Preston Reach Assessment
Entiat River

Chelan County, Washington

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Boise, Idaho

July 2009

U.S. Department of the Interior Mission Statement

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Tribes and our commitments to island communities.

Mission of the Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photo: View is to the east looking downstream at a large wood complex along river right. Subreach PR-IZ-4 (Inner Zone) – Entiat Subbasin, Washington – Bureau of Reclamation.
Date: August 21, 2008 Photo by: R. McAffee

RECLAMATION
Managing Water in the West

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Acknowledgements

The Bureau of Reclamation (Reclamation) was fortunate to have the support and cooperation of multiple United States (U.S.) Forest Service staff who participated in the effort to produce the Preston Reach Assessment, Entiat River, Chelan County, Washington. In particular, Reclamation acknowledges the collaborative efforts and contributions of U.S. Forest Service employees Phil Archibald and Dave Hopkins with the integration of the Reach-based Ecosystem Indicators (REI) that is the overarching strength of this reach assessment.

Reclamation would like to thank the Entiat Habitat subcommitee for their review and contributions to this report.

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Acronyms and Definitions

Corps	Army Corp of Engineers
DOE	Department of Ecology
ESA	Endangered Species Act
GIS	Geographic Information System
HUC	Hydrologic Unit Code
IDT	Inter-disciplinary Team
IFIM	Instream Flow Incremental Methodology
ITS	Index of Thermal Stress
IZ	Inner Zone
OZ	Outer Zone
Reclamation	Bureau of Reclamation
REI	Reach-based Ecosystem Indicators
RM	River Mile
RTT	Regional Technical Team
UCSRB	Upper Columbia Salmon Recovery Board
U.S.	United States
USFS	U.S. Forest Service
VSP	Viable Salmonid Population
WAT	Watershed Action Team
WQI	Water Quality Index

Table of Contents

Page

Table of Contents (Continued)

List of Figures

Table of Contents (Continued)

List of Tables

Table of Contents (Continued)

Photographs

Appendices

Executive Summary

The Bureau of Reclamation (Reclamation) produced this reach assessment to assist in meeting tributary habitat commitments contained in the 2008 Federal Columbia River Power System Biological Opinion (NMFS 2008). This report provides scientific information to Federal, Tribal, State, and local partners for identifying, prioritizing, and implementing sustainable field projects that improve survival and lead to the recovery of salmon and steelhead listed under the ESA (NMFS 2008).

The Entiat subbasin is located entirely in Chelan County, Washington, and the Entiat River flows into the Columbia River at river mile (RM) 482.7. As part of the Columbia River Basin, the Entiat River contains salmon and steelhead habitat of the Columbia River fish species. The Middle Entiat River section, known as the Stillwater area, has Class A waters and is a Category 1 watershed in which Protection and Restoration are recommended. The species of concern found in the Entiat River include Upper Columbia River spring Chinook salmon (*Oncorhynchus tshawysha*), Upper Columbia River steelhead (*Oncorhynchus mykiss*), and Columbia River bull trout (*Salvelinus confluentus*), which are included in the Threatened and Endangered list under the Endangered Species Act (ESA) (UCSRB 2007).

Watershed limiting factors defined as “conditions that limit the ability of habitat to fully sustain populations of salmon” identified for the Entiat subbasin are lack of overwintering juvenile rearing habitat, loss of access to spawning and rearing habitat, floodplain function, lack of large woody debris, fine sediment in spawning gravel, elevated water temperature, and water quality (Andonaegui 1999; UCSRB 2007; Appendix A: Reach-based Ecosystem Indicators).

The Regional Technical Team (RTT) selected priority reaches and drafted priority actions for implementing habitat actions on February 11, 2009 for the Stillwater area (that includes the Preston reach). Priority actions include the following: (1) protect large intact riparian areas or allow for side channel reconnection, (2) restore natural channel processes, and (3) increase large woody debris retention and recruitment to increase complexity in a manner that is consistent with natural channel structure and function. At the watershed-scale (Entiat subbasin), the priority objectives are (1) to reduce artificially high rates of sediment input and restore other upland watershed processes, (2) develop a nutrient enhancement plan, (3) increase instream flow, and (4) enhance riparian vegetation.

Preston reach, located between river miles RM 21.1 and RM 23.1 on the Entiat River, is a 6th field Hydrologic Unit Code (HUC) watershed. The Preston reach is characterized as an unconfined geomorphic reach type based on natural channel constraints. In its natural state, the Entiat River maintained dynamic equilibrium by actively migrating laterally across its floodplain within the Preston reach. Typically, unconfined geomorphic reaches have flatter slopes and a complex network of channels that result in a high degree of interaction between the active channel and its floodplain. This lateral channel migration maintains a lower energy and flatter channel gradient as sediment is stored before being eroded and transported downstream. The natural ecosystem processes of hydrologic, geomorphic, and vegetative regimes create a healthy stream characterized by a dynamic cycle of conversion from river to floodplain and vice versa, producing a continuous renewal of fish habitat. When interaction between these regimes is altered, it can negatively impact the availability of fish habitat and could threaten the continuation of the species within the basin.

Field surveys and evaluations were conducted in the Preston reach during the 2008 field season to determine the condition of the hydrologic, geomorphic, and vegetative regimes. Ecosystem processes in the Preston reach are in a moderately degraded state as a result of anthropogenic impacts. The dynamic interactions between the three regimes have been impacted by levees, bank protection, and development. These features have reduced the overall floodplain connectivity and resulted in localized changes in sediment transport and deposition. Rehabilitation strategies provided in this reach assessment are consistent with the RTT priority objectives consisting of both potential protection and rehabilitation actions to maintain and improve the riverine ecosystem.

Purpose of the assessment: Refine understanding of geomorphic potential within the Preston reach and establish environmental baseline conditions to assist in the local selection, implementation, and monitoring of potential habitat actions that will address the limiting factors through the rehabilitation of habitat-forming processes.

Goal of the assessment: Provide sound integrative river science that will assist the local watershed action group in the development of an implementation strategy and aid in project selection. The reach assessment had these objectives:

1) Determine the functional arrangement of physical and biological components of the reach.
2) Establish an understanding of the predominant physical processes.
3) Interpret and document deviations from natural processes.
4) Propose potential solutions.
5) Develop a recommended prioritization of potential habitat actions to be utilized by local watershed action groups when developing an implementation strategy and selection of projects.

This reach assessment establishes environmental baseline conditions in the Preston reach by examining dynamic interaction of the hydrologic, geomorphic, and vegetative regimes, and assessing their influences on forming and maintaining fish habitat at the reach scale. A reach is comprised of smaller-scale components that include the active main channel and the floodplain areas which are called subreaches. Subreaches are delineated by lateral and vertical controls with respect to the presence or absence of inner or outer zones. An inner zone (IZ) is an area where ground-disturbing flows take place, such as the active main channel, related side channels and active bars. An outer zone (OZ) is an area that may become inundated at higher flows, but typically does not experience ground-disturbing flows. The outer zone is typically a terrace thread that is generally coincidental with the historic channel migration zone except where the channel has been modified or incised, disconnecting the channel from the historic floodplain (modified from USDA 2008).

The river condition describes the current state of fluvial processes and their relationship to forming complex habitat. Anthropogenic features can be analyzed to establish impacts to the current river condition. Subsequently, the river condition provides a baseline for comparisons in future references. In the instance of the Preston reach, the habitat-forming processes have been unfavorably impacted, with 68 percent of the reach-based ecosystem indicators (Appendix A: Reach-based Ecosystem Indicators (REI)) being in an ***At Risk Condition*** as shown in Table 1.

With the exception of physical barriers, all other pathways for the Preston reach have at least one reach-based ecosystem indicator interpreted to be functioning in an ***At Risk Condition***. Three watershed-scale pathways (watershed condition, flow/hydrology, and water quality) are interpreted to be in an ***At Risk Condition*** due to both natural and anthropogenic causes. Two reach scale pathways (habitat quality and channel condition) are interpreted to be in an ***At Risk Condition*** due primarily to anthropogenic causes. The two reach scale pathways are symptomatic of lost geomorphic potential and habitat-forming processes. Geomorphic potential is defined in this report as the capability of adjustment or change in process/structural components of an ecosystem through the combined interaction of hydrologic, geomorphic, and vegetative regimes to form, connect, and maintain fish habitat over time.

Geomorphic potential in the Preston reach has been altered through reduced floodplain connectivity and lateral channel migration. Reduced floodplain connectivity is due to levees/push-up levees in the inner zone subreaches PR-DIZ-1, PR-DIZ-2, PR-DIZ-3, and outer zone subreaches PR-DOZ-2, PR-DOZ-5, and PR-DOZ-7. Reduced lateral channel migration is due to riprap and a wood revetment in inner zone subreach PR-IZ-4 and outer zone subreach PR-OZ-8. These subreaches are interpreted to be in an ***At Risk Condition*** and are recommended for rehabilitation actions. All other subreaches are interpreted to be in an ***Adequate Condition*** and are recommended for protection actions (Figure 1). The large woody debris reach-based ecosystem indicator is interpreted to be in an ***At Risk Condition*** that could be addressed for inner zones PR-IZ-2, PR-IZ-3, and PR-IZ-4 by strategically placing unanchored “key members” (large wood greater than 30-inch diameter at breast height and a length of 30 or more feet with rootwad attached) on point and medial bars, and allowing the river to naturally adjust their position. Unanchored large woody debris placements are not recommended in inner zone PR-IZ-1 because it is a localized transport reach.

Table 1. Reach-based ecosystem indicators (REI) for the Preston reach. Each indicator was interpreted to be in one of three conditions: *Adequate, At Risk, or Unacceptable Risk*.*

Pathway	Reach-based Indicator (REI)	Condition
Watershed Condition	Effective Drainage Network and Watershed Road Density	At Risk
	Disturbance Regime	At Risk
Flow/Hydrology	Streamflow	At Risk
Water Quality	Temperature	At Risk
	Turbidity	Adequate
	pH	At Risk
	Suspended Solids	At Risk
Habitat Access	Physical Barriers	Adequate
Habitat Quality	Substrate	Adequate
	Fine Sediment	At Risk
	Large Woody Debris	At Risk
	Pool Frequency and Quality	Adequate
	Off-channel Habitat	At Risk
Channel Condition and Dynamics	Floodplain Connectivity	At Risk
	Bank Stability/Channel Migration	At Risk
	Vertical Channel Stability	At Risk
Riparian Vegetation	Structure (Floodplain)	Adequate
	Disturbance (30 m buffer zone)	At Risk
	Canopy Cover (10 m buffer zone)	Adequate

*Existing conditions are defined based on criteria defined in the REI (Appendix A).

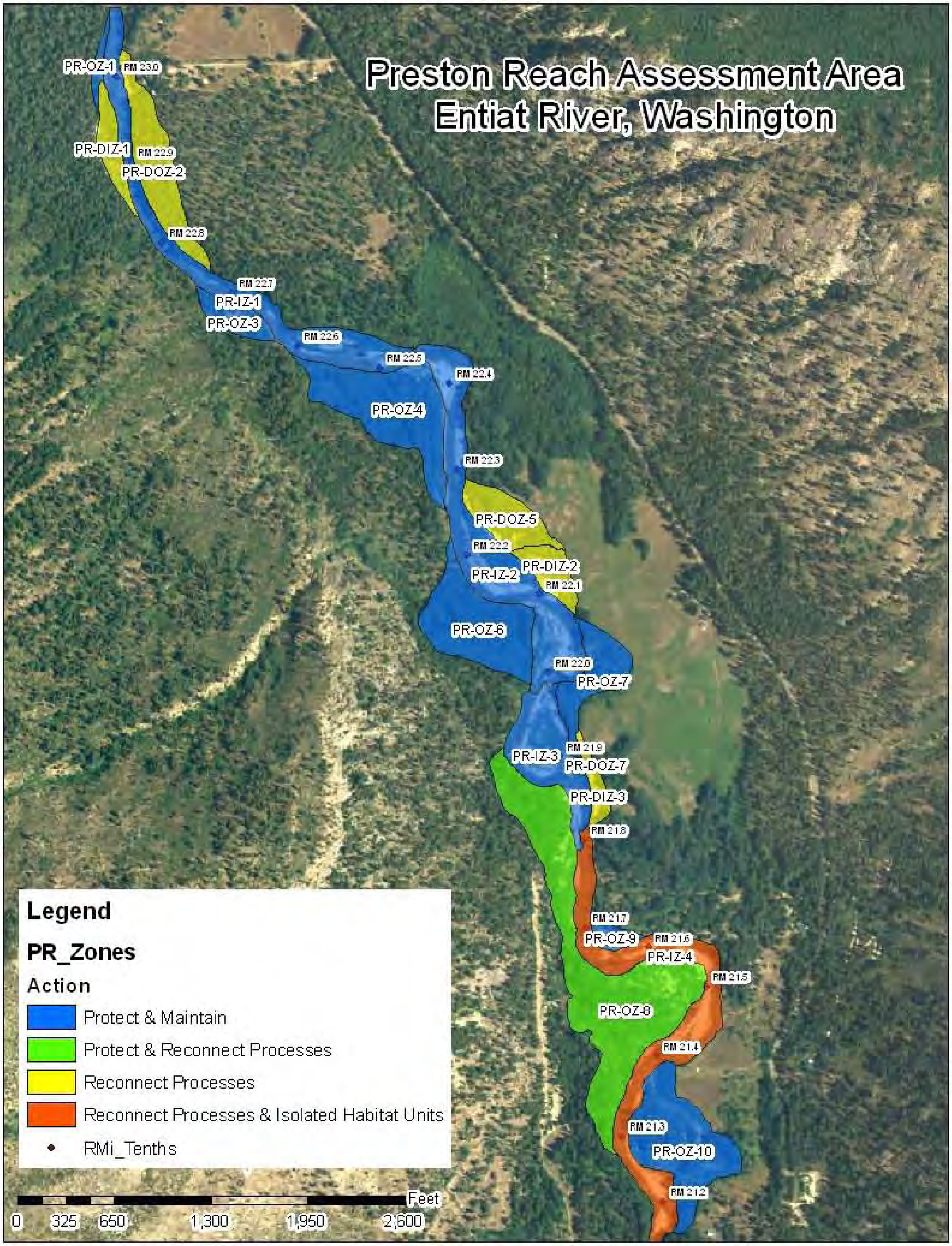


Figure 1. Potential habitat actions by subreach and their relative priority of implementation.

OVERVIEW

Many authors have documented strategies that emphasize maintaining functioning habitat, reconnecting isolated habitat, and restoring processes that form and maintain habitats (Beechie et al. 1996; Kauffman et al. 1997; Beechie and Bolton 1999; Montgomery and Bolton 2003). Habitat actions of this nature often occur at the site or reach scale. Roni et al. (2002) introduced a hierarchical strategy that places site-specific actions within a watershed context. The Reclamation reach assessment and previous objectives purposely feed into this strategy by further telescoping options through several additional filters or layers of consideration at the reach scale. This strategy can be used to prioritize potential habitat actions within a geomorphic reach context by beginning with protection and transitioning through several forms of passive and active rehabilitation.

Assessments telescope from the largest scale called a basin to a smaller scale called a reach from which habitat actions are implemented (Figure 2). This is called a top-down approach. After implementation of a habitat action, monitoring of the physical and biological variables telescope in reverse from the reach to the basin, called a bottom-up approach, from which intervention analysis or effectiveness monitoring may be conducted on the status of the

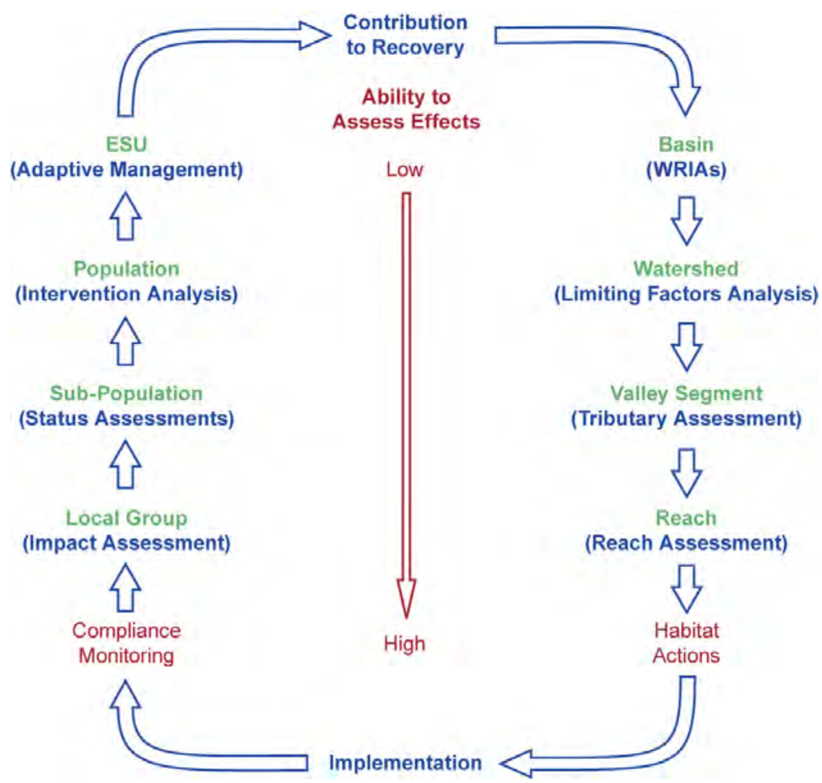


Figure 2. Idealized model showing how assessments and monitoring are hierarchically nested and related. Compiled from Hillman (2006), UCSRB (2007), and Stewart-Oaten and Bence (2001).

species of concern. This nesting approach enables development of an overall understanding of the ecosystem's current and historic conditions and how the species of concern and stream processes such as the creation and maintenance of aquatic habitat have been affected.

The hierarchical implementation strategy, which is illustrated in Figure 3, is tied to a corresponding gradational color scheme and used throughout the Subreach Unit Profile section to assist with correspondences throughout the project selection process. However, the stratified strategy does not consider landowner willingness, construction feasibility, costs, and other local considerations. There are alternative methods that can be used to sequence project selection (i.e., degree of departure, landowner willingness, and construction costs) that can be factored in along with the results of reach assessment.

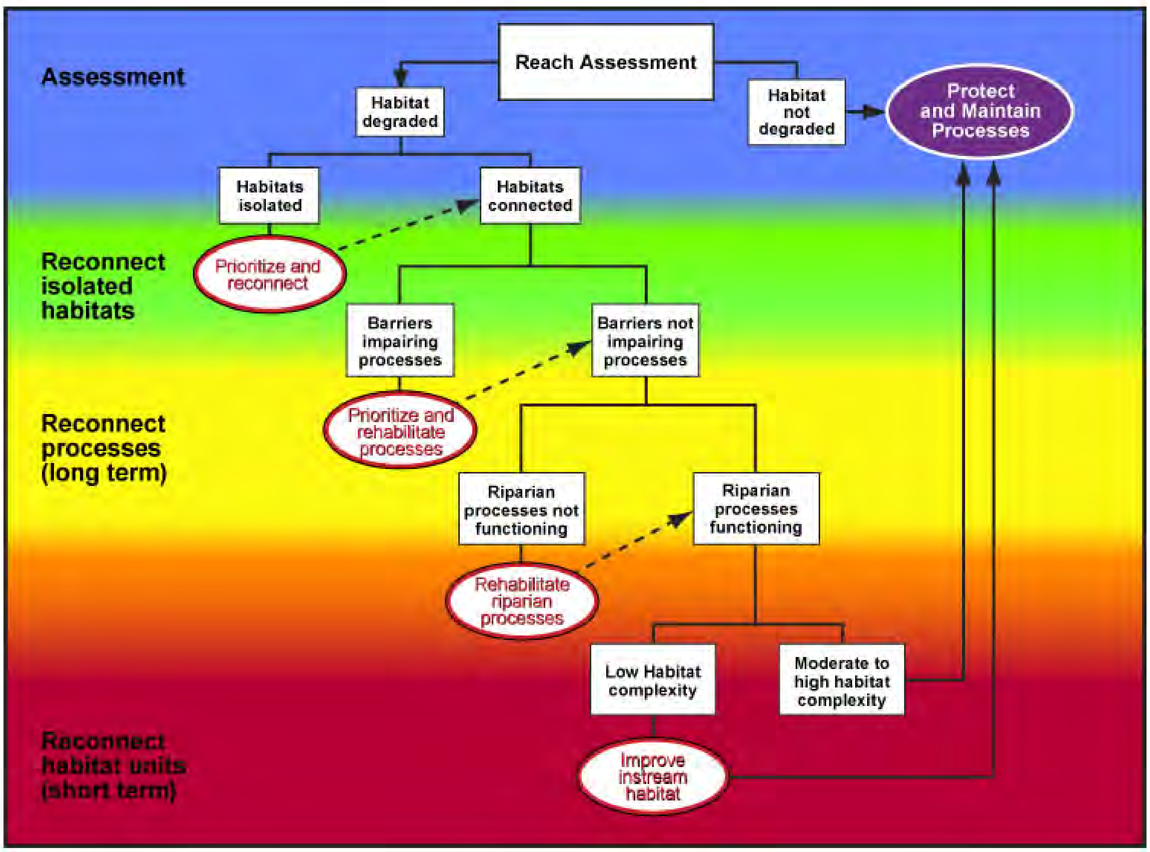


Figure 3. Implementation strategy for prioritizing potential habitat actions at the reach scale (adapted from Roni et al. 2005).

Tributary assessments are conducted to analyze impaired stream processes and their effects as well as to provide a prioritized list of geomorphic reaches based on floodplain or valley confinement (i.e., confined, moderately confined, and unconfined). Not all reaches require a reach assessment. For example, naturally confined reaches that are not severely degraded and pose little risk to property and infrastructure may not need a reach assessment. Reach assessments are generally recommended for moderately to unconfined geomorphic reaches where complex processes have been degraded and where the implementation of habitat actions may pose risks to property and infrastructure. Even in instances where a reach assessment is not conducted, some baseline data could still be collected prior to implementing any habitat action so that the action can be monitored for effectiveness.

The purpose of a reach assessment is to refine understanding of the geomorphic potential and establish environmental baseline conditions at the reach scale. The reach assessment evaluates the current condition of a group of indicators. The physical variables, which are quantifiable and have geospatial reference, are organized in a REI matrix (Appendix A: Reach-based Ecosystem Indicators (REI)). The variables measured in the REI record the baseline environmental conditions and are hierarchical in nature in that they are used as information about the condition of higher-level indicators called pathways. The REI identifies positive attributes and deficiencies in the hydrologic, geomorphic and vegetative regimes upon which appropriate habitat actions can be implemented using a cost effectiveness approach (i.e., Roni et al. 2005).

Following implementation of a habitat action or series of actions, the action is documented by including what was done, where it was done, and why it was done (i.e., compliance monitoring). After several habitat actions have been implemented in a reach, impact assessments that develop a time series of physical and biological responses to the intervention (i.e. habitat actions) can be completed using a subset of the variables from the REI in conjunction with ongoing status and trend monitoring.

Impact assessments and status and trend monitoring that document changes to physical and biological indicators can be used to evaluate how the ecosystem and the species of concern are responding to the intervention. This is known as an intervention analysis to determine the overall response of the ecosystem and if the habitat action(s) were ecologically successful. If the response is positive, then the habitat actions were effective and there is no need for adjustments. If the response is flat or negative, the habitat actions may need to be adjusted within an adaptive management framework. These checks and balances are intended to improve the processes that create and maintain complex habitat types or the species of concern and ultimately contribute to their recovery.

PURPOSE AND LOCATION

Reclamation produced this report to help meet tributary habitat commitments contained in the 2008 Federal Columbia River Power System Biological Opinion (NMFS 2008). This report provides scientific information to Federal, Tribal, State, and local partners for identifying, prioritizing, and implementing habitat actions that improve the survival and potential for recovery of salmonid species listed under the ESA.

The goal of a reach assessment is to set up local stakeholder processes for project selection based on sound integrative river science, through the following objectives:

- *Determining the functional arrangement of physical and biological components of the response reach.* Establish the geomorphic potential of the river reach through a spatial framework and relevant scaling relationships for the assessment area. This is done through scaling down the response reach to individual subreaches and channel/geomorphic units, which are smaller scale structural components of the reach. Subreach units are comprised of the active main channel and floodplain areas. A local geomorphic regime has inherent constraints and capabilities for forming, connecting, and sustaining aquatic river habitat.

- *Establishing an understanding of the predominant physical processes.* Identify linkages between physical processes and anthropogenic impacts based on the understanding of the key physical processes operating in the reach or within and among the context of subreach units; and identify how these processes have been impacted by past and present human activities.

- *Interpreting and documenting the deviations from natural channel processes.* Diagnose river conditions at the reach scale based on integrating physical, biological, and habitat information into an REI. The REI is a diagnostic tool for measuring baseline environmental conditions and identifying positive attributes and deficiencies in three regimes: hydrologic, geomorphic, and vegetative.

- *Proposing potential solutions.* Identify and prioritize potential habitat actions at the subreach scale that support the greatest cumulative biological benefit based on a refined understanding of the geomorphic potential and environmental baseline conditions.

- *Developing a recommended prioritization.* Develop a recommended prioritization of the subreaches based on refined understanding of geomorphic potential and ecosystem conditions to be utilized by local watershed action groups when developing an implementation strategy and the selection of projects.

- *Presenting the results to the local group for project selection.* Use the proposed implementation strategy along with other local factors provided by local stakeholders and partners to discuss a synthesis of all available information and ultimately, an implementation time line.

The Entiat subbasin is located in Chelan County, Washington, and the Entiat River flows into the Columbia River at river mile (RM) 482.7 (Figure 4). The Entiat River contains important habitat that support all life stages for the Columbia River salmonid species. The Middle Entiat River section, known as the Stillwater area, has Class A waters and is a Category 1 watershed in which Protection and Restoration are recommended. The species of concern found in the Entiat River include Upper Columbia River spring Chinook salmon (*Oncorhynchus tshawysha*), Upper Columbia River steelhead (*Oncorhynchus mykiss*), and Columbia River bull trout (*Salvelinus confluentus*), which are included in the Threatened and Endangered list under the ESA (UCSRB 2007).

The Regional Technical Team (RTT) selected priority reaches and drafted priority actions for implementing habitat actions on February 11, 2009 for the Stillwater area (that includes the Preston reach). Priority actions include the following: (1) protect large intact riparian areas or allow for side channel reconnection, (2) restore natural channel processes, and (3) increase large woody debris retention and recruitment to increase complexity in a manner that is consistent with natural channel structure and function. At the watershed-scale (Entiat subbasin), the priority objectives are (1) to reduce artificially high rates of sediment input and restore other upland watershed processes, (2) develop a nutrient enhancement plan, (3) increase instream flow, and (4) enhance riparian vegetation.

The Preston reach, located between river miles (RM) 21.1 and 23.1 on the Entiat River, is a 6th field Hydrologic Unit Code (HUC) watershed. The reach is characterized as an unconfined geomorphic reach type based on natural channel constraints. In its natural state, the Entiat River maintained dynamic equilibrium by actively migrating laterally across its floodplain within the Preston reach. Typically, unconfined geomorphic reaches have flatter slopes and a complex network of channels that result in a high degree of interaction between the active channel and its floodplain. This lateral channel migration maintains a lower energy and flatter channel gradient as sediment is stored before being eroded and transported downstream. The natural ecosystem processes of hydrologic, geomorphic and vegetative regimes create a healthy stream characterized by a dynamic cycle of conversion from river to floodplain and vice versa, producing a continuous renewal of fish habitat. When interaction between these regimes is altered, it can negatively impact the availability of fish habitat and could threaten the continuation of the species within the basin. Limiting factors at the watershed scale that are the result of various anthropogenic impacts include riparian condition, streambank condition, channel function, floodplain connectivity, water quality, habitat diversity, and large woody debris (Andonaegui 2001; UCSRB 2007; UCRTT 2007).

Field surveys and evaluations were conducted in the Preston reach during the 2008 field season to determine the condition of the hydrologic, geomorphic, and vegetative regimes. Ecosystem processes in the Preston reach are in a moderately degraded state as a result of anthropogenic impacts. The dynamic interactions between the three regimes have been impacted by levees, bank protection and development. These features have reduced the overall floodplain connectivity and resulted in localized changes in sediment transport and deposition. Rehabilitation strategies provided in this reach assessment are consistent with the RTT priority objectives consisting of both potential protection and rehabilitation actions to maintain and improve the riverine ecosystem.

The Upper Columbia Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan identified potential restoration strategies based on a combination of available data, aquatic ecosystem modeling, and professional judgment of a panel of scientists (UCSRB 2007). Further technical evaluation was recommended to refine the level of detail needed to implement projects and determine if the recommendations are sustainable and compatible with the geomorphic conditions of the river. Regarding physical processes, the UCSRB recommends conducting additional research to identify priority locations for protection and rehabilitation and examining fluvial geomorphic processes to assess how these processes affect habitat creation and maintenance. This reach assessment is intended to address those recommendations.

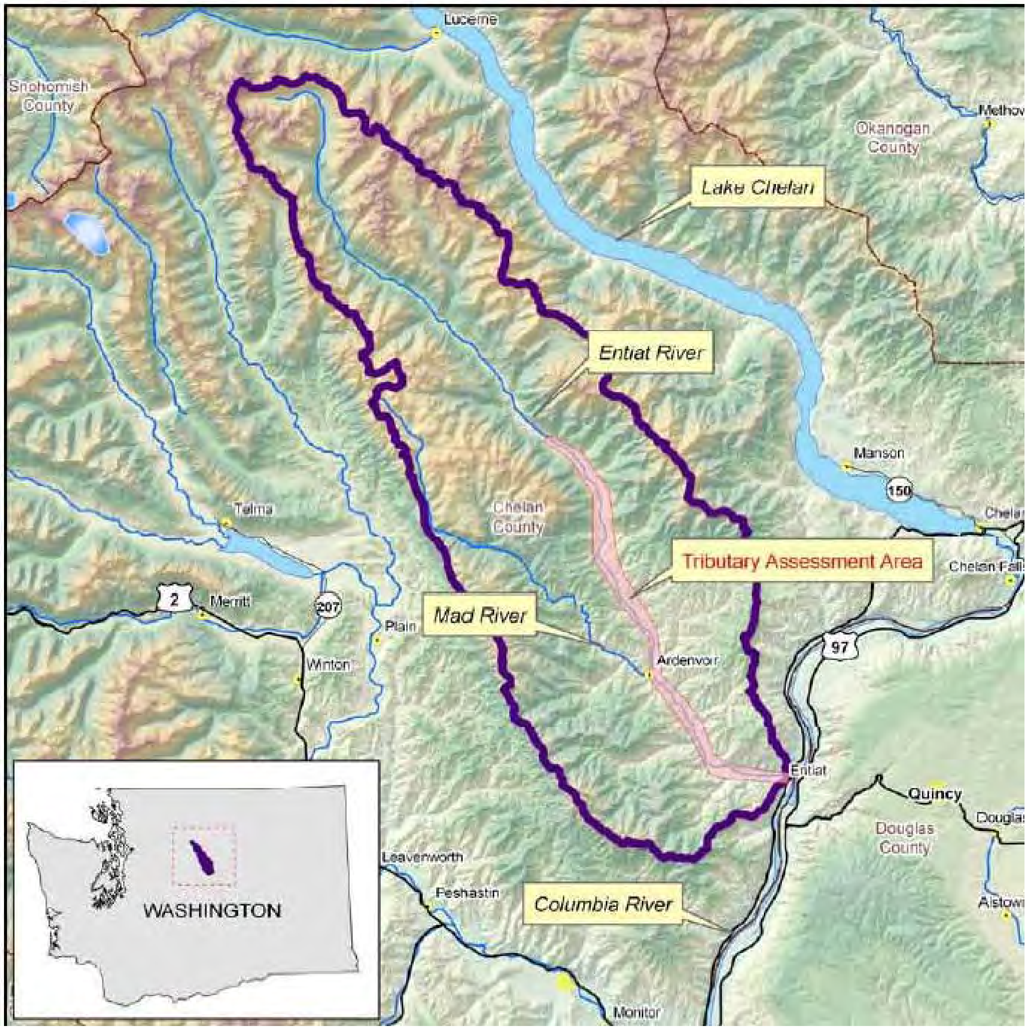


Figure 4. Location map of the tributary assessment area on the Entiat River within the Entiat subbasin.

TRIBUTARY ASSESSMENT

The Entiat Tributary Assessment, Chelan County, Washington (Tributary Assessment) was completed by a multidisciplinary team of hydraulic engineers, geologists, hydrologists, biologists, and botanists (Reclamation 2009). The focus of the Tributary Assessment was to complete a comprehensive geomorphic analysis of the fluvial system along the lower 26 miles of the Entiat River (Figure 4).

The objectives of the Tributary Assessment were to (1) delineate and characterize channel reaches on the basis of their geomorphic characteristics and biological opportunities and develop potential rehabilitation strategies organized on a reach-based approach; (2) provide technical ranking of the geomorphic reaches that can be used to prioritize the potential habitat protection and improvement of areas within the assessment area based on linkage to primary limiting factors for spring Chinook salmon, steelhead, and bull trout recovery; (3) identify the recurrence intervals of natural and human-induced disturbances and how they affect channel processes within the assessment area; and (4) evaluate the habitat-forming physical processes and disturbance regimes working at the subbasin and reach scales from both historical and contemporary context (Reclamation 2009).

At the tributary scale, three valley segments were delineated (VS-1, VS-2, and VS-3). Six geomorphic reaches were delineated for valley segment VS-3 and characterized into two general geomorphic reach types based on natural channel constraints, referred to as confined and unconfined geomorphic reaches (Table 2). The unconfined and confined reaches were ranked based on their geomorphic potential. The confined reaches identified as Reach 3B, Reach 3C, and Reach 3E in the Tributary Assessment were not assessed. Reach 3A (Preston reach) had the highest geomorphic potential and the largest impact from anthropogenic features for valley segment VS-3 (i.e., more departed from a natural condition).

Table 2. Geomorphic reach location by river mile, reach type, and floodplain area for Entiat River between RM 21.1 and RM 26 (Reclamation 2009).

Geomorphic Reach Designations for Valley Segment VS-3 (Reclamation 2009)	Reach Assessment Name	River Miles	Reach Type	Channel Complexity
Reach 3A	Preston	21.1-22.7	Unconfined	High
Reach 3B	None	22.7-23.3	Confined	Low
Reach 3C	None	23.3-24.0	Confined	Moderate
Reach 3D	None	24.0-25.0	Unconfined	High
Reach 3E	None	25.0-25.6	Confined	Low
Reach 3F	None	25.6-26.0	Unconfined	High

Within the Preston reach, there has been no large-scale change to the balance between incoming water and sediment loads that would indicate a potential for incision or aggradation (Reclamation 2009). However, several sections of the river within the reach have been artificially straightened and confined by levees and bank hardening. The absence of sediment that would have been provided and localized increase in channel slope and depth indicate a potential for increased sediment transport capacity and possible incision.

The largest impact to physical processes and habitat is from the construction of levees. The impacts of these features include channel straightening, reduced channel migration, reduced floodplain connectivity, altered sediment transport and size, large woody debris delivery and retention, and disconnected groundwater sources from the main channel. Bank protection also impact physical processes, but to a more localized degree.

REACH CHARACTERIZATION

The Preston reach assessment provides the technical evaluation to refine the level of detail necessary for selecting and implementing potential habitat actions. The reach assessment establishes environmental baseline conditions tied to a geospatial reference. This is done through an in-field evaluation of fluvial geomorphic form and processes. In turn, this reach-based environmental baseline can be used to assess the influence and feedback on habitat formation and maintenance over time.

The valley bottom is classified as a U-shaped trough with a valley bottom gradient of less than 3 percent and an unconstrained, moderately sinuous channel (Naiman et al. 1992). The stream type is predominantly a C-type channel (Rosgen 1996) showing evidence of slight to moderate incision with predominantly riffle and run bedform (Montgomery and Buffington 1993) and gravel/cobble as the dominant substrate. Landforms typically include alluvial and glacial deposits comprising terraces and alluvial fans (Hillman 2006). Alluvial fan deposits provide lateral and vertical channel controls (Reclamation 2009).

The reach is comprised of smaller-scale components that include the active main channel and floodplain areas. The reach was further broken down into two types of morphologically distinct areas or subreach unit types to denote greater local control and variability. Called inner and outer zones, these subreach unit types essentially represent areas of existing and potential habitat formation and maintenance within the response reach. The Preston reach encompasses about 116 acres of floodplain and active channel of the Entiat River within an alluvial valley from RM 21.1 to 23.1 (Table 3). Subreaches are delineated by lateral and vertical controls based on the presence/absence of inner or outer zone processes (Figure 5).

An inner zone is characterized by the presence of primary channels, a repetitious sequence of channel units, and relatively uniform physical attributes indicative of localized trends such as transport, transition, and deposition; generally associated with ground-disturbing flows with sufficient frequency that mature conifers are rare and a distinct hardwood zone is identifiable (modified from USDA 2008). In the instance of Preston reach, the active main channel was subdivided into four inner zones based on local trends of transport, transition, and deposition interpreted from the channel unit mapping, channel gradient, channel confinement and substrate. Inner zones that are not hydraulically connected to the river because of anthropogenic features are described as disconnected inner zones.

In contrast, an outer zone also known as the floodplain, is typically a terrace tread and generally coincidental with the historic channel migration zone unless the channel has been modified or incised leading to the abandonment of the floodplain. This zone includes floodplain side channels, overflow channels, and wetlands and is generally governed by riparian vegetation and hillslope processes. An outer zone is further distinguished from an inner zone by the presence of flood deposits, a change in vegetation, and bounding geologic landforms such as older terraces, bedrock or valley walls, alluvial fans, colluvium, or glacial deposits. Outer zones that are not hydraulically connected to the river at higher flows because of anthropogenic features are described as disconnected outer zones.

Table 3. Acres by zone type on the Preston reach, Entiat River, Entiat Subbasin, Chelan County, Washington.

Inner Zone	Connected Outer Zone	Disconnected Inner Zone	Disconnected Outer Zone
44.1 acres	56.6 acres	5.4 acres	10.1 acres

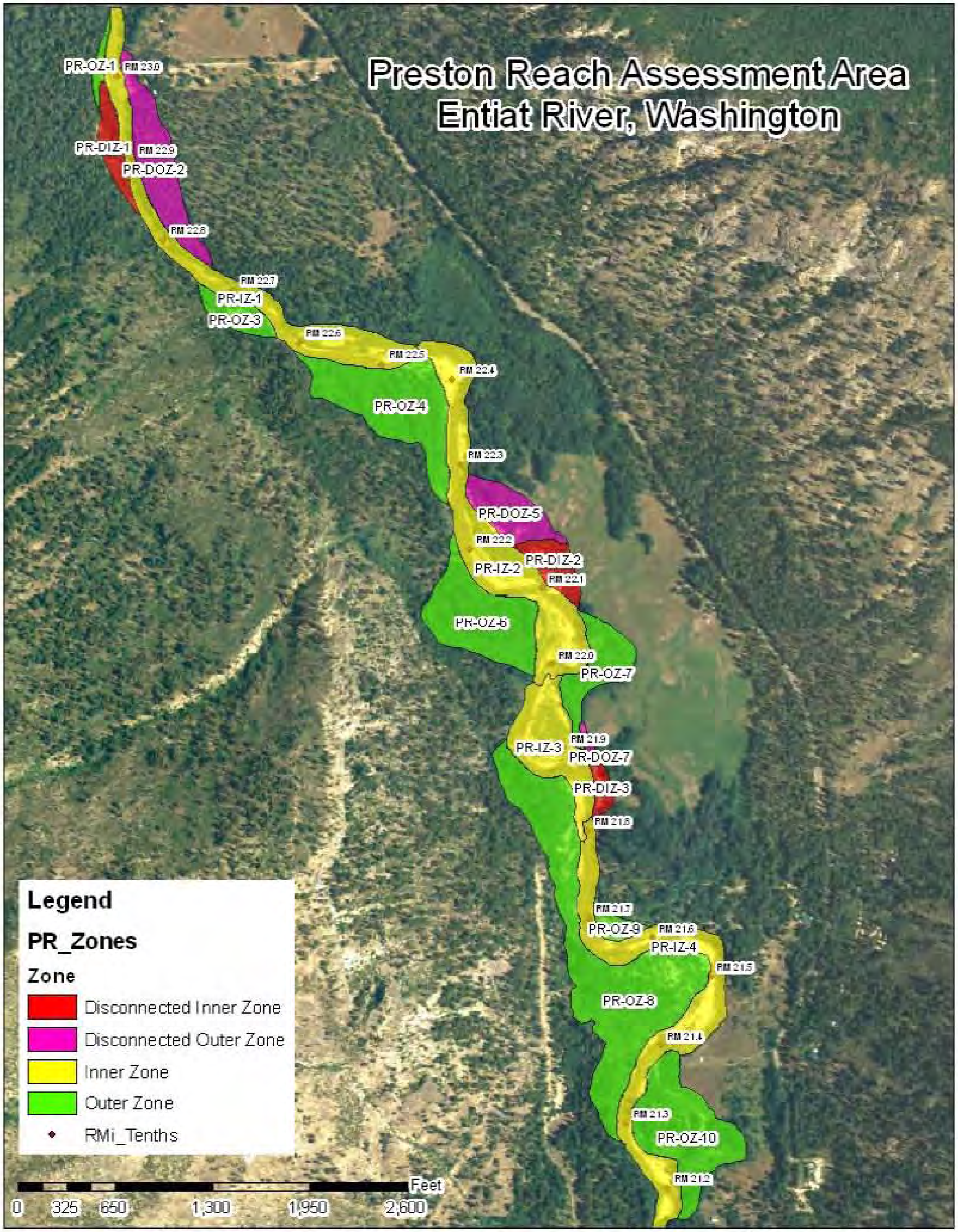


Figure 5. Location of subreaches based on a modified application of the Stream Inventory Handbook (USDA 2008).

REACH CONDITION

The reach condition is a combination of all information available at the time of the investigation. The REI matrix is a compilation of the information and data collection from multi-disciplinary analyses that were conducted prior to or during this investigation (Appendix A). Specific data collected and documented within separate disciplinary analyses are the Initial Site Assessment (Appendix B), Habitat Assessment (Appendix C), Riparian Vegetation Assessment (Appendix D), Two-dimensional Hydraulic Modeling (Appendix E), and GIS Databases (Appendix F).

Reach condition limiting factors are determined by measuring and synthesizing results from indicators within seven pathways:

- watershed condition
- flow/hydrology
- water quality
- habitat access
- habitat quality
- channel dynamics
- riparian vegetation

The indicators that are measured in the REI record baseline environmental conditions which are indicative of the condition of the higher-level indicators. The synthesis of the collected information provides a “snapshot” understanding of the combined condition of the hydrologic, geomorphic, and vegetative regimes. In turn, this information is used to develop an overall interpretation of the reach-based river condition with respect to the primary limiting factors.

Based on the available information and measurements from the field evaluation, each indicator was determined as functioning at one of three conditions: ***Adequate, At Risk, or Unacceptable Risk***, based on criteria contained in the REI (Table 4).

Table 4. Summary results of the REI for the Preston reach. Each indicator was interpreted to be in one of three conditions: *Adequate, At Risk, or Unacceptable Risk*.

Pathway	Reach-based Indicator (REI)	Condition
Watershed Condition	Effective Drainage Network and Watershed Road Density	At Risk
	Disturbance Regime	At Risk
Flow/Hydrology	Streamflow	At Risk
Water Quality	Temperature	At Risk
	Turbidity	Adequate
	pH	At Risk
	Suspended Solids	At Risk
Habitat Access	Physical Barriers	Adequate
Habitat Quality	Substrate	Adequate
	Fine Sediment	At Risk
	Large Woody Debris	At Risk
	Pool Frequency and Quality	Adequate
	Off-channel Habitat	At Risk
Channel Condition and Dynamics	Floodplain Connectivity	At Risk
	Bank Stability/Channel Migration	At Risk
	Vertical Channel Stability	At Risk
Riparian Vegetation	Structure (Floodplain)	Adequate
	Disturbance (30 m buffer zone)	At Risk
	Canopy Cover (10 m buffer zone)	Adequate

Limiting factor indicators should be monitored to gauge the response of the river to the implemented actions. The assessment team suggests that monitoring these indicators may provide pro-active opportunities to maintain or improve the overall ecosystem resiliency of the Preston reach.

WATERSHED CONDITION

Timber harvests and the addition of access roads are anthropogenic impacts that are interpreted to have changed the effective drainage network. In addition, the Tyee Fire (1994) burned about 50 percent of the watershed (about 140,000 acres). Assuming a complete burn (which is certainly not the case as fires burn in a mosaic pattern based on intensity) the fire area has recovered to a shrub/seedling-to-sapling/pole condition over the last 15 years and is now providing some hillslope stability. Based on these disturbances, the watershed condition pathway is interpreted to be in an ***At Risk Condition***.

FLOW/HYDROLOGY

The Washington Department of Ecology (DOE) completed an analysis of instream flows for the upper Entiat River. The upper Instream Flow Incremental Methodology (IFIM) site representing the upper river from RM 10 to 27.7 showed that instream flows are inadequate from August to May. There are no known diversions upstream of the site and the low flows are believed to be natural rather than a human caused condition. However, landuse practices within the watershed have negatively impacted the land cover and vegetation successional stages that maintain natural levels of water retention and infiltration. In addition, development within the alluvial valley has increased the number of domestic well withdrawals and their impacts to base flows are unknown. Because the interaction between base flows and groundwater recharge is unknown the flow/hydrology pathway is interpreted to be in an ***At Risk Condition***.

WATER QUALITY

Analysis conducted by the Washington DOE indicates the values for turbidity from 1994 to 2007 met state performance standards. Based on this finding the turbidity indicator is interpreted to be in an Adequate Condition. Additional data was collected to determine the overall Water Quality Index (WQI) for the Entiat River. The overall WQI ranged between a score of 79 to 93 which met state performance standards; however, the data showed that pH, suspended solids and water temperature occasionally did not meet state performance standards suggesting these indicators are in an ***At Risk Condition***.

Analysis conducted by the Washington DOE and the U.S. Forest Service (USFS) indicate that water temperature has exceeded the “Index of Thermal Stress” (ITS), the number of degree-days that temperature has exceeded the criterion, during summer. Anthropogenic activities have negatively impacted water temperature due to the removal of riparian vegetation for agriculture and residential development. Taking all this into account, the water temperature indicator is interpreted to be in an ***At Risk Condition***.

Overall, based on the analysis conducted by the Washington DOE and the USFS with the noted water quality deficiencies in temperature, pH and suspended solids the water quality pathway is interpreted to be in an ***At Risk Condition***.

HABITAT ACCESS

There are no main channel physical barriers on the Entiat River that impair fish passage; therefore, the habitat access pathway is interpreted to be in an ***Adequate Condition***.

HABITAT QUALITY

Dominant substrate for the Preston reach is predominantly gravel and cobbles, and no embeddedness has been noted; therefore, the dominant substrate and embeddedness indicators are interpreted to be in an ***Adequate Condition***. However, analysis conducted by the USFS found that fine sediments (< 0.85 mm) in spawning gravels exceeded 12 percent and over 12 years calculated a long-term mean of 15 percent based on McNeil Core sampling (refer to Habitat Assessment in Appendix C). Although the geology and watershed disturbances suggest the system maintains a relatively high background level of fine sediments, localized sources of fine sediment input due to accelerated bank erosion associated with agricultural disturbances have increased fine sediment input. Based on the USFS data (refer to Appendix C: Habitat Assessment) the fine sediment indicator is interpreted to be in an ***At Risk Condition***.

Wood was removed from the river in the 1970s by the Army Corp of Engineers (Corps) to reduce the threat of flooding. Large woody debris data collected for this reach assessment (refer to Habitat Assessment in Appendix C) found that the total number of large and medium wood pieces per mile was 17. Wood counts remain at depressed levels and the large woody debris indicator is interpreted to be in an ***At Risk Condition***. However, based on a geographic information system (GIS) analysis of the riparian buffer zone (30 meter width along both banks) large wood recruitment potential is in an ***Adequate Condition***.

Pool frequency was found to be 11.9 pools per mile except in the upper section of the reach where the local trend is a transport river segment. Pool quality was found to be good with 6.2 pools greater than 5 feet in depth per mile (refer to Appendix C: Habitat Assessment). Pool frequency and quality are interpreted to be in an ***Adequate Condition***.

Off-channel habitat is good in the lower section of the reach where a side channel (1,350 feet in length) has good perennial connectivity with the river. However, other areas where there were potential off-channel habitat areas have been disconnected from the river by levees. Because of anthropogenic impacts disconnecting off-channel habitat this indicator is interpreted to be in an ***At Risk Condition***.

Overall, the habitat quality is interpreted to be in an ***At Risk Condition***.

CHANNEL DYNAMICS

Floodplain connectivity has been negatively impacted by anthropogenic features such as levees and push-up levees. Therefore, the floodplain connectivity indicator is interpreted to be in an ***At Risk Condition***.

Channel migration rates have been adversely impacted by levees and riprap that constrain channel migration. There is also a localized area between RM 21.4 and 21.5 where channel migration rates have increased because of agriculture and residential disturbances that have removed riparian vegetation resulting in a destabilization of the river banks. The bank stability/channel migration indicator is interpreted to be in an ***At Risk Condition***.

Vertical channel stability has been adversely impacted by levees and riprap that constrain channel migration. Channel unit analysis using a geographic information system (GIS) suggests that the lower section of the reach has been negatively impacted and is in transition from a deposition dominated river segment towards a more transport dominated river segment. The vertical channel stability indicator is interpreted to be in an ***At Risk Condition***.

Overall, the channel dynamics pathway is interpreted to be in an ***At Risk Condition***.

RIPARIAN VEGETATION

Less than one percent of the floodplain (outer zone) riparian vegetation has been disturbed by agriculture and residential development suggesting the riparian vegetation structure indicator is in an ***Adequate Condition*** (refer to Figure 6 and Appendix D: Preston Vegetation Assessment).

About five percent of the riparian buffer zone (30 meter width along both banks of the inner zone) has been developed for agriculture and residential development. About 60 percent of the vegetation is in a small tree to large tree seral stage and the road density is relatively high (2.5 mi/mi^2) suggesting the riparian vegetation disturbance indicator is in an ***At Risk Condition***.

Greater than eighty percent of the riparian buffer zone (10 meter width along both banks of the inner zone) is in a shrub/seedling to large tree seral stage. Using the 10 meter riparian buffer zone as a surrogate for canopy cover (as densiometers were not used) this indicator is interpreted to be in an ***Adequate Condition***.

Overall, the riparian vegetation pathway is interpreted to be in an ***Adequate Condition***.

However, there are localized areas of disturbance where revegetation could be pursued to stabilize river banks and provide long-term recruitment potential.

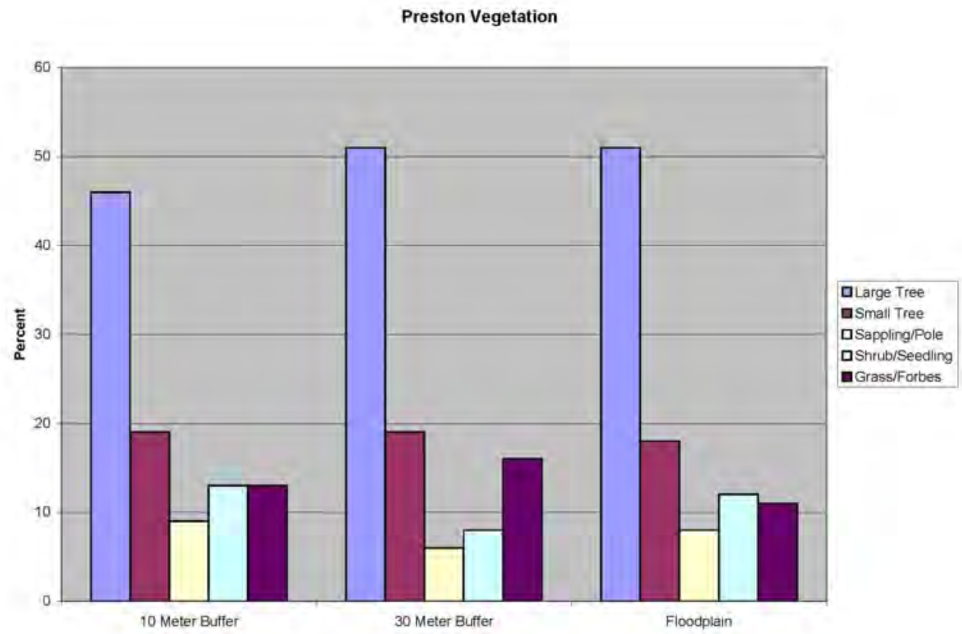


Figure 6. Percent of riparian vegetation seral stages based on classifications provided in the Stream Inventory Handbook (USDA 2008).

DISCUSSION

The reach condition describes a baseline or current condition of the hydrologic, geomorphic and vegetative regimes, and their dynamic interactions that form and maintain habitat-forming processes. Anthropogenic features can be placed within a context when using current river conditions to establish their impacts. In the instance of the Preston reach, the diagnosis is favorable with habitat access and riparian vegetation pathways interpreted to be in an ***Adequate Condition*** with the remaining pathways being in an ***At Risk Condition***. Three pathways in particular (watershed condition, flow/hydrology, and water quality) are symptomatic of larger-scale issues. At the reach scale, the channel dynamics pathway is symptomatic of the loss of geomorphic potential or the potential for geomorphic regime change.

Generally, unconfined geomorphic reaches with natural constraints at the upstream and downstream extents have flatter channel slopes indicative of localized trends of transition and deposition that create complex channel unit networks and maintain aquatic habitat. Prior to anthropogenic impacts, the Entiat River maintained dynamic equilibrium by actively migrating laterally across its floodplain within the Preston reach. This lateral channel migration helped the river maintain a flatter channel profile as sediment was stored on the floodplain before being eroded and transported down gradient. The result was a dynamic cycle of conversion from river to floodplain and vice versa, and with it continual renewal of aquatic habitat.

We hypothesize that in its natural condition, prior to anthropogenic impacts, the Preston reach had three localized trends of sediment movement. At the upstream segment of the reach, the river was naturally confined with a relatively high channel gradient and was transport dominated. Downstream of this transport segment, the river began to transition from dominantly transport towards depositional. In the lower segment it was predominantly depositional due to a natural constriction by the Dill Creek alluvial fan.

Currently, there are four localized trends of sediment movement interpreted from channel unit mapping that are graphically illustrated in Figure 7. At the upstream extent of the reach, the channel unit mapping and the two-dimensional hydraulic model velocity map (for more complete information and results of the hydraulic model refer to Appendix E) suggest PR-IZ-1 is predominantly a transport subreach due to channel confinement by the Preston Creek alluvial fan (Figure 8). The Entiat River then transitions as the channel gradient becomes flatter (Figure 9), in subreach PZ-IZ-2 and trends toward depositional in subreach PR-IZ-3. The river then becomes predominantly transitional (not depositional) again for a short section where there are anthropogenic features that limit channel migration in subreach PR-IZ-4 (Figure 10) prior to becoming transport dominated as it exits the Preston reach and is naturally confined by the Dill Creek alluvial fan. These interpretations are based on channel unit mapping, two-dimensional hydraulic model results, channel confinement, channel gradient, and dominant substrate. In general, channel units found in transport segments are predominantly rapids with relatively high gradients and cobble/boulder substrate; transition segments have predominantly runs with flatter gradients and cobble/gravel substrate; and depositional segments have predominantly riffles and bars with flatter gradients and gravel/cobble substrate.

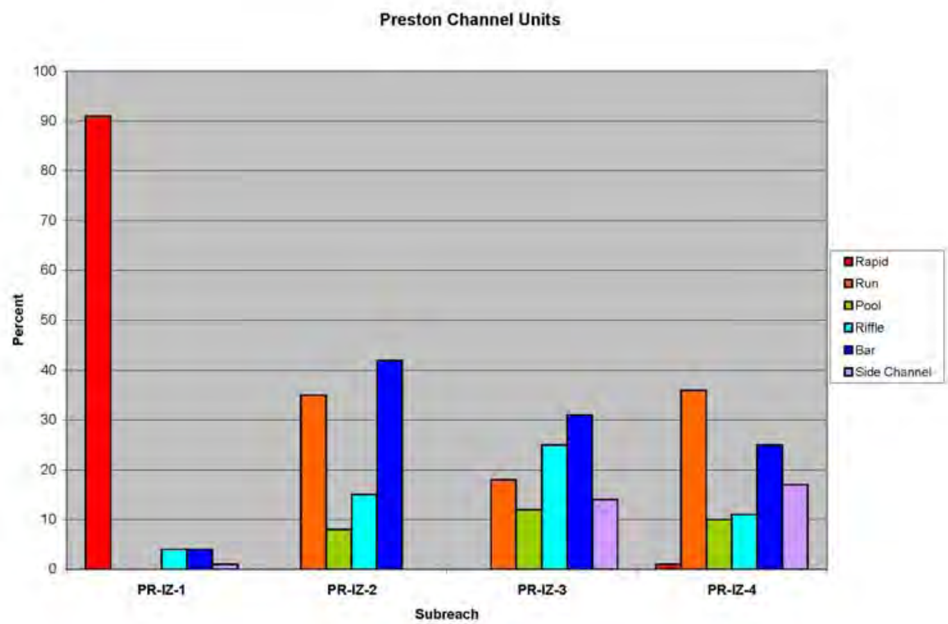


Figure 7. Percent of channel units for each inner zone subreach based on modified classifications from the Stream Inventory Handbook (USDA 2008).

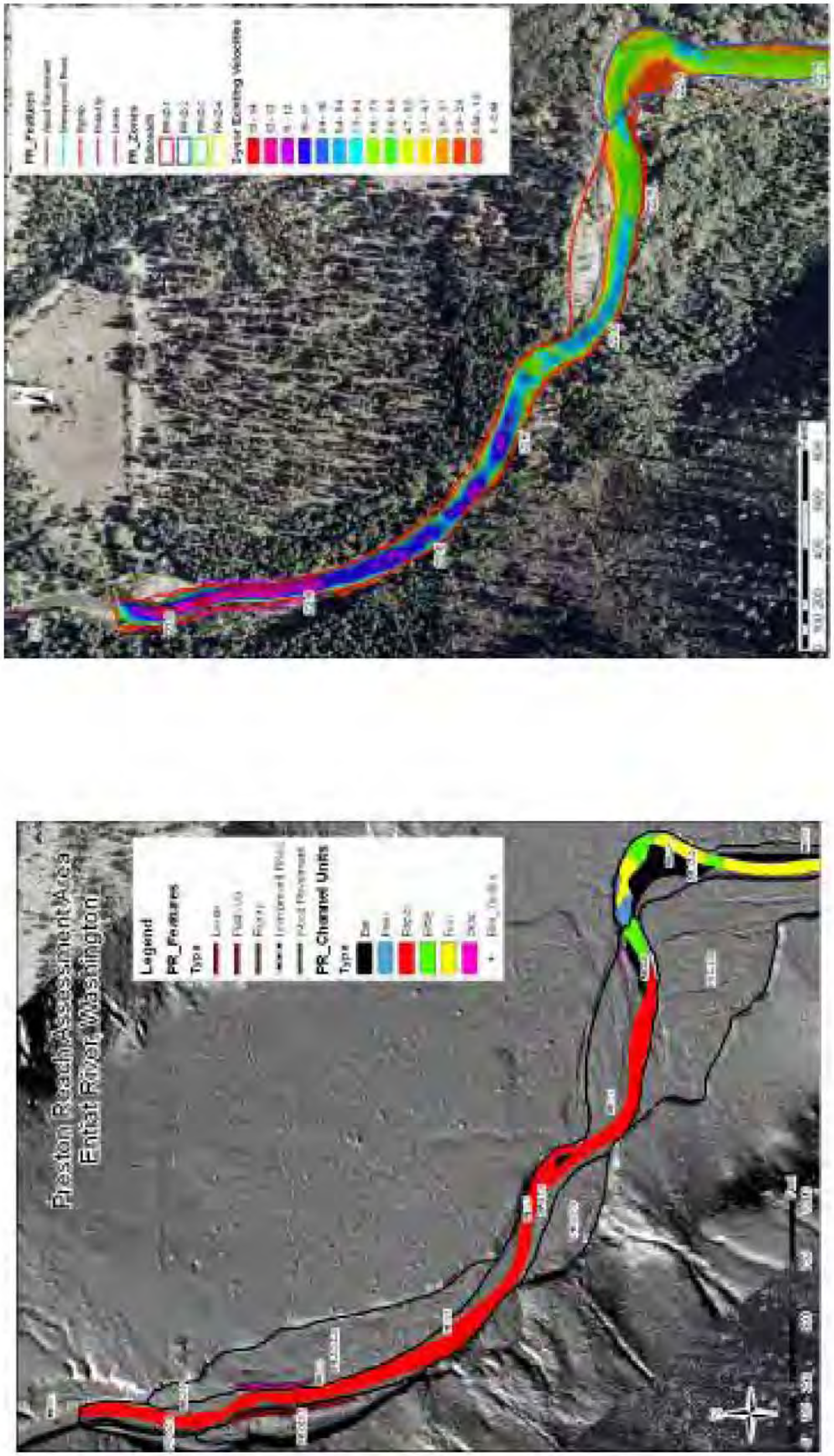
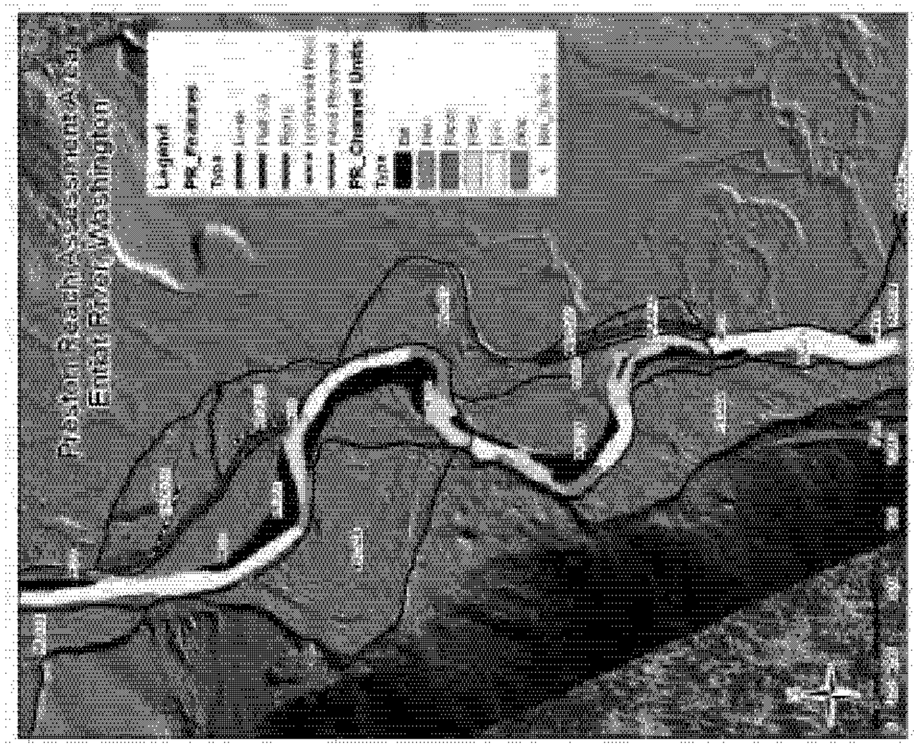


Figure 8. Channel unit map and two-dimensional hydraulic model velocity map suggest that PR-IZ-1 is predominantly a transport subreach.



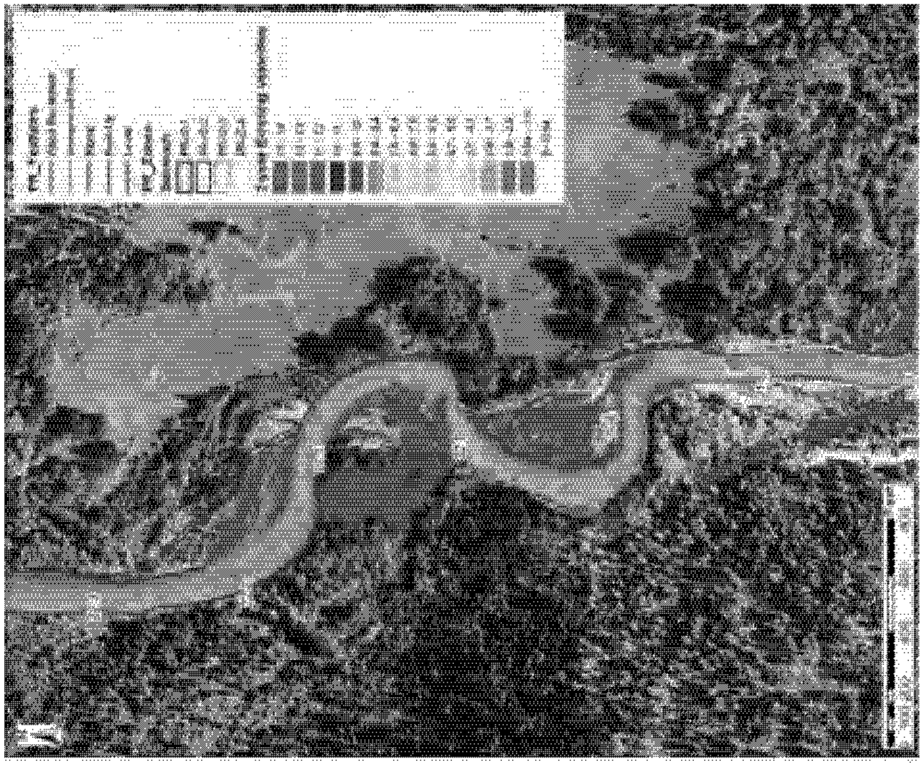


Figure 9. Channel unit map and two-dimensional hydraulic model velocity map suggest that PR-IZ-2 is predominantly a transition subreach and PR-IZ-3 is predominantly a deposition subreach.

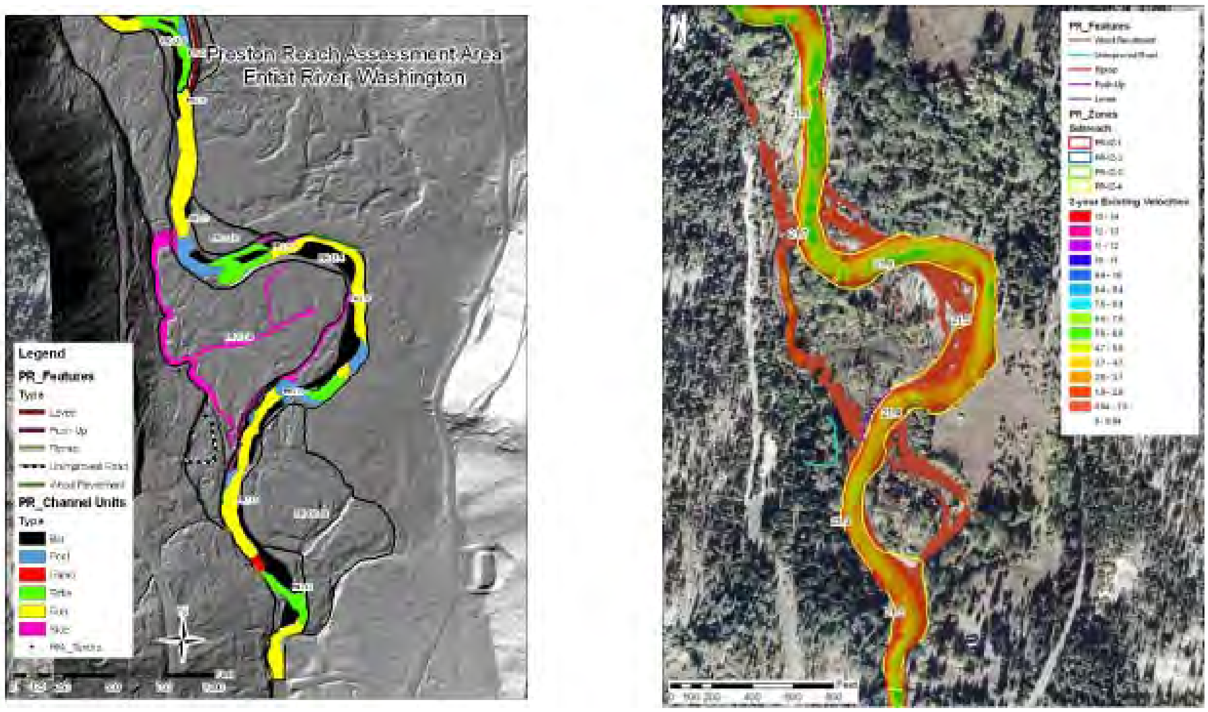


Figure 10. Channel unit map and two-dimensional hydraulic model velocity map suggest that PR-IZ-4 is predominantly a transition subreach as lateral channel migration is constrained due to anthropogenic features.

The river reach condition describes the current state of fluvial processes and their relationship to forming complex habitat within the stratified implementation strategy framework (Table 5). Anthropogenic features can be analyzed to establish impacts to the current river condition. Subsequently, the river condition provides a baseline for comparisons in future references. In the instance of the Preston reach, the habitat-forming processes have been unfavorably impacted, with 68 percent of the reach-based ecosystem indicators (Appendix A: Reach-based Ecosystem Indicators (REI) being in an ***At Risk Condition***.

A hierarchical strategy was used in the reach assessment to characterize the subreaches and prioritize potential habitat actions (Figure 3). Individual ovals represent decisions and their interconnectivity corresponds to their stratified interrelationships. Table 5 contains the definitions for the subreach conditions that are tied to the hierarchical strategy. The stratified strategy is used to filter results of the reach assessment to illustrate the differential responses expected for potential habitat protection and rehabilitation actions. Note corresponding gradational color scheme.

Table 5. Definitions for reach conditions, which are tied into the hierarchical implementation strategy in Figure 3.

Protect/Maintain Processes: off-channel and riparian areas such as wetland, channel network, side channel, and riparian buffers possessing "adequate" ecological conditions and a present high or a potential high biological benefit.
Reconnect Isolated Habitats: disconnected tributaries, and off-channel and riparian areas possessing "adequate" ecological condition, but are fragmented by anthropogenic disturbances. **Protect/Maintain and Reconnect Processes (Long-term): protect off-channel and riparian areas possessing "adequate" ecological condition, and reconnect processes that impact floodplain connectivity and channel migration.**
Reconnect Processes (Long-term): through regaining of channel dynamics and riparian interactions for areas possessing "adequate" or "at risk" ecological conditions that have a present high or potential high biological benefit.
Reconnect Processes and Isolated Habitats Units: through the regaining of channel dynamics and riparian interactions for areas possessing "at risk" ecological conditions that have a moderate to low present or high potential biological benefit.
Reconnect Isolated Habitat Units (Short-term): through in-channel replacement of wood and rock habitat features or structures.

With the exception of physical barriers, all other pathways have at least one reach-based ecosystem indicator interpreted to be functioning in an ***At Risk Condition***. Three watershed-scale pathways (watershed condition, flow/hydrology and water quality) are interpreted to be in an ***At Risk Condition*** due to both natural and anthropogenic causes. Two reach scale pathways (habitat quality and channel condition) are interpreted to be in an ***At Risk Condition*** due primarily to anthropogenic causes. The two reach scale pathways are symptomatic of lost geomorphic potential and habitat-forming processes. Reclamation defines geomorphic potential as the capability of adjustment or change in process/structural components of an ecosystem through the combined interaction of hydrologic, geomorphic, and vegetative regimes to form, connect, and maintain fish habitat over time.

Geomorphic potential is interpreted to be altered because of reduced floodplain connectivity, lateral channel migration, and channel complexity created by large wood. Reduced floodplain connectivity is due to levees/push-up levees in the inner zone subreaches PR-DIZ-1, PR-DIZ-2, PR-DIZ-3, and outer zone subreaches PR-DOZ-2, PR-DOZ-5 and PR-DOZ-7. Reduced channel migration is due to riprap and a wood revetment in inner zone subreach PR-IZ-4 and outer zone subreach PR-OZ-8. These subreaches are interpreted to be in an ***At Risk Condition*** and are recommended for rehabilitation actions. All other subreaches are in an ***Adequate Condition*** and are recommended for protection actions (Figure 11).

The large woody debris reach-based ecosystem indicator is interpreted to be in an ***At Risk Condition*** and could be addressed for inner zones PR-IZ-2, PR-IZ-3, and PR-IZ-4 by strategically placing unanchored “key members” (large wood greater than 30-inch diameter at breast height and a length of 30 or more feet with rootwad attached) on point and medial bars, and allowing the river to naturally adjust their position. These “key members” would recruit and retain wood traveling through the system, creating channel complexity and reducing stream power. This action could help return the lower two-thirds of the reach to a more natural depositional trend. It should be noted that unanchored large woody debris placements are not recommended in inner zone PR-IZ-1 because it is a localized transport reach with higher energy.

The following (Table 6) is a prioritized list of potential habitat actions that are consistent with the Upper Columbia Regional Technical Team’s recommendations and includes the Viable Salmonid Population parameters that are addressed by each action. Figure 11 illustrates the primary habitat actions for each subreach using the gradational color scheme.

Table 6. Prioritized list of potential habitat actions appropriate for the Preston reach.

High Priority/Long-term

1. Protection – protect existing riparian habitat, channel migration processes, and floodplain function listed as a Tier 1 habitat action in the Biological Strategy (UCRRT 2007). This habitat action addresses four Viable Salmonid Population (VSP) parameters: productivity, abundance, diversity, and structure.
    a. Protect and maintain areas where physical processes are in an Adequate Condition.
    b. Protect and maintain areas with off-channel habitat that are connected to the river.
2. Floodplain Rehabilitation – reconnecting floodplain processes is listed as a Tier 1 habitat action in the Biological Strategy (UCRTT 2007). This habitat action addresses four Viable Salmonid Population (VSP) parameters: productivity, abundance, diversity, and structure.
    a. Levees and push-up levees have reduced floodplain connectivity and lateral channel migration.
    b. Riprap and a wood revetment have reduced lateral channel migration and are negatively impacting channel morphology and complexity.
3. Water Quality and Quantity – improving water quality and quantity addresses four VSP parameters: productivity, abundance, structure, and diversity.
    a. The Entiat River is on the 303(d) list for water temperature and has deficiencies in water pH and suspended solids have been noted by the Washington Department of Ecology.
    b. The Stillwater area has alluvial valley fill and the groundwater is interpreted to be hydraulically connected with the Entiat River. The effects of domestic well withdrawals on river base flows is a “data gap” and should be evaluated due to valley bottom development.
4. Riparian Rehabilitation – planting appropriate vegetation to re-establish or improve a 30 meter buffer zone and throughout the floodplain addresses casual factors such as loss of bank stability, increased sediment input, elevated temperatures, depressed invertebrate production and loss of natural large wood recruitment. This habitat action is listed as a Tier 2 action in the Biological Strategy (UCRTT 2007) and addresses two VSP parameters: productivity and abundance.
    a. Riparian condition for structure, disturbance, and canopy cover are interpreted to be in an Adequate Condition. However, localized areas have been cleared for agricultural development. Re-vegetating these areas will help reduce fine sediment input due to accelerated bank erosion.
5. Large Wood Rehabilitation – increasing size and quantity of large wood in the system addresses causal factors such as loss of natural stream channel complexity, refugia and hiding cover, loss of floodplain connectivity, loss of pool-riffle formation, and spawning gravel and natural large wood recruitment. This habitat action is listed as a Tier 1 action in the Biological Strategy (UCRTT 2007) and addresses two VSP parameters: productivity and abundance.
    a. Quantity and size of large wood could be improved through strategically placing unanchored “key members” to recruit and retain wood in the system. This habitat action will create channel complexity and reduce stream power, and may re-establish a more natural depositional trend.
6. Fine Sediment Reduction – stabilizing riverbanks that have been cleared of riparian vegetation addresses causal factors such as loss of spawning gravels and infilling of pools and addresses two VSP parameters: productivity and abundance.
    a. Localized areas of accelerated bank erosion are noted in the reach (i.e. RM 21.4-21.5). Although background levels of fine sediment are interpreted to be relatively high in the Entiat drainage, fine sediment input is exacerbated at “point sources” due to removal of woody vegetation for agricultural development resulting in accellerated bank erosion.

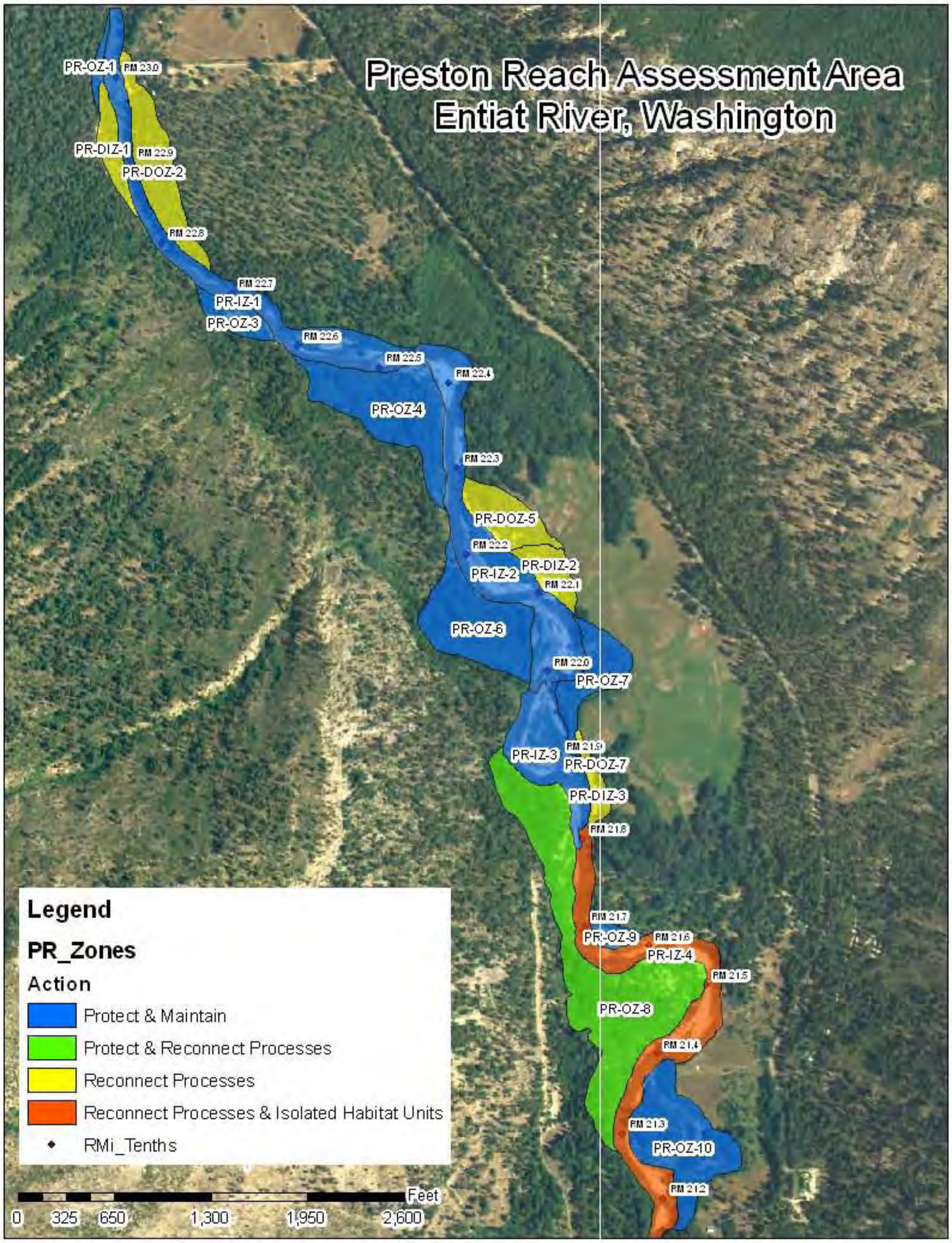


Figure 11. Potential habitat actions by subreach and their relative priority of implementation.

SUBREACH UNIT PROFILES

Within this section, the anthropogenic features and resulting existing conditions of each inner zone subreach and adjoining outer zone subreaches are discussed. Beginning at the upstream extent of the Preston reach and working downstream the inner zone subreaches are analyzed to interpret if the local trends are sediment transport, transition, or deposition. Adjacent outer zone subreaches that include disconnected zones are then discussed for a comprehensive approach for implementing potential habitat actions that are sustainable under the dynamic interaction between the hydrologic, geomorphic, and vegetative regimes. Habitat actions are intentionally generalized from the Recovery Plan which allows input from the Watershed Action Team (WAT) for project implementation. Further analysis will probably be necessary for the alternatives evaluation by the Inter-disciplinary Team (IDT).

River Mile 22.45 – 23.10 Subreaches

Between RM 22.45 and 23.10 the river is locally a transport inner subreach that was naturally confined by the Preston Creek alluvial fan. The upper section is now artificially confined by a levee along river right (RM 22.85 – 23.10) in subreach PR-DIZ-1 and a push-up levee along river left (RM 22.98 – 23.02) in subreach PR-DOZ-2 (Figure 12). The predominant channel unit is a rapid with boulder and cobble substrate, and the riparian buffer zones (30 meter width along both banks) are in an adequate condition for potential large wood recruitment and canopy cover. Overall, the primary habitat actions are to protect and maintain the inner and outer zones, and to rehabilitate the disconnected subreaches by removing or modifying the levee and push-up levee to reconnect processes (Table 7). Each subreach is discussed in the following sections.

Table 7. Summary of subreaches between RM 22.45 and 23.10.

SUBREACH	RIVER MILE	HABITAT ACTION	ACREAGE
PR-IZ-1 (inner zone)	RM 22.45 – 23.10	Protect and maintain	10.9 acres
PR-DIZ-1 (disconnected inner zone)	RM 22.85 – 23.00 (river right)	Reconnect processes	2.1 acres
PR-OZ-1 (outer zone)	RM 22.98 – 23.10 (river right)	Protect and maintain	0.7 acres
PR-DOZ-2 (disconnected outer zone)	RM 22.75 – 23.02 (river left)	Reconnect processes	6.01 acres
PR-OZ-3 (outer zone)	RM 22.60 -22.72 (river right)	Protect and maintain	2.01 acres
PR-OZ-4 (outer zone)	RM 22.28 – 22.60 (river right)	Protect and maintain	10.0 acres

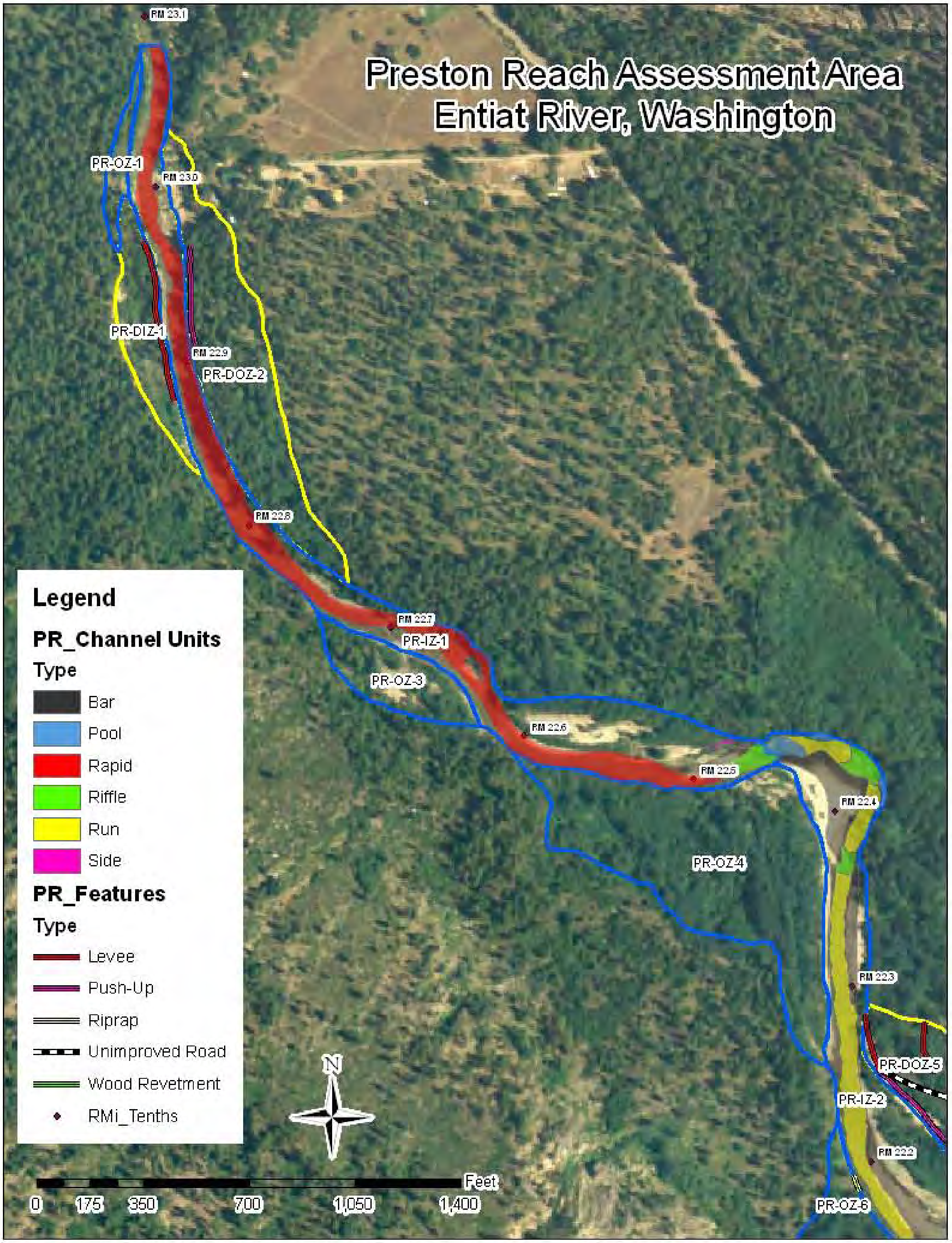


Figure 12. Location map of subreaches between RM 22.45 and 23.10 and anthropogenic features.

PR-IZ-1 (Inner Zone)

Inner zone PR-IZ-1 is located between RM 22.45 and 23.10 and covers about 10.92 acres of the active channel (Figure 12). This inner zone is locally a transport subreach with a relatively high gradient with cobble/boulder substrate (Photograph No. 1). There are two anthropogenic features that artificially confine the upper section of this river segment (see PR-DIZ-1 and PR-DOZ-2). Removal or modification of the levee and push-up levee that artificially confine the channel will reconnect the river to its historic channel path and floodplain resulting in a slight reduction in stream power. This subreach has good large wood recruitment potential and canopy cover that could be protected to maintain the current processes (Table 8) and options could be investigated to reconnect the historic channel path and floodplain.

Table 8. Potential habitat actions for PR-IZ-1.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection	Protect and maintain current levels of geomorphic, hydrologic, and vegetation function.	4; Productivity, Abundance, Diversity, and Structure	High

Photograph No. 1. View to the northwest looking upstream. (Subreach PR-IZ-1 – RM 22.6 – Reclamation photograph by R. McAffee, 2008).

PR-DIZ-1 (Disconnected Inner Zone)

Disconnected inner zone PR-DIZ-1 is located between RM 22.85 and 23.00 on river right and covers about 2.11 acres (Figure 12). There is a levee about 540-feet long in the subreach that disconnects a historic channel path. Alternatives include removing or modifying the levee (Table 9). Removal of the levee may cause more environmental damage to the system by disturbing the small and large trees that have grown along and around the levee (Photograph No. 2). However, modifying the levee with an upstream and downstream connection to the active channel will provide additional rearing habitat, dissipate stream power, and may provide high water refugia.

Table 9. Potential habitat actions for PR-DIZ-1.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes: Remove or modify the levee to reconnect historic channel path. Prior to or following removal or modification of the levee the subreach could be Protected and Maintained.	2; Productivity and Abundance	Moderate

Photograph No. 2. View to the northeast looking at the backside of a levee. (Subreach PR-IZ-1 – RM 23.0 – Reclamation photograph by R. McAffee, 2008).

PR-OZ-1 (Outer Zone)

Outer zone PR-OZ-1 is located between RM 22.98 and 23.10 on river right and covers about 0.65 acres of floodplain (Figure 12). There are no anthropogenic features within the subreach. This subreach has good large wood recruitment potential and canopy cover that could be protected to maintain the current processes (Table 10).

Table 10. Potential habitat actions for PR-OZ-1.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection	Protect and maintain current levels of geomorphic, hydrologic, and vegetative function.	4; Productivity, Abundance, Diversity, and Structure	Low

PR-DOZ-2 (Disconnected Outer Zone)

Disconnected outer zone PR-DOZ-2 is located between RM 22.75 and 23.02 on river left and covers about 6.08 acres (Figure 12). There is a push-up levee about 330-feet long in the subreach that disconnects the floodplain. Alternatives include the removing or modifying the push-up levee (Table 11). Removal of the push-up levee will reconnect the river to its floodplain and reduce stream power. Modifying or breaching the push-up levee may have a minimal effect. In addition, this subreach has good large wood recruitment potential and canopy cover, and could be considered for protection to maintain the current processes.

Table 11. Potential habitat actions for PR-DOZ-2.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes: Remove or modify the push-up levee to reconnect floodplain. Prior to or following removal or modification of the levee the subreach could be Protected and Maintained.	2; Productivity and Abundance,	Moderate

PR-OZ-3 (Outer Zone)

Outer zone PR-OZ-3 is located between RM 22.60 and 22.72 on river right and covers about 2.06 acres of floodplain (Figure 12). There are no anthropogenic features within the subreach. This subreach has good large wood recruitment potential and canopy cover that could be protected to maintain the current processes (Table 12).

Table 12. Potential habitat actions for PR-OZ-3.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection	Protect and maintain current levels of geomorphic, hydrologic, and vegetative function.	4; Productivity, Abundance, Diversity, and Structure	Moderate

PR-OZ-4 (Outer Zone)

Outer zone PR-OZ-4 is located between RM 22.28 and 22.60 on river right and covers about 9.95 acres of floodplain (Figure 12). There are no anthropogenic features within the subreach. This subreach has good large wood recruitment potential and canopy cover that could be protected to maintain the current processes (Table 13).

Table 13. Potential habitat actions for PR-OZ-4.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection	Protect and maintain current levels of geomorphic, hydrologic, and vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High

River Mile 21.98 – 22.45 Subreaches

Between RM 21.98 and 22.45 the river is locally a transition inner subreach, but is trending toward a transport state due to artificial confinement (Figure 13). A levee constricts channel migration and disconnects the river from its floodplain in subreaches PR-DIZ-2 and PR-DOZ-5. There is a small amount of riprap at RM 22.2 (river right) in PR-OZ-6 that has a minimal impact to the river processes. The predominant channel unit is a run with gravel and cobble substrate, and the riparian buffer zones (30 meter width along both banks) are in an adequate condition for potential large wood recruitment and canopy cover. Overall, the primary habitat actions are to protect and maintain this river segment, and to rehabilitate the middle section by removing or modifying the levee to reconnect processes (Table 14). Each subreach is discussed in the following sections.

Table 14. Summary of subreach between RM 21.98 and 22.45.

SUBREACH	RIVER MILE	HABITAT ACTION	ACREAGE
PR-IZ-2 (inner zone)	RM 21.98 – 22.45	Protect and maintain	13.7 acres
PR-DIZ-2 (disconnected inner zone)	RM 22.07 – 22.20 (river left)	Reconnect processes	2.3 acres
PR-DOZ-5 (disconnected outer zone)	RM 22.18 – 22.30 (river left)	Reconnect processes	3.7 acres
PR-OZ-6 (outer zone)	RM 21.80 – 22.21 (river right)	Protect and maintain	8.5 acres
PR-OZ-7 (outer zone)	RM 21.90 – 22.06 (river left)	Protect and maintain	4.2 acres

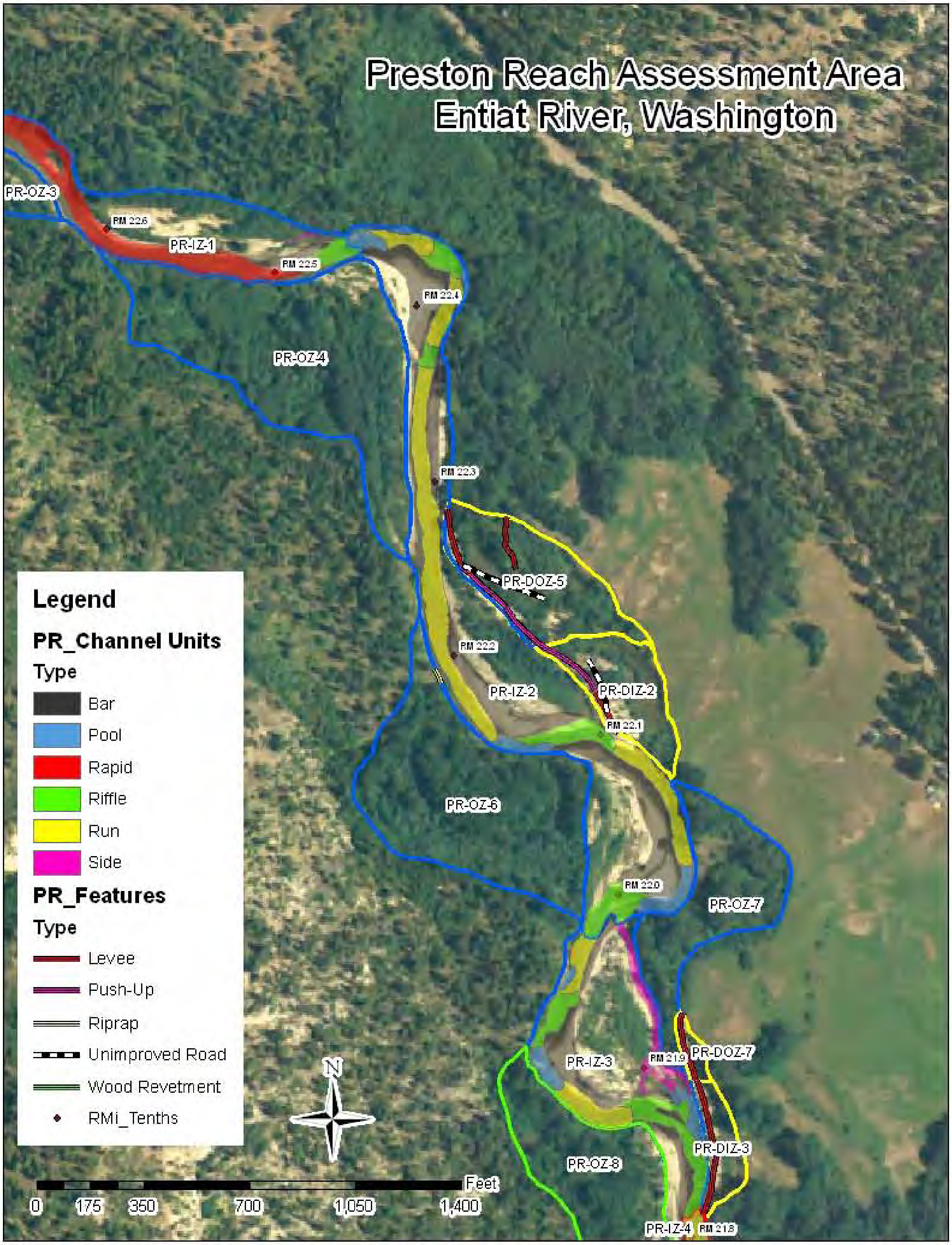


Figure 13. Location map of subreaches between RM 21.98 and 22.45 and anthropogenic features.

PR-IZ-2 (Inner Zone)

Inner zone PR-IZ-2 is located between RM 21.98 and 22.45 and covers about 13.65 acres of the active channel (Figure 13). There is a levee/push-up levee that artificially constrains lateral channel migration (see PR-DIZ-2 and PR-DOZ-5). Removal or modification to the levee/push-up levee will reconnect the river to its historic channel path and floodplain resulting in a moderate reduction in stream power and improved channel complexity. In PR-OZ-6 there is a small segment of riprap that does not appear to significantly influence the channel processes, but could be removed to promote channel migration and large wood recruitment potential. This subreach currently has good large wood recruitment potential and canopy cover, but livestock have direct access in a few areas and browse on the riparian vegetation (Photograph No. 3). As part of the rehabilitation efforts livestock could be excluded to allow the riparian buffer zone (30-meter width) to become re-established and protect and maintain current processes (Table 15).

Table 15. Potential habitat actions for PR-IZ-2.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection	Protect and maintain current levels of geomorphic, hydrologic, and vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High
2	Rehabilitation	Reconnect processes: Strategically place unanchored “key members” (large wood greater than 30-inch diameter at breast height and a length of 30 or more feet with rootwad attached) on point and medial bars, and allowing the river to naturally adjust their position.	2; Productivity and Abundance	Moderate
3	Rehabilitation	Reconnect riparian processes: Livestock could be excluded to allow the riparian buffer zone (30-meter width) to become re-established.	2; Productivity and Abundance	Moderate

Photograph No. 3. View is to the east looking at bank erosion. (Subreach PR-IZ-2 – RM 22.0 – Reclamation photograph by R. McAffee, 2008).

PR-DIZ-2 (Disconnected Inner Zone)

Disconnected inner zone PR-DIZ-2 is located between RM 22.07 and 22.20 and covers about 2.30 acres of the active channel (Figure 13). There is a levee/push-up levee that artificially constrains lateral channel migration (also see PR-DOZ-5) and impounds a groundwater fed wetland (Photograph No. 4).

Removal or modification to the levee/push-up levee (about 385 feet in length) will reconnect the river to its historic channel path and floodplain resulting in a moderate reduction in stream power and improved channel complexity. A road (about 185 feet in length) that accesses the levee may continue to constrain lateral channel migration. This access road could be obliterated following the removal or modification of the levees. Livestock can directly access the wetland area and also browse on the riparian vegetation that would be needed to stabilize the bank following levee removal or modification. As part of the rehabilitation efforts, livestock could be excluded to allow the riparian buffer zone (30-meter width) to become re-established and to protect and maintain processes (Table 16).

Table 16. Potential habitat actions for PR-DIZ-2.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes: Remove or modify the levees and push-up levee to reconnect historic channel and floodplain. This action could be in conjunction with the removal or modification to the section of the levees in subreach PR-DOZ-5. Once the levees are removed or modified the roads in the floodplain could be obliterated followed by riparian rehabilitation and livestock exclusion. Prior to or following removal or modification of the levees, the subreach could be Protected and Maintained.	2; Productivity and Abundance	High

Photograph No. 4. View is to the north looking at a wetland area. (Subreach PR-DIZ-2 – RM 22.1 – Reclamation photograph by R. McAffee, 2008).

PR-DOZ-5 (Disconnected Outer Zone)

Disconnected outer zone PR-DOZ-5 is located between RM 22.18 and 22.30 and covers about 3.74 acres of floodplain (Figure 13). There is a levee/push-up levee that disconnects the floodplain in this subreach (also see PR-DIZ-2). Removal or modification to the levees and push-up levee (about 750 feet in total lengths) will reconnect the river to its floodplain (Photograph No. 5). A road (about 290 feet in length) that accesses the levee may continue to disconnect the floodplain following levee removal or modification. This access road could be obliterated following the removal or modification of the levees. This subreach currently has fair to good large wood recruitment potential and canopy cover, but livestock have direct access and browse on the riparian vegetation. As part of the rehabilitation efforts livestock could be excluded to allow the riparian buffer zone (30-meter width) to become re-established and to protect and maintain processes (Table 17).

Table 17. Potential habitat actions for PR-DOZ-5.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes: Remove or modify the levees and push-up levee to reconnect historic channel and floodplain (Photograph No. 5). This action could be in conjunction with the removal or modification to the section of the levees in subreach PR-DIZ-2. Once the levees are removed or modified the roads in the floodplain could be obliterated followed by riparian rehabilitation and livestock exclusion. Prior to or following removal or modification of the levees, the subreach could be Protected and Maintained.	2; Productivity and Abundance	High

Photograph No. 5. View is to the south looking downstream along river left at the upstream end of a levee that is starting to fail. (Subreach PR-DOZ-5 – RM 22.3 – Reclamation photograph by R. McAffee, 2008).

PR-OZ-6 (Outer Zone)

Outer zone PR-OZ-6 is located between RM 21.80 and 22.21 on river right and covers about 8.47 acres of floodplain (Figure 13). There is a small section of riprap near RM 22.2 that does not significantly impact fluvial processes. If removal of the riprap is considered, further evaluation may be warranted to determine if the damage to the riparian vegetation outweighs the benefits. This subreach has good large wood recruitment potential and canopy cover that could be protected to maintain the current processes (Table 18).

Table 18. Potential habitat actions for PR-OZ-6.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection	Protect and maintain current levels of geomorphic, hydrologic, and vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High

PR-OZ-7 (Outer Zone)

Outer zone PR-OZ-7 is located between RM 21.90 and 22.06 on river left and covers about 4.20 acres of floodplain (Figure 13). There are no anthropogenic features within the subreach. This subreach has good large wood recruitment potential and canopy cover that could be protected to maintain the current processes (Table 19).

Table 19. Potential habitat actions for PR-OZ-7.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protected	Protect and maintain current levels of geomorphic, hydrologic, and vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High

River Mile 21.80 – 21.98 Subreaches

Between RM 21.80 and 21.98 the river is locally a depositional inner subreach, but is trending toward a transport state due to channel confinement (Figure 14). A levee constricts channel migration and disconnects the river from its floodplain in subreaches PR-DIZ-3 and PR-DOZ-7. There is a levee constructed predominantly of sand ("sugar dike") in PR-OZ-8 that has little effect on river processes, but the subreach contains a large side channel that is excellent rearing habitat for salmonids (Figures 15 and 16). The channel units' exhibit good complexity including runs, riffles, side channels, and pools with gravel and cobbles being the dominant substrate. The riparian buffer zones (30 meter width along both banks) are in an adequate condition for potential large wood recruitment and canopy cover, but could be improved in subreach PR-DIZ-3 should the levee be removed or modified. Overall, the primary habitat actions are to protect and maintain, and to rehabilitate subreaches PR-IZ-3 and PR-DOZ-7 to reconnect processes (Table 20). Each subreach is discussed in the following sections.

Table 20. Summary of subreaches between RM 21.80 and 21.98.

SUBREACH	RIVER MILE	HABITAT ACTION	ACREAGE
PR-IZ-3 (inner zone)	RM 21.80 – 21.98	Protect and maintain	6.6 acres
PR-DIZ-3 (disconnected inner zone)	RM 21.80 – 21.88	Reconnect processes	1.0 acres
PR-OZ-7 (outer zone)	RM 21.90 – 22.06 (river left)	Protect and maintain	4.2 acres
PR-DOZ-7 (disconnected outer zone)	RM 21.89 – 21.91 (river left)	Reconnect processes	0.3 acres
PR-OZ-8 (outer zone)	RM 21.29 – 21.90 (river right)	Protect and reconnect processes	20.94 acres

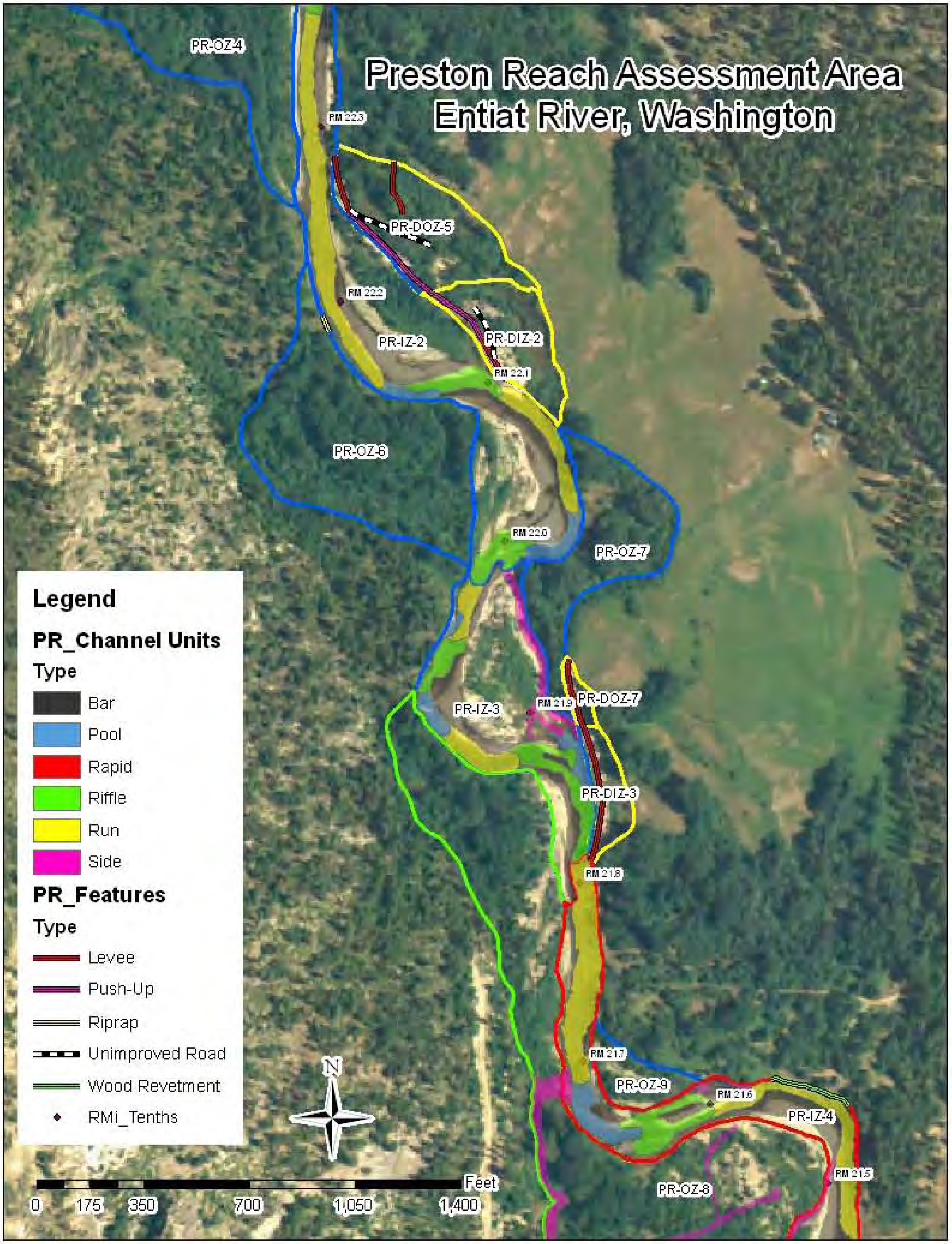


Figure 14. Location map of subreaches between RM 21.80 and 21.98 and anthropogenic features.

PR-IZ-3 (Inner Zone)

Inner zone PR-IZ-3 is located between RM 21.80 and 21.98 and covers about 6.62 acres of active channel and floodplain, and contains about 0.50 acres of off-channel habitat (Figure 14). There is a levee that artificially constrains lateral channel migration in this river segment (see PR-DIZ-3 and PR-DOZ-7). Removal or modification to the levee/push-up levee (about 700 feet in length) will reconnect the river to its historic channel path and floodplain resulting in a moderate reduction in stream power and improved channel complexity (Photograph No. 6). This subreach currently has good large wood recruitment potential and canopy cover, but livestock have direct access and browse on the riparian vegetation. As part of the rehabilitation efforts, livestock could be excluded to allow the riparian buffer zone (30-meter width) to become re-established and to protect and maintain (Table 21).

Table 21. Potential habitat actions for PR-IZ-3.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection	Protect and maintain current levels of geomorphic, hydrologic, and vegetative function (Photograph No. 6).	4; Productivity, Abundance, Diversity, and Structure	High
2	Rehabilitation	Reconnect processes: Strategically place unanchored "key members" (large wood greater than 30-inch diameter at breast height and a length of 30 or more feet with rootwad attached) on point and medial bars, and allow the river to naturally adjust their position.	2; Productivity and Abundance	Moderate
3	Rehabilitation	Reconnect riparian processes: Livestock could be excluded to allow the riparian buffer zone (30-meter width) to become re-established.		

Photograph No. 6. View is to the southeast looking downstream at a lateral scour pool along river right. (Subreach PR-IZ-3 – RM 21.9 – Reclamation photograph by R. McAffee, 2008).

PR-DIZ-3 (Disconnected Inner Zone)

Disconnected inner zone PR-DIZ-3 is located between RM 21.80 and 21.88 and covers about 1.03 acres of the active channel (Figure 14). There is a levee that artificially constrains lateral channel (also see PR-DOZ-7). Removal or modification to the levee (about 455 feet in length) will reconnect the river to its historic channel path resulting in a moderate reduction in stream power and improved channel complexity (Photograph Nos. 7 and 8). This subreach currently has good large wood recruitment potential and canopy cover, but livestock have direct access and browse on the riparian vegetation. As part of the rehabilitation efforts, livestock could be excluded to allow the riparian buffer zone (30-meter width) to become re-established and to protect and maintain processes (Table 22).

Table 22. Potential habitat actions for PR-DIZ-3.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes: Remove or modify the levee to reconnect historic channel (Photograph Nos. 7 & 8) . This action could be in conjunction with the removal or modification to the section of the levees in subreach PR-DOZ-7. Once the levee is removed or modified riparian rehabilitation and livestock exclusion could be considered. Large wood may be needed to stabilize the bank in the short-term for the revegetation to be effective for the long-term. Prior to or following removal or modification of the levee, the subreach could be Protected and Maintained.	2; Productivity and Abundance	Moderate

Photograph No. 7. View is to the south looking downstream at riprap placed along a levee on river left. (Subreach PR-DIZ-3 – RM 21.9 – Reclamation photograph by R. McAffee, 2008).

Photograph No. 8. View is to the south looking along the crest of a levee along river left that impounds a small wetland area. (Reclamation photograph by R. McAffee, 2008).

PR-OZ-7 (Outer Zone)

Outer zone PR-OZ-7 is located between RM 21.90 and 22.06 on river left and covers about 4.20 acres of floodplain (Figure 15). There are no anthropogenic features within the subreach. This subreach has good large wood recruitment potential and canopy cover that could be protected to maintain the current processes (Table 23).

Table 23. Potential habitat actions for PR-OZ-7.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection	Protect and maintain current levels of geomorphic, hydrologic, and vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High

PR-DOZ-7 (Disconnected Outer Zone)

Disconnected outer zone PR-DOZ-7 is located between RM 21.89 and 21.91 and covers about 0.32 acres of floodplain on river left (Figure 15). There is a levee that disconnects the floodplain in this subreach (see PR-DIZ-3). Removal or modification of the levee (about 230 feet in total length) will reconnect the river to its floodplain. This subreach currently has fair to good large wood recruitment potential and canopy cover, but livestock have direct access and browse on the riparian vegetation. As part of the rehabilitation efforts, livestock could be excluded and the riparian buffer zone (30 meter width) could be re-established and protected (Table 24).

Table 24. Potential habitat actions for PR-DOZ-7.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes: Remove or modify the levee to reconnect floodplain. This action could be in conjunction with the removal or modification to the section of the levee in subreach PR-DOZ-7. Once the levee is removed or modified, riparian rehabilitation and livestock exclusion could be considered. Large wood may be needed to stabilize the bank in the short-term for the revegetation to be effective for the long-term. Prior to or following removal or modification of the levee, the subreach could be Protected and Maintained.	4; Productivity, Abundance, Diversity, and Structure	High

PR-OZ-8 (Outer Zone)

Outer zone PR-OZ-8 is located between RM 21.29 and 21.90 on river right, and covers about 20.94 acres of floodplain (Figure 15). The subreach contains about 1.50 acres of off-channel habitat (i.e. side channels). There is a push-up levee (about 290 feet in length "sugar dike") comprised of predominantly sand that has some impact on lateral channel migration, but its removal may impact a functioning side channel (Photograph No. 9). There is also about 400 feet of unimproved roads that do not have a significant impact on the river processes. The subreach has good off-channel rearing habitat, good large wood recruitment potential and canopy cover that could be protected to maintain the current processes (Table 25).

Table 25. Potential habitat actions for PR-OZ-8.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection + Rehabilitation	Protect and Reconnect Processes: If prudent the levee and road could be removed or modified, but the cost/benefit ratio may not warrant the action. However the off-channel habitat is significant (Photograph No. 9) and this subreach could be considered for Protection to maintain current levels of geomorphic, hydrologic, and riparian function.	4; Productivity, Abundance, Diversity, and Structure	High
2	Rehabilitation	Reconnect Processes: Remove riprap to allow for channel migration where infrastructure is not at risk.	2; Productivity and Abundance	Moderate
3	Rehabilitation	Reconnect Isolated Habitat Units: Modify bank protection with wood placements to increase habitat units and still provide bank protection for infrastructure.	2; Productivity and Abundance	Low

Photograph No. 9. View is to the northwest looking upstream at the outlet of a side channel along river right. (Reclamation photograph by R. McAffee, 2008).

River Mile 21.10 – 21.80 Subreaches

Between RM 21.10 and 21.80 the river is generally transitional due to artificial confinement (i.e., levee in subreaches PR-DIZ-3 and PR-DOZ-7, and riprap and wood revetment in PR-IZ-4) (Figure 16). There is also a levee constructed predominantly of sand ("sugar dike") in PR-OZ-8 that has little effect on river processes, but the subreach contains a large side channel that is excellent rearing habitat for salmonids. The predominant channel units are runs and pools with gravel and cobble being the dominant substrate. The riparian buffer zones (30 meter width along both banks) are in an ***At Risk Condition*** for potential large wood recruitment and canopy cover due to floodplain development. Riparian rehabilitation would be effective between RM 21.4 and 21.5 along river left that would help stabilize the bank, re-establish an effective riparian buffer zone for future large wood recruitment potential, and improve canopy cover. Overall, the primary habitat actions are to protect and reconnect processes (Table 26). Each subreach is discussed in the following sections.

Table 26. Summary of subreaches between RM 21.10 and 21.80.

SUBREACH	RIVER MILE	HABITAT ACTION	ACREAGE
PR-IZ-4 (inner zone)	RM 21.10 – 21.80	Protect and reconnect processes	12.93 acres
PR-OZ-9 (outer zone)	RM 21.60 – 21.71 (river left)	Protect and maintain	1.12 acres
PR-OZ-10 (outer zone)	RM 21.18 – 21.40 (river left)	Protect and maintain	9.22 acres

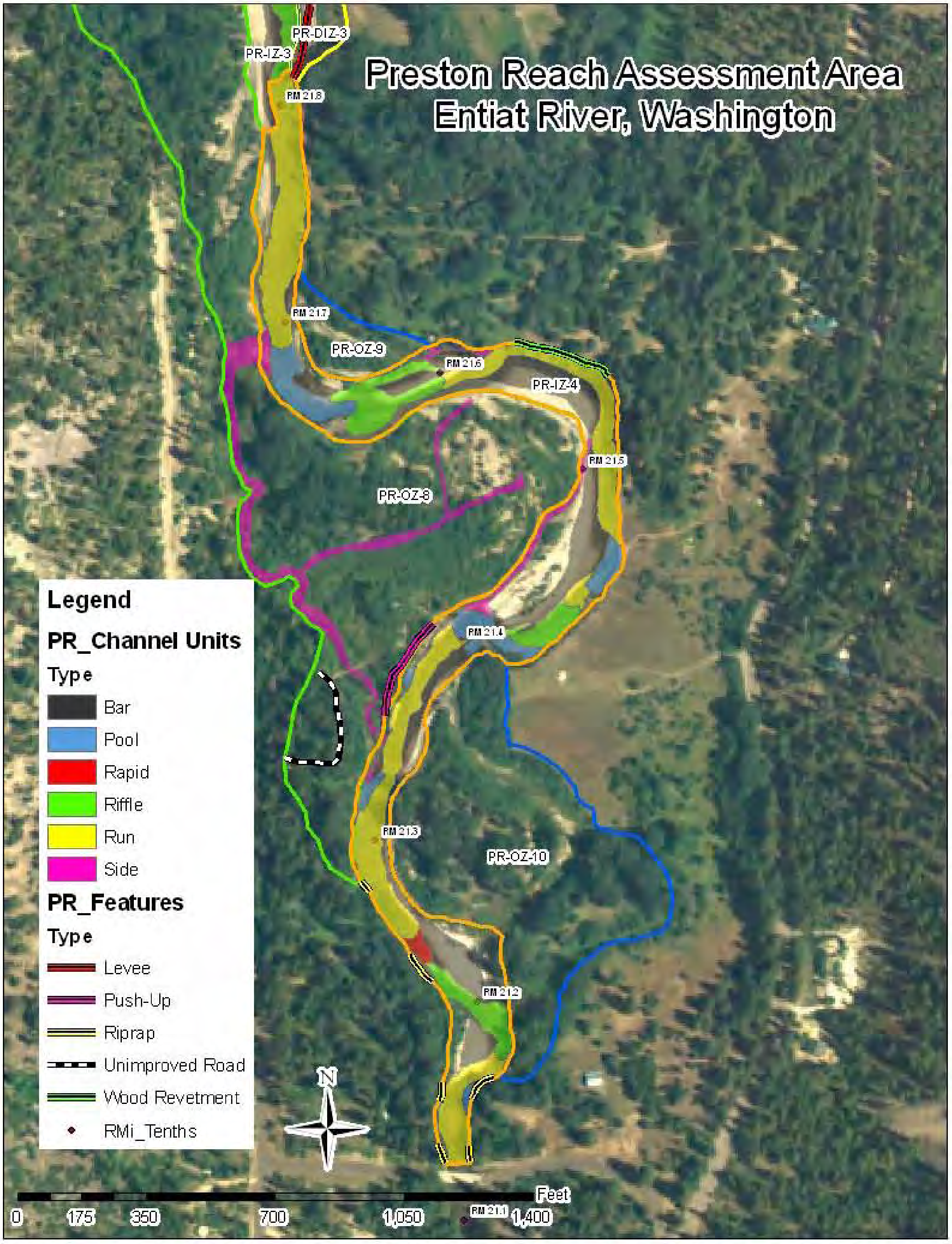


Figure 15. Location map of subreaches between RM 21.10 and 21.80 and anthropogenic features.

PR-IZ-4 (Inner Zone)

Inner zone PR-IZ-4 is located between RM 21.10 and 21.80 and covers about 12.93 acres of active channel, and the subreach contains about 0.30 acres of off-channel habitat (i.e., side channel) (Figure 16). There is about 370 feet of riprap that could be removed to promote lateral channel migration or be modified to include large wood to improve habitat conditions (Photograph No. 10). Further analysis on cost/benefit ratios would be needed before considering these options. There is a wood revetment (about 275 feet in length) that could be modified with large rootwads to increase roughness, reduce stream power, and to improve habitat conditions (Photograph No. 11). In addition, the left bank is eroding (RM 21.40 and 21.45) due to the lack of riparian vegetation that would stabilize the bank. This erosion appears to be providing elevated levels of fine sediment to spawning gravel downstream (RM 21.4) (Photograph No. 12). Consideration should be made to stabilize the bank with large wood complexes (short-term) and rehabilitate with appropriate vegetation (long-term). This subreach has fair large wood recruitment potential and canopy cover which could be augmented with riparian rehabilitation (Table 27).

Table 27. Potential habitat actions for PR-IZ-4.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes: Remove or modify riprap where feasible to promote channel migration and large wood recruitment (Photograph No. 10). Modify wood revetment to increase channel roughness and improve habitat units (Photograph No. 11). Rehabilitate riparian vegetation by stabilizing bank above spawning area with wood structures (short-term) and plant appropriate vegetation (long-term) (Photograph No. 12).	2; Productivity and Abundance	Moderate
2	Rehabilitation	Reconnect processes: Strategically place unanchored “key members” (large wood greater than 30-inch diameter at breast height and a length of 30 or more feet with rootwad attached) on point and medial bars, and allow the river to naturally adjust their position.	2; Productivity and Abundance	Moderate
3	Rehabilitation	Reconnect Isolated Habitat Units: Modify riprap bank protection and improve wood vetment with large wood placements (i.e., root boles) to increase habitat conditions and still provide bank protection for infrastructure.	2; Productivity and Abundance	Low

Photograph No. 10. View is to the south looking downstream at riprap placed along river left. (Subreach PR-IZ-4 – RM 21.2 – Reclamation photograph by R. McAffee, 2008).

Photograph No. 11. View is to the east looking downstream at a wood revetment along river left. (Subreach PR-IZ-4 – RM 21.6 – Reclamation photograph by R. McAffee, 2008).

Photograph No. 12. View is to the southwest looking downstream along river left at active bank erosion. (Subreach PR-IZ-4 – RM 21.5 – Reclamation photograph by R. McAffee, 2008).

PR-OZ-9 (Outer Zone)

Outer zone PR-OZ-9 is located between RM 21.60 and 21.71 on river left and covers about 1.12 acres of floodplain (Figure 15). There are no anthropogenic features within the subreach. This subreach has good large wood recruitment potential and canopy cover that could be protected to maintain the current processes (Table 28).

Table 28. Potential habitat actions for PR-OZ-9.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection	Protect and maintain current levels of geomorphic, hydrologic, and vegetative function.	4; Productivity, Abundance, Diversity, and Structure	Moderate

PR-OZ-10 (Outer Zone)

Outer zone PR-OZ-10 is located between RM 21.18 and 21.40 on river left and covers about 9.22 acres of floodplain (Figure 15). There are no anthropogenic features within the subreach. This subreach has good large wood recruitment potential and canopy cover that could be protected to maintain the current processes (Table 29).

Table 29. Potential habitat actions for PR-OZ-10.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection	Protect and maintain current levels of geomorphic, hydrologic, and vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High

SUMMARY AND CONCLUSIONS

The Preston reach, located between river miles RM 21.1 and RM 23.1 on the Entiat River, is a 6th field Hydrologic Unit Code (HUC) watershed. The Preston reach is characterized as an unconfined geomorphic reach type based on natural channel constraints. In its natural state, the Entiat River maintained dynamic equilibrium by actively migrating laterally across its floodplain within the Preston reach. Typically, unconfined geomorphic reaches have flatter slopes and a complex network of channels that result in a high degree of interaction between the active channel and its floodplain. This lateral channel migration maintains a lower energy and flatter channel gradient as sediment is stored before being eroded and transported downstream. The natural ecosystem processes of hydrologic, geomorphic, and vegetative regimes create a healthy stream characterized by a dynamic cycle of conversion from river to floodplain and vice versa, producing a continuous renewal of fish habitat. When interaction between these regimes is altered, it can negatively impact the availability of fish habitat and could threaten the continuation of the species within the basin.

Field surveys and evaluations were conducted in the Preston reach during the 2008 field season to determine the condition of the hydrologic, geomorphic, and vegetative regimes. Ecosystem processes in the Preston reach are in a moderately degraded state as a result of anthropogenic impacts. The dynamic interactions between the three regimes have been impacted by levees, bank protection, and development.

The geomorphic potential is interpreted to be altered because of reduced floodplain connectivity, lateral channel migration, and channel complexity created by large wood. Reduced floodplain connectivity is due to levees/push-up levees in the inner zone subreaches PR-DIZ-1, PR-DIZ-2, PR-DIZ-3, and outer zone subreaches PR-DOZ-2, PR-DOZ-5 and PR-DOZ-7. Reduced channel migration is due to riprap and a wood revetment in inner zone subreach PR-IZ-4 and outer zone subreach PR-OZ-8. These subreaches are interpreted to be in an ***At Risk Condition*** and are recommended for rehabilitation actions. All other subreaches are interpreted to be in an ***Adequate Condition*** and are recommended for protection actions.

The large woody debris reach-based ecosystem indicator is interpreted to be in an ***At Risk Condition*** and could be addressed for inner zones PR-IZ-2, PR-IZ-3, and PR-IZ-4 by strategically placing unanchored "key members" (large wood greater than 30-inch diameter at breast height and a length of 30 or more feet with rootwad attached) on point and medial bars, and allowing the river to naturally adjust their position. These "key members" would recruit and retain wood traveling through the system, creating channel complexity, and reducing stream power. This action could help return the lower two-thirds of the reach to a more natural depositional environment. It should be noted that unanchored large woody debris placements are not recommended in inner zone PR-IZ-1 because it is a localized transport reach with higher energy.

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GLOSSARY

Some terms in this glossary appear in this *Reach Assessment.*

	DEFINITION
2D-hydraulic analysis	Information derived from a two-dimensional computer model that calculates the water surface profiles and features or processes (i.e., sediment, water velocity) that may affect stream flows.
adaptive management	A management process that applies the concept of experimentation to design and implementation of natural resource plans and policies.
alluvial fan	A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream at the place where it issues from a narrow mountain valley upon a plain or broad valley, or where a tributary stream is near or at its junction with the main stream, or wherever a constriction in a valley abruptly ceases or the gradient of the stream suddenly decreases; it is steepest near the mouth of the valley where its apex points upstream, and it slopes gently and convexly outward with a gradually decreasing gradient (Neuendorf et al. 2005).
alluvium	A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream, as a sorted or semi-sorted sediment on the river bed and floodplain (Neuendorf et al. 2005).
anadromous (fish)	A fish, such as the Pacific salmon, that spawns and spends its early life in freshwater but moves into the ocean where it attains sexual maturity and spends most of its life span.
anthropogenic	Caused by human activities.
bedload	The sediment that is transported intermittently along the bed of the river channel by creeping, rolling, sliding, or bouncing along the bed. Typically includes sizes of sediment ranging between coarse sand to boulders (the larger or heavier sediment).
bed-material	Sediment that is preserved along the channel bottom and in adjacent bars; it may originally have been material in the suspended load or in the bed load.
bedrock	A general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material (Neuendorf et al. 2005). The bedrock is generally resistant to fluvial erosion over a span of several decades, but may erode over longer time periods.
canopy cover (of a stream)	Vegetation projecting over a stream, including crown cover (generally more than 1 meter (3.3 feet) above the water surface) and overhang cover (less than 1 meter (3.3 feet) above the water).
cfs	Cubic feet per second; a measure of water flows.

	DEFINITION
channel morphology	The physical dimension, shape, form, pattern, profile, and structure of a stream channel.
channel planform	Characteristics of the river channel that determine its two-dimensional pattern as viewed on the ground surface, aerial photograph, or map.
channel sinuosity	The ratio of length of the channel or thalweg to down-valley distance. Channels with a sinuosity value of 1.5 or more are typically referenced as meandering channels (Neuendorf et al. 2005).
channel stability	The ability of a stream, over time and under the present climatic conditions, to transport the sediment and flows produced by its watershed in such a manner that the stream maintains its dimension, pattern, and profile without either raising or lowering the level of the streambed.
channelization	Alteration of a natural channel typically by straightening and deepening the stream channel to permit the water to move faster, to reduce flooding, or to drain wetlands.
constructed features	Human-made features that are constructed in the river and/or floodplain areas (e.g., levees, bridges, riprap). These features are referred to as human features in the *Map Atlas*.
controls	A feature that is highly resistant to erosion by flowing water and limits the ability of a river or stream to migrate across a valley in either the lateral (horizontal) or vertical direction or both. Geologic controls are naturally occuring features such as bedrock outcrops, landslides, or alluvial fans that erode slowly over long periods of time. Human-constructed features such as highways, railroads, bridge abutments, or riprap may also act as controls and limit the ability of a river to migrate.
degradation	Wearing down of the land surface through the processes of erosion and/or weathering
depositional areas (stream)	Local zones within a stream where the energy of flowing water is reduced and sediment settles out, accumulating on the streambed.
diversity	Genetic and phenotypic (life history traits, behavior, and morphology) variation within a population.
ecosystem	A unit in ecology consisting of the environment with its living elements, plus the non-living factors, that exist in and affect it (Neuendorf et al. 2005).
floodplain	The surface or strip of relatively smooth land adjacent to a river channel constructed by the present river in its existing regimen and covered with water when the river overflows its banks. It is built on alluvium, carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current. A river has one floodplain and may have one or more terraces representing abandoned floodplains (Neuendorf et al. 2005).
flow regime	The quantity, frequency, and seasonal nature of water flow.

	DEFINITION
fluvial process	Those processes related to the movement of flowing water that shape the surface of the earth through the erosion, transport, and deposition of sediment, soil particles, and organic debris.
geomorphic potential	The capability of adjustment or change in structural/process components of an ecosystem through the combined action of hydrologic, riparian, and geomorphic regimes to form, connect, and sustain fish habitat over time.
geomorphic province	A large area comprised of similar land forms that exhibit comparable hydrologic, erosional, and tectonic processes (Montgomery and Bolton 2003); any large area or region considered as a whole, all parts of which are characterized by similar features or by a history differing significantly from that of adjacent areas (Neuendorf et al. 2005); also referred to as a basin.
geomorphic reach	An area containing the active channel and its floodplain bounded by vertical and/or lateral geologic controls, such as alluvial fans or bedrock outcrops, and frequently separated from other reaches by abrupt changes in channel slope and valley confinement. Within a geomorphic reach, similar fluvial processes govern channel planform and geometry through driving variables of flow and sediment. A geomorphic reach is comprised of a relatively consistent floodplain type and degree of valley confinement. Geomorphic reaches may vary in length from 100 meters in small, headwater streams to several miles in larger systems (Frissell et al. 1986).
geomorphology	The study of the classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes caused by the actions of flowing water.
GIS	Geographical information system. An organized collection of computer hardware, software, and geographic data designed to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.
habitat action	Proposed restoration or protection strategy to improve the potential for sustainable habitat upon which endangered species act (ESA) listed salmonids depend on. Examples of habitat actions include the removal or alteration of project features to restore floodplain connectivity to the channel, reconnection of historic side channels, placement of large woody debris, reforestation of the low surface, or implementation of management techniques.
habitat connectivity (stream)	Suitable stream conditions that allow fish and other aquatic organisms to access habitat areas needed to fulfill all life stages.
habitat unit	A morphologically distinct area within a geomorphic reach comprised of floodplain and channel areas; typically less than several channel widths in length (Montgomery and Bolton 2003). They generally correspond to different habitat types for aquatic species. Basic channel units may include pools, riffles, bars, steps, cascades, rapids, floodplain features, and transitional zones characterized by relatively homogeneous substrate, water depth, and cross-sectional averaged velocities. *Also known as channel or geomorphic units*.

	DEFINITION
indicator	A variable used to forecast the value or change in the value of another variable; for example, using temperature, turbidity, and chemical contaminents or nutrients to measure water quality.
inner zone (IZ)	Area where ground-disturbing flows take place; characterized by the presence of primary (perennial) and secondary (ephemeral) side channels, a repetitious sequence of channel units, and relatively uniform physical attributes indicative of localized transport, transition, and deposition.
intevention analysis	Consists of computer models and methods based on samples collected at an impact site before and after an intervention, such as a habitat action, so that effects of the intervention may be determined.
large woody debris (LWD)	Large downed trees that are transported by the river during high flows and are often deposited on gravel bars or at the heads of side channels as flow velocity decreases. The trees can be downed through river erosion, wind, fire, or human-induced activities. Generally refers to the woody material in the river channel and floodplain whose smallest diameter is at least 12 inches and has a length greater than 35 feet in eastern Cascade streams.
limiting factor	Any factor in the environment that limits a population from achieving complete viability with respect to any Viable Salmonid Population (VSP) parameter.
low-flow channel	A channel that carries streamflow during base flow conditions.
mass wasting	General term for the dislodgement and downslope transport of soil and rock under the influence of gravitational stress (mass movement). Often referred to as shallow-rapid landslide, deep-seated failure, or debris flow.
overflow channel	A channel that is expressed by no or little vegetation through a vegetated area. There is no evidence for water at low stream discharges. The channel appears to have carried water recently during a flood event. The upstream and/or downstream ends of the overflow channel usually connect to the main channel.
outer zone (OZ)	Area that may become inundated at higher flows but does not experience a ground-disturbing flow; generally coincidental with the historic channel migration zone unless the channel has been modified or incised leading to the abandonment of the floodplain. (also knows as the floodprone zone)
pathways	Interpretation of one or more indicators (i.e., water quality) that is used to define or refine potential environmental deficiencies caused by natural or anthropogenic impacts that negatively affect a life stage(s) of the species of concern (i.e., limiting factor). Pathways are typically analyzed at the reach, valley segment, watershed, and basin scales.
peak flow	Greatest stream discharge recorded over a specified period of time, usually a year, but often a season.
planform	The shape of a feature, such as a channel alignment, as seen in two dimensions, horizontally, as on an aerial photograph or map.

	DEFINITION
reach-based ecosystem indicators (REI)	Measure of physical variables that are quantifiable and have geospatial reference.
Reclamation	U.S. Department of the Interior, Bureau of Reclamation.
response reach	A reach that is more responsive to change and often characterized by unconfined and moderately confined alluvial plains/channels that lack geologic controls which often define confined channels. A response reach can be further broken down to individual subreach units that comprise finer morphologically distinct areas providing geomorphic control and transitional habitat and biological potential.
riparian area	An area with distinctive soils and vegetation community/composition adjacent to a stream, wetland, or other body of water.
riprap	Large angular rocks that are placed along a river bank to prevent or slow erosion.
river mile (RM)	Miles from the mouth of a river or for upstream tributaries; miles from the point where the tributary joins the main river.
side channel	A channel that is not part of the main channel, but appears to have water during low-flow conditions and has evidence for recent higher flow (e.g., may include unvegetated areas (bars) adjacent to the channel). At least the upstream end of the channel connects to, or nearly connects to, the main channel. The downstream end may connect to the main channel or to an overflow channel. May also be referred to as a secondary channel.
spawning and rearing habitat	Stream reaches and the associated watershed areas that provide all habitat components necessary for adult spawning and juvenile rearing for a local salmonid population. Spawning and rearing habitat generally supports multiple year classes of juveniles of resident and migratory fish, and may also support subadults and adults from local populations.
subbasin	A subbasin represents the drainage area upslope of any point along a channel network (Montgomery & Bolton 2003). Downstream boundaries of subbasins are typically defined in this assessment at the location of a confluence between a tributary and mainstem channel. An example would be the Twisp River Subbasin.
subreach units	Distinct areas are comprised of the floodplain and off-channel and active-channel areas. They are delineated by lateral and vertical controls with respect to position and elevation based on the presence/absence of inner or outer riparian zones.
terrace	A relatively stable, planar surface formed when the river abandons the floodplain that it had previously deposited. It often parallels the river channel, but is high enough above the channel that it rarely, if ever, is covered by water and sediment. The deposits underlying the terrace surface are alluvial, either channel or overbank deposits, or both. Because a terrace represents a former floodplain, it can be used to interpret the history of the river.

	Definition
tributary	A stream feeding, joining, or flowing into a larger stream or lake (Neuendorf et al. 2005).
UCSRB	Upper Columbia Salmon Recovery Board.
UCRTT	Upper Columbia Regional Technical Team.
valley segment	An area of river within a watershed sometimes referred to as a subwatershed that is comprised of smaller geomorphic reaches. Within a valley segment, multiple floodplain types exist and may range between wide, highly complex floodplains with frequently accessed side channels to narrow and minimally complex floodplains with no side channels. Typical scales of a valley segment are on the order of a few to tens of miles in longitudinal length.
vertical migration	Movement of a stream channel in a vertical direction; the filling and raising or the removal or erosion of streambed material that changes the level of the stream channel.
viable salmonid population	An independent population of Pacific salmon or steelhead trout that has a negligible risk of extinction over a 100-year time frame. Viability at the independent population scale is evaluated based on the parameters of abundance, productivity, spatial structure, and diversity.
watershed	The area of land from which rainfall (and/or snow melt) drains into a stream or other water body. Watersheds are also sometimes referred to as drainage basins. Ridges of higher ground form the boundaries between watersheds. At these boundaries, rain falling on one side flows toward the low point of one watershed, while rain falling on the other side of the boundary flows toward the low point of a different watershed.

APPENDICES

APPENDIX A

Preston Reach-based Ecosystem Indicators

Appendix A

Reach-based Ecosystem Indicators (REI) Version 1.1

The Preston reach assessment team was comprised of Edward W. Lyon, Jr., L.G. (Reclamation geologist), Robert McAffee (Reclamation geologist), Mike Sixta, P.E. (Reclamation hydraulic engineer), Phil Archibald (U.S. Forest Service fisheries biologist), and David Hopkins (U.S. Forest Service technician). Rating of each indicator was done as an iterative process by integrating new data collected for this reach assessment, data contained in the *Tributary Assessment* (Reclamation, 2009), *Entiat Water Resource Inventory Area (WRIA) 46 management Plan, October 2004* (CCCD 2004), and other literature review. The ranges of criteria presented here are not absolute and should be adjusted to each unique subbasin as data become available.

GENERAL CHARACTERISTICS: REGIONAL SETTING

Ecoregion	Bailey Classification	Domain - Human Temperate Domain	Province – Cascade Mixed Forest-Coniferous Forest-Alpine Meadow Province	Section – Eastern Cascades Section
	Omernik Classification	Chelan Tephra Hills	N/A	N/A
	Physiography	Division – Pacific Mountain System	Province – Cascade-Sierra Mountains	Section – Northern Cascade Mountains
	Geology	Geologic District 218	Lithology – Calc-Alkaline Intrusive	N/A

GENERAL CHARACTERISTICS: DRAINAGE BASIN

Geomorphic Features	Basin Area	Basin Relief	Drainage Density	Hydrologic Unit Code	Stream Order	Land Ownership
	268,000 acres	700’-9,249’	1.43 mi/mi^2	170200100104	4	84% public

GENERAL CHARACTERISTICS: VALLEY SEGMENT

Valley Characteristics	Valley Bottom Type	Valley Bottom Width	Valley Bottom Gradient	Valley Confinement	Channel Patterns
U-sha	ped trough *(U1)*	8.6 channel widths	0.005	Unconfined	Variable

GENERAL CHARACTERISTICS: CHANNEL SEGMENT

Channel Characteristics	Valley Type	Elevation	Dominant Channel Type	Bed-form Type	Channel Gradient	Sinuosity
Alluvial		1620’-1660’	C	Pool-riffle	.003	1.3

GENERAL CHARACTERISTICS: WATERSHED CONDITION

GENERAL INDICATORS: EFFECTIVE DRAINAGE NETWORK AND WATERSHED ROAD DENSITY

Criteria: The following criteria were developed by USFWS (1998).

General Characteristics	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Watershed Condition	Effective Drainage Network and Watershed Road Density	Increase in Drainage Network/ Road Density	Zero or minimum increases in active channel length correlated with human caused disturbance. And Road density <1 miles/miles^2.	Low to moderate increase in active channel length correlated with human caused disturbances. And Road density 1-2.4 miles/miles^2.	Greater than moderate increase in active channel length correlated with human caused disturbances. And Road density >2.4 miles/miles^2.

Data: Road density information was received from P. Archibald, U.S. Forest Service.

Area	Miles	Road Density*
Entiat watershed	693	2.5 mi/mi^2
Lower mid-Entiat subwatershed	No data	3.1 mi/mi^2

*Assuming all roads are "open" although that may not necessarily be the case

Narrative:
Based on the current data and assuming all roads are "open", the road density meets the Unacceptable Risk Condition criteria.

GENERAL INDICATORS: DISTURBANCE REGIME

Criteria: The following criteria were modified from USFWS (1998).

General Characteristics	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Watershed Condition	Disturbance Regime	Natural/ Human Caused	Environmental disturbance is short lived; predictable hydrograph, high quality habitat and watershed complexity providing refuge and rearing space for all life stages or multiple life-history forms. Natural processes are stable.	Scour events, debris torrents, or catastrophic fires are localized events that occur in several minor parts of the watershed. Resiliency of habitat to recover from environmental disturbances is moderate.	Frequent flood or drought producing highly variable and unpredictable flows, scour events, debris torrents, or high probability of catastrophic fire exists throughout a major part of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable.

Data: Fires, years, and acreage from the Tributary Assessment (Reclamation, 2008: Appendix A and P. Archibald, U.S. Forest Service).

Year	Name	Area (acres)	Recovery (years)	Estimated Seral Stage (assuming total burn)	Percentage of Drainage Basin
1910	Signal/Tyee Peak	2,560	~100	Large tree condition	< 1%
1925	Mad River, Spectacle Butte, Borealis Ridge, Three Creeks, Lake Creek, Brennagan Creek, Gray Canyon, and Mud Creek	2,900	~85	Large tree condition	1%
1961	Tenas George Fire	3,750	~45	Small tree condition	1%
1962	Forest Mountain	520	~45	Small tree condition	< 1%
1966	Hornet Creek #143	1,210	~45	Small tree condition	< 1%
1970	Entiat/Slide Ridge, and Gold Ridge	65,300	~40	Small tree condition	24%
1976	Crum Canyon	9,000	~35	Small tree condition	3%
1988	Dinkelman Canyon	53,000	~20	Sapling/pole condition	20%
1994	Tyee	140,196	~15	Shrub/seedling – sapling/pole condition	52%
2001	Tommy Creek	640	~10	Shrub/seedling condition	< 1%
2006	Tinpan	9,247	<5	Grass/forb condition	3%

Narrative:

The Tyee fire in 1994 significantly impacted the drainage basin, burning about 140,000 acres (or about 50 percent) of the drainage basin. The burn area has had about 15 years to recover and is currently in a shrub/seedling – sapling/pole condition. Based on the fire data the drainage basin is in an At Risk Condition, but is recovering.

GENERAL CHARACTERISTICS: FLOW/HYDROLOGY

GENERAL INDICATORS: STREAMFLOW

Criteria: The following criteria were developed by USFWS (1998).

General Characteristics	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Flow/ Hydrology	Streamflow	Change in Peak/Base Flows	Magnitude, timing, duration and frequency of peak flows within a watershed are not altered relative to natural conditions of an undisturbed watershed of similar size, geology and geography.	Some evidence of altered magnitude, timing duration and/or frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology and geography.	Pronounced changes in magnitude, timing, duration and/or frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology and geography.

Data: Entiat Water Resource Inventory Area (WRIA) 46 Management Plan, October 2004 (CCCD 2004).

Jan	1-31	Feb 1-28	Mar 1-15	Mar 16-31	April 1-15	April 16-30	May 1-31	Jun 1-30	Jul 1-15	Jul 16-31	Aug 1-31	Sep 1-30	Oct 1-31	Nov 1-30	Dec 1-31
"Naturalized" mean streamflow (cfs) at Stormy gage	106	114	131	167	243	410	1068	1431	813	481	219	114	100	129	126
Orchard irrigation water use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lawn irrigation water use – 20 acres	0	0	0	0	0.03	0.09	0.16	0.27	0.34	0.33	0.27	0.15	0.07	0	0
Domestic net water use* - 115 housing units according to census	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Mean streamflow (cfs) at Stormy gage	106	114	131	167	243	410	1068	1431	813	481	219	114	100	129	126
Proposed Administrative MIF	175	175	175	285	325	375	375	325	275	275	275	175	175	175	175
Water potentially available for future appropriation	-69	-61	-44	-118	-82	35	693	1106	538	206	-56	-61	-75	-46	-49
Water available for future appropriation* (cfs)	0	0	0	0	0	35	*100*	*100*	*67*	206	0	0	0	0	0

*Italicized water amounts will be based on codification of WDOE's determination of water availability during select semi-monthly periods.

Conversions/Assumptions used in calculations:
"Naturalized" = gage discharge + use total (rounded as appropriate)
1 cfs for 1 day = 1.9835 acre-feet
1 housing unit = 2.71 people per unit
Net water use = 35 gallons per capita per day
325,850 gallons = 1 acre-feet

Interpretation:

Upper Entiat River	At Risk Condition

Narrative:
The upper Instream Flow Incremental Methodology (IFIM) site representing the upper river from RM 10 to 27.7 showed that instream flows are inadequate from August 1st to May 1st. There are no known diversions upstream of the site and the low flows are believed to be natural rather than a human caused condition (http://apps.ecy.wa.gov/wats08/ViewListing.aspx?LISTING_ID=6210).

Geology of the upper Entiat in the area of the Preston reach is interpreted to be a glacial trough filled with alluvium. The river and groundwater are interpreted to be hydraulically connected. In addition, the Preston reach is in a loosing section with an aquifer depth greater than 100 feet. The upper Entiat River water budget study (CCCD 2004) suggests there is very limited available water for domestic use from August 1 through April 15. Further floodplain and valley bottom development could impact the baseflows during the August to April time period. Therefore, this indicator is interpreted to be in an At Risk Condition.

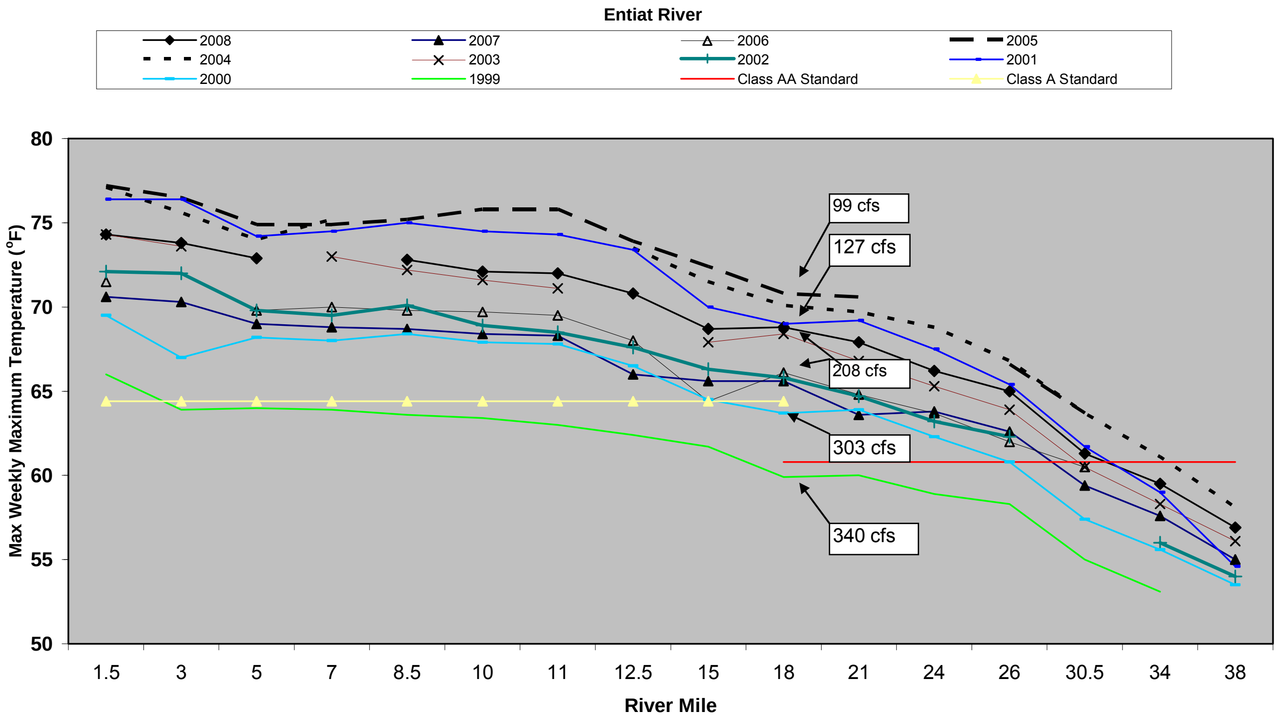
GENERAL CHARACTERISTICS: WATER QUALITY

GENERAL INDICATOR: TEMPERATURE

Criteria: The following criteria were developed by Hillman and Giorgi (2002), USFWS (1998), and WAC 173-201A-200 (http://www.ecy.wa.gov/programs/wq/swqs/criteria-freshwater/WAC173201a_200-temp.html).

General Characteristics	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Water Quality	Temperature	MWMT/ MDMT/ 7-DADMax	Bull Trout: Incubation: 2-5°C Rearing: 4-10°C Spawning: 1-9°C Salmon and Steelhead: Spawning: June-Sept 15°C Sept-May 12°C Rearing: 15°C Migration: 15°C Adult holding: 15°C Or, 7-DADMax performance standards (WDOE): Salmon spawning 13°C Core summer salmonid habitat 16°C Salmonid spawning, rearing and migration 17.5°C Salmonid rearing and migration only 17.5°C	MWMT in reach during the following life history stages: Incubation: <2°C or 6°C Rearing: <4°C or 13-15°C Spawning: <4°C or 10°C Temperatures in areas used by adults during the local spawning migration sometimes exceed 15°C. Or 7-DADMax performance standards exceeded by ≤15%	MWMT in reach during the following life history stages: Incubation: <1°C or >6°C Rearing: >15°C Spawning: <4°C or >10°C Temperatures in areas used by adults during the local spawning migration regularly exceed 15°C. Or 7-DADMax performance standards exceeded by >15%

Data: Water temperature information was received from P. Archibald, U.S. Forest Service. The Preston reach is located between RM 21.1 and 23.1.



Narrative:
The Entiat River is classified as a Class A (excellent) stream from its confluence with the Columbia River to the boundary of the Wenatchee National Forest at approximately RM 26, and as a Class AA (extraordinary) stream from the National Forest boundary to its headwaters. It supports beneficial uses including domestic, industrial and agricultural water supply and primary contact recreation (CCCD 2004).

Substantial warming tends to occur between RM 38 (Cottonwood campground) and RM 21 (Dill Creek Bridge). Exceedences about RM 20 generally occur from early August to early September (Archibald and Johnson 2002 *in* CCCD 2004). From the USFS boundary at RM 26 downstream to RM 18, the river flows through an increasingly wider U-shaped valley where it exhibits increased sinuosity and a lower gradient compared to all other areas of the Entiat River. A temperature moderating influence lies between RM 21 and RM 16, and is most likely related to a groundwater aquifer created by glacial till (CCCD 2004).

Temperature exceedences in the summer months have been identified throughout the record, beginning in 1960. Occasional temperature exceedences may have occurred naturally prior to settlement of the Entiat valley; however, it is impossible to determine the magnitude or frequency of this type of historic exceedence given the existing data record. It is likely that the number and frequency of exceedences has increased due to a combination of historic manipulation of channel geometry and removal of riparian plants, coupled with natural flood and wildfire events, which have also affected streamside vegetation (CCCD 2004).

The Planning Unit used the Stream Network Temperature Model to examine temperature exceedence patterns in the Entiat subbasin and identify actions, such as enhancing riparian vegetation, which can be implemented to help mitigate high summer water temperatures. The WDOE is recommending to the USEPA that the Entiat not be placed on the 2002/2004 303(d) list for temperature, but rather receive a “4b” categorization – impaired but has a pollution control plan – as a result of the Planning Unit’s past and current effort to address the problem (CCCD 2004).

The water temperature data and information contained in the Entiat Watershed Management Plan (CCCD 2004) suggests that water temperature is in an At Risk Condition primarily due to development and clearing of the riparian vegetation, but through the efforts of the Planning Unit this indicator will recover to an Adequate Condition over time.

GENERAL INDICATORS: TURBIDITY

Criteria: The performance standard for this indicator is from Hillman and Giorgi (2002), and Washington State Department of Ecology.

General Characteristics	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Water Quality	Turbidity	Turbidity	Performance Standard: Acute <70 NTU Chronic <50 NTU For streams that naturally exceed these standards: Turbidity should not exceed natural baseline levels at the 95% CL. <15% exceedance. Or, Turbidity shall not exceed: 5 NTU over background when the background is 50 NTU or less; or a 10 percent increase in turbidity when the background turbidity is more than 50 NTU (WDOE – 173-201A-200).	15-50% exceedance.	>50% exceedance.

Data: Entiat River near Entiat, Station 46A070, Lat. 47 39 48.0 Long. 120 14 58.0, Waterbody: WA-46-1010
(http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?theyear=&tab=final_data&scrolly=528&wria=46&sta=46A070)

Turbidity	1994	1995	1996	1997	1998	1999	2000	2001	2001	2003	2004	2005	2006	2007	Average
WQI	95	75	81	74	86	74	84	96	92	96	79	96	84	84	85

Higher scores -> better water quality, maximum possible score: 100

Data: Entiat River near Entiat, Station 46A070, Lat. 47 39 48.0 Long. 120 14 58.0, Waterbody: WA-46-1010
(http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?theyear=&tab=final_data&scrolly=528&wria=46&sta=46A070)

10/9/2006	11/14/06	12/13/06	1/8/07	2/5/07	3/5/07	4/9/07	5/8/07	6/12/07	7/9/07	8/15/07	9/11/07
1.2 NTU	1 NTU	0.5 U NTU	6.8 NTU	0.5 U NTU	0.6 NTU	3.2 NTU	7.4 NTU	2.4 NTU	1.4 NTU	1 NTU	1.7 NTU

U – not detected at the reported level

Interpretation:

Entiat River	Adequate Condition

Narrative:
Data from the DOE 46A110 station at Dill Creek was not available for this indicator. Therefore, based on NTU values reported for turbidity from 1994 to 2007 at DOE 46A070 station on the Entiat River near Entiat (about RM 1.5) this variable is interpreted to be in an Adequate Condition.

GENERAL INDICATORS: CHEMICAL CONTAMINATION/NUTRIENTS

Criteria:

General Characteristics	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Water Quality	Chemical Contamination/ Nutrients	Metals/ Pollutants, pH, DO, Nitrogen, Phosphorous	Low levels of chemical contamination from landuse sources, no excessive nutrients, no CWA 303d designated reaches. Or, Washington State Department of Ecology standards – 173-201A-200.	Moderate levels of chemical contamination from landuse sources, some excess nutrients, one CWA 303d designated reach.	High levels of chemical contamination from landuse sources, high levels of excess nutrients, more than one CWA 303d designated reach.

Data: Entiat River near Entiat (near RM 1.5), Station 46A070, Lat. 47 39 48.0 Long. 120 14 58.0, Waterbody: WA-46-1010 (WDOE, 2001, Publication No. 01-03-042)

Date	Time	Temp C°	Flow CFS	Conductivity umhos/cm	Oxygen Mg/L	pH Std. Units	Suspend. Solids mg/L	Total Pers. N. mg/L	Ammonia Nitrogen mg/L	Nitrate+ Nitrite mg/L	Total Phosp. mg/L	Turbidity NTU	Fecal Coliforms #/100/mL
10/5/1999	14:00	8.7	170	150	11	8.5	2	0.204	0.027	0.137	0.02	0.6	1 U
11/2/1999	14:50	3.2	170	130	13.1	7.6	4 J	0.16	0.01 U	0.116	0.024	0.5 U	1 U
12/7/1999	16:30	0	296	87	13.6	7.6	1	0.122	0.01 U	0.088	0.018	0.6	4
1/4/2000	18:00	-0.4	284	83	13.4	7.7	1	0.171	0.01U	0.12	0.02	0.6	9
2/8/2000	17:10	3.1	210	105	12.3	8.3	1	0.171	0.01 U	0.131	0.033	0.6	n/a
3/7/2000	17:20	4.1	216	126	12	8.2	2	0.174	0.01 U	0.145	0.018	0.9	1
4/4/2000	17:55	7.4	611	85	11.1	8.4	26	0.105	0.01 U	0.057	0.031	11	3
5/2/2000	18:00	8.2	923	58	11.1	n/a	6	0.072	0.01 U	0.01 U	0.015	2.6	30
6/6/2000	21:05	6.4	1900	27	11.2	n/a	29	0.063	0.01 U	0.02	0.01 U	4.6	8
7/11/2000	19:35	12.6	750	43	9.7	8.2	5	0.059	0.01 U	0.026	0.012	1	6
8/15/2000	18:20	16.7	223	68	9.9	8.15	2	0.092	0.01 U	0.055	0.015	0.7	4
9/5/2000	19:20	12.7	167	n/a	10	n/a	3	0.12	0.01 U	0.071	0.015	0.6	64

Data qualifiers: U – not detected at the reported level, J – estimated value.

Data: Entiat River near Entiat (near RM 1.5), Station 46A070, Lat. 47 39 48.0 Long. 120 14 58.0, Waterbody: WA-46-1010
(http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?theyear=&tab=final_data&scrolly=528&wria=46&sta=46A070)

Date	Time	COND (umhos/cm)	FC (#/100ml)	FLOW (CFS)	NH3_N (mg/L)	NO2_NO3 (mg/L)	OP_DIS (mg/L)	OXYGEN (mg/L)	PH (pH)	PRESS (mm/Hg)	SUSSOL (mg/L)	TEMP (C°)	TP_P_ICP (mg/L)	TPN (mg/L)	TURB (NTU)
10/9/06	12:02	114	4	91	0.01 U	0.167	0.0046	12.47	8.36	757.428	2	8.9	0.0035	0.22	1.2
11/14/06	11:45	57	4	495	0.01 U	0.069	0.0047	13.46	7.7	749.3	3	2.3	0.0053	0.096	1
12/13/06	11:15	81	14	223	0.01 U	0.101	0.0053	14.43	7.75	740.156	1	1.6	0.0037	0.12	0.5 U

Date	Time	COND (umhos/cm)	FC (#/100ml)	FLOW (CFS)	NH3_N (mg/L)	NO2_NO3 (mg/L)	OP_DIS (mg/L)	OXYGEN (mg/L)	PH (pH)	PRESS (mm/Hg)	SUSSOL (mg/L)	TEMP (C°)	TP_P_ICP (mg/L)	TPN (mg/L)	TURB (NTU)
1/8/07	11:45	91	4	305	0.01 U	0.107	0.0045	14.38	7.95	755.142 J	13	1.9	0.0109	0.14	6.8
2/5/07	11:31	104	1 U	175	0.01 U	0.099	0.0034	15.15	8.21	753.618	1	0.7	0.0019	0.13	0.5 U
3/5/07	11:14	119	1 U	223	0.01 U	0.061	0.003 U	14.08	8.97	751.332	2	5.3	0.0029	0.11	0.6
4/9/07	10:15	71	9	1000	0.01 U	0.01 U	0.0036	12.95	8.41	738.124	10	6.5	0.006	0.054	3.2
5/8/07	11:12	49	4	1470	0.01 U	0.016	0.0031	12.34	7.93	742.95	57	7.1	0.0087	0.06	7.4
6/12/07	11:25	39	2	1460	0.01 U	0.03	0.0051	11.83	7.51	749.046	12	8.3	0.0036 J	0.055	2.4
7/9/07	10:33	45	8	817	0.01 U	0.27	0.0038	10.61	7.64	745.236	6	13.8	0.0041	0.049	1.4
8/15/07	13:46	85	7	178	0.01 U	0.088	0.0035	9.89	8.44	741.934	3	19.5	0.0027 J	0.13	1
9/11/07	12:10	106	20 J	120	0.01 U	0.142	0.0043	10.91	8.58	748.03	3	15.3	0.0033	0.21	1.7

Data qualifiers: U – not detected at the reported level, J – estimated value

Data: Scores by constituent: Entiat River near Entiat (near RM 1.5), Station 46A070, Lat. 47 39 48.0 Long. 120 14 58.0, Waterbody: WA-46-1010
(http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?theyear=&tab=final_data&scrolly=528&wria=46&sta=46A070)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Average
Fecal coliform bacteria	90	87	99	96	100	93	92	100	96	99	96	97	96	97	96
Oxygen	88	94	93	93	92	96	92	90	95	92	89	92	94	93	92
pH	80	83	77	63	59	63	80	67	82	56	56	75	81	64	70
Suspended solids	87	70	72	69	79	68	78	92	82	90	80	95	72	76	79
Temperature	75	90	80	85	71	100	85	73	81	79	71	73	88	74	80
Total persulf nitrogen	97	95	97	96	96	96	98	97	98	98	98	97	96	97	97
Total phosphorus	97	80	87	70	81	80	91	93	94	95	100	91	100	100	90
Turbidity 95		75	81	74	86	74	84	96	92	96	79	96	84	84	85
Overall WQI	91	85	88	79	80	78	91	85	95	82	82	90	91	85	86
Adjusted for flow	n/a	84	88	79	79	85	90	83	93	81	80	88	91	85	85

Key: black – good red – moderate n/a – not sampled or not calculated
Higher scores -> better water quality, maximum possible score: 100

Interpretation:

Fecal coliform bacteria	Adequate Condition
Oxygen	Adequate Condition
pH	At Risk Condition
Suspended solids	At Risk Condition
Temperature At	Risk Condition
Total persulf nitrogen	Adequate Condition
Total phosphorus	Adequate Condition
Turbidity	Adequate Condition
Overall WQI	Adequate Condition

Narrative:
There is no indication of any significant degradation within the WRIA with respect to fecal coliform, dissolved oxygen, pH, or turbidity (CCCD 2004). Data from the DOE 46A110 station at Dill Creek was not available for this indicator, so DOE 46A070 station (near RM 1.5) was used to evaluate this indicator and may or may not be representative of the Preston reach. Three water quality variables (pH, suspended solids, and temperature) were found to be in an At Risk Condition based on averaged Water Quality Index (WQI) values reported from 1994 to 2007. It is unclear if exceedences of these variables is a natural condition or from anthropogenic impacts based on the limited data, so this indicator is interpreted to be in an At Risk Condition.
(http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?theyear=&tab=final_data&scrolly=528&wria=46&sta=46A070)

GENERAL CHARACTERISTICS: HABITAT ACCESS

GENERAL INDICATOR: PHYSICAL BARRIERS

Criteria: The following criteria have been modified from USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Habitat Access	Physical Barriers	Main Channel Barriers	No manmade barriers present in the mainstem that limit upstream or downstream migration at any flow.	Manmade barriers present in the mainstem that prevent upstream or downstream migration at some flows that are biologically significant.	Manmade barriers present in the mainstem that prevent upstream or downstream migration at multiple or all flows.

Interpretation:

Physical Barriers	Adequate Condition

Narrative:
No mainstem barriers are present on the Entiat River; therefore, this indicator is interpreted to be in an Adequate Condition.

GENERAL CHARACTERISTICS: HABITAT QUALITY

GENERAL INDICATOR: SUBSTRATE

Criteria: Performance standards for these criteria are from Hillman and Giorgi (2002).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Habitat Quality	Substrate	Dominant Substrate/ Fine Sediment	Gravels or small cobbles make-up >50% of the bed materials in spawning areas. Reach embeddedness in rearing areas <20%. <12% fines (<0.85mm) in spawning gravel or ≤12% surface fines of ≤6mm.	Gravels or small cobbles make-up 30-50% of the bed materials in spawning areas. Reach embeddedness in rearing areas 20-30%. 12-17% fines (<0.85mm) in spawning gravel or 12-20% surface fines of ≤6mm.	Gravels or small cobbles make-up <30% of the bed materials in spawning areas. Reach embeddedness in rearing areas >30%. >17% fines (<0.85mm) in spawning gravel or >20% surface fines of ≤6mm.

Data: U.S. Forest Service Habitat Assessment (Appendix C).

River Miles:	RM 21.1-22.6	RM 22.6-23.3
Habitat Reach:	Reach 3	Reach 4
Visual Estimate:		
Percent sand (< 2 mm)	20%	0%
Percent gravel (2 – 64 mm)	40%	10%
Percent cobble (64 – 256 mm)	40%	50%
Percent boulder (> 256 mm)	0%	40%
Percent bedrock	0%	0%
Pebble Count Data:		
Percent surface fines (< 6 mm)	13%	9%
D50 (mm)	50.5 mm	129.0 mm
D84 (mm)	88.8 mm	249.1 mm
Percent sand (< 2 mm)	12%	7%
Percent gravel (2 – 64 mm)	56%	28%
Percent cobble (64 – 256 mm)	34%	50%
Percent boulder (> 256 mm)	0%	15%
Percent bedrock	0%	0%
Dominant Substrate:	Gravel/Cobble	Cobble/Boulder
Embeddedness:	None Non	e
Fine Sediment:	> 12%	< 12%

Interpretation:

River Miles:	RM 21.1-22.6	RM 22.6-23.3
Habitat Reach:	Reach 3	Reach 4
Dominant Substrate	Adequate Condition	Adequate Condition
Embeddedness	Adequate Condition	Adequate Condition
Fine Sediment	At Risk Condition	Adequate Condition

Narrative:
The dominant substrate between RM 21.1 and 22.6 are gravel and cobbles, and the dominate substrate between RM 22.6 and 23.3 are cobbles and boulders. The cobble/boulder substrate between RM 22.6 and 23.3 is a natural condition. Additional substrate data can be found in the *Tributary Assessment* (Reclamation, 2009). Therefore, the dominate substrate indicator is interpreted to be in an Adequate Condition. Embeddedness was not noted in the Habitat Assessment (Appendix C) and is interpreted to be in an Adequate Condition. However, about 13% of the substrate at the pebble count sites consisted of fine sediments (< 6 mm) and data from twelve consecutive years of McNeil Core sampling from Habitat Reach 3 (RM 21.1-22,6) shows a variable trend (range 11% to 18% with a long-term mean of 15% fines (< 0.85 mm)) in the spawning gravels. Therefore, the fine sediment indicator is interpreted to be in an At Risk Condition.

GENERAL INDICATOR: LARGE WOODY DEBRIS (FREQUENCY)

Criteria: The following criteria were developed by USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Habitat Quality	Large Woody Debris (LWD)	Pieces Per Mile at Bankfull	>20 pieces/mile >12" diameter >35 ft length; and adequate sources of woody debris available for both long- and short-term recruitment.	Currently levels are being maintained at minimum levels desired for "adequate", but potential sources for long-term woody debris recruitment is lacking to maintain these minimum values.	Current levels are not at those desired values for "adequate", and potential sources of woody debris for short- and/or long-term recruitment are lacking.

Data: U.S. Forest Service Habitat Assessment (Appendix C).

River Miles:	RM 21.1-22.6	RM 22.6-23.3
Habitat Reach:	Reach 3	Reach 4
Large wood per mile (in-channel only):		
Small (> 20 feet long, > 6 inches diameter)	37.9	19.9
Medium (> 35 feet long, 12-20 inches diameter)	13.6	11.4
Large (> 35 feet long, > 20 inches diameter)	3.4	0
Total large and medium	17.0	11.4

Interpretation:

River Miles:	RM 21.1-22.6	RM 22.6-23.3
Habitat Reach:	Reach 3	Reach 4
Large Wood Per Mile	At Risk Condition	At Risk Condition

Narrative:
Wood was removed from the river in the 1970s by the ACOE to reduce the threat of flooding. Wood counts still remain lower than the Adequate Condition criteria, but wood recruitment potential is in an Adequate Condition. Therefore, this indicator is interpreted to be in an At Risk Condition.

GENERAL INDICATOR: POOLS (FREQUENCY)

Criteria: The following criteria were developed by USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Habitat Quality	Pools	Pool Frequency and Quality Large Pools (in adult holding, juvenile rearing, and over-wintering reaches where streams are >3 m in wetted width at base flow)	Pool frequency: Channel width No. pools/mile 0-5 ft 39 5-10 ft 60 10-15 ft 48 15-20 ft 39 20-30 ft 23 30-35 ft 18 35-40 ft 10 40-65 ft 9 65-100 ft 4 Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover.	Pool frequency is similar to values in "functioning adequately", but pools have inadequate cover/temperature, and/or there has been a moderate reduction of pool volume by fine sediment. Reaches have few large pools (>1 m) present with good fish cover.	Pool frequency is considerably lower than values for "functioning adequately", also cover/temperature is inadequate, and there has been a major reduction of pool volume by fine sediment. Reaches have no deep pools (>1 m) with good fish cover.

Data: Habitat units by U.S. Forest Service (Appendix C).

River Miles:	RM 21.1-22.6	RM 22.6-23.3
Habitat Reach:	Reach 3	Reach 4
Measured miles	1.77	0.70
Total number of surveyed pools	21	0
Pools per mile	11.9	0
Average wetted channel width (feet)	60	60
Number of pools > 5 feet deep per mile	6.2	0
Average maximum pool depth (feet)	6.2	0
Average pool residual depth (feet)	4.65	0
Percent Habitat Area:		
Percent pools	58%	0%
Percent riffles	24%	82%

River Miles:	RM 21.1-22.6	RM 22.6-23.3
Percent runs	12%	18%
Percent side channels/off-channel habitat	6%	0%
Required number of pools per mile	9	9
Primary Pool Form:		
Number of bedrock pools	0	0
Number of scour pools[1]	19	0
Number formed by large wood	1	0
Number formed by boulders	0	0
Number formed by others[2]	1	0

[1]Large wood increased the depth in many of these pools.
[2]Forming agents such as riprap, bridge abutments, or at confluences.

Interpretation:

River Miles:	RM 21.1-22.6	RM 22.6-23.3
Habitat Reach:	Reach 3	Reach 4
Frequency and Quality:	Adequate Condition	At Risk Condition
Large Pools:	Adequate Condition	At Risk Condition

Narrative:
Between RM 21.1 and 22.6 pool frequency and quality meets the Adequate Condition criteria. From RM 22.6 to 23.3 pool frequency and quality does not meet the Adequate Condition criteria, but this river segment is locally a transport zone and is most likely near natural levels.

GENERAL INDICATOR: OFF-CHANNEL HABITAT

Criteria: The following criteria have been modified from USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Habitat Quality	Off-channel Habitat	Connectivity with Main Channel	Reach has many ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are low energy areas. No manmade barriers present along the mainstem that prevent access to off-channel areas.	Reach has some ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are generally high energy areas. Manmade barriers present that prevent access to off-channel habitat at some flows that are biologically significant.	Reach has few or no ponds, oxbows, backwaters, and other off-channel areas. Manmade barriers present that prevent access to off-channel habitat at multiple or all flows.

Data: Off-channel habitat units analysis by U.S. Forest Service Habitat Assessment (Appendix C).

River Miles:	RM 21.1-22.6	RM 22.6-23.3
Habitat Reach:	Reach 3	Reach 4
Percent side channels/off-channel habitat	6%	0%

Data: Off-channel habitat units by U.S. Forest Service Habitat Assessment (Appendix C).

River Mile	Bank	Length (feet)	Width (feet)	Average/Maximum Depths	Notes
RM 21.3	Right	1,350	25	3 ft / 5 ft	Four beaver dams create deep pool habitat in the side channel, creating excellent rearing habitat for juvenile fish.
RM 22.1	Left	50	2	0.2 ft / 0.2 ft	The side channel becomes a dry channel after 50 feet.

Data: Channel unit analysis by Reclamation (Appendix B).

River Miles:	RM 21.10-21.80	RM 21.29-21.90 (Right)	RM 21.80-21.98	RM 22.45-23.10
Subreach:	PR-IZ-4	PR-OZ-8	PR-IZ-3	PR-IZ-1
Side Channel Area	0.30 acres	1.55 acres	0.50 acres	0.04 acres

Interpretation:

Off-channel Habitat	At Risk Condition

Narrative:
Human features have disconnected the river from its floodplain, historic channel paths, and constrain channel migration. Therefore, the off-channel habitat indicator is interpreted to be in an At Risk Condition.

GENERAL INDICATOR: DYNAMICS

Criteria: The following criteria have been modified from USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Channel	Dynamics	Floodplain Connectivity	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession.	Reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession.	Severe reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly.

Data: Channel unit analysis by Reclamation (Appendix B).

River Miles:	RM 21.10 – 21.80	RM 21.80 – 21.98	RM 21.98 – 22.45	RM 22.45 – 23.10
Subreach:	Subreach PR-IZ-4	Subreach PR-IZ-3	Subreach PR-IZ-2	Subreach PR-IZ-1
Channel Gradient:	0.23%	0.23%	0.23% - 0.57%	0.57% - 1.26%
Channel Units (acres):				
Rapid	0.08	0	0	5.05
Run	3.97	0.61	2.66	0
Riffle	1.23	0.88	1.15	0.23
Pool	1.04	0.42	0.60	0
Bar	2.71	1.07	3.22	0.24
Side Channel	1.85	0.50	0	0.04
Channel Units (percentage):				
Rapid	1%	0%	0%	91%
Run	36%	18%	35%	0%
Riffle	11%	25%	15%	4%
Pool	10%	12%	8%	0%
Bar	25%	31%	42%	4%
Side Channel	17%	14%	0%	1%
Dominant Substrate:	Cobble/Gravel	Gravel/Cobble	Cobble/Gravel	Cobble/Boulder
Interpreted Localized Trend:	Transition	Deposition	Transition	Transport

Data: Disconnected subreach analysis by Reclamation (Appendix B).

River Miles:	RM 22.85-23.00 (Right)	RM 21.80-22.10 (Left)	RM 21.80-21.89 (Left)	RM 22.75-23.02 (Left)	RM 22.18-22.29 (Left)	RM 21.89-21.91 (Left)
Subreach:	PR-DIZ-1	PR-DIZ-2	PR-DIZ-3	PR-DOZ-2	PR-DOZ-5	PR-DOZ-7
Levee (length)	540 ft	155 ft	455 ft	0 ft	375 ft	230 ft
Push-up Levee (length)	0 ft	230 ft	0 ft	325 ft	375 ft	0 ft
Disconnected Area	2.11 acres	2.30 acres	1.03 acres	6.08 aces	3.74 acres	0.32 acres

Narrative:
Human features have disconnected the river from its floodplain in several locations. Therefore, the floodplain connectivity indicator is interpreted to be in an At Risk Condition.

GENERAL INDICATOR: DYNAMICS

Criteria: The criteria for bank stability/channel migration were agreed upon by the assessment team as a relative condition of the specific indicator.

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Channel	Dynamics	Bank Stability/ Channel Migration	Channel is migrating at or near natural rates.	Limited amount of channel migration is occurring at a faster/slower rate relative to natural rates, but significant change in channel width or planform is not detectable; large woody debris is still being recruited.	Little or no channel migration is occurring because of human actions preventing reworking of the floodplain and large woody debris recruitment; or channel migration is occurring at an accelerated rate such that channel width has a least doubled, possibly resulting in a channel planform change, and sediment supply has noticeably increased from bank erosion.

Data: U.S. Forest Service Habitat Assessment (Appendix C).

River Miles:	RM 21.1-22.6	RM 22.6-23.3
Habitat Reach:	Reach 3	Reach 4
Linear feet of erosion per mile	1,155	106
Percent eroding banks (total both banks)	11%	1%

Data: Human features analysis by Reclamation (Appendix B).

River Miles:	RM 21.10 – 21.80	RM 21.80 – 21.98	RM 21.98 – 22.45	RM 22.45 – 23.10
Levee/Push-up Levee (length)	290 ft	685 ft	1145 ft	865 ft
Riprap (length)	370 ft	0 ft	55 ft	0 ft
Revetment (length)	275 ft	0 ft	0 ft	0 ft

Narrative:
Channel migration rates have been adversely impacted by levees and riprap that constrain the river. There are also localized areas where channel migration rates have increased due to the lack of woody vegetation and root mass stabilizing the river banks. Therefore, the bank stability/channel migration indicator is interpreted to be in an At Risk Condition.

GENERAL INDICATOR: DYNAMICS

Criteria: The criteria for vertical channel stability were agreed upon by the assessment team as a relative condition of the specific indicator.

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Channel	Dynamics	Vertical Channel Stability	No measurable trend of aggradation or incision and no visible change in channel planform.	Measurable trend of aggradation or incision that has the potential to but not yet caused disconnection of the floodplain or a visible change in channel planform (e.g. single thread to braided).	Enough incision that the floodplain and off-channel habitat areas have been disconnected; or, enough aggradation that a visible change in channel planform has occurred (e.g. single thread to braided).

Data: U.S. Forest Service Habitat Assessment (Appendix C).

River Miles:	RM 21.1 – 22.6	RM 22.6 – 23.3
Average Mean Daily Flow (USGS gage @ RM 18.0)	124 cfs	124 cfs
Average Wetted Width	60 ft	60 ft
Bankfull Width	106 ft	82 ft
Width/Depth Ratio	44.1	28.6
Floodplain Width	> 500 ft	160 ft
Entrenchment Ratio	> 5 to 1	1.95
Rosgen Channel Type	C3, C4	B3c, F2

Data: Channel unit analysis by Reclamation (Appendix B) and *Tributary Assessment* (Reclamation, 2009).

River Miles:	RM 21.10 – 21.80	RM 21.80 – 21.98	RM 21.98 – 22.45	RM 22.45 – 23.10
Subreach:	Subreach PR-IZ-4	Subreach PR-IZ-3	Subreach PR-IZ-2	Subreach PR-IZ-1
Channel Gradient:	0.23%	0.23%	0.23% - 0.57%	0.57% - 1.26%
Channel Units (acres):				
Rapid	0.08	0	0	5.05
Run	3.97	0.61	2.66	0
Riffle	1.23	0.88	1.15	0.23
Pool	1.04	0.42	0.60	0
Bar	2.71	1.07	3.22	0.24
Side Channel	1.85	0.50	0	0.04
Channel Units (percentage):				
Rapid	1%	0%	0%	91%
Run	36%	18%	35%	0%

River Miles:	RM 21.10 – 21.80	RM 21.80 – 21.98	RM 21.98 – 22.45	RM 22.45 – 23.10
Riffle	11%	25%	15%	4%
Pool	10%	12%	8%	0%
Bar	25%	31%	42%	4%
Side Channel	17%	14%	0%	1%
Dominant Substrate:	Cobble/Gravel	Gravel/Cobble	Cobble/Gravel	Cobble/Boulder
Interpreted Localized Trend:	Transition	Deposition	Transition	Transport

Data: Human features analysis by Reclamation (Appendix B).

River Miles:	RM 21.10 – 21.80	RM 21.80 – 21.98	RM 21.98 – 22.45	RM 22.45 – 23.10
Levee/Push-up Levee	290 ft	685 ft	1145 ft	865 ft
Riprap (length)	370 ft	0 ft	55 ft	0 ft
Revetment (length)	275 ft	0 ft	0 ft	0 ft

Narrative:
Levees and riprap constrain the river and have adversely impacted lateral channel migration and sediment transport. Areas impacted by the levees and riprap are interpreted to be transporting more sediment through the system than prior to construction (historically). Therefore, the vertical channel stability is interpreted to be in an At Risk Condition.

GENERAL CHARACTERISTICS: RIPARIAN VEGETATION

GENERAL INDICATOR: CONDITION

Criteria: The criteria for riparian vegetation structure were agreed upon by the assessment team as a "relative" indication to the functionality of the specific indicator.

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Riparian Vegetation	Condition	Structure	>80% species composition, seral stage, and structural complexity are consistent with potential native community.	50-80% species composition, seral stage, and structural complexity are consistent with potential native community.	<50% species composition, seral stage, and structural complexity are consistent with potential native community.

Data: Seral stage analysis for floodplain by Reclamation (Appendix D)

Disturbance (Floodplain):	Acres	Percentage
Agriculture Area	0.54 acres	< 1%
Residential Area	0.03 acres	< 1%
Commercial Area	0 acres	0%
Fire Area	0 acres	0%
Seral Stage (Floodplain):		
No Vegetation	0.07 acres	< 1%
Grass/Forbes	7.63 acres	11%
Shrub/Seedling	8.57 acres	12%
Sapling/Pole	5.89 acres	8%
Small Tree	13.04 acres	18%
Large Tree	36.17 acres	51%

Narrative:
Less than one percent of the riparian vegetation has been disturbed by agriculture and residential development. There are localized areas where riparian vegetation has been cleared that could be revegetated. However, overall the Preston reach's riparian vegetation composition and structure is interpreted to be in an Adequate Condition.

GENERAL INDICATOR: CONDITION

Criteria: The criteria for riparian vegetation disturbance were agreed upon by the assessment team as a "relative" indication to the functionality of the specific indicator.

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Riparian Vegetation	Condition	Disturbance (Human)	>80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m 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/mi^2 road density in the floodplain.	50-80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; 20-50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); 2-3 mi/mi^2 road density in the floodplain.	<50% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; >50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); >3 mi/mi^2 road density in the floodplain.

Data: Seral stage analysis for 30 meter buffer zone by Reclamation (Appendix D)

Riparian Buffer (30 m width):	**Acres**	**Percentage**
Agriculture Area	1.5760 acres	3%
Residential Area	1.1992 acres	2%
Commercial Area	0 acres	0%
Fire area	0 acres	0%
Seral Stage (30 m width):		
No Vegetation	0.0758 acres	< 1%
Grass/Forbes 8.8251	acres	16%
Shrub/Seedling	4.5802 acres	8%
Sapling/Pole 3.0962	acres	6%
Small Tree	10.0614 acres	19%
Large Tree	27.3247 acres	51%

Data: Road density information was received from P. Archibald, U.S. Forest Service.

Area	**Miles**	**Road Density***
Entiat watershed	693	2.5 mi/mi^2
Lower mid-Entiat subwatershed	No data	3.1 mi/mi^2

*Assuming all roads are "open" although that may not necessarily be the case

Narrative:
About five percent of the riparian buffer zone (30 meter width along both banks) has been cleared for agriculture and residential use. Road densities are relatively high throughout the watershed (assuming all roads are "open"). Therefore, the riparian buffer zone is interpreted to be in an At Risk Condition.

GENERAL INDICATOR: CONDITION

Criteria: The criteria for riparian vegetation canopy cover were agreed upon by the assessment team as a "relative" indication to the functionality of the specific indicator.

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Riparian Vegetation	Condition	Canopy Cover	Trees and shrubs within one site potential tree height distance have >80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have 50-80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have <50% canopy cover that provides thermal shading to the river.

Data: Seral stage analysis for 10 meter buffer zone by Reclamation (Appendix D).

Seral Stage (10 m width):	Acres	Percentage
No Vegetation	0.01	< 1%
Grass/Forbes 0.13		13%
Shrub/Seedling	0.12	13%
Sapling/Pole 0.09		9%
Small Tree	0.18	19%
Large Tree	0.44	46%

Narrative:
Greater than 80 percent of riparian buffer zone (10 meter width along both banks) is in the shrub/seedling to large tree condition. The 10 meter buffer zone is used as a surrogate to evaluate the condition of canopy cover and is interpreted to be in an Adequate Condition although there are localized areas where the riparian vegetation has been cleared for agricultural or residential development.

REFERENCES

Archibald and Johnson, 2002, 2002 stream temperature monitoring report, Entiat and Chelan Range Districts. USFS Wenatchee national Forest, Entiat Ranger District, Entiat, Washington.

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Chapman, D., and eight co-authors, 1994, Status of summer/fall Chinook salmon in the mid-Columbia Region: Don Chapman Consultants, Inc., Boise, Idaho.

Hillman and Giorgi, 2002, Monitoring protocols: Effectiveness monitoring of physical/environmental indicators in tributary habitats, prepared for Bonneville Power Administration: BioAnalysts, Inc., Boise, Idaho, 104 p.

Reclamation, 2009, Entiat tributary assessment, Chelan County, Washington: U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado, 92 p.

USFWS (U.S. Fish and Wildlife Service), 1998, Matrix of physical/environmental pathways and indicators for east-side streams: in Hillman and Giogi, 2002, Appendix C.

APPENDIX B

Preston Site Assessments

INITIAL SITE ASSESSMENT

Channel Units were mapped and rectified with LiDAR by geologists in the field on the most recent available ortho-photographs and the data was redrawn in ArcGIS. Channel units were interpreted based on the fluvial processes that created them, regardless of the low flow conditions in which they were observed in the field (modified from USDA, 2008). These geomorphic channel units differ from “habitat units” in that habitat units are interpreted in the field by biologists at low-flow conditions to document what habitat is available during these low-flow conditions. Habitat units typically describe physical attributes of channel units at one point in time based on biotic life stage needs. Geomorphic channel units describe those physical attributes related to the stream processes that create and maintain them over time. While the basic parameters are similar, the evaluation of the individual unit attributes is not the same nor is the applicability of the information to alternative development, evaluation and implementation. The habitat unit describe the “what” and the geomorphic channel unit mapping represents the “why” and “how”.

Inner and outer zones were mapped by geologists in the field on the most recent available ortho-photographs and the data was redrawn in ArcGIS. The inner zones are areas where ground-disturbing flows take place; characterized by the presence of primary and secondary channels, a repetitious sequence of channel units, and relatively uniform physical attributes indicative of localized transport, transition, and deposition (modified from USDA, 2008). The outer zones are areas that are bounded by the first significant terrace and may become inundated at higher flows (10-50 year event), but do not experience ground-disturbing flows; generally coincidental with the historic channel migration zone unless the channel has been modified or incised leading to the abandonment of the floodplain (modified from USDS, 2008).

The inner and outer zones were further divided into subreach units. These are distinct areas comprised of the floodplain, off-channel, and active-channel areas. They are delineated by lateral and vertical controls and processes with respect to position and elevation. Inner zone subreach units are identified by localized trends in sediment transport, transition, or deposition that occur naturally or created by anthropogenic influences.

Anthropogenic features were mapped by geologists in the field on the most recent available ortho-photographs and LiDAR, and the data was redrawn in ArcGIS (see Figures 1 through 3). Feature classes include points (i.e. culvert locations), lines (i.e. levees and roads), and polygons (i.e. fill). The attribute table contains several fields including type of feature, length or area, etc. Table 1 summarizes the anthropogenic features.

Point locations of photographs (see Figures 4 and 5) taken during the field inventory are noted on the most recent available ortho-photographs and the locations were redrawn in ArcGIS. Each photograph was captioned and includes the direction of the photograph and the subject matter.

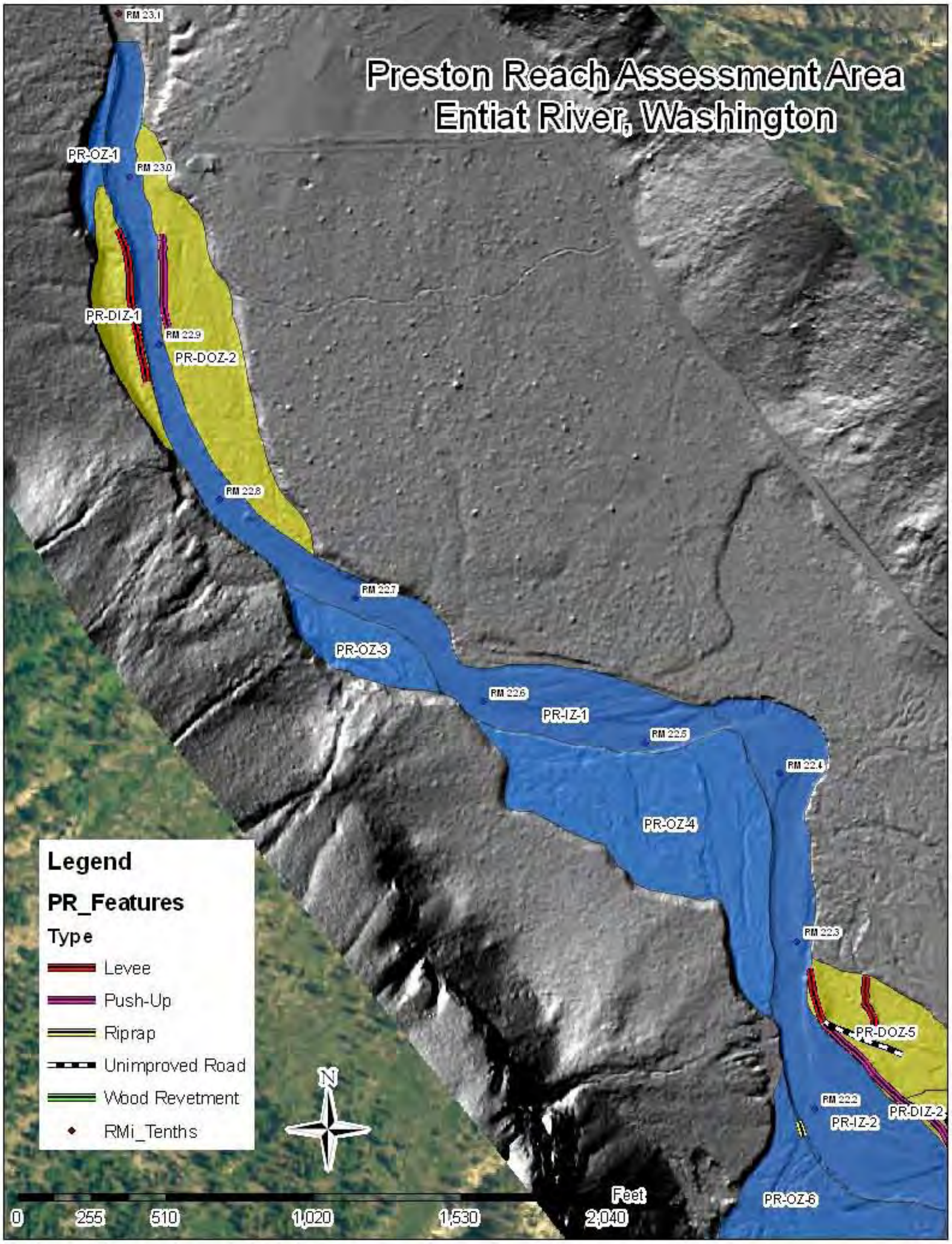


Figure 1. Subreach unit map with human features. The subreaches are color-coded based on the dominant proposed habitat action (i.e. blue is protect, green is reconnect processes and protect or reconnect isolated habitat, yellow is reconnect processes, and orange is reconnect isolated habitat units).

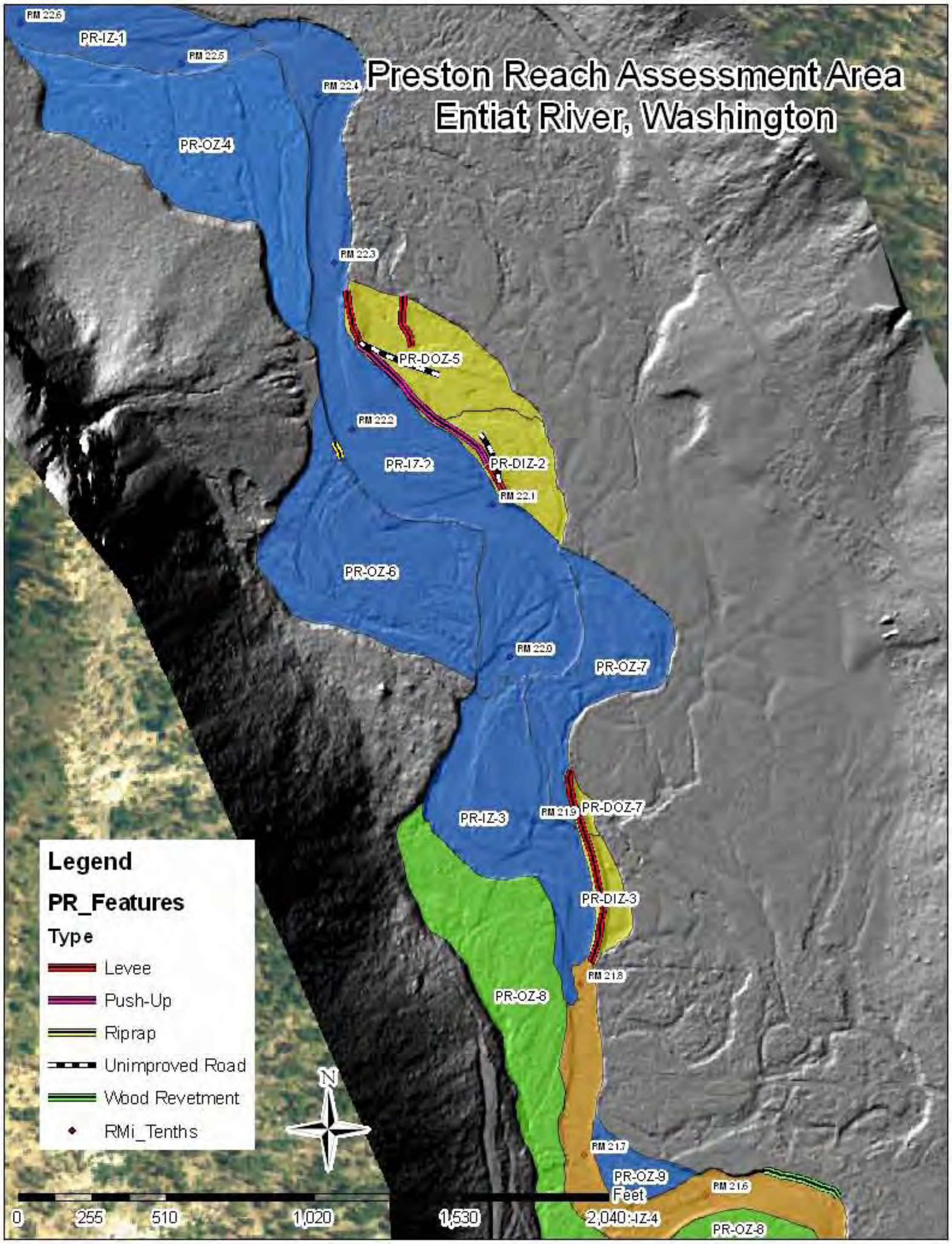


Figure 2. Subreach unit map with human features. The subreaches are color-coded based on the dominant proposed habitat action (i.e. blue is protect, green is reconnect processes and prprotect or reconnect isolated habitat, yellow is reconnect processes, and orange is reconnect isolated habitat units).

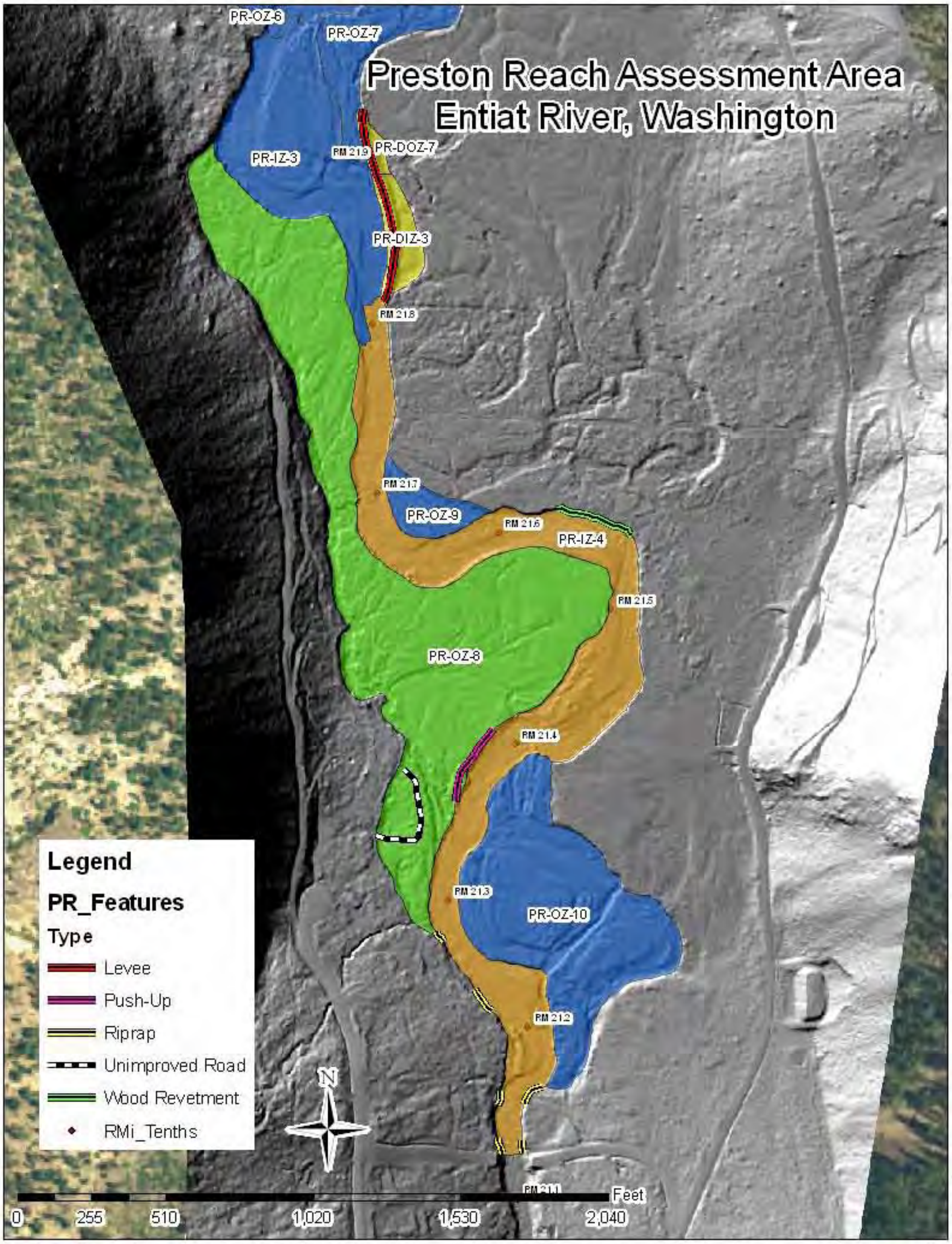


Figure 3. Subreach unit map with human features. The subreaches are color-coded based on the dominant proposed habitat action (i.e. blue is protect, green is reconnect processes and protect or reconnect isolated habitat, yellow is reconnect processes, and orange is reconnect isolated habitat units).

Table 1: Summary of anthropogenic features by subreach.

Subreach	**Count**	**Type**	**Length (feet)**
PR-IZ-1	0	NA	NA
PR-DIZ-1	1	Levee	540
PR-OZ-1	0	NA	NA
PR-DOZ-2	1	Push-up Levee	330
PR-OZ-3	0	NA	NA
PR-OZ-4	0	NA	NA
PR-IZ-2	0	NA	NA
PR-DIZ-2	2	Levee/Road	570
PR-DOZ-5	3	Levee/Road	1040
PR-OZ-6	0	NA	NA
PR-OZ-7	0	NA	NA
PR-IZ-3	0	NA	NA
PR-DIZ-3	1	Levee	455
PR-OZ-7	0	NA	NA
PR-DOZ-7	1	Levee	230
PR-OZ-8	2	Levee/Road	690
PR-IZ-4	7	Riprap/Revetment	645
PR-OZ-9	0	NA	NA
PR-OZ-10	0	NA	NA

PHOTOGRAPHIC DOCUMENTATION

Figure 4. Photograph numbers and their corresponding locations.

Figure 5. Photograph numbers and their corresponding locations.

Photograph No. 1. View is to the northeast looking at the backside of a levee located along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 2. View is to the north looking at a “disturbed” area near the head of the levee located along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 3. View is to the northwest looking upstream at side channel or wetland outflow along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 4. View is to the northwest looking at the cobble and boulder substrate in what is interpreted to be a localized transport subreach. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 5. View is to the north looking at large wood in the channel. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 6. View is to the north looking at an overflow channel along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 7. View is to the northwest looking upstream at a glide and riffle. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 8. View is to the north looking at fine-grain material over gravels along river left. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 9. View is to the southeast looking downstream at gravel bar along river right, and fine-grained material over gravel in the left riverbank. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 10. View is to the east looking at a scour pool associated with large wood along river left. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 11. View is to the east looking at large wood in the channel along river left.
Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 12. View is to the south looking at boulder, cobble and gravel substrate in the channel and along a gravel bar on river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 13. View is to the northwest looking at a large wood complex at the head of a side channel along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 14. View is to the northwest looking upstream at large wood and gravel bar formation in center of channel. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 15. View is to the south looking downstream at large wood in the channel and gravel bar along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 16. View is to the south looking downstream at large wood and gravel bar. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 17. View is to the east looking across at bank erosion occurring along river left where the riparian buffer zone has been removed. Also not the wood deposited on the gravel bar along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 18. View is to the southeast looking at large wood in the channel along river left and gravel bar along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 19. View is to the northeast looking at a side channel along river left. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 20. View is to the south looking downstream at erosion along the upper extent of a levee along river left. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 21. View is to the southwest looking across the channel at riprap placed along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 22. View is to the south looking along the crest of a levee located on river left. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 23. View is to the south looking along an access road to the levee on river left.
Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 24. View is to the south looking along the crest of an inset levee along river left.
Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 25. View is to the north looking at a wetland impounded by a beaver dam in the floodplain along river left. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 26. View is to the north looking upstream at a gravel bar along river left and across at vegetation along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 27. View is to the west looking at a lateral scour pool along river right and gravel bar along river left. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 28. View is to the southeast looking downstream along a gravel bar on river left and across at vegetation along river right where there is active wood recruitment. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 29. View to the south looking downstream along a gravel bar along river right and the downstream end of a levee on river left. Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 30. View looking to the southeast at a large wood complex at the head of a side-channel along river left. Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 31. View is to the east looking downstream at a large wood complex along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 32. View is to the east looking downstream at small-to-medium size wood being utilized for bank protection (“Christmas Tree Revetment”) along river left. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 33. View is to the southwest looking downstream at active bank erosion along river left. Note the riparian buffer zone has been removed and the fine material overlying gravels. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 34. View is to the southeast looking downstream at active erosion along river left where the riparian buffer zone has been removed. Also note the root complex in the center of the channel and gravel bar along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 35. View is to the southeast looking at a large wood complex at the head of a side channel along river left. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 36. View is to the northwest looking upstream at the outflow of a side channel along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 37. View is to the southwest looking downstream where a tributary enters the Entiat River along river right. Note the gravel embankments ("training dikes") placed along both streambanks of the tributary. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 38. View is to the south looking at riprap placed along river left and a bridge across the channel. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

Photograph No. 39. View is to the east looking at a road within the floodplain. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 25, 2008.

Photograph No. 40. View is to the southeast looking at a push-up levee ("sugar dike") located along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 25, 2008.

Photograph No. 41. View is to the southeast looking down an active side channel along river right. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 25, 2008.

Photograph No. 42. View is to the south looking at riprap placed along a levee on river left.
Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008

Photograph No. 43. View is to the south looking along the crest of a levee along river left showing a small wetland area behind the levee. Preston Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAffee August 21, 2008.

APPENDIX C

Preston Habitat Assessment

DRAFT Updated 04-01-09

ENTIAT RIVER HABITAT ASSESSMENT
RIVER MILE 18.0 TO RIVER MILE 23.3

(From the gage station below the confluence with Stormy Creek to the top of the confined channel above the confluence with Preston Creek)

Survey Dates: October 24, 27, and 28, 2008

TABLE OF CONTENTS

ENTIAT RIVER HABITAT ASSESSMENT
River Mile 18.0 to River Mile 23.3
October 2008

Methodology and Objectives: A modified Hankin-Reeves Level II habitat survey (USDA Forest Service *Stream Inventory Handbook, 2007, Version 2.7*, Pacific Northwest Region) was conducted on a 5.3 mile segment of the Entiat River located from the gage station below the confluence with Stormy Creek to the top of the constricted channel above the confluence with Preston Creek. The survey was conducted to help determine fish habitat quantity and quality in the surveyed area. The surveyed stream area was broken into four subreaches based on channel confinement, described below:

-Subreach 1: Reach 1 is a 2.7 mile river segment that begins at the gage station about 0.4 miles below the confluence with Stormy Creek and ends where the channel becomes constricted at RM 20.7. The channel in the reach is low gradient (< 1%) and unconfined. A 900' levee constructed on the left bank between RM 19.6 and RM 19.8 prevents the river from laterally migrating to the east. The levee was constructed in 1973 by the Soil Conservation Service. A short segment of rip rap (about 150') was observed on the left bank at RM 18.7.

-Subreach 2: The 0.4 mile river segment between RM 20.7 and 21.1 is a naturally confined, transport reach.

-Subreach 3: The 1.5 mile long reach located between RM 21.1 and 22.6 is a low gradient (< 1%), unconfined segment of the river similar to reach 1. A dike (circa 1973) protecting a horse ranch (the Tyee Ranch) along most of the left bank between RM 21.8 and 22.4 may be preventing the stream from laterally migrating to the east (most of the dike is set back from the stream bank).

-Subreach 4: This 0.7 mile segment of the stream begins where the channel becomes naturally constricted at RM 22.6 and ends where the floodplain opens up at RM 23.3. Much of the lower half of the reach is a Rosgen B3c channel type with a floodplain up to 235' wide. In 1972, deposition from debris torrents from Preston and Mott Creeks dammed the Entiat River near the top of this reach. The large substrate delivered to the river from the debris torrents was likely piled along the banks by bulldozers to allow the river to flow freely (P. Archibald). The deposition from the debris torrents has formed a very narrow, high energy channel in the upper half of the reach. The floodplain opens up and the river becomes lower gradient above the alluvial fans of Preston and Mott Creeks.

Habitat data was collected and compared in the five surveyed stream segment areas.

Data Attributes: The following data attributes were collected during the habitat survey conducted on October 24, 27 and 28, 2008.

●Stream Habitat Type: Habitat in the main channel and all the wetted side channels were broken into 4 main habitat unit types; riffles, pools, runs, and side channels. The % habitat type was compared in the five surveyed stream segments. Run habitat measured in the survey is non-turbulent riffle habitat. Runs are very low gradient, generally slow-moving habitat with little surface turbulence, but without the scour element associated with pools. The long tail-outs in the glide pools in the Entiat River were included as pool habitat.

●Habitat Area: The length and wetted width of all habitat units were measured. The % area (square footage) of all 4 habitat unit types was calculated.

●Pools: Pools depths were measured with a depth rod. Depths greater than 5' to 6' were estimated. Pool-tail crests were measured with a depth rod during the habitat survey. Total pools were counted and pools per mile were calculated. The average maximum depth and average residual depth (max depth minus pool crest) were calculated.

●Riffles and Runs: Habitat dimensions, average thalweg depth, and maximum thalweg depth in riffles and runs were measured.

●Large woody debris: Pieces of large wood that intersected the bankfull channel width were counted in three size categories; small (> 20' long with a diameter of at least 6"), medium (> 35' long with a diameter between 12" and 20"), and large (> 35' long with a diameter greater than 20"). Large wood was counted in the main channel, in the wetted side channels, and in dry side channels. Standing trees within the bankfull width were counted but calculated separately from the in-channel wood.

●Bank Erosion: The linear distance of eroding banks above the bankfull width was measured.

●Substrate: A total of four Wolman pebble counts were conducted during the survey. A lack of time limited the number of Wolman pebble counts that we count perform. Substrate was ocularly estimated in every habitat unit in 5 size categories (sand, gravel, cobble, boulder, bedrock) based on size categories from Wolman pebble counts.

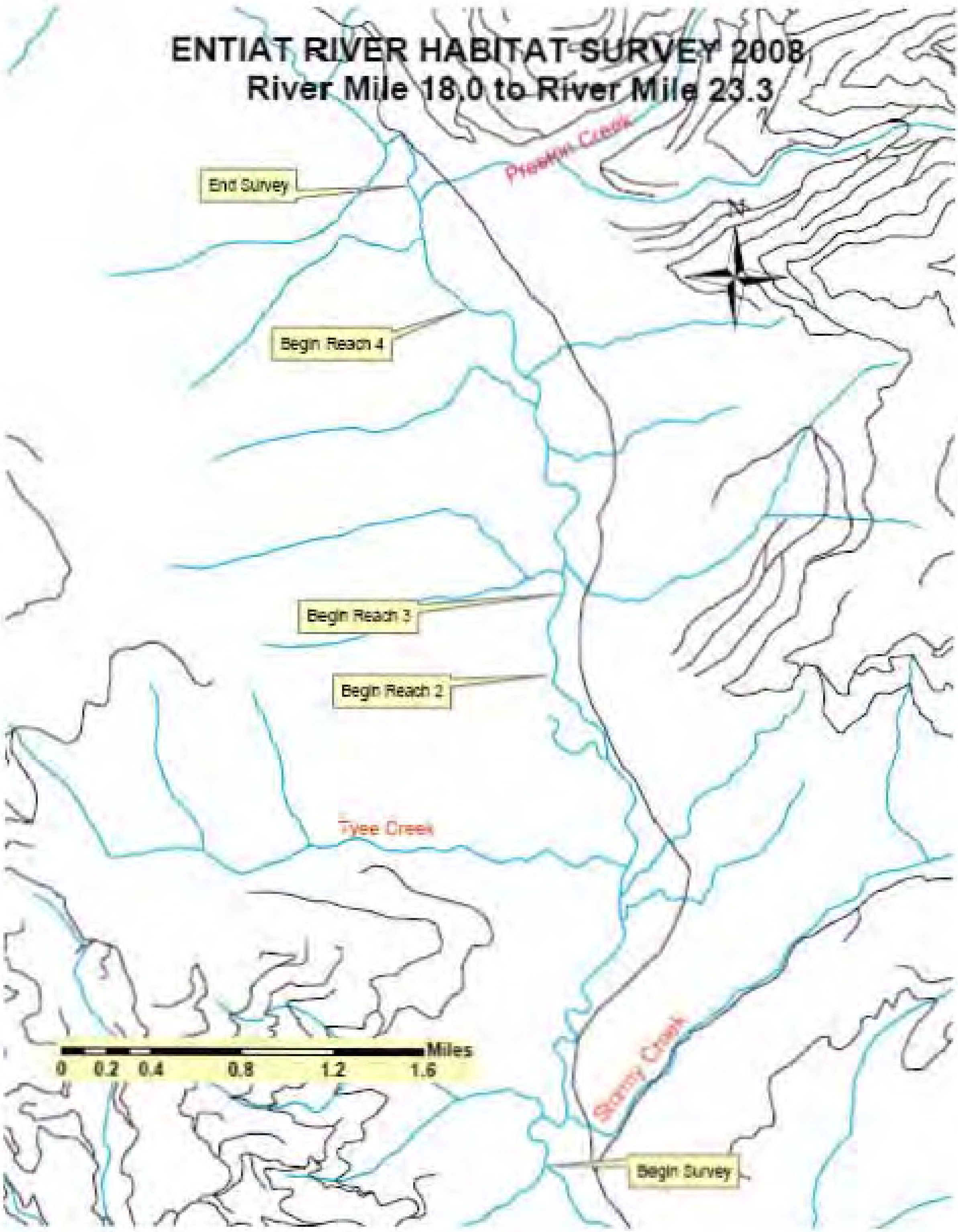
●At least two bankfull width/depth measurements were taken in each surveyed stream segment except reach 2 (one bankfull measurement was taken in reach 2). A total of 7 bankfull depths were measured and averaged across each bankfull width transect to compute width/depth ratio. The floodprone area was defined based on survey protocol (floodprone area is the elevation calculated at two times the maximum bankfull depth in each bankfull channel cross-sectioin).

Deviations from Hankin-Reeves Protocol: Certain attributes were measured differently than described in the Forest Service *Stream Inventory Handbook, 2007*. These differences and reasons for changing the protocol are described below:

1. Habitat Dimensions of a channel unit (pool, riffle, run): The protocol states that in order to consider a channel unit type as a separate unit, the channel unit length must be equal to or greater than the wetted width. The wetted width in the Entiat River was up to 100' wide. Larger streams such as the Entiat River have a significant number of riffle habitat units that are wider than long. In order to get a more accurate picture of habitat, all habitat units were recorded as separate units, even if wider than long.
2. Bankfull depth measurements: The protocol states that three bankfull depth measurements be taken across the measured bankfull width to calculate a width/depth ratio. We felt that three measurements would be insufficient, due partly to the wide lateral bars in the margins of the riffles. Seven equally-spaced bankfull measurements were taken on each bankfull width measurement. Seven measurements are likely also insufficient, but are probably more accurate than three measurements.
3. Fish Distribution: Fish distribution surveys were not conducted during the habitat survey.
4. Only four Wolman pebble counts were conducted during the survey due to a lack of time.
5. Water temperature monitors were not installed in the reach during the summer. The District Fish Biologist on the Entiat River District, Phil Archibald, has been monitoring water temperatures in the Entiat River annually since 1999. Further detail and discussion of water temperatures and temperature trends in the Entiat River can be found on the Cascadia Conservation District web site: www.cascadiacd.org/ select programs; watershed planning; WRIA 46 Entiat; Entiat Watershed Plan & Appendices; Chapter 8 Water Quality; page 8-10 "Thermal Regime in the Entiat River".

River Mileage: River mileage is determined from maps provided by Rob Mcaffee of the Bureau of Reclamation. The actual measured survey mileage in reaches 1 and 3 were significantly longer than on the maps due to the high amount of sinuosity in these reaches (3.3 measured miles in reach 1 compared with 2.7 map miles, and 1.77 measured miles in reach 3 compared with 1.5 map miles). The measured miles were the same as the map miles in reaches 2 and 4. All statistical data was generated using the measured length in each reach.

Stream Flow: The stream survey was conducted at low flow. The mean daily stream flow in the Entiat River at the gage at the beginning of reach 1 measured 84 cfs on October 24, 79 cfs on October 27, and 78 cfs on October 28 (the dates of the survey) (provisional data from USGS gage station #12452800, Entiat River near Ardenvoir).



ENTIAT RIVER HABITAT ASSESSMENT OVERVIEW
River Mile 18.0 to River Mile 23.3

High quality fish habitat currently exists in the surveyed segment of the Entiat River despite some of the habitat being simplified by human activities (e.g. bank hardening, vegetation removal and the removal of wood). Most of the surveyed segment of the river is unconfined and sinuous, but in some areas rip rap and levees that were constructed to protect property are preventing the stream's lateral migration. A 900' long levee installed between river mile (RM) 19.6 and RM 19.8 has straightened the channel for nearly a mile below the levee, simplifying the habitat. A levee on most of the left bank between RM 21.8 and RM 22.4 has the potential to prevent the river from laterally migrating to the east. The channel is fairly sinuous in this area despite the levee, as most of the levee was set back from the river bank, leaving some floodplain for the river. In 1972, deposition from debris torrents in Mott and Preston Creek dammed the Entiat River. The coarse substrate delivered by the debris torrents was likely pushed along the channel margins by bulldozers. This event narrowed the river channel in the upper third of a mile of the surveyed river segment of the Entiat River.

Large Wood: In addition to providing rearing habitat for juveniles and holding habitat for adult salmonids, large wood sorts sediment and creates spawning gravels, channel complexity and dissipates stream energy. A total of 20 pieces of large wood per mile at least 35' long with a diameter of at least 12" was counted in the main channel in the surveyed segment of the Entiat River during the survey. The amount of large wood in the channel meets the standards for wood in NOAA Fisheries and the USFWS *Matrix of Pathways and* Indicators (MPI). However, most of the surveyed segment of the Entiat River is a low gradient (< 1%), unconfined depositional river segment. Amounts of large wood are much higher on similar stream types in the Methow Valley Basin in stream segments that have relatively little disturbance history. Amounts of large wood in the surveyed segment of the Entiat River are likely well below historical levels due largely to the removal of wood for development and flood control (Entiat Water Resource Inventory Area (WRIA) 46 Management Plan [Chelan County Conservation District 2004]). Much of the large wood in the channel is found in jams at the bends in the river. A large amount of the wood is in the low flow wetted channel, providing good cover for fish and deepening scour in the pools. The future recruitment potential ranges from fair to good in the surveyed river segment. Good recruitment potential exists in a relatively undisturbed, very sinuous segment of the river between RM 18.4 and 19.0, and between RM 22.1 and RM 23. The removal of trees for ranching and development, and past fires have reduced future recruitment potential of large wood in much of the rest of the surveyed river segment. The wood count in the surveyed segment of the Entiat River is summarized in the table below by reach:

Table 1: Summary of Large Wood[1] per Mile by Reach: Entiat River RM 18.0 to 23.3

Reach	River Mile	LWD In-Channel	LWD: Side Channels[2]	Total LWD in channel	Add: Trees standing in bankfull	Total LWD
1	18.0 to 20.7	24.8	0.9	25.7	0	25.7
2	20.7 to 21.1	7.2	0	7.2	2.4	9.6
3	21.1 to 22.6	17.0	5.3	22.3	0	22.3
4	22.6 to 23.3	11.4	0	11.4	12.8	24.2
Subtotal		**19.8**	**1.9**	**21.7**	**1.6**	**23.3**

[1]Pieces of wood at least 35' long with a diameter of at least 12".

[2] Does not include ½ mile long side channel (wetland) on right bank at RM 18.95. This channel was not walked due to lack of time. Does not include wood in dry side channels.

The amount of wood counted in the 2008 survey was higher than the amount counted by a survey crew in 1994, indicating that wood levels in this segment of the Entiat River are increasing (P. Archibald). See the Reach Assessments found later in the report for more details on large wood.

Pool Habitat: Pool depth provides cover from predators, buffers against wide fluctuations in water temperatures, and acts as a refuge during fire, drought and cold water temperatures. Some excellent pool habitat exists in the surveyed segment of the Entiat River. Most of the pools in the surveyed segment are lateral scour pools formed at the bends in the river. Pieces of large wood are deepening many of the lateral scour pools, providing good habitat complexity. Almost 5 pools per mile greater than 5' deep were counted in the surveyed stream segment. The sinuous areas of the surveyed stream segment had the highest frequency of deep pool habitat due to the log jams that formed in these areas. The lower mile of reaches 1 (RM 18 to 19) and 3 (RM 21.2 to RM 22.2) were more sinuous and had the highest frequency of deep pools. A total of 9.2 streams per mile were counted in the survey, well below the frequency for an appropriately functioning stream in NOAA Fisheries MPI. However, habitat units are very large in a stream as big as the Entiat River, and pools per mile may not be a good method to determine the quantity of pool habitat. Nearly 60% of the habitat area in the low gradient, unconfined reaches (reaches 1 and 3) consisted of pools. Reaches 2 and 4 are confined, high energy transport reaches without the stream bends and large wood that create pools. Only one pool was observed in the 1.1 miles of total habitat in reaches 2 and 4. The table below summarizes pool habitat data in the surveyed segment of the Entiat River, by reach.

Table 2: Summary of Pool Habitat: Entiat River RM 18.0 to 23.3

	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**All Reaches**
River Mile: from/to	18.0 – 20.7	20.7 – 21.1	21.1 – 22.6	22.6 – 23.3	18.0 – 23.3
# Measured Miles:	3.3	0.4	1.8	0.7	6.2
% Habitat Area Pools	58.8%	12.9%	57.5%	0%	48.5%
Total # of Pools	35	1	21	0	57
Pools per Mile	10.6	2.4	11.9	0	9.2
Pools/Mile > 5' deep	5.4	0	6.2	0	4.7
Average Max Depth	4.99'	4.70'	4.65'	-	4.85'
Avg. Residual Depth[1]	3.90'	3.00'	3.59'	-	3.77'
Primary Pool Form:					
# Bedrock Pools	0	0	0	0	0
# Lateral Scour Pools[2]	29	0	19	0	48
# Formed by LWD	4	0	1	0	5
# Formed by Boulders	1	1	0	0	2
# Other Pool Form[3]	1	0	1	0	2

[1]Pool maximum depth minus maximum depth at pool crest.
[2]Large wood increased the depth in many of these pools.
[3]Forming agents such as rip rap, bridge abutments, or at confluences.

Some areas of the Entiat River, such as the first mile of reach 1 and all of reach 3, are functioning appropriately for pool frequency and pool quality. Pool habitat is more simple and shallow in the mile long, relatively straight channel directly below the levee installed at RM

19.8. The installation of levees may be putting some areas of the Entiat River at risk for pool quality. Reach 4, which has no channel spanning pools, is likely not functioning appropriately for pool habitat. See the Reach Assessments found later in the report for more details on pools.

Side-channel and Rearing Habitat: In 2008 at low flow, about 4% of the habitat area in the surveyed segment of the Entiat River consisted of side channel habitat. Channel simplification from past wood cleanouts and from construction of the levees likely has reduced the amount of off-channel habitat available to rearing fish. The percent of off-channel habitat is higher (10% to 15%) on similar stream types in the Methow Valley Basin in stream segments that have relatively little disturbance history. The table below summarizes side channel and off-channel habitat observed at low flow during the habitat survey.

Table 3: Summary of Side channel and Off-channel Habitat in the Entiat River (RM 18 to 23.3)

River Mile	Bank	Length	Width	Avg/Max Depths	Notes
18.3	Right	350'	15'	2' 3'	Channel leads to pond (130' x 25'). This channel is the Shamel Creek confluence. Substrate in the pond is 100% silt. The side channel is not connected to the river at the top.
18.8	Left	625'	24'	2' 4.5'	Mostly fast water, some wood. A ½ mile long channel is disconnected to this larger side channel at low flow. Beaver ponds store water and create wetlands in the disconnected channel, which was not flowing at the time of the survey. This ½ mile long channel was generally narrow, about 5' wide.
18.9	Right	150'	22'	1.2' 2.5'	The short side channel is a straight line channel that cuts through a meander bend.
19.2	Right	150'	40'	2' 4'	Off-channel pond that is disconnected to the river at low flow. The pond is about 7' from the river.
20.2	Right	400'	2.5'	0.2' 1.7'	The channel is nearly dry at low flow. Habitat at low flow consists of a few small pools connected by a very narrow wetted channel (2' wide). The channel becomes totally dry after 400'.
21.3	Right	1,350'	25	3' 5'	Four beaver dams create deep pool habitat in the side channel, creating excellent rearing habitat for juvenile fish.
22.1	Left	50'	2'	0.2' 0.2'	The side channel becomes a dry channel after 50'.

Some good rearing habitat for juvenile fish was observed in many of the pools in the main channel in reaches 1 and 3, with large wood, tree branches and tree stumps providing hiding cover. Backwater pool habitat and braids were observed at many of the meander bends in these reaches. The riffles and runs in the two low gradient reaches had poor rearing habitat due to the lack of hiding cover. Wood and large substrate was lacking in these habitat types in the low gradient reaches. Boulders and rip rap provide hiding cover for juvenile fish in slower water in the pocket pools and along the channel margins in reaches 2 and 4. Although high quality off-channel habitat was observed in some areas within the surveyed segment of the river, we feel that this segment of the Entiat River is functioning at risk for off-channel rearing habitat due to habitat simplification caused by levees and wood cleanouts.

Substrate and Fine Sediment: Coarse gravel and small cobble are the dominant substrate types in reaches in 1 and 3, which provides preferred spawning substrate for anadromous fish. Boulders and larger cobbles were dominant in the higher gradient, confined reaches (reaches 2 and 4). Substrate embeddedness did not appear to be excessive in our ocular estimates in any of the reaches.

The MPI has a properly functioning standard for fine sediments in spawning gravel (<12% fines < 0.85 mm), which is measured by using McNeil Core sampling.

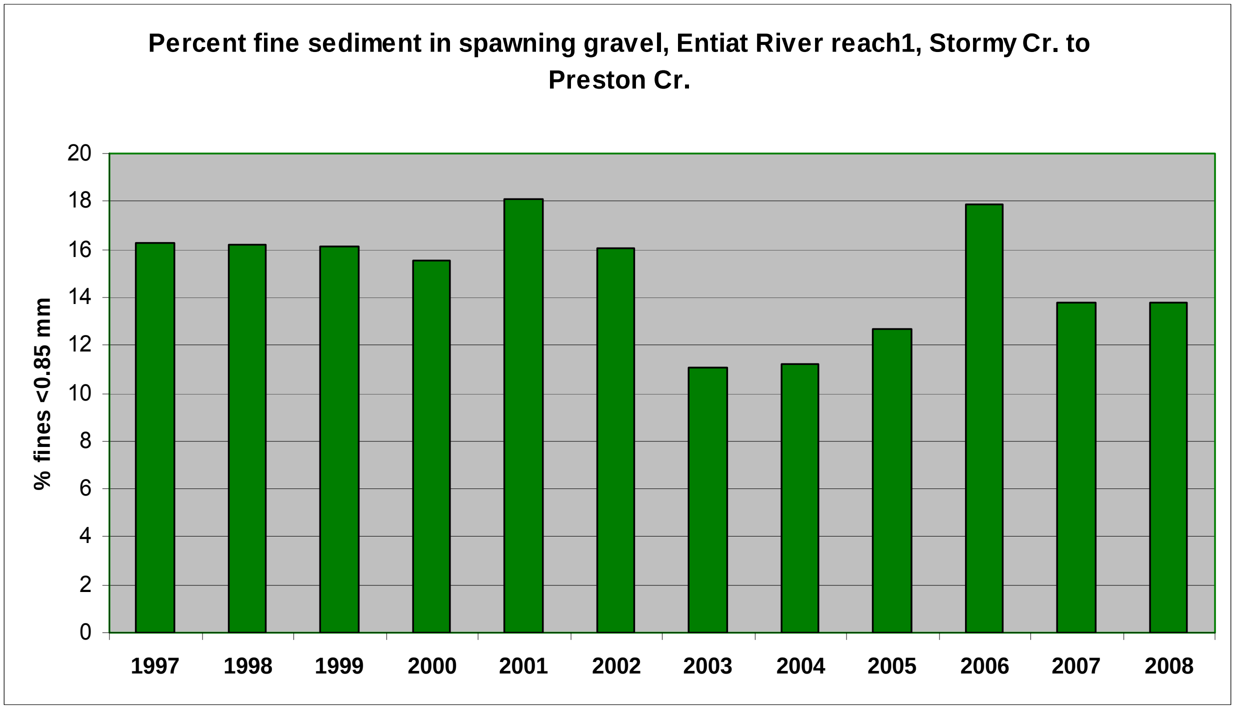


Figure x

Twelve consecutive years of McNeil Core sampling data from this reach of the Entiat River (Figure x) shows a variable trend (range 11.06% to 18.10%) with a long-term mean of 14.88% fines <0.85 mm in the spawning gravels in Reaches 1 and 3 (data provided by P. Archibald).

Surface fine sediments were measured during the survey by conducting 4 Wolman pebble counts, spaced throughout the survey. The MPI standard for an appropriately functioning stream is < 12% surface fines < 6 mm. Surface fine sediments < 6 mm in the low gradient reaches (reaches 1 and 3) averaged 14% in the three Wolman pebble counts conducted in those reaches, with a range of 13% to 15% surface fine sediments < 6 mm. Surface fines < 6 mm were about 9% of the total substrate in the pebble count that was conducted near the beginning of reach 4, where the channel is becoming constricted and higher gradient. Although the average of the 4 pebble counts show that surface fine sediments are higher than 12%, we feel that the reach is functioning appropriately for surface fine sediments (and for % fines in spawning gravel). The reach is a very low gradient, depositional reach, where fine sediments are expected to accumulate. The gravel and cobble substrate in the riffles and at the pool crests was generally very clean, with pockets of finer sediments found mainly on the bars. No cobble/coarse gravel embeddedness was observed at any of the pool crests.

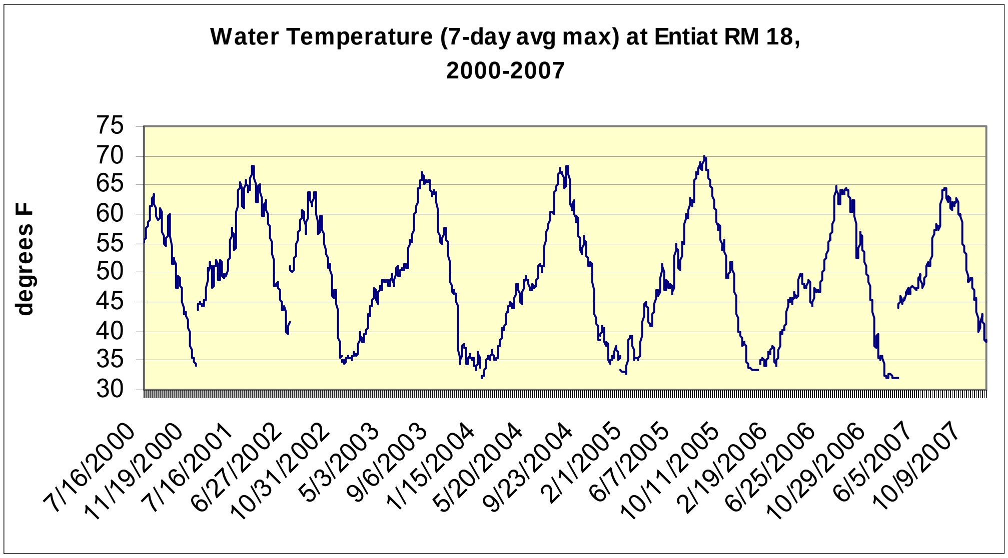
Spawning Habitat: Excellent spawning habitat for anadromous fish exist in reaches 1 and 3. Substrate in the riffles and at the pool crests consists largely of coarse gravel and small cobble substrate, ideal for spawning. Numerous deep pools in these two reaches, many with large wood for cover, provide holding habitat for anadromous fish prior to spawning. Numerous spring and summer Chinook salmon redds were observed in these two reaches during the survey. Substrate in reaches 2 and 4 are generally too coarse for spawning, as most of the substrate in these reaches consists of boulders and large size cobbles due to the high-energy, confined channel, which transports finer sediments downstream.

Bank Erosion: About 14% of the stream-banks are actively eroding, above the 10% threshold in the MPI (streams with > 90% stable banks are considered appropriately functioning in the MPI). Although the surveyed segment of the Entiat River exceeds guidelines in the MPI, most of the bank erosion is from natural causes, at the meander bends and from river's lateral migration across its floodplain. In some areas, bank erosion is being exacerbated by the removal of vegetation along the banks for development or for ranchland/past agricultural use. Although very fine sediments are the dominant bank substrate, some spawning gravels are being recruited from the eroding stream banks. Similar sized streams and stream types on the Methow Valley Ranger District have similar percentages of bank erosion. The riparian area in a 5 mile segment of the Methow River above the confluence with Wolf Creek (the Big Valley Reach) is largely intact, with very little bank hardening or vegetation removal. This stream reach, which is comparable to the Entiat River reach, had a similar percent of bank erosion.

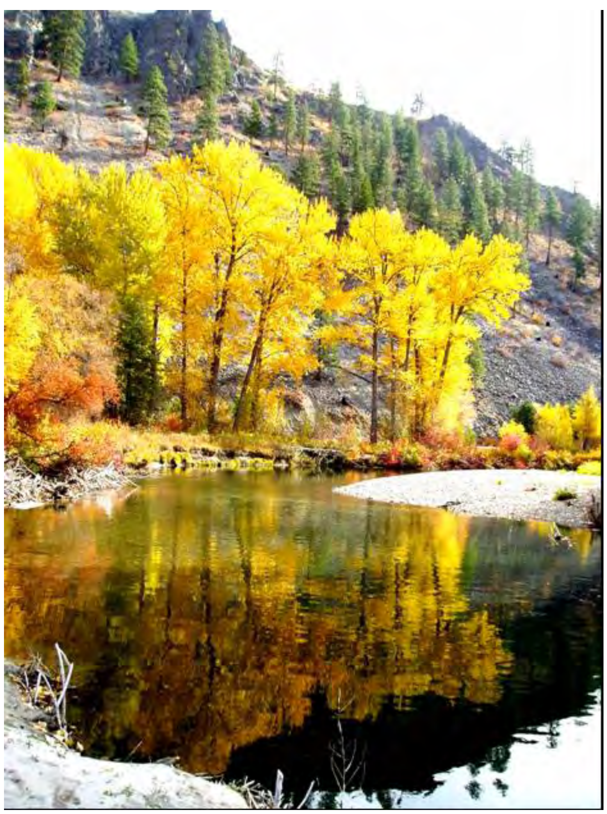
A serious consequence of bank erosion is the concern of landowners losing their property to the river, which can lead to the installation of rip rap to protect the banks. A 500' segment of the left bank of the river between RM 21.4 and RM 21.5 is eroding at a very fast rate (an average rate of 2.25 feet/year, range 0 to 8.8 feet/year, 3/22/07 to 4/28/08 [CCD 2008]) due to the lack of root structure on the banks. The 4 landowners at this site are planting trees beyond the bank, but it appears as if bank structures may be needed to stop the erosion. The banks of the river directly upstream of the eroding bank are being protected by wood structures that were installed to protect the banks. The wood structures consist of a "Christmas tree revetment", overlain by larger stems and interplanted with willows (see photo below). Velocity measurements made on 3/10/06 by Phil Archibald conclude that the wood structures are reducing velocities on the eroding bank downstream at low flow. Installing wood structures on the banks (which is preferable to rip rap), along with tree planting, may be necessary to protect the eroding bank below the bank with the installed wood structures.

Fish Barriers: No fish barriers were observed in the surveyed segment of the Entiat River. The material deposited by the debris torrents in 1972 at the top of the surveyed segment of the Entiat River is an upstream fish migration barrier in Preston Creek at lower flows. A waterfall about 300' from the mouth of Preston Creek prevents upstream fish migration in Preston Creek at all flows.

Water Temperatures: No temperature monitors were installed in the reach in conjunction with the survey. Entiat Ranger District watershed specialists maintain a year-round, continuous-recording temperature logger near the USGS gage at RM 18. The graph below presents a summary of those data for the 8-year period of 2000-2007. Winter lows are often at or below freezing and summer highs always exceed 60°F and occasionally exceed 65°F.



Further detail and discussion of water temperatures and temperature trends in the Entiat River can be found on the Cascadia Conservation District web site: www.cascadiacd.org/ select programs; watershed planning; WRIA 46 Entiat; Entiat Watershed Plan & Appendices; Chapter 8 Water Quality; page 8-10 "Thermal Regime in the Entiat River".



1. HABITAT ASSESSMENT: ENTIAT RIVER SUBREACH 1
From the gage station about 0.4 miles below the confluence with Stormy Creek to where the channel becomes confined at RM 20.7
(Map Mileage: RM 18.0 to RM 20.7)

Summary of Habitat Data:

●**Reach Description:** This 2.7 mile reach an unconfined, low gradient (< 1%) channel segment comprised mainly of lateral scour pools and short riffles. The first mile of the reach features several tortuous meander bends, and has a high sinuosity value of about 1.5. Large point bars form at the numerous river bends. Excellent fish spawning and rearing habitat exists in this segment of the reach. The river is relatively straight, and the habitat is relatively simple between RM 19 and RM 19.8 due to a levee that was installed along the river left bank between RM 19.6 and 19.8. The 900' levee is the only significant amount of bank hardening in the reach. About 150' of rip rap was installed on the left bank at RM 18.35. The channel is more sinuous and fish habitat improves between RM 19.8 and the end of the reach.

●**Habitat Area:** The habitat area in the reach is about 128,000 square yards (38,700 square yards per mile), consisting of about 59% pool habitat, 22% riffle habitat, 15% run habitat and 4% side channel habitat. Backwater pool habitat exists at some of the bends in the river.

●**Large Wood:** Amounts of large wood in the reach are higher than in upstream reaches, with about 25 pieces per mile greater than 35' long with a diameter of at least 12". The reach exceeds the 20 piece per mile guideline for a properly functioning stream in the Matrix of Pathways and Indicators. Most of the wood is in jams that form in the meander bends in the channel. A high amount of wood was observed is in the low flow river channel, increasing pool depths and providing habitat complexity. The amount of wood was very low in the simplified, straight segment of the reach located between RM 19 and RM 19.8, as surveyors counted only three pieces of large wood greater than 35' long with a diameter of at least 12" in the bankfull channel. The reach is well below historical amounts of large wood due to wood removal for flood control and development (Entiat Water Resource Inventory Area (WRIA) 46 Management Plan [Chelan County Conservation District 2004]. Much of the lower half of the reach had fair to good future wood recruitment potential, mainly from cottonwood trees growing in the riparian areas. The future wood recruitment potential was not as good in the upper half of the reach.

●**Pool Habitat:** Pools comprise almost 60% of the habitat area in the reach. A total of 10.6 pools per mile were counted in the reach. Although the number of pools is below the standard in NOAA Fisheries Matrix, habitat units are very large in a stream as big as the Entiat River. Pools per mile is probably not a good method to determine the quantity of pool habitat. Deep pool habitat is abundant in the reach, with about half the pools in the reach greater than 5' deep. Eight of the 18 deep pools (deep pools are defined as > 5' deep) were found in a highly sinuous half mile long segment of the reach located between RM 18.5 and RM 19. This segment of the reach had a relatively undisturbed riparian area. Most of the pools in the reach were lateral scour pools formed by the bends in the river. Large wood in the channel provided cover and deepened the pools. Excellent spawning habitat was observed at most of the pool crests. Fewer pools were observed in the straight segment of the channel between RM 19 and RM 19.8 (5 per mile). No pools greater than 5' deep were observed in the 0.8 mile long straight segment of the reach

●**Riffle/Run Habitat:** About 22% of the total habitat area consists of riffle habitat in the reach. Runs comprise about 15% of the total habitat area. The average thalweg depth of the riffles was 1.2', adequate for fish migration. The average thalweg depth of the runs was 1.8'. Hiding cover for juveniles in the riffles and runs at low flow was generally poor, as most of the wood was found in the pools and on the bars, and the reach lacked larger sized substrate.

●**Side Channel and Fish Rearing Habitat:** At low flow, side channels comprise about 4% of the total habitat area. Some excellent rearing habitat exists in the side channels. The table below summarizes side channel habitat in the reach:

Table: Reach 1 Side Channel Summary

River Mile	Bank	Wetted Length	Avg. Width	Depths Avg / Max	Notes
18.3	Right	350’	15’	2’ 3’	Channel leads to pond (130’ x 25’). Pond is all silt. Not connected to river at top end.
18.8	Left	625’	24’	2’ 4.5’	Mostly fast water, some wood. A ½ mile long channel is disconnected to the larger side channel at low flow. Beaver ponds create store water, create wetlands in the disconnected channel. No flow in the channel, which is very narrow (5’).
18.9	Right	150’	22’	1.2’ 2.5’	Short side channel at meander bend. Good rearing habitat in side channel.
19.2	Right	150’	40’	2’ 4’	Off-channel pond that is disconnected to the river at low flow. The pond is about 7’ from the river.
20.2	Right	400’	2.5’	0.2’ 1.7’	The channel is almost dry at low flow. A few small pools connected by a very narrow channel.

Some good rearing habitat exists in the main channel in the log jams in the lateral scour pools. Backwater pool habitat at the bends in the river provide rearing habitat to juvenile fish. Boulders from talus slopes at river mile 18.2 and at river mile 20.3 provide some hiding cover for juvenile fish, as does the rip rap at RM 18.35 and between RM 19.6 and RM 19.8. Rearing habitat in the riffles and runs is generally poor due to the lack of cover.

●**Fish Spawning Habitat:** Excellent spawning habitat for salmon and steelhead exists throughout the reach. Substrate size is ideal, with coarse gravels and small cobbles the dominant substrate type. Deep pools, some with log jams, provide good holding habitat for anadromous fish. A total of 27 Chinook salmon redds (8.2 per mile) were counted in the reach during the survey. Both spring and summer Chinook salmon redds were observed.

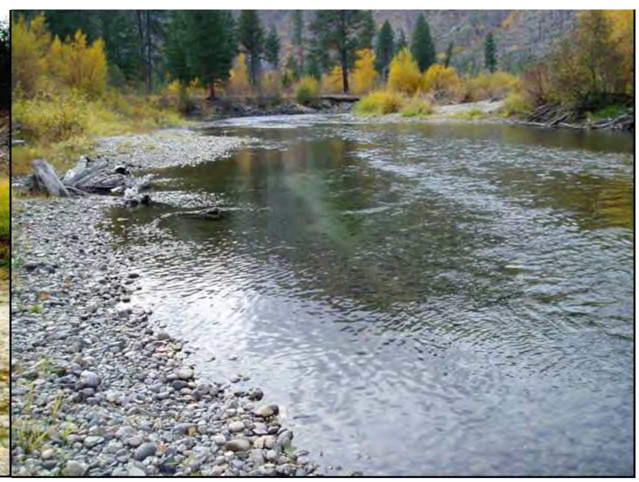
●**Substrate and Fine Sediment:** Two pebble counts were conducted in the reach. About 15% of the substrate at the pebble counts sites consisted of fine sediments < 6 mm, which is considered functioning at risk in the USFWS Matrix of Pathways and Indicators (< 12% surface fine sediments < 6 mm is considered functioning properly). Gravel is the predominant substrate type in the reach. Very fine sediments are abundant in many of the pools upstream of the tail crest (in the pool scour), often filling a large percent of the surface area of the pools (up to 90%). Substrate embeddedness did not appear to be a problem in the reach. See page 9 for information on % fines in spawning gravels.

●**Bank Erosion:** About 18% of the banks are actively eroding in the reach. Although the amount of erosion is higher than NOAA Fisheries and USFWS guidelines in their Matrix of Pathways and Indicators, most of the erosion in the reach is occurring along the outside of the meander bends. Fine sediments, including spawning gravels, are recruited from the eroding banks. Data compiled on similar sized rivers on unconfined reaches in the Methow Valley Ranger District have shown a similar amount of bank erosion.

●**Stream Temperature:** No temperature monitors were installed in the reach in conjunction with the survey. See page 11 for a summary of temperature data at RM 18

Small log jam on bar at top of pool at RM 19 **Wood providing good cover and scour in pool**

Pond in side channel at RM 18.3 **Spawning substrate and dead salmon in Reach 1**



Mouth of side channel and old beaver activity at RM 18.8 **Run habitat in reach 1**

1I. HABITAT ASSESSMENT: ENTIAT RIVER SUBREACH 2
From where the river becomes confined at RM 20.7 to the bridge crossing at RM 21.1

Summary of Habitat Data:

●**Reach Description:** This 0.4 mile subreach is a naturally confined stream segment comprised mainly of riffles. One bankfull width measurement was conducted in the reach. The floodprone width at this site was 82', about 14' wider than the bankfull width. Boulders line the banks of the reach and are abundant in the streambed. The short reach is a high energy transport reach.

●**Habitat Area:** The habitat area in the reach is about 16,700 square yards (40,600 square yards per mile), consisting of about 13% pool habitat, 78% riffle habitat, and 9% run habitat. There are no side channels in the reach. Little, if any, backwater pool habitat is found in the reach.

●**Large Wood:** Only 7.2 pieces of wood per mile greater than 35' long with a diameter of 12" was counted in the reach (9.6 pieces per mile counting trees standing in the bankfull channel). Although the amount of wood is well below guidelines in the Matrix, the reach functions as a transport reach, with wood and fine sediments being transported downstream due to the high energy, confined channel. The future recruitment potential of large wood is fair, with some large conifer trees growing above the stream banks.

●**Pool Habitat:** Only one pool was counted in the reach, a 4.7' deep pool formed by boulders near the end of the reach. Boulders and depth in the 350' long pool provided some good cover for fish. The reach lacked elements that provided scour to the channel (river bends, wood, large boulders).

●**Riffle/Run Habitat:** About 78% of the total habitat area consists off riffle habitat in the reach. Runs comprise about 9% of the total habitat area. The average thalweg depth of the riffles and runs were 1.5' and 2.2', respectively, providing good depth for fish migration. Hiding cover for juvenile fish in the riffles and runs was fair, provided by boulders.

●**Side Channel and Rearing Habitat:** No side channel habitat exists in the reach. Very little backwater pool habitat and braids along the channel margins are found in the reach. Boulders provide some rearing habitat for juvenile fish, creating pocket scour and hiding cover.

●**Fish Spawning Habitat:** Substrate is generally too coarse in the reach for fish spawning. No Chinook salmon redds were observed in the reach during the habitat survey.

●**Substrate and Fine Sediment:** No pebble counts were conducted in the reach due to the lack of time. The ocular estimate of substrate in the reach is 15% sand, 10% gravel, 40% cobble and 35% boulder. Most of the fine sediments are being transported downstream. There are few, if any, depositional features in the reach.

●**Bank Erosion:** About 14% of the banks are actively eroding in the reach. Most of the erosion was from natural causes.

●**Stream Temperature and Stream Flow:** No temperature monitors were installed in the reach in conjunction with the survey. The Washington State Department of Ecology operates a continuous-recording, real-time, telemetered stream gage sited at the geomorphic reach break between reaches 2 and 3. The graphs at the top of page 16 present streamflow and water temperature for water year 2007-2008 which is representative of years this gage has been in operation (2002-2008).

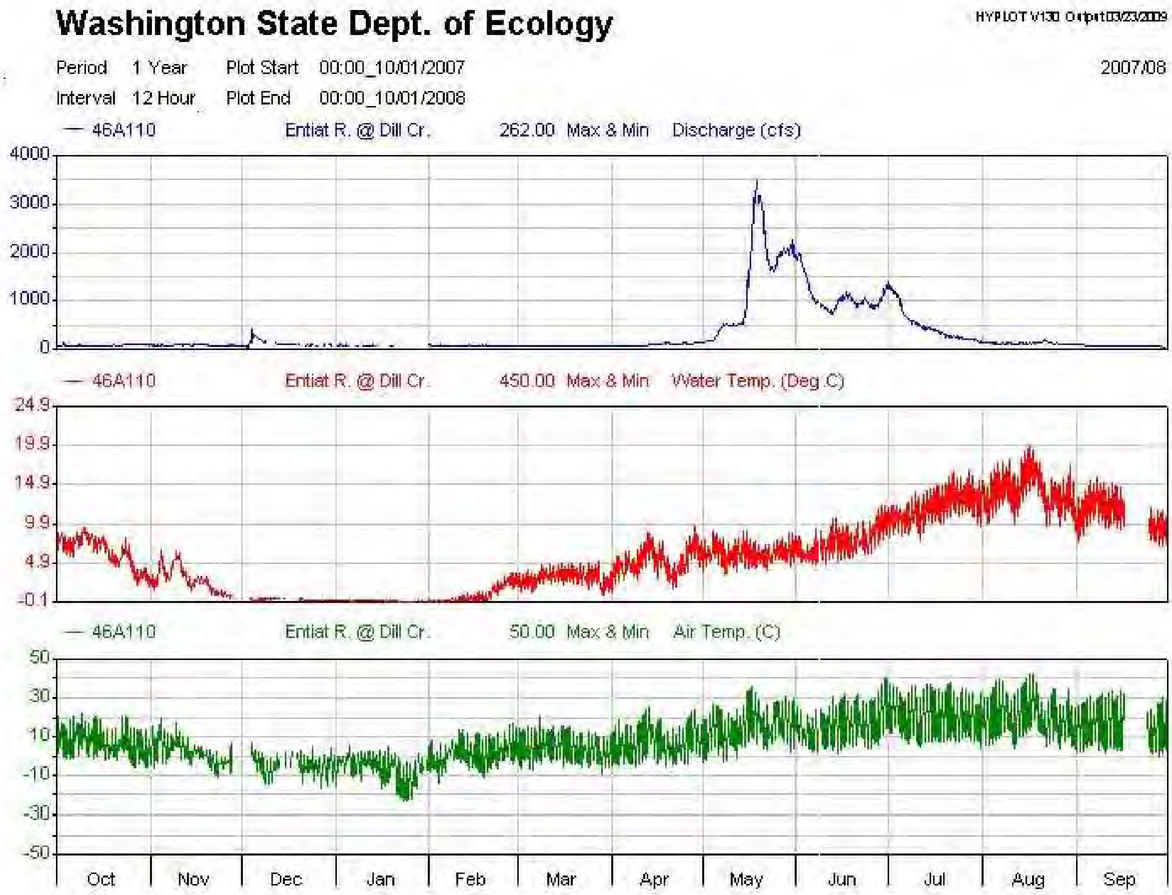


Figure z.

Confined stream channel and larger substrate in reach **Bank erosion in reach 2**

1II. HABITAT ASSESSMENT: ENTIAT RIVER SUBREACH 3
From the bridge crossing at RM 21.1 to where the channel becomes confined at RM 22.6.

Summary of Habitat Data:

●**Reach Description:** This 1.5 mile reach is a naturally unconfined, low gradient (< 1%) channel segment comprised mainly of lateral scour pools and short riffles. The reach is a depositional reach, with large point bars and frequent meander bends. A levee, which protects a horse ranch along most of the left bank between RM 21.8 and 22.4, may be preventing the stream from laterally migrating to the east (most of the dike is set back from the stream bank). The channel is fairly sinuous despite the levee, with a sinuosity value of about 1.4 (measured channel distance divided by straight line distance).

●**Habitat Area:** The habitat area in the reach is about 65,700 square yards (38,600 square yards per mile), consisting of about 58% pool habitat, 24% riffle habitat, 12% run habitat and 6% side channel habitat. Backwater pool habitat is found at the bends in the river.

●**Large Wood:** About 17 pieces of wood per mile greater than 35' long with a diameter of at least 12" were counted in the main channel in the reach, slightly below the NOAA Fisheries and USFWS guidelines in the Matrix of Pathways and Indicators. The amount of wood is low for an unconfined, low gradient, depositional river segment based on stream survey data from similar streams on the Methow Valley Ranger District. Much of the wood in the reach is in jams on the point bars, although some wood is in the low flow wetted channel (mainly in pools). The amount of wood is below historical levels of wood due to wood removal for flood control and development (Entiat Water Resource Inventory Area (WRIA) 46 Management Plan [Chelan County Conservation District 2004]).

●**Pool Habitat:** Pools comprise almost 60% of the habitat area in the reach, similar to reach 1. A total of 11.9 pools per mile were counted in the reach. Although the number of pools is below the standard in NOAA Fisheries Matrix, habitat units are very large in a stream as big as the Entiat River. Pools per mile is probably not a good method to determine the quantity of pool habitat. Deep pool habitat is abundant in the reach, with just over half of the pools in the reach greater than 5' deep. The eleven deep pools were spread throughout the reach, usually at a major bend in the river. In-channel wood was generally associated with deep pool habitat. Excellent spawning habitat was observed at most of the pool crests.

●**Riffle/Run Habitat:** About 24% of the total habitat area consists off riffle habitat in the reach. Runs comprise about 12% of the total habitat area. The average thalweg depth of the riffles and runs were 1.15' and 1.9', respectively, providing adequate to good depth for fish migration. Hiding cover for juveniles in the riffles and runs was generally poor due to a lack of hiding cover (wood or large substrate).

●**Side Channel and Fish Rearing Habitat:** At low flow, about 6% of the total habitat area in the reach consisted of side channel habitat. Only one large side channel was observed during the habitat survey. The 1,350' long side channel exited the main channel on the right bank at RM 21.65, re-entering at RM 21.35. The side channel had the best off-channel rearing habitat in the surveyed segment of the Entiat River. Four active beaver dams in the side channel created deep pool habitat (up to 5' deep). The side channel averaged about 25' wide with an average depth of about 3 feet.

●**Fish Spawning Habitat:** Excellent spawning habitat for salmon and steelhead exists throughout the reach. While the substrate size was slightly larger than in reach 1, coarse gravels and small cobbles are the dominant substrate types in the reach. One pebble count was conducted in the reach. The D50 value was 50.5 millimeters compared with a D50 of 43.3 in reach 1. Deep pools, some with log jams, provide good holding habitat for anadromous fish. A total of 9 Chinook salmon redds (2 per mile) were counted in the reach during the survey. Both spring and summer Chinook salmon redds were observed.

●**Substrate and Fine Sediment:** Two pebble counts were conducted in the reach. About 13% of the substrate at the pebble counts sites consisted of fine sediments < 6 mm, which is considered functioning at risk in the USFWS Matrix of Pathways and Indicators (< 12% surface fine sediments < 6 mm is considered functioning properly). While very fine sediments were abundant in some of the pools above the tail crests (in the scour), the pools generally had less fines than the pools in reach 1. Substrate embeddedness did not appear to be a problem in the reach. See page 9 for a details on McNeil Core sediment sampling data.

●**Bank Erosion:** About 10% of the banks are actively eroding in the reach. The erosion was caused both by natural causes, at the bends in the river, and from the removal of vegetation for agriculture and development. A 500' segment of the left bank of the river between RM 21.4 and RM 21.5 is eroding at a very fast rate. About 500' of bank just upstream of the eroding bank is protected by wood structures. Installing wood structures on the eroding bank (which is preferable to rip rap), along with tree planting, may be necessary to protect the eroding bank.

●**Stream Temperature:** No temperature monitors were installed in the reach in conjunction with the survey. See page 11 for details on water temperatures in the Entiat River.

Dike above left bank at RM 22.4

Eroding bank at RM 21.4

Side channel habitat and beaver dam at RM 21.3

Pool with large wood in Reach 3

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1V. HABITAT ASSESSMENT: ENTIAT RIVER SUBREACH 4
Confined River Segment between RM 22.6 and RM 23.3

Summary of Habitat Data:

●**Reach Description:** This 0.7 mile subreach is a naturally confined stream segment comprised mainly of riffles. Much of the lower half of the reach is a Rosgen B3c channel type, with a floodplain up to 235' wide. This half of the reach has some slow water velocities (in the run habitat) and the substrate consists mainly of large cobbles. In 1972, deposition from debris torrents in Mott and Preston Creek dammed the Entiat River. The coarse substrate delivered by the debris torrents was likely pushed along the channel margins by bulldozers. This event narrowed the river channel in the upper half of the reach.

●**Habitat Area:** The habitat area in the reach is about 24,600 square yards (35,000 square yards per mile), consisting of about 81% riffle habitat, and 19% run habitat. There are no side channels and no channel spanning pools in the reach. Little, if any, backwater pool habitat is found in the reach.

●**Large Wood:** Eleven pieces of in-channel wood per mile greater than 35' long with a diameter of 12" was counted in the reach. There are a large amount of standing trees that were in the bankfull width of the river (about 13 trees in the same size category per mile). The reach is a high energy transport reach, with wood and finer sediments expected to be transported downstream.

●**Pool Habitat:** No channel spanning pools were observed in the reach. Some pocket pool habitat exists between the large boulders in the upper half of the reach, including a 3.9' deep pocket pool at the confluence with Preston Creek.

●**Riffle/Run Habitat:** About 81% of the total habitat area consists off riffle habitat in the reach. Runs comprise about 19% of the total habitat area. The three runs were all in the lower half of the reach where the channel was wider and gradient lower. The average thalweg depth of the riffles and runs were 1.8' and 2.2', respectively, providing good depth for fish migration. Hiding cover for juvenile fish in the riffles and runs was fair, provided by boulders.

●**Side Channel and Rearing Habitat:** No side channel habitat exists in the reach. Very little backwater pool habitat or braids along the channel margins are found in the reach. Boulders and rip rap provide some rearing habitat for juvenile fish, creating pocket scour and hiding cover. Some slower water rearing habitat for juvenile fish is found in the three runs in the bottom half of the reach.

●**Fish Spawning Habitat:** Substrate is too coarse in the reach for fish spawning. No Chinook salmon redds were observed in the reach during the habitat survey.

●**Substrate and Fine Sediment:** One pebble count was conducted in reach 4, near the beginning of the reach where gradient was lower and the channel was wider. About 9% of the substrate in the pebble count consisted of surface fines < 6 mm. Most of the finer sediments in the reach are being transported downstream in the higher energy, constricted channel. Some gravels were observed in the lower part of the reach. Very few gravels exist in the upper half of the reach where the bed is predominantly boulders and large cobbles.

●**Bank Erosion:** Stream banks are very stable due to the boulder material deposited on both sides of the channel. Only 1% of the banks in the reach were eroding.

●**Stream Temperature:** No temperature monitors were installed in the reach in conjunction with the survey. See page 11 for details on water temperatures in the Entiat River

Confined channel and riffle habitat in upper half of reach 4

Standing trees in river in reach 4

Mouth of Preston Creek

ENTIAT RIVER DATA SUMMARY: RM 18.0 to RM 23.3
October 2008

	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**All Reaches**
River Mile From:	18.0	20.7	21.1	22.6	18.0
River Mile To:	20.7	21.1	22.6	23.3	23.3
River Miles – BOR maps	2.7	0.4	1.5	0.7	5.3
Measured Miles in Reach	3.31	0.42	1.77	0.70	6.20
POOLS					
-Total # of Survey Pools in Reach	35	1	21	0	57
-Survey Pools per Mile	10.6	2.4	11.9	0	9.2
-Survey Pools > 5' Deep/Mile	5.4	0	6.2	0	4.7
-Average Maximum Pool Depth	4.99'	4.70'	4.65'	-	4.85'
-Average Pool Residual Depth	3.90'	3.00'	3.59'	-	3.77'
LWD per mile (in-channel only)*					
-Small (>20'L, >6" D)	41.1	12.0	37.9	19.9	35.8
-Medium (>35'L, >12" D)	16.0	7.2	13.6	11.4	14.2
-Large (>35' L, > 20" D)	8.8	0	3.4	0	5.6
-Total > 35' L (Medium & Large)	24.8	7.2	17.0	11.4	19.8
% HABITAT AREA					
-% Pool	58.8%	12.9%	57.5%	0%	48.5%
-% Riffle	22.4%	77.8%	23.8%	80.8%	33.9%
-% Run	14.6%	9.3%	12.5%	19.2%	14.1%
-% Side Channel/Off-channel Habitat	4.2%	0%	6.2%	0%	4.0%
SEDIMENT/EROSION					
-Linear Ft. Erosion per Mile	1,945'	1,496'	1,155'	106'	1,482'
-% Eroding Banks (total both banks)	18.2%	14.2%	10.9%	1.0%	14.0%
CHANNEL MORPHOLOGY (limited data					
-Average Wetted Width in Feet	63'	65'	60'	60'	varies
-Bankfull Width in Feet	113'	68'	106'	82'	varies
-Width/Depth Ratio	45.6	22.0	44.1	28.6	varies
-Floodplain Width in Feet	> 500'	82'	> 500'	160'	varies
-Entrenchment Ratio	> 5 to 1	1.20	> 5 to 1	1.95	varies
-Rosgen Channel Types	C4	F3	C3, C4	B3c, F2	varies
SUBSTRATE (Pebble Counts/Ocular Est.)	**NOTE 1**	**NOTE 2**	**NOTE 3**	**NOTE 4**	
% Surface Fines (< 6 mm)	15%		13%	9%	
-D50 (millimeters)	43.3		50.5	129.0	
-D84 (millimeters)	80.4		88.8	249.1	
-% Sand (< 2 mm)	13%		12%	7%	
-% Gravel	58%		56%	28%	
-% Cobble	29%		34%	50%	
-% Boulder	-		-	15%	
-% Bedrock	-		-	-	

*In-channel only. Does not include standing trees or LWD in side channels. See table on next page 6 for LWD.

Note 1: Average of 2 pebble counts. Ocular estimate (incl. pools) = 25% sand, 50% gravel, 25% cobble

Note 2: No pebble count. Ocular estimate for reach is 15% sand, 10% gravel, 40% cobble, 35% boulder.

Note 3: One pebble count. The ocular estimate for the reach is 20% sand, 40% gravel and 40% cobble.

Note 4: One pebble count was done in the reach, at the very bottom of the reach where the substrate was less coarse. The ocular estimate for the entire reach is 10% gravel, 50% cobble, 40% boulder.

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APPENDIX D

Preston Vegetation Assessment

RIPARIAN VEGETATION ASSESSMENT

Riparian and upland vegetation was mapped remotely using 2006 ortho-photographs with limited field validation. The seral stage classifications are from the Stream Invenory Handbook (USDA, 2008). Summaries of the ArcGIS analysis are included in Tables 1 through 3, and the ArcGIS mapping are included as Figures 1 through 8.

Table 1: Summary of floodplain disturbance (refer to Figures 3 and 4).

Disturbance (Floodplain):	Acres Percentag	e
Agriculture Area	0.5395 acres	< 1%
Residential Area	0.0270 acres	< 1%
Commercial Area	0 acres	0%
Fire Area	0 acres	0%
Seral Stage (Floodplain):		
No Vegetation (NV)	0.0735 acres	< 1%
Grass/Forbes (GF)	7.63 acres	11%
Shrub/Seedling (SS)	8.57 acres	12%
Sapling/Pole (SP)	5.89 acres	8%
Small Tree (ST)	13.04 acres	18%
Large Tree (LT)	36.17 acres	51%

Table 2: Summary of riparian buffer zone (30 meter width along both banks) (refer to Figures 5 and 6).

Riparian Buffer (30 m width):	Acres Percentag	e
Agriculture Area	1.5760 acres	3%
Residential Area	1.1992 acres	2%
Commercial Area	0 acres	0%
Fire area	0 acres	0%
Seral Stage (30 m width):		
No Vegetation (NV)	0.0758 acres	< 1%
Grass/Forbes (GF)	8.8251 acres	16%
Shrub/Seedling (SS)	4.5802 acres	8%
Sapling/Pole (SP)	3.0962 acres	6%
Small Tree (ST)	10.0614 acres	19%
Large Tree (LT)	27.3247 acres	51%

Table 3: Summary of riparian buffer zone (10 meter width along both banks) used as a surrogate for canopy cover (refer to Figures 7 and 8).

Seral Stage (10 m width):	Acres Percentag	e
No Vegetation (NV)	0.0084	< 1%
Grass/Forbes (GF)	0.1255	13%
Shrub/Seedling (SS)	0.1231	13%
Sapling/Pole (SP)	0.0892	9%
Small Tree (ST)	0.1844	19%
Large Tree (LT)	0.4424	46%

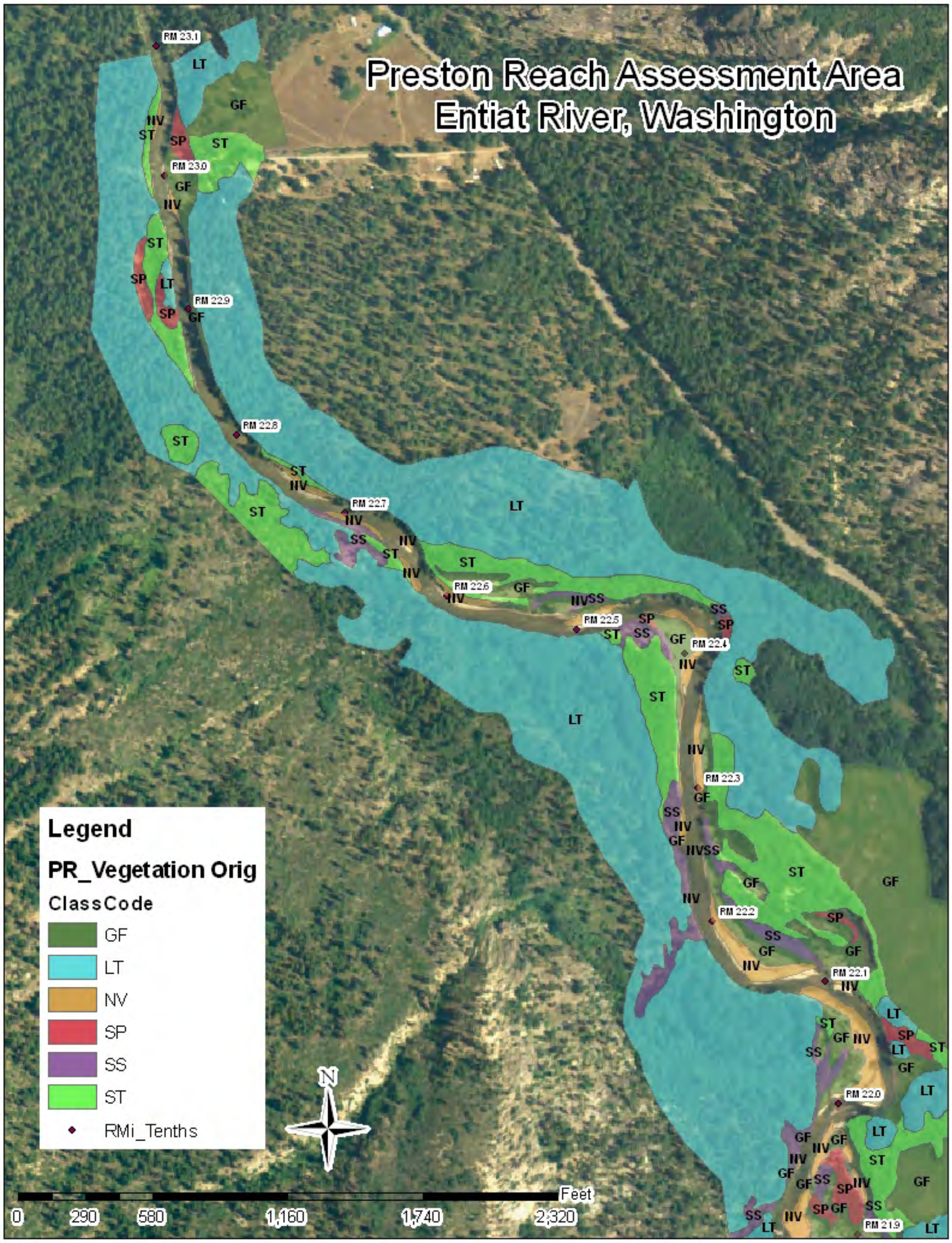


Figure 1. Seral stages for floodplain and upland areas.

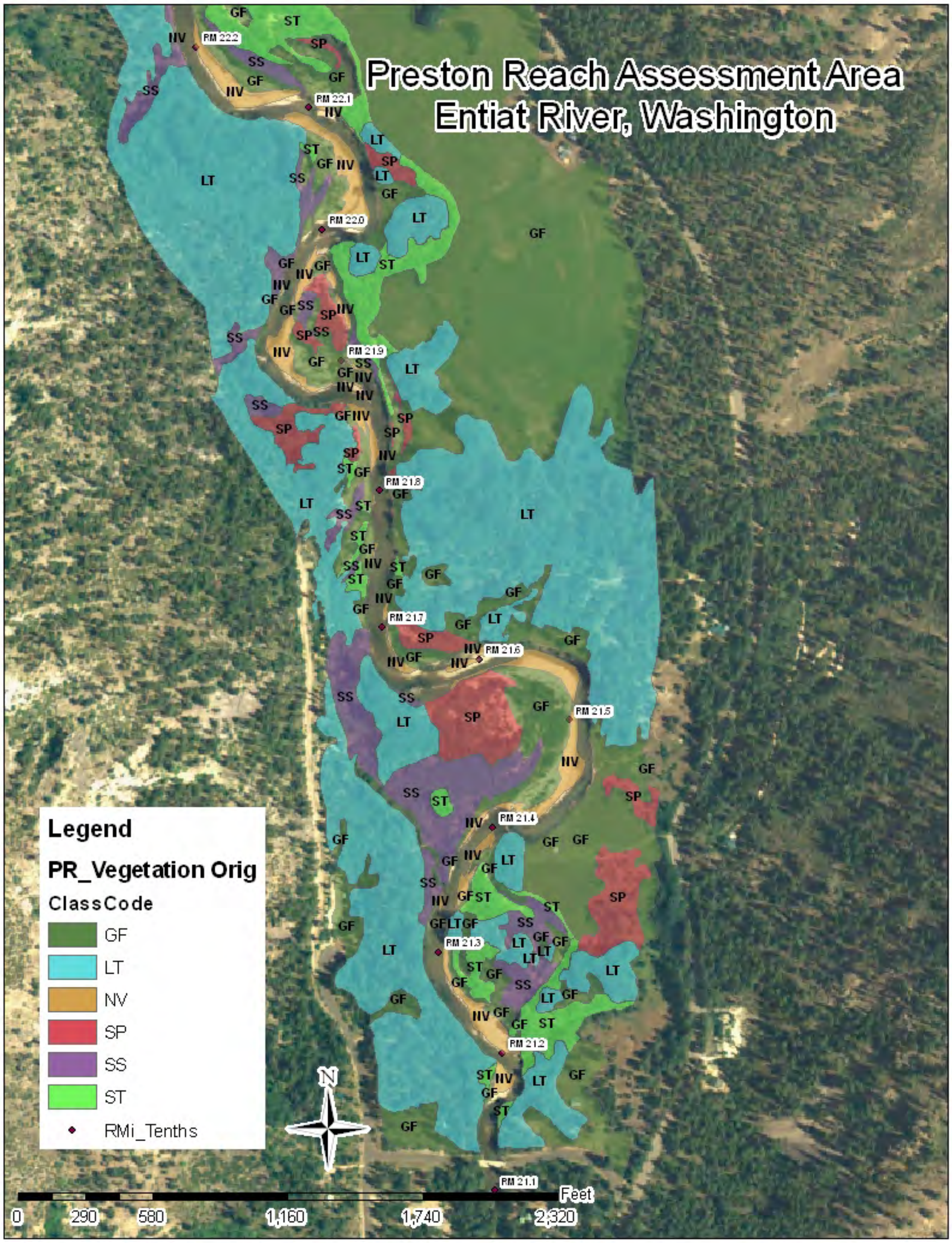


Figure 2. Seral stages for floodplain and upland areas.

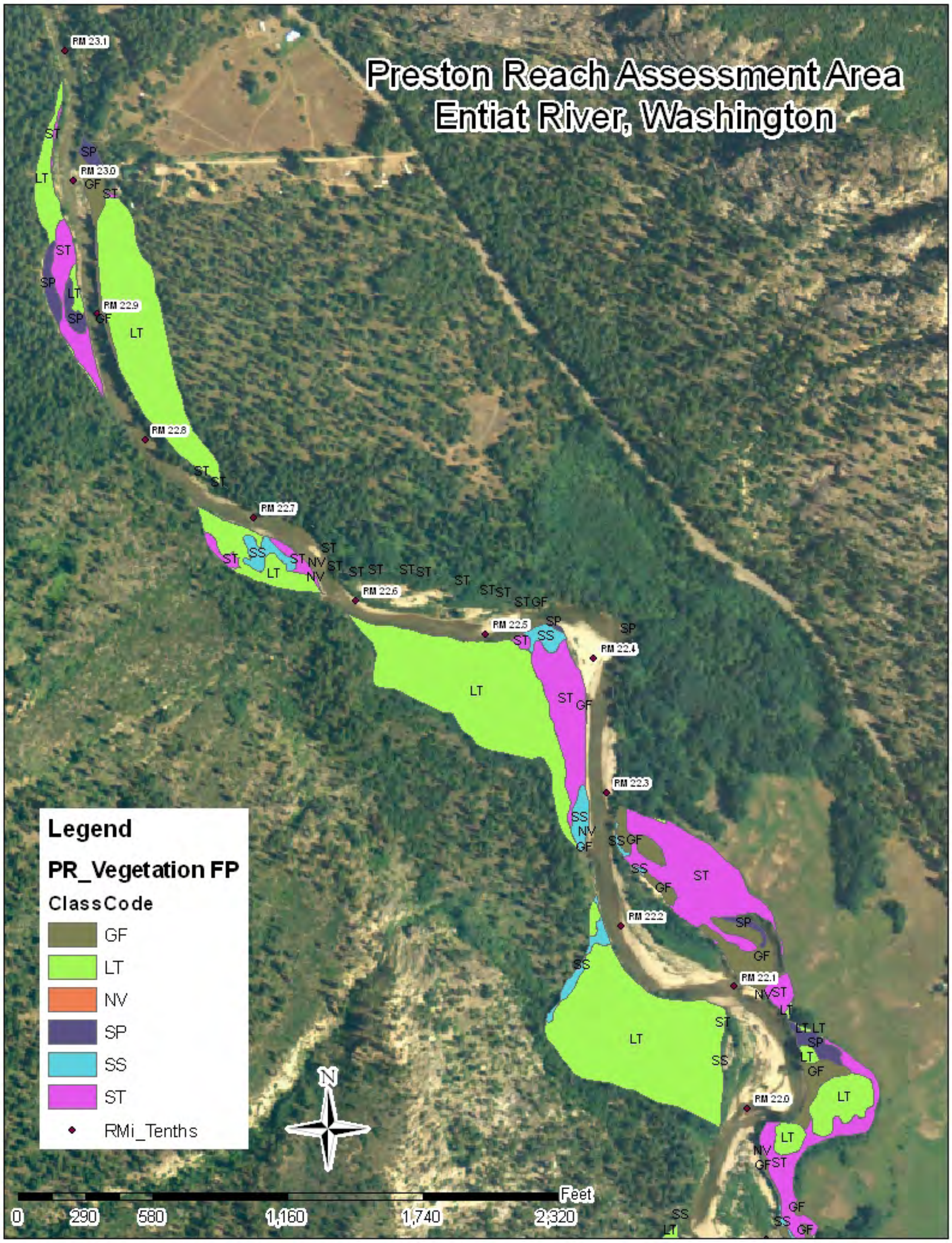


Figure 3. Seral stages for outer zone or floodplain.

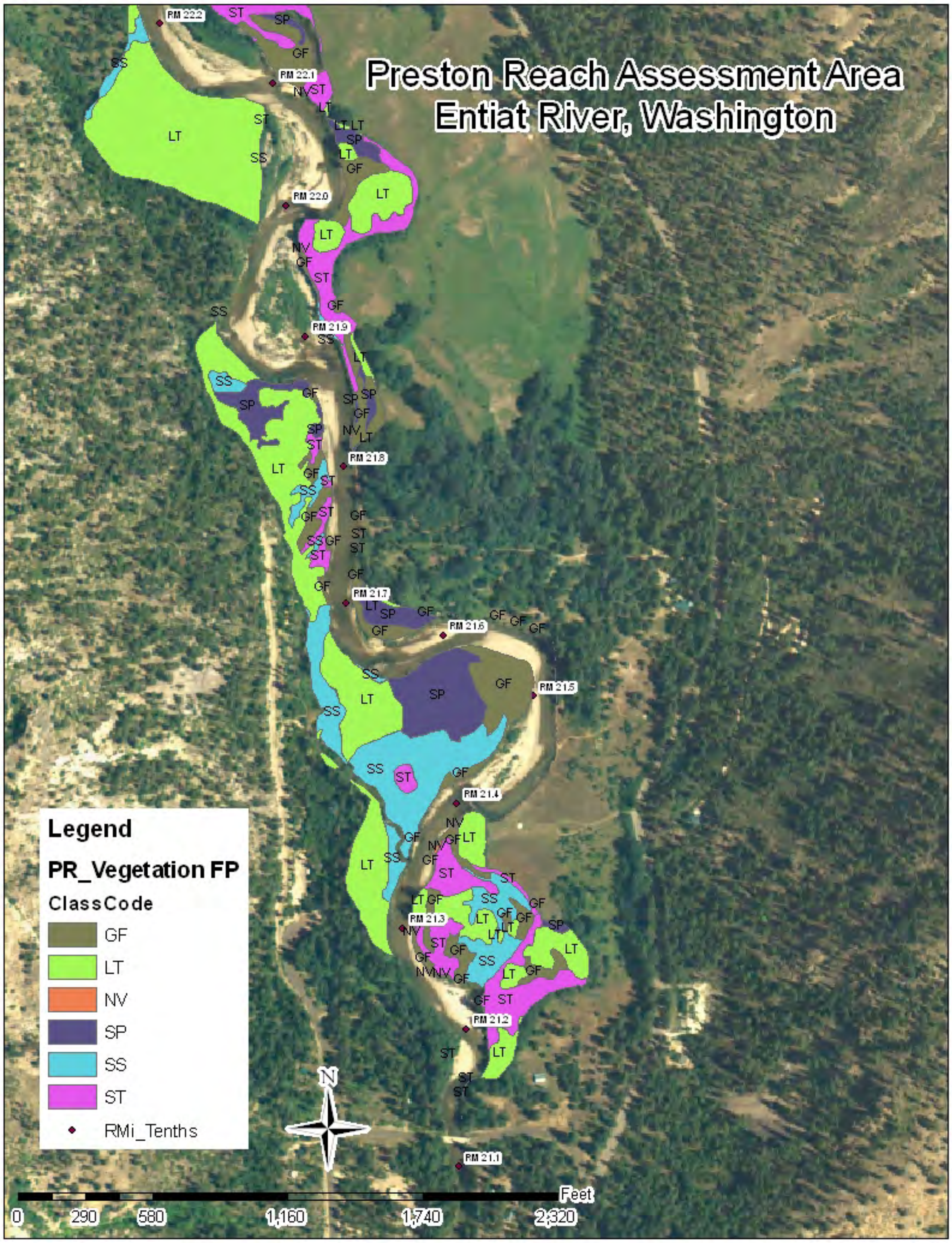


Figure 4. Seral stages for outer zone or floodplain.

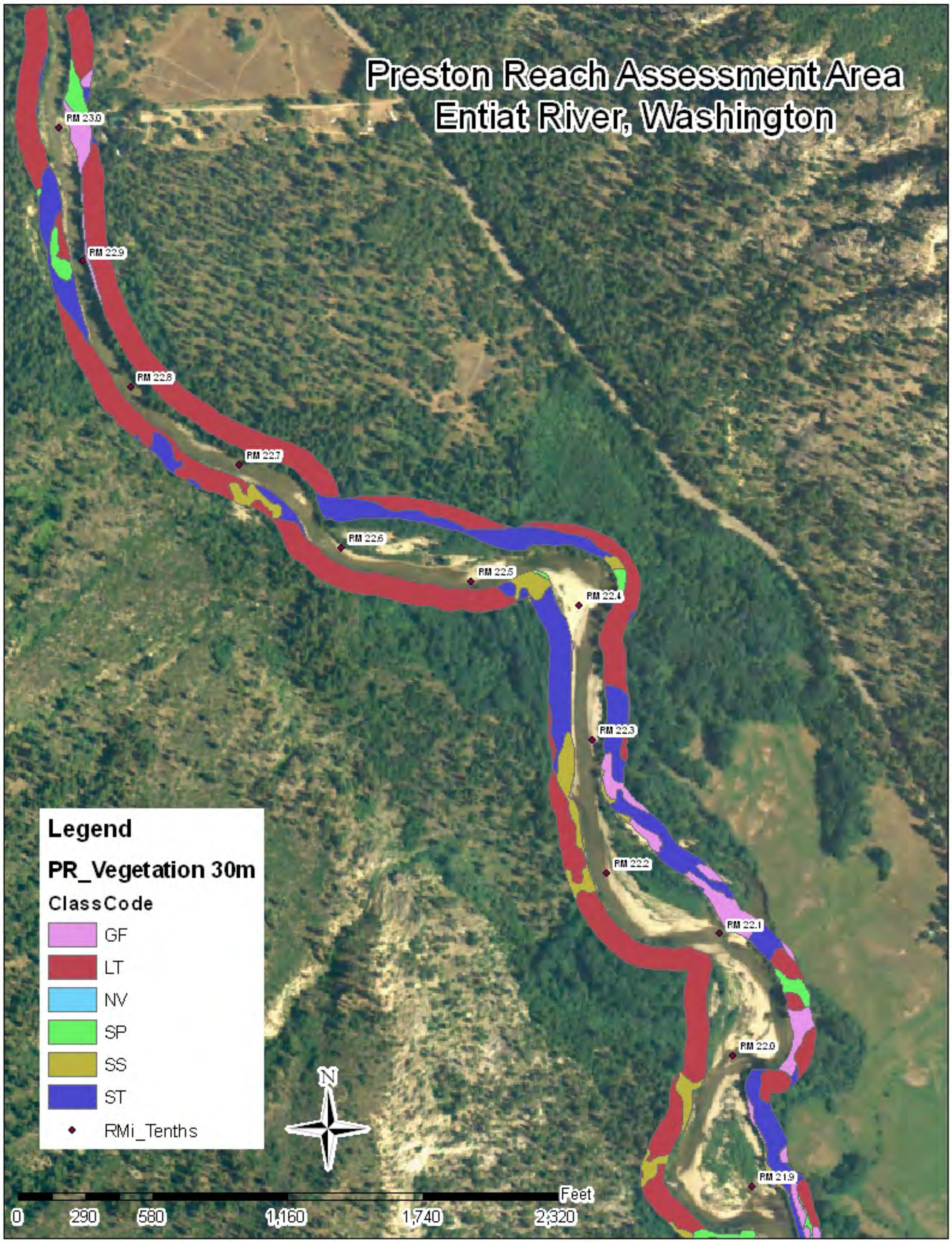


Figure 5. Seral stages for 30 meter buffer zone.

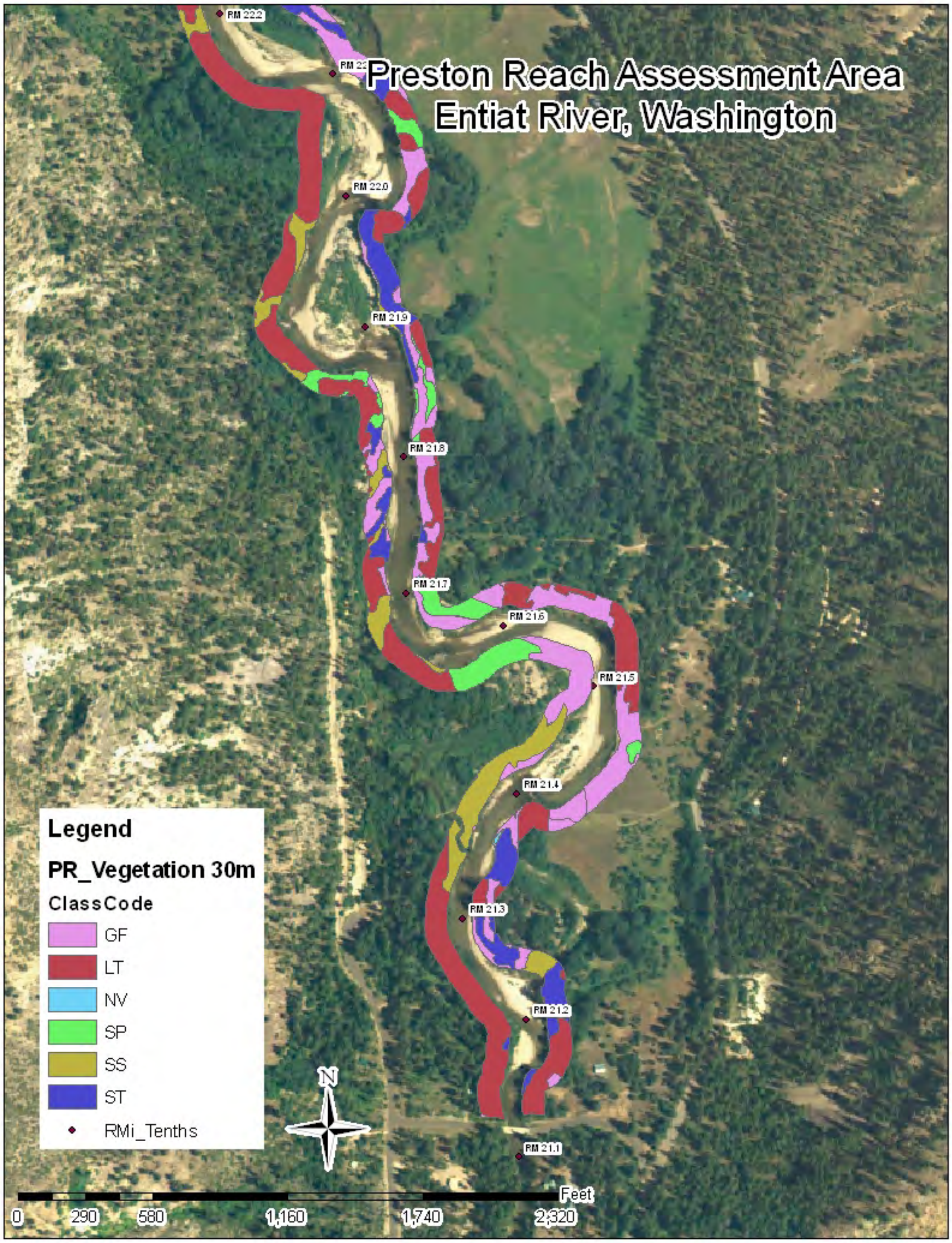


Figure 6. Seral stages for 30 meter buffer zone.

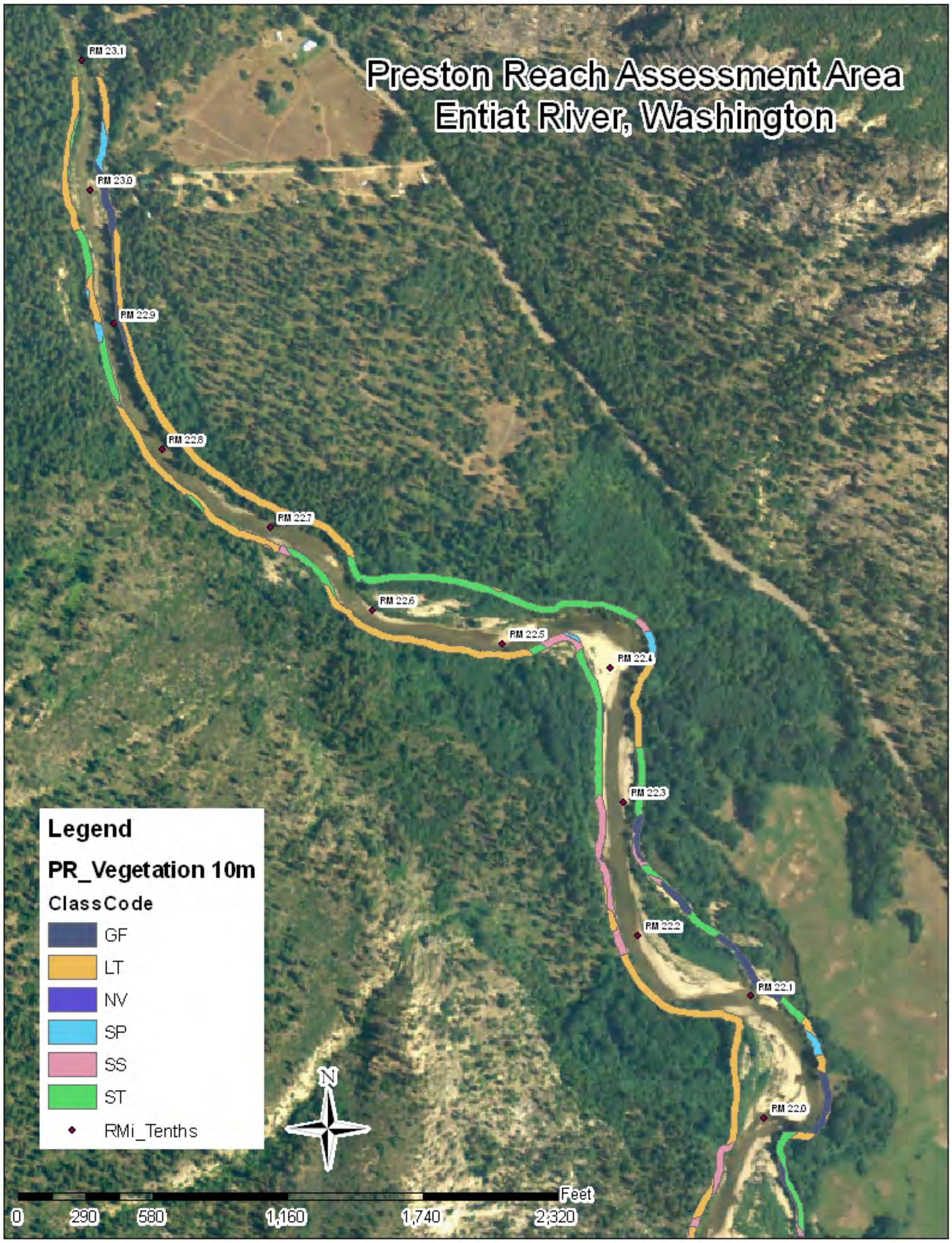


Figure 7. Seral stages for 10 meter buffer zone.

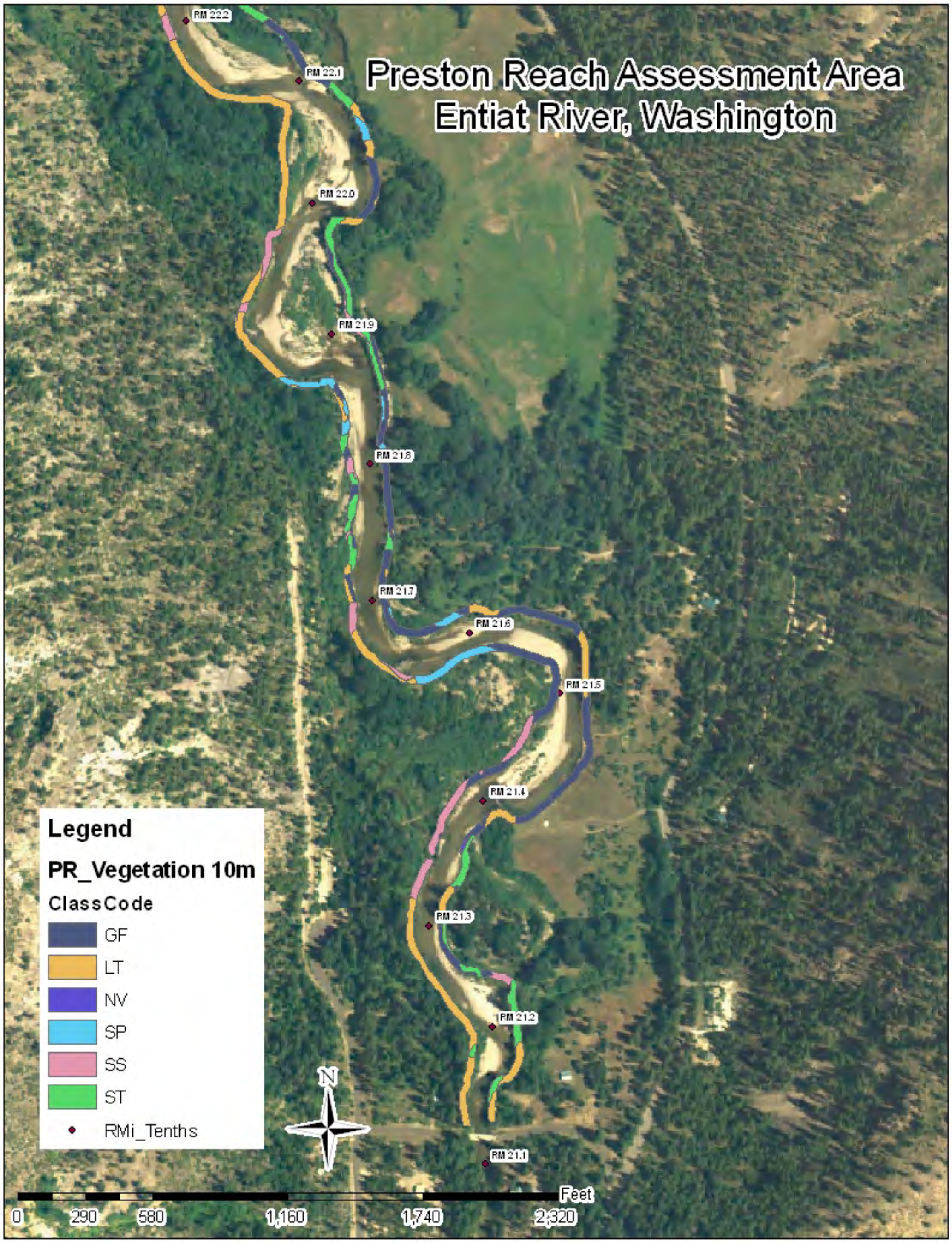


Figure 8. Seral stages for 10 meter buffer zone.

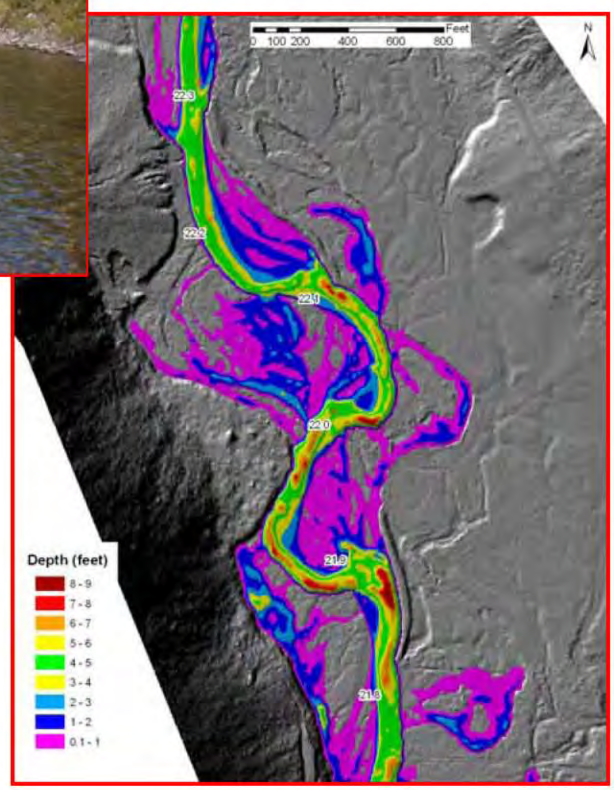
APPENDIX E

Preston Two-dimensional Hydraulic Model Results

RECLAMATION
Managing Water in the West

Hydraulic Modeling of the Preston Reach

Entiat River, Chelan County, WA



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, CO

May 2009

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover photo: Upstream view of RM 22.2. Photo taken 10/13/08 by Mike Sixta.

Hydraulic Modeling of the Preston Reach

Entiat River, Chelan County, WA

Prepared: Mike Sixta, M.S., P.E. Date
Hydraulic Engineer, Sedimentation and River Hydraulics Group

Peer Review: Robert C. Hilldale, M.S., P.E. Date
Hydraulic Engineer, Sedimentation and River Hydraulics Group

Contents

List of Figures

List of Tables

Introduction

In compliance with the Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp; NMFS 2008), “Action Agencies”, which include the Bureau of Reclamation (Reclamation), U.S. Army Corps of Engineers, and Bonneville Power Administration are working to implement salmonid habitat restoration projects in the Upper and Lower Columbia River basin. Recovery efforts are focused on limiting factors for the survival of species on the Endangered Species Act (ESA) list, as well as other culturally important salmonid fish species, within the four general sectors of harvest, hatcheries, hydropower, and habitat. Implementation of a combination of actions in all four sectors is expected to be necessary for recovery of ESA-listed species.

Within the habitat sector, Reclamation provides technical assistance for project identification, design, and construction in partnership with States, Tribes, Federal agencies, and other local workgroups. Initially, technical assistance was provided to address critical path projects such as stream flow improvement, removal of in-stream barriers, and fish screen enhancement projects. More recently, Reclamation has been incorporating habitat complexity projects. Reclamation has initiated assessments on multiple tributaries to the Columbia River to develop planning tools that can be used collectively by all partners within a particular subbasin to focus local resources on identifying and prioritizing floodplain connectivity and channel complexity restoration/protection projects.

Background

Tributary Assessment

The Entiat River is located on the east slope of the Cascade Mountains in north-central Washington. The Entiat flows approximately 53 miles from its headwaters to where it enters the Columbia River at river mile (RM) 483 (Figure 1). A Tributary Assessment (TA) was recently completed by Reclamation on the lower 26 miles of the Entiat River (Bountry et al. 2009). The primary objective of the TA was to provide resource managers and basin stakeholders with pertinent scientific information that would help them with steelhead and spring Chinook habitat restoration planning and decision making in the Entiat subbasin. This objective was met through the characterization of the biological conditions, vegetation ecosystems, geologic setting, anthropogenic constraints, geomorphic processes, basin hydrology, and hydraulic processes.

The TA subdivided the lower 26 miles into three distinct valley segments (VS; labeled with increasing numeric values of 1 to 3 from downstream to upstream) and 17 geomorphic reaches. Valley segment boundaries were defined on the basis of changes in the channel gradient and geologic features that control channel morphology. Reach boundaries were defined much the same way, but on a finer scale to further delineate variations in geomorphic characteristics. This type of demarcation provides a context for customizing different river rehabilitation strategies based on specific characteristics of each river segment or reach.

Figure 1. Location map for Entiat River (from Entiat TA; Bountry et al. 2009).

Tributary Assessment Findings

The Preston Reach, located between RM 21.1 – 22.7 (see Figure 2), is identified in the TA as '3A'; the furthest downstream reach in VS-3. This reach is generally characterized as having an unconfined floodplain (average floodplain width much greater than average active channel width) with high in-channel complexity and lateral controls consisting of alluvial fans, levees, and high terraces that constrain the channel position; further, the large size of the bed material near these controls creates a base level constraint, locally armoring the channel bed. The present impacts to the channel and floodplain in this reach are the presence of multiple levees and bank protection that limit channel migration and alter the instream hydraulics and geometry, accompanied by localized areas of cleared vegetation resulting in increased bank instabilities.

Figure 2. Preston Reach location map. (Flow is from top to bottom of page).

Geomorphically, the Preston Reach is described as a multi-threaded channel at low flow with irregular meanders and numerous point bars. Alluvial fans and high terraces create resistant banks that limit lateral migration. These surfaces are generally underlain by a sandy material covering a gravelly alluvium. There are two levees in this reach (RM 21.8-21.9 and 22.1-22.3; both on river left), constructed in the 1960's, that have disconnected areas that were formerly part of the active channel, limiting lateral migration. Noteworthy side channel entrances exist at RM 21.7 and 22.2, both on river right. At RM 22.2, large woody debris blocks the side channel entrance to what was formerly the main active channel in 1945. Another former channel (paleochannel) exists near the downstream end of this reach near RM 21.1 on river left located on a high floodplain surface. While this paleochannel is most likely older than the channels at RM 21.7 and 22.2, it is still likely less than 100 years old as it retains visible channel morphology and is inundated by 2-year recurrence interval flows (Bountry et al. 2009). At higher flows, overflow channels around vegetated islands create split flow conditions in some sections of this reach. Mapping of the surficial geology and historic channel alignments for the Preston Reach are shown in Figures 3 and 4, respectively.

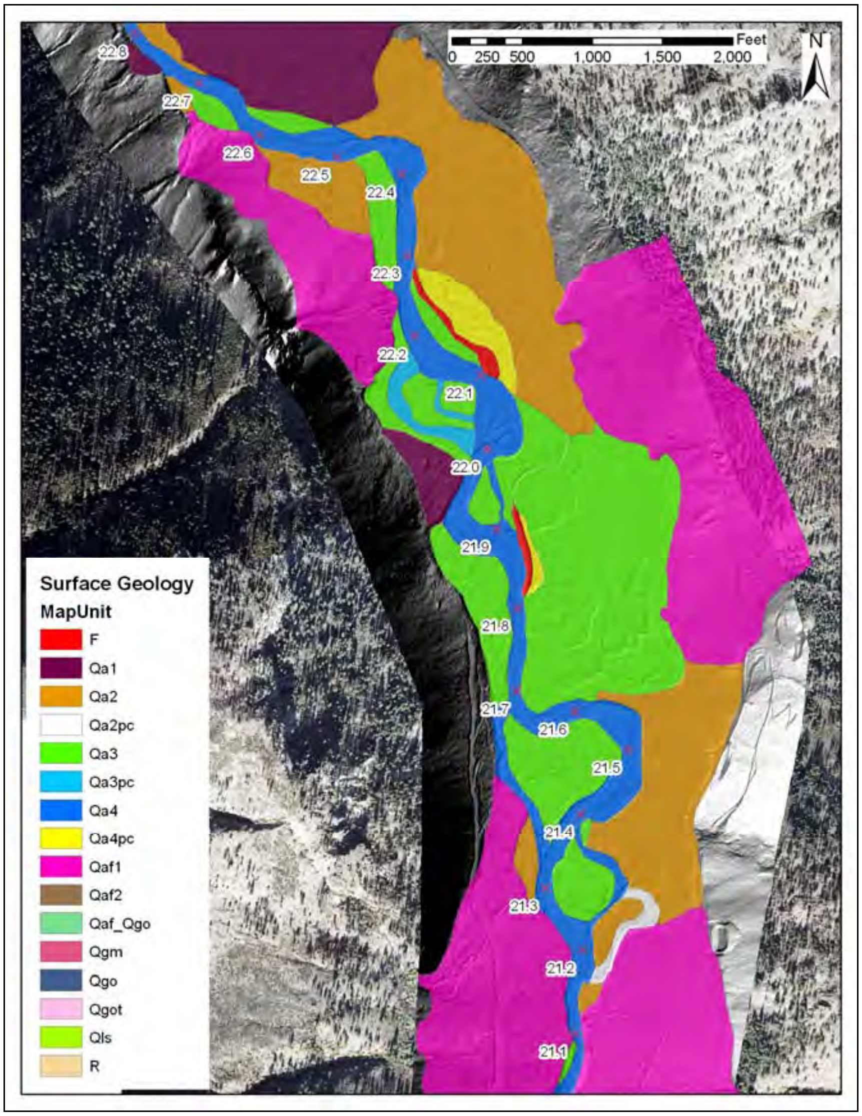


Figure 3. Surficial geologic mapping units for Preston Reach (from Entiat TA; Bountry et al. 2009).

Table 1. Surficial geologic mapping unit descriptions (from Entiat TA; Bountry et al. 2009).

Map Unit ID	Map Unit Description
Qa4	Active channel
Qa4pc	Disconnected active channel
Qa3	Historical alluvium (<100 years)
Qa3pc	Paleochannels (<100 years)
Qa2	Late holocene alluvium (historical to 2,000 years)
Qa2pc	Late holocene paleochannel (<1,000 years)
Qa1	Middle to late holocene alluvium (3,000-4,000 years)
Qaf2	Holocene alluvial fan (younger)
Qaf1	Holocene alluvial fan (older)
Qgo	Late pleistocene/early holocene glacio-fluvial deposits
Qaf/Qgo	Holocene alluvial fan overlying late pleistocene/early holocene outwash deposits
Qgot	Late pleistocene glacial outwash from terrace
Qgm	Late pleistocene moraine
Qls	Landslide deposits (holocene)
F	Fill
R	Bedrock

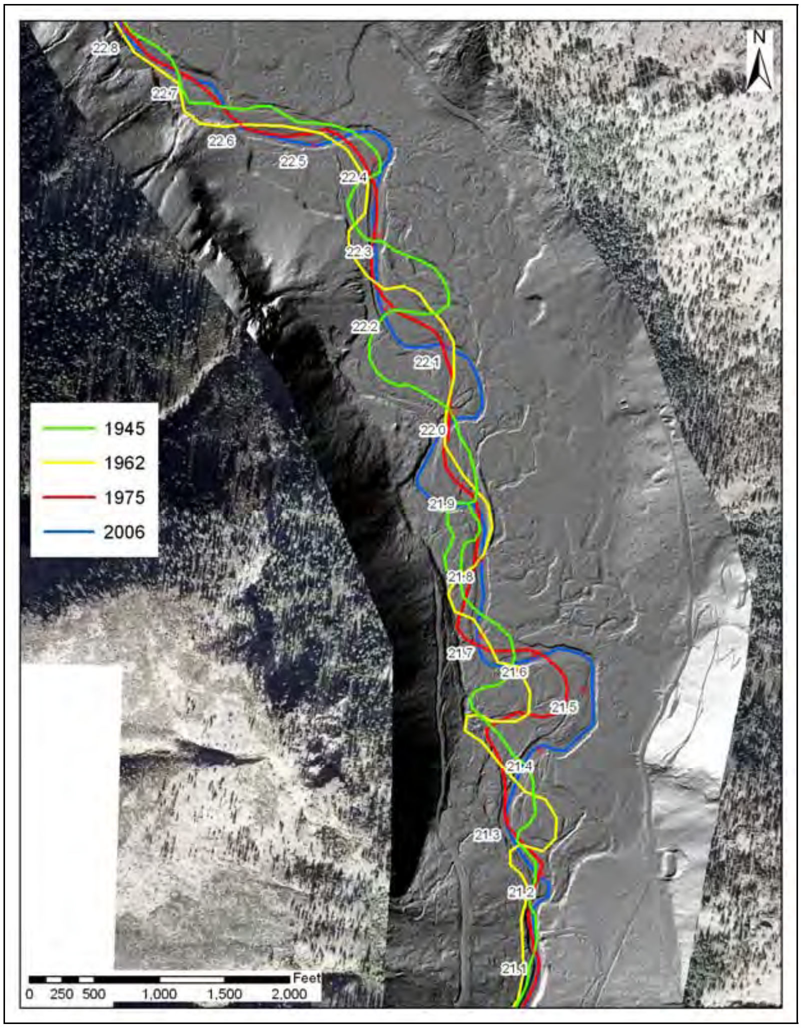


Figure 4. Historic channel alignments for Preston Reach (from Entiat TA; Bountry et al. 2009).

Opportunities for restoration/protection can be related to the level of channel complexity that is present based on documented geomorphic characteristics. The TA examined channel complexity for each geomorphic reach using active floodplain confinement, historical channel migration from 1945 to 2007, the presence of side channels and large woody debris, stream power, and channel bar frequency indicators. Each of these variables was given a numeric value based on how they relate to channel complexity. These values were tallied to get a cumulative score and subsequent rank for each reach. Using the complexity ranking of 1 to 16, restoration opportunity was assigned to reaches with the least to most, respectively. The Preston Reach, which was described as having an unconfined active floodplain, high channel migration, high presence of side channels, low presence of large woody debris, low stream power, and high bar frequency, ranked 15. A lack of juvenile rearing habitat, high percentage of fines in the spawning gravel, and high summer water temperatures were identified as habitat limiting factors for all life stages (Bountry et al. 2009).

Hydraulic Modeling Methodology

Model Selection

The model utilized for this assessment was SRH-2D (Lai 2008), a two-dimensional (2D) depth-averaged hydraulic model specifically focused on the flow hydraulics of river systems. SRH-2D adopts a zonal approach for coupled modeling of channels and floodplains. A river system is broken down into modeling zones (delineated based on natural features such as topography, vegetation, and bed roughness), each with unique parameters such as flow resistance. One of the main features of SRH-2D is the use of an unstructured hybrid mixed element mesh, which is based on the arbitrarily shaped element method of Lai (2000) for geometric representation. This meshing strategy is flexible enough to facilitate the implementation of the zonal modeling concept, allowing for greater modeling detail in areas of interest ultimately leading to increased modeling efficiency through a compromise between solution accuracy and computing demand. Other notable capabilities of SRH-2D include the following (Lai 2008):

- SRH-2D solves the 2D depth-averaged dynamic wave equations (St. Venant equations) using a finite volume numerical methodology;
- Both steady and unsteady flows may be simulated;
- An implicit scheme is used for time integration to achieve solution robustness and efficiency;
- All flow regimes (i.e. subcritical, transcritical, and supercritical) may be simulated simultaneously without the need for special treatments;
- SRH-2D contains a robust and seamless wetting-drying algorithm; and,
- Solution domain may include a combination of main channels, overland flow, and floodplains.

Model Surface Geometry

LiDAR Data

To represent the model terrain, a three-dimensional surface was generated in a Geographic Information System (GIS) using a Triangulated Irregular Network (TIN). The majority of the TIN was created using Light Detection and Ranging (LiDAR) data, which was collected on October 26, 2006 when the average daily flow was 58 cfs at the Department of Ecology’s Dill Creek Bridge monitoring station (RM 21.15). The LiDAR data collection methodology used cannot penetrate water (see Figure 5). Therefore, data that fell within the wetted portion of the channel (at the time the LiDAR was collected) was excluded from being used for surface generation. Fortunately, because the LiDAR was collected during a seasonal low flow, the amount of channel bottom not captured was minimized. The area in need of further refinement was the channel bed geometry in localized scour holes. Quality control data were collected within the assessment area using a ground-based real-time kinematic (RTK) survey that was compared to the processed LiDAR data to evaluate accuracies across the assessment area. For non-wetted (bare earth) areas, the LiDAR has ±0.14 feet of vertical accuracy (Watershed Sciences 2007). Approximately 1.9 million bare earth LiDAR data points make up the model surface for the Preston Reach.

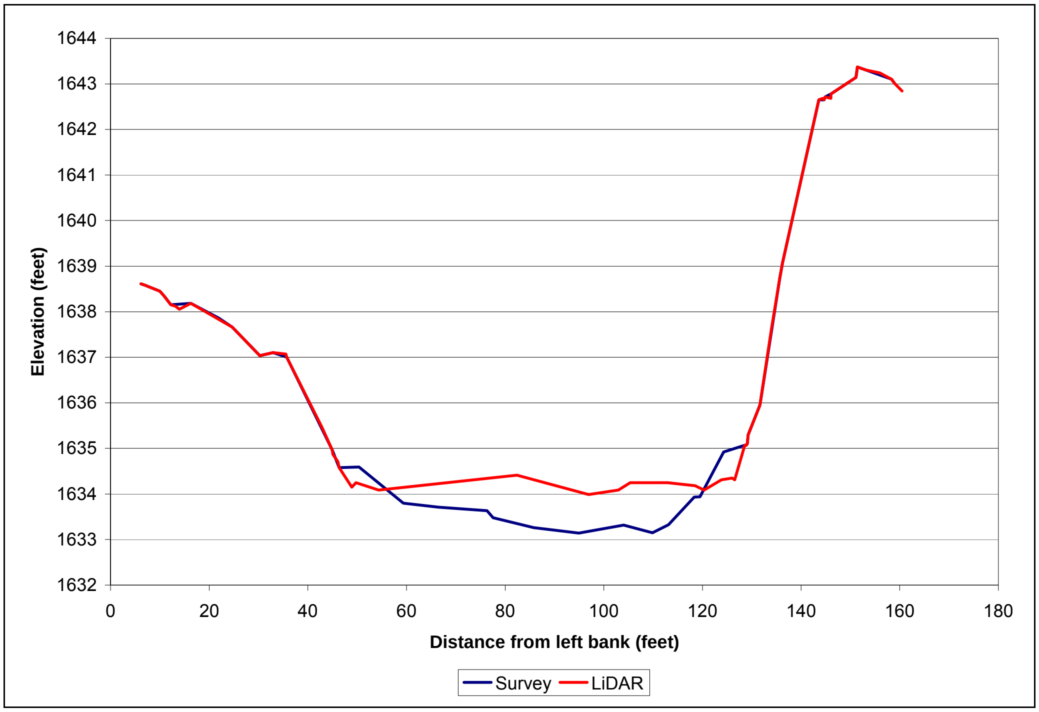


Figure 5. Survey versus LiDAR cross section profile comparison at RM 22.25. (The central portion of this cross section is the wetted portion that the LiDAR did not capture).

Even with its limitation of water penetration, the applications of LiDAR are numerous and ever growing. LiDAR data can be used to generate many useful products. One such product is a shaded relief (hillshade) topographic representation of the surface, which portrays the ground surface elevations three-dimensionally without the interference of vegetation, enabling certain features (e.g. relict side channels and levees) that may not be visible on conventional aerial photography to be distinguished. An example of the LiDAR hillshade is shown in Figure 6. Another product that can be generated from LiDAR data is an intensity image. The intensity value is a relative measure of the return signal strength. It measures the peak amplitude of return pulses as they are reflected back to the LiDAR system. The intensity image is useful for delineating water surfaces as this yields a low return value (black). Higher return values (white) within the active channel are indicative of shallow areas (e.g. riffles). An example intensity grid is shown in Figure 7.

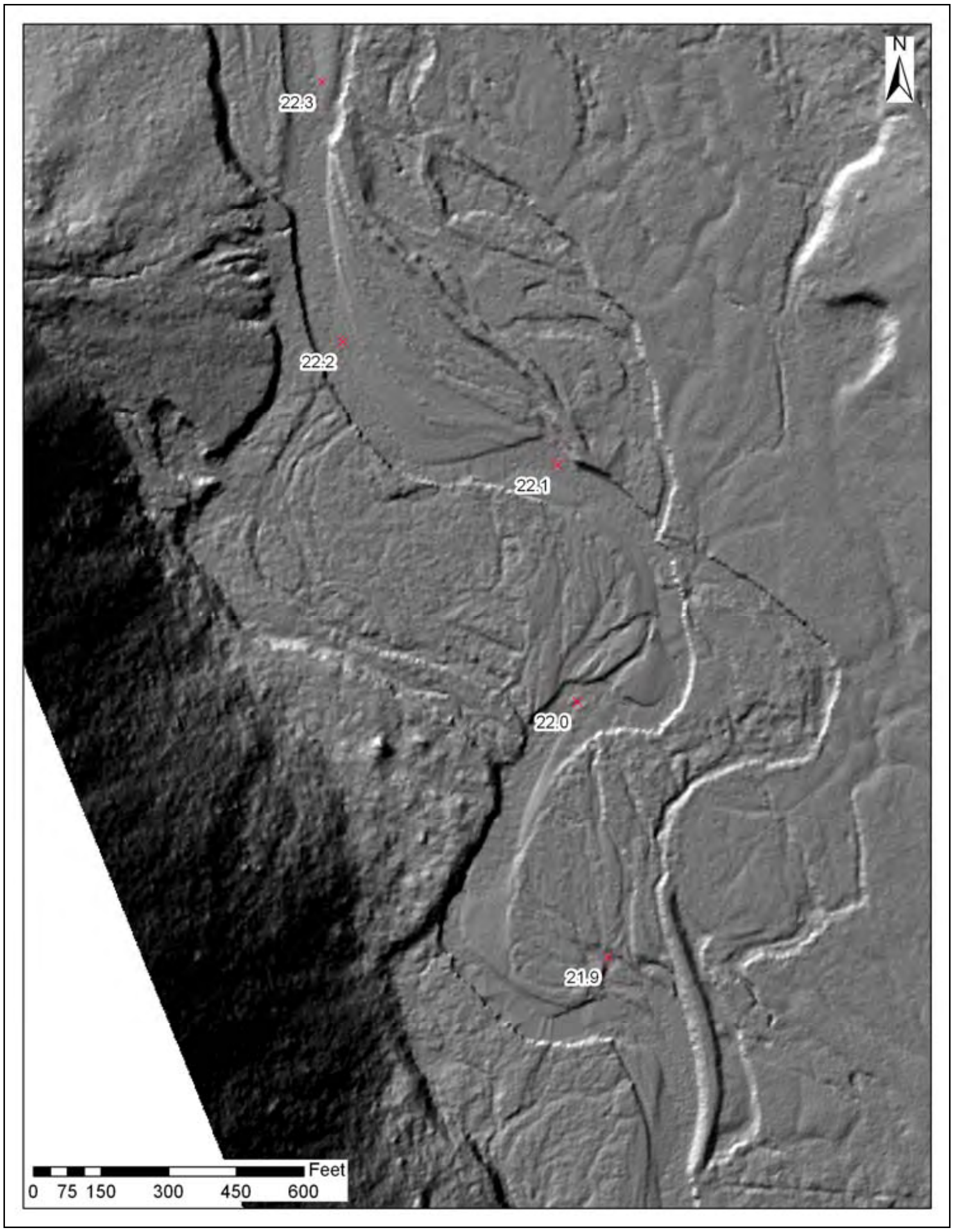


Figure 6. Example of LiDAR generated hillshade. (Note levees from RM 21.8-21.9 and 22.1-22.3 on river left.)

Figure 7. Example of LiDAR generated intensity image.

Survey Data

Channel bottom elevations for the wetted portion of the channel (bathymetry) were surveyed separately using Trimble Real Time Kinematic (RTK) Global Positioning System (GPS) equipment. This effort was conducted from October 12-15, 2008, when the average daily flows were approximately 70 cfs at the Dill Creek station. Horizontal and vertical control was obtained from a National Geodetic Survey (NGS) control point. Because the vertical control was third order, Online Positioning User Service (OPUS) solution reports were generated for each day of data collection and used to shift the data accordingly. Approximately 1,300 survey points were collected. An example area showing the collected survey data can be seen in Figure 8. To further enhance the definition of the wetted portion of the channel, a splining interpolation routine on a 5-foot grid spacing using delineated low flow channel boundary lines as a barrier was applied to the survey points. This method was chosen because it can predict highs and lows by allowing the interpolation to pass through the data set, which was envisioned to help better capture some of the deeper scour holes that weren't able to be surveyed.

Figure 8. Example of on-the-ground survey data collected October 12-15, 2008.

The survey effort was focused solely on the main channel thread. However, there is one significant side channel in this reach that starts at RM 21.7 on river right and re-enters the main channel at RM 21.35 that was wet during the LiDAR flight and not surveyed. This side channel, which cuts off a large meander bend, flows perennially with a main channel transverse riffle at the entrance. This feature is large (and deep) enough (see Figure 9) to try and better represent the channel bottom and connectivity to the main river in the model surface as opposed to solely using LiDAR data for this representation. Therefore, this channels margins (banks) were delineated separately from the main channel and the elevation of the bare earth LiDAR points that fell within this delineation were shifted to represent the channel bottom. The shift was based on field observations; walking the side channel and roughly observing channel depths.

Figure 9. Side channel roughly parallel to RM 21.5 (looking downstream).

Although bathymetric data were collected, the model was not intended to fully represent low flow conditions. Additional bathymetric data would be needed to more accurately represent the localized hydraulic conditions that exist at low flow. Refinement of the model mesh (see ‘Model Mesh’) may also be necessary.

By combining the bare earth LiDAR, survey, and interpolated data within the wetted portions of the channel, a TIN was created to represent the terrain of the Preston Reach. An example of the model surface is shown in Figure 10.

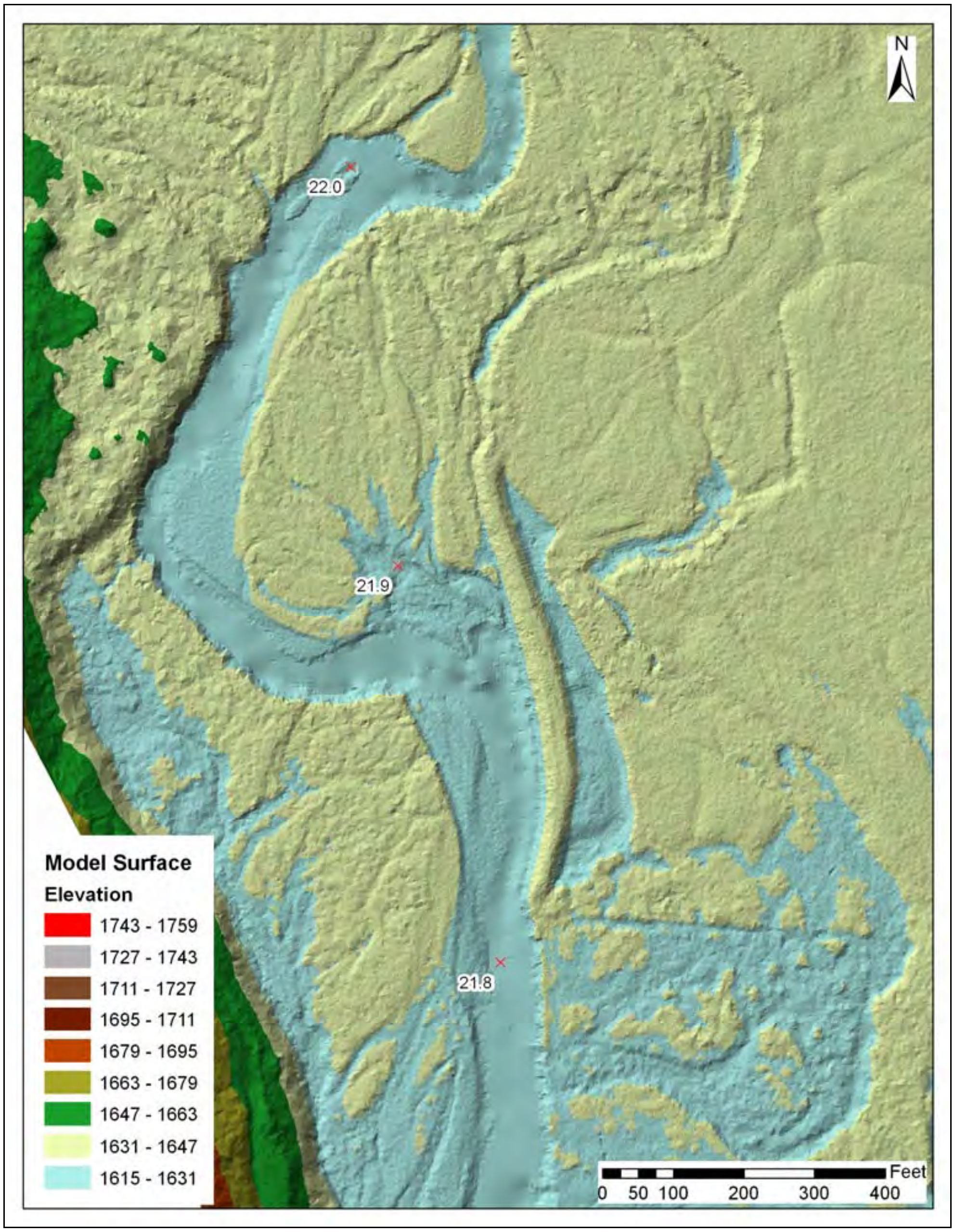


Figure 10. Example of the surface used as input for the hydraulic model. (Elevations are in feet).

Model Mesh

A computational mesh was constructed using Surface-water Modeling System (SMS) software. The mesh is comprised of quadrilateral and arbitrarily shaped triangular elements. Elevation data are stored at each mesh node and roughness data at each mesh element (see next section 'Material Types' for more roughness parameter information). The element size of the mesh varies based on location. Within the active channel elements were limited to approximately 5-10 feet in the lateral (cross stream) direction and approximately 10-15 feet in the longitudinal (downstream) direction. The shorter dimension in the lateral direction is used to capture the more rapidly changing topography transverse to the stream flow with respect to horizontal distance. Elements in the overbank areas were limited to approximately 20-25 feet in both directions. The use of an unstructured hybrid mixed element mesh allows for maximizing model computation efficiency by minimizing the number of elements to balance run time with model resolution. Approximately 120,000 elements were used to represent the Preston Reach. An example of the model mesh is shown in Figure 11.

Figure 11. Example of model mesh in SMS. Colors represent various material types (dark blue = active channel, light blue = high flow bar, yellow = sparse vegetation, red = dense vegetation, green = cleared, black = road).

Material Types

The modeled area for Preston Reach was broken into six distinct roughness zones based on material type and land cover. These include 1) active channel, 2) high flow bars, 3) cleared (open) areas/grasses, 4) sparse vegetation, 5) dense vegetation, and 6) roads. The corresponding material type roughness values used in the model are shown in Table 2. Roughness zones were spatially delineated using the 2006 aerial photography in combination with the LiDAR topography data. Roughness zone delineation for the Preston Reach is shown in Figure 12.

Table 2. Material type roughness values used in the model.

Run ID*	Channel	High Flow Bar	Clearing	Sparse Veg.	Dense Veg.	Road
1	0.035	0.040	0.025	0.045	0.065	0.020
2	0.033	0.040	0.025	0.045	0.065	0.020
3	0.030	0.040	0.025	0.045	0.065	0.020

1: low flow
2: 2/10 year flow
3: 50/100 year flow

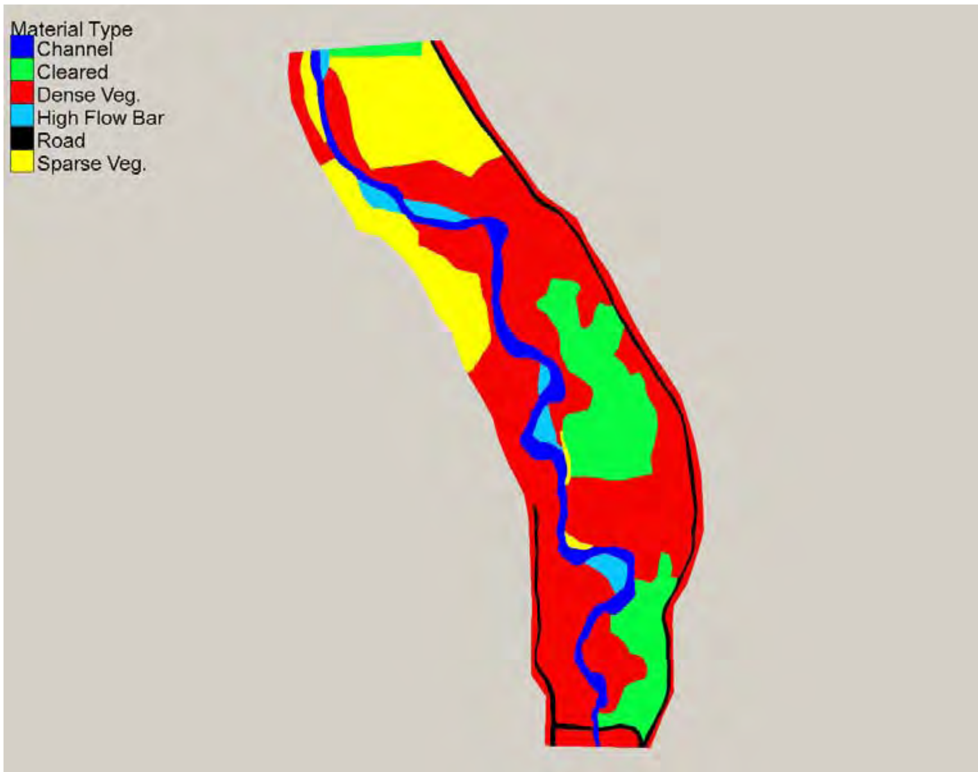


Figure 12. Material type distribution for Preston Reach.

Boundary Conditions

Upstream Boundary Condition

A flood frequency hydrologic analysis was performed on the lower 32 miles of the Entiat River as part of the TA work (Bountry et al. 2009). This analysis was performed using data from the two USGS gages on the main stem Entiat (Keystone and Ardenvoir). Because flooding in this basin occurs as a result of spring snow-melt, peak discharge is a function of both the contributing drainage area and elevation. By minimizing the sum of the squared residuals, a regression equation was generated that compared peak discharges and contributing drainage areas. Using this equation, flood frequency discharges were computed at each river mile. River mile 22 was selected as being representative for the Preston Reach. Resultant flood frequency estimates at RM 22 are shown in Table 3. Gains or losses due to groundwater exchange were not accounted for throughout the reach.

Table 3. Flood frequency discharge estimates (cfs) at RM 22.

Q2	Q5	Q10	Q25	Q50	Q100
2620	3590	4220	5010	5600	6180

Downstream Boundary Condition

A one-dimensional (1D) HEC-RAS hydraulic model was developed for the lower 26 miles of the Entiat River as part of the TA. A total of 795 cross sections spaced approximately 150 feet apart were used to represent the model geometry, which was based solely on the LiDAR data. Results from this effort were used in determining the water surface elevation at the downstream boundary of the 2D hydraulic model that was used as the boundary condition. Considering the 1D model didn't take into account the channel bottom, local bathymetric survey data collected near the downstream boundary was utilized to shift the water surface elevations accordingly. Resultant water surface elevations used for the downstream boundary condition are shown in Table 4.

Table 4. Water surface elevations at RM 21.1.

Flow Freq.	Q (cfs)	WSE (feet)	WSE_shift (feet)
Q2	2620	1623.25	1621.75
Q10	4220	1624.88	1623.38
Q50	5600	1626.04	1624.54
Q100	6180	1626.45	1624.95
low flow	70	1618.3	1616.8
high flow	3640	1624.35	1622.85

Monitoring points and lines were strategically located throughout the model mesh to monitor flow continuity as well as to examine hydraulic properties at specific locations of interest (i.e. side channel entrances). SRH-2D was set to a 1 second time step for a total simulation duration of 120 hours (5 days). At simulation's end, the water surface elevation at each of the monitoring points reached a constant value and the monitoring lines indicated a conservation of mass. Using these settings with the developed mesh resulted in a total computation time of approximately 72 hours (3 days).

Model Scenarios

Numerical simulations were conducted on surficial geometry representing the existing conditions for the 2- through 100-year recurrence interval discharges (in addition to a low and high flow event for calibration purposes) with inlet flows ranging from 70 to nearly 6,200 cfs. An additional TIN was generated for a "proposed" condition that examined how the solved hydraulic properties change following a specified restoration action. The proposed restoration action lowered the existing two levees (RM 21.8-21.9 and RM 22.1-22.3, both on river left) to the surrounding floodplain elevation (see Figure 13). Figures 14 and 15 show an example model surface for the existing and proposed conditions, respectively.

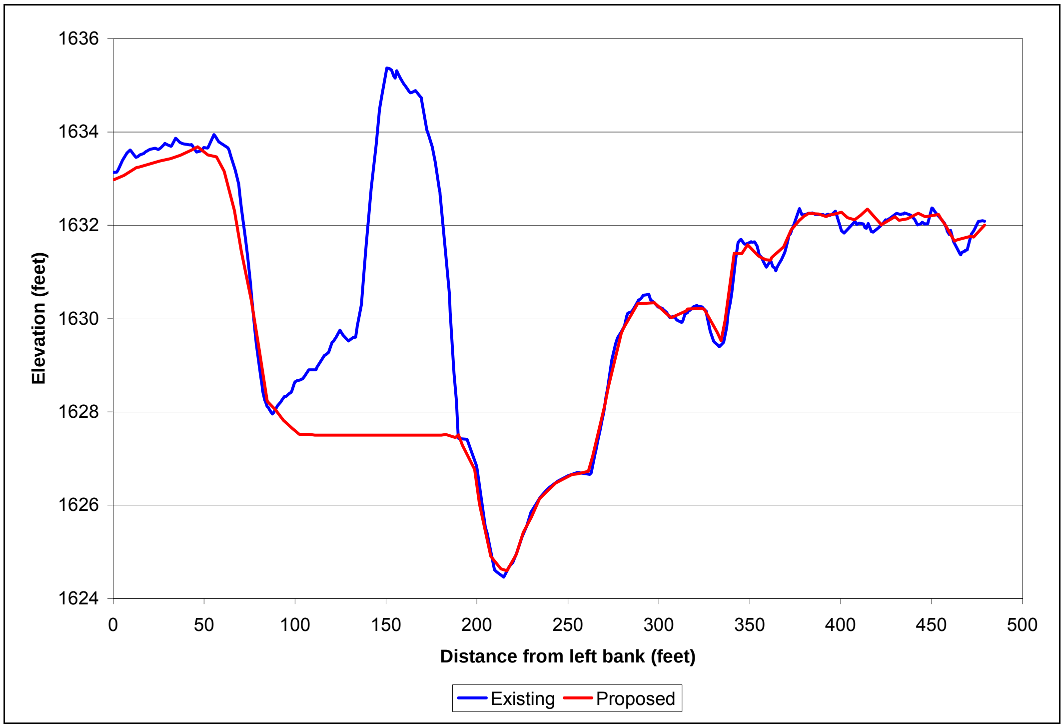


Figure 13. Existing versus proposed cross section profile at RM 21.85 showing levee removal.

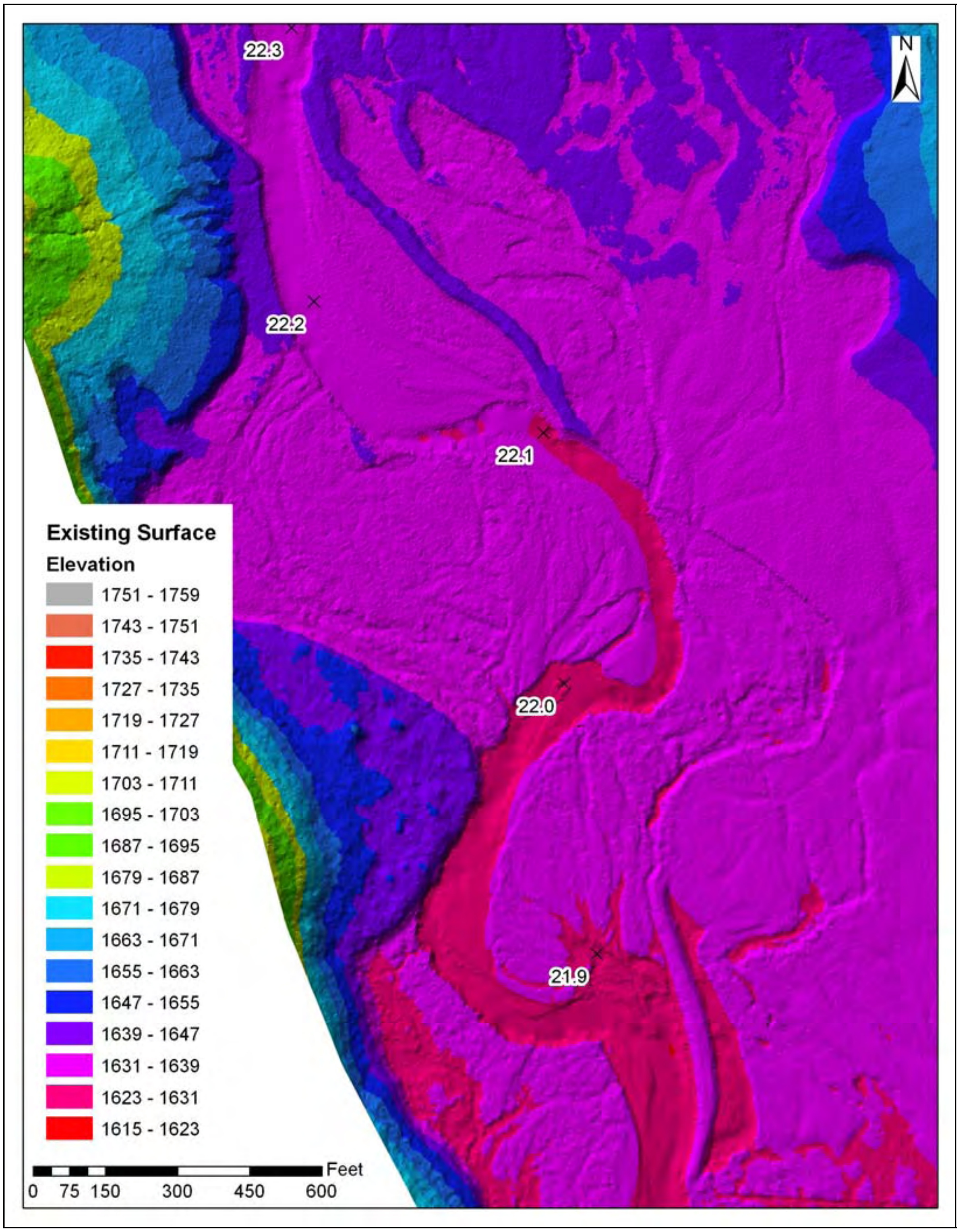


Figure 14. Example of model surface representing existing conditions. (Elevation values are in feet).

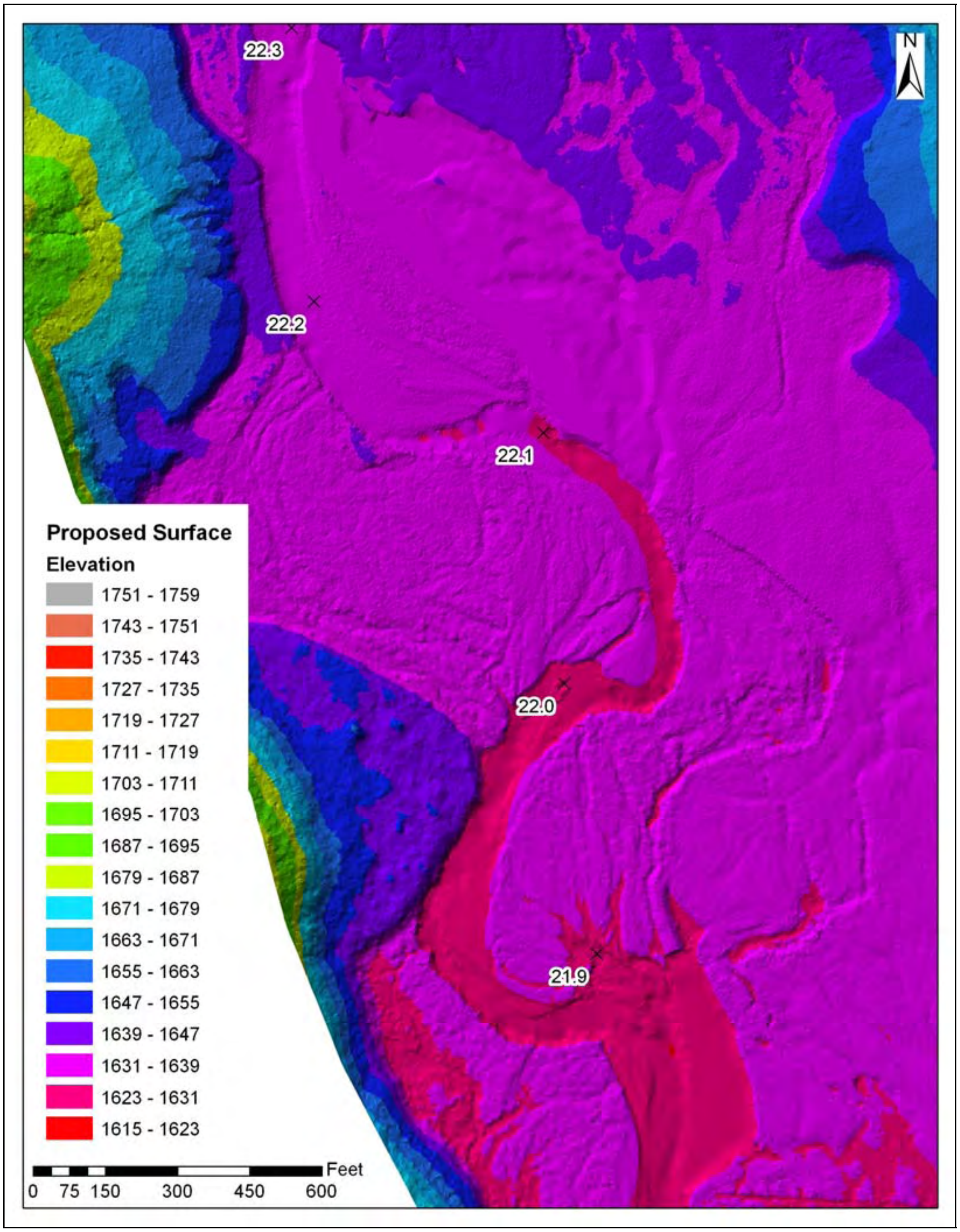


Figure 15. Example of model surface representing proposed conditions. (Elevation values are in feet).

Model Calibration

Low Flow

Roughness and interpolated topography (see 'Model Surface Geometry') are the two main input variables used in the calibration of the 2D model. Roughness values can vary depending on the discharge being modeled. Lower flows typically have higher roughness values because the channel bed grain size and vegetation presence have more influence on hydraulics when the water depths are small. Even though the collected survey data was not intended to capture enough of the channel bed intricacies to accurately model low flows, water surface elevations at various locations along the reach were surveyed at the time of data collection for purposes of model calibration (see Table 5). Various roughness coefficients were used to most closely match the collected water surface elevations for the low flow condition that existed at the time of the survey (70 cfs; Dill Creek Station). This effort resulted in a Manning's roughness coefficient of 0.035. This value of Manning's n is appropriate for the Entiat River. It is worth noting that the 1D HEC-RAS model done for the TA used a roughness value of 0.045. Roughness values in a 2D model are often lower than those in a 1D model because the 2D model solves for eddy losses independently, as opposed to these losses being lumped into the roughness value or expansion/contraction loss coefficients. The difference in roughness values can also be explained by the scale of the two studies. The TA evaluated the channel at a much coarser scale and thus tended to lump various parameters together for greater efficiency.

Table 5. Surveyed water surface elevations for Preston Reach. (Elevation values shown are shifted according to OPUS reports).

RM	X (feet)	Y (feet)	Z (feet)
22.45	1740074.40	318950.21	1640.80
21.95	1740540.66	316561.29	1629.79
21.65	1741042.80	314918.08	1625.80
21.60	1741319.92	314975.71	1624.20
21.55	1741665.00	314953.16	1622.87
21.49	1741758.88	314618.71	1622.80
21.45	1741642.05	314377.58	1622.14
21.40	1741296.65	314206.83	1621.62
21.25	1741223.76	313420.15	1620.23
21.18	1741431.44	313133.70	1618.44
21.12	1741315.12	312849.77	1618.51

Spring 2006 High Flow

No surveyed water surface elevations or high water marks were available at higher flows for which to calibrate the model. Instead, higher flows were qualitatively validated by comparing them to discharge patterns visible in ground photographs taken on May 19, 2006. The mean daily flow on this date, according to the Dill Creek Station, was 3,270 cfs, which turned out to be a high flow for that year (see Figure 16). However, this value was above the stations rating curve, and was therefore extrapolated. A more accurate discharge value was obtained from the USGS Ardenvoir Gage (#12452800) at RM 18, which not only has a longer period of record, but was also used in the flood frequency analysis for the TA. This gage yielded a mean daily flow value of 3,720 cfs on this day, which roughly corresponds to a 5-year event recurrence. Using trend results from the flood frequency analysis, a value of 3,640 cfs was approximated at RM 21.5 (the location of the ground photograph). At this discharge, the roughness was decreased to reflect a more appropriate value for a high discharge and model results predicted similar flow patterns evidenced during the observed discharge. The lower Manning's roughness value is 0.033. Figures 17-18 and 19 show the ground photographs and corresponding modeled flow depths, respectively.

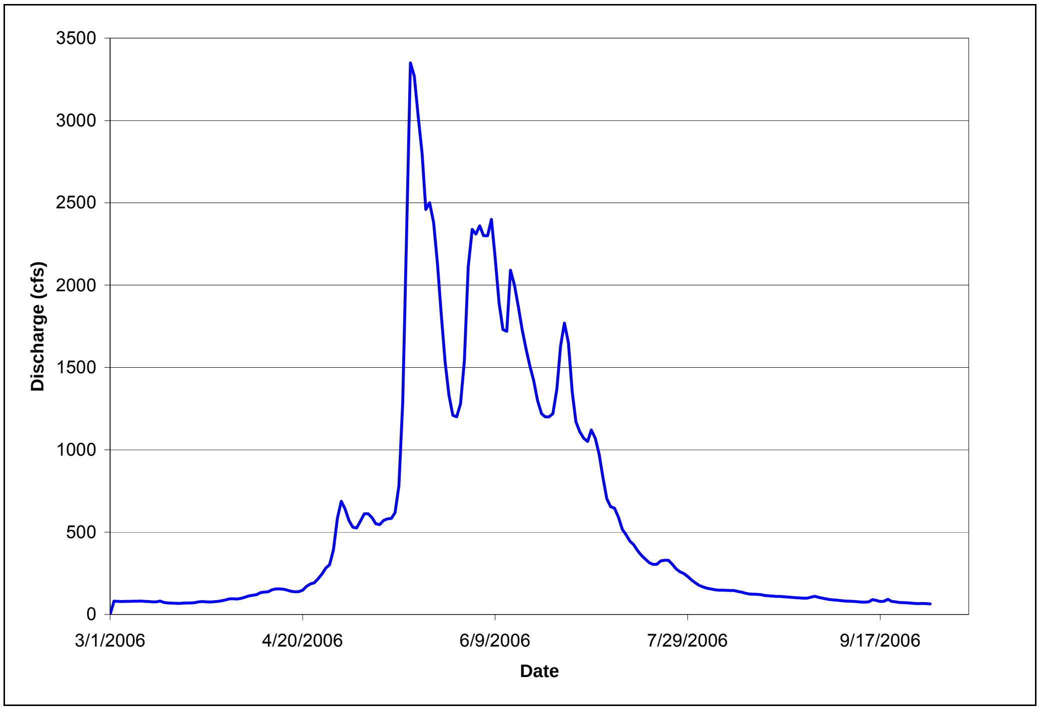


Figure 16. 2006 spring hydrograph at Dill Creek Station.

Figure 17. Ground photograph #1 at RM 21.5 (looking downstream) during spring high flow event (5/19/06).

Figure 18. Ground photograph #2 at RM 21.4 (looking upstream) during spring high flow event (5/19/06).

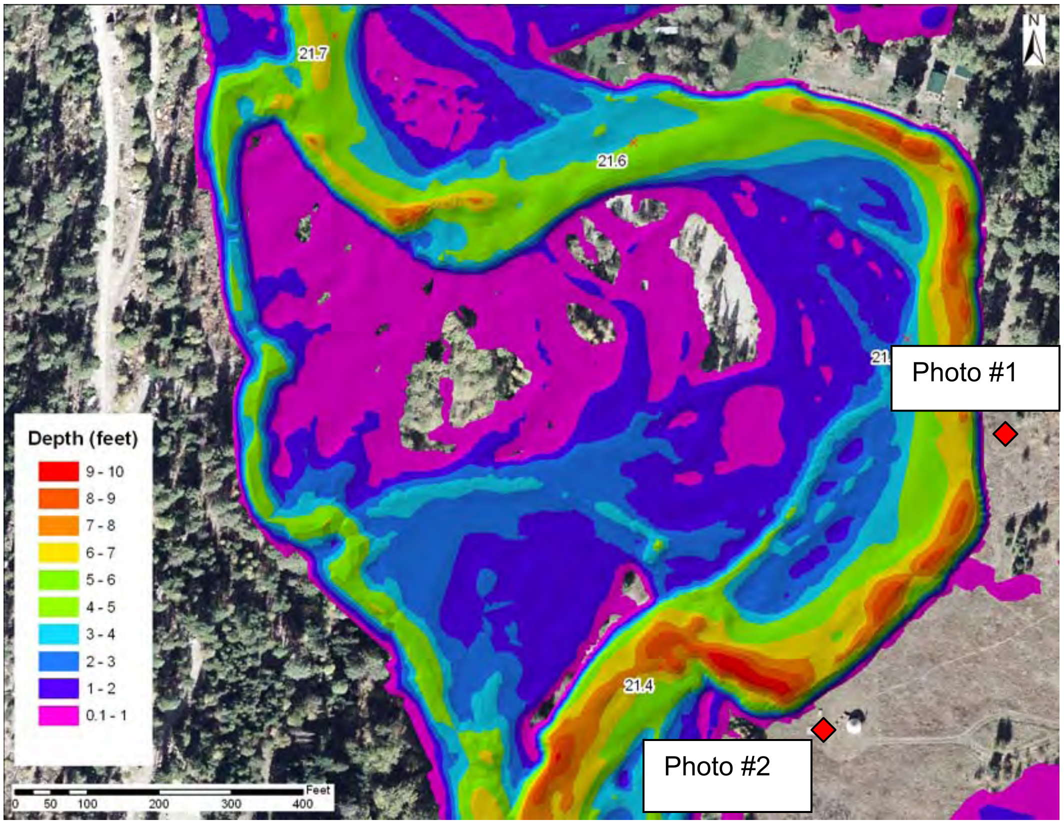


Figure 19. Modeled flow depths at RM 21.5 for spring high flow event (5/19/06).

Model Results

Centerline Profile

A centerline profile of Preston Reach was created in order to extract data such as bed and water surface elevations using the developed surface geometry and model results (see 'Model Surface Geometry'). This profile, shown in Figure 20, shows the variability in the channel bed as well as a trending decrease in the bed slope in the downstream direction. This slope decrease would also indicate a decreasing trend in the total stream power (QS), which is a measure of a river's transport ability.

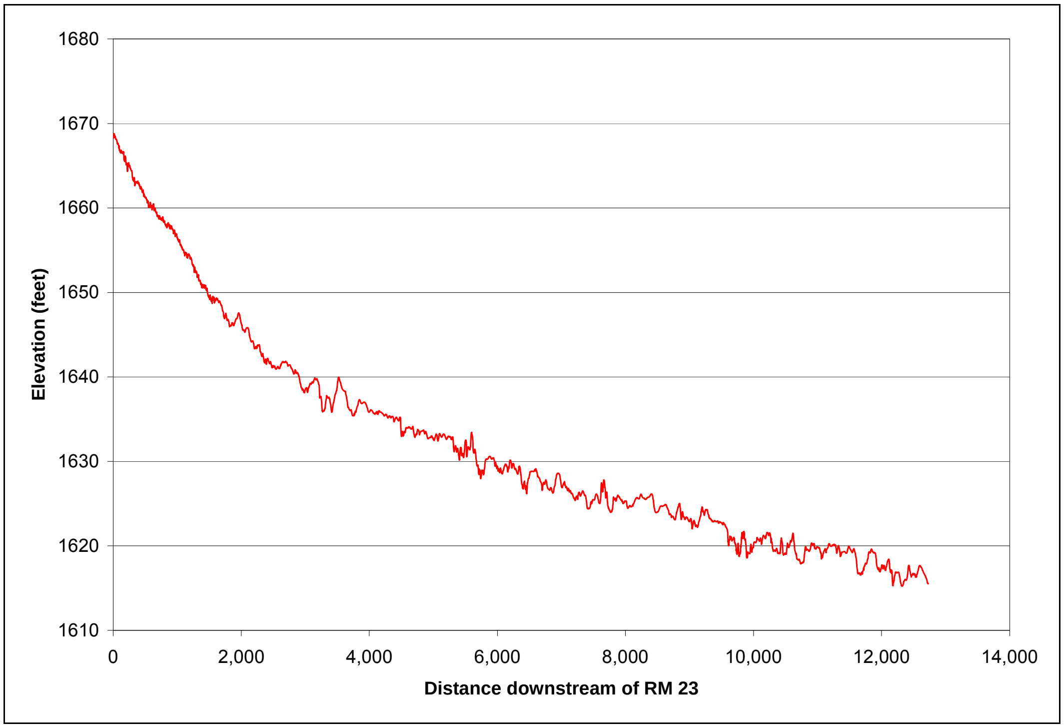


Figure 20. Centerline bed surface profile for the Preston Reach.

Water Surface Elevation Profiles

Profiles of the water surface elevation for the 2-year flow event were developed for both the existing and proposed conditions. As expected, the most significant reduction in water surface elevation occurred at the two levee locations (RM 21.8-21.9 and 22.1-22.3), where decreases of up to 0.5 feet were predicted. The changes appear to be fairly localized, not persisting very far upstream and downstream of the levees. Figure 21 shows a portion of the 2-year water surface elevation profile along with the general locations of both levees. There was no difference between the two (existing and proposed) profiles outside of the extent shown in the figure.

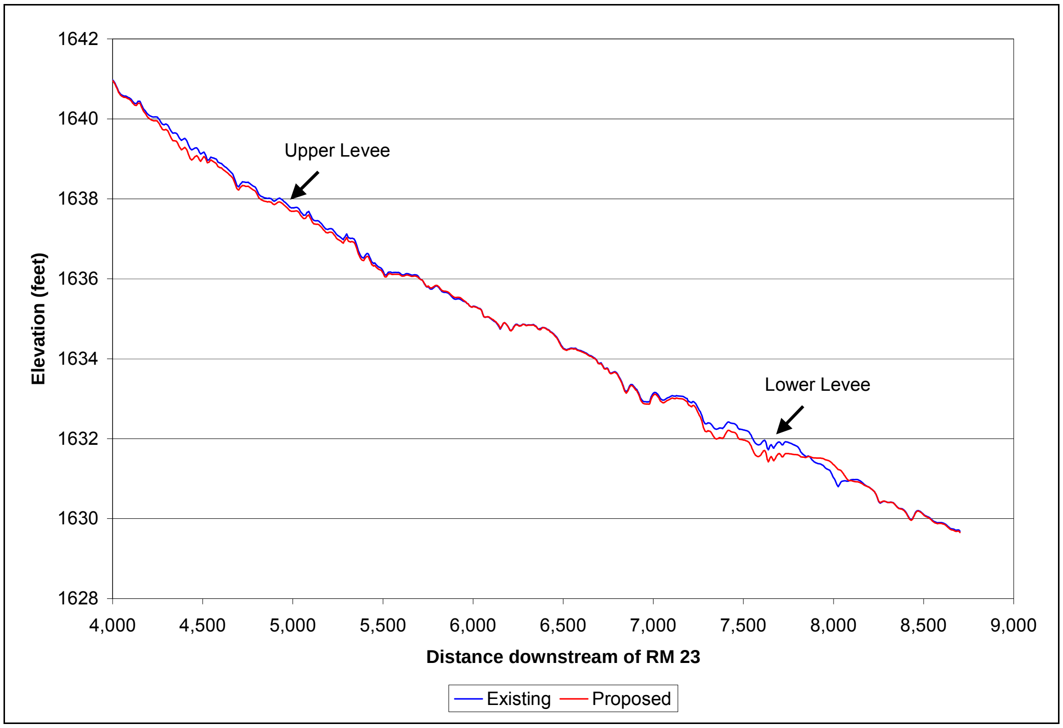


Figure 21. 2-year (2,620 cfs) water surface elevation profiles for the existing and proposed conditions.

Hydraulic Parameters

Restoration of lateral connectivity is a high priority for the Preston Reach. Therefore, the spatial distributions of certain hydraulic parameters (flow depth, bed shear stress, and depth-averaged velocity) were examined at various flow events to determine differences between existing and proposed conditions. This was accomplished using TIN surfaces generated in GIS for both conditions. Spatial distributions provide a means by which to demonstrate changes in the hydraulic properties (where and how they increase or decrease from one scenario to the next). The location and magnitude of the differences between the existing and proposed conditions were determined by differencing the TIN's representing specific hydraulic parameter for each condition. The following sections show some of these modeled results for flow depth, depth-averaged velocity, and bed shear stress around the vicinity of the proposed actions (levee removals).

Flow Depth

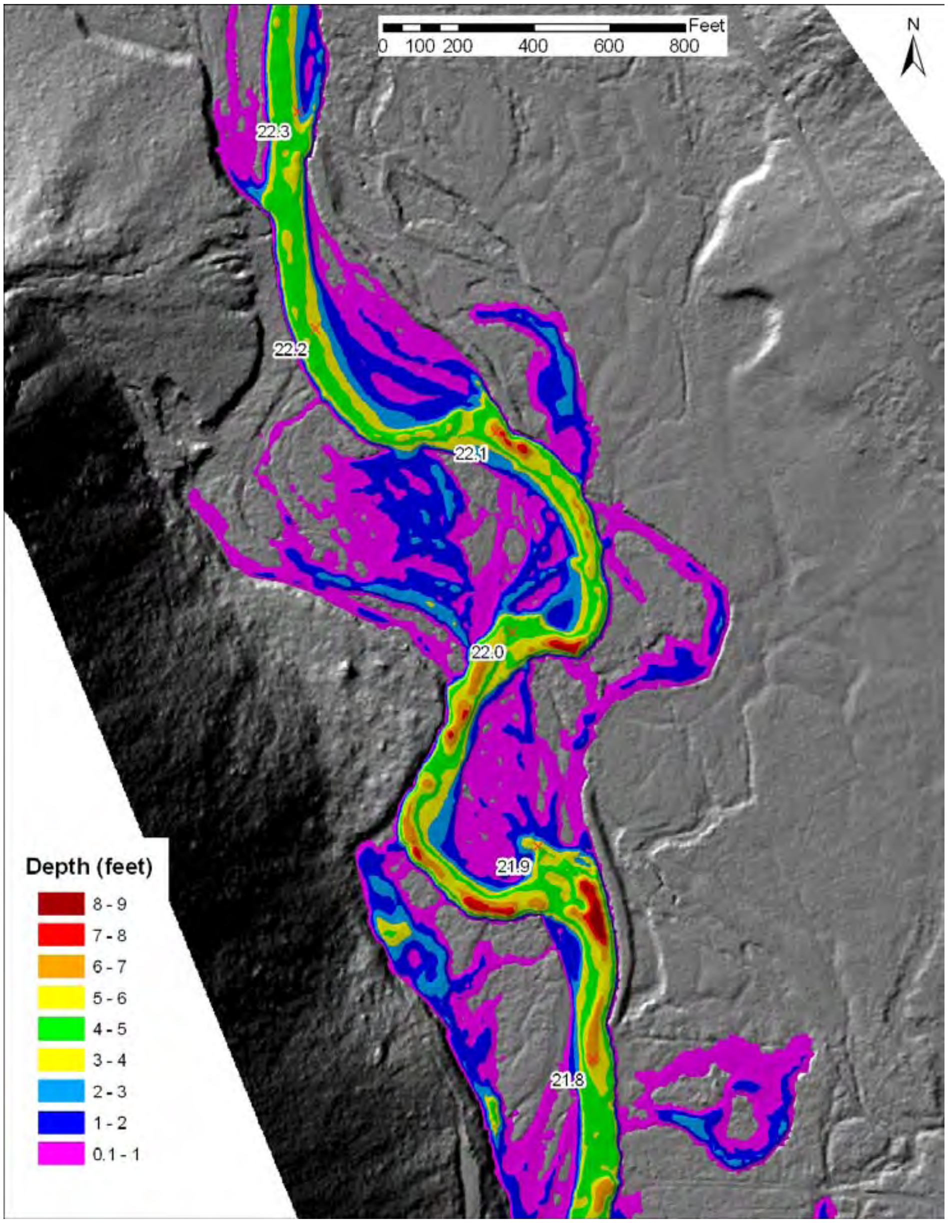


Figure 22. Model results showing modeled depths for 2-year peak discharge under existing conditions.

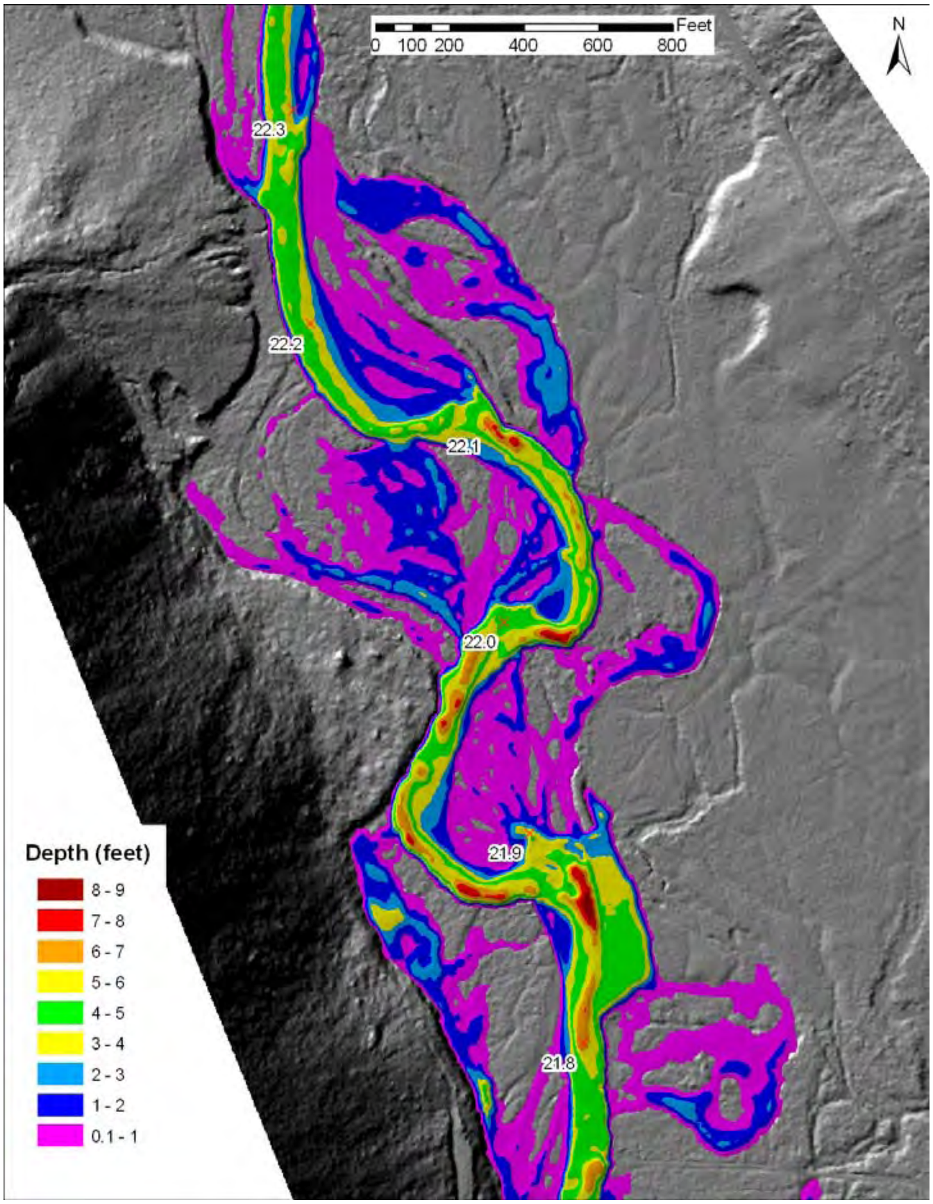


Figure 23. Model results showing modeled depths for 2-year peak discharge under proposed conditions.

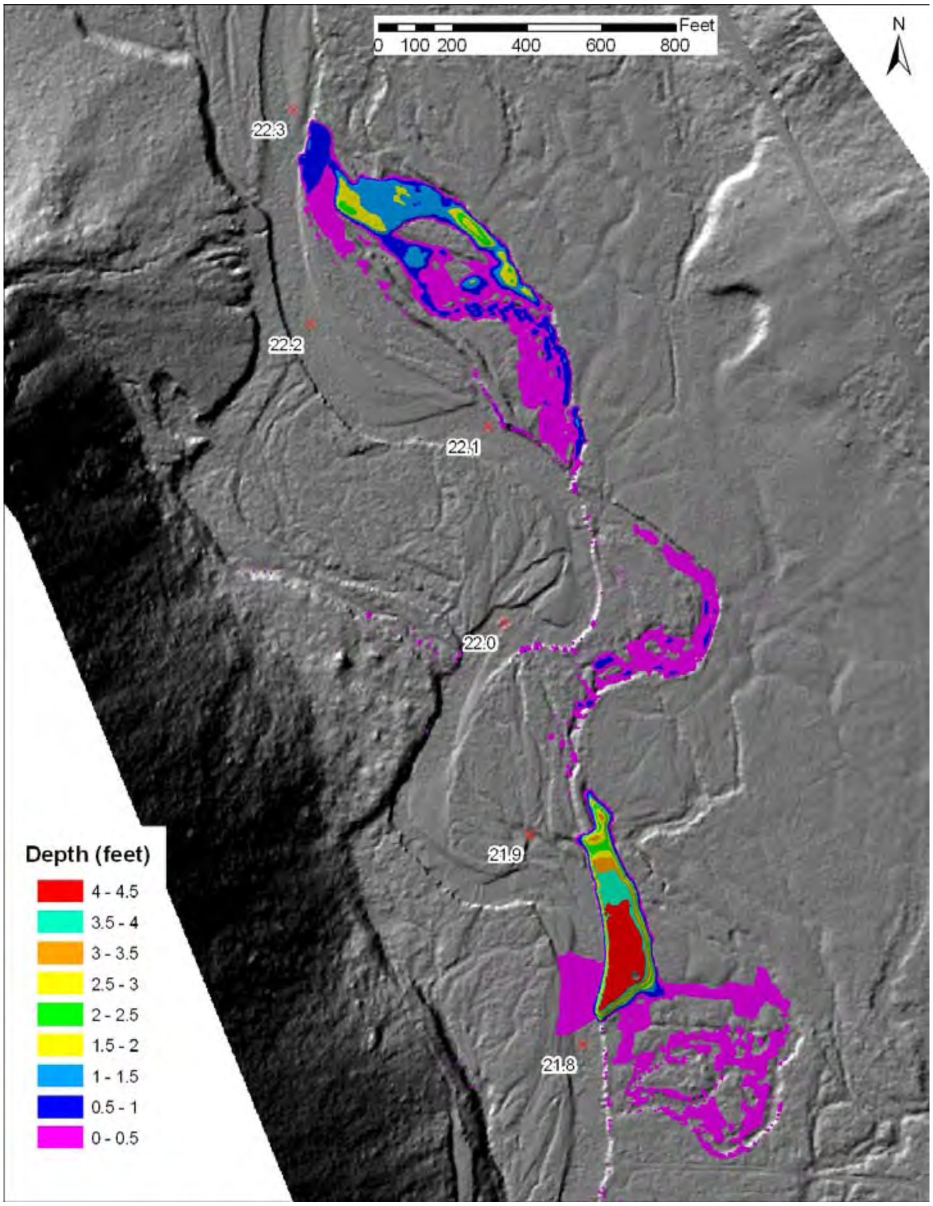


Figure 24. Differences in flow depths for the 2-year peak discharge between the existing and proposed conditions.

Velocity

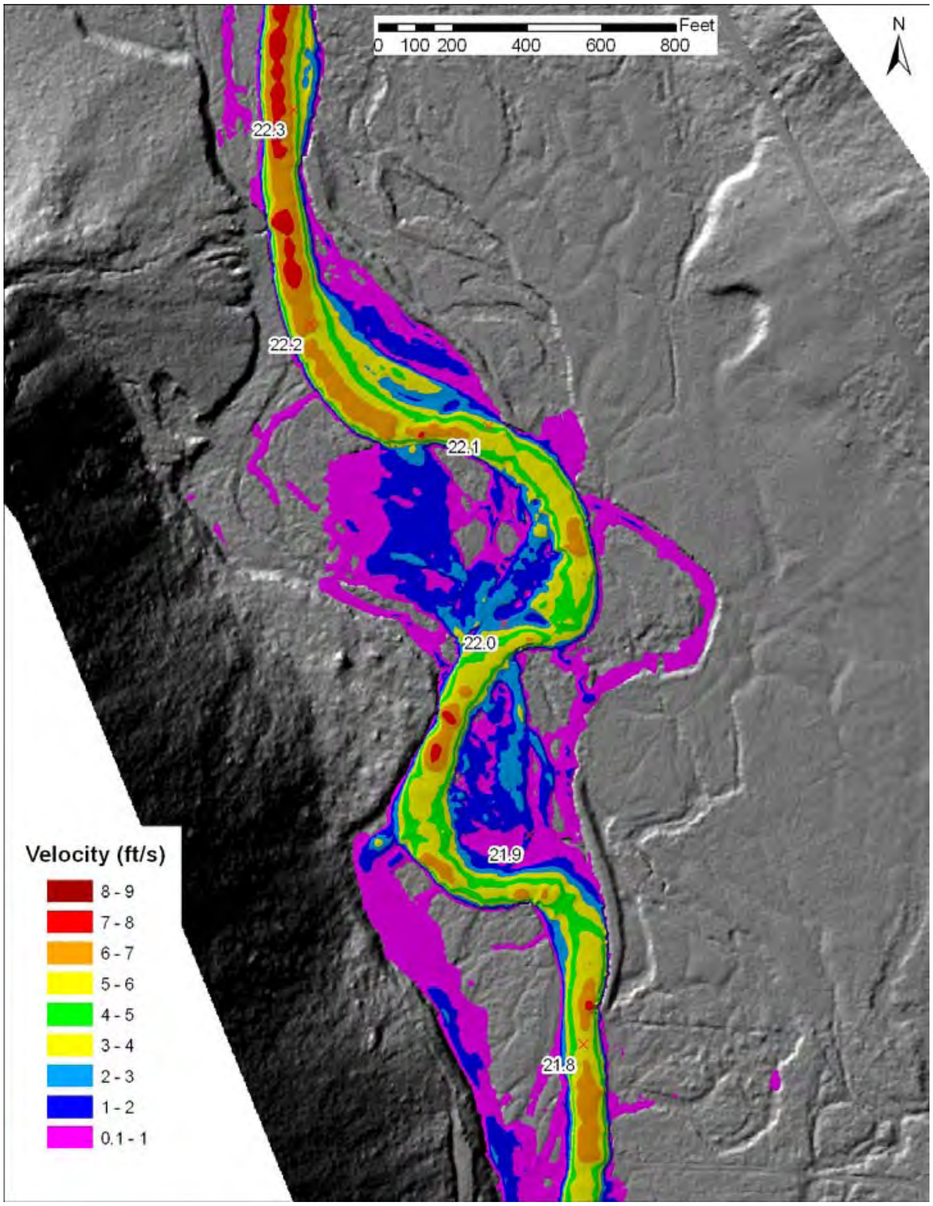


Figure 25. Model results showing velocity magnitude for 2-year peak discharge under existing conditions.

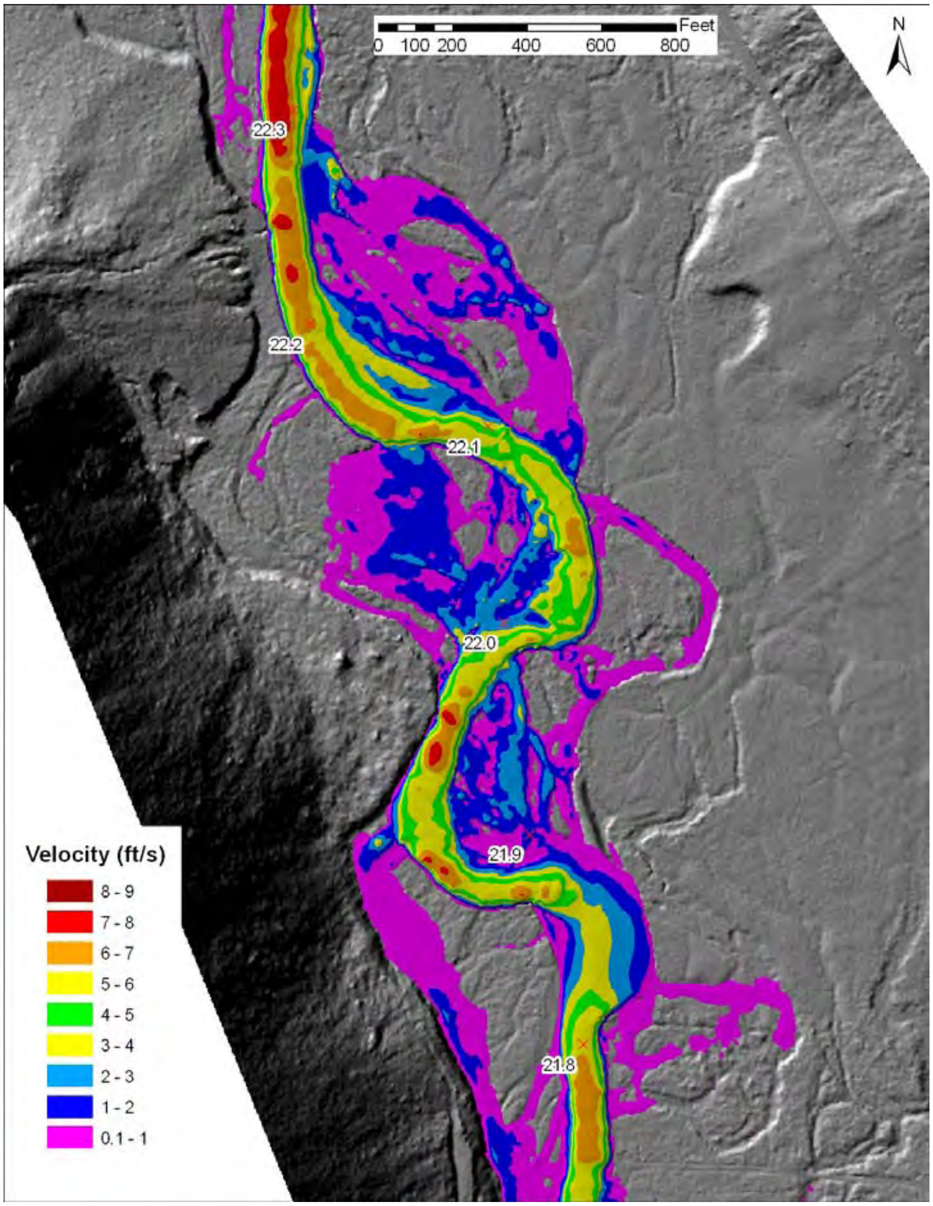


Figure 26. Model results showing velocity magnitude for 2-year peak discharge under proposed conditions.

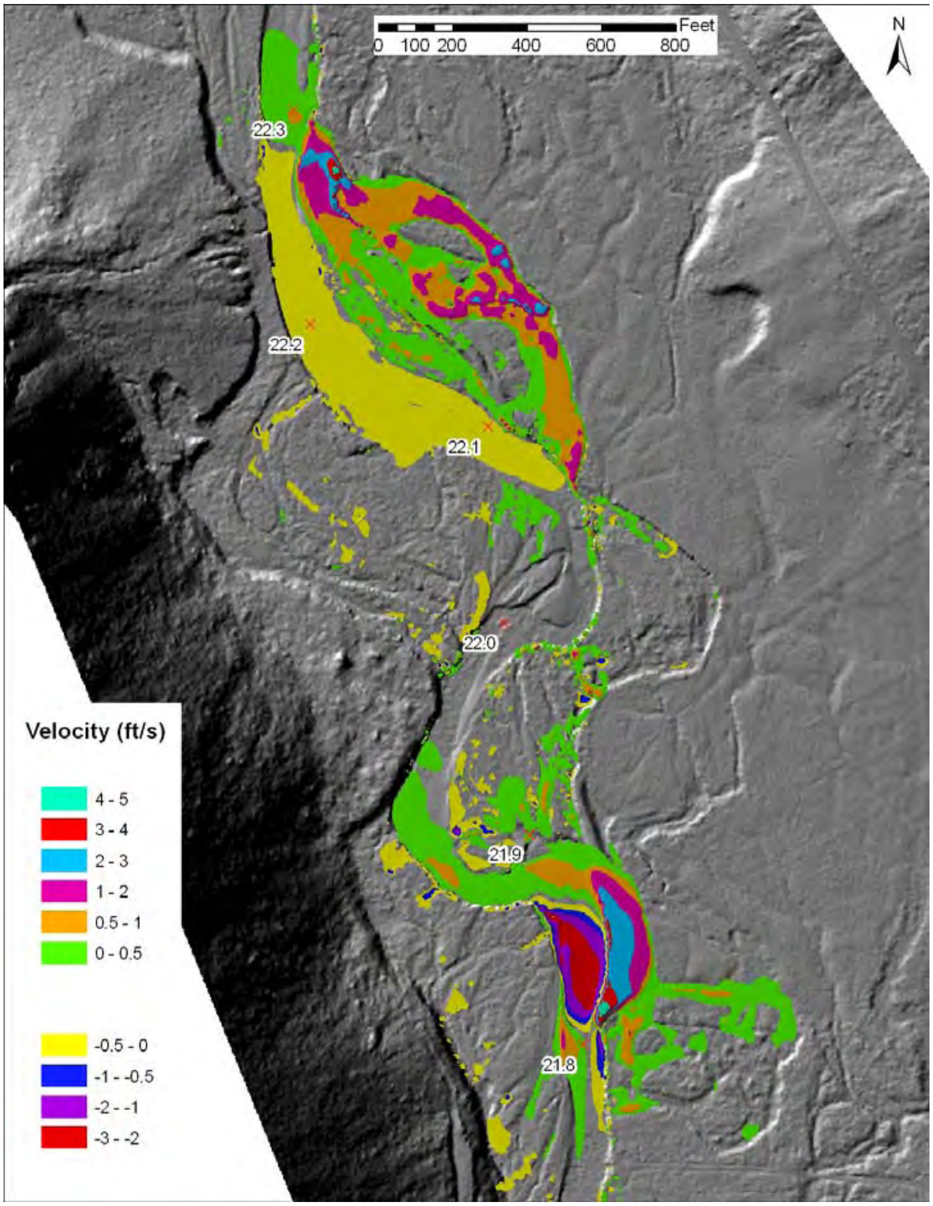


Figure 27. Differences in velocity magnitude for the 2-year peak discharge between the existing and proposed conditions. (Negative values indicate a decrease from the existing condition).

Shear Stress

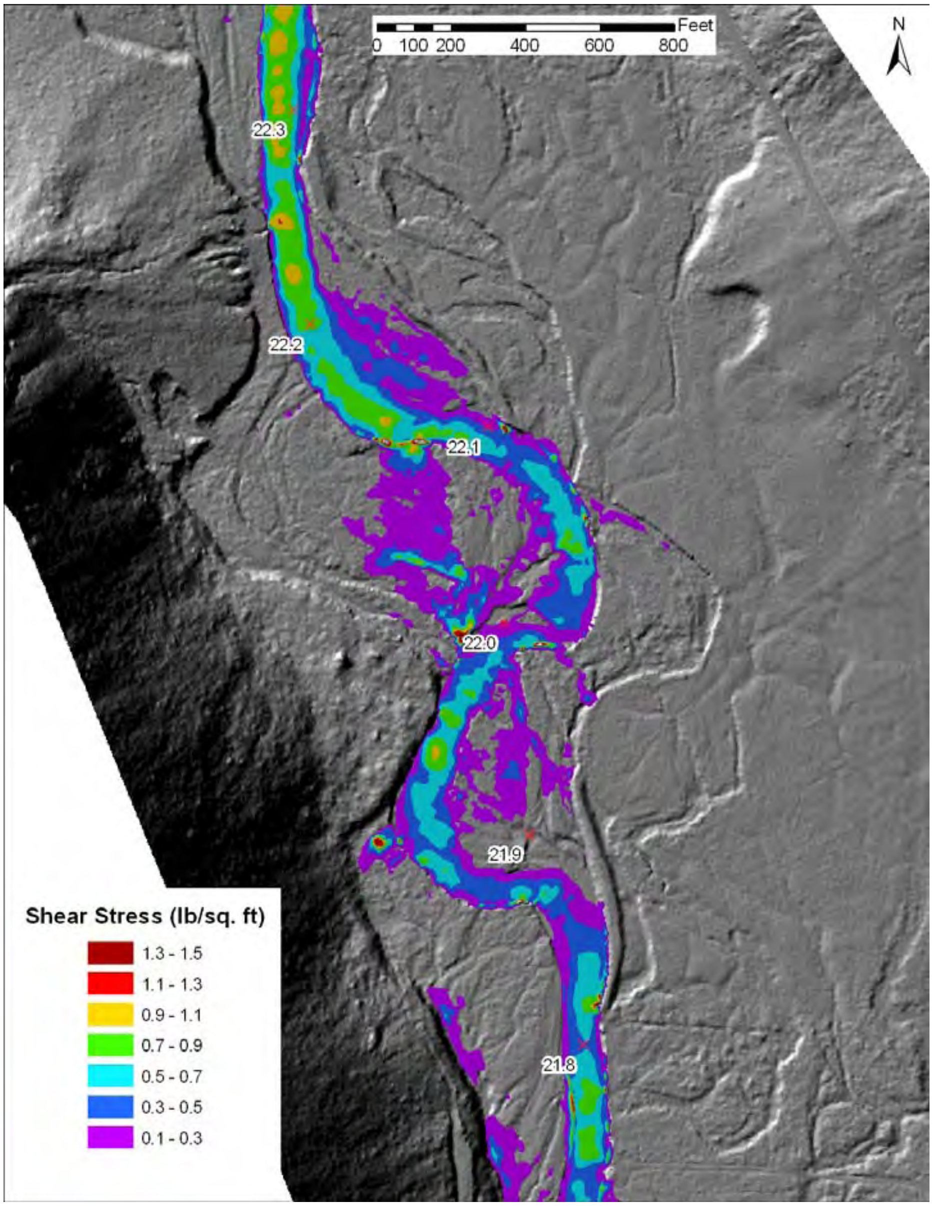


Figure 28. Model results showing shear stress for 2-year peak discharge under existing conditions.

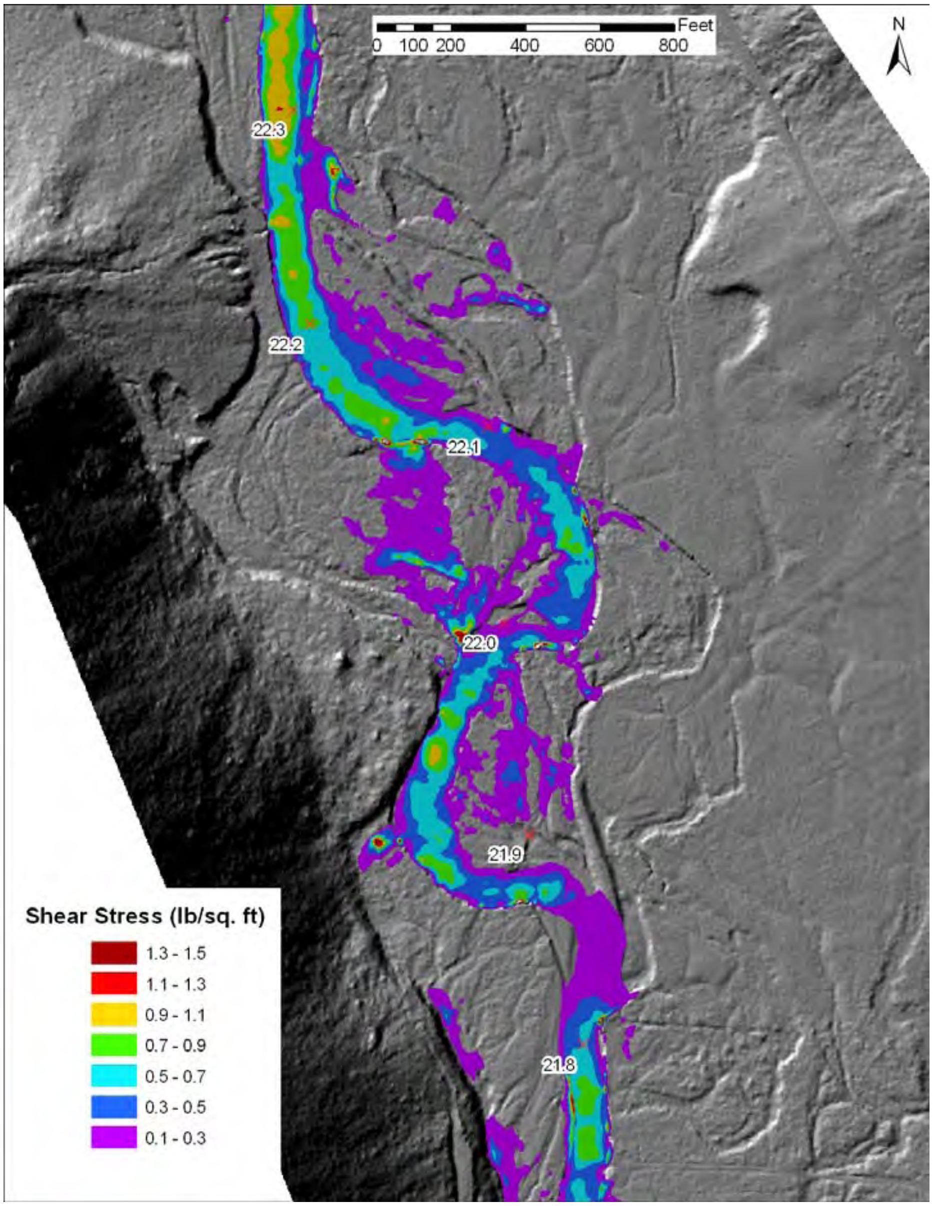


Figure 29. Model results showing shear stress for 2-year peak discharge under proposed conditions.

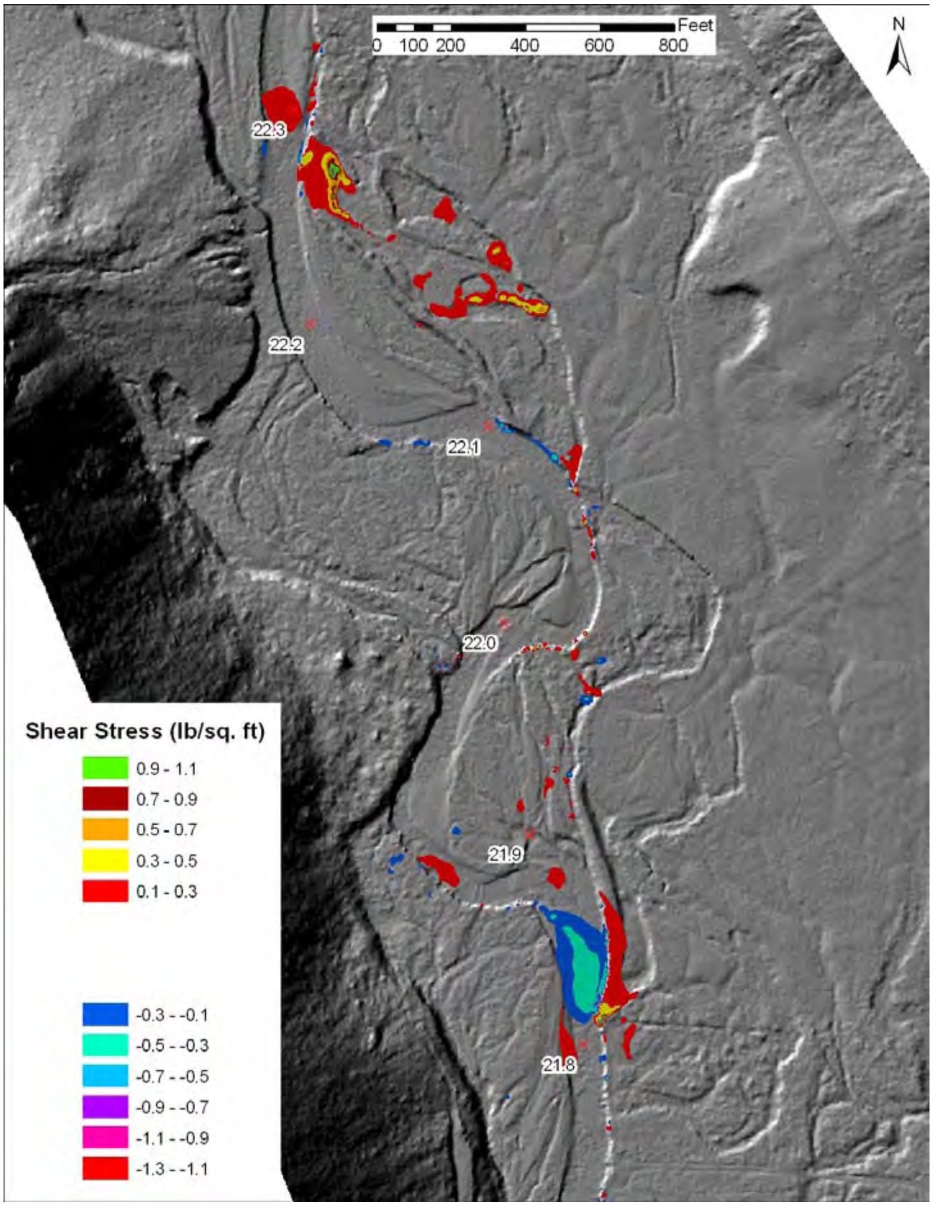


Figure 30. Differences in shear stress for the 2-year peak discharge between the existing and proposed conditions. (Negative values indicate a decrease from the existing condition).

Linking Model Results to Field Mapping

Channel Units

An additional aspect of this assessment effort included a field mapping of channel units performed by Lyon, 2009. A channel unit is a morphologically distinct area within a geomorphic reach that is typically less than several channel widths in length (Montgomery and Bolton 2003). They generally correspond to different habitat types including pools, riffles, runs, glides, bars, steps, cascades, etc. Biologists often use channel units to partition sample variance along a river, using stratified sampling procedures assuming that physical conditions within the channel units and differences between them will be reasonably consistent (Jowett 1993).

Defining a channel unit based on certain flow properties such as water depths and velocities or surface characteristics is useful as it describes an aspect of those physical conditions. However, subjective definitions can introduce unintended variation. Past studies have looked at distinguishing among different channel units using various quantifiable hydraulic parameters in an effort to reduce subjectivity by identifying a set of classification criteria. One such hydraulic parameter is the Froude number.

Because of the free water surface, gravity is the driving force in open channel flow. The Froude number (F_r), which is one of the most important governing dimensionless parameters in open channel flow, is the ratio of inertial to gravitational forces as defined by the following:

$$F_r = \frac{V}{\sqrt{gh}}$$

where: V = depth-averaged velocity
g = gravitational acceleration (constant)
h = flow depth

Henderson (1966) described the Froude number as a “universal indicator of the state of affairs in free surface flow.” Although typically used to distinguish among flow regimes (subcritical/tranquil flow versus supercritical/rapid flow), it has also been recognized as a criterion to distinguish between pools and riffles (Wolman 1955). More recently Hilldale and Mooney (2007) identified pool, run, and riffle habitat types on rivers in the Pacific Northwest using the Froude number as the indicator. The break in habitat Froude classification was set to match field surveys of identified habitat types. Results were found to be similar with previous studies. The following Froude number values were used for channel unit determination:

Fr < 0.1 → pool
0.1 ≤ Fr ≤ 0.42 → run
Fr > 0.42 → riffle

Figures 31 and 32 shows an example area of the channel unit field mapping as compared to the stratified Froude number results from a low flow (70 cfs) hydraulic model simulation using the above break down, respectively.

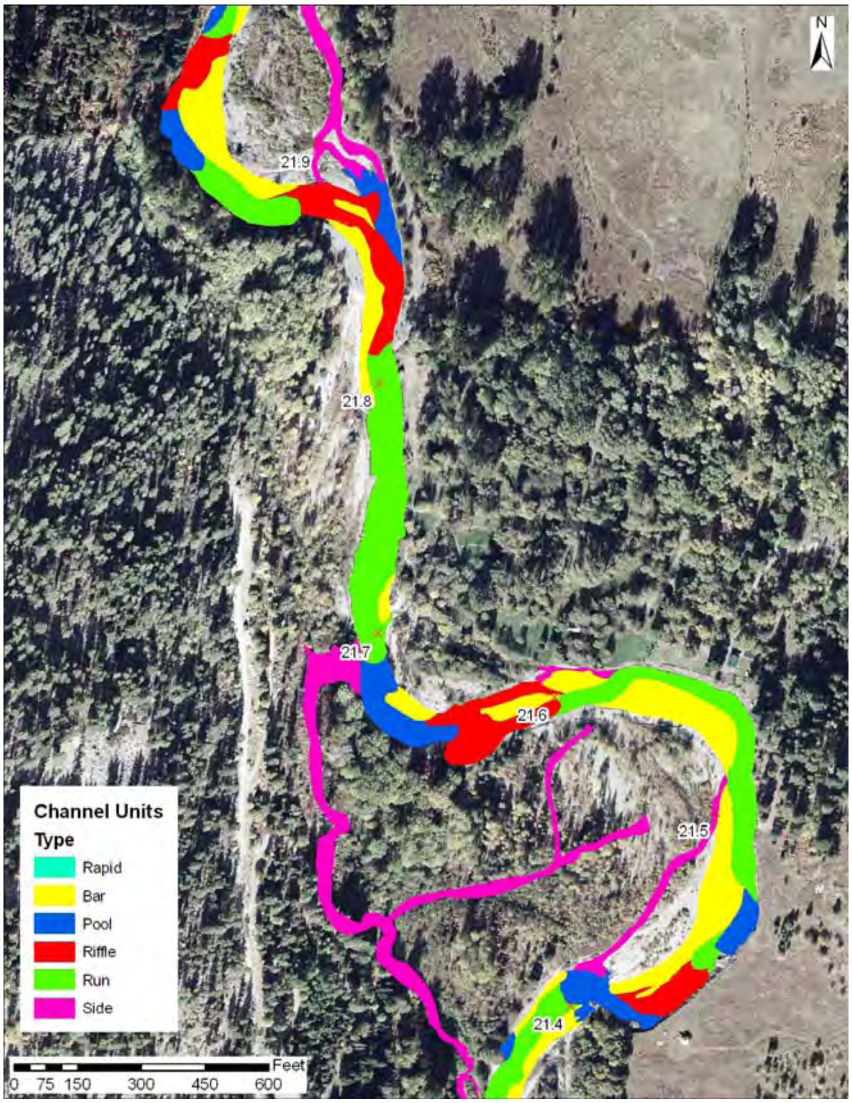


Figure 31. Channel unit field mapping (Lyon 2009).

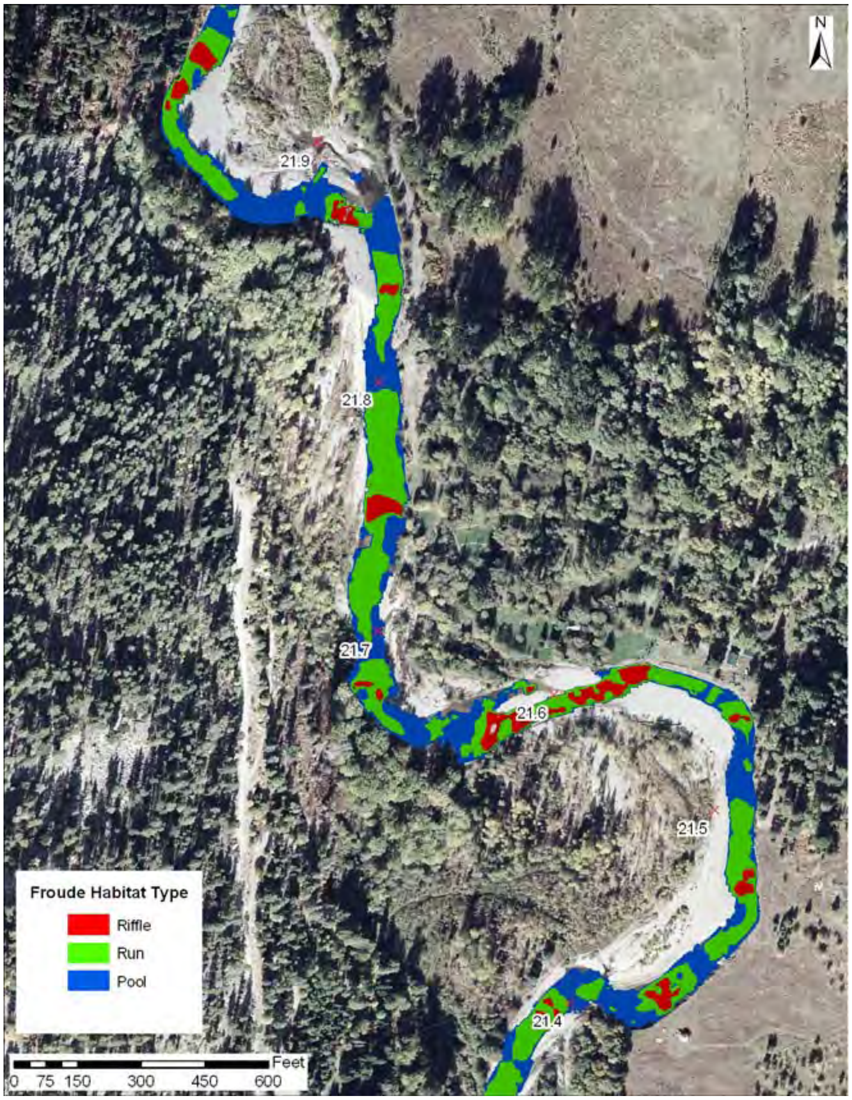


Figure 32. Modeled Froude number results for low flow scenario.

Inner Zone

Another concept incorporated into the reach assessment by Lyon, 2009 is that of the inner zone (IZ), and is included in this report for comparison purposes. The active main channel of the Preston Reach was subdivided into four inner zone subreaches based on field observed local trends of transport, transition, and deposition interpreted from the channel unit mapping, channel gradient, and dominant substrate (Lyon 2009). The IZ is the area where ground disturbing flows take place, such as the active main channel, side channels, and active bars. An IZ is characterized by the presence of primary channels, a repetitious sequence of channel units, and relatively uniform physical attributes indicative of localized transport and deposition. The four IZ subreaches, which were delineated by lateral and vertical controls based on the presence/absence of IZ processes, essentially represent areas of existing and potential habitat formation and maintenance within Preston Reach.

Currently, there are four localized trends of sediment movement (one per IZ) interpreted from the channel unit mapping (Lyon 2009). Each IZ is labeled one through four, increasing in the downstream direction. At the upstream extent of Preston Reach, IZ-1 was seen as being predominantly a transport subreach due to the increased bed slope (see Figure 20) as a result of a natural channel confinement from the Preston Creek alluvial fan. This observation was supported with the observed increase in modeled velocities in this area compared to the rest of the reach (see Figure 33). The channel gradient lessens in the IZ-2 subreach, which was viewed as being a transitional area before entering the deemed depositional IZ-3 subreach. Shortly after the IZ-3 delineation however, the river was viewed as going back to a predominantly transitional area in IZ-4 due to existing anthropogenic features that limit the channel migration. A complete mapping and detailed description of each of the four IZ subreaches can be found in the main report (Lyon 2009).

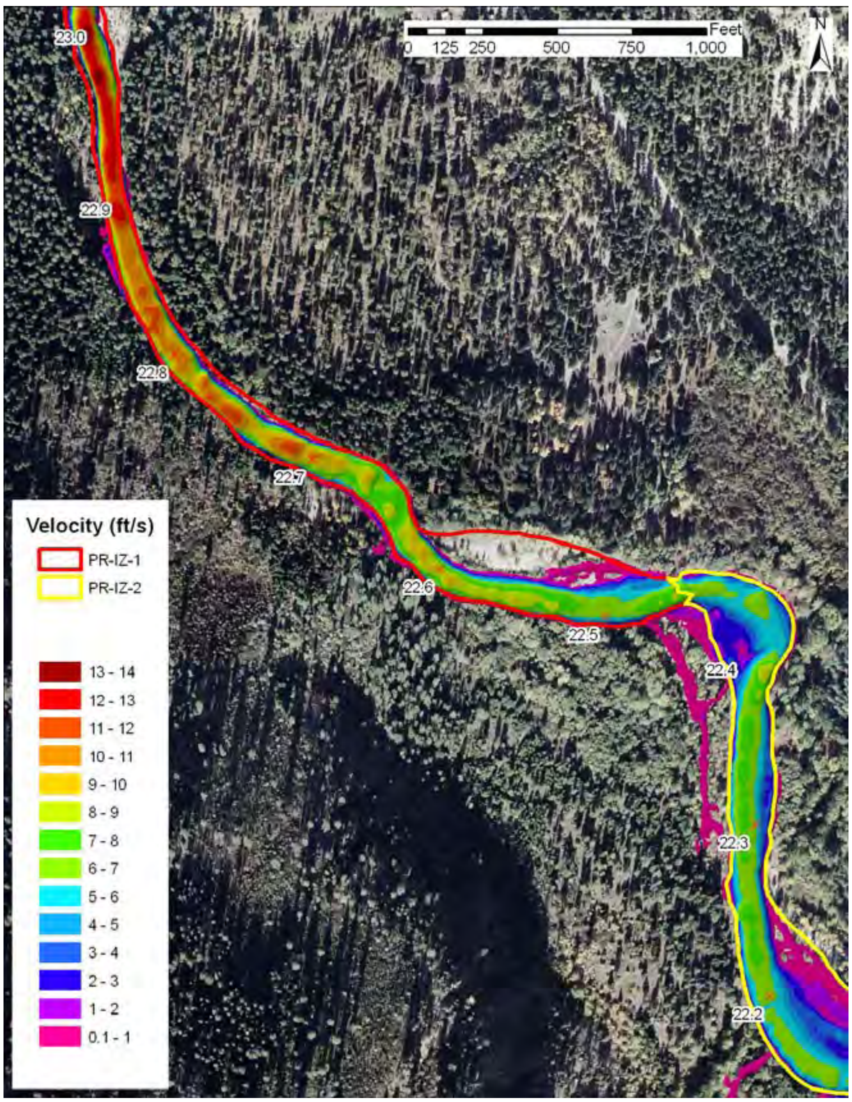


Figure 33. Modeled velocity results compared with IZ-1/IZ-2 delineation.

Conclusions

Using results of the 2D model, comparisons were made between existing and proposed (two levee removals) conditions based on predicted changes to water surface elevation, depth, depth-average velocity, and bed shear stress. These hydraulic parameters were compared along the active channel and across the floodplain. According to the modeling results, both levees are able to contain the 100-year discharge event, indicating loss of lateral connectivity. Also, the upper levee removal opens up more floodplain connectivity (6 acres) as compared to the lower levee removal (1.2 acres), and neither levee appears to be protecting significant infrastructure. Finally, the majority of the changes (both in-channel and overbank) between the existing and proposed conditions occurred within near proximity of the levee removals; effects of the proposed actions do not appear to propagate very far upstream or downstream of the levees, which are posing risk of erosion on nearby banks and creating a condition of bed erosion at the toe.

In general, the Preston Reach appears to have good channel form complexity, as evidenced through meander bends, distinct (and repetitive) bed form types, frequent bed undulations/high mobility, large and numerous point bars, and localized pools in the majority of the meander bends at a low flow. Increasing lateral connectivity in the Preston Reach through the removal of levees should be a primary goal that would lead to the restoration of this limiting factor, which in turn would likely lead to the creation of in-stream channel units more capable of supporting rearing/holding habitat. The newly available floodplain would become inundated at flows less than the 2-year event. The bank instability at the ‘Yurt Site’, located at RM 21.5 (see Figure 34), appears to be a localized phenomenon, representing approximately 5 percent of the total bankline throughout Preston Reach. Because bank erosion is a natural process in rivers, and significant bank erosion in the Preston Reach is limited to this relatively small site, there appears to be no cause for restoration measures. The clearing of riparian vegetation is likely a significant contributor to the instability at the ‘Yurt Site.’ The large side channel at RM 21.35 - 21.7 has good diversity with a well established perennial connection and should be preserved and requires no restoration.

Figure 34. Bank instability at RM 21.5 (looking upstream).

References

Parenthetical Reference	**Bibliographic Citation**
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Hilldale and Mooney 2007	Hilldale, R.C., and Mooney, D.M. 2007. Identifying Stream Habitat Features With a Two-Dimensional Hydraulic Model. A component of: Yakima River Basin Water Storage Feasibility Study, Washington. U.S. Department of the Interior, Bureau of Reclamation, Technical Service Center, Denver, CO.
Jowett 1993	Jowett, I.G. 1993. “A method for objectively identifying pool, run, and riffle habitats from physical measurements.” *New Zealand Journal of Marine and Freshwater Research*, vol. 27, pp. 2421-248.
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Montgomery and Bolton 2003	Montgomery, D., and Bolton, S. 2003. Hydrogeomorphic Variability and River Restoration. p. 39-80 in: *American Fisheries Society*.
NMFS 2008	National Marine Fisheries Service. 2008. *Consultation on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Project in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program (Revised and reissued pursuant to court order, NWF v. NMFS, Civ. No. CV 01-640-RE (D. Oregon)).* May 5, 2008, F/PNR/2005/05883.
Watershed Sciences 2007	Watershed Sciences, Inc. 2007. True Color Ortho-Photos: Wenatchee River, Entiat River, White River, Washington. Submitted February 14, 2007 to: Puget Sound LiDAR Consortium, Jerry Harless, GIS Manager, Puget Sound Regional Council, Seattle, WA.

Parenthetical Reference	**Bibliographic Citation**
Wolman 1955	Wolman, M.B. 1955. “The natural channel of Brandywine Creek, Pennsylvania.” *United States Geological Survey professional paper 271*.

APPENDIX F

Preston Geodatabase

(Geographic Information System files are for layer files on attached CD)

Appendix F

GIS Databases

The Preston Reach GIS (Geographic Information System) File Geodatabase was produced in support of the document, *Preston Reach Assessment, Entiat River, Chelan County, Washington*. More file geodatabases at the valley segment spatial scale are contained in the *Entiat Tributatary Assessment, Chelan County, Washington* (Reclamation, 2009)

The ***PrestonReach*** File Geodatabase includes multiple feature classes and 5 tables:

Feature Classes	**Description**
Channel Units	Physical attributes of the channel
HabitatFeatures_Human	Human created features
HabitatFeatures_LWD	Large Woody Debris/Count
HabitatFeatures_Natural	Natural processes features
HabitatFeatures_Pools	Pools - locations/depths
HabitatFeatures_Redds	Redds - locations
HabitatFeatures_WoodComplexes	Wood Complexes-location/size/count/stability
InnerZone	Active Channels – Primary/Secondary
Photopoints	Photo location points
Subreaches	Inner/Outer Zone Divisions
Vegetation_10m	Vegetation 10 meters off Inner Zone
Vegetation_30m	Vegetation 20 meters off Inner Zone
Vegetation_FP	Vegetation at full Flooplain
Veg_Grid	Vegetation grid at full floodplain

Tables	**Description**
ZonalStatistics_10mVeg	Veg stats from veg_grid for 10 meter buffer off Inner Zone
ZonalStatistics_30mVeg	Veg stats from veg_grid for 30 meter buffer off Inner Zone
Vegetation_10m_Frequency	Comparison veg tables using Vegetation_10m polygon
Vegetation_30m_Frequency	Comparison veg tables using Vegetation_30m polygon

DrainageDensity.xls   Drainage density of stream length/Entiat subbasin area.

For more information or to request a copy of the Preston Reach GIS File Geodatabase on DVD, contact Melanie Paquin at the Reclamation's Pacific Northwest Regional Office, mpaquin@usbr.gov.

Preston Reach File Geodatabase

Project Feature Classes

Feature Class –Outer Zone (available by selecting from Subreaches feature class)
Title – Outer zone: This feature class was created for the Preston reach assessment
Keyword – Reach assessment, outer zone
Abstract – This feature class contains a polygon that shows the location and extent of the outer zone of the Preston reach assessment area.

Feature Class –InnerZone
Title – Inner zone: This feature class was created for the Preston reach assessment
Keyword – Reach assessment, inner zone
Abstract – This feature class contains a polygon that shows the location and extent of the inner zone of the Preston reach assessment area.

Feature Class –Subreaches
Title – Subreaches: This feature class was created for the Preston reach assessment
Keyword – Inner zone, outer zone, subreaches
Abstract – This feature class contains polygons that show the location and extent of subreach units, inner/outer zones, and connected/disconnected zones within the Preston reach assessment area.

Feature Class –ChannelUnits
Title – Channel units: This feature class was created for the Preston reach assessment
Keywords – Channel units
Abstract – This feature class contains polygons that show the location and extent of channel units within the reach assessment area.

Feature Class – HabitatFeatures_Natural
Title – Anthropogenic features: This feature class was created for the Preston reach assessment
Keywords – Anthropogenic features, human features
Abstract – This feature class contains polylines that show the location and extent of anthropogenic features that impact channel processes and floodplain connectivity.

Feature Class –Habitat Features_Human
Title – Habitat features: This feature class was created for the Preston reach assessment

Keywords – habitat features
Abstract – This feature class contains polylines that show the location and extent of habitat features (levees, riprap, roads, etc) that impact channel processes and floodplain connectivity.

Feature Class –Habitat Features_WoodComplexes
Title – Habitat features: This feature class was created for the Preston reach assessment
Keywords – habitat features
Abstract – This feature class contains points that show the location and extent of habitat features (large woody debris, beaver dams, etc) that impact channel processes and floodplain connectivity.

Feature Class –Habitat Features_Redds
Title – Habitat features: This feature class was created for the Preston reach assessment
Keywords – habitat features
Abstract – This feature class contains points that show the location and extent of habitat features (redds) that impact channel processes and floodplain connectivity.

Feature Class –Photopoints
Title – Photopoints: This feature class was created for the Preston reach assessment
Keywords – Photographs, photopoints
Abstract – This feature class contains points that display location and photograph number that correlate to the initial site assessments in Appendix B.

Feature Class –Vegetation_FP
Title – Floodplain vegetation: This feature class was created for the Preston reach assessment
Keywords – Riparian, vegetation, composition, successional stages
Abstract – This feature class contains polygons that illustrates location of different successional stages of vegetation that correlate to the vegetation assessment in Appendix D.

Feature Class –Vegetation_30m
Title – Recruitment potential: This feature class was created for the Preston reach assessment
Keywords – Riparian, vegetation, composition, successional stages, buffer zone
Abstract – This feature class contains polygons that show the different successional stages of vegetation along a 30 meter buffer zone that correlate to the vegetation assessment in Appendix D.

Feature Class –Vegetation _10m
Title – Canopy cover: This feature class wascreated for the Preston reach assessment

Keywords – Riparian, vegetation, composition, successional stages, canopy
Abstract – The data file contains polygons that show the different successional stages of vegetation along a 10 meter buffer zone that correlate to the vegetation assessment in Appendix D.

Feature Class –Veg_grid
Title – Floodplain vegetation grid: This raster grid was created for the Preston reach assessment
Keywords – Riparian, vegetation, composition, successional stages
Abstract – This raster grid was converted from the Vegetation_FP polygon feature class and illustrates location of different successional stages of vegetation that correlate to the vegetation assessment in Appendix D.

Table –ZonalStatistics_10mVeg
Title – Vegetation Statistics for the 10m Veg: This table was created for the Preston reach assessment
Keywords – Riparian, vegetation, composition, successional stages
Abstract – This tables includes the 10m buffer off inner zone vegetation summary statistics by ClassCode and acreages for the different successional stages of vegetation that correlate to the vegetation assessment in Appendix D.

Table –ZonalStatistics_30mVeg
Title – Vegetation Statistics for the 30m Veg: This table was created for the Preston reach assessment
Keywords – Riparian, vegetation, composition, successional stages
Abstract – This tables includes the 30m buffer off inner zone vegetation summary statistics by ClassCode and acreages for the different successional stages of vegetation that correlate to the vegetation assessment in Appendix D.

References

Reclamation, 2009, Entiat Tributary Assessment, Chelan County, Washington: Bureau of Reclamation, Technical Service Center, Denver, CO