Confederated Tribes of the Umatilla Indian Reservation

Desolation Creek Geomorphic Assessment and Action Plan

July 2017

TETRA TECH

Desolation Creek
Geomorphic Assessment and Action Plan

Submitted to:

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North Fork John Day Fish Habitat Project
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Executive Summary

Historically, the Desolation Creek watershed supported robust populations of native fish, wildlife, and plants, sustained by pristine stream, riparian, and upland habitat conditions and naturally functioning ecosystem processes. However, the Desolation Creek watershed has been impacted by direct and indirect anthropogenic alterations, including livestock grazing, timber harvest, wildfire management, road construction, invasive species introductions, and other activities. These alterations to the Desolation Creek watershed have decreased water quality and quantity along with valuable fish habitat, resulting in inhibited fish passage, altered sediment supply and sorting, reduced frequency of large woody debris (LWD) and habitat features such as high-quality pools, disconnection of adjacent floodplains, springs, and wetlands, and reduced water storage in upland wet meadows.

These degraded conditions have negatively impacted populations of native fish species that rely on cold, clean, and plentiful water, complex and high quality stream and riparian habitat, and ecological connectivity. Among the native salmonid species in Desolation Creek, Middle Columbia River steelhead (*Oncorhynchus mykiss*) and Columbia River bull trout (*Salvelinus confluentus*) are listed as threatened under the Endangered Species Act (ESA). Middle Columbia River spring Chinook salmon (*O. tshawytscha*) and Pacific lamprey (*Entosphenus tridentatus*) are not listed under the ESA, but they are of key conservation interest as species of cultural importance to the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO). Improvements to stream, riparian, and upland habitat, connectivity, and function are necessary to restore these fish species.

The CTUIR has a vested interest in the restoration and enhancement of ecological conditions in the Desolation Creek watershed and has been working with co-managers, landowners, and stakeholders to develop the Desolation Creek Geomorphic Assessment and Action Plan (the Project) as a guiding tool for future restoration planning and implementation within Desolation Creek and to benefit focal fish species. Given that the Desolation Creek watershed contains mixed ownerships as well as land management authority and responsibilities, the aim is to develop the Project as a cooperative effort. The CTUIR, the CTWSRO, and the Oregon Department of Fish and Game (ODFW) are designated co-managers of the Desolation Creek watershed, and key landowners and stakeholders include the Umatilla National Forest (UNF), which owns all federal land within the watershed; Desolation Creek LLC, which is the primary private landowner; and the North Fork John Day Watershed Council (NFJDWC).

The Project study area includes the mainstem Desolation Creek and tributaries, from its confluence with the North Fork of the John Day River to the Creek's headwaters, with emphasis on the primary assessment area (PAA) that includes approximately 10.5 miles of private land from river miles (RM) 1.8 to 12.3 owned by Desolation Creek LLC. The study area also includes the balance of the remaining lands within the watershed that are under ownership of the U.S. Department of Agriculture Forest Service (USFS), and identified as the secondary assessment area (SAA).

Through this Project, the CTUIR assessed watershed- and reach-scale existing conditions, including hydrology, sediment, fish habitat, and fish passage, in the Desolation Creek watershed in order to identify opportunities to protect, enhance, and restore watershed and floodplain processes to sustain and maintain high-quality habitat, increase habitat quantity and quality, and improve spawning, rearing, and migration habitat for focal fish species. The data and analyses in the Project's watershed- and reach-scale assessments were used to inform the identification and prioritization of potential projects, and to guide the development of conceptual and final designs. Potential restoration and enhancement opportunities were identified during field surveys and through desktop assessments, along with co-managers, landowners, and stakeholder input. Following their identification, potential opportunities were prioritized using biological and physical habitat attributes, and then weighed against project feasibility and constraints. Project designs were then developed consistent with biological needs of the focal fish species, local geomorphology, and implementation feasibility.

The Project builds upon past assessments, planning efforts, and restoration and land management efforts. Field surveys, empirical data, and local knowledge were also critical in supplementing past efforts and developing the Project. The Project will provide the framework upon which future assessments and planning efforts for Desolation Creek can be built. The key topics covered in each section of the Geomorphic Assessment and Action Plan are as follows:

- Section 1: Introduces the Project, identifies the Project's purpose and need, describes the Project context, and outlines the stakeholder involvement. The Project Context subsection goes into further detail regarding the relationship of the Project to applicable federal and state regulations, and integration with past and future assessments and planning efforts.
- Section 2: Describes the Project mission, goals, and objectives. The mission, goals, and objectives are identified for each of the three co-managers as well as for the landowners and stakeholders. The Project Goal and Objectives are then identified, and the Project objectives are connected to discrete actions that can be clearly defined and the results measured to evaluate progress towards meeting each objective.
- Section 3: Describes the Project metrics, existing data, and assessment methods. Quantifiable and repeatable metrics are identified to establish baseline conditions and evaluate progress toward addressing processes and limiting factors following implementation of actions. Existing data and reports that were compiled and used in the Project are described and included as appendices. Assessment methods for the reach assessments of the delineated geomorphic reaches are described.
- Section 4: Presents the watershed-scale assessment of the Desolation Creek watershed based on existing data and information gathered, and observations made during field surveys. This section includes a watershed physical description, a description of fish use, a summary of land-use history and associate impacts, a description of limiting factors and restoration potential, and an assessment of the potential for future impacts related to climate change.
- Section 5: Presents the reach-scale assessment results that provide the scientific foundation and site-specific information needed to develop the project opportunities and potential

restoration actions included in the Action Plan (Section 6). Reach descriptions and geomorphic and habitat characteristics are provided for the seven geomorphically delineated reaches. Desired future conditions are described for Desolation Creek, and the reaches with the greatest potential to guide prioritization in the Action Plan (Section 6) are identified.

- Section 6: Describes the Action Plan that was developed to prioritize restoration and enhancement projects and designs that can demonstrate progress toward addressing limiting factors through quantifiable and repeatable metrics. Development of the Action Plan followed nine sequential steps to achieve Project objectives:
    1. Review existing restoration plans and past actions to incorporate past work and to avoid duplication of efforts.
    2. Identify and rank biologically significant reaches (BSRs) based on common fish use and limiting factor characteristics.
    3. Refine and rank limiting factors tied to general restoration and enhancement actions, and define metrics to evaluate impact of project actions on limiting factors.
    4. Identify and select restoration actions to achieve desired future conditions.
    5. Prioritize restoration actions within each BSR.
    6. Score Project opportunities to facilitate identifying types of scalable project actions that would be typical of project sizes.
    7. Evaluate Project feasibility based on 10 criteria prior to making final decisions on whether or not a project should be funded.
    8. Develop Project designs based on prioritized restoration and enhancement projects and consistent with biological needs of the focal fish species, local geomorphology, and implementation feasibility.
    9. Develop an implementation schedule for implementing projects based on the project prioritization and expected future design development process.
- Section 7: Identifies the conclusions and next steps in the development of the Project. This section includes recommendations for initiating the Action Plan and next steps including ongoing data collection and research efforts, developing site-specific projects designs, implementing projects, and monitoring completed projects. Addressing these steps will help ensure the Geomorphic Assessment and Action Plan will be a flexible and useful living document both in the short term and well into the future.

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ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
2008 Fish Accords	2008 Columbia Basin Fish Accords Memorandum of Agreement between the Three Treaty Tribes and FCRPS Action Agencies
BiOp	Biological Opinion
BPA	Bonneville Power Administration
BSR	biologically significant reach
CHaMP	Columbia Habitat Monitoring Program
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CTWSRO	Confederated Tribes of the Warm Springs Reservation of Oregon
CWA	Clean Water Act
DEIS	Draft Environmental Impact Statement
DEM	digital elevation model
DNR	Department of Natural Resources
DPS	distinct population segment
DVD	digital versatile disc
EDT	Ecosystem Diagnosis and Treatment
EFM	Ecotrust Forest Management
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FCRPS	Federal Columbia River Power System
FLIR	forward looking infrared
GIS	geographic information system
GLO	General Land Office
GPS	Global Positioning System
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HUC	Hydrologic Unit Code
LiDAR	light detection and ranging
LWD	large woody debris
mm	millimeter
NAIP	National Agriculture Imagery Program
NFJDWC	North Fork John Day Watershed Council

NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NPCC	Northwest Power and Conservation Council
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OHV	off-highway vehicle
PAA	primary assessment area
PHAMS	Physical Habitat Monitoring Strategy
Project	Desolation Creek Geomorphic Assessment and Action Plan
QHA	Quality Habitat Assessment
QSI	Quantum Spatial Inc.
REM	Relative Elevation Model
RM	river mile
RTK	real-time kinematic
SAA	secondary assessment area
TMDL	Total Maximum Daily Load
UNF	Umatilla National Forest
USACE	U.S. Army Corps of Engineers
USFS	U.S. Department of Agriculture Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

GLOSSARY

Alluvium – a deposit of unconsolidated sediments left by flowing streams in a river channel, delta, estuary, or floodplain.

Biologically Significant Reaches – stream reaches with similar fish use and limiting factor characteristics.

Channel Stability – a general term that refers to the resistance of bed and bank erosion from a river in response to changes in flow or sediment transport. Natural stream channels have varying degrees of stability. A naturally stable channel has the ability to transport water and sediment over time without an overall net increase in aggradation or degradation. Under this definition, streams may migrate laterally if they maintain their natural dimensions (width, depth), pattern (sinuosity), and profile (gradient and bed features).

Channel Substrate – the composition of the river channel bed materials within the active channel.

Clean Water Act – the primary federal law in the United States governing water pollution.

Confinement – a general term used to describe the degree to which a stream is laterally contained. Confinement widths would include natural high terraces, hillslopes, or artificial features.

Embeddedness – the extent that larger cobbles or gravel are surrounded by or covered by fine sediment.

Ecological Concerns (also referred to as Limiting Factors) – physical, biological, or chemical features experienced by fish that result in reductions in viable salmonid population parameters (abundance, productivity, spatial structure, and diversity).

Ecological Node – A smaller geographic area within a lower ranked (Tier 2 or Tier 3) biologically significant reach (BSR) that may have significant fish use based on close proximity to known spawning habitat, refuge habitat (thermal refugia, hiding cover, or available floodplain), or important tributary junctions.

Endangered Species Act – a 1973 Act of Congress that mandated that endangered and threatened species of fish, wildlife, and plants be protected and restored.

Enhancement – activities designed to increase, or further improve the quality, value, or extent of, particular habitat features that are already present.

Entrenchment – the degree to which a stream is vertically confined from its floodplain. Usually expressed as the ratio of the width of the flood-prone area to the bankfull width, in which higher entrenchment ratios indicate higher floodplain connectivity. May be impacted by both human and natural causes.

First Foods – the foods ritualistically served in the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) Tribal meals that include Water, Salmon, Deer, Cous, and Huckleberry. The

First Foods mission of the CTUIR is "[t]o provide proactive planning and policy analysis and development to protect, restore and enhance the First Foods and the exercise of associated rights reserved in the Treaty of 1855."

Fish Utilization Potential – a ranking value assigned by assessing current fish species use, limiting factors, and biologically significant reaches relative to current and potential geomorphic function.

Flood Refugia – areas of slower water velocity during higher discharges, also referred to as high-flow refugia.

Floodplain – the areas of land adjacent to a river out to the enclosing valley walls that are inundated with water during flooding events. Soils within the floodplain are largely made up of alluvium from river deposits.

Floodplain Connectivity – a general description of the degree of interaction river flows have with the floodplain at a range of flows.

Focal Fish Species – fish species that are identified as at risk, of cultural significance to the Confederated Tribes of the Umatilla Indian Reservation, and toward which Project restoration and enhancement actions are directed. For this document, the focal fish species include Chinook salmon, steelhead, bull trout, and Pacific lamprey.

Geomorphic Function – a ranking value assigned by assessing the degree to which channel process and form in a reach are functioning to support in-channel, off-channel, and floodplain habitats.

Geomorphic Potential – a ranking value assigned by assessing the potential for a reach to enhance processes to develop an inset floodplain, create or reconnect existing side-channel or off-channel habitat, and create complex in-channel habitats.

Geomorphology – the scientific study of the origin and evolution of topographic and bathymetric features created by physical or chemical processes operating at or near the Earth's surface.

Incised River – a river that cuts its channel through the bed of the valley floor, as opposed to one flowing on a floodplain; it is formed by the process of degradation.

Limiting Factors (also referred to as Ecological Concerns) – physical, biological, or chemical features experienced by fish that result in reductions in viable salmonid population parameters (abundance, productivity, spatial structure, and diversity).

Meander Belt Width – the width between points of inflection defining the lateral extents of opposing meanders over which the stream naturally moves over time. This width does not necessarily correspond with the width of the valley.

Off-Channel Habitat – habitat that is not part of the active channel but has a direct connection to it.

Pool Frequency – a measure of the pool-to-pool spacing in a river channel.

Rearing – Refers to the period of time and/or locations (rearing habitat) that juvenile fish spend feeding in nursery areas of rivers, lakes, streams and estuaries before migration.

Restoration – The renewing or repairing of a natural system so that its functions and qualities are comparable to its original, unaltered state.

Riparian Zone – a riparian zone (or riparian area) is the interface between upland lands and a river or stream.

River Miles – number of miles from the mouth of a river to a specific destination.

River Vision – defines a functional river that can support First Foods as a "river that is dynamic and shaped not only by physical and biological processes, but the interactions and interconnections between those processes" (Jones et al. 2008). The vision then defines the key components and processes of functional rivers, identifies management implications and challenges, and links key attributes and processes with specific management applications. The five key components (or touchstones) of functional rivers that are considered to be vital in the management and restoration of river ecosystems, and which are tied directly to the CTUIR's First Food mission, include hydrology, geomorphology, habitat and network connectivity, riverine biotic communities, and riparian vegetation.

Streambank – the terrain alongside the bed of a river that comprises the sides of the channel.

Total Maximum Daily Load – a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant.

Turbidity – a measure of water clarity determined by how much the material suspended in water decreases the passage of light through the water.

1 Introduction

The Desolation Creek watershed (10-digit Hydrologic Unit Code [HUC] 1707020204) is located southeast of the town of Dale in Grant County, Oregon. The watershed has been impacted by livestock, timber harvest, wildfires, roads, and other activities that have decreased water quality and quantity along with valuable fish habitat, resulting in inhibited fish passage, altered sediment supply and sorting, reduced frequency of large woody debris (LWD) and habitat features such as high-quality pools, poor connectivity of adjacent floodplains, springs, and wetlands, and reduced water storage in upland wet meadows. The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) is working with co-managers, landowners, and stakeholders (see Section 1.3) to develop the Desolation Creek Geomorphic Assessment and Action Plan (the Project) as a guiding tool for future restoration planning and implementation within Desolation Creek and to benefit focal fish species including steelhead (*O. mykiss*), bull trout (*Salvelinus confluentus*), spring Chinook salmon (*O. tshawytscha*), and Pacific lamprey (*Entosphenus tridentatus*).

Through this Project, the CTUIR assessed watershed- and reach-scale existing conditions, including hydrology, sediment, fish habitat, and fish passage, in the Desolation Creek watershed in order to identify opportunities to protect, enhance, and restore watershed and floodplain processes to sustain and maintain high-quality habitat, increase habitat quantity and quality, and improve spawning, rearing, and migration habitat for focal fish species.

The Project area includes the mainstem Desolation Creek and tributaries, from its confluence with the North Fork of the John Day River to the Creek's headwaters. Special emphasis is given to the primary assessment area (PAA) that includes approximately 10.5 miles of private land from river miles (RM) 1.8 to 12.3. The Project area also includes the balance of the remaining lands within the watershed that are under ownership of the U.S. Department of Agriculture Forest Service (USFS), and is identified as the secondary assessment area (SAA). The location of the PAA and SAA are shown in Figure 1-1. Information provided in the watershed- and reach-scale assessments has been used to develop an action plan for improving fish habitat conditions, along with restoration designs at various stages, leading to the design and implementation of the highest ranked project within the PAA. The reach-scale assessment within the PAA was utilized for identifying and prioritizing potential project designs for development.

The remainder of this section describes the purpose and need for the Project, the context for the assessment and action plan, and stakeholder involvement.

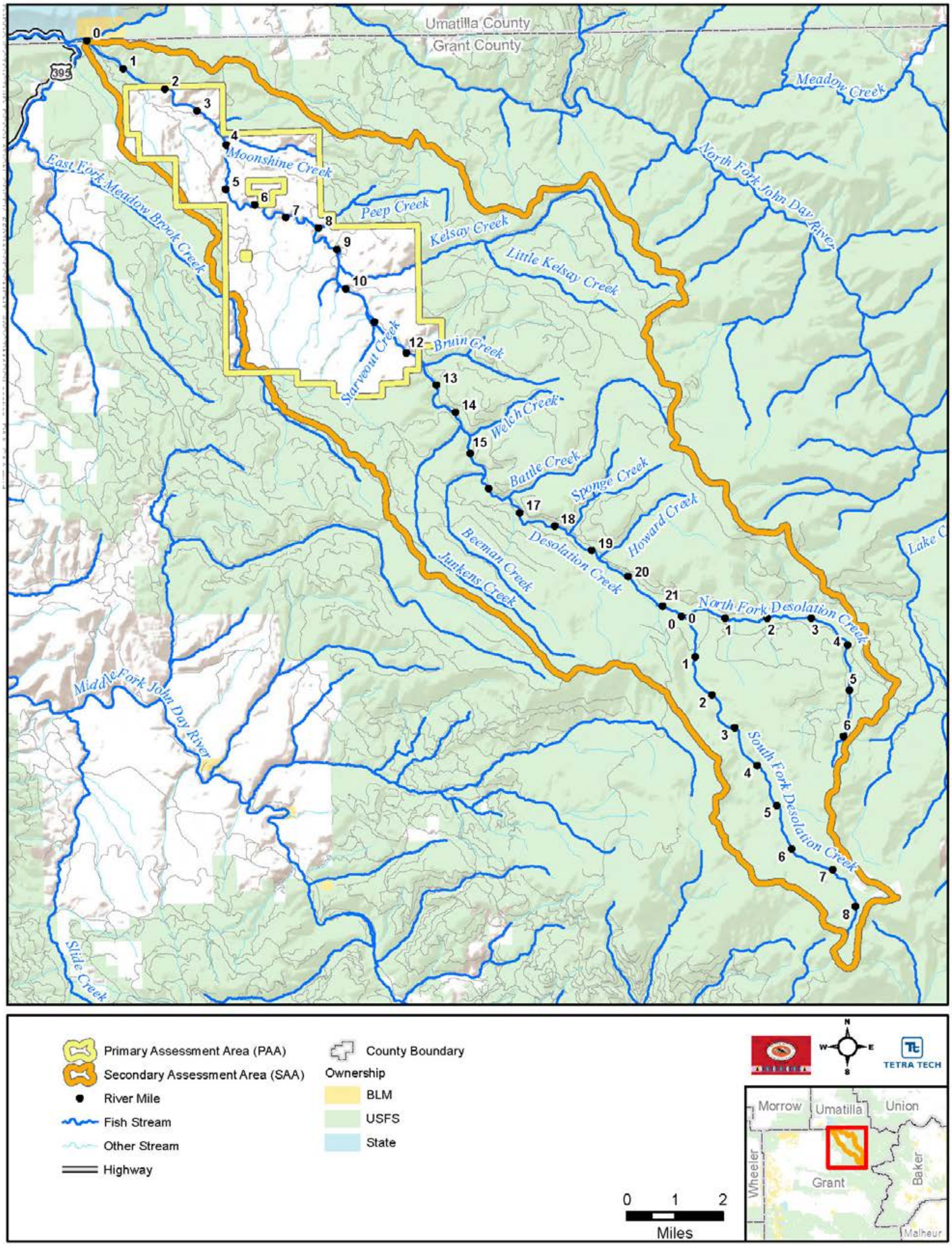

Figure 1-1. Desolation Creek Project Area Map Showing the PAA and SAA

1.1 PURPOSE AND NEED

In its efforts to understand and address habitat issues and concerns in the Desolation Creek watershed, the CTUIR determined that a strategic approach in the form of a geomorphic assessment and action plan was necessary. To address this need, the CTUIR is implementing the Project for the following purposes:

1. Obtain new empirical data for use in evaluating degraded conditions and identifying and prioritizing restoration and enhancement projects;
2. Use existing and new information to develop scientifically based designs for prioritized restoration projects that address factors limiting focal fish species population performance;
3. Implement one of the designs for the highest priority project within the PAA; and
4. Identify and utilize metrics that will aid in tracking restoration actions that are most effective at improving degraded conditions and providing benefits to focal fish species in the Desolation Creek watershed.

As contract administrator and technical lead for the Project, the CTUIR recognizes that the Desolation Creek watershed contains mixed ownerships as well as land management authority and responsibilities. In recognition of this, the CTUIR aims to develop the Project as a cooperative effort with the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO) and the Oregon Department of Fish and Wildlife (ODFW), which are designated watershed co-managers (Three Treaty Tribes-Action Agencies 2008); the Umatilla National Forest (UNF), which owns all federal land within the watershed; Desolation Creek LLC, which is the primary private landowner; and the North Fork John Day Watershed Council (NFJDWC). Therefore, an approach involving active participation by these key stakeholders who are likely to be involved at vital phases of Project development is needed to attain long-term consensus and support through future regulatory and funding pathways.

1.2 ASSESSMENT AND ACTION PLAN CONTEXT

1.2.1 Relationship to Applicable Federal and State Regulations

The Project will assist the co-managers in implementing restoration and enhancement projects in Desolation Creek that address fish habitat associated with Endangered Species Act (ESA)-listed fish species. The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) have developed or are in the process of finalizing recovery plans (see NMFS 2009 and USFWS 2015, respectively) for ESA-listed species that include actions to address fish limiting factors. Furthermore, the Northwest Power and Conservation Council (NPCC), Bonneville Power Administration (BPA), NMFS, and USFWS have adopted the Desolation Creek Watershed Action Plan (USFS 2009) to help meet requirements under the 2000 Federal Columbia River System Biological Opinion (BiOp). In addition, the 2008 Columbia Basin Fish Accords Memorandum of Agreement between the Three Treaty Tribes and Federal Columbia River Power System (FCRPS) Action Agencies (2008 Fish Accords; Three Treaty Tribes-Action Agencies 2008) establishes an agreement between the action agencies that include BPA, the U.S. Army Corps of Engineers

(USACE), and the U.S. Bureau of Reclamation and tribes that include the CTUIR, the CTWSRO, the Confederated Tribes and Bands of the Yakama Nation, and the Columbia River Inter-Tribal Fish Commission. The agreement establishes various commitments, including the funding and implementation of habitat projects to address the needs of ESA-listed fish.

Two fish species that occur in Desolation Creek have been listed as threatened under the ESA: steelhead and bull trout. Middle Columbia River steelhead were listed as threatened under the ESA in 1999 (65 *Federal Register* 14517), with that status reaffirmed on January 5, 2006 (71 *Federal Register* 834). Columbia River bull trout were listed as threatened under the ESA in 1998. The action plan provided in Section 6 of this document provides prioritized restoration and enhancement actions for Desolation Creek that will assist in the recovery of these listed fish species.

The Clean Water Act (CWA) of 1977, and subsequent amendments, makes it unlawful for any person to discharge any pollutant into waters of the United States, unless a permit was obtained under its provisions. Under Section 303 of the CWA, states must prepare a list of water bodies not meeting water quality standards and to conduct an analysis of the extent of the problem and develop a water cleanup plan to address Total Maximum Daily Loads [TMDLs] for various pollutants. The Oregon Department of Environmental Quality (ODEQ) maintains a list of impaired waterbodies and water quality standards that apply to all waters of the state. The action plan provided in Section 6 provides prioritized restoration and enhancement actions for Desolation Creek that will assist in water quality enhancement related primarily to sedimentation and turbidity, and temperature.

1.2.2 Integration with Past Assessments and Planning Efforts

The intent of the Project is not to replicate, but rather to supplement and work in concert with existing planning documents. These include the following:

- John Day River Basin Watershed Restoration Strategy (CTWSRO 2014),
- John Day Subbasin Plan (NPCC 2005),
- Draft Desolation Creek Watershed Action Plan (USFS 2009),
- 2008 Fish Accords (Three Treaty Tribes-Action Agencies 2008),
- CTUIR Umatilla River Vision (Jones et al. 2008),
- Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan (NMFS 2009),
- Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River Steelhead Distinct Population Segment (Carmichael and Taylor 2010),
- Recovery Plan for the Coterminous United States Population of Bull Trout (USFWS 2015),
- NFJDWC Strategic Plan (NFJDWC 2010), and
- Recommendations of the Upper North Fork John Day Focus Group for accelerated restoration (NFJDWC 2014).

In addition, numerous assessments and limiting factors analyses () were accessed to develop the Project. Field surveys, empirical data, and local knowledge were also critical in developing the Project. Throughout this document, past assessments and plans are cited where applicable.

1.2.3 Integration with Future Assessments and Planning Efforts

In addition to developing the Project in association with federal and state requirements and past assessments and planning efforts, the Project provides the framework upon which future assessments and planning efforts for Desolation Creek can be built. Although the Project has been developed from the best available science and quantifiable data, additional studies, alterations in land use, upstream assessments and plans, and implementation of restoration and enhancement projects will contribute toward refinements to this Project. For example, the continuing efforts completed as a part of the CTUIR Biomonitoring Plan (Stillwater Sciences 2012) on Desolation Creek may provide additional information that could be used to inform future assessments and planning efforts. As new applicable assessments and plans are developed, the results from this Project will assist future restoration and enhancement projects that focus on further protecting, restoring, and enhancing fish habitat.

1.3 STAKEHOLDER INVOLVEMENT

Stakeholder involvement and outreach is a key element of the Project and a critical aspect to attaining the desired future conditions of Desolation Creek. The development of the Project incorporated local knowledge, available data, and review from co-managers (CTUIR, CTWSRO, ODFW), landowners (UNF, Desolation Creek LLC), and stakeholders (NFJDWC). This section highlights individuals and organizations that provided assistance with meetings and presentations, field data collection, review of Project data, and guidance related to the future implementation of restoration and enhancement projects on Desolation Creek. A list of participants is provided in Table 1.3-1.

Table 1.3-1. Participants Who Facilitated the Development of the Project

Individual	Affiliation	Individual	Affiliation
Jenna Peterson	BPA	Darin Stringer	Desolation Creek LLC
Sean Welch	BPA	Russ Powell	ODFW
Jessie Wilson	BPA	Ian Tattam	ODFW
Kaylyn Costi	CTUIR	Trevor Watson	ODFW
Delbert Jones	CTUIR	Shelley Reich	NFJDWC
Michael Lambert	CTUIR	Valeen Madden	NFJDWC
Gene Shippentower	CTUIR	Eileen Eisenbraun	NFJDWC
John Zakrajsek	CTUIR	Richard Cissel	UNF
Allen Gillette	CTWSRO	Hugo Magana	UNF
Nich Smith	CTWSRO	Lori Seitz	UNF
Marty Eisenbraun	Desolation Creek LLC		

2 Mission, Goals, and Objectives

This section describes goals and objectives of the Project at both the programmatic and the Project level. The Project involved extensive coordination between numerous agencies, organizations, and stakeholders with vested interests in the welfare of Desolation Creek. The missions, goals, and objectives of the co-managers, landowners, and stakeholders are first described, followed by the Project specific goal and objectives.

2.1 NORTH FORK JOHN DAY CO-MANAGER PROGRAMMATIC MISSION, GOALS, AND OBJECTIVES

The mission, goals and objectives of recognized North Fork John Day watershed (8-digit HUC 17070202) co-managers as related to the Project and restoring watersheds for ESA-listed and culturally significant species are described in the following subsections.

2.1.1 The Confederated Tribes of the Umatilla Indian Reservation

As contract administrator, technical lead, and designated co-manager, the CTUIR intends to accomplish this Project in accordance with their Department of Natural Resources (DNR) First Foods Policy with a mission to provide proactive planning and policy analysis and development to protect, restore, and enhance the First Foods and the exercise of associated rights reserved in the Treaty of 1855. This mission is based on the significant foods ritualistically served in a Tribal meal and include, in the order they are served, Water, Salmon, Deer, Cous, and Huckleberry. The First Foods and associated Policy Program is utilized by the CTUIR DNR as a management approach to ensure the minimum ecological products necessary to sustain CTUIR culture are protected and sustained to meet treaty-reserved resources (Quaempts et al. 2014). Further, through the Umatilla River Vision (Jones et al. 2008), the CTUIR has identified ecological characteristics for meeting the mission of implementing the First Foods Policy Program. The characteristics are founded on five fundamental "touchstones" that include: (1) hydrology, (2) geomorphology, (3) riverine connectivity, (4) native riparian vegetation, and (5) native aquatic biota.

2.1.2 The Confederated Tribes of the Warm Springs Reservation of Oregon

As one of three co-managers, the CTWSRO Fisheries Habitat Program mission is to protect, manage, and enhance habitat that supports culturally significant fish populations for the CTWSRO. Objectives supporting the Habitat Program mission include:

- Maintain and restore high-quality aquatic habitat to support harvestable fish populations.
- Ensure access to these populations for the Tribal membership.
- Foster partnerships to achieve holistic watershed-scale benefits.
- Demonstrate a conservation ethic that supports multiple use and harmony in rural communities with natural resource based economies.

2.1.3 Oregon Department of Fish and Wildlife

As one of three co-managers, ODFW's mission is to "[p]rotect and enhance Oregon's fish and wildlife and their habitats for use and enjoyment by present and future generations." With regard to watershed and fisheries restoration, ODFW follows State of Oregon policy based on the Oregon Plan for Salmon and Watersheds, whose mission is "[r]estoring our native fish populations and the aquatic systems that support them to productive and sustainable levels that will provide substantial environmental, cultural, and economic benefits." Additionally, the ODFW John Day Fish Habitat Program, like the CTUIR and CTWSRO fisheries programs, is funded by the BPA. Therefore, all three entities use BPA funding that is directed toward mitigation of ESA-listed fish species, and to that end have many objectives and work elements in common.

2.2 LANDOWNER PROGRAMMATIC MISSION, GOALS, AND OBJECTIVES

The mission, goals, and objectives of landowners as related to property management, the Project, and restoring watersheds for ESA-listed species are described in the following subsections. Each respective landowner retains final authority regarding decisions to implement any restoration actions advocated by co-managers or stakeholders.

2.2.1 Umatilla National Forest

As the largest landowner in the watershed, the mission of the USFS, which manages the UNF, is "[to] sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations." The UNF operates under various forest management plans, some of which are specific to the Desolation Creek watershed, such as the Draft Desolation Creek Watershed Action Plan (USFS 2009). Existing UNF plans and watershed objectives are described in Section 6.1.

2.2.2 Desolation Creek LLC

Desolation Creek LLC purchased 13,440 acres of the lower Desolation Creek watershed in 2014. The property is managed by Ecotrust Forest Management (EFM), a for-profit subsidiary of Ecotrust formed to manage forestlands for financial, ecological, and social returns. The Desolation Creek Land Management Plan (EFM 2015) describes the purpose and need of the plan as follows: "Forests throughout the Blue Mountains face challenges resulting from past timber harvests, fire suppression, and overgrazing. Well-planned stewardship of these lands is critical to the long term sustainability of these resources and improvement of property values. Climate change adds an additional impetus for sound decision making in this ecologically complex landscape. This management plan provides a coordinated strategy towards these outcomes while meeting requirements for Forest Stewardship Council (FSC) certification." Existing restoration efforts currently underway through Desolation Creek LLC are described in Section 6.1.1.

2.3 STAKEHOLDER MISSION, GOALS, AND OBJECTIVES

The mission, goals, and objectives of other collaborators as related to the Project and restoring watersheds for ESA-listed and culturally significant species are described in the following subsection.

2.3.1 North Fork John Day Watershed Council

As a key stakeholder in the watershed, the mission of the NFJDWC is "[t]o actively participate in the planning, funding, and implementation of actions and projects that advance and sustain the health of the North/Middle Fork John Day Watershed, honor tribal treaty rights, and strengthen the long-term economic stability of individuals and communities that rely on the watershed's natural resources." The Restoration Program goal in the North Fork John Day Watershed Council Strategic Plan (NFJDWC 2010) is to "[i]mprove upland range conditions, instream, and riparian habitats." This is supported by measureable objectives including Objective #3: "Improved overall instream and riparian conditions, and the reduction of impacts to fish habitat."

2.4 PROJECT GOAL AND OBJECTIVES

The overarching goal of the Project is to provide rigorous, data-driven, and science-based analyses leading to prioritized restoration and enhancement projects and designs that, when implemented over time, will accelerate process-based geomorphic function to rehabilitate Desolation Creek to the benefit of terrestrial and aquatic First Foods including but not limited to ESA-listed species such as steelhead and bull trout, as well as other native species (e.g., spring Chinook salmon, lamprey, freshwater mussels [*Anodonta* sp.], and redband trout [*O. mykiss* ssp.]). Included in this goal is the need to understand the geomorphic and ecological processes and limiting factors affecting Desolation Creek in order to prioritize and implement restoration projects that will make quantifiable progress toward addressing the key limiting factors. Progress toward these goals should complement appropriate land management strategies of landowners and be in accordance with established planning documents that include the following:

- CTUIR's North Fork John Day Fisheries Enhancement Strategy, approved by the Independent Scientific Review Panel during the 2013 Geographic Review
- John Day River Subbasin Plan (NPCC 2005)
- 2008 Columbia Basin Fish Accords (Three Treaty Tribes-Action Agencies 2008)
- Umatilla River Vision (Jones et al. 2008)
- John Day River Basin Watershed Restoration Strategy (CTWSRO 2014)
- Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan (NMFS 2009)
- Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River Steelhead Distinct Population Segment (Carmichael and Taylor 2010)
- Recovery Plan for the Coterminous United States Population of Bull Trout (USFWS 2015)

- Decision Notice/Decision Record, Finding of No Significant Impact, Environmental Assessment for Interim Management of Anadromous Fish-Producing Watersheds on Federal Lands in Eastern Oregon, Washington, Idaho, and Portions of California (USFS and BLM 1995)

The objectives established for this Project are connected to discrete actions that can be clearly defined and the results measured over time to evaluate progress toward meeting each objective. To address the goal of the Project, the following objectives and associated tasks were developed:

- Determine the factors that are negatively influencing physical and biological processes resulting in degraded physical conditions (e.g., high eroding banks, limited floodplain and riparian areas, etc.) and limiting productivity (e.g., stream temperature, instream flows, etc.). This objective has been met by completion of the watershed- and reach-scale assessment tasks that include:
  - Descriptions of historical and current watershed processes, including land use, geology, geomorphology, water quality and quantity, hydrology, and hydraulics;
  - Identification of stream channel characteristics (primary and secondary channel lengths; channel width, depth, cross section area, gradient, incision and entrenchment, stream classification; habitat units and features such as pools and large wood);
  - Characterization of riparian, floodplain, wetland, and upland meadow areas (flood inundation, stream bank stability, channel migration rates, vegetative community complexity/health, and off-channel habitat);
  - Determination of sediment distribution and mobility, and identifying any concerns related to sediment transport, erosion or deposition;
  - Descriptions of current and historic fish abundance, species composition, distribution, timing, and passage-related concerns; and
  - Refinements at the reach level for the geomorphic and habitat limiting factors affecting salmonid population performance.
- Describe and develop desired future conditions that are realistic given the needs associated with private and public land uses, and the roles and responsibilities of the co-managers, landowners, and stakeholders by completing tasks that include:
  - Define co-manager and stakeholder roles and responsibilities as related to terrestrial and aquatic ESA-listed and focal fish species;
  - Incorporate management plans and strategies of landowners and take into consideration the objectives developed through their management plans;
  - Ensure adequate opportunities for co-manager and stakeholder involvement; and
  - Determine areas of common ground and cooperation.
- Identify and prioritize restoration and enhancement projects and actions utilizing information from the assessments and by completing associated tasks that include:

  - Target significant stream reaches of concern (i.e., biologically significant reaches), and prepare a higher-level analysis of conditions at those locations;
  - Identify the most effective approach to address limiting factors and terrestrial/aquatic physical or biological processes; and
  - Strategically identify and categorize and clearly display restoration actions or channel reaches to produce measurable benefits for aquatic species and terrestrial floodplain and riparian communities.
- Develop conceptual levels of designs, based on developed lists of prioritized restoration and enhancement projects, that are practical to implement and able to be adapted and scaled to multiple sites.
- Relate the design plan components to desired future conditions based on the restoration actions ranking process.
- Aid in articulating landowner and cooperator objectives and geomorphic assessment results.
- Compile implementable restoration and enhancement actions based on their potential to affect limiting factors and processes in a concise and commonly understandable way.
- Develop designs that will promote desired future conditions for the highest ranked project within the PAA to the 100 percent, construction-ready level.
- Use data from the assessments and analyses to develop creative and effective treatments addressing watershed- and reach-specific processes and limiting factors within the PAA.
- Develop permittable and fundable project opportunities based upon the project's ability to measurably influence limiting factors and processes and meet restoration goals and objectives within floodplain, riparian, and stream channel habitats.
- Determine and measure the quantifiable and repeatable metrics to establish baseline conditions, and that can be utilized to evaluate progress toward addressing processes and limiting factors following the implementation of restoration actions (e.g., projects, land-use alterations, regulatory changes, etc.) at various scales (individual sites, reaches, and the Desolation Creek watershed).

3 Metrics, Existing Data, and Methods

This section describes the Project metrics, the assessment methods, and the existing data and reports that were compiled to provide the background information to develop the geomorphic assessment.

3.1 PROJECT METRICS

The Project objectives include the identification and application of metrics that can be utilized to establish baseline conditions and that evaluate progress toward addressing processes and limiting factors following implementation of actions at various scales. Based on this objective, quantifiable and repeatable metrics were identified for Desolation Creek. The metrics were developed by building on the monitoring metrics included in the CTUIR Physical Habitat Monitoring Strategy (PHAMS) that were developed in association with the CTUIR Umatilla River Vision (Jones et al. 2008). Table 3.1-1 presents metrics for the Project, including evaluation methods, and directly links the metrics to CTUIR North Fork John Day Habitat Program objectives, limiting factors, River Vision Touchstones (Jones et al. 2008), the John Day River Basin Watershed Restoration Strategy (CTWSRO 2014), and PHAMS (Jones et al. 2015).

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Table 3.1-1. Summary of CTUIR Habitat Objectives, River Vision Touchstones, Limiting Factors, Metrics, and Evaluation Methods Identified for Desolation Creek

CTUIR NFJD Habitat Program Objectives	River Vision Touchstones[1/]	Primary Limiting Factors[2/]	Ecological Concerns[3/]	Metrics	Evaluation Methods
Protect and conserve habitat and ecological processes supporting native fish population viability	Aquatic Biota; Connectivity; Geomorphology; Hydrology	In-Channel Characteristics (Degraded Channel)	6.1 Channel Structure and Form: Bed and Channel Form	Primary Channel Length	Measure primary channel length from bathymetric survey or imagery
				Secondary Channel Lengths	Measure secondary channel lengths from bathymetric survey or imagery
				Bankfull and Wetted Width[4/]	Measure channel dimensions from field and bathymetric survey
				Bankfull Depth[3/]	Measure channel dimensions from field and bathymetric survey
				Bankfull Cross-Sectional Area	Calculate bankfull cross-sectional area from cross sections
				Width/Depth Ratio (W_{bkf}/D_{bkf})[4/]	Calculate width/depth ratio (bankfull width/bankfull depth)
				Gradient	Measure channel gradient from bathymetric survey
				Channel Incision	Calculate ratio of low bank height to bankfull height (Rosgen 1996)
				Entrenchment Ratio[4/]	Calculate entrenchment ratio (flood prone area width/bankfull width) (Rosgen 1996)
			6.2 Channel Structure and Form: Instream Structural Complexity	Channel Morphology	Classify channel morphology and process (Montgomery and Buffington 1997; Rosgen 1996)
				Braided-Channel Ratio[4/]	Ratio of the total channel length to the primary channel length (Friend and Sinha 1993)
				Pool Frequency or Spacing[4/]	Count of number of pools per channel length or spacing between pools (Montgomery et al. 1995; Beechie and Sibley 1997)
				Percent Pools and Pool Depths	Percent of primary channel length classified as pools (Beechie and Sibley 1997) and measure residual pool depths (Lisle 1987)
				Habitat Units	Measure pool, riffle, run and glide habitat and calculate as a percentage of primary channel length
				LWD Counts[4/]	Field survey counts and aerial photography determination of LWD
Improve passage to existing high quality habitats	Aquatic Biota; Hydrology; Connectivity	Passage / Entrainment (Impaired Fish Passage)	1.1 Habitat Quantity: Anthropogenic Barriers	Fish Passage Conditions	Review current and historical fish distribution
					Identify natural and artificial fish passage barrier locations
					Determine passage criteria (flow, timing, jump heights, etc.) based on state and federal criteria
Improve riparian and floodplain complexity; Improve floodplain connectivity	Riparian Vegetation; Aquatic Biota; Connectivity; Geomorphology; Hydrology	Riparian / Floodplain (Degraded Floodplain; Degraded Riparian)	4.1 Riparian Condition: Riparian Vegetation	Riparian Characteristics	Measure riparian characteristics using USGS LANDFIRE data (USGS 2013) and RapidEye satellite data and GIS techniques
					Measure of wetlands, springs, and upland meadows from field surveys and aerial imagery and GIS techniques
			4.2 Riparian Condition: LWD Recruitment	Floodplain Inundation	Measure percentage of floodplain area disconnected from the main channel from aerial photography, field data, and flood inundation modeling
			5.1 Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	River Complexity Index[4/]	Sinuosity times the number of nodes unitized by valley distance (Brown 2002)
				Sinuosity[3/]	Measure from bathymetric survey or imagery (channel length/valley length)
				Channel Migration Rate[4/]	Measure channel migration from multiple sequential aerial photographs (Latterell et al. 2006)
			5.2 Peripheral and Transitional Habitats: Floodplain Condition	Meander Belt Width	Measure meander belt width from multiple sequential aerial photographs (Williams 1986)
				Confinement Width	Measure width between confining features (natural or anthropogenic) from aerial photographs and/or bathymetric survey
				Off-Channel Habitat Length	Measure off-channel habitat from aerial photographs and/or bathymetric survey
Improve sediment routing and sorting	Aquatic Biota; Geomorphology	Sediment (Altered Sediment Routing)	7.2 Sediment Conditions: Increased Sediment Quantity	Sediment Size Distribution: Channel	Pebble counts of surface grain sizes (Bunte and Abt 2001)
				Sediment Size Distribution: Bars	Pebble counts and bulk samples of surface and subsurface grain sizes (Bunte and Abt 2001)
				Percent Fine Sediment in Bed	Measurement of fine sediment proportion in bed material from surface or bar sediment samples
				Erosion/Deposition	Measure channel erosion and deposition with repeat LIDAR/topographic surveys (Li et al. 2006)
					Construct a watershed sediment budget (Reid and Dunne 1996)
				Bank Stability	Examine the effects of riparian vegetation on stream channel stability and form (Eaton et al. 2004)
				Road Density	Measure of road density within the watershed (USFS 2011)
				Road Proximity to Streams	Measure of stream percent of stream length within 300 feet of roads (USFS 2011)
				Bar Height	Bar height above thalweg measured from topographic survey surface data (Wallick et al. 2010)
				Bar Area	Bar area measured from topographic survey data and high resolution aerial imagery (O'Connor et al. 2009)
				Grain Size Threshold of Motion	Calculates the threshold of motion of minimum sediment particle size based on Shields equation (Shields 1936)
				Sediment Transport Rate	Calculate bed material transport rates (Wallick et al. 2010)

Table 3.1-1. Summary of CTUIR Habitat Objectives, River Vision Touchstones, Limiting Factors, Metrics, and Evaluation Methods Identified for Desolation Creek (continued)

CTUIR NFJD Habitat Program Objectives	River Vision Touchstones1[/]	Primary Limiting Factors[2/]	NOAA Ecological Concerns[3/]	Metrics	Evaluation Methods
Improve or preserve water quality	Aquatic Biota; Geomorphology	Water Quality and Quantity (Degraded Water Quality; Altered Hydrology)	8.1 Water Quality: Temperature	Water Temperature	Calculate the 7-Day Average Daily Maximum (7DAYMax) water temperature (ODEQ 1995). Evaluate potential impacts to temperatures in out years associated with climate change, and restoration actions that may buffer against climate change
			9.2 Water Quantity: Decreased Water Quantity	Instream Flow Volume	Measure instream flows at stream gage. Evaluate the effect of water withdrawals on instream flows. Evaluate the potential future impacts associated with climate change, and restoration actions that may buffer against climate change.
			9.3 Water Quantity: Altered Flow Timing	Main Channel Low Flows or Off-channel Flows	Characterize low flows from stream gage data (Risley et al. 2008) and utilize hydraulic modeling to determine water elevations in off-channel areas using HEC RAS and GIS. Evaluate the potential future impacts associated with climate change, and restoration actions that may buffer against climate change.

[1/] River Visions Touchstones are based on the Umatilla River Vision (Jones et al. 2008).
[2/] Primary limiting factors are based on the 2008 Fish Accords (Three Treaty Tribes-Action Agencies 2008) and the John Day River Restoration Strategy (CTWSRO 2014) in parentheses.
[3/] NOAA (2012) Ecological Concerns are often referred to as standardized limiting factors.
[4/] Metrics included in the CTUIR PHAMS (Jones et al. 2015).

3.2 EXISTING DATA

Numerous studies, assessments, and planning efforts focused on water resources, fish, and habitat have been conducted on Desolation Creek. The most critical first step in project development was to search for, and review, relevant studies, assessments, and plans. This entailed internet and library searches, as well as obtaining studies, assessments, and plans from the co-managers, landowners, and stakeholders. The studies, assessments, and plans that were compiled covered a range of data types, topics, and time periods which included:

- Historical studies, assessments, and plans (describing fisheries, habitat, hydrology/ hydraulics, geomorphology, sediment, land use, botany, etc.);
- Fish habitat and presence surveys;
- Historic photographs and imagery; and
- Existing conditions spatial data and maps.

An index of all existing non-spatial data compiled for the Project has been created and is being provided separately on a digital versatile disc (DVD). A geodatabase has also been created in GIS for all the spatial data. This geodatabase will make it possible to integrate empirical data from field surveys with existing spatial data, and present results from technical analyses. The final geodatabase will be submitted separately on DVD. The outcome from this compilation will be a synthesis of studies, assessments, and plans, as well as the identification of data gaps.

3.3 ASSESSMENT METHODS

Utilizing the metrics shown in Table 3.1-1, existing data, and field surveys, the reach assessments evaluated land use, riparian vegetation, channel morphology, channel migration, floodplain inundation and connectivity, sediment mobility and transport, stream evaluation, and fish habitat for each of the delineated geomorphic reaches. The geomorphic assessment results provide further information for use in identifying and analyzing limiting factors and biologically significant reaches that facilitate the development of desired future conditions. Assessment methods are described in the following subsections.

3.3.1 Field Surveys

Two field survey efforts were conducted for this Project: a reconnaissance-level survey and a reach-scale survey in the high-priority areas. The reconnaissance survey occurred from July 18 to July 22, 2016, and included areas of the PAA and SAA with a focus on the PAA. The reconnaissance survey included the field verification of geomorphic reaches, geomorphic and habitat data collection (described below), and the field identification of potential projects incorporated into the development of Project designs described in Section 6. The geomorphic and habitat data were primarily collected in sample reaches within each geomorphic reach that included survey lengths of 20 times the bankfull width.

Additional reach-based field surveys were conducted in October 2016 to collect data sufficient for further developing restoration designs in Reach 6, as described in Section 6. The reach-based field survey included topographic survey data collection (described in Section 3.3.2) and additional geomorphic and habitat data collection (described in Sections 3.3.4 to 3.3.7) to support the development of Project designs.

3.3.2 Project Topography

Development of the Project topography included utilizing an existing topo-bathymetric light detection and ranging (LiDAR) survey of the PAA provided by the CTWSRO. The topo-bathymetric LiDAR survey was acquired by Quantum Spatial Inc. (QSI) using a combination of traditional LiDAR and topo-bathymetric (or "green") LiDAR merged into a single topographical surface. While the traditional LiDAR laser pulses do not penetrate water surfaces, the topo-bathymetric sensor uses a narrow green beam laser that penetrates the water surface. The traditional LiDAR data were collected on November 14, 2015, and the topo-bathymetric LiDAR data collection was conducted on July 20, 2016. The technical data report describing topo-bathymetric LiDAR acquisition, processing, and accuracy estimates may be found in QSI (2016). The resulting surface and the wetted extent at the time of survey are shown in Figures A-1a through A-1k of Appendix A. The surface has been used for detailed visualization of channel and floodplain features as well as for reach assessment analyses.

In October 2016, land-based topographic surveys using real-time kinematic (RTK) global positioning system (GPS) surveys were conducted in Reach 6 to cross-check the accuracy of the LiDAR, provide supplemental topographic data, identify specific features (e.g., bankfull), and provide a surface for developing the Desolation Creek Reach 6 (RM 9.5 – 11.8) Habitat Restoration design submittals. The final topographic surface was used for the reach-based geomorphic analyses described below and developing Project designs, as described in Section 6.

3.3.3 Geomorphic Reach Delineation

Project reaches in the PAA were delineated based on desktop- and field-identified habitat and geomorphic characteristics, channel morphology classification, riverine processes, and governing conditions. The purpose of the delineation was to identify differences in geomorphology in Desolation Creek. Changes in the following characteristics were used to identify the geomorphic reach breaks:

- Habitat types (including the presence of side channels and off-channel areas),
- Geologic controls on channel confinement,
- Existing channel pattern and form,
- Channel morphology,
- Channel substrate, and
- Significant tributary junctions.

3.3.4 Geomorphic Characteristics

Geomorphic characteristics were used to establish baseline conditions using a variety of methods, including examining aerial imagery, field sampling, and hydraulic modeling and calculating metrics at a series of 86 cross sections throughout the PAA. The cross sections were derived from the topo-bathymetric survey data described in Section 3.3.2 and are a subset of the cross sections used for planning-level hydraulic modeling. Included in Table 3.1-1 are geomorphic assessment metrics for the Project, including evaluation methods, and directly links the metrics to CTUIR Habitat Program objectives, limiting factors, River Vision Touchstones (Jones et al. 2008), and PHAMS (Jones et al. 2015).

Channel Morphology

The channel morphology of Desolation Creek was described using the classification systems of Montgomery and Buffington (1997) and Rosgen (1996) and other geomorphic characteristics. These systems use river form and process to described channel morphology through a set of standard metrics such as channel dimensions (bankfull width and depth, gradient, etc.), sediment characteristics, channel plan form (e.g., single-thread, braided, anastomosing etc.) bed forms, channel meander process (stable, wandering meandering etc.), and the presence of floodplain features (e.g., side channels, vegetated islands, cutoffs, and oxbows).

Channel Migration

The evaluation of channel migration considered available data including aerial images, bathymetric survey data, and other existing datasets to identify changes in the location and pattern of Desolation Creek in the unconfined reaches of the PAA over time. A series of historic aerial images for photo years 1946, 1966, 1967, and 1980 were obtained from the Oregon State University Libraries. National Agriculture Imagery Program (NAIP) imagery was obtained for photo years 1995, 2005, 2011, and 2014. High-resolution aerial images were collected in July 2016 during the topo-bathymetric LiDAR data collection.

The channel migration evaluation assessed natural and anthropogenic channel boundary controls, pinch points, and land use constraints. Specific metrics quantified were sinuosity, percent of floodplain disconnected, channel migration rate, and average belt width.

Substrate, Sediment Supply and Transport Characteristics

Sediment size distributions, characteristic sediment sizes, and percent composition by sediment type (e.g., sand, gravel, and cobble) were calculated from surface (pebble count) and subsurface (bulk) sediment samples.

Geomorphic change detection of the digital elevation model (DEM) was used to identify areas of erosion and deposition by creating DEMs of difference following the methods of Wheaton et al. (2010). Recent LiDAR data were compared with previous LiDAR data collected in 2006 to identify areas where substantial changes have occurred.

Specific sediment transport characteristics were calculated including shear stress, unit stream power, and threshold grain size. Threshold of motion sediment size estimates were calculated using the

Shields threshold of motion equation (Shields 1936). The equation is based on the Shields number, which is a non-dimensional number that relates the fluid force acting on sediment to the weight of the sediment. The results were calculated based on outputs from the hydraulic model for channel hydraulics, channel gradient, and sediment size estimated from surface sediment samples.

3.3.5 Floodplain Inundation and Connectivity

A planning-level hydraulic model was developed to determine flood inundation for a range of flows. Estimates of peak flood discharges in the PAA were completed for the 2-, 5-, 10-, 25-, 50-, and 100-year return period using regional regression equations following the methods described in Cooper (2006). Peak flow rates were adjusted for tributary inputs in order to develop flow estimates for the entire length of the PAA. The hydraulic model was developed with the Hydrologic Engineering Centers River Analysis System (HEC-RAS), which is a cross section–based one-dimensional model developed by the USACE (USACE 2016) for computing velocity, flow depth, shears stress, and other hydraulic characteristics in riverine systems. Hydraulic model outputs were exported to HEC-GeoRAS, which is a custom interface between HEC-RAS and geographic information system (GIS), for mapping HEC-RAS water surfaces, flow depths, and velocities (USACE 2009). The flood inundation tool in HEC-GeoRAS interpolates the water surface elevations from HEC-RAS cross sections to two-dimensional geospatial data.

3.3.6 Vegetation Classification

A vegetation classification analysis was conducted to map and describe vegetation communities within the Desolation Creek watershed. The analysis included remote sensing 5-band (red, green, blue, near infra-red and infra-red) imagery and field surveys within sample plots to ground truth the predominant vegetation association. A detailed description of the vegetation classification methods and results, along with comparison with other existing data sources is included in Appendix B.

3.3.7 Large Woody Debris

LWD was inventoried during field assessments in the PAA. The number of pieces and locations of large wood was identified in the field and used to quantify and develop a LWD budget from high-resolution aerial imagery collected in 2016. The analysis also describes instream wood quantities as related to historical conditions and compares current instream wood quantities to federal targets for streams east of the Cascades (NMFS 1996; USFWS 1998), and to other quantities observed in the literature (Fox and Bolton 2007).

3.3.8 Biologically Significant Reaches

For the purpose of this Project, biologically significant reaches (BSRs) were defined as stream reaches with similar focal fish species use and limiting factor characteristics. These reaches represent the "fish's view of the river." For example, sections of a stream that are used for spawning, incubation, and rearing require specific functional physical and biological parameters (e.g., flow, temperature, substrate size and type fall within specific ranges). If these conditions are not present, they will limit fish species presence or survival, such as a stream reach that is only used for migration due to limited flow or high temperatures.

BSR delineations entailed evaluating existing data on focal fish species presence, timing and utilization by life stage, and limiting factors, but at a finer geographic scale than typically found in planning documents, along with new field survey data and local scientific knowledge of preferred biological and physical habitat for focal fish species within the Desolation Creek watershed.

4 Watershed-Scale Assessment

This section provides an overview of the Desolation Creek watershed based on existing data and information gathered, and observations made during field surveys. The watershed-scale assessment includes a watershed physical description, a description of fish use, a summary of land-use history and associate impacts, a description of limiting factors and restoration potential, and an assessment of the potential for future impacts related to climate change. The reach-scale assessment results focused on the PAA can be found in Section 5.

4.1 WATERSHED PHYSICAL DESCRIPTION

Numerous publications, studies, assessments, and plans describe the physical characteristics of the Desolation Creek watershed. In particular, the Desolation Ecosystem Analysis (USFS 1999), the Farley Vegetation Management Project Draft Environmental Impact Statement (USFS 2008), the Draft Desolation Creek Watershed Action Plan (USFS 2009), and the Desolation Creek Land Management Plan (EFM 2015) provide extensive information about watershed physical conditions. This section does not attempt to provide a comprehensive description of the physical conditions in the watershed, but rather a summary of information applicable to this Project.

4.1.1 Setting and Climate

The Desolation Creek watershed (10-digit HUC 1707020204) drains approximately 109 square miles of Grant County in eastern Oregon. The Desolation Creek watershed includes the Headwaters Desolation Creek subwatershed (12-digit HUC 170702020401), the Upper Desolation Creek subwatershed (12-digit HUC 170702020402), the Middle Desolation Creek subwatershed (12-digit HUC 170702020403), and the Lower Desolation Creek subwatershed (12-digit HUC 170702020404).

The headwaters of Desolation Creek originate in the Greenhorn Mountains within the southern Blue Mountains, and the mouth is approximately 1 mile northeast of the town of Dale, Oregon. The topography of the watershed is predominantly mountainous, averaging 5,253 feet above sea level with a maximum elevation of 7,765 feet at Sunrise Butte, dropping to 2,810 feet at the confluence of Desolation Creek with the North Fork John Day River (USFS 1999, 2009). As Desolation Creek flows northwest out of the Blue Mountains, the mountainous topography transitions to the John Day/Clarno Highlands with rolling plateaus incised by steep drainages (NRCS 2005; EFM 2015).

Federal land management within the watershed is primarily by the UNF. State agencies with jurisdiction in the watershed include the ODFW, Oregon Department of Forestry, ODEQ, Oregon Water Resources Department, Oregon Division of State Lands, and the Oregon Department of Agriculture.

Private land ownership constitutes approximately 18 percent of the watershed, and is concentrated at the downstream lower elevations (USFS 1999; Zakrajsek 2011). As discussed previously in Section 2.2.2, Desolation Creek LLC purchased 13,440 acres of the lower Desolation Creek watershed in

2014, comprising most of the private ownership within the watershed area. The property is managed by EFM, a for-profit subsidiary of Ecotrust formed to manage forestlands for financial, ecological, and social returns (EFM 2015).

The Desolation Creek watershed lies within a continental climate characterized by seasonal extremes of temperature and precipitation, with hot, dry summers and cold winters (USFS 1999; NPCC 2005). Temperatures and precipitation in the watershed are highly influenced by altitude, with the climate ranging from sub-humid in the upper areas to semi-arid in the lower (NPCC 2005; EFM 2015). Average temperatures for the watershed range from 14 degrees Fahrenheit (°F) in the winter to 82°F in the summer, and with mean annual temperatures varying from 38°F in the higher altitudes to 58°F in the lower part of the watershed (NPCC 2005; EFM 2015). Rainfall for the watershed ranges from less than 20 inches a year near the confluence of Desolation Creek with the North Fork John Day River, to more than 40 inches per year in the upper areas of the watershed, with most precipitation falling as winter snow (USFS 1999). The NPCC (2005) John Day Subbasin Revised Draft Plan includes figures illustrating precipitation patterns in the North Fork John Day watershed, including the Desolation Creek watershed.

4.1.2 Geology and Soils

The topography of the Desolation Creek watershed is the result of geologic processes, including uplift, volcanic massive flows, and glacial action, that have produced the mountainous topography and plateau loess deposits characteristic of the area (NPCC 2005). The geology of the watershed is dominated by volcanic materials (e.g., metabasalts/andesites) as well as the tuffs and breccias that are derived from those materials. Other rock types that occur in the watershed in smaller quantities include granodiorite and bedded sedimentary rocks including argillite, and sandstone (USFS 1999). Metamorphosed volcanics and sedimentary rock types are common throughout the watershed and were observed during the field survey in the PAA, particularly near RM 4.6.

Within the PAA, there are extensive, prehistoric landslide and debris flow deposits, much of which are from the erosion of volcanic flow materials (USFS 1999). These deposits form much of the rolling topography of the gentle to moderate northeast-facing hillslopes in the PAA (see Figure 4.1-1). Over time, Desolation Creek has eroded through the prehistoric landslide deposits to varying extents resulting in the confined channel conditions throughout much of the PAA.

Glacial till deposits from alpine glaciation are also common in the central and upper portions of the watershed. Mazama volcanic ash has also been overlain, reworked and redeposited in many areas. The glacial till, Mazama ash, and other tuffs and breccias were observed in several eroding cutbanks along Desolation Creek during the reconnaissance field survey. The presence of large deposits of unconsolidated materials (e.g., glacial till, alluvium, colluvium) and Mazama ash result in a high water-holding capacity and the large wet meadow complexes that are a distinguishing characteristic of Desolation Creek (USFS 1999) and the many coldwater springs (see Section 4.1.5).

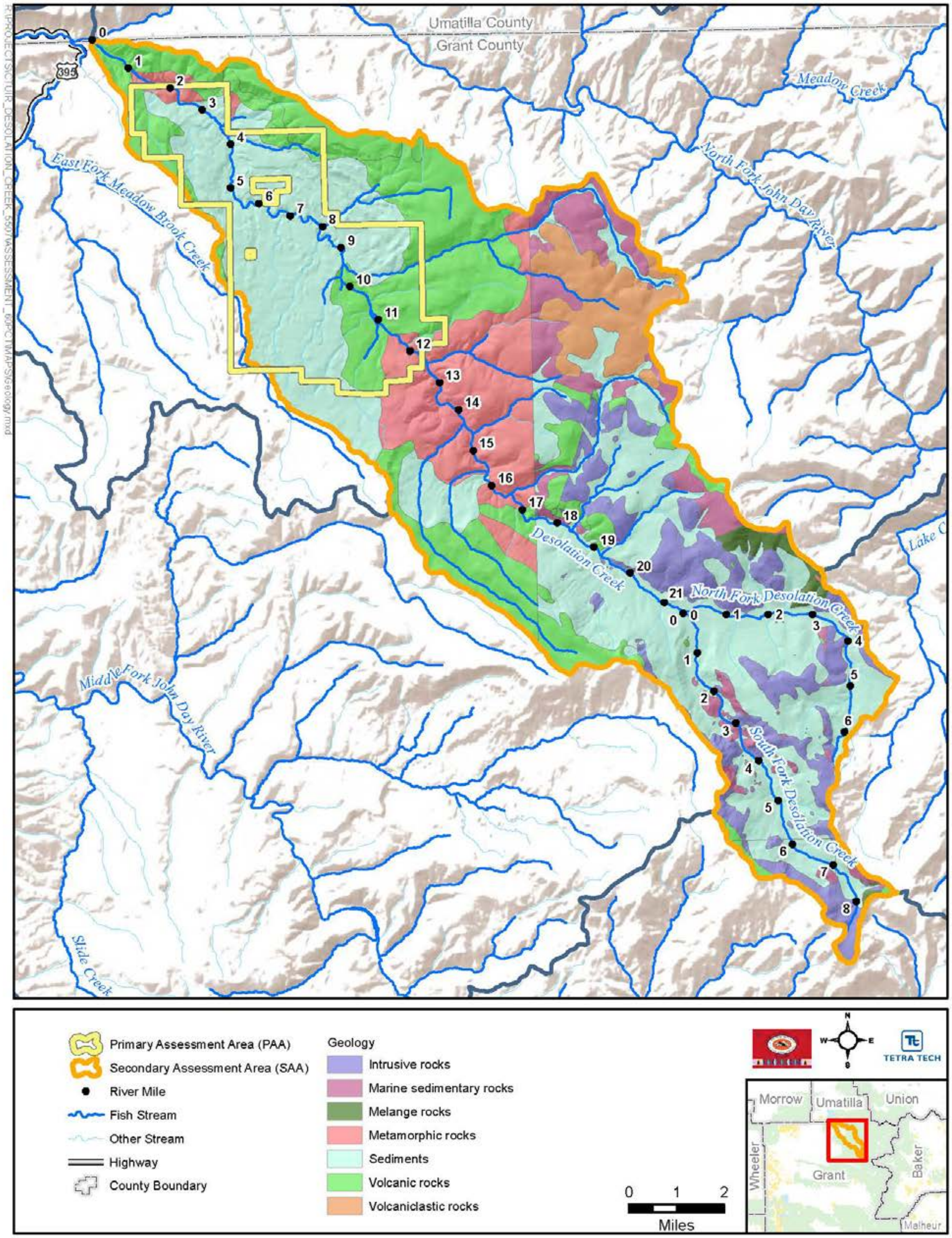


Figure 4.1-1. Surficial Geology of the Desolation Creek Watershed

As described in the Desolation Creek Management Plan (EFM 2015), soils within the PAA are ashy loams to ashy silty loams underlain by basalt. Soils are moderately deep with clays and cobbles increasing with depth. With the exception of hydric soils found on terraces and meadows, soils are typically well drained. The high levels of ash increase soil moisture retention but also increases erosion potential (EFM 2015). Soils generally support cold, upland plant associations except for the lowest elevations, which support warm, dry plant associations. Deep soils at upper elevations generally maintain adequate soil moisture throughout the growing season while lower elevations are dry enough to induce late summer stress (USFS 1999). A detailed description of soils for the PAA can be found in the Desolation Creek Management Plan (EFM 2015), with additional soils information for the remainder of the watershed in the Desolation Ecosystem Analysis (USFS 1999).

Land use practices such as livestock grazing, timber harvest, roads, and recreation, described in Section 4.3, have the potential to increase soil erosion rates. Wildfires, particularly in combination with high-intensity storm events on hydrophobic (wildfire-induced water repellency) soils, may also contribute to increased erosion and sedimentation rates (Wondzell and King 2003) as well as landslides and debris flows (Benda et al. 2003).

4.1.3 Hydrology

The USFS estimates there are approximately 252 miles of streams in the Desolation Creek watershed (USFS 2008). Compared with the rest of the UNF, the Desolation Creek watershed has 1.5 times greater the percentage of perennial streams, and approximately half the percentage of intermittent streams. Historically, the flows in Desolation Creek watershed are dominated by storm events in the winter, snowmelt in the spring and early summer, and groundwater inflow during the summer and dry cold periods in the winter (USFS 1999; NPCC 2005). Snowmelt from winter accumulations contributes the majority of the annual runoff for much of the watershed, with water levels dropping substantially for many streams during late summer and early fall months (USFS 1999, 2009). Low-flow periods generally occur between August and October, with average annual high flows peaking between April and June.

The U.S. Geological Survey (USGS) maintains records of a gage on Desolation Creek (USGS 14041000), near the mouth, operating from 1949 to 1958, and a gage on Bruin Creek (USGS 14040900) operating from 1969 to 1981. The USFS operated another gage on Desolation Creek at the NF-10 Road Bridge, near RM 10.0, beginning in the 1980s. The exact period of record for this gage is uncertain and the data have not been analyzed (USFS 1999).

Figure 4.1-2 shows the seasonal flow pattern at the Desolation Creek gage (USGS 14041000) from 1949 to 1958, which reflects the general pattern described above of winter and spring rains and snowmelt. Minimum, mean, and maximum monthly flows show the range of streamflow patterns over the period of record. While the long-term average flow pattern indicates peak flows typically occur between April and June, in some years smaller pulses of flow may occur in the winter or fall.

The current runoff patterns have shifted compared to historic runoff across the entire John Day River Subbasin (6-digit HUC 170702), with higher peak flows and diminished late season flows. This pattern is likely due to reduced soil infiltration rates; reduced groundwater storage capacity, including both wet riparian and upland meadows; and reduced storage in the form of beaver ponds (NPCC 2005).

Characteristic Flows

Analysis of the streamflow data was completed to determine characteristic flows for Desolation Creek including average annual flow, low-flow statistics, flood flows, and monthly flows (monthly mean, minimum, and maximum). Table 4.1-1 contains the 7-day average 10-year low flow, base flow, average annual flow, and one-day average 2-year flood flow for Desolation Creek. Monthly flows (monthly mean, minimum, and maximum) for Desolation Creek from 1949 to 1958 are shown in Figure 4.1-2 overlain by typical spawning and rearing periods for Chinook salmon, steelhead, and bull trout. For more information regarding focal fish species see Section 4.2.

Table 4.1-1. Characteristic Discharges for the Mouth of Desolation Creek

Characteristic Flow	Discharge (cfs)
Measured Discharge near RM 0.1 (July 22, 2016)	8.9
7-Day Average 10–year Low Flow[1/]	8.3
Base Flow (August – October)[2/]	11.0
Average Flow (annual average)	101
2-Year Peak Flow (daily average)[3/]	874

1/ Low flow statistics calculated following the methods of Risley et al. (2008)
2/ Base flow calculated using the Web-based Hydrograph Analysis Tool (WHAT): https://engineering.purdue.edu/mapserve/WHAT/
3/ Flows estimated using regional regression equations following the methods of Cooper (2006)
cfs = cubic feet per second

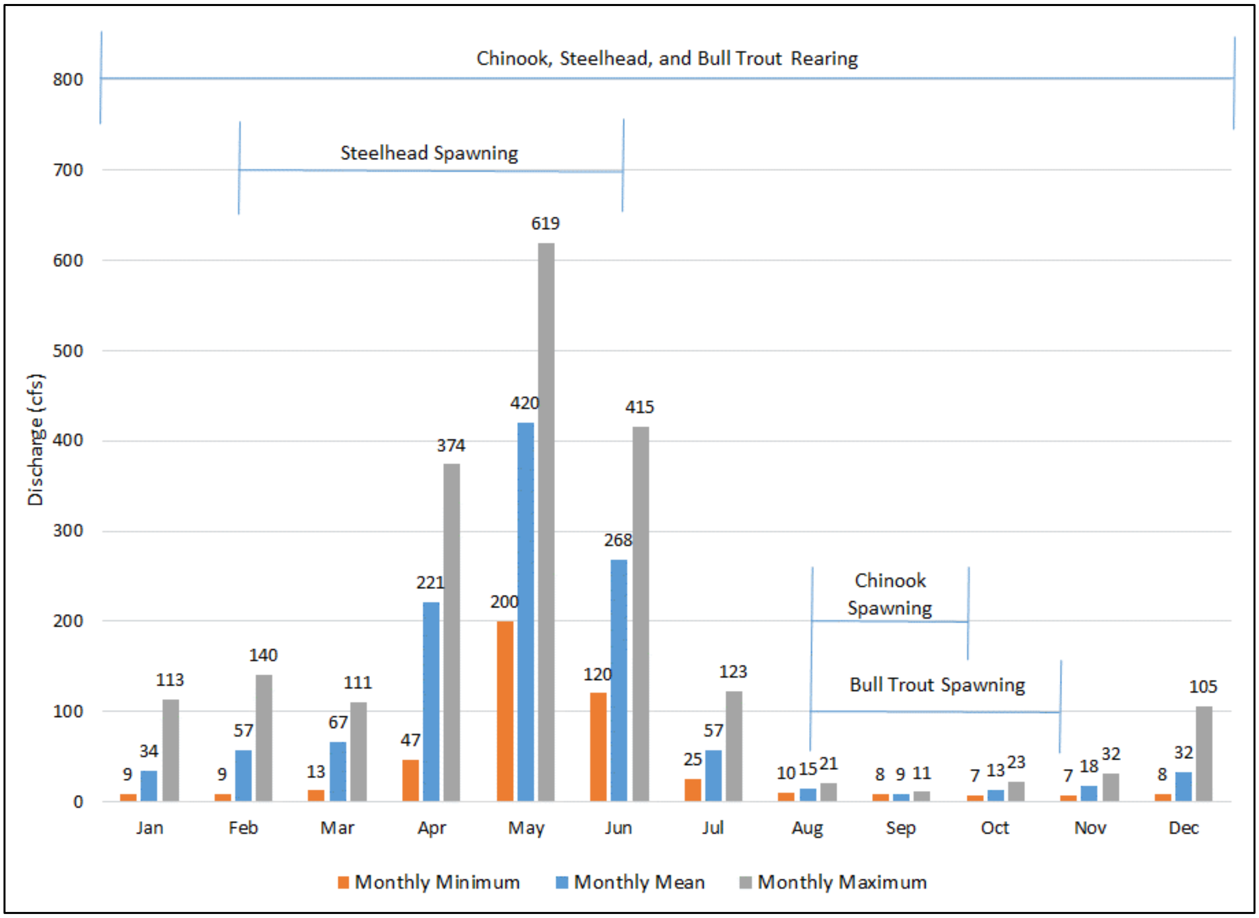


Figure 4.1-2. Monthly Minimum, Mean, and Maximum Flows for Desolation Creek Overlain by Typical Spawning and Rearing Periods for Chinook, Steelhead, and Bull Trout

Peak Flows

USGS stream gages in proximity to the PAA were evaluated to determine if weighting by a ratio of drainage areas would be applicable for determining peak flows. Nearby USGS gage stations included a gage on Desolation Creek (USGS 14041000), one on the North Fork John Day River near Dale (USGS 14041500), Bruin Creek (USGS 14040900), and Granite Creek (USGS 14043900). The North Fork John Day River gage near Dale, Bruin Creek, and Granite Creek were all outside of the range of applicability (between 50 percent and 150 percent of the drainage area for the gage) described in Cooper (2006). The Desolation Creek gage, while providing useful information for cross-checking results, was only in operation for a relatively short duration (13 peak flow events) in the 1950s and early 1960s and therefore was not used for developing peak flow estimates. Due to these factors associated with these gages, peak flood discharges were calculated for Desolation Creek and major tributaries using regional regression equations following the methods described in Cooper (2006). Table 4.1-2 contains the 2-, 5-, 10-, 25-, 50-, and 100-year return period estimated peak flood discharges throughout the watershed. Tributaries within the PAA include Moonshine Creek, Peep Creek, Kelsay Creek, Starveout Creek, and Park Creek, as shown in Figure 4.1-3.

Table 4.1-2. Peak Discharges for the 2-Year, 5-Year, 10-Year, 25-Year, 50-Year, and 100-Year Flood Events at Key Points in the Watershed [1/]

Location	Recurrence Interval (years)					
	2-year (cfs)	5-year (cfs)	10-year (cfs)	25-year (cfs)	50-year (cfs)	100-year (cfs)
Desolation Creek (RM 0.0)	874	1,210	1,440	1,740	1,970	2,220
Moonshine Creek	12	20	26	35	42	48
Peep Creek	43	67	85	109	128	148
Kelsay Creek	126	185	227	284	328	375
Starveout Creek	32	50	63	81	96	111
Park Creek	22	34	43	55	64	74
Bruin Creek	54	80	99	123	143	163
Junkens Creek	68	97	117	143	164	185
Welch Creek	38	56	69	86	100	113
Beeman Creek	40	58	70	86	99	112
Battle Creek	87	124	149	183	210	238
Sponge Creek	56	81	98	120	138	156
Howard Creek	63	88	105	128	145	163
North Fork Desolation Creek	228	300	347	407	453	499
South Fork Desolation Creek	195	257	296	344	380	416

1/ Flows estimated using regional regression equations (Cooper 2006).
cfs = cubic feet per second

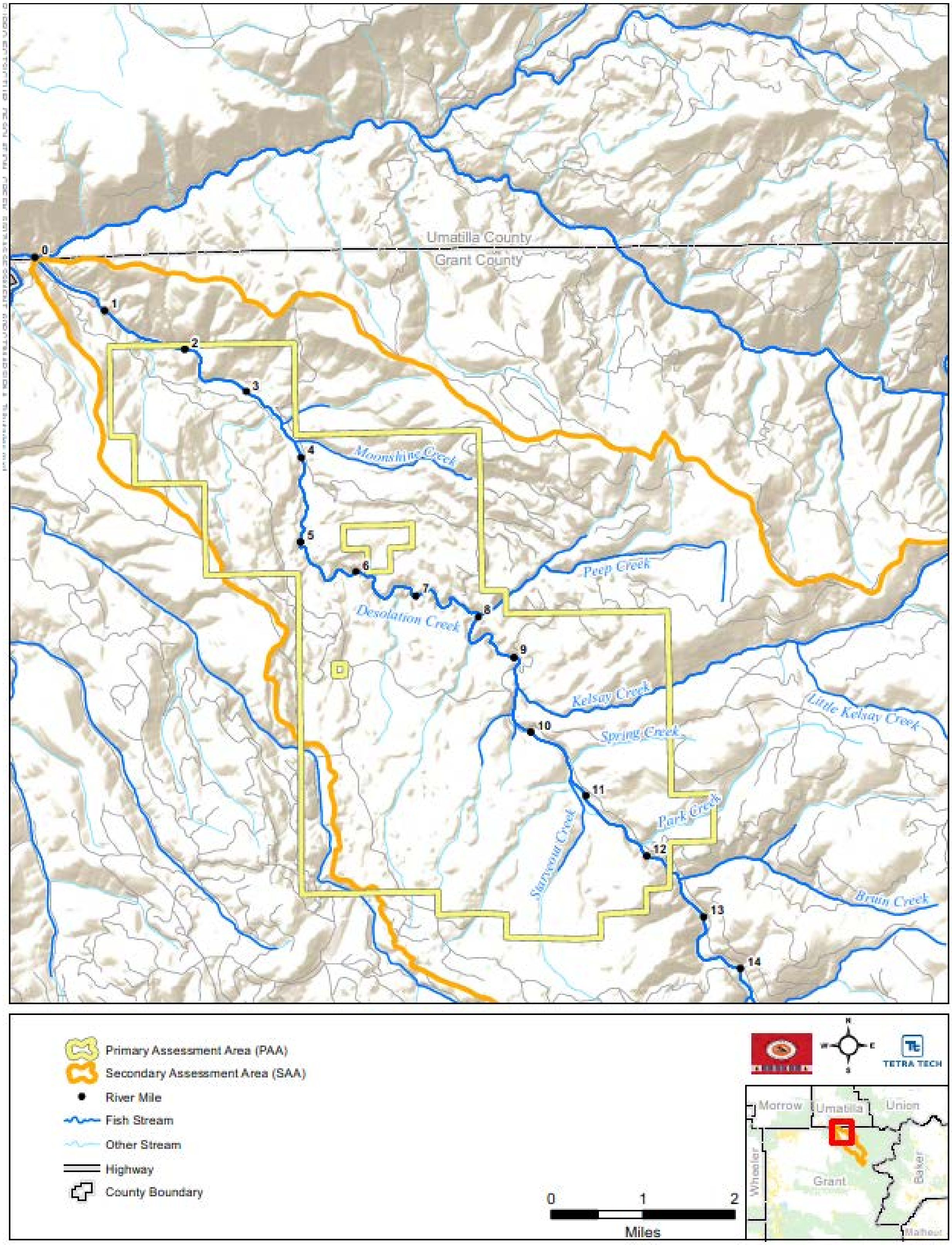


Figure 4.1-3. Desolation Creek Tributaries in the PAA

4.1.4 Vegetation

Land management practices (including grazing, road construction, timber harvesting, and fire suppression) have led to significant changes to vegetation communities in the Desolation Creek watershed. Grazing and timber harvest represent major land use practices both historically and currently, with extensive watershed impacts including changes to vegetation composition, density and age classes. Decades of fire suppression along with extensive grazing and the extirpation of beavers have caused extensive losses of riparian and upland hardwoods, including the current near-absence of alder (*Alnus* spp.) and willow (*Salix* spp.) (EFM 2015).

Riparian vegetation plays an important role in overall stream health and productivity (FEMAT 1993; Spence et al. 1996; Naiman et al. 1998; Poff et al. 2011). Riparian tree cover provides shade, which reduces stream temperatures (FEMAT 1993). Additionally, riparian vegetation supplies organic input to streams, including insects and leaf matter, which provide direct and indirect food sources for fish (Murphy and Meehan 1991). Where trees are present, riparian areas are the main source of LWD to streams (Bisson et al. 1987). LWD helps create important stream habitat, such as pools, and moderates sediment storage and movement within a stream system. Riparian areas also help filter runoff, thereby reducing the delivery of fine sediments and potentially undesirable toxins or oversupply of nutrients to stream systems. Lastly, root systems of riparian vegetation stabilize stream banks, reducing erosion potential and increasing channel complexity (FEMAT 1993).

Anthropogenic impacts in the Desolation Creek watershed have also led to the introduction and spread of numerous nonnative invasive plants including houndstongue (*Cynoglossum officinale*), St. John's wort (*Hypericum perforatum*), bull thistle (*Cirsium vulgare*), Canada thistle (*Cirsium arvense*), spotted knapweed (*Centaurea stoebe* subsp. *Micranthos*), diffuse knapweed (*Centaurea diffusa*), and sulfur cinquefoil (*Potentilla recta*) (USFS 2008). Other invasive non-native plant species that have made their home in the riparian zones of Desolation Creek include reed canarygrass (*Phalaris arundinacea*), mullein (*Verbascum thapsus*), and oxeye daisy (*Leucanthemum vulgare*).

The private lands in the watershed, the majority of which are owned by Desolation Creek LLC, are managed for timber and grazing (EFM 2015). The 2015 Desolation Creek Land Management Plan for that property describes management challenges as a result of past timber and grazing practices including overstocked forest stands, overused wet meadows, degraded riparian and upland habitats, and outlines new management practices to address these concerns while continuing grazing and timber harvest (EFM 2015). Timber harvest and grazing have caused the forest composition on that property to shift from more than 80 percent Old Forest Single and Multi-Stratum forest in the 1940s, to the present where mature stands with large trees have been replaced by predominantly young stands with densities much higher than reference conditions (EFM 2015). This same forest structural change, with mature stands replaced by young and dense stands, characterizes the majority of the Desolation Creek watershed (Powell 1998; USFS 2008) and has been reported across the Blue Mountains (Langston 1995). Analyses of historical General Land Office (GLO) survey data from the 1880s indicates that ponderosa pine (*Pinus ponderosa*) woodlands were more prevalent compared to the current extensive lodgepole pine (*Pinus contorta*) and subalpine fir (*Abies lasiocarpa*) forests throughout the UNF (Powell 2008).

A remote sensing vegetation classification of the Desolation Creek watershed was completed for this Project. The results indicated that vegetation in the watershed was dominated by conifers (82.1 percent), followed by riparian vegetation (8.1 percent), grasslands and wet meadows (7.4 percent), Cliff, scree, rock and barren (2.2 percent), shrubland (0.1 percent), and open water (0.1 percent). The technical methods and completed results for the vegetation classification analysis are described in Appendix B.

4.1.5 Meadows

The riparian wet meadow and upland meadow complexes are a distinguishing characteristics of the Desolation Creek watershed (USFS 1999), as are the many cold-water springs. Wet meadows occur in open wet depressions, basins, and flats with low-velocity surface and subsurface flows. They are typically found on flat areas or gentle slopes, but may also occur on sub-irrigated sites with slopes up to 10 percent. Sites are usually seasonally wet (often tightly associated with snowmelt) and often dry out by late summer. They may have surface water for part of the year, but depths rarely exceed a few centimeters (Comer et al. 2015).

Extensive large and small meadows and associated springs and seeps are found in chains along the upper half of the Desolation Creek mainstem and the North and South Forks, and are described as unique morphologic and biologic settings (USFS 1999). Additionally, small meadows and seeps are found along most of the perennial creeks in the watershed, and throughout the mid- and upper-elevation forests (USFS 1999). For example, Desolation Creek LLC has identified 40 such springs on their property in the PAA (some of which are shown in Figures A-1a through A-1k in Appendix A), and 174 acres of wet meadows (EFM 2015). These areas are particularly important due to their biodiversity and productivity.

Properly functioning wet meadows provide considerable ecosystem benefits. Despite their relatively small size, these meadow areas are of disproportionate importance due to the water storage and water filtration functions they provide. Functioning meadows and meadow stream channels increase groundwater levels and subsurface storage, increase floodplain inundation, attenuate peak floods, and augment late summer low flows (Hammersmark et al. 2008; USFS 2010a). During times of high precipitation, wet meadows become saturated and store water, and in the process filter excess nutrients. In dry months, the wet meadows slowly release the stored water, helping to buffer low flows and high temperatures in the summer and providing cold water refugia for fish.

Meadows also provide critical habitat for terrestrial and avian wildlife species, and provide critical islands of green forage during the hot and dry summer months (USFS 1999). Wet meadows have a unique vegetation composition directly related to the shallow groundwater table and intermittent water storage (Hammersmark et al. 2009).

Wet meadows in the Desolation Creek watershed have been impacted since the beginning of European settlement, first by beaver extirpation and later by grazing and timber harvest. The highly productive soil and water storage provided by wet meadows has made them attractive locations for livestock grazing, and much of the historical and current grazing impacts have been concentrated in wet meadows, leading to overgrazing along with the replacement of native grasses and sedges with introduced species. Fire management and timber harvest have also impacted wet meadows through encroachment of conifers, altered hydrology, and road construction (USFS 1999; EFM 2015). The Desolation Meadow area on the North Fork of Desolation Creek (along RMs 1.0 to 3.0), the largest and most studied meadow complex in the Desolation Creek watershed, has been impacted by road construction, grazing, timber harvest, diversion ditches, and beaver removal, which together have led to a drying of the meadow and significant conifer encroachment (Powers et al. 2003).

4.2 FISH USE

Numerous publications and data sources were used to develop and refine the description of fish use in the Desolation Creek watershed in this section. These data sources include the John Day River Basin Watershed Restoration Strategy (CTWSRO 2014); John Day Subbasin Plan (NPCC 2005); the Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River Steelhead Distinct Population Segment (Carmichael and Taylor 2010); the Desolation Ecosystem Analysis (USFS 1999); and CTUIR annual reports. In addition, other sources from ODFW (e.g., index redd counts, smolt trap counts near the confluence with the North Fork, etc.), the USFS, and others were reviewed.

4.2.1 Fish Presence, Passage, and Utilization

The Desolation Creek watershed has more than twice the percentage of anadromous fish streams, by area, when compared with the rest of the UNF (USFS 2008). Desolation Creek contains six salmonid species: spring Chinook salmon, summer steelhead/rainbow/redband trout (*O. mykiss*), bull trout, Westslope cutthroat trout (*O. clarki lewisi*), brook trout (*Salvelinus fontinalis*), and mountain whitefish (*Prosopium williamsoni*) (USFS 1999). Middle Columbia River steelhead and Columbia River bull trout are ESA-listed as threatened. Desolation Creek has been included as part of the critical habitat for Middle Columbia River summer steelhead (NMFS 2009), and for the overwintering, spawning, and rearing habitat used by bull trout (USFWS 2010). For other anadromous species, spawning and rearing habitat is likely to be similarly reduced or limited when compared to our knowledge of historic carrying capacity.

While Middle Columbia River spring Chinook salmon are not listed under the ESA, they are of key conservation interest and considered a focal fish species for this Project. Westslope cutthroat trout in the watershed are a naturalized population from individuals introduced from Deardorff Creek in 1960 (NPCC 2005). Brook trout are an introduced, naturally spawning population. Brook trout can hybridize with bull trout, and the resulting hybrid offspring are often sterile. This may lead to diminished reproductive effort and likely competition with the remaining bull trout for food and space and lead to declines in abundance. Mountain whitefish are a native species; adults typically inhabit deep fast water and deeper pools, while juveniles tend to be present in shallower waters.

Anadromous fish species in Desolation Creek spend part of their life cycle migrating to and from the Pacific Ocean. There are no full passage barriers on the mainstem John Day River, thus providing migrating fish uninhibited access along the mainstem and Columbia River for fish destined for Desolation Creek. Within the Desolation Creek watershed, however, there are multiple natural and artificial barriers where fish movement is blocked or impeded. The mainstem of Desolation Creek is relatively free of major passage impediments but many partial barriers exist, including log and rock weirs installed in the 1980s and early 1990s; these were installed for habitat reasons but some currently inhibit upstream migration of juvenile salmonids. Natural partial barriers also exist, such as steep cascades in highly confined areas such as the natural waterfalls on the South Fork Desolation Creek that block migration and isolate resident fish populations above the falls. Tributaries provide important rearing habitat for Chinook, steelhead, bull trout, and cutthroat trout (USFS 2012a-d). However, dozens of culverts near the mouths or other portions of tributaries are known passage barriers that restrict both adults and juveniles (USFS 1999 and 2009); some of these culverts have been replaced in recent years, but others, such as those on Beeman, Junkens, Kelsay, and other creeks remain. Locations of current barriers identified from past documents or discovered during field reconnaissance surveys are included in the Project geodatabase. In addition, seasonally high water temperatures and low water levels can temporarily isolate populations during parts of the year (USFWS 2002).

Chinook salmon, steelhead, and bull trout utilize various portions of the Desolation Creek watershed for spawning and rearing. The general distribution of Chinook salmon, steelhead, and bull trout spawning and rearing throughout the watershed is shown in Figure 4.2-1, which shows the lumped number of spawning and rearing life stages for these three species in each reach (e.g., if a reach contains both Chinook salmon and steelhead and both life stages, then it falls into category 4). The figure shows that spawning and rearing of all three species occur along the mainstem of Desolation Creek and lower portion of the South Fork, while the North Fork and other fish-bearing tributaries have fewer species and life stages. This figure provides a good overview of fish use in the watershed based on the most recent updates in the CTWSRO's GIS database (updated May 2016), but this database and others (e.g., StreamNet) typically do not incorporate all local knowledge. For example, the database does not show bull trout use in Junkens Creek.

Table 4.2-1 provides the timing for different life-stages of Chinook salmon, steelhead, and bull trout in the Desolation Creek watershed as a whole. More specific fish distribution and periodicity charts for each BSR were subsequently developed for use in prioritizing project areas. Chinook salmon, steelhead, bull trout, Pacific lamprey, and freshwater mussel presence and their distribution and use are more fully described in the subsections below.

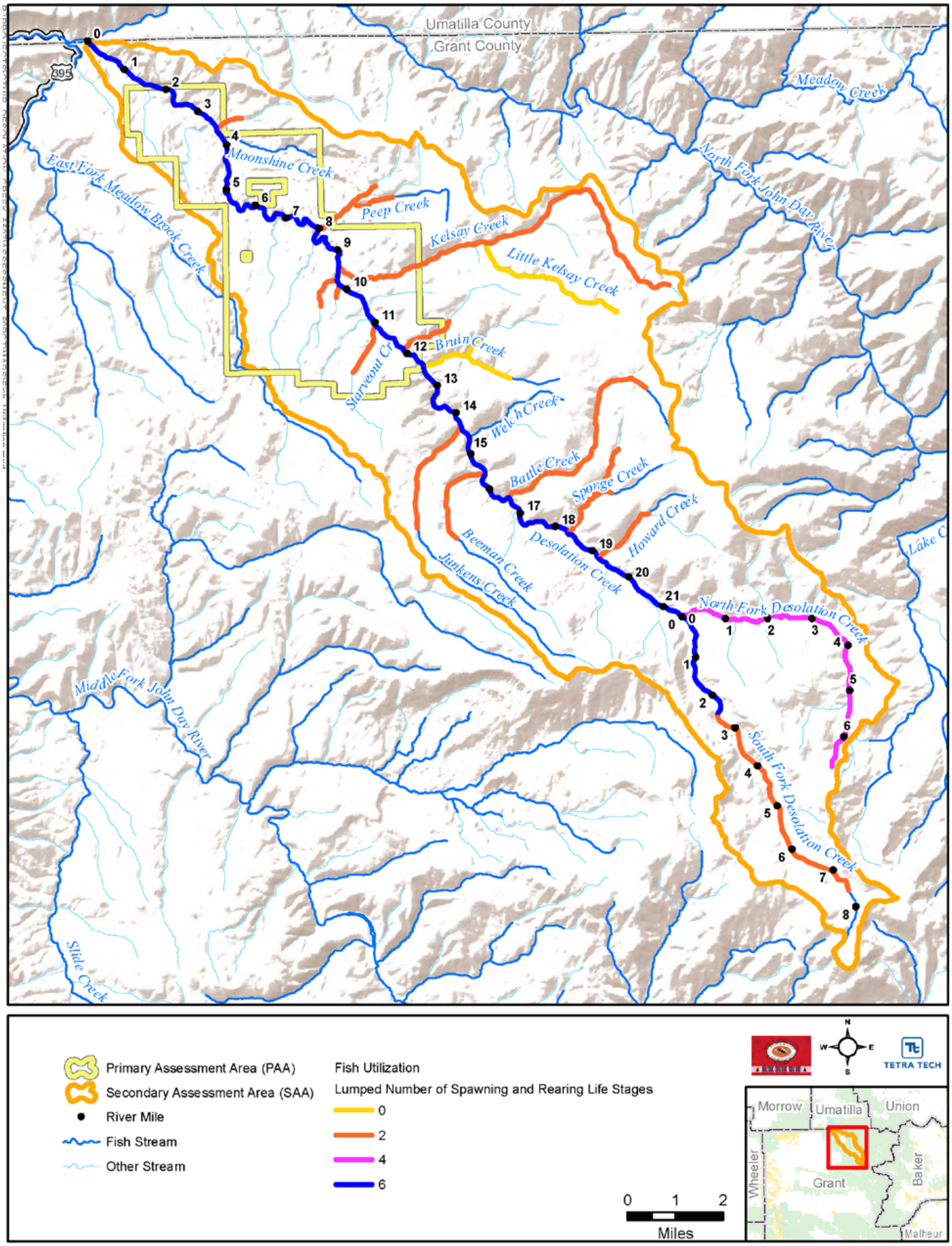
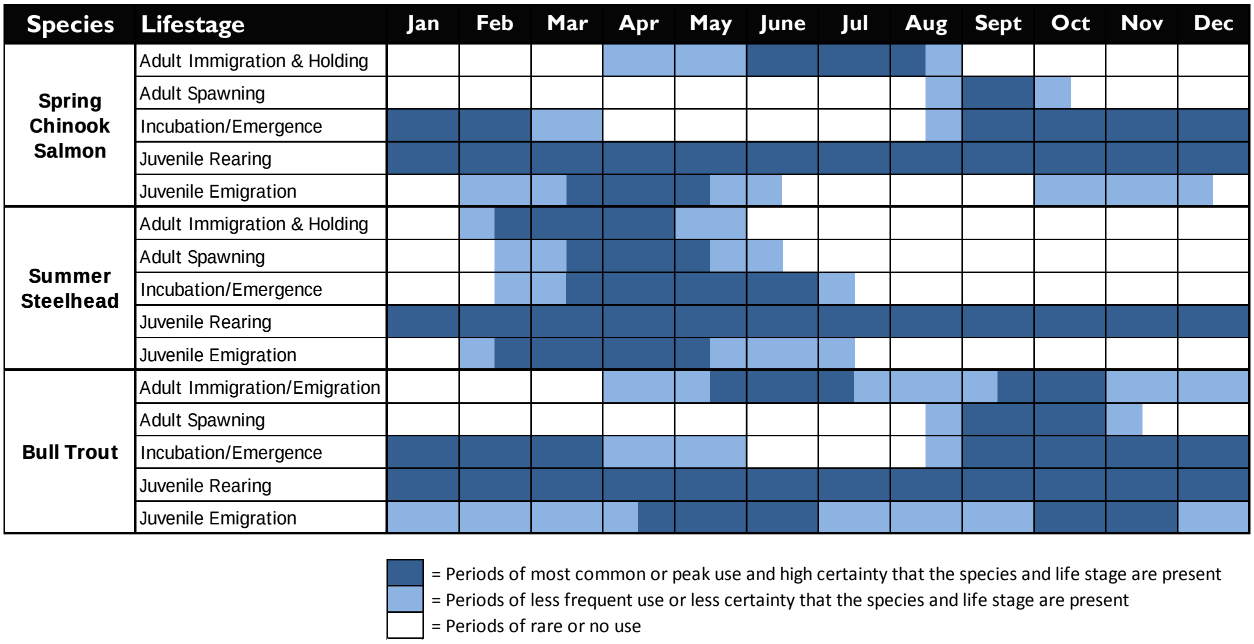


Figure 4.2-1. Lumped Number of Life Stages of Focal Fish Species in the Watershed

Table 4.2-1. Desolation Creek Watershed Focal Fish Periodicity



Sources: Lindsay et al. 1985, McCullough 1999, Lichatowich and Mobrand 1995, Olsen et al. 1992, Olsen et al. 1994, Starcevich et al. 2012, CTWSRO 2014, StreamNet 2016

Steelhead

Middle Columbia River steelhead are part of the North Fork John Day River population within the John Day major population group. Both anadromous steelhead and resident rainbow/redband trout are present in Desolation Creek and are the most abundant salmonids in the system; they are found spawning from the mouth to above Desolation Meadows in the North Fork (USFWS 2015). This population is part of the Middle Columbia River steelhead Evolutionary Significant Unit (ESU) listed as threatened in 1999 under the ESA, which, at the time, included both anadromous and resident forms (69 *Federal Register* 33101). Revision of species determinations resulted in the anadromous distinct population segment (DPS) being listed as Threatened on January 5, 2006 (71 *Federal Register* 834; Carmichael and Taylor 2010). The North Fork John Day River population is considered a large population and of low risk for extinction (Carmichael and Taylor 2010) based on current abundance levels. Desolation Creek is considered one of the eight major spawning areas within the North Fork John Day River population. The Desolation Creek steelhead subpopulation is a summer type, migrating up through the John Day watershed through fall and winter to spawn in the spring and early summer (see Table 4.2-1).

Portions of Desolation Creek are in relatively good condition, especially within the South Fork, and conservation strategies emphasize protection as a priority action within the watershed (Carmichael and Taylor 2010). Additional recommendations include implementing restoration actions targeting riparian conditions, sediment issues, and lack of quality habitat (Carmichael and Taylor 2010).

Limited ODFW redd counts have documented low numbers of summer steelhead spawning in the mainstem Desolation Creek, Battle Creek, Howard Creek, Sponge Creek, and the North Fork. A total of 13 redds were found between 2004 and 2012, with 8 of those redds occurring in Battle Creek. Few studies of summer steelhead use in Desolation Creek have occurred; however, in 2015 and 2016 the CTUIR Biomonitoring Program conducted snorkel surveys in Desolation Creek at Columbia Habitat Monitoring Program (CHaMP) sites. These surveys are summarized in the CTUIR Biomonitoring Summary (CTUIR 2016c), and showed low densities of juvenile steelhead in both the treatment and control reaches (ranging from 0.01 to 0.07 fish/meter^2).

Bull Trout

Bull trout are part of the Columbia River bull trout DPS (63 *Federal Register* 31647), federally listed as threatened. Resident bull trout spend their life in the headwater streams, while migratory bull trout spawn and rear in the headwaters before migrating downstream to mainstem river habitats (USFWS 2002).

Bull trout in Desolation Creek are part of the North Fork John Day River population. This population is considered distinct from other populations due to geography and habitat (Sankovich and Anglin 2014). In addition, there is an isolated distinct resident population above the falls on South Fork Desolation Creek that is considered an important genetic reservoir (USFWS 2002). It is assumed that the majority of the population comprises resident forms, with only a small percentage being anadromous (USFS 1999). This low anadromy rate has been observed for the entire North Fork John Day River during tagging studies as well (Sankovich and Anglin 2014).

Juvenile bull trout rear in headwater streams, reaching sexual maturity at 4 to 6 years. Migratory forms may rear for 1 to 2 years before migrating downstream as subadults to larger mainstem areas, generally in the spring, and potentially out to the Columbia River (Sankovich and Anglin 2014). Spawning generally occurs in the fall (September to October). Under reasonable conditions, bull trout may live up to 10 years, and in rarer cases they can reach ages older than 20 years (Sankovich and Anglin 2014).

Bull trout require more specific habitats than many other salmonids, including cooler water temperatures and complex habitat with cover (such as wood, undercut banks, boulders, and pools). Habitat degradation, fragmentation, migration barriers, and reduced stream flow and increased water temperatures are all factors impacting bull trout populations. Water quality within the Desolation Creek watershed is considered to be good; however, stream temperatures are of particular concern for bull trout. Bull trout primarily occur in the mainstem of Desolation Creek from RM 5.5 upstream to the confluence of North and South Forks, and throughout the South Fork. Upstream of the falls (at RM 2.3) on the South Fork, it is unclear if this population migrates downstream.

Spring Chinook Salmon

The North Fork John Day Middle Columbia River spring Chinook salmon are not an ESA-listed species since the population meets all interim population criteria: existence, distribution, abundance, productivity, independence, and hybridization (ODFW 2005).

Middle Columbia River spring Chinook salmon generally enter and migrate through the lower Columbia River between February and May, passing through the Bonneville Dam between March 1 and May 31 and the Dalles Dam between March 31 and June (Fulton 1968). While spawning for this ESU can occur from late July to late September (Fulton 1968), spawning in the John Day Subbasin is generally limited to August through early to mid-September (Lichatowich and Mobrand 1995; McCullough 1999).

Fry emergence in the John Day River Subbasin occurs between February and July, though most years they emerge between March and June (Olsen et al. 1992). Emergence in the North Fork John Day River occurs in April (Lichatowich and Mobrand 1995). Temperature appears to be a major limiting factor for juvenile Chinook salmon rearing areas within the North Fork John Day River, with studies indicating that they were not found downstream of areas where temperatures reach 20 degrees Celsius (°C; Lichatowich and Mobrand 1995). Smolt outmigration occurs from February through June, with almost all juveniles migrating as yearlings (Lichatowich and Mobrand 1995). Juvenile peak outmigration timing peaks from late February through mid-April, while mainstem migration was extended into June (Olsen et al. 1992; Lichatowich and Mobrand 1995).

ODFW redd counts have been conducted in the mainstem of Desolation Creek from the mouth to the confluence of the North and South forks; counts have been done annually beginning in 2009 to the present. Total redds in that 21-mile reach have ranged from 31 to 80 each year. Redd counts within Desolation Creek range from approximately 0.5 percent to 8 percent of the total redd counts for the North Fork John Day River (Ruzycki et al. 2008). Routine surveys for juvenile Chinook salmon have not been conducted, but it is assumed the majority of the mainstem is utilized. A survey of summer holding habitat showed juvenile Chinook salmon were also observed in both the North Fork and South Fork Desolation Creek (USFS 2003).

Pacific Lamprey

Pacific lamprey are a species of concern that are present in the John Day River Subbasin, with an estimated annual run size of approximately 10,000 individuals per year (Close 2000). Presence of Pacific lamprey in the North Fork John Day River has been documented; however, the extent of use is relatively unknown. In 1990, an acid spill in the North Fork John Day River killed thousands of fish, with an estimated mortality for Pacific lamprey at 9,500 (USFWS 1994); the majority of the estimated mortality was out-migrating ammocoetes (Jackson et al. 1996). The USGS conducted a tracking survey of adult lamprey in 2000 (Robinson and Bayer 2005) and detected adult lamprey in the North Fork John Day River. No detectors were installed in Desolation Creek. Ammocoetes were collected in 1998 in the North Fork John Day River and Camas Creek, a tributary just downstream of Desolation Creek. Though there is no documented evidence of Pacific lamprey in Desolation Creek, proximity to locations of known lamprey occupancy mean that it should be considered as potential habitat for Pacific lamprey.

Freshwater Mussels

Freshwater mussels occur throughout the North Fork John Day River (Brim Box et al. 2004). Surveys have identified freshwater mussels both upstream and downstream of Desolation Creek (Brim Box et al. 2006). This suggests that freshwater mussels could be present in Desolation Creek, but available literature does not confirm their presence.

4.2.2 Fish Habitat

The presence of suitable aquatic habitat is critical for the survival and propagation of the focal salmonid species. There have been several previous field assessments of habitat conditions in Desolation Creek by the ODFW, UNF, and CTUIR. In addition, Ecosystem Diagnosis and Treatment (EDT) and Qualitative Habitat Assessment (QHA) analyses were conducted within the Desolation Creek watershed to assess spring Chinook salmon, steelhead, and bull trout habitat as part of the John Day Subbasin Plan (NPCC 2005). These data include reach-level information based on field observations, historic data, and expert judgment.

Starting in 1990, ODFW started consolidating and collecting habitat and fish data for various streams in Oregon as part of the Aquatic Inventories Project (AIP). A search of the ODFW database showed that fish habitat and occurrence data were collected for the full length of the mainstem of Desolation Creek in 1994 (August through October) as part of this inventory process (ODFW 2014). The data includes spatially referenced physical and biological information at both the reach and habitat unit level.

Beginning in 2000, the UNF conducted surveys in various tributaries and the mainstem of Desolation Creek that were summarized in the Desolation Habitat Summary Report (USFS 2006). Since then, additional tributary surveys have been conducted throughout the watershed as well. In 2010, habitat surveys were conducted on Battle Creek (USFS 2010b), Little Kelsay Creek (USFS 2010c), and Sponge Creek (USFS 2010d), while aquatic biota surveys were conducted on Beeman Creek (USFS 2012a), Howard Creek (USFS 2012b), Junkens Creek (2012c), and an unnamed tributary to Howard Creek (USFS 2012d). The Biological Evaluation and Fisheries Specialist Report (USFS 2016) contains habitat information for a number of small tributaries in the Desolation Creek drainage. Table 4.2-2 includes a summary of the described habitat characteristics from USFS (2016).

Table 4.2-2. Desolation Creek and Tributary Habitat Characteristics

Tributary	Gradient (%)	Pools/ Mile	Meets RMO[1]/: Pools	Meets RMO[1/]: Temp.	Meets RMO[1]/: LWD	Notes
Lower Desolation Creek Subwatershed						
Mud Springs	–	–	–	–	–	No Survey
Moonshine Creek	–	–	–	–	–	No Survey
Peep Creek	–	–	–	–	–	No Survey. 2.1 miles are Designated Critical Habitat (DCH) for Middle Columbia River (MCR) steelhead
Middle Desolation Creek Subwatershed						
Desolation Creek USFS Reach 1	1	12.1	No	No	No	Entire length is DCH for MCR steelhead
Kelsay Creek	1.3–2.9	8.9–10.7	No	No	No	7.1 miles are DCH for MCR steelhead; Culvert fish barrier on FS 1011-000 Road
Little Kelsay Creek	5	26.7	No	Yes	No	3.5 miles are DCH for MCR steelhead
Spring Creek	–	–	–	–	–	No surveys performed: 0 miles of DCH for MCR steelhead or bull trout
Starveout Creek	–	–	–	–	–	0.8 miles of DCH for MCR steelhead
Park Creek	–	–	–	–	–	1.3 miles of DCH for MCR steelhead; Fish barrier culvert at FS 10 Road intersection; 1.5 miles was dry during 2015 survey attempt
Bruin Creek	5–19.3	13.8–38.0	No	No	No	2.5 miles of DCH for MCR steelhead
Upper Desolation Creek Subwatershed						
Desolation Creek Reaches 2 and 3	1.7–2.4	16.5–42.6	No	No	No	DCH for MCR steelhead and bull trout; 44 and 122 man-made cross channel structures in Reaches 2 & 3, respectively; Westslope Cutthroat present from Sponge Creek to North Fork/South Fork split
Junkens Creek	5.0 – 8.0	34.8–51.1	No	No	No	2.5 miles of DCH for MCR steelhead; 15 foot waterfall downstream of FS 3988-070 Road
Welch Creek	–	–	–	–	–	Has about 1 mile of MCR steelhead; 0 miles of DCH for MCR steelhead or bull trout
Beeman Creek	3.6–12.6	95.8–154.4	Yes	Yes	Yes	4.3 miles of DCH for MCR steelhead
Battle Creek	2.8–6.0	2.0–33.6	No	Yes	No	4.6 miles of DCH for MCR steelhead; Temperature typically does not meet criteria
Sponge Creek	4.9–13.5	25.6–32.7	No	No	No	2.6 miles of DCH for MCR steelhead; 303d listed for Temperature
Howard Creek	6.2–12.6	31.5–35.9	No	Yes	Yes	1.5 miles of DCH for MCR steelhead
Headwaters Desolation Creek Subwatershed						
South Fork Desolation	1.2–9.0	–	Yes	Yes	Yes	2.5 miles of DCH for MCR steelhead; 8.7 miles of DCH for bull trout; Westslope cutthroat present; 13 waterfalls
North Fork Desolation	0.05–4.0	–	No	No	Yes	6.2 miles of DCH for MCR steelhead; old relic road that passes through the meadows; Fish passage barrier culvert at FS 1000-400 Road
East Fork Desolation	8	–	No	No	Yes	–
West Fork Desolation	15	–	No	No	Yes	–
Skinner Creek	9	71.5	No	No	No	0 miles of DCH for MCR steelhead; Juvenile *O. mykiss* sighted often during snorkel survey
Line Creek	9	81.3	No	No	No	0 miles of DCH for MCR steelhead; *O. mykiss* and 1 brook trout

1/ Riparian Management Objectives (RMO)
Source: USFS (2016)

The CTUIR has collected habitat data for monitoring sites on Desolation Creek as a component of their Biomonitoring Program. These two monitoring sites are also included in the BPA Action Effectiveness Monitoring (AEM) Program (BPA 2016). The monitoring treatment reach is located between RM 11.0 and RM 12.0 (see Section 5.1 for Reach 6 description), while the control reach is located between RM 15.0 and RM 16.0 (upstream of the PAA). These sites have been surveyed for habitat conditions and geomorphic change in September 2015 and 2016. At this time, no restoration actions have been conducted on the treatment reach. The results of the monitoring on Desolation Creek, as well as additional site photos and data, are contained in the CTUIR Biomonitoring Summary for Desolation Creek (CTUIR 2016c) and can be found on the AEM website (BPA 2016).

4.3 LAND-USE HISTORY AND IMPACTS

Numerous publications, studies, assessments, and plans describe the historical and current land uses within the Desolation Creek watershed. Some of the many applicable sources of information include EFM (2015), NPCC (2001, 2005), Thayer (1977), USFS (1999, 2008, 2009), Kenny (1959), CTUIR (2016a, 2016b), Zakrajsek (2011), and CTWSRO (2016). This section does not attempt to provide a comprehensive description of land use, land ownership, and jurisdiction, but rather it provides a summary of information applicable to this Project.

4.3.1 Early Settlement

For more than 10,000 years, the members of what are now the CTUIR (formed from the Walla Walla, Umatilla, and Cayuse tribes) and the CTWSRO (formed from the Wasco, Warm Spring, and Paiute tribes) used the Desolation Creek watershed seasonally for fishing, hunting, gathering, and habitation (CTUIR 1995, 2016a, 2016b; USFS 1999; CTWSRO 2016). To open the region for immigration and alleviate conflicts, in 1855 the U.S. Government signed the treaties that created the CTUIR and the CTWSRO (CTUIR 2016a; CTWSRO 2016). In exchange for the Tribes ceding millions of acres of land, the treaties guaranteed the right to fish in traditional and accustomed places, as well as hunting and gathering of wildlife and vegetative resources (CTUIR 2016a). Today, the CTUIR and CTWSRO are recognized as co-managers of the North Fork John Day watershed, including the Desolation Creek watershed (Three Treaty Tribes-Action Agencies 2008).

European settlement of the area began in the early 1800s with explorers and fur trappers, including the party that included John Day in 1812, and intensified after discoveries of gold in the 1840s brought many immigrants to the area (Kenny 1959; Thayer 1977; NPCC 2005). Prior to European settlement, beavers were abundant in the area, but extensive trapping nearly extirpated the local populations (Demeter 2010; EFM 2015). Historically, beavers had a significant impact on stream systems within the Desolation Creek watershed through creation of off-channel and floodplain habitat, moderation of stream flow regimes, and recharge of shallow aquifers (Demeter 2010; NPCC 2005). Activities associated with European settlement, including grazing, timber harvest, managing wildfires, and mining have all created extensive impacts in the Desolation Creek watershed and surrounding areas.

4.3.2 Livestock Grazing

Livestock grazing has been extensive in the watershed since the early to mid-1800s and has contributed to degraded watershed conditions (USFS 1999; EFM 2015). Livestock grazing, as illustrated in Figure 4.3-1, included sheep, horses, and cattle, with both seasonal and year-round use, and grazing allotments covered about three-quarters of the watershed area (USFS 1999). Cattle grazing likely peaked in the 1950s, and sheep grazing likely peaked prior to the dominance of cattle (USFS 1999). Overall, grazing impacts in the Desolation Creek watershed have been, and continue to be, extensive on both public and private land, and currently include three active grazing permits on the property owned by Desolation Creek LLC (USFS 1999; EMF 2015). Impacts from grazing include upland soil compaction, damage to streambanks, vegetation impacts, and water quality impacts from animal waste (USFS 2009). Impacts from grazing are concentrated in riparian and wet meadow areas, which are areas of particular concern for watershed function and health (USFS 1999). Grazing in riparian meadows has been shown to considerably reduce soil pore space, and as a result soil water storage, which in turn impacts ecosystem productivity, biogeochemistry, stream temperature, and stream flows (Hammersmark 2008). Grazing also reduces the density of roots and rhizomes in the soil, which has important consequences including a reduction in streambank stability (Kauffman et al. 2004).

Source: Rector (1960), obtained from USFS, Umatilla National Forest

Figure 4.3-1. Desolation Creek in the Vicinity of Desolation Meadows Showing Early Cattle Grazing Impacts

4.3.3 Timber Harvesting

Timber harvesting began in the 1800s and accelerated during and after the 1940s with extensive clearcut logging and high grading of timber, and combined with beaver extirpation and fire exclusion has changed the forest composition (USFS 1999, 2008; EFM 2015). In the subwatersheds on public lands analyzed in the Desolation Ecosystem Analysis (USFS 1999), predominant disturbances were reported as affecting 55 percent of the watershed, including 15 percent of the area clearcut, 16 percent partially cut, 11 percent thinned, with the balance consisting of wildfires (13 percent). A historical range of variation study of the Desolation Creek watershed found that in 1939 old forest structure exceeded young forest multi strata, but that by the late 1990s the situation was reversed, with timber harvest after 1939 having eliminated much of the old forest structure (USFS 1999).

4.3.4 Wildfires

Large wildfires have also impacted the watershed. Historically, the watershed would have had a fire regime characterized by more frequent low intensity and low severity fires (USFS 2008; EFM 2015), including active use of fire by the tribes to manage vegetation and improve conditions for desired species that had shaped the landscape for centuries before the arrival of settlers (Boyd 1999; Langston 2015). Cessation of traditional burning techniques and the conversion of much of the landscape to agriculture and timber harvest meant that since the early 1900s most fires have been suppressed, creating the conditions for high intensity and high severity fires (USFS 2008).

Recent wildfires in the Desolation Creek watershed include the Summit Fire and Bull Fire in 1996, the Sharps Ridge Fire in 2006, the Otter Fire in 2007 (USFS 2008), and the North Fork Complex Fire in 2009 (WFDSS 2010). Table 4.3-1 shows the locations, acres, and the percent of each drainage burned within the Desolation Creek watershed. The Summit Fire burned a large proportion (70 percent) of the South Fork Beaver Creek drainage, with most of the burn being described as a low-intensity ground fire. A moderate burn intensity was reported for 15 percent of the drainage area (USFS 1999).

Table 4.3-1. Burned Areas by Drainage in the Desolation Creek Watershed

Drainage	Wildfire Name	Year Burned	Burned Area (acres)	Percent of Drainage Burned
Battle Creek	Bull Fire	1996	152	2%
Howard Creek	Bull Fire	1996	867	13%
North Fork Desolation	Summit Fire	1996	1,630	20%
South Fork Desolation	Summit Fire	1996	5,001	70%
Junkens Creek	Sharps Ridge Fire	2006	1,336	41%
Beeman Creek	Sharps Ridge Fire	2006	1,137	53%
Peep Creek	Otter Fire	2007	648	19%
Kelsay Creek	North Fork Complex	2009	419	6%

4.3.5 Mining

Historic mining activities in the John Day River Subbasin included lode and placer gold mining in the upper parts of the subbasin beginning with the gold rush in the 1840s, and continuing with extensive historic gold mining and dredging activities which contributed to changed watershed conditions (NPCC 2005). Impacts of historic mining on landscape and rivers in the Desolation Creek watershed are still visible (EFM 2015; USFS 1999) and mining activity was reported in Junkens, Beeman, Battle, North Fork Desolation, and South Fork Desolation Creek subwatersheds (USFS 1999). Evidence of historic placer mining is reported along Junkens, Welch, and Skinner creeks in the Desolation Creek watershed (USFS 1999). Mines and access roads are reported at the headwaters of South Fork Desolation Creek (NPCC 2005), though the Donaldson Mine on South Fork Desolation Creek has been inactive for several decades (USFS 1999). The USFS (1999) Desolation Ecosystem Analysis reported that one active lode mine and three inactive placer mines were present on public lands in the watershed, and that multiple lode and placer mines of unknown status were present on private lands, including the Portland Mine in the South Fork Desolation Creek subwatershed.

The Fremont Powerhouse was constructed near Olive Lake in 1908 and remained in continuous service until 1967 (USFS 2016). It was originally constructed to operate the Red Boy Mine more economically, in response to decreasing earnings (USFS 2016). Although the Fremont Powerhouse is outside of the Desolation Creek watershed, an 8-mile-long wood and metal pipe and ditch was constructed to bring water from the Desolation Creek watershed to the powerplant, as shown below in Figure 4.3-2 (USFS 2016).

Source: [Photographer unknown] (1926), obtained from USFS, Umatilla National Forest

Figure 4.3-2. The Desolation Creek Ditch Carried Water into Olive Lake to Supplement the Water in the Lake for the Fremont Powerhouse

4.3.6 Current Land Use

The dominant land use in the Desolation Creek watershed is public land ownership (USFS 1999). Although extractive and commodity uses of the public land predominated in the past, current public land management in the watershed emphasizes scenic, recreational, and ecological values (USFS 1999, 2009). Portions of two designated roadless areas extend within the Desolation Creek watershed, including portions of Jumpoff Joe and Greenhorn Mountain roadless areas, and total approximately 14 percent of the total watershed area (USFS 1999).

The Desolation Creek watershed is a popular area for recreation. There are over 200 dispersed campsites located on USFS land throughout the watershed (USFS 1999). Potential impacts related to dispersed campsites include surface erosion from access roads, stream bank erosion, and cutting of vegetation for firewood. Within the watershed, there are also seven trailheads, and over 45 miles of trail, with over 23 miles of motorized trails accessible by off-highway vehicles (OHVs). The Welch Creek Campground is the main staging area for OHVs and all motorized trails in the Desolation Creek trail system are accessible from this trailhead (USFS 1999). Motorized trails also have the potential to increase fine sediment inputs through surface erosion. The potential for increased sediment input is reduced through the implementation of trail construction and maintenance Best Management Practices including route selection to avoid sensitive areas and the use of well-designed stream crossing and drainage control structures.

Although extractive and commodity uses in the watershed have been diminished, many of the impacts of these historic uses are still affecting watershed processes. Infrastructure built for timber harvest, mining, and other activities, such as road construction and stream crossings, can impact channel stability and lead to detrimental effects to watershed health. Overall road construction in the Desolation Creek watershed has been extensive, much of that from extensive road construction in the 1970s. Seven of the nine subwatersheds had road densities ranked as “high” based on the Interior Columbia Basin Ecosystem Management Project criteria of road densities greater than 1.7 miles of road per mile squared (USFS 1999). The Farley Vegetation Management Project Draft Environmental Impact Statement (DEIS) reported approximately 235 miles of roads in the Desolation Creek watershed covering approximately 563 acres, 182 stream crossings, and a road density of 2.16 miles/square mile (USFS 2008). Comparison of GIS road layers obtained from the USFS and EFM showed that road densities were significantly under-reported for private lands in the Lower desolation subwatershed. On the private land owned by Desolation Creek LLC, 98 miles of roads are reported, with a density of 4.7 miles/square mile, as well as additional unmapped roads and skid trails (EFM 2015).

Forest roads can have a variety of potential impacts, including stream crossings that can contribute towards altered hydrologic and geomorphic regimes and result in fish barriers. Figure 4.3-3 shows an example of a gabion ford crossing of Desolation Creek from 1965 severely impacting natural stream processes and fish passage. In another more recent example from 2011, a culvert crossing on Bruin Creek, a tributary to Desolation Creek, became plugged with debris and washed out the crossing, eroding the approximately 25-foot-high road prism (Zakrajsek 2012). Road decommissioning has been identified as a watershed restoration strategy, and over 6 miles of road were decommissioned between 2001 and 2007 (USFS 2009). Closing non-essential roads is listed as one of their management objectives. Many roads have since been closed or managed for limited access, and others are proposed for removal or relocation, including portions of the NF-10 road where it runs adjacent to Desolation Creek near RM 10.0.

Source: [Photographer unknown] (1965), obtained from USFS, Umatilla National Forest

Figure 4.3-3. Gabion Ford on Desolation Creek

Road density and stream proximity to roads were calculated as key indicators of watershed health for this assessment using existing road and stream data layers. In 2011, the USFS established a nationally consistent framework for classifying watershed conditions (USFS 2011). The approach was designed to foster integrated watershed assessments, target restoration in priority watersheds, enhance collaboration with partners, and improve outcome-based performance measures for documenting improved watershed conditions. Twelve core indicators were evaluated to classify watershed conditions using a Watershed Condition Classification (WCC) rating system. Open road densities and road proximity to streams are two of the twelve core WCC indicators used in this analysis.

The WCC rating for open road/trail densities that are greater than 2.4 miles per square mile is classified as “Poor (3) Impaired Function”. Similarly, the USFWS pathways and indicators standards identify greater than 2.4 miles of road per square mile area with many valley bottom roads as “Functioning at Unacceptable Risk” (USFWS 1998). Road density averaged 3.1 miles of road per square mile for the Desolation Creek watershed as a whole (Table 4.3-2). The 2.16 miles/square mile previously noted in the Farley Vegetation Management Project Draft Environmental Impact Statement (DEIS) (USFS 2008) would have received a WCC rating of “Fair (2) Functioning at Risk”, but was inaccurate due to under-reporting roads on private lands in the lower portions of the watershed. Subwatershed road densities ranged from 2.5 miles of road per square mile in the Headwaters Desolation Creek and the Upper Desolation Creek subwatersheds, to a maximum of 4.2 miles per square mile in the Lower Desolation Creek subwatershed. As indicated in Table 4.3-2, the watershed as a whole, and all four individual subwatersheds fell into the WCC rating of “Poor (3) Impaired Function”.

The percent of road miles within 300 feet of waterbodies indicator is another one of the twelve core WCC indicators and is used to evaluate the potential for sediment to enter streams based on road location. Although this WCF indicator originally provided an approach to evaluate watershed function based on road miles near waterbodies, a bias in this indicator was identified in a policy primer (Rissien 2011). For example, if roads are removed outside the 300-foot streamside buffer to reduce road density, the percentage of roads within the buffer could increase, which could downgrade the WCC rating. Because of that bias, the primer recommended that the percentage of waterbodies within 300 feet of a road, and not the percentage of road miles within 300 feet of waterbodies, should be used to evaluate watershed function. Using this criterion, the watershed would be considered “Good (1) Functioning Properly” if less than 10 percent of the waterbodies’ length in a watershed is within 300 feet of roads, “Fair (2) Functioning at Risk” if between 10 and 25 percent, and “Poor (3) Impaired Function” if greater than 25 percent are within 300 feet of water bodies, relative to the effects of this factor on the hydrology and sediment regime.

Analysis of stream proximity to roads (rather than road proximity to stream) showed these values varied considerably from 30 percent of the stream length located within 300 feet of a road in the Upper Desolation Creek subwatershed, to 53 percent in the Lower Desolation Creek subwatershed (Table 4.3-2). Based on the criteria described above, in all cases the WCC rating for stream and waterbodies located within 300 feet of roads is considered “Poor - Impaired Function”.

Table 4.3-2. Road Density and Stream Proximity to Roads by Hydrologic Unit Code

Hydrologic Unit Code (HUC)	HUC Name	Road Density[1/] (miles/ mile^2)	Stream Proximity to Roads[2/]
10-digit HUC 1707020204	Desolation Creek Watershed	3.1	43%
12-digit HUC 170702020401	Headwaters Desolation Creek	2.5	43%
12-digit HUC 170702020402	Upper Desolation Creek	2.5	30%
12-digit HUC 170702020403	Middle Desolation Creek	3.3	50%
12-digit HUC 170702020404	Lower Desolation Creek	4.2	53%

1/ Road layer provided by Desolation Creek LLC.
2/ Percent of stream length within 300 feet of roads using routed stream hydrography layer (MSHv3.1) provided by StreamNet

Based on these two core road rating criteria, the density and distribution of roads and trails within the Desolation Creek watershed indicates a high probability that the hydrologic regime (timing, magnitude, duration, and spatial distribution of runoff flows) and sediment routing is substantially altered.

4.3.7 Water Quantity and Quality

Water quantity and quality are two important factors for sustainable anadromous populations. Salmonids require clean, cool, highly oxygenated water. Reduced water quantity restricts the overall amount of available habitat, can impede fish passage at key life stages, and can inhibit overall fish health and development (Crozier 2016).

Water quantity in Desolation Creek has been impacted by the loss of wetland and meadow habitat, as described in Section 4.1.5. Functioning wet meadows and wetlands attenuate flood waters and slowly release the stored water in dry months, helping to buffer low flows and providing cold water refugia for fish (Hammersmark et al. 2008; USFS 2010a). Late summer low flows in Desolation Creek have been reduced because these important subsurface storage areas have been severely degraded.

Water quality standards and information associated with water quality in the watershed can be found in the John Day Subbasin Plan (NPCC 2005), and the John Day Basin TMDL and Water Quality Management Plan (ODEQ 2010). A summary of water temperature and other water quality issues are described in the following subsections.

Water Temperature

Desolation Creek and several tributary streams in the watershed were added to the CWA section 303(d) list in 2004 for water temperature. The waterbodies included Desolation Creek, Junkens Creek, Sponge Creek, and North Fork Desolation Creek. While these waterbodies were de-listed in 2010, following approval of the TMDL for temperature, the ODEQ (2012) 303d database currently identifies them as Category 4, water quality limited.

Waterbodies listed for stream temperature exceed criteria for salmonids, where water temperature is measured by the 7-day average of the daily maximum temperatures. The applicable biologically based temperature thresholds (numeric criteria) in the watershed include:

- Salmon and steelhead spawning: 13°C (55°F), during spawning periods;
- Core cold-water habitat: 16°C (61°F), year-round; and
- Bull trout spawning and juvenile rearing: 12°C (54°F), year around.

The USFS (1999) summarized temperature data collected in the 1990s, reporting that maximum summer water temperatures (7-day moving averages) ranged from 13°C (56°F) on Junkens Creek at the mouth (in 1993), to 28°C (83°F) on Desolation Creek at the mouth (in 1995). Junkens Creek and the South Fork Desolation were the coldest tributaries, while Kelsay Creek was one was the warmest tributaries at 23°C (74°F) in 1992. Data for Bruin, Battle, Sponge, and Howard creeks, and the North Fork Desolation Creek, were also reported and ranged from 15 to 23°C (59 to 73°F).

Thermal infrared remote, also known as forward-looking infrared (FLIR), sensing data were collected for the full extent of Desolation Creek, including the North and South Forks, in July of 2001. Results indicated that stream temperatures in the North Fork Desolation Creek were 2.0°C (3.6 °F) warmer than those in the South Fork. The longitudinal temperature profile of Desolation Creek showed typical patterns of downstream warming with notable cooling near RM 0.6, RM 5.0, and RM 12.5 (Figure 4.3-4). Possible sources of cooling could not be readily identified from the FLIR imagery but are likely related to cool water seeps, side channels, and tributaries. Surface water inflows were shown to reduce stream temperature at local scales but they did not appear to alter spatial temperature patterns at the watershed scale (Watershed Sciences 2002).

Recent research indicates that water temperature impairments are likely to become more pronounced with expected regional changes in air temperature and stream discharge associated with climate change (Isaak et al. 2012). Associated increases in water temperature have the potential to alter distributions of native riverine organisms. Based on climate change forecasts, summer temperatures in rivers are projected to warm with air temperatures (Isaak et al. 2012), which will compress the amount of habitat available for cold-water aquatic communities.

The extent and location of potential losses in available cold-water habitat relative to air temperature increases, however, may be minimized by localized river geomorphology, and particularly by floodplains. Alluvial river valleys are often zones of water temperature (Arscott et al. 2001), habitat (Ward et al. 1999), and biotic diversity (Stanford et al. 1996; Ward et al. 1999). Complex floodplains including functional wetlands and wet meadows can decrease water temperatures by increasing the volume of groundwater storage, which attenuates peak floods and releases relatively cool discharge to the channel during summer low flow periods (Hammersmark and Mount 2005). Complex, multi-threaded channel forms also create opportunities for hyporheic exchange (Poole et al. 2008) that can moderate water temperature extremes (Arrigoni et al. 2008), provide important cold-water habitat (Torgersen et al. 1999), and even reverse the expected increasing trend in channel temperature as water moves downstream (O'Daniel et al. 2003).

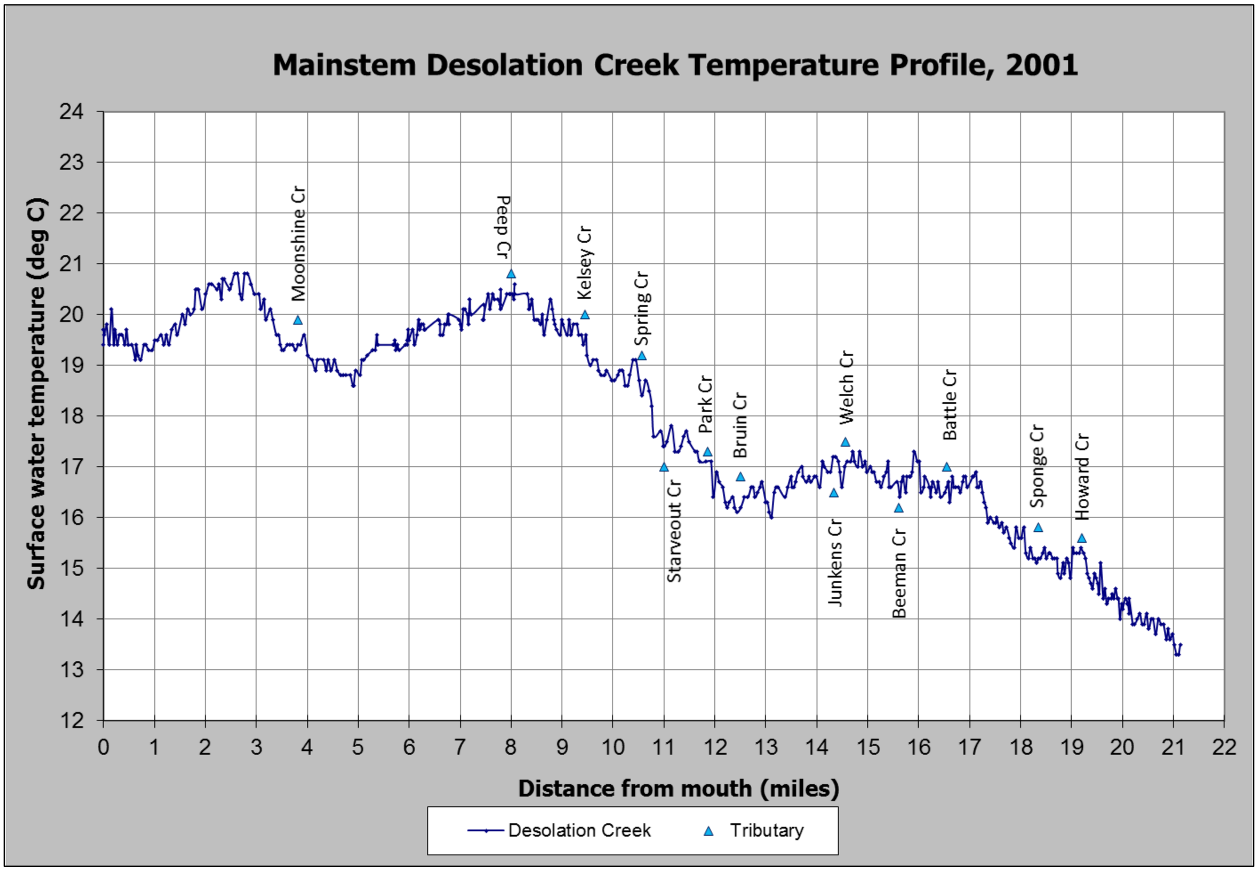


Figure 4.3-4. Temperature Profile from FLIR Data, July 2001

Other Water Quality Issues

Additional water quality concerns present include sediment from roads and livestock grazing, and animal waste from livestock grazing. The Farley Vegetation Management Project DEIS (USFS 2008) reported that, while natural background erosion rates in the watershed range from 1 to 6 tons of sediment per square mile per year, based on the Watershed Erosion Prediction Model the road system in the watershed contributes approximately 1.8 tons of sediment per square mile, about 30 percent above the higher rate of natural background erosion. The contribution of livestock grazing to sediment production in the watershed is mentioned, but has not been quantified (USFS 1999, 2008). The Draft Desolation Creek Watershed Action Plan and the Desolation Ecosystem Analysis (USFS 1999, 2009) mention the impacts of animal waste from livestock grazing on water quality, including nutrient and bacterial contamination of waterways, but these impacts are not quantified.

The USFS Dale Work Center sewage treatment facility near the mouth of Desolation Creek represents a potential water quality risk. The sewage treatment lagoons are upslope from the confluence and, in the event of seepage or a structural failure, could pose a risk to Desolation Creek and/or the North Fork John Day River. Under normal operations, however, the sewage treatment lagoons have no discharge to surface waters.

4.4 LIMITING FACTORS AND RESTORATION POTENTIAL

As described in Section 4.3, land uses and management practices in the Desolation Creek watershed have resulted in the removal of riparian vegetation, altered upland characteristics and run-off patterns, increased sediment input and incision rates, reduced floodplain connectivity, and altered instream habitat conditions. Numerous assessments have identified limiting factors and restoration potential in the watershed as a result of these impacts. In general, watershed-wide assessments and studies have listed loss of fish passage, habitat complexity, habitat quantity, riparian condition, sedimentation, erosion, and temperature as limiting conditions for the various fish species in the Desolation Creek watershed. Temperature is listed as one of the key limiting factors for all species.

This section is not intended to provide a complete list of those assessments but instead provide a summary of the limiting factors and restoration potential development process with a focus on the results of the John Day Subbasin Plan (NPCC 2005), the 2008 Fish Accords (Three Treaty Tribes-Action Agencies 2008), and the John Day River Basin Watershed Restoration Strategy (CTWSRO 2014). Although there are differences in limiting factor terminology and ranking among the various assessments, there is good agreement on the limiting factor types and root causes.

The EDT and QHA utilized as part of the John Day Subbasin Plan (NPCC 2005) ranked Desolation Creek for protection and restoration benefits. Many of the EDT reaches received moderate to high ratings for protection, especially in the upper reaches of Desolation Creek, although they ranked lower in potential benefit for restoration action. Key habitat quantity, temperature, and sedimentation were identified as factors that could be improved to address steelhead limiting factors (NPCC 2005). For Chinook salmon, the EDT analysis again identified protection as a high priority and potential benefit, while restoration actions received a medium priority. Identified limiting factors receiving a medium priority were key habitat quantity and habitat complexity, while flow and temperature received low priority rankings (NPCC 2005).

As described above in Section 1.2.1, the 2008 Fish Accords (Three Treaty Tribes-Action Agencies 2008) established an agreement describing various commitments, including funding and implementing habitat projects to address the needs of ESA-listed fish. The 2008 Fish Accords cover the three watersheds of the North Fork John Day River, and included estimates of current function for each watershed and the primary limiting factors (PLF) for the Desolation Creek watershed (Three Treaty Tribes-Action Agencies 2008). At that time, the PLF ratings for summer steelhead, expressed as a percentage out of a total of 100, included Riparian/Floodplain (PLF=60), Water Quality-Temperature (PLF=60), In-Channel Characteristics (PLF=60), Sediment (PLF=60), and Passage/Entrainment (PLF=70) (Three Treaty Tribes-Action Agencies 2008). Estimated future function following restoration for all categories in the next 25 years was scored as 80, except for Passage/Entrainment which was scored at 90. Table 3.1-1 above provides a cross-walk of the 2008 Fish Accords PLFs with the River Vision touchstones, NOAA ecological concerns (NOAA 2012, CTUIR objectives, and Project metrics and evaluation methods.

The John Day River Basin Watershed Restoration Strategy (CTWSRO 2014) assessed each watershed within the John Day River Basin for seven distinct fish limiting factors and how they affected anadromous populations. The restoration strategy identified the Desolation Creek watershed as a high priority for restoration based on Restoration Potential Benefit prioritization scoring, ranking it at 8 out of a possible 9 (with 9 being highest) (CTWSRO 2014). Figure 4.4-1 shows the distribution of the number of limiting factors present in stream reaches throughout the Desolation Creek watershed, as identified by the CTWSRO and a science technical advisory committee. Table 4.4-1 shows the specific limiting factors occurring within each of the 24 stream reaches.

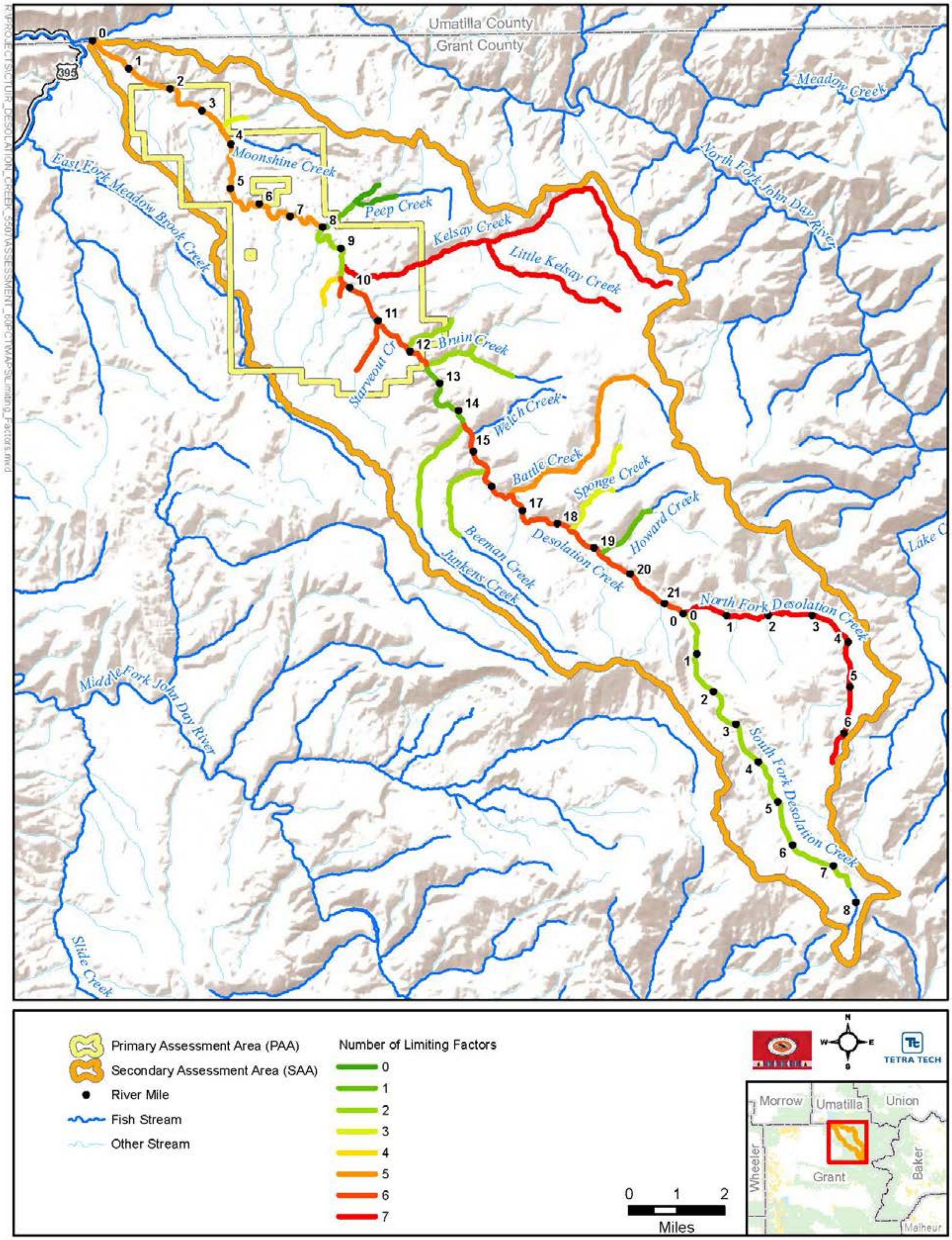


Figure 4.4-1. Focal Species Limiting Factors in the Desolation Creek Watershed

Table 4.4-1. Identified Limiting Factors by Reach

Reach	CTWSRO Limiting Factors						
	Impaired Fish Passage	Degraded Water Quality	Degraded Riparian	Degraded Floodplain	Degraded Channel	Altered Sediment Routing	Altered Hydrology
Unnamed Desolation Creek tributary near RM 3.6			X	X	X		
Peep Creek from mouth to unnamed tributary	X						
Peep Creek from unnamed tributary to forks[1/]							
Unnamed Peep Creek tributary[1/]							
Kelsay Creek	X	X	X	X	X	X	X
Little Kelsay Creek from Kelsay Creek confluence to headwaters	X	X	X	X	X	X	X
Unnamed Desolation Creek tributary near RM 9.7		X	X		X		X
Starveout Creek		X	X	X	X	X	X
Park Creek			X			X	
Bruin Creek			X		X		
Unnamed Bruin Creek tributary			X		X		
Junkens Creek	X					X	
Beeman Creek	X					X	
Battle Creek		X	X	X	X	X	
Sponge Creek					X	X	X
Unnamed Sponge Creek tributary					X	X	X
Howard Creek	X						
Desolation Creek: John Day River confluence to Peep Creek		X	X	X	X	X	
Desolation Creek: Peep Creek to Kelsay Creek					X	X	
Desolation Creek: Kelsay Creek to Bruin Creek		X	X	X	X	X	X
Desolation Creek: Bruin Creek to Junkens Creek					X		
Desolation Creek: Junkens Creek to North Fork/South Fork confluence		X	X	X	X	X	X
North Fork Desolation	X	X	X	X	X	X	X
South Fork Desolation from Desolation Creek to falls			X	X			
South Fork Desolation upstream of falls			X	X			

1/ Peep Creek and the unnamed Peep Creek tributary were listed as having none of the seven limiting factors.
Source: CTWSRO (2014)

Recognizing the differences in limiting factor definitions used by various entities, the CTUIR and the CTWSRO worked collaboratively to combine limiting factor data and weightings for the Upper North Fork John Day River Assessment Unit into a mutually agreed upon data set (Iverson 2015). Therefore, this Project utilized the NOAA ecological concerns (NOAA 2012) as the standardized definitions for limiting factors, as shown in Table 4.4-2. Although differing in terminology, the NOAA ecological concerns in Table 4.4-2, the primary limiting factors from the 2008 Fish Accords (Three Treaty Tribes-Action Agencies 2008), and limiting factors used in the John Day River Basin Watershed Restoration Strategy (CTWSRO 2014) are functionally similar and were linked via the crosswalk shown in Table 3.1-1.

Table 4.4-2. Desolation Creek Ecological Concerns Descriptions

Ecological Concern[1/]	ID Number and Sub-category	Definition
Habitat Quantity	1.1: Anthropogenic Barriers	Loss of access to habitat and/or habitat sub-types due to anthropogenic activity. Includes partial or ephemeral barriers.
Riparian Condition	4.1: Riparian Vegetation	Disturbance to streamside ecological relationships, including but not limited to, loss of flora, erosion and increased light and temperatures.
	4.2: LWD Recruitment	Loss of mature streamside trees that may become instream structures and associated decline in habitat complexity.
Peripheral and Transitional Habitats	5.1: Side Channel and Wetland Conditions	Degradation, elimination and loss of access to peripheral freshwater habitat, including side-channels and freshwater wetlands.
	5.2: Floodplain Condition	Degradation, elimination and loss of access to the over or beyond bank habitat, of streams and rivers that is periodically inundated during high flows.
Channel Structure and Form	6.1: Bed and Channel Form	Changes to river, stream, lake, estuarine tributary and distributary channel form, including width to depth ratios, sinuosity and bedload movement such as the loss (scour) or fill (aggradation) of the channel.
	6.2: Instream Structural Complexity	Decline of the instream habitat quality. Based on the degree of habitat complexity and variety, includes the quantity and variability of stream depth and pools of varying size and depth.
Sediment Conditions	7.2: Increased Sediment Quantity	Increased input of sediment to the stream system.
Water Quality	8.1: Temperature	Water temperature deviations, either in intensity or duration, sufficient to have adverse effects on listed salmonids.
Water Quantity	9.2: Decreased Water Quantity	Habitat disturbances associated with abnormally (compared to background) low water flow, including but not limited to, increased temperature, loss of sediment, nutrients and barriers to passage and redd dewatering.
	9.3: Altered Flow Timing	Habitat changes associated with alterations to the background (natural) timing of water quantity instream.

1/ NOAA ecological concerns are commonly referred to as standardized limiting factors.
Source: NOAA (2012)

4.5 CLIMATE CHANGE

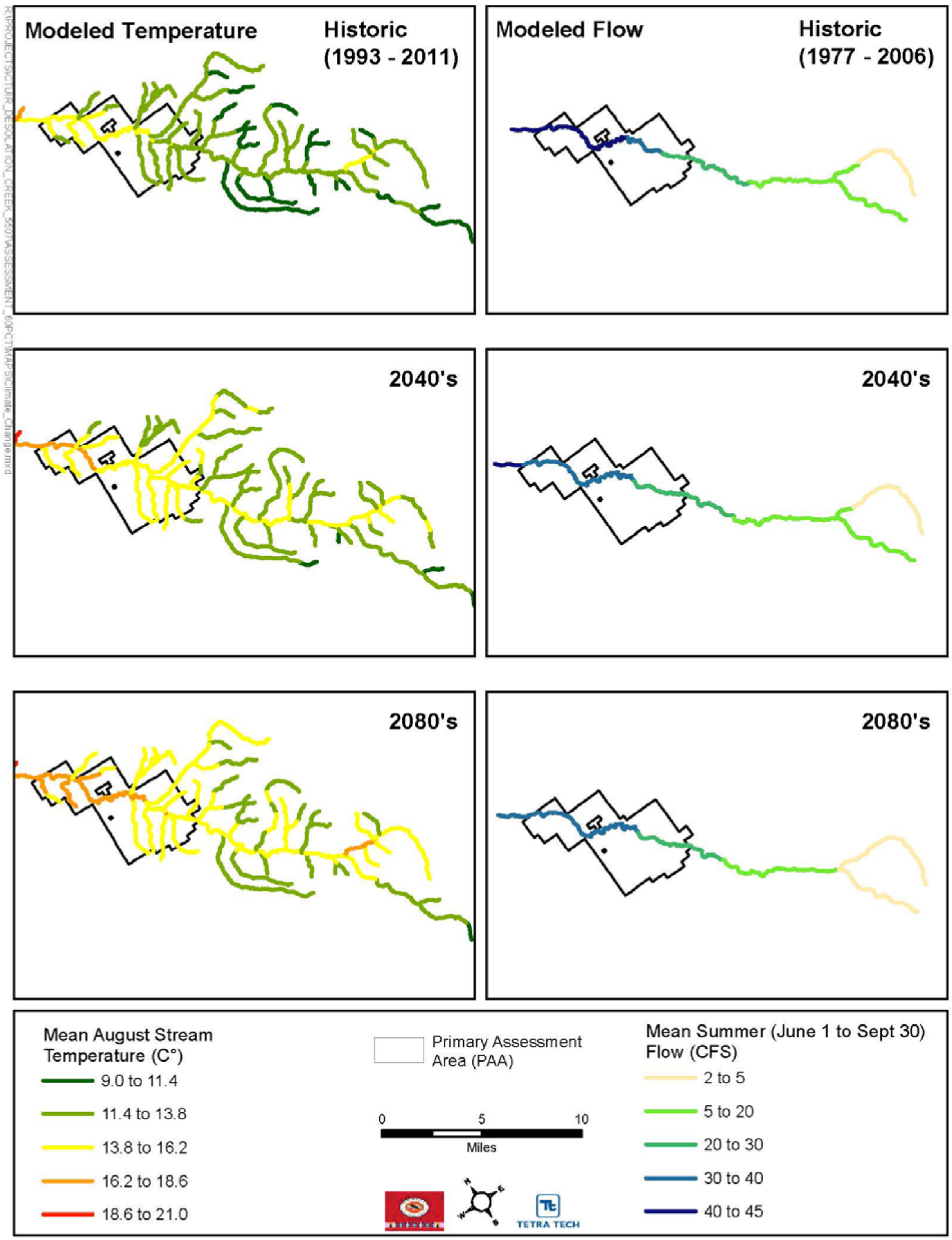
Changes in water quantity and temperature are expected to occur throughout the Pacific Northwest as a result of climate change (Casola et al. 2005). Changes in the timing of water availability are expected to have broad ecological and socioeconomic consequences due to numerous competing demands in the state, including for instream flow management for salmonids and agriculture (Snover et al. 2013).

Results from the Columbia Basin Climate Change Scenarios Project indicate dramatic changes in spring snowpack and a shift from snow and mixed-rain-and-snow to rain-dominant systems across most of the Pacific Northwest (Hamlet et al. 2013). Corresponding shifts in streamflow from spring and summer to winter are likely for basins that currently experience large winter snow accumulation (Hamlet et al. 2013). For areas on the east side of the Cascades, such as Desolation Creek, climate models do not show a significant decrease in late summer base flows; however, this is due to the very low late summer flows that occur under current conditions, therefore, increasing drought stress cannot significantly decrease base flows in the simulations (Tohver et al. 2014).

Stream temperatures are expected to increase in most rivers in the Pacific Northwest due to climate change (Independent Scientific Advisory Board 2007). Warming stream temperatures threaten salmon recovery particularly when temperatures are currently near tolerance thresholds. Changes in stream flow and temperature will effect species differently as they occupy different habitats and vary in timing of life history events, leading to varied exposure to altered conditions (Beechie et al. 2012). Hydrologically functional floodplains with complex channel patterns and associated high rates of hyporheic exchange, and functional streams and upland meadows providing water storage and temperature buffering may be important landscape nodes for river conservation in the face of ongoing disruption of global climate systems.

Figure 4.5-1 presents recent USFS modeling results for changes in mean summer flows along Desolation Creek and mean August stream temperature in the watershed. Both datasets use the global climate model A1B emissions scenario for the future periods, representing a medium warming scenario (USFS 2015a, 2015b). The trend toward warmer stream temperatures and lower summer flows is clear. In the PAA, the mean August stream temperature is expected to rise by approximately 2.5°C (4.5°F) and the mean summer flows are expected to drop by approximately 5.6 cubic feet per second by the 2080s.

Ruesch et al. (2012) identified the potential for dramatic negative effects for cold-water fish species in the John Day River Basin based on the projected increase in stream temperature and the decrease in flows associated with climate change. They predicted that climate induced changes in suitable summer thermal habitat would result in a sharp decline in the volume of suitable habitat by 2100. Isaak et al. (2015) provide a thorough summary of the expected effects of climate change on fish habitat and a vulnerability analysis for spring Chinook salmon, summer steelhead, bull trout, and redband trout.



Date source: USFS 2015a, 2015b

Figure 4.5-1. Modeled Historic and Future Climate Change Scenarios for Mean August Stream Temperatures, and Mean Summer Flows in the Desolation Creek Watershed

Studies that have evaluated the combined effects of climate change and habitat restoration suggest that restoration projects are likely to result in a net benefit to salmonids even with future shifts in temperature and flow (Battin et al. 2007; Justice et al. 2017). Particularly, restoration actions that increase habitat diversity could potentially increase the resilience of populations to climate change (Beechie et al. 2012) and restore or maintain natural thermal regimes to minimize future stream temperature increases (Isaak et al. 2015). Restoration of water availability (both surface and groundwater sources), as well as connections between hyporheic and surface flows (through floodplain and wet meadow restoration and reconnection projects), may provide these moderating conditions to Desolation Creek. Restoration strategies established for Desolation Creek and included in the action plan were developed with an understanding of the predicted local climate change impacts described above.

5 Reach-Scale Assessment

The reach-scale assessment results included in this section provide the scientific foundation and site-specific information needed to develop the project opportunities and potential restoration actions included in the action plan and project designs. The reach-scale assessment incorporates the existing watershed-scale data reported in Section 4 with the results from the analysis of field survey data to identify and quantify the limiting factors in Desolation Creek. The quantification of limiting factors facilitates identifying linkages between fish timing and use. By understanding these connections, reaches that are significant to the focal fish species can be determined, thereby providing a mechanism to identify desired future conditions for Desolation Creek.

The following subsections describe the reach assessment results including reach descriptions (Section 5.1), geomorphic and habitat characteristics (Section 5.2), and desired future conditions (Section 5.3). The Desolation Creek existing conditions and results of the reach assessment are also shown in Figures A-1a through A-1k of Appendix A.

5.1 REACH DESCRIPTIONS

Seven distinct reaches were delineated in Desolation Creek beginning from the mouth (RM 0.0) to the upstream extent of the PAA (RM 12.5). The reaches were first delineated in a desktop analysis (see Section 3.3.3) and the reach breaks were then field-verified during the reconnaissance survey. The reaches ranged from less than 1.0 mile in length to 4.2 miles in length.

The physical characteristics of each of the reaches are qualitatively summarized below, and the location of each reach is shown in Figure 5.1-1. Tables 5.1-1 through 5.1-7 (placed at the end of this section) include quantified reach characteristics, a reach map showing relative elevation maps, and representative photographs. The relative elevation maps in Tables 5.1-1 to 5.1-7 are colored by the difference in elevation compared to the water surface elevation at the time of survey (July 20, 2016).

Reach 1: Reach 1 is downstream of the PAA and extends from the confluence with the North Fork John Day River (RM 0.0) to RM 0.8. The Tollbridge Campground is on the right bank floodplain near the downstream end of this reach. The lower NF-10 Road Bridge crossing of Desolation Creek is near the upstream extent of this reach. There are no tributary inputs to Desolation Creek in Reach 1.

Reach 1 is a slightly sinuous, single-thread channel with a cobble-dominated substrate and riffle/rapid habitats. The reach is partially confined and has some available floodplain habitat including high-flow floodplain channels. There are occasional point bars in this reach and instream LWD is relatively scarce. Bank vegetation is dominated by grasses with a moderate amount of willows with riparian trees generally further back from the bank.

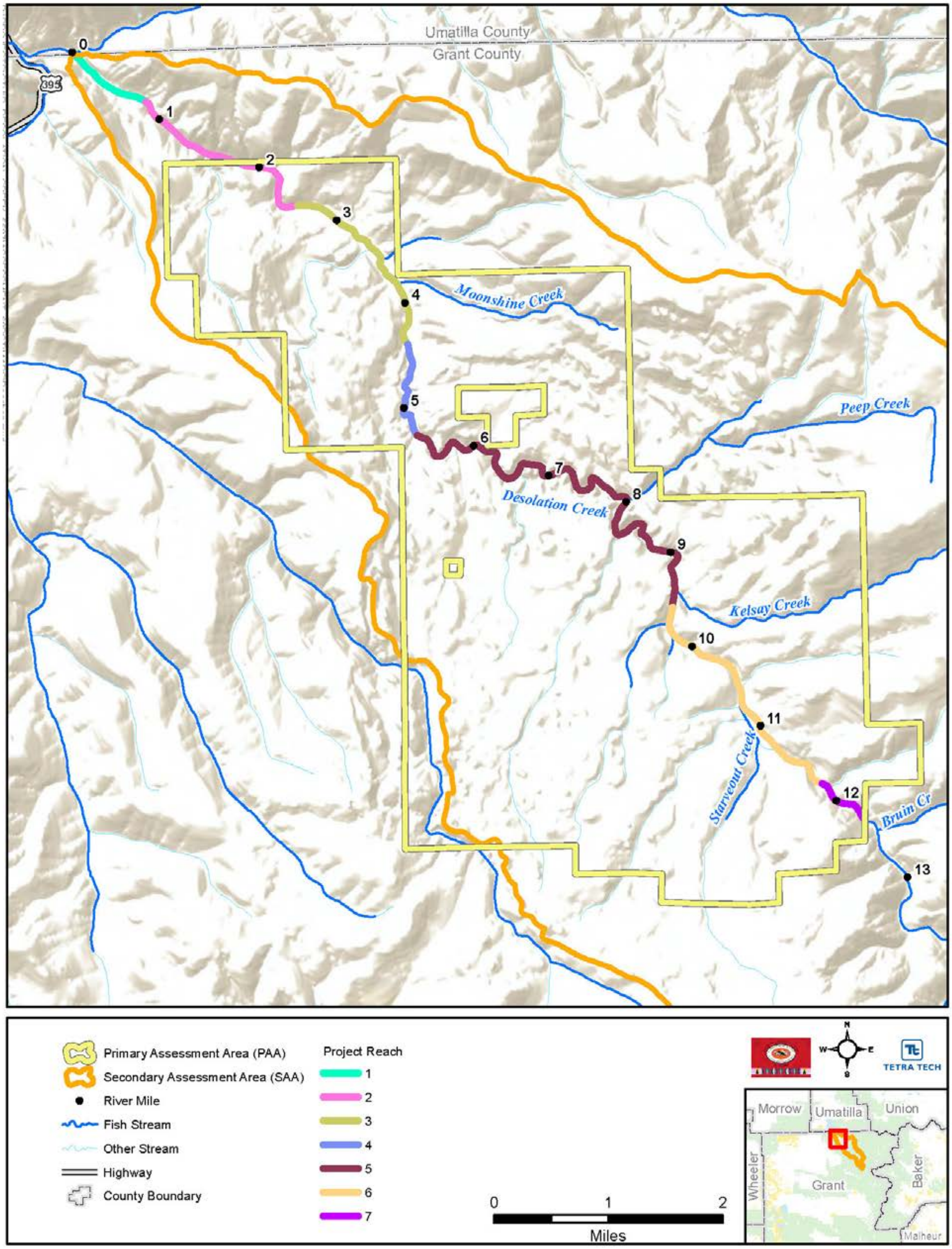


Figure 5.1-1. Project Reaches Identified within the PAA

Reach 2: Reach 2 extends from RM 0.8 to RM 2.6. Although this reach is relatively inaccessible by vehicle today, the remnants of the original access road for the Desolation Creek watershed remain to the north of the creek throughout most of this reach. The downstream extent of the PAA is located within this reach at approximately RM 2.0. There is one unnamed tributary stream that enters Desolation Creek from the south in this reach.

Reach 2 is a slightly sinuous, single-thread channel with cobble-dominated substrate in a highly confined, relatively steep, v-shaped valley. This reach has more boulders present than in Reach 1 and the presence of scour pools formed at bedrock outcrops was documented during the reconnaissance survey. There is very limited sediment storage potential and few bars in this reach. Instream LWD was low in this reach although more was observed during the reconnaissance survey than in Reach 1.

Near the upstream extent of this reach (approximately RM 2.3), Desolation Creek turns abruptly and flows north through a narrow, steep-sided, canyon with a vertical bedrock wall to the west. This approximately 0.25-mile segment of Reach 2 has boulder-dominated substrate and cascade habitat. In the middle of this segment, there is a partial barrier boulder step with a 4- to 5-foot drop (see photograph in Table 5.1-2). In this area, the original access road is cut into the bedrock valley wall. Boulders from road construction and maintenance that have been deposited in the creek are likely impacting current conditions and may contribute to the existing partial barrier.

Reach 3: Reach 3 extends from RM 2.6 to RM 4.4. The NF-1003 Road Bridge crossing of Desolation Creek is in this reach near RM 3.4. Reach 3 is one of two unconfined meadow reaches in the PAA; the other is Reach 6 described below. The presence of abandoned roads and other floodplain modifications is fairly extensive in this reach as are the visible impacts from livestock grazing in the riparian area (e.g., soil compaction, damage to streambanks, and vegetation impacts). Two unnamed tributaries and Moonshine Creek enter Desolation Creek in this reach.

Reach 3 is slightly sinuous and naturally unconfined, although roads and other anthropogenic modifications are confining features in this reach. The valley hillslopes in this reach are relatively low angle with hummocky, rolling topography. This reach is cobble-dominated and characterized by riffle and glide habitat with isolated pools. Mid-channel and point bars as well as secondary channels are frequent in this reach. There is more existing LWD in this reach than in downstream reaches; however, there are very few log jams (only one was observed during the reconnaissance survey). The floodplain is complex, with existing functional side-channels with good habitat and observed fish use. Multiple abandoned off-channel areas and high-flow channels exist within this reach.

Reach 4: Reach 4 extends from RM 4.4 to RM 5.3. The abandoned mainline road and campgrounds confine the channel and cut off the floodplain throughout much of this reach and riprap armored banks are present near RM 4.7. There are no tributaries entering Desolation Creek in this reach. Two high eroding cut banks are contributing sediment in this reach. A preliminary LiDAR change detection analysis (see Section 5.2.4) from 2006 to 2015 showed relatively large volumes of erosion during that time period.

Reach 4 is slightly sinuous and moderately confined. The surrounding topography is gently rolling and hummocky, characteristic of the prehistoric landslide deposits described in Section 4.1.2. Desolation Creek is moderately incised into these landslide deposits. This reach is characterized by cobble-dominated substrate, although there are more boulders than in neighboring reaches. The habitat of the reach consists of rapids and riffles with isolated pools and more LWD than in downstream reaches; however, no log jams were observed during the reconnaissance survey or are visible in 2016 aerial imagery. Small conifers and shrubs dominate the riparian zone, where vegetated. There are occasional point bars and isolated areas with accessible floodplain in this reach.

Reach 5: Reach 5 extends from RM 5.3 to RM 9.5 making it the longest reach in the PAA at 4.2 miles. The NF-1009 Road Bridge crossing of Desolation Creek is in this reach near RM 9.2. This reach is largely inaccessible by vehicle today. The abandoned mainline road follows the north side of the creek throughout this reach with washouts in several areas. Peep Creek, Kelsay Creek, and two unnamed tributaries enter Desolation Creek in this reach.

Reach 5 is a sinuous, single-thread channel that is moderately confined by V-shaped valley wall hillslopes. This reach is cobble dominated but the proportion of gravel is higher than in downstream reaches. The habitat comprises pools and riffles with some steeper rapids. During the July 2016 reconnaissance surveys, this was the only reach where an adult Chinook salmon was observed. Relatively large conifer trees are the dominate vegetation type in the riparian area of this reach. The quantity of LWD is low in this reach and there is only one jam that is visible in the 2016 aerial imagery near RM 8.6. There are occasional point and mid-channel bars with limited accessible floodplain in this reach, primarily on the inside of meander bends. These areas exhibit a stepped terrace topography indicating meander development as Desolation Creek eroded through deep valley fill likely consisting of prehistoric landslide debris, glacial, and volcanic deposits.

Reach 6: Reach 6 extends from RM 9.5 to RM 11.8. The upper NF-10 Road Bridge crossing of Desolation Creek is in this reach near RM 10.0. Reach 6 is one of two unconfined meadow reaches in the PAA; the other is Reach 3 described above. The impact of roads and other floodplain modification is fairly extensive in this reach as are the visible impacts from livestock grazing in the riparian area (e.g. soil compaction, damage to streambanks, vegetation impacts). Spring Creek, Starveout Creek, and several unnamed tributaries enter Desolation Creek in this reach. There is a Columbia Habitat Monitoring Program monitoring site in this reach located near RM 11.2.

Reach 6 is slightly sinuous and unconfined except for roads and other floodplain modifications. The reach is cobble-dominated; however, isolated gravel bars are found in this reach in areas with greater channel complexity and hydraulic conditions that allow for finer sediment storage. This reach is characterized by lower gradient riffle and glide habitat, with some pools. LWD is more abundant in Reach 6 than in downstream reaches with log jams and side-channels present, especially in the more unconfined portions of the reach. Sediment depositional areas, including point bars, lateral bars, and mid-channel bars, are frequent in this reach. The floodplain in this reach is complex with existing functional side-channels, good habitat, and observed fish use. Multiple abandoned off-channel areas and high-flow channels exist within this reach.

Reach 7: Reach 7 extends from RM 11.8 past the top of the PAA near RM 12.3. The NF-10 Road parallels the creek but is located high upslope and out of the floodplain. Upstream of the PAA there is a series of boulder and log weirs that were installed as restoration structures in the past. Park Creek enters Desolation Creek at the bottom of the reach at RM 11.9, and Bruin Creek enters Desolation Creek just upstream of the top of the PAA near RM 12.6.

Reach 7 is slightly sinuous and moderately confined by high valley hillslopes. This reach has a cobble-dominated substrate with relatively low gradient riffle and glide habitats and isolated pools. LWD is relatively abundant in this reach including the presence of two small log jams near RM 12.0. Point bars and sediment deposits associated with log jams are frequent in this reach although smaller in volume and consisting of coarser material than the deposits in Reach 6.

Table 5.1-1. Reach 1 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	0.0 to 0.8
Reach Length (miles)	0.89
Valley Setting	Partially confined
Channel Morphology	Single channel, sinuous, no islands and infrequent bars
Migration Process	Confined meandering
Rosgen Type	B3
Gradient	2.0%
Sinuosity	1.08
Bankfull Width (feet)	70
Width-to-Depth Ratio	39
Valley Bottom Width (feet)	167
Entrenchment Ratio	2.0
Substrate (dominant (%), subdominant (%))	Cobble (53%), gravel (39%)
LWD (pieces/mile)	13.5
Jams (jams/mile)	0
Pools (pools/mile)	3.4
Stream Power (watts/meter)	224

Location Map and Photos

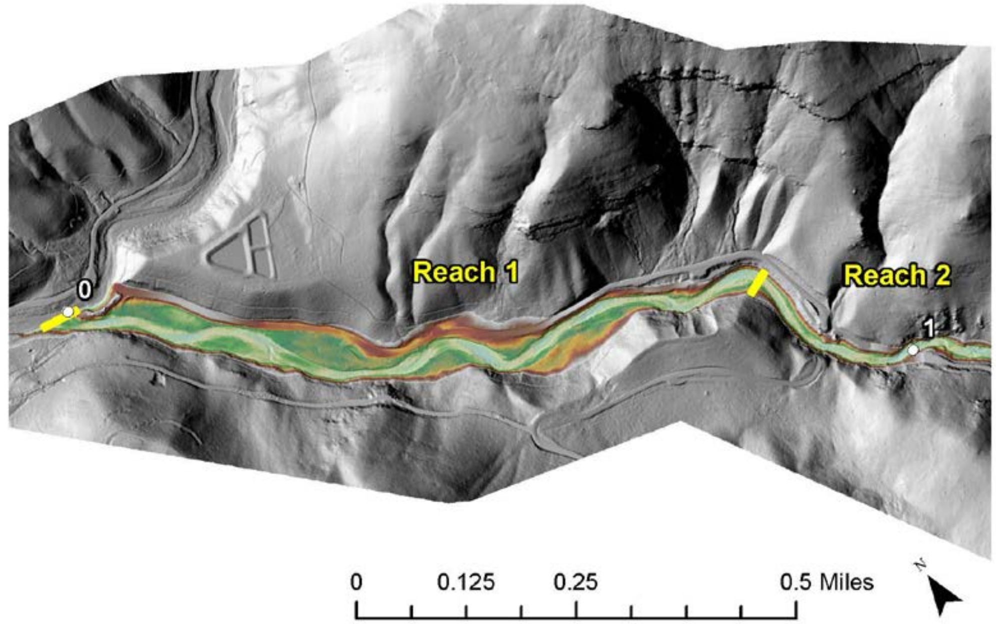


Table 5.1-2. Reach 2 Physical Characteristics, Location Map, and Photos

Reach Characteristics

River Miles (mapped)	0.8 to 2.6
Reach Length (miles)	1.91
Valley Setting	Confined
Channel Morphology	Single channel, straight, no islands and very infrequent bars
Migration Process	stable
Rosgen Type	B3
Gradient	2.8%
Sinuosity	1.06
Bankfull Width (feet)	51.4
Width-to-Depth Ratio	22
Valley Bottom Width (feet)	71
Entrenchment Ratio	1.4
Substrate (dominant (%), subdominant (%))	Cobble/boulder
LWD (pieces/mile)	12.6
Jams (jams/mile)	0.5
Pools (pools/mile)	17.3
Stream Power (watts/meter)	429

Location Map and Photos

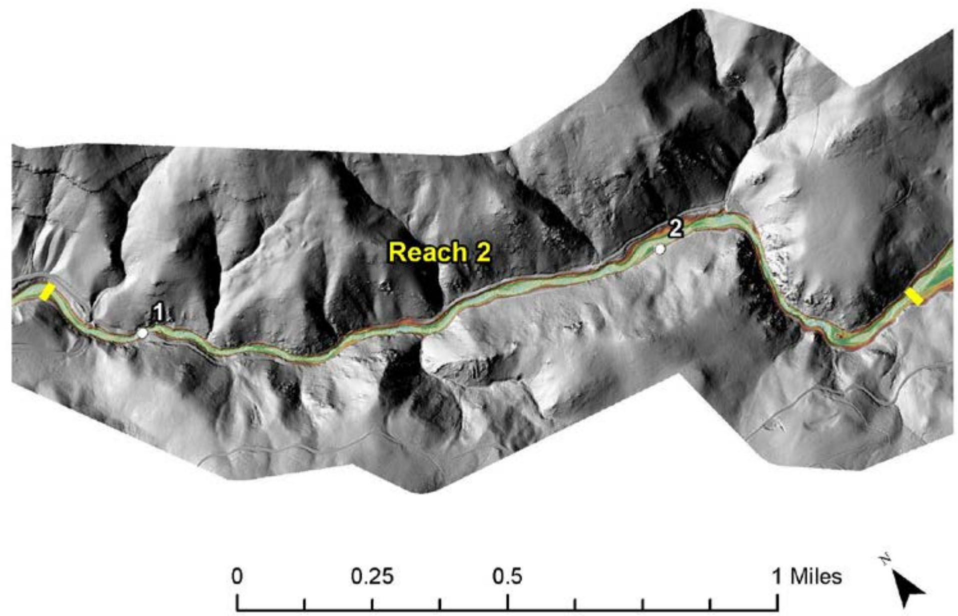


Table 5.1-3. Reach 3 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	2.6 to 4.4
Reach Length (miles)	1.84
Valley Setting	Unconfined
Channel Morphology	Multiple channels, sinuous, sparse islands and frequent bars
Migration Process	Irregular lateral, avulsions
Rosgen Type	C3
Gradient	1.9%
Sinuosity	1.07
Bankfull Width (feet)	81
Width-to-Depth Ratio	47
Valley Bottom Width (feet)	422
Entrenchment Ratio	5.2
Substrate (dominant (%), subdominant (%))	Cobble (53), boulder (23) and gravel (22)
LWD (pieces/mile)	26.0
Jams (jams/mile)	1.1
Pools (pools/mile)	4.3
Stream Power (watts/meter)	184

Location Map and Photos

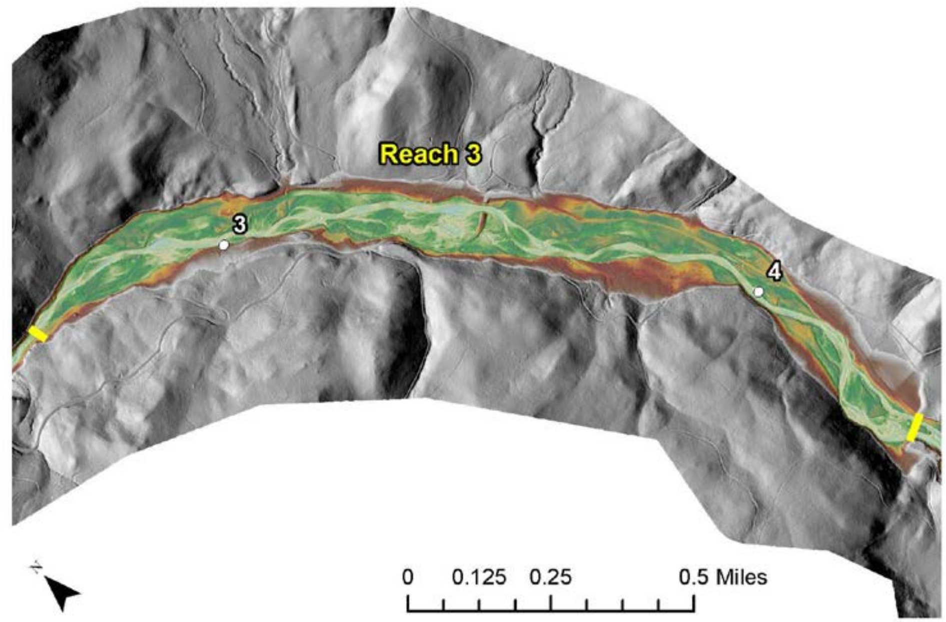


Table 5.1-4. Reach 4 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	4.4 to 5.3
Reach Length (miles)	0.98
Valley Setting	Partially confined
Channel Morphology	Single channel, sinuous, no islands and infrequent bars
Migration Process	Confined wandering
Rosgen Type	B3
Gradient	2.5%
Sinuosity	1.21
Bankfull Width (feet)	66
Width-to-Depth Ratio	35
Valley Bottom Width (feet)	153
Entrenchment Ratio	1.9
Substrate (dominant (%), subdominant (%))	Cobble/boulder
LWD (pieces/mile)	24.4
Jams (jams/mile)	0
Pools (pools/mile)	10.2
Stream Power (watts/meter)	305

Location Map and Photos

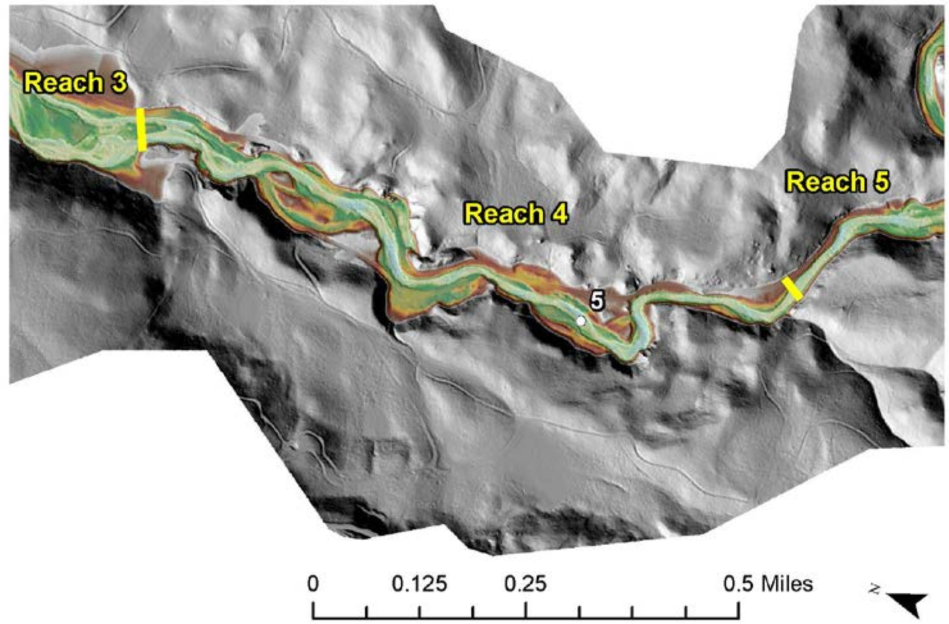


Table 5.1-5. Reach 5 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	5.3 to 9.5
Reach Length (miles)	4.68
Valley Setting	Partially confined
Channel Morphology	Single channel, meandering
Migration Process	Confined meandering
Rosgen Type	B3
Gradient	2.3%
Sinuosity	1.56
Bankfull Width (feet)	63
Width-to-Depth Ratio	30
Valley Bottom Width (feet)	129
Entrenchment Ratio	1.9
Substrate (dominant (%), subdominant (%))	Cobble (44), gravel (36)
LWD (pieces/mile)	18.4
Jams (jams/mile)	0.2
Pools (pools/mile)	6.4
Stream Power (watts/meter)	286

Location Map and Photos

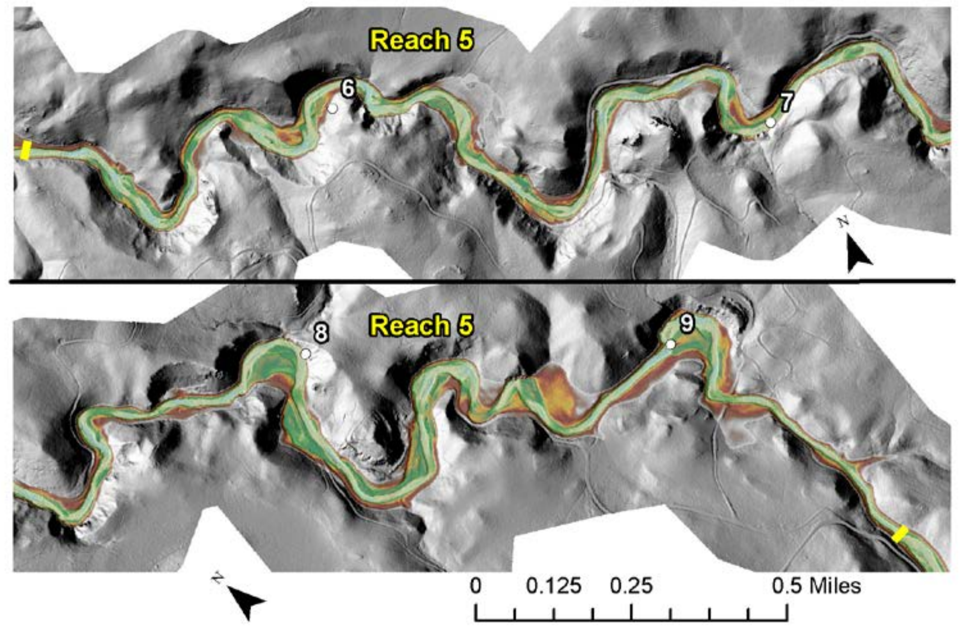


Table 5.1-6. Reach 6 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	9.5 to 11.8
Reach Length (miles)	2.39
Valley Setting	Unconfined
Channel Morphology	Multiple channels, sinuous, sparse islands and frequent bars
Migration Process	Irregular lateral, avulsions
Rosgen Type	C3
Gradient	1.3%
Sinuosity	1.08
Bankfull Width (feet)	79
Width-to-Depth Ratio	53
Valley Bottom Width (feet)	359
Entrenchment Ratio	4.7
Substrate (dominant (%), subdominant (%))	Cobble (65), gravel (27)
LWD (pieces/mile)	72.2
Jams (jams/mile)	3.8
Pools (pools/mile)	4.2
Stream Power (watts/meter)	112

Location Map and Photos

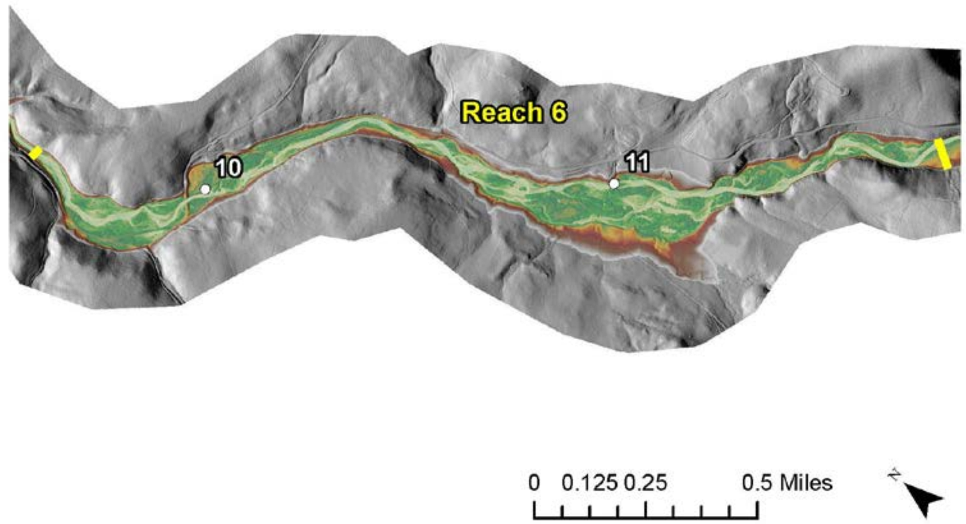
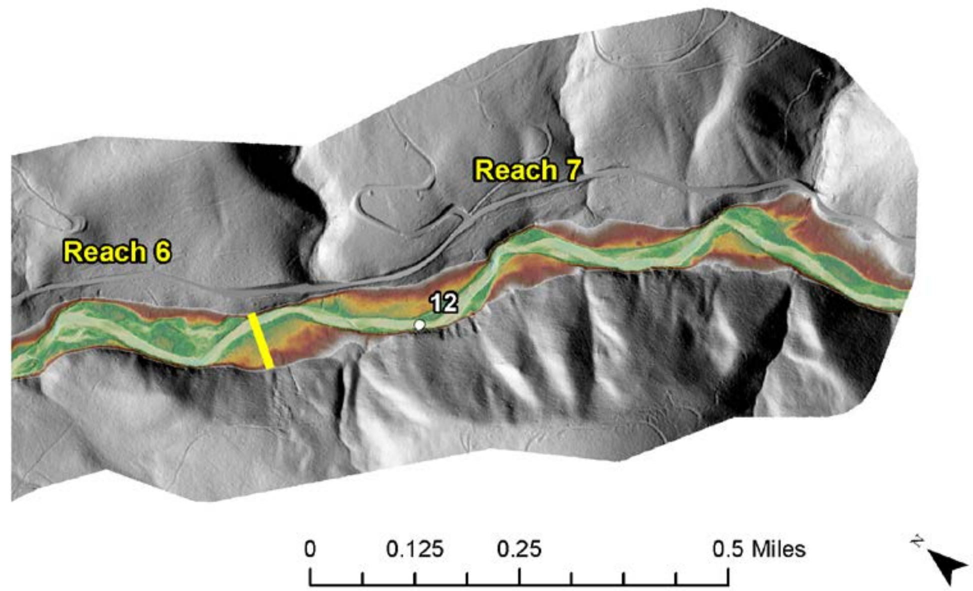


Table 5.1-7. Reach 7 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	11.8 to 12.3
Reach Length (miles)	0.56
Valley Setting	Partially Confined
Channel Morphology	Single channel, sinuous, no islands and infrequent bars
Migration Process	Confined meandering
Rosgen Type	B3
Gradient	1.3%
Sinuosity	1.11
Bankfull Width (feet)	66
Width-to-Depth Ratio	31
Valley Bottom Width (feet)	122
Entrenchment Ratio	1.6
Substrate (dominant (%), subdominant (%))	Cobble/Gravel
LWD (pieces/mile)	68.1
Jams (jams/mile)	3.6
Pools (pools/mile)	5.4
Stream Power (watts/meter)	123

Location Map and Photos



5.2 GEOMORPHIC AND HABITAT CHARACTERISTICS

Geomorphic and habitat conditions were recorded during field surveys, and desktop analyses were conducted to characterize conditions with respect to channel migration and channel evolution, floodplain connectivity, sediment transport dynamics, the role of LWD, and the impact of land use practices (historical and current) on reach-scale processes and habitat availability. The geomorphic analyses utilized aerial photography, topographic data, historical information, geologic mapping, and other data sources to identify features such as gradient, confinement, geologic setting, sediment characteristics, channel dimensions (width-to-depth ratios), stream bed morphology, number of pools and frequency, sinuosity, discharge, and other functional characteristics within the PAA. The metrics used for the reach assessment were calculated from a combination of field measurements and the topographic surface. The metrics are intended to provide quantifiable measures to evaluate channel morphology and in-channel characteristics in terms of limiting factors.

The geomorphic and habitat conditions in Desolation Creek are tightly coupled with the local geology and glacial history, as described in Section 4. Human disturbance has also had an impact on geomorphic conditions, particularly in reaches that are more sensitive to disturbance. The relative confinement from valley hillslopes has a strong influence on the reach-specific geomorphic characteristics of Desolation Creek.

The level of confinement impacts the potential for the channel to adjust laterally or vertically, as well as affecting bed material transport characteristics and the availability for sediment storage in bars. Reaches with higher sediment storage capacity and lateral mobility are commonly referred to as storage, or response reaches, whereas reaches with limited sediment storage areas and limited lateral mobility are referred to as transport reaches. In Desolation Creek, the unconfined Reaches 1, 3, and 6 are good examples of response reaches while Reach 2 is a good example of a transport reach. Reaches 4 and 5 primarily transport reaches, but have isolated areas with response reach characteristics.

Figure 5.2-1 shows the longitudinal profile of the Beaver Creek channel bed elevation, along with the valley width and bankfull width. The location of the seven reaches, their average channel gradient, and the location of the PAA and road crossings are shown on the figure for reference. The channel gradient of Desolation Creek is lowest in Reaches 3 and 6, at 1.9 to 1.3 percent respectively. These reaches are also the unconfined reaches with the greatest valley width, as shown in Figure 5.2-1. The highest gradient is in Reach 2 at 2.8 percent.

The following subsections describe specific geomorphic and habitat characteristics that have been evaluated including channel morphology and migration processes (Section 5.2.1), channel and floodplain complexity (Section 5.2.2), floodplain inundation and connectivity (Section 5.2.3), sediment characteristics (Section 5.2.4), LWD (Section 5.2.5), riparian vegetation (Section 5.2.6), and reach-scale fish habitat (Section 5.2.7).

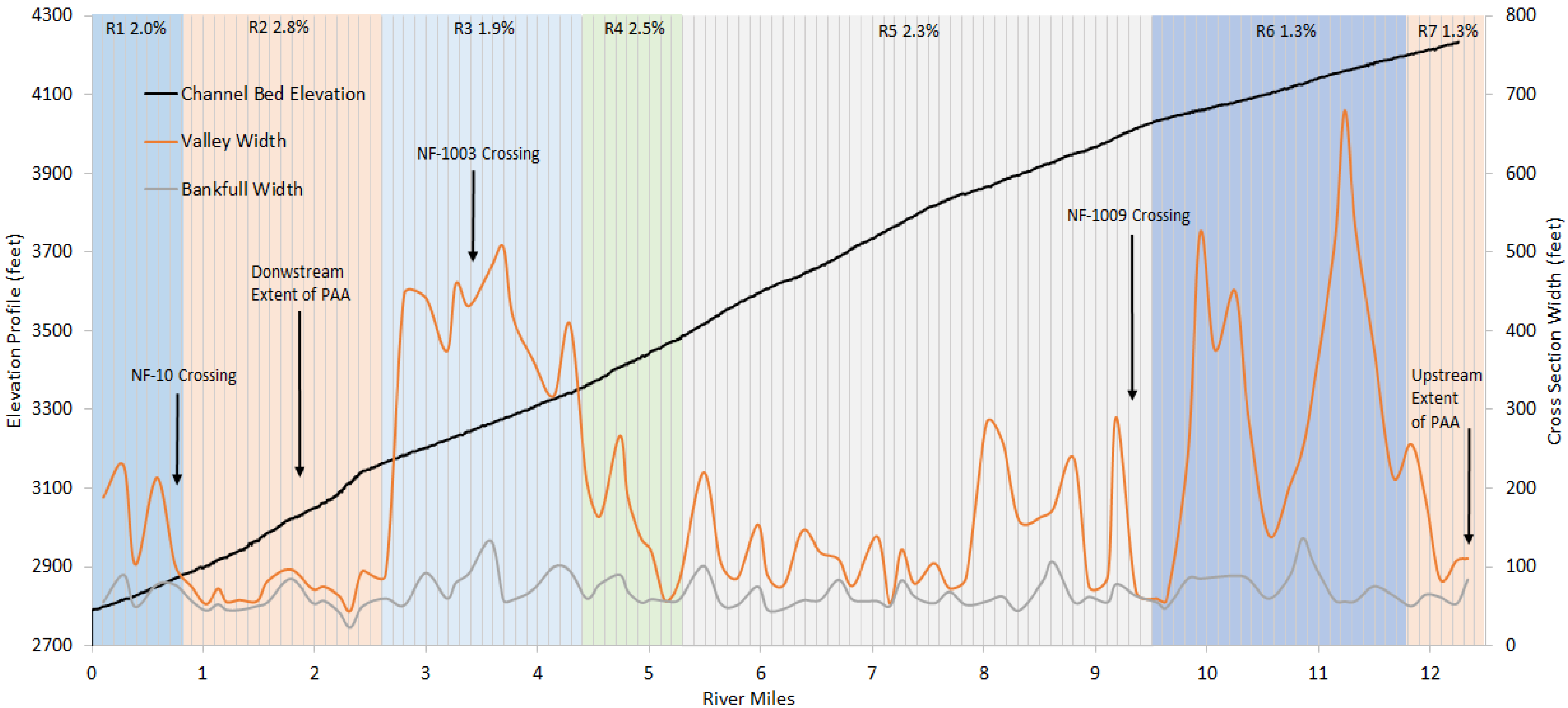


Figure 5.2-1. Longitudinal Profile of Channel Bed Elevation, Valley Width, and Bankfull Width in the PAA

5.2.1 Channel Morphology and Migration Processes

Many factors govern the physical processes and resulting channel morphology of rivers. As described in Section 4.1.2, a history of tectonic uplift, volcanism, massive landslides, and alpine glaciation has formed the complex landscape of the Desolation Creek watershed. This landscape complexity is a dominant factor controlling the channel morphology of Desolation Creek as shown by differences between reaches in valley confinement, gradient, channel dimensions, and substrate characteristics. The metrics in Tables 5.1-1 through 5.1-7 provide descriptive characteristics of channel morphology for each reach.

The source and size of substrate and bank materials is also a dominant factor controlling channel morphology and limiting the rate and character of channel migration. Purely alluvial rivers, meaning those that are formed only in sediments carried there by the flow of the river, have the greatest capacity for channel migration. Rivers with substrates and/or banks that have a proportion of material that is over-sized (e.g., glacial deposits, landslide deposits) have limited channel migration potential. This effect can be exaggerated by channel incision and the resulting substrate coarsening.

The channel migration analyses included an assessment of historic channel locations over time and the presence of bank erosion, which is a key indicator for active channel migration. The locations of eroding banks, armored banks, and floodplain berms were mapped during field surveys. The analysis utilized a series of historic aerial images acquired from 1946, 1966, 1967 (incomplete coverage), and 1980; NAIP imagery from 1995, 2005, 2006, 2011, and 2014; as well as the high resolution aerial images collected in 2016 simultaneously with the topo-bathymetric LiDAR data collection. A review of the imagery for the entire PAA indicates that Desolation Creek is generally stable laterally in the confined reaches (Reaches 1, 2, 4, 5, and 7) and therefore channel migration characteristics were not evaluated further in these areas. Historic channel locations were mapped in the unconfined reaches (Reaches 3 and 6) from the aerial imagery from 1946, 1966, 1980, 1995, 2006, 2011, and 2016. In general, there was more lateral channel migration in Reach 6 than in Reach 3 from 1946 to 2016, as shown in Figure 5.2-2. The most laterally active areas were near RM 3.1 in Reach 3 and from RM 9.8 to 10.2 and RM 10.6 to 11.5 in Reach 6. It should be noted that the aerial images show many paleochannels that could not be confirmed as active during the period from 1946 to 2016. These channels could have been briefly active in-between the gaps in imagery (e.g., between 1946 to 1966, between 1966 to 1980, etc.) or could also have been active prior to 1946. If paleochannels were active prior to 1946 it could not be determined if the paleochannels were tens, hundreds, or thousands of years old. In any case, they do show additional evidence or channel migration in the unconfined reaches.

The historic channel mapping was also used to calculate channel migration rates and the meander belt width using the Channel Migration Toolbox (Legg et al. 2014). Table 5.2-1 includes channel migration characteristics and migration rates for Reaches 3 and 6. The highest rate of channel migration in Reach 3 was from 1946 to 1966 with average channel migration rates of approximately 2 feet per year and maximum rates of 14 feet per year. Reach 6 had the highest rate of channel migration from 2006 to 2011 with an average of approximately 4 feet per year and a maximum of approximately 35 feet per year.

Table 5.2-1. Channel Migration Characteristics for Unconfined Reaches (Reaches 3 and 6)

Reach	Sinuosity	Maximum Valley Bottom Width (ft)	Meander Belt Width (ft)	Photo Years	Average Channel Migration Rate (ft/yr)	Maximum Channel Migration Rate (ft/yr)
Reach 3	1.07	497	350	1946 to 1966	1.7	14.3
				1966 to 1980	0.8	2.7
				1980 to 1995	0.9	2.4
				1995 to 2006	1.6	3.4
				2006 to 2011	1.4	6.4
				2011 to 2016	0.6	2.7
Reach 6	1.08	670	450	1946 to 1966	1.8	14.4
				1966 to 1980	2.4	19.4
				1980 to 1995	2.3	20.0
				1995 to 2006	1.0	4.5
				2006 to 2011	3.6	35.2
				2011 to 2016	1.1	5.1

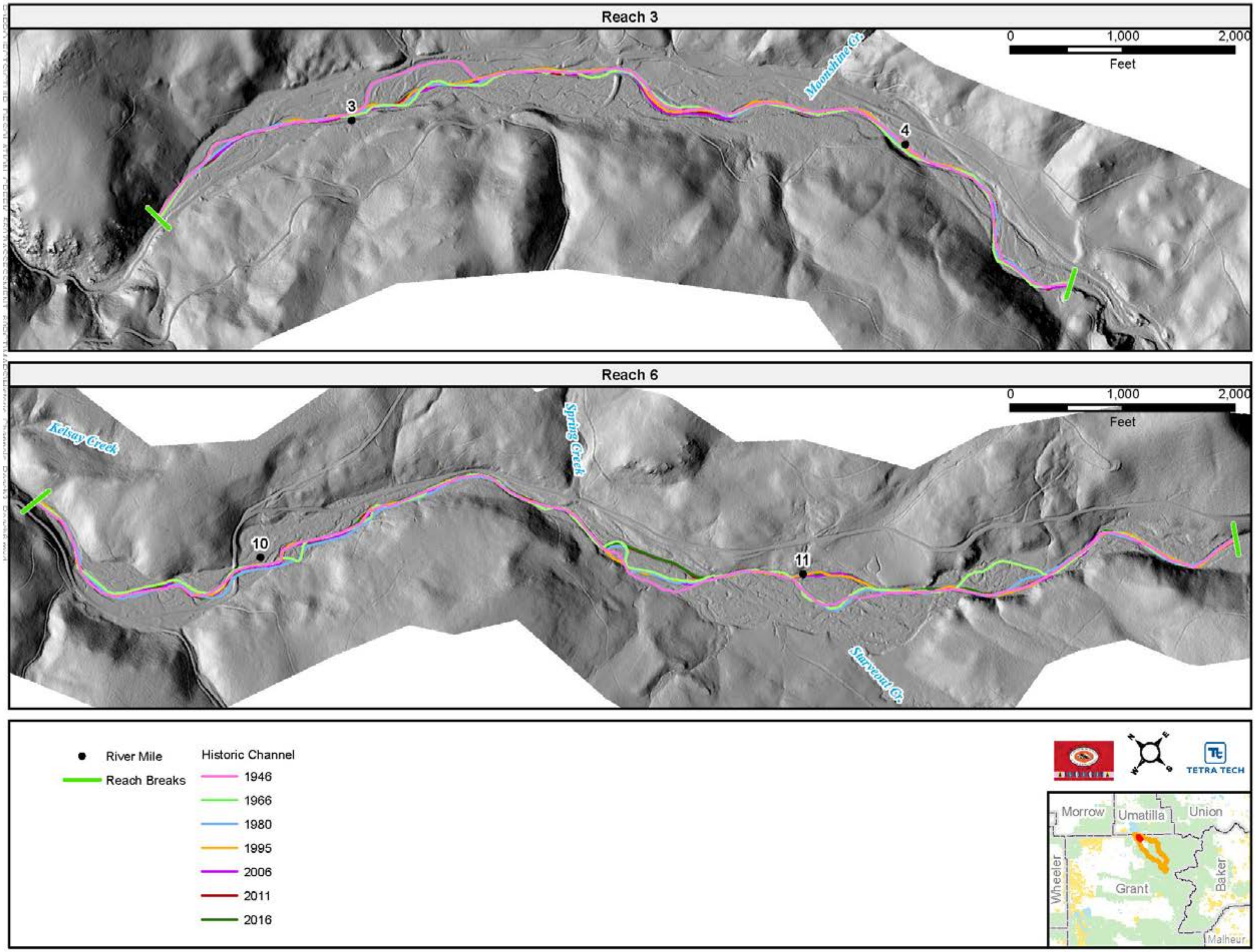


Figure 5.2-2. Historic Channel Mapping From 1946 to 2016 in Reaches 3 and 6

5.2.2 Channel and Floodplain Complexity

The 2016 topo-bathymetric LiDAR data, described in Section 3.3.2, and associated orthoimagery allowed for a detailed investigation of channel and floodplain complexity under existing conditions. A Relative Elevation Model (REM) was developed using the 2016 topo-bathymetric LiDAR as shown in Figures A-1a through A-1k of Appendix A. The REM is a powerful tool for visualizing floodplain features because it removes the slope of the valley (i.e., detrending) and reveals subtle changes in floodplain topography. The visualization provided by the REM allows for identification of landforms and floodplain features including alluvial fans, terraces, tributary channels, high-flow channels, and disconnected floodplain channels. The REM also helps to identify anthropogenic features including roads, bridges, earthen berms, and other bank protection. It assists in identifying the location of terraces and the network of abandoned and disconnected channels along with areas with a high potential for restoring side-channel habitat versus areas with low potential.

In general, the greatest channel and floodplain complexity was found in the unconfined reaches (Reaches 3 and 6). These reaches had greater instream complexity and more side channels, off-channel habitat, as well as high-flow and disconnected floodplain channels. Roads, bridges, bank protection, and floodplain berms were found to be impacting floodplain complexity, particularly in Reaches 3 through 6.

Channel and floodplain complexity was assessed for Reach 6, in part, by channel and floodplain mapping of landforms and relevant topographic features. The results of this analysis are included in the Desolation Creek Reach 6 (RM 9.5 – 11.8) Habitat Restoration – 30 Percent Design Alternatives Submittal (Tetra Tech 2017b).

5.2.3 Floodplain Inundation and Connectivity

Floodplain inundation and connectivity specifically within the PAA were evaluated based on the results from hydraulic modeling, floodplain inundation mapping and identification of disconnected areas. A planning-level hydraulic model was developed based on the 2016 topo-bathymetric LiDAR data. The peak discharges used for input into the hydraulic model and later used in project designs are contained in Table 5.2-2. Hydraulic model outputs of water surface elevation, flow depth, and velocity were used to map floodplain inundation and evaluate floodplain connectivity for the 2-year, 10-year, and 100-year flood events. The inundation map series Figures A-2a through A-2k of Appendix A show the water surface extent at the time of survey (July 20, 2016), the flood inundation extent for the 100-year flood, and the depth for the 2-year event.

Table 5.2-2. Peak Discharges for the 2-Year, 5-Year, 10-Year, 25-Year, 50-Year, and 100-Year Flood Events within the PAA [1/]

Location Range	Recurrence Interval (years) 2-year (cfs)	5-year (cfs)	10-year (cfs)	25-year (cfs)	50-year (cfs)	100-year (cfs)
Bruin Creek (RM 12.5) to Park Creek (RM 11.9)	688	922	1,080	1,280	1,430	1,590
Park Creek (RM 11.9) to Spring Creek (RM 10.5)	707	949	1,110	1,320	1,480	1,640
Spring Creek (RM 10.5) to Kelsay Creek (RM 9.5)	743	1,000	1,180	1,410	1,580	1,760
Kelsay Creek (RM 9.5) to Peep Creek (RM 8.0)	840	1,140	1,350	1,620	1,820	2,030
Peep Creek (RM 8.0) to Moonshine Creek (RM 3.9)	871	1,190	1,410	1,700	1,920	2,150
Moonshine Creek (RM 3.9) to the confluence (RM 0.0)	874	1,210	1,440	1,740	1,970	2,200

1/ Flows estimated using regional regression equations (Cooper 2006).
cfs = cubic feet per second

Floodplain connectivity is restricted to varying degrees throughout the PAA. Table 5.2-3 includes the floodplain inundation and connectivity for each reach. In some areas, flood inundation and floodplain connectivity is physically obstructed due to the presence of roads, floodplain berms, or other land modifications. Floodplain connectivity has also been reduced due channel simplification and incision which are the result of a combination of land-use impacts related to timber harvesting, instream wood removal, and channel straightening and others (described in Section 4.3). Reaches 3, 4, and 6 have the highest percentage of disconnected floodplain with 45.7, 48.6, and 39.9 percent respectively. Reaches 2 and 7 have the least amount of disconnected floodplain with 1.2 and 1.7 percent, respectively.

Table 5.2-3. Floodplain Inundation and Connectivity by Reach in the PAA

Reach	100-Year Inundation Area (acres)	Disconnected Floodplain Area (acres)	Total Floodplain Area (acres)	Percent of Floodplain Disconnected
Reach 1	9.3	3.0	12.2	24.2%
Reach 2	14.4	0.2	14.6	1.2%
Reach 3	41.7	35.0	76.7	45.7%
Reach 4	9.0	8.5	17.5	48.6%
Reach 5	44.6	14.0	58.7	23.9%
Reach 6	46.8	31.1	77.9	39.9%
Reach 7	6.5	0.1	6.7	1.7%

A reach-scale hydraulic model was been developed for Reach 6 to assist in the design development process. The results of this analysis are included in the Reach 6 (RM 9.5 – 11.8) Habitat Restoration – 30 Percent Design Alternatives Design Submittal (Tetra Tech 2017b).

5.2.4 Substrate, Sediment Supply, and Transport Characteristics

The analysis of sediment characteristics is based on field data, observations, modeling, and previous assessments of sediment in the North Fork John Day River (BLM 2010). Field data and observations were made on two occasions during the reconnaissance survey and the reach-based survey of Reach 6. The field data and observations identified sediment sources and patterns of erosion and deposition, and were used to calculate grain-size distributions at sample locations. The sediment transport analyses used empirical data from field surveys and hydraulic modeling results.

Sediment Grain Size Distributions

Pebble counts and a bulk sediment sample were collected at various locations in the PAA and SAA to characterize sediment grain size distributions. Pebble counts were conducted in Reach 1 near RM 0.2, in Reach 3 near RM 3.1, in Reach 5 near RM 9.0, in Reach 6 near RM 10.0, downstream of Junkens Creek near RM 14.3, downstream of Battle Creek near RM 16.4, and in both the North Fork and South Fork of Desolation Creek downstream of the NF-45 Road. A bulk sediment sample was also collected at the Reach 6 site near RM 10.0. Sediment sample locations within the PAA are shown in Figures A-1a through A-1k of Appendix A. Sediment characteristics such as sediment grain size distribution, characteristic grain sizes (i.e., D_{16}, D_{50}, D_{84}), and the percentage sediment in each size class (i.e., sand, gravel, cobble, and boulder) have been calculated for each sample location, as shown in Table 5.2-4.

Table 5.2-4. Sediment Characteristics at Sample Locations on Desolation Creek, South Fork Desolation Creek, and North Fork Desolation Creek

Sample Location	Characteristic Grain Size			Percent Sand	Percent Gravel	Percent Cobble	Percent Boulder
	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)				
Reach 1 (RM 0.2)	25	85	180	2%	39%	53%	7%
Reach 3 (RM 3.1)	46	130	320	2%	22%	53%	23%
Reach 5 (RM 9.0)	24	87	280	2%	36%	44%	18%
Reach 6 (RM 10.0)	23	49	82	0%	70%	30%	0%
Reach 6 Bulk (RM 10.0)	3	35	93	12%	56%	32%	0%
Reach 6 (RM 11.8)	38	110	210	0%	27%	65%	7%
Downstream of Junkens Creek (RM 14.3)	51	110	290	1%	22%	59%	18%
Downstream of Battle Creek (RM 16.4)	23	63	180	2%	49%	41%	9%
South Fork of Desolation Creek (near NF-45 Rd)	12	32	59	4%	84%	11%	1%
North Fork Desolation Creek (near NF-45 Rd)	38	120	260	2%	24%	58%	17%

Sediment samples reveal a relatively consistent cobble-dominated substrate throughout most (6 out of 8) sample locations with the proportion of cobbles ranging from 41 to 58 percent, and the D_{50} ranging from 63 to 130 millimeters (mm). There were two gravel-dominated sediment sample locations; one in Reach 6 near RM 10.0, and the other on the South Fork of Desolation Creek. The pebble count and bulk sample location near RM 10.0 represents the isolated depositional areas of

Reach 6 (described in Section 5.1) that have a finer size distribution and a high percentage of gravel (70 percent) and a D_{50} of 49 mm. The South Fork Desolation Creek sediment sample is representative of the substrate throughout this reach with the highest percentage of gravel (84 percent) and a D_{50} of 32 mm.

Sediment Sources and Sediment Supply

The background erosion rates in the Desolation Creek watershed are estimated to be in the range of 1 to 6 tons of sediment per square mile (USFS 2008). Periods of increased sediment supply occur episodically due to large storm events or disturbance such as wildfire. Landslides, bank erosion, channel incision, road failures, and post-fire erosion are the main sources of coarse sediments supplied to Desolation Creek. Fine sediment sources include runoff from roads, disturbed soils, and burned areas. The source of fine sediments extends to the upper extent of the perennial and ephemeral stream network.

Landslides adjacent to Desolation Creek and larger tributaries produce episodic sediment pulses and also may be chronic sediment sources from erosion at the toe. Several landslides were observed during the reconnaissance survey that have contributed considerable quantities of coarse sediment. One recent large landside in Reach 4 was detected in the DEM comparison from 2006 to 2016. This landslide, shown in Figure 5.2-3, was located near RM 4.5.

Figure 5.2-3. Recent Landslide Example in Reach 4 near RM 4.5

Bank erosion and channel migration, particularly channel avulsions, can contribute large quantities of sediment. Vegetation clearing, cattle grazing, and other land uses can make streambanks more susceptible to erosion by reducing the cohesion effect provided from root systems. Bank erosion was more common in the unconfined reaches (Reaches 3 and 6) than in the remaining reaches which had a low proportion of eroding banks and relatively coarse, erosion resistant, banks.

As described in Section 4.1.5, wet meadows and upland meadows are a defining characteristic of the Desolation Creek Watershed. Incised meadow channels are a chronic source of both coarse and fine sediments. The photographs in Figure 5.2-4 show two examples of incised meadow channels: one from Starveout Creek near the Desolation Creek confluence (photograph on the left) and another from an unnamed tributary flowing through an upland tributary in Reach 6. Depending on stream size and gradient, incised tributary channels can contribute considerable quantities of both coarse and fine sediments.

Figure 5.2-4. Channel Incision Examples on Starveout Creek and an Unnamed Tributary in an Upland Meadow

Road surface erosion can result in an increased fine sediment supply. As noted in Section 4.3-6, the Watershed Erosion Prediction Project model estimate of erosion from the existing road system is approximately 1.8 tons of sediment per square mile, which is about 30 percent above the natural background erosion, assuming a high rate of hillslope erosion (USFS 2008).

Forest fires can increase sediment sources in several ways. An increase in the fine sediment supply often occurs in intensely burned areas due to changes in runoff processes and the presence of fire-induced hydrophobic (water-repellent) soils. The potential of an increase in coarse sediment supply also occurs in burned areas due to an increased potential for floods, debris flows, and landslides. As described in Section 4.3.4, there have been recent wildfires in the Desolation Creek watershed in 1996, 2006, and 2007 ranging from 152 acres to 5,001 acres in size (USFS 2008).

Sediment Transport Characteristics

Patterns of bed material transport and storage are determined by a complex interaction between the sediment supply, transport capacity (i.e., the ability to transport the incoming sediment supply), the availability for sediment storage in bars and islands, and the potential for the channel to adjust laterally or vertically. Reaches with high sediment storage availability and lateral mobility are commonly referred to as storage, or response, reaches whereas reaches with limited sediment storage areas and limited lateral mobility are referred to as transport reaches. In Desolation Creek, Reaches 3 and 6 are good examples of response reaches due to their relatively high capacity for sediment storage and lateral mobility because of their wider valley bottoms, favorable entrenchment ratios, and lower gradients and stream power (see Tables 5.1-3 and 5.1-6).

The sediment transport patterns and processes have been assessed by evaluating channel adjustments over time (erosion and deposition), and hydraulic characteristics determined from hydraulic modeling. The sediment transport analyses utilize the results from sediment data collected at sediment sample sites within each reach (see Table 5.2-4). Sediment transport was evaluated, in part, by evaluating excess shear stress based on the Shields' number, which relates the fluid force acting on sediment to the weight of the sediment. The inputs were calculated from the hydraulic modeling results, channel gradient, and sediment size estimated from surface sediment samples. The analysis was performed by comparing the critical shear stress (shear stress required to initiate motion) for the median particle size (see Table 5.2-4) with the bed shear stress for the peak flows (see Table 5.2-2).

Figure 5.2-5 shows the longitudinal distribution of shear stress, threshold grain size, and excess shear stress ratio. The excess shear stress ratio, which is the measure of how much additional shear stress is present than what is required to transport bed material, was calculated at sediment sample locations in reaches 1, 3, 5, and 6. The figure shows that Reach 2 has the highest shear stress and threshold grain size, while, reaches 3, 6, and 7 have lower shear stresses and threshold grain sizes than the other reaches. These data provide further evidence that Reach 2 is a sediment transport reach, while Reaches 3, 6, and 7 are sediment storage or response reaches.

Sediment transport analyses completed to support the alternatives analyses for the Reach 6 design development process are included in the Desolation Creek Reach 6 (RM 9.5 – 11.8) Habitat Restoration – 30 Percent Design Alternatives Submittal (Tetra Tech 2017b).

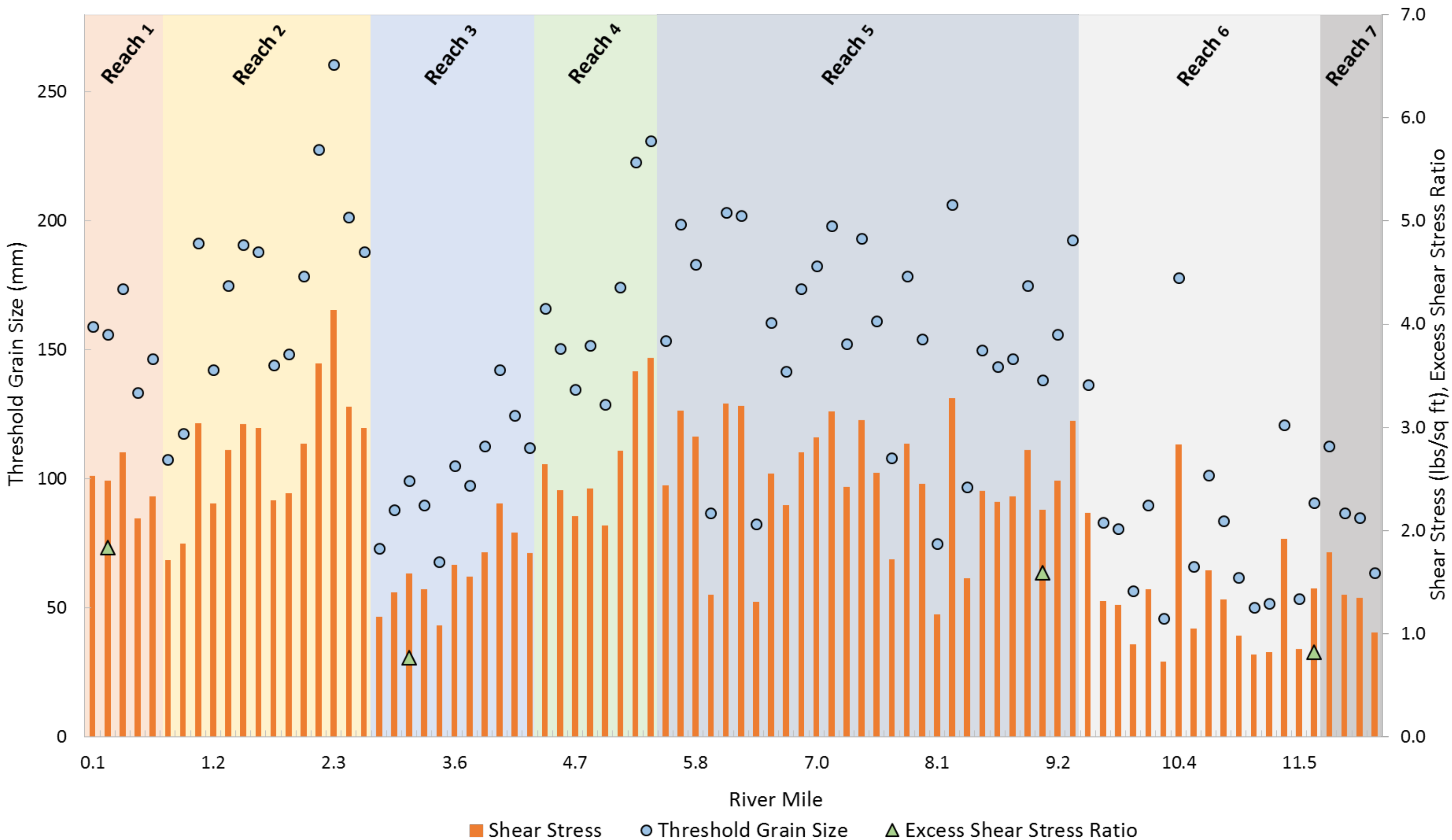


Figure 5.2-5. Hydraulics and Sediment Transport Characteristics in the PAA

5.2.5 Large Woody Debris

Pre-settlement LWD abundance in Desolation Creek is uncertain; however, a helicopter-based stream survey conducted by the Fish Commission of Oregon in 1961 documented the presence of large jams (Haas and Warren 1961). Although the aerial survey was not intended to be an LWD inventory, they noted the presence of eight log jams on Desolation Creek in a 10-mile section from about 0.5-mile upstream of Spring Creek (RM 11.1) to the confluence of the North and South Forks of Desolation Creek (RM 21.4). The surveys indicated that five of the eight log jams were quite large relative to most log jams observed during the field survey. The log jams were estimated to range from 40 to 90 feet wide and 30 to 140 feet long and were all noted to be impounding water (Haas and Warren 1961).

Historic LWD conditions for project area Reach 6 were described as having included a complex mixture of single large pieces and log jams, while the current conditions are described as a moderate mixture (BLM 2008). Previous surveys of Desolation Creek by the USFS found an average of about 8 pieces per mile for the mainstem ranging from 6.1 to 9.3 pieces per mile (USFS 2006).

The current quantity of LWD and log jams is low to moderate throughout the PAA of Desolation Creek. During the reconnaissance field survey, LWD within the bankfull channel was inventoried in the areas surveyed. LWD was counted and size classes were measured for each reach in sample areas during field surveys, and an additional LWD inventory was done throughout the PAA using high-resolution aerial imagery. Only the LWD in the medium (greater than 12 inches in diameter and 35 feet in length) and large (greater than 20 inches in diameter and 35 feet in length) LWD size classes were included in the LWD frequency estimates to be compared to the federal target of 20 pieces per mile. As shown in Table 5.2-5, the density of LWD ranged from 7 pieces per mile in Reaches 1 and 2, to 39 pieces per mile in Reach 6. Reach 6 also had the most log jams at 9 with a density of 3.8 jams per mile.

Table 5.2-5. LWD and Log Jam Abundance by Reach in the PAA

Reach Number	LWD[1/] Frequency (pieces/mile)	Number of Log Jams	Log Jam Frequency (jams/mile)	Percent in LWD Size Class[2/]		
				Small[3/]	Medium[4/]	Large[5/]
Reach 1[6/]	7	0	0.0	--	--	--
Reach 2[6/]	7	1	0.5	--	--	--
Reach 3	14	2	1.1	33%	50%	17%
Reach 4	13	0	0.0	45%	36%	18%
Reach 5	10	1	0.2	28%	50%	22%
Reach 6	39	9	3.8	54%	34%	12%
Reach 7	37	2	2.5	52%	26%	23%

1/ Large woody debris (LWD) were inventoried using high resolution orthoimagery and LWD frequency estimates adjusted for size error based on a complete LWD inventory in Reach 6 and LWD sample surveys in each reach. LWD pieces per mile were LWD larger than 12 inches diameter at breast height (dbh) and 35 feet in length (medium and large size class pieces).
2/ Percent of LWD in each size class determined from field survey data collected for a length of 20 times the bankfull width in Reaches 1 through 5 and 7, and a complete LWD inventory in Reach 6.
3/ Small size class LWD ranged from 6 to 12 inches dbh and greater than 20 feet in length
4/ Medium size class LWD ranged from 12 to 20 inches dbh and greater than 35 feet in length
5/ Large size class LWD was greater than 20 inches dbh and greater than 35 feet in length
6/ The quantity of LWD with size class measured was too low to determine distribution.

Reaches 1 through 5 were at or below the federal target of 20 pieces per mile with a diameter greater than 12 inches dimeter at breast height and 35 feet in length (NMFS 1996; USFWS 1998). However, Fox and Bolton (2007) determined that standard was low for larger streams east of the cascades (16 to 164 feet bankfull width). They found that those streams had an average of over 40 pieces per mile in unmanaged forested basins while others have observed quantities up to 140 pieces per mile (Inter-Fluve 2012). All reaches of the PAA were below the proposed Fox and Bolton (2007) LWD standard. The lack of LWD in Desolation Creek has resulted in channel incision, reduced instream complexity, and a lack of effective sediment sorting and sediment storage.

There is considerably more LWD stored on the floodplain, on bars and islands, and in abandoned channels than within the bankfull channel. This pattern has been observed in other river systems (Lassettre and Harris 2001). The floodplain LWD occurs in the greatest abundance in the unconfined meadow areas in Reaches 3 and 6.

Based on the description of Haas and Warren (1961) and documented impacts from previous land-use practices (described in Section 4.3), it is expected that the amount of naturally occurring LWD is well below historic levels due to riparian clearing, instream wood removal, and limited upstream recruitment potential.

Past restoration actions included adding some wood into the system, on USFS lands upstream of the PAA. The restoration actions included the placement of individual logs or channel-spanning boulders acting as weirs. Past restoration actions completed by the UNF are described in Section 6.1.2 and 6.1.3.

A complete inventory of LWD and jams was conducted in Reach 6 to support the alternatives analyses and design development process included in the Desolation Creek Reach 6 (RM 9.5 – 11.8) Habitat Restoration – 30 Percent Design Alternatives Submittal (Tetra Tech 2017b).

5.2.6 Riparian Vegetation

General vegetation descriptions and management implications were discussed earlier in Section 4.1.4, while this section describes riparian vegetation within the PAA. Lowland vegetation in Desolation Creek is generally characterized by ponderosa pine and Douglas-fir (*Pseudotsuga menziesii*), whereas grand fir (*Abies grandis*), subalpine fir, and lodgepole pine are the dominant trees in the higher elevations (USFS 2008). The vegetation analysis (Appendix B) classified 8.1 percent of the watershed as riparian, with the majority of the riparian corridor along Desolation Creek within the Northern Rocky Mountain Lowland – Foothill Riparian Forest Group (USNVC 2016). The dominant vegetation for the Northern Rocky Mountain Lowland-Foothill Riparian Forest Group is typically dominated by cottonwood (*Populus* spp.), with some conifers (typically ponderosa pine and spruce [*Picea* spp.]) or tall shrubs such as mountain alder (*Alnus incana*), red-osier dogwood (*Cornus sericea*), birch (*Betula* spp.), chokecherry (*Prunus virginiana*), and black hawthorn (*Crataegus douglasii*). Low shrubs, such as snowberry (*Symphoricarpos albus*) and currant (*Ribes* spp.) are also present. The herbaceous layer is usually relatively sparse and is dominated by either forbs or graminoids, with common species often including baneberry (*Actaea rubra*), western water hemlock

(*Cicuta douglasii*), horsetail (*Equisetum* spp.) and western mountain aster (*Symphyotrichum spathulatum* [*Aster occidentalis*]) (USNVC 2016).

Currently, riparian vegetation along Desolation Creek consists of tree species including ponderosa pine, Douglas-fir, and alder, as well as shrub and small trees, including willow, red-osier dogwood, mallow ninebark (*Physocarpus malvaceus*), black hawthorn, and chokecherry. A variety of grasses, sedges, and forbs are also present (see Appendix B).

Previous efforts by McAllister (2008) have reconstructed riparian conditions based on historical documentary records including GLO survey notes, photographs, and written accounts. This riparian vegetation reconstruction provides useful information about historic conditions in the region; however, it is not sufficient to quantify riparian vegetation changes. Written accounts specific to Desolation Creek are limited and there are no GLO survey notes available.

5.2.7 Reach-Scale Fish Habitat

There are a number of existing data sources that describe the reach-scale existing fish habitat and fish habitat potential in the PAA. For example, as described in Section 4.2.2, ODFW aquatic inventory surveys were conducted throughout the PAA in 1994. In addition, a steelhead intrinsic potential analysis has been completed by Cooney and Holzer (2006), and spawning survey data have been collected since 2004 are also available.

Fish habitat data were also collected during both the reconnaissance and reach field surveys for this Project. During the reconnaissance survey, habitat data were collected in each reach for a length of 20 times the bankfull width to obtain a representative sample, with the exception of reach 6 where habitat data were collected throughout the entire length. The current distribution of pools (e.g., pools/mile and percent pools) throughout the PAA was determined from a combination field survey data and a desktop assessment of hydraulic modeling results, the topo-bathymetric surface, and aerial imagery.

Table 5.2-6 contains summary data on fish habitat characteristics, intrinsic potential, and Chinook salmon redds. Reaches 2 and 4 have the greatest number of pools per mile and highest percent pool habitat. The ODFW aquatic habitat inventory identified Reaches 1 through 5 as being dominated by rapid habitat and Reaches 6 and 7 dominated by riffle habitat. Field surveys for this Project identified riffles as the dominant habitat in all reaches. The discrepancy in the proportion of riffle and rapid habitat in the 1994 ODFW inventory compared with the recent survey may be related to changing criteria for defining habitat types over time rather than a change in on-the-ground habitat conditions.

Reaches 1 and 6 have the highest percentage of length estimated as high intrinsic potential; however, Reach 1 has no observed redds while Reach 6 has a total of 42.2 total redds per mile based on all survey data over the period of data collection (2009 to 2015). Figures A-1a through A-1k in Appendix A show the survey redd locations.

Table 5.2-6. Fish Habitat Characteristics by Reach

Reach	Pools (pools/ mile)	Percent Pools (%)	ODFW Habitat Distribution (%)[1/]	Intrinsic Potential (%)[2/]	Total Redds per Mile 2009 to 2015[3/]
1	3.4	4.4	Riffle (2.9), rapid (91.7), cascade (0.2), pool (5.2), glide (0)	Low (2.9), medium (0), high (97.1)	0.0
2	17.3	19.7	Riffle (1.8), rapid (63.7), cascade (16.9), pool (17.6), glide (0)	Low (65.6), medium (0), high (34.4)	2.1
3	4.3	5.0	Riffle (1.9), rapid (96.7), cascade (0), pool (1.4), glide (0)	Low (2.0), medium (0), high (98.0)	2.7
4	10.2	11.0	Riffle (6.3), rapid (87.5), cascade (0.5), pool (5.8), glide (0)	Low (13.9), medium (0), high (86.1)	16.3
5	6.4	7.3	Riffle (3.5), rapid (92.6), cascade (0.1), pool (3.8), glide (0)	Low (50.9), medium (0), high (49.1)	12.0
6	4.2	3.2	Riffle (88.2), rapid (4.4), cascade (0.2), pool (5.9), glide (1.2)	Low (0), medium (5.6), high (94.4)	42.2
7	5.4	4.9	Riffle (89.4), rapid (4.0), cascade (0), pool (6.6), glide (0)	Low (45.3), medium (0), high (54.7)	34.0

1/ Source: ODFW Aquatic Inventories Project Data (1994). Calculated as percent of total length in each reach.
2/ Source: Cooney and Holzer (2006). Calculated as percent of total length in each reach.
3/ Total field survey redd locations for Chinook salmon (2009 to 2015)

5.3 DESIRED FUTURE CONDITIONS

This section describes the desired future conditions for Desolation Creek, with a focus on the PAA, and taken within the context of current geomorphic conditions, geomorphic potential, and focal fish species utilization potential. Desired future conditions are intended to assist in identifying, prioritizing, and guiding the restoration and enhancement actions included in the action plan (see Section 6) by defining the ideal outcomes, and thereby providing specific restoration objectives. The desired future conditions for Desolation Creek within the PAA are to have:

- Unrestricted anadromous fish access to all historic habitat with no artificial barriers;
- Riparian areas that function similar to historic conditions, are not negatively impacted by livestock grazing or other land-use practices, and maintain a diverse community of self-sustaining populations of native riparian vegetation;
- Mature stream-side vegetation that has the potential to be recruited into streams and form instream LWD structures in the future;
- A diversity of side channel and wetland habitat similar to historic conditions including wet meadows with restored hydrologic, geomorphic, and ecologic functions;
- Hydrologically connected floodplains that function similar to historic conditions with frequent inundation, flood attenuation and are that not negatively impacted by artificial channel confinement;
- Channels that have geomorphic form and processes similar to historic conditions and are not impacted by armoring, incision, and artificial straightening;
- Instream structural complexity that provides habitat similar to historic conditions including LWD, pool, and boulder quantities that provide diverse habitat and fish cover;

- Sediment transport, sorting, and storage processes that are similar to historic conditions without excessive sediment inputs;
- Summer stream temperatures similar to historic conditions including a diversity of habitats and thermal refugia in a variety of conditions;
- Instream flow volumes that are similar to historic conditions and support focal species at all life stages and do no not result in negative impacts such as redd dewatering; and
- Patterns and timing of flow similar to historical conditions with restored soil water storage and raised groundwater tables in wet meadows and riparian areas.

The desired future conditions described above are intended to address the identified watershed-wide limiting factors as described in Section 4.4 and the reach-specific limiting factors for the PAA. Since the stream reaches used by the CTWSRO (see Table 4.4-1) differed from the geomorphic reaches defined for the PAA, the limiting factors within each geomorphic reach were broken out and are shown in Table 5.3-1.

Table 5.3-1. Identified Limiting Factors by Reach

	CTWSRO Limiting Factors						
Reach	**Impaired Fish Passage[1/]**	**Degraded Water Quality – Temperature**	**Degraded Riparian**	**Degraded Floodplain**	**Degraded Channel**	**Altered Sediment Routing**	**Altered Hydrology**
Reach 1		X	X	X	X	X	
Reach 2		X	X	X	X	X	
Reach 3		X	X	X	X	X	
Reach 4		X	X	X	X	X	
Reach 5		X[2/]	X[2/]	X[2/]	X	X	
Reach 6		X[3/]	X[3/]	X[3/]	X	X	X
Reach 7		X	X	X	X	X	X

1/ Although there are no mainstem fish passage barriers in the PAA, fish passage barriers on tributary channels are a limiting factor.
2/ A total of 64 percent of the reach length is listed for the limiting factors noted.
3/ A total of 93 percent of the reach length is listed for the limiting factors noted.
Source: CTWSRO (2014)

5.3.1 Geomorphic Conditions and Restoration Potential

The current geomorphic conditions and restoration potential are intended to assist with identifying which reaches have the greatest potential to guide prioritization in the action plan (see Section 6). Current geomorphic function for the PAA was determined by analysis of existing data and field surveys in Section 5.2. This included analyzing land use, riparian vegetation, channel morphology, channel migration, floodplain inundation and connectivity, sediment mobility and transport, and fish habitat.

Geomorphic restoration potential was evaluated based on the results of the reach-scale assessment presented in this section and takes into consideration the relative potential for restoring or enhancing natural geomorphic processes in each reach. In particular, geomorphic restoration potential was evaluated using historic channel and floodplain conditions relative to current geomorphic function. Figure 5.3-1 shows the geomorphic restoration potential rankings for each reach.

Reach 2 was the only reach that ranked as having poor geomorphic restoration potential. This is because Reach 2 is highly confined, stable, relatively narrow, with coarse substrate and high-intensity hydraulic characteristics. The current condition of Reach 2 is likely the closest to historic conditions when compared to all other reaches in the PAA. These existing geomorphic conditions in Reach 2 limit the types of restoration opportunities available to restore geomorphic processes as well as the potential for project success.

Reach 4 was ranked as having fair geomorphic restoration potential. Although somewhat less confined than Reach 2, Reach 4 also has coarse substrate, high-intensity existing hydraulic conditions, and limited accessible floodplain. Roads are impacting Reach 4 by confining the channel in several areas. The existing geomorphic conditions in Reach 4 provide some limited opportunities to restore geomorphic processes; however, full restoration of geomorphic processes in Reach 4 would be challenging and more uncertain than in other reaches.

Reaches 1, 5, and 7 were ranked as having good geomorphic restoration potential. These reaches are partially confined and have isolated floodplains with varying levels of connectivity. Existing geomorphic conditions indicate these reaches have good potential for addressing limiting factors with process-based restoration actions in select areas. Full restoration of geomorphic processes in Reach 5 would be more challenging than in Reaches 1 and 7 due to narrower valley bottom widths, a more confined channel, steeper gradients and higher velocities, shear stress, and stream power that inhibit lateral movement of the channel.

Reaches 3 and 6 were ranked as having excellent restoration potential. These are the two unconfined reaches in the PAA and are laterally active. These reaches have been greatly impacted by the land-use history described in Section 4.3. They also contain sensitive areas including wet meadows that provide key ecosystem functions in Desolation Creek. Existing geomorphic conditions in Reaches 3 and 6 indicate they have excellent potential for addressing limiting factors with process-based restoration actions. Currently, these reaches also have high-quality habitat characteristics indicating that geomorphic conditions are suitable for enhancing those characteristics.

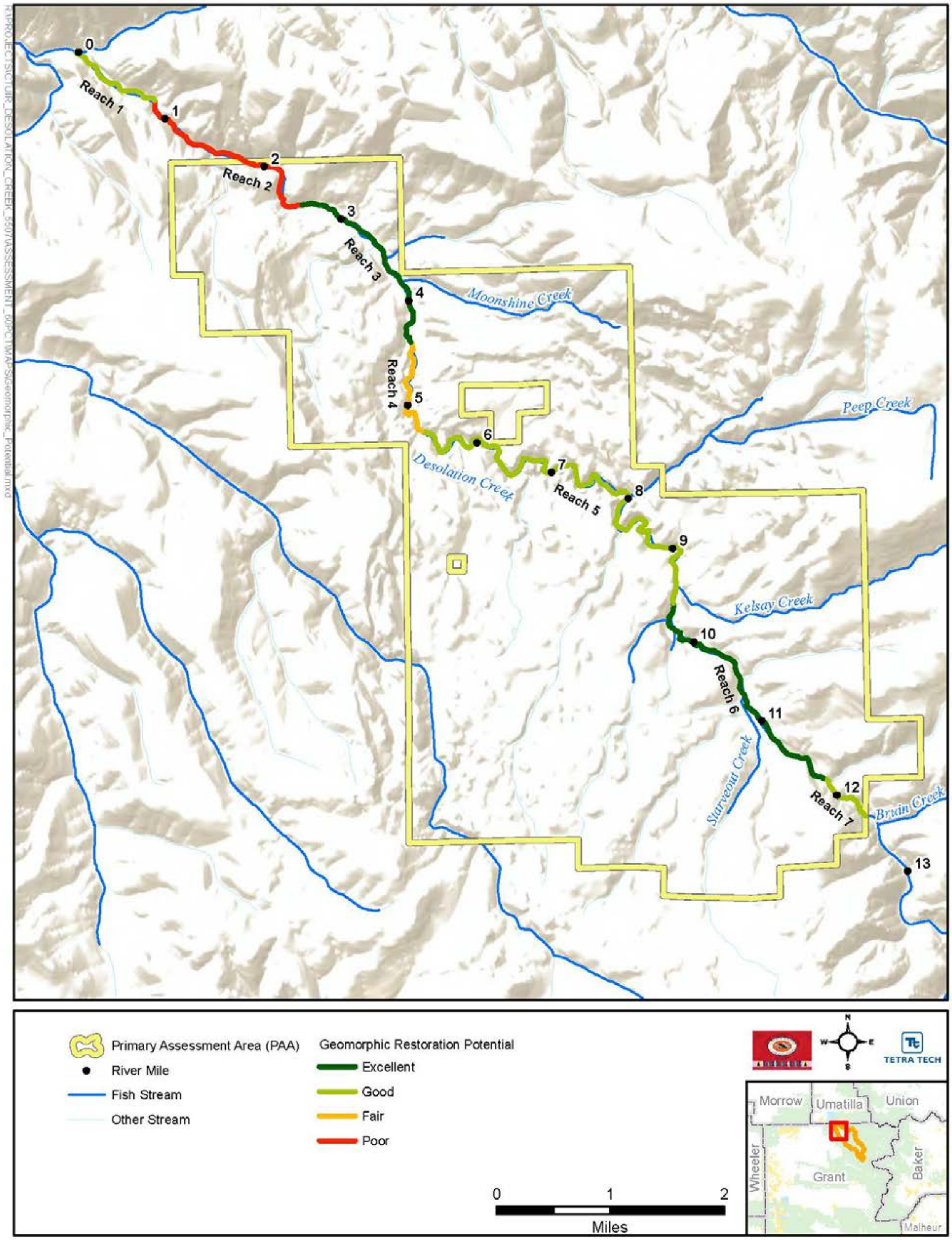


Figure 5.3-1. Geomorphic Potential Ranking by Reach

5.3.2 Focal Fish Species Utilization Potential

Focal fish species utilization potential was determined for each Project reach by assessing current fish species utilization and limiting factors described in Section 4.2 and Section 4.4 respectively, and by comparing current geomorphic conditions to geomorphic potential in terms of ability to increase fish habitat quantity such as substrate and habitat types, as described in Section 5.2. Figure 5.3-2 shows the focal fish species utilization potential rankings for each reach based on the following descriptions.

Reaches 1 and 2 were ranked as having fair utilization potential. This rating was based on the determination that the current confined channel geomorphology in most areas was unlikely to change and produce additional wetted areas in the form of side-channel or off-channel habitat; this is particularly the case in Reach 2 where steep rock bluffs constrict the stream. The confined nature and high stream power results in a large cobble and boulder–dominated substrate, and limits the amount of suitable spawning gravel in these reaches. Stream temperatures are fairly high in these reaches, but are generally not lethal; if summer temperatures are lowered over time through moderation of the warming that occurs in the downstream end of Reach 3 near RM 3.0 (see Figure 4.3-4), it could improve fish summer-rearing capacity.

Reaches 4, 5, and 7 were ranked as having good utilization potential. Current fish habitat includes existing spawning and rearing habitat that was classified as good, but could improve to excellent with proper restoration actions. Some opportunities exist to improve floodplain connectivity and increase side-channel and off-channel habitats. Current pool numbers are low and could be increased through additions of LWD that would also increase habitat complexity. Summer stream temperatures were considered good, but could also improve fish summer rearing capacity if lowered over time.

Reaches 3 and 6 were ranked as having excellent utilization potential. The rating was based on the determination that these two unconfined and lower gradient reaches have considerable potential for additional side-channel and off-channel habitat, thus increasing the overall quantity of habitat available. Improvements in floodplain connectivity and sediment sorting could increase available spawning and rearing habitat, and reduce summer stream temperatures. These lower gradient reaches also have the potential for much higher quantities of instream LWD and improved habitat complexity such as deep, complex pools. Restoration actions could markedly improve riparian habitat leading to increased stream shading and future LWD recruitment.

The geomorphic restoration potential and focal fish species utilization potential together provide a cross walk between the geomorphic reaches, BSRs, and the identification of restoration and enhancement opportunities. In addition, they provide a framework for identifying approaches and prioritizing project areas and restoration actions to address limiting factors. The following action plan describes the restoration strategy intended to achieve full geomorphic restoration and focal fish species utilization potential for the Desolation Creek watershed.

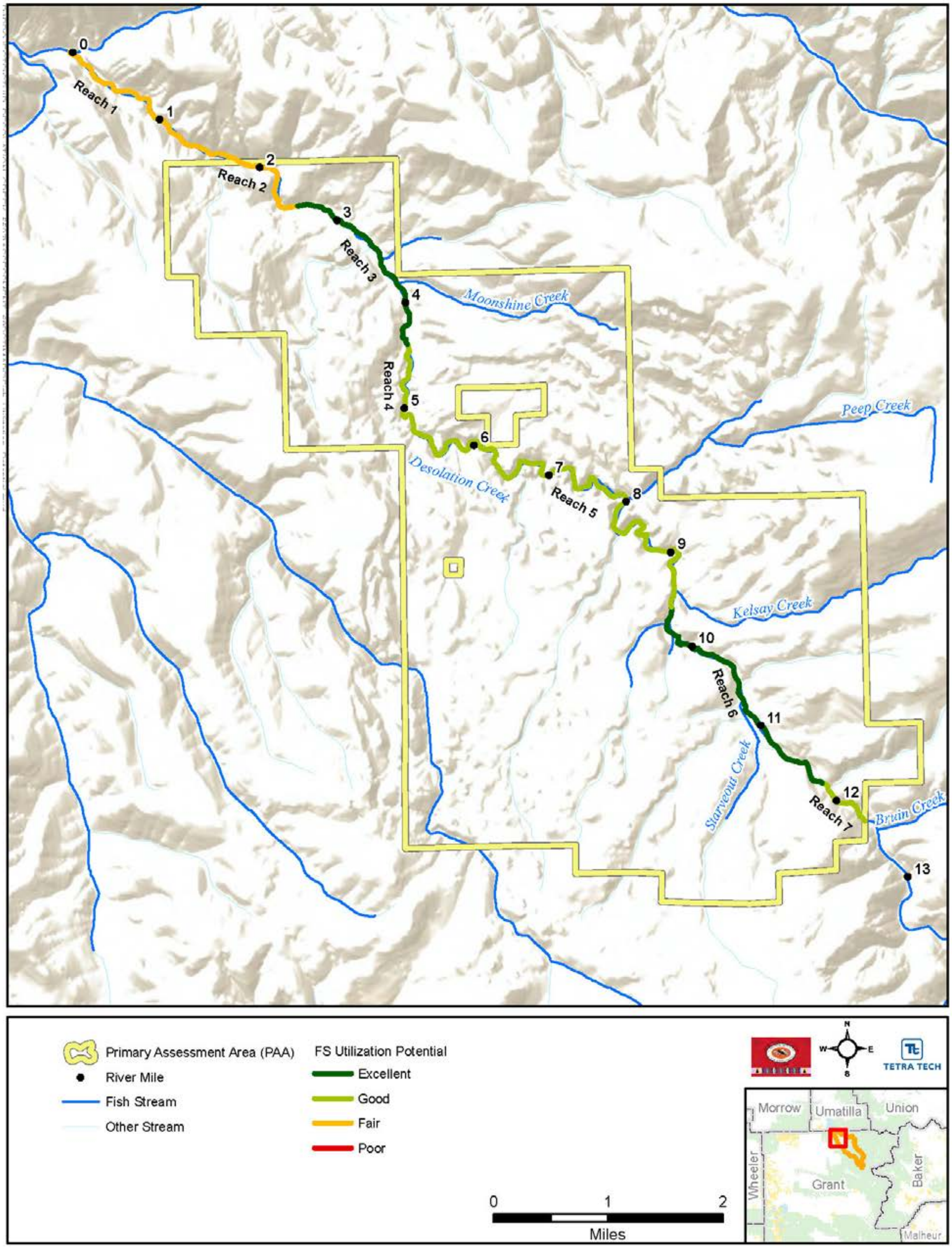


Figure 5.3-2. Focal Species Utilization Potential Ranking by Reach

6 Action Plan

As stated in Section 2.3, the overarching goal of this Project is to provide rigorous, data-driven, and science-based analyses leading to prioritized restoration and enhancement projects and designs that, when implemented over time, will accelerate process-based geomorphic function to rehabilitate Desolation Creek to the benefit of terrestrial and aquatic species. Included in this goal is the need to understand the geomorphic and ecological processes and limiting factors affecting Desolation Creek in order to prioritize and implement restoration projects that will make quantifiable progress toward addressing the key limiting factors. The data and analyses in the watershed- and reach-scale assessments in Sections 4 and 5 provide the foundation for consistency with past assessments, action plans, visions, agreements, and recovery plans, and the necessary empirical data for identifying and prioritizing actions that are practical to implement and address factors limiting aquatic productivity. These were used to develop the action plan presented in this section.

The goal of this action plan is to provide the CTUIR, co-managers, landowners, and stakeholders with prioritized restoration and enhancement projects that can demonstrate progress toward addressing limiting factors which can be documented through quantifiable and repeatable metrics. The objectives of this action plan are (1) to identify and prioritize restoration and enhancement projects using a scientifically based framework, with a focus on the PAA; (2) to develop conceptual and final designs for the highest ranked project areas; and (3) to identify metrics for use in tracking progress toward addressing limiting factors in Desolation Creek.

Development of this action plan followed nine sequential steps to achieve these objectives:

1. **Review Existing Restoration Plans and Past Actions**. This first step was important to incorporate past work and avoid duplication of efforts (Section 6.1).
2. **Identify and Rank BSRs**. In this step, BSRs were delineated based on common fish use and limiting factor characteristics, and then ranked relative to each other into Tier I, Tier II, or Tier III categories based on the potential to affect changes in geomorphic potential, current habitat conditions, stream temperature, and impacts to fish limiting life stages and overall number of life stages present (Section 6.2.1).
3. **Refine and Rank Limiting Factors**. This step took limiting factors previously identified in higher level planning documents and refined them within each BSR based on local knowledge. Limiting factors were linked to general restoration and enhancement actions to evaluate the impact of project actions on addressing limiting factors, and were also linked to monitoring metrics (Section 6.2.2).
4. **Identify and Select Restoration Actions**. In this step, a complete suite of restoration and enhancement action categories and individual actions were identified and described that are intended to achieve progress toward meeting desired future conditions (Section 6.2.3).
5. **Prioritize Restoration Actions**. In this step, the varying impacts that the restoration action categories described in Step 4 can have on one or more limiting factors were described, and

then the potential restoration and enhancement actions were prioritized and ranked within each BSR (Section 6.2.4).

6. **Score Project Opportunities**. In this step, project opportunities were ranked beginning with their previously assigned tier ranking (Tier I, II, or III from Step 2). An alternative Ecological Node ranking category is described, followed by descriptions of six additional biological and physical criteria, leading to a list of ranked project opportunities throughout the watershed (Section 6.2.5).
7. **Evaluate Project Feasibility**. As a separate but important project prioritization step, potential projects were evaluated based on 10 cost/benefit and feasibility criteria prior to making final decisions on whether or not a project should be funded (Section 6.2.6).
8. **Develop Project Designs**. This step included development of conceptual and final designs of highly ranked projects. Proposed project actions incorporated into designs were consistent with the biological needs of the focal fish species, local geomorphology, and implementation feasibility (Section 6.3).
9. **Implementation Schedule**. This step developed a preliminary schedule for implementing projects based on the project prioritization and expected future design development process (Section 6.4).

The results of this action plan will be contained in a geodatabase that provides useful information for organizing and executing the plan including providing source information. The geodatabase will facilitate tracking the location of potential projects over time, providing restoration planners with a tool to evaluate potential impacts and identify where resources should be best allocated. Available data have been incorporated to also provide information on where previous restoration projects have already been implemented. The geodatabase, provided separately, will also be used to create priority project area maps, which include information on the geomorphic reaches, BSRs, and other relevant data.

6.1 EXISTING RESTORATION PLANS AND PAST ACTIONS

As discussed in Section 1.2, this Project intends to supplement and work in concert with existing planning documents. These plans and documents outline restoration strategies and actions that are applicable to Desolation Creek, but with varying scales of analysis, with only the Draft Desolation Creek Watershed Action Plan (USFS 2009) focusing exclusively on the watershed. This Project also builds from other local restoration plans and projects, including several that were previously developed for the watershed and are discussed in the subsections below.

6.1.1 Desolation Creek Land Management Plan

The Desolation Creek Land Management Plan (EFM 2015) was developed by EFM, a for-profit subsidiary of Ecotrust formed to manage forestlands for financial, ecological, and social returns. The plan was developed to provide land management strategies to address challenges from past land management that has included timber harvests, fire suppression, and overgrazing, as well as addressing climate change. Overall restoration activities include forest thinning and timber harvest targeting successional forest management, grazing management including riparian exclusion, removing invasive species, road closures, and restoring springs, seeps, and upland wet meadows. The plan provides management strategies targeting specific limiting factors for the property, based on Desired Vegetative Conditions and overall goals and objectives, as well as detailed proposed treatments and actions for each management strategy (EFM 2015).

Since acquiring the property in 2014, Desolation Creek LLC, in collaboration with the NFJDWC, has secured grants through various funders and facilitated the implementation of a number of restoration actions including (NFJDWC 2017a):

- Developed 11 springs to provide off-source water to livestock.
- Protected 75 acres of wet meadows using exclosure fences.
- Worked with ODFW to install riparian exclosure fencing along Desolation Creek in Reach 3.
- Conducted pre-commercial thinning of 52 forested acres.
- Conducted surveys of invasive weeds on 950 acres, and treated 78 acres.
- Implemented channel erosion treatments on five wet meadows.
- Installed protective fencing around two aspen stands.

Desolation Creek LLC and the NFJDWC are also proposing to implement a groundwater storage and retention project on several small tributaries within the PAA. The proposed restoration actions include installing small woody debris dams, beaver dam analogs, and riparian planting (NFJDWC 2017b).

6.1.2 Granite-Desolation Aquatic Restoration Project

The North Fork John Day Ranger District of the USFS has proposed the Granite-Desolation Aquatic Restoration Project (USFS 2015c). This project was designed to address road-related impacts to streams, restore wet meadows, and improve aquatic habitat and connectivity in both the Granite and Desolation Creek watersheds. Specific restoration actions will include road improvements and/or decommissioning of 128.8 miles of roads, removal and/or replacement of eight culverts to restore connectivity to 20 miles of fish habitat, implementing instream restoration on 99 miles of stream, and restoring 265 acres of meadows (USFS 2015c).

The USFS's restoration strategies are also discussed in other documents, including the Draft Desolation Creek Watershed Action Plan (USFS 2009) and the Desolation Ecosystem Analysis (USFS 1999). The Draft Desolation Creek Watershed Action Plan, building off of the earlier Desolation Ecosystem Analysis, outlined the process by which the Desolation watershed was ranked as a high priority watershed for watershed, fish/aquatics, and vegetation condition. It identified critical restoration needs for the next 5 to 10 years, and provided both broad strategies and specific restoration actions (USFS 2009). Specific restoration actions include culvert removals, road decommissioning, vegetation management and planting, forest thinning and selective logging, low intensity burns, repairs to previous restoration actions, and instream and meadow restoration (USFS 2009).

Past restoration actions included several habitat enhancement projects that were implemented on Desolation Creek upstream of the PAA from 1985 to 1989, as well as on Kelsay Creek in 1996 to 1997 (USFS 1999). The habitat enhancement treatments installed were typically log and boulder weir structures. The effect of these structures on fish habitat variables in Desolation Creek and other streams in the region has been evaluated by McCown (2001). In general, the effectiveness of instream structures on the UNF could not be predicted; however, Desolation Creek had the largest number of fish habitat variables that increased in treated reaches and the most fish habitat variables that met agency-defined targets.

6.1.3 Desolation Meadow Restoration

The Desolation Meadow Restoration Analysis was developed by the Wind River Watershed Restoration Team for the USFS on the North Fork Desolation Creek, with the goals of restoring the meadow habitat by reconnecting surface and subsurface hydrology, restoring historic groundwater tables, reduce maximum water temperatures, and restoring a stable and functional channel morphology (Powers et al. 2003; Zakrajsek 2011). Limiting factors were identified, along with previous restoration actions that have had both positive and negative effects (Powers et al. 2003). Past restoration actions that were identified included installation of brush dams, rock weirs, single log wood structures, and introduced spawning gravel. Many of the grade control structures were identified as at risk for creating channel avulsions and recommended for analysis and potential modifications or removal. Specific restoration actions proposed included road decommissioning and vehicle exclusion, culvert replacements, continued livestock exclusion, channel and floodplain restoration activities, and riparian plantings (Powers et al. 2003). In 2011, the CTUIR and USFS jointly developed a draft multi-year restoration strategy for Desolation Meadows building on the 2003 USFS plan and using many of the same restoration elements, as well as updated survey and monitoring activities (Zakrajsek 2011).

6.2 RESTORATION STRATEGY FOR PRIORITIZING PROJECT AREAS

In conjunction with existing restoration plans and knowledge of past actions (see Section 6.1 above), the importance of prioritizing projects in a strategic manner is increasingly being recognized by river restoration practitioners. During recent Independent Scientific Review Panel (ISRP) evaluations of habitat projects funded by the BPA, considerable emphasis has been placed on developing a strategic framework to ensure that funding entities direct efforts toward the most important restoration priorities; restoration projects should be conducted in the right locations and in the right order centered on a process-based, landscape-scale approach (ISRP 2013). Past efforts have often not considered or did not have adequate information available to make determinations of how and where priority work should occur, particularly at the watershed level or finer geographic scales. In recognition of this, beginning in 2013, BPA initiated the Atlas Restoration Prioritization Framework (BPA 2017) to facilitate focused, collaborative, and biologically beneficial restoration projects in subbasins of northeast Oregon and Idaho. Based on principles and lessons learned from those efforts, the prioritization strategy used for Desolation Creek integrates past and best available current data to assist in prioritizing the appropriate types of restoration actions in strategically defined locations to address key fish limiting factors. To that end, project areas in Desolation Creek were ranked by developing a Prioritization Matrix spreadsheet that uses existing data along with new information gathered during the reach assessment. The development of the Prioritization Matrix takes into consideration biological and physical habitat attributes considered to have the most impact on improving fish population performance.

This section describes the restoration strategy for the watershed, with a focus on the PAA, and identifies the types of potential restoration actions that are most suitable to address the limiting factors in prioritized reaches. Building on the results presented in Sections 4 and 5, the following subsections describe the step by step procedures used to arrive at prioritized project areas and ranking of individual project opportunities.

6.2.1 Biologically Significant Reaches

The first level of hierarchy in the development of the Prioritization Matrix was to subdivide the watershed into BSRs, which are defined as stream reaches with similar focal fish species use and limiting factor characteristics. Focal fish species that were considered for Desolation Creek were ESA-listed steelhead and bull trout, along with non-listed spring Chinook salmon. Lamprey were considered but not included as there has been no document presence in Desolation Creek.

BSRs represent the “fish’s view of the river.” For example, segments of a stream that are used for spawning, incubation, and rearing require specific functional physical and biological parameters (e.g., flow, temperature, substrate size, and type). If these conditions are not present, they will limit fish species presence or survival, such as a stream reach that is only used for migration due to seasonally limited flow or high temperatures.

BSR delineations entailed evaluating existing data on focal fish species presence and utilization, (such as fish periodicity as shown in Table 4.2-1, but at a finer geographic scale), and the limiting factors/ecological concerns (described in Sections 4.4 and 5.3), along with field survey data and local scientific knowledge of preferred biological and physical habitat for focal fish species within the Desolation Creek watershed. Designation of BSRs represents the first level of hierarchy in the overall watershed ranking system (i.e., the BSRs determine the broader geographic areas where restoration work should occur first). Based on analysis of those criteria, the Desolation Creek was divided into 11 distinct BSRs. Figure 6.2-1 shows the location of the BSRs in the watershed and Table 6.2-1 provides the BSR names, locations, and brief descriptions that include fish use and the geomorphic reaches present in each BSR.

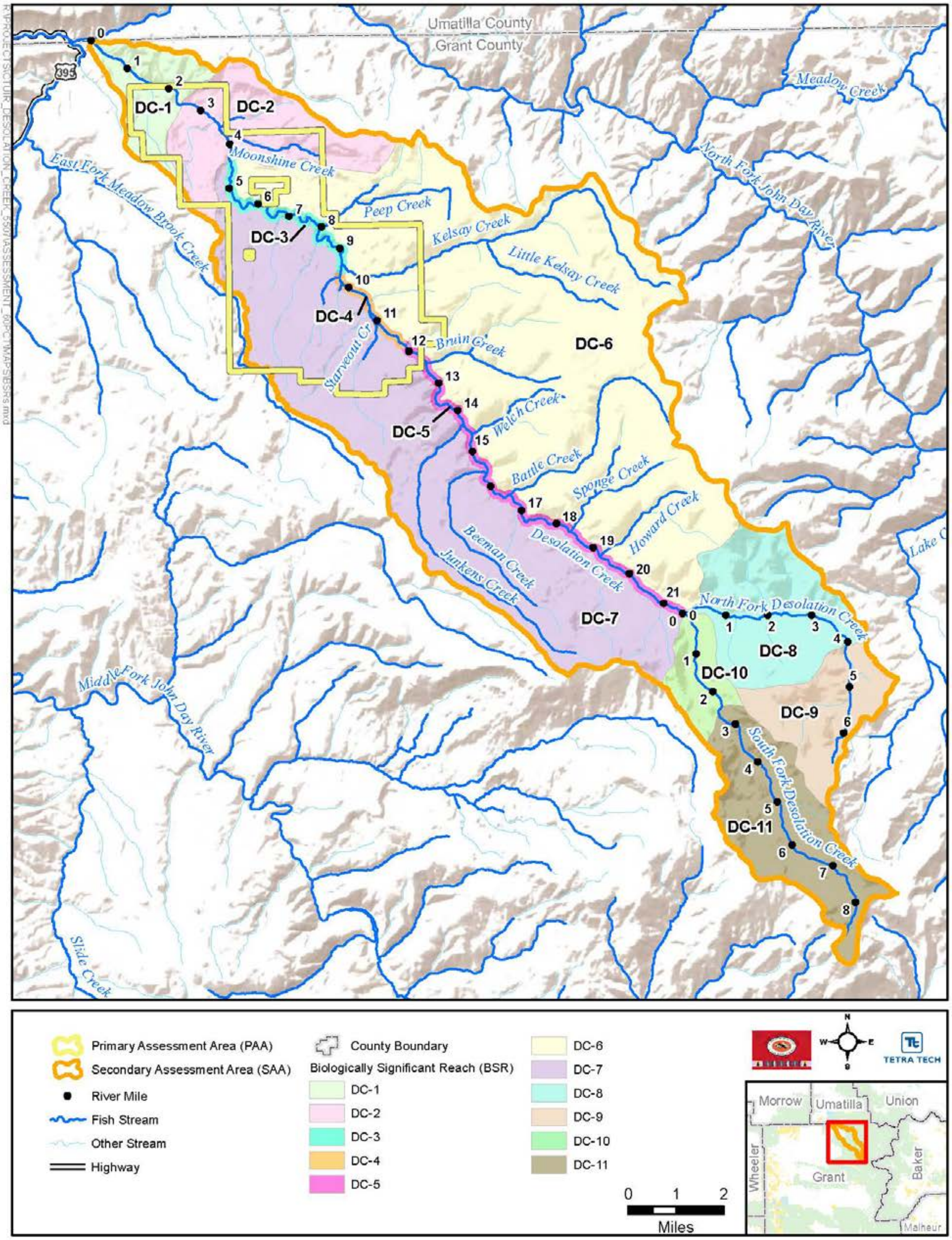


Figure 6.2-1. Biologically Significant Reaches in the Desolation Creek Watershed

Table 6.2-1. Desolation Creek Watershed Biologically Significant Reach Delineations

BSR (Geomorphic Reach)	Location	Description
DC-1 (R-1, R-2)	RM 0.0 to 2.6	Includes the mainstem of Desolation Creek in PAA Geomorphic Reaches 1 and 2 and contributing drainages, including one non-fish-bearing stream on the south side. The stream channel is mostly confined, especially in Reach 2, and has limited spawning gravels. Fish use includes all species, but use by some species is primarily during migration. Summer fish use limited by higher stream temperatures.
DC-2 (R-3)	RM 2.6 to 4.4	Includes the mainstem of Desolation Creek in PAA Geomorphic Reach 3, and contributing drainages (Moonshine Creek and two unnamed tributaries). The mainstem is mostly unconfined, but lacks significant spawning gravels. This BSR includes the lower end of Chinook salmon spawning. Steelhead use is likely low to moderate in the mainstem, unknown in Moonshine Creek, and noted as present in Mud Springs.
DC-3 (R-5, R-5)	RM 4.4 to 9.5	Includes only the mainstem of Desolation Creek in PAA Geomorphic Reaches 4 and 5. The channel is moderately unconfined. Includes moderate Chinook spawning and rearing, steelhead rearing, and likely low use by bull trout. Stream temperatures in this reach and upstream become increasingly more favorable.
DC-4 (R-6)	RM 9.5 to 11.8	Includes only the mainstem of Desolation Creek in PAA Geomorphic Reach 6. The channel is mostly unconfined and includes some side channels. This BSR has the highest use for Chinook spawning and rearing, and moderate steelhead and bull trout use.
DC-5 (R-7)	RM 11.8 to 21.5	Includes only the mainstem of Desolation Creek, and all of PAA Geomorphic Reach 7 and USFS (SAA) lands above that. The upper end of the reach is at the confluence of the North and South forks, and the channel is moderately confined. This BSR has high Chinook spawning and rearing use, some steelhead spawning and rearing, and likely some bull trout rearing with lower stream temperatures.
DC-6	RM 4.4 to 21.5	Includes north-side tributaries (Peep, Kelsay, Little Kelsey, Spring, Park, Bruin, Welch, Battle, Sponge, and Howard creeks, and other unnamed tributaries). Channel morphology is mixed. The BSR has very low or no Chinook use with the exceptions of confluences with Desolation Creek, mixed steelhead use depending on gradient and temperature, and little or no bull trout use.
DC-7	RM 4.4 to 21.5	Includes south-side tributaries (Starveout, Junkens, and Beeman creeks, and other unnamed tributaries). This BSR has very low or no Chinook use with the exceptions of confluences with Desolation Creek, mixed steelhead use, and some bull trout use in Junkens Creek and possibly lower Beeman Creek.
DC-8	RM 0.0 to 4.0	North Fork Desolation Creek from the mouth up to FS 400. Includes the low gradient, unconfined Desolation Meadows, Skinner and Line creeks, and unnamed tributaries. There is no known Chinook use, some use by bull trout, and majority of use by rainbow/steelhead.
DC-9	RM 4.0 to Headwaters	North Fork Desolation Creek upstream of FS 400 Road to headwaters. High gradient at the FS 400 Road and mix of steep and confined with some lower gradient meadows upstream. Fish use is rainbow/steelhead trout.
DC-10	RM 0.0 to 2.3	South Fork Desolation Creek up to the falls upstream of FS Road 45. Moderately unconfined and habitat is in very good condition. Lots of spawning gravel and has Chinook, steelhead, and bull trout use.
DC-11	RM 2.3 to Headwaters	South Fork Desolation Creek upstream of the falls to headwaters, and includes many small unnamed tributaries and springs. The falls blocks migratory Chinook and steelhead. Roadless area with mixed habitat, and much of it burned in recent years. Rainbow and bull trout use.

Following the geographic designation of BSRs, a scoring system was developed to rank each BSR relative to each other. The framework for prioritizing BSRs was founded on relevant literature related to fisheries restoration priorities (Roni et al. 2002; Beechie et al. 2008), and is based on the following principles:

1. Target areas where there is geomorphic potential to affect change (i.e., areas with available floodplain to implement a broader range of restoration actions).
2. Target areas where the current habitat condition allows the ability to affect change (i.e., habitat condition is somewhere between completely degraded, requiring great effort for little change, and pristine conditions in which there is little room for improvement).
3. Build from existing production areas (current spawning and rearing areas).
4. Target areas with critical species and life stages present.

Within the Prioritization Matrix, a BSR Rankings worksheet was developed to evaluate BSRs based on those four principles. Scoring categories were classified as either providing impacts on the ability to affect change, or impacts to fish species. To evaluate the first two principles related to the ability to affect change (geomorphic potential and current habitat condition), various data layers were assessed, including those that were made available in a GIS-based map format, such as the relative elevation and flood inundation maps, along with existing or newly acquired habitat data (LWD, sediment, habitat unit composition, intrinsic potential ratings, etc.). To evaluate the last two principles, the BSR ranking system used BSR-specific information on fish periodicity, life stages, and critical limiting factors. The scoring categories and rationale for use are summarized as follows:

Geomorphic Potential Score: Targets areas with the ability to affect change in terms of geomorphic potential and is based on the assumption that moderately confined or unconfined reaches present more physical opportunities to implement restoration actions that can increase both habitat quantity and quality. An initial qualitative score (Excellent, Good, Fair, or Poor) was assigned to each BSR, which was later converted to a numeric score to account for up to 25 percent of the total possible.

Current Habitat Condition Score: Targets areas with the ability to affect change by restoring or enhancing habitat conditions. Scores reflect the expected improvements, and are based on the assumption that areas with fair to good habitat provide the most opportunity for improvement. Areas with poor habitat would require larger investments for minimal improvement, and areas with excellent habitat provide little opportunity for improvement beyond their current condition. This category also used an initial qualitative score (Excellent, Good, Fair, or Poor) assigned to each BSR, which was later converted to a numeric score to account for up to 25 percent of the total possible.

Current Temperature Score: This was included as a sub-score within the Current Habitat Condition Score, and acts primarily as a filter for the ability to effect change. This category had a smaller impact on the Current Habitat Condition Score and overall BSR rankings, but was listed as a separate item because of its significance to fish health and survival. If stream temperatures were poor (near-lethal), then existing or newly created habitat cannot be fully utilized. In similar fashion, this category also used an initial qualitative score (Excellent, Good, Fair, or Poor) assigned to each

BSR, which was later converted to a numeric score, but only accounted for up to 5 percent of the total possible.

Fish Utilization (U)-score: Targets areas based on the number of fish limiting life stages present and their rankings (High, Medium, Low) as determined from the fish limiting life stage utilization rankings. Rankings were assigned based on current fish use, using the following definitions:

High (H): High-priority lifestage use in need of *immediate to short-term action* (1-3 years) to improve fish population abundance, productivity, distribution, and sustainability.

Medium (M): Medium-priority lifestage use in need of *intermediate-term action* (4-15 years) to improve fish population abundance, productivity, distribution, and sustainability.

Low (L): Low-priority lifestage use in need of *long-term action* (15 or more years) but is currently minimally affected by existing conditions; could improve future fish population performance.

N/A: Lifestage not present and therefore not applicable.

Table 6.2-2 illustrates fish limiting life stage rankings in one of the BSRs of Desolation Creek, including the associated comments providing the rationale behind the rankings. The initial qualitative scores (High, Medium, Low, Not Applicable) were assigned to each BSR, and were later converted to a numeric score to account for up to 25 percent of the total possible.

Table 6.2-2. Fish Limiting Life Stage Utilization Rankings for Desolation Creek (DC-4)

Lifestage	Spring Chinook	Steelhead	Bull Trout	Comments
Adult Immigration & Holding	M	L	L	Pools for Chinook staging are important in low-flow years.
Adult Spawning	H	M	L	High Chinook use; possible steelhead spawning in side channels.
Incubation/Emergence	H	M	L	High Chinook use; possible steelhead spawning in side channels.
Summer Rearing	H	H	M	Temperatures likely too high for bull trout use.
Winter Rearing	H	H	M	Data gap for all species.
Juvenile Emigration	L	L	L	

Periodicity (P)-score: Targets areas based on the raw count of the number of life stages of each focal fish species present, as determined from the BSR-specific periodicity tables. The length of time that a life stage is present was not factored in as an indication of importance (i.e., spawning may only occur over a few weeks, but is equally important as summer or winter rearing which occurs over months). BSRs that have multiple species and more life stages present received the highest scores, which are based on the combined total count of those species and life stages present. This category accounted for up to 25 percent of the total possible.

Within the Prioritization Matrix and the BSR Rankings worksheet, the qualitative scores were entered for all of these scoring categories, which were automatically converted to numeric values. The resulting cumulative scores were then automatically calculated for each BSR. Based on the raw scores, each BSR was placed into one of the three following groups as defined below:

- Tier I – High-priority areas for restoration; actions within these BSRs should be considered for early implementation.
- Tier II – Medium-priority areas; actions within these BSRs should be considered for strategic implementation.
- Tier III – Low-priority areas; actions should be implemented within these BSRs when Tier 1 or Tier 2 actions are either complete or not available due to feasibility constraints.

The Prioritization Matrix allows for adaptive management such that any of the categories can be automatically updated if new information comes forth that would indicate the need to change any rankings. Table 6.2-3 shows the results of the BSR rankings and assignment of raw scores into Tier I, Tier II, or Tier III, showing that DC-2, DC-4, and DC-5 achieved the highest (Tier I) ranking. Following the selection and ranking of BSRs, refining and scoring limiting factors, as well as identifying and ranking of potential restoration actions within each BSR, was completed, as described in the following two sections.

Table 6.2-3. Biologically Significant Reach Scoring and Rankings

BSR Number	Ability to Affect Change Inputs			Species Impact Scoring		Ability to Affect Change Scoring		Results		
	Geomorphic Potential Classification	Current Habitat Condition	Current Temperature	U-Score (Fish Limiting Life Stage Utilization)	P-Score (No. Fish Life Stages Present)	Geomorphic Potential Score	Current Condition & Temperature Score	Cumulative Score	Ranking (Tier I,II,III)	Comments
DC-1	Fair	Fair	Fair	9	17	5	25	**55**	**Tier III**	Reaches 1 and 2; confined and mostly a migration corridor.
DC-2	Excellent	Fair	Fair	11	22	25	25	**83**	**Tier I**	Mainstem geomorphic Reach 3; unconfined and moderate fish use.
DC-3	Good	Good	Good	11	25	15	28	**79**	**Tier I/II**	Mainstem geomorphic Reaches 4 & 5.
DC-4	Excellent	Fair	Good	15	25	25	28	**93**	**Tier I**	Mainstem Reach 6, unconfined & very high fish use.
DC-5	Good	Good	Good	15	25	15	28	**83**	**Tier I**	Mainstem PAA Reach 7 to USFS confluence of the North & South Forks.
DC-6	Good	Fair	Good	6	8	15	28	**57**	**Tier II**	North-side tributaries; mostly steelhead. Temperatures vary by stream.
DC-7	Fair	Fair	Good	11	17	5	28	**61**	**Tier II**	South-side tributaries; Temperatures in Junkens very good and bull trout use.
DC-8	Excellent	Good	Good	8	17	25	28	**78**	**Tier II**	North Fork to Road 400.
DC-9	Fair	Good	Good	1	8	5	28	**42**	**Tier III**	North Fork at Road 400 to headwaters; only Steelhead/Rainbow use.
DC-10	Excellent	Excellent	Good	8	25	25	8	**66**	**Tier II**	South Fork to falls.
DC-11	Good	Poor	Good	5	8	15	8	**36**	**Tier III**	South Fork above falls.

6.2.2 Refining and Ranking Limiting Factors

Once the BSRs were identified and mapped, additional biological data were used to refine the limiting factors that had been previously identified within higher level planning documents (such as subbasin plans and recovery plans), or by technical advisory groups. Temperature, flow, habitat surveys, and other data sets were evaluated relative to existing BSR locations to update or confirm previously determined watershed-level limiting factors at a finer resolution. For this analysis, National Oceanic and Atmospheric Administration (NOAA 2012) standardized limiting factors (ecological concerns), as jointly identified and weighted for the North Fork John Day watershed by the CTUIR and CTWSRO in October 2015 (Iverson 2015), were used as the starting point. Four limiting factors not originally listed were added based on local knowledge of conditions in the Desolation Creek watershed as identified during stakeholder meetings.

Based on review of previous data on fish periodicity and life stage utilization, qualitative rankings of high, medium, or low were assigned to limiting factors within each BSR. Definitions were based on urgency for addressing each limiting factor were assigned using the following criteria:

> High (H): High-priority limiting factor that needs to be addressed in the immediate to short-term (1-3 years) to improve fish population abundance, productivity, distribution, and sustainability.
>
> Medium (M): Medium-priority limiting factor that needs to be addressed in the intermediate-term (4-15 years) to improve fish population abundance, productivity, distribution, and sustainability.
>
> Low (L): Low-priority limiting factor that could to be addressed in the long-term (15 or more years) but are currently not limiting fish population performance.
>
> Not Applicable (N/A): Limiting factor was not present in that BSR.

An example of the results for one of the BSRs is shown in Table 6.2-4 below. Comments specific to the BSR were added to the spreadsheet data to document the rationale behind the scores. These qualitative rankings were also converted to numerical scores within the Prioritization Matrix spreadsheet.

Table 6.2-4. Example of Limiting Factors Weightings and Rankings for Desolation Creek (DC-4)

Limiting Factors Rankings from CTUIR and CTWSRO[1/]			BSR Specific Rankings	
Weight	**No.**	**NOAA Standardized Limiting Factor Description[2/]**	**Score**	**Comments**
20%	1.1	Habitat Quantity: Anthropogenic Barriers	**N/A**	No mainstem barriers.
10%	4.1	Riparian Condition: Riparian Vegetation	**H**	Impacted from road prisms, cattle, and past logging.
0%	4.2	Riparian Condition: LWD recruitment[3/]	**H**	Impacted from road prisms, cattle, and past logging.
0%	5.1	Peripheral and Transitional Habitats: Side Channels & Wetland Conditions[3/]	**H**	Unconfined reach.
20%	5.2	Peripheral and Transitional Habitats: Floodplain Condition	**H**	Unconfined reach.
15%	6.1	Channel Structure and Form: Bed and Channel Form	**H**	Most habitat is very long riffles.
15%	6.2	Channel Structure and Form: Instream Structural Complexity	**H**	Low quantities of large wood and complex pools.
10%	7.2	Sediment Conditions: Increased Sediment Quantity	**M**	Larger substrate, some spawning gravel.
10%	8.1	Water Quality: Temperature	**H**	High summer temperatures.
0%	9.2	Water Quantity: Decreased Water Quantity[3/]	**L**	Increasing summer flows from upriver would be beneficial.
0%	9.3	Water Quantity: Altered Flow Timing[3/]	**N/A**	
Source Data: CTUIR & CTWSRO [X] Sub-Basin [ ] Recovery Plan [ ]				

[1/] Rankings are for the Upper North Fork of the John Day (Iverson 2015). They were jointly determined by CTUIR and CTWSRO staff and were identical for both Chinook salmon and steelhead.
[2/] NOAA Fisheries uses the term "ecological concern" instead of "limiting factor," but the two are used interchangeably.
[3/] Limiting factors that were added based on local knowledge within Desolation Creek.

As noted earlier as the third objective of the action plan, this framework links project restoration actions to specific metrics that are used to compare design alternatives and measure the success of implemented projects over time through monitoring. The methods presented in Table 3.1-1 and results presented in Sections 4.0 and 5.0 provide the baseline for monitoring project effectiveness in Desolation Creek. Table 6.2-5 shows how the metrics and evaluation methods are used to evaluate the impact of generalized project restoration actions on limiting factors that ultimately determine project effectiveness. More detailed information on selection of appropriate restoration actions and their rankings is described in the following section.

Table 6.2-5. Evaluation Methods and Metrics to Evaluate Effects of Restoration Actions on Addressing Limiting Factors

Ecological Concerns[1/] (Limiting Factors)	General Restoration and Habitat Enhancement Actions	Evaluation Methods/Metrics[2/]
1.1 Anthropogenic Barriers	Remove or repair structural passage barriers. Remove or replace fish passage barrier culverts.	Field survey of completed projects and determine barrier status; monitor the barrier status over time to determine longevity of barrier replacement and upstream fish presence.
4.1 Riparian Vegetation	Meadow habitat restoration; livestock exclusion; riparian planting; and remove invasive vegetation.	Measure riparian and meadow characteristics including soil water storage and groundwater characteristics.
4.2 LWD Recruitment	Protect and maintain existing mature riparian trees; riparian planting.	Measure riparian characteristics over time.
5.1 Side Channel and Wetland Conditions	Meadow habitat restoration; reconnect existing floodplain channels; construct perennial side channels, alcoves, and perennial off-channel habitat, evaluate the potential for beaver reintroduction.	Measure the River Complexity Index and length of floodplain channels; measure wetland and meadow area over time.
5.2 Floodplain Condition	Remove existing bank armoring; removal or setback of floodplain berms; floodplain benching.	Measure floodplain inundation and connectivity with hydraulic modeling.
6.1 Bed and Channel Form	Install instream structures that promote the development of natural geomorphic processes; remove artificial channel constraints.	Measure channel dimensions; evaluate channel dynamics over time (incision, aggradation).
6.2 Instream Structural Complexity	Install instream LWD structures; place additional LWD to promote sediment sorting, scour, and pool development; boulder placements.	Conduct habitat surveys; measure pool frequency or spacing; and instream complexity; instream LWD counts.
7.2 Increased Sediment Quantity	Install structures that limit further erosion in incised channels; road decommissioning or abandonment; bank stabilization; install instream LWD structures that split flows and promote efficient sediment sorting.	Measure sediment size distribution, percentage fine sediment in bed; measure bar characteristics over time; calculate sediment transport characteristics; evaluate bank condition and stability.
8.1 Temperature	Meadow habitat restoration; reconnect floodplains; riparian planting; construct perennial side channels, and alcoves.	Measure stream temperature; measure meadow areas, floodplain inundation, and floodplain connectivity.
9.2 Decreased Water Quantity	Protect instream flows; install instream and floodplain structures to raise the water table and increase floodplain groundwater storage.	Install and maintain stream gage; measure riparian and meadow characteristics including soil water storage and groundwater characteristics.
9.3 Altered Flow Timing	Meadow habitat restoration; install instream and floodplain structures to raise the water table and increase floodplain groundwater storage.	Measure riparian and meadow characteristics including soil water storage and groundwater characteristics.

[1/] NOAA Ecological Concerns, often referred to as standardized limiting factors (NOAA 2012).
[2/] See Table 3.1-1 for a more detailed list of metrics and methods.

6.2.3 Identifying and Selecting Restoration Actions

Potential restoration and enhancement opportunities were identified during field surveys (both the reconnaissance-level survey and the reach-based survey), through desktop assessments in areas not visited during field surveys, and through co-manager, landowner, and stakeholder feedback during meetings and reviews of submitted information. The desktop identification of potential project opportunities utilized the topographic surface and high-resolution aerial imagery as well as other available data to identify potential opportunities.

The potential restoration and enhancement actions identified for this Project were chosen from a comprehensive list of 40 potential restoration actions shown in Table 6.2-6. Potential restoration actions were generally organized from passive to active and grouped into 10 broader action categories (e.g., land and water preservation, channel modification, floodplain reconnection, etc.); a total of 40 individual actions were then assigned action numbers (1-40) within those categories.

Table 6.2-6. Potential Restoration and Enhancement Actions Grouped by Action Category and Number

Action Category	Action Number	Potential Restoration Actions
Land and Water Preservation	1	Protection: (Acquisitions, Easements, Coop. Agreements)
	2	Land Management: (Grazing Plans, Fire management, etc.)
Water Quality Improvements	3	Reduce - Mitigate Point or Non-Point Source Impacts
	4	Nutrients Additions (carcasses)
	5	Upland Vegetation Treatment - Management
Sediment Reduction	6	Road Grading - Drainage Improvements
	7	Road Decommissioning or Abandonment
Water Quantity	8	Water Management - Improve Irrigation Efficiency
	9	Acquire or Increase Instream Flow (Lease/Purchase; Groundwater Storage)
Riparian Restoration and Management	10	Remove Non-native Plants
	11	Off--Site Water Developments
	12	Riparian Buffer Strip, Planting
	13	Selective Thinning
	14	Beaver Re-introduction or Management
	15	Riparian Fencing
Bank Restoration or Modification	16	Bank Shaping and Stabilization
	17	Removal of Bank Armoring
	18	Restore Streambanks with LWD - Bioengineering
Instream Structures and Habitat Complexity	19	Boulder Placements
	20	LWD Placements - Individual Whole Trees, Log Jams, etc.
	21	Weirs for Grade Control
Floodplain Reconnection	22	Levee Modifications: Removal, Setback, Breach
	23	Remove and/or Relocate Floodplain Infrastructure
	24	Restoration of Floodplain Topography and Vegetation
	25	Floodplain Excavation: Benching
Side-Channel / Off-Channel Habitat Restoration	26	Improve Thermal Refugia (reconnect cold springs, winter temps)
	27	Perennial Side Channel
	28	Secondary Channel (non-perennial)
	29	Floodplain Pond
	30	Wetland
	31	Alcove
	32	Hyporheic Off-Channel Habitat (Groundwater)

Table 6.2-6. Potential Restoration and Enhancement Actions Grouped by Action Category and Number (continued)

Action Category	Action Number	Potential Restoration Actions
Stream Channel Modifications	33	Spawning Gravel Cleaning and Placement
	34	Pool Construction
	35	Riffle Construction
	36	Meander (Oxbow) Re-connect - Reconstruction
	37	Channel Reconstruction
Fish Passage Restoration	38	Structural Passage (Diversions, Screening)
	39	Barrier or Culvert Replacement or Removal
	40	Dam Removal or Breaching

Each of the action categories and specific actions within each category are described in subsections below.

Land and Water Preservation

Restoration actions related to land and water preservation tend to be more passive in nature and include acquisitions, easements, cooperative agreements, and land management planning (i.e., grazing plans, fire management). Long-term and cooperative land and water preservation can be used to protect existing high-quality habitat, as well as improve land and water management in order to improve existing degraded habitat (Beechie et al. 2010). Existing restoration and land management plans for the Desolation Creek watershed include those discussed above in Section 6.1, and together provide significant land and water preservation in the watershed covering almost the entirety of the watershed area.

Acquisitions and easements are mostly applicable to private land. Currently, the majority of the private land in the watershed is under the management of Desolation Creek LLC, with management guided by the Desolation Creek Land Management Plan (EFM 2015). Future refinements to this management plan may provide additional land and water preservation for this land, or potentially additional preservation measures could be provided through easements on some or all of this land. Updates or revisions to the UNF forest planning and management, as well as updates to the Draft Desolation Creek Watershed Action Plan (USFS 2009), may provide opportunities for additional land management protections for the majority of the watershed that is under the ownership of the USFS.

Water Quality Improvements

Restoration actions related to water quality improvements include reducing and mitigating point or non-point source impacts, nutrient additions (i.e., carcasses), and upland vegetation treatment and management. Project focal species are sensitive to water quality and require clean, cold water to thrive. Point source impacts are not known to be a major issue in the Desolation Creek watershed, but non-point source impacts may be addressed through restoration actions in several action categories, as well as upland vegetation treatment and management. Given the functions provided by wet meadows and their unique importance in the Desolation Creek watershed, restoration and enhancement of stream and upland wet meadows offers a critical tool for water quality improvements.

Nutrient additions are most often considered in depleted systems that may benefit from adding adult salmonid carcasses, thus returning marine-derived nutrients to the watershed. The determination of the need for this restoration action is usually made by local fisheries managers.

Upland vegetation treatment and management overlaps with the land and water management planning discussed above under *Land and Water Preservation*, particularly for timber harvest, fire management, and grazing. Restoration actions related to water quality improvements may address one or more of these issues, and have the potential for significant impacts because of the high percentage of the watershed affected by the management plans discussed above.

Sediment Reduction

Road grading and drainage improvements, and road decommissioning or abandonment are included in this treatment group. As described above in Section 5.2.4, degraded and incised meadow channels are a chronic source of sediments, so projects that restore or enhance upland and stream wet meadows have the potential to reduce excess sediment. Additionally, as described in Section 4.3, the existing road system contributes sediment at a rate approximately 30 percent above the natural background erosion (USFS 2008). Roads that are deemed necessary for recreation, timber harvest, and other land uses may be improved to reduce sediment inputs through grading and improved drainage. Roads that are no longer needed, or that can be replaced by new roads built in less sensitive areas, may be decommissioned or abandoned.

When roads have been constructed adjacent to channels or within floodplains, road decommissioning or abandonment may offer additional benefits to channel and floodplain function by removing the constricting effect of the road prism, allowing unobstructed access for floodplain inundation, channel migration, and riparian vegetation recovery. Road decommissioning in sensitive areas typically involves decompacting the road surface, removing culverts and other infrastructure, blending the slopes to provide improved infiltration and drainage, and replanting the abandoned roadway with site-appropriate native vegetation.

Water Quantity

Changes in water management and irrigation efficiency improvements, acquisition or leases of instream flow, and actions to restore and improve delivery of groundwater to tributaries are included in this action category. Water rights and irrigated lands are mostly non-existent in the watershed, therefore water management and irrigation efficiency improvements are generally not applicable in Desolation Creek. Groundwater actions, however are very appropriate, and include those actions that restore or enhance upland and stream wet meadows such that they provide significant additional clean, cold water during times of low flow, or provide winter thermal refuge during periods of icing. Because wet meadows store water from periods of heavy precipitation and then release it slowly, they provide important buffering of both water quantity and quality (Hammersmark et al. 2008; Pumas National Forest 2010), releasing water when it is most needed by focal fish species. Stream gaging, modeling, and wet meadow field surveys would provide additional information on the expected impacts of climate change on streamflow and wet meadow function and assist in the creation of additional resiliency.

Wet meadow restoration and enhancement actions have been shown to help recover cool-water habitats by increasing floodplain water storage, raising the groundwater table, and restoring meadow vegetation (Hammersmark and Mount 2005; Plumas National Forest 2010). Meadow restoration actions can also reduce sediment inputs by restoring incised channels. Specific actions for meadow restoration may include actions identified in other restoration action categories, such as beaver dam analogs or post-assisted log structures to promote the recovery of incised channels, livestock exclusion, riparian planting, instream LWD structures designed to increase floodplain connectivity and raise the water table, conifer thinning, fire management, removal of levees and diversion ditches, and road decommissioning.

Riparian Restoration and Management

The riparian restoration and management action category includes the removal of non-native plants, off-site water developments, planting of riparian buffer strips, selective thinning, beaver reintroduction, and riparian fencing. Riparian plant communities are intricately tied to stream functions by providing bank stability, shading, cover, nutrient input, and future supply of LWD.

Removal of invasive plant species (weed control) should be part of any riparian management plan and may be the responsibility of individual landowners or cooperating parties. Off-site water developments are included in this category because, when properly installed, they help alleviate grazing pressure in riparian areas. Riparian buffer strips or plantings may accelerate recovery and are often required when natural regeneration of vegetation is expected to occur at a slow pace.

Streams or wet meadows that have been degraded by grazing pressure and channel incision may become impacted by conifer encroachment and require thinning; in those cases, a potential advantage to selective thinning of the encroaching conifers would be the immediate and cost-effective reuse of those trees in the adjacent channels and floodplains to provide LWD structures and habitat.

Beaver management is included in this group because beaver are dependent upon, and can greatly impact, riparian plant communities. Historically, beaver were abundant in Desolation Creek and contributed considerably to habitat diversity and ecosystem function. Recent research has demonstrated that beaver restoration can considerably decrease recovery time for deeply incised channels (Pollock et al. 2007; Beechie et al. 2008). This approach is best addressed through the development of a beaver restoration management plan. Such a plan should include analysis of potential flooding concerns when infrastructure is present, along with possible impacts to newly planted riparian areas and protection measures that may be needed.

New riparian conservation zones and livestock exclusion via riparian fencing, where applicable, will ensure that existing native vegetation or riparian plantings survive and provide long-term protection. Sensitive wet meadows and springs are especially sensitive to overgrazing, and will benefit from livestock exclusion and/or management.

Bank Restoration or Modification

Bank shaping and stabilization, removal of bank armoring, and the restoration of streambanks with LWD and/or bioengineering fall within this action category. Except in cases where removal of bank armoring (e.g., rip rap) is recommended, restoration actions within this category might generally be described as habitat creation given that they focus on construction of specific bank-related habitat features that may be used in cases where full restoration of geomorphic processes may not be possible (Beechie et al. 2010). Bank shaping and stabilization in selected areas may be necessary to protect land or infrastructure. Although these techniques often require use of rock or rip rap, in many cases they can be constructed in a manner that meets many restoration and habitat enhancement objectives.

Based on recent advances in LWD placements and streambank bioengineering, larger scale bank stabilization treatments may be appropriate at some sites where banks are very steep, contribute to excess sediment, and recovery on their own would not be expected within a reasonable time frame; these techniques may be used at sites where a softer bioengineering approach is considered more appropriate than traditional "hard" engineering techniques. Bank stabilization structures typically incorporate bank sloping combined with live cuttings that sprout and grow to further strengthen the stabilization structure over time (Polster 2003; NRCS 2007), and may be combined with LWD structures or beaver analog structures.

Instream Structures and Habitat Complexity

Restoration actions related to instream structures and habitat complexity include boulder placements, LWD placements (i.e., individual whole trees, log jams, etc.), and weirs for grade control. Correct design and placement of instream structures aid in creating complex pools, creating or maintaining side channels and islands, and aid in sediment retention and sorting, along with improving habitat diversity, complexity, and cover. Where endangered species are of concern, Roni et al. (2002) recommend that instream habitat enhancement (e.g., additions of wood, boulders, or nutrients) should be employed after restoring natural processes or where short-term improvements in habitat are needed.

Placement of individual boulders and boulder clusters may be incorporated into the riffles and runs to create areas of varying water depth, substrate, and velocity, thereby increasing habitat diversity. The large-scale roughness effects of boulder placements also increase geomorphic stability though structural resistance to high-flow energy and disruptions of velocity fields and shear stress. Scour pockets often form around the boulders that provide cover and forage habitat for fish during low flows and resting cover during high flows. Boulders also provide diversity in the form of interstitial spaces between adjacent elements, relatively deep water, and local turbulence; they also create water velocity gradients where slow water velocities occur in close proximity to faster ones. They may also aid in prevention of the formation of anchor ice.

Individual LWD placements or habitat structures may be used in conjunction with other restoration actions, and in any areas where large wood is limited. LWD placements may aid in pool formation, activation of side channels, and sediment sorting or retention, help improve bank stability, or perform many other stream functions. Placement of the root wad and other portions of whole trees into the wetted area provides hiding cover from predators, breaks up stream velocities, and aids in sediment sorting and partitioning. Individual pieces of LWD should be sized appropriately, and portions of LWD habitat structures may be buried to reduce potential risks and increase stability where applicable. Sizes of LWD to be used should be determined during development of project designs. LWD should consist of durable species (generally, conifers are recommended). Scour and stability calculations may be necessary during the design development process to create stable features.

LWD may be placed on point or lateral bars, which develop on the inside of meander bends in areas of active channel migration. In areas where the supply of coarse gravel is not limited, these bars can promote increased lateral movement and the development of an inset floodplain. Bars increase hydraulic diversity, retain mobile sediments, and provide unique habitats for focal fish species. Point bar structures can promote natural sediment deposition processes on bars.

LWD structures may be placed specifically at the head of existing mid-channel bars to divert flows into split-flow channels immediately downstream of the main channel. Formation of such channels encourages aggradation in incised areas by slowing velocities, and increases habitat diversity by creating pools at the head of, or adjacent to the structure.

Most of the LWD structures mentioned above should also include live willow stakes and riparian plantings for cover, shading, bank stability, and habitat complexity. As discussed above under *Riparian Restoration and Management*, selective thinning of conifers could provide a cost-effective source of LWD material as well as benefitting wet meadow and upland areas.

The use of weirs to control grade may be necessary in some instances to aid in restoring incised channels, reduce erosion, or restore fish passage. Weirs may come in many forms (e.g., rocks or boulders, straight or log-Vs, or roughened riffles), and designs of these structures must be carefully thought out and consider state and federal guidelines for fish passage.

Floodplain Reconnection

Levee modifications (i.e., removals, setbacks, or breaches), the removal or relocation of floodplain infrastructure, the restoration of floodplain topography and vegetation, and floodplain excavation (i.e., benching) are included in this action category. Floodplain and off-channel habitat is critical for juvenile salmonid rearing and high-flow refugia (Bjornn and Reiser 1991). A properly functioning floodplain acts as an extension of the alluvial aquiver, attenuating stream flows as floodwaters disperse onto the floodplain and discharging stored water during drier months. Connected floodplains regulate stream flows, water temperature, and water quality. Floodplain groundwater inputs into streams provide cool water areas for rearing fish. Floodplain water storage has also been shown to attenuate flows in river channels (Acreman et al. 2003), particularly with wet meadow areas on the floodplain (Hammersmark et al. 2008).

Removal or setback of levees or berms is a preferred method for restoring floodplain connectivity, but, in cases where complete removal is not an option, carefully located breaches may help serve similar functions. Direct actions in this category may include restoring floodplain topography using selective excavation of depressions or swales and/or site-specific ripping of artificially compacted areas and excavating floodplain benches in areas where there is only limited floodplain access. Placing instream structures (see *Instream Structures and Habitat Complexity* above) may be required in many areas to help restore geomorphic processes that result in well-connected floodplains. Properly designed instream structures provide a backwater effect that can increase sediment retention and raise the channel bed and water-table, which increases overbank flows and floodplain connectivity. Road decommissioning (see *Sediment Reduction* above) and beaver analog structures (see *Riparian Restoration and Management* above) may indirectly assist in floodplain reconnection and restoration. Revegetation of these improved floodplain areas (see *Riparian Restoration and Management* above) is usually required.

Side-Channel or Off-Channel Habitat Restoration

Restoration actions related to side-channel or off-channel habitat restoration include the improvement of thermal refugia, perennial side channels, secondary channels, floodplain ponds, wetlands, alcoves, and hyporheic off-channel habitat (groundwater). Roni et al. (2002) found that projects involving reconnection of existing off-channel habitats had a high probability of success, while projects that involved creating new off-channel habitat had a moderate probability of success. These types of restoration actions might be classified as full restoration because they restore riverine ecosystem processes, or selected processes that create and maintain habitats and biota to its normative state (Beechie et al. 2010). Martens and Connolly (2014) found higher densities of salmonids in seasonally disconnected, partially connected, and fully connected side channels than in mainstem channels.

Thermal refugia can be improved where side channels, wet meadows, ponds, seeps, and springs are enhanced or restored, as well as in locations where hyporheic upwelling and exchange are enhanced. Side-channel habitat restoration can involve both perennial and ephemeral side channels, as well as off-channel habitat such as spring channels and oxbows. Side-channel habitat is typically enhanced with LWD and riparian planting and may be associated with beaver analog structures, wet meadow restoration, and other potential project actions. Related actions such as removal of constraining features such as levees, mine tailings, and roads allows natural inundation of perennial and ephemeral side channels and wetlands.

Floodplain ponds may be constructed to simulate abandoned oxbows or meander cutoffs and can support diverse assemblages of aquatic herbaceous and wetland vegetation. When connected to fish-bearing channels, these features can provide zero-velocity refuge fish habitat during flood flows, and year-round thermal refuge. Wetland habitat enhancements can assist in connecting multiple floodplain side channels, sediment filtering and sorting, and groundwater exchange.

Alcoves are recessed areas (small pools) off of the main channel, and were identified as a restoration and habitat enhancement action for project areas where the channel characteristics are otherwise uniform and featureless. Alcoves provide eddies or other areas of velocity diversity that juvenile salmonids use as refuge during high flows. Alcoves are intended to mimic naturally occurring edge habitats with lower velocity and cover, and sites may be chosen where opportunity exists to tie in to cold-water influxes such as tributary mouths or groundwater seeps. These features provide high-quality off-channel habitat for juvenile salmonids, and the propensity for fine material deposition driven by recirculation eddies may also support lamprey habitat. Alcoves may be excavated out of the existing channel banks and a stable LWD structure installed at the head of the pool to maintain flow diversity and prevent sedimentation.

Stream Channel Modifications

Many natural streams migrate laterally across the floodplain, leaving relic oxbows, creating complex pool and riffle habitat, and providing sorted and cleaned sediments for spawning and other uses. In some cases, streams are so severely degraded that restoring geomorphic processes requires active stream channel modifications including spawning gravel cleaning and placement, pool and riffle construction, meander (oxbow) reconnection and reconstruction, and channel reconstruction. These actions are used where severely degraded, simplified, and disconnected stream channels are not able to perform their historical ecological functions. Addressing the causes and impacts of those changes requires modifications to the physical shape and structure (i.e., meander pattern and/or profile) of the stream channel in many cases. Stream channel modifications may be required to jump start the stream evolution process when streams are stuck in a degraded state with an erosion-resistant layer that stabilizes incised channel banks (Cluer and Thorne 2013).

While cleaning or placing spawning gravels and riffle construction may have limited use in Desolation Creek, pool construction may be considered in reaches where they are identified as a limiting factor and are usually done in conjunction with LWD placements. Meander and channel reconnection and reconstruction may provide opportunities to restore a channel to its historical function and provide benefits to focal fish species at both low and high flows. Generally, these actions take place in coordination with floodplain reconnection, side-channel habitat development, and the construction of instream structures and habitat, as well as a range of other potential project actions such as the removal of anthropogenic barriers to channel migration and the reduction of fine sediments.

Fish Passage Restoration

Fish passage restoration actions include structural passage (i.e., diversions, screening), barrier or culvert replacement or removal, and dam removal or breaching. In Desolation Creek, barrier removals or culvert replacements would be the primary tool needed. Additionally, fish passage restoration may be accomplished by implementing other actions that involve the removal or alleviation of thermal and low-flow barriers created by degraded channel and watershed conditions. Resolving partial or full passage barriers is important for restoring longitudinal connectivity in stream systems, which is critical for the success of focal fish species. Additionally, barrier removal can open access to high quality headwater streams, where water quantity and quality, habitat, and sediment are all optimal for key lifestages of the focal species of fish.

Fish passage restoration may be implemented as a discrete action (e.g., removal of a culvert), or as the result of numerous other indirect actions (e.g., elimination of a low flow barrier through improvements in water quantity from wet meadow restoration, riparian vegetation that shades the stream and reduces summer temperatures, and upland land management changes). Overall, fish passage restoration should be implemented through the combination of restoring natural stream function and processes, and the removal of anthropogenic impacts in the floodplains and channel.

6.2.4 Prioritizing Restoration Actions

Based on the preceding lists of potential restoration actions and descriptions on their appropriate use, the next step in the restoration strategy was to select and rank the most effective restoration actions within each BSR. The limiting factors previously identified in Section 4.4 were cross-checked against proposed restoration actions to ensure they would be addressed, both in quantity (number addressed) and severity. A matrix of the focal fish species limiting factors potentially addressed by each of the proposed restoration action categories is shown in Table 6.2-7. Limiting factors and associated actions were classified as low, medium, or high based on their relative significance for improving population performance (abundance, productivity, and sustainability) of the focal fish species.

Table 6.2-7. Significance of Potential Restoration and Enhancement Actions in Addressing Limiting Factors

Restoration Action Category	Ecological Concerns[1/] (Limiting Factors)										
	1.1 Anthropogenic Barriers	4.1 Riparian Vegetation	4.2 LWD Recruitment	5.1 Side Channel and Wetland Conditions	5.2 Floodplain Condition	6.1 Bed and Channel Form	6.2 Instream Structural Complexity	7.2 Increased Sediment Quantity	8.1 Temperature	9.2 Decreased Water Quantity	9.3 Altered Flow Timing
Land and Water Preservation		H	H	M	M				L		L
Water Quality Improvements									H		
Sediment Reduction							M	H			
Water Quantity									H	H	M
Riparian Restoration & Management		H	H	M			L	M	M	M	H
Bank Restoration or Modification		L					L	M			

Table 6.2-7. Significance of Potential Restoration and Enhancement Actions in Addressing Limiting Factors (continued)

Restoration Action Category	Ecological Concerns[1/] (Limiting Factors)										
	1.1 Anthropogenic Barriers	4.1 Riparian Vegetation	4.2 LWD Recruitment	5.1 Side Channel and Wetland Conditions	5.2 Floodplain Condition	6.1 Bed and Channel Form	6.2 Instream Structural Complexity	7.2 Increased Sediment Quantity	8.1 Temperature	9.2 Decreased Water Quantity	9.3 Altered Flow Timing
Instream Structures & Habitat Complexity			L	M	M	H	H	H	L		
Floodplain Reconnection		M	M	M	H	H	M	H	H	M	M
Side Channel / Off-Channel Habitat Restoration		M	M	H	M	H	M	H	L	M	L
Stream Channel Modifications		M			L	M	H	M	L	L	M
Fish Passage Restoration	H					M	L	L			

1/ NOAA Ecological Concerns, often referred to as standardized limiting factors (NOAA 2012).

H = High – Factors that are critical to be addressed to improve focal fish species population performance (abundance, productivity, and sustainability) in the immediate term.
M = Medium – Factors that are important (not critical) to be addressed to improve focal fish species population performance in the long term.
L = Low – Beneficial to address, but not critical to improve focal fish species population performance.

Continuing to build on the foundation established in the previous stages, the next step in the prioritization strategy was to identify and rank potential restoration actions specifically within each BSR using the restorations actions worksheet within the Prioritization Matrix. The purpose of the restoration action worksheets was to ensure that proposed restoration actions align with current fish use and critical limiting factors based on the best available and most current data; therefore, restoration actions were assigned while taking into consideration the fish limiting life stage utilization rankings (see Table 6.2-2 above), in combination with the limiting factor scores (see Table 6.2-4 above). Within the Prioritization Matrix, the restoration actions described above were identified and ranked within each BSR based on the following definitions:

> High (H): High-priority actions that should be implemented in the *immediate to short-term* (1-3 years), and have the ability to provide benefits to key life stages (fish limiting life stages ranked as High), and improve fish population performance.

Medium (M): Medium-priority actions that should be implemented in the intermediate term (4-15 years), and have the ability to provide benefits to less critical life stages (Medium or Low fish life stage utilization rankings), and improve fish population performance.

Low (L): Low-priority actions that should be implemented in the long term (15 or more years), and have the ability to provide some benefits to any life stage, but are currently not critical to improving fish population performance.

N/A: Not Applicable because restoration action would not provide short term or future benefits to any fish life stage or improve fish population performance.

An example of a list of 40 potential restoration actions and rankings for one of the BSRs is shown in Table 6.2-8 below.

In combination, the previous rankings of BSRs, fish limiting life stages, limiting factors, and restoration actions served as the framework for scoring project opportunities within each BSR, as described in the following section.

Table 6.2-8. Example of a Completed Restoration Actions Worksheet

Treatment Categories & Action Numbers - Reach 6: RM's 9.5 to 11.8		Ranking	Comments
Land and Water Preservation:			
1	Protection: (Acquisitions, Easements, Coop. Agreements)	**H**	Should be a high priority for most projects. ODFW agreements in place.
2	Land Management: (Grazing Plans, Fire management, etc.)	**M**	
Water Quality Improvements:			
3	Reduce - Mitigate Point or Non-Point Source Impacts	**L**	
4	Nutrients Additions (carcasses)	**L**	TBD by local biologists.
5	Upland Vegetation Treatment - Management	**L**	
Sediment Reduction:			
6	Road Grading - Drainage Improvements	**M**	
7	Road Decommissioning or Abandonment	**H**	Decommission or obliterate unnecessary roads and old stream crossings.
Water Quantity:			
8	Water Management-Improve Irrigation Efficiency	**N/A**	
9	Acquire or Increase Instream Flow (Lease/Purchase; GW Storage)	**H**	Groundwater storage in Spring and Starveout creeks and other unnamed tribs.
Riparian Restoration and Management:			
10	Remove Non-native Plants	**L**	Includes noxious weeds.
11	Off--Site Water Developments	**H**	Alleviate cattle pressure in creek bottoms.
12	Riparian Buffer Strip, Planting	**H**	
13	Selective Thinning	**N/A**	Generally not recommended unless for non-native vegetation.
14	Beaver Re-introduction or Management	**H**	After vegetation is restored.
15	Riparian Fencing	**H**	Scheduled for 2017.
Bank Restoration or Modification			
16	Bank Shaping and Stabilization	**L**	
17	Removal of Bank Armoring	**L**	
18	Restore Banklines with LWD - Bioengineering	**L**	
Instream Structures and Habitat Complexity:			
19	Boulder Placements	**M**	Selective sites.
20	LWD Placements - Individual Whole Trees, Logjams, etc.	**H**	High priority throughout this reach.
21	Weirs for Grade Control	**N/A**	
Floodplain Reconnection:			
22	Levee Modifications: Removal, Setback, Breach	**M**	One small berm at upper end of reach.
23	Remove and/or Relocate Floodplain Infrastructure	**H**	Road 10 & bridge, campsites close to stream.
24	Restoration of Floodplain Topography and Vegetation	**H**	
25	Floodplain Excavation: Benching	**L**	
Side Channel / Off-Channel Habitat Restoration:			
26	Improve Thermal Refugia (reconnect cold springs, winter temps)	**H**	Some springs are aready fenced, protected.
27	Perennial Side Channel	**H**	Multiple side channels near Starveout Creek.
28	Secondary Channel (non-perennial)	**H**	
29	Floodplain Pond	**L**	Potential opportunities but connected side channels preferred.
30	Wetland	**M**	
31	Alcove	**H**	Utilize mouth of Spring Creek.
32	Hyporheic Off-Channel Habitat (Groundwater)	**H**	
Stream Channel Modifications:			
33	Spawning Gravel Cleaning and Placement	**N/A**	
34	Pool Construction	**L**	Can excavate pools where LWD structures are placed.
35	Riffle Construction	**N/A**	
36	Meander (Oxbow) Re-connect - Reconstruction	**H**	
37	Channel Reconstruction	**N/A**	
Fish Passage Restoration:			
38	Structural Passage (Diversions, Screening)	**N/A**	
39	Barrier or Culvert Replacement or Removal	**N/A**	
40	Dam Removal or Breaching	**N/A**	

6.2.5 Project Opportunity Scoring

A project opportunity ranking system was included as a separate opportunity scoring worksheet within the Prioritization Matrix spreadsheet and was used to list and rank project opportunities within specific areas of each BSR.

Project opportunities within each BSR were prioritized based on input variables that included:

1. The previous ranking of the BSR they are located within (Tier I, II, or III), as described Section 5.3.1;
2. The number and importance of restoration actions chosen for an opportunity;
3. The cumulative effects of the restoration action’s ability to address the most important and the greatest number of limiting factors;
4. Determination of whether the project meets the criteria for full restoration, partial restoration, or short-term habitat restoration based on Beechie et al. (2010);
5. Assessment of the restoration action’s ability to address climate change based on Beechie et al. (2012); and
6. Project scale and connectivity.

Project opportunities and potential restoration actions within those areas were initially identified during field surveys, and later supplemented with desktop assessments and landowner, co-manager, and stakeholder input. The additional steps involved in ranking project opportunities are described below.

Project Descriptions and Restoration Actions

Within the Prioritization Matrix and worksheet for each BSR, project areas were described and named based on geomorphic reaches and RM locations. Project areas typically consist of a single spot location (e.g., replacing a culvert) or much larger extents (an entire reach), but generally were sized such that they could be implemented within 1 to 2 years. Within each designated project area, the next step was to identify the specific restoration actions from the comprehensive list of 40 potential actions (previously shown in Table 6.2-6) that could be applicable to an individual project site. Restoration actions that could occur in that project area were identified and the action number entered into the worksheet (see Table 6.2-9, column 1). The action names associated with the action numbers would then be automatically generated (see Table 6.2-9, column 2). When entering in the restoration actions, the action type may be categorized as either being direct or passive (see Table 6.2-9, column 3), but the choice between these had no influence on score.

Table 6.2-9. Example Scoring of an Individual Project Opportunity

Action No.	DC-4: PAA Reach 6, RM's 9.5 to 11.8 Project Descriptions and Actions Opportunity Location (BSR No., Reach, & RM's)/Project Name	Action Type	Biological Rankings: BSR ranking	Biological Rankings: Restoration Actions Score	Biological Rankings: Action Effects on Limiting Factors Score	Physical Processes Rankings: Natural Processes Score	Physical Processes Rankings: Climate Change Score	Physical Processes Rankings: Project Scale and Connectivity Score	Subtotal Biological Scores	Subtotal Physical Scores	TOTAL PROJECT SCORE	Comments
Action No.	DC-4: Reach 6, RM's 9.5 to 11.8	Action Type	Tier I	171	268	Full Restoration		Excellent				
1	Protection: (Acquisitions, Easements, Cooperative Agreements)	Passive Effect		10	24		8					Both Phases (upper & lower)
2	Land Management: (Grazing Plans, Fire management, etc.)	Passive Effect		5	8		8					
3	Reduce - Mitigate Point or Non-Point Source Impacts	Direct Action		2	6		2					
6	Road Grading - Drainage Improvements	Direct Action		5	3		2					
7	Road Decomissioning or Abandonment	Direct Action		10	3		2					NF-10 and others.
9	Acquire or Increase Instream Flow (Lease/Purchase; GW Storage)	Direct Action		10	5		6					Tributary confluences.
11	Off--Site Water Developments	Direct Action		10	12		0					ODFW to provide.
12	Riparian Buffer Strip, Planting	Direct Action		10	17		4					Focus on cottonwoods
15	Riparian Fencing	Direct Action		10	28		6					ODFW 2017.
20	LWD Placements - Individual Pieces, WholeTrees, Logjams, etc.	Direct Action		10	13		2					
23	Remove and/or Relocate Floodplain Infrastructure	Direct Action		10	16		6					Road 10 bridge and camp sites.
24	Restoration of Floodplain Topography and Vegetation	Direct Action		10	21		6					
25	Floodplain Excavation: Benching	Direct Action		2	19		2					Following NF-10 reroute.
26	Improve Thermal Refugia (cold spring reconnect, winter temps)	Direct Action		10	6		4					
27	Perennial Side Channel	Direct Action		10	8		7					
28	Secondary Channel (non-perennial)	Direct Action		10	11		6					
30	Wetland	Direct Action		5	14		6					
31	Alcove	Direct Action		10	17		4					
32	Hyporheic Off-Channel Habitat (Groundwater)	Direct Action		10	11		5					
36	Meander (Oxbow) Re-connect - Reconstruction	Direct Action		10	16		6					
39	Barrier or Culvert Replacement or Removal	Direct Action		0	0		2					Spring Creek, Unnamed tributary.
10	Remove Non-native Plants	Direct Action		2	10		2					
		Direct Action		0	0		0					
		Direct Action		0	0		0					
DC-4: Reach 6, RM's 9.5 to 11.8		Scores:	Tier I	34	54	15	19	15	87.8	49.2	137.0	

Action Type

While the majority of action types were direct actions, the Atlas Development Team thought it would be useful to identify whether a restoration action type used a passive action; therefore, this category was added into the opportunity prioritization matrix as a drop-down item (see Table 6.2-9, column 3). The selection of an action as a passive type helps address situations where only a few limited physical actions might be implemented (such as a project opportunity which only requires an easement or beaver restoration management) by indicating they can indirectly lead to broader restoration benefits, especially for larger scale restoration opportunities. For example, if removing a levee (Action 7) also contributes to the restoration of floodplain connectivity, then Action 9 (Restoration of Floodplain Topography and Vegetation), Action 11 (Perennial Side Channel), and Action 12 (Secondary [non-perennial] Channel) could also be selected as passive effects, and thus give credit to those indirect actions. While most restoration actions were direct actions, this category helped highlight more passive actions such as Protect Land and Water, Riparian Fencing, and Beaver Restoration Management.

BRS Ranking

The BSR ranking (Tier I, Tier II, Tier III, or Node) was chosen from a drop-down menu (see Table 6.2-9, column 4), setting up the initial project hierarchy. Under this system, it is possible for a project opportunity in a Tier III BSR to have a higher opportunity score than an opportunity in a Tier I BSR, but that higher score does not override the initial hierarchy. The use of the "Node" category, short for Ecological Node, did provide some limited override to the Tier I group based on the following definition:

> *A smaller geographic area within a lower ranked (Tier 2 or Tier 3) biologically significant reach (BSR) that may have significant fish use based on close proximity to known spawning habitat, refuge habitat (thermal refugia, hiding cover, or available floodplain), or important tributary junctions.*

With the addition of this category, actions identified within an ecological node could be considered a higher priority for implementation.

Restoration Actions Score

For each potential action entered into a project opportunity site, the opportunity scoring worksheet automatically tallied biological scores based on the previous qualitative ranking of the restoration action's importance (see Section 6.2.4 and Table 6.2-8), by converting the High, Medium, Low, or N/A rankings into scores of 10, 5, 2, or 0, respectively, as illustrated in the Restoration Actions Score in Table 6.2-9 (column 5). If a large number of restoration actions within an opportunity were identified, it could result in a very large cumulative score; therefore, the cumulative Restoration Actions Score was divided by a factor of 5 to better align with the weightings of the other scoring categories.

Actions Effects on Limiting Factors Score

The Actions Effects on Limiting Factors Score automatically tallied biological scores based on the previous qualitative rankings of limiting factors (see Section 6.2.2 and Table 6.2-4), along with an action's ability to directly or indirectly affect limiting factors. For example, a levee removal project (Action No. 22) can directly affect Peripheral and Transitional Habitats: Floodplain Condition (NOAA limiting factor 5.2), but also indirectly affect other limiting factors, such as Riparian Condition (NOAA limiting factor 4.1) and Channel Structure & Form (NOAA limiting factors 6.1 and 6.2). To account for these multiple effects, the restoration actions for an opportunity were cross-walked against the limiting factors' earlier qualitative scores (High, Medium, Low), and then factored in if actions had either direct or indirect effects. The conversion from qualitative limiting factors severity and effects types to numerical scores is shown in Table 6.2-10 below, and results are illustrated in Table 6.2-9 (column 6).

Table 6.2-10. Limiting Factors Ratings, Effects Type, and Scores

Limiting Factor Rating	Effect Type	Score
High	Direct	5
High	Indirect	3
Medium	Direct	3
Medium	Indirect	2
Low	Direct	2
Low	Indirect	1

In this fashion, the more restoration actions within an opportunity that were identified, combined with a high number limiting factors that occurred in that BSR, could result in a very large cumulative score; therefore, the Actions Effects on Limiting Factors Score was also divided by a factor of 5 to better align with the weightings of the other scoring categories.

Natural Processes Score

The next step involved in project scoring was the Natural Processes Score, which prioritizes the project area as a whole based on the assumption that restoration of natural processes (full restoration) is preferred over partial restoration or habitat creation. Restoration alternatives that have the ability to restore processes that create and maintain habitats and biota are preferred over those that can only improve the quality of habitat by treating specific symptoms through creation of locally appropriate habitat types. Precedence for this strategy is found in *Process-based Principles for Restoring River Ecosystems* (Beechie et al. 2010). This score was selected from a drop-down menu and automatically converted the selection to a numeric value of up to 15 points for full restoration (see Table 6.2-9, column 7).

Climate Change Score

Within the opportunity portion of the Prioritization Matrix, a Climate Change Score was automatically tallied for each restoration action based on its ability to ameliorate temperature increases, base flow decreases, and peak flow increases, and its capacity to increase salmon resilience. Scoring is based on criteria described in *Restoring Salmon Habitat for a Changing Climate* (Beechie et al. 2012), with up to 8 points available for any given restoration action (see Table 6.2-9, column 8).

Project Scale and Connectivity Score

The final step was to select a ranking for the Project Scale and Connectivity Score in which a project opportunity is scored based on the project scale (stream length or acres treated), longitudinal connectivity such as ability to increase flow, restored fish passage, and lateral connectivity to the adjacent floodplain, as well as considering connection with adjacent restoration projects. This score was also selected from a drop-down menu and automatically converted the selection to a numeric value of up to 15 points (see Table 6.2-9, column 9).

Following entry of all the project areas within each BSR, each was ranked relative to one another as shown in Table 6.2-11, with Tier I (the highest ranked BSRs) grouped at the top, followed by Tier II and Tier III opportunities. Table 6.2-11 represents a preliminary list and is expected to change following additional co-manager and stakeholder reviews of the feasibility of specific project restoration actions for each opportunity, and the identification of more specific project opportunities in the SAA. Some project opportunities in this preliminary list were based on evaluating large areas that are likely to later be scaled down to smaller, more manageable projects, and therefore at this time they simply help illustrate their relative importance compared to other opportunities. It is also important to acknowledge that opportunity scores were relative scores and should *not* be considered absolute rankings for sequential project implementation, but should guide project implementers in determining which potential projects should be pursued first. As noted above, project feasibility can impact the likelihood of moving from a project opportunity to an actual project proposed for funding, as described in the following section.

Table 6.2-11. Preliminary List of Project Opportunities and Rankings in Desolation Creek

Tier	Project Opportunity: [BSR Number, Reach Number, River Miles, other descriptors]	Total Project Score	Rank
Tier I	DC-4: Reach 6, RMs 9.5 to 11.8	137	1
Tier I	DC-2: Reach 3, RMs 2.6 to 4.4	124	2
Tier I/II	DC-3: Reach 5, RMs 7.5 to 9.5	88	3
Tier I	DC-5: Reach 7 & USFS, RMs 11.8 to 21.5	85	4
Tier II	DC-8: Desolation Meadows, RMs 1.0 to 2.3	130	5
Tier II	DC-7: South Tribs. (RMs 4.4 to 21.5)	125	6
Tier II	DC-6: North Tribs (RMs 4.4 to 21.5)	124	7
Tier II	DC-10: South Fork, RMs 0.0 to 2.3	33	8
Tier III	DC-1: Reaches 1 & 2, RMs 0.0 to 2.6	77	9
Tier III	DC-9: North Fork, RM 4.0 to Headwaters	70	10
Tier III	DC-11: South Fork, RM 2.3 to Headwaters	34	11

6.2.6 Project Feasibility Criteria

A project feasibility evaluation system was developed within the Prioritization Matrix using 10 individual criteria, followed by an overall summary column. Estimated cost and benefit/cost ratios were the only categories converted to numerical scores. Other categories were assigned qualitative high, moderate, low, or to be determined (TBD) rankings using best professional judgement. For example, some categories, such as landowner willingness, would be difficult to evaluate until the potential project was farther along in the planning process. In addition, quantitative scoring leading to a total score would make little sense if a single category (e.g., an unwilling landowner, or inaccessibility) would limit the chance of a potential project area from becoming an actual project. For those reasons, the feasibility criteria were kept as a separate component of the biological/physical scores. The preliminary feasibility rankings for the 11 previously listed project opportunities are shown in Table 6.2-12. The feasibility rankings can be easily modified as new information becomes available or if any circumstances change.

Table 6.2-12. Project Feasibility Criteria Rankings

Desolation Creek Project Opportunities Summary Table				Project Feasibility Criteria											
General Information															
TIER	PROJECT OPPORTUNITY: BSR Number, Reach Number, River Miles, other descriptors	TOTAL PROJECT SCORE	RANK	Estimated Cost	Benefit/Cost Ratio	Landowner Willingness	Design Effort	Construction Effort	Site Access Effort	Site Management - Dewatering and Erosion Control Effort	Risk & Uncertainty (Goals and Objectives Achieveable?)	Risk & Uncertainty (Public Safety, Infrastrucure)	Regulatory Requirements, Permitting Effort	Overall Feasibility Constraints	Comments
Tier I	DC-4: Reach 6, RM's 9.5 to 11.8	137	1	10	14	YES	M	M	H	H	L	L	M	M	HIP III Medium to Hish Risk.
Tier I	DC-2: Reach 3, RM's 2.6 to 4.4	124	2	8	16	YES	M	M	M	H	L	M	M	M	HIP III Medium to Hish Risk.
Tier I/II	DC-3: Reach 5, RM's 7.5 to 9.5	88	3	6	15	YES	M	M	H	M	M	H	M	M	This reach nearly a Tier 1 so ranked higher.
Tier I	DC-5: Reach 7 & USFS, RM's 11.8 to 21.5	85	4	6	14	TBD	M	M	H	M	H	M	M	M	Retrofit juvenile barriers is a high priority.
Tier II	DC-8: Desolation Meadows, RM's 1.0 to 2.3	130	5	8	16	TBD	H	H	M	H	M	M	M	M	Highest ranked Tier II.
Tier II	DC-7: South Tribs. (RM's 4.4 to 21.5)	125	6	10	12	TBD	M	H	M	H	M	M	M	M	Remaining barriers is top priority.
Tier II	DC-6: North Tribs (RM's 4.4 to 21.5)	124	7	10	12	TBD	H	H	M	H	M	M	M	M	Remaining barriers is top priority.
Tier II	DC-10: South Fork, RM's 0.0 to 2.3	33	8	2	17	TBD	L	L	H	L	L	L	L	L	Very little work needed.
Tier III	DC-1: Reaches 1 & 2, RM's 0.0 to 2.6	77	9	6	13	YES	M	H	M	M	L	M	M	M	Some worthwhile work, after others done.
Tier III	DC-9: North Fork, RM's 4.0 to Headwaters	70	10	6	12	TBD	M	M	M	M	M	M	H	M	Need more fish data on steelhead use.
Tier III	DC-11: South Fork, RM's 2.3 to Headwaters	34	11	2	17	TBD	L	L	L	L	L	L	L	L	Recovering from past fires.

6.3 DESIGN DEVELOPMENT

The next step in the development of the action plan was to select from the list of prioritized project opportunities, and initiate the design development process for conceptual and final designs for highly ranked restoration and enhancement projects that can demonstrate progress toward addressing focal fish species limiting factors. The data and analyses in the watershed- and reach-scale assessments in Section 4 and Section 5 were used to inform the identification and prioritization of potential projects, and to guide the development of conceptual and final designs. Potential restoration and enhancement opportunities were identified during field surveys, through desktop assessments, and co-manager, landowner, and stakeholder input as described above in Section 6.2. Following their identification, potential opportunities were prioritized using biological and physical habitat attributes and project feasibility and constraints, as described above in Sections 6.2.5 and 6.2.6. Project designs were then developed consistent with biological needs of the focal fish species, local geomorphology, and implementation feasibility. During stakeholder meetings, it was determined that protection of critical areas using passive approaches (e.g., riparian fencing) would be conducted by project landowners, co-managers, or stakeholders, while engineer-level components such as additions of large wood structures and reactivation of side channels would be provided in the detailed final designs.

The design process began with the development of 15 percent alternative designs for the entire PAA and throughout the SAA, along the mainstem and primary tributaries, and included conceptual drawings of potential restoration and enhancement actions (Tetra Tech 2016). Potential actions shown in the 15 percent alternatives designs were based on reviews of project area needs checked against the comprehensive list of 40 project actions described in Section 6.2.3 and illustrated above in Table 6.2-8. These actions are intended to provide sustainable instream, riparian, and floodplain restoration features to restore natural geomorphic processes and address multiple limiting factors.

Conceptual (30 percent) designs were developed for Reach 6, which ranked as the highest priority project area, and the upper half of Reach 5, which ranked as the third highest priority project area (see Table 6.2-12). The rationale for choosing the upper half of Reach 5, as opposed to Reach 4 (the second highest ranked project) was decided by CTUIR early on in development of the action plan during which it was determined that it would be beneficial to develop project designs in both an unconfined as well as a confined reach. The reasoning was that each type of design could be used as a template for considering appropriate restoration actions in each type of system. The upper half of Reach 5 represented the highest ranked project in a confined reach. This reach was also contiguous with Reach 6 which was considered an added benefit in that implementation of both projects would encompass treatment of a total of 4.3 miles. The Reach 6 conceptual (30 percent) designs included full restoration, partial restoration, and habitat creation design alternatives (Tetra Tech 2017b), and the Reach 5 conceptual (30 percent) designs included full restoration and habitat creation design alternatives (Tetra Tech 2017a). Following reviews by the Project co-managers, landowners, and stakeholders, in both cases the full restoration alternative was selected.

The conceptual (30 percent) designs for Reach 6 were advanced to the preliminary (60 percent) design level (Tetra Tech 2017c). At that time, it was decided to break Reach 6 into Lower Reach 6 (RM 9.5 to RM 10.5) and Upper Reach 6 (RM 10.5 to RM 11.8). This occurred following agreement between Desolation Creek LLC and the USFS that the NF-10 road and associated bridge near RM 10.0 would be abandoned and relocated. Since those planned actions would not occur until 2018 or beyond, the decision was made to phase the Reach 6 project. The first phase entailed completing restoration designs and implementing actions in the unaffected Upper Reach 6 portion, starting at

Spring Creek and continuing to the top of Reach 6. The Desolation Creek – Upper Reach 6 (RM 10.5 to 11.8) Habitat Restoration Final Design Submittal (Tetra Tech 2017d) was completed in June 2017, with project construction scheduled to start in July 2017.

6.4 IMPLEMENTATION SCHEDULE

This section describes the project sequencing and preliminary implementation schedule for the potential restoration and enhancement projects identified in the action plan. The intent of the schedule is to provide the CTUIR, co-managers, landowners, and stakeholders with a target schedule for restoration and enhancement projects to assist with project implementation planning by identifying timeframes for allocating necessary resources. The implementation schedule, shown in Table 6.4-1, was developed in collaboration with the CTUIR, co-managers, landowners, and stakeholders. The initial focus was to list planned projects in the PAA, but it will be updated to add projects in the SAA.

Implementation of this preliminary plan will rehabilitate over 8 miles of Desolation Creek within the PAA, make demonstrated progress toward addressing limiting factors, and will improve conditions in Desolation Creek over time to the benefit of terrestrial and aquatic First Foods including ESA-listed and other native species.

Table 6.4-1. Action Plan Preliminary Implementation Schedule

Project Area	Project Ranking	Potential Project Actions	Implementation Schedule
Upper Reach 6, Phase I	Tier I	Meadow habitat restoration; road decommissioning or abandonment; reconnect existing floodplain channels and off-channel habitat; install instream structures that promote the development of natural geomorphic processes; install instream and floodplain structures to raise the water table and increase floodplain groundwater storage; removal or setback of floodplain berms. Based on Tetra Tech (2017d) 100% design.	Design 2016/2017; Construction 2017
Lower Reach 6 & Upper Reach 5	Tier I	Survey NF-10 Road realignment and determine new easement boundaries.	Survey & Easement 2017
Lower Reach 6 & Upper Reach 5	Tier I	Realign NF-10 Road and remove bridge at RM 10.0.	Design 2017/2018; Construction 2018
Lower Reach 6, Phase 2	Tier I	Restore meadow habitat; decommission or abandon roads; reconnect existing floodplain channels and off-channel habitat; install instream structures that promote the development of natural geomorphic processes; install instream and floodplain structures to raise the water table and increase floodplain groundwater storage; removal or setback of floodplain berms. Advance Tetra Tech (2017c) 30% design to final.	Design 2018/19; Construction 2019

Table 6.4-1. Action Plan Preliminary Implementation Schedule (continued)

Project Area	Project Ranking	Potential Project Actions	Implementation Schedule
Upper Reach 5	Tier I/II	Decommission or abandon roads; reconnect existing floodplain channels and off-channel habitat; install instream structures that promote the development of natural geomorphic processes; install instream and floodplain structures to raise the water table and increase floodplain groundwater storage. Advance Tetra Tech (2017a) 30% design to final.	Design 2019/20; Construction 2020
Reach 3	Tier I	Advance Tetra Tech (2016) 15 percent design alternatives. Details to be determined.	Design 2020/2021; Construction 2021
Lower Reach 5	Tier I/II	Advance Tetra Tech (2016) 15 percent design alternatives. Details to be determined.	Design 2021/22; Construction 2022

7 Conclusion and Next Steps

This geomorphic assessment and action plan report was developed to evaluate existing biological and physical conditions in Desolation Creek, with a focus on the PAA, in order to identify and prioritize potential project areas and restoration and habitat enhancement actions for Desolation Creek. The report is based on available existing data and field surveys conducted in 2016.

The watershed- and reach-scale assessments (Sections 4 and 5) provide a rigorous, science-based evaluation of existing and desired future conditions in Desolation Creek. The assessments identify the factors that are negatively influencing biological and physical processes resulting in the current degraded habitat conditions, which are limiting productivity. The reach-scale assessment includes a thorough evaluation of current geomorphic conditions and restoration potential in order to identify which reaches of Desolation Creek, within the PAA, have the greatest restoration potential. Focal fish species utilization potential was also determined for each reach in the PAA by assessing current fish utilization and the limiting factors specifically affecting each reach. Together, the geomorphic restoration potential and focal fish species utilization potential provide an effective means of identifying and evaluating restoration alternatives and potential restoration actions to address limiting factors in Desolation Creek.

The action plan (Section 6) presented in this report provides a framework for restoring natural processes in Desolation Creek, with a focus on the PAA, and also aids in planning and allocation of financial resources. The resources provided in the action plan will assist in tracking and prioritizing future projects, providing restoration planners with a tool to evaluate which areas are being under-represented, and aid in identifying how various restoration projects interact with each other and important features.

The action plan uses the scientific information, analyses, data synthesis, and interpretation from the watershed- and reach-scale assessments (Sections 4 and 5) to identify targeted restoration actions that benefit ESA-listed salmonids and other fish species. The action plan provides a scientifically defensible ranking and selection framework for prioritizing restoration projects, and sets the baseline for future adaptive management. It also provides objective scoring rationale that can be used in communication with landowners, co-managers and stakeholders who may choose to participate in habitat restoration in the watershed. The framework recognizes that conditions in Desolation Creek may change over time and/or additional data may become available. Future research may increase our understanding of the effects of climate change or other factors on aquatic conditions. Therefore, it is imperative that this action plan remain flexible and adaptable. The Prioritization Matrix is capable of incorporating future data collection, analyses, or scientific advances.

Next steps were identified throughout the development of this geomorphic assessment and action plan. These include ongoing data collection and research efforts, developing site-specific projects designs, implementing projects, and monitoring completed projects. The preliminary list of next steps identified for Desolation Creek is provided below:

- Continue to perform stakeholder outreach and communicate the results of this geomorphic assessment and action plan.
- Continue to implement the prioritized projects identified in the action plan and update the implementation schedule, as necessary.
- Identify opportunities to fill data gaps including:
  - Summarize existing data and collect additional stream temperature data;
  - Conduct groundwater monitoring and analysis;
  - Install a stream gage and monitor flows;
  - Develop a complete passage barrier and culvert inventory;
  - Conduct surveys to better identify focal fish species distribution (particularly bull trout and lamprey); and
  - Determine fish fall outmigration patterns and over-winter rearing distribution in lower Desolation Creek and the North Fork John Day River.
- Evaluate all opportunities to reduce sediment inputs and increase water storage on incised tributary channels, building on the NFJDWC proposed restoration and enhancement actions (NFJDWC 2017b).
- Conduct riparian vegetation growth and future wood recruitment models to determine if LWD additions are needed and for how many years.
- Implement felling of trees along Desolation Creek where access is not feasible.
- Incorporate recommendations and evaluate potential opportunities for future habitat improvement and habitat preservation based on predicted climate changes.
- Continue the CTUIR Biomonitoring Program surveys in Desolation Creek at CHaMP sites and evaluate additional project effectiveness monitoring opportunities for completed projects.
- Continue to integrate the results of ongoing research, monitoring, and data collection and evaluation into the project prioritization and the action plan.

Updates should made to the action plan as limiting factors or river conditions change, new empirical data and research evidence become available, or as projects are implemented (i.e., removed from the rankings list), thus contributing to the adaptive management of habitat restoration programs into the future. Addressing these next steps will ensure the plan is not only useful in the short term, but will serve as a “living” document now and well into the future.

8 References

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APPENDIX A – EXISTING CONDITIONS AND INUNDATION MAP SERIES

List of Figures

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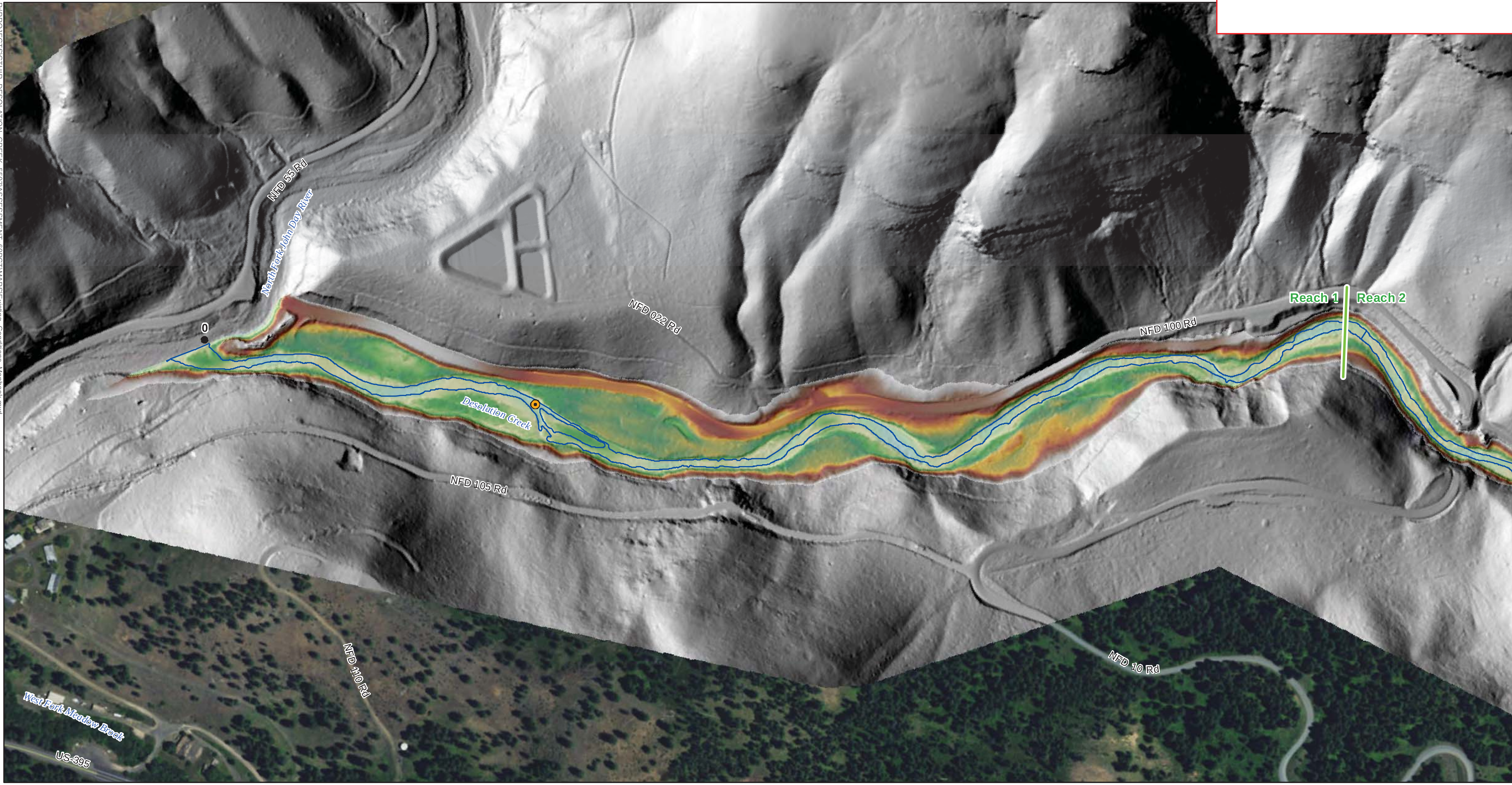


Primary Assessment Area (PAA)
River Mile
Reach Breaks
Low Flow Extent
CHaMP Treatment
Seeps/Springs
Sediment Sample Site

Redd Location
Chinook (2009-2015)
Steelhead (2004-2012)

Relative Elevation Model
High : 125
Low : 90.6824

0 500 1,000
Feet

TETRA TECH

Figure A-1a
Existing Conditions in the PAA RM 0.0 to 0.9

Primary Assessment Area (PAA)
River Mile
Reach Breaks
Low Flow Extent
CHaMP Treatment
Seeps/Springs
Sediment Sample Site

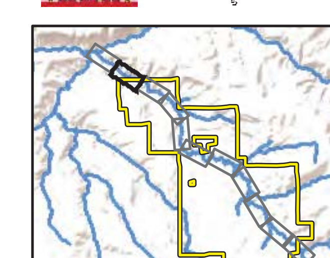
Redd Location
Chinook (2009-2015)
Steelhead (2004-2012)

Relative Elevation Model
High : 125
Low : 90.6824

Figure A-1b
Existing Conditions in the PAA RM 0.9 to 1.9

0 500 1,000
Feet

TETRA TECH



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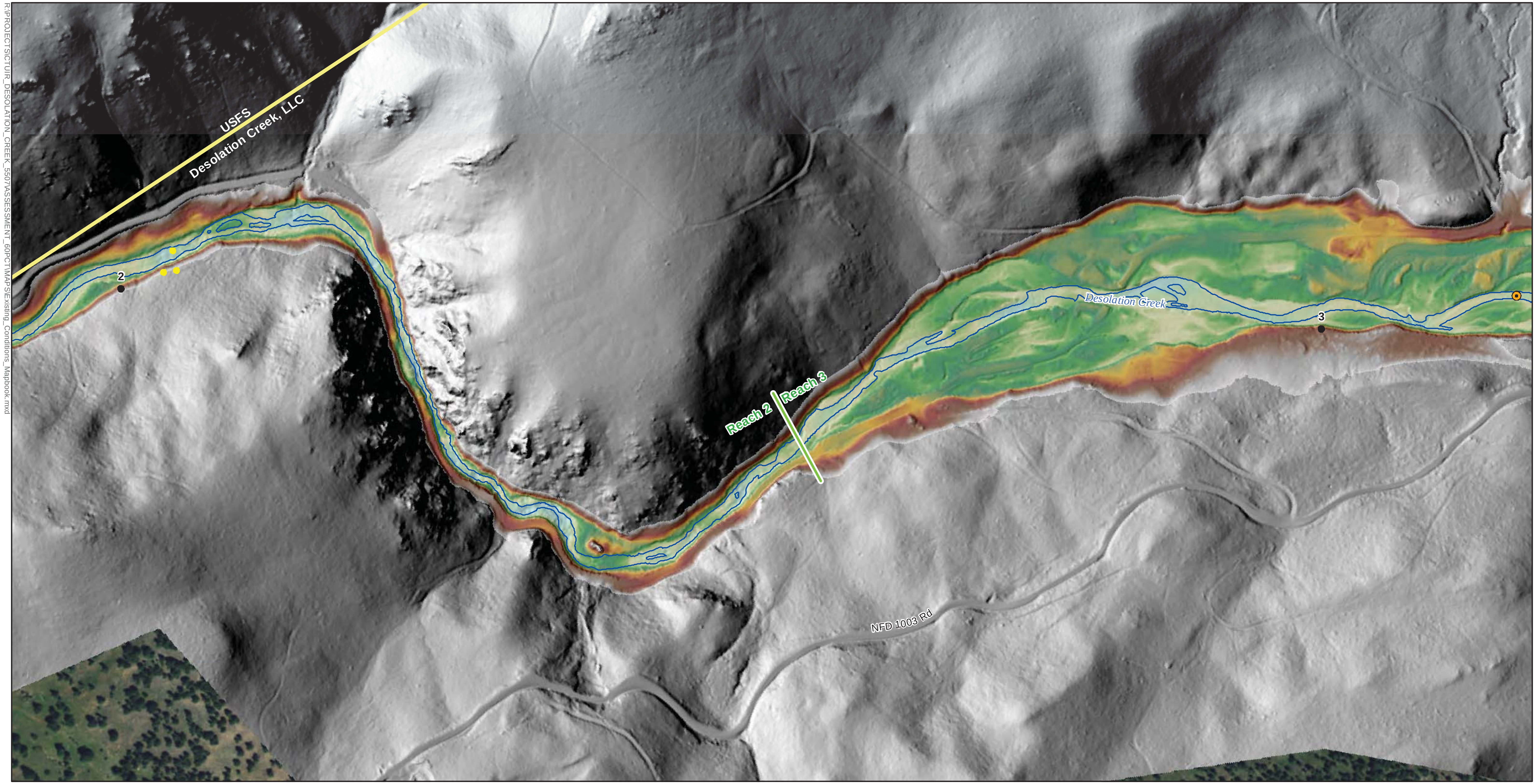

Primary Assessment Area (PAA)
River Mile
Reach Breaks
Low Flow Extent
CHaMP Treatment
Seeps/Springs
Sediment Sample Site

Redd Location
Chinook (2009-2015)
Steelhead (2004-2012)

Relative Elevation Model
High : 125
Low : 90.6824

0 500 1,000
Feet

Figure A-1c
Existing Conditions in the PAA RM 1.9 to 3.1

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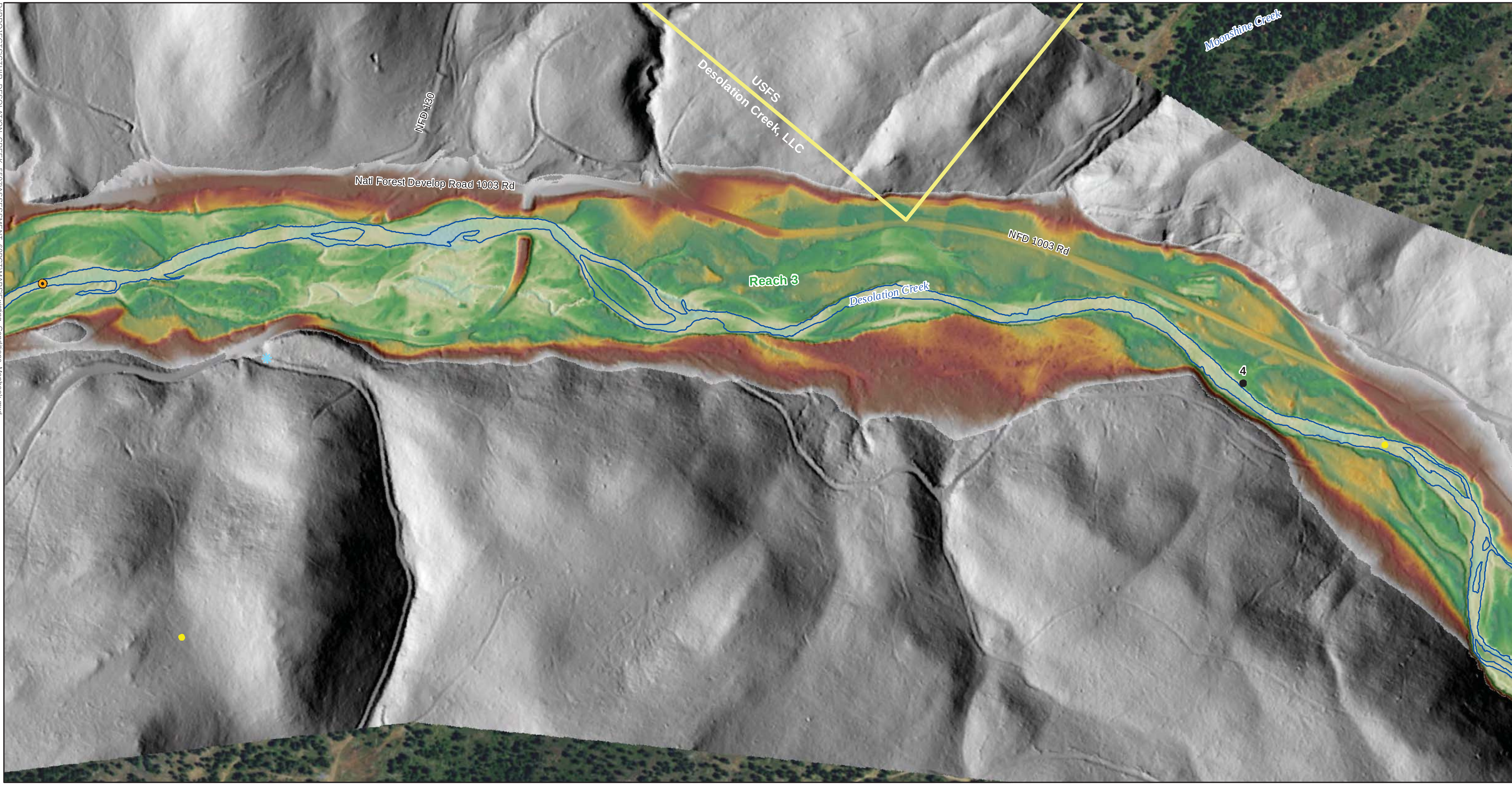


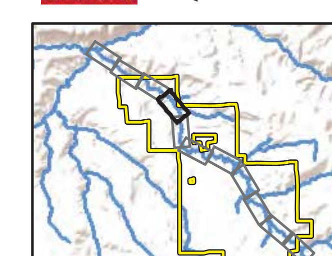
Primary Assessment Area (PAA)
River Mile
Reach Breaks
Low Flow Extent
CHaMP Treatment
Seeps/Springs
Sediment Sample Site

Redd Location
Chinook (2009-2015)
Steelhead (2004-2012)

Relative Elevation Model
High : 125
Low : 90.6824

Figure A-1d
Existing Conditions in the PAA RM 3.1 to 4.2

0 500 1,000
Feet



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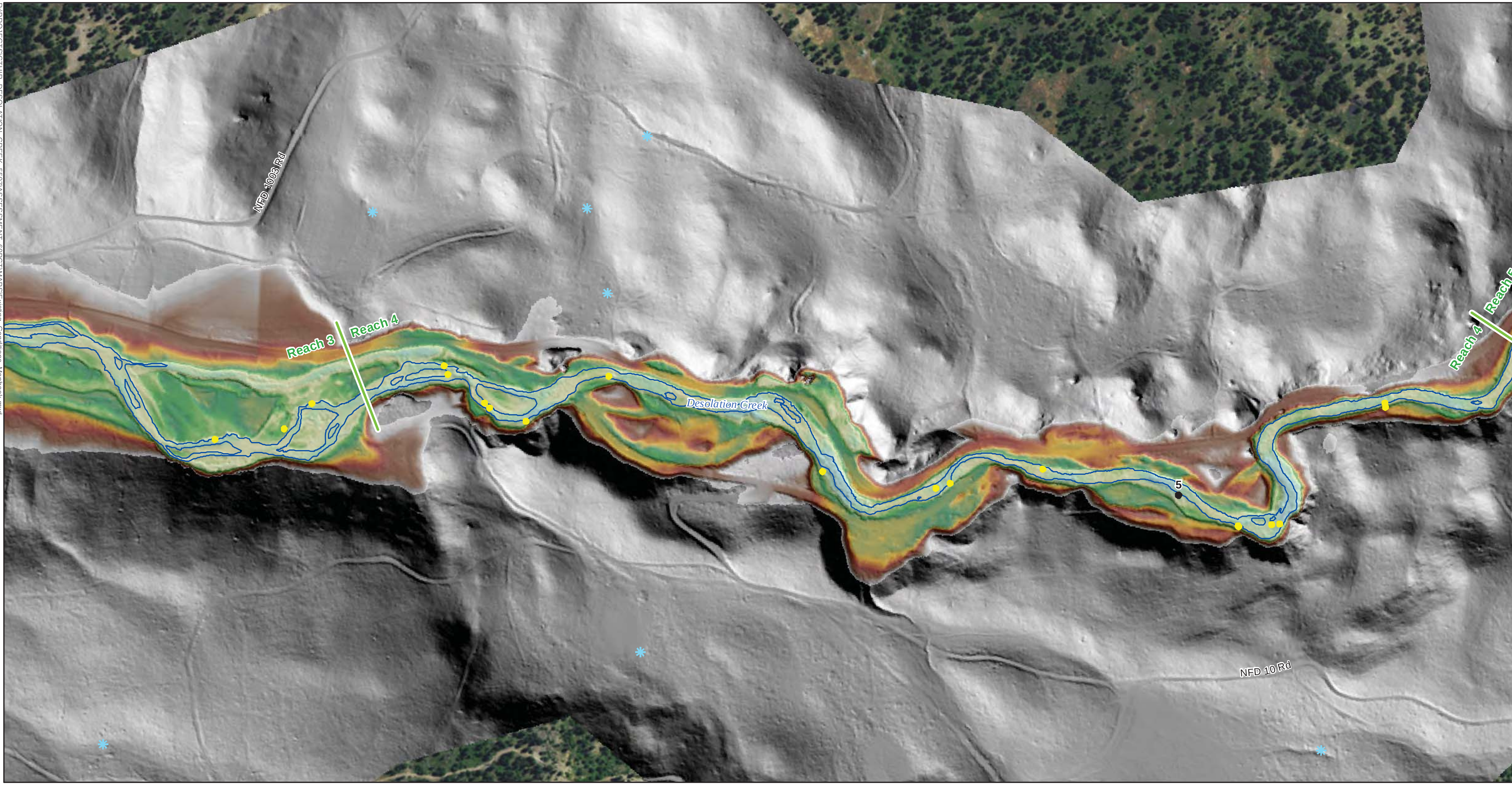


Primary Assessment Area (PAA)
River Mile
Reach Breaks
Low Flow Extent
CHaMP Treatment
Seeps/Springs
Sediment Sample Site

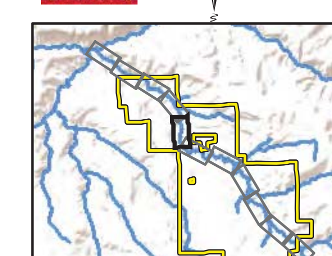
Redd Location
Chinook (2009-2015)
Steelhead (2004-2012)

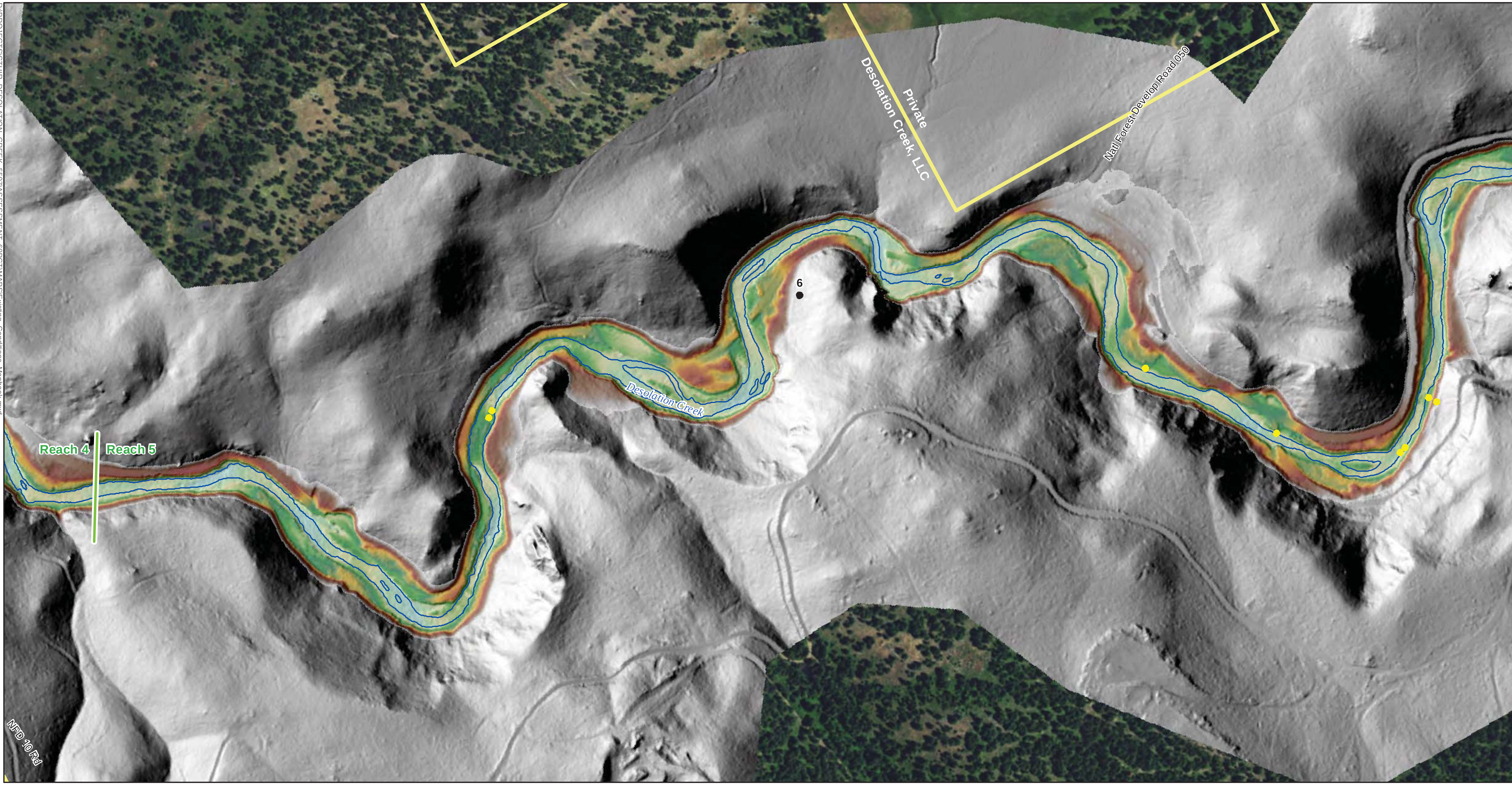
Relative Elevation Model
High : 125
Low : 90.6824

Figure A-1e
Existing Conditions in the PAA RM 4.2 to 5.2

0 500 1,000
Feet

TETRA TECH





Primary Assessment Area (PAA)
River Mile
Reach Breaks
Low Flow Extent
CHaMP Treatment
Seeps/Springs
Sediment Sample Site

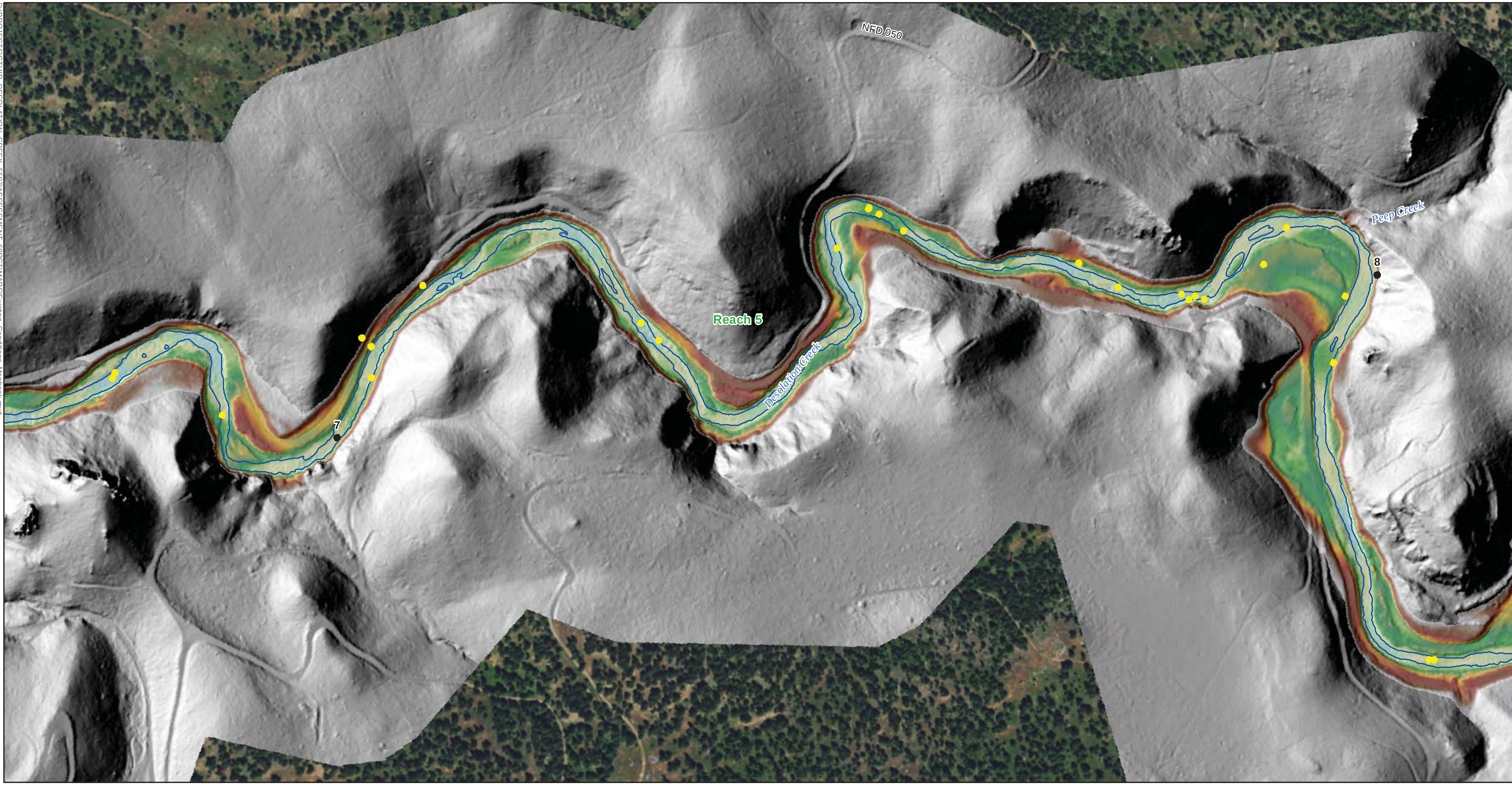
Redd Location
Chinook (2009-2015)
Steelhead (2004-2012)

Relative Elevation Model
High : 125
Low : 90.6824

Figure A-1f
Existing Conditions in the PAA RM 5.2 to 6.7

0 500 1,000
Feet

TETRA TECH



Primary Assessment Area (PAA)
River Mile
Reach Breaks
Low Flow Extent
CHaMP Treatment
Seeps/Springs
Sediment Sample Site

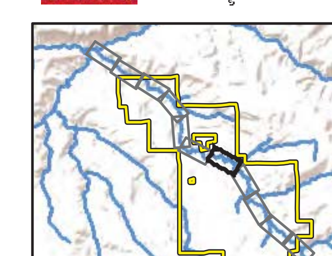
Redd Location
Chinook (2009-2015)
Steelhead (2004-2012)

Relative Elevation Model
High : 125
Low : 90.6824

Figure A-1g
Existing Conditions in the PAA RM 6.7 to 8.3

0 500 1,000
Feet

TETRA TECH



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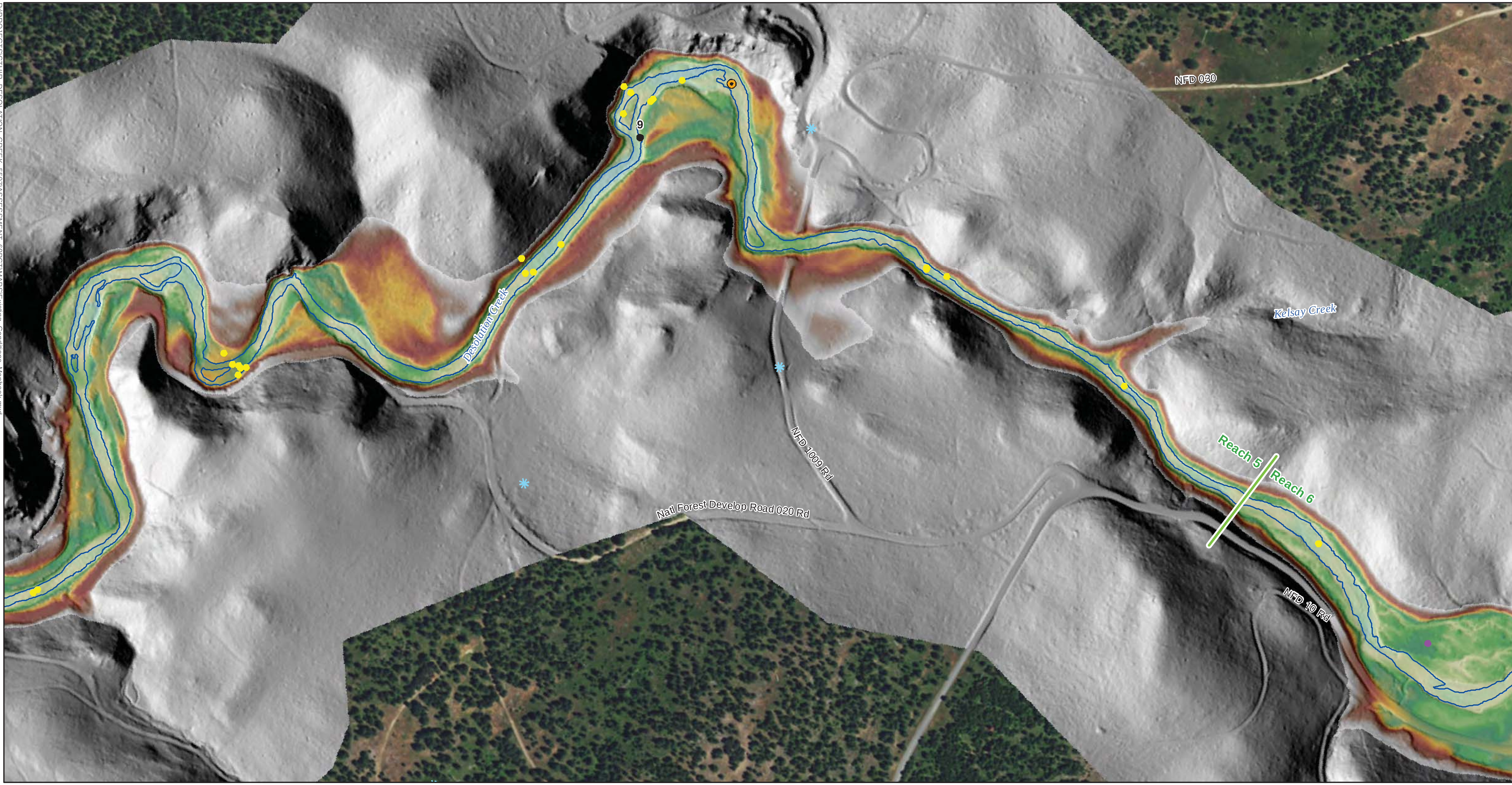

Primary Assessment Area (PAA)
River Mile
Reach Breaks
Low Flow Extent
CHaMP Treatment
Seeps/Springs
Sediment Sample Site

Redd Location
Chinook (2009-2015)
Steelhead (2004-2012)

Relative Elevation Model
High : 125
Low : 90.6824

0 500 1,000
Feet

Figure A-1h
Existing Conditions in the PAA RM 8.3 to 9.8

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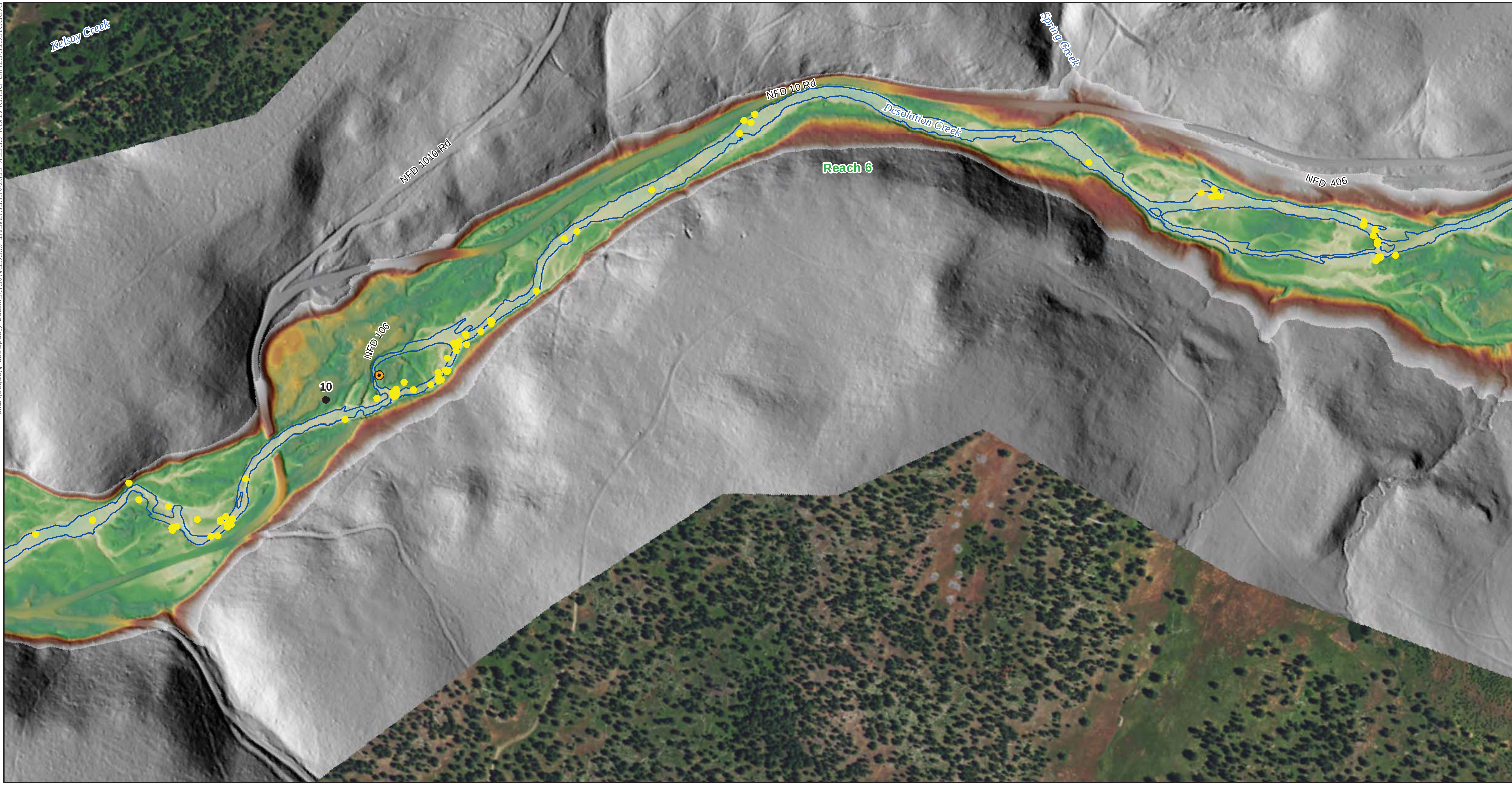


Primary Assessment Area (PAA)
River Mile
Reach Breaks
Low Flow Extent
CHaMP Treatment
Seeps/Springs
Sediment Sample Site

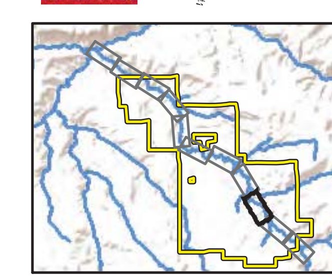
Redd Location
Chinook (2009-2015)
Steelhead (2004-2012)

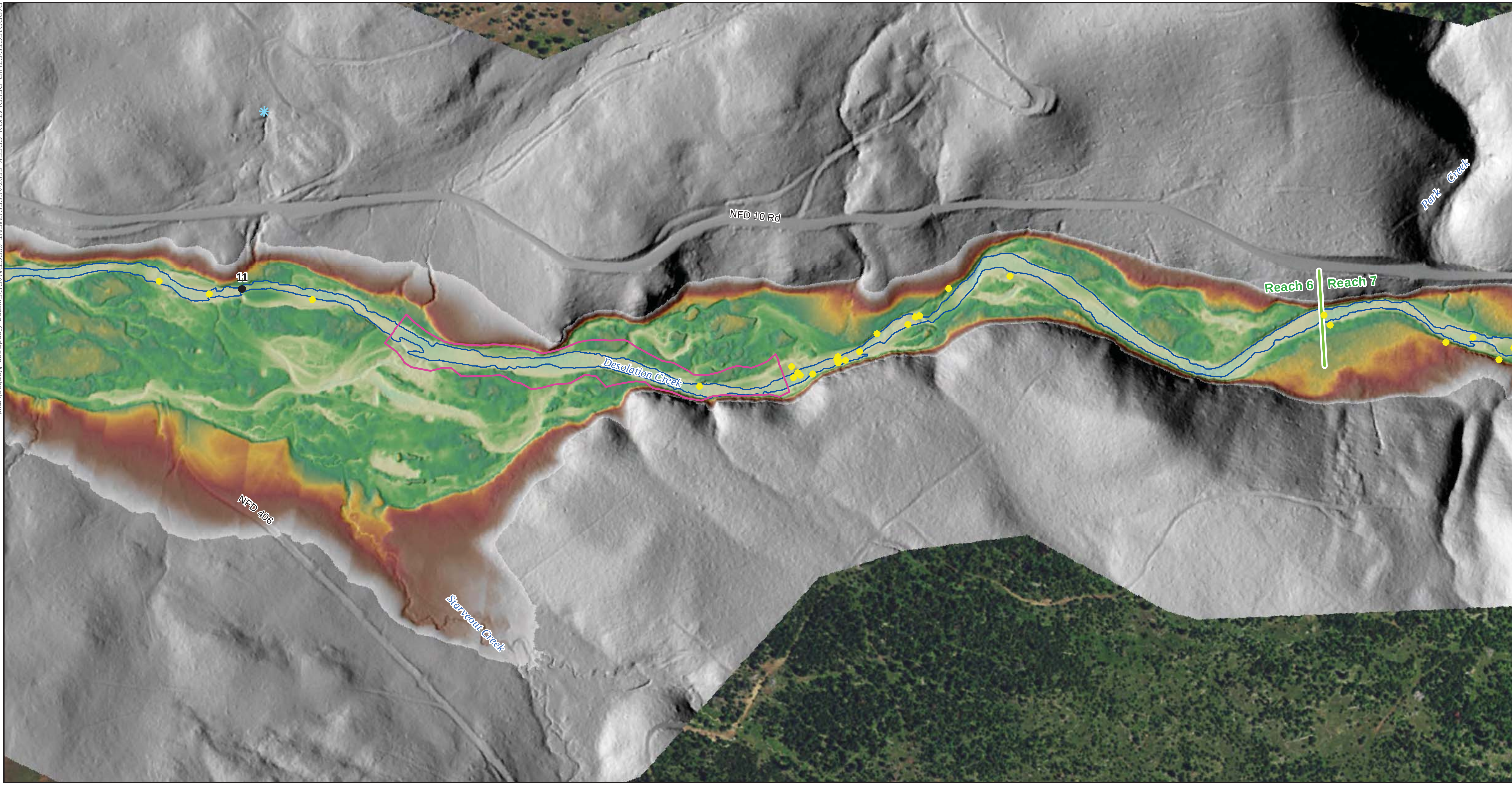
Relative Elevation Model
High : 125
Low : 90.6824

Figure A-1i
Existing Conditions in the PAA RM 9.8 to 10.8

0 500 1,000
Feet

TETRA TECH





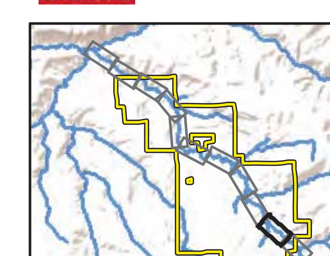
Primary Assessment Area (PAA)
River Mile
Reach Breaks
Low Flow Extent
CHaMP Treatment
Seeps/Springs
Sediment Sample Site

Redd Location
Chinook (2009-2015)
Steelhead (2004-2012)

Relative Elevation Model
High : 125
Low : 90.6824

0 500 1,000
Feet

Figure A-1j
Existing Conditions in the PAA RM 10.8 to 11.8



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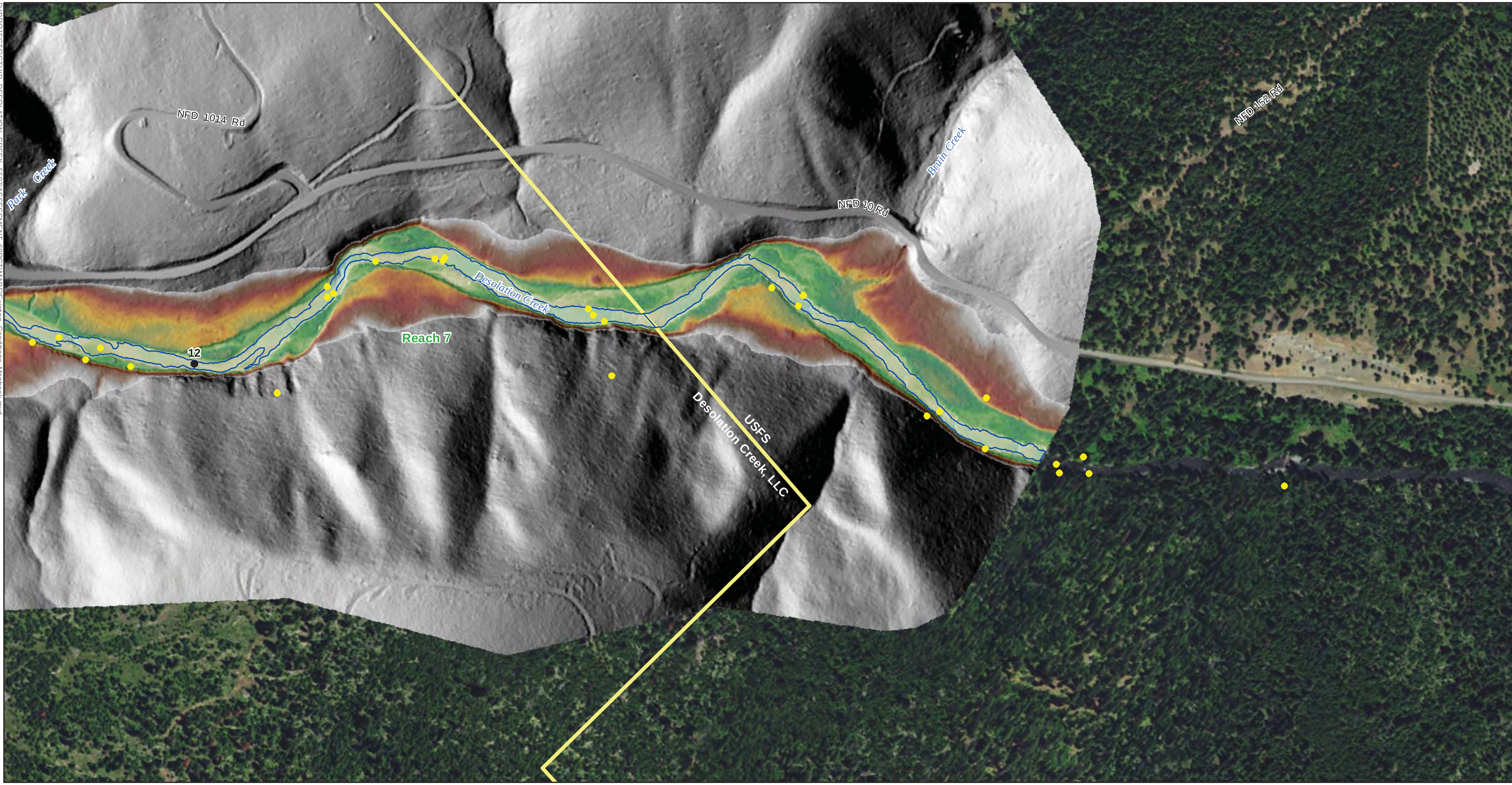


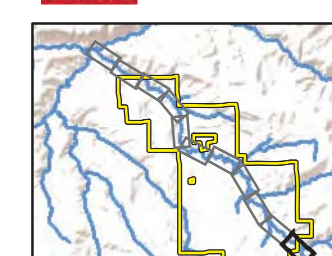
Primary Assessment Area (PAA)
River Mile
Reach Breaks
Low Flow Extent
CHaMP Treatment
Seeps/Springs
Sediment Sample Site

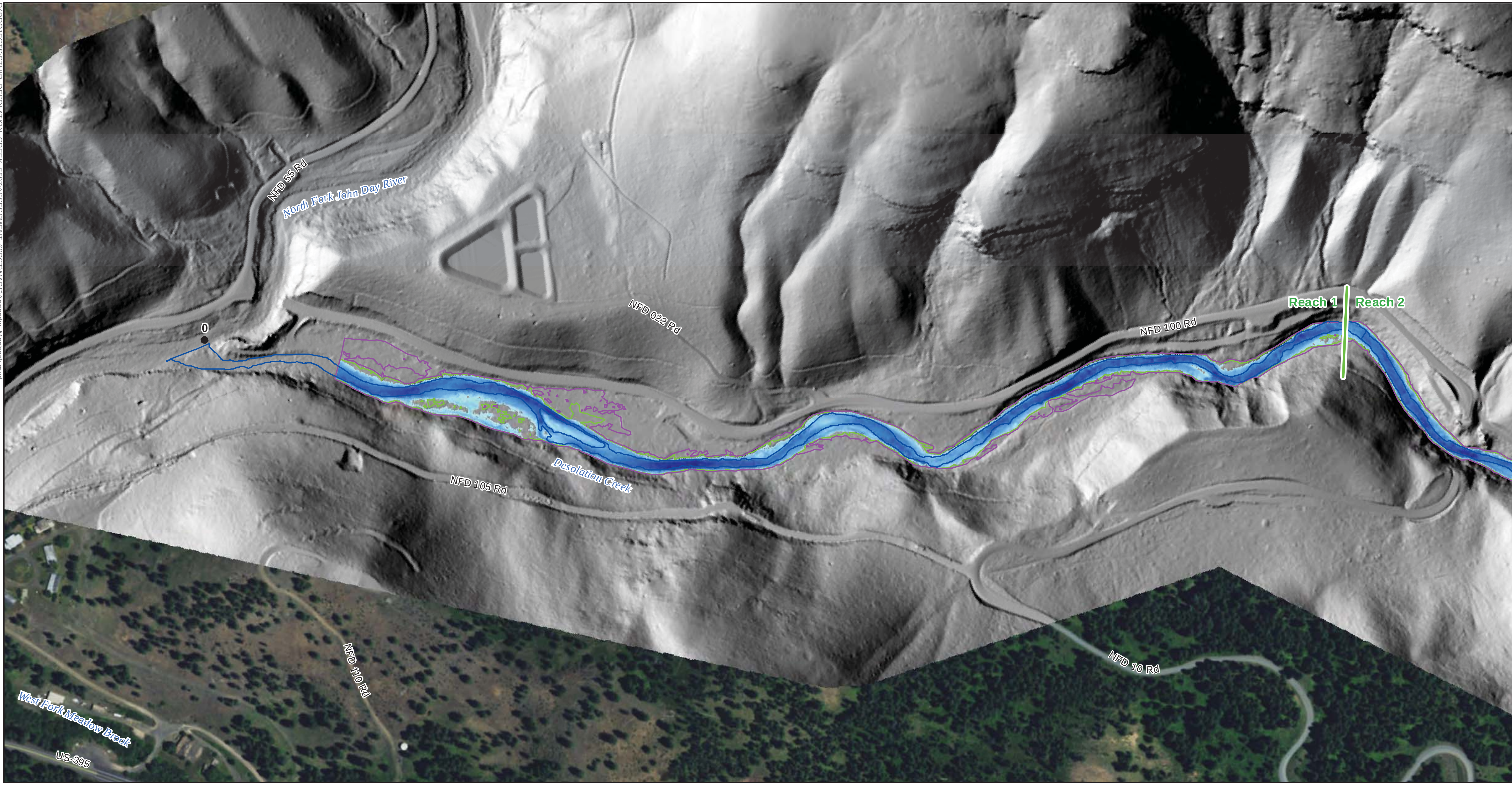
Redd Location
Chinook (2009-2015)
Steelhead (2004-2012)

Relative Elevation Model
High : 125
Low : 90.6824

Figure A-1k
Existing Conditions in the PAA RM 11.8 to 12.8

0 500 1,000
Feet





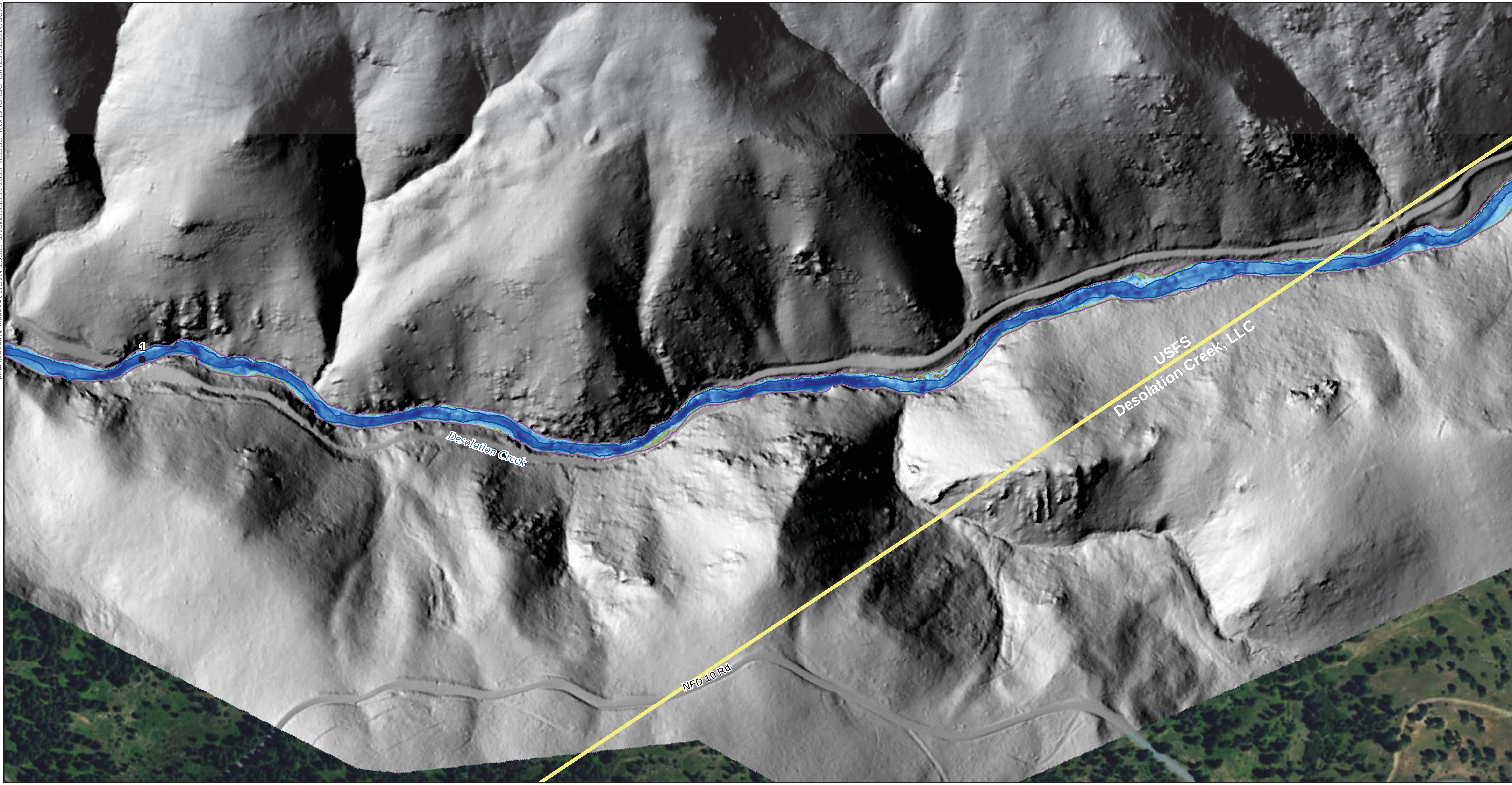
Primary Assessment Area (PAA)
River Mile
Reach Breaks
2-year Depth
High
Low

10-year Inundation Boundary
100-year Inundation Boundary
Low Flow Extent

Figure A-2a
Flood Inundation in the PAA RM 0.0 to 0.9

0 500 1,000
Feet

TETRA TECH

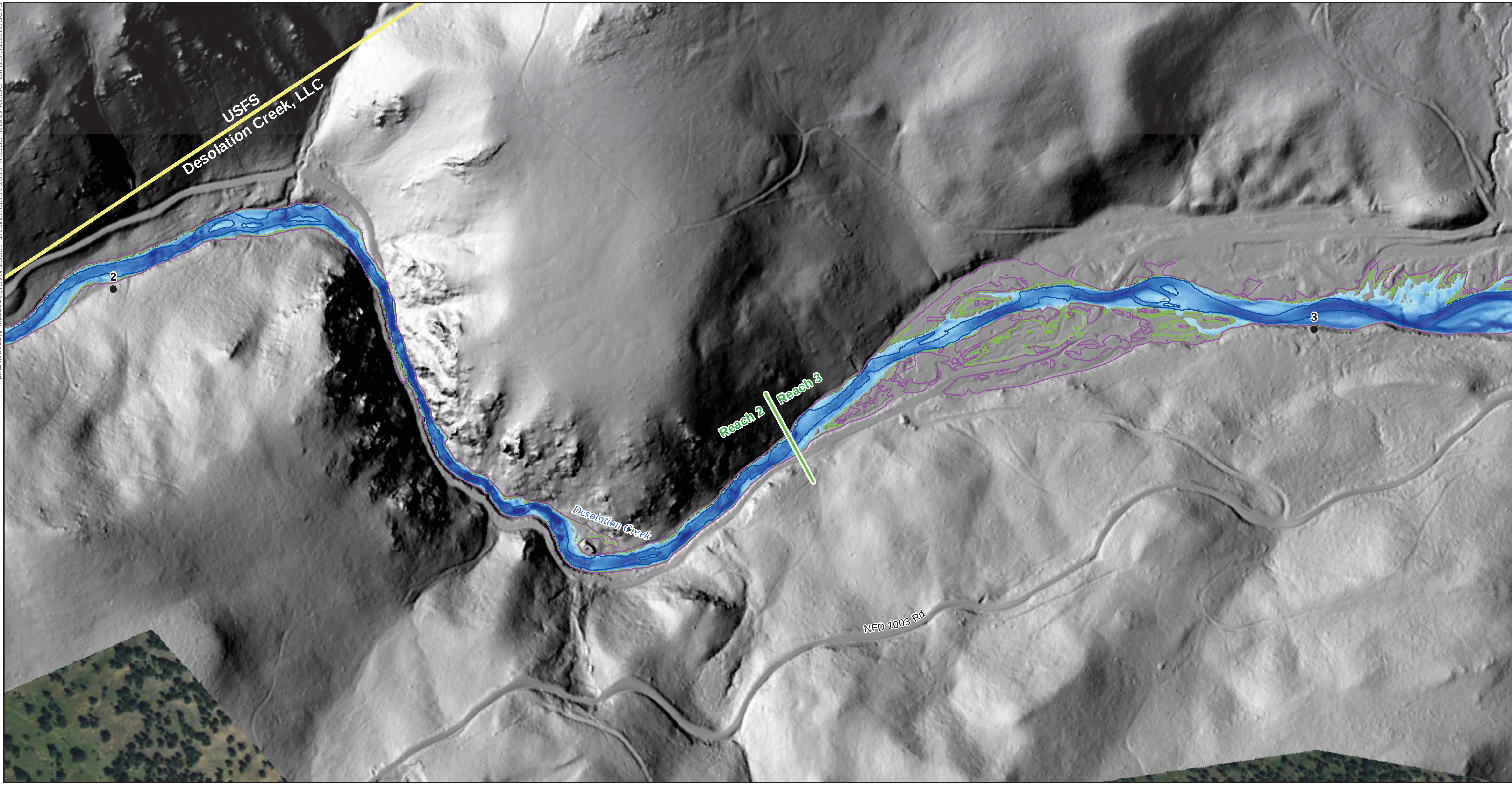


Primary Assessment Area (PAA)
River Mile
Reach Breaks
2-year Depth
High
Low
10-year Inundation Boundary
100-year Inundation Boundary
Low Flow Extent

Figure A-2b
Flood Inundation in the PAA RM 0.9 to 1.9

0 500 1,000
Feet

TETRA TECH

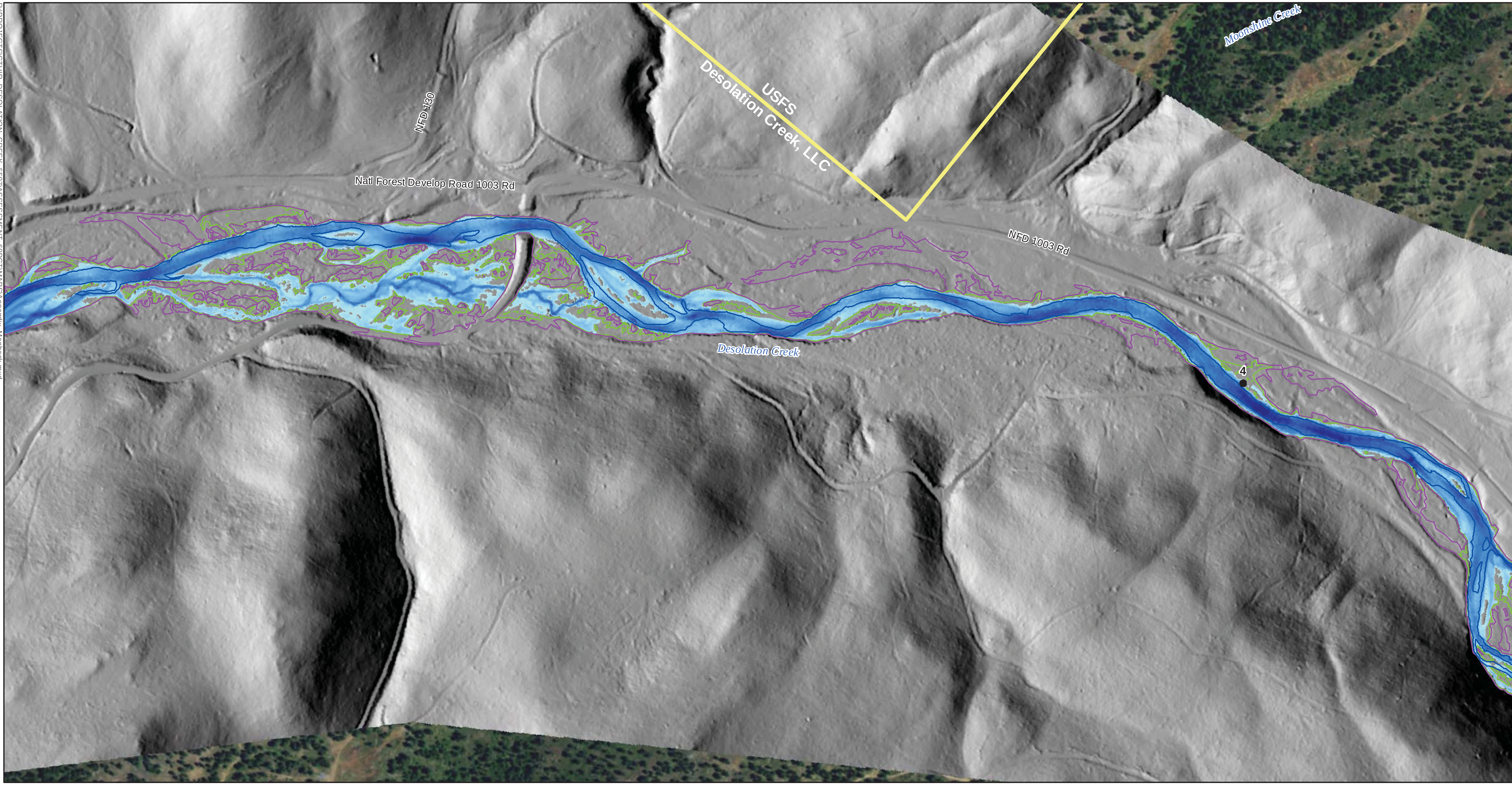


Primary Assessment Area (PAA)
River Mile
Reach Breaks
2-year Depth
High
Low
10-year Inundation Boundary
100-year Inundation Boundary
Low Flow Extent

Figure A-2c
Flood Inundation in the PAA RM 1.9 to 3.1

0 500 1,000
Feet

TETRA TECH

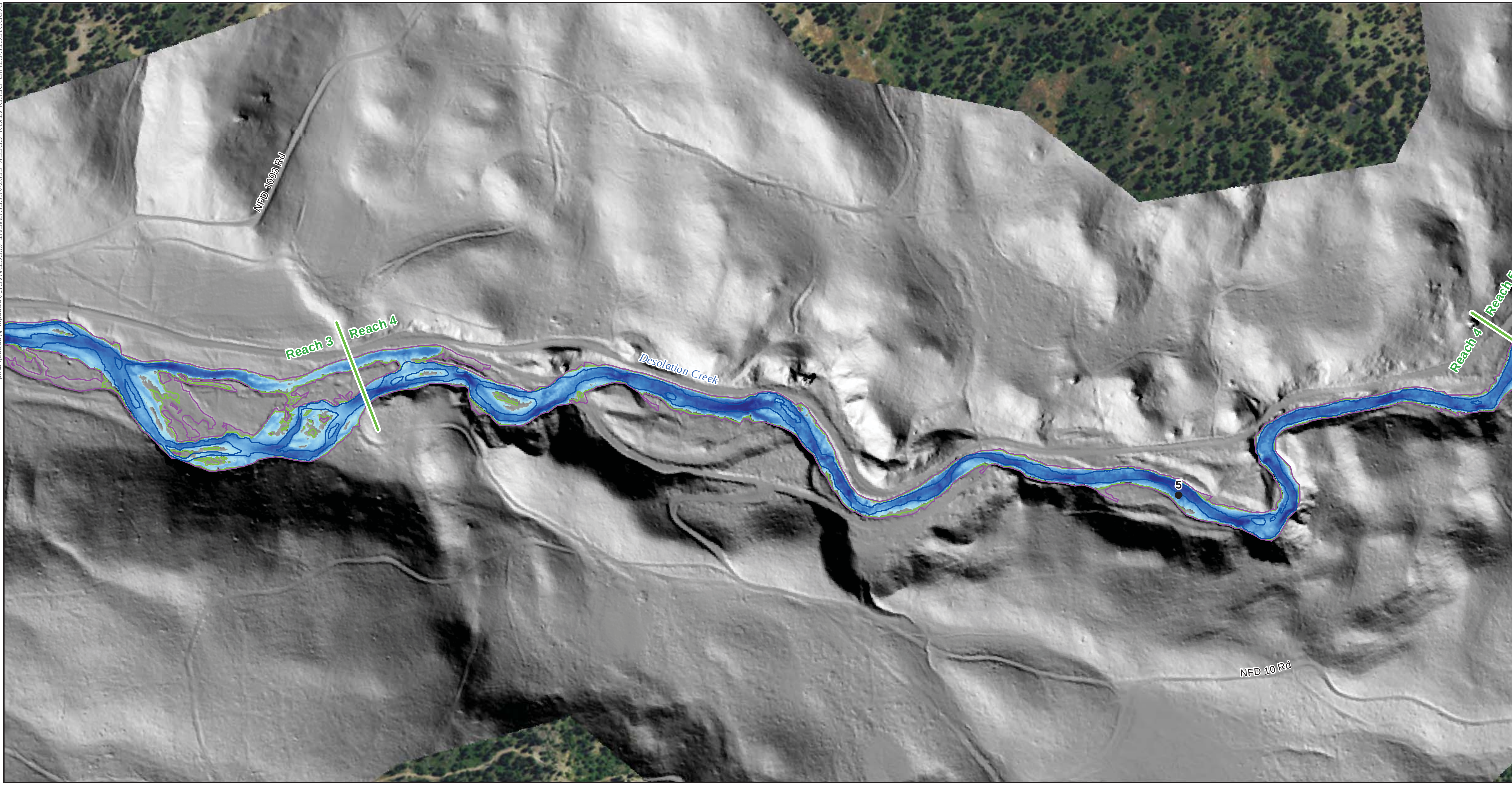


Primary Assessment Area (PAA)
River Mile
Reach Breaks
2-year Depth
High
Low
10-year Inundation Boundary
100-year Inundation Boundary
Low Flow Extent

Figure A-2d
Flood Inundation in the PAA RM 3.1 to 4.2

0 500 1,000
Feet

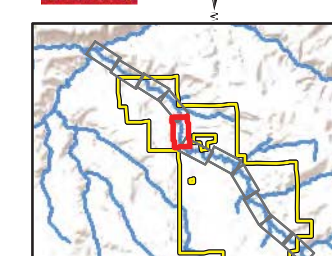
TETRA TECH



Primary Assessment Area (PAA)
River Mile
Reach Breaks
2-year Depth
High
Low
10-year Inundation Boundary
100-year Inundation Boundary
Low Flow Extent

Figure A-2e
Flood Inundation in the PAA RM 4.2 to 5.2

0 500 1,000
Feet



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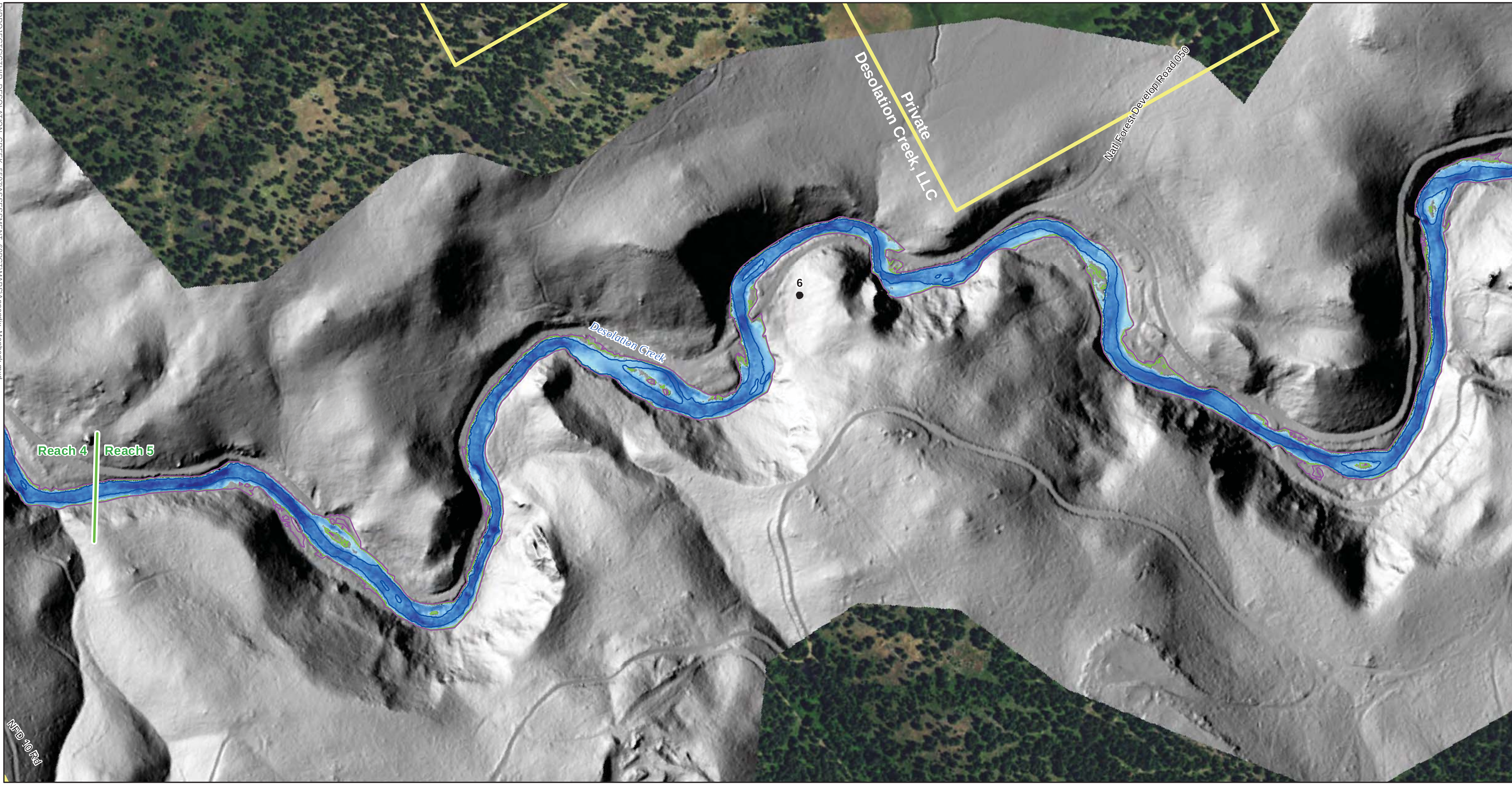
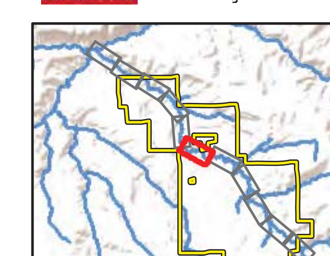


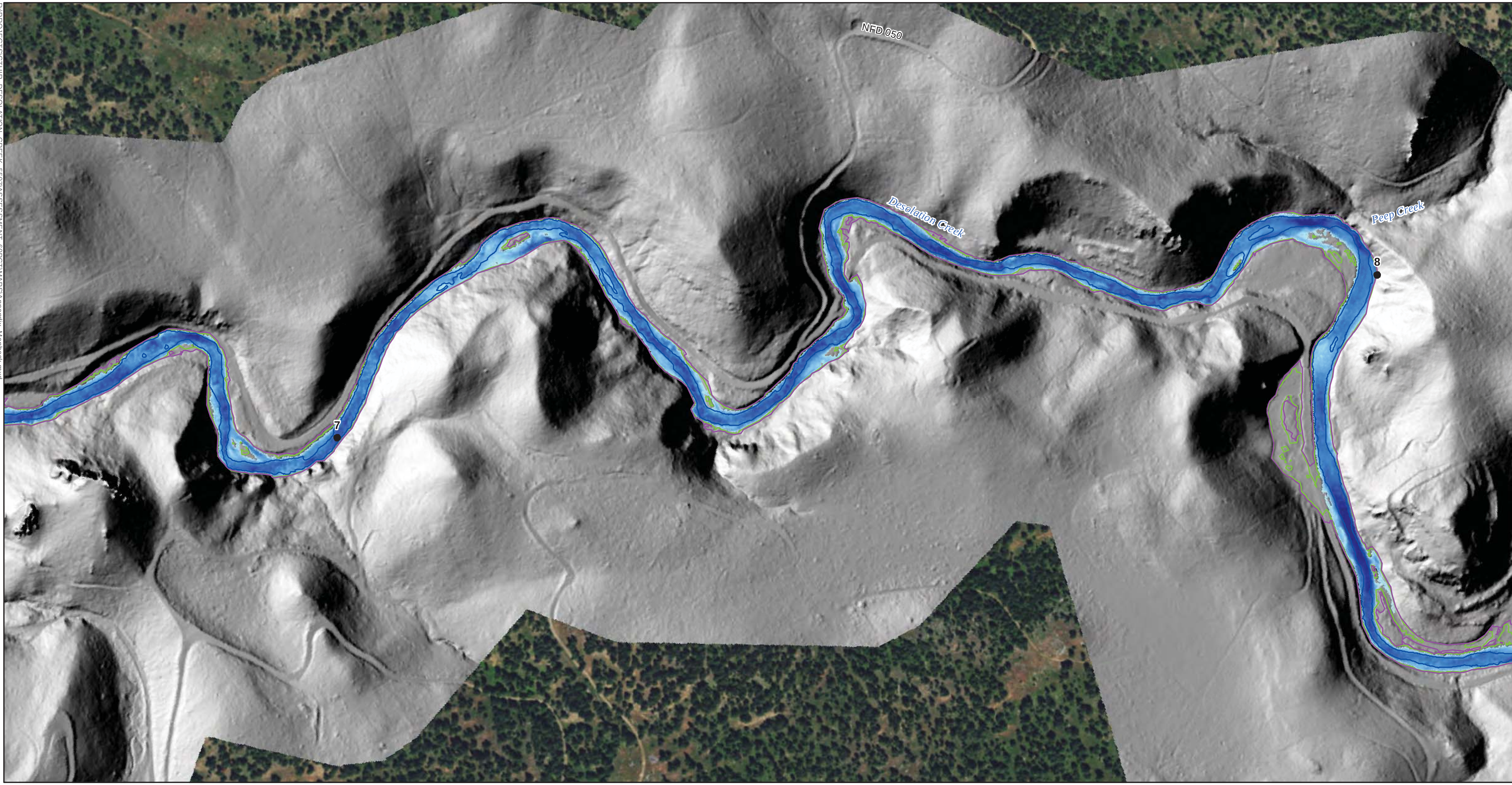
Primary Assessment Area (PAA)
River Mile
Reach Breaks
2-year Depth
High
Low
10-year Inundation Boundary
100-year Inundation Boundary
Low Flow Extent

Figure A-2f
Flood Inundation in the PAA RM 5.2 to 6.7

0 500 1,000
Feet

TETRA TECH



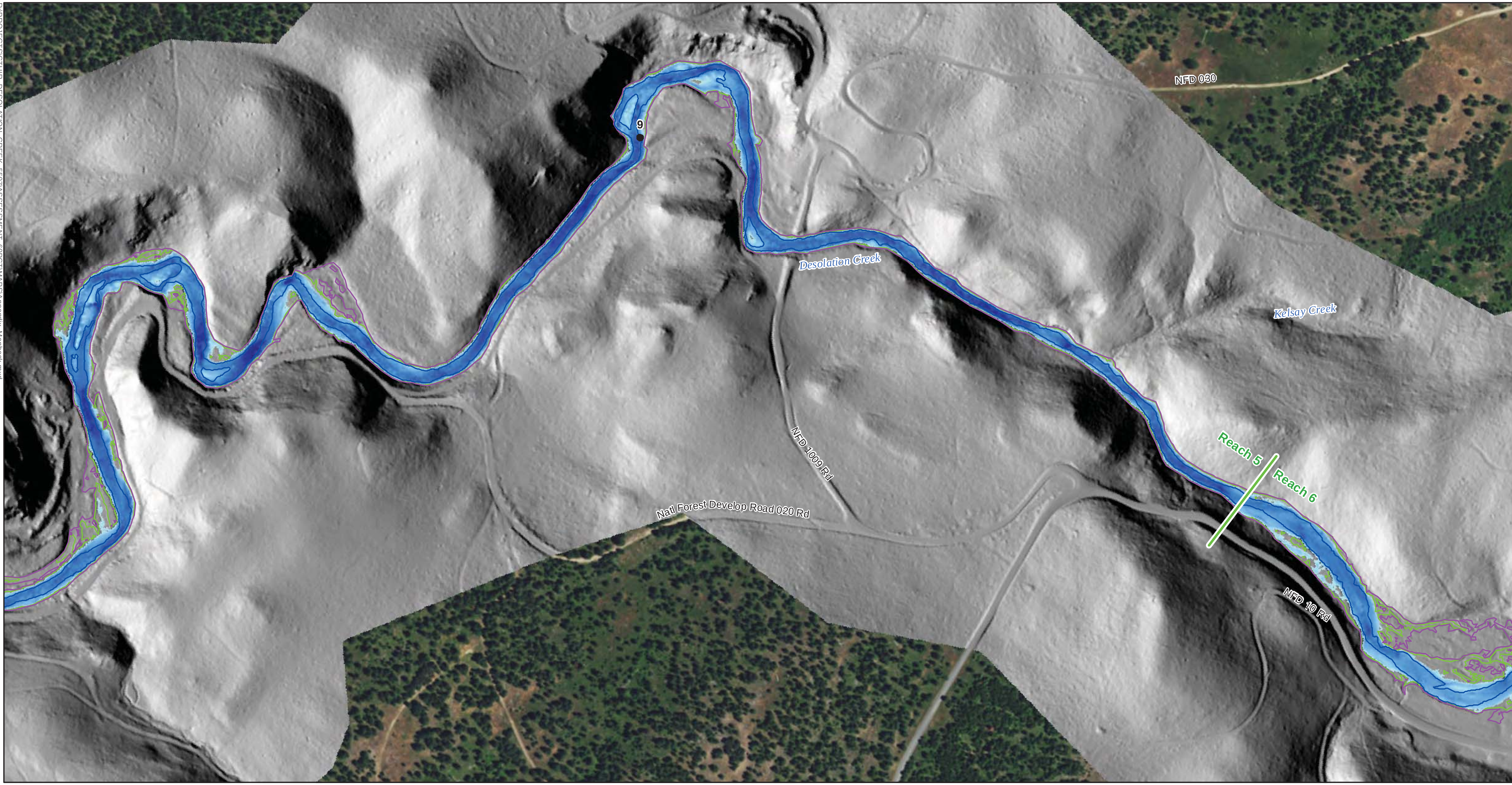


Primary Assessment Area (PAA)
River Mile
Reach Breaks
2-year Depth
High
Low
10-year Inundation Boundary
100-year Inundation Boundary
Low Flow Extent

Figure A-2g
Flood Inundation in the PAA RM 6.7 to 8.3

0 500 1,000
Feet

TETRA TECH

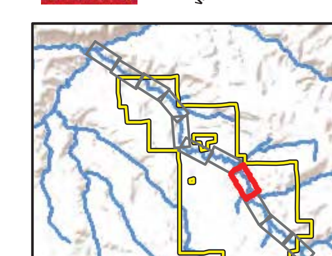


Primary Assessment Area (PAA)
River Mile
Reach Breaks
2-year Depth
High
Low
10-year Inundation Boundary
100-year Inundation Boundary
Low Flow Extent

Figure A-2h
Flood Inundation in the PAA RM 8.3 to 9.8

0 500 1,000
Feet

TETRA TECH



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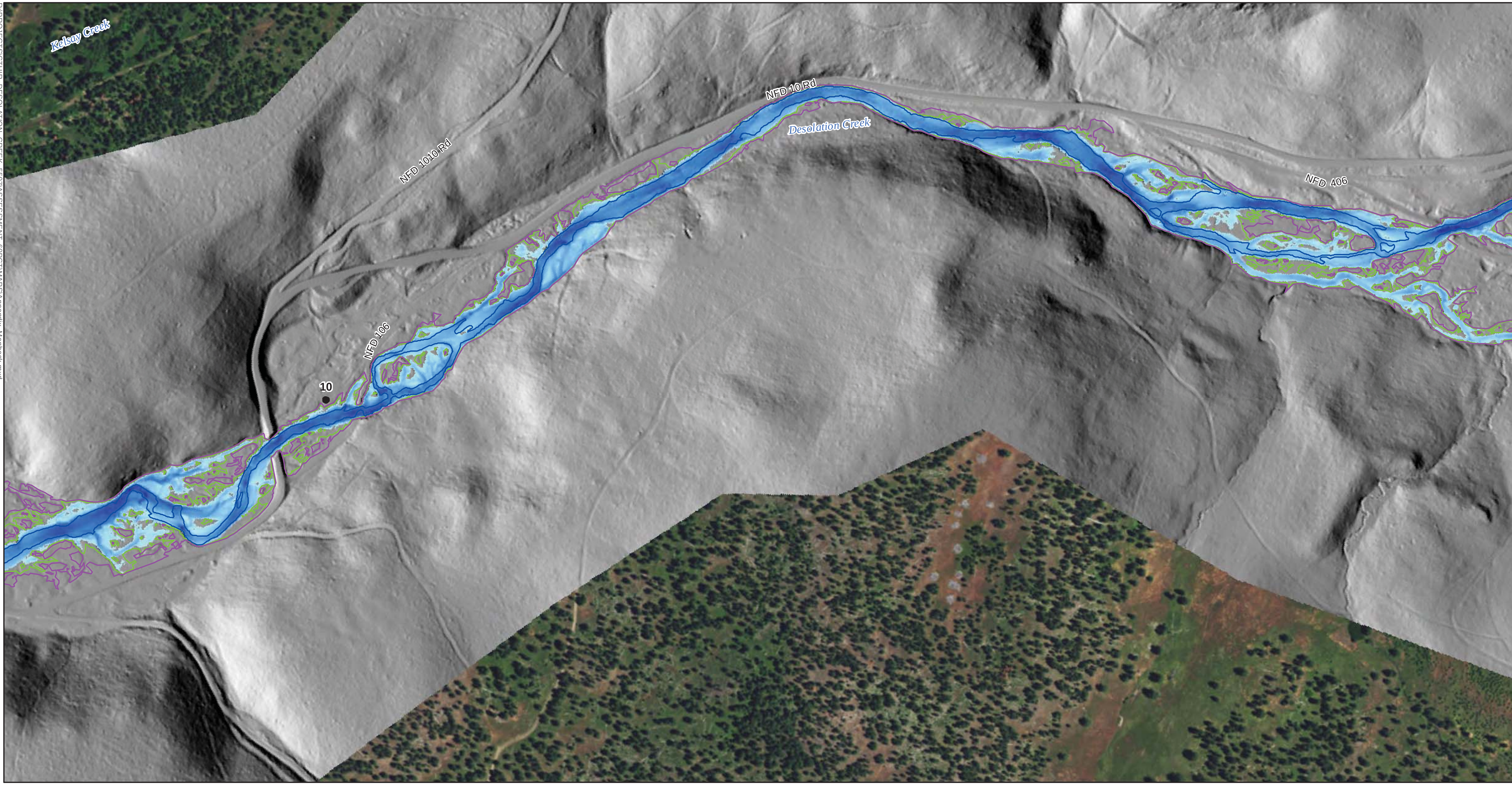
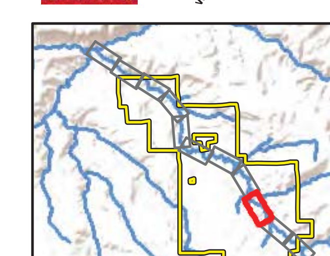


Primary Assessment Area (PAA)
River Mile
Reach Breaks
2-year Depth
High
Low
10-year Inundation Boundary
100-year Inundation Boundary
Low Flow Extent

Figure A-2i
Flood Inundation in the PAA RM 9.8 to 10.8

0 500 1,000
Feet

TETRA TECH



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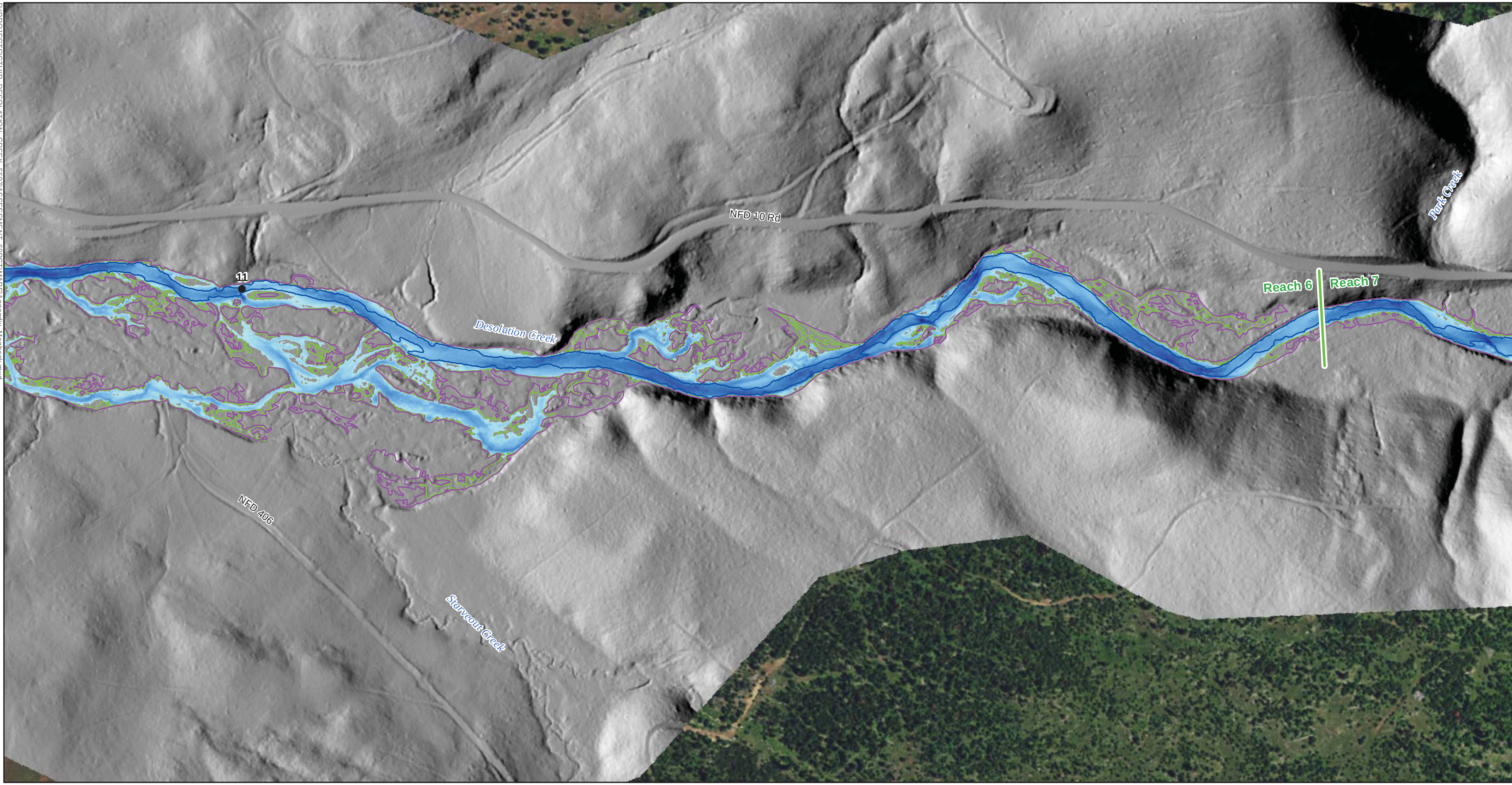
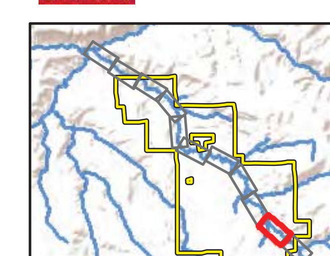


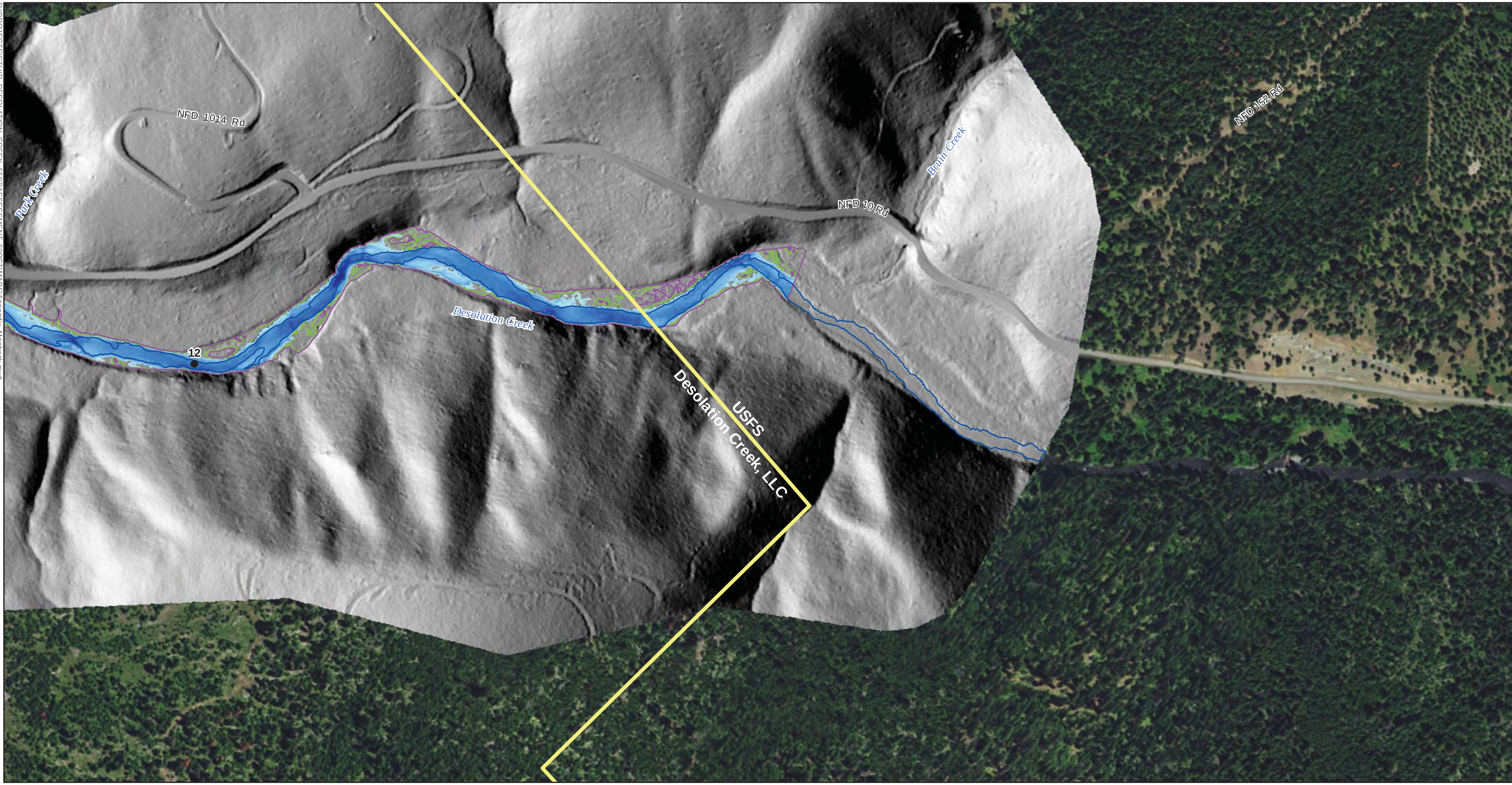
Primary Assessment Area (PAA)
River Mile
Reach Breaks
2-year Depth
High
Low
10-year Inundation Boundary
100-year Inundation Boundary
Low Flow Extent

TETRA TECH

Figure A-2j
Flood Inundation in the PAA RM 10.8 to 11.8

0 500 1,000
Feet



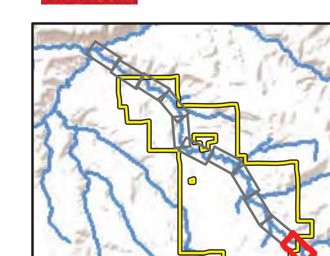


Primary Assessment Area (PAA)
River Mile
Reach Breaks
2-year Depth
High
Low
10-year Inundation Boundary
100-year Inundation Boundary
Low Flow Extent

Figure A-2k
Flood Inundation in the PAA RM 11.8 to 12.8

0 500 1,000
Feet

TETRA TECH



APPENDIX B – VEGETATION CLASSIFICATION

INTRODUCTION

Classification of remote sensing data was performed to identify land cover types and vegetation characteristics throughout the Desolation Creek watershed. The following sections describe the technical methods and results of the analysis.

METHODS

Hexagon Geospatial ERDAS Imagine 2016 was used to create a mosaic of 5-band (red, green, blue, near infrared, and infrared) imagery obtained by the Rapid Eye remote sensing satellite system on September 20, 2015. This imagery was then classified using image segmentation via Harris Geospatial Solutions ENVI and ERDAS Imagine software. Image segmentation employs spatial statistics to identify and group regions of pixels within an image that have similar absolute values, ratios of values, spatial distributions, and shape of grouped area. Classification of remote sensing data can be performed on two bases: "supervised" and "unsupervised." Supervised classification is performed using areas within a given image (raster dataset) that are of a known land cover type and requires that all land cover types to be classified are represented within that set of confirmed land cover areas. These "training" areas are then used to classify all of the other pixels or polygons within the dataset. Unsupervised classification does not require confirmed land cover data within the raster dataset prior to the creation of generic classes.

Tetra Tech used unsupervised classification to identify contiguous areas of land cover in polygons at or above the specified minimum mapping unit for the study (0.5 acre) that represented the relevant vegetation associations understood to be present within the study area based on previous land cover classifications and local expert knowledge. From the polygons identified in this analysis, sample plots were made for field characterization by creating a grid of half-acre cells and then selecting those within polygons determined to best represent known land cover within the study area.

Field surveys were conducted from August 16 to 20, 2016, and November 3 to 9, 2016, within each of the sample plots to identify the dominant vegetation and to classify the vegetation of area, to the extent possible, to the U.S. National Vegetation Classification (USNVC) "Group" level. Thirty-one individual areas were surveyed, characterized, and photographed during the August survey, and 34 areas were surveyed in November. The original intention in performing an initial survey and a follow-up was to provide data first for the supervised classification and second to provide areas of verified land cover to perform an accuracy assessment. As detailed below, all survey data were needed for training in the supervised classification due to the issues encountered with the satellite data, as discussed in the following section. These "ground-truth" data were then used to perform a supervised classification of the study area dataset. The results of the supervised classification were compared to the best available recent imagery as well as photointerpretation of the original image dataset. Where classification results appeared to clearly differ from photointerpretation of imagery, the training areas were adjusted and the supervised classification were re-run.

RASTER DATA QUALITY AND PROCESSING

The raster (image) data used in this study were delivered by the vendor as four individual tiles or scenes that cover the watershed extent. A mosaic of these scenes was also produced by the vendor and delivered as part of the contract. This mosaic was "color-balanced" meaning that differences in illumination between scenes were corrected. Unfortunately, this mosaic included only the three bands of data in the visible spectrum. Tetra Tech performed an analysis of all spectral bands in the data in each of the four scenes and applied a variety of color-balancing algorithms in order to create a 5-band color balanced mosaic. While these efforts resulted in a dataset that was preferable to the 3-band mosaic we received from the vendor, the 5-band product Tetra Tech developed was not ideally balanced in all areas, resulting in differences in brightness in some bands in some areas of the mosaic. This created challenges in classification. Specifically, these differences made the training data collected in one area of diminished or no value in identifying the same vegetation type in another area of the study area.

The selection of a 5-band data set with a 5-meter resolution (5 square meter [m^2] pixel) was made with the assumption that a mid-resolution dataset with superior spectral resolution would allow classification of areas at the minimum mapping unit and provide better results than a higher spatial resolution dataset with lower spectral resolution (fewer bands). However, the heterogeneity of the vegetation within the study area and the size of some of the key land cover types (open water and riparian types in particular) resulted in a high proportion of "mixed pixels." A mixed pixel is one that represents the reflectance of multiple cover types – open water and conifer forest, for instance. In areas where there is a large extent of uniform land cover (lakes, agricultural fields, etc.), this would be a problem only at the edges of the land cover extents. In the case of Desolation Creek, areas of open water do not exceed 10 meters in width in all but the rarest instances. Therefore, nearly all water pixels in the scene are a mix of the reflectance of water and some other cover type.

Tetra Tech also employed standard methods to enhance vegetation differentiation and detection. The most accurate classification results were achieved using a Normalized Differential Vegetation Index (NDVI), which is the ratio of the difference of near-infrared subtracted and the red band to the sum of the near-infrared and the red band ((NIR-Red)/(NIR+Red)). NDVI is directly correlated to photosynthetic capacity of the plant cover. A mosaic of the infrared, NDVI, green and blue bands provided more accurate results, using the same training areas as the 5-band mosaic.

For these reasons, the classification results achieved using only the field-acquired training data and the 5-band mosaic were not deemed to be of sufficient accuracy to provide value or improve on previous classification efforts. Therefore, the approach Tetra Tech took in creating a final classification result required that where additional reliable land cover data were available, they were brought to bear; for instance, water, while easily identifiable by photointerpretation of imagery or other means, could not be included in the supervised classification analysis without the result returning large areas of misclassified non-water areas. Therefore, Tetra Tech dropped the water class from the remote sensing classification analysis and, in mapping and reporting, water is represented using the surveyed wetted width of the creek. While this results in an underrepresentation of the actual open water present in the study area, the result better represents the open water present in the study area than the alternative Tetra Tech was able to achieve by other means.

Because of the differences in scene illumination and imperfect color-balancing results, Tetra Tech made the judgement that all ground-truth data should be used in supervised classification and that separate classes for different areas of the study area be created so that, where possible, differences in illumination would not result in misclassification of cover types. Because ground-truth data for all classes were not collected in all areas covered by the four individual tiles, it was not possible to perform a classification analysis on each tile individually. However, where ground-truth data were available for a given cover type in multiple areas, these were used to create discrete classes that were later combined for reporting and mapping.

The utilization of all field data does preclude the computation of overall accuracy, Kappa Coefficient score, or other quantitative measures of accuracy.

RESULTS

Nine different vegetation communities were classified within the Desolation Creek watershed based on the field surveys and remote sensing analysis. Table B-1 summarizes the acres and percent of the Desolation Creek watershed classified as each vegetation community. The distribution of the vegetation communities classified within the watershed is displayed on Figure B-1. Each vegetation community is described further in the sections below.

Table B-1. Vegetation Communities Mapped within the Desolation Creek Watershed

Vegetation Community	Acres within Watershed	Percent of Watershed
Conifer Forest	**57,156**	**82.1**
Douglas-fir – Ponderosa Pine Central Rocky Mountain Forest Group (Central Rocky Mountain Douglas-fir – Pine Forest)	24,663	35.4
Engelmann Spruce – Subalpine Fir – Lodgepole Pine Dry-Mesic Forest & Woodland Group (Rocky Mountain Subalpine Dry-Mesic Spruce - Fir Forest & Woodland)	12,665	18.2
Lodgepole Pine Rocky Mountain Forest & Woodland Group (Rocky Mountain Lodgepole Pine Forest & Woodland)	12,234	17.6
Regenerating Forest	7,594	10.9
Riparian Northern Rocky Mountain Lowland – Foothill Riparian Forest Group (Northern Rocky Mountain Lowland & Foothill Riparian Forest)	**5,623**	**8.1**
Grassland and Wet Meadow	**5,142**	**7.4**
Cliff, Scree, Rock and Barren	**1,546**	**2.2**
Shrubland Big Sagebrush – Threetip Sagebrush – Antelope Bitterbrush Big Sagebrush Steppe & Shrubland Group (Intermountain Mesic Tall Sagebrush Steppe & Shrubland)	**104**	**0.1**
Open Water	**63**	**0.1**
TOTAL	**69,633**	**100**

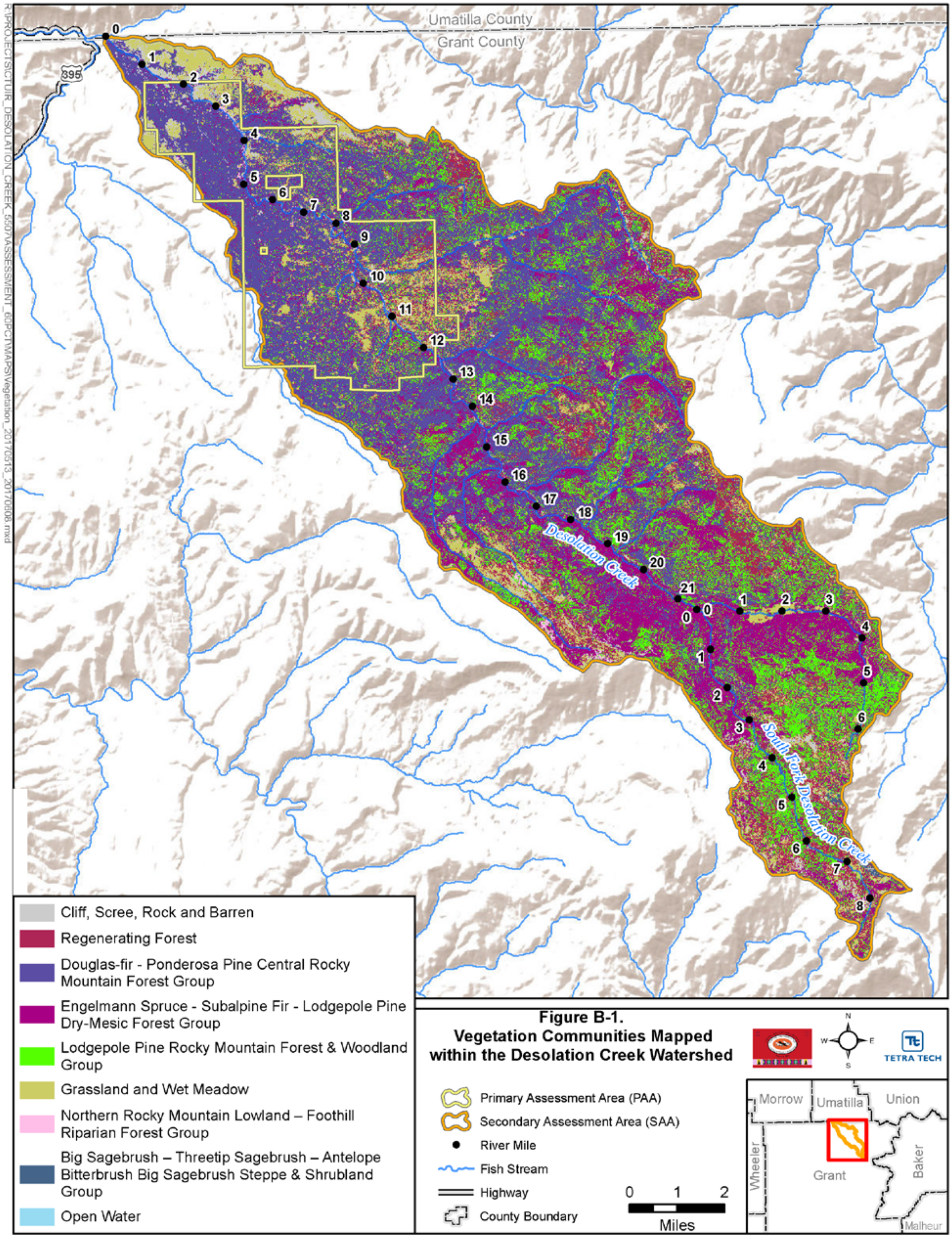


Figure B-1. Vegetation Communities Mapped within the Desolation Creek Watershed

CONIFER FOREST

Based on the vegetation classifications, approximately 57,156 acres (82.1 percent) of the Desolation Creek watershed was classified as conifer forest. Four different conifer forest vegetation communities were observed in sample plots during field surveys; each of these is briefly discussed below. Approximately 7,593 acres of the acres classified as conifer forest was classified as currently regenerating forest.

Douglas-fir – Ponderosa Pine Central Rocky Mountain Forest Group

This vegetation community is composed of highly variable montane coniferous forests found in the interior Pacific Northwest. Most occurrences of this group are dominated by a mix of Douglas-fir (*Pseudotsuga menziesii*) and/or ponderosa pine (*Pinus ponderosa*) and other typically seral species, including western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*), and western white pine (*Pinus monticola*) (Reid and Schulz 2015). This vegetation community typically consists of a matrix of large patches dominated or co-dominated by one or combinations of the above species. Grand fir (*Abies grandis*), a fire-sensitive and shade-tolerant species, has increased on many sites once dominated by Douglas-fir and ponderosa pine, which were formerly maintained by low severity wildfire (Reid and Schulz 2015). The understory of this vegetation community is typically dominated by graminoids, such as pinegrass (*Calamagrostis rubescens*), elk sedge (*Carex geyeri*), Ross' sedge (*Carex rossii*), and bluebunch wheatgrass (*Pseudoroegneria spicata*), and a variety of shrubs, such as Rocky Mountain maple (*Acer glabrum*), common juniper (*Juniperus communis*), mallow ninebark (*Physocarpus malvaceus*), shinyleaf spiraea (*Spiraea betulifolia*), snowberry (*Symphoricarpos albus*), or tall huckleberry (*Vaccinium membranaceum*) on mesic sites (Reid and Schulz 2015). Pre-settlement fire regimes were likely characterized by frequent, low-intensity surface fires that maintained relatively open stands of a mix of fire-resistant species; however, under present conditions, the fire regime is mixed severity and more variable, with stand-replacing fires more common, and thus the forests are more homogeneous (Reid and Schulz 2015). The dominant tree species observed during field surveys in sample plots classified as Douglas-fir – Ponderosa Pine Central Rocky Mountain Forest Group were lodgepole pine, western larch, grand fir, and Douglas-fir.

Engelmann Spruce – Subalpine Fir – Lodgepole Pine Dry-Mesic Forest & Woodland Group

This vegetation community is found on drier sites within the subalpine zone of the Cascades and Rocky Mountains and is characterized by stands dominated by Engelmann spruce (*Picea engelmannii*) and/or subalpine fir (*Abies lasiocarpa*) (Schulz 2013). These forests often represent the highest elevation forests in an area. Douglas-fir may persist in this vegetation community for long periods without regeneration and lodgepole pine is common in this vegetation community, and patches of pure lodgepole pine are not uncommon (Schulz 2013). The understory of this vegetation community often includes xeric species, such as serviceberry (*Amelanchier alnifolia*), common juniper, creeping Oregon-grape (*Mahonia repens*), mallow ninebark, russet buffaloberry (*Shepherdia canadensis*), or grouseberry (*Vaccinium scoparium*). Disturbance within this vegetation community includes occasional blowdown, insect outbreaks, and stand-replacing fire (Schulz 2013).

The dominant tree species observed in sample plots classified as Engelmann Spruce – Subalpine Fir – Lodgepole Pine Dry Mesic Forest & Woodland Group was subalpine fir. Engelmann spruce, western larch, grand fir, and lodgepole pine were also observed in sample plots classified as this vegetation community.

Lodgepole Pine Rocky Mountain Forest & Woodland Group

This vegetation community occurs at upper montane to subalpine elevations of the Rocky Mountains, from Colorado north into the Canadian Rockies, west across Idaho into the eastern Cascades in Washington, the Blue Mountains in Oregon, and east into northcentral Montana (Hall 2013). Lodgepole pine, an aggressively colonizing, shade-intolerant conifer, is the dominant conifer species found in this vegetation group and the dominance of lodgepole pine is related to fire history and topo-edaphic conditions (Crawford et al. 2010; Hall 2013). Following stand-replacing fires, lodgepole pine will rapidly colonize and develop into dense, even-aged stands, and most forests in this vegetation group occur as early to mid-successional forests that developed following fires. These stands, while frequently persistent for more than 100 years, may succeed to spruce-fir forests or woodlands.

The understory of this vegetation community ranges from relatively conspicuous cover of shrubs and grasses to barren understories. Common shrubs found in this vegetation community include kinnikinnick, common juniper, snowbrush ceanothus (*Ceanothus velutinus*), twinflower, creeping Oregon-grape, big sagebrush (*Artemisia tridentata*), shinyleaf spiraea, russet buffaloberry, grouseberry, dwarf huckleberry, tall huckleberry, common snowberry, and gooseberry (*Ribes* spp.). Common herbaceous species include Idaho fescue (*Festuca idahoensis*), squirreltail (*Elymus elymoides*), pinegrass, elk sedge, and Ross' sedge (Hall 2013).

During field surveys, sample plots classified as Lodgepole Pine Rocky Mountain Forest & Woodland Group typically consisted of dense, young stands of lodgepole pine in previously burned areas. Other tree species observed in these sample plots included Engelmann spruce, subalpine fir, grand fir, and western larch. Species observed in the understory included pinegrass, grouseberry, snowbrush ceanothus, California false-hellebore/corn lily (*Veratrum californicum*), and northern mule's ear (*Wyethia amplexicaulis*).

Regenerating Forest

Areas classified as regenerating forest did not readily meet the characteristics of any of the USNVC Groups. Regenerating forest areas within the Desolation Creek watershed are characterized by fallen and standing dead trees, low cover of shrubs and forbs in the understory, and abundant bare soil. Areas classified as regenerating forest have a distinct spectral signature that is created by multiple components that are not species-specific, meaning for instance, that regenerating Douglas-fir forest is not significantly spectrally distinct from regenerating lodgepole pine forest.

RIPARIAN

Based on the vegetation classifications, approximately 5,623 acres (8.1 percent) of the Desolation Creek watershed was classified as riparian. Riparian areas were classified as the Northern Rocky

Mountain Lowland – Foothill Riparian Forest Group. This riparian forest group occurs on alluvial terraces along major streams and rivers throughout the northwestern United States (Kittel 2015a). It can occur on alluvial terraces of major streams and rivers, margins of lakes, meadows, deltas, river mouths, and terraces. Stands can occupy broad floodplains or form narrow stands adjacent to streams with a much steeper slope. This group is typically characterized by broad-leaved deciduous trees with a moderately dense canopy cover (50 to 80 percent cover). The understory typically consists of an open to moderately dense shrub layer (10 to 50 percent cover) and sparse (up to 20 percent cover) forb layer (Kittel 2015a). Vegetation within this group is typically dominated by cottonwood (*Populus balsamifera*), although other trees and shrubs often found in this vegetation group include ponderosa pine, gray alder (*Alnus incana*), paper birch (*Betula papyrifera*), willow, red-osier dogwood (*Cornus sericea*), black hawthorn (*Crataegus douglasii*), chokecherry (*Prunus virginiana*), and snowberry (Kittel 2015a). Low shrubs, such as snowberry (*Symphoricarpos albus*) and currant (*Ribes* spp.), are also present. The herbaceous layer is usually relatively sparse and is dominated by either forbs or graminoids, with common species often including baneberry (*Actaea rubra*), western water hemlock (*Cicuta douglasii*), horsetail (*Equisetum* spp.), and western mountain aster (*Symphyotrichum spathulatum* [*Aster occidentalis*]) (Kittel 2015a). In the Desolation Creek watershed, scattered patches of aspen (*Populus tremuloides*) are also found in riparian areas.

One sample plot was classified as Northern Rocky Mountain Lowland – Foothill Riparian Forest Group during field surveys. This sample plot was located along Desolation Creek near its confluence with the North Fork John Day River. Patches of Douglas-fir and ponderosa pine were observed on the hillslopes above the creek. Dominant tree and shrub species observed along the creek include mallow ninebark, black hawthorn, red-osier dogwood, gray alder, snowberry, chokecherry, and willow, and forb species included reed canarygrass and sedges (*Carex* spp.).

GRASSLAND AND WET MEADOW

Based on the vegetation classifications, approximately 5,142 acres (7.4 percent) of the Desolation Creek watershed was classified as grassland and wet meadow. Wet meadows observed during field surveys could generally be classified into two different USNVCS vegetation groups: Sedge Species – Reedgrass Species Montane Wet Meadow & Marsh Group and the Kentucky Bluegrass – Canadian Horseweed – Canada Thistle Ruderal Marsh, Wet Meadow & Shrubland Group. Grasslands observed during field surveys could generally be classified into two different USNVCS vegetation groups: Rough Fescue – Idaho Fescue – Bluebunch Wheatgrass Central Rocky Mountain Foothill Grassland Group and Western North American Interior Ruderal Grassland & Shrubland Group. Each of these groups is described below. However, due to limitations in the ability of spatial imagery to discern spectral differences between native wet meadows and ruderal wet meadows and native grasslands and ruderal grasslands, breaking down the acres of wet meadow and grasslands into the different USNVCS vegetation groups was not possible. Four sample plots were located within wet meadow vegetation communities. Five sample plots were located within grassland vegetation communities, and the majority of these grassland sample plots consisted of heavily grazed grasslands dominated by non-native species.

Sedge Species - Reedgrass Species Montane Wet Meadow & Marsh Group

This vegetation group consists of open wet meadows found in montane and subalpine elevations dominated by perennial cold-dormant graminoids or forbs (usually less than 3.3 feet (1 meter) in height), often in large or small patches surrounded by forests or intermixed with shrubland (Comer et al. 2015). Vegetation in this group can occur as a mosaic of several plant associations, or be a monotypic stand of a single association dominated by graminoids or forbs. Dominant vegetation typically includes grasses and sedges such as *Calamagrostis canadensis*, tufted hairgrass (*Deschampsia caespitosa*), fowl mannagrass (*Glyceria striata*), water sedge (*Carex aquatilis*), inflated sedge (*Carex utriculata*), Bolander's sedge (*Carex bolanderi*), sheep sedge (*Carex illota*), small-wing sedge (*Carex microptera*), mountain sedge (*Carex scopulorum*), as well as rushes (*Eleocharis palustris*), Drummond's rush (*Juncus drummondii*), Sierra rush (*Juncus nevadensis*) or forbs such as common camas (*Camassia quamash*), tall mountain shooting star (*Dodecatheon jeffreyi*), arrowleaf groundsel (*Senecio triangularis*), and California false-hellebore/corn lily (Comer et al. 2015).

Wet meadows occur in open wet depressions, basins, and flats with low-velocity surface and subsurface flows. They are typically found on flat areas or gentle slopes, but may also occur on sub-irrigated sites with slopes up to 10 percent. Sites are usually seasonally wet (often tightly associated with snowmelt) and often dry out by late summer. They may have surface water for part of the year, but depths rarely exceed a few centimeters (Comer et al. 2015).

Kentucky Bluegrass - Canadian Horseweed – Canada Thistle Ruderal Marsh, Wet Meadow & Shrubland Group

This group contains disturbed wet meadows found in lowland, montane, and subalpine elevations throughout the western United States dominated by non-native species such as redtop (*Agrostis gigantea*), creeping bentgrass (*Agrostis stolonifera*), meadow foxtail (*Alopecurus pratensis*), Canadian horseweed (*Conyza canadensis*), Canada thistle, sow thistle (*Sonchus* spp.), prickly lettuce (*Lactuca serriola*), reed canarygrass, common reed (*Phragmites australis*), fowl bluegrass (*Poa palustris*), and/or Kentucky bluegrass (*Poa pratensis*) (Kittel 2015b). Disturbances that have converted native wet meadows to ruderal wet meadows include continuous heavy grazing by domestic livestock, soil disturbance/ compactions, significant change in hydrologic regime, or invasion by non-native species after natural disturbance such as fire, floods, or landslides (Kittel 2015b). Native species may be present in this vegetation group, but their abundance is often so low that the original native plant association may be impossible to determine.

Rough Fescue – Idaho Fescue – Bluebunch Wheatgrass Central Rocky Mountain Foothill Grassland Group

This vegetation community, found in lower montane and foothill zones, consists of herbaceous communities dominated by cool-season bunchgrasses (Reid et al. 2015). The dominant grasses include bluebunch wheatgrass, Idaho fescue, and rough fescue (*Festuca campestris*), although a diversity of other grass species occur, including needle-and-thread grass (*Hesperostipa comata*), needlegrass (*Achnatherum* spp.; *Hesperostipa* spp.), oat-grass (*Danthonia* spp.), Great Basin wildrye (*Leymus cinereus*), prairie junegrass (*Koeleria macrantha*), western wheatgrass (*Pascopyrum smithii*), or

Sandberg bluegrass (*Poa secunda*) (Reid et al. 2015). Forb diversity is also typically high in this vegetation community.

This vegetation community ranges from small meadows to large open parks surrounded by conifers in the lower montane, to extensive foothill and valley grasslands below the lower treeline. Long-term heavy grazing on moister sites can result in a shift to a community dominated by Kentucky bluegrass or timothy (*Phleum pratense*). Other nonnative species tend to invade these native grassland areas, and remnant grasslands are now typically associated with steep and rocky sites or small and isolated sites within an agricultural landscape (Reid et al. 2015).

Western North American Interior Ruderal Grassland & Shrubland Group

This vegetation community includes contains ruderal vegetation with an open to dense shrub canopy and/or herbaceous vegetation found on human-disturbed sites and is dominated by non-native and generalist native species that occur in temperate areas throughout the western United States (Schulz 2014). Vegetation in these areas can be a monoculture of a single nonnative species, or a mix of several nonnative forbs and graminoids, often associated with generalist native species. Common graminoids include redtop, creeping bentgrass, cheatgrass (*Bromus tectorum*), orchardgrass (*Dactylis glomerata*), quackgrass (*Elymus repens*), timothy, meadow foxtail, and Kentucky bluegrass (which may have been purposefully seeded for forage or to prevent soil erosion). Numerous other non-native forb species, such as Russian knapweed (*Acroptilon repens*), whitetop (*Cardaria draba*), musk thistle (*Carduus nutans*), knapweed (*Centaurea* spp.), Canada thistle, and toadflax (*Linaria* spp.), may also occur in this vegetation community. Native grasses and forbs may be present; however, they often are not very abundant, or if abundant they tend to be generalists or ruderal species (Schulz 2014).

CLIFF, SCREE, ROCK, AND BARREN

Based on the vegetation classifications, approximately 1,546 acres (2.2 percent) of the Desolation Creek watershed was classified as cliff, scree, rock, or barren areas. Portions of the area classified as cliff, scree, rock, and barren correspond with the Nonvascular Rocky Mountain Cliff, Scree & Rock Vegetation Group. This vegetation community consists of dry, barren, and sparsely vegetated rock outcrops and cliff faces (Kittel and Reid 2010). These sparsely vegetated areas (generally less than 10 percent plant cover) are found from foothill to subalpine elevations on steep cliff faces, narrow canyons, and smaller rock outcrops and also on unstable scree and talus slopes that can occur below cliff faces (Kittel and Reid 2010). There is often very high cover of nonvascular lichens and, in wetter places, mosses and there may be small patches of scattered trees and/or shrubs that reflect the tree and/or shrub species from the surrounding landscape. Soil development is limited, as is herbaceous cover (Kittel and Reid 2010). The remaining areas classified as cliff, scree, rock, and barren consist of exposed rock in barren areas, as well as borrow pits and roads.

SHRUBLAND

Approximately 104 acres (0.1 percent) of the Desolation Creek watershed was classified as shrubland vegetation. During field surveys, one sample plot was located within shrubland vegetation. The USNVCS vegetation group observed in this plot was the Big Sagebrush – Threetip Sagebrush –

Antelope Bitterbrush Big Sagebrush Steppe & Shrubland Group. This vegetation community is characterized by an open to sparse shrub layer of big sagebrush or threetip sagebrush (*Artemisia tripartita* subsp. *tripartita*) with an often dense herbaceous layer dominated by perennial bunchgrasses such as needlegrass, Idaho fescue, Great Basin wildrye, Sandberg bluegrass, and bluebunch wheatgrass (Hall and Schulz 2015). Under a natural fire regime, this vegetation community maintains a patchy distribution of shrubs; however, shrub cover may increase following heavy grazing and/or with fire suppression (Hall and Schulz 2015). Dominant species observed during field surveys within this vegetation group included big sagebrush and bunchgrasses including needlegrass and bluebunch wheatgrass. The sagebrush observed in the sample plot appeared to be dead or dying and the area was very rocky (approximately 30 percent cover of rocks).

OPEN WATER

Approximately 63 acres (0.1 percent) of the Desolation Creek watershed was classified as open water. This classification corresponds to open water associated with Desolation Creek.

DISCUSSION

The results of this classification analysis are best understood within the context of other/previous classifications of the study area's land cover. The U.S. Geological Survey (USGS) Gap Analysis Program (GAP) (USGS 2011) land cover classification is the most directly comparable product. The 30 m^2 resolution of the GAP dataset does not resolve smaller patches of vegetation identifiable in the 5 m^2 classification. However, the quality of the input data and sophistication of the classification methodology and ancillary inputs used to create the GAP classification combine to yield a reliable classification, having a specificity or "class resolution" that greatly exceeds that achieved in the study result.

Comparing the GAP classification to the study result by area, the study result shows significantly more cliff, scree, rock, and barren area than does the GAP, with less than a tenth of a percent. The GAP also has somewhat less area classified as grassland and wet meadow (4.3 percent). GAP classification has more area in conifer forest than the study result (89.3 percent as opposed to 82.1 percent). There is no obvious pattern or trend in the constituent classes of the study result where there was disagreement between the study result and GAP conifer forest classes. However, a notable amount of GAP conifer forest is classified as riparian tree in the study result and the study result does have 2 percent more of the basin area in that class, suggesting that the riparian tree class in the study result may be over-represented. A more influential factor may be the finer scale of the study result, which results in areas of conifer forest in the GAP classification being classified as conifer forest interspersed with grassland, barren, and other classes in the study result. Given the specificity of the GAP classification, it is likely that the study result is achieving a lower accuracy in resolving riparian vegetation and that the 2 percent riparian area coverage in the GAP may be closer to actual ground conditions than the 8 percent in the study result.

The USGS LANDFIRE classification system (LANDFIRE 2008) is also a nominally 30-meter-resolution product designed specifically for reporting and planning management activities. Again, while the application of ancillary data and multiple remote sensed datasets provides a product with a specific (classification) detail that far exceeded that achieved by the classification result, LANDFIRE cover is at a coarser scale and the USGS cautions against the consideration of single pixels or groups of pixels in any particular area.

LANDFIRE Vegetation Type class breaks and GAP Land Use Ecological System classes are not entirely consistent (all though they do share some common class names). Therefore, comparison of LANDFIRE classes to the analysis result requires grouping of specific classes to correspond to the more general classes of the analysis product. Not all of these groupings are the same between GAP and LANDFIRE, adding a confounding factor in a three-way comparison. That noted, the dominant cover macro-group, conifer forest, represents 86 percent of the land cover in the LANDFIRE data as opposed to 82 percent in the analysis result. Open water was again better represented in the LANDFIRE data at 2 percent, as opposed to 0.1 percent in the analysis result. Riparian vegetation was again over-represented in the analysis result in comparison to the LANDFIRE data, again by a factor of two. Grasslands and wet meadow were equally represented in the LANDFIRE classification and the analysis result with both at approximately 7 percent of basin area.

Again, the analysis result significantly indicated bare or barren land over the comparison dataset, with LANDFIRE showing less than 1 percent and the analysis result showing 2 percent. This is likely a product of greater spatial resolution in the analysis product and better class resolution in the LANDFIRE classification.

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