a means of understanding the relative importance of each stream with respect to overall restoration priorities for coho salmon habitat.

There is substantial variation in the density of existing habitat among streams we analyzed. For example, East Austin Creek and Wallace Creek provide as much as six times the habitat density of other streams such as Thompson Creek and Yellowjacket Creek (Figure 48 & Table 7). In our opinion, based on the data evaluated in this study, the streams with the highest potential to support coho population are those with relatively high habitat densities, high coho utilization, and persistent late-summer flow conditions. These streams include Mill Creek, Palmer Creek, Woods Creek, and East Austin Creek. Several streams have relatively low habitat densities, very dry late summer conditions, and/or have relatively low coho utilization. Habitat enhancement work aimed at improving conditions for coho may not be warranted in these marginal streams such as Wallace Creek, Pechaco Creek, Thompson Creek, and Yellowjacket Creek.

Streams such as Gray Creek and Gilliam Creek have relatively high coho utilization and favorable late summer flow conditions but have relatively low habitat densities suggesting high potential for supporting coho populations if significant habitat enhancement work can be implemented to improve available winter rearing habitat. Other streams such as Pena Creek, Felta Creek, and Redwood Creek experience very dry late summer flow conditions and it is uncertain whether significant habitat enhancement work is warranted in these severely flow-limited streams given the low survival rates expected in these streams due to unfavorable summer flow conditions.

Table 7: Comparison of the density of available habitat area (expressed using the Weighted Useable Area averaged across the 4 simulated flow conditions) and Sea Grant monitoring data results for the 15 streams evaluated in this study.

Watershed	WUA (ac/mi)	% Connected Pools	Coho (#/mi)
Mill	0.74	83%	37
Wallace	0.98	0%	2
Felta	0.68	47%	26
Palmer	0.83	100%	19
Pena	0.90	14%	48
Pechaco	0.32	0%	1
Redwood Log	0.77	na	na
Woods	0.68	73%	141
East Austin	1.01	na	44
Gray	0.38	94%	90
Gilliam	0.45	100%	120
Thompson	0.17	na	2
Redwood	0.49	60%	4
Kellogg	0.38	na	na
Yellowjacket	0.18	na	na

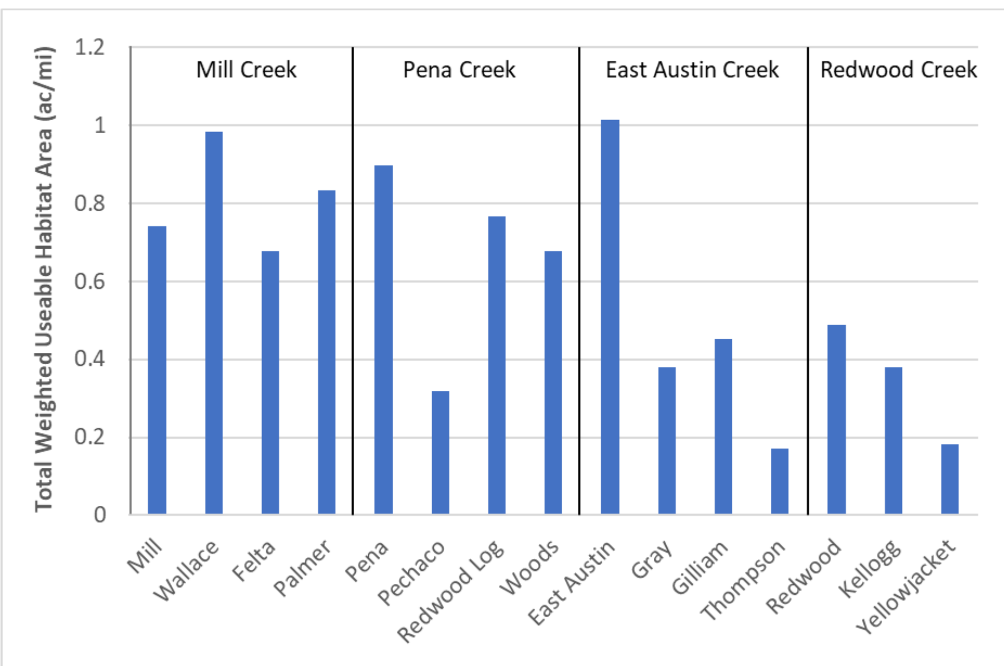


Figure 48: Comparison of the density of available habitat area (expressed using the Weighted Useable Area averaged across the 4 simulated flow conditions) for the 15 streams evaluated in this study.

Chapter 8 - Conceptual Design Development

Each of the 92 potential sites identified for off-channel habitat enhancement projects has been classified based on the existing geomorphic features derived from interpretation of 2013 LiDAR DEM data and hydraulic modeling results (Tables 5 & 6). These feature types suggest preliminary design objectives for the type of enhancement suitable for each site.

Enhancement projects at the sites classified as side-channels or multi-thread side-channels may involve sediment removal to activate existing side-channels at lower flows and increase the frequency with which these features provide habitat. For multi-thread side-channels, the various channels could be graded to increase the frequency and extent of inundation by low-velocity flow, thus providing habitat value over a wider range of flow conditions. Other potential actions may include installation of large wood structures to provide cover, to slow velocities in side-channels, and/or grading and re-vegetation to improve stability of existing low capacity channels with limited separation from the main-channel.

Enhancement projects at the sites classified as floodplains or floodplains with alcoves may involve sediment removal to enhance existing alcoves and/or develop new alcoves or side-channels in floodplains lacking these features under existing conditions. Other potential actions may include installation of large wood structures to provide cover and slow velocities in created side-channels, and/or re-vegetation to create shade and complexity.

Seven concept designs for habitat enhancement have been developed for three stream reaches of about one-half mile in length in East Austin Creek, Redwood Creek and Mill Creek. We were unable to obtain access to private property to develop concept designs in Pena Creek. The concept design plan sheets are included with this document as Appendix A. These conceptual habitat enhancement design plans demonstrate the utility of habitat prioritization and demonstrate specific project design elements for enhancement of coho rearing habitat.

Each of the three design reaches include both off-channel habitat enhancement that is expected to function primarily as winter rearing habitat, and instream LWD structures distributed through project reaches that is expected to function both as winter and summer rearing habitat. Off-channel habitat enhancement concept designs are more specific than those for LWD structures. Field reconnaissance of design reaches focused on evaluating the feasibility of access for heavy equipment for excavation of off-channel habitat and placement of LWD structures. Field reconnaissance confirmed that suitable riparian trees were present and channel bank conditions were favorable for stable placement of LWD with relatively modest anchoring using techniques described below. Subsequent design work is needed to locate and design individual LWD habitat enhancement structures.

An overview of the seven designs, estimated number of logs, estimated cut and fill volumes, and estimated quantity of improved habitat are provided in Table 8. General design guidance for installation of LWD structures using "soft engineering" approaches to install structures that are low cost, stable, and effective is provided below, followed by a discussion of the three project design reaches and the major elements of each of the seven conceptual designs.

Table 8: Overview of the conceptual habitat enhancement designs developed in East Austin, Redwood, and Mill Creeks.

Site ID	Design Components	Length of Channel Improved (ft)	Length of Side Channel Enhanced (ft)	Area of Alcove Enhanced/ Created (ft^2)	Length of Bank Stabilized (ft)	Pieces of LWD Placed	Approx. Cut Volume (cy)	Approx. Fill Volume (cy)
EA 14	- Enhance existing alcove - Increase separation of side channel by raising gravel bar - Place LWD	600	450	1,600	-	9+	200	440
EA 16	- Enhance existing slough - Place LWD	700	500	-	-	27+	240	0
R3	- Enhance two existing alcoves - Place LWD	900	-	6,000	-	48+	820	70
R4	- Stabilize collapsed bank - Place LWD	900	100+	-	300	22+	900	0
M1	- Enhance existing side channel and gravel bar	250	80	750	-	15+	40	40
M3	- Create alcove - Place LWD	850	-	1,000	-	24+	250	0
M3B	- Enhance existing side channel - Place LWD	400	50	-	-	16+	130	130

General LWD Structure Design Guidance

For this conceptual design phase, LWD structure locations have been approximately determined and general anchoring strategies have been developed. LWD (large woody debris) may alternatively be referred to as LWM (large woody material) with no change in meaning. During subsequent design phases, detailed LWD placement designs and anchoring strategies should be developed and tailored to specific conditions at each location. Design flow depths at each site for large magnitude floods (e.g. the 100-year flood) should be considered in the evaluation of stability of placed LWD. LWD structures should be designed to have multiple stabilizing features including wedging among riparian trees in an orientation that resists flotation and transport, and connecting placed logs to one another in complex structures with some rigidity. Structures should generally also include one or two boulders to provide ballast against buoyancy and drag forces; the use of boulder ballast is necessary because opportunities to wedge placed logs in highly stable locations among riparian trees are limited in the project reaches.

Sites for LWD placement were selected based on accessibility from existing roads on one or both banks. Sites where dense and desirable riparian vegetation would be excessively disturbed by installation were avoided. Some degree of disturbance is considered unavoidable, and the combined use of heavy equipment (restricted to the adjacent roads and top of bank) and skilled labor crews is intended to minimize overall disturbance. Some sites have existing deep pools with insufficient cover, while others have potential for development of deeper scour pools owing to a stable bank (typically bedrock) and mobile bed material on the bed at least 2 ft thick.

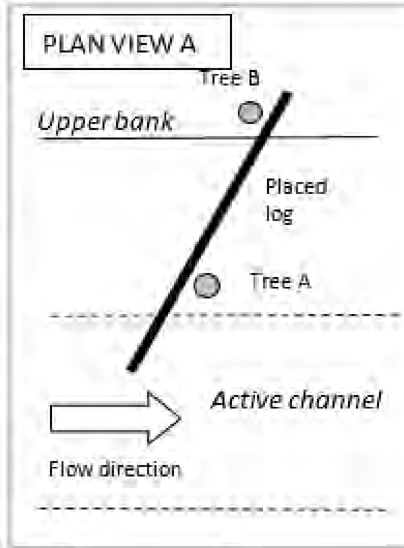
Stability of placed logs must be reasonably ensured so that the expected habitat enhancements will be effective for a significant period of time and to limit risk to downstream infrastructure from transport of logs and potential formation of debris jams. A variety of factors affect stability of placed wood (NRCS, 2007); foremost among these is buoyancy. For this conceptual design phase, we have located structures such that the upper ends of the logs can be placed above the bankfull (1.5-yr) water surface elevation at minimum and above the 10-yr flood water surface elevation in many locations. As described in greater detail in Chapter 2, we examined canopy height data near the top of banks from the Sonoma County Vegetation Mapping and LiDAR Program and located structures where canopy heights exceeded 50-ft indicating the presence of large-diameter trees rooted above the frequently active channel and suitable for providing stable anchor points. Field reconnaissance suggests suitable diameter trees may be found where canopy height is less than 50-ft.

As part of a subsequent design phase, log stability should be evaluated at each proposed placement site with respect to buoyancy of placed logs. Log stability in relation to estimated drag force on wood structures may need to be considered at some sites where risk to downstream infrastructure is greater (e.g. Mill Creek). Based on this assessment, specific stabilization techniques expected to be sufficient to prevent significant downstream transport of placed logs for design flows equivalent to stream discharge during a 100-year recurrence interval flow event can be developed for each location. Some movement of log structures is considered acceptable and/or unavoidable; the emphasis of the design should be to prevent significant downstream transport of floating logs. General design strategies for stable log placement are described below.

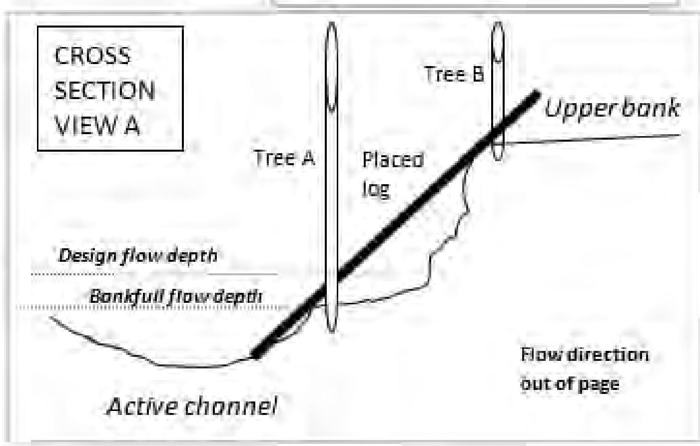
One of the primary design elements promoting log stability is connecting logs at points of contact with other logs with a length of 3/4 to 1-inch diameter threaded steel rebar driven through both logs and secured by nuts and plates (and not generally anchored to the bed). In general, these "ties" are used in combinations of two (preferably three) crossing logs with ties to form a semi-rigid "vee" or triangle. Alternatively, ties between two logs located high on the bank above a large riparian tree with additional log ties lower on the bank ("A" shape) or strings of connected logs arrayed on the banks and entangled with riparian tree stems in shapes of "W" or "M" will create sufficient rigidity or resistance to movement. Wedging logs among riparian trees can create another form of stability element to the structure; ideally, a log angled upstream subjected to the force of flowing water would be restrained from rotation by the trunks of riparian trees. Logs anchored to boulders for ballast can be added as well.

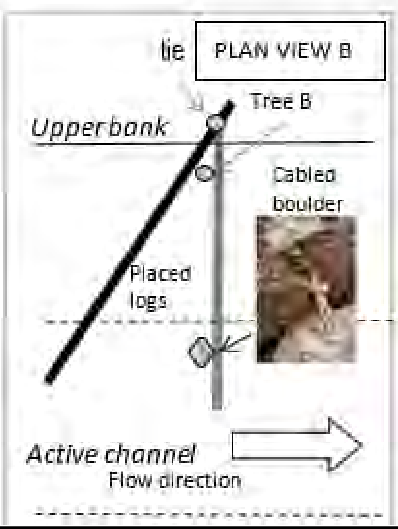
Each structure should be designed to have at least three such "stability elements", generally including one ballast boulder. Logs connected together in this manner that become mobile during a flood event would have limited potential for downstream transport owing to the combined effects of the geometry of rigid structures, boulder ballast, and being "hooked" on or entangled among riparian trees. The following schematic provides additional installation criteria that will promote stability of placed logs at the project sites. Not all of these criteria are expected to be satisfied at each location.

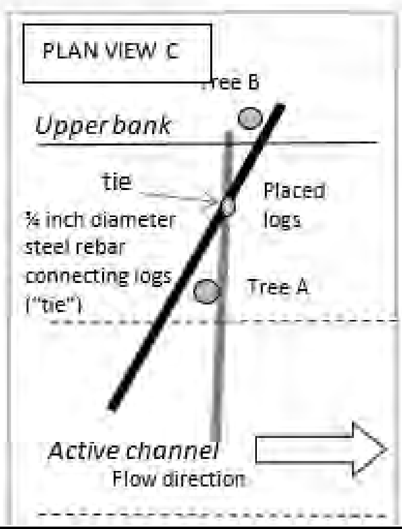
- Orientation of logs at oblique angles to flow, preferably pointed upstream
- Placement of logs wedged against stable trees on the stream bank in a manner that will inhibit rotation of logs if buoyancy and drag force affects the stream end of the log. The ideal arrangement is shown in the diagrams Plan View A and Cross Section View A. Bracing against a tree on the downstream side of the log somewhere in the middle portion of the log length (Tree A) is desirable. A more stable arrangement is created by bracing the log against an upstream tree higher on the bank (Tree B).



- Weighting stream end of placed log with a placed boulder with epoxied cable loop attached to log by rebar with shackle (see diagram below).
- Alternative arrangements of logs attached to one-another ("ties") using riparian trees to "hook" placed logs are shown in Plan View B and Plan View C.







East Austin Creek Conceptual Design

EA14 Existing Conditions

Site EA14 is located within the Austin Creek State Recreation Area on the mainstem of East Austin Creek between the confluences with Gray and Gilliam Creeks (Appendix A). This site was selected because it includes the longest frequently activated side-channel complex identified in any of the four study watersheds. This feature provides some habitat value in its existing configuration but there is potential for significantly increasing the quantity and quality of the available habitat. The site is also desirable because it is located immediately downstream of a reach with a high number of observed coho (reach EA37).

The primary side-channel at Site EA14 runs along the north side of the creek for approximately 960 feet. This side-channel is separated from the main channel by a series of gravel bars. In the upstream and downstream portions of the side-channel, it flows across shallow, unvegetated bars and has less than 2-feet of vertical separation from the thalweg of the main channel. In the middle section where it flows around a taller gravel bar with established deciduous trees, vertical separation increases to 3 to 4-feet. There is also a secondary side-channel which connects from the main channel into the primary side-channel through the downstream gravel bar.

During winter baseflow, flow is confined to the main channel and habitat is available in velocity-sheltered areas such as the left bank (Figure 49). Habitat is also available in a large (at least six-foot deep) pool at the upstream-end of the site. The secondary side-channel activates during the 10-percent exceedance flow, providing lower-velocity habitat as the main channel becomes unsuitable due to elevated velocities (Figure 50). At bankfull flow, the primary side-channel is activated and the gravel bars at its upstream and downstream ends are completely inundated. Velocities on these bars, in the main channel, and the lower secondary side-channel are unsuitable, but habitat is present in velocity-sheltered areas of the primary side-channel. An alcove at the upstream end of the highest gravel bar near the middle of the side-channel also provides significant habitat value, as does the area near this bar’s downstream end (Figure 51). During the 10-year flood, suitable habitat is only found along the margins of the channels where velocities are lowest (Figure 52).

EA14 Proposed Design

To enhance the habitat suitability of these existing side-channel features it is desirable to increase the frequency of inundation and persistence of low-velocity conditions. The existing alcove can be excavated to increase its frequency of inundation. The base of this alcove would need to be excavated by approximately two feet to activate it during the 10-percent exceedance flow. The excavated sediment from the alcove will be placed on top of the existing gravel bar defining the secondary side-channel and the downstream end of the primary side-channel. Raising this bar will maintain separation from the main channel and lower velocities in the main side-channel during higher flow events. Approximately two feet of fill is required to raise the top of this bar above the bankfull flow. Log structures will be placed in the main side-channel both to further reduce velocities and to increase habitat complexity (Appendix A).

These improvements will enhance approximately 450 feet of side channel and approximately 1,600 ft^2 feet of alcove habitat. Locations for three log structures, each containing at least three pieces of LWD have been identified. Depending on anchoring sites and equipment access, there may be suitable locations for several additional structures at this site. Raising the gravel bar will require 440 cubic yards of fill and excavation of the existing alcove will require 200 cubic yards of cut. The balance of the fill needed for the gravel bar will be obtained from cut generated at Site EA16.

EA16 Existing Conditions

Site EA16 is located within the Austin Creek State Recreation Area on the mainstem of East Austin Creek between the confluences with Gray and Gilliam Creeks (Appendix A). This site was selected because it includes a long side-channel feature and because it is in a reach with a high number of observed coho (Reach EA38). The existing side-channel currently provides suitable habitat but intermittently disconnects from the main-stem posing a risk of fish stranding. Improvements to the side-channel may reduce the risk of fish-stranding and provide high-quality habitat across a broad range of flows.

The primary side-channel at Site EA16 runs along the west side of the creek for more than 800 feet and is separated from the main channel by a large gravel bar. The uppermost portion of the side-channel is formed by a slough that is likely the remains of an abandoned mill race. This slough connects to the main channel upstream of a riffle crest. Where it connects to the main channel, the invert of this slough is less than one foot above the water surface associated with winter baseflow. This slough continues for approximately 575 feet until it is intersected by an unnamed tributary. The tributary crosses the slough and connects directly to the main channel. Below the tributary, the side-channel has more natural geomorphic conditions and reconnects to the main channel at the downstream end of the gravel bar. Vertical separation from the thalweg of the main channel varies greatly along the length of the side-channel. Separation increases from less than one foot above the riffle crest to approximately four feet near the unnamed tributary. Vertical separation may be greater further downstream of this tributary. There is also a well-established gallery forest along the main channel.

During bankfull flows and above, the bar separating the side-channel from the main channel is inundated and the side-channel is fully connected to the main channel. Modeling shows that during these high flow events, the side-channel provides the most suitable habitat within this reach (Figures 55 and 56). As flows decrease, connectivity between the side-channel and the main channel also decreases, with the side-channel becoming fully disconnected at winter baseflow (Figures 53 and 54). Pools persists in the side-channel even when disconnected but they possibly dry out, posing a stranding hazard. During a site visit performed by OEI staff on February 8th, 2018 at winter baseflow, a series of interconnected pools was observed throughout this side-channel. These pools are recharged by lateral inflows from the right bank and from discharge from the unnamed tributary which is active at winter baseflow. These side-channel flows do connect back to the main channel farther downstream, however water depths during winter baseflow are too shallow to allow for fish passage.

EA16 Proposed Design

The existing configuration provides suitable habitat at higher flows but may strand fish at lower flows. The frequency and persistence of flows in the side-channel may be increased by excavating the existing slough. The invert of the upstream end of the slough will be lowered to increase how frequently it is activated. Less than one foot of sediment removal will activate the slough at winter baseflow. Flow persistence may be enhanced by lowering the slough elevation. This may increase lateral inflow from the right bank and decrease lateral outflows into the main channel, improving habitat quality at lower flows. The risk of stranding may be further decreased by connecting the bottom of the side-channel to the main channel with a series of step-pools. Excavated sediment will be placed on the enhanced bar in Site EA14 which is located approximately 1,400 feet downstream. Log structures will be placed in the slough both to further reduce velocities and to increase habitat complexity. Log structures will also be placed in the main channel and anchored to trees in the existing gallery forest (Appendix A).

These improvements will enhance approximately 500 feet of side channel habitat. Locations for four log structures have been identified in the slough and locations for five log structures, each containing at least three pieces of LWD, have been identified in the main channel. Depending on anchoring sites and equipment access, there may be suitable locations for several more structures, both within the slough and in the main channel. Improvements to the side channel will generate approximately 240 cubic yards of fill which will be used to raise the gravel bar at Site EA14.

Redwood Creek Conceptual Design

R3 Existing Conditions

Site R3 is located along the mainstem of Redwood Creek, just upstream of where it exits Knights Valley and flows into a confined canyon en route to its confluence with Maacama Creek (Appendix A). Site R3 was selected because it includes some of the largest active floodplains along Redwood Creek. Fish counts and wet/dry mapping are not available for the majority of Redwood Creek. However, this site's location at the downstream end of an alluvial valley and the presence of observed springs indicates that it may stay wet for longer than other floodplain sites along Redwood Creek. Furthermore, frequent bedrock outcrops in the channel bed indicate that the thickness of alluvium is limited such that the water table cannot drop far below the channel bed.

Site R3 includes approximately 900 feet of channel and approximately 1.7 acres of floodplain. This floodplain is formed by alluvial deposits immediately upstream of a bedrock constriction in the channel. There are multiple side-channel threads on top of this floodplain, typically ending in alcoves. At the upstream end of the floodplain, there is approximately five feet of vertical separation between these side-channels and the thalweg of the main channel. At the downstream end, vertical separation increases to up to eight feet. The base of the existing alcove features typically have two to four feet of vertical separation from the main channel. During a site visit conducted by OEI staff on March 30th, 2018, a spring was observed flowing out of the toe of the gravel bar and into the downstream-most alcove.

Flows are very shallow during winter baseflow and habitat is found primarily in pools within the main channel (Figure 57) which are not explicitly included in the hydraulic model and habitat suitability analysis. During the 10-percent exceedance flow, velocities in the main channel become unsuitably high but none of the alcoves or the floodplain are activated. Suitable habitat is at a minimum at these flows (Figure 58). At bankfull flows, the alcoves and a small portions of the floodplain are activated; these provide low-velocity habitat of suitable depth (Figure 59). During the 10-year flood, the entire floodplain becomes active. Velocities are too high in the main channel and the alcoves but are suitable in the floodplain periphery and in a small side-channel located immediately downstream of the floodplain (Figure 60).

R3 Proposed Design

To enhance the habitat suitability of these existing side-channel features it is desirable to increase the frequency of inundation and persistence of low-velocity conditions, particularly at intermediate flows such as the 10-percent exceedance flow. This may be accomplished by excavating two of the existing alcoves in the floodplain. Approximately two to three feet of excavation is required to activate these alcoves during the 10-percent exceedance flows. These alcoves will function as low-velocity backwater habitats and will be graded to provide a range of depths and to promote fish passage to/from the main channel. Because these alcoves have the potential to fill in during the highest flow events, such as the 10-year flood, small areas of fill will be placed at the heads of these alcoves to direct sediment-laden flows around them.

Log structures will be placed throughout the project site. Small structures will be placed in the alcoves to provide vertical cover and shade. Larger structures will be placed in the main channel to reduce velocities and to create scour pools; these scour pools will increase available habitat at winter baseflow. Carefully located log structures will also be placed just upstream of the alcove entrances to promote scour and reduce the likelihood of the alcove mouths closing off due to sediment deposition (Appendix A).

These improvements will enhance habitat along approximately 900 feet of channel and enhance approximately 6,000 ft^2 of alcove habitat. Locations for nine log structures, each containing at least three pieces of LWD have been identified in the main channel. Depending on anchoring sites and equipment access, there may be suitable locations for several more structures at this site. Enhancements to the existing alcoves will generate 820 cubic yards of fill. Approximately 70 cubic yards of this will be placed at the alcove heads. The remainder will be spread on the open fields north of the creek and stabilized in accordance with regional erosion control BMPs.

R4 Existing Conditions

Site R4 is located on the same parcel as Site R3 and may easily be improved at the same time. This site also includes a large, 8 – 10-foot tall, approximately 300-foot long bank that recently collapsed. Stabilization of the bank will eliminate a substantial source of fine sediment and provide the opportunity to create more complex habitat.

This site consists of an approximately 500-foot long straight section of channel downstream of an approximately 300-foot long sharp bend. The substrate within the straight section of channel is predominately sand and gravel. The recent bank retreat occurred in the winter of 2016/17 along the right bank of the channel bend and it resulted in a new channel alignment approximately 75 feet north of the previous alignment. The previous alignment now functions as an alcove at low flows and as a side-channel at higher flows and is separated from the new alignment by a small gravel bar. Upstream of the collapsed bank there is a riffle crest and a large, deep pool. The right bank of the channel also features an approximately 1.1-acre floodplain. The vertical separation between this floodplain and the thalweg of the main channel is approximately 6 feet.

Habitat availability at Site R4 is similar to that at Site R3. During winter baseflow, velocities are low but flows are unsuitably shallow throughout much of the site. Habitat is found primarily in pools such as the one located upstream of the collapsed bank (Figure 61). At the 10-percent exceedance flow, velocities in the main channel become unsuitable but off-channel features are not activated (Figure 62). Suitable habitat is at a minimum at these two flows. During bankfull flow, several off-channel features become activated and during the 10-year flood large portions of the floodplain are activated (Figures 61 – 64).

The hydraulic modeling and habitat suitability analysis performed as part of this study are based on LiDAR data collected in 2013. This data does not reflect the bank collapse which took place in the Winter of 2016/2017. As such, these analyses and Figures 61 - 64 do not reflect habitat conditions following this bank collapse. Based on observations made by OEI staff on March 30th, 2018 the alcove formed by the previous channel alignment is believed to provide habitat during intermediate flows such as the 10-percent exceedance flows.

<u>R4 Proposed Design</u>

Habitat at Site R4 will be enhanced by stabilizing the collapsed bank and placing log structures. The bank will be stabilized by laying it back at a 2H:1V grade and stabilizing it with riparian vegetation. The grade needs to be extended up 8 to 10 feet to meet the existing ground surface. Deflector logs will also be used to direct flows away from the bank and towards the center of the channel. Fill can be spread on the open fields north of the creek and stabilized in accordance with applicable erosion control BMPs

Log structures will be placed throughout the project site. Structures will be placed in the main channel to reduce velocities and to create scour pools; these scour pools will increase available habitat at winter baseflow. Structures will also be placed in the old channel alignment to reduce velocities and increase habitat complexity (Appendix A).

Locations for seven log structures, each containing at least three pieces of LWD have been identified. Depending on anchoring sites and equipment access, there may be suitable locations for several more structures at this site. Laying back the collapsed bank will generate 900 cubic yards of fill. This may be spread on the open fields north of the creek and stabilized in accordance with applicable erosion control BMPs. At least six deflector logs will be placed on the graded bank. These improvements will enhance habitat along approximately 900-feet of channel and stabilize approximately 300-feet of collapsed bank.

Mill Creek Conceptual Design

M1 Existing Conditions

Site M1 is located on the mainstem of Mill Creek, at and immediately downstream of the confluence with Palmer Creek (Appendix A). This site was selected because it contains floodplain and alcove features that can be enhanced to provide habitat across a broad range of flows. The site is also located in a reach with pools that generally remain connected by surface flows but which have little to no LWD, making them particularly suitable for enhancement.

The channel at Site M1 makes two right angle bends around an approximately 4,500 ft^2 gravel bar with two shallow side-channels. These two side-channels connect into the main-stem downstream of the two bends. There is approximately two feet of vertical separation between the top of this bar and the thalweg of the main channel, and there is between one and one and a half feet of vertical separation between the side-channels and the thalweg. A small pool is located at the upstream bend and contains a piece of LWD spanning the channel at winter baseflow. A larger pool is located immediately upstream of the bar at the confluence of Mill and Palmer Creeks.

At winter baseflow and at the 10-percent exceedance flow, suitable habitat is found throughout much of the site but particularly in the two shallow side-channels and in the two pools. At the 10-percent exceedance flow, large portions of the gravel bar are activated and also provide suitable habitat (Figures 65 and 66). Modeling shows that in its current condition, this site provides limited habitat at high flows such as bankfull flow and the 10-year flood. During these higher flows, depths and velocities in much of the main channel become unsuitable, including in the small pool. Marginal habitat is found on top of the gravel bar (Figures 67 and 68), but no off-channel features are activated.

M1 Proposed Design

The suitability of habitat during high flows will be improved by increasing the persistence of low-velocity conditions at higher flows. Currently, the gravel bar only provides marginal habitat during high flow conditions. Habitat on this bar will be improved by placing fill at its head. This fill will create a backwater on the bar, lowering velocities and improving habitat conditions. To locate the top of this fill above the bankfull flows, between four and five feet of fill will be placed. Fill for this bar will be sourced from the lower, left side-channel. Excavation of this side-channel will increase the area inundated at winter baseflow, providing additional low-velocity habitat. Placement of fill on the gravel bar will remove a small area of suitable habitat at intermediate flows but will improve the quality of habitat on the bar by reducing velocities at these flows (Appendix A).

These improvements will enhance approximately 250 feet of the channel and enhance habitat on approximately 750 ft^2 feet of the gravel bar. Locations for three log structures, each containing at least three pieces of LWD have been identified in the main channel and sites for at least two structures have been identified in the shallow side channel. Depending on anchoring sites and equipment access, there may also be suitable locations for additional structures at this site. Excavating the shallow side channel will generate 40 cubic yards of cut, all of which will be placed at the head of the side channel and gravel bar.

M3 Existing Conditions

Site M3 is located a third of a mile downstream of the confluence of Mill and Palmer Creeks (Appendix A). This site consists of a long straight segment of channel. A small, approximately 10,000 ft^2 floodplain is located on the left bank. There is between five and six feet of vertical separation between this floodplain and the thalweg of the channel. Except for this floodplain, the channel is confined by steep banks that greatly exceed the depth of the 100-year flow. Much of this channel substrate is gravel and it contains very little LWD.

At winter baseflow, moderately suitable depths and velocities are found in much of the main channel; however, channel complexity is limited (Figure 69). At the 10-percent exceedance and bankfull flows, velocities in most of the main channel are unsuitable and off-channel features are not activated (Figures 70 and 71). During the 10-year flood the floodplain is activated and provides suitable, low-velocity habitat (Figure 72).

M3 Proposed Design

Habitat availability at Site M3 can be improved by increasing the inundation frequency of off-channel features and the persistence of low-velocity conditions. Lowering the base of the existing floodplain to create an alcove below the water surface associated with the 10-percent exceedance flow will provide a backwater with suitable velocities at both the 10-percent exceedance flow and at bankfull flow where habitat is limited. This will require approximately five feet of excavation. A carefully located log structure will also be placed to create scour at the entrance of the alcove and reduce the potential for sediment deposition that could result in alcove closure (Appendix A).

These improvements will enhance approximately 850 feet of the channel and create an approximately 1,000 ft^2 alcove. Locations for six log structures, each containing at least three pieces of LWD have been identified in the main channel and sites for at least six structures have been identified in the shallow alcove. Depending on anchoring sites and equipment access, there may be suitable locations for additional structures at this site. Creating the alcove will generate 250 cubic yards of cut which will either be spread on the onsite floodplain or disposed of offsite.

M3B Existing Conditions

A third site was identified approximately half a mile downstream of the confluence of Mill and Palmer Creeks (Appendix A). Although not originally included in the project prioritization, it was identified in the field as a site with suitable off-channel habitat and equipment access.

This site consists of a pool riffle sequence around a bend in the channel. There are long, gravel substrate pools located upstream and downstream of the riffle. A steep-sided gravel bar is located on the inside of the bend and contains a small side-channel active at bank-full flow. There is between two and five feet of vertical separation between this side channel and the thalweg of the main channel. This side channel ends in the lower of the two pools, immediately upstream of a large, partially submerged redwood stump that forms a deeper scour pool.

At winter baseflow and the 10-percent exceedance flow there is moderately suitable habitat in the main channel (Figures 69 and 70). Velocities in the main channel at bankfull flow are unsuitable, but the side-channel is activated and provides suitable habitat (Figure 71). During the 10-year flood, velocities in the main channel and in the side-channel are unsuitable (Figure 72).

M3B Proposed Design

Similar to Site M3, habitat availability at this site can be improved by increasing the inundation frequency of off-channel features and the persistence of low-velocity conditions. Lowering the base of the side-channel to below the 10-percent exceedance flows would provide a backwater with suitable velocities during flows between the 10-percent exceedance flow and bankfull flow. This would require between two feet of excavation at the downstream end and up to five feet of excavation at the upstream end. The persistence of suitably-low velocities in this area can be further improved by placing excavated material at the head of the side-channel to create an alcove. Between one and two feet of fill will be placed to elevate the head of the alcove above bankfull flows. This fill will further decrease velocities in the excavated side-channel and may also deflect sediment-laden flows. Small log structures will be placed in the alcoves and side-channels to provide vertical cover and shade. Larger structures will be placed in the main channel to reduce velocities and create scour pools; these scour pools will increase available habitat at winter baseflow. Carefully located log structures will also be buried within the fill to deflect flows away from the bar and to stabilize the fill (Appendix A).

These improvements will enhance approximately 400 feet of the main channel and enhance habitat in approximately 50 feet of side channel. Locations for three log structures, each containing at least three pieces of LWD have been identified in the main channel and sites for at least two structures have been identified in the shallow side-channel. Depending on anchoring sites and equipment access, there may also be suitable locations for additional structures at this site. Excavating the shallow side channel will generate 130 cubic yards of cut, all of which will be placed at the head of the side channel and gravel bar.

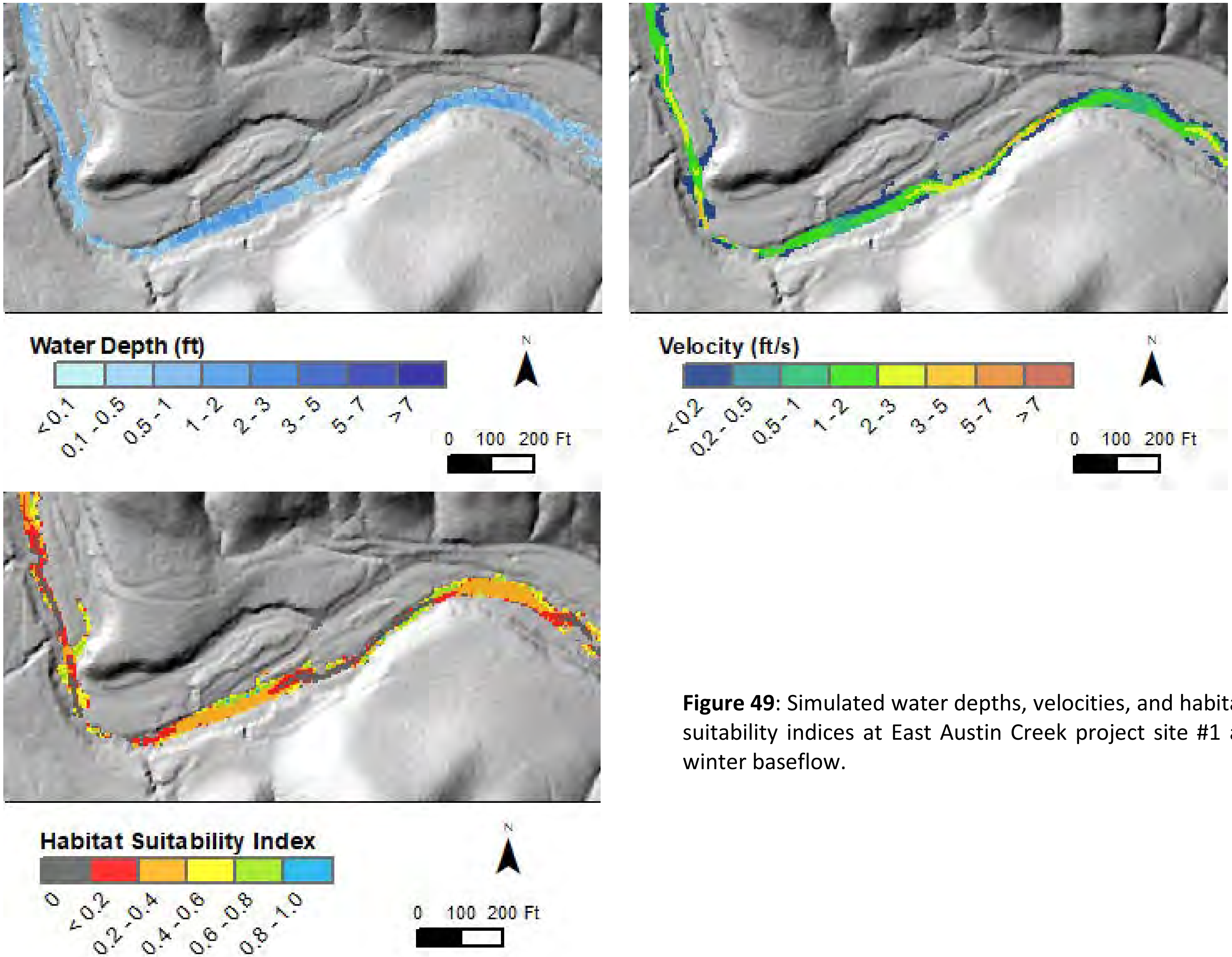
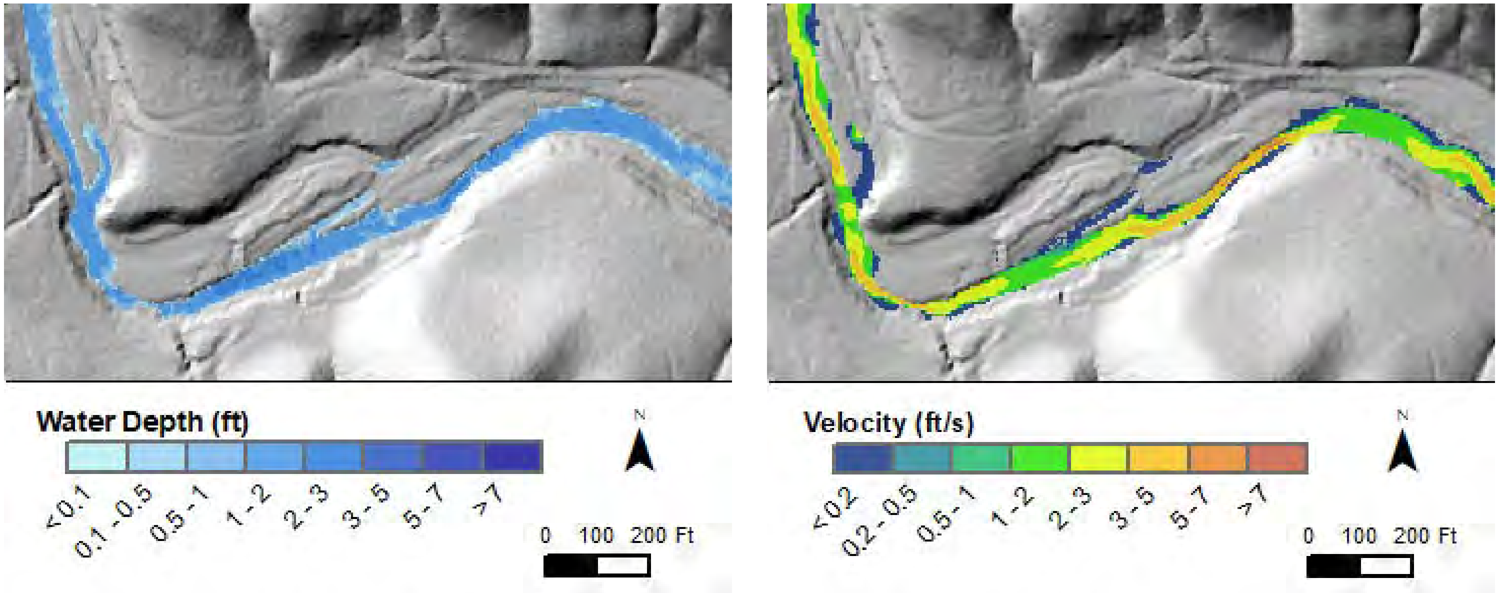


Figure 49: Simulated water depths, velocities, and habitat suitability indices at East Austin Creek project site #1 at winter baseflow.



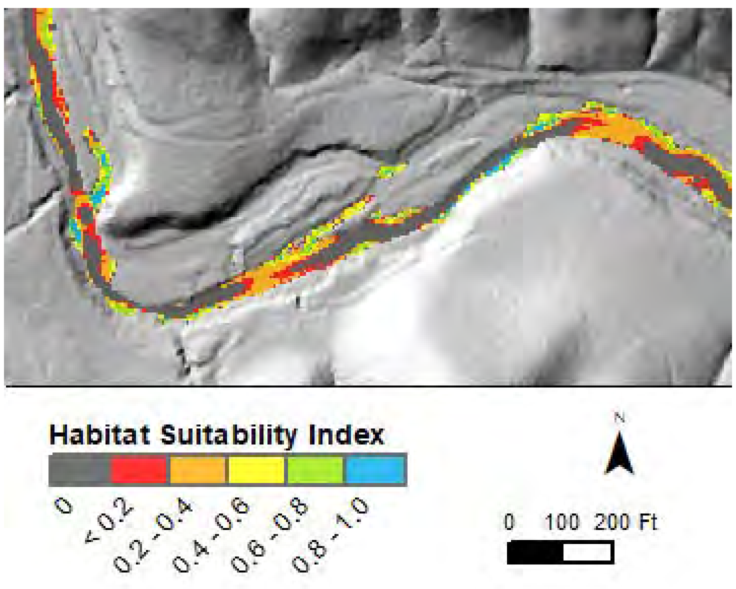


Figure 50: Simulated water depths, velocities, and habitat suitability indices at East Austin Creek project site #1 at the 10% exceedance flow.

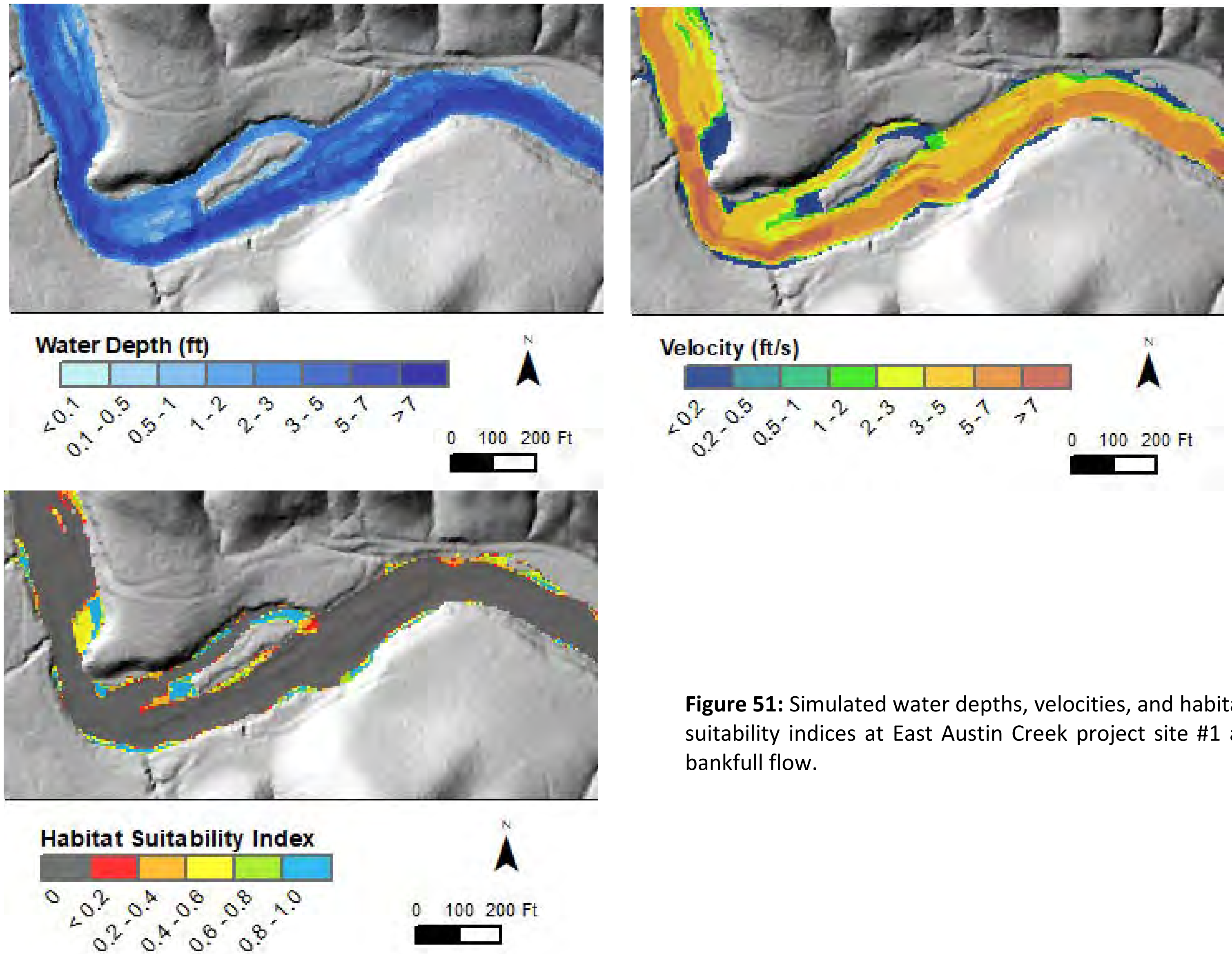


Figure 51: Simulated water depths, velocities, and habitat suitability indices at East Austin Creek project site #1 at bankfull flow.

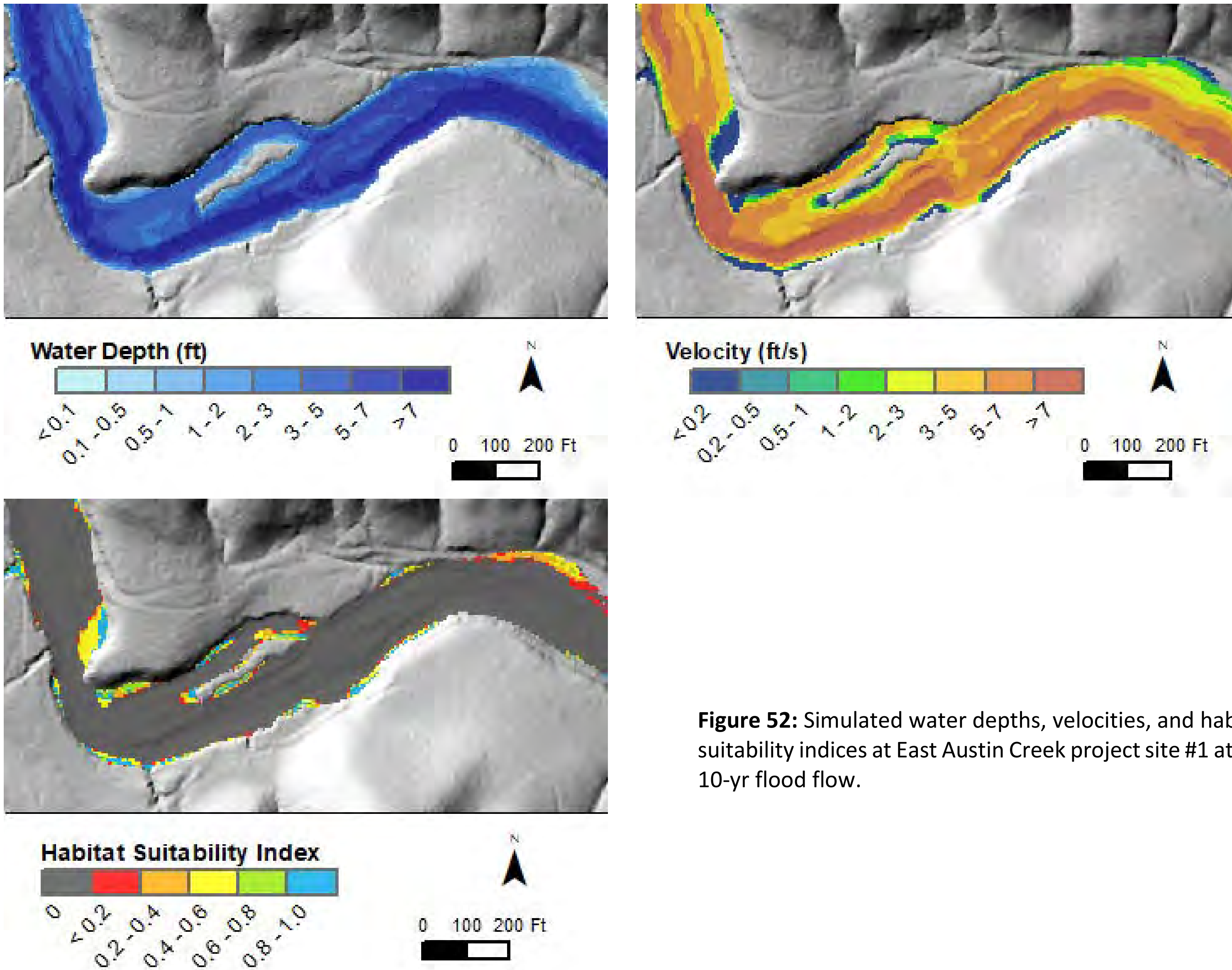


Figure 52: Simulated water depths, velocities, and habitat suitability indices at East Austin Creek project site #1 at the 10-yr flood flow.

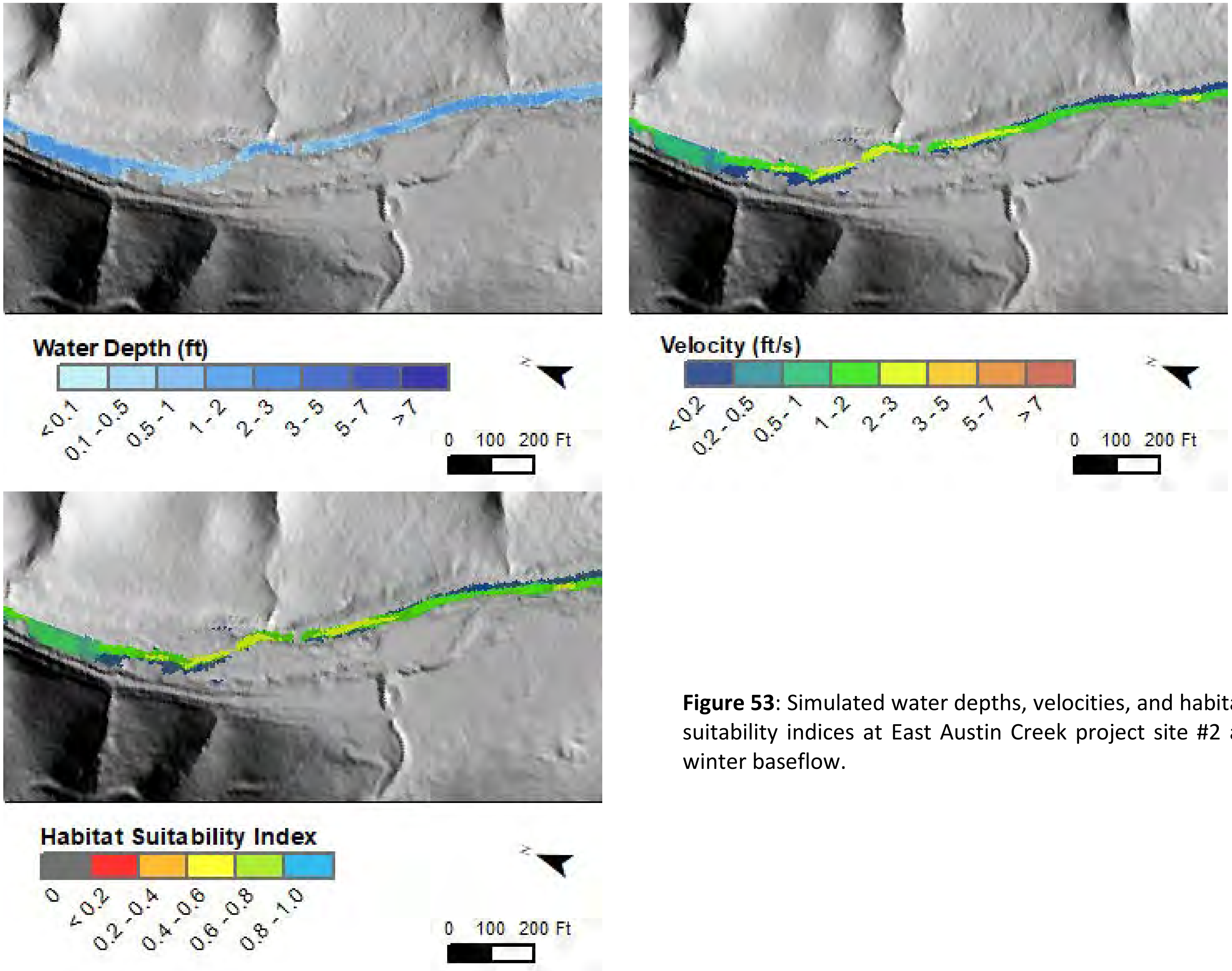
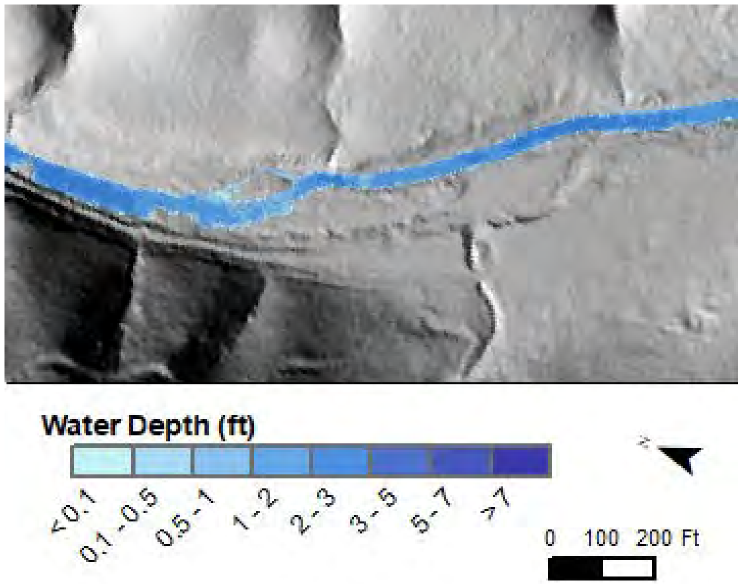
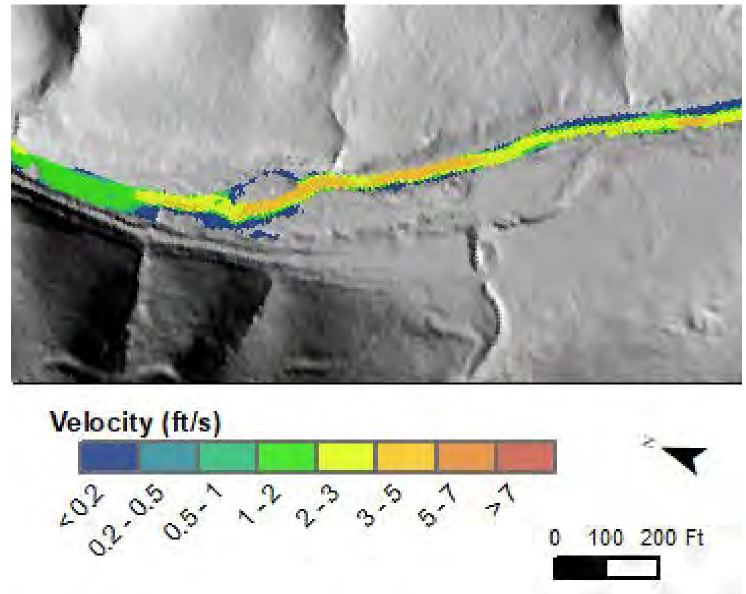


Figure 53: Simulated water depths, velocities, and habitat suitability indices at East Austin Creek project site #2 at winter baseflow.





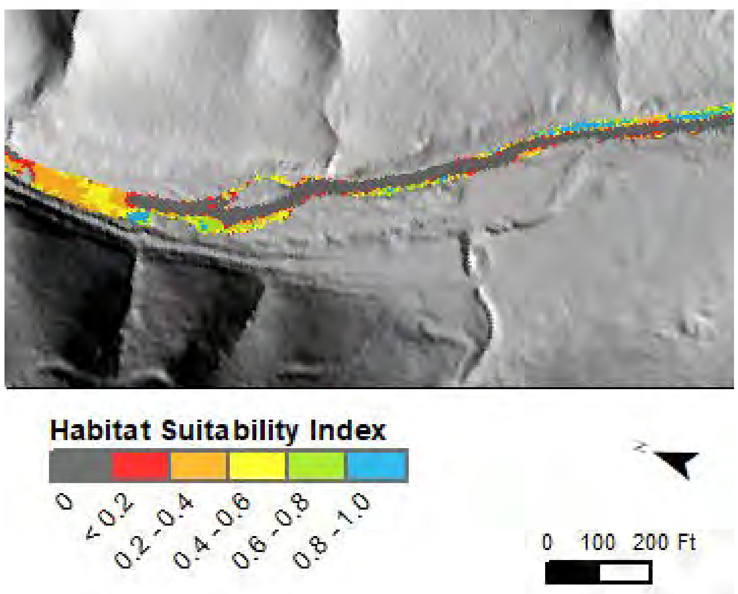
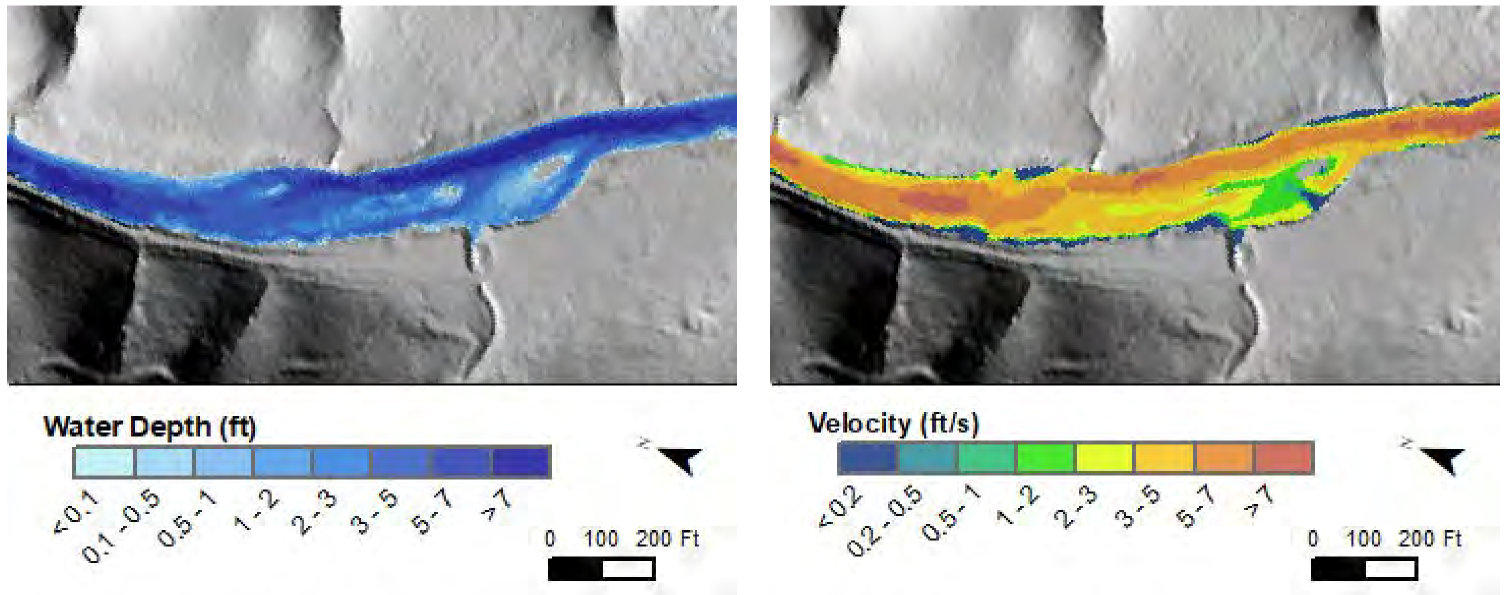


Figure 54: Simulated water depths, velocities, and habitat suitability indices at East Austin Creek project site #2 at the 10% exceedance flow.



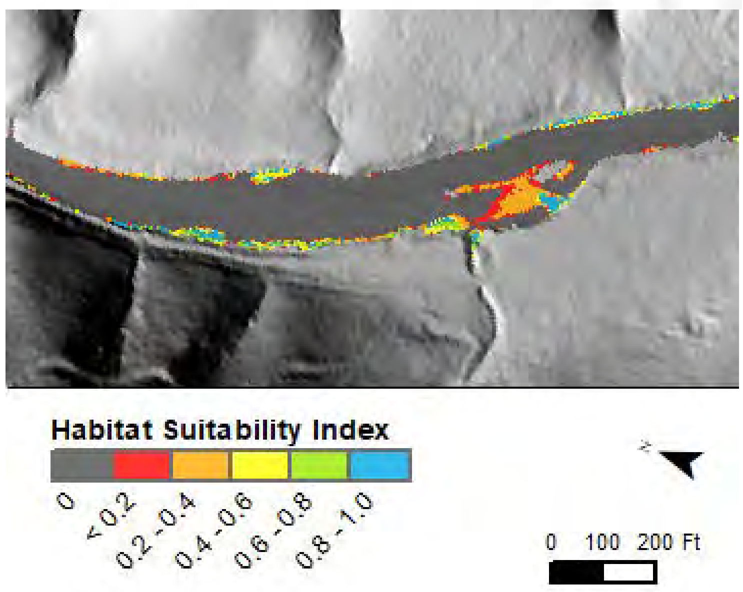
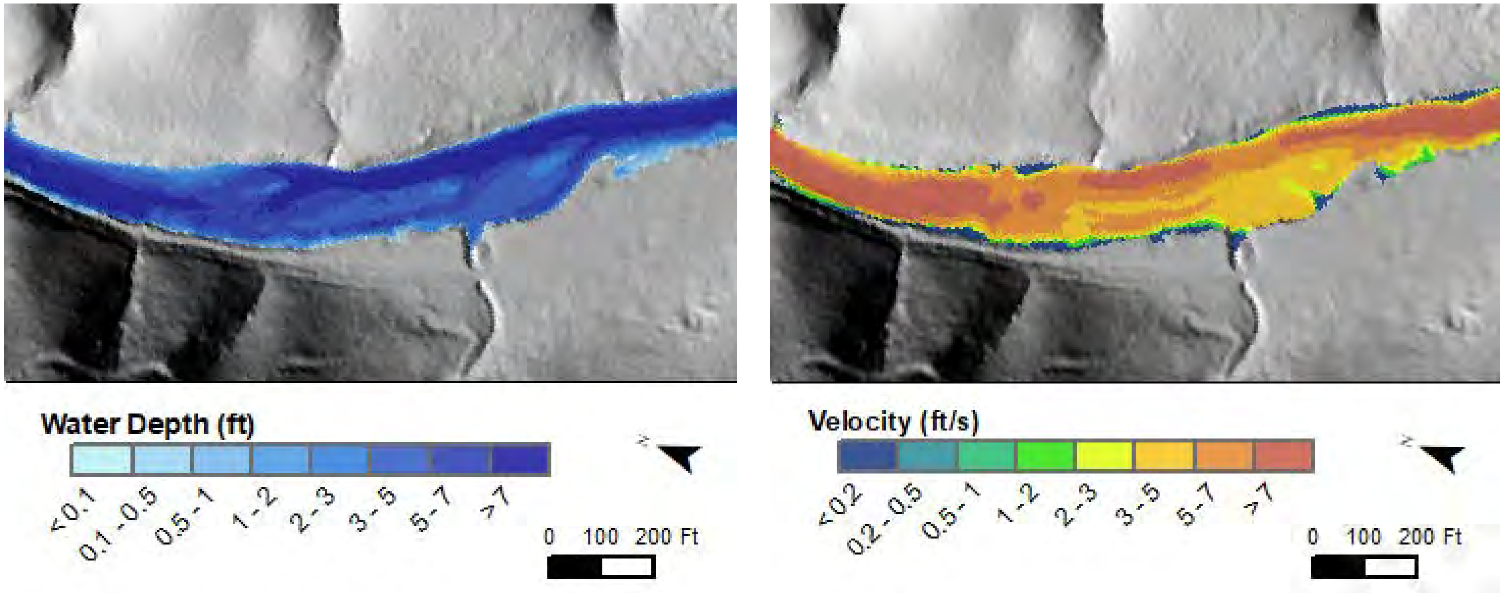


Figure 55: Simulated water depths, velocities, and habitat suitability indices at East Austin Creek project site #2 at bankfull flow.



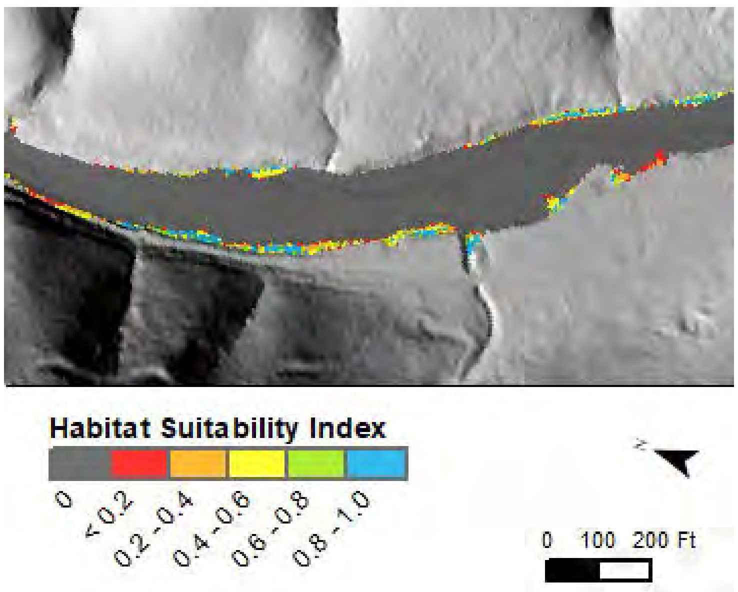


Figure 56: Simulated water depths, velocities, and habitat suitability indices at East Austin Creek project site #2 at the 10-yr flood flow.

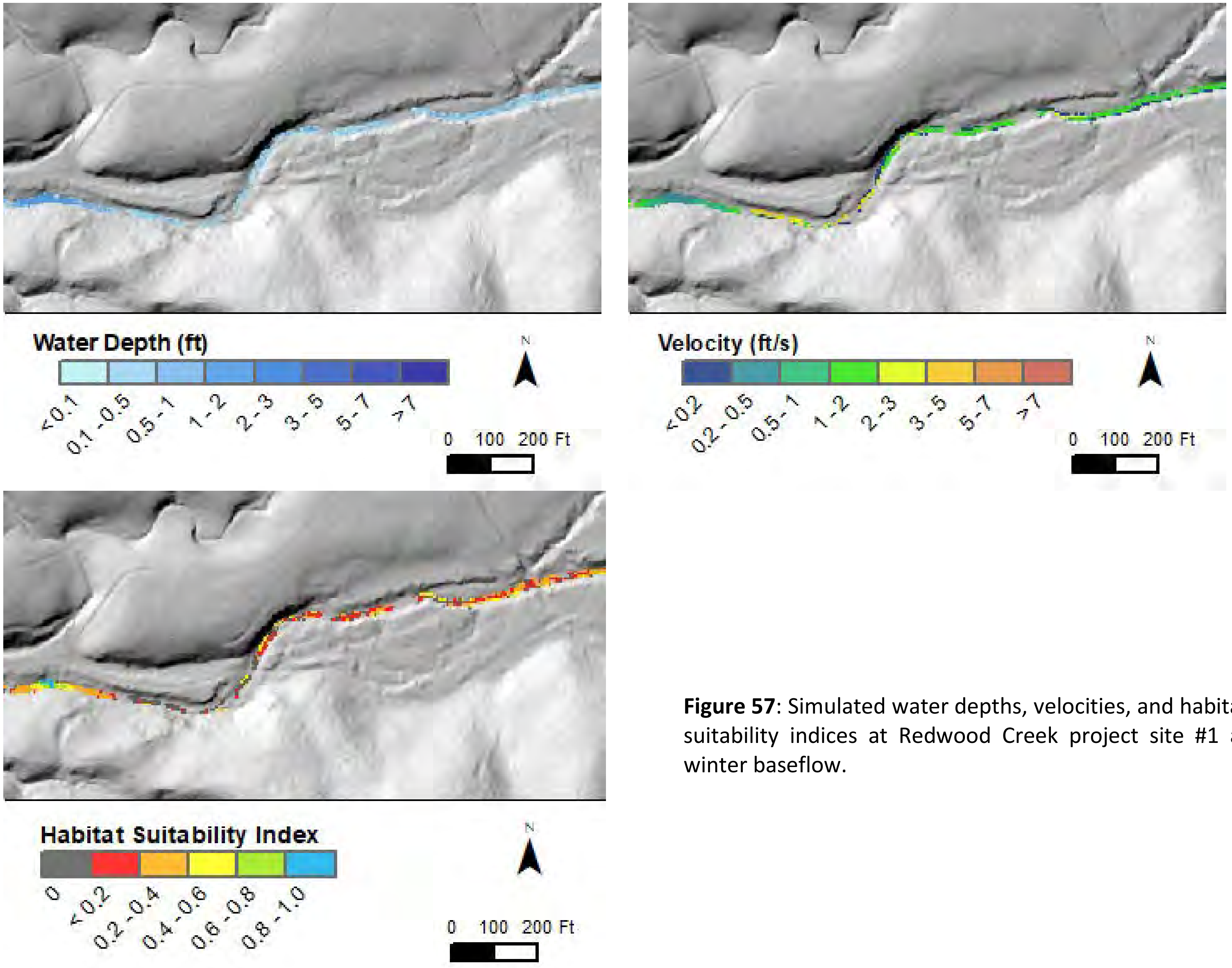


Figure 57: Simulated water depths, velocities, and habitat suitability indices at Redwood Creek project site #1 at winter baseflow.

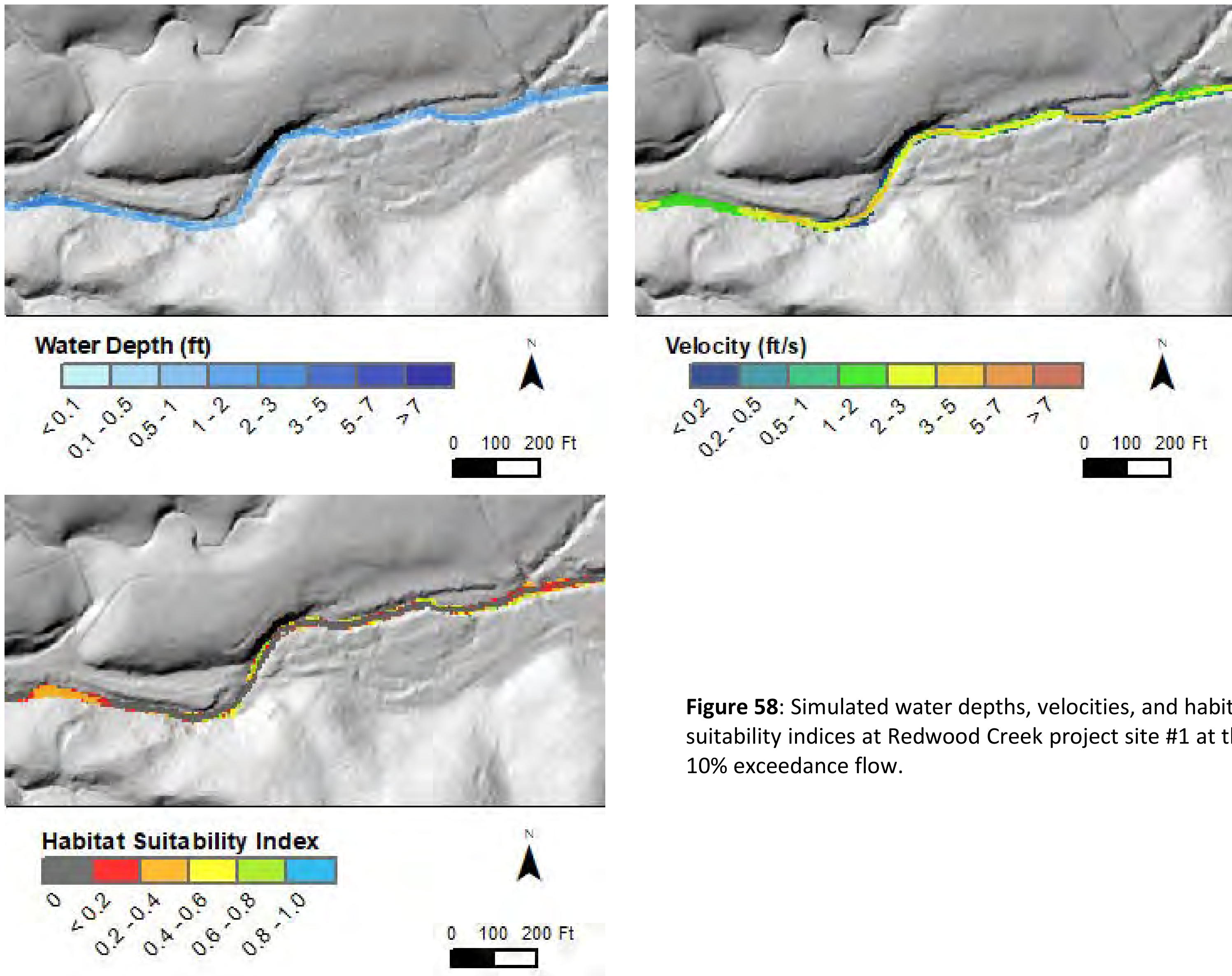
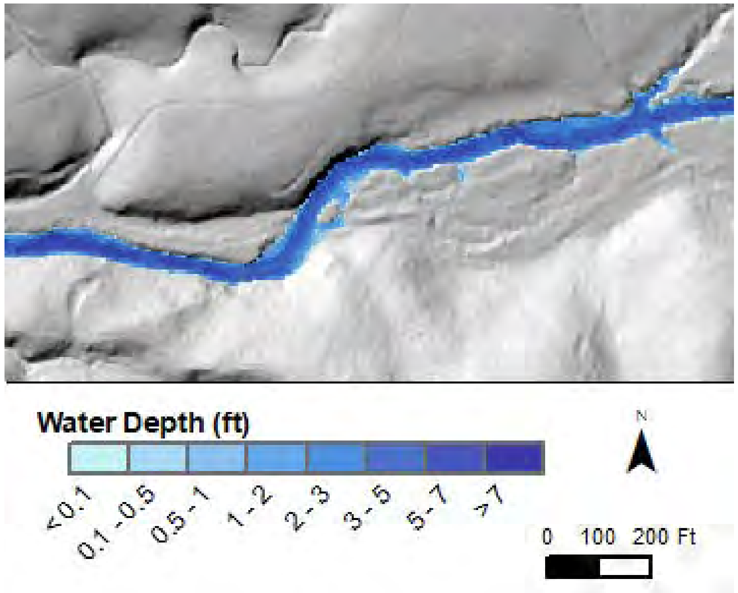
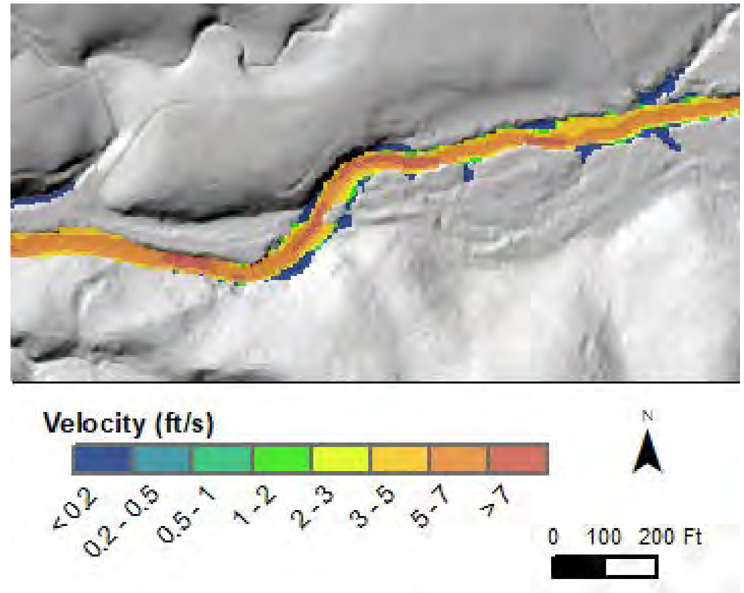


Figure 58: Simulated water depths, velocities, and habitat suitability indices at Redwood Creek project site #1 at the 10% exceedance flow.





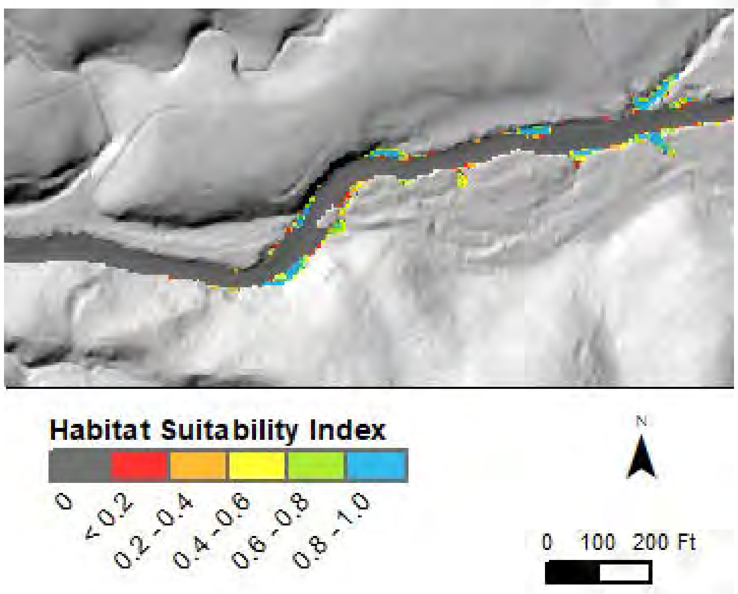


Figure 59: Simulated water depths, velocities, and habitat suitability indices at Redwood Creek project site #1 at bankfull flow.

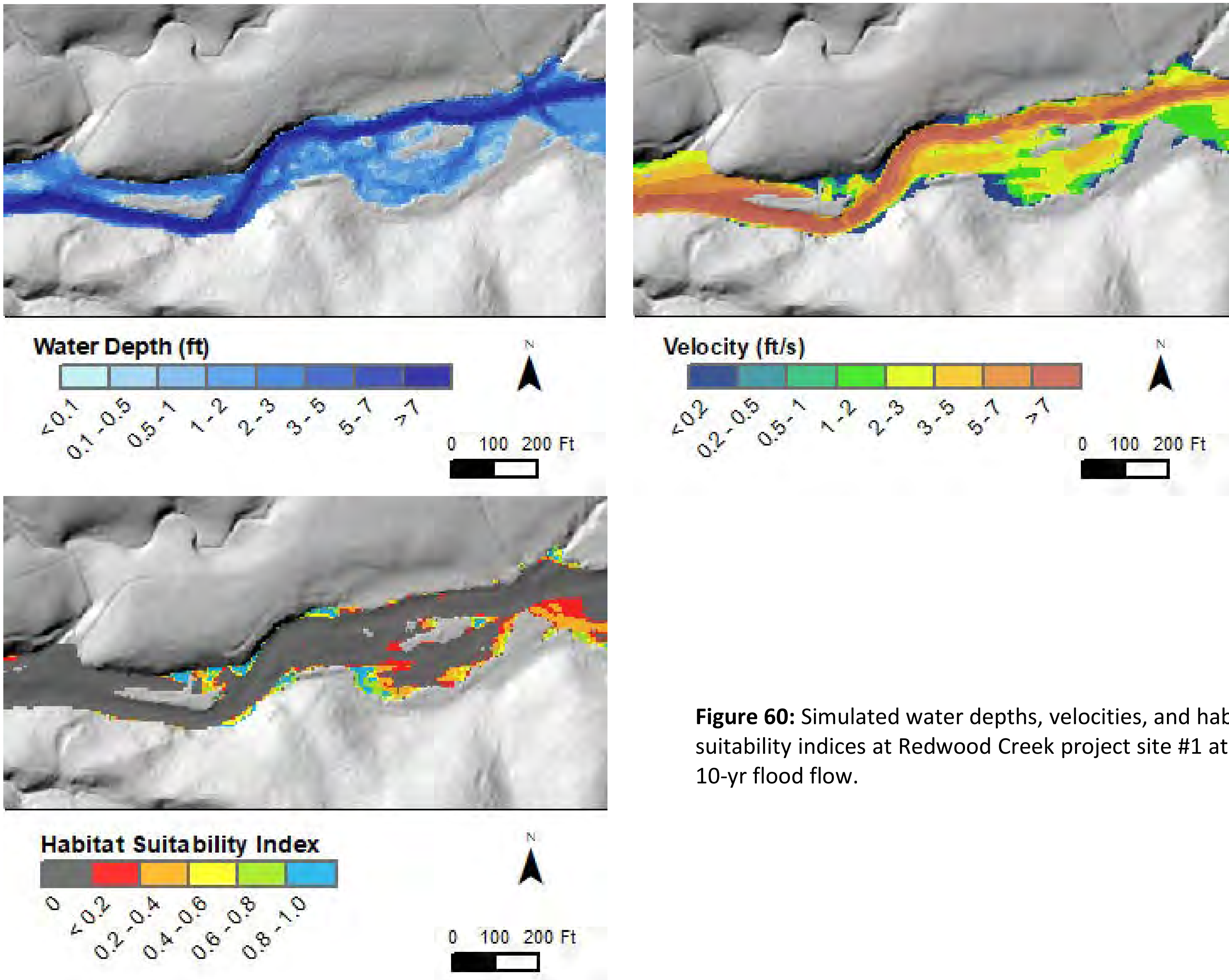


Figure 60: Simulated water depths, velocities, and habitat suitability indices at Redwood Creek project site #1 at the 10-yr flood flow.

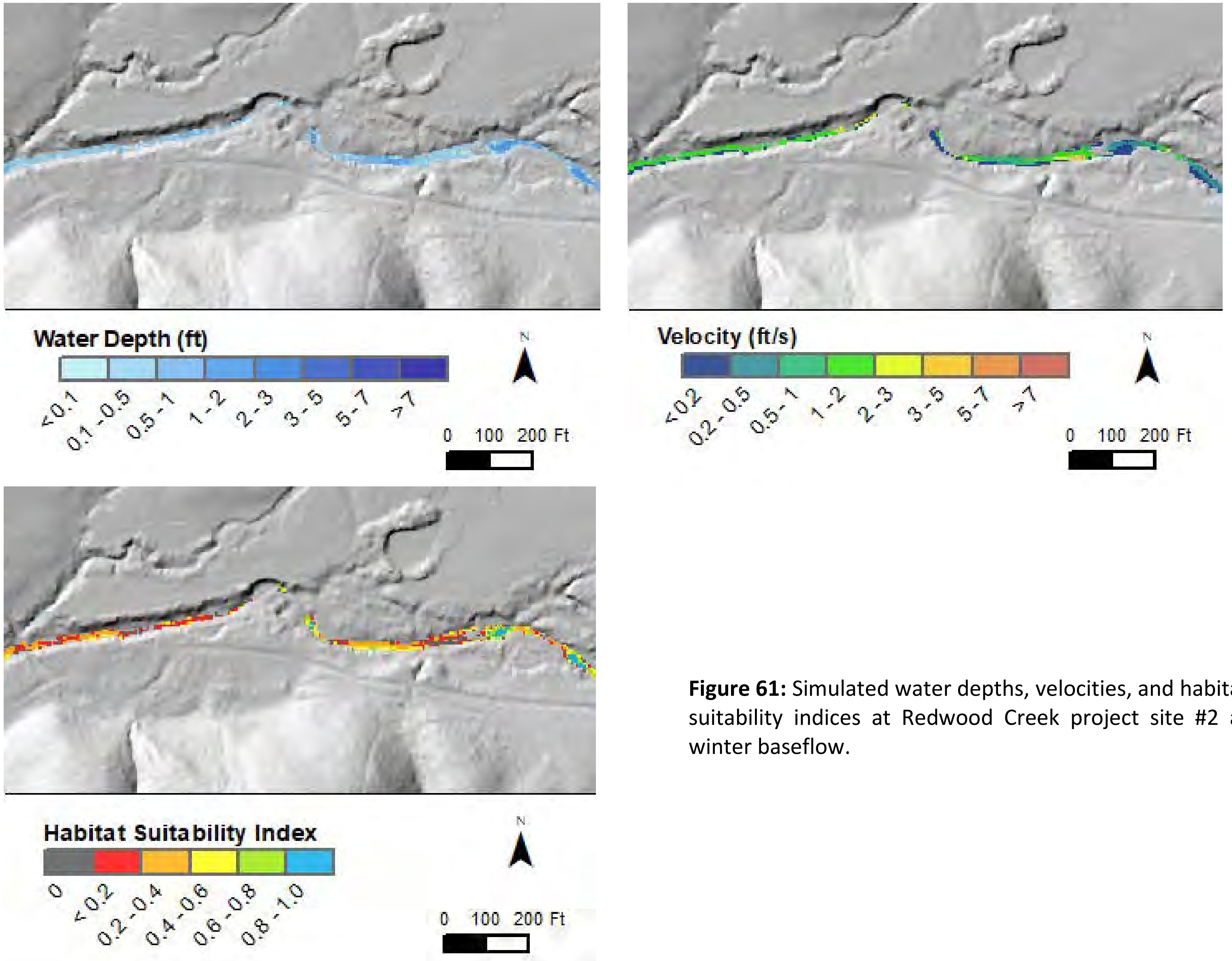
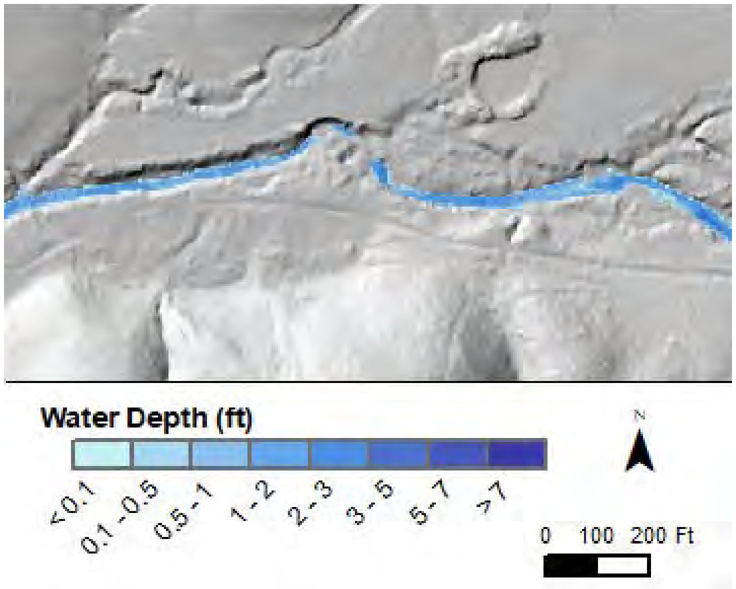
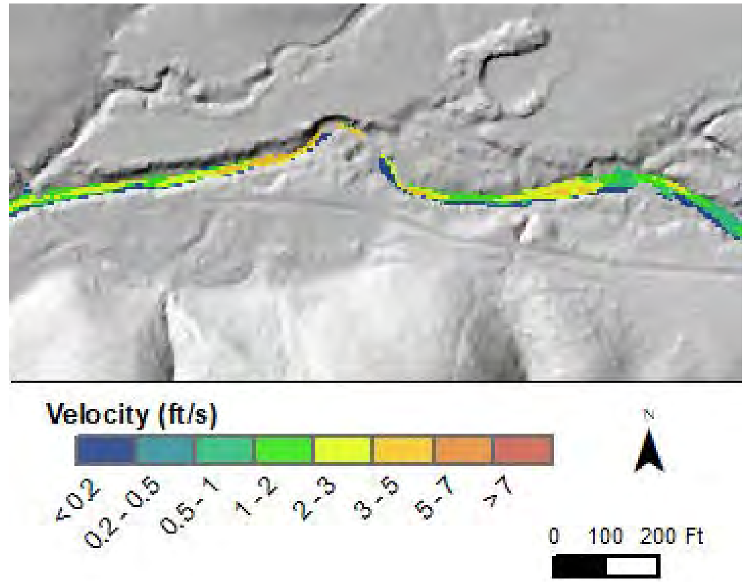


Figure 61: Simulated water depths, velocities, and habitat suitability indices at Redwood Creek project site #2 at winter baseflow.





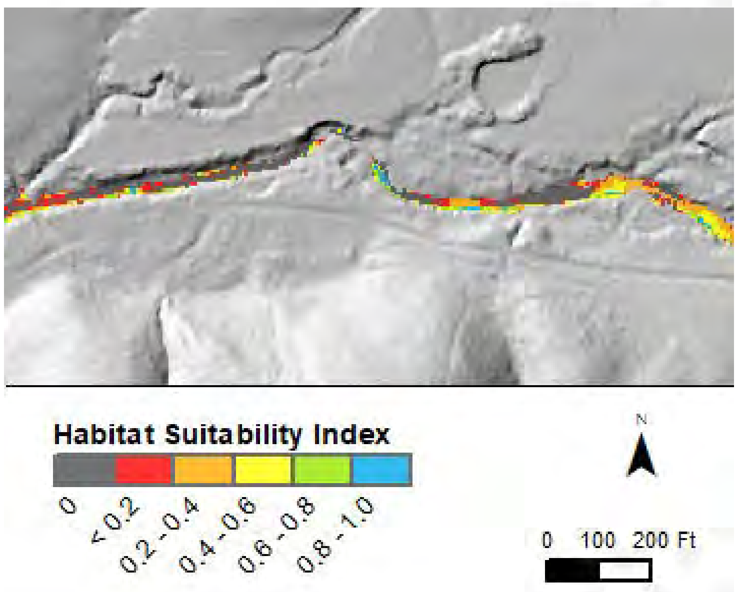
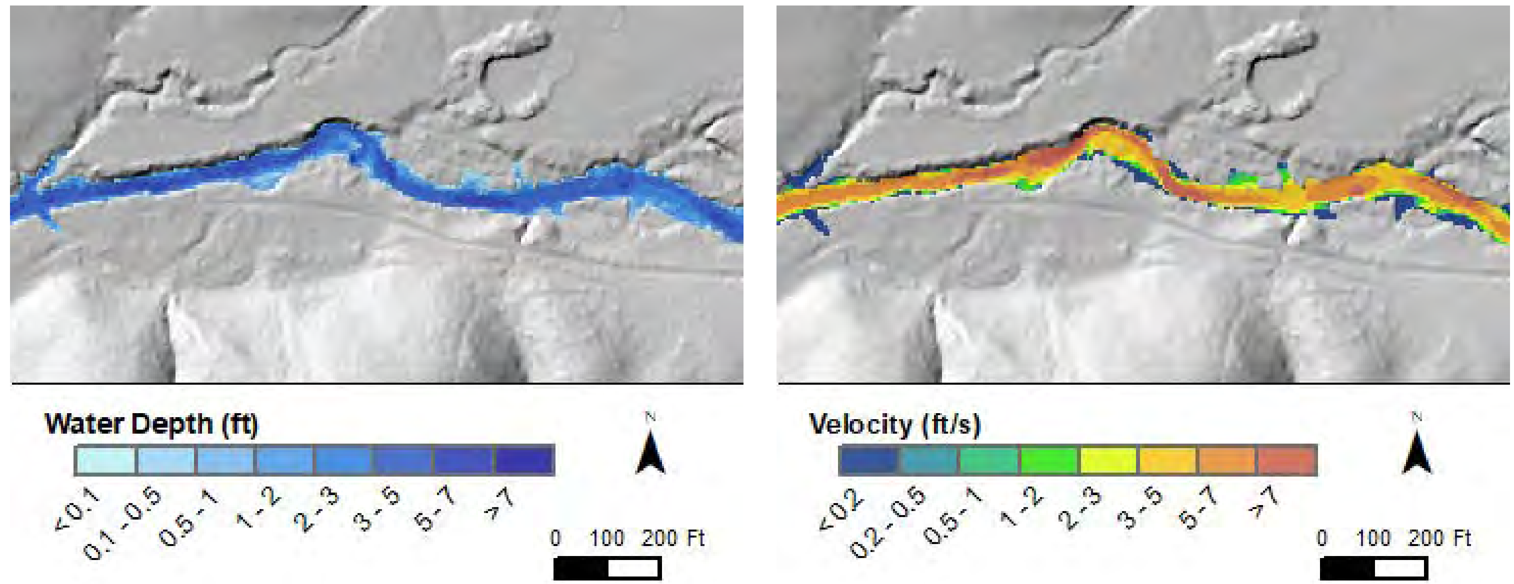


Figure 62: Simulated water depths, velocities, and habitat suitability indices at Redwood Creek project site #2 at the 10% exceedance flow.



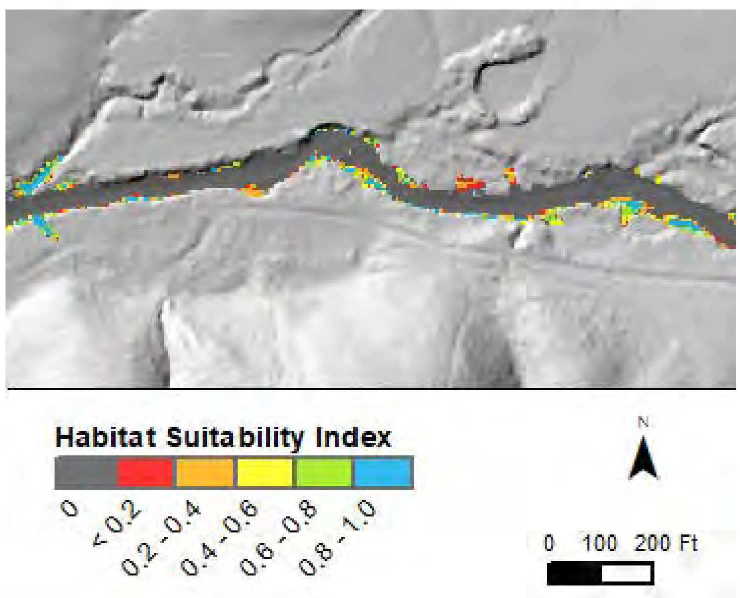
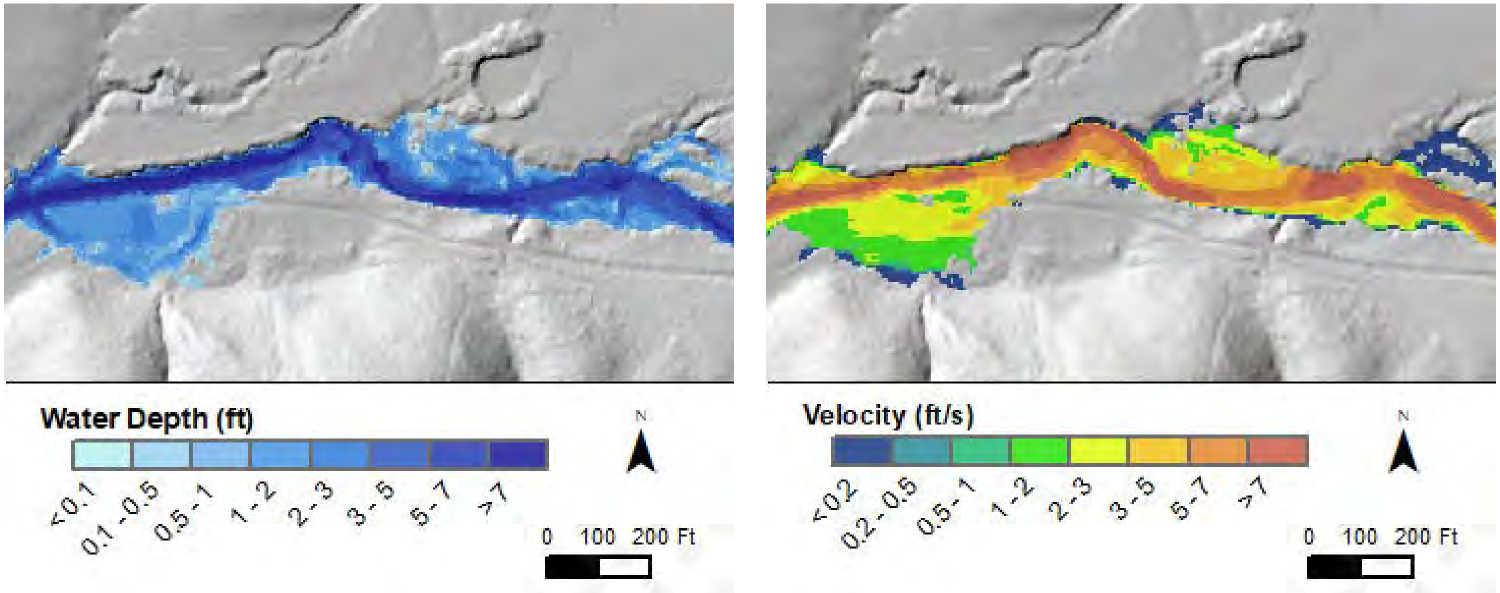


Figure 63: Simulated water depths, velocities, and habitat suitability indices at Redwood Creek project site #2 at bankfull flow.



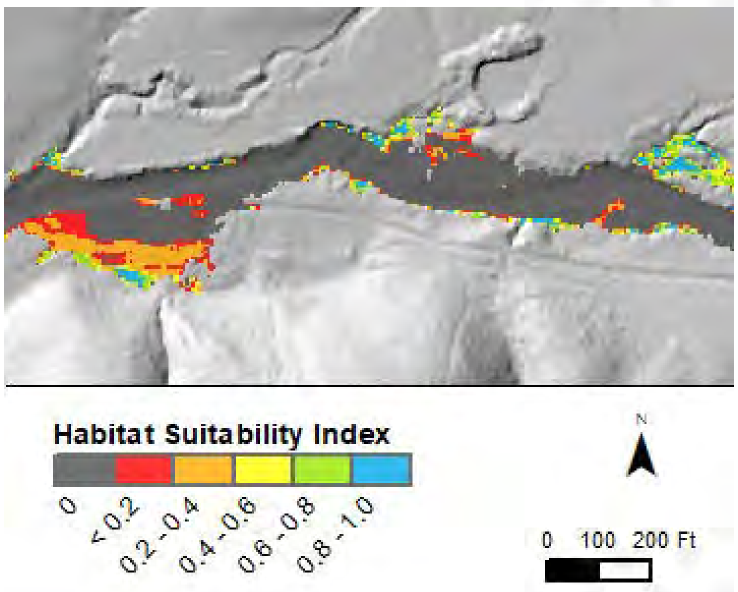


Figure 64: Simulated water depths, velocities, and habitat suitability indices at Redwood Creek project site #2 at the 10-yr flood flow.

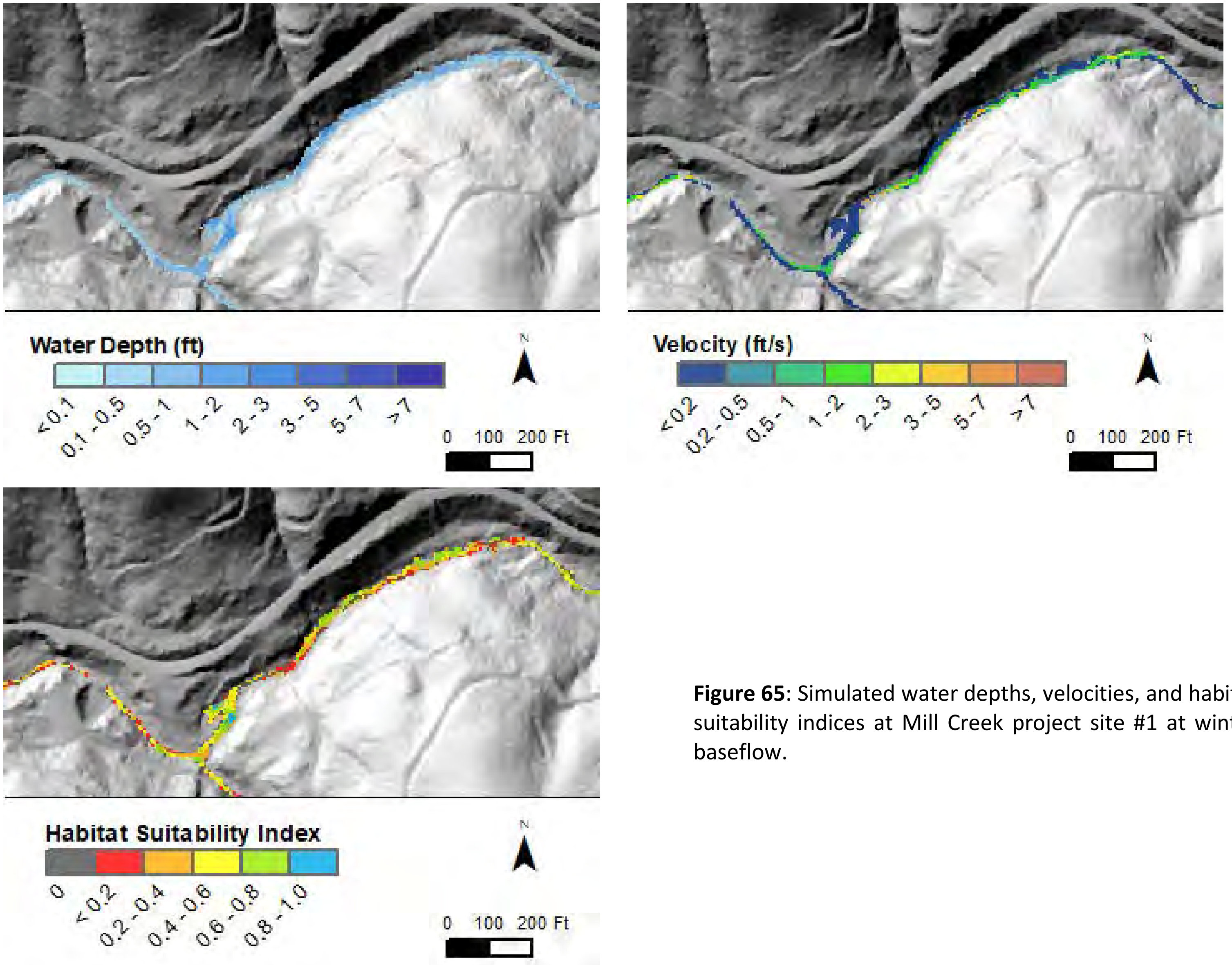


Figure 65: Simulated water depths, velocities, and habitat suitability indices at Mill Creek project site #1 at winter baseflow.

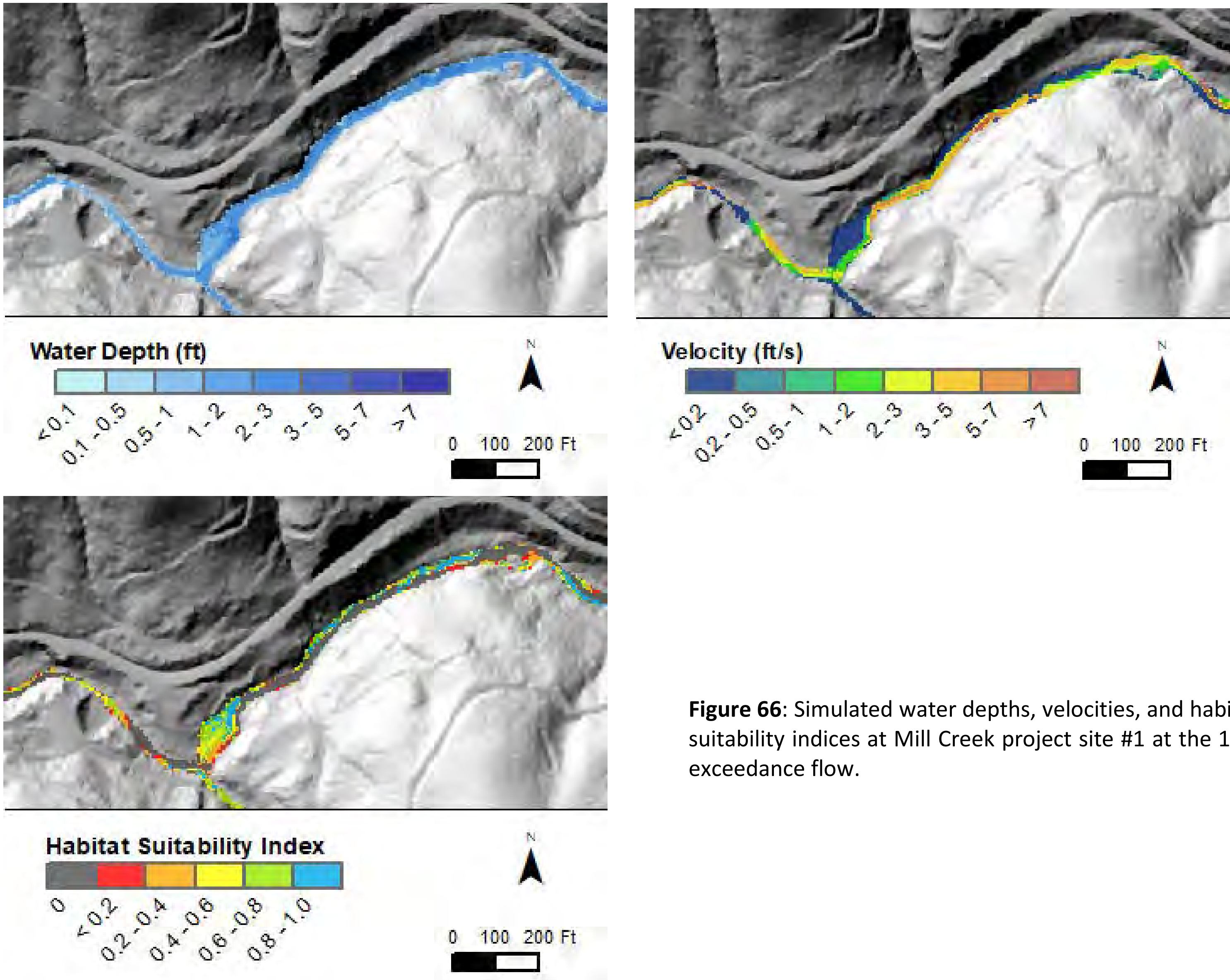


Figure 66: Simulated water depths, velocities, and habitat suitability indices at Mill Creek project site #1 at the 10% exceedance flow.

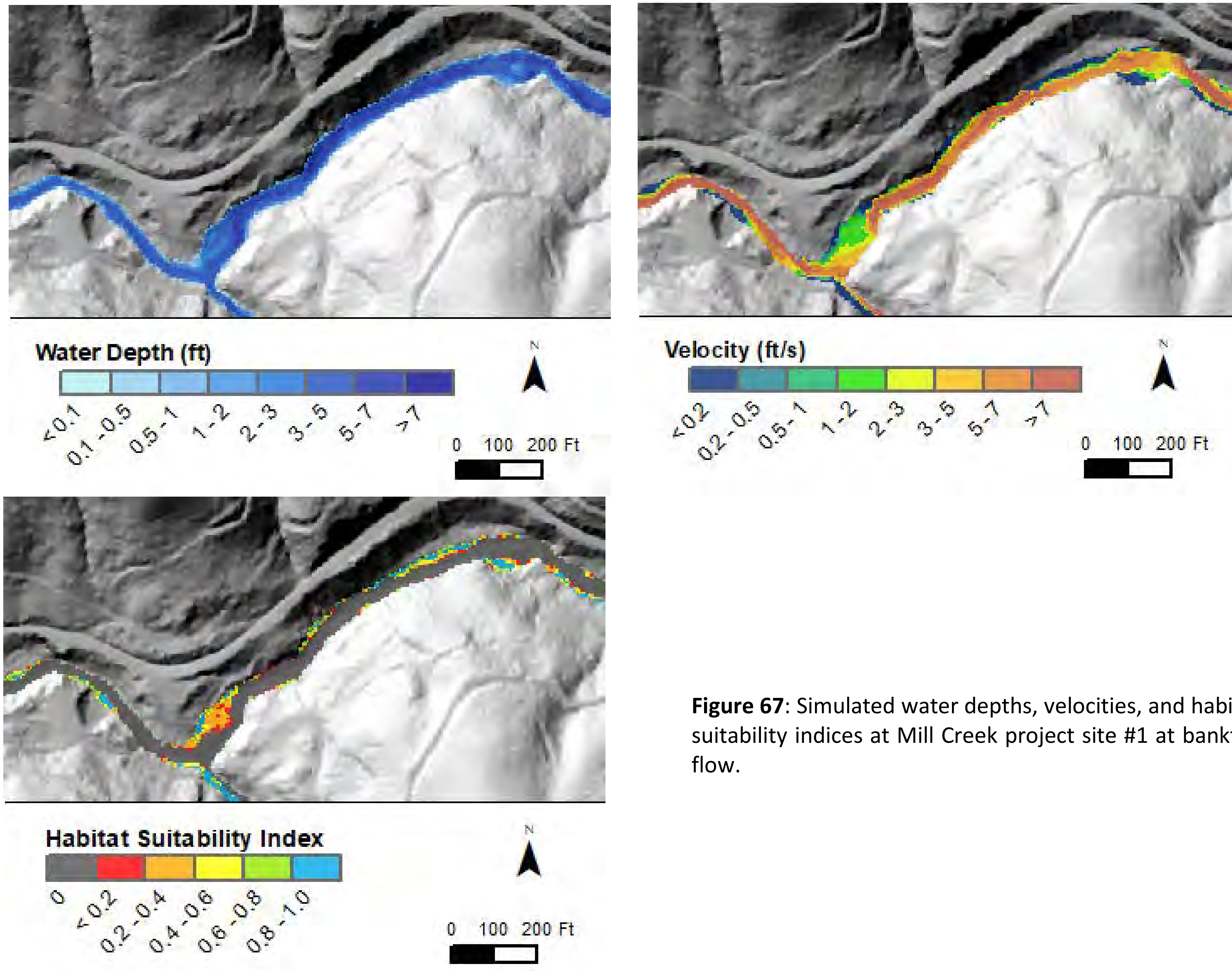
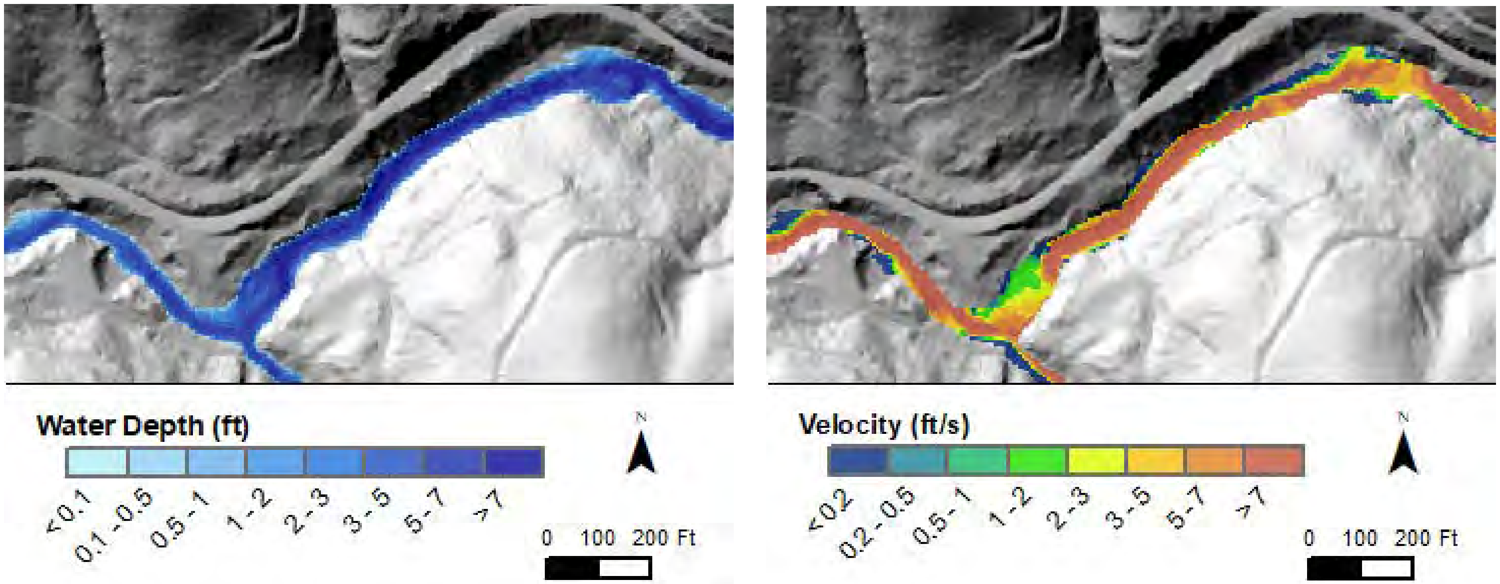


Figure 67: Simulated water depths, velocities, and habitat suitability indices at Mill Creek project site #1 at bankfull flow.



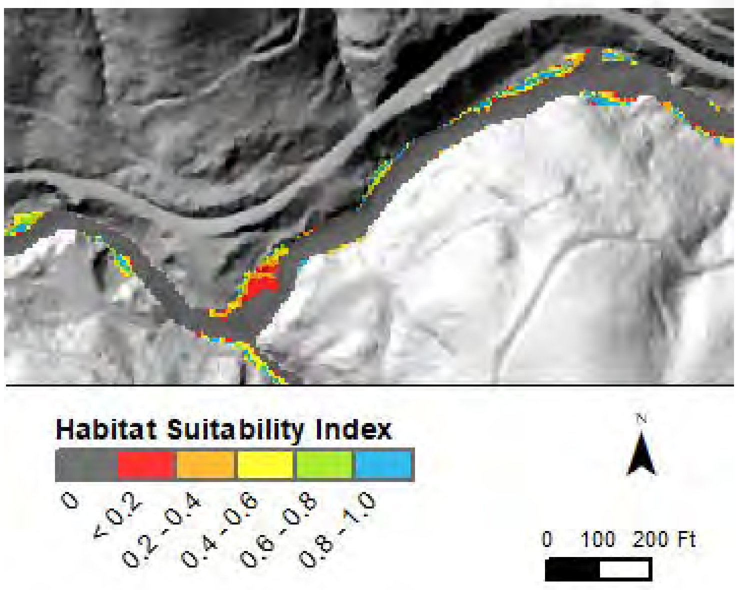


Figure 68: Simulated water depths, velocities, and habitat suitability indices at Mill Creek project site #1 at the 10-yr flood flow.

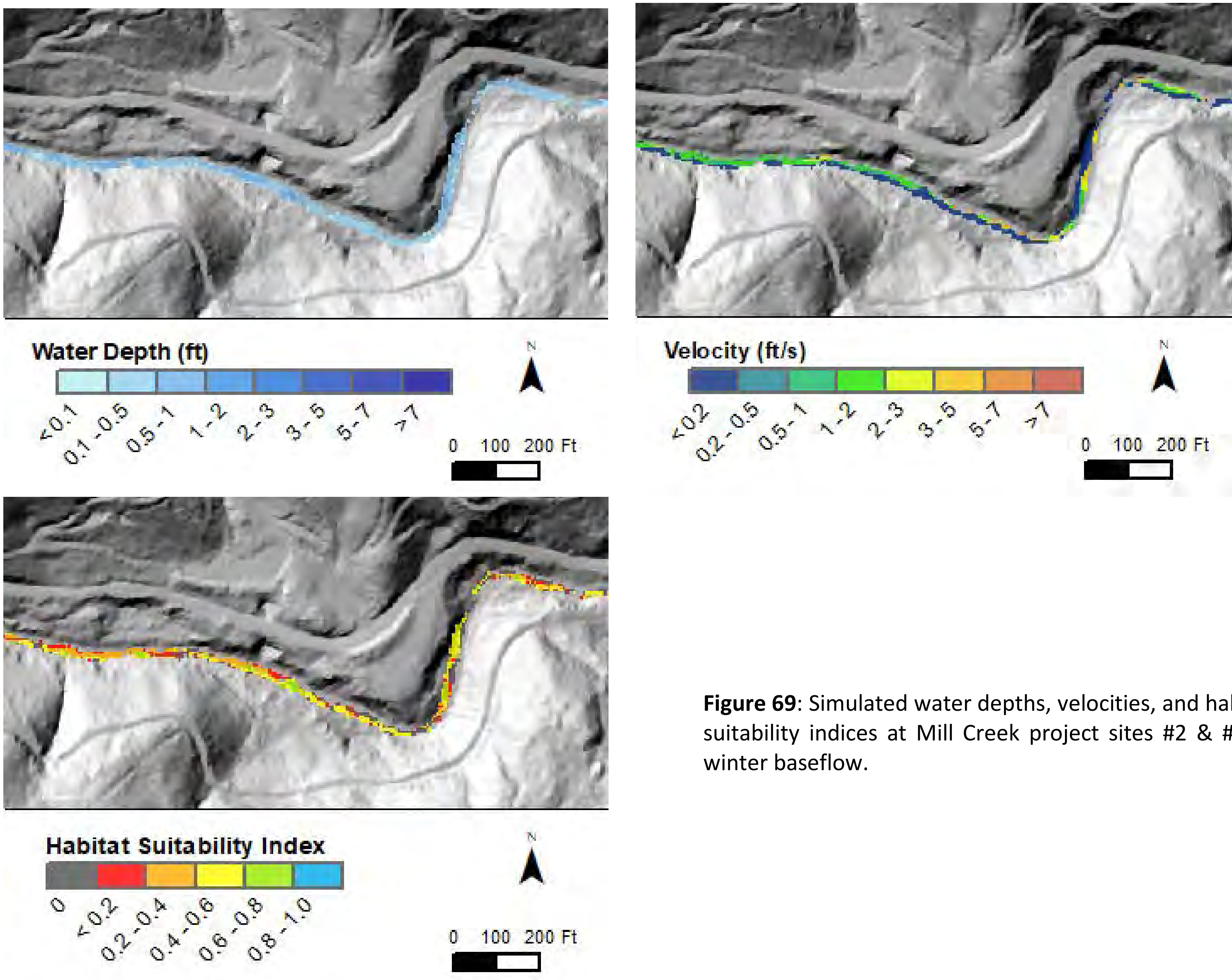


Figure 69: Simulated water depths, velocities, and habitat suitability indices at Mill Creek project sites #2 & #3 at winter baseflow.

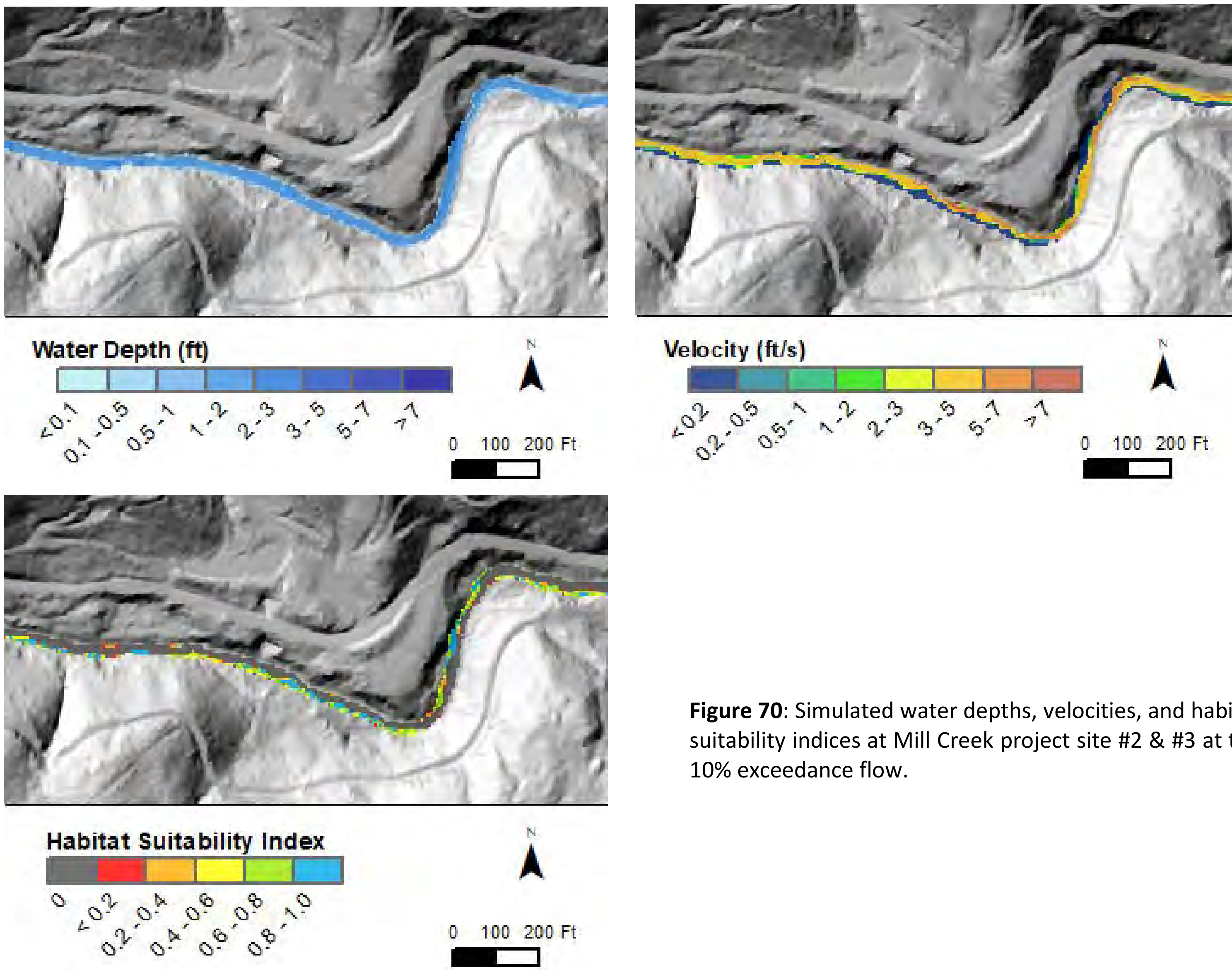


Figure 70: Simulated water depths, velocities, and habitat suitability indices at Mill Creek project site #2 & #3 at the 10% exceedance flow.

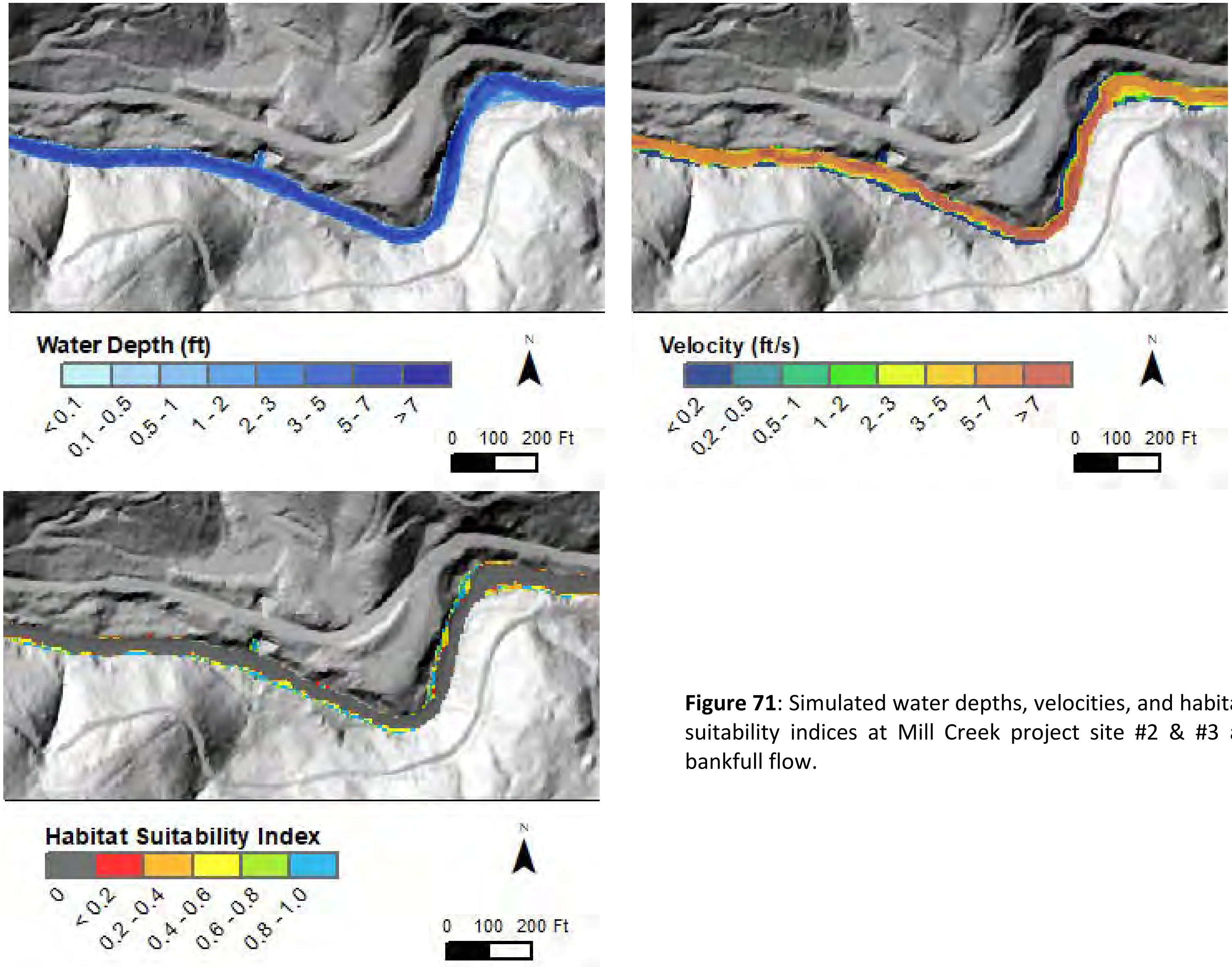


Figure 71: Simulated water depths, velocities, and habitat suitability indices at Mill Creek project site #2 & #3 at bankfull flow.

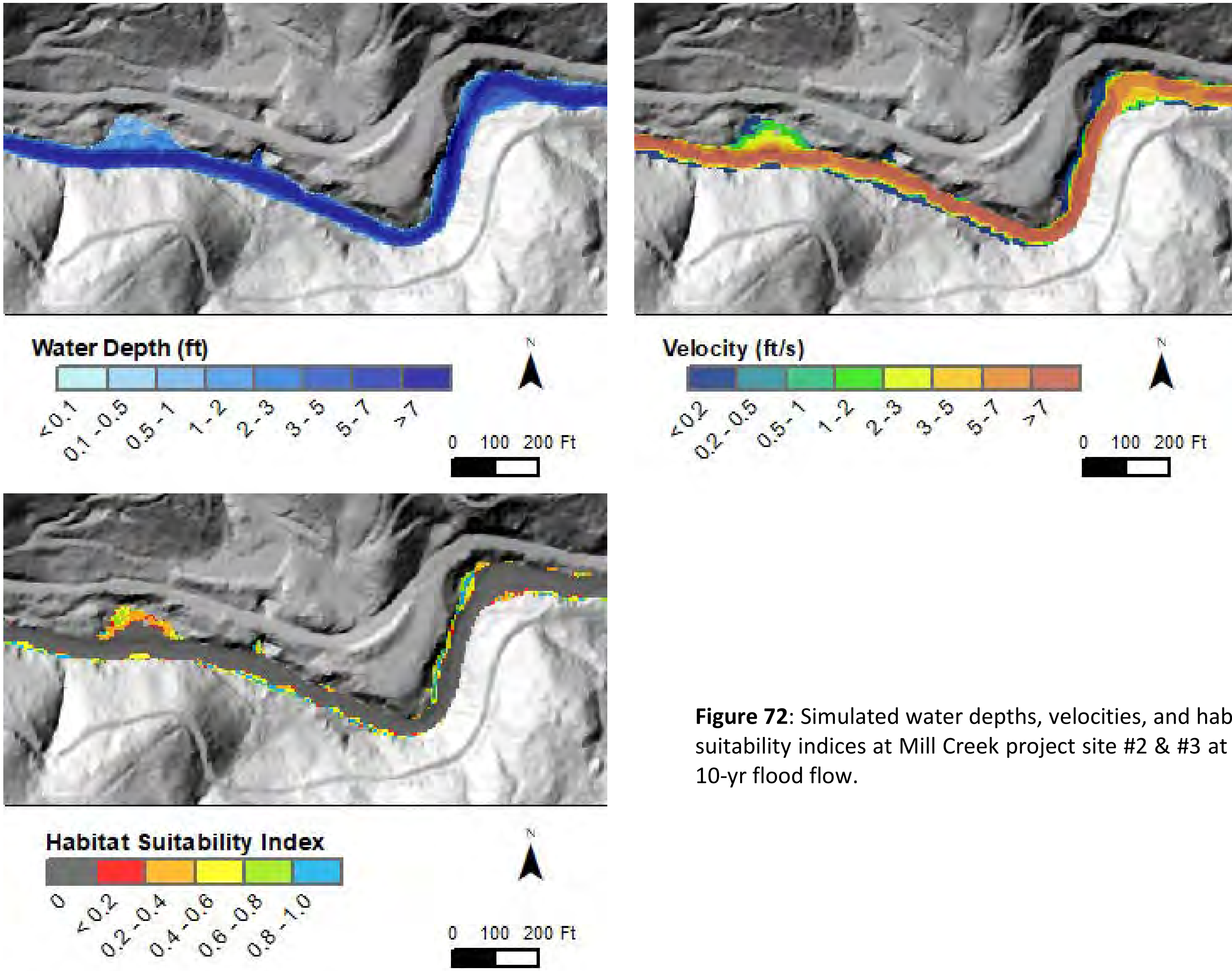


Figure 72: Simulated water depths, velocities, and habitat suitability indices at Mill Creek project site #2 & #3 at the 10-yr flood flow.

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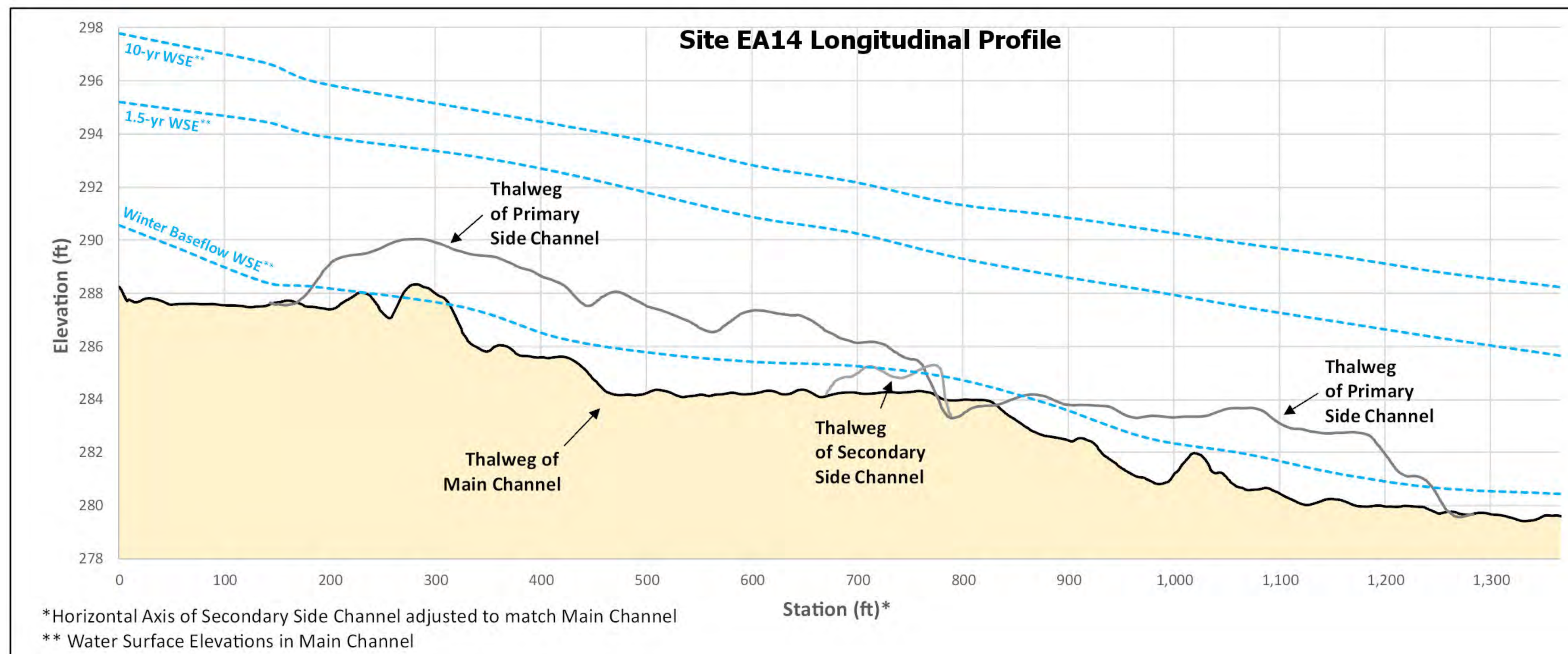
Appendix A – Conceptual design plans for East Austin Creek, Redwood Creek, and Mill Creek project sites.

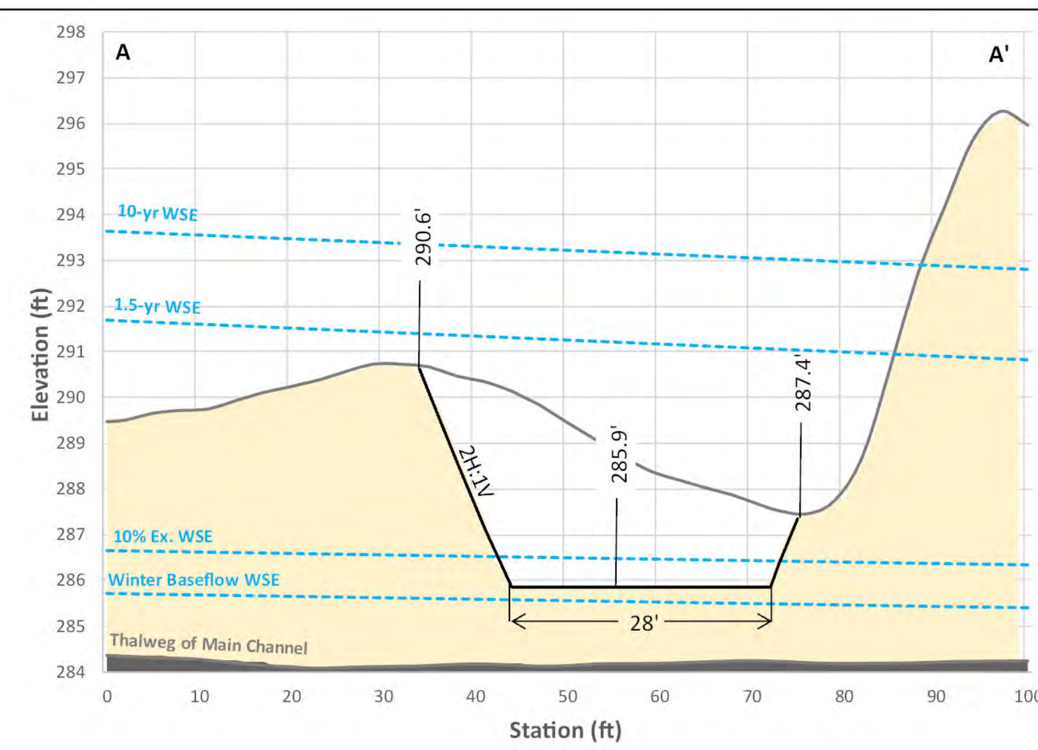
Site EA14 Summary

- Enhance existing alcove
- Raise existing gravel bar to better define primary side channel
- Place log strucutres in main channel and primary side channel
- Total Cut: 200 cubic yards
- Total Fill: 440 cubic yards
- Balance Fill with cut from Site 2
- Pieces of ~30' Large Woody Debris Placed: 9+
- Area Planted with Riparian Veg.: ~3,000 square feet
- Length of Side Channel Enhanced: ~450 feet
- Area of Alcove Enhanced: ~1,600 square feet

Legend

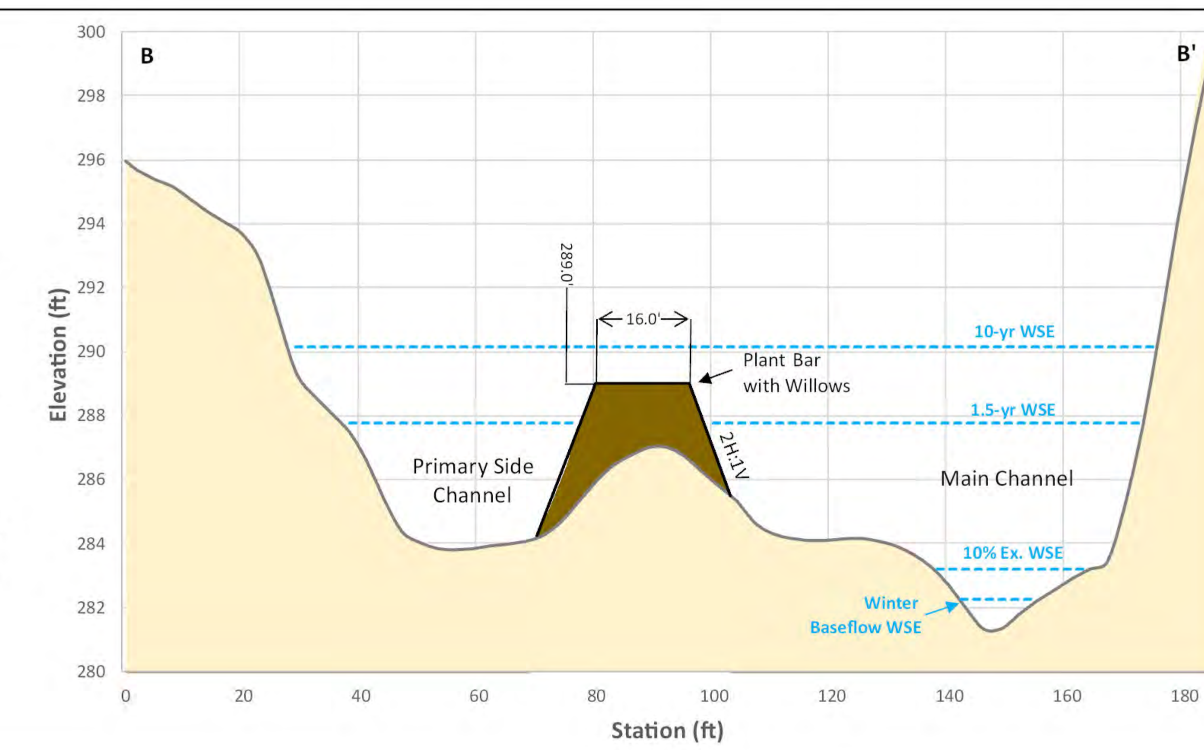
- Thalweg
- 2-ft Contours, Existing
- 2-ft Contours, Proposed
- Cut
- Fill
- Log Structures
- Planted Vegetation
- Modeled 10-yr Floodplain
- Modeled Bankfull Flow
- Modeled Winter Baseflow
- Fireroad





Cross-Section A - A' Notes

- Excavation should mimic the existing alcove
- Invert of alcove to be less than the water surface elevation associated with the 10-Percent Exceedence flow
- Side slopes should be graded at a maximum grade of 2H:1V and should be extended to tie in with existing topography
- Bottom of excavated alcove to be graded at appropriate slope (~2%) decrease potential fish strandings
- Do not extend alcove into flow path in primary side channel to avoid excessive changes to flow patterns
- Exact dimensions to be determined in field to balance fill for the raised gravel bar in Site 1 and cut from the graded mill race in Site 2
- Need to stabilize cut slopes against flows from side-channel into main channel to be determined at final design



Cross-Section B - B' Notes

- Raise existing unvegetated gravel bar using material from excavation in Sites 1 & 2
- Top elevation of bar should be at least 289 feet to establish vegetation outside of bankfull flow
- Minimum Top Width: 16 feet
- Maximum Side Slope Grade: 2H:1V
- Stabilize bar with live willow cuttings and other suiable vegetation

East Austin Creek Salmonid Winter Habitat Improvement Conceptual Plan - Site EA14

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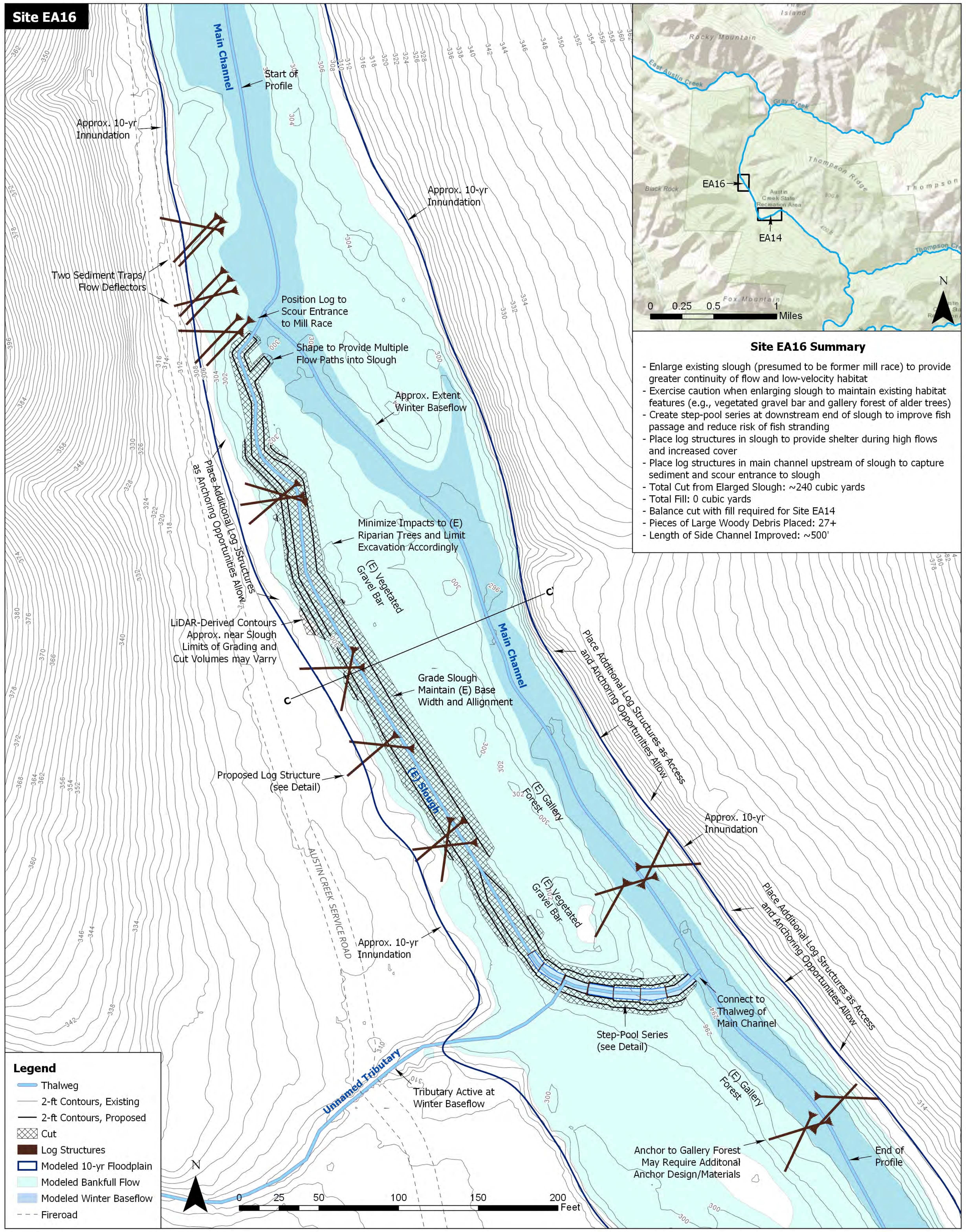
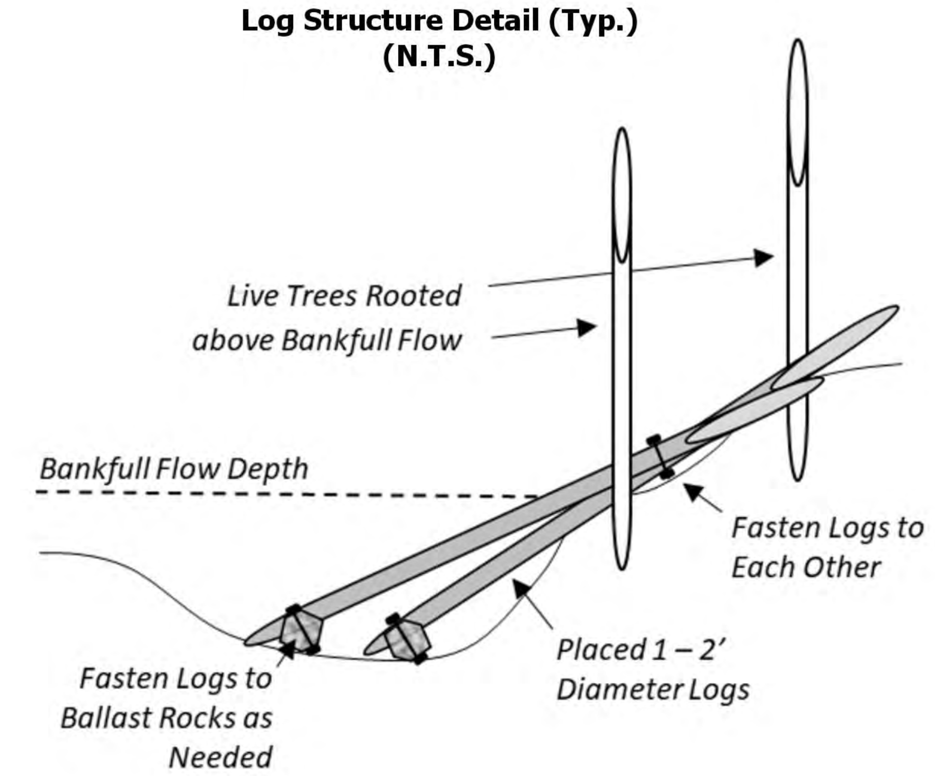


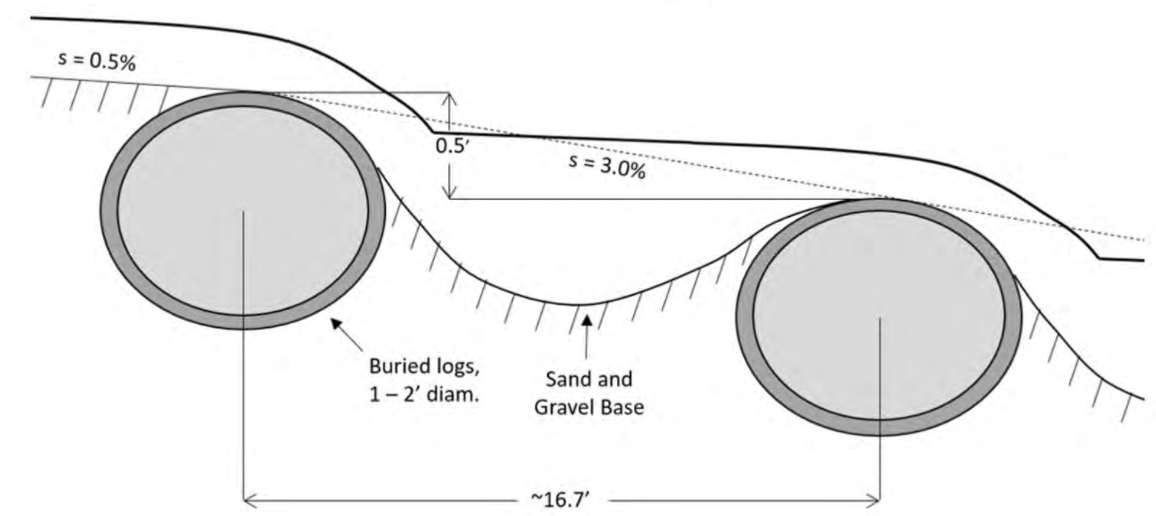
Site EA16 Summary

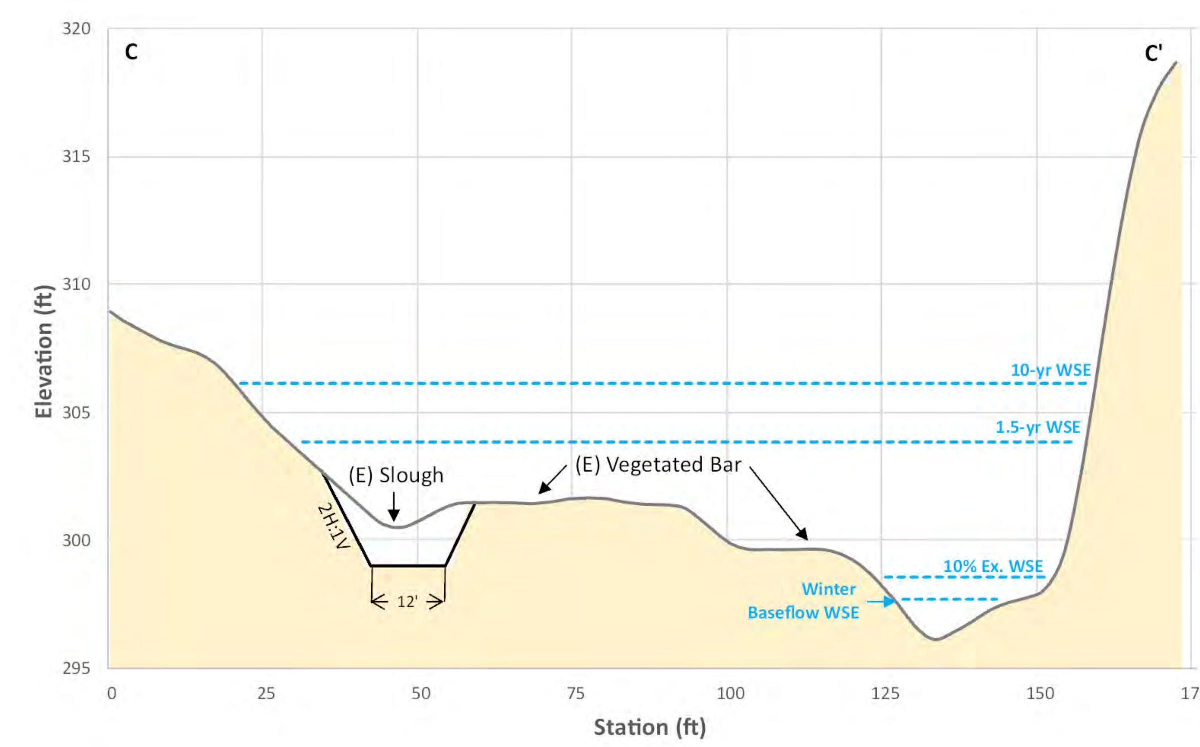
- Enlarge existing slough (presumed to be former mill race) to provide greater continuity of flow and low-velocity habitat
- Exercise caution when enlarging slough to maintain existing habitat features (e.g., vegetated gravel bar and gallery forest of alder trees)
- Create step-pool series at downstream end of slough to improve fish passage and reduce risk of fish stranding
- Place log structures in slough to provide shelter during high flows and increased cover
- Place log structures in main channel upstream of slough to capture sediment and scour entrance to slough
- Total Cut from Elarged Slough: ~240 cubic yards
- Total Fill: 0 cubic yards
- Balance cut with fill required for Site EA14
- Pieces of Large Woody Debris Placed: 27+
- Length of Side Channel Improved: ~500'

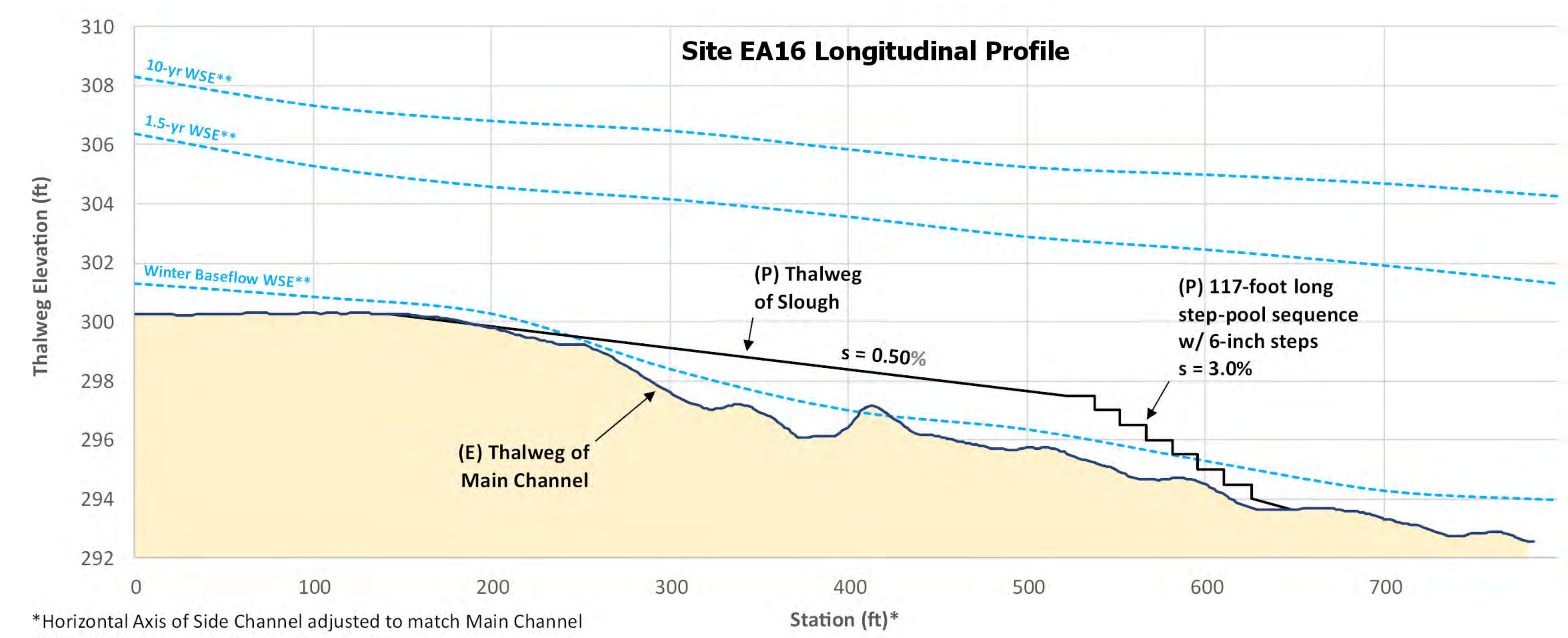
Log Structure Detail (Typ.)
(N.T.S.)



Step-Pool Detail (Typ.)
(N.T.S)







*Horizontal Axis of Side Channel adjusted to match Main Channel
** Water Surface Elevations in Main Channel

Log Structure Detail Notes

- Place logs where channel substrate allows scour to occur
- Avoid placing logs on insides of channel bends
- In main and primary side channels, each log structure to contain a minimum of three interlocking 30'+ logs with a minimum diameter of 1'
- In lower force areas such as the slough, log structures to contain one or more 30'+ logs with a minimum diameter of 1'
- Weave logs among live 1'+ diameter trees rooted above the bankfull depth
- Where possible the placed logs should be braced against a live tree downstream of the middle portion of the placed log and a live tree upstream of the upper end of the placed log
- Weight lower portion of log with a placed ballast rock
- Fasten logs to each other and to ballast rocks using threaded 1" steel rebar and locking nuts (see example photographs)
- Logs should include rootwads when available

Step-Pool Detail Notes

- Steps to be constructed out of 1 - 2' diameter logs buried in banks or out of appropriately sized rocks sourced onsite
- Logs formin steps can be notched as needed to attain desired flow conditions
- Space between logs and/or rocks to be filled with high-density mixture per CDFW Salmonid Stream Habitat Restoration Manual
- Width of pools to be ~8 feet
- Step Height (H)/Step Spacing (L)/Slope (S): 1.00
- Step Spacing (L)/Width (W): ~2.00

Site 2 Profile Notes

- To ensure connectivity of surface flows, grade uppermost portion of slough such that thalweg of slough is above the thalweg of the main channel but below the water surface elevation at winter baseflow in the main channel
- Sill of the lowest step in the step-pool sequence to be less than 0.50 feet above water surface elevation in main channel at winter baseflow.
- Above the step-pool sequence, sloughl to be graded at an average slope of 0.50%. Slope should vary along length of sloughl to provide additional habitat and complexity.
- Existing elevations along slough are LiDAR-derived and are approximate. Average slough slope and cut volumes should be verified using survey data.

East Austin Creek Salmonid Winter Habitat Improvement Conceptual Plan - Site EA16

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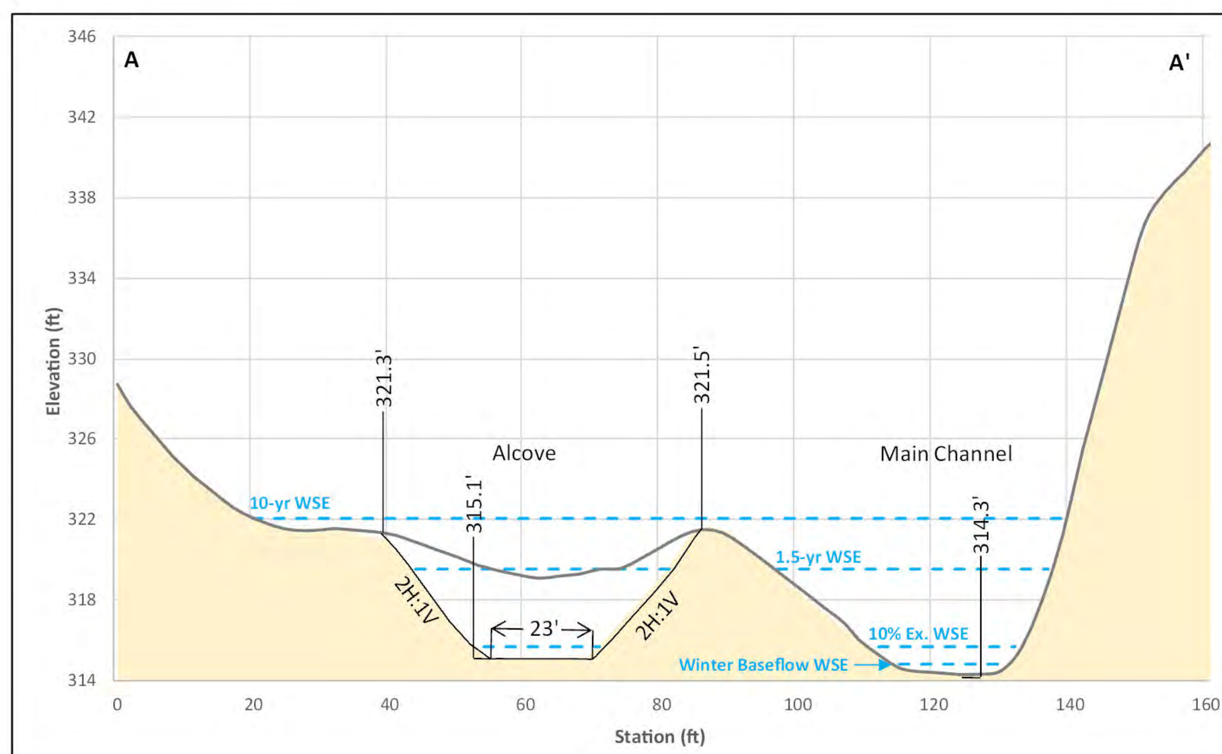
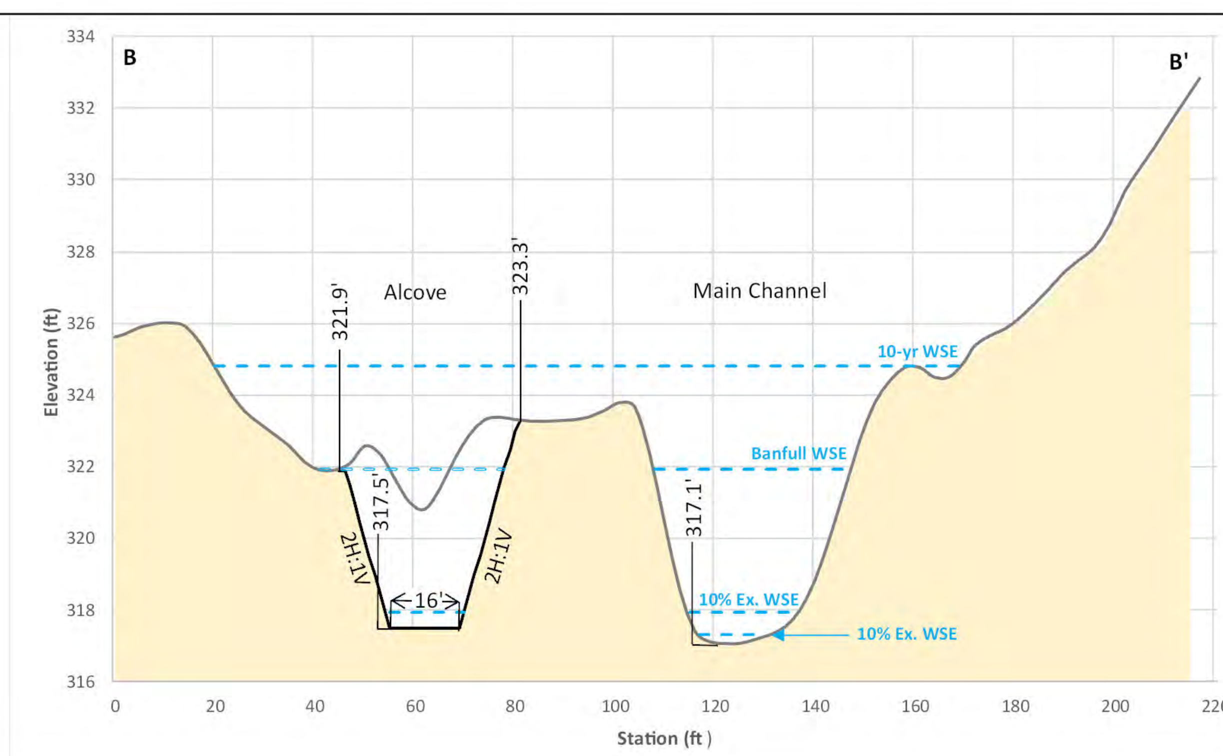
Site R3 Summary

- Enhance existing alcoves in 10-yr floodplain
- Use fill to better define alcove heads and sides
- Place log strucutres in main channel and enhanced alcoves
- Total Cut: ~820 cubic yards
- Total Fill: 70 cubic yards
- Spread surplus fill on onsite field and stabilize with native vegetation
- Pieces of Large Woody Debris Placed in Channel: 27+
- Pieces of Large Woody Debris Place in Alcoves: 21+
- Area of Alcoves Enhanced: ~6,000 square feet
- Length of Channel Improved: 900 feet



Cross-Section A - A' and Cross - Section B - B' Notes

- Excavation should mimic the existing alcoves
- Design alcoves grades to activate between winter baseflowand the 10% exceedence flow
- Top of alcove banks to be above the bankfull water surface elevation
- Side slopes should be graded at a maximum grade of 2H:1V and should be extended to tie in with existing topography
- Base of alcoves to be graded at appropriate slope (~2%) to decrease fish strandings
- Place log structures in alcove to provide cover
- Water surface elevations shown in figures are for main channel only



Redwood Creek Salmonid Winter Habitat Improvement Conceptual Plan - Site R3

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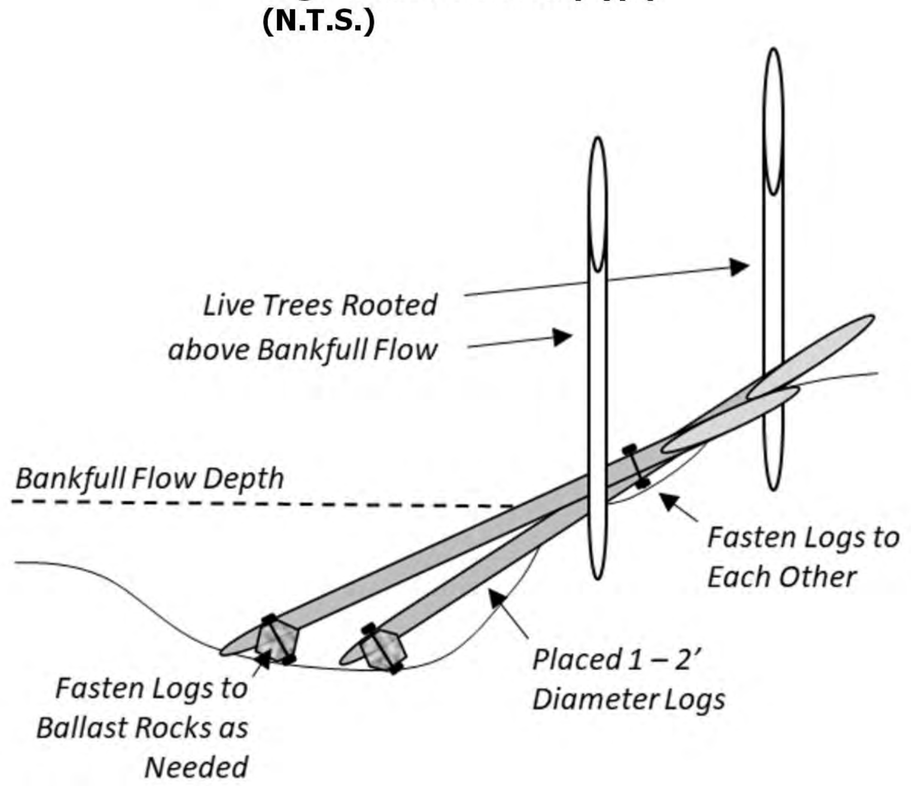
Site R4 Summary

- Stabilize recent bank failure by laying back slope and planting with riparian vegetation. Direct flows away from bank with approximately 6 deflector logs.
- Place log structures in main channel and in alcove formed in alcove formed after bank faulure
- Total Cut: 900 cubic yards
- Total Fill: 0 cubic yards
- Spread surplus fill on onsite field and stabilize with native vegetation
- Pieces of Large Woody Debris Placed in Channel: 22+
- Length of Channel Improved: ~900 feet

Legend

- Channel Alignment
- Old Channel Alignment
- 2-ft Contours, Existing
- 2-ft Contours, Proposed
- Bank Failure
- Cut
- Fill
- Wood Structure
- Modeled 10-yr Flows
- Modeled Bankfull Flows
- Modeled Winter Baseflow
- Parcel Boundary

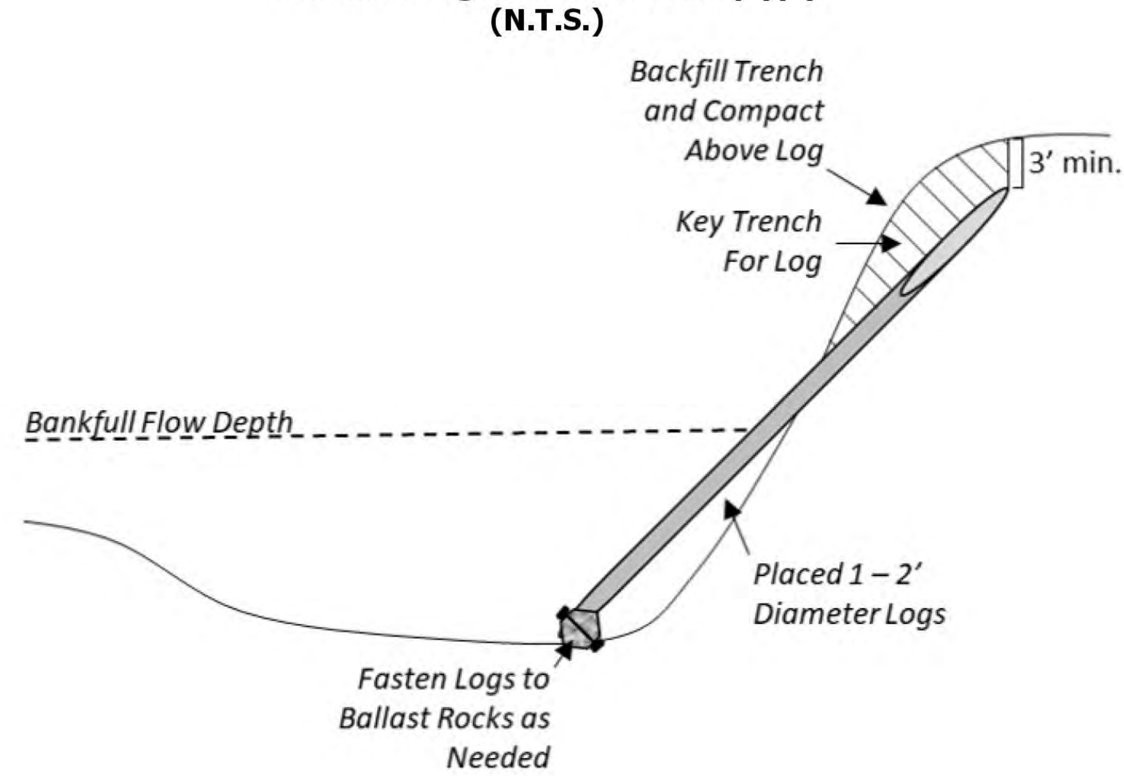
Log Structure Detail (Typ.)
(N.T.S.)



Log Structure Detail Notes

- Place logs where channel substrate allows scour to occur
- Avoid placing logs on insides of channel bends
- In main channel each log structure to contain a minimum of three interlocking 30'+ logs with a minimum diameter of 1'
- In alcoves log structures to contain one or more 30'+ logs with a minimum diameter of 1'
- Weave logs among live 1'+ diameter trees rooted above the bankfull depth
- Where possible the placed logs should be braced against a live tree downstream of the middle portion of the placed log and a live tree upstream of the upper end of the placed log
- If bank height or lack of anchoring trees requires, logs may also be trenched into banks (see Trenched Log Structure Detail)
- Weight lower portion of log with a placed ballast rock
- Fasten logs to each other and to ballast rocks using threaded 1" steel rebar and locking nuts (see example photographs)
- Logs should include rootwads when available

Trenched Log Structure Detail (Typ.)
(N.T.S.)



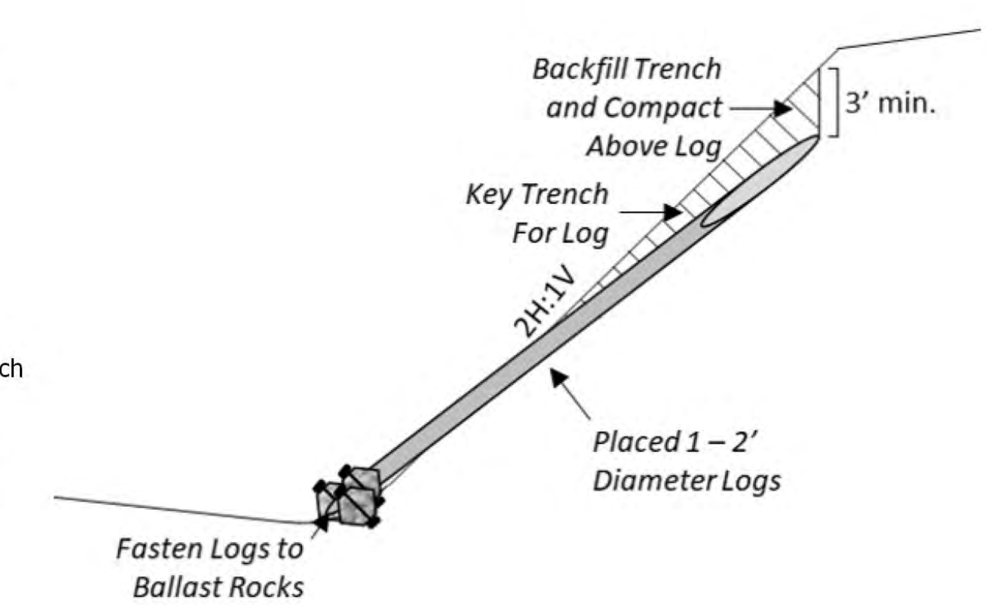
Trenched Log Structure Detail Notes

- Key upper portion of log into bank with 3-ft deep (min.) trench
- Backfill trench and compact material over log
- Attach soil anchors to logs if less than 50% burried
- Maximize length of log in contact with bank
- All other design details same as for standard log strcuture

Deflector Log Detail Notes

- Logs to have minimum diameter of 1' and sufficient length to extend to top of bank
- Orient logs upstream at 30 - 45 degree angle
- Position bottom of log flush with cut slope
- Key upper portion of log into bank with 3-ft deep (min.) trench
- Backfill trench and compact material over log
- Place multiple ballast rocks at base of log
- Fasten log to ballast rocks using 1" steel rebar and locking nuts (see example photographs)
- Attach soil anchors to logs if less than 50% burried

Deflector Log Detail (Typ.)
(N.T.S.)



Redwood Creek Salmonid Winter Habitat Improvement Conceptual Plan - Site R4

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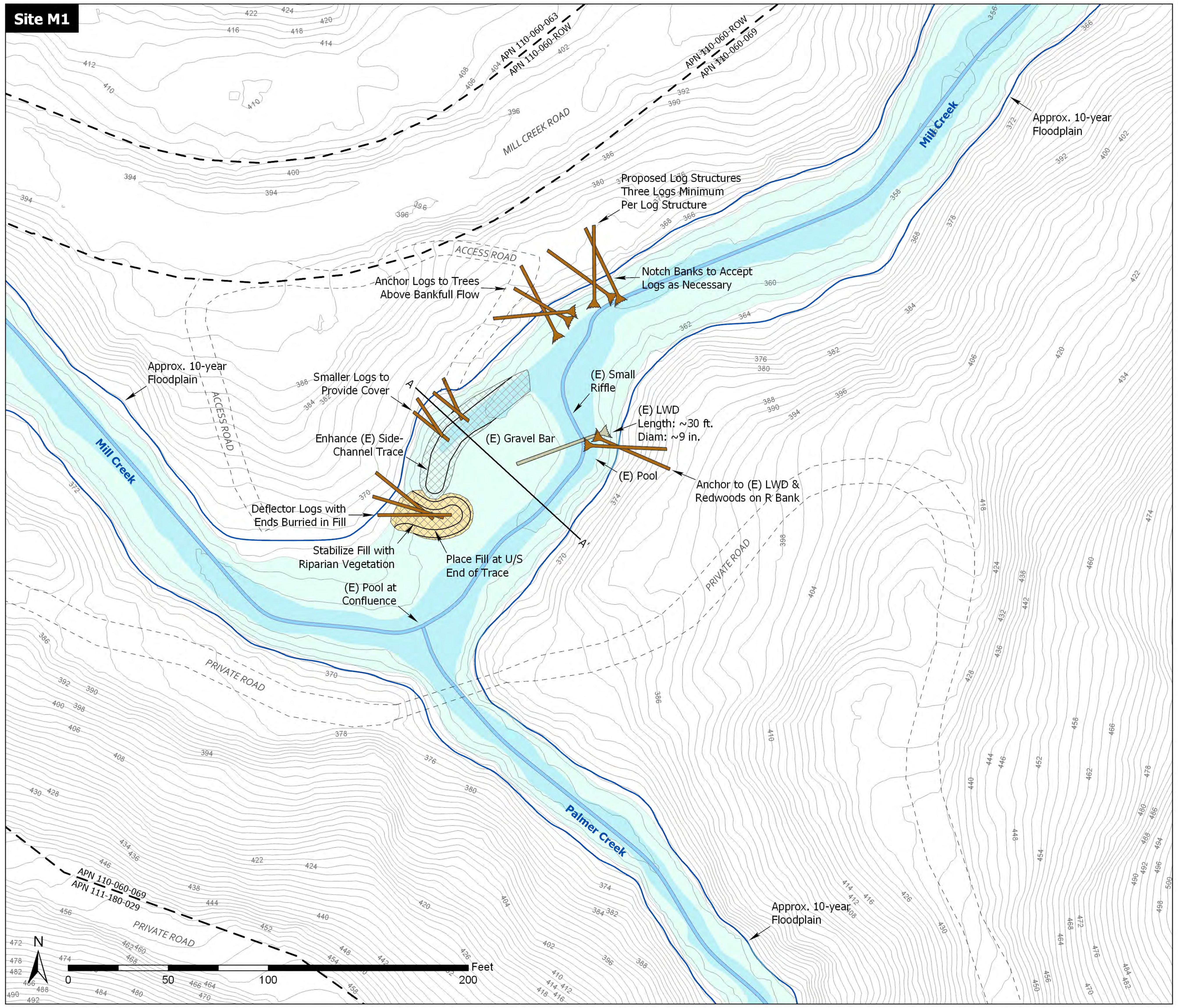
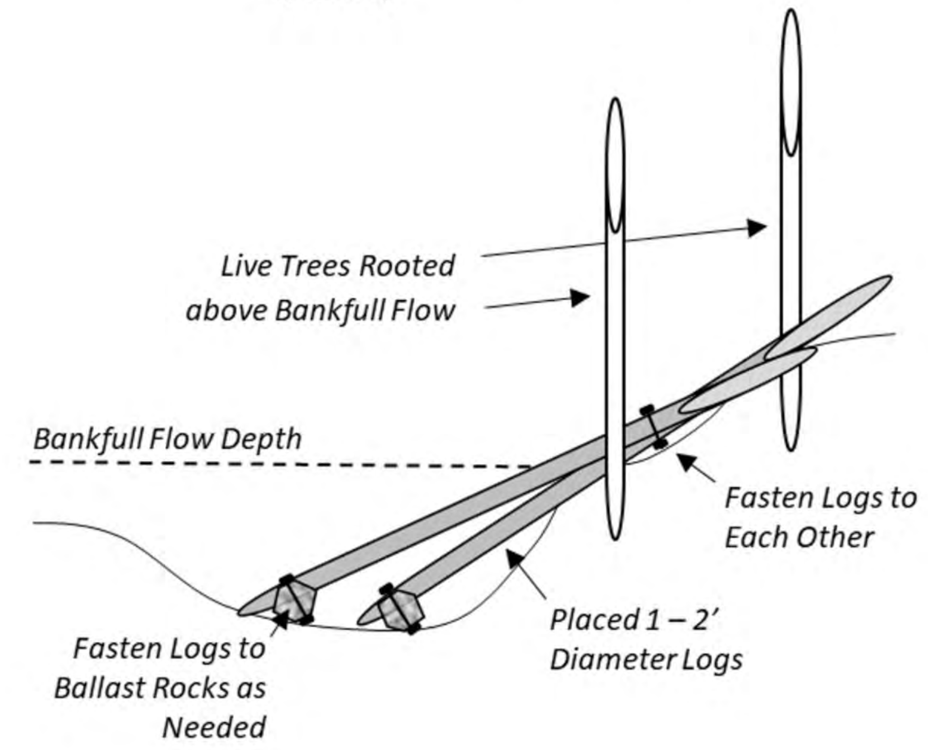


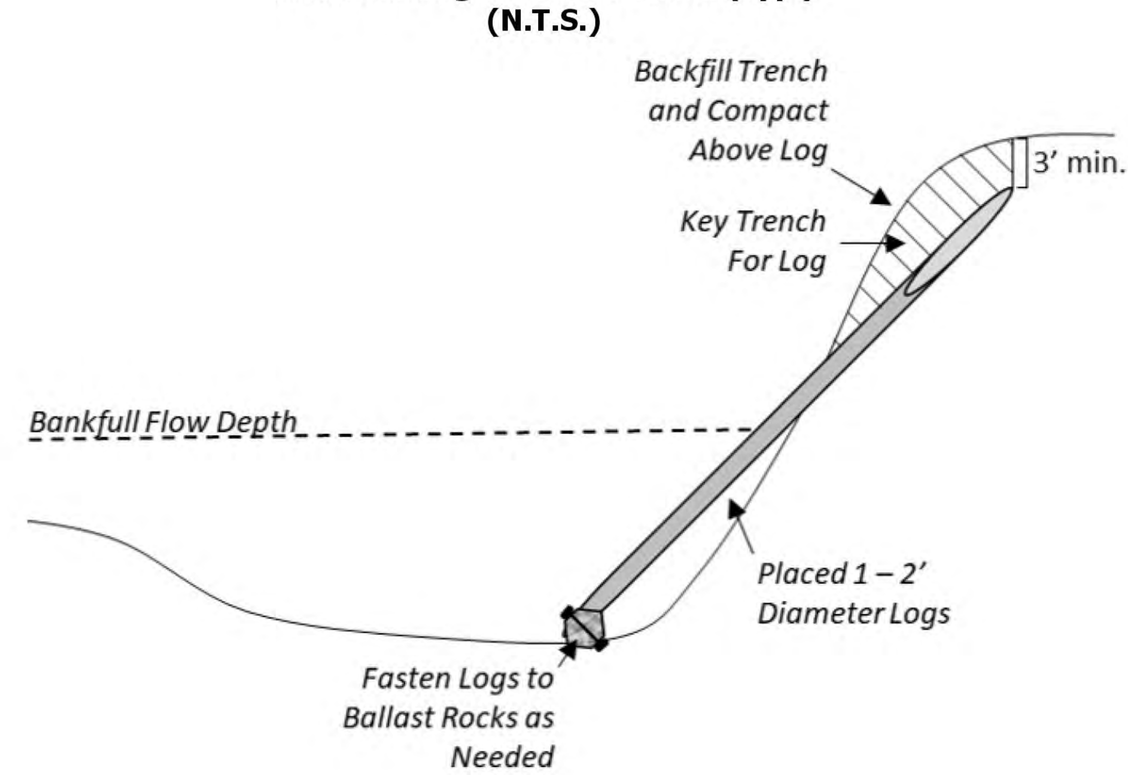
Log Structure Detail (Typ.) (N.T.S.)



Log Structure Detail Notes

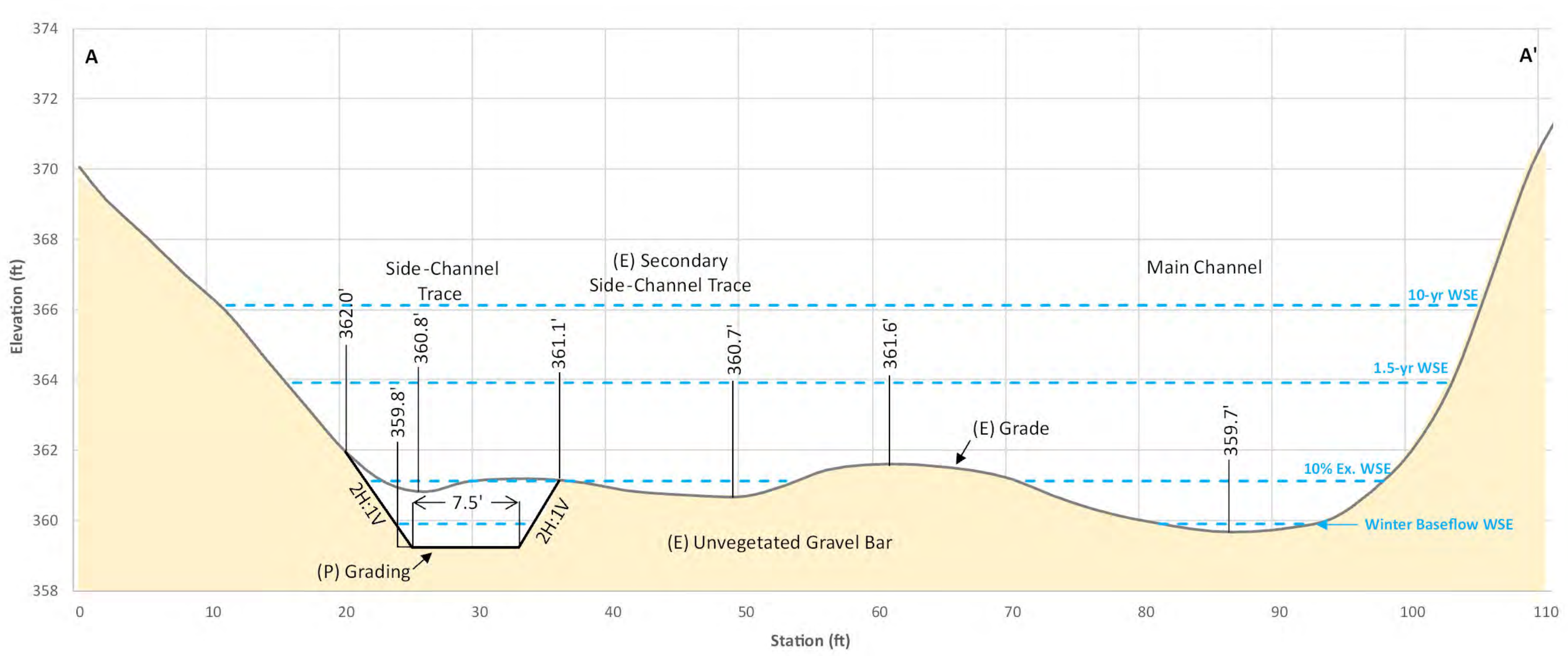
- Place logs where channel substrate allows scour to occur
- Avoid placing logs on insides of channel bends
- In main channel each log structure to contain a minimum of three interlocking 30'+ logs with a minimum diameter of 1'
- In alcoves log structures to contain one or more 30'+ logs with a minimum diameter of 1'
- Weave logs among live 1'+ diameter trees rooted above the bankfull depth
- Where possible the placed logs should be braced against a live tree downstream of the middle portion of the placed log and a live tree upstream of the upper end of the placed log
- If bank height or lack of anchoring trees requires, logs may also be trenched into banks (see Trenched Log Structure Detail)
- Weight lower portion of log with a placed ballast rock
- Fasten logs to each other and to ballast rocks using threaded 1" steel rebar and locking nuts (see example photographs)
- Logs should include rootwads when available

Trenched Log Structure Detail (Typ.) (N.T.S.)



Trenched Log Structure Detail Notes

- Key upper portion of log into bank with 3-ft deep (min.) trench
- Backfill trench and compact material over log
- Attach soil anchors to logs if less than 50% burried
- Maximize length of log in contact with bank
- All other design details same as for standard log strcuture



Cross-Section A - A' Notes

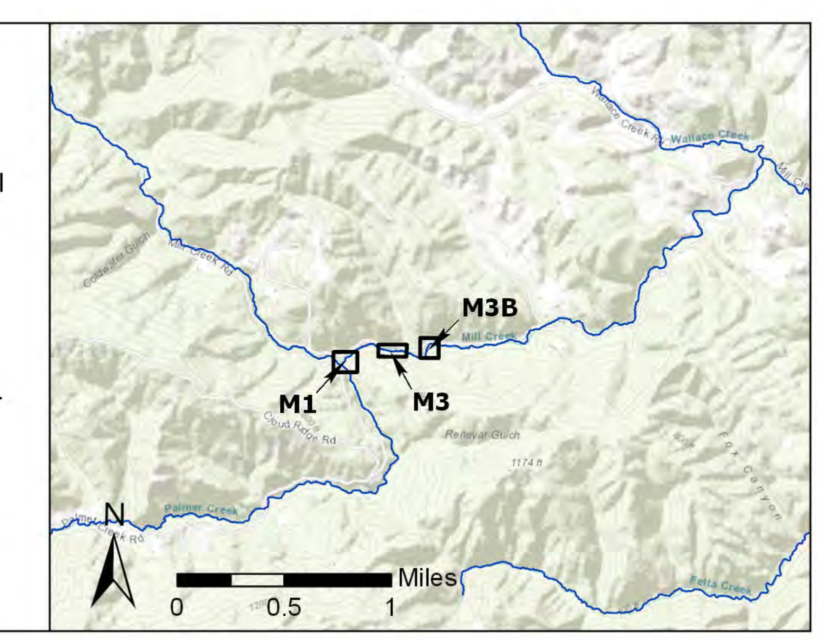
- Excavation should mimic the existing shallow side-channel and should be adjuste in the field to minimize disturbances to steep banks
- Invert of excavated side-channel to be less than water surface elevation associated with winter baseflow
- Side slopes should be graded at a maximum grade of 2H:1V and should be extended to tie in with existing topography
- Base width of excavation to be approximately 10 feet at downstream end narrowing to approximately 5 feet at upstream end
- Base of excavated side-channel to be graded at appropriate slope (~2 %) to decrease potential fish strandings
- Top of fill placed at upstream end of side-channel thread to be above water surface elevation associated with bankfull flow
- Place log structures in side-channel trace to provide cover
- Water surface elevations shown in figures are for main channel only

Legend

- Thalweg
- 2ft Contours, Existing
- 2ft Contours, Proposed
- Cut
- Fill
- Existing Large Woody Debris
- Proposed Wood Structure
- Modeled Winter Baseflow
- Modeled Bankfull Flow
- Modeled 10-yr Flow
- Parcel Boundary
- Unpaved_Roads

Site M1 Summary

- Enhance existing shallow side-channel
- Place fill at upstream end of side-channel to deflect flows and minimize sediment deposition within enhanced channel
- Stabilize fill with riparian vegetation and log structures
- Place log structures in main channel and in enhanced side-channel
- Total Cut: 40 cubic yards
- Total Fill: 40 cubic yards
- Pieces of Large Woody Debris Placed in Channel: 11+
- Pieces of Large Woody Debris Place in Enhanced Trace: 4+
- Area of Gravel Bar Enhanced: ~750 square feet
- Length of Channel Improved: ~250 feet



Mill Creek Salmonid Winter Habitat Improvement Conceptual Plan - Site M1

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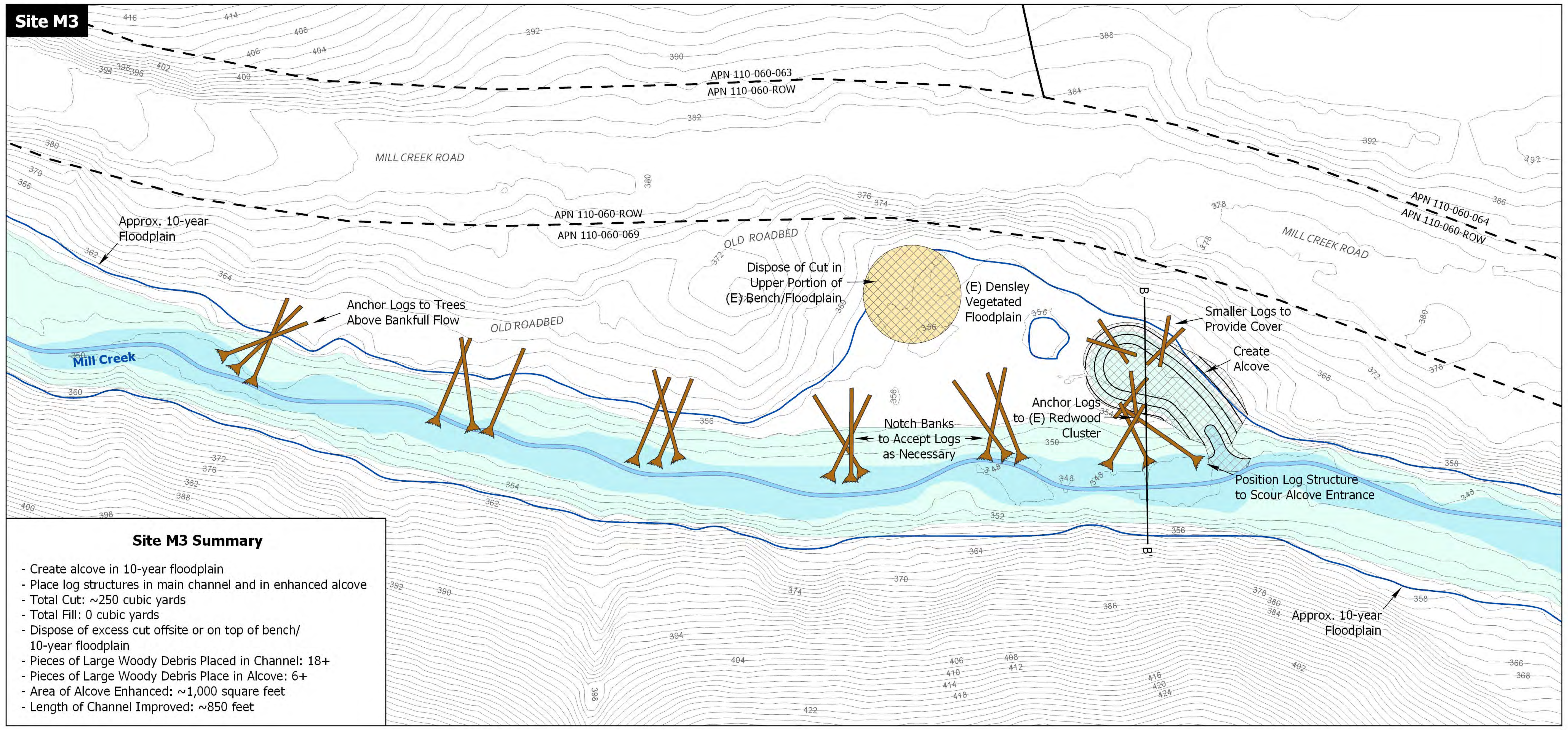
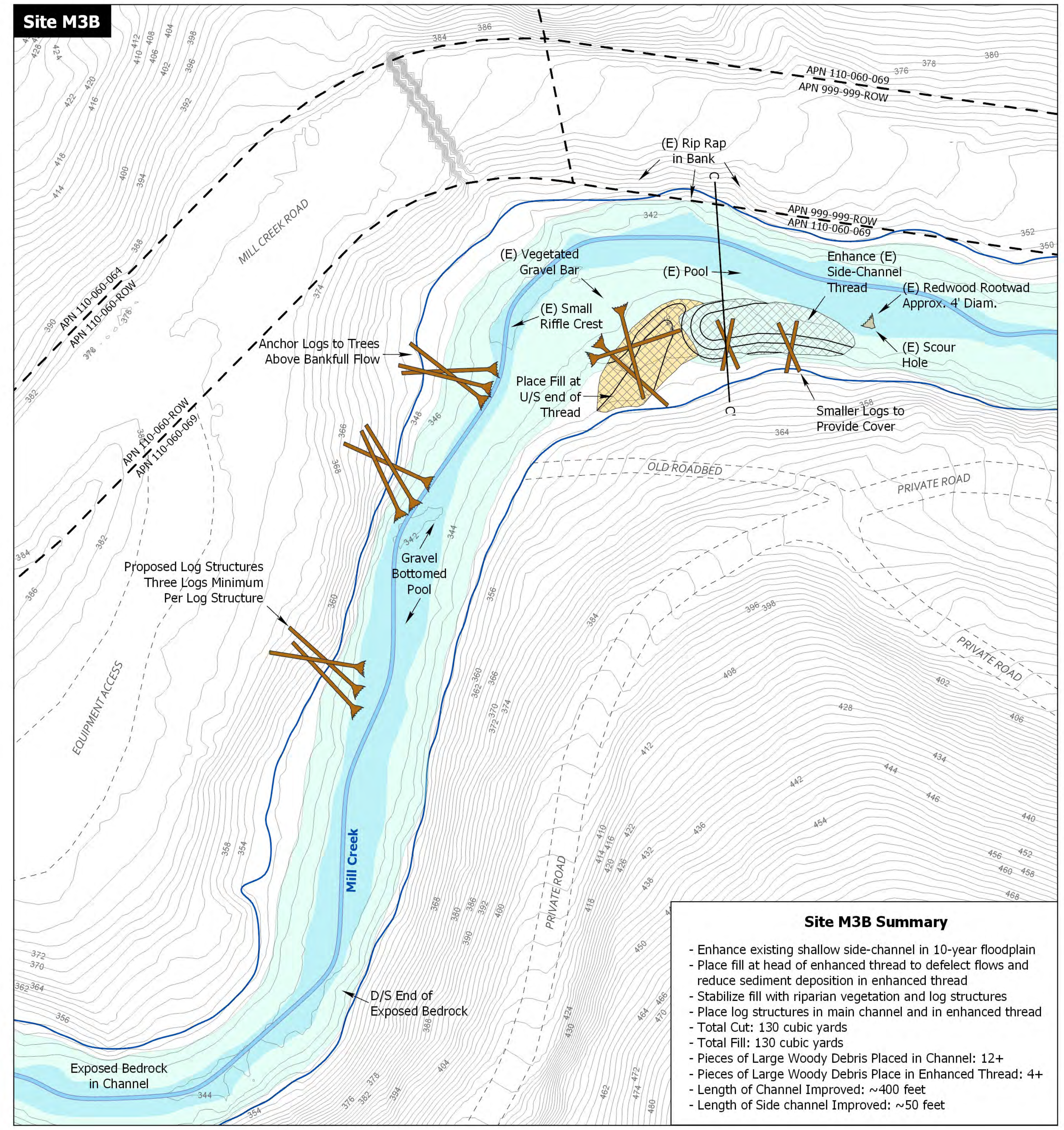


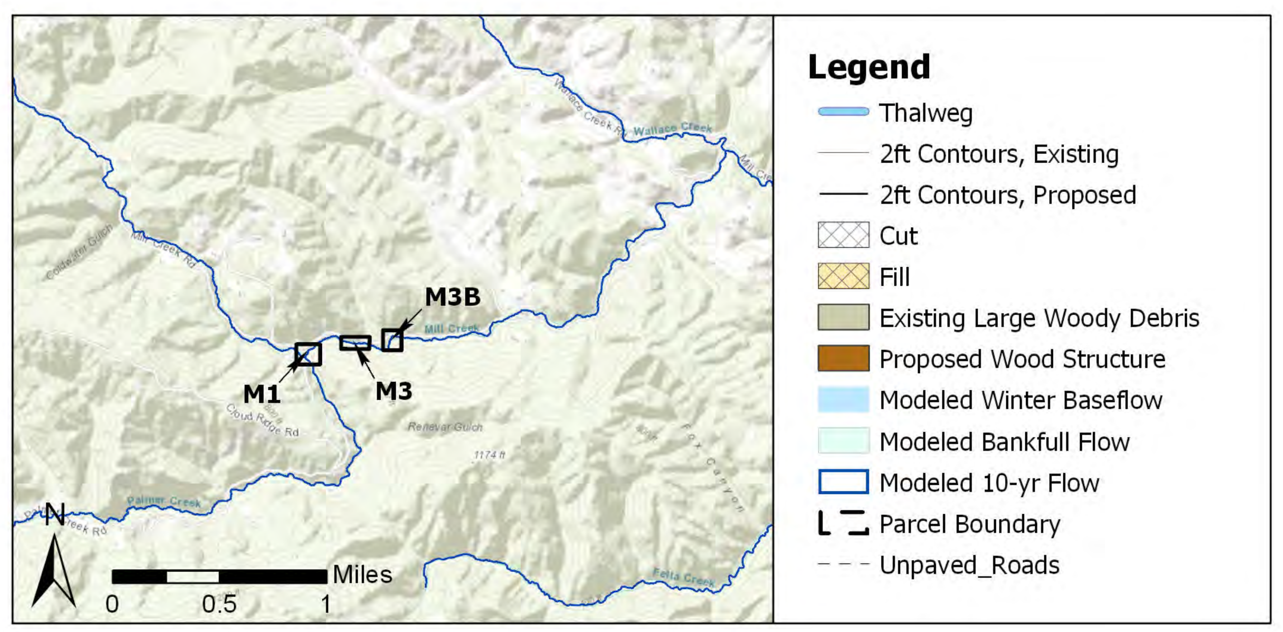
Site M3 Summary

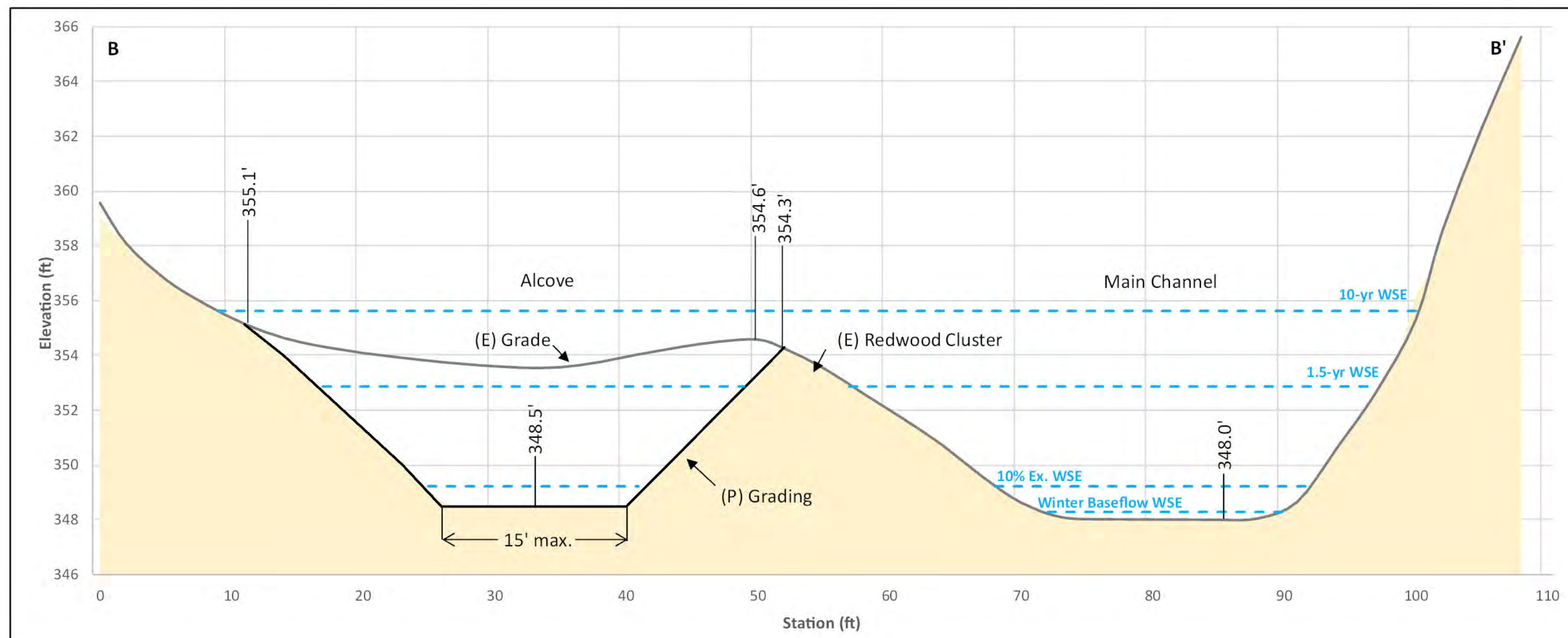
- Create alcove in 10-year floodplain
- Place log structures in main channel and in enhanced alcove
- Total Cut: ~250 cubic yards
- Total Fill: 0 cubic yards
- Dispose of excess cut offsite or on top of bench/ 10-year floodplain
- Pieces of Large Woody Debris Placed in Channel: 18+
- Pieces of Large Woody Debris Place in Alcove: 6+
- Area of Alcove Enhanced: ~1,000 square feet
- Length of Channel Improved: ~850 feet



Site M3B Summary

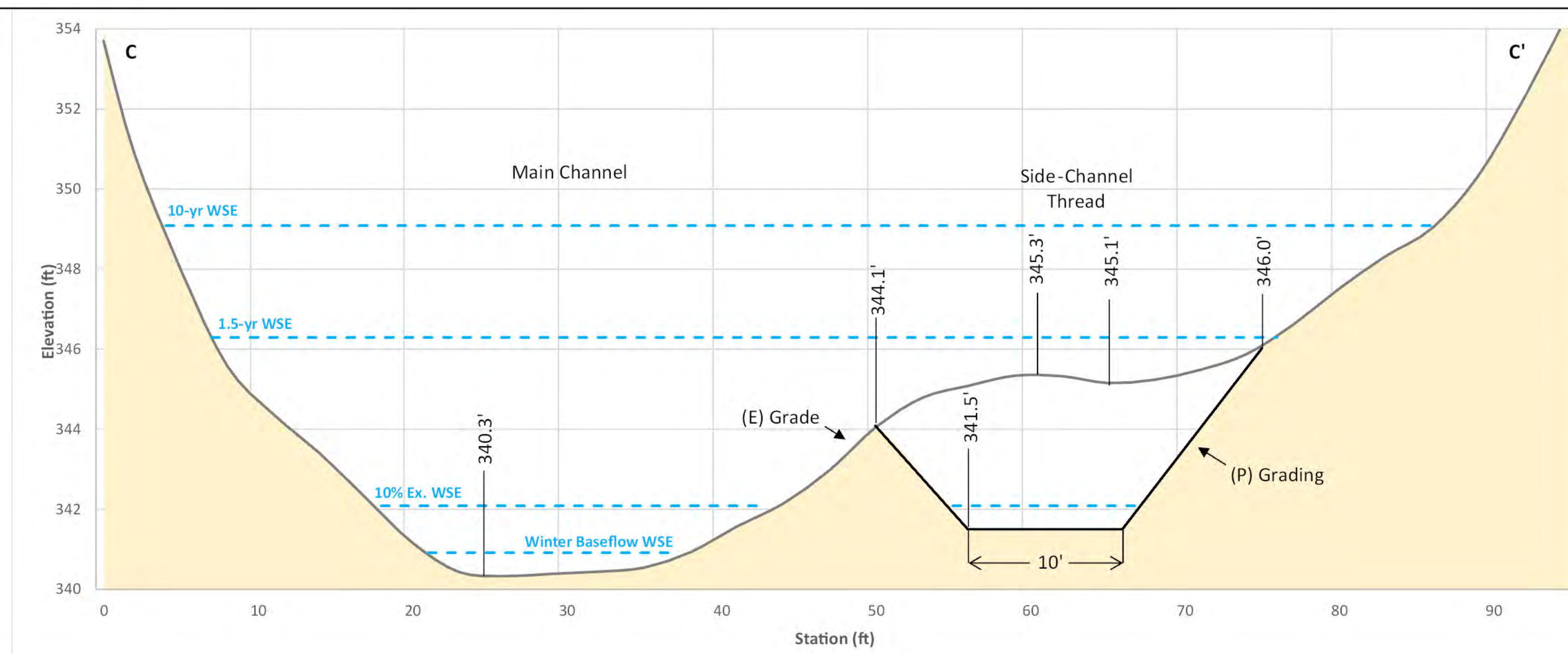
- Enhance existing shallow side-channel in 10-year floodplain
- Place fill at head of enhanced thread to defelect flows and reduce sediment deposition in enhanced thread
- Stabilize fill with riparian vegetation and log structures
- Place log structures in main channel and in enhanced thread
- Total Cut: 130 cubic yards
- Total Fill: 130 cubic yards
- Pieces of Large Woody Debris Placed in Channel: 12+
- Pieces of Large Woody Debris Place in Enhanced Thread: 4+
- Length of Channel Improved: ~400 feet
- Length of Side channel Improved: ~50 feet





Cross-Section B - B' Notes

- Excavation should mimic existing topography and should be adjusted in the field to minimize disturbances to steep banks
- Invert of alcove entrance to be less than the water surface elevation associated with winter baseflow
- Side slopes should be graded at a maximum grade of 2H:1V and should be extended to tie in with existing topography
- Entrance of alcove to have a minimum base width of 5 feet and to be oriented facing slightly downstream
- Adjust limits of grading in field to avoid impacts to existing multi-trunk redwood cluster immediately upstream of entrance to alcove
- Base of alcove to be graded at appropriate slope (~2%) to decrease fish strandings
- Place log structures in alcove to provide cover
- Water surface elevations shown in figures are for main channel only



Cross-Section C - C' Notes

- Excavation should mimic the existing shallow side-channe and should be adjusted in field to minimize impacts to steep banks
- Invert of excavated shallow side-channel to be less than the watersurface elevation associated with the 10% exceedence flow and greater than the water surface elevation associated with winter baseflow
- Side slopes should be graded at a maximum grade of 2H:1V and should be extended to tie in with existing topography
- Downstream end of excavated to have a minimum base width of approximately 10 feet and to be oriented facing slightly downstream
- Base of excavated side channel to be graded at appropriate slope (~2%) to decrease potential fish strandings
- Place log structures in excavated trace to provide cover
- Water surface elevations shown in figures are for main channel only

Mill Creek Salmonid Winter Habitat Improvement Conceptual Plan - Sites M3 & M3B

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