Yakama Nation Fisheries

ENTIAT RIVER RESTORATION DESIGN:

Upper Stillwaters Reach

CONCEPT LEVEL DESIGN

TETRA TECH

May 2018

ENTIAT RIVER RESTORATION DESIGN - UPPER STILLWATERS REACH

CONCEPT LEVEL DESIGN

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1. PREFACE

This report for the Entiat River Restoration Design – Upper Stillwaters Reach (Project) is based on the General Project Data Summary Requirements (GPDSR) Basis of Design Report template for Bonneville Power Administration (BPA) Habitat Improvement Program (HIP III) projects (BPA 2017). Some formatting changes have been made to the template but the sections and requested information follow the template structure.

The design process for the Project as established by the Yakama Nation Fisheries includes the following steps and review junctures:

- Development of Concept-level Report and Drawings (this submittal)
- Development of Permit-level Report and Drawings
- Development of Final Construction Plan

1.1 Name and titles of sponsor, firms and individuals responsible for design

Project Name: Entiat River Restoration Design – Upper Stillwaters Reach (Project)

Project Location: Entiat River, River Mile (RM) 25.6 to 31.5, approximately 20 miles northeast of Entiat, Washington (See Figure 1-1)

Sponsor: Yakama Nation Fisheries,1885 S. Wenatchee Avenue, Wenatchee, WA 9801

Yakama Habitat Biologist: Chris Clemons

Engineering firm: Tetra Tech, Inc. (Tetra Tech), 19803 North Creek Parkway, Bothell, WA 98011

Project Manager: Jonathan Thompson

Lead Design Engineer: Chad Bailey, PE, CFM

Water Resources Engineer: Chad McKinney, PE, CFM

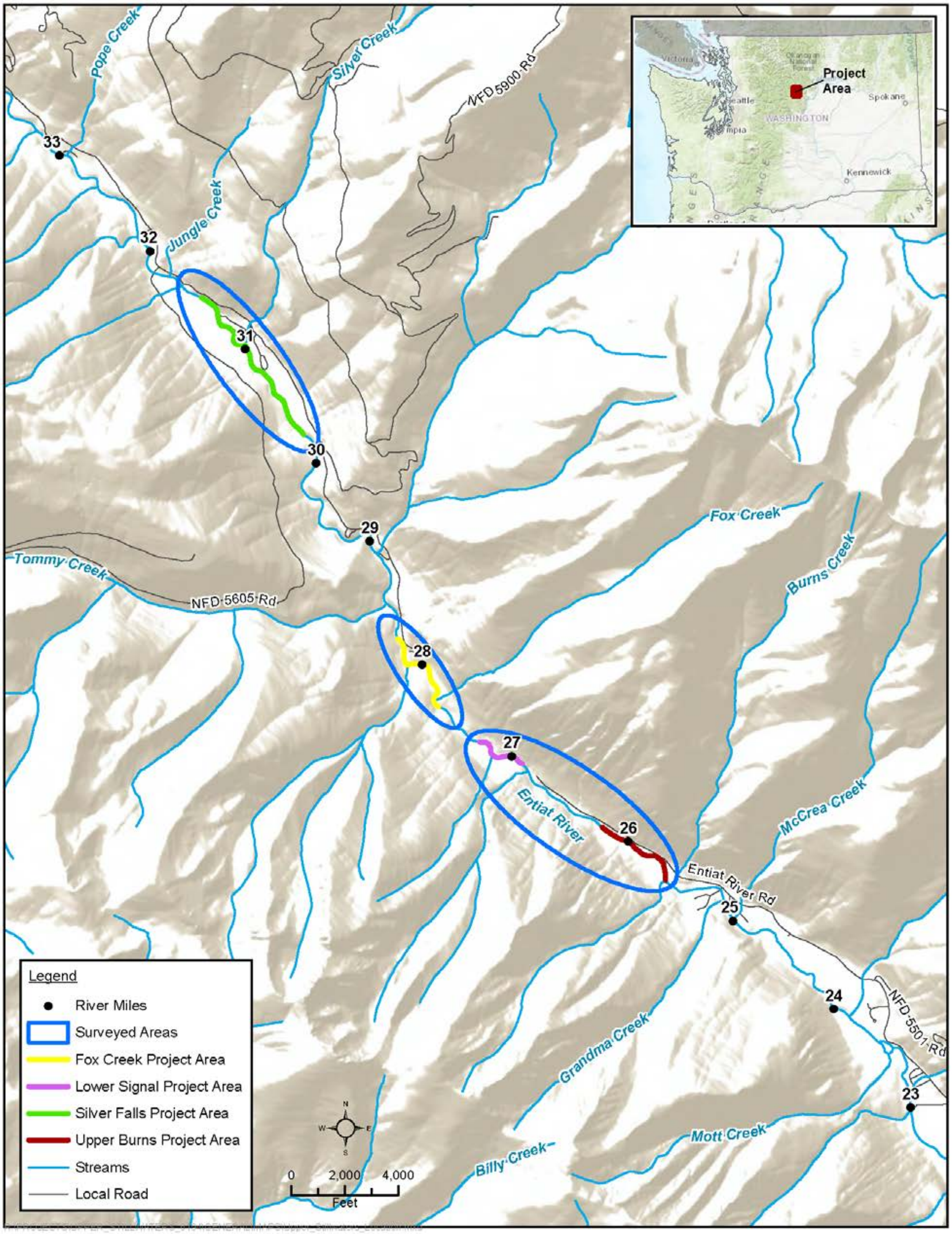


Figure 1-1. Project Vicinity Map

1.2 List of project elements that have been designed by a licensed professional engineer

Project Plan Sheets (see Appendix A). The Construction Specifications and Engineer's Cost Estimate will be provided at the Permit Level Design stage.

1.3 Identification and description of risk to infrastructure or existing resources

The Project is located on the Entiat River, within the area commonly referred to as the Upper Stillwaters Reach. The overall Project area covers the stream between river miles (RMs) 25.6 and 31.5. Most of the surrounding property is publicly owned forests managed by the U.S Department of Agriculture - Forest Service (USFS), except for small parcels of private land ownership near the downstream end of the Project (near RM 25.7). Project reaches that were identified for restoration work within the overall Project area include the following:

- Burns Reach – between RM 25.56 and RM 26.10 (0.54 miles)
- Lower Signal Reach – between RM 26.95 and RM 27.18 (0.23 miles)
- Fox Creek Reach – between RM 27.66 and RM 28.28 (0.62 miles)
- Silver Falls Reach – between RM 30.28 and RM 31.50 (1.22 miles)

Collectively these four reaches total 2.61 stream miles. Stream reaches where gaps occurred were not proposed for restoration actions at this time. The majority of the Project lies within undeveloped and remote lands. Specific locations within the Project that were identified as areas of concern to infrastructure include the Entiat River Road, which runs parallel to the Entiat River in portions of the Burns, Lower Signal, and Fox Creek reaches. There are several locations where current bank erosion is putting the road at risk. Other potential infrastructure risks include residences located in the Burns Reach on river left at RM 25.6 to 25.7, the Fox Creek Campground, and the Silver Falls Campground and associated streamside trails and interpretive stations.

Other risks presented by the anticipated Project elements include mobilization of LWD, and potential boater safety concerns. The risk of mobilization of LWD will be addressed through Project design criteria for stability and construction methods that will create stability through anchoring, ballasting, excavation, and entwining with existing vegetation. Boater safety concerns involve those associated with potential collisions with installed LWD structures and will be evaluated to determine public boat use, and if necessary include any necessary safety measures such as bumper logs or other means to promote safe boater passage around proposed structures.

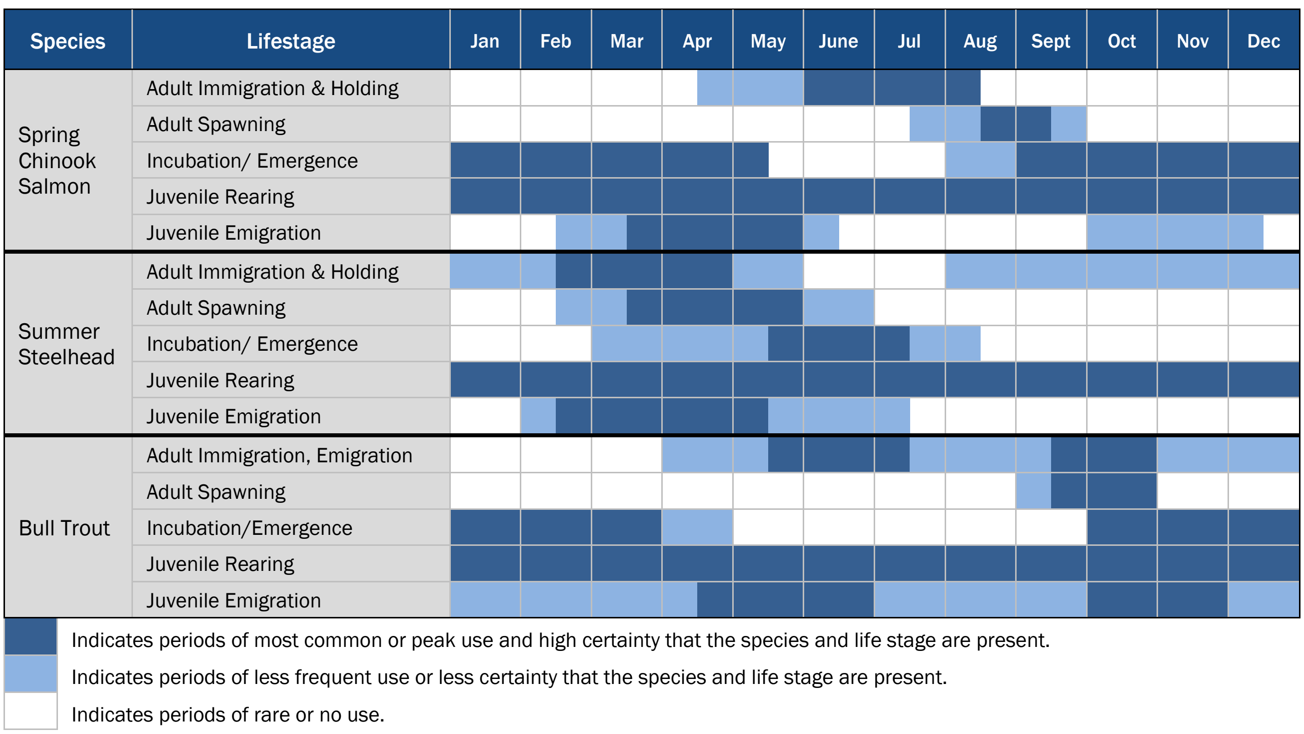
1.4 Explanation and background on fisheries use (by life stage - period) and limiting factors addressed by project

1.4.1 Project Background

The Yakama Nation Fisheries (YNF) Upper Columbia Habitat Restoration Program is focused on implementing science-based restoration projects in the Upper Columbia River Basin that benefit Endangered Species Act (ESA)-listed fish species. Habitat restoration priorities, objectives, and treatments are guided by the Upper Columbia Spring Chinook Salmon, Steelhead Recovery Plan (UCSRB 2007), that also covers bull trout, and by A Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region (Biological Strategy) (UCRTT 2014). While there are many fish species, both native and introduced, that reside in the Entiat River, the Project is primarily concerned with future restoration and enhancement actions that will benefit ESA-listed spring Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), and bull trout (*Salvelinus* *confluentus*). Other species may also benefit from these action, including summer Chinook salmon, sockeye salmon (*O. nerka*), resident rainbow/redband (*O. mykiss gairdneri*), westslope cutthroat trout (*O. clarki lewisi*), mountain whitefish (*Prosopium williamsoni),* and Pacific lamprey (*Entosphenus tridentatus*), and the introduced eastern brook trout (*Salvelinus fontinalis*) (NPCC 2005; USFWS 2015a). Coho salmon (*O. kisutch*) were extirpated from the Entiat River, but reintroduction is being considered by fishery co-managers.

1.4.2 Fish Use and Limiting Factors

As mentioned above, there are three fish populations within the Entiat River that are protected under the ESA: spring Chinook salmon, summer steelhead, and bull trout. The Upper Columbia River (UCR) spring Chinook salmon evolutionary significant unit (ESU) was listed as endangered in 1999. This status determination was reaffirmed in 2005 (NOAA Fisheries 2017). The UCR steelhead distinct population segment (DPS) was originally listed as endangered in 1997, but was relisted as threatened in 2007. The revised status was confirmed in 2009. The National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries) designated the Entiat River and certain tributaries as critical habitat for spring Chinook salmon and steelhead in 2005 (NOAA Fisheries 2005). Bull trout were listed as threatened in 1999. The U.S. Fish and Wildlife Service (USFWS) designated the Entiat River as critical habitat for bull trout in 2010. The Entiat River in this reach is an important migration corridor for spring Chinook salmon, steelhead, and bull trout, and contains spawning and rearing habitat for all three species (Figure 1-2).



Sources: Andonaegui (1999), NPCC 2005

Figure 1-2 Fish Periodicity Chart for the Focal Fish Species

Ecological concerns (also commonly known as limiting factors) are defined as the physical, biological or chemical features experienced by fish that result in reductions in viable salmonid population parameters (abundance, productivity, spatial structure, and diversity). Several documents discuss ecological concerns/limiting factors within the Entiat River subbasin, including the following:

- Salmon and Steelhead Habitat Limiting Factors Report for the Entiat Watershed (Andonaegui 1999)

- Entiat Subbasin Plan (NPCC 2005)
- Columbia Basin Fish Accords (Three Treaty Tribes-Action Agencies 2008)
- Upper Columbia Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan (UCSRB 2009)
- Entiat Tributary Assessment (USBR 2009)
- Federal Columbia River Power System Biological Opinion Tributary Habitat Program (FCRPS 2012) Lower Entiat Reach Assessment
- Lower Entiat Reach Assessment (USBR 2012)
- Entiat River – Upper Stillwaters Reach Stream Corridor Assessment and Habitat Restoration Strategy (Inter-Fluve 2013)
- A Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region. (Biological Strategy; UCRTT 2014)

The Entiat Subbasin plan (NPCC 2005) conducted an Ecosystem Diagnosis and Treatment (EDT) analysis of the subbasin to evaluate aquatic habitat conditions. Based on that analysis, within the Middle Entiat Assessment Unit (from RMs 16.2 to 33.8), the factors limiting focal species fish production were summarized as follows:

- Low stream channel complexity and habitat diversity;
- Loss of large wood and key side channel habitat;
- Surface erosion and sediment delivery;
- Possible harassment and poaching of spawning salmonids; and
- Lack of nutrients from salmon carcasses and loss in primary productivity and salmonid food sources.

In some areas riparian and floodplain conditions have been impacted by harvest, fires, and roads in the riparian zones. Fish passage in several tributaries is hindered or blocked for juveniles, but is good within the mainstem.

The Bands of the Yakama Nation were one of three tribes included in a memorandum of agreement with BPA, the U.S. Army Corps of Engineers (USACE), and the U.S. Bureau of Reclamation (USBR). The memorandum, referred to as the Columbia River Basin Fish Accords (Three Treaty Tribes-Action Agencies 2008), listed three Primary Limiting Factors for the Entiat River in the Middle – Stillwater reach. Those limiting factors were Ecological-Community, In-Channel Characteristics, and Passage/Entrainment. These limiting factors applied to both spring Chinook salmon and steelhead.

Another recent document is the Entiat River – Upper Stillwaters Reach Stream Corridor Assessment and Habitat Restoration Strategy (Inter-Fluve 2013). That assessment determined Reach-based Ecosystem Indicators (REI) for 13 geomorphic reaches. The REI analysis provides a standardized method to summarize habitat impairments and compare geomorphic and ecosystem functionality. Each metric was evaluated against specific REI criteria and rated as adequate, at risk, or unacceptable condition. The results for the Entiat River for geomorphic reaches 2, 3, 5, and 9 that correspond very closely with the project designated Burns, Lower Signal, Fox Creek, and Silver Falls reaches are presented in Table 1-1. The results indicate that within the Project the habitat quality indicators for LWD and pools were “Unacceptable.” Five REI categories were identified as “At Risk,” and the remaining four indicators were considered to be “Acceptable.”

Table 1-1. Entiat River Reach-Based Ecosystem Indicator Ratings

General Characteristics	General Indicators	Specific Indicators	Reach 2 Rating	Reach 3 Rating	Reach 5 Rating	Reach 9 Rating	Existing Conditions	Target Values/Condition
Habitat Access	Physical Barriers	Main Channel Barriers	Adequate	Adequate	Adequate	Adequate	All are adequate	No manmade barriers present
Habitat Quality	Substrate	Dominant substrate/Fine sediment	Adequate	Adequate	Adequate	Adequate	All are adequate	Dominant substrate is gravel or cobble; embeddedness <20%, 12% fines in spawning gravel
	LWD	Pieces/mile at bankfull	Unacceptable	Unacceptable	Unacceptable	Adequate	Reach 2: 29 pieces per mile Reach 3: 24 pieces per mile Reach 5: 36 pieces per mile Reach 9: 92 pieces per mile	42.5 pieces/mile >35 feet long
	Pools	Pool frequency and quality	Unacceptable	Adequate	Adequate	At risk	Reach 2: 3.9 pools per mile Reach 3: 7.1 pools per mile Reach 5: 5.2 pools per mile Reach 9: 5.7 pools per mile	4 per mile, with good cover, cool water, low sediment volume, and >1 meter deep
	Off-Channel Habitat	Connectivity with main channel	At risk	At risk	At risk	At risk	Percent side channel habitat: Reach 2: 1 Reach 3: 7 Reach 5: 1 Reach 9: 10	Reach has ponds, oxbows, backwaters, and other low-energy off-channel areas with cover; similar to conditions that would be expected in the absence of human disturbance.
Channel	Dynamics	Floodplain connectivity	Adequate	Adequate	Unacceptable	Adequate	Reach 5: 50% disconnected	<10% floodplain disconnected
		Bank stability/Channel migration	Adequate	At risk	Unacceptable	Adequate	Bank Armoring or Erosion Percent: Reach 3: 5% Armored Reach 5: 15% Armored	Channel is migrating at near natural rates
		Vertical channel stability	Adequate	Adequate	At risk	Adequate	Reach 5: Presence of bridges or roads, and campground.	No measurable trend of aggradation or incision and no visible change in channel planform.
Riparian Vegetation	Condition	Structure	At risk	At risk	At risk	Adequate	Reaches 2, 3, and 5 with few mature or large trees.	>80% species composition, seral stage, and structural complexity are consistent with potential native community.
		Disturbance (human)	At risk	Adequate	Unacceptable	At risk	Reach 5: Road density was 14 miles of road per square mile	>80% mature trees (medium---large) in the riparian buffer zone (defined as a 30-meter belt along each bank) that are available for recruitment by the river via channel migration; <20% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); <2 mi/mi2 road density in the floodplain.
		Canopy cover	At risk	Adequate	Adequate	Adequate	Reach 2: clearing due to residential and road developments	Trees and shrubs within one site potential tree height distance have >80% canopy cover that provides thermal shading to the river.

Adequate At risk Unacceptable

Adapted from Inter-Fluve (2013)

In addition to the REI indicators mentioned above, the Entiat River – Upper Stillwaters Reach Stream Corridor Assessment and Habitat Restoration Strategy (Inter-Fluve 2013) and the Entiat Subbasin Plan (NPCC 2005) both describe how icing of the river in the winter can have adverse effects on both stream habitat and fish. River ice may form as anchor ice or frazil ice (needle shaped ice crystals). Anchor ice can scour stream bed and banks, damage riparian vegetation, and be harmful or lethal to macroinvertebrates and incubating eggs and emerging fry.

The revised Biological Strategy document for the Upper Columbia River region (UCRTT 2014) contains the most recent information on ecological concerns. This document indicates that within the Upper-Middle Entiat River Assessment Unit (from RMs 26.0 to 36.0), the ecological concerns are as follows:

1. Channel Structure and Form (Instream Structural Complexity); and
2. Food (Altered Primary Productivity and Food Competition).

The factors affecting habitat conditions identified in the revised Biological Strategy for the Upper-Middle Entiat Assessment Unit include:

- Poor large woody debris recruitment and retention potential;
- Levees and rip-rapped banks;
- Entiat River Road;
- Forest management practices and road densities in the upper watersheds leading to reduced large wood recruitment and increased sediment input;
- Historic channel straightening for flood control;
- Reduced riparian condition and few mature trees decreasing the input of key wood pieces that would form persistent log jams; and
- Decades of depressed salmon returns resulting in reduction in marine-derived nutrients.

Collectively, these analyses of ecological concerns and REIs, combined with field survey results, were used to guide selection of Project features as discussed in the following section.

1.5 List of primary project features including constructed or natural elements

The primary Project features were selected based on regional and Project goals and objectives as described in Section 1.5.1. Based on those goals and objectives, a variety of constructed or natural design elements were then considered at the Concept Level Design stage (Section 1.5.2).

1.5.1 Project Goal and Objectives

Key recovery planning efforts that have addressed conditions in the Entiat Subbasin include the Entiat Subbasin Plan (NPCC 2005), the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (Recovery Plan; UCSRB 2007), the Recovery Plan for the Coterminous United States Population of Bull Trout (USFWS 2015b) and an update to that, the Mid-Columbia Recovery Unit Implementation Plan for Bull Trout (Salvelinus confluentus) (USFWS 2015c), and the revised Biological Strategy (UCRTT 2014). Additionally, in 2012, tribes and state and federal agencies signed the Conservation Agreement for Pacific Lamprey, which was developed “to promote implementation of conservation measures for Pacific Lamprey in Alaska, Washington, Oregon, Idaho, and California” (USFWS 2012).The goal of the Project is to design restoration actions that benefit ESA-listed Chinook salmon, steelhead and bull trout, and address the priority ecological concerns for the Entiat River identified in the Revised Biological Strategy (UCRTT 2014) and the reach impairments identified in the Entiat River – Upper Stillwaters Reach Stream Corridor Assessment and Habitat Restoration Strategy (Inter-Fluve 2013). To address the Project goal, the Recovery Plan established regional objectives for habitat restoration along streams that currently support or may support ESA-listed salmonids (UCSRB 2007). The following regional objectives and general recovery actions identified in the Recovery Plan support the development of the Project restoration strategy.

Regional Objectives

- Protect existing areas where high ecological integrity and natural ecosystem processes persist.
- Restore or maintain connectivity (access) throughout the historical range where feasible and practical for each listed species.
- Protect and restore water quality where feasible and practical within natural constraints.
- Increase habitat diversity by adding instream structures (e.g., LWD, boulders, etc.) where appropriate.
- Protect and restore riparian habitat along spawning and rearing streams and identify long-term opportunities for riparian habitat enhancement.
- Protect and restore floodplain function and reconnection, off-channel habitat, and channel migration processes where appropriate and identify long-term opportunities for enhancing these conditions.
- Restore natural sediment delivery processes by improving road networks, restoring natural floodplain connectivity, riparian health, natural bank erosion, and wood recruitment.
- Reduce the abundance and distribution of non-native species that compete and interbreed with or prey on listed species in spawning, rearing, and migration areas.

The revised Biological Strategy (UCRTT 2014) provides specific support and guidance on implementing the 2007 Recovery Plan described above. In the revised Biological Strategy, the Entiat River Upper-Middle assessment unit is designated as a Priority 1 area (on scale of 1 to 4, with 1 being highest priority) within the Entiat River Subbasin. Restoration priority action types should include restoring natural geomorphic and fluvial processes such as channel structure and form and migration, floodplain interaction, instream structural complexity, and sediment transport (UCRTT 2014). Ecological concerns and restoration actions recommended for improving these functions are listed in the revised Biological Strategy. These include (in priority order):

1. Channel Structure and Form (Instream Structural Complexity – Install large wood and engineered log jams (ELJs) in strategic locations to provide short-term habitat benefits and intermediate-term channel form and function benefits. The scale and locations should be consistent with the biological objectives and geomorphic potential for the reach and site.
2. Food (Altered Primary Productivity) – place carcasses or analogs in streams to supplement marine derived nutrients where known shortages exist, within current and historic range of anadromy, and tie to existing monitoring programs where feasible.

During field surveys opportunities were identified to address the ecological concern for Peripheral and Transitional Habitats (Side Channel and Wetland Habitat), by reconnecting disconnected side channels, or where low wood loading has changed the inundation frequency, improve hydraulic connection of side channels and wood complexity within side channels.

1.5.2 Concept Level Design

Concept Level designs were developed based on the topographic and geomorphic site surveys conducted by Tetra Tech; evaluation of existing light detection and ranging (LiDAR) data from 2015 (QSI 2016); evaluation of available background documents; and discussion with Yakama Nation Fisheries staff.

The three general alternative strategies that were considered included:

Alternative 1 - Full Floodplain, Fish Passage, and Habitat Restoration
This alternative included restoring stream and watershed processes that create and maintain habitats and biota in an effort to return the Project area to its historic and normative state as described by Beechie et al. (2010). Restoration actions under this alternative should address the root causes of degradation.

Alternative 2 - Partial Floodplain, Fish Passage, and Habitat Restoration
This alternative considered an intermediate approach to restore or improve selected processes to partially return the Project area to its historic and normative state.

Alternative 3 - Habitat Enhancement
This alternative considers a more site-specific approach to improve the quality of habitat by treating specific symptoms such as the lack of pools or LWD through the creation of locally appropriate habitat structures within the Project area. Restoration actions under this alternative provide some local habitat improvements when more holistic process-based options are not available, or may not occur in the short term.

Restoration opportunities were identified during the topographic surveys conducted in October 2017 and April 2018. The Concept Level Design Drawings were developed based on the risks identified in Section 1.3, using information collected during the surveys, and reviews of background information. The topographical data in the Concept Level Design Drawings were from field survey data and from the 2015 LiDAR surface.

The selection of proposed actions in the Concept Level Designs was mostly based on the strategy of Alternative 1, except where infrastructure was involved. Specific restoration actions include the following:

- Adding stable LWD structures in the stream channel to increase pool frequency and quality, retain mobile sediment and wood to aggrade the streambed and reduce channel incision, and facilitate reconnection of side channels and adjacent floodplains to increase habitat quantity and to create hydraulic diversity and dissipate energy;
- Enhance existing backwater alcoves and pools with additional LWD instream cover;
- Improve connectivity of existing side channels or create new side channels and increase high flow relief; and
- Plant all disturbed or deficient areas with native vegetation.

1.6 Description of performance / sustainability criteria for project elements and assessment of risk of failure to perform, potential consequences and compensating analysis to reduce uncertainty

Performance/sustainability criteria for Project elements, including associated risks to infrastructure or risk of failure to perform, and compensating analyses will be fully developed at later design stages. These criteria are intended to ensure that the engineering design meets Project objectives and maintains compliance with applicable codes, standards, and established criteria. General performance/sustainability criteria at this design stage include:

- Activation of existing or relic side channels and high flow channels (includes increasing perennial flows in existing side channels);
- Floodplain restoration and reconnection (e.g., reduce main channel incision to increase floodplain connectivity and frequency of inundation).
- Channel enhancement and restoration (e.g., increase main channel complexity and habitat diversity, fish cover and velocity refugia).
- LWD structure stability and performance criteria where necessary (e.g., pile anchoring, ballast, bank protection, deposition, pool scour, boater safety).
- Protection of existing infrastructure (roads and private residences).

Performance criteria for Project elements, including associated risks to infrastructure or failure to perform, and compensating analyses are summarized in Table 1-2. Performance criteria and habitat benefits for LWD structures are provided in Table 1-3.

Table 1-2. Project Actions and Performance Criteria

Project Actions	Performance Criteria	Risk Assessment	Compensating Analyses or Measures
Side Channel Creation or Reactivation	• Increase floodplain inundation at lower flows in locations where infrastructure is not present. • Where feasible provide perennial flow in side channels. • Side channels are to be self-sustaining and allowed to evolve over time. • Increase hydraulic connectivity to existing wetlands.	• The proposed side channels will be excavated into floodplain deposits of native alluvium. • Potential for channel dewatering and fish stranding.	• Hydrologic and hydraulic analyses to ensure delivery of perennial design flows at next design stage. • Velocity and shear stress calculations for lateral stability at next design stage.
Alcove Enhancement	• Increase cover and increase scour of alcove pool.	• Like natural alcoves, may fill in with fines over time, but overall risk is low.	• Alcoves are intentionally over-excavated for the short term, and some deposition is expected to occur over time.
Revegetation	• Revegetation of all disturbed areas • 12-month plant survival of >75 percent	• Potential for low survival and ungulate browsing. • Noxious weed infestations.	• Use site appropriate native vegetation, and preserve and replant existing native vegetation where feasible. • Technical specifications for plant handling, care, installation, and survival. • Installation of fencing or caging to protect vegetation from livestock browsing. • Noxious weeds shall be monitored and removed.

Table 1-3. Large Wood Structure Performance Criteria and Habitat Benefits

LWD Structure	Primary Purpose	Performance Criteria	Risk Assessment	Compensating Analyses or Measures	Habitat Benefits
Log Jam Structure	Promote lateral migration of main channel; Encourage flow splitting to facilitate side channel and floodplain reconnection	• Maintain side channel inlet dimensions to withstand up to the proposed 100-year flood hydraulic conditions.	• The proposed side channels inlets require lateral stability to control side channel entry flow and maintain consistent inlet cross sectional area. • Boater safety where necessary downstream of Box Canyon	• LWD stability calculations (To be provided at Permit Level Design). • Bumper logs for boater safety.	• Provide complex pool habitat for adults and margin habitat for juveniles. • Encourage lateral migration in straight sections when placed to act as deflectors. • Local scour pools at edges of structure. • Aggrade sediment downstream of structure.
2-Log Cross Structures with Boulders or Pilings	Side channel and alcove instream cover and habitat diversity	• Increase pool frequency and complexity.	• Assess proximity to infrastructure and downstream impacts. • Boater safety where necessary downstream of Box Canyon	• LWD stability calculations (To be provided at Permit Level Design). • Bumper logs for boater safety.	• Provide complex pool habitat and bank hydraulic complexity for adults and juveniles. • Provide cover in scour pools for adults and juveniles.
Bank Jam Structure	Instream habitat diversity	• Increase pool frequency and complexity.	• No infrastructure immediately downstream. • Increased roughness can elevate flood stage. • Boater safety where necessary downstream of Box Canyon.	• LWD stability calculations (To be provided at Permit Level Design). • Placed in main channel and interlocked with existing bank vegetation to provide additional roughness. • Bumper logs for boater safety.	• Provide complex instream and overhanging cover in scour pools for adults and juveniles. • Provide bank stability in some locations. • Aggrade sediment downstream of structure.

1.7 Description of disturbance including timing and areal extent and potential impacts associated with implementation of each element

Construction is not yet scheduled but is anticipated to occur during the Washington Department of Fish and Wildlife (WDFW) in-water work window. According to WDFW guidelines, the in-water work window for the Entiat River is July 1 to August 15. A detailed construction schedule will be developed at later design stages, and will include an implementation plan that describes the areal extent and potential impacts such as temporary turbidity releases to the stream, wetland impacts, minor impacts to resident fish populations from de-fishing activities, possible spills from construction equipment, colonization of disturbed ground by invasive vegetation, damage to existing vegetation along designated access routes, and short term disturbance issues for landowners. Overall impacts will be minimized through incorporation of BPA HIP III Best Management Practices (BMP) and conservation measures.

2. RESOURCE INVENTORY AND EVALUATION

2.1 Description of past and present impacts on channel, riparian and floodplain conditions

Substantial anthropogenic impacts to the Entiat River started in the late 1800s, including mining, timber harvest, debris clearing, and grazing, and activities that impacted fish passage such as mill pond dams, and splash dams. Shortly after European settlers had established residence in the region, a dam was initially built at RM 1, and soon thereafter replaced by one that completely prevented anadromous fish passage. Before the complete barrier was finished, the combination of other dams and unscreened water diversions greatly diminished anadromous fish populations. By the 1930s, salmon sightings in the Entiat River had become rare, mostly attributed to issues with passage barriers. To help alleviate the loss of the salmon, the Entiat Hatchery was built in 1941 at Packwood Springs (RM 7). By 1950 all the barrier dams were either removed or renovated to allow passage (i.e., fish ladders), and a majority of the irrigation diversions were retrofitted with fish screens (Inter-Fluve 2013).

Timber harvest was the other significant anthropogenic activity that resulted in substantial channel and riparian impacts. Log drives along the river to the mills located in the lower drainage resulted in the removal of large instream boulders and log jams, and altered channel beds and bank riparian structure, resulting in channel simplification, degraded pools, and disconnected floodplains. While logging activity continued on for the rest of the twentieth century, the river was no longer used to transport timber downstream during the logging peak in the 1970s and 1980s (Inter-Fluve 2013). However, debris flow and sediment transport after clear cuts and wildfires continued to adversely affect the Entiat River.

2.2 Instream flow management and constraints in the project reach

Flows are not known as a limiting factor for the Entiat River. The Project is located up in the watershed, mostly within USFS property, with no known water diversions present within or above the Project. There is a segment of the Entiat River (at the mouth) which is currently 303(d) listed (initially listed in 1995) as a Category 4C due to inadequate instream flow. A second representative segment downstream of Stormy Creek, is Category 1, but includes notes that there are periods of naturally low flows that occur in the Entiat River. The Washington Department of Ecology website indicates that in 1980 there were 21 diversions present in the watershed, with the furthest upstream located at approximately RM 10.5 (Ecology 2017).

2.3 Description of existing geomorphic conditions and constraints on physical processes

Previous geomorphic analyses have been performed for the Entiat River in the general vicinity of the Project. The Entiat Tributary Assessment (USBR 2009), and a follow-up paper titled Fluvial Geomorphology of the Entiat River, WA, and Implications for Stream Restoration (Godaire, Russell, and Bountry 2009), includes geomorphic information on the lower 26 river miles downstream of the Project. The Entiat River Upper Stillwaters Reach - Stream Corridor Assessment and Habitat Restoration Strategy (Inter-Fluve2013) includes a summary of geomorphic conditions of the Entiat River from RM 23.3 to RM 33.8, which includes the Project reaches. This summary includes reach level data including gradient, sinuosity, dominant channel morphology, average flood prone width, and percentages of habitat area. Inter-Fluve reaches 2, 3, 5, and 9 (which closely correspond to the Burns, Lower Signal, Fox Creek, and Silver Falls Project reaches) were described as dominated by riffles, and with floodprone widths of 90, 113.5, 87, and 390 feet, respectively. The floodprone widths are indicative of varying degrees of confinement and narrower widths represent natural constraints to floodplain connectivity in these reaches.

Additional analyses were completed as part of Project field surveys conducted in 2017 and 2018. Geomorphic and habitat characteristics specific to the Burns Creek, Lower Signal Reach, and Fox Creek Project reaches are provided in Section 3. Additional data analysis and geomorphic parameters specific to the Silver Falls reach will be developed in later design stages.

2.4 Description of existing riparian condition and historical riparian impacts

Historical impacts to the riparian community may be considered less severe than found in other watersheds in the region. While timber harvest did occur in the Entiat River watershed, the impacts to the vegetation corridor found in the Project area are now minimal. The greatest current impacts are due to the presence of the Entiat River Road that encroaches into the riparian zone in many places.

Descriptions of existing riparian conditions are found in previous surveys of the Entiat River. The Entiat River Subbasin Plan (NPCC 2005) includes brief descriptions of the riparian communities typical of the Entiat River subbasin, broken down by the three major stream zones: transport, transitional and depositional. The Project area includes vegetation communities typical of the of depositional type in the lower (Burns) reach, and the transitional type in the upper three reaches. The community of the transitional zone consists of black cottonwood (*Populus balsamifera* ssp. *trichocarpa)*, red cedar (*Thuja plicata*), grand fir (*Abies grandis*), and Engelmann spruce (*Picea engelmannii*), with dogwood (*Cornus sericea*) and alder (*Alnus* sp.) understory. The depositional zone has many of the same species, but also includes willows (*Salix* spp.), aspen (*Populus tremuloides*), elderberry (*Sambucus* sp.), water birch (*Betula occidentalis*) vine maple (*Acer circinatum*), ponderosa pine (*Pinus ponderosa*), and Douglas fir (*Pseudotsuga menziesii*).

The Entiat River Upper Stillwaters Reach - Stream Corridor Assessment and Habitat Restoration Strategy (Inter-Fluve2013) includes brief summaries of riparian conditions in each reach:

> **Reach 2 (Burns Reach)** – Riparian canopy is mostly intact except for locations where the Entiat River Road impinges on the riparian zone. Cottonwoods are the dominant overstory species.
>
> **Reach 3 (Lower Signal Reach)** – Riparian canopy is dense and intact. High terraces include ponderosa pine and grand fir overstory, with shrubs such as red osier dogwood in floodplain pockets.
>
> **Reach 5 (Fox Creek Reach)** – The riparian corridor is densely vegetated and intact except for clearing around the Fox Creek campground.

Reach 9 (Silver Falls Reach) – The riparian canopy consists of mixed older forest on the higher terraces, while understory varies depending on groundwater. Floodplain areas show various age classes from before and after major floods. Shrubs such as willows are present in the active channel banks where smaller substrate is present.

Field surveys conducted in October 2017 confirmed that riparian corridors are mostly dense and intact. Plant species identified during the surveys indicated species composition consisting of more hardwoods (cottonwood, alder, willow, red osier dogwood) in the lower elevation Burns Reach, or in other areas with low terraces, while the transitional reaches with more confined channels and corridors with mostly higher terraces were dominated by conifers of mixed age stands (red cedar, Douglas fir, grand fir, Engelmann spruce, and sparse lodgepole pine [*Pinus contorta*]). Representative riparian conditions of depositional reaches are shown in Figure 2-1, while conditions typical of transition reaches are illustrated in Figure 1-4.

Figure 2-1. Riparian Corridor in the Burns Reach

Figure 2-2. Riparian Corridor in the Silver Falls Reach

2.5 Description of lateral connectivity to floodplain and historical floodplain impacts

The Entiat River within the Project is mostly naturally engaged with the adjacent floodplain, with very varying degrees of connectivity depending on valley settings within the drainage. The Entiat River Road is the main source of artificial confinement as it runs along the hillslope (on river left), parallel with the river, and within the floodplain in a few areas. Floodplain connectivity was analyzed using existing condition hydraulic modeling for the Burns, Lower Signal and Fox Creek reaches, as illustrated in Appendix C – Hydraulic Figures, and varies throughout the Project. The Silver Falls Reach was not evaluated for connectivity due to the lack of topographic survey data. In the Burns reach (RM 25.56 to 26.10), confinement is moderate and incision relatively low. A large floodplain exists to river right with the river confined by a high terrace on river left that contains the Entiat River Road and multiple private residences near the downstream end. Numerous existing or relic side channels are evident. In the Lower Signal reach (RM 26.95 to 27.18), confinement is high with one side channel near the middle of the reach. In the Fox Creek reach (RM 27.66 to 28.28), confinement is high. A relic side channel exists through the campground but is currently blocked by a historic masonry wall and undersized campground road crossing culverts. A small inset floodplain exists on river right downstream from the campground with relic side channels that potentially become activated at high flow conditions. Besides the private residences near the downstream end of the Burns Reach and the Fox Creek Campground area, there are no other anthropogenic structures or development within the Project (see Appendix C).

3. TECHNICAL DATA

3.1 Incorporation of HIP III specific Activity Conservation Measures for all included project elements

The BPA HIP III Handbook Version 4.1 (BPA 2016) identifies General Aquatic Conservation Measures Applicable to all restoration actions that include:

- Project Design and Site Preparation;
- Work Area Isolation & Fish Salvage;
- Construction and Post-Construction Conservation Measures;
- Staged Rewatering Plan;
- HIP III Turbidity Monitoring Protocol;
- Stormwater Management Guidance; and
- Terrestrial Plants, Wildlife, and Aquatic Invertebrates.

Restoration action categories and risk levels applicable to the Project will be identified by the BPA Restoration Review Team (RRT) and included in future design stages.

3.2 Summary of site information and measurements (survey, bed material, etc.) used to support assessment and design

The following sections describe site information that was collected to support the assessment and design alternatives in each Project reach.

3.2.1 Topographic Survey and Surface Development

Consistent with the direction provided by the Washington Board of Registration for Professional Engineers and Land Surveyors for incidental survey work, site surveys were conducted under the direction of a licensed professional engineer and are intended for his or her own use toward the development of an engineered design.

A reconnaissance survey was performed on October 17, 2017 for the Silver Falls Reach, but that survey did not include the collection of any topographic survey data. The field collected topographic survey data for the Project were acquired between October 15 to 17, 2017 for the Lower Signal and Fox Creek reaches, and on April 5 and 6, 2018 for the Burns Reach. Field data included topographic and bathymetric northing, easting, and elevation Global Positioning System (GPS) coordinates, as well as geomorphic and habitat data collection. Additional GPS locations and descriptions of key features including existing LWD structures, control monuments, edges of pavement, and other points of interest were collected during field surveys. Data were acquired using a Trimble R10 real-time kinematic (RTK) GPS with Global Navigation Satellite System (GLONASS) receivers operating from established control points. In areas of dense canopy in the Fox Creek reach, a conventional Nikon Total Station was used. Three survey control points were established for each of the two separate survey efforts by collecting raw static GPS data for a minimum of 2 hours. Data were sent in to the Online Positioning User Service (OPUS) for post-processing and conversion to the preferred coordinate system: North American Datum (NAD) 83, Washington State Plane, North Zone, horizontal projection, and to the North American Vertical Datum (NAVD) 88, using U.S. survey feet as the vertical projection.

The topographic surveys included longitudinal profiles of the thalweg, with data collected at approximately 20-foot intervals, and capturing all major breaks in slope necessary for hydraulic analyses. The profiles for the Burns, Lower Signal, and Fox Creek reaches are illustrated in Figures 3-1, 3-2, and 3-3, respectively, and show how the gradient decreases significantly in the downstream reaches.

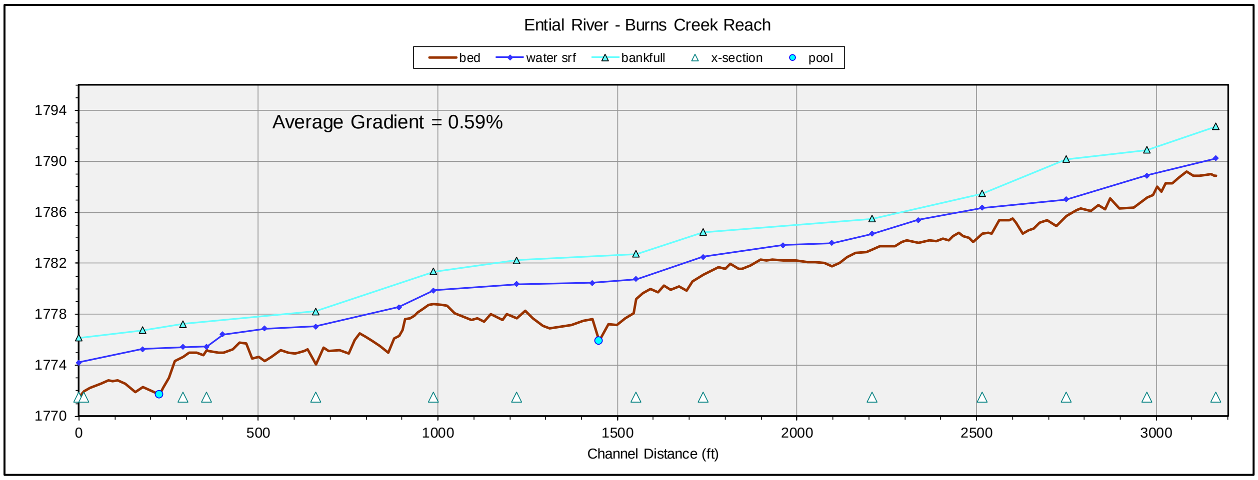


Figure 3-1. Longitudinal Profile of the Entiat River, Burns Reach

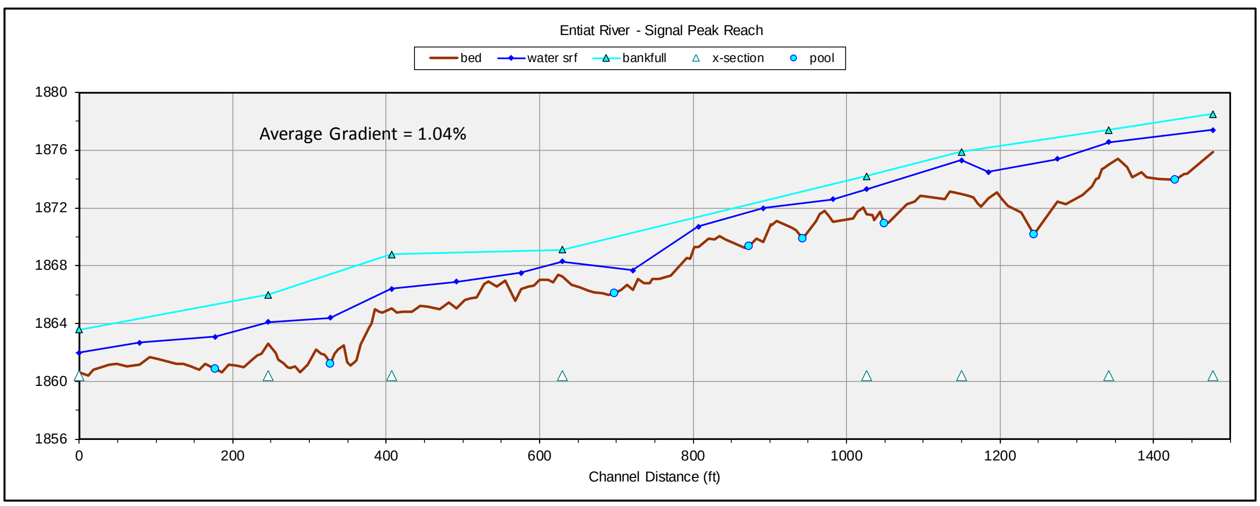


Figure 3-2. Longitudinal Profile of the Entiat River, Lower Signal Reach

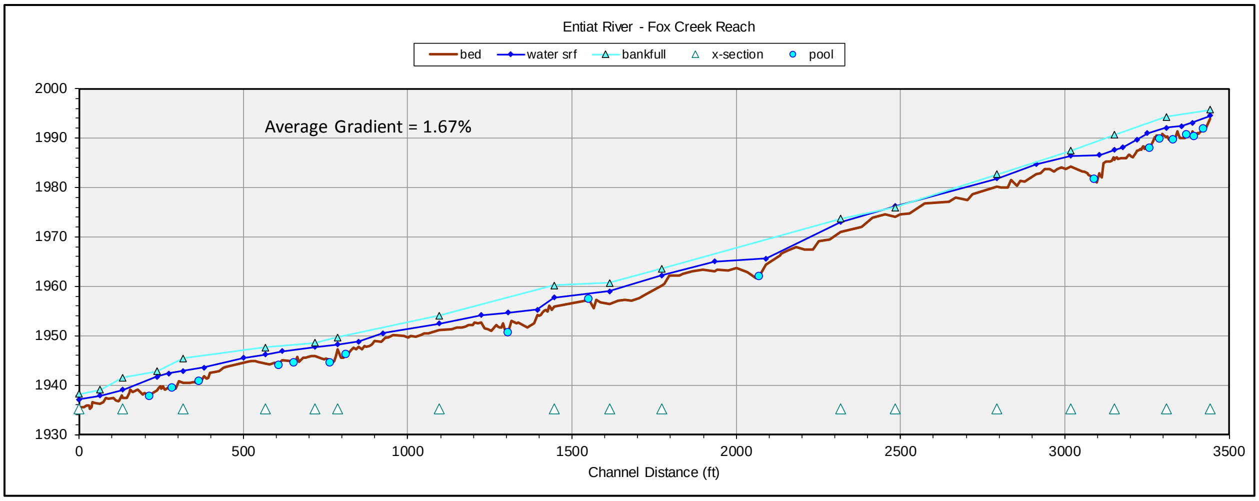


Figure 3-3. Longitudinal Profile of the Entiat River, Fox Creek Reach

A total of 13, 8, and 17 cross sections were collected in the Burn, Lower Signal, and Fox Creek reaches, respectively. Additional data such as intermediate channel bottom and gravel bar data were collected throughout the reach to improve the surface resolution for suitability for hydraulic modeling and account for any changes in bed or banks since the LiDAR flight.

Traditional 1-meter resolution LIDAR data were collected in 2015 for the Oregon LiDAR Consortium Okanogan Federal Emergency Management Agency (FEMA) Study (QSI 2016). Traditional LiDAR laser pulses do not penetrate water surfaces, but rather reflect off the surface. Therefore, to produce an accurate surface for hydraulic modeling and designs, the water surface data was removed and replaced with field collected GPS bathymetric data. LiDAR data were compared against field collected GPS points to determine if any adjustments of the data were required. These comparisons indicated that no horizontal or vertical adjustments to LiDAR northing, easting, or elevation data were needed. The survey data was merged with the LiDAR data to provide a final surface for hydraulic modeling and design development.

The USFS is anticipated to provide LiDAR data for the area encompassing the Silver Falls reach in 2018. These data have not been received to support hydraulic modeling or design development at this time.

3.2.2 Geomorphic and Habitat Data Collection and Observations

Geomorphic and habitat data were collected during the field surveys and detailed potential restoration actions, site photographs, and related notes were recorded on iPads. These data were gathered to characterize current in-channel and riparian habitat, establish baseline conditions in the Entiat River, and identify potential restoration opportunities. During field data collection, specific attention was given to observations related to sediment transport and response conditions, channel incision and channel stability trends (erosion or aggradation), substrate characteristics (e.g., size, distribution, supply), the abundance and influence of instream wood, floodplain connectivity, the influence of human alterations, and the interaction of the stream with riparian ecological processes.

Table 3-1 illustrates the existing conditions geomorphic characteristics for the Project reaches calculated from survey data including channel gradient, sinuosity, bankfull width and depth, bankfull cross-sectional area, width-to-depth ratio, floodprone width, and entrenchment ratio. The existing channel morphology (Montgomery and Buffington 1997) and stream type (Rosgen 1996) was also evaluated based on field data and observations. Existing conditions habitat data collected during field surveys were used to calculate pool spacing, and the length and percent composition of habitat units (i.e. rapids, riffles, pools, and glides), as shown in Table 3-1.

Table 3-1. Entiat River Geomorphic and Habitat Characteristics

Site Characteristics	Burns Reach	Lower Signal Reach	Fox Creek Reach
Stream Length (feet)	3,167	1,447	3.447
Channel Gradient (percent)	0.52	1.04	1.67
Sinuosity	1.19	1.28	1.39
Bankfull Width (feet)	97.6	78.9	67.5
Bankfull Depth (feet)	2.46	1.82	2.02
Bankfull Cross Sectional Area (square feet)	240.0	143.7	136.7
Width-to-Depth Ratio	39.7	43.3	33.3
Floodprone Width (feet)	159.0	110.6	89.4
Entrenchment Ratio	1.6	1.4	1.3
Channel Morphology	Plane Bed/Pool-Riffle	Plane Bed	Plane Bed, Step Pool
Rosgen Stream Type	B4c, C4	B3c, F3	F3
Pool-to-Pool Spacing (feet)	1,223	179	196
Percent Rapid	0.0	0.0	13.5
Percent Riffle	64.5	50.3	63.3
Percent Glide	21.0	14.0	2.3
Percent Pool	14.5	35.7	21.9

Additional geomorphic data collected during field surveys included pebble counts using sampling methods similar to those described in Bunte and Abt (2001). The pebble count substrate samples were collected both at the upstream and downstream extent of the Project area. Table 3-2 contains the sediment characteristic metrics for characteristic grain sizes (e.g., D_{50}, D_{84}), and the percentages based on size categories (percent fines, gravels, cobbles, boulders, and bedrock) of the bed material.

Table 3-2. Sediment Sizes and Distribution for the Entiat River Project Reaches

Substrate Size Characteristics	Burns Reach	Lower Signal Reach, Site 1	Lower Signal Reach, Site 2	Fox Creek Reach
Percent Silt/Clay	0	0	0	0
Percent Sand	0	5	4	1
Percent Gravel	55	26	21	9
Percent Cobble	43	63	67	41
Percent Boulder	2	6	8	49
Percent Bedrock	0	0	0	0
D_{16} (mm)	20	41	45	83
D_{35} (mm)	39	69	84	170
D_{50} (mm)	57	88	110	250
D_{65} (mm)	78	130	140	350
D_{84} (mm)	120	180	200	480
D_{95} (mm)	180	270	310	830

3.3 Summary of hydrologic analyses conducted, including data sources and period of record including a list of design discharge (Q) and return interval (RI) for each design element

The Project reaches reside in the fifth field Hydrologic Unit Code (HUC) Entiat River watershed (HUC 1702001002). There have been previous hydrologic analyses performed for the Entiat River. The Entiat Tributary Assessment (USBR 2009) and the Lower Entiat Reach Assessment (USBR 2012) include general descriptions of historical and existing conditions hydrology of the Entiat River. The Entiat River Upper Stillwaters Reach Restoration, Stream Corridor Assessment & Habitat Strategy (Inter-Fluve 2013) includes a description of the hydrology of the Entiat River at RM 33.83 to RM 25.0 and RM 23.98 to RM 23.3.

The U.S. Geological Survey (USGS) operates a gage (#12452800) near the town of Ardenvoir, WA that was installed in September 1957 and has recorded a total of 60 peak flow records to date. The gage is just downstream (0.5 miles) of where Stormy Creek enters the Entiat River, and has a drainage area of 203 square miles (USGS 2017). The USACE Hydraulic Engineering Center Statistical Software Package, HEC-SSP version 2.1.1 (USACE 2017), and Log-Pearson III analysis with Bulletin 17B Methods (USGS 1982) were used to calculate peak flow values at the gage. Gage transfer analyses were performed for the Burns, Lower Signal, and Fox Creek reaches to determine peak flows using a basin-area ratio and regional adjustment factor (Mastin et al. 2016). For estimating peak flows at an ungaged site, the USGS accepted basin-area ratio to perform a gage transfer analysis is 0.5 to 1.5.

The recurrence interval for bankfull discharge is typically around 1.5 to 2 years but can range from 1 to 32 years (Hey 1997). While evaluating modeled results under existing conditions, the 1.5- and 2-year peak flows were compared to bankfull survey points collected from the topographical field data for each reach.

Burns Reach

Basin characteristics, specifically the drainage area, for the Burns Reach were obtained using the USGS StreamStats watershed delineation tool (USGS n.d.). The drainage area for Burns Reach is approximately 161.0 square miles resulting in a basin-area ratio value of 0.8 to be used in the gage transfer analysis. Table 3-3 shows the peak flows at the gage and the estimated Burns Reach gage transfer peak flows.

3.4 Summary of sediment supply and transport analyses conducted, including data sources including sediment size gradation used in streambed design

This section will be developed in later design stages.

3.5 Summary of hydraulic modeling or analyses conducted and outcomes – implications relative to proposed design

Restoration designs require a fundamental model to evaluate the hydraulic behavior of the existing channel conditions. Detailed two-dimensional (2D) models utilizing GeoHECRAS version 2.1.0 were generated, coupled with AutoCAD Civil 3D (Civil 3D) 2018 as the primary software applications. GeoHECRAS combines Geographic Information Systems (GIS)and Hydraulic Engineering Center – River Analysis System (HEC-RAS) software into one user interface for efficient task management, while Civil 3D was used as the main engine behind surface generation. Existing surfaces were created with LiDAR and field collected topographical survey data described in Section 3.2.1. The two data sets for each reach were merged together in Civil 3D to represent an existing condition surface, and then inserted into GeoHECRAS to create a terrain for each hydraulic model. The Silver Falls Reach was not evaluated due to the lack of topographic survey data.

Unsteady flow analyses included scenarios ranging from flows at the time of survey through the 100-year recurrence interval. The bankfull, 2-, 5-, 10-, 25-, 50- and 100-year recurrence intervals were evaluated using the peak flow values obtained from the hydrologic analyses and match the values listed in each respected reach peak flow table in Section 3.3 (Table 3-3). Model geometry includes the terrain created from the existing conditions surface, a 2D mesh representing the entire flow area, breaklines to define changes in grade, and 2D land cover. The Geolocation feature within Civil 3D was used to overlay an aerial map on the project extents. Based on the aerial map, a 2D land cover file was generated to represent Manning's roughness values.

Boundary conditions were set for each terminus, including inflow at the upstream end representing the recurrence interval flow rate, and normal depth at the downstream end representing the energy slope measured at the end of each reach. After entering the geometry and hydraulic parameter information, unsteady flow analyses were computed for time of survey flows to review geometry input parameters and model calibration.

Burns Reach

During topographical survey activities in April 2018 at the Burns Reach, the flow in the Entiat River was estimated at 177 cfs utilizing the provisional daily average flow recorded at the gage and the same gage transfer methodology discussed in Section 3.3. Edge of water survey points were reviewed against survey flow inundation model extents. Model calibration was an iterative process using modeled results for survey flow and adjusting the Manning's roughness of the channel until inundation results matched up with the edge of water survey points at time of survey. A channel Manning's roughness value of 0.06 was selected for Burns Reach. Upon completion of model calibration, unsteady flow analysis computations were computed for the remainder of the scenarios. Modeled results for the 2- and 100-year existing conditions hydraulic scenarios for the Burns Reach are provided in Appendix B. Figure 3-4 below illustrates the inundation extents for the existing conditions 2- and 100-year gage transfer peak flows for the Burns Reach.

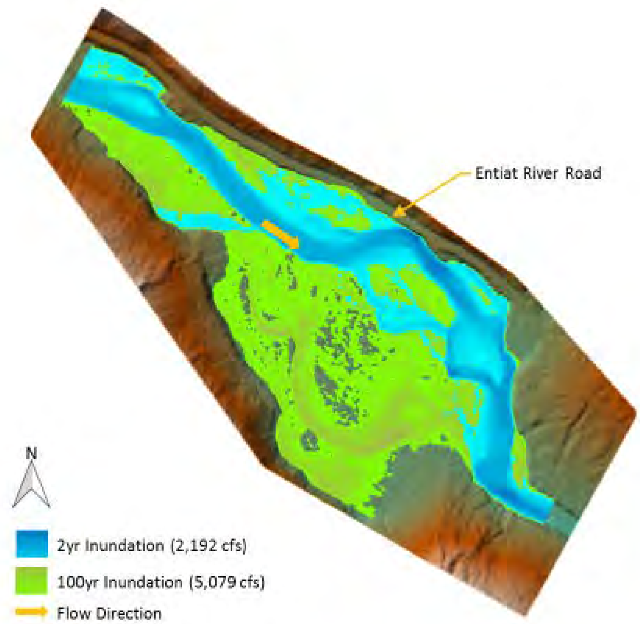


Figure 3-4. Burns Reach Inundation Extents: Existing Conditions 2- and 100-Year Gage Transfer Peak Flows

Lower Signal Reach

During topographical survey activities at the Lower Signal Reach in October 2017, the flow in the Entiat River was estimated as 70.5 cfs, utilizing the same methodology discussed earlier. Edge of water survey points were reviewed against survey flow inundation extents. Model calibration was an iterative process using survey flow and adjusting the Manning's roughness of the channel until inundation results matched up with the edge of water survey points at time of survey. A channel Manning's roughness value of 0.07 was selected for the Lower Signal Reach. Upon the completion of model calibration, unsteady flow analysis computations were completed for the remainder of the scenarios. Modeled results for the 2- and 100-year existing conditions hydraulic scenarios for Lower Signal Reach are provided in Appendix B. Figure 3-5 below illustrates the inundation extents for the existing conditions 2- and 100-year gage transfer peak flows for the Lower Signal Reach.

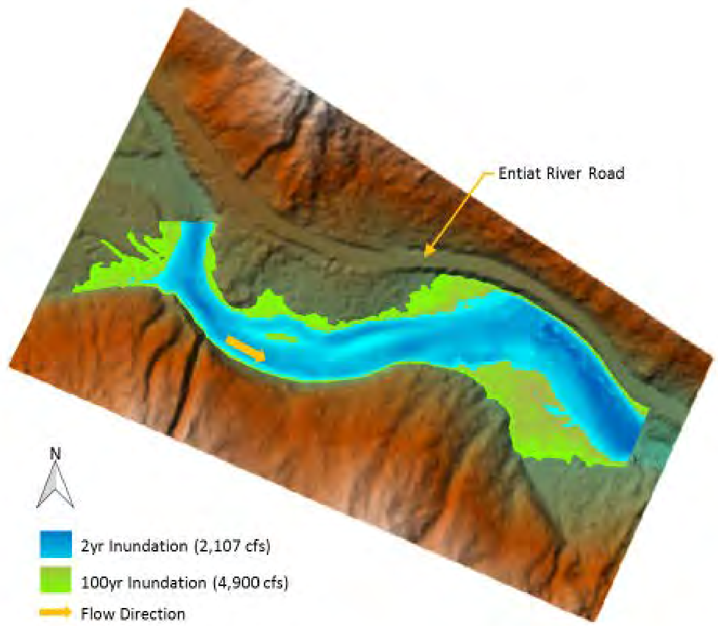


Figure 3-5. Lower Signal Reach Inundation Extents: Existing Conditions 2- and 100-Year Gage Transfer Peak Flows

Fox Creek Reach

During topographical survey activities at the Fox Creek Reach, the flow in Entiat River was estimated as 70.5 cfs. Edge of water survey points were reviewed against survey flow inundation extents. Model calibration was an iterative process using survey flow and adjusting the Manning's roughness of the channel until inundation results matched up with the edge of water survey points at time of survey. A channel Manning's roughness value of 0.06 was selected for Fox Creek Reach. Upon the completion of model calibration, unsteady flow analysis computations were computed for the remainder of the scenarios. Modeled results for the 2- and 100-year existing conditions hydraulic scenarios for Fox Creek Reach are provided in Appendix B. Figure 3-6 below illustrates the inundation extents for the existing conditions 2- and 100-year gage transfer peak flows for Fox Creek Reach.

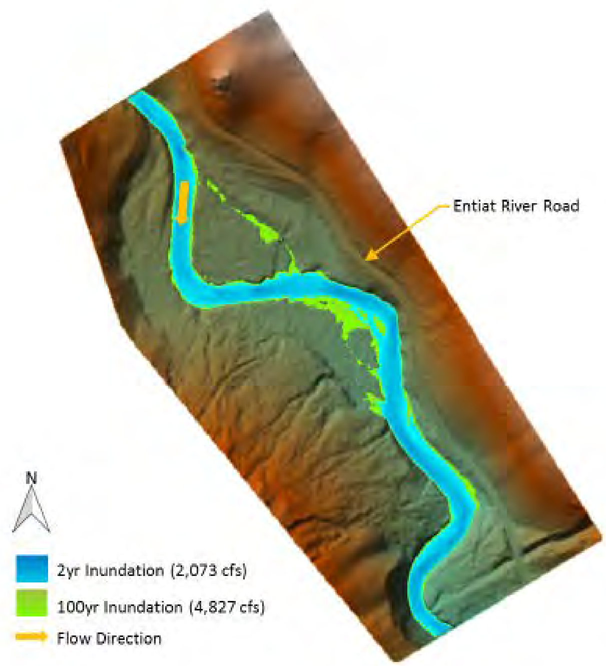


Figure 3-6. Fox Creek Reach Inundation Extents: Existing Conditions 2- and 100-Year Gage Transfer Peak Flows

Modeled results for each reach include an inundation map for survey flow (model calibration) and depth, velocity, and shear stress maps for the 2- and 100-year peak flows; results are provided in Appendix B. Restoration design improvements for floodplain connection and activation of relic channels are anticipated for all reaches. The proposed conditions hydraulic models will be fully developed in later design stages.

3.6 Stability analyses and computations for project elements, and comprehensive project plan

This section will be developed at the Permit Level Design stage.

3.7 Description of how preceding technical analysis has been incorporated into and integrated with the construction – contract documentation

This section will be developed at the Permit Level Design stage.

3.8 For projects that address profile discontinuities (grade stabilization, small dam and structure removals): A longitudinal profile of the stream channel thalweg for 20 channel widths upstream and downstream of the structure shall be used to determine the potential for channel degradation

If profile discontinuities are addressed, a longitudinal profile will be provided at a later design stage.

3.9 For projects that address profile discontinuities (grade stabilization, small dam and structure removals): A minimum of three cross-sections – one downstream of the structure, one through the reservoir area upstream of the structure, and one upstream of the reservoir area outside of the influence of the structure) to characterize the channel morphology and quantify the stored sediment

If profile discontinuities are addressed, cross sections will be provided at a later design stage.

4. CONSTRUCTION – CONTRACT DOCUMENTATION

4.1 Incorporation of HIPIII general and construction conservation measures

Conservation measures will be included in the contract documentation for construction, and relevant items will be included in the design drawings and construction specifications in later design stages. The overall design will be compliant with all HIP III activity conservation measures.

4.2 Design – construction plan set including but not limited to plan, profile, section and detail sheets that identify all project elements and construction activities of sufficient detail to govern competent execution of project bidding and implementation

This section will be fully developed in later design stages.

4.3 List of all proposed project materials and quantities

This section will be fully developed in later design stages.

4.4 Description of best management practices that will be implemented and implementation resource plans including:

This section and the following subsections will be fully developed in later design stages.

4.4.1 Site Access Staging and Sequencing Plan

4.4.2 Work Area Isolation and Dewatering Plan

4.4.3 Erosion and Pollution Control Plan

4.4.4 Site Reclamation and Restoration Plan

4.4.5 List Proposed Equipment and Fuels Management Plan

4.5 Calendar schedule for construction/implementation procedures

This section will be fully developed in later design stages.

4.6 Site or project specific monitoring to support pollution prevention and/or abatement

No site- or Project-specific monitoring for pollution prevention and/or abatement will be required

5. MONITORING AND ADAPTIVE MANAGEMENT PLAN

If a Monitoring and Adaptive Management Plan is deemed necessary for this Project, the YNF will develop and submit as required.

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APPENDIX B

Other Supporting Documents

Legend

Land Use

Channel

Forested

Road

Land Use/ Land Cover	Manning's n Value
Channel	0.06
Forested	0.08
Road	0.015

Entiat River
Burns Reach
Chelan County, Washington

N

0 250 500
Feet

Figure B-1-1
Land Use

TETRA TECH

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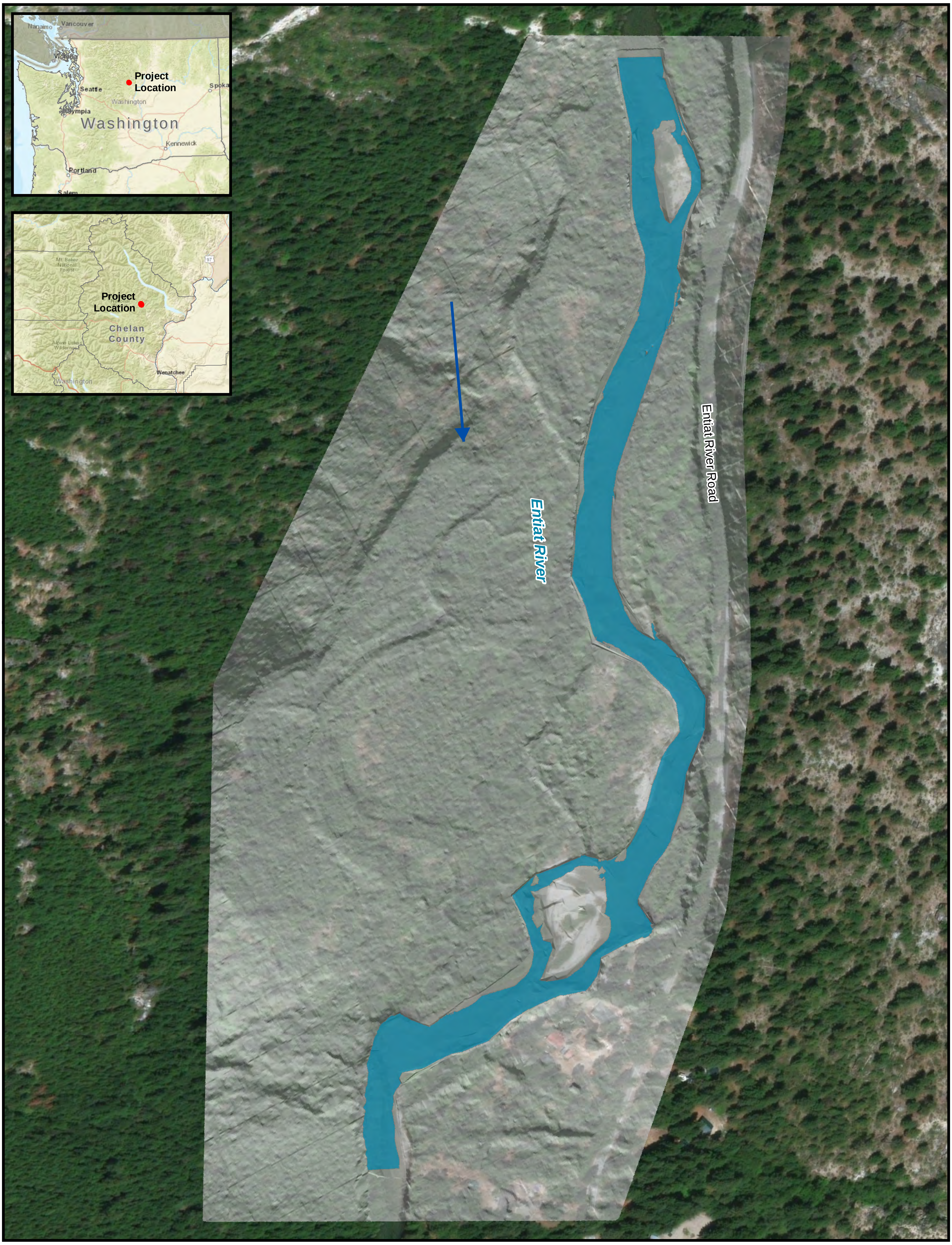


Entiat River
Burns Reach
Chelan County, Washington

Legend

Flow Direction

Inundation Area

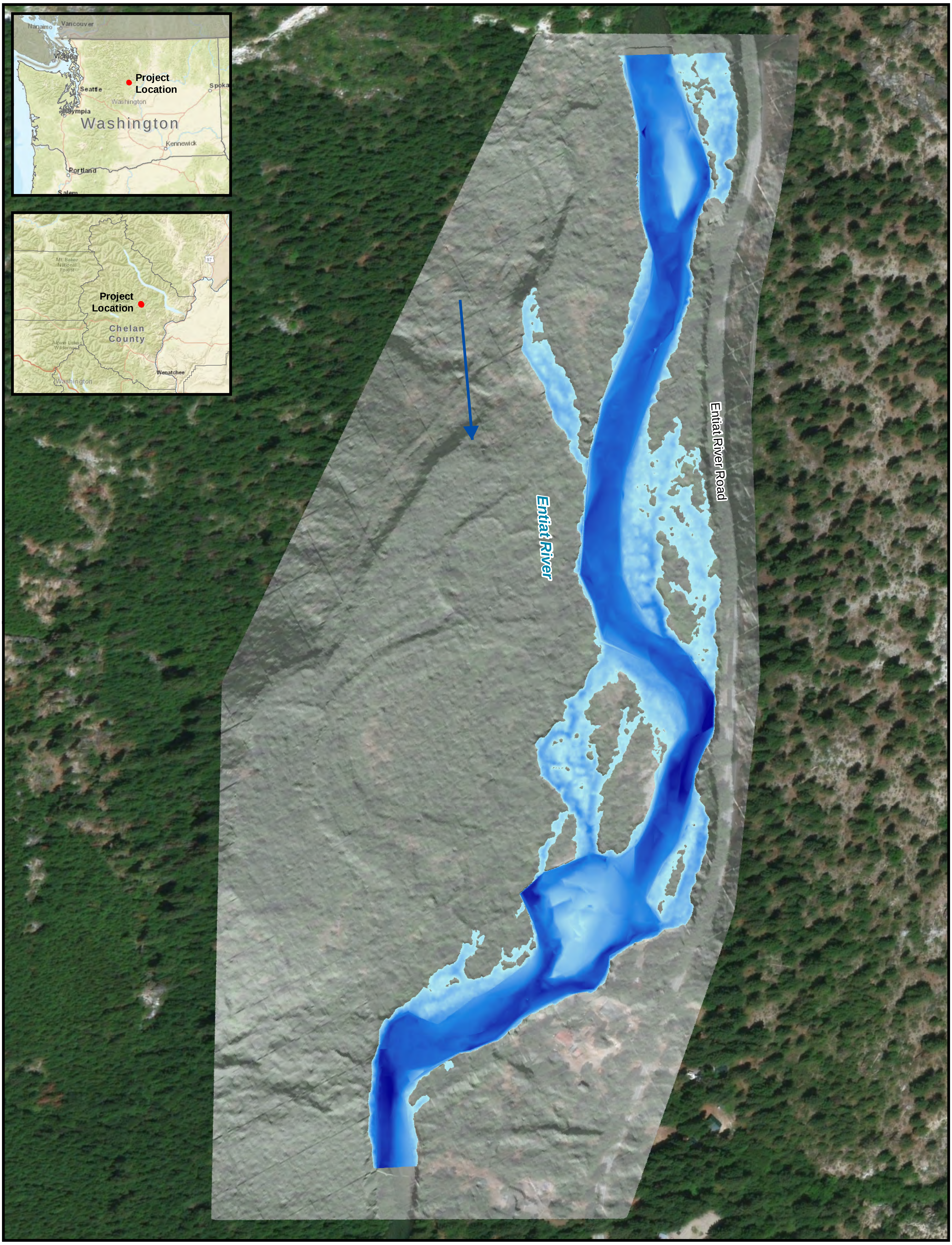
N

0 250 500
Feet

Figure B-1-2
Survey Flow
Channel Roughness
Hydraulic Model Calibration

Entiat River = 177 cfs

TETRA TECH



Entiat River
Burns Reach
Chelan County, Washington

Legend

Flow Direction

Inundation Depth (ft)

High : 9.5

Low : 0

N

0 250 500

Feet

Figure B-1-3
2-year Flow
Existing Conditions
Hydraulic Model Inundation

Entiat River = 2,192 cfs

TETRA TECH

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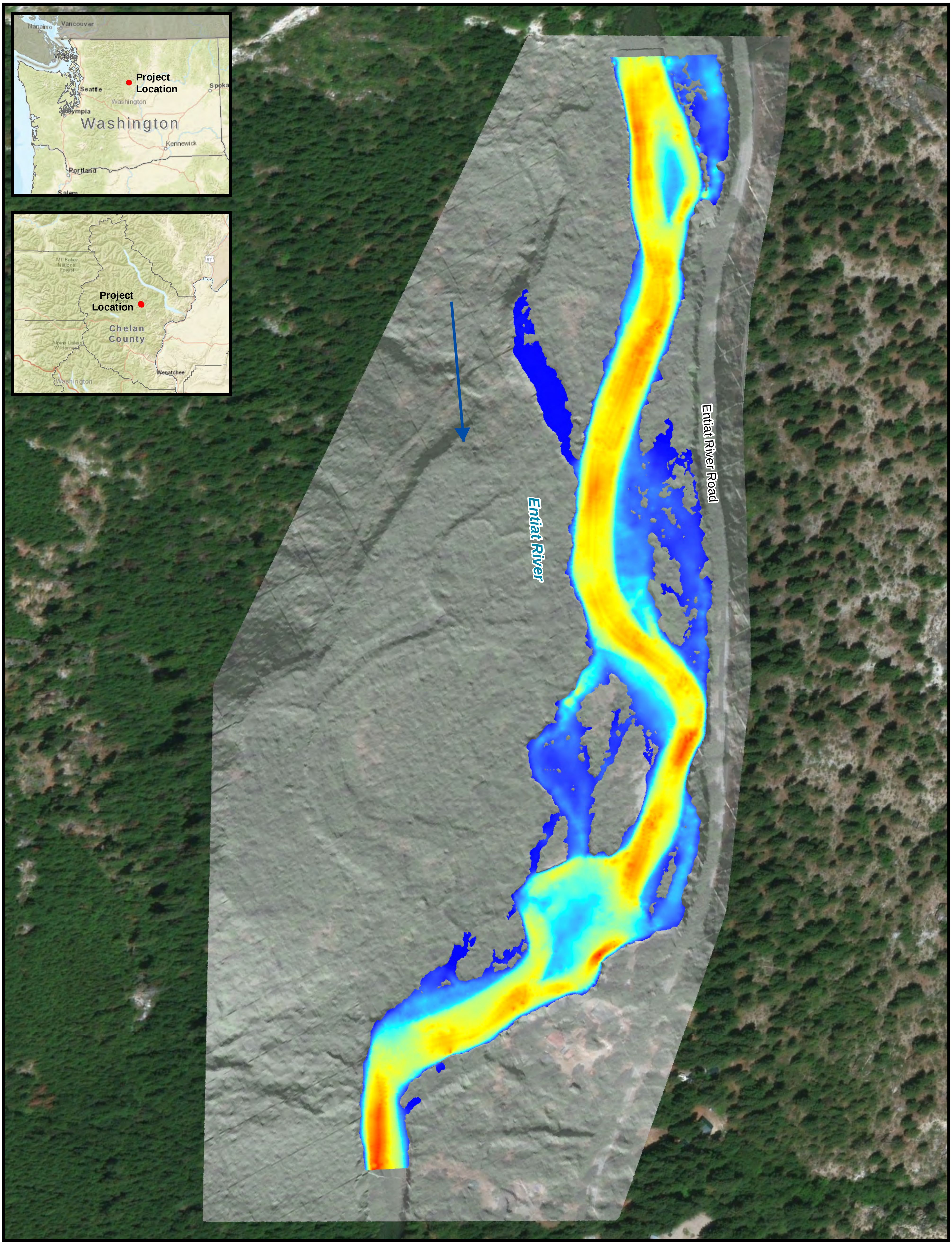

Entiat River
Burns Reach
Chelan County, Washington

Legend

Flow Direction

Velocity (ft/s)

High : 7.3

Low : 0

N

0 250 500

Feet

Figure B-1-4
2-year Flow
Existing Conditions
Hydraulic Model Velocity

Entiat River = 2,192 cfs

TETRA TECH

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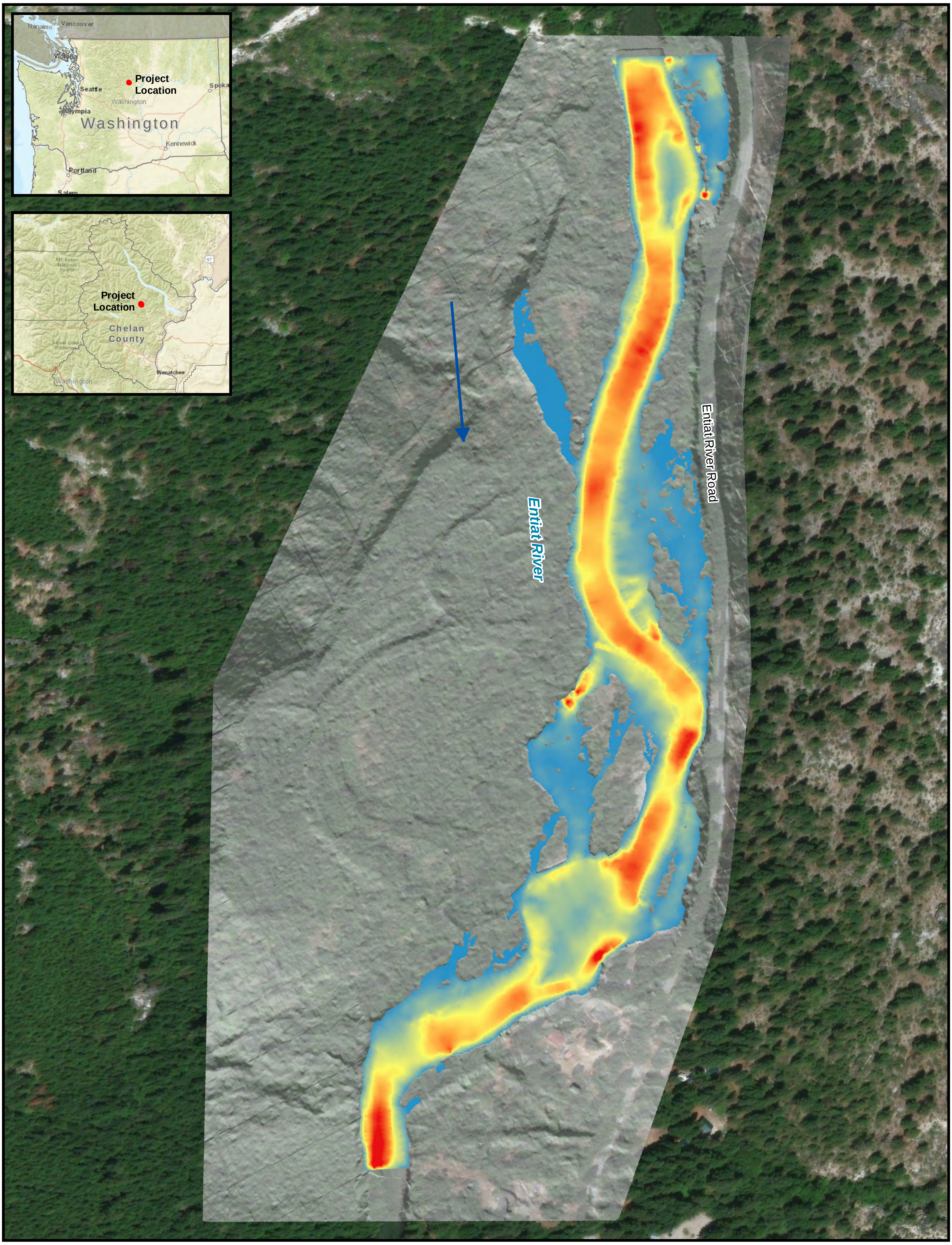

Entiat River
Burns Reach
Chelan County, Washington

Legend

Flow Direction

Shear Stress (psf)
High : 2.7
Low : 0

N

0 250 500
Feet

Figure B-1-5
2-year Flow
Existing Conditions
Hydraulic Model Shear Stress

Entiat River = 2,192 cfs

TETRA TECH

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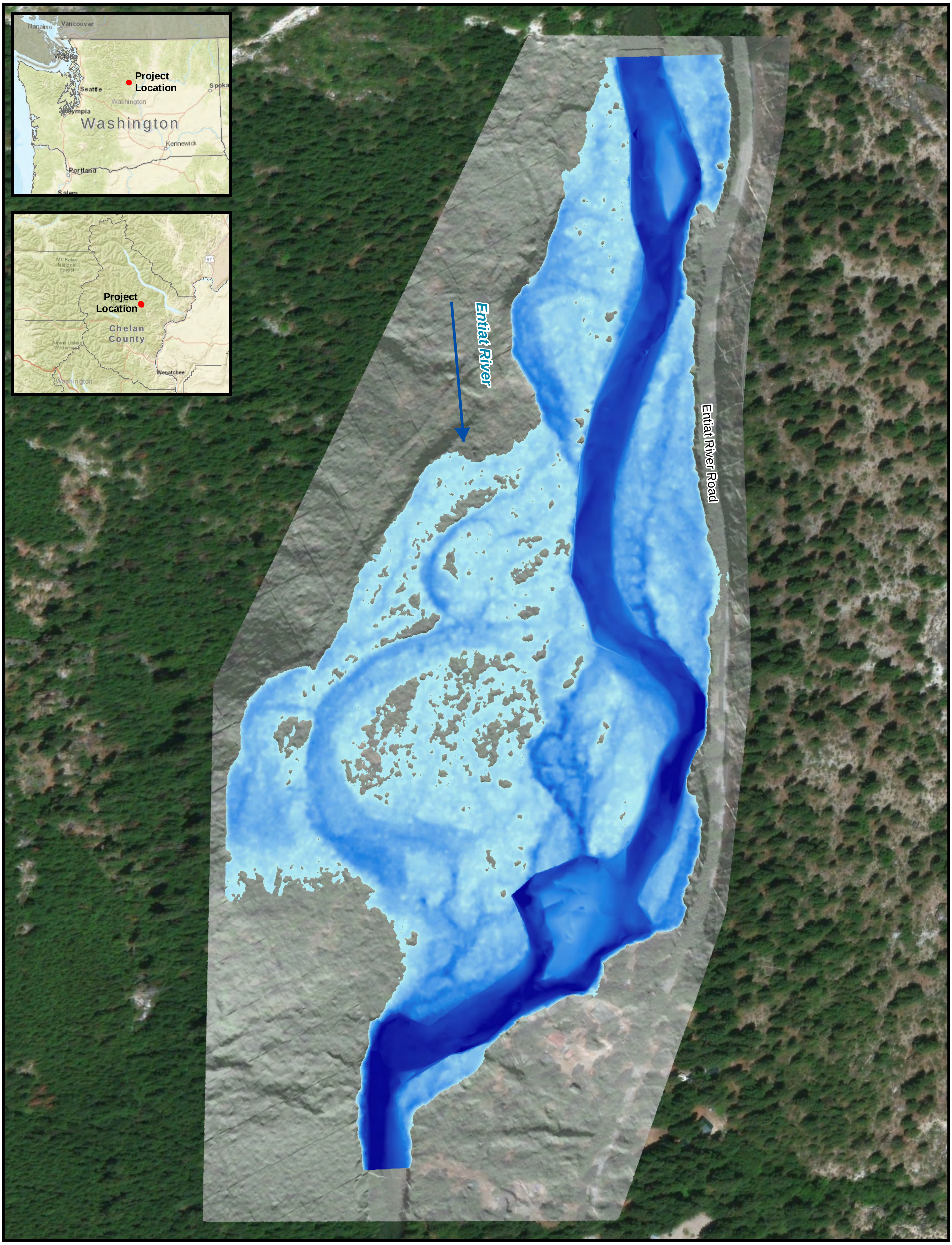

Entiat River
Burns Reach
Chelan County, Washington

Legend

Flow Direction

Inundation Depth (ft)

High : 11.3

Low : 0

N

0 250 500

Feet

Figure B-1-6
100-year Flow
Existing Conditions
Hydraulic Model Inundation

Entiat River = 5,079 cfs

TETRA TECH

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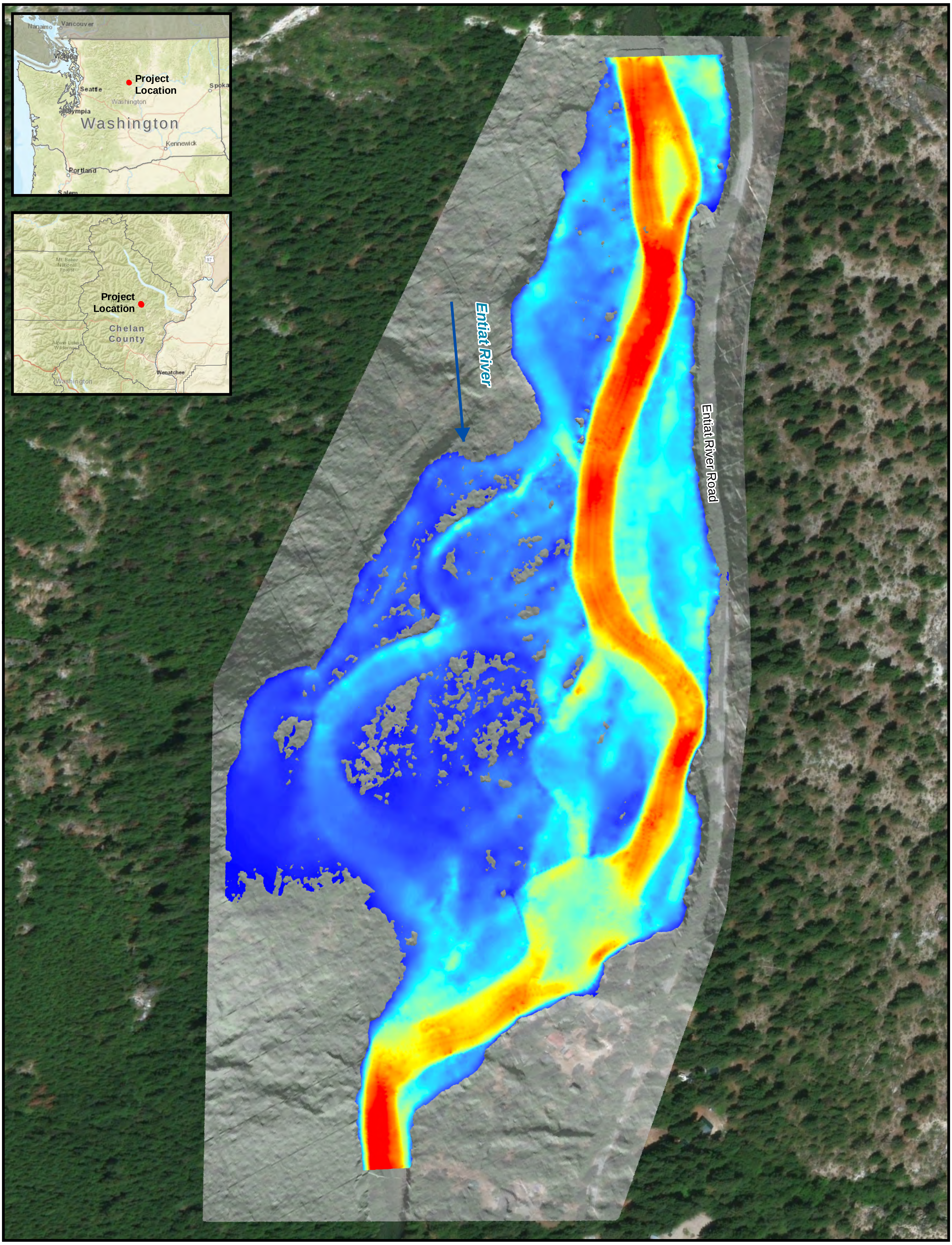

Entiat River
Burns Reach
Chelan County, Washington

Legend

Flow Direction

Velocity (ft/s)

High : 9.2

Low : 0

N

0 250 500

Feet

Figure B-1-7
100-year Flow
Existing Conditions
Hydraulic Model Velocity

Entiat River = 5,079 cfs

TETRA TECH

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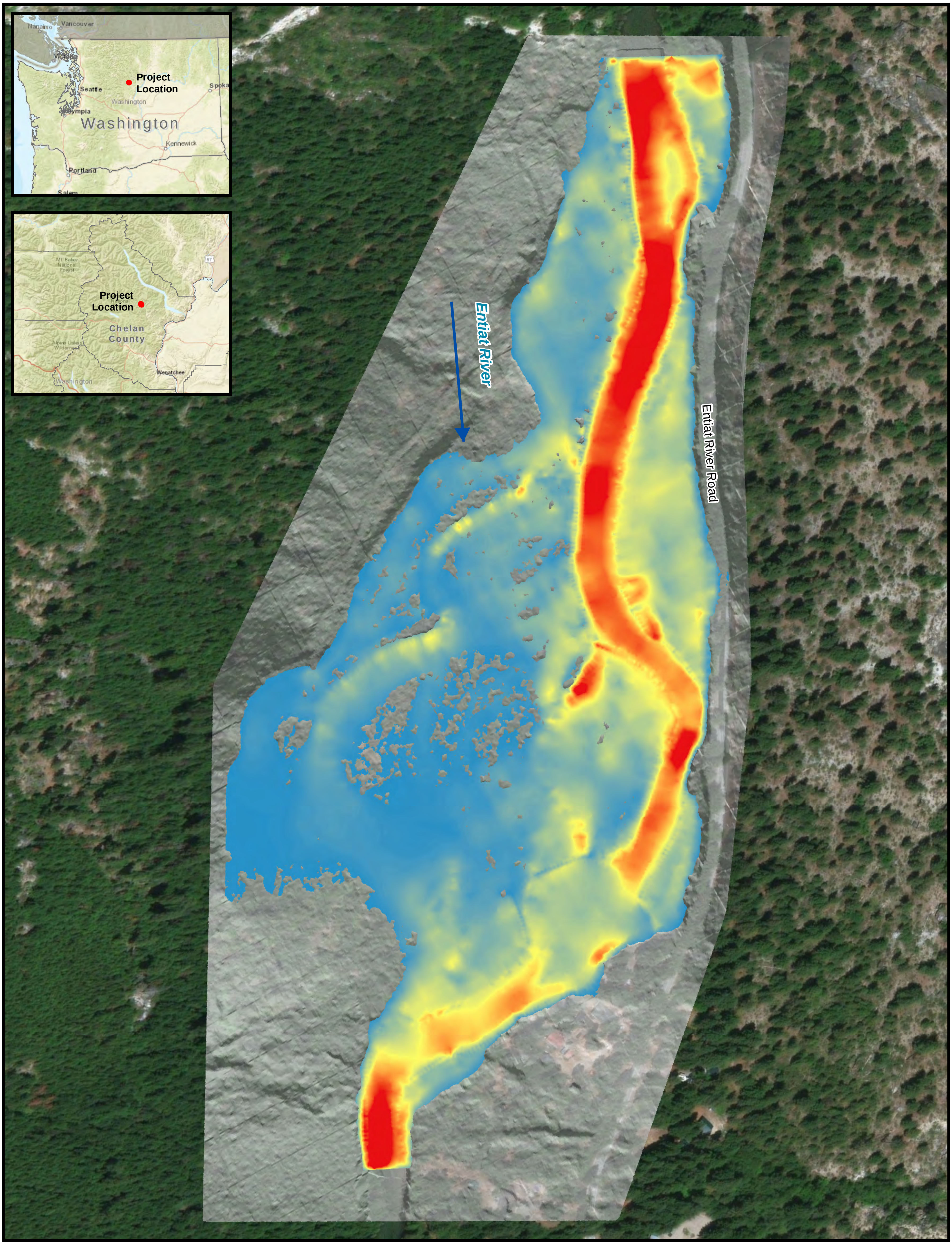

Entiat River
Burns Reach
Chelan County, Washington

Legend

Flow Direction

Shear Stress (psf)
High : 3.8
Low : 0

0 250 500
Feet

Figure B-1-8
100-year Flow
Existing Conditions
Hydraulic Model Shear Stress

Entiat River = 5,079 cfs

TETRA TECH

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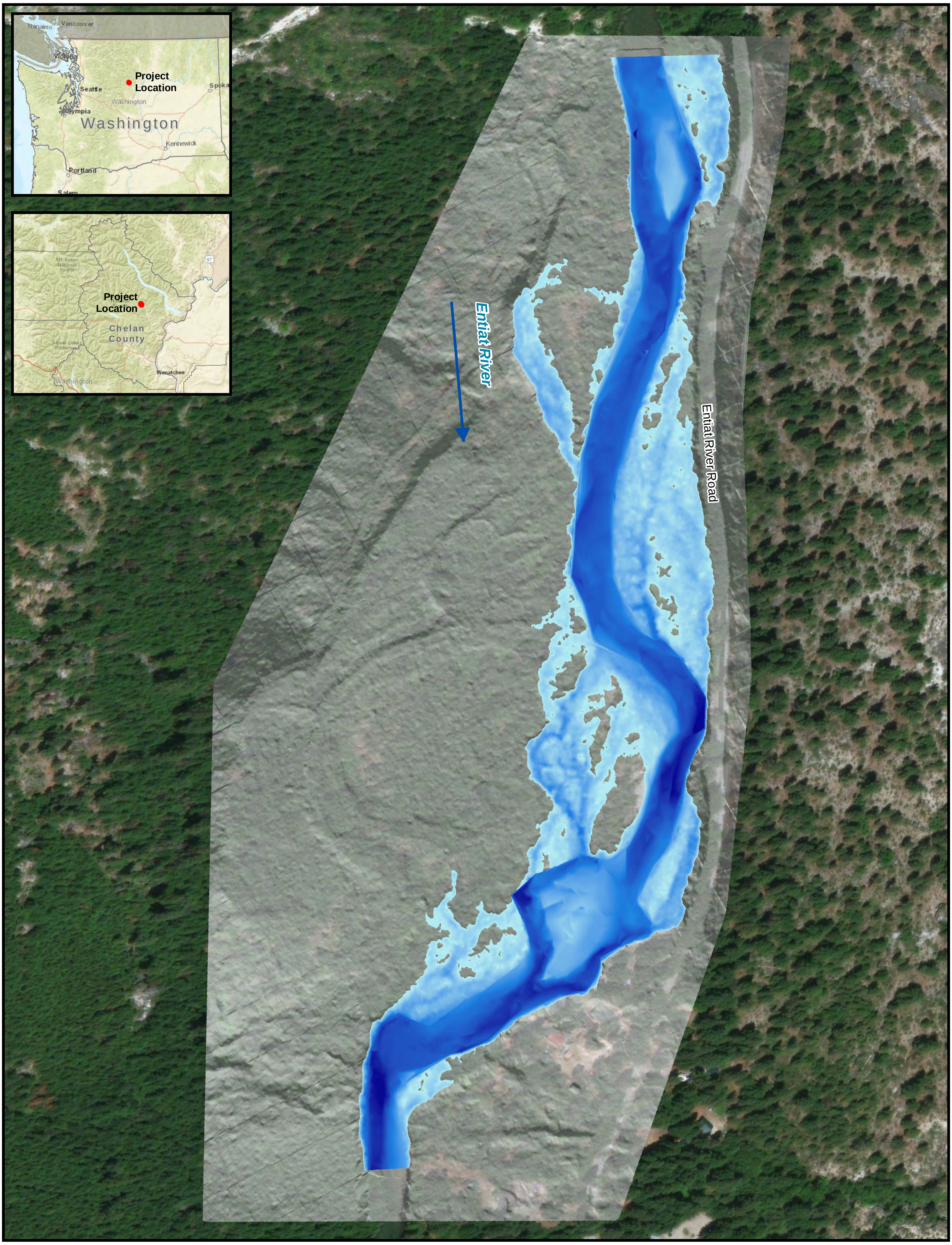

Entiat River
Burns Reach
Chelan County, Washington

Legend

Flow Direction

Inundation Depth (ft)

High : 10.2

Low : 0

0 250 500
Feet

Figure B-1-9
5-year Flow
Existing Conditions
Hydraulic Model Inundation

Entiat River = 2,984 cfs

TETRA TECH

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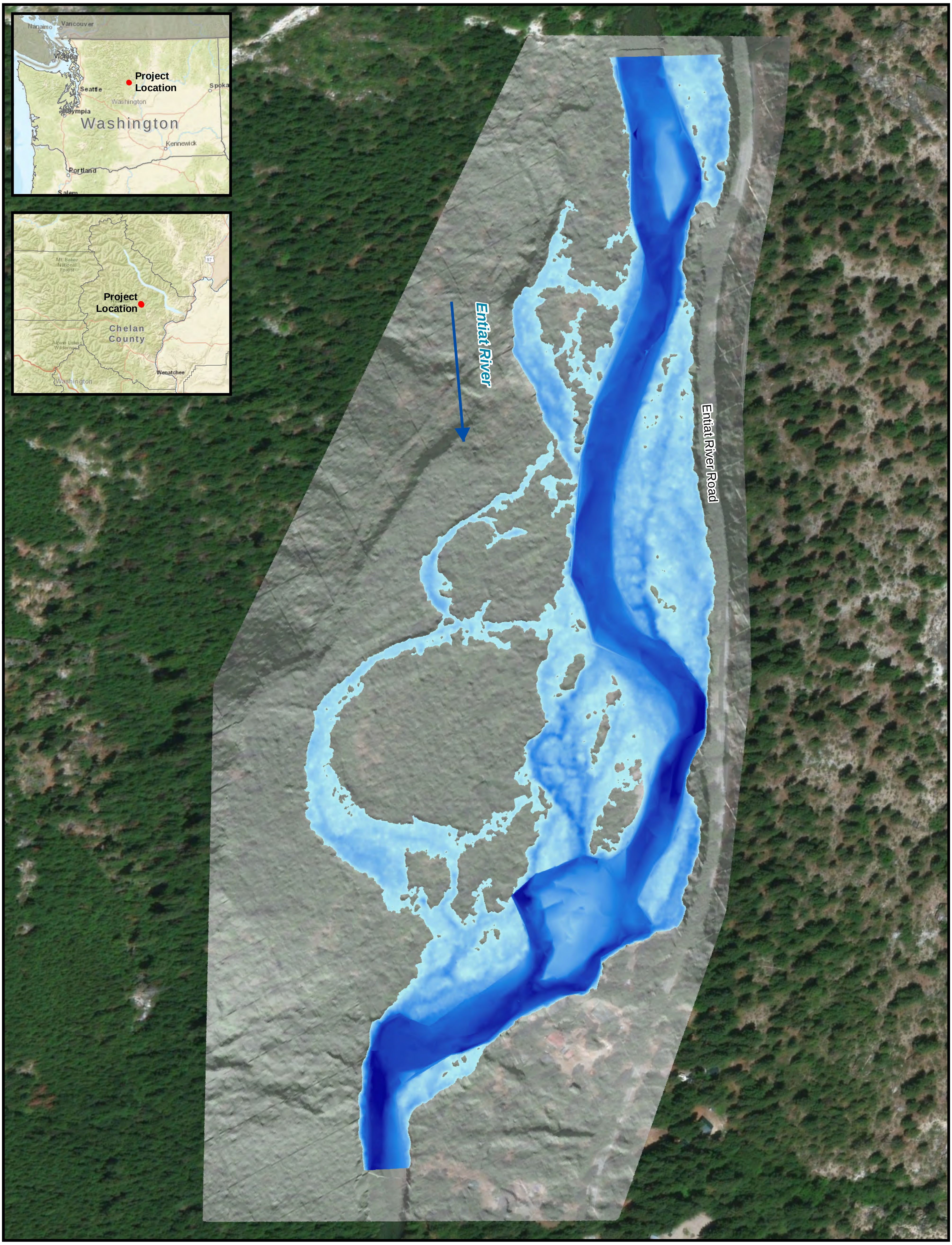

Entiat River
Burns Reach
Chelan County, Washington

Legend

Flow Direction

Inundation Depth (ft)

High : 10.6

Low : 0

N

0 250 500

Feet

Figure B-1-10
10-year Flow
Existing Conditions
Hydraulic Model Inundation

Entiat River = 3,499 cfs

TETRA TECH

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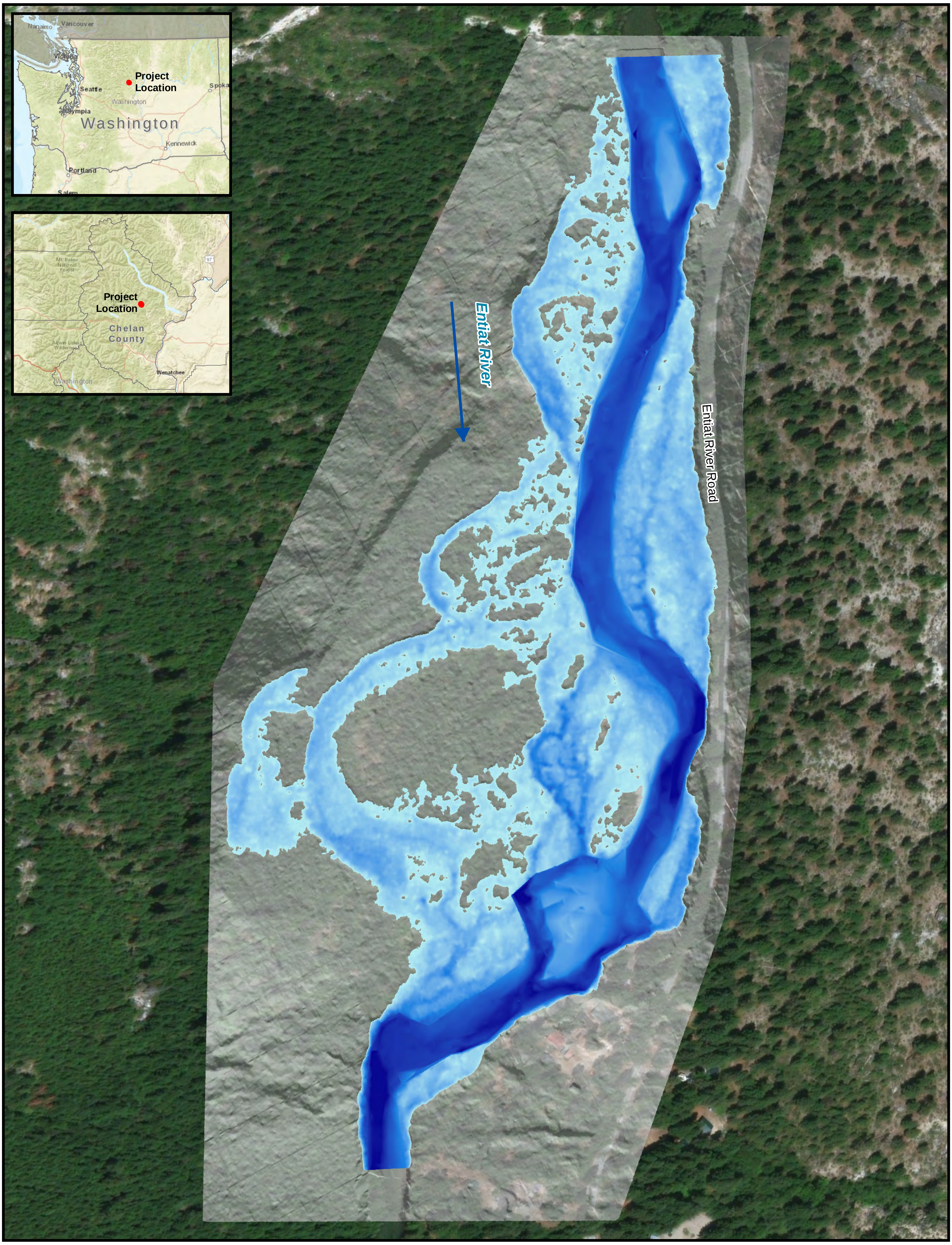

Entiat River
Burns Reach
Chelan County, Washington

Legend

Flow Direction

Inundation depth (ft)

High : 10.9

Low : 0

N

0 250 500

Feet

Figure B-1-11
25-year Flow
Existing Conditions
Hydraulic Model Inundation

Entiat River = 4,142 cfs

TETRA TECH

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Legend

Land Use

- Channel
- Engineered Log Jam
- Forested
- Road

Land Use/ Land Cover	Manning's n Value
Channel	0.07
Engineered Log Jam	0.08
Forested	0.09
Road	0.015

Entiat River
Lower Signal Reach
Chelan County, Washington

N

0 200 400
Feet

Figure B-2-1
Land Use

TETRA TECH

R:\PROJECTS\UPPER_STILLWATERS_6194\LOWER_SIGNAL\MAPS\C-2-1_LowerSignal_LandUse.mxd

Legend
Flow Direction
Inundation Area

Entiat River
Lower Signal Reach
Chelan County, Washington

N

0 200 400
Feet

Figure B-2-2
Survey Flow
Channel Roughness
Hydraulic Model Calibration

Entiat River = 70.5 cfs

TETRA TECH

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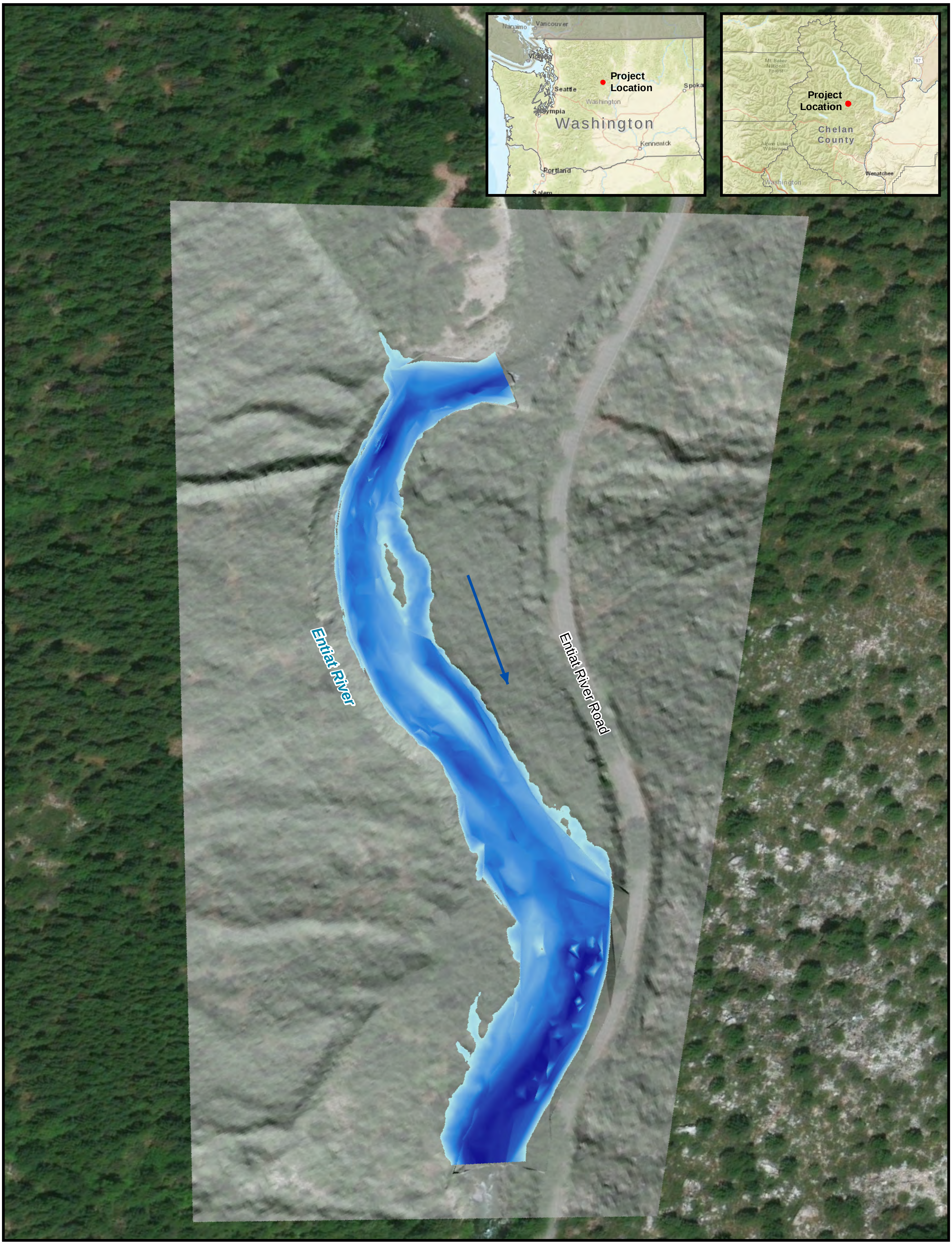

Legend

Flow Direction

Inundation Depth (ft)

High : 9.8

Low : 0

Entiat River
Lower Signal Reach
Chelan County, Washington

N

0 200 400

Feet

Figure B-2-3
2-year Flow
Existing Conditions
Hydraulic Model Inundation

Entiat River = 2,107 cfs

TETRA TECH

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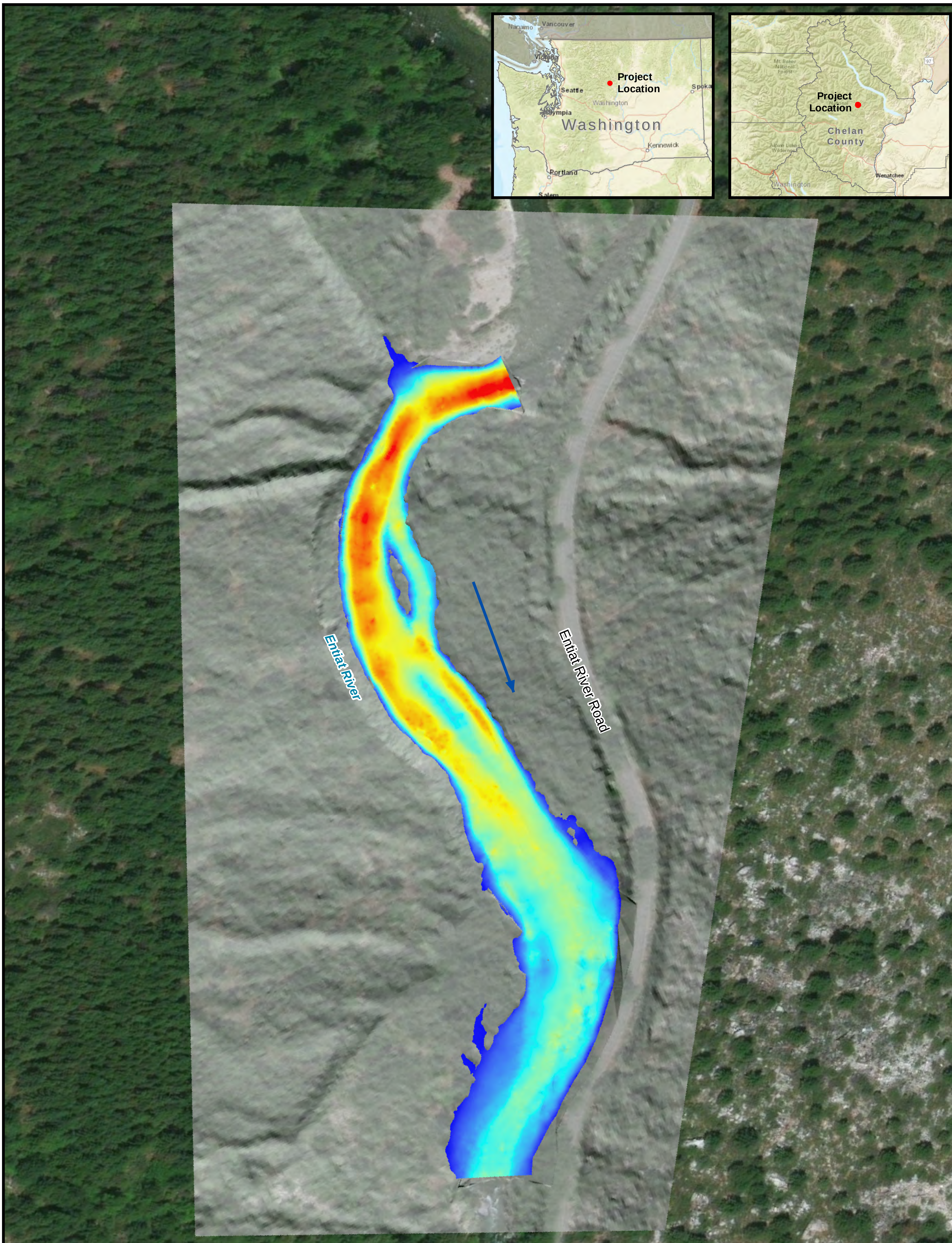

Legend

Flow Direction

Velocity (ft/s)

High : 9.8

Low : 0

Entiat River
Lower Signal Reach
Chelan County, Washington

N

0 200 400

Feet

Figure B-2-4
2-year Flow
Existing Conditions
Hydraulic Model Velocity

Entiat River = 2,107 cfs

TETRA TECH

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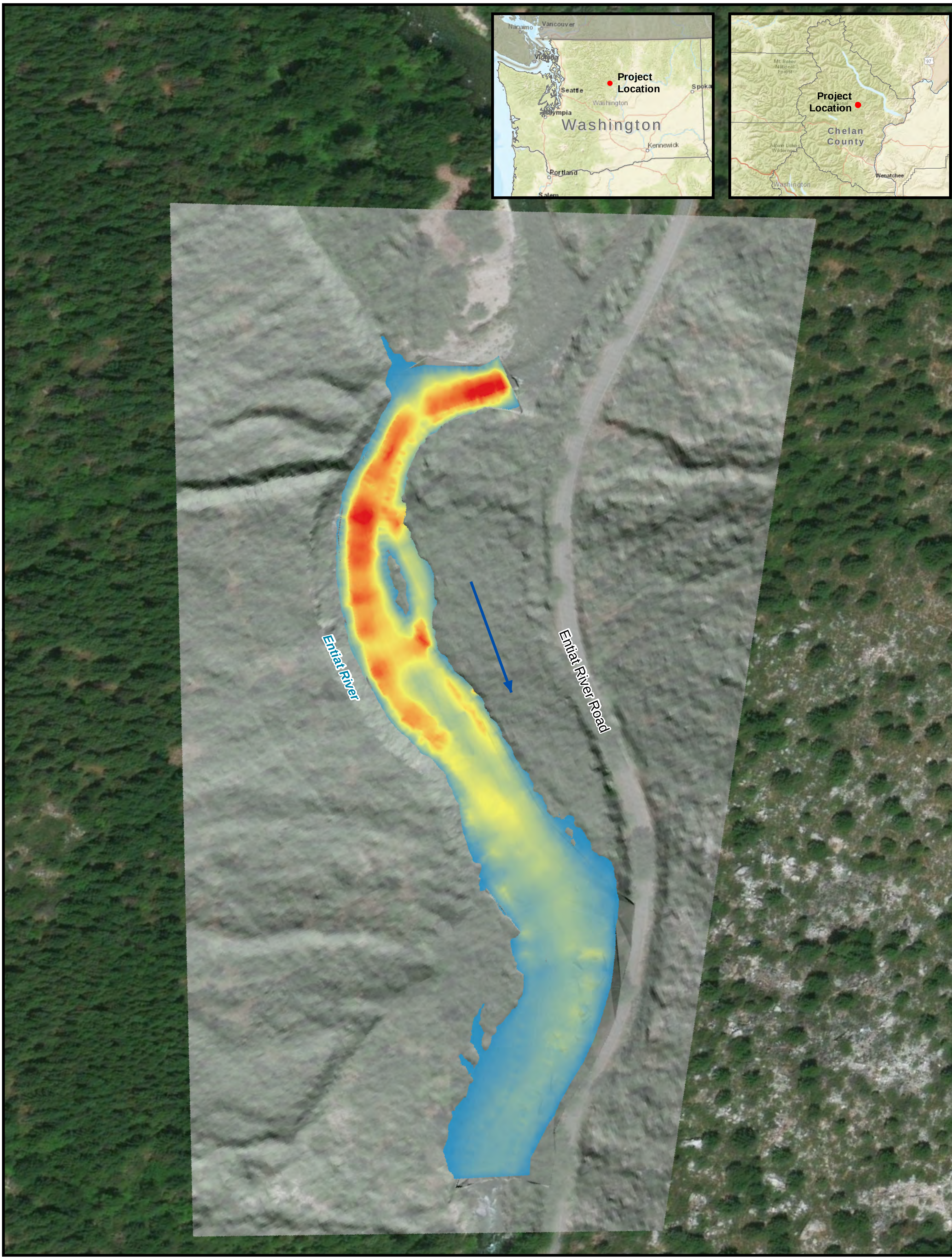

Legend

Flow Direction

Shear Stress (psf)

High : 6.3

Low : 0

Entiat River
Lower Signal Reach
Chelan County, Washington

N

0 200 400

Feet

Figure B-2-5
2-year Flow
Existing Conditions
Hydraulic Model Shear Stress

Entiat River = 2,107 cfs

TETRA TECH

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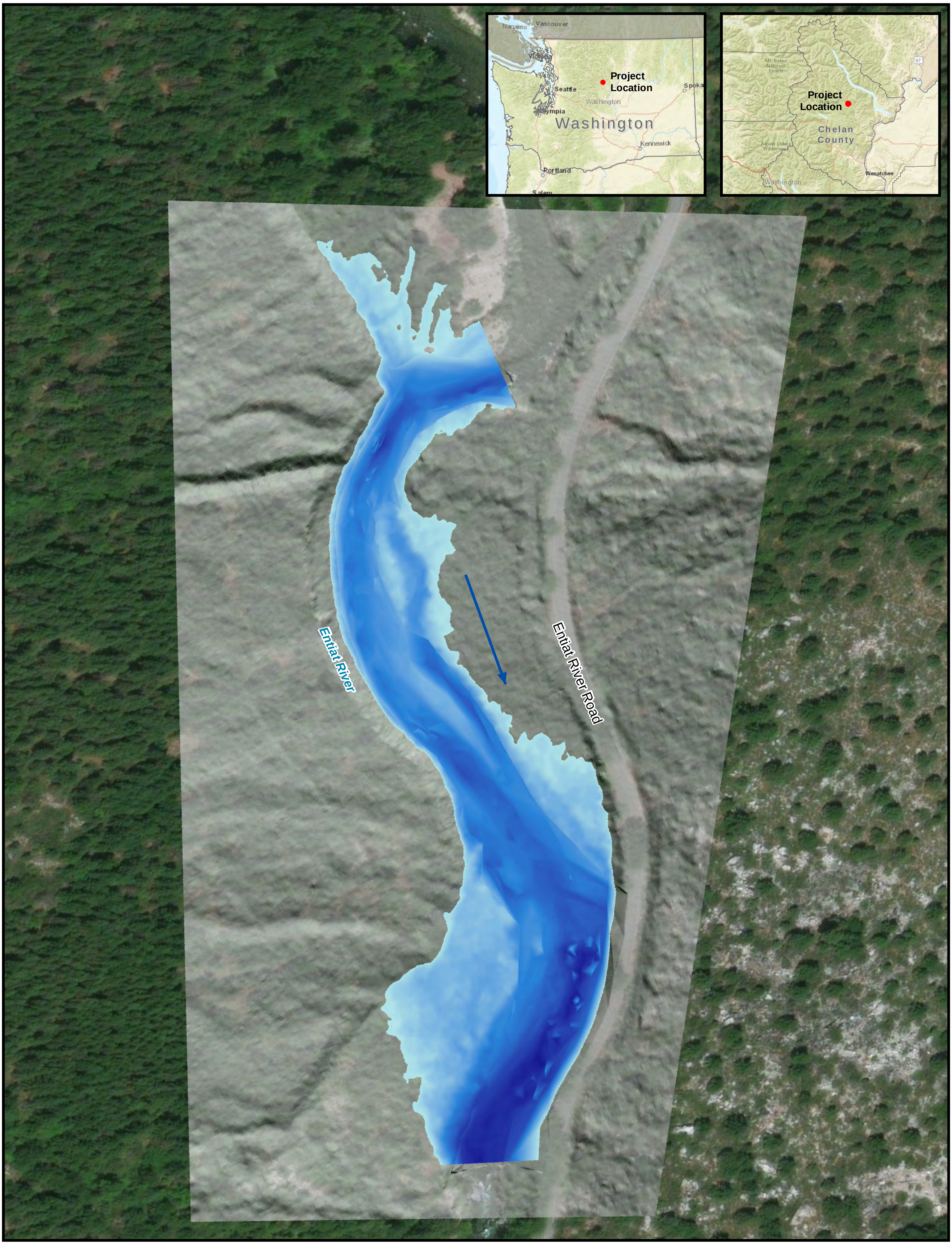

Legend

Flow Direction

Inundation Depth (ft)

High : 14.3

Low : 0

Entiat River
Lower Signal Reach
Chelan County, Washington

N

0 200 400
Feet

Figure B-2-6
100-year Flow
Existing Conditions
Hydraulic Model Inundation

Entiat River = 4,900 cfs

TETRA TECH

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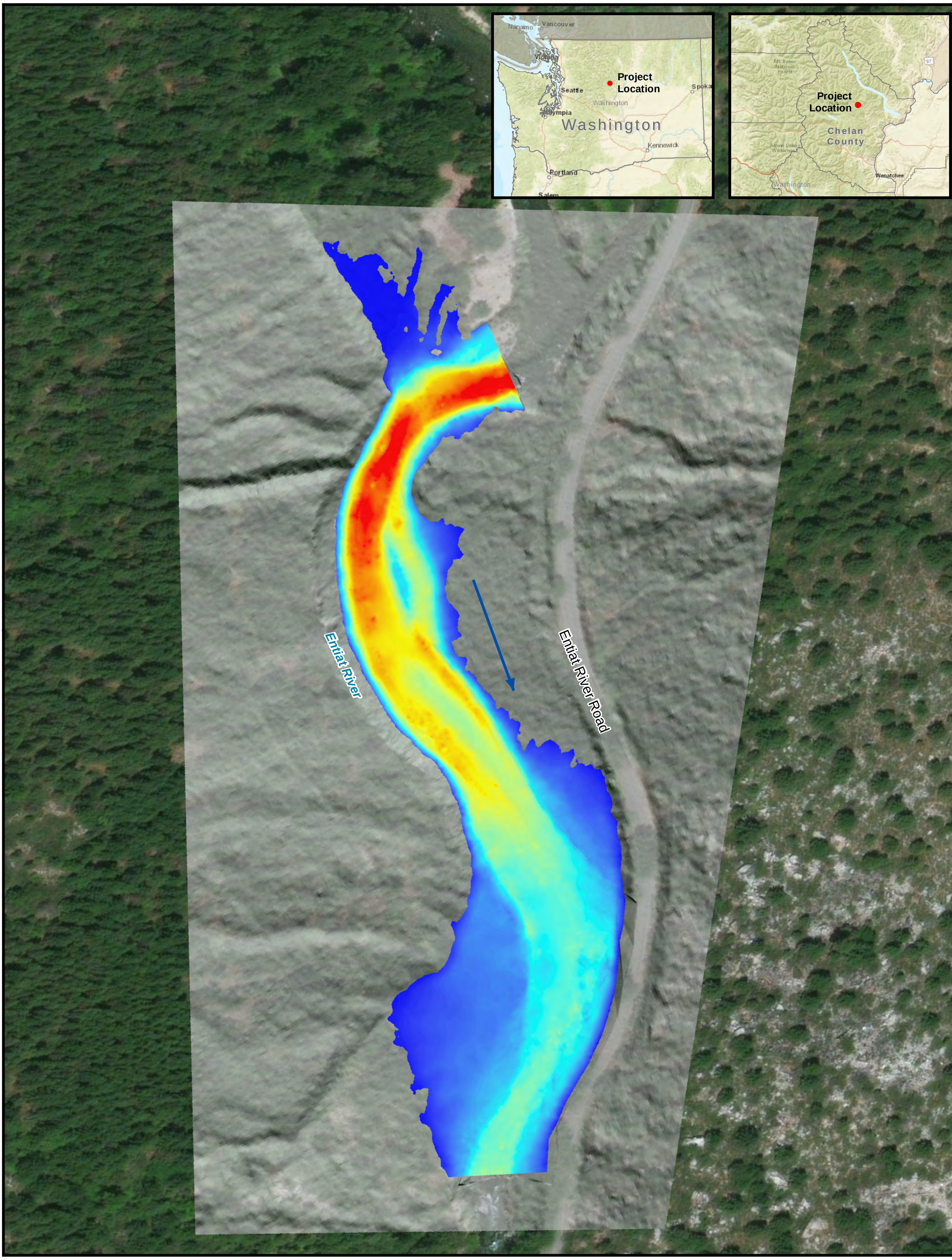

Legend

Flow Direction

Velocity (ft/s)

High : 13.6

Low : 0

Entiat River
Lower Signal Reach
Chelan County, Washington

N

0 200 400
Feet

Figure B-2-7
100-year Flow
Existing Conditions
Hydraulic Model Velocity

Entiat River = 4,900 cfs

TETRA TECH

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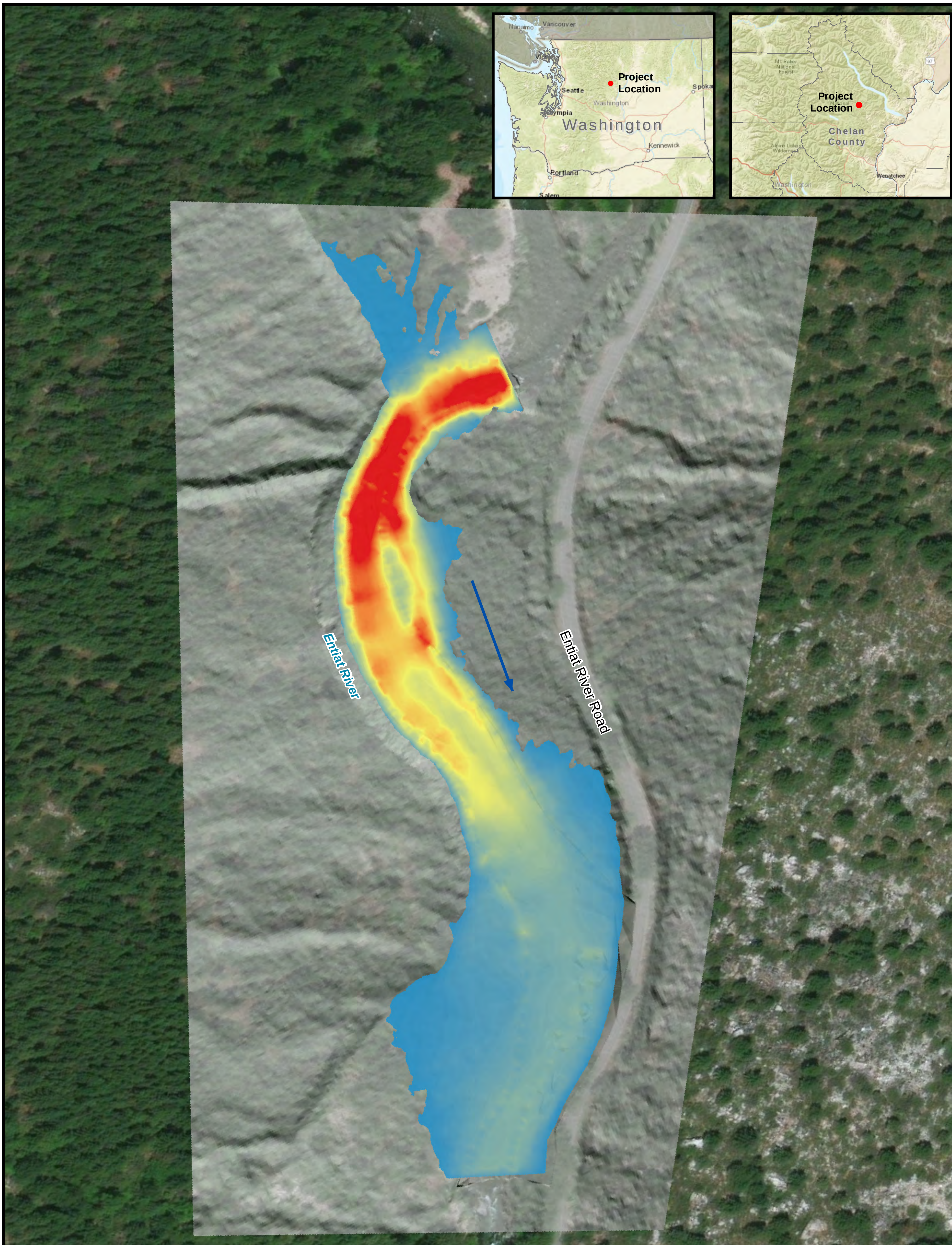

Legend

Flow Direction

Shear Stress (psf)

High : 10.3

Low : 0

Entiat River
Lower Signal Reach
Chelan County, Washington

N

0 200 400
Feet

Figure B-2-8
100-year Flow
Existing Conditions
Hydraulic Model Shear Stress

Entiat River = 4,900 cfs

TETRA TECH

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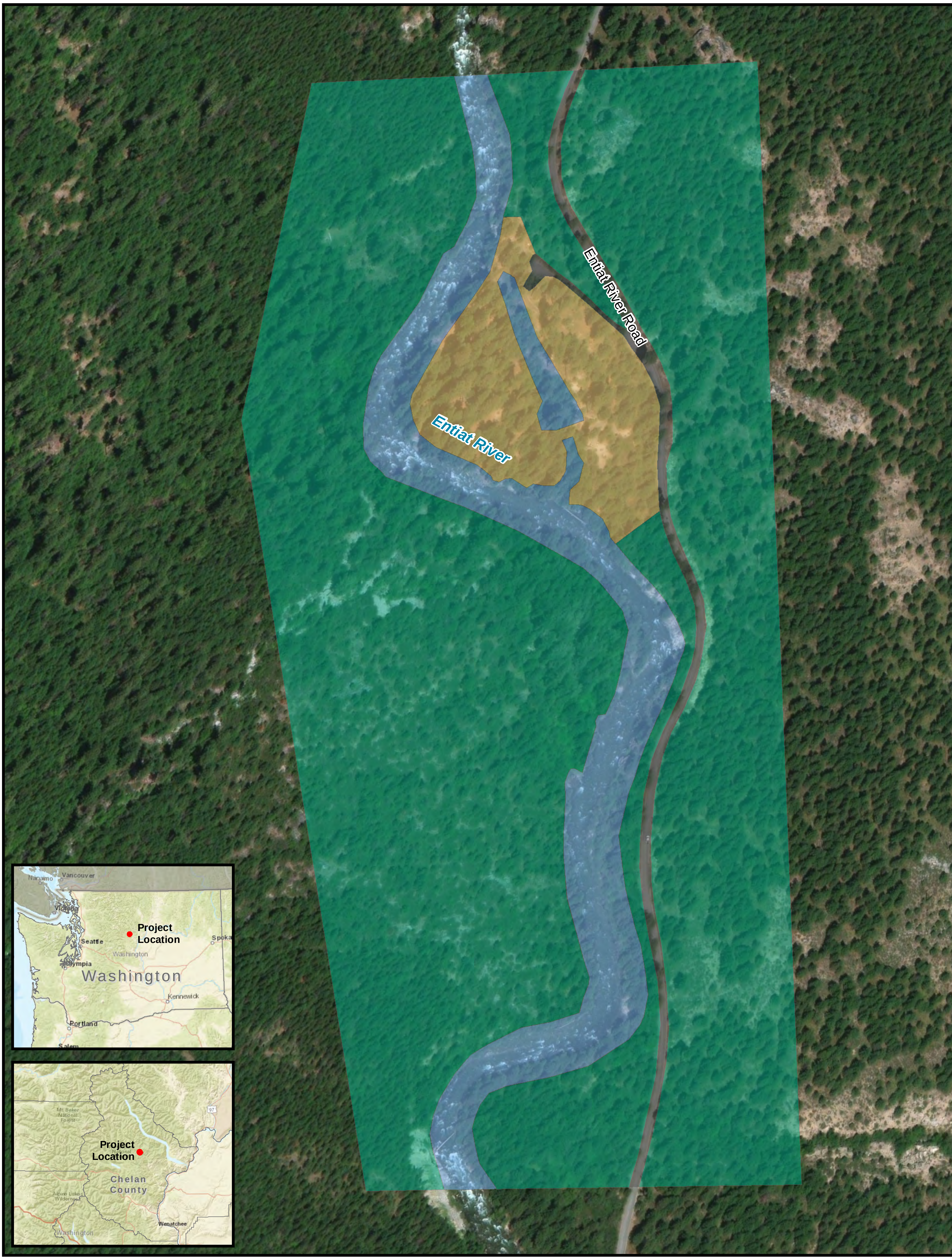

Legend

LandUse

- Campground
- Channel
- Forested
- Road

Land Use/ Land Cover	Manning's n Value
Campground	0.07
Channel	0.06
Forested	0.08
Road	0.015

Entiat River
Fox Creek Reach
Chelan County, Washington

N

0 200 400
Feet

Figure B-3-1
Land Use

TETRA TECH

R:\PROJECTS\UPPER_STILLWATERS_6194\FOX_CREEK\MAPS\C-3-1_FoxCr_LandUse.mxd

Legend

Flow Direction

Inundation Area

Entiat River
Fox Creek Reach
Chelan County, Washington

N

0 200 400
Feet

Figure B-3-2
Survey Flow
Channel Roughness
Hydraulic Model Calibration

Entiat River = 70.5 cfs

TETRA TECH

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Legend

Flow Direction

Inundation Depth (ft)

High : 8.7

Low : 0

Entiat River
Fox Creek Reach
Chelan County, Washington

N

0 200 400
Feet

Figure B-3-3
2-year Flow
Existing Conditions
Hydraulic Model Inundation

Entiat River = 2,073 cfs

TETRA TECH

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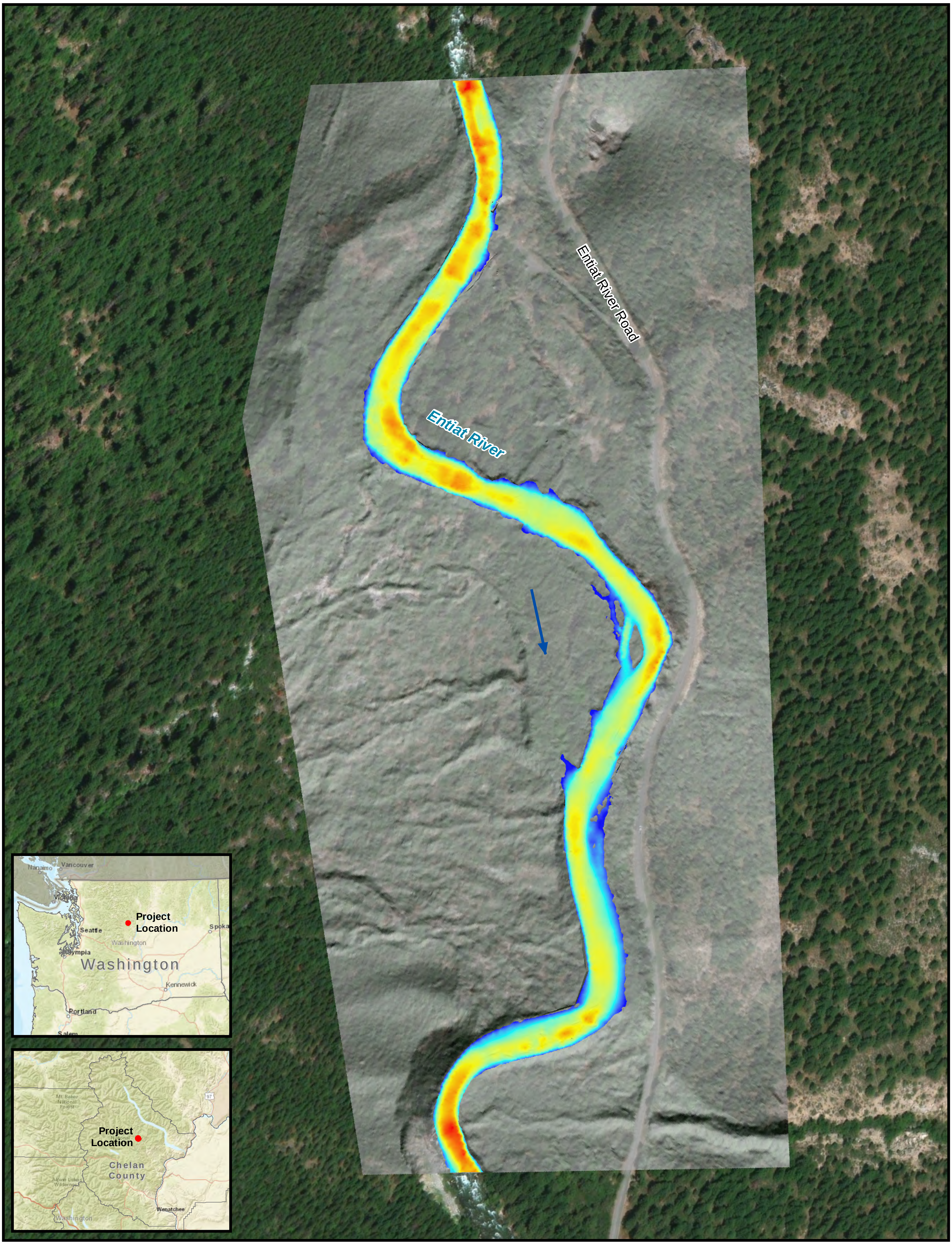

Legend

Flow Direction

Velocity (ft/s)

High : 12.7

Low : 0

Entiat River
Fox Creek Reach
Chelan County, Washington

N

0 200 400
Feet

Figure B-3-4
2-year Flow
Existing Conditions
Hydraulic Model Velocity

Entiat River = 2,073 cfs

TETRA TECH

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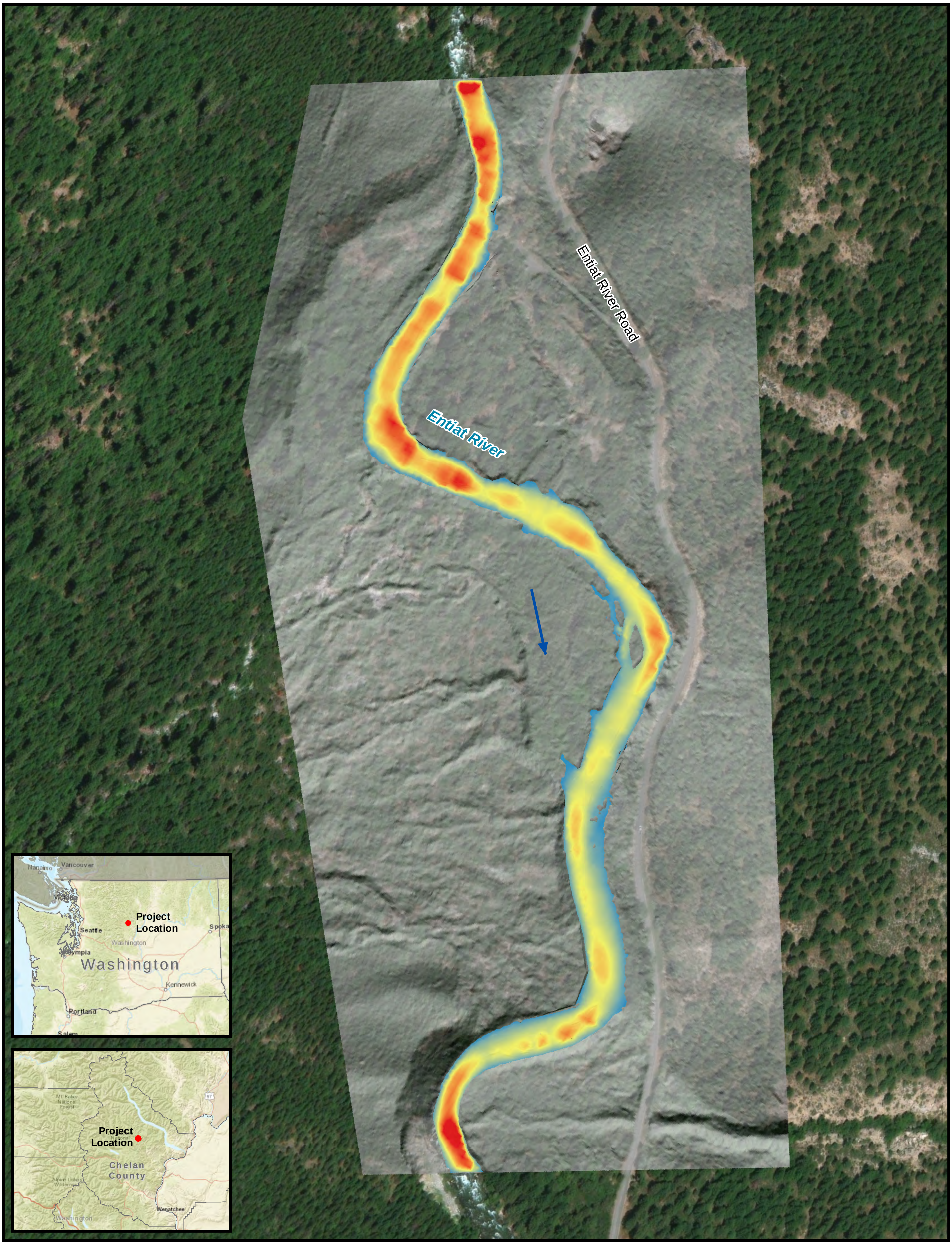

Legend

Flow Direction

Shear Stress (psf)

High : 9.4

Low : 0

Entiat River
Fox Creek Reach
Chelan County, Washington

N

0 200 400

Feet

Figure B-3-5
2-year Flow
Existing Conditions
Hydraulic Model Shear Stress

Entiat River = 2,073 cfs

TETRA TECH

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Legend

Flow Direction

Inundation Depth (ft)

High : 11.0

Low : 0

Entiat River
Fox Creek Reach
Chelan County, Washington

N

0 200 400

Feet

Figure B-3-6
100-year Flow
Existing Conditions
Hydraulic Model Inundation

Entiat River = 4,827 cfs

TETRA TECH

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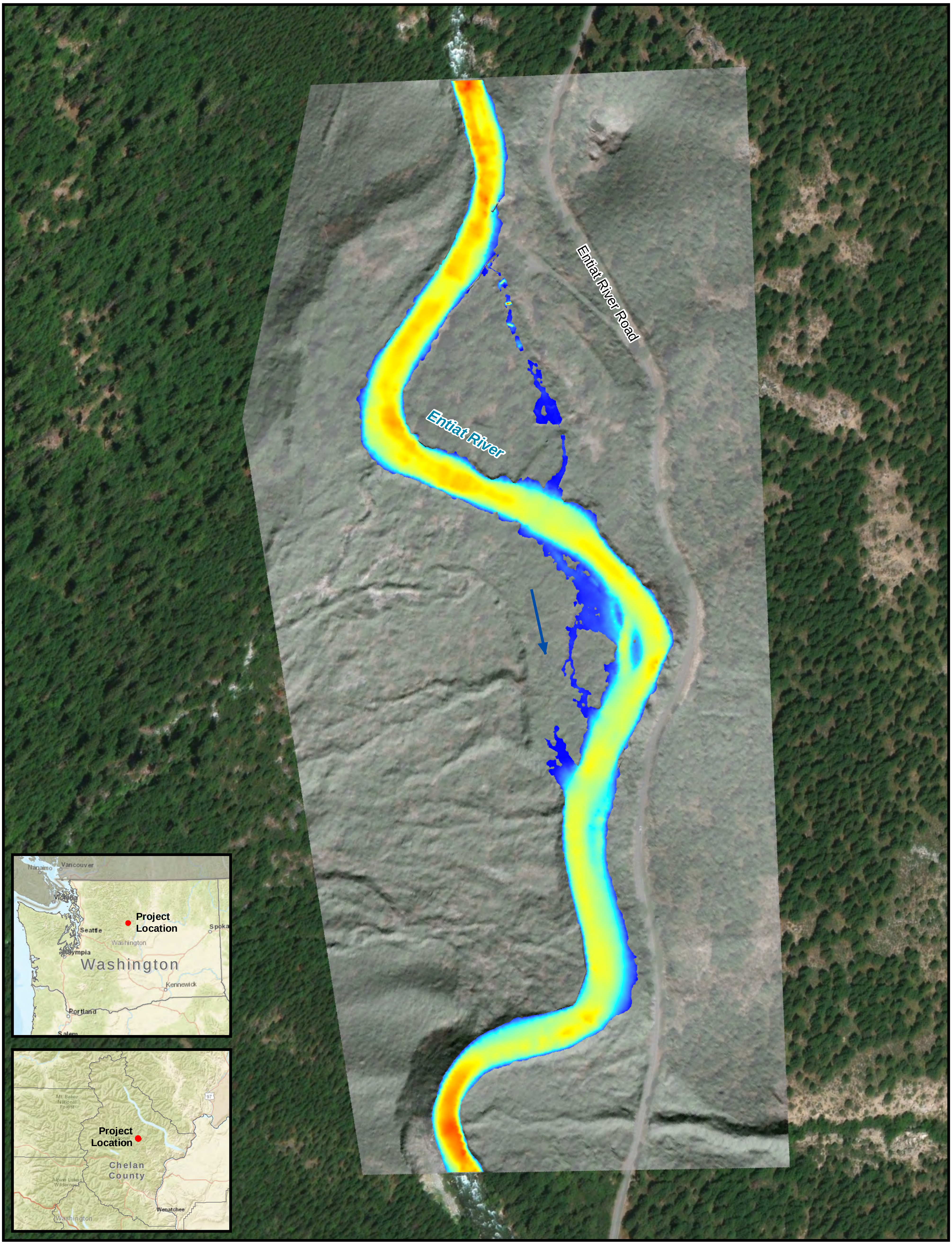

Legend

Flow Direction

Velocity (ft/s)

High : 18.2

Low : 0

Entiat River
Fox Creek Reach
Chelan County, Washington

N

0 200 400
Feet

Figure B-3-7
100-year Flow
Existing Conditions
Hydraulic Model Velocity

Entiat River = 4,827 cfs

TETRA TECH

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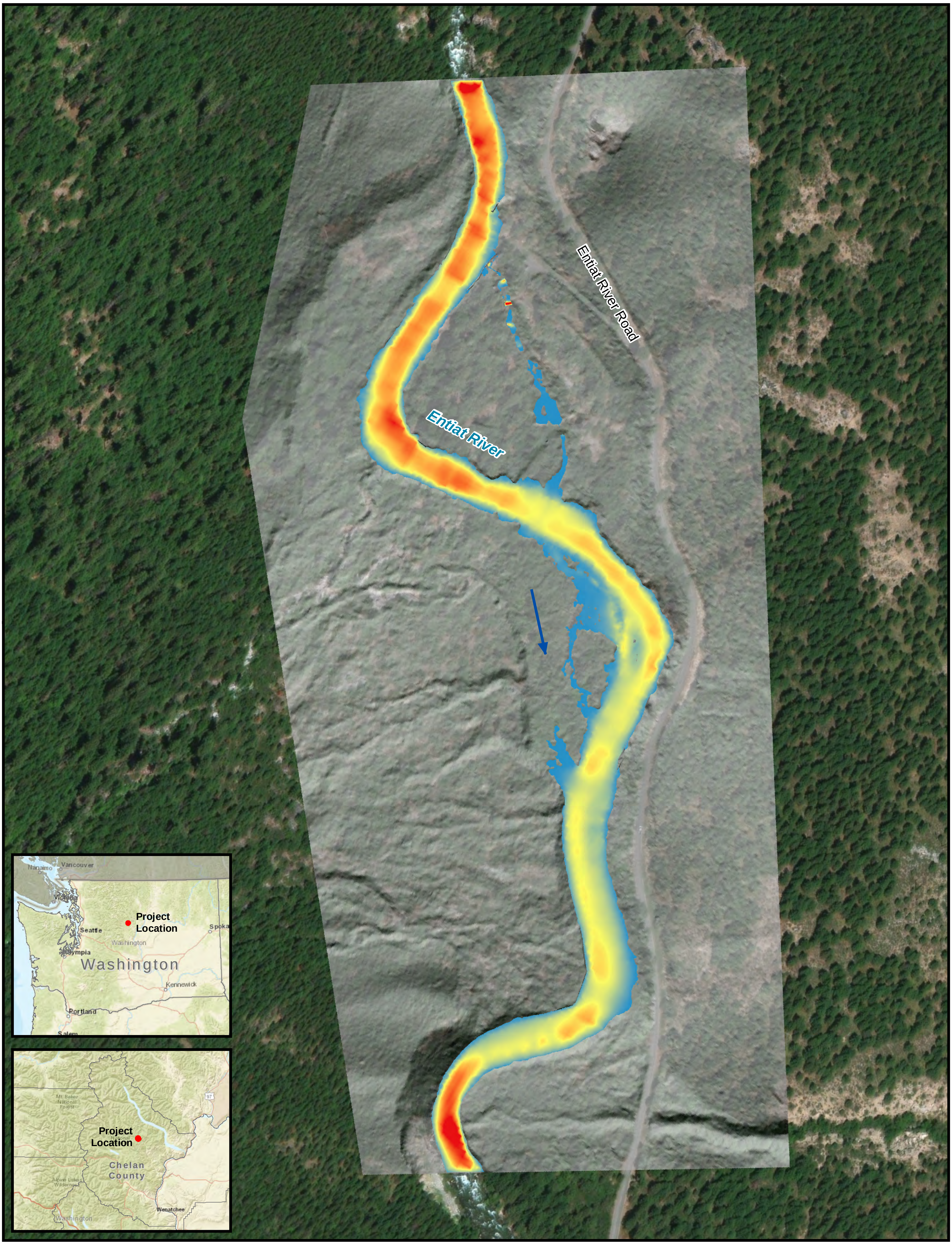

Legend

Flow Direction

Shear Stress (psf)

High : 16.4

Low : 0

Entiat River
Fox Creek Reach
Chelan County, Washington

N

0 200 400
Feet

Figure B-3-8
100-year Flow
Existing Conditions
Hydraulic Model Shear Stress

Entiat River = 4,827 cfs

TETRA TECH

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TETRA TECH