

RECLAMATION

Managing Water in the West

Stormy Reach Assessment Entiat River

Chelan County, Washington



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

November 2009

U.S. Department of the Interior

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.

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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 of multiple bars comprised of gravel and sand. The dominant channel units are riffle and run. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation.

Date: August 6, 2008

Photo by: R. McAfee

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Acknowledgements

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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

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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 provide adequate potential for 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 Stormy 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.

Stormy reach, located between river miles RM 18.02 and RM 20.85 on the Entiat River, is a 6th field Hydrologic Unit Code (HUC) watershed. The Stormy reach is characterized as an unconfined geomorphic reach type based on natural channel constraints. 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. In its natural state, the Entiat River maintained dynamic equilibrium by actively migrating laterally

across its floodplain within the Stormy reach. This lateral channel migration maintains a balanced energy regime with flatter channel gradient as sediment is reworked before being 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 upon which aquatic species within the basin depend.

Field surveys and evaluations were conducted in the Stormy reach during the 2008 field season to determine the condition of the hydrologic, geomorphic, and vegetative regimes. Ecosystem processes in the Stormy reach are in a slightly 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 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 Stormy 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 documents environmental baseline conditions in the Stormy 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). Inner and outer zones that are not hydraulically connected to the river because of anthropogenic features are described as disconnected inner or outer zones (DIZ) or (DOZ).

The river condition describes the current state of fluvial processes and their relationship to formation of 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 monitoring or assessments. In the instance of the Stormy reach, the habitat-forming processes have been unfavorably impacted, with 63 percent of the specific indicators (Appendix A: Reach-based Ecosystem Indicators (REI)) being in an *At Risk Condition* as shown in Table 1.

With the exception of habitat access, all other general indicators for the Stormy reach have at least one specific 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 at the watershed scale. Two general indicators (habitat quality and channel dynamics) are interpreted to be in an *At Risk Condition* due primarily to anthropogenic causes, with a third general indicator of riparian vegetation being at risk due to fire. The conditions of the three general indicators are symptomatic of lost geomorphic potential and habitat-forming processes through decreased floodplain/riverine interaction as a result of increased stream power and thus incision and decreased shading and large wood recruitment potential. 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 in the Stormy reach has been altered through reduced floodplain connectivity and lateral channel migration. Reduced floodplain connectivity is due to a levee along the left bank that disconnects SR-DIZ-1 and SR-DOZ-1 from riverine processes in addition to decreasing channel migration, increasing stream power and thus incision. There are human features in the lower section of the reach (SR-IZ-6 and 7) that include a total of two rock spurs, a historic bridge abutment in addition to two active abutments and a small section of riprap. These human features reduce lateral channel migration and increase the potential for vertical channel migration locally. These subreaches are interpreted to be in an *At Risk Condition* and are recommended for rehabilitation actions. Other subreaches (SR-OZ-6 and 7) that are recommended for habitat actions are those subreaches that were interpreted to have a reduced level of interaction between the hydrologic, geomorphic and vegetative regimes due to local incision. 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 *Adequate Condition*.

However, other conditions such as increased stream power, increased incision and lack of floodplain interaction could be addressed by placing “key members” (large wood greater than 30-inch diameter at breast height and a length of 30 or more feet with rootwad attached) at strategic locations on point and medial bars in SR-IZ-2, SR-IZ-3, SR-IZ-5, and SR-IZ-6 on point and medial bars, and allowing the river to naturally adjust their position.

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

General Indicator	Specific Indicator (REI)	Specific Indicator Condition	General Indicator Condition
Water Quality	Temperature	At Risk	At Risk
	Turbidity	Adequate	
	pH	At Risk	
	Suspended Solids	At Risk	
Habitat Access	Physical Barriers	Adequate	Adequate
Habitat Quality	Substrate	Adequate	At Risk
	Fine Sediment	At Risk	
	Large Woody Debris	Adequate	
	Pool Frequency and Quality	Adequate	
	Off-channel Habitat	At Risk	
Dynamics	Floodplain Connectivity	At Risk	At Risk
	Bank Stability/Channel Migration	At Risk	
	Vertical Channel Stability	At Risk	
Riparian Vegetation	Structure (Floodplain)	Adequate	At Risk
	Disturbance (30 m buffer zone)	At Risk	
	Canopy Cover (10 m buffer zone)	At Risk	

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

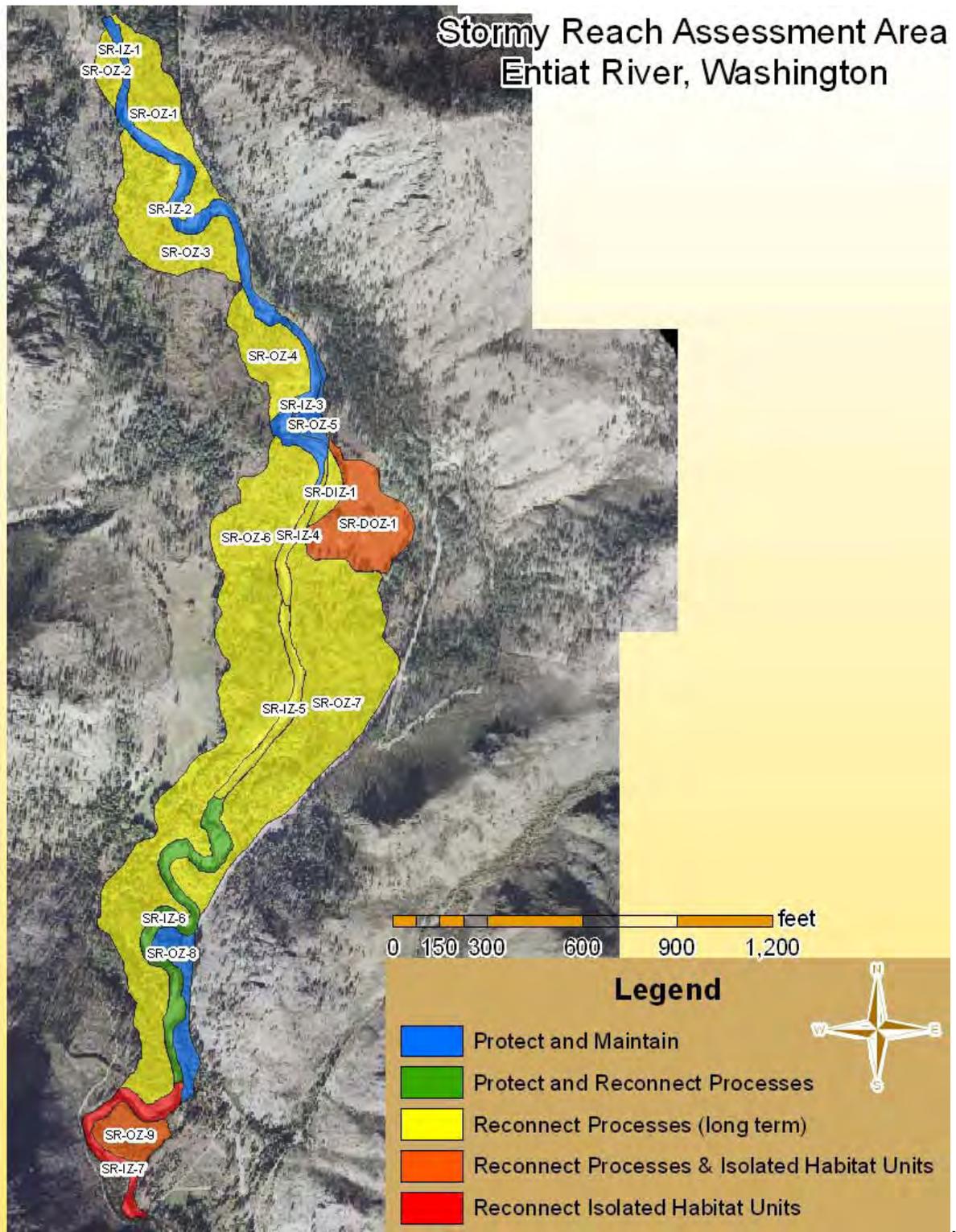


Figure 1. Potential habitat actions by subreach and their relative priority of implementation.

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 feeds into this strategy by defining options and consideration at the reach scale after the reach has been identified and prioritized at the tributary or valley segment 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.

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

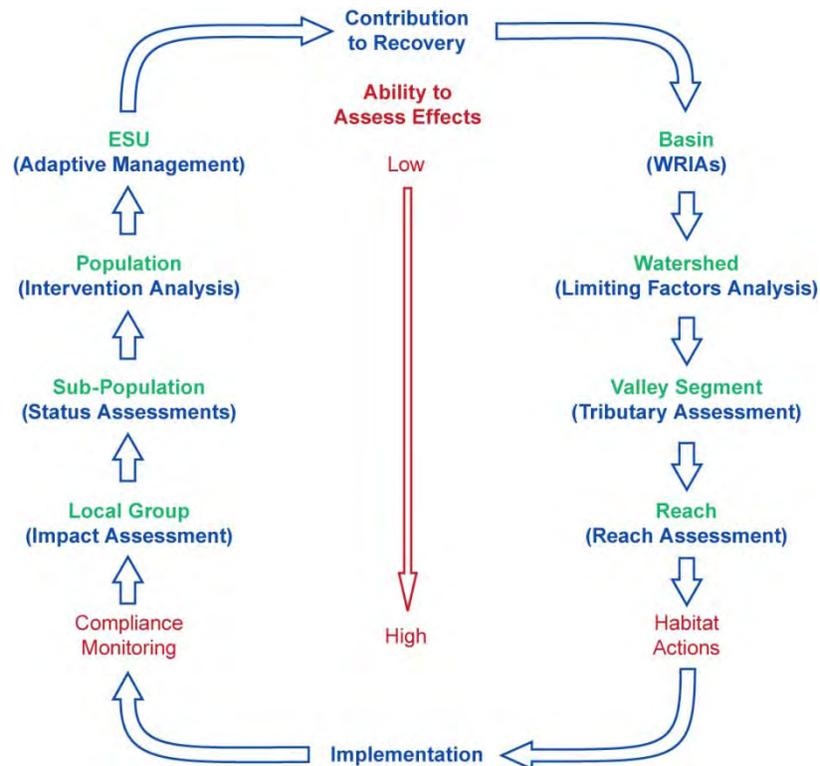


Figure 2. Idealized model showing how assessments and monitoring are nested and related. Compiled from Hillman (2006), UCSRB (2007), and Stewart-Oaten and Bence (2001).

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 of each reach assessment to assist with correspondences throughout the project selection process. However, this 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.

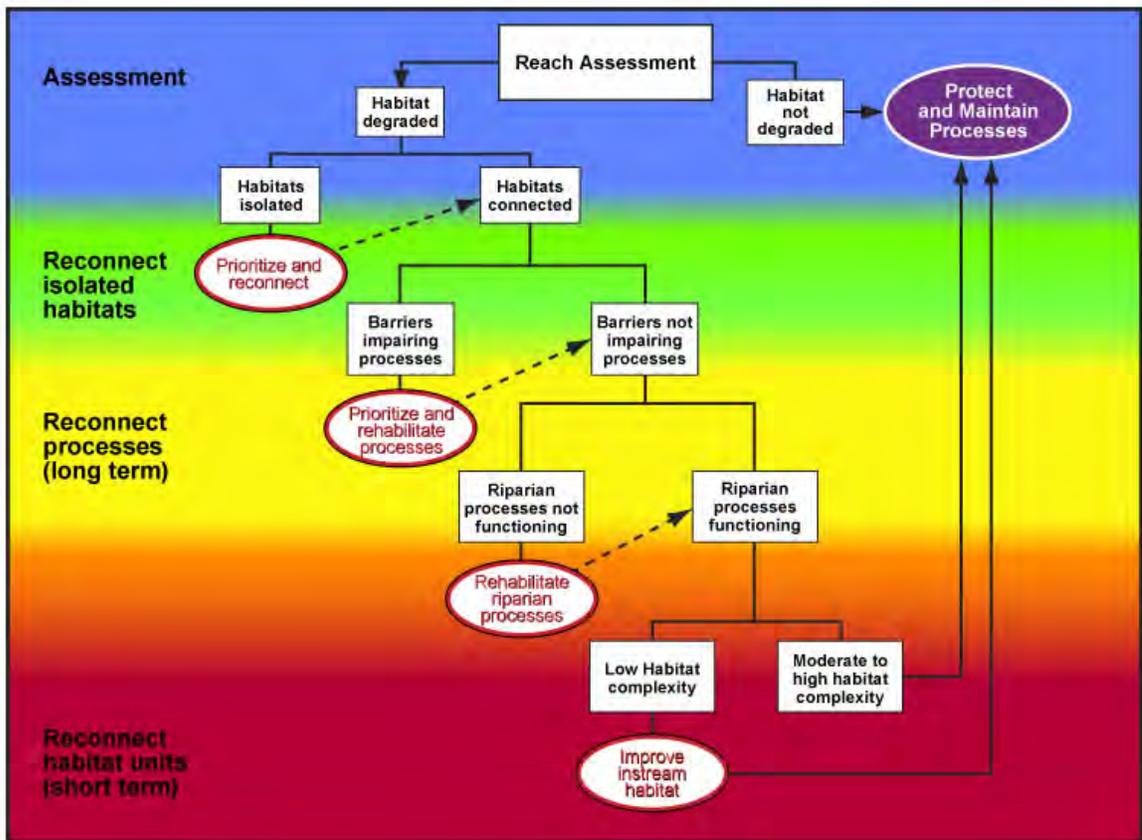


Figure 3. Implementation strategy for prioritizing potential habitat actions at the reach scale (adapted from Roni et al. 2005).

Prior to completing individual reach assessments, tributary assessments are conducted at the valley segment scale 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 confined 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 table (Appendix A: Reach-based Ecosystem Indicators (REI)). The variables measured in the REI document the baseline environmental conditions and 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 document and evaluate 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 intervention analysis will 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 for 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 of the species of concern by increasing abundance and productivity and provide adequate potential for recovery of salmonid species listed under the ESA (NMFS 2008).

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.* Describe river conditions at the reach scale based on integrating physical, biological, and habitat information into an REI matrix. The REI is a descriptive format for documenting baseline environmental conditions and identifying 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 reach scale understanding of the geomorphic potential and environmental baseline conditions.
- *Developing prioritization recommendations.* Develop prioritization recommendations of the subreaches based on reach scale 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 Stormy 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 Stormy reach, located between river miles (RM) 18.02 and 20.85 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. 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. In its natural state, the Entiat River maintained dynamic equilibrium by actively migrating laterally across its floodplain within the Stormy reach. This lateral channel migration maintains a balanced energy regime with flatter channel gradient as sediment is reworked before being 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 Stormy reach during the 2008 field season to determine the condition of the hydrologic, geomorphic, and vegetative regimes. Ecosystem processes in the Stormy reach are in a slightly 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 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 Upper Columbia Salmon Recovery Board (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.

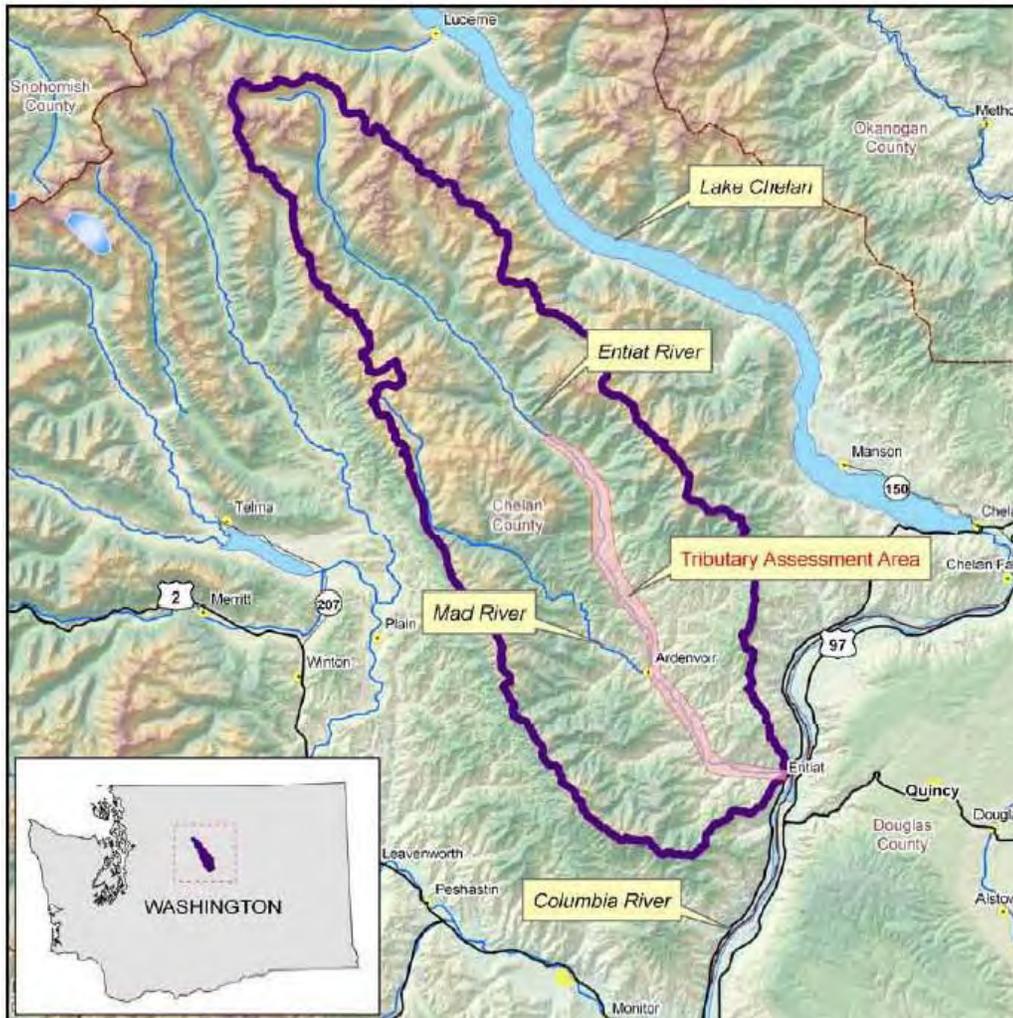


Figure 4. Location map of the tributary assessment area on the Entiat River within the Entiat subbasin.

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). Four geomorphic reaches were delineated for valley segment VS-2 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 were identified as Reach 2B and Reach 2D. Reach 2C (Stormy reach) had the highest geomorphic potential and the largest impact from anthropogenic features (i.e., more departed from a natural condition), followed by reach 2A (Potato/Gray) in valley segment VS-3.

Table 2. Geomorphic reach and response 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-2 (Reclamation 2009)	Reach Assessment Name	River Miles	Reach Type	Channel Complexity
Reach 2A	Potato/Gray	16.1-17.9	Unconfined	High
Reach 2B	None	17.9-18.1	Confined	Low
Reach 2C	Stormy	18.02-20.85	Unconfined	High
Reach 2D	None	20.9-21.1	Confined	Low

Within the Stormy 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 due to bank hardening 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 reduced channel migration, reduced floodplain connectivity, altered sediment transport and size, reduced large woody debris delivery and retention, and disconnected groundwater sources from the main channel. Bank protection also impacts physical processes, but to a more localized degree.

REACH CHARACTERIZATION

The Stormy reach assessment provides the technical evaluation at 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 of implemented habitat actions and 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 aquatic habitat formation and maintenance within the response reach. The Stormy reach encompasses about 289 acres of floodplain and active channel of the Entiat River within an alluvial valley from RM 18.02 to 20.85 (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 (adapted from USDA 2008). In the instance of Stormy reach, the active main channel was subdivided into seven 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 referred to 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 typified 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 Stormy reach, Entiat River, Entiat Subbasin, Chelan County, Washington.

Inner Zone	Connected Outer Zone	Disconnected Inner Zone	Disconnected Outer Zone
49.0 acres	218.0 acres	2.7 acres	18.8 acres

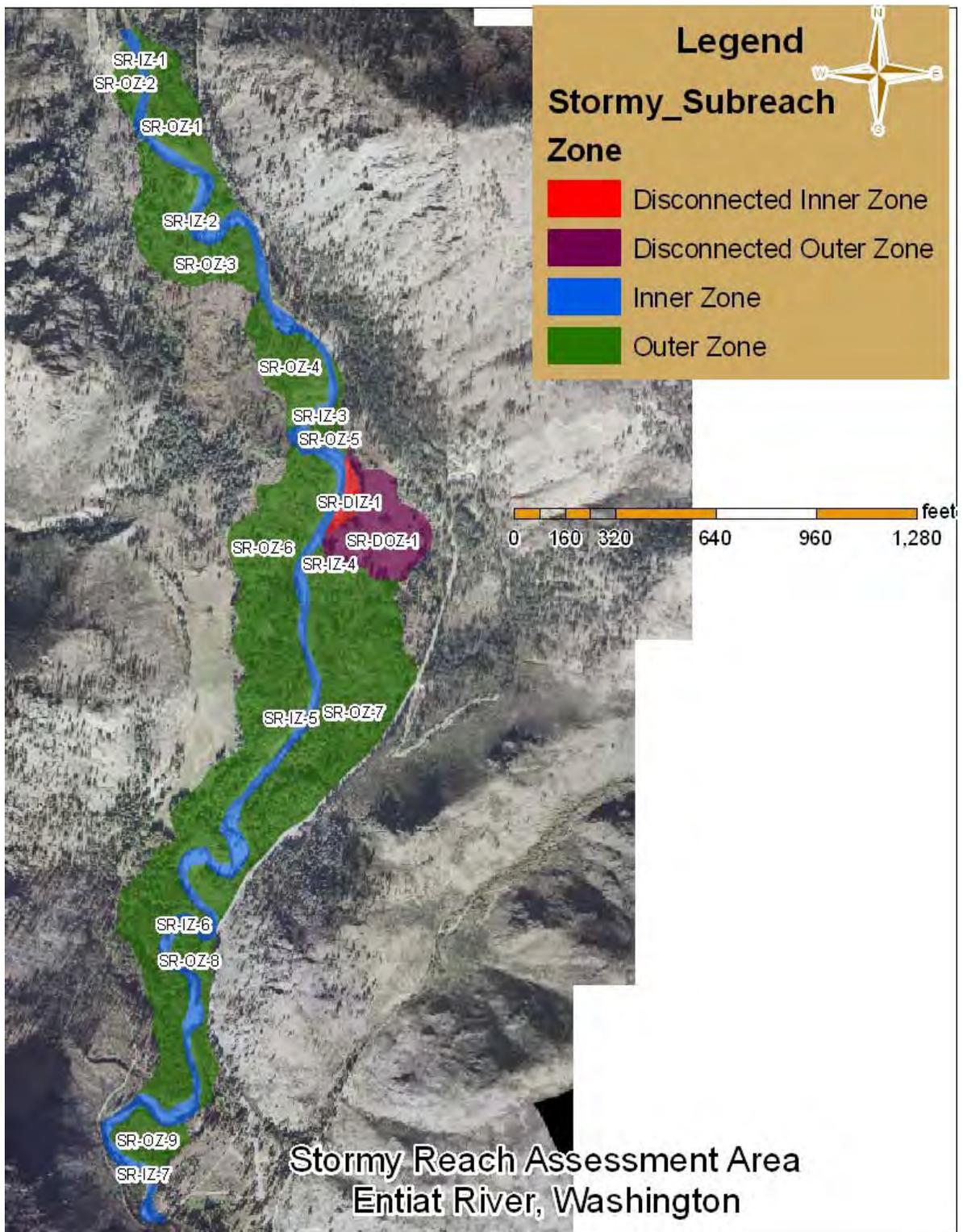


Figure 5. Location of inner zones and outer zones based on a modified application of the Stream Inventory Handbook (USDA 2008).

REACH CONDITION

The evaluation of the reach condition is a combination of all information available at the time of the investigation. The REI table 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 analyses are the Initial Site Assessment (Appendix B), Habitat Assessment (Appendix C), Riparian Vegetation Assessment (Appendix D), One-dimensional Hydraulic Modeling (Appendix E), and GIS (Appendix F).

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

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

The specific indicators that are described in the REI record baseline environmental conditions which are indicative of the condition of the higher-level general indicators that in turn inform on the condition of pathways. 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. Selected general and specific reach-based ecosystem indicators (REI) for the Stormy reach. Each indicator was interpreted to be in one of three conditions: *Adequate, At Risk, or Unacceptable Risk.*

General Indicator	Specific Indicator (REI)	Specific Indicator Condition	General Indicator Condition
Water Quality	Temperature	At Risk	At Risk
	Turbidity	Adequate	
	pH	At Risk	
	Suspended Solids	At Risk	
Habitat Access	Physical Barriers	Adequate	Adequate
Habitat Quality	Substrate	Adequate	At Risk
	Fine Sediment	At Risk	
	Large Woody Debris	Adequate	
	Pool Frequency and Quality	Adequate	
	Off-channel Habitat	At Risk	
Dynamics	Floodplain Connectivity	At Risk	
	Bank Stability/Channel Migration	At Risk	
	Vertical Channel Stability	At Risk	
Riparian Vegetation	Structure (Floodplain)	Adequate	At Risk
	Disurbance (30 m buffer zone)	At Risk	
	Canopy Cover (10 m buffer zone)	At Risk	

Limiting factor general indicators such as habitat access, habitat quality, and dynamics 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 Stormy 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 Tye Fire (1994) burn about 50 percent of the watershed (about 140,000 acres). Even assuming a complete burn (which is likely not the case as fires typically burn in a mosaic pattern based on intensity) the watershed condition has recovered significantly. Vegetation throughout the

burned area has recovered to a shrub/seedling to sapling/pole condition over the last 15 years and is now providing some soil and 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, land use 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, occasionally did not meet state performance standards suggesting this indicator is 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. As a result, 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 Stormy 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 removal of the riparian vegetation 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) for the stated purpose of reducing 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 25.0. The large woody debris indicator is interpreted to be in an *Adequate Condition*. In addition, 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 10.6 pools per mile in the reach. Pool quality was found to be good with 5.4 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 totaled 1,675 feet in length within the reach (refer to Habitat Assessment in Appendix C). Most of the measured side channel 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 a levee. The levee also impacts off-channel habitat in the adjacent downstream subreach as well. 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 a levee and small sections of riprap and highway. The result is reduced floodplain/riverine interactions due to slight incision from increased stream power. Therefore, the floodplain connectivity indicator is interpreted to be in an *At Risk Condition*.

Channel migration rates have been adversely impacted by levees and small sections of riprap that constrain channel migration. Due to the levee and riprap, the bank stability/channel migration indicator is interpreted to be in an *At Risk Condition*.

Channel unit analysis using a geographic information system (GIS) suggests that the middle section of the reach has been negatively impacted by a levee and is a 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

Much of the vegetation in the Stormy reach was burned by the 1994 Tye fire. The vegetation is recovering. The dominant vegetation class is sapling/pole. Just over ten 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: Riparian Vegetation Assessment).

About seven percent of the riparian buffer zone (30 meter width along both banks of the inner zone) has been impacted by clearing for road and/or replacement by riprap as well as agricultural and residential development. About 16 percent of the vegetation is in a small tree to large tree seral stage and the watershed road density is relatively high (2.5 mi/mi²) suggesting the riparian vegetation disturbance indicator is in an *At Risk Condition*.

Less than thirty-five 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 falls within the unacceptable risk condition. However, the vegetation is considered to be at a younger seral stage due to burning and so is interpreted to be in an *At Risk Condition*.

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

There are localized areas of disturbance where re-vegetation should be pursued to improve riverine-vegetation interaction and provide long-term recruitment potential.

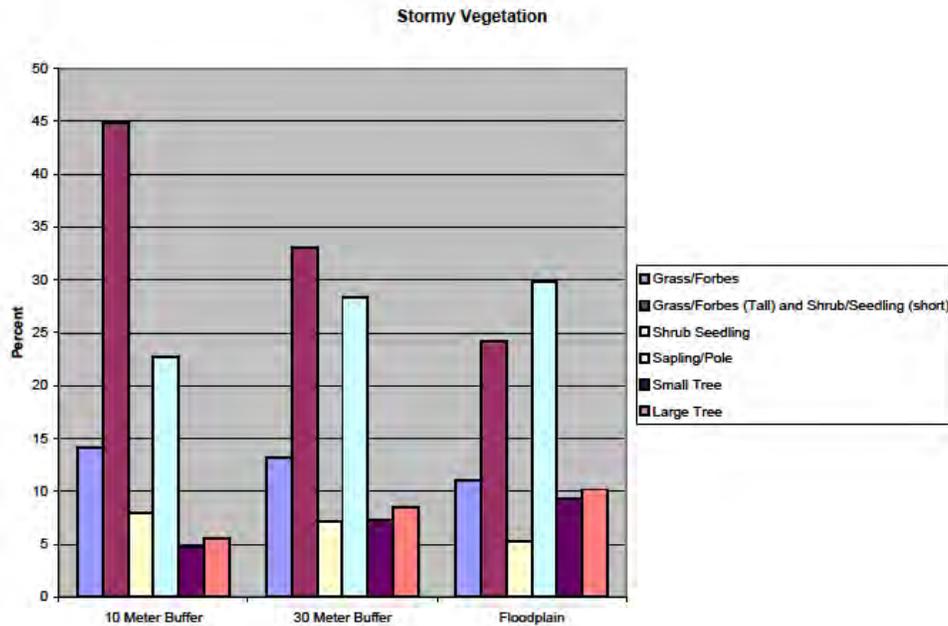


Figure 6. Percent of riparian vegetation seral stages based on classifications modified from those provided in the Stream Inventory Handbook (USDA 2008).

DISCUSSION

Based on field observation, channel unit mapping and the one-dimensional hydraulic model (Appendix E), the Bremer levee reduces channel migration, increased stream power and incision. Over all, there are five localized trends of sediment movement in the Stormy Reach, and are noted by designated inner zones. These inner zones are graphically illustrated in Figure 7. At the upstream end of the reach, subreach SR-IZ-1 is still predominantly transporting sediment due to channel confinement by the Dill Creek alluvial fan. IZ-2 is a transitional subreach, with the channel gradient decreasing. However this is where the similarity between pre- and post-anthropogenic impacts becomes apparent. The third breach (SR-IZ-3) still trends toward depositional, but then changes back to predominantly transitional again where there are anthropogenic features that limit channel migration in subreaches SR-IZ-4. The influence of the levee continues through SR-IZ-5 which is a transition to deposition reach. In SR-IZ-6, the sediment deposition trend becomes depositional with a marked increase in sinuosity and decrease in gradient. At the end of the final subreach, SR-IZ-7, the river is confined by the Shamel Creek and Stormy Creek alluvial fans.

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.

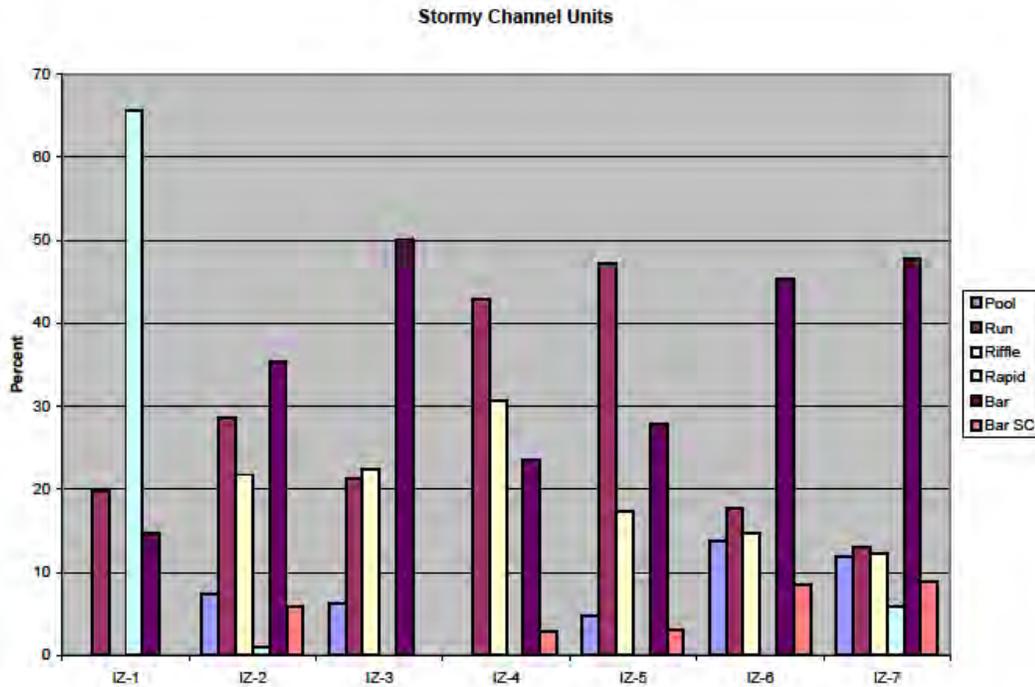


Figure 7. Percent of channel units for each inner zone subreach based on modified classifications from the Stream Inventory Handbook (USDA 2008).

IMPLEMENTATION STRATEGY

The river reach condition describes the current state of fluvial processes, prioritized habitat actions and their relationship to forming complex habitat within the implementation strategy framework (Figure 8 and Table 5). This builds on and is directly related to the reach characterization strategy discussed and illustrated in Figure 8. Table 5 contains the definitions for the subreach conditions and differential responses expected for potential habitat protection and rehabilitation actions. Note the corresponding gradational color scheme.

Table 5. Definitions for prioritized habitat actions based on 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.

Anthropogenic features can be analyzed to establish impacts to the current river condition. Subsequently, the river condition provides a baseline for comparisons in future assessments. In the instance of the Stormy reach, the habitat-forming processes have been unfavorably impacted, with 63 percent of the specific indicators (Appendix A: Reach-based Ecosystem Indicators (REI)) being in an *At Risk Condition*.

Habitat access is interpreted to be in an Adequate Condition with the remaining general indicators being in an *At Risk Condition*. Three general indicators in particular (watershed condition, flow/hydrology, and water quality) are symptomatic of larger-scale issues. At the reach scale, riparian vegetation in an *At Risk Condition* is due to burning by the Tyee fire in

1994 and possibly other fires prior to that. The channel dynamics general indicator is symptomatic of the loss of geomorphic potential or the potential for geomorphic regime change.

Geomorphic potential is interpreted to be altered because of reduced floodplain connectivity, lateral channel migration, large wood recruitment potential. Reduced floodplain connectivity is due to a levee in the inner zone subreach SR-DIZ-4. Reduced channel migration and increased vertical migration are due to the levee, and small sections of highway and riprap in inner zone subreaches SR-IZ-2, SR-IZ-3 and, SR-IZ-6. 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 12).

The large woody debris specific indicator is interpreted to be in an *Adequate Condition* based on number of pieces observed during the habitat assessment (Appendix B). However large wood could be used to address issues including increased stream power and incision in inner zones SR-IZ-3 and SR-IZ-6 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 reduce stream power, retain sediment traveling through the system; therefore, elevating the bed to increase floodplain-riverine interaction. Wood pieces with some type of anchoring (i.e. buried) could be utilized at appropriate locations in those inner zones that are transitioning toward deposition, but still have higher energy levels, such as SR-IZ-2 and SR-IZ-5. This action could help return section in the upper and lower areas 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 SR-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 8 illustrates the primary habitat actions for each subreach using the gradational color scheme.

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

High Priority/Long-term	
1.	<p>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.</p> <ol style="list-style-type: none"> Protect and maintain areas where physical processes are in an Adequate Condition. Protect and maintain areas with off-channel habitat that are connected to the river.
2.	<p>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.</p> <ol style="list-style-type: none"> Levees have reduced floodplain connectivity. Historic bridge abutment and two rock spurs have reduced lateral channel migration and are negatively impacting channel morphology and complexity.
3.	<p>Water Quality and Quantity – improving water quality and quantity addresses four VSP parameters: productivity, abundance, structure, and diversity.</p> <ol style="list-style-type: none"> The Entiat River is on the 303(d) list for water temperature and deficiencies in water pH and suspended solids have been noted by the Washington Department of Ecology. 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.	<p>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.</p> <ol style="list-style-type: none"> 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.	<p>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.</p> <ol style="list-style-type: none"> 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.	<p>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.</p> <ol style="list-style-type: none"> 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 accelerated bank erosion.

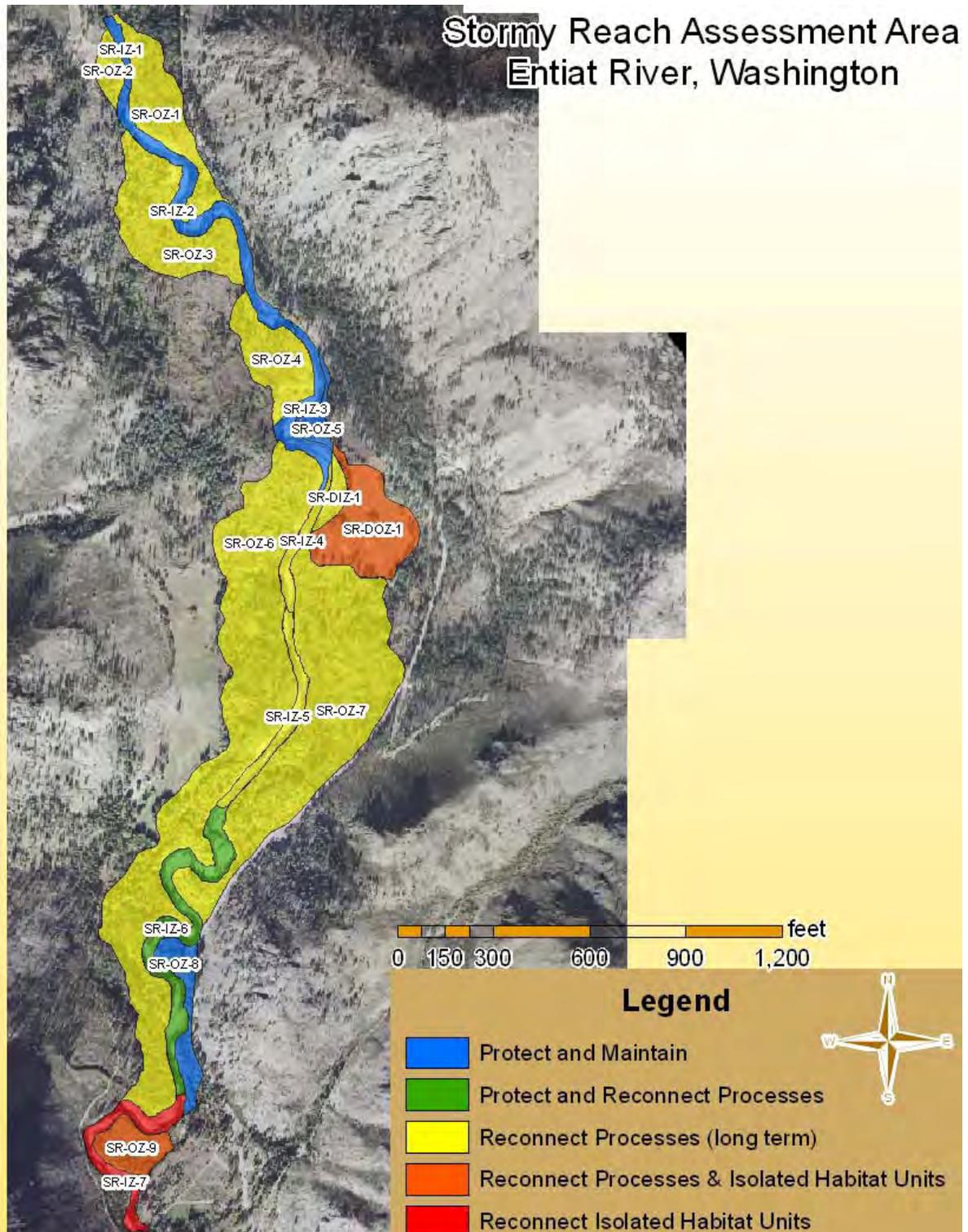


Figure 8. Potential habitat actions by subreach and their relative priority of implementation.

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 end of the Stormy 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 an inter-disciplinary team (IDT).

River Mile 18.02 – 20.85 Subreaches

Between RM 20.73 and 20.85 the river is a transport inner zone subreach (SR-IZ-1) that is naturally confined by opposing alluvial fans; Dill Creek on river left and a composite fan from two small un-named creeks on river right. The predominant channel unit is a rapid with cobble and boulder substrate. From RM 20.1 to 20.73 in SR-IZ-2 the river begins to transition toward deposition. The predominant channel unit is a run with cobble and gravel substrate. A short section of the highway slightly reduces available floodplain along the left bank at RM 20.3 and 20.05, and promotes local vertical scour and decreased channel migration. Within the outer zones, there are no disconnecting features. However, within the riparian buffer zones (30 meter width along both banks) the vegetation is recovering from the Tyee fire of 1994, and is in an at risk condition for potential large wood recruitment and canopy cover due to the young seral stage. Overall, the primary habitat actions are to protect and maintain SR-IZ-1; reconnect the riparian processes through planting in the 30 meter buffer zones within the outer zones; and reconnect floodplain/riverine processes through the addition of large wood to decrease water velocities that will in turn capture spawning sized gravels, increase floodplain and fluvial process interaction and protect existing infrastructure (Table 7). Each subreach is discussed in the following sections.

Table 7. Summary of subreaches between RM 20.1 and 20.85.

SUBREACH	RIVER MILE	HABITAT ACTION	ACREAGE
SR-IZ-1 (inner zone)	RM 20.73 – 20.85	Protect and maintain	1.5 acres
SR-IZ-2 (inner zone)	RM 20.1 – 20.73	Protect and maintain	11.0 acres
SR-OZ-1 (outer zone)	RM 20.36 – 20.85 (river left)	Reconnect Processes (Riparian), then protect	16.0 acres
SR-OZ-2 (outer zone)	RM 20.67 – 20.84 (river right)	Reconnect Processes (Riparian), then protect	3.6 acres
SR-OZ-3 (outer zone)	RM 20.2 -20.64 (river right)	Reconnect Processes (Riparian), then protect	22.7 acres

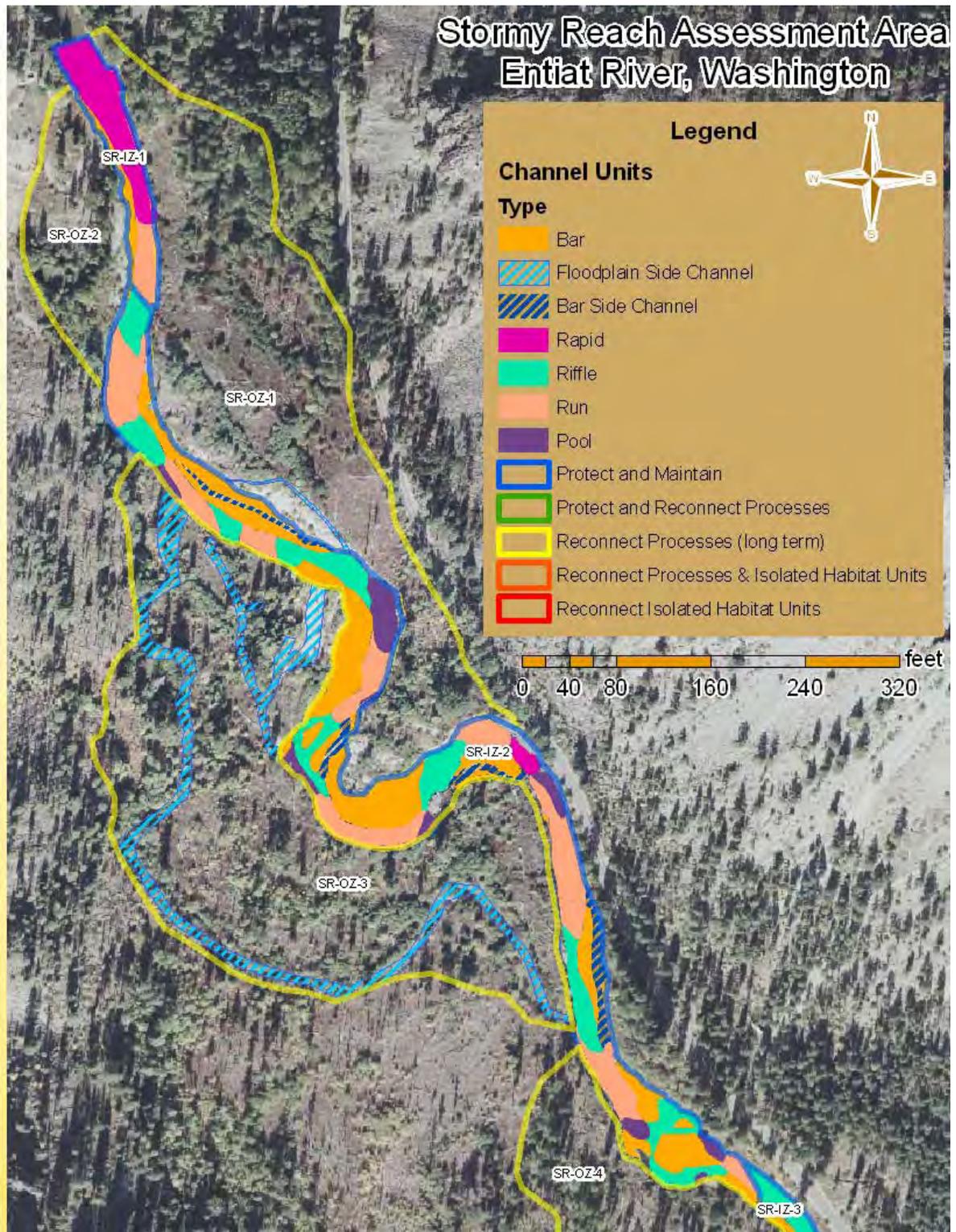


Figure 9. Location map of subreaches between RM 20.1 and 20.85 with channel units shown.

SR-IZ-1 (Inner Zone)

Inner zone SR-IZ-1 is located between RM 20.73 and 20.85 and covers about 1.5 acres of the active channel (Figure 9). This inner zone is a transport subreach with a relatively high gradient with cobble/boulder substrate (Photograph No. 1). There are no anthropogenic features that artificially affect this river segment. Large wood recruitment potential and shading are impeded (see SR-OZ-1, SR-OZ-2, and SR-OZ-3). SR-IZ-1 should be protected to maintain the current processes (Table 8).

Table 8. Potential habitat actions for SR-IZ-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	High



Photograph No. 1. View to the east showing a channel unit of rapids with boulder and cobble substrate. Note the local bank erosion. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation. Photograph by R. McAfee, August 5, 2008.

SR-IZ-2 (Inner Zone)

Inner zone SR-IZ-2 is located between RM 20.01 and 20.73, covers about 11.0 acres of active channel, including about 3.5 acres of off-channel habitat (Figure 9). This inner zone is a transitional subreach with a relatively lower gradient when compared to SR-IZ-1, with gravel and cobbles, with sections of boulder substrate (Photograph No. 2). There are no human features along the banks or in-channel (see Table 9). Large wood recruitment potential and shading are impeded (see SR-OZ-1, SR-OZ-2, and SR-OZ-3). Protection of current levels of geomorphic, hydrologic and vegetative function is recommended.

Table 9. Potential habitat actions for SR-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



Photograph No. 2. View to the southwest of alluvial material that includes gravel and cobbles with boulders along both banks. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation. Photograph by R. McAfee, August 5, 2008.

SR-OZ-1 (Outer Zone)

Outer zone SR-OZ-1 is located between RM 20.36 and 20.85 on river left and covers about 16.0 acres of floodplain (Figure 9). There are no anthropogenic features within the subreach. This subreach has impaired large wood recruitment potential and canopy cover due to the 1994 Tye fire and possibly other fires. The riparian vegetation is recovering with the dominant vegetation class being sapling/pole. However, riparian planting to improve riparian processes (large wood recruitment potential and shading) could be implemented to improve vegetative function. Upon completion of the riparian planting, protection is recommended to maintain current levels of hydrologic and geomorphic function and the improved vegetative function (Table 10).

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

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes (long-term): Rehabilitate riparian interactions through the replanting of appropriate riparian vegetation within the 30 meter buffer zone.	4; Productivity, Abundance, Diversity, and Structure	High
2	Protection	Protect and maintain rehabilitated levels of geomorphic, hydrologic, and vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High

SR-OZ-2 (Outer Zone)

Outer zone SR-OZ-2 is located between RM 20.67 and 20.84 on river right and covers about 3.6 acres of floodplain (Figure 9). There are no anthropogenic features within the subreach. This subreach has impaired large wood recruitment potential and canopy cover due to the 1994 Tyee fire and possibly other fires. The riparian vegetation is recovering with the dominant vegetation class being sapling/pole. However, riparian planting to improve riparian processes (large wood recruitment potential and shading) could be implemented to improve vegetative function. Upon completion of the riparian planting, protection is recommended to maintain current levels of hydrologic and geomorphic function and the improved vegetative function (Table 11).

Table 11. Potential habitat actions for SR-OZ-2.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes (long-term): Rehabilitate riparian interactions through the replanting of appropriate riparian vegetation within the 30 meter buffer zone.	4; Productivity, Abundance, Diversity, and Structure	High
2	Protection	Protect and maintain rehabilitated levels of geomorphic, hydrologic, and improved vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High

SR-OZ-3 (Outer Zone)

Outer zone SR-OZ-3 is located between RM 20.2 and 20.64 on river right and covers about 22.7 acres of floodplain (Figure 9). There are no anthropogenic features within the subreach. This subreach has impaired large wood recruitment potential and canopy cover due to the 1994 Tyee fire and possibly other fires. The riparian vegetation is recovering with the dominant vegetation class being sapling/pole. However, riparian planting to improve riparian processes (large wood recruitment potential and shading) could be implemented to improve vegetative function. Upon completion of the riparian planting, protection is recommended to maintain current levels of hydrologic and geomorphic function and the improved vegetative function (Table 12).

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

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes (long-term): Rehabilitate riparian interactions through the replanting of appropriate riparian vegetation within the 30 meter buffer zone.	4; Productivity, Abundance, Diversity, and Structure	High
2	Protection	Protect and maintain rehabilitated levels of geomorphic, hydrologic, and improved vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High

River Mile 19.79 – 20.1 Subreaches

Between RM 19.79 and 20.1 in subreach SR-IZ-3, the river is predominantly transitional with transport being the dominant mechanism at the top of the reach due to the highway on river left. Moving downstream, small pockets of local deposition do occur. The predominant channel unit is a riffle with cobble and gravel substrate. The riparian buffer zones (30 meter width along both banks) are recovering from the Tyee fire of 1994, and are in an at risk condition for potential large wood recruitment and canopy cover. Overall, the primary habitat actions are to reduce water velocities with large wood and/or boulder placements in SR-IZ-3. The result would be increased floodplain/riverine interaction through a reduction in stream power that help in the detainment of sediment and raise the bed elevation over time. In addition riparian plantings in SR-OZ-4 would improve large wood recruitment potential over time. The habitat action for SR-OZ-5 is to protect and maintain (Table 13). Each subreach is discussed in the following sections.

Table 13. Summary of subreaches between RM 19.79 and 20.1.

SUBREACH	RIVER MILE	HABITAT ACTION	ACREAGE
SR-IZ-3 (inner zone)	RM 19.79 –20.1	Reconnect Processes	6.0 acres
SR-OZ-4 (outer zone)	RM 19.9 – 20.1 (river right)	Reconnect Processes (Riparian), then protect	16.0 acres
SR-OZ-5 (outer zone)	RM 19.8 – 20.05 (river left)	Protect and maintain	2.7 acres

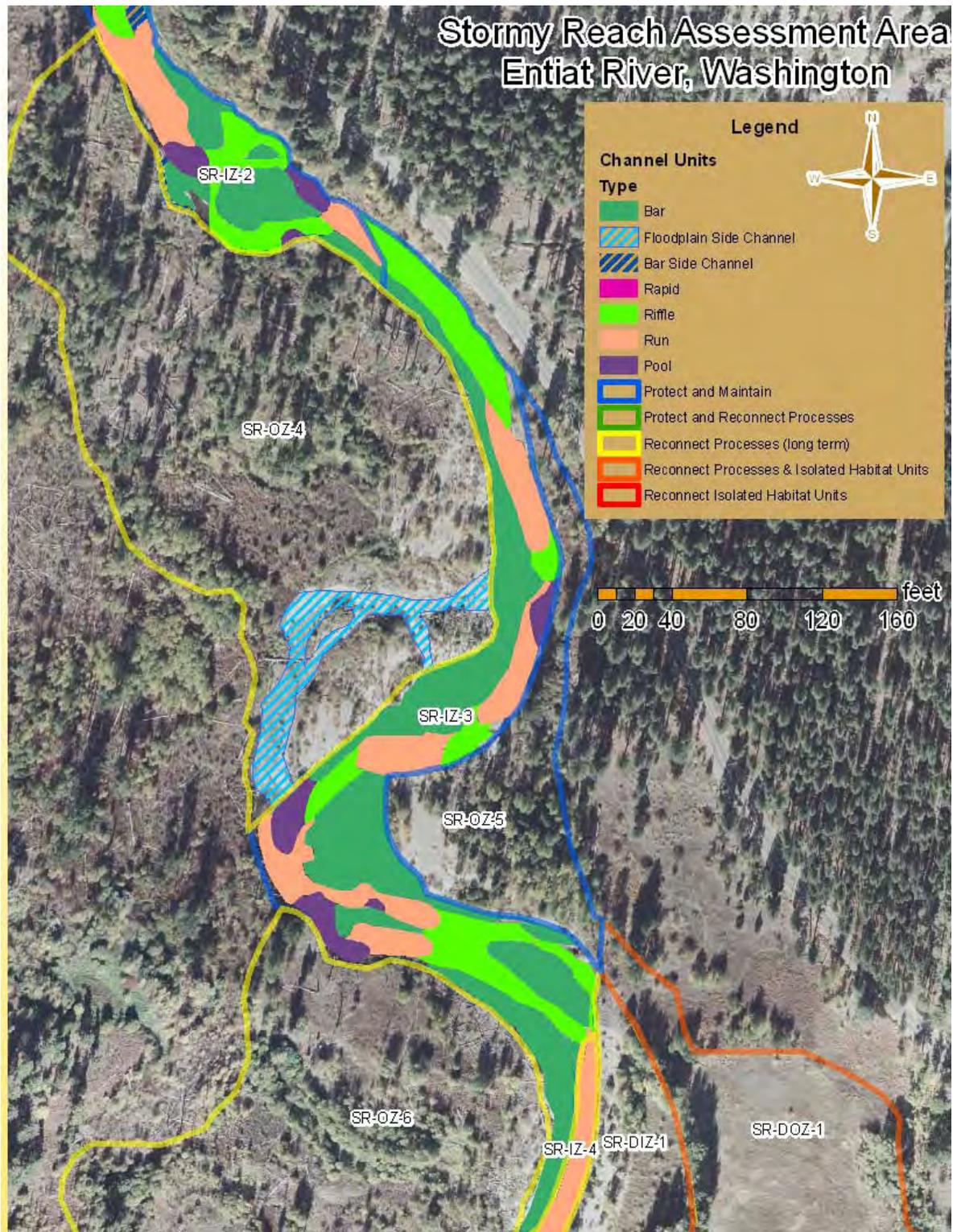


Figure 10. Location map of subreaches between RM 19.79 and 20.1 with channel units shown.

SR-IZ-3 (Inner Zone)

Inner zone SR-IZ-3 is located between RM 19.79 and 20.1 and covers about 6 acres of the active channel (Figure 10). This inner zone is a transition-to-deposition subreach with a relatively lower gradient when compared to SR-IZ-1, with predominantly gravel and cobble substrate (Photograph No. 3). The only human feature along the banks or in the active channel in this subreach is a small section of highway along the left bank at the top of the reach. The highway slightly reduces the channel migration width; therefore, increasing stream energy and promoting local incision. Large wood loading or log/boulder placement could be implemented to help dissipate stream energy and promote floodplain interaction by raising the bed elevation through detainment of sediment (Table 14). Large wood recruitment potential and shading are impeded in the large adjacent subreach (see SR-OZ-4 description) and could be improved through riparian planting.

Table 14. Potential habitat actions for SR-IZ-3.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect processes: Strategically place unanchored/anchored “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.	4; Productivity and Abundance	Moderate
2	Protection	Protect and maintain rehabilitated levels of geomorphic, hydrologic, and vegetative function.	2; Productivity, Abundance, Diversity, and Structure	High



Photograph No. 3. View to the south of a cobble and gravel point bar along the right bank and wood accumulation along the left bank. The channel unit sequence is run to riffle. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation. Photograph by R. McAfee, August 6, 2008.

SR-OZ-4 (Outer Zone)

Outer zone SR-OZ-4 is located between RM 19.9 and 20.2 on river right and covers about 16.0 acres of floodplain (Figure 10). There are no anthropogenic features within the subreach. This subreach has impaired large wood recruitment potential and canopy cover due to the 1994 Tye fire and possibly other fires. The riparian vegetation is recovering with the dominant vegetation class being sapling/pole. However, riparian planting to improve riparian processes (large wood recruitment potential and shading) could be implemented to improve vegetative function. Upon completion of the riparian planting, protection is recommended to maintain current levels of hydrologic and geomorphic function and the improved vegetative function (Table 15).

Table 15. Potential habitat actions for SR-OZ-4.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes (long-term): Rehabilitate riparian interactions through the replanting of appropriate riparian vegetation within the 30 meter buffer zone.	4; Productivity, Abundance, Diversity, and Structure	High
2	Protection	Protect and maintain rehabilitated levels of geomorphic, hydrologic, and improved vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High

SR-OZ-5 (Outer Zone)

Outer zone SR-OZ-5 is located between RM 19.8 and 20.05 on river left and covers about 2.7 acres of floodplain (Figure 10). There are no anthropogenic features within the subreach. This subreach has good large wood recruitment potential and canopy cover. Protection is recommended to maintain current levels of hydrologic and geomorphic function and the improved vegetative function (Table 16).

Table 16. Potential habitat actions for SR-OZ-5.

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

River Mile 19.07 – 19.79 Subreaches

Between RM 19.07 and 19.79, there are two inner zones; SR-IZ-4 and SR-IZ-5. From RM 19.5 to 19.79 in (SR-IZ-4), the river is a transport inner zone subreach that is artificially confined by 1,033 feet of levee on the left bank. The predominant channel unit is a run with cobble and gravel substrate. From RM 19.07 to 19.5 (SR-IZ-5), the river begins to transition toward deposition. The predominant channel unit is a run with cobble and gravel substrate. From RM 19.63 to 19.8 and 19.62 to 19.8 are SR-DIZ-1 and SR-DOZ-1, respectively on river left. These two subreaches are disconnected by the levee. SR-OZ-6, on river right from 18.28 to 19.86 and SR-OZ-7 from RM 18.76 to 19.62 on river left have no directly associated human features. However, the levee located in SR-IZ-4 impacts floodplain dynamics in both SR-OZ-6 and SR-OZ-7 through continued incision in SR-IZ-5. In both outer zones, riparian buffer zones (30 meter width along both banks) are recovering from the Tyee fire of 1994, and are in an at risk condition due to reduced potential large wood recruitment and canopy cover.

The levee affects all of the subreaches in this section of the Stormy reach. With the artificial confinement of the river, stream power is increased. With an increase in stream power, there is also an increase in vertical scour. The resulting incision inhibits both channel migration as well as floodplain/riverine interactions. In addition to decreased floodplain/riverine interactions, the vegetation within the 30 meter buffer zone is recovering from the 1994 Tyee fire. The dominant seral stage of the vegetation is sapling-pole, so stream shading and large wood recruitment potential is reduced. The primary habitat actions are to increase the channel migration area by the removal, modification or relocation of the levee located in SR-IZ-4; reconnect the floodplain/riverine processes in SR-OZ-6 and SR-OZ-7 by the adding of large wood in SR-IZ-5 to dissipate stream energy further and promote floodplain/riverine interaction, once the levee is addressed. The third habitat action is to improve stream shading and large wood recruitment potential by replanting in the 30 meter buffer zones within the outer zones (Table 17). Each subreach is discussed in the following sections.

Table 17. Summary of subreaches between RM 19.07 and 19.79 (miles based on Inner Zone, Outer Zones do not directly correspond).

SUBREACH	RIVER MILE	HABITAT ACTION	ACREAGE
SR-IZ-4 (inner zone)	RM 19.5 –19.79	Reconnect Processes then protect	3.2 acres
SR-IZ-5 (inner zone)	RM 19.07-19.5	Reconnect Processes	5.5 acres
SR-DIZ-1 (disconnected inner zone)	RM 19.63-19.8 (river left)	Reconnect Processes (riverine), then protect	2.7 acres
SR-DOZ-1 (disconnected outer zone)	RM 19.62 – 19.8 (river left)	Reconnect Processes (riverine), then protect	18.8 acres
SR-OZ-6 (outer zone)	RM 18.28-19.86 (river right)	Reconnect Processes (Riparian) then protect	84.9 acres
SR-OZ-7 (outer zone)	RM 18.76-19.62 (river left)	Reconnect Processes (Riparian) then protect	60.8 acres

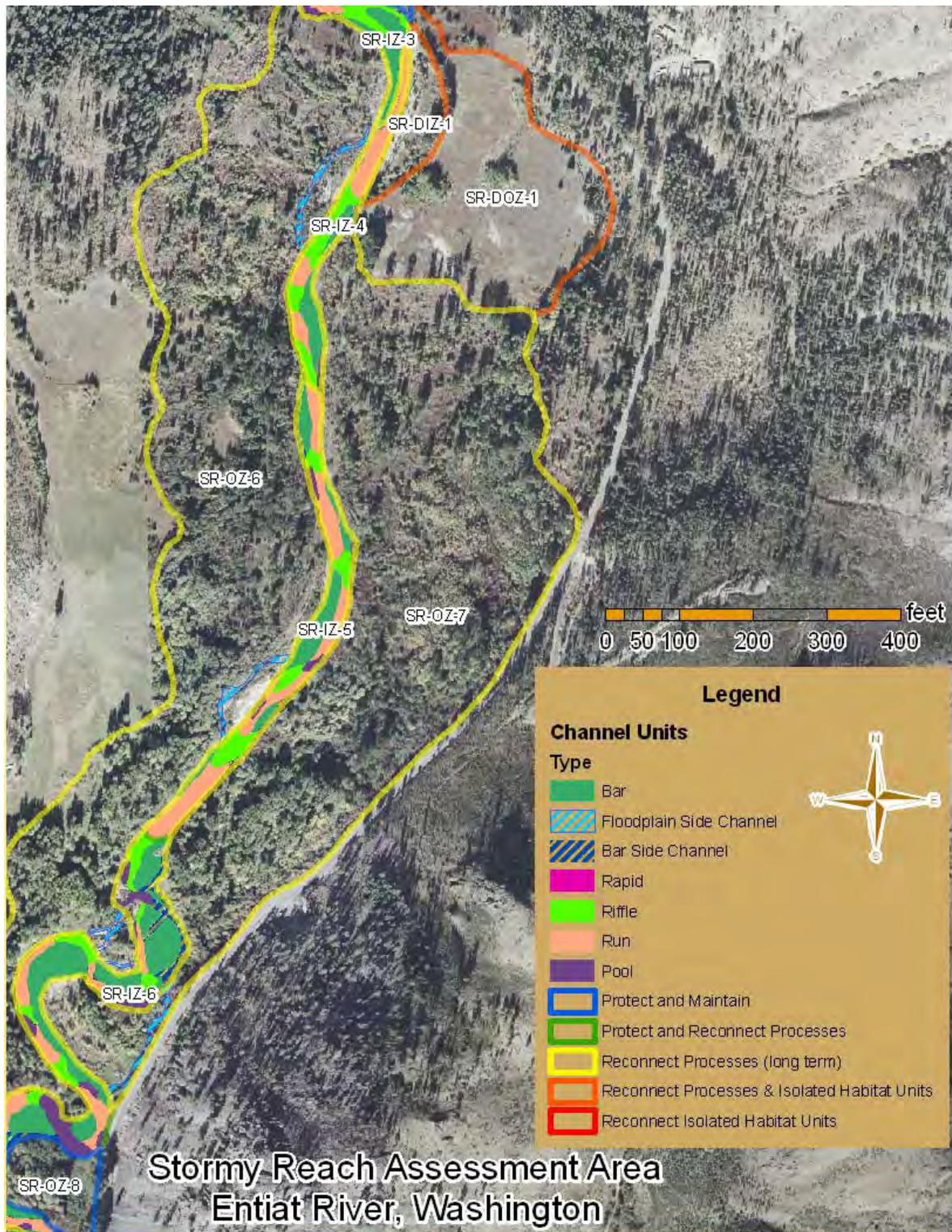


Figure 11. Location map of subreaches between RM 18.76 and 19.79 with channel units and anthropogenic features shown.

SR-IZ-4 (Inner Zone)

Inner zone SR-IZ-4 is located between RM 19.5 and 19.79 and covers about 3 acres of the active channel (Figure 11). This inner zone is artificially confined by 1,033 feet of levee along the left bank (Photograph No. 4). The result is a fairly straight plan form, disconnection of floodplain processes, increased water velocities, and thus increased incision. The dominant fluvial process is transport due to the restriction of channel migration. Wood recruitment potential is impaired due to the 1994 Tye fire, and possibly other fires in addition to the levee and the clearing of riparian vegetation for agricultural use. The levee could be removed, modified or set back to reduce stream energy, and to allow increased channel migration in subreaches DIZ-1 (Table 18). If the levee is addressed, flood plain/riverine interactions could also be reconnected through the use of large wood and/or boulder placement to further dissipate stream energy and allow the bed elevation to increase through sedimentation. Riparian planting efforts could be implemented to increase large wood recruitment potential and shading (see SR-DIZ-1, DOZ-1 and SR-OZ-6).

Table 18. Potential habitat actions for SR-IZ-4.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes: Remove or modify the levee to reconnect floodplain. Following removal or modification of the levee, large wood could be installed to further aid in energy dissipation and promote sediment retention. Upon addressing the levee, the subreach could be Protected and Maintained.	2; Productivity and Abundance	High



Photograph No. 4. View is to the south of a levee along the left bank and a gravel point bar along the right. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation. Photograph by R. McAfee, August 6, 2008.

SR-IZ-5 (Inner Zone)

Inner zone SR-IZ-5 is located between RM 19.07 and 19.5 and covers about 5.5 acres of the active channel (Figure 11). The dominant fluvial process in this subreach is transition and the dominant substrate gravel with cobbles. Although no human features constrict this subreach, the effects of the levee on the left bank upstream in SR-IZ-4 propagate into this subreach. Elevated water velocities decrease the variety of channel units; increase the potential for vertical migration, which in turn decreases floodplain connectivity. Channel migration is also impaired. Reconnection of floodplain/riverine interaction through large wood loading or log/boulder placement is recommended for this subreach (Table 19). Large wood recruitment potential is impaired due to the 1994 Tye fire, and possibly other fires (see SR-OZ-6 and SR-OZ-7).

Table 19. Potential habitat actions for SR-IZ-5.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes: Strategically place unanchored/anchored “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. Upon placing the wood, the subreach could be Protected and Maintained .	2; Productivity and Abundance	Moderate



Photograph No. 5. View is to the south of a gravel and cobble point bar along the right bank and a channel unit sequence of glide-riffle-glide. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation. Photograph by R. McAfee, August 6, 2008.

SR-DIZ-1 (Disconnected Inner Zone)

Disconnected inner zone SR-DIZ-1 is located between RM 19.63 and 19.8 on river left and covers about 2.7 acres (Figure 11). There is a levee about 1,033-feet long that disconnects the subreach from the active channel (see SR-IZ-1). Within this subreach there is about 570 feet of historic access road associated with the levee that also acts to dissect the historic channel path. In addition to disconnected channel and floodplain processes, this subreach has impaired large wood recruitment potential and canopy cover due to replacement of riparian vegetation by the levee. With the removal or modification of the levee, the historic roads should be removed to improve riverine-floodplain processes. Riparian plantings should be considered to increase large wood recruitment potential and shading (Table 20). Upon completion of recommended actions to the most appropriate level, protection is recommended to maintain rehabilitated levels of geomorphic, hydrologic, and improved vegetative function.

Table 20. Potential habitat actions for SR-DIZ-1.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes: By removal of the historic access road behind the levee to reconnect the historic channel path and floodplain processes, if the levee is addressed to some degree.	2; Productivity and Abundance	High
2	Protection	Protect and maintain rehabilitated levels of geomorphic, hydrologic, and improved vegetation function.	2; Productivity, Abundance, Diversity, and Structure	Low



Photograph No. 6. View is to the east of an access road that is connected to the back side of the levee in the historic channel path. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation. Photograph by R. McAfee, August 6, 2008.

SR-DOZ-1 (Disconnected Outer Zone)

Disconnected outer zone SR-DOZ-1 is located between RM 19.62 and 19.8 on river left and covers about 18.8 acres (Figure 11). The subreach is disconnected by 1,033 feet of levee (see SR-IZ-4). In addition to disconnected floodplain processes, this subreach has impaired large wood recruitment potential and canopy cover due to removal of riparian vegetation for agricultural uses. With the reconnection of riverine processes through the removal or modification of the levee and historic access roads, riparian plantings should be considered to increase riparian processes that include large wood recruitment potential and shading (Table 21). Upon completion of recommended actions to the most appropriate level, protection is recommended to maintain rehabilitated levels of geomorphic, hydrologic, and improved vegetative function.

Table 21. Potential habitat actions for SR-DOZ-1.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes (long-term): Rehabilitate riparian interactions through the replanting of appropriate riparian vegetation within the 30- meter buffer zone.	2; Productivity, Abundance, Diversity, and Structure	High
2	Protection	Protect and maintain rehabilitated levels of geomorphic, hydrologic, and vegetation function.	Productivity, Abundance, Diversity, and Structure	High

SR-OZ-6 (Outer Zone)

Outer zone SR-OZ-6 is located between RM 18.28 and 19.86 on river right and covers about 84.9 acres of floodplain (Figures 11 and 12). There are no anthropogenic features within the subreach that impair floodplain connectivity. Although there are pockets of good riparian vegetation (RM 18.6-19.0), the large wood recruitment potential and canopy cover are impaired as a result of the 1994 Tye fire and possibly other fires, as well as agricultural uses. Riparian planting to improve riparian processes (large wood recruitment potential and shading) could be implemented to improve vegetative function. Upon completion of the riparian planting, protection is recommended to maintain current levels of hydrologic and geomorphic function and the improved vegetative function (Table 22). In addition, actions recommended for SR-IZ-5 may increase floodplain connection and function within this subreach.

Table 22. Potential habitat actions for SR-OZ-6.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes (long-term): Rehabilitate riparian interactions through the replanting of appropriate riparian vegetation within the 30 meter buffer zone.	4; Productivity, Abundance, Diversity, and Structure	High
2	Protection	Protect and maintain rehabilitated levels of geomorphic, hydrologic, and improved vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High

SR-OZ-7 (Outer Zone)

Outer zone SR-OZ-7 is located between RM 18.76 and 19.62 on river left and covers about 60.8 acres of floodplain (Figures 11 and 12). There are no anthropogenic features within the subreach that impair floodplain connectivity. Although there are pockets of good riparian vegetation (RM 18.9-19.1) the large wood recruitment potential and canopy cover are impaired as a result of the 1994 Tyee fire and possibly other fires, as well as agricultural uses. Riparian planting to improve riparian processes (large wood recruitment potential and shading) could be implemented to improve vegetative function. Upon completion of the riparian planting, protection is recommended to maintain current levels of hydrologic and geomorphic function and the improved vegetative function (Table 23). In addition, actions recommended for SR-IZ-5 may increase floodplain connection and function within this subreach.

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

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Processes (long-term): Rehabilitate riparian interactions through the replanting of appropriate riparian vegetation within the 30 meter buffer zone.	4; Productivity, Abundance, Diversity, and Structure	High
2	Protection	Protect and maintain rehabilitated levels of geomorphic, hydrologic, and improved vegetative function.	4; Productivity, Abundance, Diversity, and Structure	High

River Mile 18.05 – 19.07 Subreaches

Between RM 18.02 and 19.07, there are two inner zones. From RM 18.42 to 19.07 (SR-IZ-6) the river is a depositional inner-zone subreach with higher sinuosity and lower gradient. The predominant channel unit is run with gravel and sand substrate. Human features in this subreach include 150 feet of riprap along the toe of the road at RM 18.76, in addition to a rock spur on the left bank and a historic bridge abutment along the left bank at RM 18.32. From RM 18.02 to 18.42 (SR-IZ-7), the river begins to transition toward transport. The dominant channel unit is run with gravel and sand, and boulder substrate. Human features include a bridge at RM 18.02. From RM 18.39 to 18.76, and 18.1 to 18.35 on river left is SR-OZ-8 and SR-OZ-9 respectively. Both outer zone subreaches have no disconnecting human features.

However, in SR-OZ-9, riparian buffer zones (30 meter width along both banks) have been cleared for historic agricultural use and are in an at risk condition for potential large wood recruitment and canopy cover.

The primary habitat actions are to protect and maintain SR-OZ-8; reconnect and then protect the riparian processes through planting in the 30 meter buffer zones within the outer zones in SR-OZ-9; reconnect isolated habitat units with the modification of riprap and then protect and maintain in SR-IZ-6, and reconnect floodplain/riverine processes and riparian processes through planting and then protect and maintain SR-IZ-7 (Table 24). Each subreach is discussed in the following sections.

Table 24. Summary of subreaches between RM 19.79 and 20.2.

SUBREACH	RIVER MILE	HABITAT ACTION	ACREAGE
SR-IZ-6 (inner zone)	RM 18.42-19.07	Protect/Maintain Reconnect processes	13.9 acres
SR-IZ-7 (inner zone)	RM 18.02-18.42	Reconnect Processes and then Protect and Maintain	7.7 acres
SR-OZ-8 (outer zone)	RM 18.39-18.76 (river right)	Protect and Maintain	7.2 acres
SR-OZ-9 (outer zone)	RM 18.1-18.35 (river right)	Reconnect Processes (riparian) and Protect and Maintain	7.0 acres

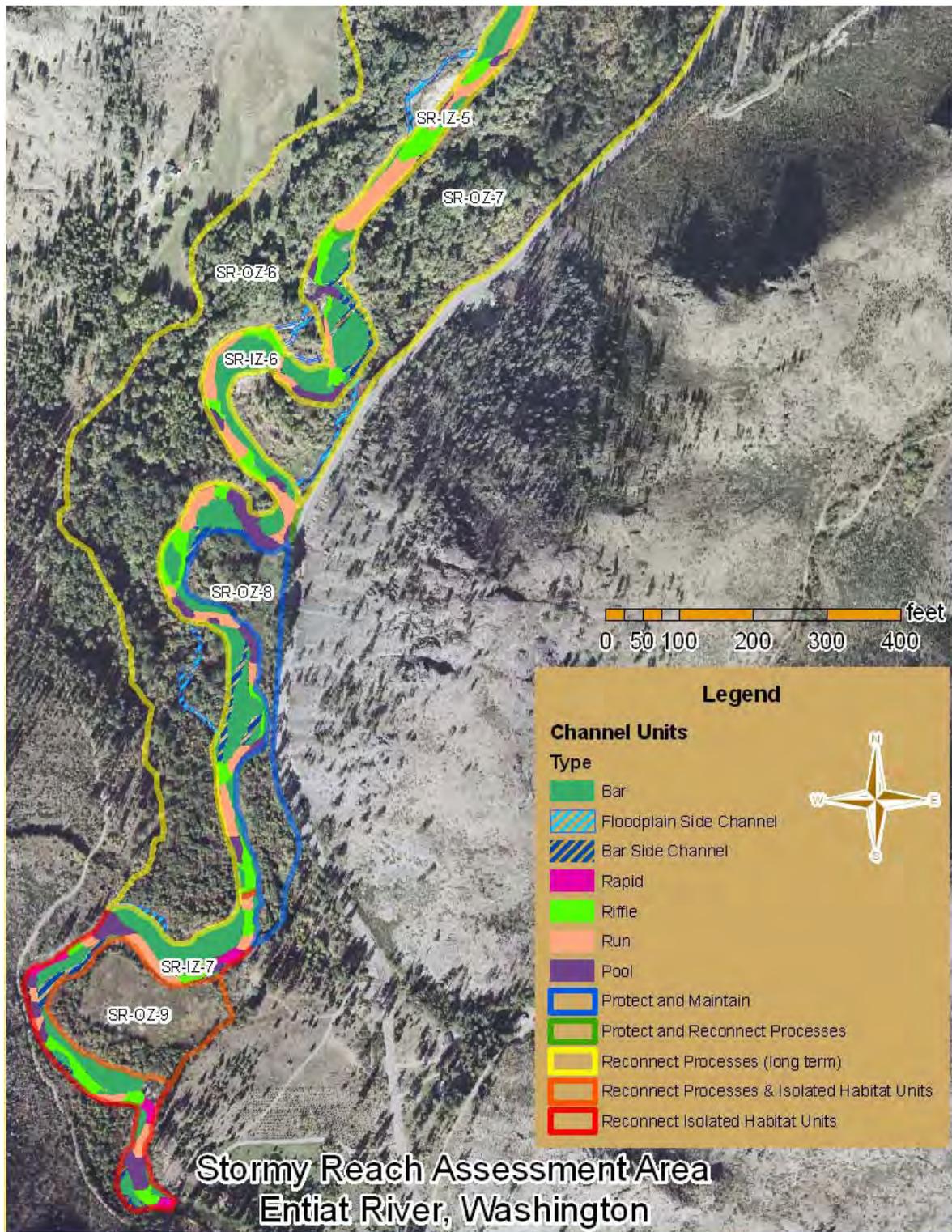


Figure 12. Location map of subreaches between RM 18.02 and 19.07 with channel units and anthropogenic features shown.

SR-IZ-6 (Inner Zone)

Inner zone SR-IZ-6 is located between RM 18.42 and 19.07 and covers about 13.9 acres of the active channel (Figure 12). This inner zone is a deposition subreach with a relatively lower gradient and higher sinuosity compared to SR-IZ-4 and SR-IZ-5. The subreach also contains a varied mix of channel units that include a locally high number of deep pools. The dominant substrate is gravel and cobbles with sand. Anthropogenic features include 150 feet of riprap along the left bank at RM 18.46 that protects the highway and a rock spur on the right bank and a historic bridge abutment on the left bank at RM 18.32 (Photograph Nos. 7 and 8). The effects of the riprap may promote vertical migration due to increased energy and shear stress within the channel and may also slightly diminish channel migration. The riprap could be modified with large wood to address increased energy and shear stress and increase complexity of in-stream habitat units while still providing protection to the infrastructure (Table 25). If feasible, the historic bridge abutment could be removed and the rock spur could be modified with wood to increase the number of habitat units; however, disturbance associated with these actions should be compared to value of already existing habitat and stability. Large wood recruitment potential and shading are adequate in this subreach. Protect/maintain and reconnect processes by the treatment of riprap is recommended for this subreach.

Table 25. Potential habitat actions for SR-IZ-6.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Protection	Protect and maintain rehabilitated levels of geomorphic, hydrologic, and improved vegetative function, and reconnect processes that impact floodplain connectivity and channel migration through the modification of bank protection and modification/removal of rock structures and historic abutments with wood placements to increase habitat units and still provide bank protection for infrastructure.	4; Productivity, Abundance, Diversity, and Structure	High



Photograph No. 7. View is to the east showing a rock spur near RM 18.73 along the right bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation. Photograph by R. McAfee, August 7, 2008.



Photograph No. 8. View is to the north of a historic bridge abutment near RM 18.73 along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation. Photograph by R. McAfee, August 7, 2008.

SR-IZ-7 (Inner Zone)

Inner zone SR-IZ-7 is located between RM 18.02 and 18.42 and covers about 7.7 acres of the active channel (Figure 13). This inner zone is a transition to transport subreach with a section of boulder-sized material from an adjacent talus slope in the mid-section near RM 18.2, and a bridge constriction at the downstream end. Other human features include at least one rock spur, with two other crude clusters of cobble and small boulder-sized material along the left bank near RM 18.36 (Photograph No. 9). Overall, the dominant substrate is gravel and cobble with sand and boulders with varied channel units that include rapids and deep pools.

Although the dominant process is interpreted to be a transition-to-transport, at higher flows, the constriction of the bridge may cause a backwater effect and thus local deposition during higher flows. Large wood recruitment potential and shading are limited in this subreach due to the 1994 Tyee fire and possibly other fires, in addition to historic agricultural use (see SR-OZ-9). Reconnection of processes and isolated habitat units through riparian planting is recommended for this subreach. Upon completion of the vegetation planting, the subreach should be protected (Table 26).

Table 26. Potential habitat actions for SR-IZ-7.

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect Isolated Habitat Units: Modify rock spur with wood placements to increase habitat units and still provide bank protection for infrastructure.	2; Productivity and Abundance	Moderate
2	Protection	Protect and maintain rehabilitated levels of geomorphic, hydrologic, and improved vegetative function.	4; Productivity, Abundance, Diversity, and Structure	Low



Photograph No. 9. View to the southwest showing a channel unit of rapids and three rock spurs along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation. Photograph by R. McAfee, August 7, 2008.

SR-OZ-8 (Outer Zone)

Outer zone SR-OZ-8 is located between RM 18.39 and 18.76 on river left and covers about 7.2 acres of floodplain (Figure 13). There are no anthropogenic features within the subreach that impede floodplain connection or function. This subreach has good large wood recruitment potential and canopy cover. Protection is recommended to maintain current levels of hydrologic and geomorphic function and the improved vegetative function (Table 27).

Table 27. Potential habitat actions for SR-OZ-8.

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

SR-OZ-9 (Outer Zone)

Outer zone SR-OZ-9 is located between RM 18.1 and 18.35 on river left and covers about 7.0 acres of floodplain (Figure 13). There are no anthropogenic features within the subreach that impede floodplain connectivity or function. This subreach has impaired large wood recruitment potential and canopy cover due to the clearing of riparian vegetation for agricultural use. Riparian planting to improve riparian processes (large wood recruitment potential and shading) is recommended. Upon completion of the riparian planting, protection is recommended to maintain current levels of hydrologic and geomorphic function and the improved vegetative function (Table 28).

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

Option	Habitat Action	Prioritized Habitat Actions	VSP Parameters Addressed	Geomorphic Potential
1	Rehabilitation	Reconnect riparian processes: Replant appropriate riparian vegetation within the 30 meter buffer zone. Protect and maintain rehabilitated levels of geomorphic, hydrologic, and improved vegetative function.	4; Productivity, Abundance, Diversity, and Structure	Moderate

SUMMARY AND CONCLUSIONS

The Stormy reach, located between river miles RM 18.02 and RM 20.85 on the Entiat River, is a 6th field Hydrologic Unit Code (HUC) watershed. The Stormy 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 Stormy reach. This lateral channel migration maintained a lower energy and flatter channel gradient and supported a dynamic cycle of conversion from river to floodplain and vice versa, producing a continuous renewal of fish habitat. Alteration of these processes has negatively impacted the availability of fish within the basin.

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

The geomorphic potential is interpreted to be altered because of reduced floodplain connectivity, lateral channel migration, and channel complexity due to impacts to recruitment of large wood. Reduced floodplain connectivity is due to a levee in the inner zone subreach SR-IZ-4. This levee also effects floodplain connectivity in the upper sections of PR-OZ-6 and PR-OZ-7 as a result of incision. Reduced channel migration is due to small sections of highway and riprap, bridge abutments and rock spurs in inner zone subreaches PR-IZ-5, PR-IZ-6, and PR-IZ-7. Although these human features have been documented, the impact that they currently have on the ecosystem may be less than the disturbance to existing habitat and processes that would be caused by their removal. Both indicators of canopy cover for shading and large wood recruitment potential are in an **At Risk Condition** for almost every outer zone due to the 1994 Tye fire. Although the vegetation is recovering, the dominant seral stage is sapling/pole. These subreaches are interpreted to be in an **At Risk Condition** and are recommended for rehabilitation actions.

The large woody debris reach-based ecosystem indicator is interpreted to be in an **Adequate Condition** based on observations in the habitat assessment (Appendix B).

However, large wood or wood/boulder placements could be used to address those areas of increased stream power and resulting incision, such as inner zones SR-IZ-2, SR-IZ-3, and SR-IZ-5 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 mid-section 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 SR-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*.

TERM	DEFINITION
2D-hydraulic analysis	Information derived from a hydraulic model 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.

TERM	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 hydraulic model 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 <i>Map Atlas</i> .
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 occurring 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 including the lowering of a stream bed due to scouring (incision). Also refers to loss of functional elements within an ecosystem and subsequent negative impacts to fluvial processes and dependant life forms.
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).

TERM	DEFINITION
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.
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 interaction of hydrologic, riparian, and geomorphic regimes to form, connect, and sustain fluvial systems (including 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.

TERM	DEFINITION
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. <i>Also known as channel or geomorphic units.</i>
indicator	A variable used to forecast the value or change in the value of another variable; for example, using temperature, turbidity, and chemical contaminants 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.
intervention 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 known as the floodprone zone)

TERM	DEFINITION
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.
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.

TERM	DEFINITION
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.
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

Stormy Reach-based Ecosystem Indicators

Appendix A

Reach-based Ecosystem Indicators (REI) Version 1.1

The Stormy reach assessment team was comprised of Robert McAfee (Reclamation geologist and reach assessment lead), Edward W. Lyon, Jr., L.G. (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, 2008), *Entiat Water Resource Inventory Area (WRIA) 46 management Plan, October 2004* (CCCD 2004), and 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
	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'	-----	170200100104	4	84% public

GENERAL CHARACTERISTICS: VALLEY SEGMENT

Valley Characteristics	Valley Bottom Type	Valley Bottom Width	Valley Bottom Gradient	Valley Confinement	Channel Patterns
	U-shaped trough (<i>U1</i>)	8.6	.005	Unconfined	Variable

GENERAL CHARACTERISTICS: CHANNEL SEGMENT

Channel Characteristics	Valley Type	Elevation	Dominant Channel Type	Bed-form Type	Channel Gradient	Sinuosity
	Alluvial	1560'-1640	C	Pool-riffle	.0019	1.4

GENERAL CHARACTERISTICS: WATERSHED CONDITION

GENERAL INDICATORS: EFFECTIVE DRAINAGE NETWORK AND WATERSHED ROAD DENSITY

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

General Pathway	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 at the watershed scale is at an 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
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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 Stormy reach is interpreted to be a glacial trough filled with alluvium. The river and groundwater are interpreted to be hydraulically connected. Although within the Stormy reach the aquifer depth is mostly greater than 100 feet, sites of groundwater up welling between RM 19 and 22 were identified (CCCD 2004). However, 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. As a result stream flow at the watershed scale is interpreted to be in an at risk condition.

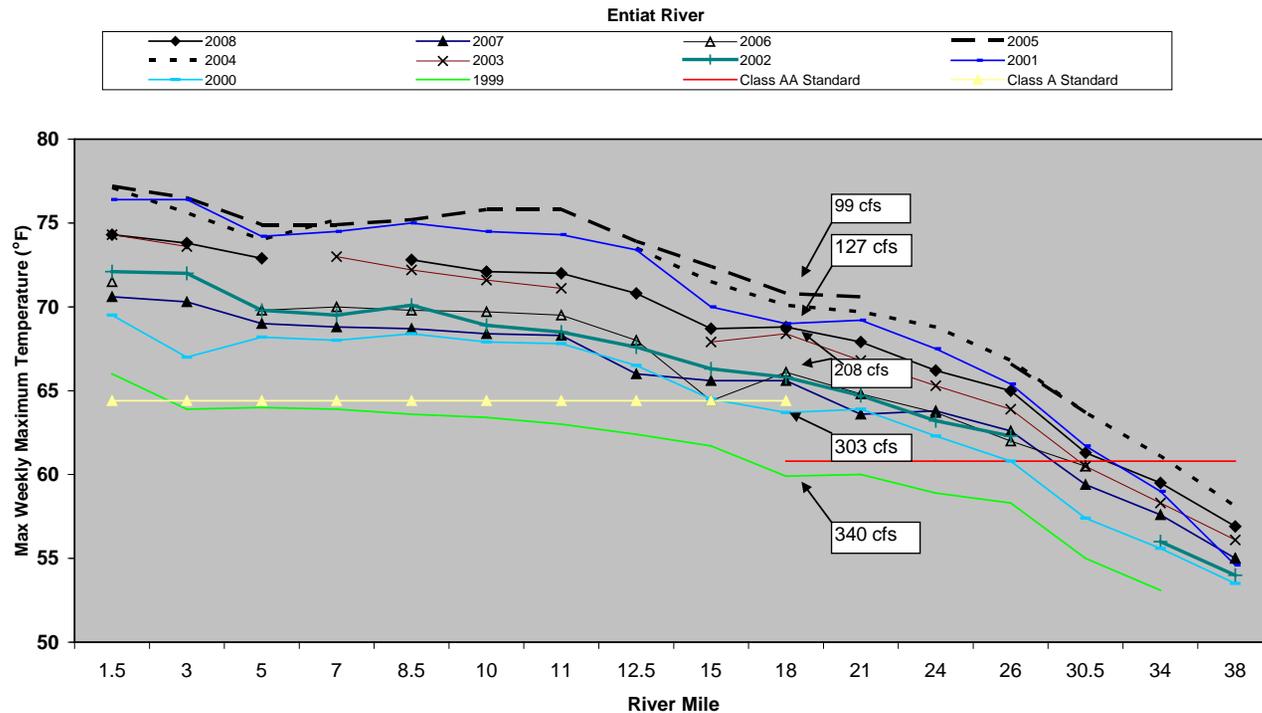
GENERAL CHARACTERISTICS: WATER QUALITY

GENERAL INDICATOR: TEMPERATURE

Criteria: The following criteria were developed by Hillman and Giorgi (2002), USFWS (1998), and WDOE (2008).

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 Stormy reach is located between RM 18.02 and 20.85.



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). Maximum temperature criteria 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
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Narrative:

Data from the DOE 46A110 station at Dill Creek was not available for this indicator. Therefore, based on averaged Water Quality Index (WQI) values reported for turbidity from 1994 to 2007 at DOE 46A070 station on the Entiat River near Entiat 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, 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: 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&scroll=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
1/8/07	11:45	91	4	305	0.01 U	0.107	0.0045	14.38	7.95	755.142	13	1.9	0.0109	0.14	6.8

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)
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, 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
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
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 was used to evaluate this indicator.

One chemical water quality variable (pH), was 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 this variable is a natural condition or from anthropogenic impacts based on the limited data, and all other chemical variables are in Adequate Condition 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
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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 18.0-20.7
Habitat Reach:	Reach 1
Visual Estimate:	
Percent sand (< 2 mm)	25%
Percent gravel (2 – 64 mm)	50%
Percent cobble (64 – 256 mm)	25%
Percent boulder (> 256 mm)	0%
Percent bedrock	0%
Pebble Count Data:	
Percent surface fines (< 6 mm)	15%
D50 (mm)	43.3 mm
D84 (mm)	80.4 mm
Percent sand (< 2 mm)	13%
Percent gravel (2 – 64 mm)	58%
Percent cobble (64 – 256 mm)	28%
Percent boulder (> 256 mm)	0%
Percent bedrock	0%
Dominant Substrate:	Gravel/Cobble
Embeddedness:	None
Fine Sediment:	> 12%

Interpretation:

River Miles:	RM 18.0-20.7
Habitat Reach:	Reach 1
Dominant Substrate	Adequate Condition
Embeddedness	Adequate Condition
Fine Sediment	At Risk Condition

Narrative:

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 removal of the riparian vegetation 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*.

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 18.0-20.7
Habitat Reach:	Reach 1
Large wood per mile (in-channel only):	
Small (> 20 feet long, > 6 inches diameter)	41.1
Medium (> 35 feet long, 12-20 inches diameter)	16.0
Large (> 35 feet long, > 20 inches diameter)	8.8
Total large and medium	24.8

Interpretation:

River Miles:	RM 18.0-20.7
Habitat Reach:	Reach 1
Large Wood Per Mile	At risk

Narrative:

Wood was removed from the river in the 1970s by the ACOE to reduce the threat of flooding. Large and medium wood counts in this reach meet the criteria for adequate 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 18.0-20.7
Habitat Reach:	Reach 1
Measured miles	3.31 mi
Total number of surveyed pools	35
Pools per mile	10.6
Average wetted channel width (feet)	63 ft
Number of pools > 5 feet deep per mile	5.4
Average maximum pool depth (feet)	4.99 ft
Average pool residual depth (feet)	3.90 ft
Percent Habitat Area:	
Percent pools	59%
Percent riffles	22%

River Miles:	RM 18.0-20.7
Percent runs	15%
Percent side channels/off-channel habitat	4%
Required number of pools per mile	9
Primary Pool Form:	
Number of bedrock pools	0
Number of scour pools ¹	29
Number formed by large wood	4
Number formed by boulders	1
Number formed by others ²	1

¹Large wood increased the depth in many of these pools.

²Forming agents such as riprap, bridge abutments, or at confluences.

Interpretation:

River Miles:	RM 18.0-20.7
Habitat Reach:	Reach 1
Frequency and Quality:	Adequate Condition
Large Pools:	Adequate Condition

Narrative:

Between RM 18.0 and 20.7 pool frequency and quality meets the Adequate Condition criteria.

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 18.0-20.7
Habitat Reach:	Reach 1
Percent side channels/off-channel habitat	4%

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 18.3	Right	350 ft	15 ft	2 ft / 3 ft	The Shamel Creek confluence leads to a pond. Substrate in the pond is 100% silt. The side channel is not connected to the river at the top.
RM 18.8	Left	625 ft	24 ft	2 ft / 4.5 ft	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.
RM 18.9	Right	150 ft	22 ft	1.2 ft / 2.5 ft	The short side channel is a straight line channel that cuts through a meander bend.
RM 19.2	Right	150 ft	40 ft	2 ft / 4 ft	Off-channel pond that is disconnected to the river at low flow. The pond is about 7' from the river.
RM 20.2	Right	400 ft	205 ft	0.2 ft / 107 ft	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'.

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

River Miles:	RM 20.1-20.73	RM 19.5-19.79	RM 19.08-19.5	RM 18.42-19.08	RM 18.02-18.42
Subreach:	PR-IZ-2	PR-IZ-4	PR-IZ-5	PR-IZ-6	PR-IZ-7
Side Channel Area	0.61 acres	0.09 acres	0.16 acres	1.16 acres	0.65 acres

River Miles:	RM 20.6	RM 20.54-20.62	RM 19.95	RM 19.71, 19.25, 19.02, 18.6, 18.32	RM 18.95
Subreach:	SR-OZ-1 (Left)	SR-OZ-3 (Right)	SR-OZ-4 (Right)	SR-OZ-6 (Right)	SR-OZ-7 (Left)
Side Channel Area	0.07 acres	2.7 acres	0.78 acres	1.29 acres	0.34 acres

Side channel Area:	RM 18.0-20.7
Inner Zone	3.44 acres
Outer Zone	4.5 acres

Interpretation:

Off-channel Habitat	At Risk Condition
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Narrative:

Human features in the form of levees and highways disconnect the river from or reduce the amount of available

River Miles:	RM 20.05 -20.1	RM 19.5-19.79	RM18.42 – 19.07	RM 18.02 – 18.42
Reach		SR-IZ-4	SR-IZ-6	SR-IZ-7
Levee		1,033 ft		
Constraining Highway (length)	511 ft		147 ft	
Rock Spurs (individual)			1	1
Bridge Abutments (individual)			1 (historic)	2 (active)

floodplain and disrupt fluvial processes that create and maintain side channels within the floodplain. 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: Disconnected subreach analysis by Reclamation (Appendix B).

River Miles:	RM 19.64-19.8 (Left)	RM 19.6-19.82 (Left)
Subreach:	SR-DIZ-1	SR- DOZ-1
Levee (length)	1,033 ft	1,033 ft
Road Embankment (Historic)	573 Ft	
Disconnected Area	2.72 acres	18.84 acres

Narrative:

Human features in the form of a levee have disconnected the river from its floodplain at RM 19.64 to 19.8. The levee also affects the downstream inner and outer zones downstream through increased water velocities that likely leads to incision. 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 at 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 18.0-20.7
Habitat Reach:	Reach 1
Linear feet of erosion per mile	1,945 ft
Percent eroding banks (total both banks)	18.2%

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

River Miles:	RM 20.05 -20.1	RM 19.5-19.79	RM18.42 – 19.07	RM 18.02 – 18.42
Reach		SR-IZ-4	SR-IZ-6	SR-IZ-7
Levee		1,033 ft		
Constraining Highway (length)	511 ft		147 ft	
Rock Spurs (individual)			1	1
Bridge Abutments (individual)			1 (historic)	2 (active)

Narrative:

Locally, lateral channel migration rates have been adversely impacted by a levee and sections of highway that constrain the river. It may be close to a natural condition given the location of the adjacent talus slope. However localized sections of increased stream energy and thus vertical migration (incision) are likely increased. 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 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	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 18.0 – 20.7
Average Mean Daily Flow (USGS gage @ RM 18.0)	124 cfs
Average Wetted Width	63 ft
Bankfull Width	113 ft
Width/Depth Ratio	45.6
Floodplain Width	> 500 ft
Entrenchment Ratio	> 5 to 1
Rosgen Channel Type	C4

Data: Reclamation channel unit analysis (Appendix b and Tributary assessment).

River Miles:	RM 18.02 – 18.42	RM 18.42 – 19.07	RM 19.07 – 19.5	RM 19.5 – 19.79
Subreach:	Subreach SR-IZ-7	Subreach SR-IZ-6	Subreach SR-IZ-5	Subreach SR-IZ-4
Channel Gradient:	0.23%	0.23%	0.23% - 0.57%	0.57% - 1.26%
Channel Units (acres):				
Pool	0.88 acres	1.84 acres	0.25 acres	0 acres
Run	0.97 acres	2.38 acres	2.49 acres	1.29 acres
Riffle	0.9 acres	0.98 acres	0.91 acres	0.93 acres
Rapid	0.43 acres	0 acres	0 acres	0 acres
Bar	3.5 acres	6.1 acres	1.47 acres	0.71 acres
Side Channel	0.65 acres	1.16 acres	0.16 acres	0.09 acres
Channel Units (percentage):				
Pool	12%	14%	5%	0%
Run	13%	18%	47%	43%
Riffle	12%	15%	17%	31%
Rapid	6%	0%	0%	0%
Bar	48%	45%	28%	23%
Side Channel	9%	9%	3%	3%
Dominant Substrate:	Cobble/Gravel	Gravel/Cobble	Cobble/Gravel	Cobble/Boulder
Interpreted Localized Trend:	Transition	Deposition	Transition	Transport

Data: Reclamation channel unit analysis (Appendix b and Tributary assessment).

River Miles:	RM 19.79 – 20.1	RM 20.1 – 20.73	RM 20.73 – 20.85
Subreach:	Subreach SR-IZ-3	Subreach SR-IZ-2	Subreach SR-IZ-1
Channel Gradient:	0.23%	0.23%	0.23% - 0.57%
Channel Units (acres):			
Pool	0.35 acres	0.76 acres	0 acres
Run	1.18 acres	2.95 acres	0.31 acres
Riffle	1.25 acres	2.24 acres	0 acres
Rapid	0 acres	0.11 acres	1.02 acres
Bar	2.79 acres	3.64 acres	0.23 acres
Side Channel	0 acres	0.61 acres	0 acres
Channel Units			

River Miles:	RM 19.79 – 20.1	RM 20.1 – 20.73	RM 20.73 – 20.85
(percentage):			
Pool	6%	7%	0
Run	21%	29%	20
Riffle	22%	22%	0
Rapid	0%	1%	66%
Bar	50%	35%	15%
Side Channel	0%	6%	0%
Dominant Substrate:	Cobble/Gravel	Gravel/Cobble	Cobble/Gravel
Interpreted Localized Trend:	Transition to Deposition	Transition	Transport

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

River Miles:	RM 20.05 -20.1	RM 19.5-19.79	RM18.42 – 19.07	RM 18.02 – 18.42
Reach		SR-IZ-4	SR-IZ-6	SR-IZ-7
Levee		1,033 ft		
Constraining Highway (length)	511 ft		147 ft	
Rock Spurs (individual)			1	1
Bridge Abutments (individual)			1 (historic)	2 (active)

Narrative:

Levees and sections of highway constrain the river and have adversely impacted lateral channel migration through increased water velocities, especially between RM 19.64 and 19.8 (appendix) 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	26	9.20%
Residential Area	0.34	0.12%
Roads Area	2.14	0.76%
Seral Stage (Floodplain):		
No Vegetation	2.14	0.76%
Grass/Forbes	31.16	11.03%
Tall Grass/Forbes & Short Shrub/Seedling	68.41	24.22%
Shrub/Seedling	14.94	5.29%
Sapling/Pole	84.41	29.88%
Small Tree	26.34	9.32%
Large Tree	28.76	10.18%

Narrative:

Most of the vegetation within the Stormy reach has been impacted by fires. Concerning human impacts, about ten percent of the floodplain vegetation has been altered by agriculture and residential development. There are localized areas where vegetation has been cleared that could be re-vegetated. However, overall the Stormy reach’s riparian vegetation composition and structure is interpreted to be in an Adequate Condition although at a younger seral stage.

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	0.33	0.41%
Residential Area	3.24	3.99%
Roads Area (No vegetation)	2.10	2.59%
Seral Stage (30 m width):		
No Vegetation	2.10	2.59%
Grass/Forbes	10.72	13.21%
Tall Grass/Forbes & Short Shrub/Seedling	26.78	32.99%
Shrub/Seedling	5.76	7.10%
Sapling/Pole	23.00	28.34%
Small Tree	5.91	7.28%
Large Tree	6.90	8.50%

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:

Only about seven percent of the vegetation within the 30 meter buffer zone has been altered by agriculture and residential use. However, less than 20 % mature trees are found in the 30 meter buffer zone. In addition, road densities within the lower-mid Entiat watershed are around 3.1 mi/mi². 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		
Grass/Forbes	3.82	14.15%
Tall Grass/Forbes & Short Shrub/Seedling	12.11	44.85%
Shrub/Seedling	2.16	8.00%
Sapling/Pole	6.13	22.70%
Small Tree	1.28	4.74%
Large Tree	1.50	5.56%

Narrative:

About 41 percent of riparian buffer zone (10 meter width along both banks) is in the shrub/seedling to large tree condition and is in recovery from fire. The 10 meter buffer zone is used as a surrogate to evaluate the condition of canopy cover and is interpreted to be in an At Risk Condition due to the young seral stage.

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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.

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APPENDIX B

Stormy Reach Initial Site Assessment

INITIAL SITE ASSESSMENT

Channel units were mapped and rectified with LiDAR by geologist 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 the 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 process that create and maintain them over time. While the basic parameters are similar, the evaluation of the individual unit attributes is not the same not is the applicability of the information to alternative development, evaluation and implementation. The habitat unit describes 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 2006 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 the first significant terrace tread 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) and lines (i.e. levees and roads). The attribute table contains several fields including type of feature, length or area, etc.

Point locations of photographs 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.

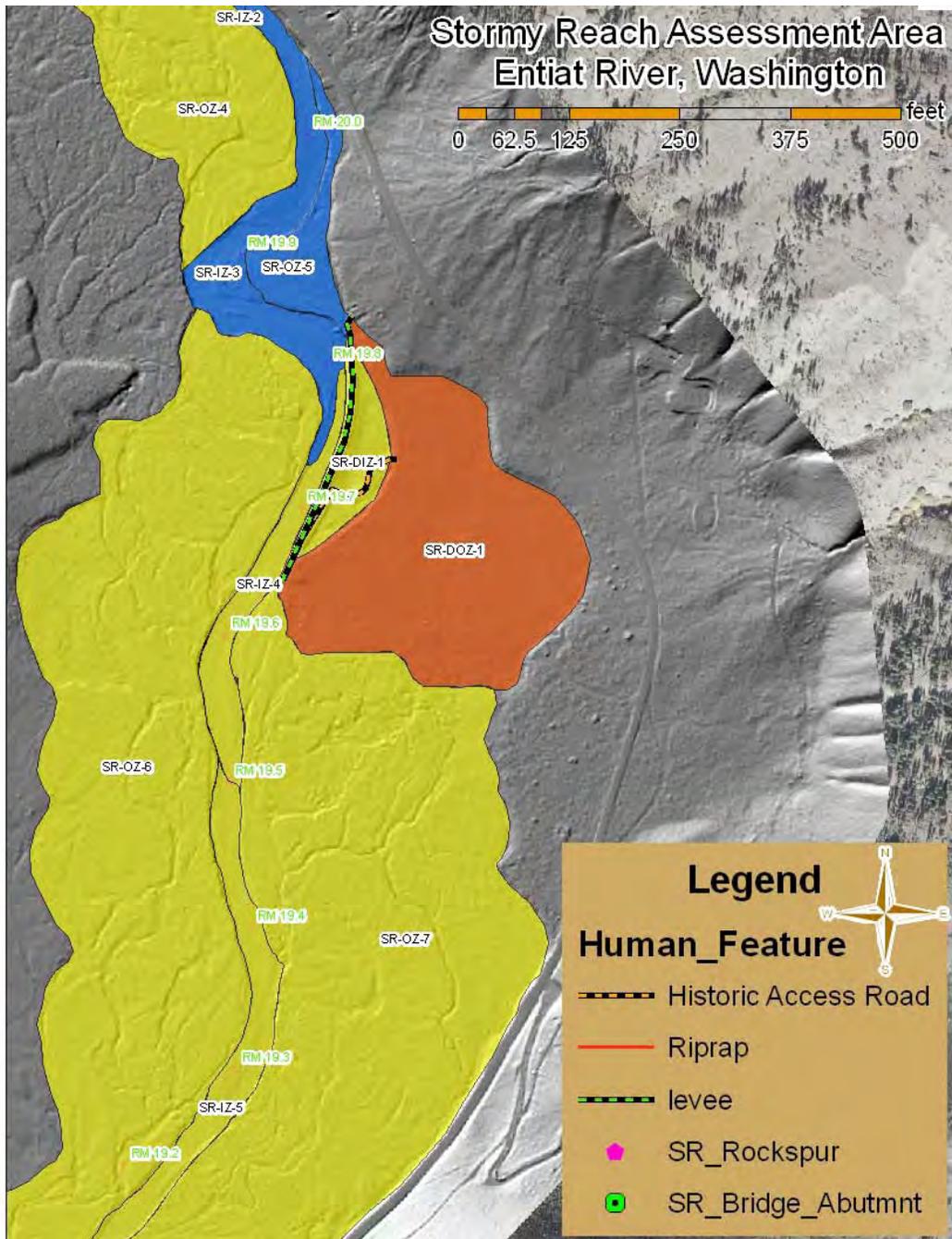


Figure 2. Subreach unit map with human features. The subreaches are color-coded based on the dominant proposed habitat action (i.e. green is reconnect processes and protect or reconnect isolated habitat, yellow is reconnect processes, orange is reconnect isolated habitat units, etc.).

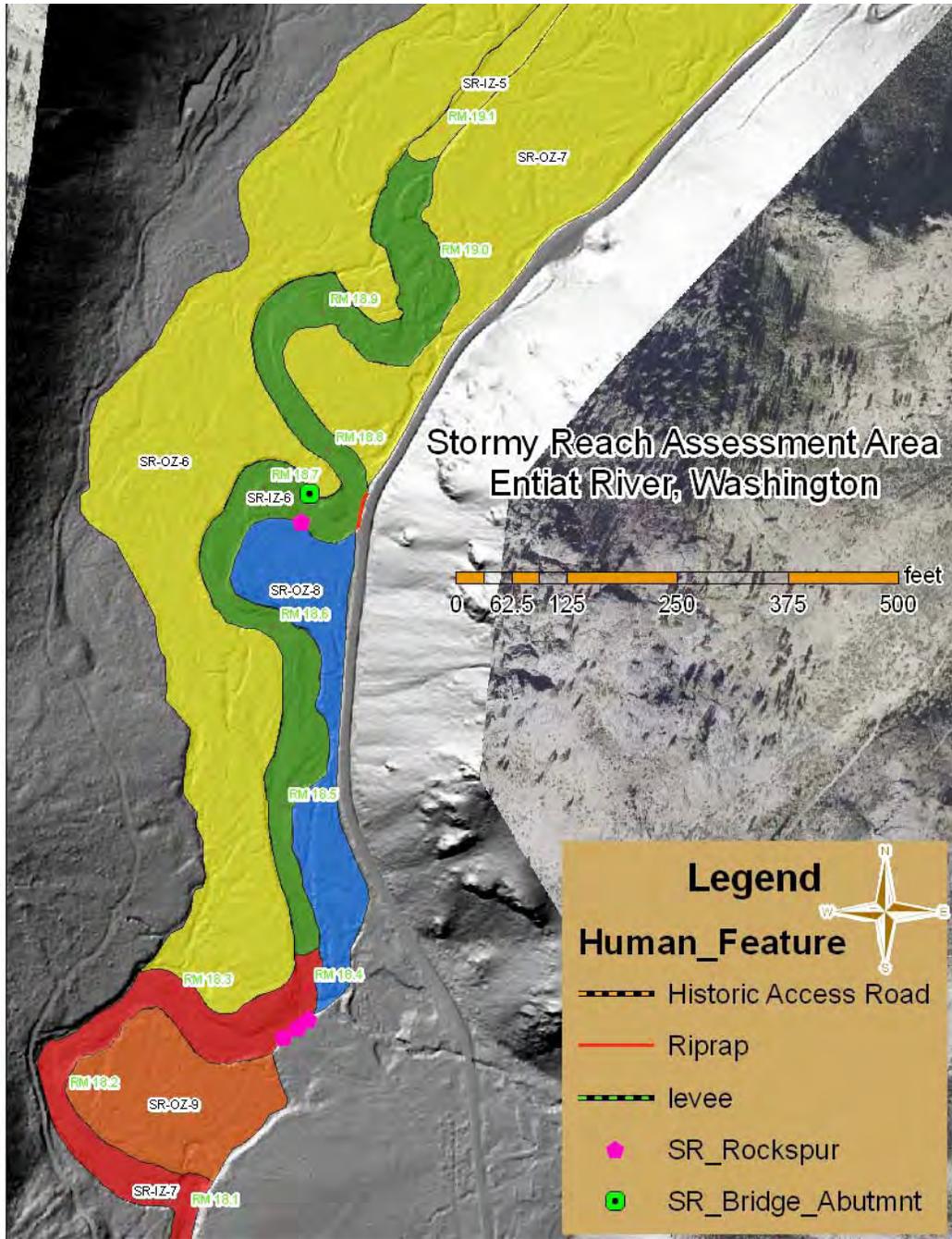


Figure 3. Subreach unit map with human features. The subreaches are color-coded based on the dominant proposed habitat action (i.e. blue is protect and maintain, green is reconnect processes and protect or reconnect isolated habitat, yellow is reconnect processes, orange is reconnect isolated habitat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

Table 1: Summary of human features by subreach

Subreach	Count	Type	Length (feet)
SR-IZ-4	1	Levee	1,033
SR DIZ-1	1	Historic Access Road	573
SR-IZ-6	1	Historic Bridge Abutment	NA
SR-IZ-6	1	Rock Spur/Revetment	NA
SR-IZ-6	1	Riprap	147
SR-IZ-7	3	Rock Spur/Revetment	NA
SR-IZ-7	2	Active Bridge Abutment	NA



Figure 4. Photograph points and numerical sequence.



Figure 5. Photograph points and numerical sequence.

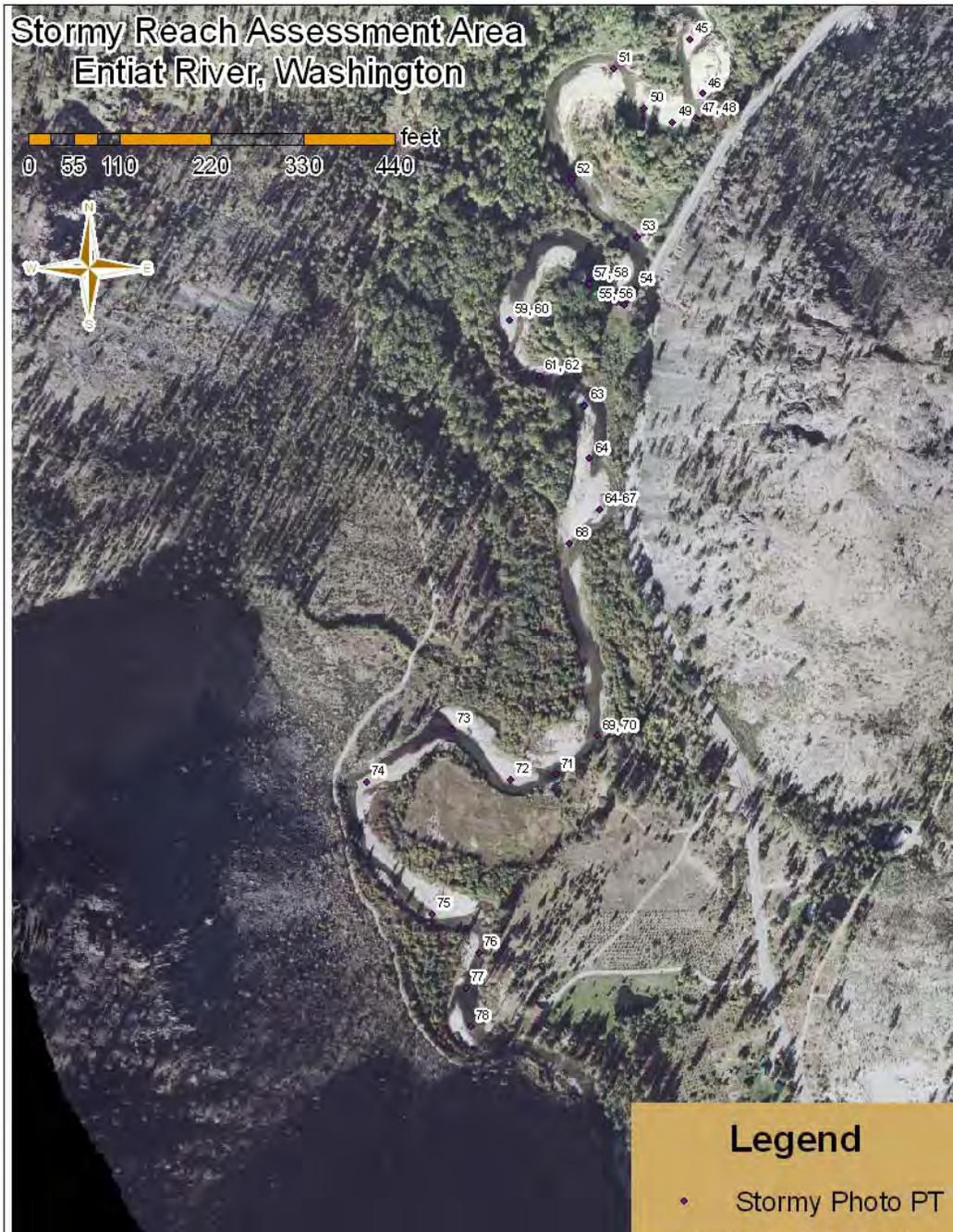


Figure 6. Photograph points and numerical sequence.



Photograph No. 1. View to the southwest looking at erosion of the right bank which contains high levels of fine-grained material. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 2. View to the east looking at local erosion along the left bank. Note the apparent clearing of riparian vegetation. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 3. View to the east looking at young seral stage vegetation along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 4. View to the southwest of alluvial material that includes boulders along the right bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 5. View to the south of a cobble with boulder point bar along the left bank and a riffle-pool channel unit sequence. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 6. View to the southwest of local erosion along the right bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 7. View to the southeast showing a riffle-pool channel unit sequence and varied successional stages of vegetation along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 8. View to the northeast of channel-spanning large wood. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 9. View to the south showing woody debris along the left bank and a channel unit sequence of riffle to run. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 10. View to the southwest showing varied seral stage of vegetation along the right bank and a pool associated with wood. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 11. View to the south showing a gravel point-bar on the left bank and varied successional stage vegetation along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 12. View to east showing varied successional stage vegetation along the left bank and large wood with root-wad intact within the channel. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 13. View to the northeast showing gravel point bars along the left bank and wood accumulation along the bank and within the channel. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 14. View to the north of wood accumulation along the left bank, and gravel substrate. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 15. View to the northeast of a channel unit sequence of riffle-pool, and vegetation of varied successional stage along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 16. View to the southeast of the highway along the left bank and boulders in the channel. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 17. View to the southwest of shrub/seedling vegetation and finer material along the right bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 18. View to the southwest of local bank erosion along the right bank. Note the lack of mature vegetation. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 19. View to the south of cobble and gravel substrate and channel unit sequence of riffle-pool. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 20. View to the south of a cobble and gravel bar with a large wood complex in the channel. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 21. View to the southeast showing a channel unit sequence of riffle to run, with gravel and cobble substrate. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 22. View to the south of local bank erosion along the right bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 5, 2008.



Photograph No. 23. View to the northwest, looking upstream at a gravel bar with large wood accumulation and a channel unit sequence of riffle to run. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 24. View to the south showing a gravel and cobble bar along the toe of the right bank. Note the varied successional stage of the vegetation. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 25. View to the south of boulder and cobble armoring along the toe of the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 26. View to the south of a cobble and gravel point bar along the right bank and wood accumulation along the left bank. The channel unit sequence is run to riffle. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 27. View to the southwest of a one-meter plus left bank comprised of gravels and finer material. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 28. View to the southwest of small wood along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 29. View to the north of gravel and cobble substrate on both banks and a channel unit sequence of riffle to run. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 30. View to the northwest of the return of a side channel along the right bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 31. View to the southwest of a gravel and sand point bar along the left bank and wood accumulation in the channel along the right bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 32. View to the east of multiple bars comprised of gravel with sand. The dominant channel units are riffle and run. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 33. View to the southeast of sandy flood-deposits along the top of the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 34. View to the south of a levee along the left bank and a gravel point bar along the right. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 35. View to the south along the crest a levee located along the left bank of the channel. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 36. View to the east of an access road that is connected to the back side of the levee. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 37. View to the west of varied successional stages of vegetation on the right bank and a transition in channel units from run to riffle. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 38. View to the west of a channel unit sequence of run-riffle pool, and local bank erosion along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 39. View to the south of a gravel and cobble bar along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 40. View to the south of a gravel and cobble point bar along the right bank and local bank erosion along the left. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 41. View to the south of a gravel point bar along the right bank and a channel unit sequence of glide-riffle-glide. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 42. View to the south of a channel unit sequence of riffle-run-pool, and wood accumulation along the right bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 43. View to the southeast looking at large wood accumulation along the left bank. The bank is locally comprised of fine material. The channel unit is pool. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 44. View to the southeast looking at large wood accumulation along the left bank. The channel unit sequence is pool-riffle-pool. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 45. View to the west of the head of an active side channel off the right bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 46. View to the southeast of sand bars and wood accumulation near the head of a side channel off the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 47. View to northeast, looking upstream at a pool with good shading from mature vegetation along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 48. View to the southwest looking at a gravel bar along the right bank and a channel unit sequence of run-riffle-pool. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 49. Close up view showing wood accumulation and local erosion along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 50. View to the south of a gravel point bar along the right bank and medium-to-large wood in the active channel. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 51. View to the west of a channel unit sequence of riffle-to-run and local erosion along the right bank. Note the vegetation consisting of grass/forbes. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 52. View to the southwest of a channel unit of a run and local erosion along the right bank. Note the gestation of grass/forbes. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 53. View to northeast looking upstream at the return of a floodplain side-channel. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 54. View to the west of a pool and local erosion along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 6, 2008.



Photograph No. 55. View to the northeast of riprap along the road-base along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 56. View to the west of a pool and alternating gravel point bars. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 57. View to the east showing a rock spur near RM 18.73 along the right bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



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Photograph No. 59. View to the west of a gravel point bar along the left bank and a poll associated with large wood along the right bank of the right split flow. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 60. View to the southeast of a channel unit transition from run to riffle and local erosion along the left bank of the left split flow. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 61. View to the east of wood accumulation along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



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Photograph No. 63. View to the east of a channel unit of run, and local erosion along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 64. View to the northeast of a channel unit transition of run to riffle and a piece of large wood in the channel. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 65. View to the northeast of a run along the highway on the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 66. View to the southeast looking downstream an a pool and large wood in the active channel. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 67. View to the southeast of local vertical scour and erosion of the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 68. View to the southwest of a channel unit transition from riffle to run. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



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Photograph No. 70. View to the southwest of a channel unit of rapid and three rock spurs along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 71. View to the southwest showing a channel unit of pool and grass/forbes and shrub seedling vegetation along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 72. View to the west showing a gravel and cobble point bar along the right bank and local erosion along the left bank. Note the grass/forbes vegetation along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 73. View to the west showing a channel unit transition from pool to run and a gravel with cobble and sand point bar along the left bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 74. View to the southwest of a cobble and gravel bar, and boulders along the right bank and in channel from the talus slope. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 75. View to the south of local scour and erosion along the right bank. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 76. View to the northeast of a channel unit of run with a channel-spanning piece of large wood. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 77. View to the south of a transition from run to pool and ravel/sand bars. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.



Photograph No. 78. View to the southeast showing a transition from pool to riffle, a gravel point bar along the left bank a bridge. Stormy Reach – Entiat Subbasin, Washington – Bureau of Reclamation Photograph by R. McAfee, August 7, 2008.

APPENDIX C

Stormy Reach 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



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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 could perform. Substrate was visually estimated in every habitat unit in 5 size categories (sand, gravel, cobble, boulder, bedrock) based on size categories from Wolman pebble counts.

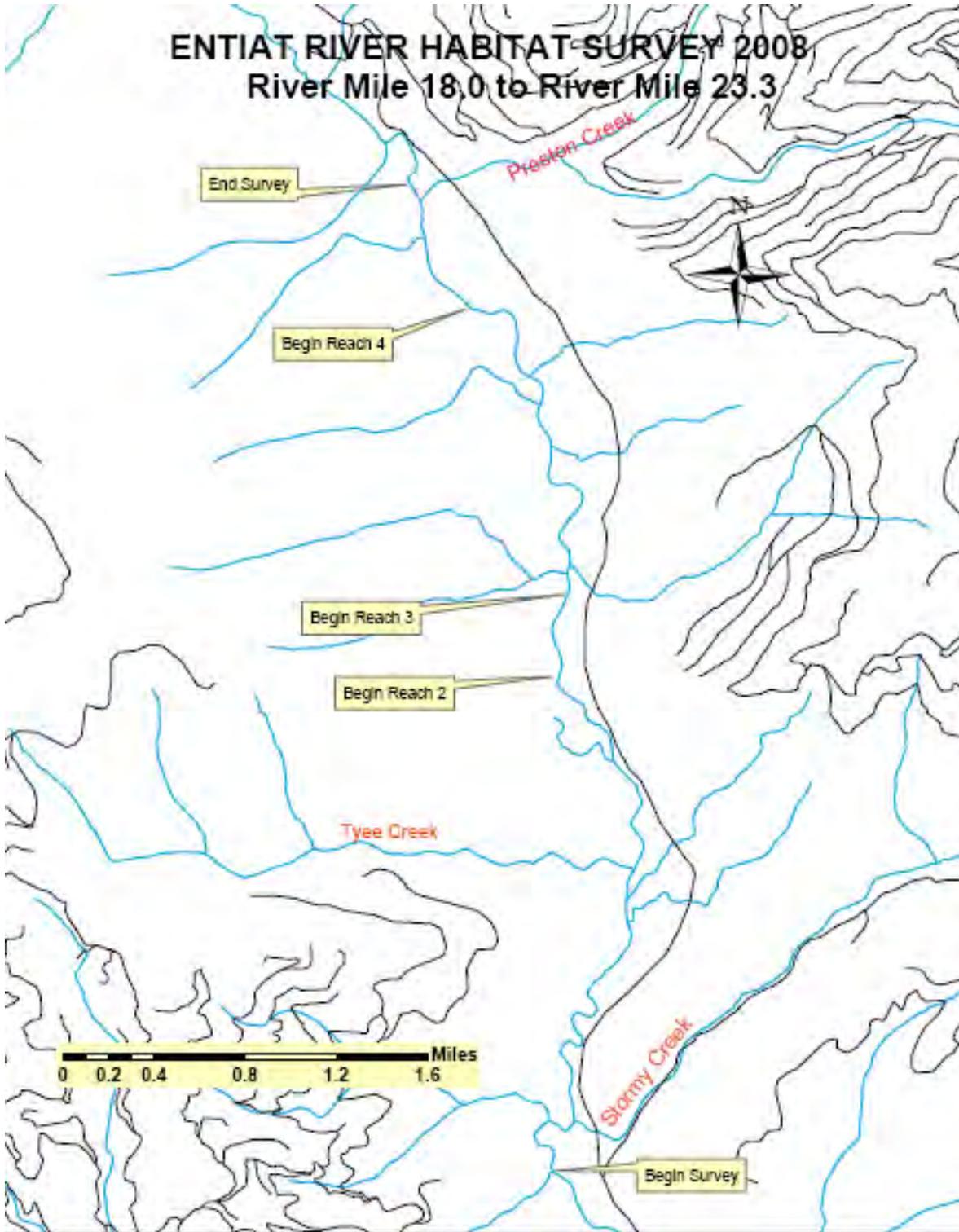
- At least two bankfull width/depth measurements were taken in each surveyed stream segment except reach 2 (one bankfull measurement was taken in reach 2). A total of 7 bankfull depths were measured and averaged across each bankfull width transect to compute width/depth ratio. The floodprone area was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

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 Wood¹ 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

¹Pieces 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

¹Pool maximum depth minus maximum depth at pool crest.

²Large wood increased the depth in many of these pools.

³Forming 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.

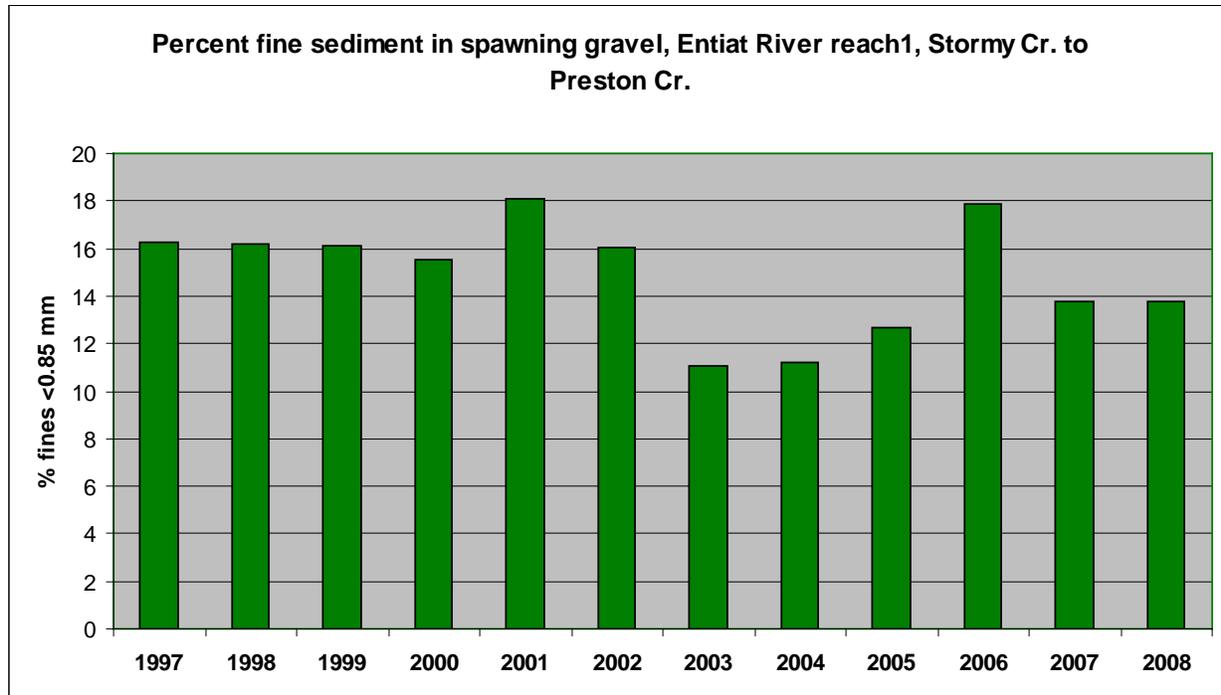


Figure x

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.

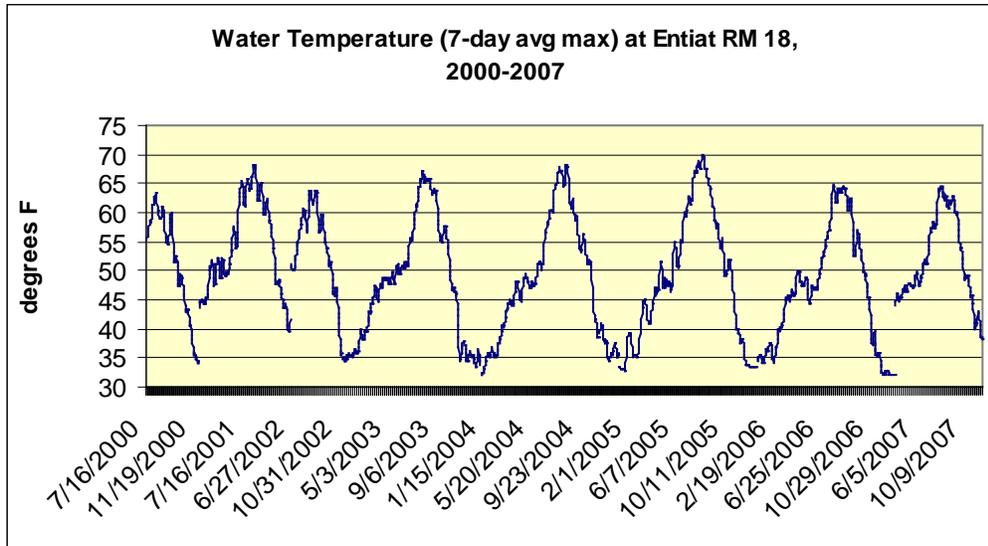
Bank Erosion: About 14% of the stream-banks are actively eroding, above the 10% threshold in the MPI (streams with > 90% stable banks are considered appropriately functioning in the MPI). Although the surveyed segment of the Entiat River exceeds guidelines in the MPI, most of the bank erosion is from 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 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

II. 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 of 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).

Period 1 Year Plot Start 00:00_10/01/2007
Interval 12 Hour Plot End 00:00_10/01/2008

2007/08

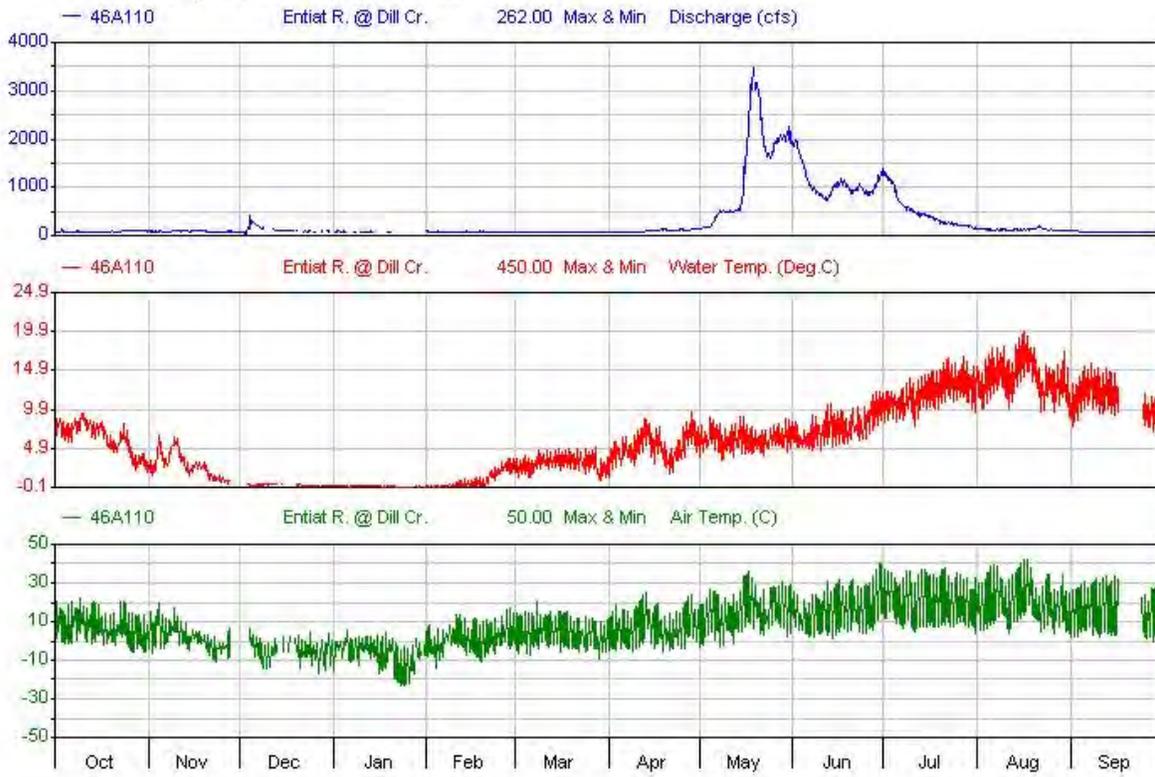


Figure z.



Confined stream channel and larger substrate in reach



Bank erosion in reach 2

III. 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 of 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

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 of 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.)					
% 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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USGS gage station #12452800 website, Entiat River near Ardenvoir.

APPENDIX D

Stormy Reach Vegetation Assessment

Riparian vegetation was mapped using first return lidar data that gives the canopy height. The feature height range was then related to groups of height used by Hudak et al. 2008. Those groups were then related to a modified version of the seral stage identified in the Stream Inventory Handbook (USDA, 2008). The summaries of the ArcGIS analysis are included in tables 1 through 3 and ArcGIS map images are included as figures 1 through 9.

Table 1. Summary of floodplain disturbance and seral stage of vegetation (See figures 1-3).

Disturbance (Floodplain):	Acres	Percentage
Agriculture Area	26	9.20%
Residential Area	0.34	0.12%
Roads Area	2.14	0.76%
Seral Stage (Floodplain):		
No Vegetation	2.14	0.76%
Grass/Forbes	31.16	11.03%
Tall Grass/Forbes & Short Shrub/Seedling	68.41	24.22%
Shrub/Seedling	14.94	5.29%
Sapling/Pole	84.41	29.88%
Small Tree	26.34	9.32%
Large Tree	28.76	10.18%

Table 2. Summary of riparian buffers zone (30 meters width along both banks) disturbance and seral stage of vegetation (See figures 4 - 6).

Riparian Buffer (30 m width):	Acres	Percentage
Agriculture Area	0.33	0.41%
Residential Area	3.24	3.99%
Roads Area (No vegetation)	2.10	2.59%
Seral Stage (30 m width):		
No Vegetation	2.10	2.59%
Grass/Forbes	10.72	13.21%
Tall Grass/Forbes & Short Shrub/Seedling	26.78	32.99%
Shrub/Seedling	5.76	7.10%
Sapling/Pole	23.00	28.34%
Small Tree	5.91	7.28%
Large Tree	6.90	8.50%

Table 3. Summary of riparian buffers zone (10 meters width along both banks) disturbance and seral stage of vegetation (See figures 7 - 9).

Seral Stage (10 m width):	Acres	Percentage
No Vegetation		
Grass/Forbes	3.82	14.15%
Tall Grass/Forbes & Short Shrub/Seedling	12.11	44.85%
Shrub/Seedling	2.16	8.00%
Sapling/Pole	6.13	22.70%
Small Tree	1.28	4.74%
Large Tree	1.50	5.56%

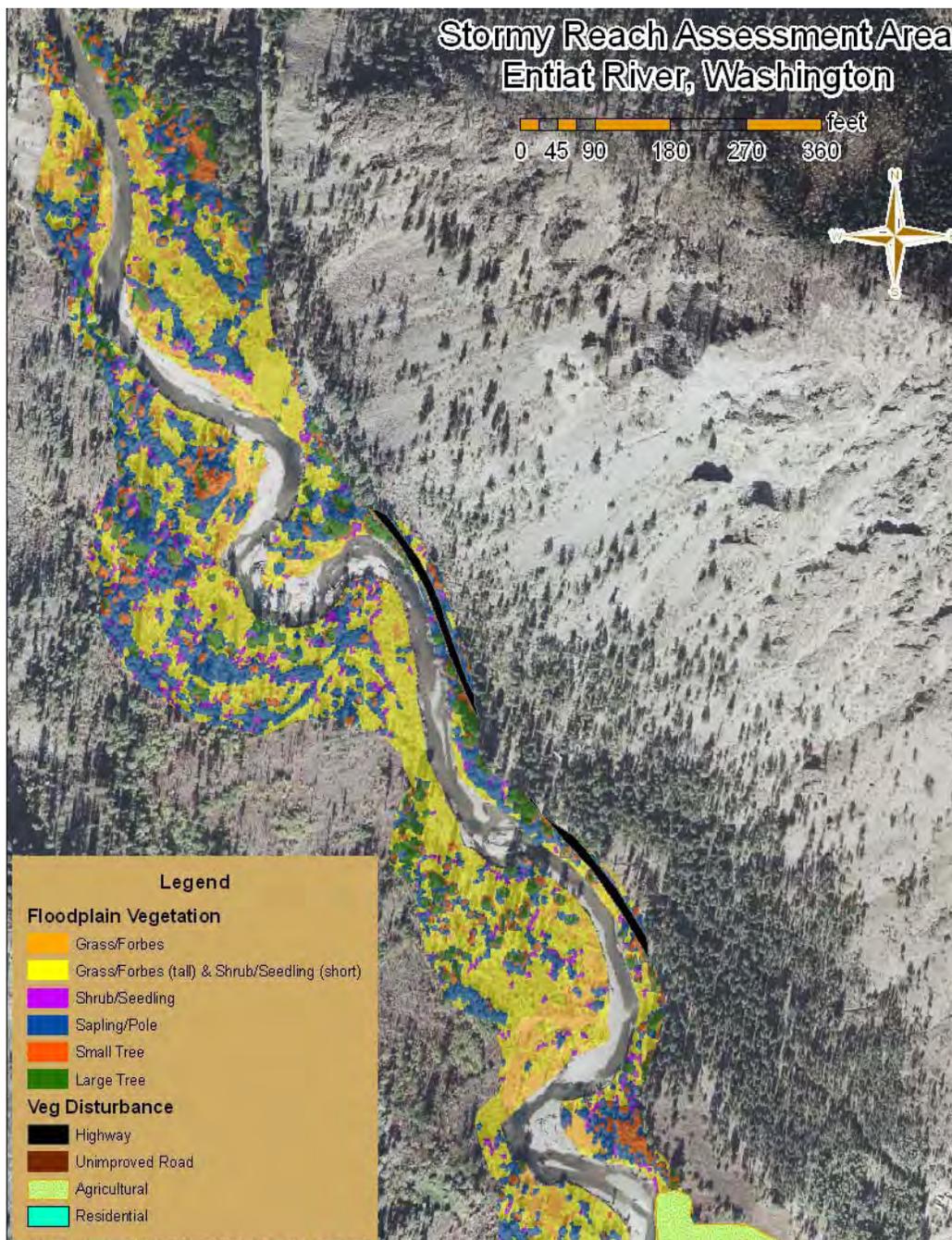


Figure 1. Vegetation seral stage and disturbances in the outer zone (floodplain).

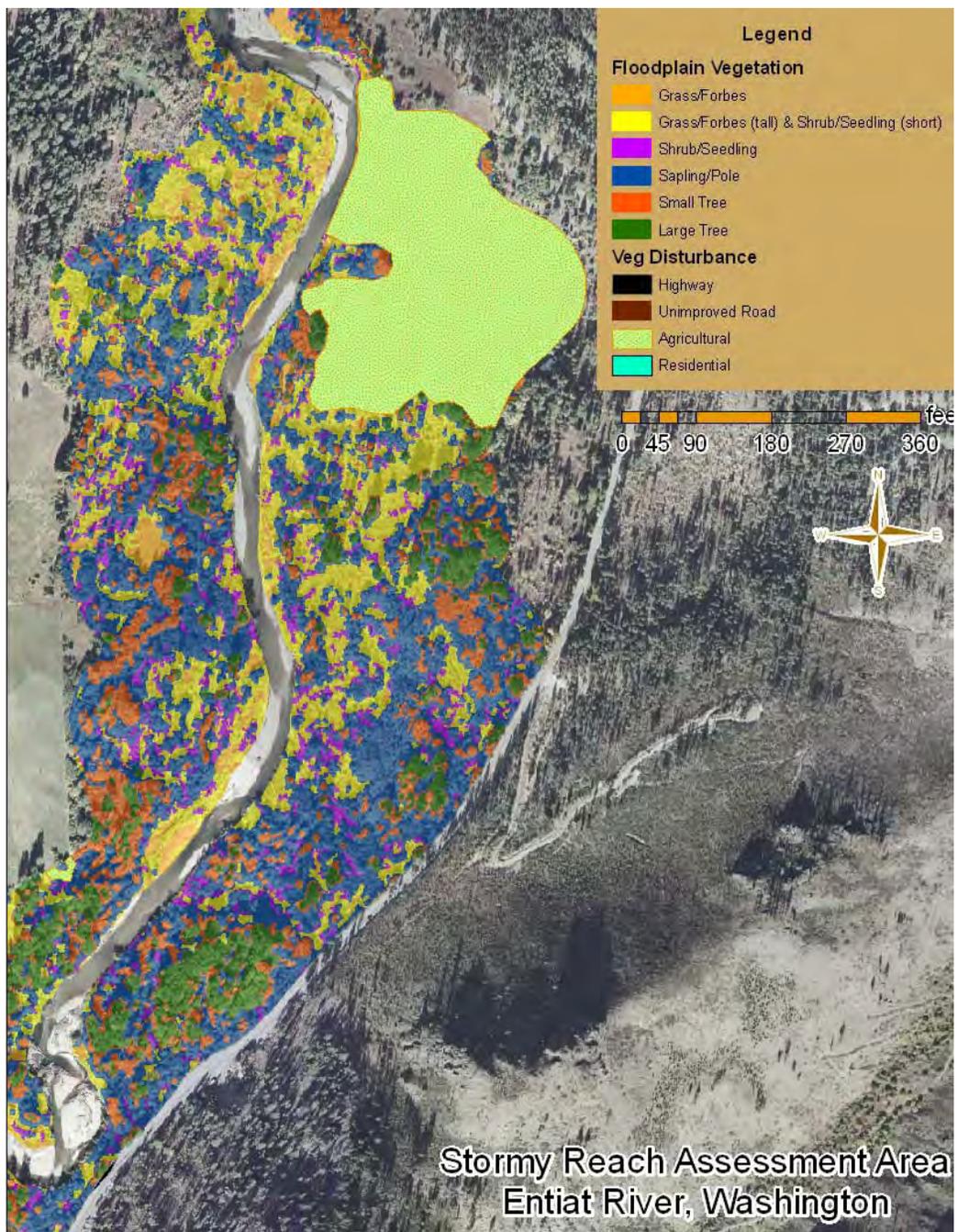


Figure 2. Vegetation seral stage and disturbances in the outer zone (floodplain).

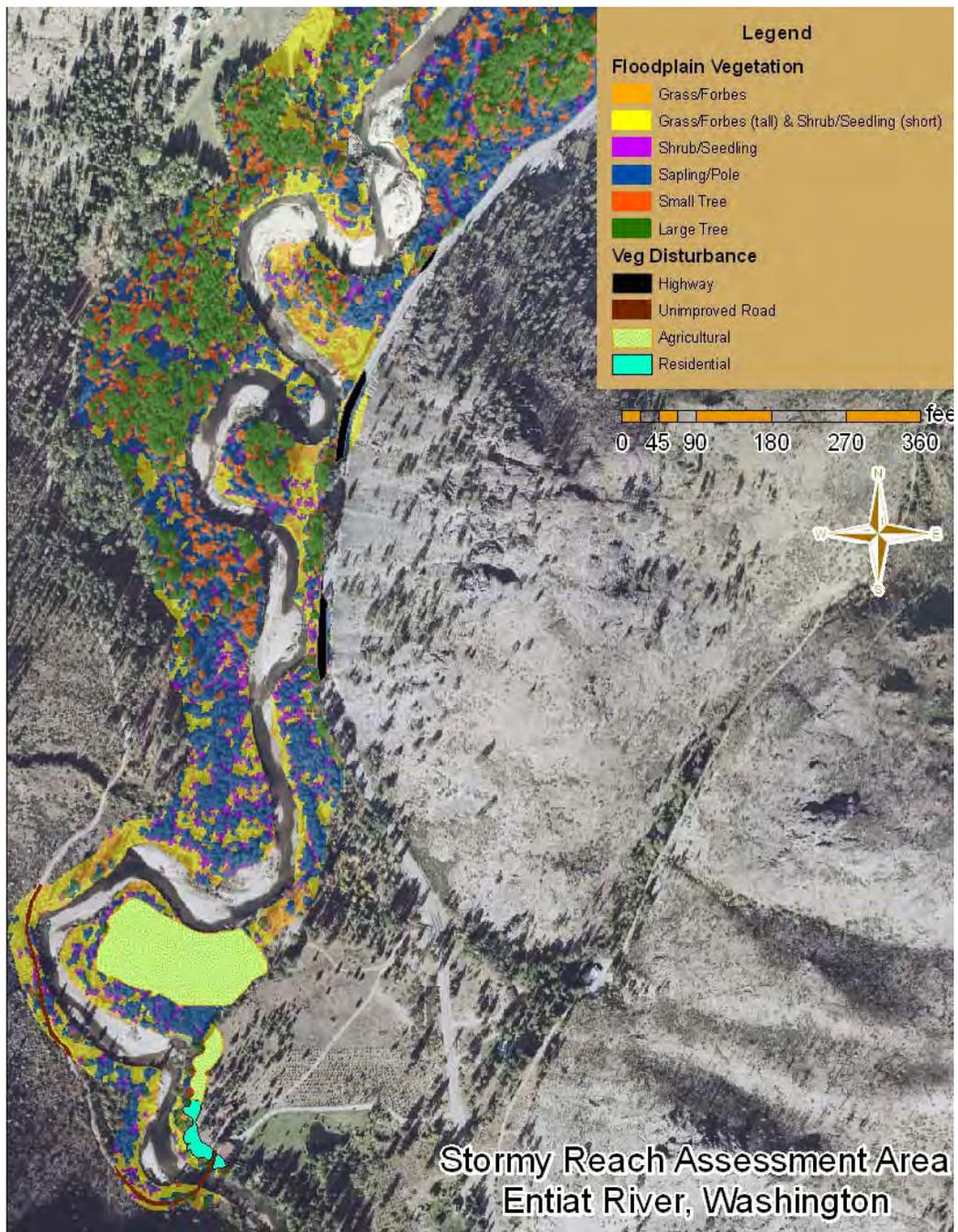


Figure 3. Vegetation seral stage and disturbances in the outer zone (floodplain).

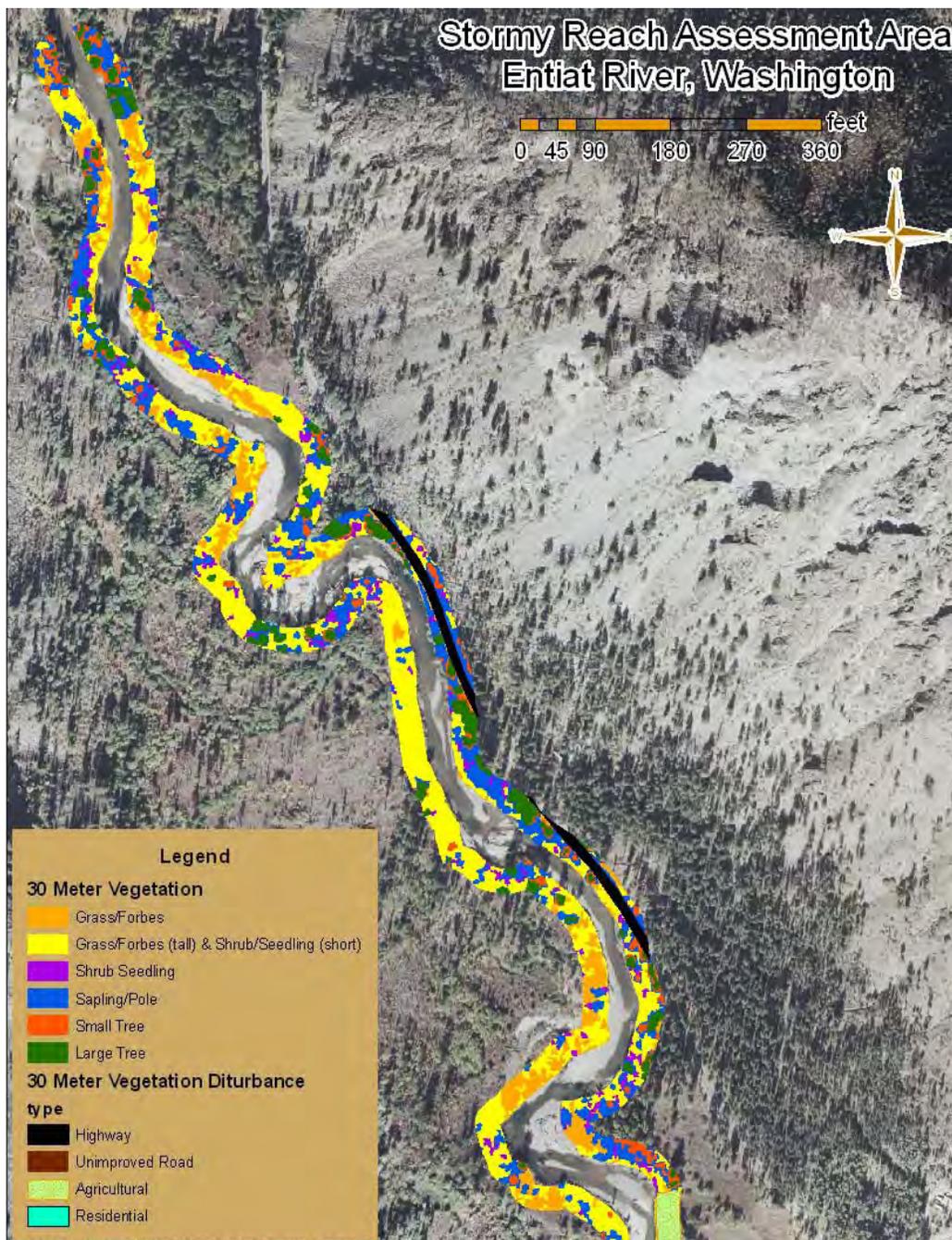


Figure 4. Vegetation seral stage and disturbances within the 30 meter Buffer zone.

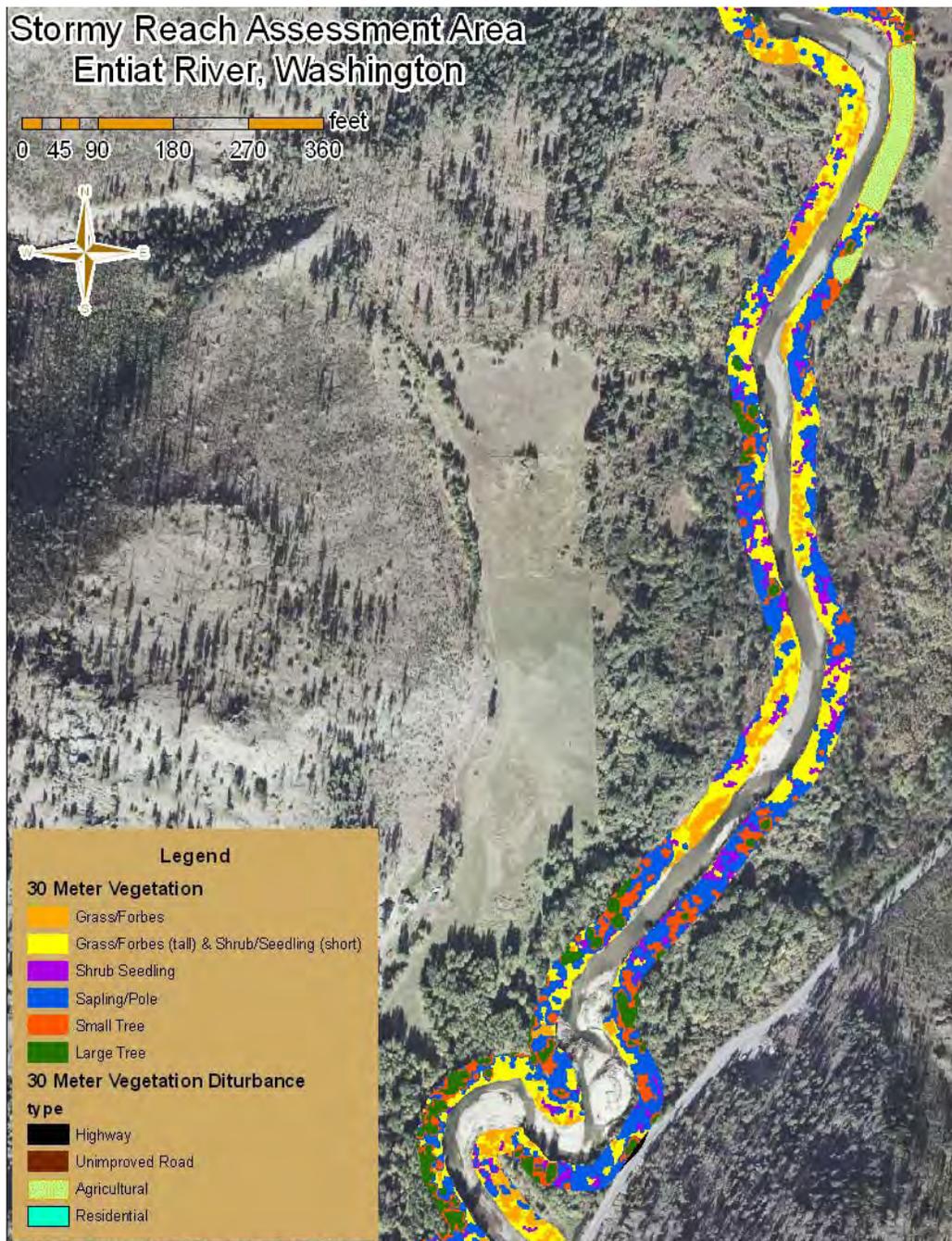


Figure 5. Vegetation seral stage and disturbances within the 30 meter Buffer zone.

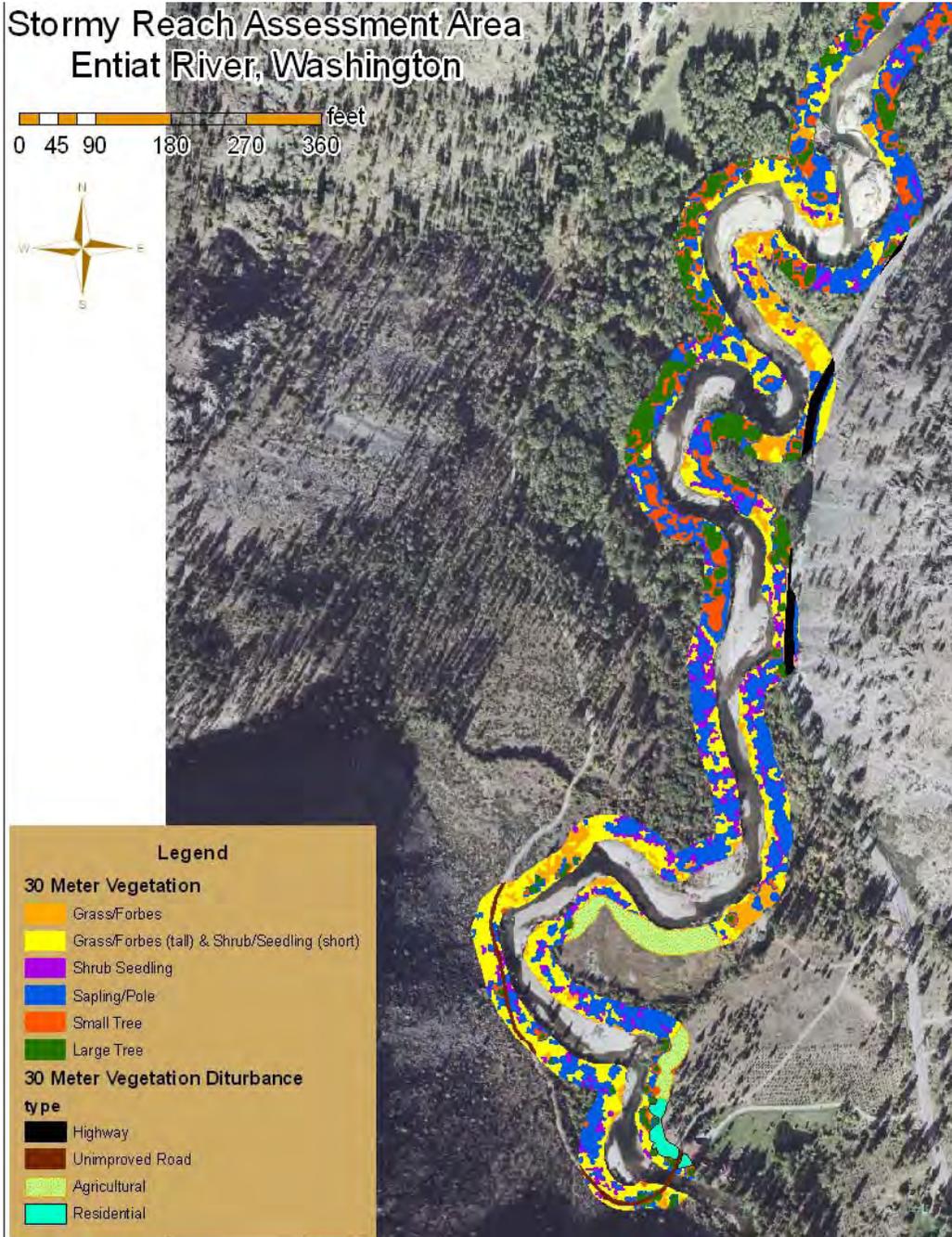


Figure 6. Vegetation seral stage and disturbances within the 30 meter Buffer zone.

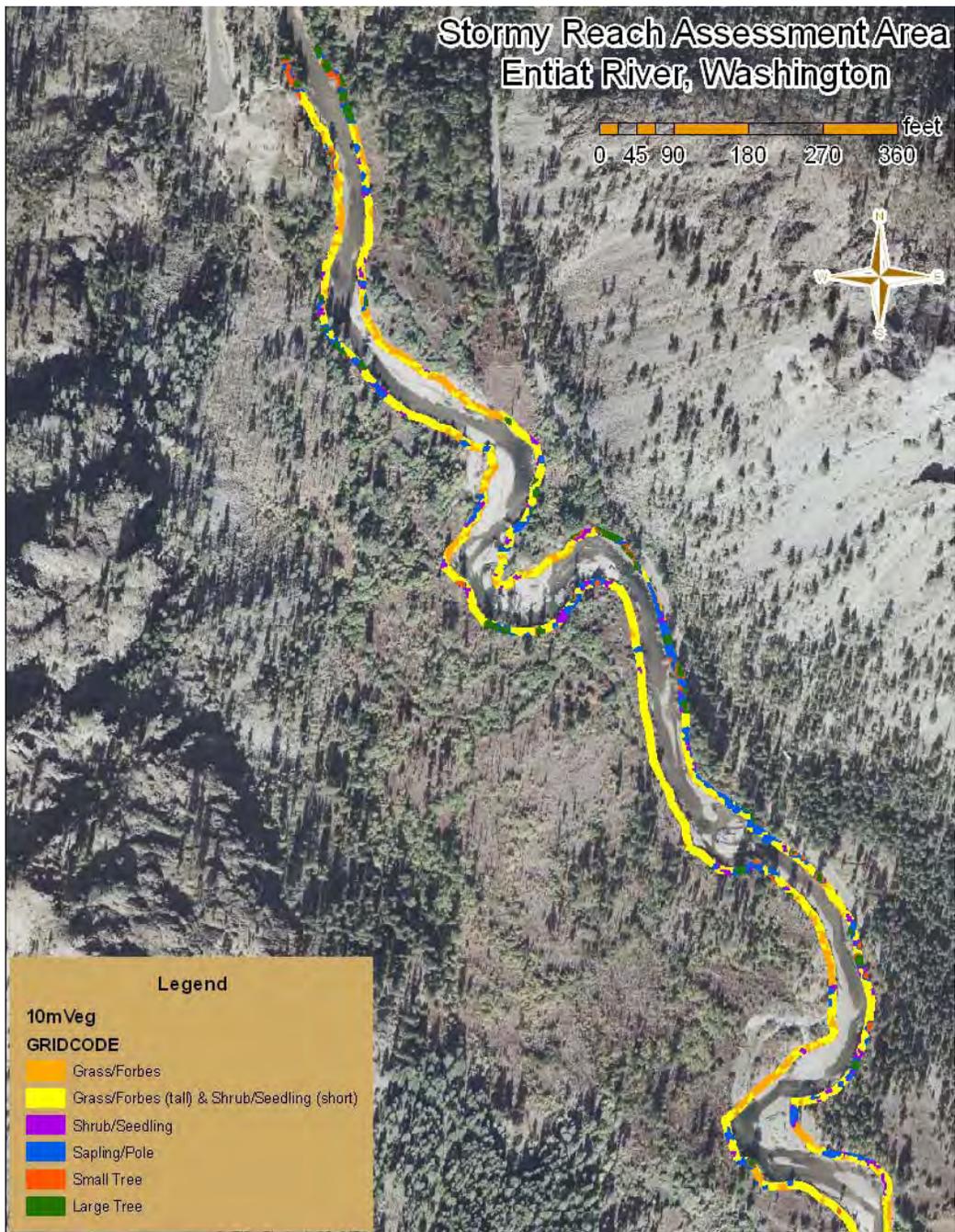


Figure 7. Vegetation seral stage and disturbances within the 30 meter Buffer zone.

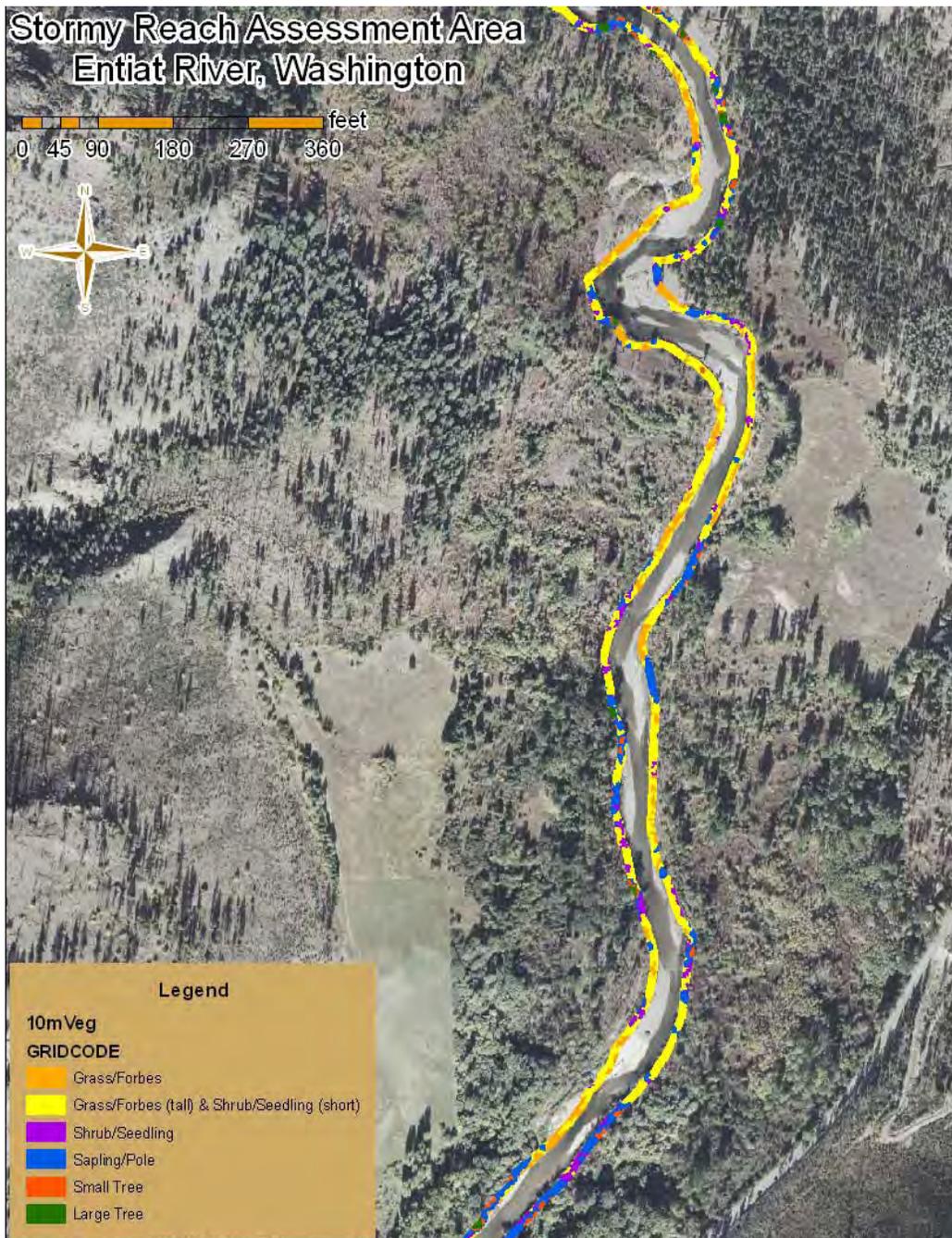


Figure 8. Vegetation seral stage and disturbances within the 30 meter Buffer zone.

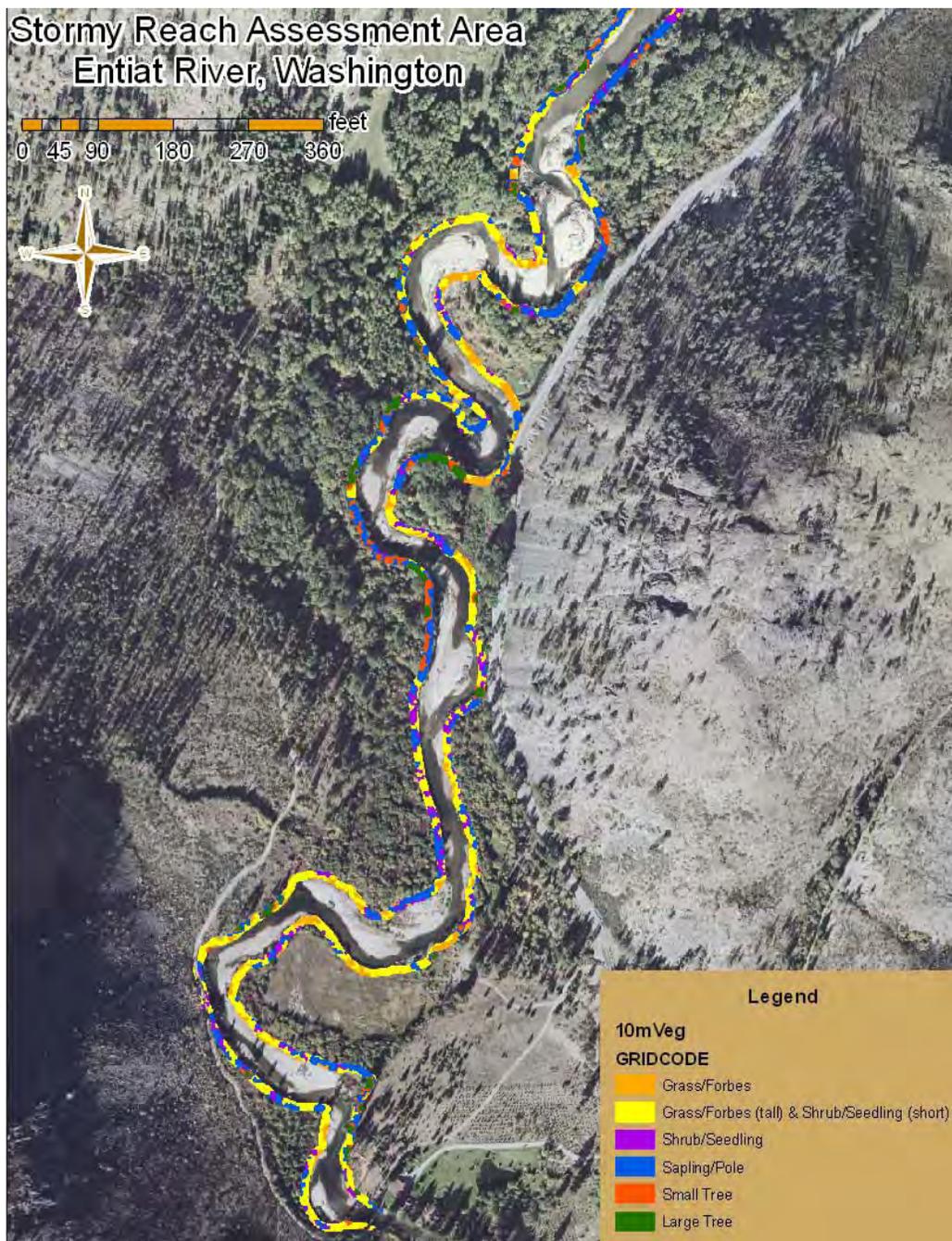


Figure 9. Vegetation seral stage and disturbances within the 30 meter Buffer zone.

APPENDIX E

Stormy Reach Hydraulic Modeling

RECLAMATION

Managing Water in the West

Hydraulic Modeling of the Stormy Reach

Entiat River, Chelan County, WA



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

August 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.

Hydraulic Modeling of the Stormy Reach

Entiat River, Chelan County, WA

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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, and has initiated assessments on multiple tributaries to the Columbia River in an effort to provide local resource managers and basin stakeholders with the pertinent scientific information to aid in habitat restoration planning and decision making.

This report outlines the hydraulic modeling effort for a reach in the Upper Entiat watershed that was determined (through a basin-scale tributary assessment; Bountry et al. 2009) as having a high opportunity for restoration/protection. In the Entiat subbasin, human induced changes to channel processes are believed to have historically reduced the quality and availability of aquatic habitat (CCCD 2004). The purpose of this modeling effort was to supplement a larger reach assessment by evaluating the effects of anthropogenic features within the Stormy Reach through in-channel hydraulics to ultimately help identify and prioritize 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 local resource managers and basin stakeholders with the necessary information to help 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.

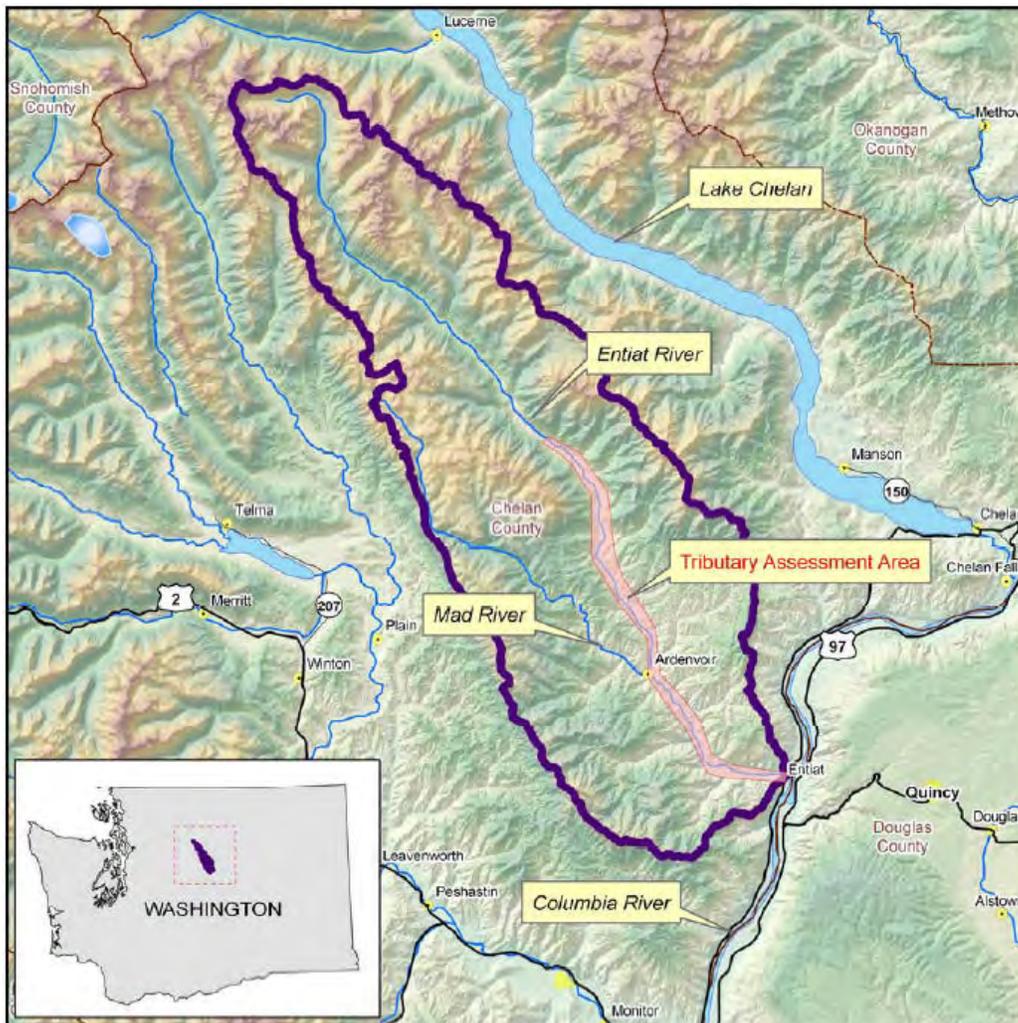


Figure 1. Location map for Entiat River (from Entiat TA; Bountry et al. 2009).

Tributary Assessment Findings

The Stormy Reach, located between RM 18.1 – 20.9 (see Figures 2A and 2B), was identified in the TA as ‘2C’; the furthest upstream unconfined geomorphic reach in VS-2. This reach was 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, bedrock, and levees 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. High complexity reaches with an unconfined active floodplain typically represent the highest potential for habitat restoration actions in terms of habitat diversity and floodplain connectivity (Bountry et al. 2009).

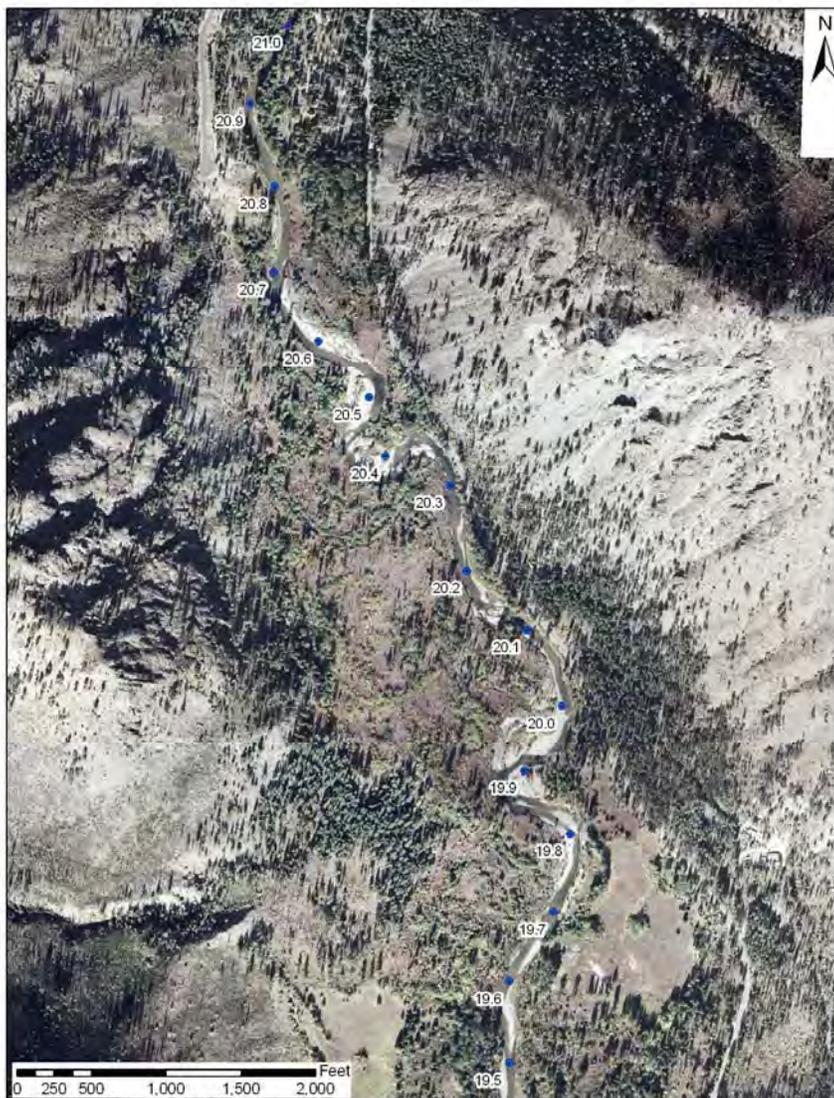


Figure 2A. Stormy Reach location map. (Flow is from top-to-bottom of page).

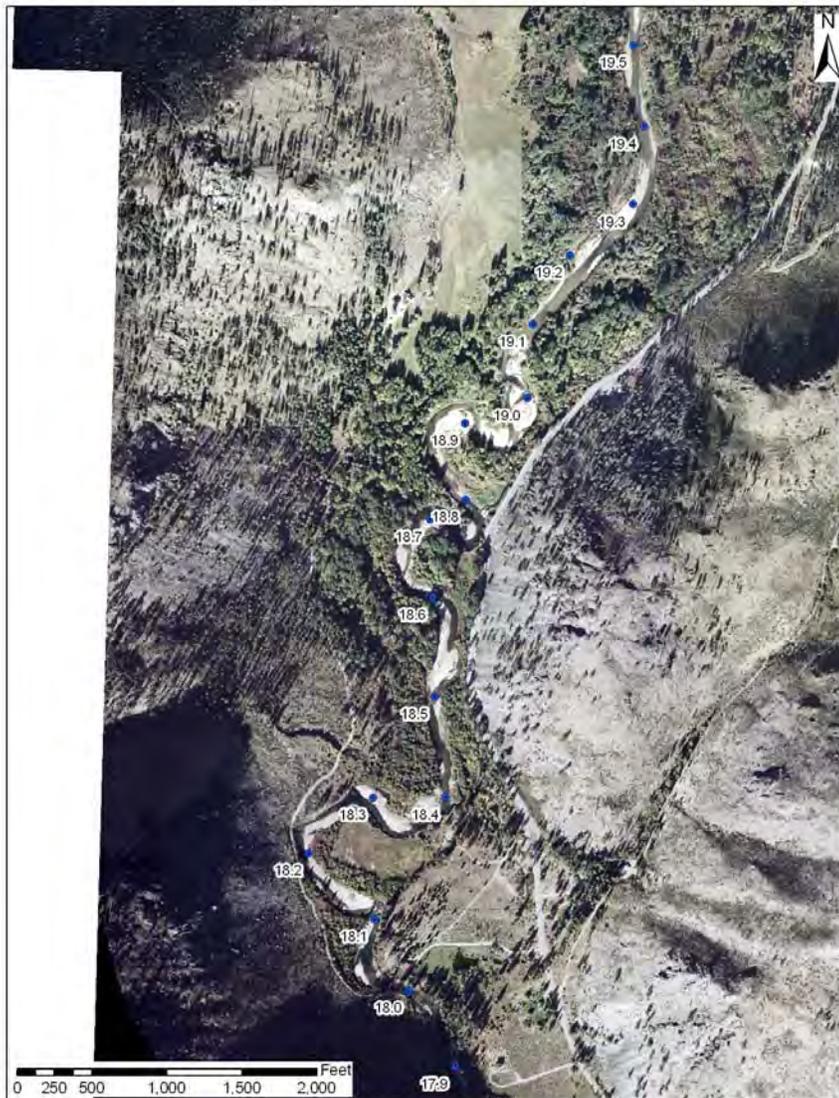


Figure 2B. Stormy Reach location map. (Flow is from top-to-bottom of page).

Reach Characteristic Features

The significant present impacts to the channel and floodplain in the Stormy Reach include the Bremer Levee (RM 19.65-19.8; left bank) along with various areas of bank protection that limit channel migration and alter instream hydraulics and channel geometry, accompanied by localized areas of cleared vegetation resulting in increased bank instabilities. The Bremer Levee (Figures 3 and 4) was built in 1973 by the Soil Conservation Service (SCS) and overtopped in a February 1974 flood after which time it was raised by an unknown amount (Bountry et al. 2009). This armored levee, located directly across from the Tye Creek alluvial fan, has not only prevented the river from accessing part of its active floodplain, but has also limited channel migration, likely playing a role in the channel planform change from a high sinuosity channel in 1945 to a low sinuosity channel with sparse large woody debris (LWD). This section of river has also likely incised.

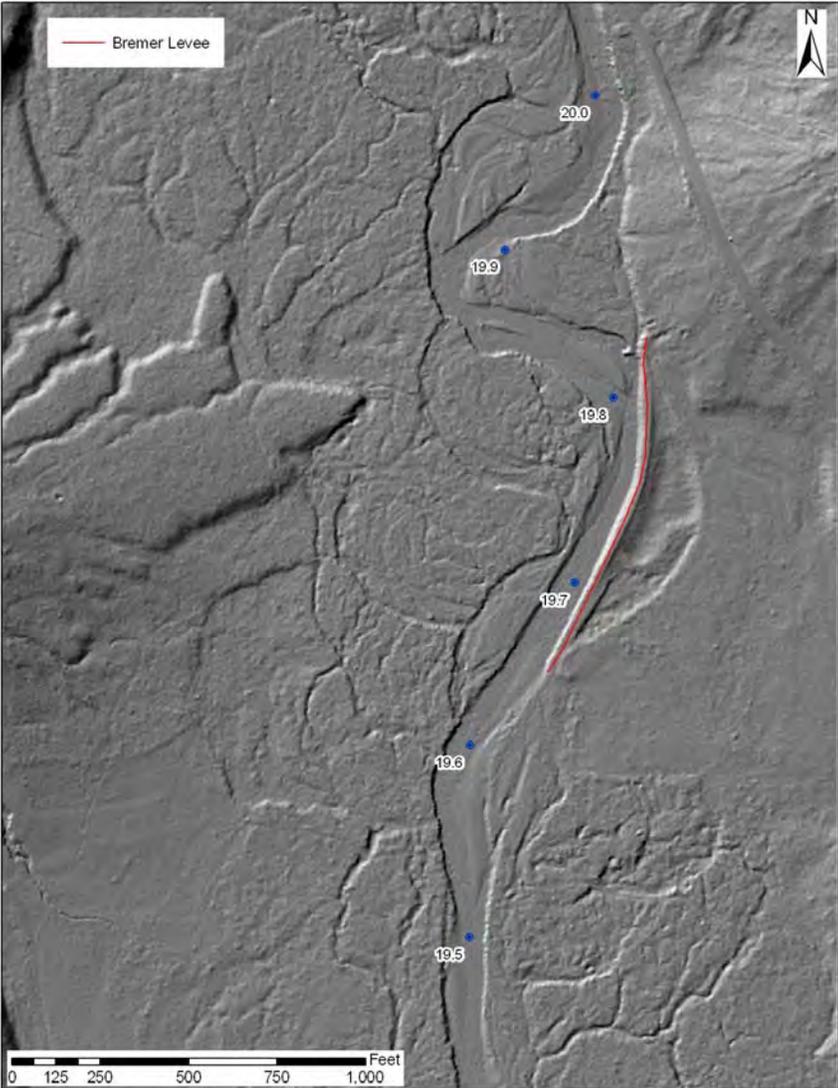


Figure 3. Bremer Levee location. (Note Tye alluvial fan directly across from levee).



Figure 4. Bremer Levee. (Photo looking upstream).

Stormy Reach Hydraulic Modeling

Even though there were LWD clearing efforts from the Army Corps of Engineers (USACE) in the early 1970's throughout this reach, there exist areas of numerous LWD, especially in meander bends (Figure 5). In fact, this reach actually has several more log jams currently than in 1971 (Bountry et al. 2009). Near the downstream end of Stormy Reach (RM 18.2-18.4), there has been some vegetation clearing on the Stormy Creek Preserve that has resulted in a localized increase in bank erosion (Figure 6) as well as some talus rockfall from a nearby hillslope that has made its way into the active channel (Figure 7). The rockfall provides both bank stability and localized hydraulic diversity (pools) and cover for salmonid species. Fires, in particular the 1994 Tye Fire, have also had an impact on this reach, affecting vegetation on the surrounding hillslopes and likely increasing fine sediment input to the active channel.

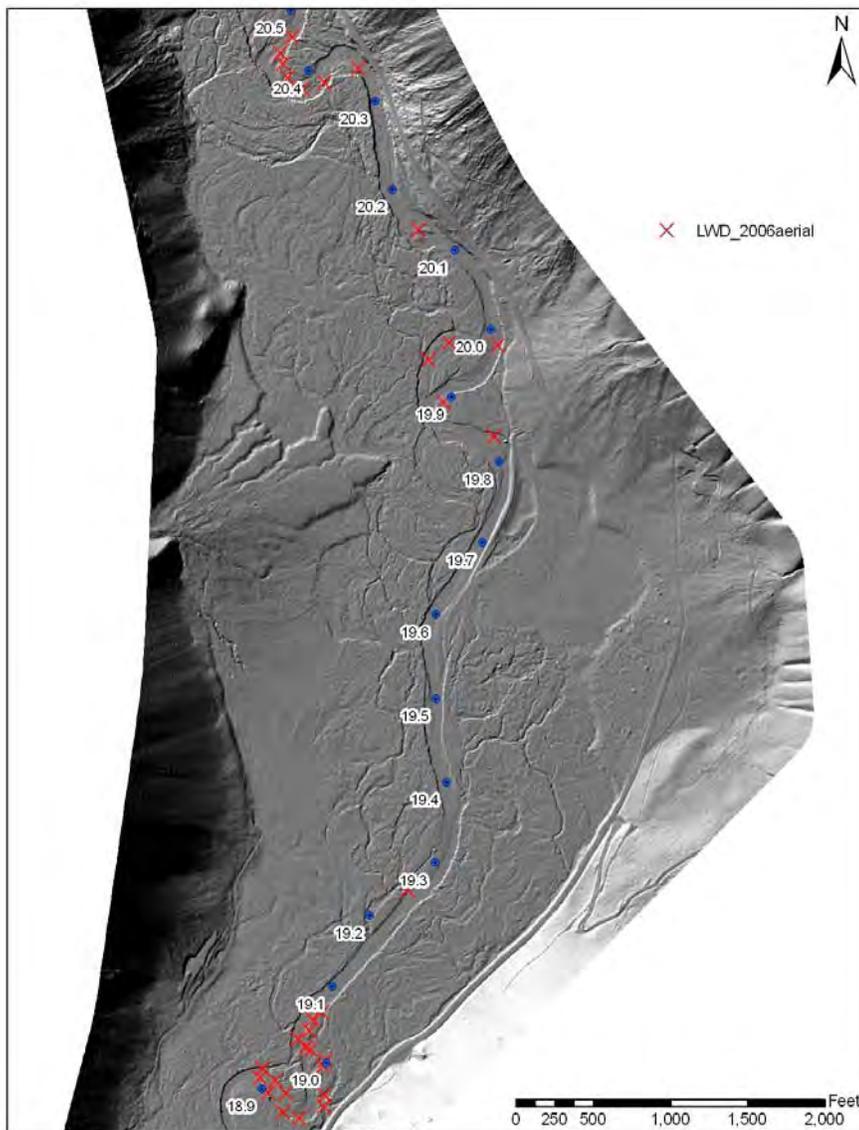


Figure 5. LWD locations based on 2006 aerial photography.

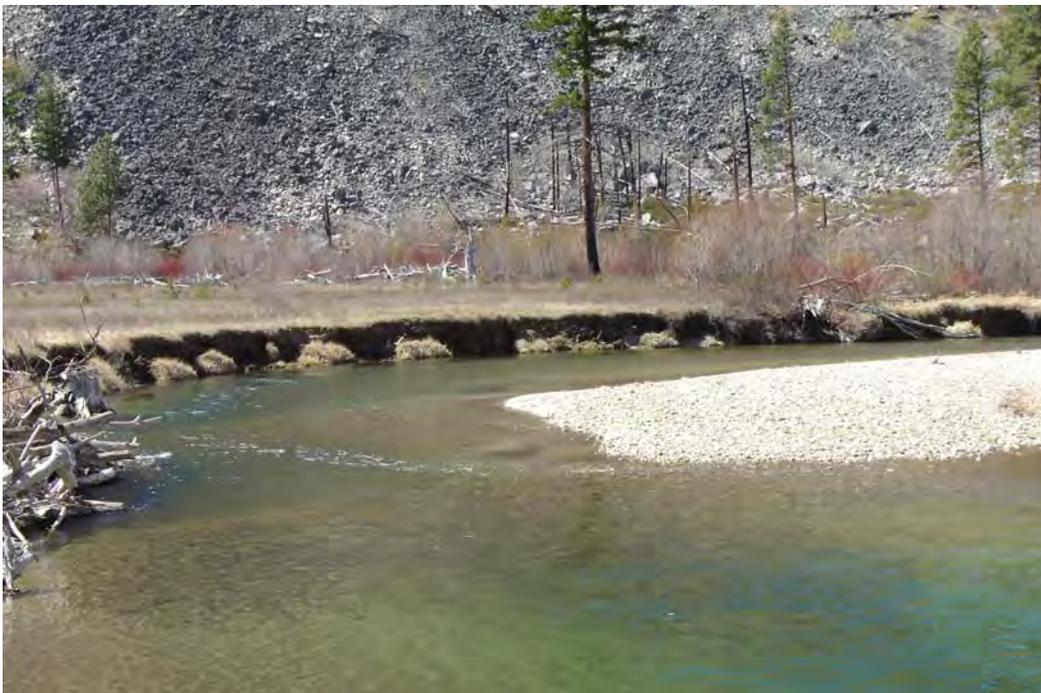


Figure 6. Erosion along bank with cleared vegetation near RM 18.35. (Photo looking downstream).



Figure 7. Hillslope material that has fallen into the active channel. (Photo looking upstream).

Reach Morphology

Channel morphology for the Stormy Reach is variable and ranges from a multi-thread channel at low flow to a mostly single-thread channel with irregular meanders and numerous point bars. Alluvial fans from Shamel, Stormy, and Tye Creeks act as local base level controls, illustrated by the irregular highly sinuous meanders from RM 18.1-19.1. The Stormy Reach has wide, low floodplains that allows for lateral channel migration into unconsolidated banks of sandy material covering a gravelly alluvium. However, the alluvial fans and armored Bremer Levee create resistant banks in localized areas that limit lateral migration.

Channel changes in this reach take the form of decreasing sinuosity and transitions from a multi-thread to a single-thread channel. From RM 19.0-20.2, channel sinuosity decreases dramatically between 1945 and 2006 with the majority of change occurring between 1945 and 1962 (Figure 8). It is likely that the 1948 flood was the catalyst for many of the avulsions that cutoff meandering sections of the 1945 channel (Bountry et al. 2009). The construction of the Bremer Levee along with the LWD clearing may have also been factors in some of the changes from a sinuous meandering channel to a low sinuosity straight channel between 1962 and 1975; however, many of the meander cutoffs occurred prior to these alterations. No evidence is available documenting any mechanical straightening of the channel in this reach between 1945 and 1962. Mapped historic channel alignments are shown in Figure 8.

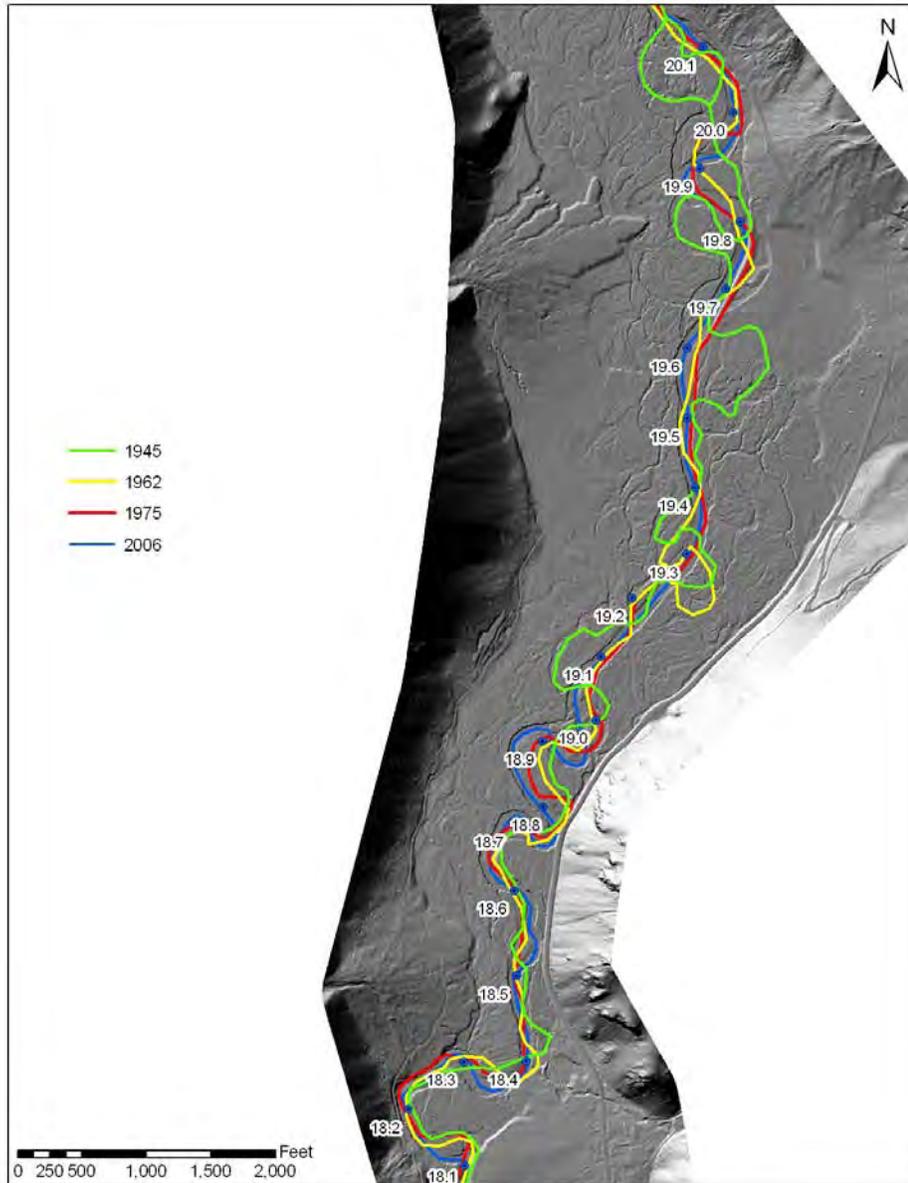


Figure 8. Historic channel alignments (Bountry et al. 2009).

Noteworthy side channel entrances exist at RM 18.95 and 19.25, on river left and right, respectively. Both have LWD present at the entrances, which is common in this system. A meander bend cutoff channel exists at RM 19.0 on river right. Each of these channels appears to be perennially flowing. The main tributary entering this reach is Stormy Creek, at RM 18.4 on river left. There is also some small input from Shamel Creek entering at RM 18.28 on river right.

Another effort of the TA was the delineation of surficial geologic features on the landscape, which included stream terraces, bedrock outcrops, axial and tributary stream channels, and other deposits along the valley margins, such as landslide and glacial deposits. The extent and character of these features provide

information concerning controls on lateral and vertical channel movement over longer time frames than the historical period and many times are important factors in explaining variation in channel morphology along the length of the study reach. The surficial geologic units in the TA were described on the basis of surface morphology, character of deposits, vertical and lateral relation to other mapped units, relative or absolute age, and geographic location.

Most of the surfaces adjacent to the channel in the Stormy Reach are mapped as active floodplain, and composed of unconsolidated sandy alluvium or a thin cap of sandy alluvium over gravelly sand. While there are a few areas where the channel is against alluvial fans and talus slopes, the total length of these sections is relatively minor compared to the length of the active floodplain surface along the active channel. The most obvious paleochannels were mapped and are linked to the 1945 channel position. However, the paleochannel near RM 18.7 is not part of the 1945 main channel according to the historical aerial photography but instead acts as an overflow channel this is inundated occasionally during high flows; modeling showed it taking an approximate 10-year event to inundate this area. Mapping of the surficial geology units is shown in Figure 9 with the corresponding unit descriptions listed in Table 1.

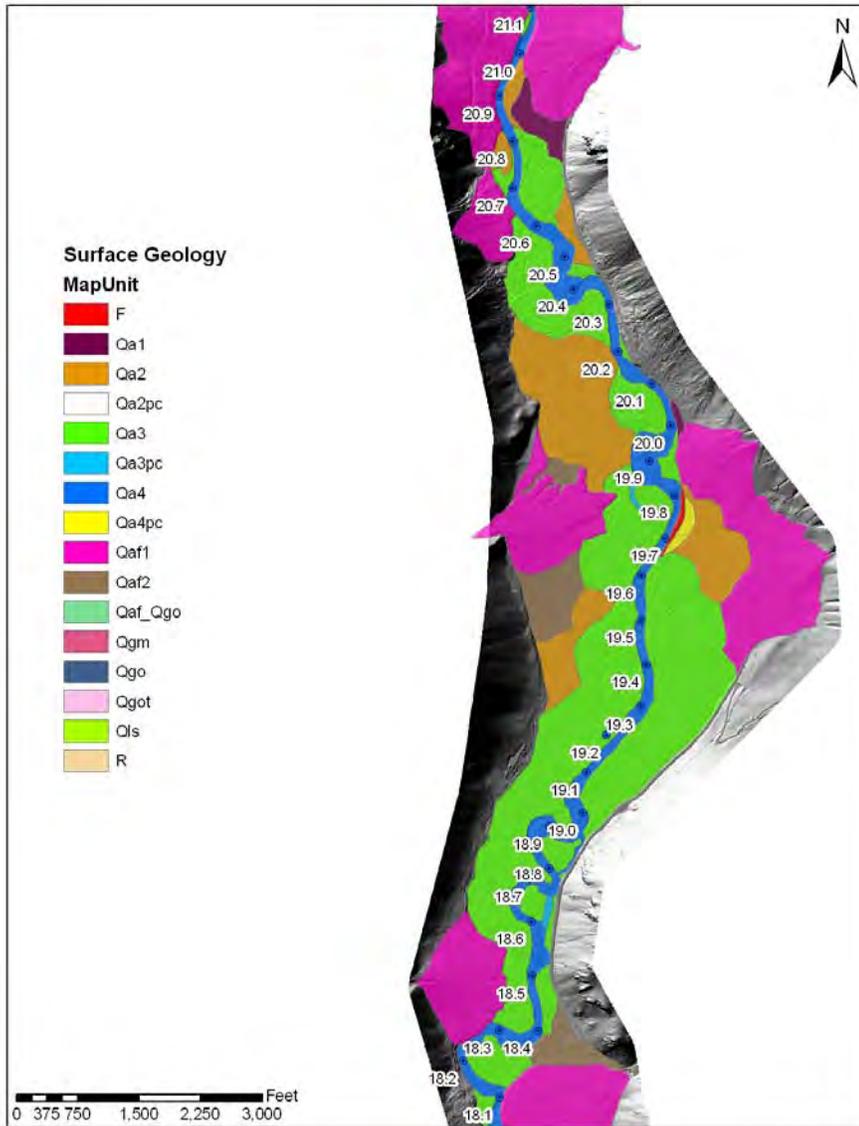


Figure 9. Surficial geologic mapping units for Stormy Reach (Bountry et al. 2009).

Table 1. Surficial geologic mapping unit descriptions (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

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 Stormy Reach, which was described as having an unconfined active floodplain, high channel migration, high presence of side channels, high presence of large woody debris, low stream power, and high bar frequency, ranked 16. In this reach, 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 spring Chinook, and a lack of juvenile rearing habitat, and adult holding habitat was identified for steelhead (Bountry et al. 2009). These habitat limiting factors apply to all life stages.

Hydraulic Modeling Methodology

Model Selection

The hydraulic model utilized for this assessment was the Hydrologic Engineering Center-River Analysis System (HEC-RAS) version 4.0 developed by the U.S. Army Corps of Engineers (Brunner 2008), which focuses on the flow hydraulics of river systems. This is a one-dimensional (1D) model that utilizes a standard-step methodology, in which iterative hydraulic calculations are performed at specific locations and proceed incrementally in the upstream direction; known as a backwater model. The computational procedure used in this model is based on the solution of the one-dimensional energy equation. Energy losses are represented through friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The key steady flow input parameters consist of cross sections, a downstream boundary condition, roughness values (Manning's n), and flow discharges. The model was run as subcritical flow; therefore, an upstream boundary condition was not required.

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 53 cfs at the USGS Ardenvoir Gage (#12452800) at RM 18.0. The LiDAR data collection methodology used cannot penetrate water (see Figure 10). 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. 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 3.2 million bare earth LiDAR data points make up the model surface for the Stormy Reach.

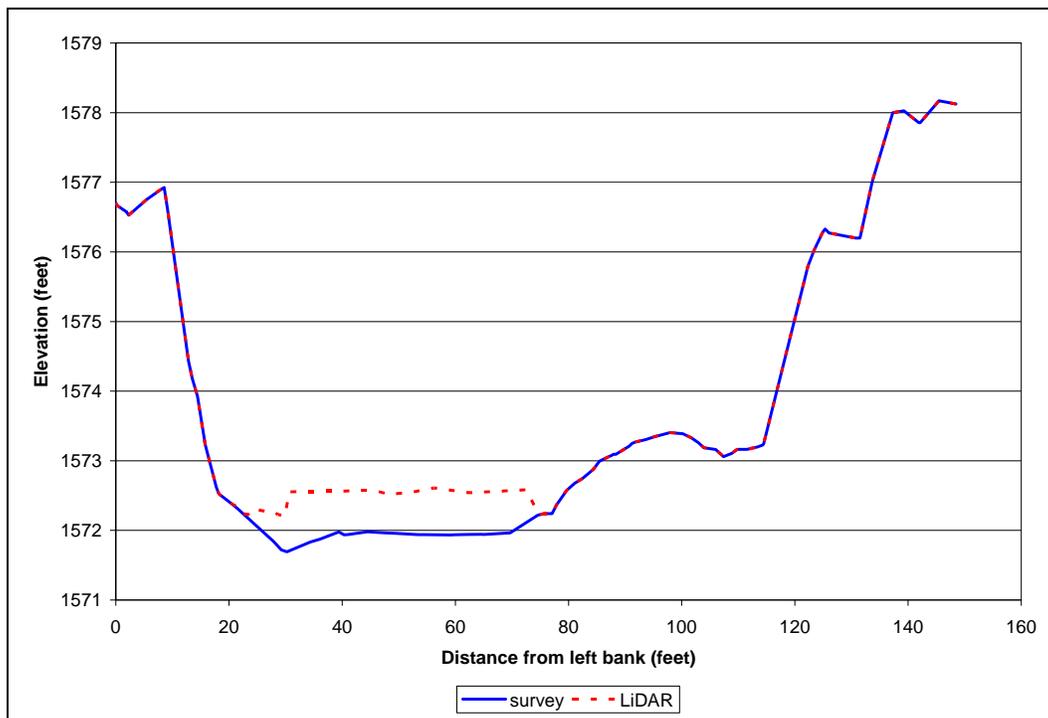


Figure 10. Survey versus LiDAR cross section profile comparison near RM 18.4. (The central portion of this cross section is the wetted portion that the LiDAR did not capture).

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, levees, and alluvial fans) that may not be visible on conventional aerial photography to be distinguished. An example of the LiDAR

hillshade is shown in Figure 11. 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 12.

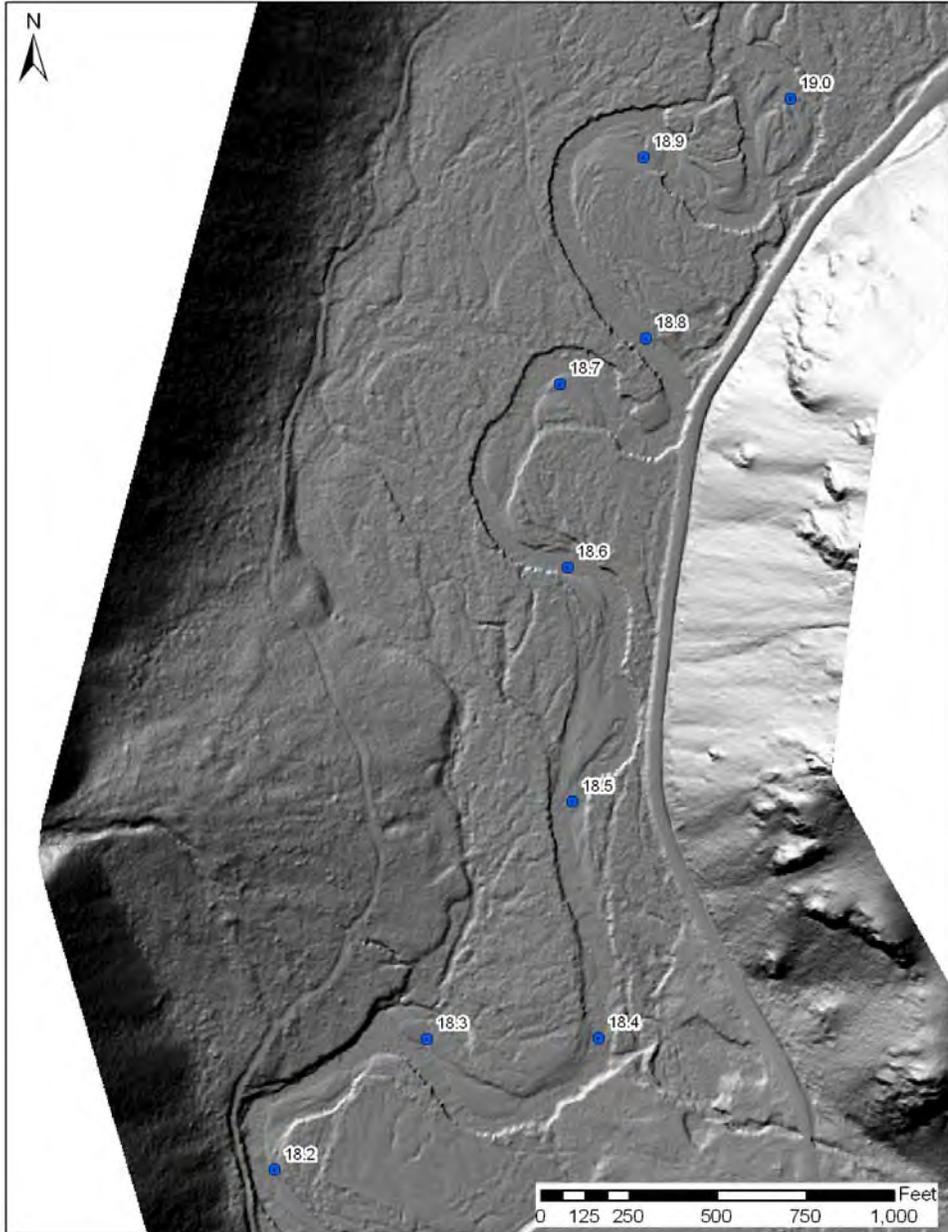


Figure 11. Example of LiDAR generated hillshade. (Note Shamel Creek alluvial fan directly across from RM 18.5 and side channel near RM 18.8 on river left).

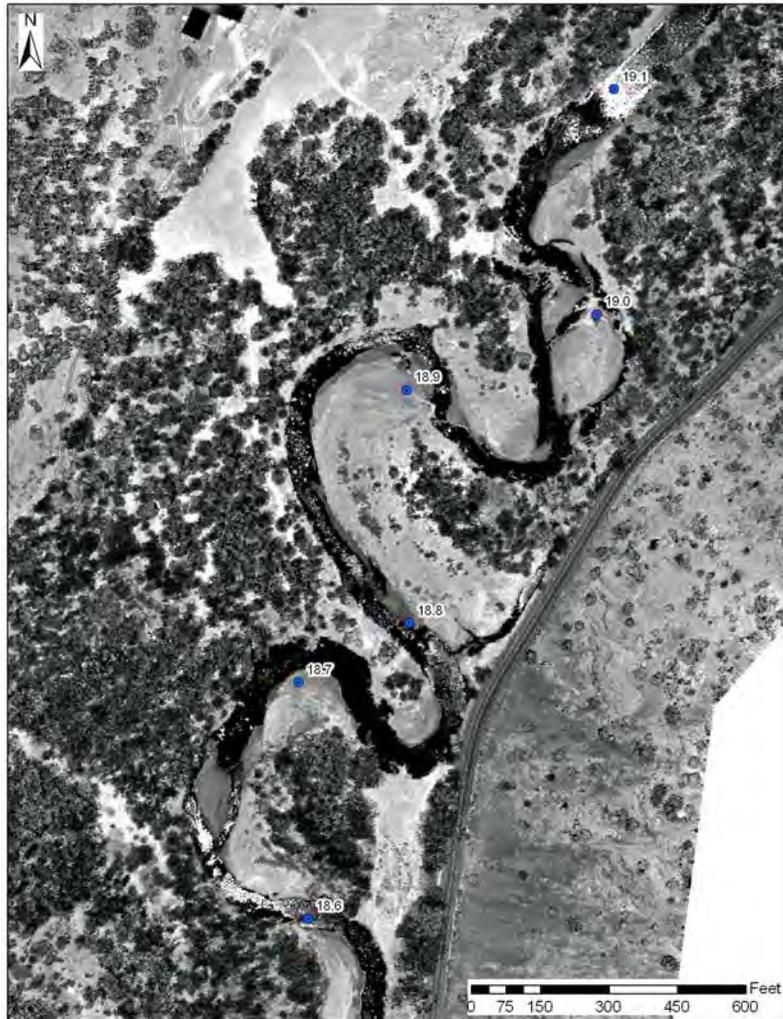


Figure 12. Example of LiDAR generated intensity image.

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 October 14-15, 2008 and March 17-19, 2009. The average daily flows were approximately 90 and 82 cfs for the first and second trip, respectively at the Ardenvoir gage station (RM 18.0). 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 4,800 survey points were collected to represent the Stormy Reach area. An example area showing the collected survey data can be seen in Figure 13. 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 13. Example area of collected on-the-ground survey data.

The survey effort was focused on the main channel thread. However, there is one significant side channel in this reach that starts at RM 18.95 on river left and re-enters the main channel at roughly RM 18.8 (see Figure 11). This is a perennially flowing side channel that cuts off a large meander bend. This feature is large (and deep) enough (see Figure 14) 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, the 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 survey data collected on the bottom half of the channel. (The upper half was too vegetated to get a GPS signal).



Figure 14. Side channel at RM 18.8 (looking upstream).

Although bathymetric data were collected, the model was not intended to fully represent low flow conditions due to insufficient data density. Additional bathymetric data would be needed to more accurately represent the localized hydraulic conditions that exist at low flow. Refinement of the model 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 Stormy Reach. An example of the model surface is shown in Figure 15.

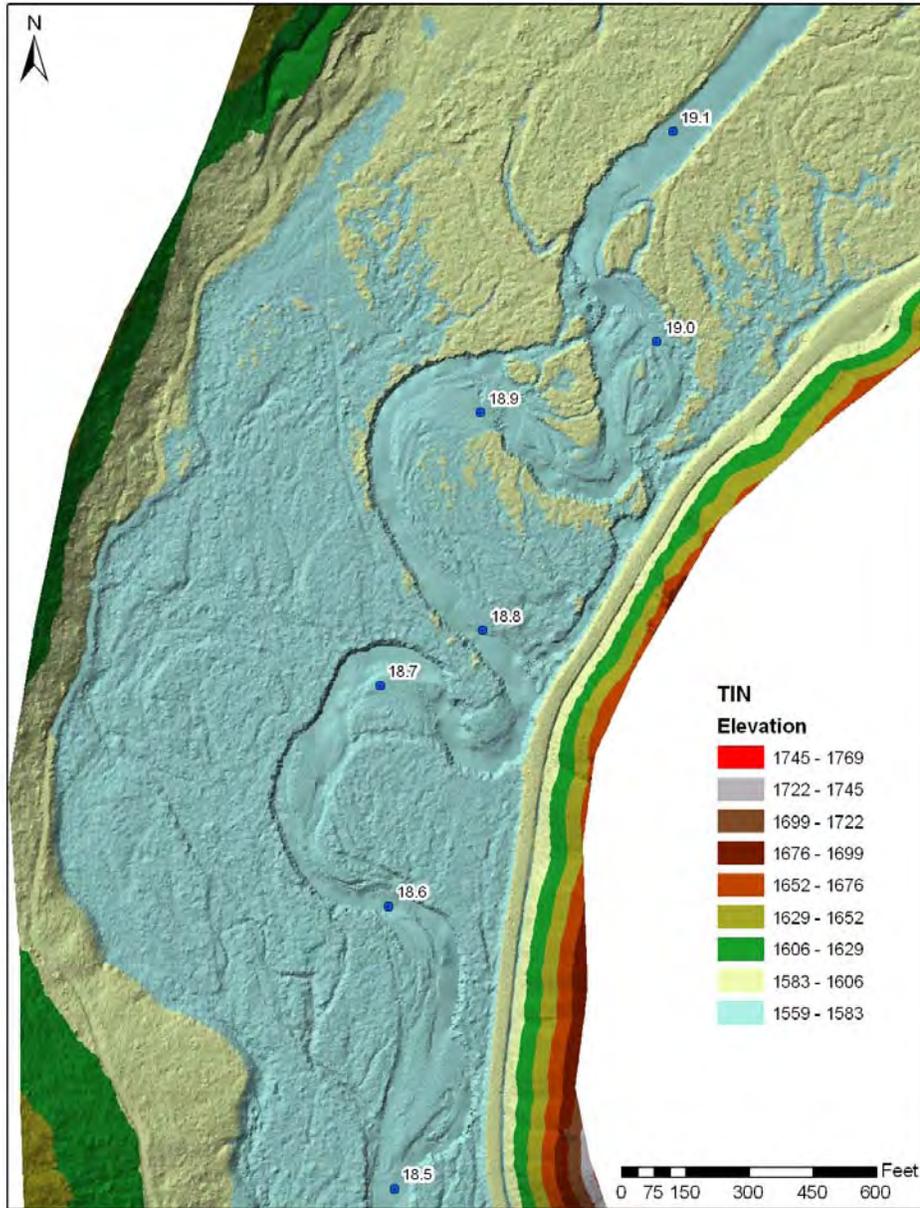


Figure 15. Example of the surface used as input for the hydraulic model. (Elevations are in feet).

Cross Section Generation

Cross sections were generated using the topographic surface representation (TIN) with HEC-GeoRAS, a custom interface within GIS that provides tools to process geospatial data for use with HEC-RAS. The alignment of the cross section lines were based on the 2006 aerial photography and hillshade; both products of the LiDAR collection effort. A total of 154 cross sections, spaced approximately every 75-125 feet throughout the reach, were used to represent reach hydraulics. Since this model is one-dimensional, the cross section lines should be

perpendicular to the direction of flow and therefore may change direction when crossing a floodplain that has a different flow path than the main channel. Cross section alignments, especially through the sections with tight meander bends, changed direction frequently (dog-legging) in the overbanks to avoid crossing while maintaining perpendicular in-channel alignments. Therefore, overbank flow through these areas are not accurately represented with this model. An example of several cross sections and their spacing and alignment is shown in Figure 16, with an example cross section profile shown in Figure 17.



Figure 16. Example cross section spacing and alignment (highlighted cross section shown in Figure 17).

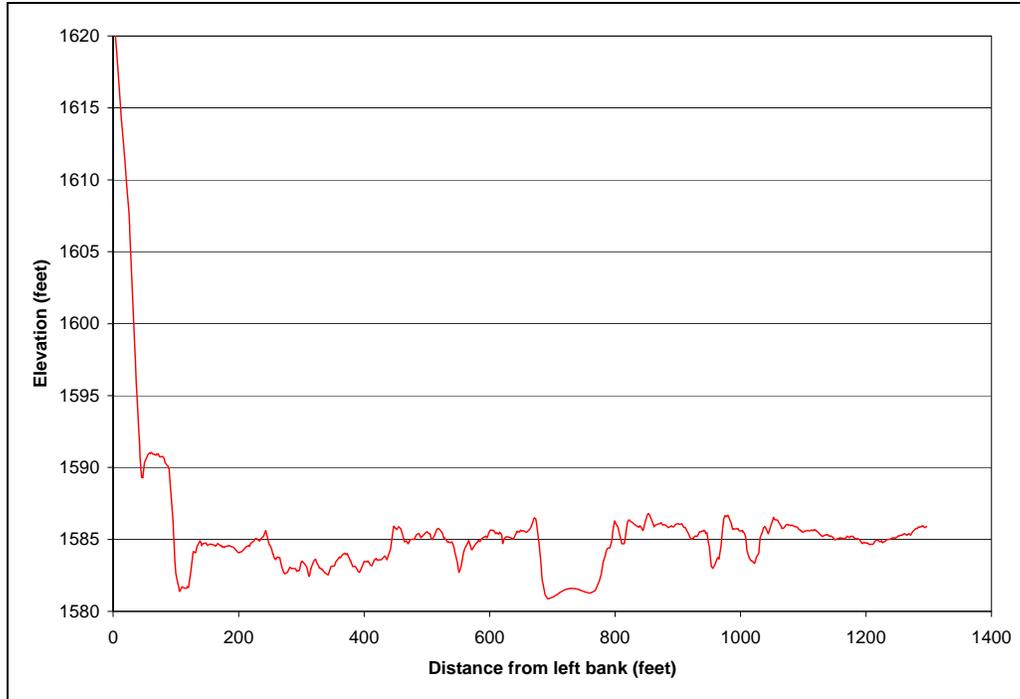


Figure 17. Example cross section used in HEC-RAS model.

Model Boundaries

The upstream extent of the HEC-RAS model is RM 21.15 and downstream boundary is RM 17.65. Both boundaries were located outside of the assessment area at confined bridge crossings; the upstream boundary at the Dill Creek Bridge and the downstream boundary at the ‘Bridge to Nowhere’. Also, placing the downstream boundary outside of the assessment reach allows the backwater model to come to equilibrium prior to entering the area of interest. The downstream boundary condition was set to a normal depth using the average slope of the lower section. The upstream boundary utilized various discharge inputs relating to storm recurrence intervals determined from a Flood Frequency Analysis (Sutley 2009).

Model Discharges

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 19 was selected as representative of the Stormy Reach. Resultant flood frequency estimates at RM 19 are shown in Table 2. Gains or losses due to groundwater exchange were not accounted for throughout the reach.

Table 2. Flood frequency discharge estimates (cfs) at RM 19.

Q2	Q5	Q10	Q25	Q50	Q100
2,650	3,620	4,260	5,070	5,660	6,250

It is worth noting that the channel capacity of each geomorphic reach was estimated in the TA by averaging the first flow modeled that went above each cross section's top of bank. In general, reaches with higher channel capacity had lower floodplain widths, higher slopes, and higher floodplain confinement (i.e. lower complexity; Bountry et al. 2009). The Stormy Reach channel capacity was estimated at approximately 3,000 cfs. Also, the flood of record in the Entiat Subbasin occurred in 1948 which was estimated at 10,800 cfs (Erickson 2004); greater than the 100-year recurrence event.

Roughness Values

Manning's n roughness values were assigned to the left floodplain, right floodplain, and active channel. The boundaries of the active channel (top of bank locations) were determined using 2006 aerial photography and LiDAR data. Roughness values were based on field observations of the size of channel bed material and floodplain conditions. The modeling efforts in the TA, which included a roughness calibration and sensitivity analysis, were also utilized to gage roughness values. The selected roughness values were 0.05 for the floodplain, and 0.04 for the active channel.

Model Results

In general, model results showed fluctuations in hydraulic parameters throughout the reach including depth, velocity, and shear stress. Higher velocities (and corresponding shear stresses) were noted along the Bremer Levee as well as at locations of visually observed instability where some localized vegetation clearing has occurred (i.e. RM 18.35; Figure 6). The model also showed that the 100-year event (6,250 cfs) does not overtop the levee; this containment is indicative of a loss of lateral connectivity.

Centerline Profile

A centerline profile of Stormy Reach was created by extracting bed elevation data from the developed topographic surface (see 'Model Surface Geometry'). This profile, shown in Figure 18, shows the large variability in the channel bed (pool/riffle/run) as well as an overall trending decrease in the bed slope in the downstream direction. This slope decrease is indicative of a decreasing trend in the total stream power (QS), which is a measure of a river's transport ability.

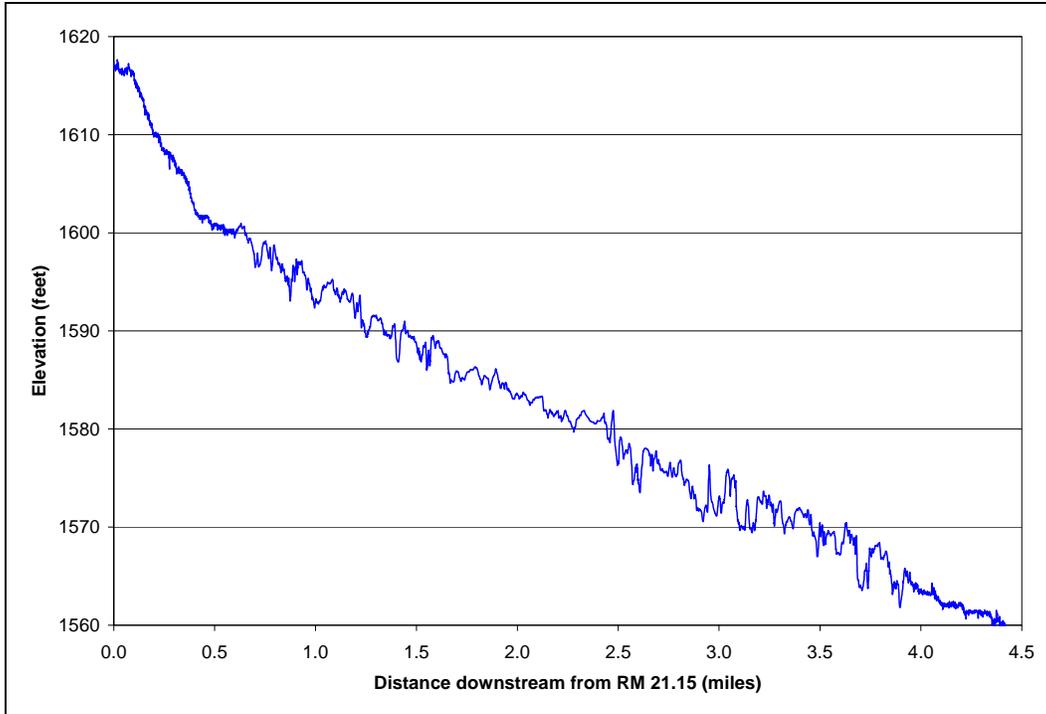


Figure 18. Centerline bed surface profile for Stormy Reach.

Water Surface Elevation Profiles

Water surface elevation profiles for the 2-year and 100-year flow events are shown in Figure 19. The average elevation difference between the two events is 1.8 feet, with a maximum difference of 3.7 feet. The majority of the 2-year event flow is confined to the active channel. The stair-step pattern seen in the 100-year profile is where the overbank flows are returning to being confined solely to the main channel. Further, the model shows the Bremer Levee containing the 100-year flow event; no overtopping (Figure 20).

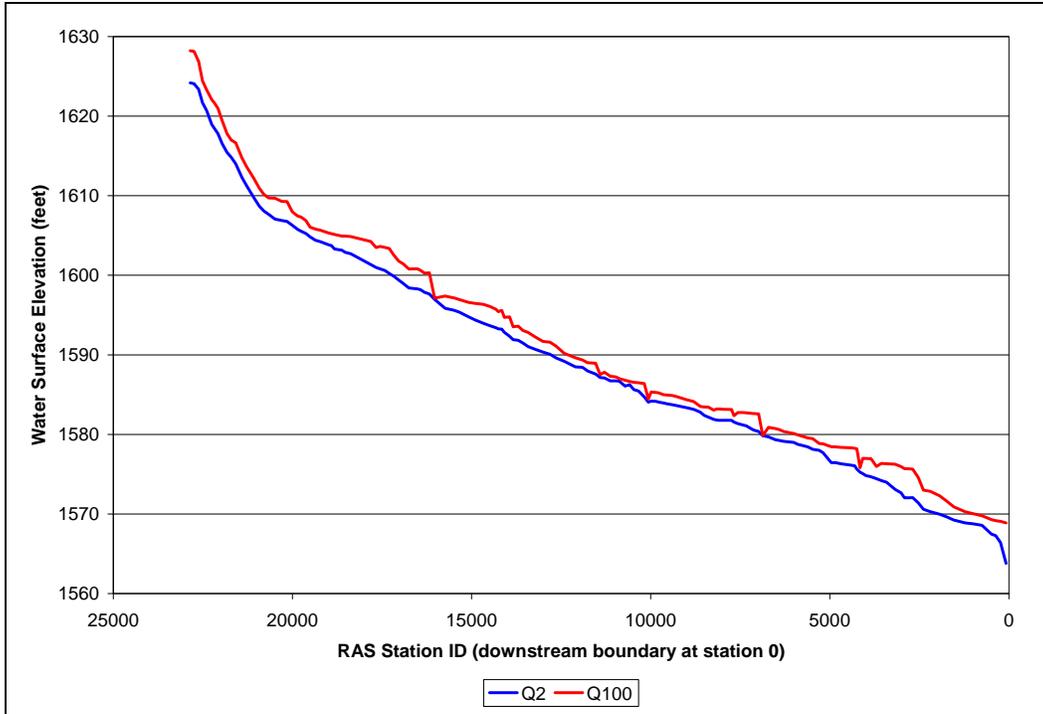


Figure 19. 2-year (2,650 cfs) and 100-year (6,250 cfs) water surface elevation profiles.

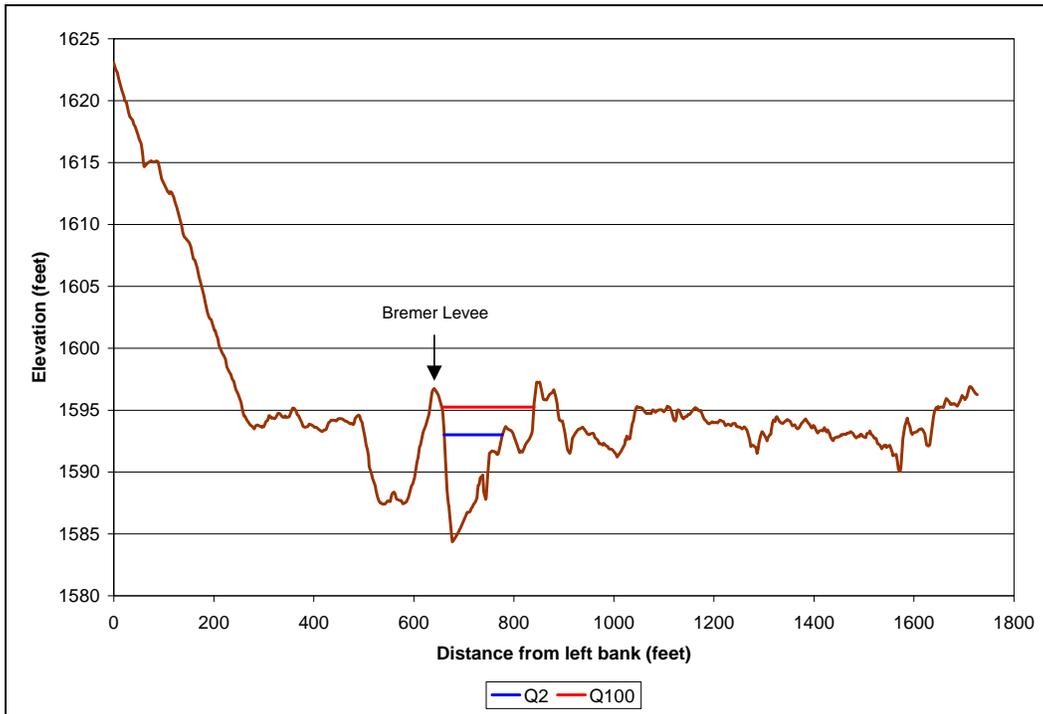


Figure 20. Cross section at RM 19.75 showing Bremer Levee with modeled water surface elevations for the 2-year and 100-year events.

Bremer Levee Removal

One of the primary goals in the Stormy Reach is restoring pre-existing channel function through the removal of anthropogenic features. One such feature is the Bremer Levee (RM 19.65-19.8), whose removal will increase lateral floodplain connectivity. The effects of removing this levee were simulated as a ‘proposed’ condition. Figure 21 shows an example cross section profile located at RM 19.75 portraying the existing and proposed conditions (with and without levee removal) along with the simulated 2-year water surface elevation (WSE) for each scenario.

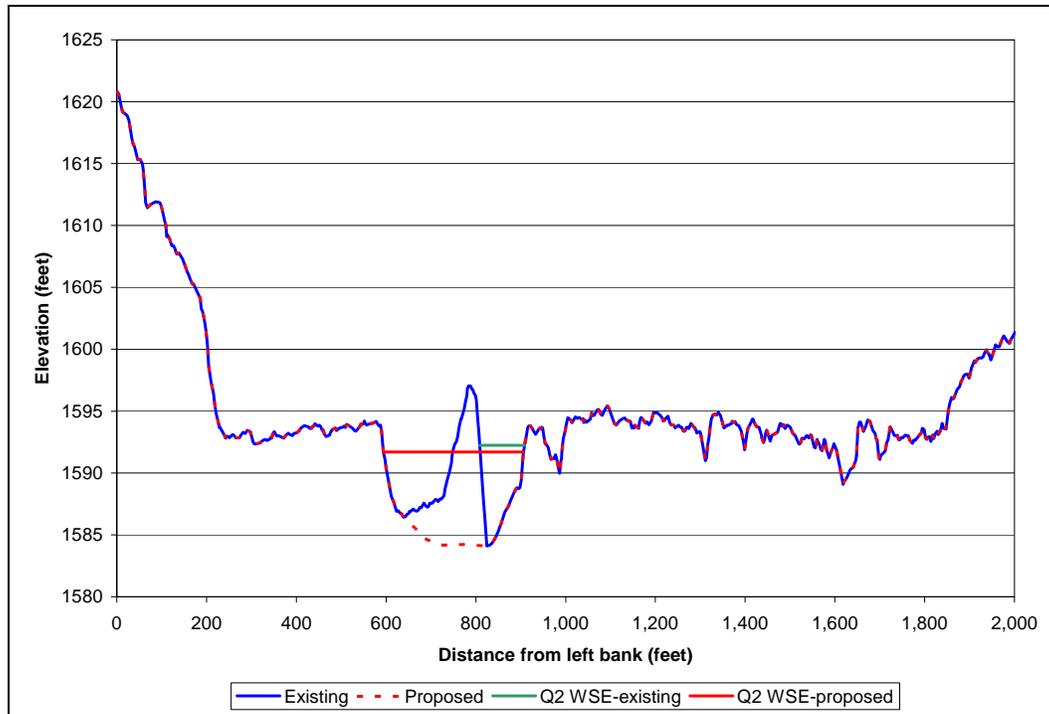


Figure 21. Cross section at RM 19.75 showing pre/post levee removal geometry and resulting 2-year water surface elevation.

Six cross sections were used in the model to represent the 1,000-foot long Bremer Levee. Figures 22-24 show pre/post levee removal model results for the flow area, velocity, and shear stress hydraulic parameters throughout the levee removal area, respectively. Given that the overbank areas in this model are not accurately represented due to the increased skewness that was required with the cross section alignments, the 2-year event (2,650 cfs), which is generally confined to the active channel, was chosen to portray the selected resultant hydraulic parameters from the model. As expected, an overall increase in flow area, and decrease in velocity and shear stress result from removal of the levee. The flow area increased an average 53% while the velocity and shear stress decreased an average 53% and 74%, respectively. Also, the in-channel hydraulic depth (Area/Top Width) increased an average 19% (1 foot) in this area. These expected changes should lead ultimately to increased channel stability and habitat sustainability.

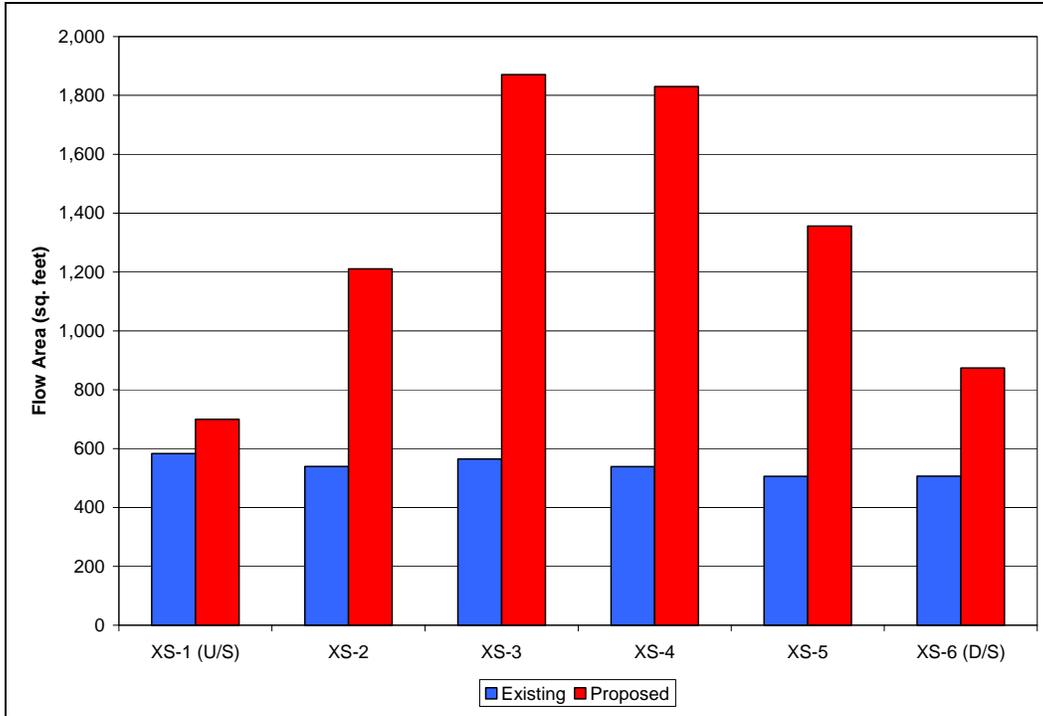


Figure 22. Flow area model results for the removal of Bremer Levee.

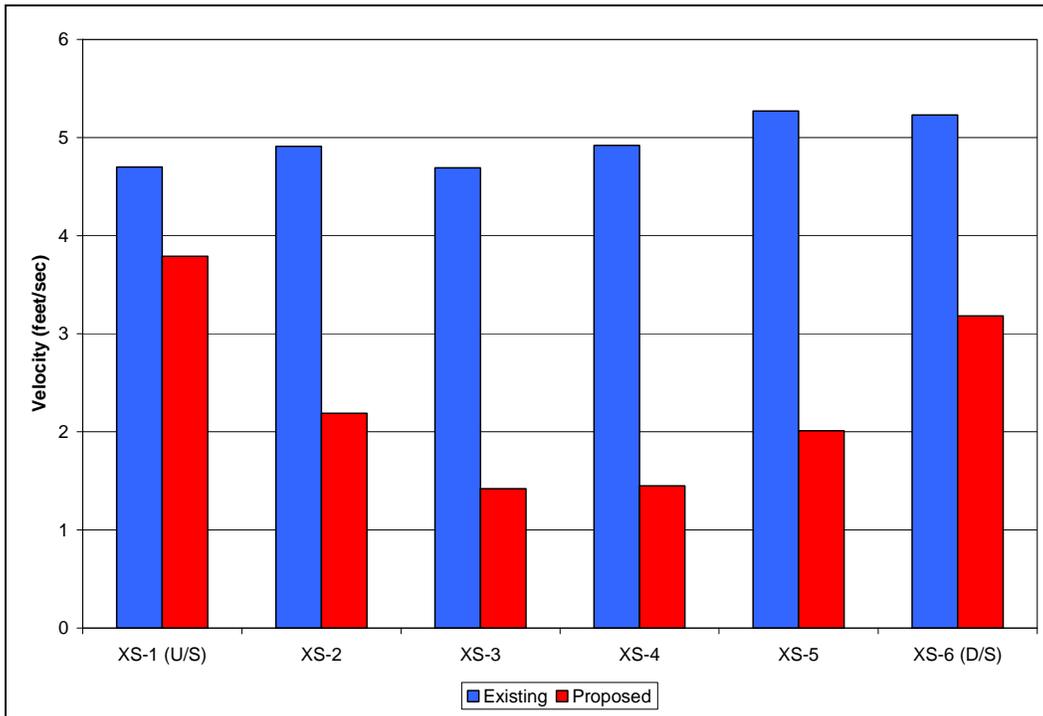


Figure 23. Velocity model results for the removal of Bremer Levee.

Stormy Reach Hydraulic Modeling

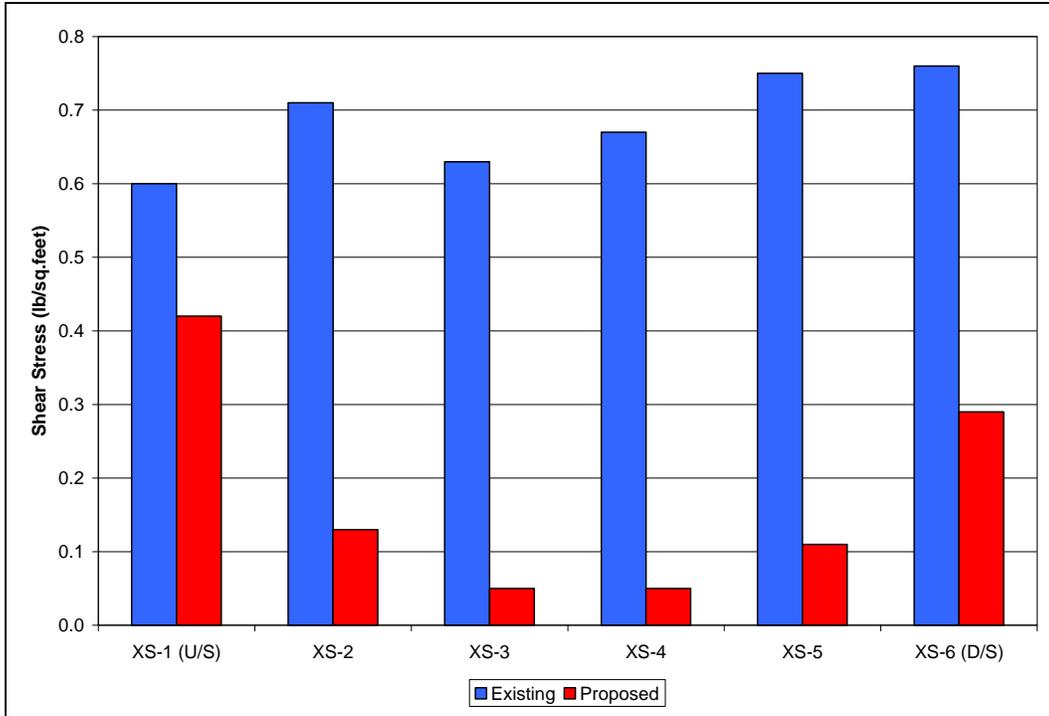


Figure 24. Shear stress model results for the removal of Bremer Levee.

Conclusions

A one-dimensional (1D) hydraulic model was developed for the Stormy Reach to evaluate in-channel hydraulics. Although the model covered the entire valley floor, overbank areas were not well represented due to required cross section alignments through the existing sets of tight meander bends. If increased modeling accuracy is deemed necessary in these areas, a two-dimensional (2D) model is recommended. Model results showed fluctuations in hydraulic parameters throughout the reach including depth, velocity, and shear stress. Higher velocities (and corresponding shear stresses) were noted along an existing armored levee as well as at locations of visually observed instability where some localized vegetation clearing has occurred (i.e. RM 18.35; Figure 6). The model also showed that the 100-year event (6,250 cfs) does not overtop the levee; this containment is indicative of a loss of lateral connectivity.

In general, the Stormy Reach appears to have good channel form complexity as evidenced through meander bends with high LWD, perennially connected side channels, 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. Restoring some of the lateral connectivity limiting factor in this reach should be a primary goal, and can be accomplished with the removal of the Bremer Levee (RM 19.65-19.8). Modeling showed this action to result in localized increases to flow area and channel depths and decreases to velocities and shear stresses. This in turn would likely lead to the creation of additional stable in-stream channel units more capable of supporting rearing/holding habitats. Removing (or setting back) this levee would allow the river to access an additional 3.3 acres of floodplain. The newly available floodplain would become inundated at flows less than the 2-year event (2,650 cfs). This levee also appears to be having an affect on the surrounding channel planform as well as LWD recruitment and retention potential. Bank instabilities throughout this reach appear to be localized in nature with riparian clearing being the likely contributor, and could be addressed as such.

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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.

APPENDIX F

Stormy Geodatabase

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

Appendix F

GIS Databases

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

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

<u>Feature Classes</u>	<u>Description</u>
Channel Units	Physical attributes of the channel
HabitatFeatures_Points	Habitat features i.e., pools, large wood, Redds, mapped during USFS Biologic Assessment
HabitatFeatures_Lines	i.e., bank erosion
Human Feature Line	Human features such as: roads and levees mapped by geologist in the field
InnerZone	Active Channels – Primary/Secondary
Photopoints	Photo location points
Subreaches	Inner/Outer Zone Divisions
Vegetation_10m	Vegetation 10 meters off Inner Zone
Vegetation_10m Disturbances	i.e., roads, residential, agricultural within 10m buffer zone
Vegetation_30m	Vegetation 20 meters off Inner Zone
Vegetation_30m Disturbances	i.e., roads, residential, agricultural within 30m buffer zone
Bridge Abutment	Bridge abutment mapped in the field by geologist
Rock Spurs	Bank treatments mapped in the field by geologist

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