May 2021
Lower Grande Ronde Basin Habitat Restoration

Geomorphic Assessment and Restoration Prioritization – Final Draft

Prepared for Asotin County Conservation District

DRAFT

May 2021
Lower Grande Ronde Basin Habitat Restoration

Geomorphic Assessment and Restoration Prioritization – Final Draft

Prepared for
Asotin County Conservation District
720 6th Street, Suite B
Clarkston, Washington 99403

Prepared by
Anchor QEA, LLC
1605 Cornwall Avenue
Bellingham, Washington 98225

Project Number: 180687-02.01
\\fuji\bellingham\Projects\Asotin County Conservation District\Grande Ronde Assessment\Reports and Deliverables\Single Report\Grande-Ronde_GA_RP_Report_FINAL-DRAFT_2021-05-11.docx

TABLE OF CONTENTS

1 Introduction 1

1.1 Purpose 1

1.2 Report Organization 1

1.3 Strategies Followed for Prioritization of Restoration Projects 2

2 Basin Description 4

2.1 Historical Geomorphic Conditions 6

2.2 Regional Geology 6

3 Study Area Description 8

3.1 Study Area Delineation 8

3.1.1 Upland Areas and Non-Fish-Bearing Tributaries 12

3.2 Basin Hydrology 12

3.2.1 Basin Wide Precipitation and Runoff 12

3.2.2 Historical Floods and Peak Flows of Record 14

3.3 Land Use and Anthropogenic Influences 14

3.3.1 Impacts to Hydrology and Geomorphic Processes 15

3.3.2 Dams and Invasive Species 16

3.3.3 Climate Change 16

3.3.4 Restoration Actions To-Date 17

3.4 Upstream Effects and Influence of the Upper Grande Ronde Basin 18

4 Fish Habitat, Distribution, and Management 19

4.1 Summer Steelhead 19

4.2 Spring Chinook Salmon 24

4.3 Fall Chinook Salmon 24

4.4 Bull Trout 25

4.5 Other Species of Concern 26

5 Limiting Factors and Impaired Processes 27

5.1 Mainstem Grande Ronde 27

5.2 Joseph Creek 29

5.3 Other Tributaries 31

5.4 Upland Areas and Non-Fish-Bearing Tributaries 32

DRAFT

6 Summary of Geomorphic Assessment 34
6.1 Floodplain Connectivity 35
6.2 Complexity 35
7 Restoration Strategies 38
7.1 Mainstem Grande Ronde Restoration Actions 38
7.1.1 Promote Fish Access to Tributary Inlets 38
7.1.2 Protect Established Islands and Side Channels 39
7.1.3 Encourage Riparian Growth on Bars and Islands 39
7.2 Joseph Creek and Tributary Restoration Actions 40
7.2.1 Reconnect Side Channels and Disconnected Habitat 40
7.2.2 Address Encroaching Features 41
7.2.3 Develop Instream Structure 41
7.2.4 Riparian Zone Enhancement 44
7.2.5 Modify or Remove Obstructions 44
7.3 Upland Areas and Non-Fish-Bearing Tributaries 45
7.4 Restoration Actions for Climate Change Resiliency 46
7.4.1 Target Resiliency and Diversity 46
7.4.2 Reduce Peak Stream Temperatures 46
8 Project Area Prioritization 47
8.1 Prioritization of Mainstem Project Areas 47
8.2 Prioritization of Joseph Creek Project Areas 51
8.3 Prioritization of All Other Tributaries 54
9 Next Steps and Further Evaluations 57
10 Limitations 58
11 References 59

TABLES

Table 1-1 Restoration and Prioritization Framework 2
Table 3-1 Mainstem Reaches 11
Table 3-2 Joseph Creek and Other Tributary Reaches 11
Table 5-1 Restoration Strategies to Address Impaired Processes and Limiting Factors of the Mainstem Grande Ronde 29

Table 5-2	Restoration Strategies to Address Impaired Processes and Limiting Factors of Joseph Creek	31
Table 5-3	Upland and Tributary Effects on Instream Limiting Factors and Management Strategies	32
Table 8-1	Mainstem Prioritization Framework	49
Table 8-2	Mainstem Restoration Site Scoring for Restoration Potential	49
Table 8-3	Mainstem Restoration Site Tiers	51
Table 8-4	Joseph Creek Prioritization Framework	53
Table 8-5	Joseph Creek Project Area Scoring for Restoration Potential	53
Table 8-6	Joseph Creek Project Area Tiers	54
Table 8-7	Project Area Scoring for Restoration Potential of All Other Tributaries	55
Table 8-8	Project Area Tiers for All Other Tributaries	56

FIGURES

Figure 2-1	Grande Ronde Basin Overview	5
Figure 3-1	Reach Delineations	9
Figure 3-2	Joseph Creek Watershed	10
Figure 3-3	Mean Annual Precipitation Distribution, Grande Ronde River Basin	13
Figure 3-4	Projected Surface Air Temperatures and Stream Temperatures in Washington	17
Figure 4-1	WDFW LSRCP Hatchery Facilities (hatcheries and acclimation ponds) in SE Washington	22
Figure 4-2	Oregon Program	23

APPENDICES

Appendix A	Hydrologic Analysis Methods and Results
Appendix B	Hydraulic Modeling
Appendix C	Desktop Geomorphic Analysis Results
Appendix D	Mainstem Reaches
Appendix E	Tributary Reaches
Appendix F	Project Area Maps

ABBREVIATIONS

1D	one-dimensional
2D	two-dimensional
ACCD	Asotin County Conservation District
BDA	beaver dam analog
cfs	cubic foot per second
EDT	Ecosystem Diagnosis and Treatment
ELJ	engineered log jam
ESA	Endangered Species Act
LiDAR	Light Detection and Ranging
LSRCP	Lower Snake River Compensation Plan
LWM	large woody material
MPG	Major Population Group
ODFW	Oregon Department of Fish and Wildlife
PAL	post-assisted log structure
RM	river mile
SE WA Recovery Plan	*Snake River Salmon Recovery Plan for SE Washington*
WDFW	Washington Department of Fish and Wildlife

1 Introduction

Anchor QEA, LLC, was retained by the Asotin County Conservation District (ACCD) to provide a Geomorphic Assessment, Habitat Restoration Prioritization, and Conceptual Restoration Plan for the Lower Grande Ronde basin in Washington. While some assessment of fisheries and habitat in this region has been done (Nowak 2004; SRSRB 2011), the Lower Grande Ronde basin has not been studied or documented to the degree that the Grande Ronde basin in Oregon has. This Assessment and Prioritization is intended to help restoration decision making and set a baseline for evaluating future restoration locations and progress toward goals in the Lower Grande Ronde.

1.1 Purpose

This assessment is intended to support river restoration efforts to improve habitat conditions for focal aquatic species, encourage a thriving fluvial ecosystem, and restore geomorphic processes of the Lower Grande Ronde basin in Washington. The Lower Grande Ronde basin supports Endangered Species Act (ESA)-listed summer steelhead, spring Chinook salmon, and bull trout, which have been identified as aquatic focal species of concern in the *Grande Ronde Subbasin Plan* (Nowak 2004), along with several other species of concern. These focal species are discussed further in Section 4.

The goals of this assessment are:

1. Use the available data and field observations to assess key components of habitat targets and basin goals.
2. Prioritize areas for restoration and recommend restoration actions that can provide the most benefit and uplift to species.
3. Provide data on key components of habitat targets for future evaluation and set targets for each of these key components.

1.2 Report Organization

This Geomorphic Assessment and Restoration Prioritization includes two distinct components. The main body of the report provides the project setting; background on the status of fish stocks and fish management within the basin; and information about the habitat goals, restoration strategies, and final prioritizations. The technical and supporting appendices provide detailed information and findings about the technical analyses performed as a part of this study. Following is a brief description of these appendices:

- **Appendix A – Hydrologic Analysis Methods and Results:** Detailed methods and results of the hydrology used for this assessment
- **Appendix B – Hydraulic Modeling:** Detailed methods and results of the hydraulic modeling used for this assessment

- **Appendix C – Desktop Geomorphic Analysis Results:** Overview of the geomorphic analyses including floodplain connectivity, channel complexity, encroachments, and restoration potential
- **Appendix D – Mainstem Reaches:** Description and interpretation of assessment results for each project area in the mainstem Grande Ronde, organized by reaches
- **Appendix E – Tributary Reaches:** Description and interpretation of assessment results for each project area in the tributaries, organized by reaches.
  - **Note:** The mainstem of Rattlesnake Creek is not included in this assessment because a comprehensive restoration assessment was already completed by Rio Applied Sciences and Engineering following the catastrophic dam failure and flood in spring 2017. For more information on mainstem Rattlesnake Creek, see Rio's report (Rio ASE 2019).
- **Appendix F – Project Area Maps:** PDF maps showing locations, relative elevations model, digitized levees and encroachments, and identified restoration actions for each project area.

1.3 Strategies Followed for Prioritization of Restoration Projects

Restoration strategies and recommendations were developed for each delineated reach based on habitat limiting factors identified in the *Grande Ronde Subbasin Plan* (Nowak 2004) and the *Snake River Salmon Recovery Plan for SE Washington* (SE WA Recovery Plan; SRSRB 2011), as well as salmonid life history, and site-specific physical, hydrologic, and geomorphic conditions observed during field research. The restoration framework was loosely based on the process described in Figure 2 from Roni et al. (2002). The restoration actions in the Grande Ronde mainstem and the Grande Ronde tributaries that correspond to the framework proposed by Roni are shown in Table 1-1.

Table 1-1
Restoration and Prioritization Framework

Roni et al. (2002)	Grande Ronde Tributaries	Grande Ronde Mainstem
Protect and maintain natural processes	Promote natural hydrologic and sediment routing throughout the system, allow natural migration and wood recruitment	Promote natural hydrologic and sediment routing throughout the system, allow natural migration and wood recruitment
Connect disconnected habitats	Reconnect oxbows, wetlands, and former mainstem and side channels	Protect tributary inlets and promote fish access to habitat throughout the watershed
Address roads, levees, and other human infrastructure impairing processes	Remove or modify culverts, levees, dredge spoils, diversion dams, and grade control structures	Address levees, roads, and bridges where they impede natural processes
Restore riparian processes	Isolate and protect healthy riparian areas, eradicate invasive species, and plant native communities	Promote native vegetation on bars and islands and eradicate invasive species

Roni et al. (2002)	Grande Ronde Tributaries	Grande Ronde Mainstem
Improve instream habitat conditions	Install large individual trees and large woody material structures in the mainstem channel	Install wood collection features to add instream habitat, and isolate and protect islands and side channel for diversity of habitat

Source: Adapted from Roni et al. 2002, Figure 2.

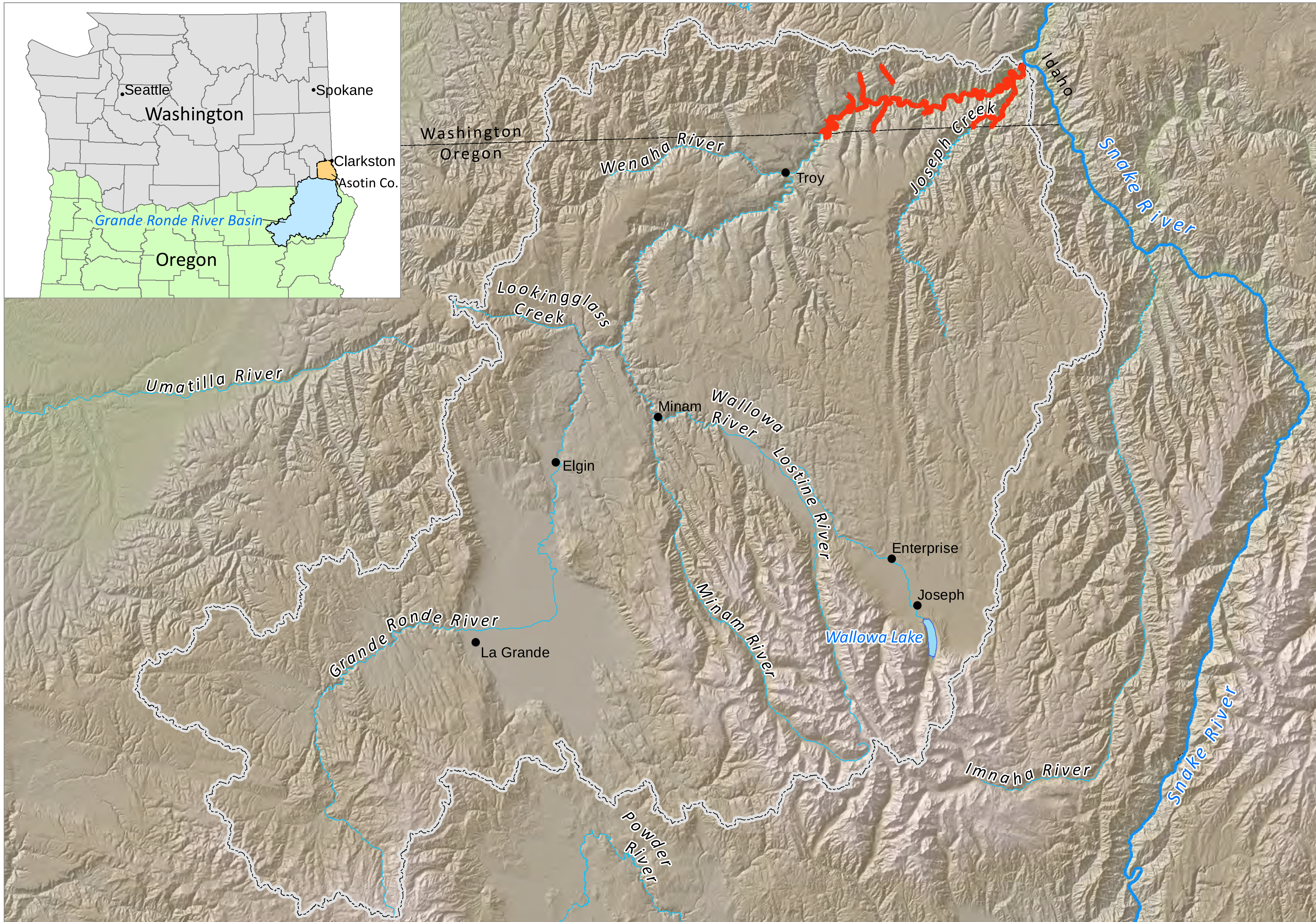
2 Basin Description

The Grande Ronde basin drains the northeast corner of Oregon and the southeast corner of Washington, with headwaters in the Blue and Wallowa mountains. The Grande Ronde River flows approximately 212 miles from its origin to the confluence with the Snake River and drains more than 4,000 square miles of northeast Oregon and southeast Washington including the following major tributaries: Catherine Creek, Joseph Creek, Wallowa River, and Wenaha River (Nowak 2004).

Land use within the basin includes cattle grazing and ranchland, highways and local roads, some residential property, and forestry at high elevations. Portions of the watershed upstream in the vicinity of La Grande, Oregon, are more developed and agricultural, while the Washington portion is more remote and sparsely inhabited. The entire basin is within the Blue Mountains ecoregion, and much of the lower elevation of the basin is categorized as "Canyons and Dissected Uplands," which feature arid soil and support bunchgrasses and drought-tolerant shrubs (Thorson et al. 2003).

Agricultural fields represent a significant land use, especially in the upper basin. Crops grown in the La Grande area include wheat, hay, peppermint, and potatoes (Nowak 2004). Irrigated agriculture is minimal within the assessment reaches, although some non-irrigated grain fields are present on the surrounding mesas and hillsides. The city of La Grande with a population of 13,000 people is located on the upper mainstem, and diverts a large percentage of the river's water for irrigation and water supply (Fissekis 2007). Urban development has negatively affected the watershed by removing geomorphic complexity and riparian habitat and promoting unsuitably high water temperatures for salmonids (Nowak 2004).

Logging and logging road creation are additional land use impacts even today, and influence soil compaction, snowmelt timing, and fine sediment supply to streams. It is hypothesized that logging in the basin may have shifted the timing of spring peak flows forward 1 month because the removal of shade has accelerated snowmelt (Wissmar et al. 1994). The U.S. Forest Service and Bureau of Land Management manage 46% of the land in the Grande Ronde basin, and the national forests are currently managed for multiple uses including timber production, grazing, and recreation (USFWS 2002).



LEGEND:

Assessment Extent

Grande Ronde Watershed

NOTE(S):
1. Horizontal datum is WA State Plane South Zone, NAD 83, Feet.
2. Geologic unit data provided by Washington State Department of Natural Resources.

0 5
Miles

Publish Date: 2021/05/10, 1:42 PM | User: thutchison
Filepath: Q:\Jobs\Asotin_Conservation_District_0847\Geomorphic Assessment\Working\TAH\Main Body Report Figures\Maps\Figue 2-X Basin Overview\Grande Ronde Full Basin Overview.mxd

ANCHOR QEA

Figure 2-1
Grande Ronde Basin Overview
Grande Ronde River Geomorphic Assessment
Asotin County Conservation District, Clarkston, WA

2.1 Historical Geomorphic Conditions

Historical practices including mining, logging, and splash damming have reduced pool densities and increased fine sediment in the Grande Ronde basin. Additionally, stream channelization and confinement by levees and roads have decreased channel sinuosity and complexity. A study comparing stream surveys from 1934 to 1992 showed 66% reductions in large pool density in the Grande Ronde basin and an increase in fine sediment caused by both mining and logging in headwater streams (McIntosh et al. 1994). Woody debris densities were also greatly reduced in logged upper Grande Ronde streams relative to unlogged streams. Before widespread road construction, logging efforts were targeted in the riparian areas and logs were transported by splash damming in the late 19th and early 20th century (McIntosh et al. 1994). This practice used temporary dams and intentional dam releases to transport logs downstream. These splash dam events were associated with scouring of alluvium, removal of large wood, and channel straightening complexity. These historical riparian logging operations disconnected the river from its floodplain, eliminated beneficial wood-driven geomorphic processes, and removed the sustainable supply of instream wood to support stream recovery (McIntosh et al. 1994).

Channel complexity and floodplain connectivity have also been reduced in the mainstem Grande Ronde and its tributaries by anthropogenic channelization. Stream channelization in the Grande Ronde basin began after World War II using available heavy machinery (Wissmar et al. 1994). The striking impact of channelization can be observed through the La Grande valley between the former meandering channel and the current path through the State Ditch. Numerous smaller channelized reaches are found throughout the basin where riprap and levees were used to protect private property and infrastructure. Channelization efforts specifically increased after destructive floods such as the one in the winter of 1964 (McIntosh et al. 1994).

Despite these impacts in the tributaries and the upper basin, the geologic history indicates that the lower canyon of the mainstem Grande Ronde is more geomorphically similar to its historical condition. The river's incised meanders through the basaltic canyon naturally have few side channels and avulsions and little lateral migration through the floodplain (Caldwell 2007). Even so, past land use practices in the basin may have had major impacts on the riparian vegetation, sediment dynamics, and abundance of woody debris throughout the lower mainstem.

2.2 Regional Geology

The Grande Ronde is surrounded by the Wallowa Mountains, which were derived from the late Jurassic granitic Wallowa pluton (Hales et al. 2005). The lower basin is predominated by layers of Miocene era basalts—specifically the Grande Ronde basalts that were a part of the Columbia River Basalt Group that erupted 17.5 to 11.5 million years ago and were sourced from the Yellowstone hotspot in the mantle (Caldwell 2007). During this period, approximately 2 kilometers of uplift in the

Wallowa Mountains and Columbia Plateau occurred (Hales et al. 2005). The ancient Grande Ronde channel formed in shallow soils overlaying these basalts and surrounding uplift caused the river to incise and form meanders over time to adjust to the increased slope. These incised meanders were essentially locked in place by the extremely resistant basalts; thus, the Grande Ronde has maintained its present course within the steep canyons of the lower river for millennia (Caldwell 2007). Pleistocene era glaciation in the higher elevation areas of the basin supplied sediment, which helped form large floodplains and terraces in the low gradient reaches of the river, but floodplain and terrace formation in the steep basaltic canyons was minimal (Caldwell 2007). The surrounding geology has important ramifications for restoration because it explains why little floodplain is available in the mainstem for active channel migration. The primary targeted areas to reconnect floodplain are within the tributaries.

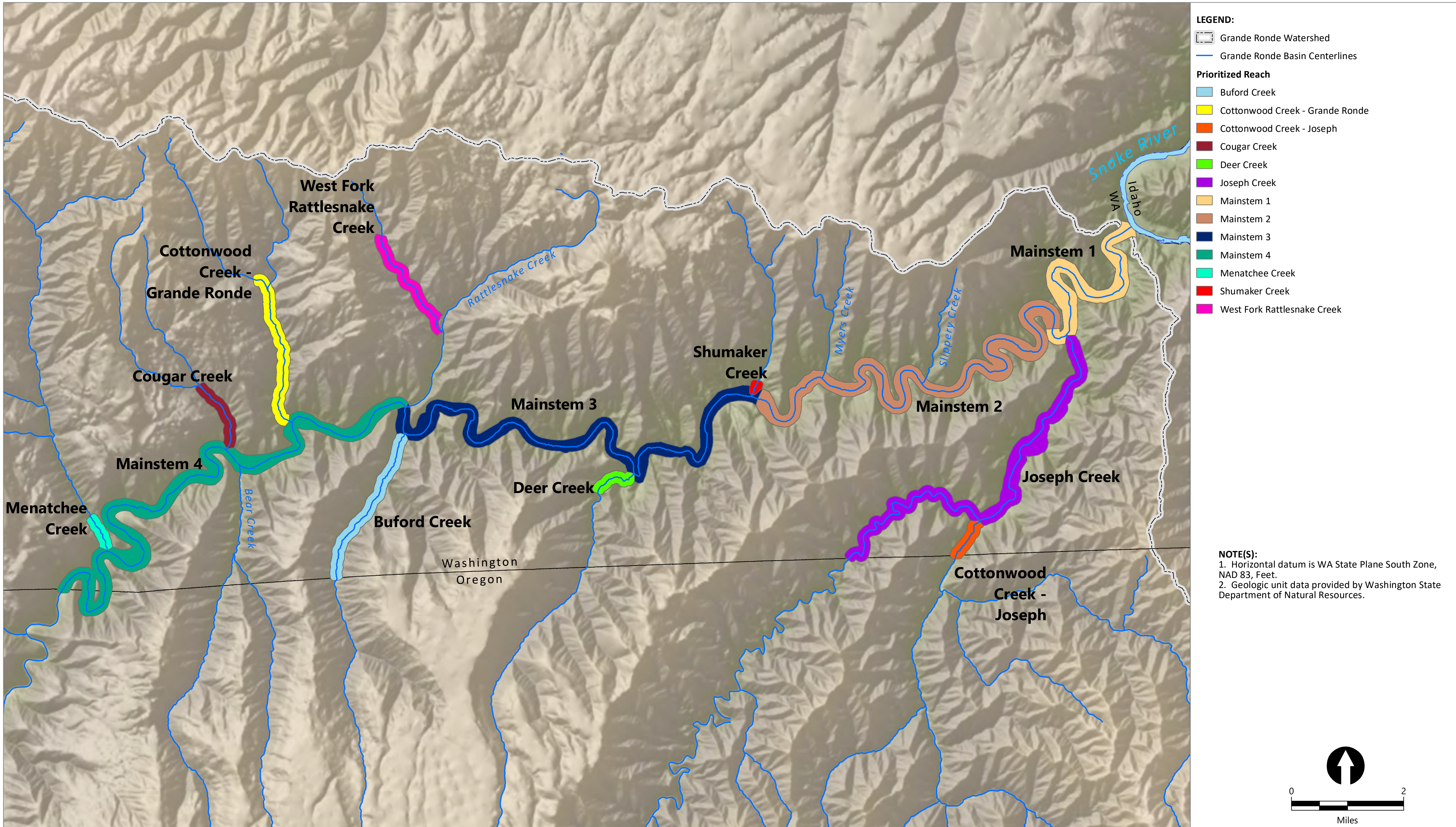
3 Study Area Description

The assessment portion of the Grande Ronde basin comprises the mainstem Grande Ronde from the Washington/Oregon border to the confluence with the Snake River. This also includes the largest tributary in the Lower Grande Ronde, Joseph Creek and its tributary Cottonwood Creek from the Oregon border to the mainstem, as well as seven other smaller tributaries to the mainstem. These tributaries include Menatchee, Cougar, Cottonwood, West Fork Rattlesnake, and Shumaker creeks draining the north side of the valley and Buford and Deer creeks draining the south side. Figure 3-1 shows the extents of the Lower Grande Ronde assessment area, as well as the individual assessment reach delineations.

3.1 Study Area Delineation

The study area was subdivided into assessment reaches by tributary, and the mainstem was divided into four reaches based on significant changes in geomorphic condition, water temperature, and natural and anthropogenic bounding features. These assessment reaches were evaluated in three classifications:

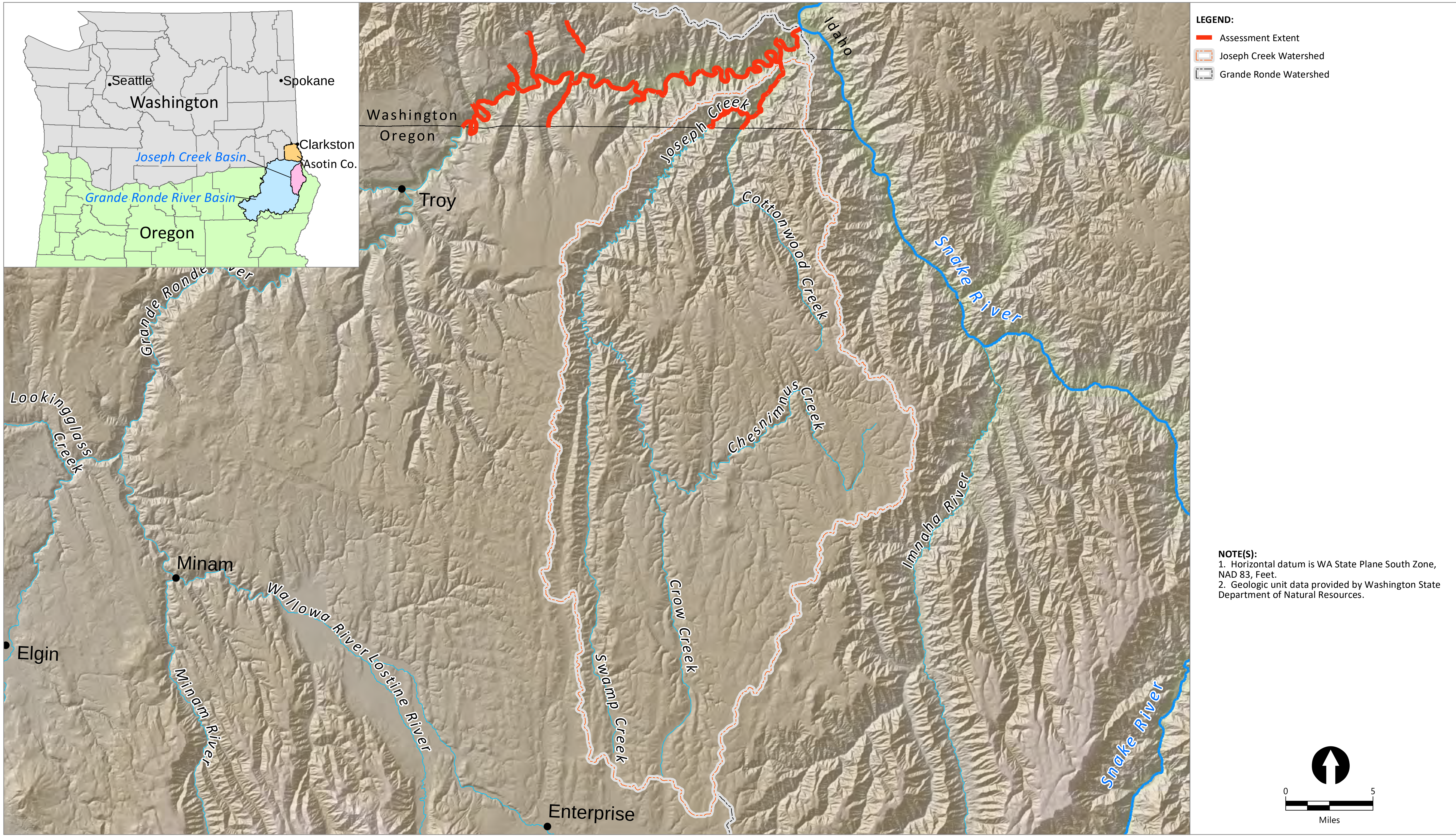
- **Mainstem reaches:** These reaches are within the mainstem Grande Ronde. Limiting factors impaired processes and restoration actions of the mainstem Grande Ronde are all significantly different than those concerns in the tributaries. Four reaches in the mainstem were delineated based on geomorphic, hydrologic, and land use characteristics described in Table 3-1. Portions of each of these reaches have been singled out as project areas and are the focus of the restoration prioritization and conceptual plans.
- **Major tributary (Joseph Creek):** Joseph Creek is the largest tributary to the Grande Ronde River within the assessment area. The Joseph Creek drainage is approximately 556 square miles and includes many tributaries of its own large enough to provide potential habitat and has a unique population of steelhead. For these reasons, Joseph Creek and its limiting factors are significantly different than both the mainstem and the other tributaries. The portion of Joseph Creek included in this assessment (in Washington) is just a small part of the larger watershed as shown in Figure 3-2. For this assessment, Joseph Creek was delineated into eight project areas based on similar geomorphic characteristics.
- **Tributary reaches:** The remaining tributary reaches of Menatchee, Cougar, Cottonwood, West Fork Rattlesnake, Buford, Deer, and Shumaker creeks were divided and ranked according to project areas based on similar geomorphic characteristics such as complexity and confining features. Based on similar size and data available, these project areas were compared and prioritized amongst all the tributary reaches (excluding Joseph Creek). These reaches are described in Table 3-2.



Publish Date: 2021/05/10, 1:51 PM | User: thutchison
Filepath: Q:\Jobs\Asotin_Conservation_District_0847\Geomorphic Assessment\Working\TAH\Main Body Report Figures\Maps\Figue 2-X Reach Delineations\Reach Delineation New Template.mxd

ANCHOR QEA

Figure 3-1
Reach Delineations
Grande Ronde River Geomorphic Assessment
Asotin County Conservation District, Clarkston, WA



Publish Date: 2021/05/10, 1:54 PM | User: thutchison
Filepath: Q:\Jobs\Asotin_Conservation_District_0847\Geomorphic Assessment\Working\TAH\Main Body Report Figures\Maps\Figure 2-X Joseph Creek Basin Overview\Joseph Creek Basin Overview.mxd

ANCHOR QEA

Figure 3-2
Joseph Creek Watershed
Grande Ronde River Geomorphic Assessment
Asotin County Conservation District, Clarkston, WA

The assessment completed for the tributary reaches differed from the assessment completed for the mainstem based on the difference in Light Detection and Ranging (LiDAR) datasets and the significant difference in size and stream order between the tributary and mainstem reaches. The differences in the prioritization framework between tributary and mainstem reaches are summarized in the following tables.

Table 3-1
Mainstem Reaches

Class	Reach	Location Description	River Miles	Valley Miles	Number of Restoration Sites
Mainstem	1	Confluence with Snake River to upstream of “Narrows”	4.83	4.56	6
Mainstem	2	Upstream of “Narrows” to Shumaker Creek	11.03	10.37	4
Mainstem	3	Shumaker Creek to Rattlesnake Creek	10.69	10.16	8
Mainstem	4	Rattlesnake Creek to Oregon Border	12.64	12.01	9

Table 3-2
Joseph Creek and Other Tributary Reaches

Class	River	Study Area	River Miles	Valley Miles	Number of Project Areas
Major Tributary	Joseph Creek	Mouth to WA/OR Border	8.44	7.97	8
Tributary	Cottonwood Creek (Joseph)	Mouth to WA/OR Border	0.93	0.84	2
Tributary	Shumaker Creek	Mouth to LiDAR Extent	0.32	0.31	1
Tributary	Deer Creek	Mouth to LiDAR Extent	0.97	0.87	2
Tributary	Buford Creek	Mouth to WA/OR Border	3.16	3.03	4
Tributary	West Fork Rattlesnake	Mouth to LiDAR Extent	2.35	2.27	5
Tributary	Cottonwood Creek (Grande Ronde)	Mouth to LiDAR Extent	3.23	2.96	5
Tributary	Cougar Creek	Mouth to LiDAR Extent	1.46	1.42	3
Tributary	Menatchee Creek	Mouth to LiDAR Extent	0.75	0.69	2

3.1.1 *Upland Areas and Non-Fish-Bearing Tributaries*

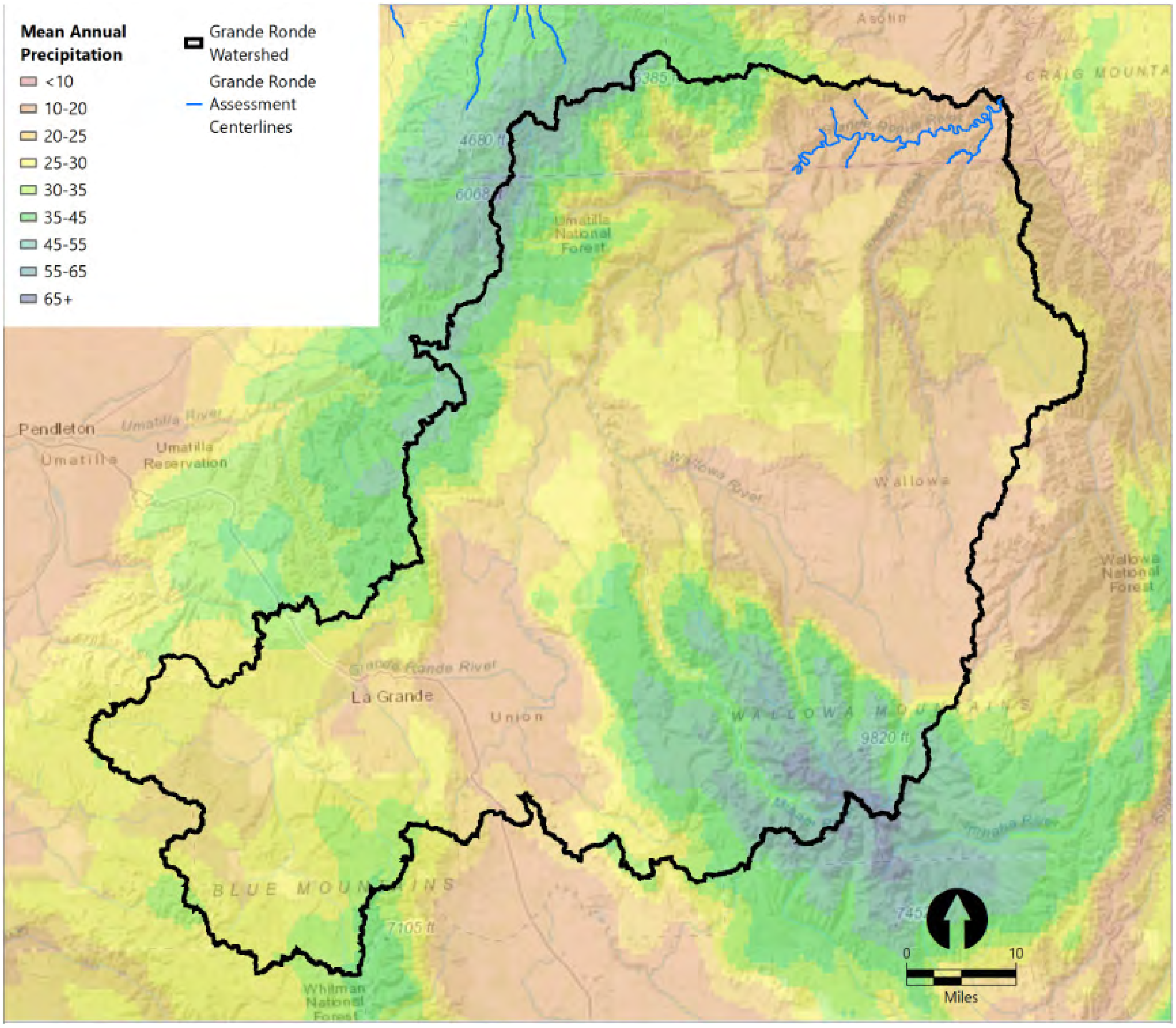
While fish-bearing streams are the focus of this assessment, the contributing hillslope and upland areas also have major effects on the in-channel and fluvial processes of the rivers and streams in the study area. Many of the limiting factors of the fish-bearing streams in this study area, discussed in Section 5, have their roots in process and land use practices occurring outside of the primary fluvial corridor. In addition, there are numerous smaller tributaries and draws in the Grande Ronde basin that may have only intermittent or ephemeral flows and are not directly fish-bearing. However, the processes that occur in these non-fish-bearing streams can still have a large effect on fluvial processes in the streams and rivers they contribute to, including hydrology, sediment supply, and LWM supply. Therefore, a "ridgetop-to-ridgetop" view is necessary when considering restoration of the waterbodies in this assessment. While instream restoration is the focus of this assessment and prioritization, restoration work in the upland areas and smaller tributaries should be considered as a vital part of restoring watershed-scale processes. General restoration techniques for these areas and their benefits to restore instream and watershed processes are discussed in Sections 7 and 5, respectively.

3.2 Basin Hydrology

3.2.1 *Basin Wide Precipitation and Runoff*

The Grande Ronde basin has a modified continental climate with cold, wet winters and warm, dry summers (USFWS 2002). Precipitation or lack thereof in the Grande Ronde basin is greatly influenced by the Cascade rain shadow, as the Cascades west of the basin block much of the marine-derived precipitation from the Pacific Ocean (Fissekis 2007). Precipitation in the Grande Ronde basin primarily occurs in the winter as snow with some spring rainstorms. The Blue Mountains to the northwest and Wallowa Mountains to the southeast both locally affect precipitation and are the source of snow that supplies this snowmelt dominant watershed. Most of the yearly precipitation in the basin falls as snow with peak river flows occurring from April to May with the spring freshet and flows declining during the dry summer months into November (Fissekis 2007). Timing of the peak flows differs throughout the basin. The Upper Grande Ronde experiences earlier snowmelt and peak flows in March to April. The southern portion of the basin draining the north-facing slope of the Wallowa Mountains peaks in May to June along with the lower mainstem (Nowak 2004). The precipitation distribution varies significantly with elevation and on average increases 5 inches per 1,000 feet of elevation gained (Nowak 2004). Mean annual precipitation data were available geospatially from Oregon State University through the PRISM climate model (OSU 2019), as shown in Figure 3-3.

Figure 3-3
Mean Annual Precipitation Distribution, Grande Ronde River Basin



3.2.2 Historical Floods and Peak Flows of Record

The stream gage most relevant to this assessment area is operated by the U.S. Geological Survey on the mainstem Grande Ronde at Troy, Oregon (USGS 2020; Gage 13333000). Daily average flow data measured in cubic feet per second (cfs) are available from 1944 to the present, and 15-minute interval data are available from 1989 to the present. The following major flood events were recorded at this gage:

- 42,200 cfs in 1964 (December 23)
- 51,800 cfs in 1996 (February 9)
- 32,600 cfs in 2014 (March 10)
- 31,100 cfs in 2017 (March 19)

Of these events, it is notable that two of the four biggest floods in history have occurred in the last decade. This corresponds with the prediction of more severe spring flood events caused by the cumulative effects of logging and climate change on snowmelt (Rheinheimer 2007). The legacy of the 1964 flood is also relevant to the basin's geomorphology, as widespread installation of levees and bank armoring followed this catastrophic flood (McIntosh et al. 1994).

3.3 Land Use and Anthropogenic Influences

The Grande Ronde basin is currently used for agriculture, livestock grazing, and timber production, and the upper basin has developed urban areas. The Lower Grande Ronde River is also used for recreational purposes including fishing and whitewater rafting. Livestock grazing plays a key factor in the assessed reaches of the basin, and over 90% of livestock in the Grande Ronde basin are cattle (McIntosh et al. 1994). Livestock can be detrimental to riparian vegetation and contribute to soil compaction, which increases runoff and erosion (Fissekis 2007). Timber production increased throughout the basin in the 20th century while logged areas shifted from riparian forests to clearcutting and selective harvest in high elevation headwater forests (Wissmar et al. 1994; McIntosh et al. 1994).

The Lower Grande Ronde basin is not as densely populated at the upper basin, but has some residential development within the riparian area. Roads and highways are another significant land impact, with Interstate 84 running parallel to the mainstem Grande Ronde upstream of La Grande. Highway 129 crosses the assessment reach of the mainstem, but smaller gravel roads along the mainstem and tributaries have a major impact on the assessed basin. These roads act as confining features in the floodplain and multiple culverts at crossings are undersized and act as impediments to fish passage and sediment transport.

Anthropogenic activities have adversely affected the hydrology, geomorphology, and aquatic ecosystem in the Lower Grande Ronde River in ways that undermine salmonid survival throughout their life cycle.

3.3.1 Impacts to Hydrology and Geomorphic Processes

Forestry practices, grazing, and urbanization have all impacted the hydrology of the basin causing more intense floods and increased water temperatures. As mentioned in Section 2, historical forestry targeted riparian areas and then shifted upslope to high elevation forests with the expansion of logging roads (Wissmar et al. 1994). Removal of riparian trees directly removed critical riparian shade. The disconnection of rivers and streams from floodplains also reduced potential to support riparian vegetation and lowered the water table, causing streams to go subsurface more often. Removal of shade near clearcuts in headwater streams accelerated snowmelt and has shifted the timing of peak flows a month earlier in the year, reducing snowpack stored to provide cool summer flow (Wissmar et al. 1994; Fissekis 2007). The removal of vegetation by logging, agriculture, grazing, and urban expansion has accelerated erosion, intensified overland runoff during rainfall events, and increased water temperatures throughout the basin (Fissekis 2007; Hersh-Burdick 2007). On top of these direct impacts, climate change further threatens the watershed with increased temperatures and a predicted reduction of moderate elevation snowpack (Rheinheimer 2007). Hydrologic models predict peak runoff will continue to shift earlier in the year while increasing in intensity, causing decreased flow and warmer summer water temperatures (Rheinheimer 2007).

Historical land use practices impacted geomorphic processes by removing woody debris and disconnecting rivers from their floodplain. Splash damming scoured sediment promoting incision and loss of channel complexity. Stream channelization and bank armoring contributed to the problem by increasing excess transport capacity and exacerbating incision. Mining and logging practices also embedded headwater streams with fine sediment (McIntosh et al. 1994). Remaining levees and bank armoring in the subbasins continue to isolate significant portions of the tributary channels from their floodplain. Roads within the floodplain also act as encroaching features, constricting the available floodplain width. Culverts and road crossings in the tributaries act as bottlenecks on the floodplain as well, and may hinder fish passage. Overall, land use in the subbasins has removed beneficial channel complexity and woody debris and disconnected tributaries from their floodplains.

3.3.1.1 Rattlesnake Creek Dam Failure and Assessment

A recent catastrophic impact to the subbasin occurred in April 2017, when a private dam in the Rattlesnake Creek headwaters broke and released a catastrophic flood. The result of this deluge was systemic scouring of gravel to bedrock and removal of most beneficial riparian vegetation. A conceptual rehabilitation plan for Rattlesnake Creek was prepared by Rio Applied Science and

Engineering in 2019 detailing a restoration approach sponsored by the responsible party (Rio ASE 2019). Investigations by Rio ASE and Sage Environmental Research following the flood revealed fish passage barriers formed by steep vertical steps and debris, lateral and vertical erosion of the channel, removal of large woody material (LWM) and streamside vegetation, and proliferation of invasive weeds in the disturbed floodplain. The developed restoration plan includes placement of boulders and LWM to store gravel and restore geomorphic processes, removal of debris-caused fish passage barriers, planting of native vegetation, and removal of invasive weeds (Rio ASE 2019). See Rio's Rattlesnake Creek Adaptive Management Plan Report for reach-scale restoration plans and design drawings.

3.3.2 Dams and Invasive Species

The installation of dams on the Columbia and Snake rivers is not a direct impact in the basin, but it poses arguably the greatest threat to the health of salmonids in the Lower Grande Ronde watershed. The anadromous salmonids returning to the Grande Ronde have to pass four mainstem dams on the Columbia River and four on the Snake River going both directions on their way to and from the ocean. This journey is a primary cause of mortality for juveniles because this chain of reservoirs is now home to numerous introduced invasive and native warmwater piscivorous species including bass and northern pikeminnow that thrive in these warm, lentic environments. These piscivorous fish are also thriving in the Lower Grande Ronde River and their range continues to expand upstream as summer water temperatures increase and cold-water salmonid habitat is erased. The return journey also poses challenges to adult fish returning to spawn as elevated water temperatures increase fish metabolism while reducing available dissolved oxygen. Together these challenges can cause direct mortality or make it so that the long journey from the Pacific Ocean to the Grande Ronde River is no longer energetically possible.

3.3.3 Climate Change

In a larger context and in addition to the above, the effects of climate change have begun to affect fluvial processes and will continue to play a larger role in these processes in the future. Changing precipitation patterns and rain/snowfall dynamics will affect the timing and duration of major flow events causing variability in geomorphic processes and major channel shaping events. Additionally, warmer stream temperatures are projected throughout the Snake River basin and will place stress on salmonids particularly at key life history stages. Figure 3-4 shows projected stream temperatures and air surface temperatures from *The Washington Climate Change Impacts Assessment* (CIG 2009). The Lower Grande Ronde basin and Snake River basin as a whole will likely experience much warmer stream temperatures. Section 6 discusses in more detail how the effects of climate change on the focal species life history can be addressed with restoration actions.

Figure 3-4
Projected Surface Air Temperatures and Stream Temperatures in Washington

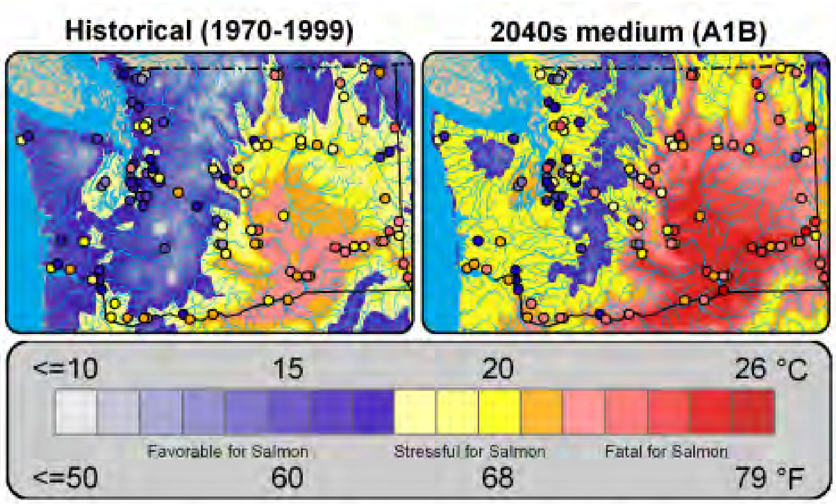


Figure 9. August mean surface air temperature (colored patches) and maximum stream temperature (dots) for 1970-1999 (left) and the 2040s (right, medium emissions scenario, (A1B)). The area of favorable thermal habitat for salmon declines by the 2040s in western Washington, and in eastern Washington many areas transition from stressful to fatal for salmon. Circles represent selected stream temperature monitoring stations used for modeling stream temperatures.

Note: Excerpted from the Washington Climate Change Impacts Assessment (CIG 2009)

3.3.4 Restoration Actions To-Date

While instream restoration has not been widespread so far, some work to improve riparian vegetation and reduce fine sediment influx has been implemented in the Grande Ronde basin in Washington with the assistance of ranchers and farmers in the area (SRSRB 2011). These programs have worked cooperatively with local landowners and stakeholders to complete land management restoration actions such as the following:

- Riparian plantings
- Fish passage barrier removals
- Improved grazing practices
- Livestock exclusions
- Off-channel water sources for livestock

The following are a few examples of restoration projects implemented to date in the Lower Grande Ronde basin:

- Cottonwood Creek Culvert Replacement (2020)
- Buford Creek Culvert Replacement (2019)
- Conservation Reserve Enhancement Program (CREP): 17 miles of stream and 70,000+ trees

3.4 Upstream Effects and Influence of the Upper Grande Ronde Basin

Urbanization and irrigated agriculture have led to habitat degradation, specifically in the upper basin. More than 80% of anadromous salmon habitat in the Upper Grande Ronde basin is considered degraded (Jonasson et al. 2006). Water withdrawals, channel straightening, and floodplain development are all prevalent in the vicinity of La Grande. The State Ditch was constructed in the late 1800s for irrigation, which reduced the channel length by 29 miles (Nowak 2004). Since then, the State Ditch became the main channel and now conveys the majority of flow in a highly confined, channelized 40-mile reach from La Grande to Elgin (Fissekis 2007). The majority of the floodplain in the La Grande vicinity has been converted to agricultural fields to grow wheat, hay, peppermint, and other grains (Nowak 2004). Extensive diversions in the valley have reduced stream flow and lowered the water table (Fissekis 2007). Land clearing and removal of riparian vegetation associated with agriculture has decreased infiltration and streamside shade, and increased surface runoff. Fine sediment and water temperature are both associated with anthropogenic activities in the upper basin. As a result, the Oregon Department of Environmental Quality has instituted a TMDL (total maximum daily load) for water temperature in critical areas in the upper basin to prevent further development or grazing adjacent to streams that are categorized as critical habitat for spring Chinook salmon and bull trout (Hersh-Burdick 2007). Anthropogenic impacts of irrigation and urbanization are concentrated in the upper basin, but impacts of grazing and logging are widespread throughout the whole Grande Ronde watershed. Even though the remote lower canyon is deemed a Wild and Scenic River, these anthropogenic impacts have hydrologic and geomorphic impacts on the entire watershed.

4 Fish Habitat, Distribution, and Management

The Grande Ronde watershed is inhabited by populations of spring Chinook salmon, summer steelhead, and bull trout, and is also used to some extent by fall Chinook salmon (Nowak 2004). All of the salmonid populations within the Grande Ronde basin are ESA-listed as threatened as part of larger Columbia or Snake river population units (Jonasson et al. 2006; Carmichael et al. 2011; USFWS 2002). The Washington portion of the basin is inhabited by populations of summer steelhead spawning in the tributaries and Joseph Creek, and the lower mainstem Grande Ronde supports migrating and overwintering spring Chinook salmon as well as Snake River fall Chinook salmon (Jonasson et al. 2006; Carmichael et al. 2012; Nowak 2004). Historical records suggest Menatchee Creek also supports a resident population of bull trout, but the current status of the population is unconfirmed (USFWS 2002). The Grande Ronde basin was historically home to runs of coho as well as sockeye salmon originating from Wallowa Lake (Nowak 2004). The sockeye went extinct by 1920, and the coho population was extinct by the 1980s after the construction of the mainstem Snake River dams (Nowak 2004). Both the Umatilla and Nez Perce tribes have a stake in and play a management role in fisheries within the basin.

There are numerous threats to salmonid populations within the basin including high summer water temperatures, low flows in tributaries, high fine sediment loads, loss of habitat in the form of pools and woody debris, degraded riparian areas, channelization, predation, and genetic pollution and competition with hatchery fish (Moran and Waples 2004; SRSRB 2011; McCullough et al. 2017). In addition, the mainstem Columbia and Snake river dams and harvest fisheries are a primary threat to salmonids during their migration (Jonasson et al. 2006). Within the assessment basin, primary limiting factors in the mainstem Grande Ronde include sedimentation, lack of pools, high temperatures, lack of woody debris, and anthropogenic confinement (SRSRB 2011). Much of the mainstem is a naturally confined wood transport zone, and increasing woody debris will be challenging (SRSRB 2011). In the Lower Grande Ronde tributaries and lower Joseph Creek, high fine sediment loads, high water temperatures, and lack of pools are the primary limiting factors (SRSRB 2011).

Restoration actions already taken in the Lower Grande Ronde basin include conservation measures to reduce fine sediment by helping farmers and ranchers implement minimum till agriculture, prevent livestock from grazing in the riparian zone, and construct sediment retention basins (SRSRB 2011). Fish passage barrier removal projects on the tributaries have also been implemented. Future restoration efforts in the assessment basin should be geared towards addressing the issues of water quantity and quality, habitat structure, and complexity (SRSRB 2011).

4.1 Summer Steelhead

Summer steelhead in the Snake River were listed as an ESA threatened species in 1994, and the Grande Ronde steelhead are classified as their own Major Population Group (MPG) (Carmichael et al.

2012). The Grande Ronde MPG is divided into four populations: Lower Mainstem, Joseph Creek, Wallowa River, and Upper Grande Ronde. Of these populations, the Joseph Creek population is the only population in the Snake River basin that is considered “highly viable,” while the Upper Grande Ronde is considered “maintained,” and there are not enough data for these distinctions on the Wallowa River and the Lower Mainstem, which comprises the majority of this assessment (Carmichael et al. 2012). According to a Nez Perce tribal evaluation, Joseph Creek is considered a stronghold population, and the tribe established a sustainable escapement objective of 3,600 fish in Joseph Creek and 5,700 fish in the Lower Grande Ronde River (Nez Perce Tribe 2013). Summer steelhead in the Snake River spend 1 to 4 years in freshwater prior to ocean migration, and outmigration can occur from February to June. Adults can be either A-run or B-run fish, with A-runs entering the Columbia River from June to August and B-runs from August to October, then spawning the following spring from February to May (SRSRB 2011).

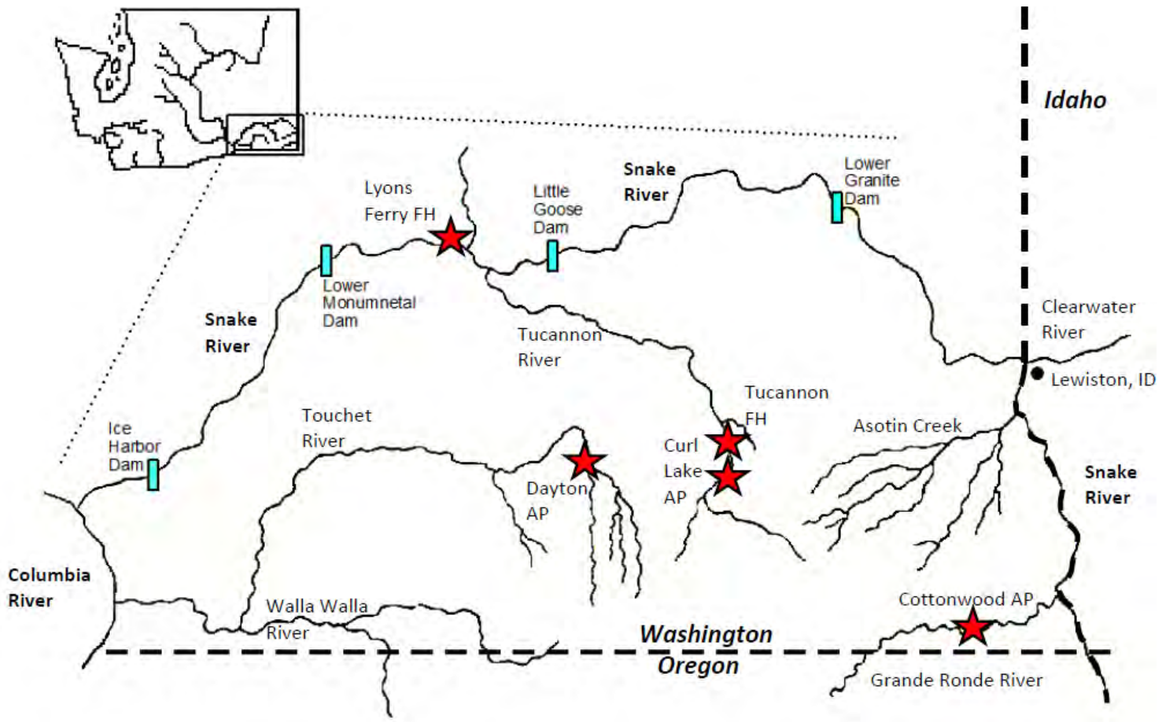
Within the assessment area, the Joseph Creek watershed holds the largest run of wild summer steelhead, but degraded habitat and high temperatures in the Washington portion of the basin currently limit utilization of the lower reaches. Extensive spawning surveys conducted by the Oregon Department of Fish and Wildlife (ODFW) indicate that the Joseph Creek basin maintains a healthy wild steelhead population with a 10-year average annual return of around 2,300 adults from 2007 to 2017 and hatchery proportions below 5% (ODFW 2017). ODFW has delineated three major spawning areas within the basin—Elk, Swamp, and Chesnimnus creeks—all of which are tributaries upstream in Oregon (ODFW 2017). Surveys of the lower Joseph Creek reach and Cottonwood Creek in Washington have painted a different picture of steelhead status. A 2006 Washington Department of Fish and Wildlife (WDFW) survey of the section of Joseph Creek in Washington found no steelhead redds in 6.8 river miles, and an electrofishing survey in August 2006 found only 5 steelhead in the reach, but reported high smallmouth bass densities throughout (Ullman and Barber 2009). Water temperatures in the Washington portion recorded in the summers of 1994 and 2009 indicated lower Joseph Creek and its tributary Cottonwood Creek had the highest temperatures of any tributary in the Lower Grande Ronde River. Summer average temperatures in the 20°C to 25°C range exceeded the survivable threshold for salmonids (Ebersole et al. 2001; Ullman and Barber 2009). Research suggests primary limiting factors to summer steelhead in lower Joseph Creek include high summer water temperatures, eroding incised banks with poor riparian buffers, and competition from warmwater fish species (Ullman and Barber 2009).

Both ODFW and WDFW have maintained hatchery programs for summer steelhead in the Grande Ronde River since 1976. Both departments release hatchery fish of the Wallowa stock, which is a broodstock developed from fish captured at the Snake River dams in the 1970s (Bumgarner and Schuck 2012). Both programs were initiated as part of the Lower Snake River Compensation Plan (LSRCP), which began in 1976 in response to the construction of the four Snake River dams and the loss of 48% of the Snake River summer steelhead population (Carmichael et al. 2012). The goals of the LSRCP program were to promote tribal and sport fisheries while restoring wild populations and protecting Joseph Creek, the Wenaha River, and the Minam River solely for wild steelhead (Carmichael et al. 2012).

WDFW produces Wallowa stock fish at the Lyons Ferry hatchery near the mouth of the Tucannon River and they are transported to the Cottonwood Creek Acclimation Pond on the Grande Ronde River where they are released (Figure 4-1). Adults return to Cottonwood Creek in mid-March to mid-April and are trapped and spawned (Bumgarner and Schuck 2012). Currently 60 full-spawned females are required to meet the goal of 200,000 smolts released yearly at the Cottonwood Creek Acclimation Pond. The program goal is for 4,500 fish to return to the Columbia River and after fishing and mortality, that 1,500 fish return above Ice Harbor Dam (Bumgarner and Schuck 2012). Of the hatchery origin adults trapped in Cottonwood Creek, 14% are spawned, 70% are killed for data or killed to prevent straying and spawning, 6% are lost to prespawn mortality, and 10% are donated to food banks. This regimen was instituted in 2009—previously 64% of the hatchery fish were allowed to spawn naturally in Cottonwood Creek (Bumgarner and Schuck 2012). This practice likely had deleterious effects on the wild spawning populations in the creek, and the 2009 procedure update was intended to minimize spawning of hatchery fish in the creek. On record, 99.8% of the tagged adults trapped in Cottonwood Creek have been hatchery adults released at that acclimation pond (Bumgarner and Schuck 2012).

DRAFT

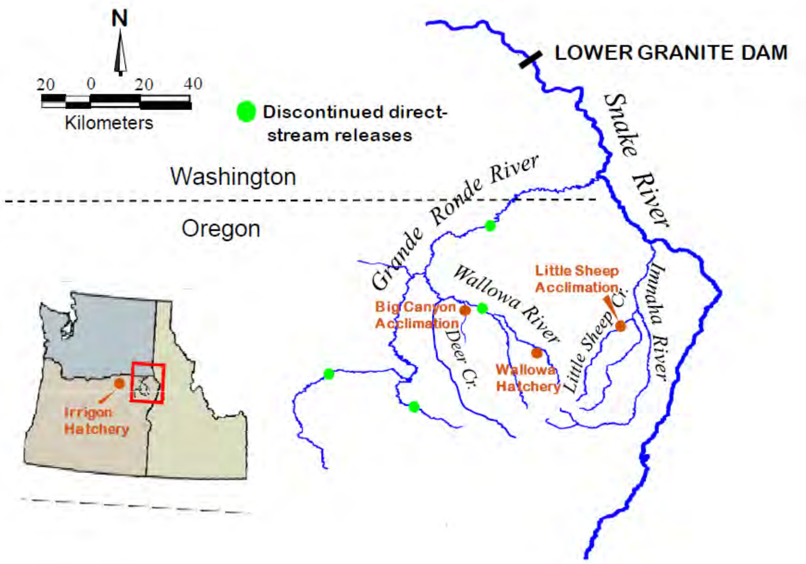
Figure 4-1
WDFW LSRCP Hatchery Facilities (hatcheries and acclimation ponds) in SE Washington



Source: Bumgarner and Schuck 2012

The ODFW program uses multiple hatcheries in the development of its Wallowa stock summer steelhead (Figure 4-2). Fish are captured at the Wallowa Hatchery in Enterprise, Oregon, spawned, and incubated until eggs are eyed. Embryos are then transferred to the Irrigon hatchery for 10 to 13 months of rearing before being transferred back to the Wallowa Hatchery and Big Canyon Acclimation facility as smolts for acclimation and release (Carmichael et al. 2012). The current goal for the ODFW program is 800,000 smolts released and a return of 9,184 adults above Lower Granite Dam (Carmichael et al. 2012). ODFW has also conducted extensive monitoring of wild fish in the Joseph Creek basin and a 2009 assessment estimated a mean population of 2000 adults (Carmichael et al. 2012). Few hatchery fish have been observed to stray into Joseph Creek (Bumgarner and Schuck 2012).

Figure 4-2
Oregon Program



Source: Carmichael et al. 2012

Both states' hatchery programs have been successful in supplementing hatchery summer steelhead for sport and harvest, but the programs have done little to benefit wild stocks, and successful spawning of hatchery fish has likely been detrimental to wild populations (Bumgarner and Schuck 2012; Carmichael et al. 2012). Concern about straying Wallowa stock steelhead arose in 1999 with a high stray rate of Wallowa stock fish in the Deschutes River (Carmichael et al. 2012). Surveys conducted in the assessment basin in 2000 and 2001 attempted to determine the proportion of hatchery fish straying into nearby Washington tributaries including Rattlesnake, Cottonwood, and Menatchee creeks. Spring trapping surveys revealed 4/17 fish of hatchery origin in Menatchee Creek in 2001, and 43/55 fish of hatchery origin in Rattlesnake Creek in 2000. Meanwhile, total hatchery fish captured in Cottonwood Creek in 2000 and 2001 were 288 and 749 respectively, illustrating most steelhead in these tributaries are of hatchery origin (Bumgarner et al. 2002). Separate genetic and statistical analyses also suggest viable hatchery fish spawning in Cottonwood, Menatchee, and Rattlesnake creeks (Moran and Waples 2004).

Future management practices for the summer steelhead in the basin intend to better monitor and protect the wild populations in the basin to meet the LSRCP's goal of preserving wild populations (Bumgarner and Schuck 2012). Fisheries management geared toward restoring habitat and limiting the interference of hatchery populations with wild populations will help support this objective.

4.2 Spring Chinook Salmon

The Grande Ronde population of spring Chinook salmon is the most at-risk of the salmonid species in the basin. Snake River spring Chinook salmon, which included the Grande Ronde population unit, were ESA-listed as threatened in 1992 (Jonasson et al. 2006). The spring Chinook salmon in the Grande Ronde River are divided into six populations: the Wenaha River, Wallowa-Lostine River, Minam River, Catherine Creek, Upper Grande Ronde, and Lookingglass Creek. There are no spawning populations within the assessment basin, but Grande Ronde spring Chinook salmon use the lower mainstem for both migration and overwintering habitat (Jonasson et al. 2006). Spring Chinook yearling smolts usually migrate to the ocean from March to June. Adults enter the Grande Ronde River from late April through late June or early July, move to colder headwater streams for the summer, and spawn from mid-August to late September (SRSRB 2011).

A captive broodstock hatchery program in the Grande Ronde basin began in 1995 with the goal of preventing extinction of this dwindling population (Carmichael et al. 2011). The hatchery program expanded to include a separate hatchery broodstock of fish composed of both wild and hatchery genetics. The program encourages hatchery fish to spawn in the wild, attempting to augment total production of naturally spawning wild and hatchery fish (Carmichael et al. 2011). The program is based out of ODFW’s Lookingglass Hatchery in Elgin, Oregon, and the adult and smolt trapping facilities on the Upper Grande Ronde River are operated by the Confederated Tribes of the Umatilla Indian Reservation. The program’s goals include preventing extinction, maintaining and enhancing natural production, producing hatchery fish that mimic the genetics and life histories of wild fish, maintaining wild populations in the Wenaha and Minam rivers, and re-establishing tribal and recreational fisheries (Carmichael et al. 2011). The program attempts to reach an annual goal of 1,617 returning adults and 250,000 smolts. The smolt goal has only been met once, and the adult goal has never been met (Carmichael et al. 2011). Population trends suggest that the hatchery program is acting as a lifeline for the Grande Ronde spring Chinook salmon, and future management attempts to better understand limiting factors in the spring Chinook life cycle that cause such low smolt to adult returns. The assessment of the programs suggests degraded tributary spawning and mainstem migration habitat, and limited survival through the Columbia and Snake river dams will continue to threaten this population unless major restoration is undertaken (Carmichael et al. 2011).

4.3 Fall Chinook Salmon

Fall Chinook salmon were ESA-listed as threatened in 1992 (SRSRB 2011). Fall Chinook salmon are not considered an aquatic focal species in the Grande Ronde River because fish in the Grande Ronde River only occur in the mainstem Grande Ronde and are part of the broader Snake River fall Chinook salmon population (Nowak 2004). Fall Chinook salmon migrate as subyearlings from July to August and migrate upstream through the Columbia and Snake rivers in August to October. Fall Chinook salmon spawn in large, low elevation rivers including the lower mainstem Grande Ronde (SRSRB 2011).

4.4 Bull Trout

Bull trout in the Columbia River were listed as threatened in 1998, and the Grande Ronde basin is one of the 22 recovery units in the Columbia basin (USFWS 2002). There are nine confirmed local populations with both fluvial and resident life histories in the Grande Ronde including the Upper Grande Ronde, Catherine Creek, Indian Creek, Minam River/Deer Creek, Lostine River/Bear Creek, upper Hurricane Creek, Wenaha River, Lookingglass Creek, and the Little Minam River. An estimated 6,000 adults are present in the basin. All of these populations are wild individuals because there are no hatchery programs for bull trout (USFWS 2002). All known Grande Ronde local bull trout populations are in Oregon except the upper part of the Wenaha River population. The presence of bull trout is historically suggested but unconfirmed in the Menatchee Creek watershed, and a waterfall barrier at river mile 2.5 likely impedes fluvial bull trout migration making any Menatchee Creek individuals isolated residents (USFWS 2002). Bull trout exhibit migratory and resident life history forms. Fluvial migrants rear 1 to 4 years in tributary streams and then migrate to larger rivers before returning to headwater streams to escape warm summer temperatures and to spawn (SRSRB 2011). Spawning typically occurs in August to October, and emergence can happen throughout spring and summer, meaning eggs and fry are in stream gravels year-round. This makes bull trout especially vulnerable to stream sedimentation (SRSRB 2011). Bull trout also require the highest standards for cold water and dissolved oxygen of the salmonids, with optimal dissolved oxygen concentrations above 11 milligrams per liter and maximum temperatures below 12°C (Nez Perce Tribe 2013).

Threats to bull trout in the basin include: small dams and migration barriers, water withdrawals and irrigation infrastructure, warm temperatures causing thermal barriers, excess fine sediment from logging and grazing, removal of riparian vegetation and instream wood, invasive brook trout, and angling pressure (USFWS 2002). One of the primary concerns with maintaining a thriving bull trout population in the basin is allowing gene flow and migration between local populations. Currently it is believed that some of the larger fluvial bull trout may migrate out to the Snake River to overwinter (USFWS 2002). Bull trout migration is threatened by both thermal and manmade physical barriers such as small dams in the basin, and the mainstem Snake River dams (USFWS 2002). Current bull trout recovery efforts in the basin involve expanding monitoring of populations and their migration. Better monitoring and surveys are specifically needed to determine the status of the Menatchee Creek population to determine if bull trout exist within the extent of this assessment. Bull trout recovery will also be benefited by restoration actions that restore riparian vegetation and instream wood and reduce the impacts of agricultural diversions on summer discharge and water temperature. Since bull trout have a specific requirement for cold water, reducing areas of thermal stress and thermal barriers to migration should be a primary goal for recovery.

4.5 Other Species of Concern

Pacific Lamprey are another aquatic species of concern that historically existed in the basin but their current distribution is unknown (Nowak 2004). They are a culturally important food source for native Americans and also exhibit anadromous life cycles. Redband trout are a federally listed species of concern, and are a resident variation of rainbow trout/steelhead that are present in the basin (Nowak 2004).

Introduced smallmouth and largemouth bass are also a species of negative concern for their predatory impact on salmonid species. Their distribution is assumed to be confined to the lower mainstem Grande Ronde with greater population density in the warm reach from the Highway 129 bridge to the river’s mouth. Native northern pikeminnow are also present in the mainstem and are noted for similar predatory effects on salmonid species. Finally, introduced common carp are another species of concern in the mainstem for their harmful effects on water quality and nutrient loading.

5 Limiting Factors and Impaired Processes

Many efforts have been made to understand the factors negatively affecting salmon and steelhead growth and survival across varying life history stages throughout the Pacific Northwest. The priority habitat factors limiting survival and production within a given river segment, tributary, or basin change over time as conditions continue to degrade or improve. Early watershed assessments often focused on limiting factors, which were directly killing fish (called imminent threats), such as dewater streams, migratory blockages, or unscreened diversions. As the imminent threats were addressed across the watershed, restoration efforts transitioned toward limiting factors that indirectly killed fish or limited their growth or survival over all or part of their life cycle.

The overall approach to developing process-based restoration alternatives is to restore a sufficient area (i.e., a restoration corridor) along the river, and provide the materials necessary (i.e., LWM or sediment) and time to allow for natural processes to occur in order to create and sustain a diversity of natural and resilient habitats over the long term. An appropriate corridor that could form aquatic habitats over time must consider both the historical and current extent of the floodplain, off-channel habitats, and potential channel migration. The restoration plan identifies potential restoration actions that are intended to treat and potentially address impaired processes and target specific limiting factors identified in the basin.

In the Lower Grande Ronde basin, limiting factors and restoration actions were evaluated for three categories:

- Mainstem Grande Ronde
- Joseph Creek
- Other tributaries to the mainstem

Each of these categories in the basin serve different functions for the focal species of this assessment and have different limiting factors that contribute to a decline in the focal species.

5.1 Mainstem Grande Ronde

In the mainstem Grande Ronde, primary limiting factors were identified in the *Grande Ronde Subbasin Plan* in 2004 (Nowak 2004) specifically for steelhead but largely apply to the other focal species as well and remain relevant today. These limiting factors were identified as follows:

- Decreased riparian function
- Sedimentation
- Lack of key habitat (pools)
- Flow modifications
- Temperature
- Predation

Notably, a lack of large wood is not listed as a limiting factor in the mainstem. Although Ecosystem Diagnosis and Treatment (EDT) modeling suggested a lack of habitat diversity and large wood, it was noted that large wood is not and likely never was a major component of habitat diversity in the mainstem because this section of the mainstem Grande Ronde in Washington is heavily affected by high flows and ice (Nowak 2004). For this reason, the mainstem Grande Ronde serves mostly as a migration reach for the focal species, and a large portion of its value lies in the continued connection to tributaries.

Finally, several of the limiting factors identified are mostly controlled by upstream influences and will be difficult if not impossible to counteract with restoration actions in the Lower Grande Ronde River. Specifically, these upstream controlled limiting factors include: sedimentation, flow modifications, and temperature. The following restoration actions were identified for the *Grande Ronde Subbasin Plan* and expanded upon in the SE WA Recovery Plan (SRSRB 2011):

- Protect existing habitat from future degradation
- Restore channel floodplain and riparian condition
- Restore/enhance passage and habitat connectivity
- Surface water conservation and/or acquisition
- Implement best management practices to reduce sediment origination and delivery

The approach of this assessment is to provide suggestions for restoration actions that address the limiting factors and impaired processes within the subbasin. Table 5-1 describes potential restoration strategies, how they address the underlying processes, and the limiting factors that are targeted for the mainstem Grande Ronde. The implementation of these restoration strategies and specific restoration actions are discussed in Section 6 and the project area maps are provided in Appendix F.

Table 5-1
Restoration Strategies to Address Impaired Processes and Limiting Factors of the Mainstem Grande Ronde

Potential Restoration Strategies	Processes Addressed	Limiting Factors Addressed or Mitigated
Promote fish access to tributary inlets	• Improves in-channel structure • Promotes watershed connectivity • Retains and sorts sediments	• Increases diversity and complexity of in-channel habitats (e.g., creates cold-water refuge pools) • Reduces temperatures at cool-water input of tributaries • Promotes connectivity with off-channel habitats • Promotes riparian function at tributary confluence
Establish native riparian plantings on islands and bars	• Reduces solar heating of river over long term • Improves food web cycling and function	• Promotes riparian function and ecosystem benefits • Reduces temperature
Protect side channels and islands that do exist	• Reduces solar heating of river over long term • Improves food web cycling and function	• Increases shading and reduces local air temperature • Increases diversity and complexity of off-channel habitats • Provides insects, detritus to food web • Provides nesting and foraging habitats for wildlife
Manage invasive species	• Improves riparian condition and functions • Reduces competition and predation	• Increases diversity and complexity of off-channel habitats • Improves nesting and foraging habitats for wildlife • Reduces competition and predation

5.2 Joseph Creek

Joseph Creek is the primary tributary to the Grande Ronde River within the assessment area and was assessed independently for limiting factors in the *Grande Ronde Subbasin Plan* (Nowak 2004) and reviewed and updated in the SE WA Recovery Plan (SRSRB 2011). Joseph Creek supports a wild population of steelhead, and the mainstem of Joseph Creek and all of its tributaries were identified as a major spawning area by the Snake River Regional Technical Team (SRSRB 2011) Limiting factors in Joseph Creek were identified for steelhead only because Joseph Creek is not considered a Chinook salmon population unit. The limiting factors include the following:

- Habitat diversity
- Pathogens
- Predation
- Sediment load
- Temperature
- Key habitat quantity

Of these limiting factors, sediment load, temperature, and key habitat quantity due to reduced wetted widths are identified as having the largest impact to steelhead in the subbasin. Joseph Creek is identified as a protection area for wild steelhead population and is noted to have significantly higher stream flows than other tributaries, less irrigation withdrawal impacts, and more heavily forested floodplains than other tributaries in the Lower Grande Ronde basin (SRSRB 2011). Despite this, large portions of the upper parts of Joseph Creek in Oregon have been harvested for timber and are engaged in cattle grazing land use. The combination of these upstream land uses has likely been the major contributor to the limiting factors of temperature, pathogens, and sediment load. While this assessment focuses on the lower reaches of Joseph Creek (Figure 3-1), some of the effects from these upstream land uses can be addressed and mitigated in the Washington portion of the Joseph Creek subbasin. The SE WA Recovery Plan lists the following restoration actions for use in Joseph Creek within Washington:

- Protect existing habitat from future degradation
- Restore channel floodplain and riparian condition
- Restore/enhance passage and habitat connectivity
- Surface water conservation and/or acquisition
- Implement best management practices to reduce sediment origination and delivery

The approach of this assessment is to provide suggestions for restoration actions that address the limiting factors and impaired processes within the subbasin. Table 5-2 describes potential restoration strategies, how they address the underlying processes, and the limiting factors that are targeted for Joseph Creek (within Washington). How these restoration strategies can be implemented are discussed in more detail in Section 6.

It should be noted that Joseph Creek presents high potential for supporting fish from all the focal species. While this assessment presents a restoration prioritization and plan for the lower basin, many impaired processes originate upstream. A restoration prioritization and conceptual restoration plan that encompasses the entire basin would be an important next step in restoring impaired processes and limiting factors of the whole basin.

Table 5-2
Restoration Strategies to Address Impaired Processes and Limiting Factors of Joseph Creek

Potential Restoration Strategies	Processes Addressed	Limiting Factors Addressed or Mitigated
Reconnect side channels and disconnected habitats	• Improves in-channel structure • Promotes watershed connectivity • Retains and sorts sediments	• Increases diversity and complexity of in-channel habitats (e.g., creates cold-water refuge pools) • Reduces temperatures at cool-water input of tributaries • Promotes connectivity with off-channel habitats • Promotes riparian function at tributary confluence
Address encroaching features	• Reduces solar heating of river over long term • Improves food web cycling and function	• Promotes riparian function and ecosystem benefits • Reduces temperature
Develop instream structure	• Reduces solar heating of river over long term • Improves food web cycling and function	• Increases shading and reduces local air temperature • Increases diversity and complexity of off-channel habitats • Provides insects, detritus to food web • Provides nesting and foraging habitats for wildlife
Enhance riparian vegetation	• Improves riparian condition and functions • Reduces competition and predation	• Increases diversity and complexity of off-channel habitats • Improves nesting and foraging habitats for wildlife • Reduces competition and predation
Modify or remove obstructions	• Improves sediment transport and large woody material transport • Improves watershed hydraulic connection	• Sediment transport allows pools to form increasing diversity and quality of habitat • Transport of large woody material causes active channel migration and formation of diverse habitat conditions • Improved connection to the mainstem provides cold-water refugia for migration and survival in the Grande Ronde basin

5.3 Other Tributaries

Several other small tributaries to the Lower Grande Ronde basin are all listed as major spawning areas for steelhead in the SE WA Recovery Plan (SRSRB 2011). These tributaries include Cougar Creek, Menatchee Creek, Cottonwood Creek, Buford Creek, Deer Creek, Rattlesnake Creek, and Shumaker Creek, all of which are part of the study area of this assessment. Less is known about these smaller tributaries, but the SE WA Recovery Plan identifies the following limiting factors:

- Excess fine sediment
- Water quality (high temperatures)
- Degraded riparian conditions

- Limited habitat quality and diversity
- Fish passage
- Water quantity due to withdrawals

Because many of these limiting factors largely mimic those of Joseph Creek, the same restoration strategies and the ways in which they address limiting factors and impair processes in Table 5-2 are recommended for the other tributaries as well. However, because these tributaries are significantly smaller, the restoration strategies will often be scaled down from those recommended for Joseph Creek. These recommendations are discussed more in Section 7 of this report, as well as in the cut sheets (Appendices D and E), and the project area maps (Appendix F).

5.4 Upland Areas and Non-Fish-Bearing Tributaries

In addition to the main rivers and fish-bearing tributaries in the Lower Grande Ronde basin, there are many other small ephemeral or intermittent non-fish-bearing tributaries. Furthermore, much of the contributing area to the waterways of the Grande Ronde basin is outside of the fluvial corridor. These areas all impact the fluvial processes of the basin through hillslope erosion, groundwater storage, sediment supply, and large woody material supply. In addition, land use in these areas includes a wide range of anthropogenic activities such as agriculture, rangeland, and forestry management, which can affect the upland process. Table 5-3 lists common impacts of upland and tributary processes, how they affect the limiting factors described in Sections 5.1 to 5.3, and management or restoration strategies that can help mitigate the effects of these processes to the limiting factors of fish-bearing streams in the basin.

Table 5-3
Upland and Tributary Effects on Instream Limiting Factors and Management Strategies

Upland and Tributary Impacts	Instream Limiting Factors Affected	Management and Restoration Strategies for Upland or Tributary Areas
Fine sediment load	• Sedimentation	• Vegetation plantings and weed control • Improving tributary riparian areas • Slope stabilization • Forestry practices and stand management • Grazing and livestock management strategies • Improving stream crossings
Water quality	• Water quality • Pathogens • Temperature	• Grazing and livestock management strategies
LWM supply	• Key habitat quantity • Habitat diversity • Habitat quality	• Upland vegetation planting • Tributary riparian vegetation planting • Forestry practices and stand management

Upland and Tributary Impacts	Instream Limiting Factors Affected	Management and Restoration Strategies for Upland or Tributary Areas
Alluvium supply (gravel)	• Key habitat quantity • Habitat diversity • Habitat quality	• Forestry practices and stand management
Groundwater, peak flow timing	• Water quantity • Temperature	• Irrigation practice improvement • Water storage in tributaries • Change of point of diversion projects

6 Summary of Geomorphic Assessment

The intent of the geomorphic analysis is to document and assess the fluvial processes of the study area, where and why those processes are impaired and opportunities for restoration actions that address the impaired processes and limiting factors. Our assessment consisted of two components: desktop analysis and field assessments. The desktop analyses included floodplain inundation, relative elevation, and levee/encroachment digitization, and were largely based on LiDAR data flow in 2018 (QSI 2019), as well as a 1D HEC-RAS model developed for this assessment and described in greater detail in Appendix B. Both the field and desktop portions of the assessment focused on identifying geomorphic indicators that can be grouped into three metrics that form the basis of this assessment and prioritization:

- Floodplain connectivity and channel migration ability
- Planform and instream complexity
- Riparian vegetation

Each of these metrics play an important role in most fluvial processes and through assessment of these indicators we can determine what restoration actions will be most beneficial, as described in more detail below. Sediment transport also plays a large role in fluvial process, but was not directly evaluated in this assessment due to lack of data. However, the metrics described above all play an important role in sediment transport and will allow the system to adjust and adapt to changes in sediment delivery. Following are some of the indicators identified during field and desktop analyses, and which gage the functionality of river processes in a reach:

- Floodplain connectivity and channel migration ability
  - Floodplain encroachments (i.e., levees, roads, berms)
  - Channel incision and confinement
  - Floodplain inundation and 1-, 2-, and 5-year events
  - Disconnected low-lying floodplain areas
  - Longitudinal obstructions (i.e., bridges, culverts, and fords)
- Planform and instream complexity
  - Split flows and side channels (island count)
  - Pool quantity and quality
  - Variety of riffles, pools, and glides
  - Instream wood
- Riparian vegetation
  - Presence of mature native riparian vegetation
  - Presence of invasive species
  - Floodplain inundation at regular events

The mainstem Grande Ronde, Joseph Creek, and the other smaller tributaries of the Lower Grande Ronde basin all have their own set of limiting factors, impaired processes, and restoration objectives. Additionally, there are differing sets of data for the mainstem Grande Ronde, Joseph Creek, and the other tributaries. Therefore, different indicators from different data sources were used for each available data set.

6.1 Floodplain Connectivity

Floodplain connectivity is an important metric for gauging the state of a riparian area. In this analysis, floodplain connectivity refers to floodplains that are connected hydraulically to the river through periodic inundation at 1- to 5-year return intervals, hyporheic flows, and groundwater connectivity. In other words, this analysis looks only at the hydraulic connection of the floodplain to the river channel. However, hydraulic connections in the floodplain are the building blocks for riparian ecosystems processes that provide multiple habitat benefits. Connected floodplains provide benefit for nearly all riverine aquatic species in the form of hyporheic and riparian habitat, high-flow refugia, nutrient influx, and woody material supply. Additionally, connected floodplains and the resilient ecosystems they support provide the material for instream wood, which in turn are key pieces of geomorphic processes associated with the functioning and resilient river system. Connected areas of the floodplain are also typically areas where the channel is free to migrate to. Channel migration is an important process that supports complex channels, habitat diversity, and wood recruitment.

Confining features along the banks of the rivers in this assessment as well as on the floodplain have influenced hydraulic conditions during large floods, affecting local and reach-scale geomorphic processes such as sediment mobility and channel migration. Confining features may be both natural and influenced by anthropogenic activities. Inspections of aerial photography, LiDAR, and field reconnaissance were used to identify confining features within the study area. These features include bedrock along the valley wall, alluvial fan deposits, bank armoring (e.g., riprap), levees and pond berms, and road prisms. Additionally, the rivers of the Lower Grande Ronde basin can be disconnected from the floodplain through channel incision and downcutting. Channel incision is often associated with encroaching features such as levees or bedrock valley walls because straightened channels provide more stream power for sediment transport. Channel incision is often the beginning of a cycle of sediment starvation.

6.2 Complexity

Complexity has taken on many meanings in the realm of fluvial sciences in multiple contexts, including ecologically and geomorphically. For this assessment, complexity primarily refers to the geomorphic concept of spatial heterogeneity of planforms and channel types within the fluvial corridor. River reaches with multiple side channels, split flows, or high sinuosity are thought of here as complex.

Historically, the mainstem Grande Ronde was probably never significantly more complex than it is now, being naturally highly confined and locked into its current path. However, even today, islands and side channels exist on the mainstem and provide important habitat diversity in an area that is mostly a migration reach for focal species.

The tributaries to the Grand Ronde River with high slopes also likely had lower planform complexities, particularly tributaries such as Cougar Creek (avg. 11.14% slope), West Fork Rattlesnake Creek (8.47%), and to some degree Shumaker Creek (7.0%). These tributaries all have significant sections where habitat diversity is derived primarily from instream complexity including step-pool boulder sequences, and large wood in the channel, but little planform complexity such as split flows and side channels. There are, however, sections in some of these tributaries where channel migration area is available and the slope is low enough for planform complexity, or inundated complexes such as beaver dams could occur.

The remaining tributaries to the Grande Ronde River with lower slopes, however, historically likely had a high degree of habitat diversity derived from planform complexity. The tributaries of Joseph Creek, Menatchee Creek, and Cottonwood Creek (both the Grande Ronde tributary and the Joseph Creek tributary) all have the low slopes and available floodplain that make complex planforms of split flows, side channels, and wetland complexes possible. However, many of the reaches of these tributaries have single-thread channels due to artificial confinement through levees, gravel berms, or channel incision as well as a lack of instream wood to trigger geomorphic change and channel migration.

Complexity is an important factor for both the geomorphic and ecological processes in a river corridor and the benefits of complexity have been discussed thoroughly in the literature of fluvial sciences (Amoros 2001; Sheldon 2006; Jeffres 2008; Harrison 2011; Wohl 2016). However, the geomorphic significance of complexity to river corridors has been well summarized into key points in Wohl 2016, of which four are directly relevant here:

1. Provides habitat and biodiversity to the river system
2. Attenuates downstream fluxes of water (floods), sediment, and instream wood
3. Provides resistance and resilience to catastrophic change
4. Influences river processes: sediment and wood transport, groundwater recharge, floodplain connectivity

Note: Adapted from Wohl 2016, Part II

Channel and floodplain complexity have been identified as primary objectives because complexity has increasingly been associated with juvenile salmonid rearing and overwintering, as well as benefits for many other aquatic species of relevance. Because of this multi-species and multi-lifestage benefit, it is important to examine a reach's complexity at several different flow levels—typically at lower, sustained flows. When complexity is maintained during summer low flows and winter flows, it indicates that side channels, backwaters, and other off-channel areas that are important for a variety of ecological process are sustained for longer periods of time and will, therefore, provide these ecological benefits including juvenile salmonid rearing for a large portion of the hydrograph.

7 Restoration Strategies

This section describes and provides implementation methods for restoration strategies recommended to address the limiting factors and impaired process of the rivers of the Lower Grande Ronde basin. Section 5 discusses how these restoration actions are related to the impaired processes and limiting factors.

As discussed in Section 5, the tributaries to the Grande Ronde and the mainstem Grande Ronde present very different process impairments and limiting factors to the focal species. The restoration actions in the mainstem, discussed in Section 7.1, will provide some benefit and uplift to focal species in multiple life history stages. However, while the mainstem Grande Ronde does support multiple life history stages for focal species in some sections, it is recognized that the mainstem is primarily a migration corridor for access to the tributaries and reaches further upstream in the watershed. Because many of the limiting factors for the mainstem are primarily effects from upstream impairments (temperature, sedimentation), and the steep meandering canyon valley shape of the mainstem limits floodplain availability, restoration actions in the mainstem Grande Ronde are likely to be longer term actions such as management and planning that focus primarily on restoring riparian vegetation and managing temperature rather than restoring instream habitat.

Much of the time that a salmon or steelhead spends in the rivers or tributaries is for rearing as a juvenile. In the Grande Ronde basin, juvenile rearing primarily takes place in the tributaries, not the mainstem, and for this reason the primary focus for habitat restoration that promotes juvenile rearing should occur in the tributaries. The restoration actions for Joseph Creek and the other tributaries, discussed in Section 7.2, are the most likely to provide uplift and benefit to multiple life history stages of the focal species.

7.1 Mainstem Grande Ronde Restoration Actions

The mainstem Grande Ronde presents a different set of limiting factors, impaired processes, and fluvial conditions that make restoration strategies different than those that would be used in the tributaries. These strategies are intended to use the natural processes to address the limiting factors that are specific to the mainstem Grande Ronde.

7.1.1 Promote Fish Access to Tributary Inlets

The mainstem Grande Ronde serves in part as a migration corridor for the focal species of this assessment and provides access to the habitat conditions that many of its tributaries provide. As such, maintaining hydraulic flow conditions necessary for the focal species is a key part of providing the habitat diversity options in the mainstem. These tributaries are a source of gravel and cobble as well as fine sediment to the mainstem that form alluvial fans into the mainstem as the material deposits at the confluence. During high-flow events in the mainstem, these deposits can be transported downstream, often leaving steep banks at the tributary confluence that may serve as impediments to fish passage at low flows. Tributaries where riparian vegetation is established on these fans, such as was observed on Shumaker Creek, seem to maintain these alluvial fans better than those such as Deer Creek with very little vegetation at the confluence. Establishing vegetation at the confluences of the tributaries will help maintain the lower slopes needed for connection to these tributaries. Furthermore, the tributaries provide a source of cooler water to the mainstem creating cold-water refuges for fish migrating to tributaries further up the basin. Adding vegetation will help promote habitat diversity in the form of complexity and pools downstream of these areas.

7.1.2 Protect Established Islands and Side Channels

The objective of this restoration action is to increase planform complexity through stabilizing gravel bars and islands. Several low-lying islands and gravel bars or “beaches” are scattered throughout the mainstem Grande Ronde, which tends to follow a pattern of alternating riffles and deep runs or pools, often spaced at half-mile or greater intervals due to the large meander length of the river. Where gravel bars and islands are present in the riffles, split flows and riparian vegetation provide diversity of habitat in the mainstem that is difficult or impossible to achieve elsewhere on the mainstem. Stable islands like these are critical to salmonid habitat because trees within the channel can help provide some shade and cover. Stable islands also provide hydraulic refuge and ideal feeding locations for salmonids and increase the percent of shallow edge habitat per river mile, benefiting juveniles. Additionally, few of these islands are occupied by mature trees due to their frequent inundation during floods, and by the destructive forces of winter ice flows.

For restoration of tributaries, islands can be stabilized through placement of apex engineered log jams. However, on the mainstem Grande Ronde, log jams such as these are unlikely to survive large flow events or destructive winter ice flows. Therefore, more creative and resilient approaches will be necessary to stabilize these bars and will likely vary with each implementation. Placing log piles with unsecured large wood at the head of these islands is a possible solution. These pile fields will provide some protection to the bar and riparian vegetation during high-flow events. Some wood placed or collected on these piles will be lost with large flow events but should be replenished from upstream woody debris as flood flows recede, creating a more resilient structure. This restoration action will go hand in hand with “encouraging riparian growth on bars and islands” as described below, and both will be necessary for the long-term stabilization and habitat benefit targeted with these actions.

7.1.3 Encourage Riparian Growth on Bars and Islands

Similar to riparian enhancement in the tributaries, riparian growth on islands and bars in the mainstem will involve protection of healthy riparian areas, removal of undesirable vegetation, and planting of native riparian communities on the gravel bars and islands that already exist. Because of the confined nature of the Grande Ronde valley, few other opportunities exist to establish vegetation, and vegetation on these islands and bars will provide the most benefit. In the mainstem Grande Ronde, riparian vegetation will provide stabilization for gravel bars and islands, allowing them to be more resilient during high-flow events. These islands and gravel bars provide essential planform complexity that can act as refugia for salmonids in migration. Additionally, fully developed mature riparian growth can shade and reduce ambient air temperatures, which can reduce local stream temperatures especially in the presence of deep pools. Riparian restoration on the mainstem will likely require some protection from high flows to initially become established. While a permanent log jam is unlikely to be able to withstand continuous high flows or ice flows, adding piles that can collect and shed wood during high-flow events could help protect these areas while large vegetation becomes established. This restoration strategy is identified in locations on the mainstem that are inundated between the 2-year and 5-year event, which should provide some time to establish vegetation. Removing invasive plants and vegetation and replacing with native species in appropriate environments should be performed. For example, cottonwoods or willows may be planted in wetter areas such as along the 1-year flow bank line, as opposed to drier floodplain terraces where more upland species may be appropriate.

7.2 Joseph Creek and Tributary Restoration Actions

The restoration strategies for Joseph Creek and the other tributaries in the assessment are largely similar to each other and are summarized together in this section. However, some of the tributaries such as Cougar Creek and Deer Creek are much smaller in scale than Joseph Creek or Menatchee Creek and may require a different scale to these approaches, as discussed below. In general, the restoration strategies for the tributaries focus on restoring geomorphic processes by widening the available floodplain area, increasing planform complexity, and restoring riparian vegetation.

7.2.1 Reconnect Side Channels and Disconnected Habitat

Off-channel habitat provides critical holding and rearing habitat for juvenile salmonids during moderate to high flows and often provides preferred habitat conditions to main channel habitat at lower flows. Several disconnected features are present in the floodplains of the Lower Grande Ronde basin, including off-channel wetlands that are wetted during part of the year and become disconnected at lower flow periods.

Encouraging reconnection of these features will increase habitat complexity by providing off-channel habitat and increased connectivity with the channel where disconnected features become cut off or create stagnant conditions during the dry season. Reconnecting these areas will allow fish to move in and out of these features for longer periods of time and enhance water quality conditions, particularly during low winter flows. This will also help lessen the possibility of entrapment of fish associated with the long periods of disconnection from the main channel.

Actions for reactivating disconnected habitat may include earthwork to establish hydraulic connections with the main channel and installation of LWM to provide cover or assist in keeping pathways to the main channel accessible.

Side channels often provide preferred rearing habitat during low flows and provide hydraulic refuge and cover during high flows. Encouraging multiple flow paths will increase habitat complexity by diversifying the planform, dissipating stream energy, distributing sediment load, and providing hydraulic complexity. Diverse floodplain and side channel networks often have multiple flow paths at various elevations across the valley bottom. Therefore, different channels are accessed at different water surface elevations. In this manner, off-channel habitat is accessed in different areas of the channel network under changing flow regimes providing a multitude of habitat during a large range of flow conditions.

7.2.2 Address Encroaching Features

Many of the tributaries in the Lower Grande Ronde assessment area have significant levees or other encroaching features. Additionally, for many of the tributaries such as Buford, Cougar, and West Fork Rattlesnake creeks, the nearby road occupies a significant portion of the floodplain and limits channel migration. In areas where levees exist, levee removal and/or setback may be used to increase the active floodplain area, thereby promoting floodplain and side channel connectivity and more natural channel migration processes. Roads in the floodplain pose a larger challenge because the only solution is to relocate the road onto the valley wall and out of the floodplain. This action can present an enormous cost and is unlikely to occur during normal circumstances. However, if the road ever needs to be replaced due to flood damage or other reasons, the option of setting roads back out of the floodplain should be advocated for over simply rebuilding in the same location.

Removing levees, setting back roads, and promoting floodplain connectivity encourages geomorphic processes while dissipating velocities during high flows as floodwaters are distributed onto the floodplain. This also allows fine sediment to deposit on the floodplain, promoting ecological processes. Decreased channel velocities may also lessen erosive energy along the banks in areas of concern for landowners. Allowing the channel to migrate throughout a wider corridor will encourage development of complex channel and planform geometry, distributing energy and sediment load. It will be important to consider the reach-scale effects of widening the floodplain, particularly at the downstream end of confined reaches. For example, creating an unconfined floodplain below a tightly confined section will likely result in a large amount of sediment deposition and channel migration.

7.2.3 Develop Instream Structure

Instream habitat complexity is correlated to hydraulic complexity created by the channel geometry, bedforms such as gravel bars and pools, hardpoints such as bedrock, and perhaps most importantly to the presence of LWM. The primary biological function of LWM in rivers and streams is to provide complexity that creates hydraulic refuge and cover for adult and juvenile salmonids. Geomorphically, LWM also plays a major role in influencing the channel form.

In natural systems, riparian trees often enter a watercourse as the result of erosion, windfall, disease, beaver activity, or natural mortality. However, in most Pacific Northwest river systems, including the tributaries to the Grande Ronde River, LWM has been removed from the river channels and cleared from riparian areas. In addition, a significant quantity of natural LWM that would otherwise be recruited from riparian areas has been removed by logging and agricultural practices. Anthropogenic activities in the basin have been detrimental to the system, leading to a decrease in the number, size, and volume of LWM being introduced to the river through natural processes. Therefore, installing LWM is necessary to supplement existing conditions, recognizing that it will take decades of riparian planting and development to begin to provide natural replenishment rates. In the long term, the added channel and bank roughness created by wood structures will help retain additional mobile wood and sediment, diversifying hydraulic and bedform complexity and contributing to increased floodplain connectivity and functionality of floodplain processes over time. The types of large wood placements necessary and suitable will vary between individual project areas and span a range of options from small-scale beaver dam analogs and post-assisted log structures, to placement of unsecured LWM, to stable engineered log jams. The following descriptions outline in more detail what these options might entail.

7.2.3.1 Small Wood Placement or BDAs

Wood structures such as beaver dam analogs (BDAs) and post-assisted log structures (PALS) are potential low-cost structures that can provide numerous benefits in most of the small tributaries. These small structures are designed to create backwater and inundated floodplain areas, effectively mimicking a beaver pond or inundated floodplain area. BDAs and PALS promote conditions that help store sediment and promote aggradation, which raises the water table, supporting nutrient exchange and aquifer recharge. Even during low-flow conditions, these processes help increase water storage in the floodplain, which can augment summer baseflow. These structures also effectively promote geomorphic change and habitat diversity in smaller systems.

The benefit of using PALs or BDAs is that they are low cost and easy to implement, without requiring the use of construction equipment of stabilized access routes. However, these structures are only applicable for the smaller tributaries, or side channels of the larger tributaries where they will not be washed out by the first flood flows. Additionally, where significant geomorphic change is desired, these structures may not be large enough to produce the desired effect.

7.2.3.2 LWM Placements

LWM placements that are suitable for placement in the tributaries of the Grande Ronde River include single-log placements or multiple-log assemblies with rootwad that are installed in the channel bed or bank to create beneficial fish habitat and desired geomorphic effects. Single log placements are primarily used to promote localized habitat diversity and in-channel complexity. These features emulate natural tree fall of mature riparian trees and provide a base for mobile wood to accumulate. When unsecured LWM is placed in large numbers, natural log jams will form and promote natural processes of sediment deposition, split flows and channel morphology, and floodplain inundation. This can be an effective method of creating log jams as they would form naturally. However, without restoring wood supply impairments upstream, these unsecured log jams could eventually disperse or become ineffective without additional natural or placed wood supply. The different types of LWM placements such as single buried logs or multiple log assemblies have varying levels of engineering and construction effort and range in magnitude of physical and biological benefit.

7.2.3.3 Engineered Log Jams

Engineered log jams (ELJs) are large wood structures that can be placed in the main channel that emulate naturally occurring, stable log jams. Historically, several log jams per mile were likely present in the main channel, but they have either been cleared or are no longer able to become established due to a lack of mature riparian trees being recruited to the system, particularly in reaches where the local riparian conditions are poor. ELJs are typically placed along the bank or mid-channel with the bottom of the structure at the anticipated scour depth and the top built to the approximate height of the design storm event The structure can be backfilled with streambed materials for stability, and a gravel bar deposit may be placed in the lee of the structure that emulates the natural sediment deposit that would occur in the lee of this type of structure.

ELJs can create large flow stagnation areas upstream and downstream of the structure and contain a substantial amount of void space within the logs and root masses, providing considerable area for fish refuge. During high flows, the rootwads interact with hydraulic forces from the river and scour large, deep pools that provide holding areas for adults, while the void space within the face of the structure is used by juveniles. In addition, these structures are able to retain mobile wood debris. Because of the hydraulic conditions and hard points created by ELJs, they may also be used as "deflectors" to influence flow direction to promote channel expansion or activation of side channels.

On a reach scale, installation of multiple ELJs can influence gravel movement and deposition to create localized pool-riffle sequences, increased hydraulic complexity, and a more stable channel profile. Sediment storage and deposition adjacent to the ELJs can create large gravel bars in the active channel allowing for colonization of riparian vegetation and eventually the development of forested islands. The overall roughening of the active channel and aggrading of the riverbed promotes rehabilitation of natural processes by increasing floodplain connectivity and promoting channel migration.

Unlike mass unsecured LWM placements, which can form natural log jams, ELJs do not rely solely on an upstream supply of wood to remain effective, although a continuous supply of wood will add to ELJs over time. Instead, these structures are typically designed to stay in one place and not break apart, providing a hard point where placed. While these structures may require less maintenance and adaptive management, the downside is they are engineered structures in the floodplain and will not change or adapt to differing flow conditions. When large channel avulsions occur, these structures can occasionally be left "in the dry" and no longer provide any benefit to the system.

7.2.4 Riparian Zone Enhancement

Riparian habitat enhancement will involve protection of healthy riparian areas, removal of undesirable vegetation, and planting of native riparian communities on the channel banks, on higher elevation gravel bars, and in the floodplain. However, establishment of the ideal riparian buffer width may be limited by the location of agricultural fields, infrastructure, and the feasibility of irrigating and maintaining plantings. Riparian planting may also be conducted in conjunction with LWM structure placement, including ELJs.

The riparian zone provides several habitat and physical process benefits including increased bank and floodplain roughness, cover, and nutrients for instream species and wildlife. Increased roughness encourages sediment deposition and decreased channel and overbank velocities during floods. Additionally, fully developed mature riparian areas are a source of LWM to the river over time. Riparian restoration should begin with protection of existing healthy riparian areas through programs such as the Conservation Reserve Enhancement Program. Where riparian habitat has been degraded, removing invasive plants and vegetation and replacing with native species in appropriate environments should be performed. For example, cottonwoods or willows may be planted in wetter areas such as along the banks, as opposed to drier floodplain terraces. Monitoring and maintenance of plantings for at least the first few years after planting, which will greatly contribute to the success of the restoration effort, may be required for permitting approval. Eradication of invasive species such as reed canarygrass will likely require a longer and more involved maintenance and monitoring effort.

7.2.5 Modify or Remove Obstructions

The primary obstructions that exist on the tributaries to the Lower Grande Ronde River exist as road crossings, which include bridges, culverts, and fords. Notably many of the tributaries require some sort of crossing due to the Grande Ronde Road, which occupies the left bank of the mainstem for the upper portion of the study area. Most of these crossings do not present a fish barrier or hindrance, although they may present limitations to juveniles making use of all available habitat (SRSRB 2011). In addition, the hydraulic conditions created by flow obstructions can adversely affect habitat quality. Extensive sections of upstream backwater often lead to deposition of sands and gravels on the upstream side, potentially starving the channel downstream of easily transportable material and

LWM. The low-flow velocities in backwater areas prolong water residence time and allow for increased heating from solar radiation and atmospheric exchange. Removal of obstructions would allow for more natural sediment and woody debris transport and better allow natural evolution of the channel grade and planform. Hence, a consequence of obstruction removal would likely be some adjusting of the channel bed elevation; removal must consider the future evolution associated with this action. For crossings at the confluence of the tributary with the mainstem, the transport of this gravel material is particularly important because it allows alluvial fans into the mainstem to form, allowing easier access for fish from the mainstem.

It should be noted that, at the time of this report, two culvert replacements at the confluences of tributaries have been planned by ACCD on Cougar Creek and Cottonwood Creek. Converting these pipe culverts to wider crossings that allow the natural transport of sediment and wood material will both help improve fish passage capabilities at the crossing and also form better connections with the mainstem Grande Ronde.

7.3 Upland Areas and Non-Fish-Bearing Tributaries

The restoration actions described in Sections 7.1 and 7.2 are focused on instream and floodplain habitat restoration in the Grande Ronde basin. However, many fluvial and geomorphic processes can be highly influenced by processes and impacts occurring in the uplands. In addition, the Grande Ronde basin, and the Snake River basin in the vicinity of the Grande Ronde River confluence, have many smaller ephemeral and intermittent streams that may not provide habitat for focal fish species but can have major effects on the instream process of the streams and rivers to which they contribute. Section 5.4 discusses how these upland processes can contribute to the limiting factors of fish-bearing streams in this assessment. These upland impacts to instream limiting factors can be mitigated through a variety of restoration and management techniques, and these should be considered as part of a watershed-scale restoration of processes throughout the Lower Grande Ronde basin. Examples of restoration and management techniques for upland and tributary areas include the following:

- Vegetation plantings and weed control
- Improving native vegetation in tributary riparian areas
- Slope stabilization
- Forestry practices and stand management
- Grazing and livestock management strategies
- Irrigation practice improvement in agriculture areas
- Water storage strategies in tributaries (i.e., BDAs, and PALs where appropriate)

7.4 Restoration Actions for Climate Change Resiliency

Climate change is one of the major anthropogenic influences on fluvial processes and instream habitat for the Grande Ronde basin and should be a primary consideration in any restoration project in the basin. While climate change will likely have complex and far-reaching effects on fluvial processes, many experts (CIG 2009; Mantua 2010; Beechie 2013) agree that for southeast Washington major changes for salmon can be summarized as follows:

- Increased variability in timing and magnitude of flows
  - Higher high flows and at different times of the water year
  - Lower low flows and at different times of the water year
- Increased stream temperatures

Fluvial restoration projects focused on recovery of the focal species should, therefore, look to counter the effects of the above. Increased variability and unpredictability should be met with targeting resiliency and diversity of habitat and ecosystems and should be taken whenever possible to reduce peak stream temperatures.

7.4.1 Target Resiliency and Diversity

Many habitat restoration projects today are focused on restoring the physical and ecological processes that promote diverse habitat conditions for focal species. With increased variability and unpredictability, it is important that river systems maintain resiliency through diverse habitat conditions. The restoration actions listed above are focused on actions that will allow natural processes to occur, such as sediment and large wood transport, floodplain connection and channel migration, and riparian growth. These processes all help maintain a dynamic equilibrium that promotes more habitat conditions at all levels of flow, allowing flow timings and magnitudes to change but habitat conditions to remain.

7.4.2 Reduce Peak Stream Temperatures

Peak stream temperatures are already a problem for salmonids in many parts of the Lower Grande Ronde basin. In general, the restoration actions recommended above can have far-reaching effects on ameliorating peak stream temperatures. Reconnecting side channels allows for more residence time, often in areas that are more shaded and more connected to groundwater. Removing encroaching features allows more lateral connection to the floodplain for many of the same benefits. Finally, enhancing and promoting riparian vegetation increases shaded areas and provides wood recruitment, which can provide overhanging cover.

8 Project Area Prioritization

Prioritization of project areas was based on the results of the assessment of geomorphic characteristics and impaired processes. Due to differing data sets and general fluvial characteristics of the reaches in the Lower Grande Ronde basin, three slightly different prioritization methods were used for the mainstem Grande Ronde, Joseph Creek, and all other tributaries. All of the methods are based on the concept of identifying what reaches have the most potential to provide benefit to focal species through the restoration of impaired processes. This was accomplished through identification of processes and conceptualization of potential restoration strategies for each reach as well as a basic assessment of the feasibility of doing restoration work.

For each of the prioritization methods, the project areas are grouped into three tiers for restoration priority. While the scores for each project area (shown in the following tables) could be combined to find an exact score and rank, it is more useful to consider project areas in terms of these tiers:

- **Tier 1 Project Areas:** These project areas show the most potential for restoration actions to provide uplift to the focal species and restore geomorphic processes that create resilient and diverse habitat conditions.
- **Tier 2 Project Areas:** These project areas show some potential for restoring geomorphic processes, but they will likely be more difficult to achieve and require a larger effort for possibly less benefit than the Tier 1 projects. However, restoration work in these reaches will likely improve the impaired process and limiting factors.
- **Tier 3 Project Area:** These project areas will be the most difficult to implement in terms of restoration work that restores impaired processes and alleviates limiting factors. These project areas are likely to have valley shapes or land ownerships that limit the amount of restoration work possible.

8.1 Prioritization of Mainstem Project Areas

Prioritization methods for the mainstem project areas are based on criteria that are unique to the mainstem Grande Ronde in Washington. A unique framework was developed for the mainstem to account for the different scale relative to the tributaries and different restoration opportunities present in the mainstem. Project areas on the mainstem were delineated only at locations where restoration actions would be most effective, unlike the tributaries where a project area was assigned to every reach and restoration actions were identified within those project areas. The assessed section of the mainstem is divided into four large reaches (Mainstem 1, 2, 3, and 4), each containing a handful of restoration sites. Project areas in the mainstem were chosen from islands, floodplain "beaches," and tributary mouths and selected to target goals for establishing riparian vegetation, improving complexity and connectivity, and improving tributary fish passage connections. Due to the geology of the mainstem, areas of low-lying floodplain and channel migration are minimal, and islands and gravel bars represent the primary available areas within the floodplain to promote riparian vegetation, complexity, and connectivity. The historical removal of riparian trees combined with the thermal threat observed for much of the mainstem make establishing riparian trees and shade a principal concern.

The mainstem prioritization framework reflects challenges specific to the mainstem including destructive ice flows, extreme hydraulic forces during floods, and limited site accessibility. The prioritization framework is based on five categories: 1) potential for riparian vegetation improvement; 2) potential benefit to complexity and connectivity; 3) summer water temperatures; 4) potential benefit to multiple life history stages and species of salmonids; and 5) ease of access and surrounding land ownership. The first two categories assess the potential for restoration from a geomorphic process-based standpoint while the last three categories assess the benefit to fish and feasibility of projects. The last three categories were specifically included in the mainstem framework after discussions with the client because presumed fish use, temperature suitability, and ease of access varies significantly across the four mainstem reaches.

The mainstem categories for restoration prioritization are based on the following indicators:

- Potential to establish riparian vegetation
  - Field observations of island and bar conditions
  - 1-year to 25-year floodplain extents to show wetted floodplain
- Potential to promote planform complexity and floodplain connectivity
  - Islands at 1-, 2-, and 5-year inundation extents
  - Relative elevation model used to determine high-flow channels
  - Available area of low-lying floodplain determined from relative elevation model
- Summer water temperatures ideal for salmonid use
  - Temperature observed during field visits
  - Background information from prior studies and stakeholder discussions
- Potential for uplift to multiple life history stages
  - Fisheries assessment data on population life history and distribution
  - Observations of fish use and available habitat during site visits
  - Observations of invasive fish and predatory species during site visits
- Ease of access to site
  - Field visits and aerial imagery for road and access locations

These indicators were used to score each project area for the mainstem restoration prioritization categories, as shown in Table 8-1.

Table 8-1
Mainstem Prioritization Framework

Prioritization Category	Restoration Action Potential Rating		
	1 (Poor Potential)	3 (Moderate Potential)	5 (High Potential)
Establish riparian vegetation on islands and bars	Intensive restoration would be required to establish vegetation, and any installed large wood would likely not withstand floods.	Existing vegetation is dense, or restoration would help establish vegetation and wood, but vulnerable to ice flows and washout.	Existing vegetation is minimal, but restoration would help stabilize islands or reconnect riparian vegetation.
Promote complexity and connectivity	Minimal floodplain is available to reconnect.	Some floodplain is available to reconnect, some opportunity for split flow.	Ability to promote split flow and abundant floodplain. Ability to expand floodplain.
Summer water temperatures ideal for salmonid use	Water temperature is above threshold for salmonids in summer.	Peak temperatures are above salmonid threshold.	Water is cold enough for salmonids all summer.
Uplift and benefit to multiple life history stages and species	Reach is used for only a single life history stage (migration).	Reach supports multiple salmonid life history stages (i.e., rearing, spawning, migration) of a single species.	Reach supports multiple species at multiple life history stages.
Ease of access	Site is inaccessible except by primitive road or river. Too close to homes or non-cooperative landowner.	Site is accessible by gravel road only or is remote.	Site is accessible by paved or gravel road and is close to highway, land ownership is conducive to restoration.

As shown in Table 8-2, each mainstem restoration site was given a score from 1 to 5 (with 5 having the highest restoration potential) for the five restoration prioritization categories. Appendix D provides more details on the reasoning behind these scores.

Table 8-2
Mainstem Restoration Site Scoring for Restoration Potential

Mainstem Reach	Restoration Site	Prioritization Category				
		Establish Riparian Vegetation	Increase Complexity, Connectivity	Summer Water Temperature	Fish Life History Stage Benefit	Ease of Access
Mainstem 1	Island Complex RM 3.6-3.9	4	5	1	2	4
	Island Complex RM 3.2-3.3	4	3	1	2	4
	Wild Steelhead Coalition Property	3	2	1	2	5
	Island RM 1.6-1.7	3	2	1	2	4
	Island RM 0.9-1.0	3	2	1	2	3
	Joseph Creek Beach	1	2	1	2	4

Mainstem Reach	Restoration Site	Prioritization Category				
		Establish Riparian Vegetation	Increase Complexity, Connectivity	Summer Water Temperature	Fish Life History Stage Benefit	Ease of Access
Mainstem 2	Island RM 6.6-6.9	4	4	1	2	1
	Island RM 8.2-8.4	4	3	1	2	1
	Myers Creek Site	3	3	2	2	3
	Beach RM 11.9-12.1	2	2	1	2	1
Mainstem 3	Buford Creek Mouth and Island	4	4	3	3	4
	Island Complex RM 24.5-24.6	4	4	3	3	3
	Island Complex RM 25.1-25.4	3	4	3	3	4
	Island RM 17.0-17.2	2	2	2	2	3
	Shumaker Take Out Gravel Bar	2	2	2	2	3
	Deer Creek Mouth and Bar	3	3	2	2	1
	Shumaker Creek Mouth	2	1	2	2	3
	Gravel Bar RM 23.9-24.1	2	1	3	3	1
Mainstem 4	Gravel Bar RM 36.7-36.9	3	4	4	5	4
	4-0 Land and Livestock Ranch and Island	3	4	4	5	3
	Cottonwood Creek Mouth	3	3	4	4	4
	Island RM 29.9-30.1	2	3	4	4	4
	Beach RM 27.0-27.3	2	2	3	4	3
	McNeill Island RM 33.5-33.6	2	2	4	4	4
	Cougar Creek Mouth	2	1	4	4	4
	Beach RM 31.9-32.1	2	2	4	4	4
	Menatchee Creek Mouth	2	1	4	4	4

RM: river mile

Table 8-3 shows the mainstem restoration sites grouped into three tiers for restoration priority. As noted previously, Tier 1 project areas have the most potential for restoration, Tier 2 project areas have some potential for restoration, and Tier 3 project areas have the least potential for restoration or may be the most difficult to implement.

Table 8-3
Mainstem Restoration Site Tiers

Mainstem Reach	Restoration Site Tier		
	Tier 1	**Tier 2**	**Tier 3**
Mainstem 1	• Island Complex RM 3.6-3.9	• Island Complex RM 3.2-3.3 • Wild Steelhead Coalition Property • Island RM 1.6-1.7	• Island RM 0.9-1.0 • Joseph Creek Beach
Mainstem 2		• Island RM 6.6-6.9 • Myers Creek Site	• Island RM 8.2-8.4 • Beach RM 11.9-12.1
Mainstem 3	• Buford Creek Mouth and Island • Island Complex RM 24.5-24.6 • Island Complex RM 25.1-25.4		• Island RM 17.0-17.2 • Shumaker Take Out Gravel Bar • Deer Creek Mouth and Bar • Shumaker Creek Mouth • Gravel Bar RM 23.9-24.1
Mainstem 4	• Gravel Bar RM 36.7-36.9 • 4-0 Land and Livestock Ranch and Island • Cottonwood Creek Mouth • Island RM 29.9-30.1 • McNeill Island RM 33.5-33.6 • Beach RM 31.9-32.1	• Beach RM 27.0-27.3 • Cougar Creek Mouth • Menatchee Creek Mouth	

8.2 Prioritization of Joseph Creek Project Areas

The eight project areas of Joseph Creek use their own prioritization methods due to fish, geomorphic, and data availability considerations. Joseph Creek has its own designated wild steelhead population that is considered separately from the mainstem or other tributary populations. Joseph Creek is by far the largest tributary, both by flow amount and drainage area. Especially upstream of the Washington/Oregon border, multiple tributaries support fish populations, some of which have relatively pristine riparian and fluvial conditions. Geomorphically, portions of Joseph Creek within the study area are similar to the mainstem Grande Ronde in Washington with steep narrow canyons and little available floodplain. However, downstream of the confluence with Cottonwood Creek, Joseph Creek enters a wider valley with historically more room for complexity of planforms. Finally, the data set available for Joseph Creek included blue green LiDAR/bathymetry and a 1D hydraulic model, which is different than the other tributaries.

The Joseph Creek prioritization framework is based on providing the most restoration uplift through three categories of restoration that encompass the fluvial processes: 1) floodplain connectivity; 2) instream and planform complexity; and 3) riparian vegetation. The prioritization is based on both desktop and field analysis results described in Section 5. The field observations are grouped into three categories of fluvial processes and restoration actions. Detailed results and descriptions for each of the project areas are provided in Appendix E. Where numerical data are available, those are provided in the Appendix C.

The Joseph Creek categories for restoration prioritization are based on the following indicators:

- Potential to increase connected floodplain
  - Inundation at 2-year and 5-year events compared to 1-year event
  - Levees or other encroachments disconnecting floodplain
  - Low-lying floodplain in relative elevation map
- Potential to add instream or planform complexity
  - Disconnected side channel opportunities
  - Existing side channels and split flows
  - Existing instream wood
  - Substrate sizes during field observations
  - Channel slope, valley slope and sinuosity
- Potential to improve riparian vegetation
  - Existing native vegetation in the riparian area
  - Floodplain inundation at the 1- to 2-year event
  - Presence of invasive species

These indicators were used to score each project area for the Joseph Creek restoration prioritization categories, as shown in Table 8-4.

Table 8-4
Joseph Creek Prioritization Framework

Prioritization Category	Restoration Action Potential Rating		
	1 (Poor Potential)	3 (Moderate Potential)	5 (High Potential)
Increase connected floodplain	Little or no floodplain is disconnected by encroachments. Channel aggradation has little opportunity to reverse incision.	A floodplain encroachment impacts the connected floodplain. Removing it would allow for more floodplain connection. Additional floodplain is available at the 2- and 5-year events.	Multiple levees or encroachments disconnect large areas of low-lying floodplain. Channel aggregation could connect floodplain at the 2- and 5-year events.
Add instream or planform complexity	Few side channel opportunities exist. Large wood addition is unlikely to promote geomorphic change.	One or two side channel reconnection opportunities exist. Adding large wood to the channel is likely to cause some localized complexity.	Opportunity to connect multiple side channels. Adding large wood has the potential to promote split flows and complex planforms.
Establish riparian vegetation	Riparian vegetation is already well established. Or floodplain is rarely inundated and would require large effort to establish native species.	Some floodplain inundation occurs allowing vegetation to establish with some effort. Invasive species may be present and required to be removed.	Multiple areas receive inundation and have potential to establish riparian vegetation.

As shown in Table 8-5, each project area in Joseph Creek was assigned a score from 1 to 5 (with 5 having the highest restoration potential) for the three restoration prioritization categories. Appendix E provides more details on the reasoning behind these scores.

Table 8-5
Joseph Creek Project Area Scoring for Restoration Potential

Project Area	River Mile Start	Prioritization Category		
		Increase Connected Floodplain	Add Instream or Planform Complexity	Establish Riparian Vegetation
JC-1	0.00	1	2	2
JC-2	1.20	5	5	4
JC-3	1.94	4	5	4
JC-4	3.01	4	2	3
JC-5	3.85	4	3	3
JC-6	4.41	2	3	2
JC-7	5.48	1	2	1
JC-8	6.85	1	1	1

Table 8-6 shows the Joseph Creek project areas grouped into three tiers for restoration priority. As noted previously, Tier 1 project areas have the most potential for restoration, Tier 2 project areas have some potential for restoration, and Tier 3 project areas have the least potential for restoration or may be the most difficult to implement.

Table 8-6
Joseph Creek Project Area Tiers

Tier 1	Tier 2	Tier 3
JC-2	JC-4	JC-1
JC-3	JC-6	JC-7
JC-5		JC-8

8.3 Prioritization of All Other Tributaries

The prioritization methods for the tributaries closely follow those used for Joseph Creek. The same three categories of restoration prioritization apply: 1) floodplain connectivity; 2) instream and planform complexity; and 3) riparian vegetation. The main difference between the two methods is the type of indicators used to assess the three categories for Joseph Creek versus all other tributaries. The prioritization is based on both desktop and field analysis results listed below and described in Section 5.

The categories for restoration prioritization of all other tributaries are based on the following indicators:

- Potential to increase connected floodplain
  - Levees or other encroachments disconnecting floodplain
  - Low-lying floodplain in relative elevation map
- Potential to add instream or planform complexity
  - Disconnected side channel opportunities
  - Existing side channels and split flows
  - Existing instream wood
  - Substrate sizes during field observations
  - Channel slope, valley slope, and sinuosity
- Potential to improve riparian vegetation
  - Existing native vegetation in the riparian area
  - Presence of invasive species

The same prioritization framework shown in Table 8-4 for Joseph Creek was used for the other tributaries as well. It should be noted that the main difference between these indicators and the geomorphic indicators used in the assessment of Joseph Creek is the lack of inundation at the 2- and 5-year events. Bathymetric LiDAR was not available for the tributaries and no hydraulic model was developed so indicators that relied on that information were excluded.

As shown in Table 8-7, each project area for the other tributaries was assigned a score from 1 to 5 (with 5 having the highest restoration potential) for the three restoration prioritization categories. Appendix E provides more details on the reasoning behind these scores.

Table 8-7
Project Area Scoring for Restoration Potential of All Other Tributaries

Project Area	River	River Mile Start	Prioritization Category		
			Increase Connected Floodplain	Add Instream or Planform Complexity	Establish Riparian Vegetation
CJC-1	Cottonwood Creek (Joseph Trib.)	0.00	2	1	3
CJC-2	Cottonwood Creek (Joseph Trib.)	0.62	0	1	3
SC-1	Shumaker Creek	0.00	2	4	3
DC-1	Deer Creek	0.00	0	3	3
DC-2	Deer Creek	0.20	0	3	3
BC-1	Buford Creek	0.00	4	4	3
BC-2	Buford Creek	0.29	0	3	4
BC-3	Buford Creek	0.98	3	3	4
BC-4	Buford Creek	2.11	0	3	5
WFRC-1	WF Rattlesnake Creek	0.00	0	1	2
WFRC-2	WF Rattlesnake Creek	0.33	1	1	3
WFRC-3	WF Rattlesnake Creek	0.71	3	1	3
WFRC-4	WF Rattlesnake Creek	1.17	1	1	3
WFRC-5	WF Rattlesnake Creek	1.74	2	1	2
CCGR-1	Cottonwood Creek (Grande Ronde Trib.)	0.00	5	2	5
CCGR-2	Cottonwood Creek (Grande Ronde Trib.)	0.61	5	1	5
CCGR-3	Cottonwood Creek (Grande Ronde Trib.)	1.53	3	1	5
CCGR-4	Cottonwood Creek (Grande Ronde Trib.)	2.33	1	1	3
CCGR-5	Cottonwood Creek (Grande Ronde Trib.)	2.73	3	1	4
CC-1	Cougar Creek	0.00	2	2	3

Project Area	River	River Mile Start	Prioritization Category		
			Increase Connected Floodplain	Add Instream or Planform Complexity	Establish Riparian Vegetation
CC-2	Cougar Creek	0.67	0	2	2
CC-3	Cougar Creek	1.16	0	1	1
MC-1	Menatchee Creek	0.00	5	2	5
MC-2	Menatchee Creek	0.34	5	2	5

Table 8-8 shows the project areas for the tributaries grouped into three tiers for restoration priority. As noted previously, Tier 1 project areas have the most potential for restoration, Tier 2 project areas have some potential for restoration, and Tier 3 project areas have the least potential for restoration or may be the most difficult to implement.

Table 8-8
Project Area Tiers for All Other Tributaries

Tier 1	Tier 2	Tier 3
BC-1	CJC-1	CJC-2
BC-3	SC-1	DC-1
WFRC-3	BC-2	DC-2
CCGR-1	BC-4	WFRC-1
CCGR-2	WFRC-4	CCGR-4
CCGR-3	WFRC-5	CC-2
MC-1	CCGR-5	CC-3
MC-2	CC-1	

9 Next Steps and Further Evaluations

The findings of this report present a geomorphic assessment of the study area, described in Section 2, and provide strategy for selecting and performing restoration actions to maximize benefit to the focal instream species throughout this area. However, this report is also meant to provide a baseline evaluation of the watershed for future evaluations to build on. Through the field assessments and desktop analysis performed for this report, Anchor QEA identified where future evaluations and assessment would be most useful for improving habitat throughout the watershed.

Many of the tributaries evaluated in this assessment were only studied a few miles upstream of the confluence with the mainstem Grand Ronde. For some of these tributaries with low summer flows and steep upper reaches, it is unlikely that significant instream restoration needs exist upstream of the assessment extents. However, for the tributaries Menatchee and Cottonwood creeks, there were many indications that reaches past where this study ended would provide highly beneficial restoration opportunities. These tributaries and particularly the upper reaches would benefit from further evaluation and restoration strategies focused on these individual watersheds.

Joseph Creek was only studied to the Washington and Oregon border as part of the scope of this assessment. However, Joseph Creek is a much larger tributary of the Grande Ronde that differed from the other tributaries in this assessment. With larger contributing watershed, Joseph Creek has a combination of factors that make it unique: high baseflow throughout the year, tributaries that present their own restoration opportunities, and a large amount of available floodplain. Furthermore, Joseph Creek has its own population of focal species and is the first tributary to the Grande Ronde after the Snake River, allowing migrating species to spend less time in the Grande Ronde itself. Therefore, a restoration strategy that is focused solely on the Joseph Creek watershed would likely be highly beneficial to instream restoration and focal species habitat in the region.

Finally, there are few examples of instream habitat restoration on a river such as the mainstem Grande Ronde. With steep valley walls, limited natural floodplain availability, difficult access routes, recreational boater considerations, and yearly ice flows, there are many barriers to implementing successful restoration projects. This report outlines some of the most beneficial and feasible locations and strategies for implementing restoration work. As some of these "low hanging fruit" projects on the mainstem Grande Ronde are implemented, and more information is available about what can be successful and where, it is possible more locations and opportunities for restoration on the mainstem will become apparent and may benefit from further evaluation.

10 Limitations

Anchor QEA has prepared this report for use by the ACCD to evaluate existing physical conditions in the Lower Grande Ronde River and tributaries and to identify appropriate potential restoration opportunities in the study area. The information presented in this report is based on available data and limited site reconnaissance at the time of report development. Conditions within the study reach may have changed both spatially and with time, and additional scientific data may become available. Significant changes in site conditions or the available information may require re-evaluation. Within the limitations of scope, schedule, and budget, our services have been executed in accordance with generally accepted scientific and engineering practices in this area at the time this report was prepared.

11 References

Amoros, C., 2001. "The concept of habitat diversity between and within ecosystems applied to river side-arm restoration." *Environmental management* 28.6 (2001): 805-817.

Beechie, T.J., H. Imaki, J. Greene, A. Wade, H. Wu, G. Press, P. Roni, J. Kimball, J. Stanford, P. Kiffney, and N.J. Mantua, 2013. "Restoring salmon habitat for a changing climate." *River Research and Applications* 29.8 (2013): 939-960.

Bumgarner, J.D., and M.L. Schuck, 2012. *Summer Steelhead Releases into the Grande Ronde River. Wallowa Stock - Hatchery Program Review: 1982-2012*. Washington Department of Fish and Wildlife Snake River Lab.

Bumgarner, J.D., M.L. Shuck, S. Martin, J. Dedloff, and L. Ross, 2002. *Lyons Ferry Complex Hatchery Evaluation: Summer Steelhead and Trout Report 1998, 1999, and 2000 Run Years*. Washington Department of Fish and Wildlife. Prepared for: U.S. Fish and Wildlife Service Lower Snake River Compensation Plan Office. October 2002.

Caldwell, D.J., 2007. *Geologic Controls on Physical Habitat Distribution, Grande Ronde River, Oregon and Washington*. The Center for Watershed Sciences, U.C. Davis. Accessed at: https://watershed.ucdavis.edu/education/classes/files/content/page/Caldwell.pdf

Carmichael, R.W., T. Hoffnagle, J. Feldhaus, D. Eddy, and N. Albrecht, 2011. *Upper Grande Ronde River Spring Chinook Salmon Hatchery Program Review*. Oregon Department of Fish and Wildlife.

Carmichael, R.W., L.R. Clarke, M. Flesher, D. Eddy, S. Warren, and H. Stanton, 2012. *Grande Ronde River Summer Steelhead Hatchery Program Review*. Oregon Department of Fish and Wildlife.

CIG (Climate Impacts Group), 2009. *The Washington climate change impacts assessment: evaluating Washington's future in a changing climate*. Climate Impacts Group, University of Washington, Seattle, Washington., 2009.

Ebersole, J.L., W.J. Liss, and C.A. Frissell, 2001. “Relationship between stream temperature, thermal refugia and rainbow trout *Oncorhynchus mykiss* abundance in arid-land streams in the northwestern United States.” *Ecology of Freshwater Fish* 10:1-10.

Fissekis, A.D., 2007. *The Effects of Flow Regime and Land Use Practices on Ecological Health in the Grande Ronde Sub-basin*. The Center for Watershed Sciences, U.C. Davis. Accessed at: https://watershed.ucdavis.edu/education/classes/files/content/page/Fissekis.pdf

Hales, T.C., D.L. Abt, E.D. Humphreys, and J.J. Roering, 2005. "A Lithospheric Instability Origin for Columbia River Flood Basalts and Wallowa Mountains Uplift in Northeast Oregon." *Nature*, 438(7069): 842–845. DOI:10.1038/nature04313.

Harrison, L.R., C.J. Legleiter, M. Wydzga, and T. Dunne, 2011. "Channel dynamics and habitat development in a meandering, gravel bed river." *Water Resources Research* 47.4 (2011).

Hersh-Burdick, R., 2007. *The Highs and Lows of the Grande Ronde River (Temperature in the Grande Ronde Watershed)*. The Center for Watershed Sciences, U.C. Davis. Accessed at: https://watershed.ucdavis.edu/education/classes/files/content/page/HershBurdick.pdf

Jeffres, C.A., J.J. Opperman, and P.B. Moyle, 2008. "Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river." *Environmental Biology of Fishes* 83.4 (2008): 449-458.

Jonasson, B., A. Reischauer, F. Monzyk, E. Van Dyke, and R. Carmichael, 2006. *Investigations into the Early Life-history of Naturally Produced Spring Chinook Salmon and Summer Steelhead in the Grande Ronde River Basin*, 2002 Annual Report, Project No. 199202604, 137 electronic pages, (BPA Report DOE/BP-00004119-2).

Mantua, N., I. Tohver, and A. Hamlet, 2010. "Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State." *Climatic Change* 102.1-2 (2010): 187-223.

McCullough, D.A., S. White, C. Justice, L. Burns, D. Kelsey, and D. Graves, 2017. *Assessing the Status and Trends of Spring Chinook Habitat in the Upper Grande Ronde River and Catherine Creek: Annual Report 2016*. Columbia River Inter-Tribal Fish Commission (CRITFC) Technical Report 17-03. April 30, 2017.

McIntosh, B.A., J.R. Sedell, J.E. Smith, R.C. Wissmar, S.E. Clarke, G.H. Reeves, and L.A. Brown, 1994. "Historical Changes in Fish Habitat for Select River Basins of Eastern Oregon and Washington." *Northwest Science* 68: 36-53.

Moran, P., and R. Waples, 2004. *Monitor and Evaluate the Genetic Characteristics of Supplemented Salmon and Steelhead*, 1999-2003 Progress Report, Project No. 198909600, 42 electronic pages, (BPA Report DOE/BP-00015834-1).

Nez Perce Tribe, 2013. *Management Plan 2013-2028*. Nez Perce Tribe Department of Fisheries Resources Management. July 17, 2013.

Nowak, M.C., 2004. *Grande Ronde Subbasin Plan*. Prepared for the Northwest Power and Conservation Council. May 28, 2004.

ODFW (Oregon Department of Fish and Wildlife), 2017. Salmon and Steelhead Recovery Tracker. Accessed June 15, 2020. Available at: http://www.odfwrecoverytracker.org/explorer/species/Steelhead/run/summer/esu/271/298/

OSU (Oregon State University Climate Service), 2019. PRISM Climate Group. Available at: http://prism.oregonstate.edu. Map Created July 2019.

QSI (Quantum Spatial, Inc.), 2019. *Topobathymetric LiDAR Technical Data Report: Grande Ronde River Basin, WA*. Prepared for Asotin County Conservation District. February 2019.

Rheinheimer, D.E., 2007. *Hydrologic and ecologic impacts of climate change in the Grande Ronde River Basin*. The Center for Watershed Sciences, U.C. Davis. Accessed at: https://watershed.ucdavis.edu/education/classes/files/content/page/Rheinheimer.pdf

Rio ASE (Rio Applied Science and Engineering), 2019. *Rattlesnake Creek Adaptive Management Plan Report*. Prepared by Rio Applied Science and Engineering, Boise, ID. Prepared for Bonasa Breaks, LLC.

Roni, P., T. Beechie, R. Bilby, F. Leonetti, M. Pollock, and G. Pess, 2002. "A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds." *North American Journal of Fisheries Management* 22.1 (2002): 1-20.

Sheldon, F., and M.C. Thoms, 2006. "In-channel geomorphic complexity: The key to the dynamics of organic matter in large dryland rivers?" *Geomorphology* 77.3-4 (2006): 270-285.

SRSRB (Snake River Salmon Recovery Board), 2011. *Snake River Salmon Recovery Plan for SE Washington*. Prepared by Snake River Salmon Recovery Board. Prepared for Washington Governor's Salmon Recovery Office. December 2011.

Thorson, T.D., Bryce, S.A., Lammers, D.A., Woods, A.J., Omernik, J.M., Kagan, J., Pater, D.E., and Comstock, J.A., 2003. *Ecoregions of Oregon*. Reston, Virginia, U.S. Geological Survey). Accessed at: http://people.oregonstate.edu/~muirp/FuelsReductionSWOregon/ToolsResources/EcoregionsOregonLevelIVEPA.pdf

Ullman, J.L., and M.E. Barber, 2009. *Middle Snake Watershed Instream Habitat Assessment, WRIA 35*. Prepared for Middle Snake Watershed Planning Unit. Washington State University.

USFWS (U.S. Fish and Wildlife Service), 2002. "Chapter 11, Grande Ronde River Recovery Unit, Oregon and Washington." *Bull Trout (Salvelinus confluentus) Draft Recovery Plan*. U.S. Fish and Wildlife Service. Portland, Oregon. 95 pp.

DRAFT

USGS (U.S. Geological Survey), 2020. Monitoring Location 13333000, Grande Ronde River at Troy, Oregon. Accessed June 2020. Available at: https://waterdata.usgs.gov/or/nwis/inventory/?site_no=13333000&agency_cd=USGS.

Wissmar, R.C., J.E. Smith, B.A. McIntosh, H.W. Li, G.H. Reeves, and J.R. Sedell, 1994. "A History of Resource Use and Disturbance in Riverine Basins of Eastern Oregon and Washington (Early 1800s-1990s)." *Northwest Science*, 68: 1-35. Accessed at: https://research.libraries.wsu.edu/xmlui/bitstream/handle/2376/1565/v68%20p1%20Wissman%20et%20al.PDF?sequence=1

Wohl, E., 2016. "Spatial heterogeneity as a component of river geomorphic complexity." *Progress in Physical Geography* 40.4 (2016): 598-615.

Appendix A
Hydrologic Analysis Methods and Results

Appendix A
Hydrologic Analysis Methods and Results

1.1 Introduction

This appendix details the methodology used to obtain the hydrologic inputs to the Grande Ronde River HEC-RAS model. The Grande Ronde River drains the Wallowa and Blue Mountains of northeast Oregon and southeast Washington and has a basin area of 4,104 square miles (USGS 2019a). The modeled portion of the basin incudes the tributaries and the last approximately 40 miles of the mainstem in Washington before entering the Snake River. A map of the model extent is shown in Figure A-1.

1.2 Peak Flow Hydrology

Peak flow profiles were developed for the 2-, 5-, 10-, 25-, 50-, and 100-year events for both the mainstem Grande Ronde River above the U.S. Geological Survey (USGS) gage at Troy, Oregon, and the tributaries of the mainstem and Joseph Creek. The additional flow of each tributary was added in at the nearest cross section downstream of the creek mouth in the HEC-RAS model.

1.2.1 Mainstem Upstream of Troy Gage

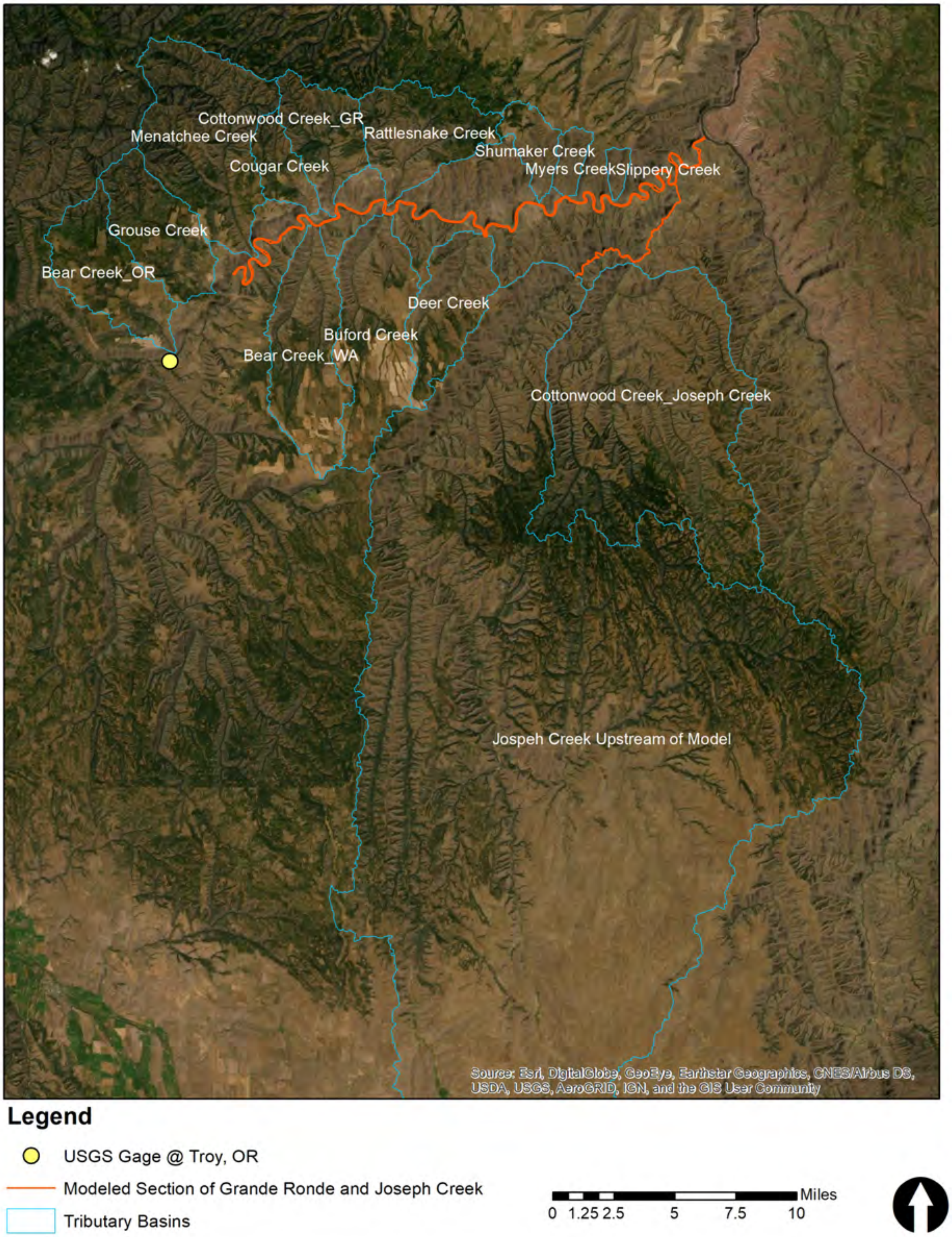
The USGS gage 13333000 at Troy, Oregon, has daily data and annual peak flow data from water year 1945 to present (USGS 2019b). The annual peak flow data taken from the USGS website were analyzed using a Log-Pearson Type III distribution to determine the recurrence intervals for the 2- to 100-year floods. The results for the mainstem upstream of Troy are shown in Table A-1.

Table A-1
Peak Flow Profiles for the Mainstem Above Troy, Oregon

Return Interval	Discharge (cfs)
2-year	14,895
5-year	22,001
10-year	27,152
25-year	34,148
50-year	39,707
100-year	45,560

cfs: cubic foot per second

Figure A-1
Grande Ronde Hydrologic Model Overview



1.2.2 Tributaries

There were no gages on any of the tributaries of the Grande Ronde River or Joseph Creek, so regressions from the USGS StreamStats database were used to determine peak flow profiles for these tributaries (USGS 2019a). In the StreamStats database, the peak flow profiles from the tributaries with outlets in Washington were calculated directly from the website using a regression equation that accounted for basin area, mean annual precipitation, and basin percent forest cover (Mastin et al. 2016). The flow profiles from the tributaries Bear Creek and Grouse Creek in Oregon were manually calculated using the same regression equation from Mastin et al. 2016 as shown in Equation A-1. The constants from Region 1 encompassing southeast Washington and Northeast Oregon were used, and the basin area, annual precipitation, and percent forest cover were obtained using the data in the StreamStats database (USGS 2019a).

Equation A-1 (Mastin et al. 2016)

$$Q = \frac{aA^{b}10^{cP}}{10^{dCAN}}$$

where:

a,b,c,d	=	given constants for the particular regression region and recurrence interval
A	=	basin area (mi^2)
P	=	mean basin annual precipitation (in)
CAN	=	basin % forested

Regression region	Number of stations used in analysis	Form of the regression equation	Annual exceedance probability	Constant	Coefficents			S_p (percent)	R^2_{pseudo}	SEM (percent)	Range of values		
				a	*b*	*c*	*d*				*A*	*P*	CAN
1	93	$Q = aA^{b}10^{cP}/10^{dCAN}$	0.5	3.846	0.745	0.032	0.0078	95.04	85.1	90.72	0.25–3,304	9.82–52.45	0.0–77.4
			0.2	12.106	0.713	0.028	0.0098	71.93	87.66	68.33			
			0.1	22.080	0.695	0.026	0.0107	70.67	86.72	66.91			
			0.04	42.170	0.674	0.024	0.0117	77.42	83.38	73.12			
			0.02	63.826	0.661	0.023	0.0124	84.76	80.32	79.92			
			0.01	92.470	0.649	0.022	0.0130	93.55	77.01	88.08			
			0.005	129.42	0.637	0.021	0.0136	103.98	73.32	97.75			
			0.002	193.20	0.624	0.020	0.0143	118.69	68.66	111.33			

1.3 Low Flow Hydrology

A summer low flow, winter low flow, and 1-year profile were also developed for all the tributaries and the mainstem. For the summer low-flow profiles, the 50% flow duration discharges from the three lowest flow months of August, September, and October were averaged. For the winter low-flow profiles, the 50% flow duration discharges from the months of December, January, and February were averaged. For the tributaries, 1-year profiles were calculated by interpolating the 2- to 100-year flood data from the StreamStats database and extrapolating a 1-year flow. For the mainstem, the 1-year profile was calculated using the Log-Pearson Type III distribution.

1.3.1 Mainstem Upstream of Troy Gage

The summer and winter low flows for the mainstem upstream of the gage were taken from the online gage data by averaging the monthly average discharges for August to October and December to February, respectively (USGS 2019b). The 1-year flow for the mainstem upstream of the USGS gage was estimated using the same Log-Pearson Type III distribution on the annual peak data going back to water year 1945 (USGS 2019b).

1.3.2 Tributaries

1.3.2.1 Summer and Winter Low Flows

The USGS StreamStats database only offered low-flow calculations for basins in Oregon, so the regression equations from Region 6 for Northeast Oregon were used to calculate the August to October and December to February 50% flow durations for all the tributaries in Washington (Risley et al. 2008). The results were then verified by comparing the hand calculated results for Bear Creek and Grouse Creek in Oregon to the automatic outputs from the USGS StreamStats database. The regressions from Risley et al. 2008 for monthly 50% flow duration differ by month and were dependent on a variety of parameters including basin drainage area, basin mean precipitation, basin drainage density, and basin maximum, minimum, and mean elevation (Risley et al. 2008). The equations for each month are shown in Equation A-2. Drainage density was obtained by delineating stream networks in GIS, dividing stream length by basin area, and normalizing the drainage density values for each tributary to the results obtained from the StreamStats database for Grouse and Bear creeks in Oregon (USGS 2019a). Basin max, min, and mean elevations were determined in GIS for the basins in Washington. The remainder of the parameters were obtained from the StreamStats database (USGS 2019a).

Equation A-2 (Risley et al. 2008)

Monthly 50% Flow Duration

August:

$$P50 = 1.27 * 10^{-17.3} * DA^{.843} * P^{3.53} * XE^{2.95}$$

September:

$$P50 = 1.40 * 10^{-17.9} * DA^{.912} * P^{4.06} * XE^{2.85}$$

October:

$$P50 = 1.24 * 10^{-15.8} * DA^{.933} * P^{3.59} * XE^{2.49}$$

December:

$$P50 = 1.07 * 10^{-2.89} * DA^{.974} * P^{2.15} * DD^{-.968} * NE^{-.277}$$

January:

$$P50 = 1.07 * 10^{-1.56} * DA^{.906} * P^{2.05} * NE^{-.533}$$

February:

$$P50 = 1.05 * 10^{1.59} * DA^{1.02} * P^{1.87} * E^{-1.33} * DD^{-.802}$$

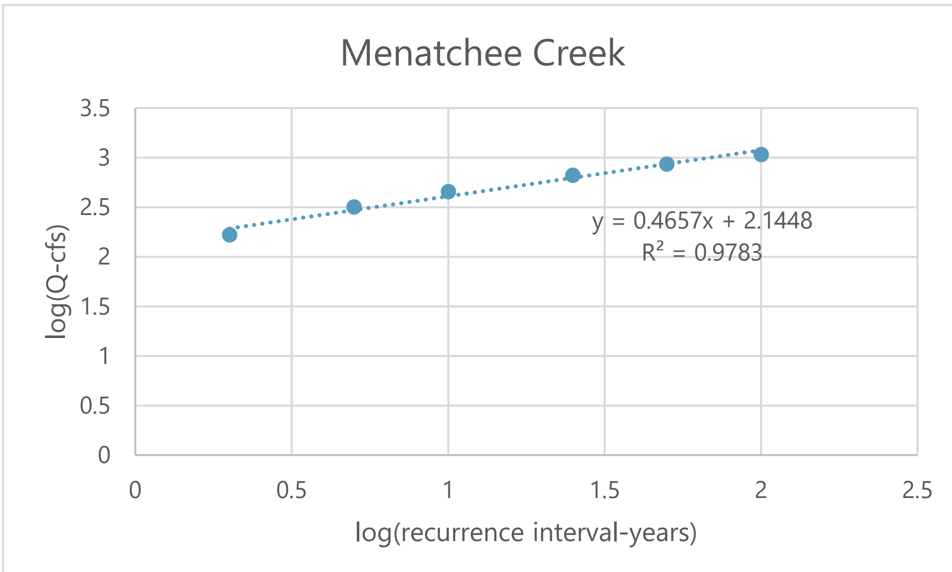
where:

P	=	mean annual basin precipitation (in)
DA	=	basin drainage area (mi^2)
XE	=	basin max elevation (ft)
NE	=	basin min elevation (ft)
DD	=	drainage density (km/km^2)
E	=	basin mean elevation (ft)

1.3.2.2 1-Year Flows

The 1-year flows for all the tributaries were estimated by graphical interpolation using the discharges for the 2- to 100-year peak floods previously obtained from the StreamStats database. The 2- to 100-year floods for each creek were plotted on a log-log plot, and the linear trendline was calculated and used to determine the 1-year flood. The same graphical method was used to estimate the 1-year flood for the mainstem gage data at Troy for which we had an accurate 1-year flood determined from the Log-Pearson Type III method. The difference between the graphical method and the Log-Pearson Type III method for the mainstem data was then used as a multiplicative correction factor to correct all the tributary values to obtain a more accurate set of 1-year discharges. An example of the graphical interpolation process is shown in Figure A-2.

Figure A-2
Graphical Interpolation to Determine 1-Year Discharge for Tributaries



1.4 Final Model Hydrology

The final inputs to the HEC-RAS model including the peak flow and low-flow profiles are shown in Table A-2. The discharge for the mainstem Grande Ronde River upstream of the gage at Troy was added to the discharges from Bear and Grouse creeks in Oregon to comprise the flow "Grande Ronde Upstream of Model." Each tributary flow is added to the total, and the two flow change locations on Joseph Creek are added to the Grande Ronde below Slippery Creek to get the largest discharge value "Junction of Joseph Creek and Grande Ronde."

Table A-2
Model Hydrology

Tributary/ Location Name	Flow (cfs) per Return Period							Summer Low Flow (cfs)	Winter Low Flow (cfs)
	1-year	2-year	5-year	10-year	25-year	50-year	100-year		
Grande Ronde Upstream of Model	5,596	15,084	22,348	27,636	34,844	40,595	46,658	794	2,367
Menatchee Creek	5,678	15,251	22,667	28,090	35,509	41,454	47,738	795	2,376
Cougar Creek	5,695	15,288	22,748	28,215	35,708	41,724	48,093	796	2,377
Bear Creek_WA	5,758	15,419	23,041	28,663	36,418	42,689	49,353	796	2,382
Cottonwood Creek_Grande Ronde	5,790	15,487	23,190	28,888	36,772	43,166	49,973	796	2,384
Rattlesnake Creek	5,826	15,561	23,345	29,119	37,127	43,638	50,580	796	2,387
Buford Creek	5,906	15,729	23,722	29,698	38,046	44,888	52,220	796	2,393
Deer Creek	5,953	15,828	23,947	30,047	38,605	45,653	53,230	796	2,396
Shumaker Creek	5,972	15,868	24,046	30,208	38,875	46,033	53,744	796	2,397
Myers Creek	5,984	15,893	24,113	30,319	39,067	46,309	54,125	796	2,398
Slippery Creek	5,992	15,910	24,158	30,396	39,202	46,505	54,398	796	2,398
Junction of Joseph Creek and Grande Ronde	6,660	17,255	26,769	34,103	44,602	53,465	63,078	803	2,492
Joseph Creek Upstream of Model	528	1,060	2,040	2,880	4,170	5,350	6,650	5	77

1.5 References

Mastin, M.C., C.P. Konrad, A.G. Veilleux, and A.E. Tecca, 2016. *Magnitude, frequency, and trends of floods at gaged and ungaged sites in Washington, based on data through water year 2014*. Version 1.1, October 2016. U.S. Geological Survey Scientific Investigations Report No. 2016–5118, 70 pp. Available at: https://pubs.er.usgs.gov/publication/sir20165118.

Risley, J., A. Stonewall, and T. Haluska, 2008. *Estimating flow-duration and low-flow frequency statistics for unregulated streams in Oregon*. U.S. Geological Survey Scientific Investigations Report 2008-5126, 22 pp. Available at: https://pubs.usgs.gov/sir/2008/5126/.

USGS (U.S. Geological Survey), 2019a. StreamStats in Washington and Oregon. Available at: https://streamstats.usgs.gov/ss/.

USGS, 2019b. Monitoring Location 13333000, Grande Ronde River at Troy, Oregon. Accessed July 2019. Available at: https://waterdata.usgs.gov/or/nwis/inventory/?site_no=13333000&agency_cd=USGS.

Appendix B
Hydraulic Modeling

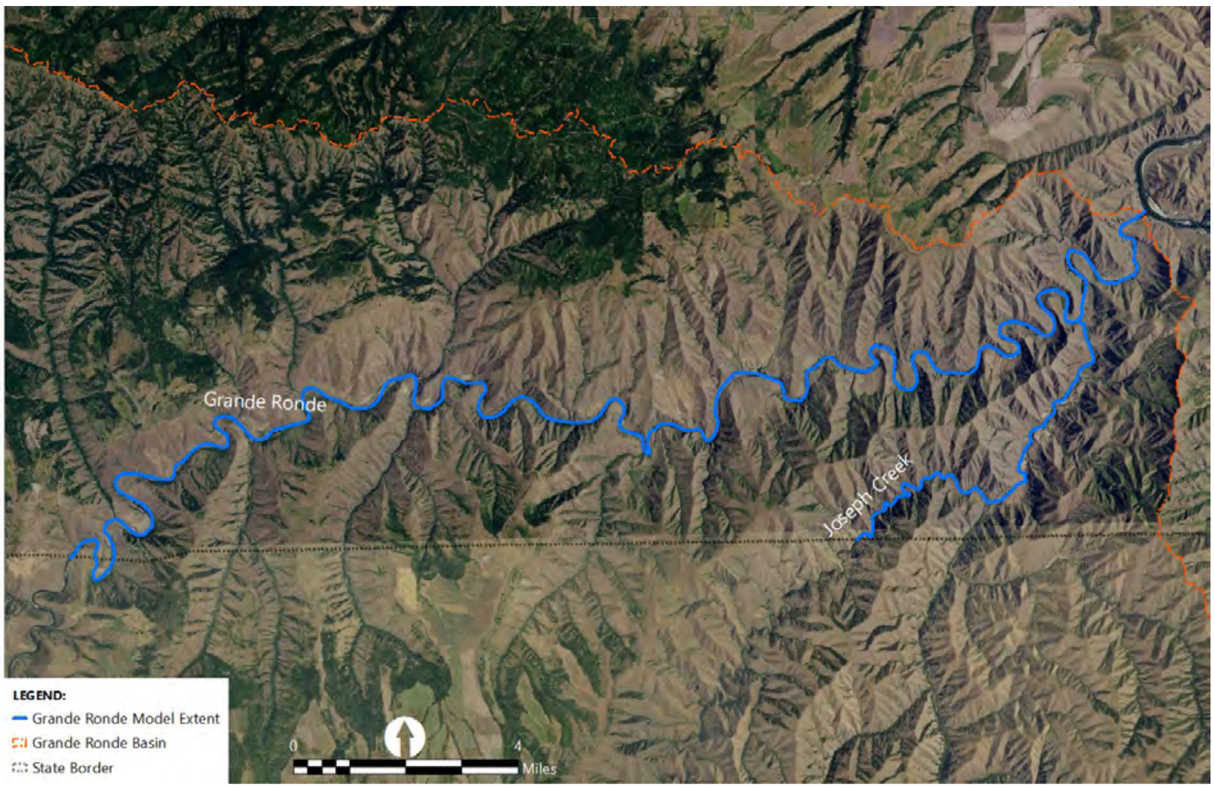
DRAFT

Appendix B
Hydraulic Modeling

1.1 Hydraulic Model Overview

A 1D hydraulic model was developed using U.S. Army Corps of Engineers (USACE) HEC-RAS 5.0.7 for this assessment. The hydraulic model includes the portion of the Grande Ronde River and its major tributary, Joseph Creek, within Washington State. The extent of the model is shown in Figure B-1.

Figure B-1
Grande Ronde Model Extent



The model contains peak flow data for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year floods as well as summer and winter low-flow profiles. The flow data for the mainstem Grande Ronde River were determined from the U.S. Geological Survey (USGS) gage at Troy, Oregon, with daily data dating back to water year 1945 (USGS 2019a). Flows for the tributaries were estimated using regressions from the USGS StreamStats database (USGS 2019b). Comparisons between the 1-, 5-, and 10-year inundated areas were used to assess floodplain connectivity in the mainstem and Joseph Creek as well as prioritize restoration sites in the mainstem.

1.2 Hydraulic Model Development

1.2.1 Model Data

1.2.1.1 LiDAR Data

The 1D model is based on a topobathymetric Light Detection and Ranging (LiDAR) dataset gathered by Quantum Spatial, Inc. (QSI) in November 2018 (QSI 2019). The QSI aerial survey included green wavelength bathymetric data for the mainstem Grande Ronde River and Joseph Creek, while near-infrared (NIR) data were gathered for reaches of the tributaries Buford, Rattlesnake, Cottonwood, and Cougar creeks (QSI 2019). The green wavelength data penetrate the water column and can resolve the bed depending on water depth, while NIR data do not penetrate the water surface. Only the areas with topobathymetric data were incorporated into the 1D HEC-RAS model. Flows ranged from 694 to 917 cubic feet per second at the USGS gage in Troy during the week of LiDAR collection (QSI 2019; USGS 2019a).

1.2.1.2 Manning's N Data

A land use dataset spanning the entire United States was downloaded into HEC-RAS to inform Manning's n values for the model cross sections (USGS 2014). Horizontal variation in Manning's n values within cross sections was based on this USGS land use dataset as well as satellite imagery. Another set of values categorizing Manning's n for each land type was consulted to help determine a standard for Manning's n values. This dataset comes from Manning's n estimates by land type in Kansas (Janssen 2016). The Manning's n values used for this model were consistent with previous assessments on the Tucannon River and are shown in Table B-1.

Table B-1
Standard Manning's n Values

Land Cover Type	Manning's n Value
River Channel	0.04
Agricultural Field	0.045
Developed-Low Intensity, Shrub/Scrub	0.06
Developed-Medium Intensity	0.08
Developed-High Intensity, Evergreen Forest, Deciduous Forest	0.1

1.2.1.3 Hydrology Data

Hydrology data for the mainstem were derived from USGS gage data, and hydrology data for the tributaries were determined with regressions from the USGS StreamStats database (USGS 2019a, 2019b). The record of the USGS gage 13333000 at Troy, Oregon, contains daily data and annual peak flow data from water year 1945 to present (USGS 2019a). The yearly peak flow dataset was analyzed using a Log-Pearson Type III distribution to estimate 2- to 100-year flood recurrence intervals for the mainstem Grande Ronde River. Summer and winter low-flow profiles for the mainstem were created using monthly average flows for August to October and December to February, respectively (USGS 2019a). Peak flow recurrence intervals for the tributaries were calculated using regressions from USGS StreamStats in Washington, while summer and winter low-flow profiles were developed using StreamStats in Oregon for the August to October and December to February 50% flow duration statistics (USGS 2019b). For both the tributaries and the mainstem, 1-year floods were estimated using curve interpolation from the 2- to 100-year floods. For all flow profiles, tributary flows were manually added at the cross section immediately downstream of the tributary. For more information on development of model hydrology, see Appendix A, Hydrologic Analysis Methods and Results.

1.2.2 Model Geometry

The first step in model geometry development was manually delineating channel centerlines and approximate bank lines using both satellite imagery and LiDAR data for guidance. Next, cross sections were generated in intervals of 660 feet or 1/8 mile for both the mainstem and Joseph Creek. 1/8-mile intervals were considered sufficiently spaced to develop the backbone of the model, and additional cross sections were manually added in sections of high complexity or near islands to further resolve the model. Elevations for the cross sections were cut directly from the terrain derived from the topobathymetric LiDAR (QSI 2019), providing accurate bathymetric and floodplain elevations for the model. Manning's n data were manually entered for each cross section using the land cover data set (USGS 2014) and satellite imagery for guidance and conforming to the standards listed in Table B-1. There were few manmade levees in the Grande Ronde system besides roads. Inundated areas behind roads were modeled as ineffective flow areas, omitting them from flow velocity calculations.

1.2.3 Model Results

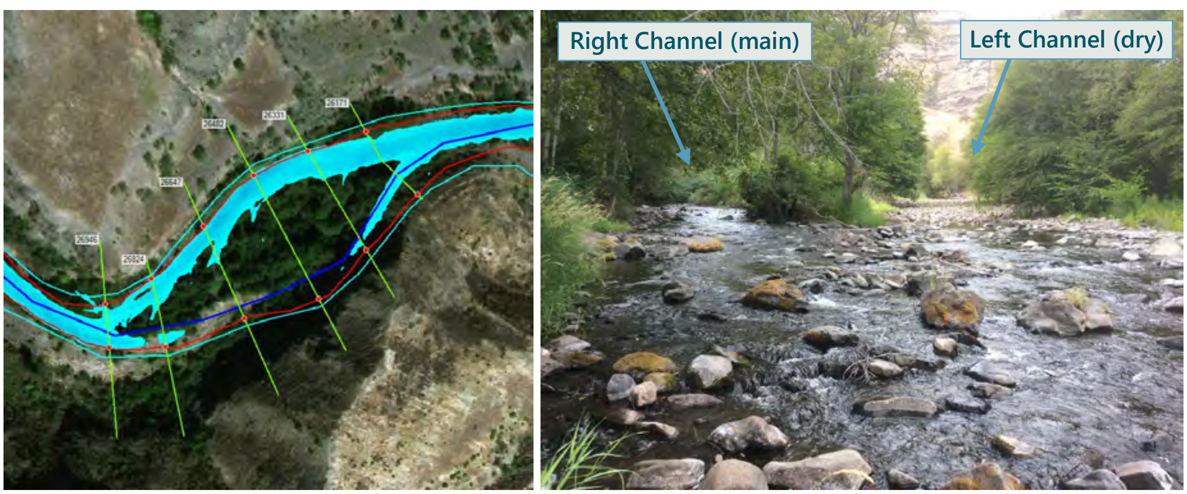
The model produces results for water depth, velocity, inundation extent, water surface elevation, and shear stress. The modeled inundation extents at different recurrence intervals were used as inputs for channel complexity and connectivity analyses on the mainstem and tributaries. The difference between the 1-, 5-, and 10-year floods was used to assess connectivity potential in the Joseph Creek prioritization. Differences between floods from the 1-year to the 25-year flood were used to evaluate areas of potential floodplain connectivity in the mainstem and to locate specific restoration sites.

1.2.4 Model QA/QC

Quality assurance/quality control (QA/QC) tasks included checking the model results for stream continuity as well as confirming flow patterns with field observations. In 1D model results, high points between cross sections may cause a discontinuity in the river. Addition of more closely spaced cross sections in these areas provides HEC-RAS a shorter distance to calculate slope, helping to eliminate these false discontinuities. In addition, inundated areas behind natural and manmade levees may appear isolated from the river. These areas were checked to ensure proper connection to the main flow. Lastly, island complexes forming multiple side channels were QC'ed. For certain flows, side channels appear to be disconnected, but addition of more cross sections provides enough resolution to render these side channels continuous.

Water depth and side channel connection were also checked following the site visit from August 26 to 29, 2019. Anchor QEA field staff walked and rafted the entire section of the mainstem Grande Ronde River included in the model, as well as sections of Joseph Creek and lower reaches of the tributary creeks to the mainstem and Joseph Creek. The field survey was conducted during the lowest summer flow conditions, providing an opportunity to QC the summer low-flow profile. Field observations were used to QC water levels in the tributary and mainstem and to confirm side channel connectivity. One inconsistency between the model and observations was observed in Joseph Creek, indicating either an avulsion since the LiDAR was gathered in November 2018 or an error in the model. The noted discrepancy is shown in Figure B-2. The model indicates the left channel is the main channel, but the field visit revealed that the left channel was dry during low flow. Ground truthing the model in the field was invaluable to the modeling process.

Figure B-2
Discrepancy Between Model and Observations, Joseph Creek Side Channel



Left: Joseph Creek flows from left (upstream) to right (downstream) in this image. The modeled split flow reach indicates the left channel is the main channel (as indicated by the light blue water depth output). Right: During the field visit, the view from downstream of the split looking upstream shows that the left channel is dry at low flow and the right channel is the main channel. Photograph credit: Tom Hutchison, August 29, 2019.

1.3 References

Janssen, C., 2016. Manning's n Values for Various Land Covers To Use for Dam Breach Analyses by NRCS in Kansas. Available at: https://www.wcc.nrcs.usda.gov/ftpref/wntsc/H&H/HecRAS/NEDC/lectures/docs/Manning%92s%20n-values%20for%20Kansas%20Dam%20Breach%20Analyses%20-%20Adopted%20071216.pdf.

QSI (Quantum Spatial, Inc.), 2019. Topobathymetric LiDAR Technical Data Report: Grande Ronde River Basin, WA.

USGS (U.S. Geological Survey), 2014. NLCD 2011 Land Cover - National Geospatial Data Asset (NGDA) Land Use Land Cover. Available at: https://www.mrlc.gov/sites/default/files/metadata/landcover.html.

USGS, 2019a. Monitoring Location 13333000, Grande Ronde River at Troy, Oregon. Accessed July 2019. Available at: https://waterdata.usgs.gov/or/nwis/inventory/?site_no=13333000&agency_cd=USGS.

USGS, 2019b. StreamStats in Washington and Oregon. Available at: https://streamstats.usgs.gov/ss/

Appendix C
Desktop Geomorphic Analysis Results

Appendix C
Desktop Geomorphic Analysis Results

This appendix presents relevant data from the desktop geomorphic analyses of the assessed reaches of Joseph Creek, the other tributaries, and the mainstem. These data were used to develop the conceptual restoration prioritization rankings. Channel characteristics of slope and sinuosity were determined from GIS analyses conducted on the river centerlines and valley lines. Levees and road encroachments were visually delineated based on areas where roads and levees constrained floodplain connectivity. Areas of bank incision in the tributaries were also visually delineated using a high slope classification of Light Detection and Ranging (LiDAR) data. In addition to these manual analyses, the inundation results from the hydraulic model were output for the modeled sections of Joseph Creek and the mainstem and compared to assess floodplain availability.

1.1 Confinement Analysis

The confinement analysis included delineation of levees, encroachments, and areas of bank incision. Levees were defined as structures in the floodplain that disconnected the active channel from areas of low-lying floodplain. Levees were manually delineated using visual guidance from the relative elevation map and the inundation extents output from the model. Road encroachments were delineated as areas where paved, gravel, or dirt roads exist within the floodplain. Encroachments differ from levees because they are roads or structures along the valley wall with no floodplain area behind them. For encroachments, the road prism or road surface takes up some floodplain width, narrowing the active channel. Bank incision is the third confinement metric delineated using the guidance of LiDAR data characterized by a slope field. Areas of high slopes along the active channel were delineated as incised banks where high slopes were not the result of naturally steep valley walls. All three confinement categories were generated for Joseph Creek and the tributaries, and the levee and encroachment categories were generated for the mainstem. These statistics were used in the conceptual restoration prioritization to assess potential floodplain connectivity following confinement removal and to target restoration in incised areas.

1.2 Floodplain Inundation Analysis

Hydraulic model results for the inundated extents during the 1-, 2-, 5-, 10-, and 25-year floods were compared between the modeled project areas of Joseph Creek and the four mainstem reaches. Floodplain areas were normalized to river length to assess relative floodplain availability. The 1-year flood values were then subtracted from the larger floods to determine the potential to expand floodplain connectivity. These values were incorporated into the prioritization to assess the potential to increase connected floodplain area and promote expansion of riparian vegetation.

1.2.1 Joseph Creek

Table C-1 shows channel characteristics for all Joseph Creek reaches. Relative to other tributaries, Joseph Creek has a moderate slope. Confined project areas like JC-1, JC-2, and JC-6 have notably low sinuosity.

Table C-1
Joseph Creek Channel Data

Project Area	RM Start	River Length (mi)	Valley Length (mi)	Sinuosity	Average Channel Slope
JC-1	0.00	1.20	1.16	1.03	1.23%
JC-2	1.20	0.75	0.73	1.02	0.92%
JC-3	1.95	1.07	1.02	1.04	0.90%
JC-4	3.02	0.84	0.66	1.27	0.83%
JC-5	3.86	0.56	0.54	1.04	0.91%
JC-6	4.42	1.07	1.05	1.01	1.12%
JC-7	5.49	1.38	1.31	1.05	1.08%
JC-8	6.87	1.59	1.49	1.06	1.10%

mi: mile
RM: river mile

Table C-2 contains results for the three confinement categories for Joseph Creek. The reaches downstream of JC-7 are affected by confinement by roads and levees, causing widespread incision. Project areas JC-7 and JC-8 are remote and unconfined and are less incised.

Table C-2
Joseph Creek Confinement Analysis

Project Area	Levee Length (mi)	Levee Length per RM (mi/rm)	Road Encroachment Length (mi)	Road Encroachment Length per RM (mi/rm)	Bank Incision Length (mi)	Bank Incision Length per RM (mi/rm)
JC-1	0.50	0.42	0.40	0.33	0.90	0.75
JC-2	0.94	1.25	0.09	0.11	0.61	0.82
JC-3	0.59	0.55	0.59	0.55	1.46	1.38
JC-4	0.06	0.07	0.00	0.00	0.73	0.87
JC-5	0.08	0.14	0.19	0.34	0.66	1.16
JC-6	0.04	0.04	0.38	0.35	0.66	0.62
JC-7	0.00	0.00	0.00	0.00	0.36	0.26
JC-8	0.00	0.00	0.00	0.00	0.29	0.18

Tables C-3 and C-4 present the results from the inundation analysis on Joseph Creek. Results show project areas JC-2 through JC-5 have the greatest floodplain area and the greatest potential to expand floodplain through confinement removal.

Table C-3
Joseph Creek: Modeled Inundation at 1-year to 25-year Flow Events

Project Area	RM Start	Length (RM)	Inundated Area per RM (ac/rm)				
			1-year	2-year	5-year	10-year	25-year
JC-1	0.00	1.20	6.9	8.2	9.6	10.5	13.1
JC-2	1.20	0.75	9.0	11.0	15.3	19.0	29.5
JC-3	1.95	1.07	8.8	11.1	15.1	19.9	29.1
JC-4	3.02	0.84	8.3	10.1	12.8	15.1	18.4
JC-5	3.86	0.56	7.1	8.9	11.2	13.6	16.3
JC-6	4.42	1.07	7.0	8.4	10.5	12.2	15.0
JC-7	5.49	1.38	7.4	8.7	10.1	11.1	12.3
JC-8	6.87	1.59	7.2	8.3	9.4	10.0	10.9

ac: acre

Table C-4
Joseph Creek: Increase in Inundated Area from the 1-year Inundated Area

Project Area	RM Start	Length (RM)	Increase in Inundated Area per RM (ac/rm)			
			2-year	5-year	10-year	25-year
JC-1	0.00	1.20	1.3	2.7	3.6	6.2
JC-2	1.20	0.75	2.0	6.4	10.0	20.6
JC-3	1.95	1.07	2.3	6.3	11.1	20.4
JC-4	3.02	0.84	1.8	4.5	6.9	10.1
JC-5	3.86	0.56	1.8	4.1	6.5	9.2
JC-6	4.42	1.07	1.4	3.5	5.2	8.0
JC-7	5.49	1.38	1.3	2.7	3.6	4.9
JC-8	6.87	1.59	1.1	2.2	2.8	3.7

1.2.2 Other Tributaries

Table C-5 contains characteristics for the tributaries outside Joseph Creek. Many of these tributaries are very steeply sloped and sinuosity varies between confined and unconfined project areas.

Table C-5
Tributary Channel Data

Project Area	Tributary	RM Start	River Length (mi)	Valley Length (mi)	Sinuosity	Average Channel Slope
CJC-1	Cottonwood Creek	0.00	0.62	0.57	1.09	2.82%
CJC-2	Cottonwood Creek	0.62	0.31	0.27	1.14	2.06%
SC-1	Shumaker Creek	0.00	0.32	0.31	1.03	7.00%
DC-1	Deer Creek	0.00	0.27	0.24	1.11	6.17%
DC-2	Deer Creek	0.27	0.70	0.63	1.11	5.57%
BC-1	Buford Creek	0.00	0.29	0.29	1.02	4.48%
BC-2	Buford Creek	0.29	0.68	0.66	1.03	4.09%
BC-3	Buford Creek	0.97	1.13	1.08	1.05	4.45%
BC-4	Buford Creek	2.10	1.06	1.00	1.06	4.58%
WFRC-1	WF Rattlesnake Creek	0.00	0.33	0.33	1.00	8.45%
WFRC-2	WF Rattlesnake Creek	0.33	0.38	0.37	1.05	7.17%
WFRC-3	WF Rattlesnake Creek	0.71	0.46	0.45	1.03	7.67%
WFRC-4	WF Rattlesnake Creek	1.17	0.56	0.54	1.03	9.72%
WFRC-5	WF Rattlesnake Creek	1.73	0.61	0.58	1.06	9.34%
CCGR-1	Cottonwood Creek	0.00	0.61	0.57	1.07	5.28%
CCGR-2	Cottonwood Creek	0.61	0.92	0.82	1.12	5.10%
CCGR-3	Cottonwood Creek	1.53	0.80	0.73	1.10	4.95%
CCGR-4	Cottonwood Creek	2.33	0.40	0.37	1.09	5.40%
CCGR-5	Cottonwood Creek	2.73	0.50	0.48	1.04	6.67%
CC-1	Cougar Creek	0.00	0.67	0.66	1.01	9.37%
CC-2	Cougar Creek	0.67	0.49	0.46	1.06	10.54%
CC-3	Cougar Creek	1.16	0.31	0.30	1.03	13.50%
MC-1	Menatchee Creek	0.00	0.34	0.30	1.12	2.95%
MC-2	Menatchee Creek	0.34	0.42	0.39	1.07	2.69%

Tables C-6, C-7, and C-8 display data from the three confinement analysis metrics for the tributary project areas. Reaches in lower Cottonwood Creek—Grande Ronde, Cougar Creek, and Menatchee Creek have the most levees, while road encroachments are significant in Buford Creek and West Fork Rattlesnake Creek. Incision was widespread, but more confined project areas in Buford Creek, Cottonwood Creek—Grande Ronde, and Cougar Creek had the highest normalized incision values.

Table C-6
Tributary Levee Statistics

Project Area	Tributary	RM Start	Length (RM)	Levee Length (mi)	Levee Length per RM (mi/rm)
CJC-1	Cottonwood Creek	0.00	0.62	0.22	0.36
CJC-2	Cottonwood Creek	0.62	0.31	0.00	0.00
SC-1	Shumaker Creek	0.00	0.32	0.31	0.96
DC-1	Deer Creek	0.00	0.27	0.03	0.12
DC-2	Deer Creek	0.27	0.70	0.12	0.18
BC-1	Buford Creek	0.00	0.29	0.06	0.22
BC-2	Buford Creek	0.29	0.68	0.00	0.00
BC-3	Buford Creek	0.97	1.13	0.30	0.26
BC-4	Buford Creek	2.10	1.06	0.09	0.08
WFRC-1	WF Rattlesnake Creek	0.00	0.33	0.00	0.00
WFRC-2	WF Rattlesnake Creek	0.33	0.38	0.00	0.01
WFRC-3	WF Rattlesnake Creek	0.71	0.46	0.11	0.24
WFRC-4	WF Rattlesnake Creek	1.17	0.56	0.09	0.16
WFRC-5	WF Rattlesnake Creek	1.73	0.61	0.04	0.06
CCGR-1	Cottonwood Creek	0.00	0.61	0.73	1.19
CCGR-2	Cottonwood Creek	0.61	0.92	0.51	0.55
CCGR-3	Cottonwood Creek	1.53	0.80	0.15	0.19
CCGR-4	Cottonwood Creek	2.33	0.40	0.00	0.00
CCGR-5	Cottonwood Creek	2.73	0.50	0.15	0.31
CC-1	Cougar Creek	0.00	0.67	0.31	0.47
CC-2	Cougar Creek	0.67	0.49	0.10	0.20
CC-3	Cougar Creek	1.16	0.31	0.00	0.00
MC-1	Menatchee Creek	0.00	0.34	0.33	0.97
MC-2	Menatchee Creek	0.34	0.42	0.40	0.95

Table C-7
Tributary Road Encroachment Statistics

Project Area	Tributary	RM Start	Length (RM)	Road Encroachment Length (mi)	Road Encroachment Length per RM (mi/rm)
CJC-1	Cottonwood Creek	0.00	0.62	0.37	0.59
CJC-2	Cottonwood Creek	0.62	0.31	0.00	0.01
SC-1	Shumaker Creek	0.00	0.32	0.20	0.63
DC-1	Deer Creek	0.00	0.27	0.00	0.00
DC-2	Deer Creek	0.27	0.70	0.00	0.00
BC-1	Buford Creek	0.00	0.29	0.05	0.17
BC-2	Buford Creek	0.29	0.68	0.66	0.96
BC-3	Buford Creek	0.97	1.13	1.01	0.89
BC-4	Buford Creek	2.10	1.06	0.19	0.18
WFRC-1	WF Rattlesnake Creek	0.00	0.33	0.30	0.93
WFRC-2	WF Rattlesnake Creek	0.33	0.38	0.29	0.74
WFRC-3	WF Rattlesnake Creek	0.71	0.46	0.09	0.20
WFRC-4	WF Rattlesnake Creek	1.17	0.56	0.45	0.80
WFRC-5	WF Rattlesnake Creek	1.73	0.61	0.36	0.59
CCGR-1	Cottonwood Creek	0.00	0.61	0.00	0.00
CCGR-2	Cottonwood Creek	0.61	0.92	0.00	0.00
CCGR-3	Cottonwood Creek	1.53	0.80	0.00	0.00
CCGR-4	Cottonwood Creek	2.33	0.40	0.00	0.00
CCGR-5	Cottonwood Creek	2.73	0.50	0.00	0.00
CC-1	Cougar Creek	0.00	0.67	0.35	0.52
CC-2	Cougar Creek	0.67	0.49	0.32	0.64
CC-3	Cougar Creek	1.16	0.31	0.00	0.00
MC-1	Menatchee Creek	0.00	0.34	0.00	0.00
MC-2	Menatchee Creek	0.34	0.42	0.00	0.00

Table C-8
Tributary Bank Incision Statistics

Project Area	Tributary	RM Start	Length (RM)	Bank Incision Length (mi)	Bank Incision Length per RM (mi/rm)
CJC-1	Cottonwood Creek	0.00	0.62	0.37	0.59
CJC-2	Cottonwood Creek	0.62	0.31	0.03	0.10
SC-1	Shumaker Creek	0.00	0.32	0.30	0.93
DC-1	Deer Creek	0.00	0.27	0.15	0.56
DC-2	Deer Creek	0.27	0.70	0.13	0.19
BC-1	Buford Creek	0.00	0.29	0.20	0.68
BC-2	Buford Creek	0.29	0.68	0.39	0.57
BC-3	Buford Creek	0.97	1.13	0.87	0.77
BC-4	Buford Creek	2.10	1.06	1.03	0.98
WFRC-1	WF Rattlesnake Creek	0.00	0.33	0.10	0.30
WFRC-2	WF Rattlesnake Creek	0.33	0.38	0.05	0.13
WFRC-3	WF Rattlesnake Creek	0.71	0.46	0.06	0.14
WFRC-4	WF Rattlesnake Creek	1.17	0.56	0.16	0.29
WFRC-5	WF Rattlesnake Creek	1.73	0.61	0.13	0.20
CCGR-1	Cottonwood Creek	0.00	0.61	0.07	0.12
CCGR-2	Cottonwood Creek	0.61	0.92	0.31	0.34
CCGR-3	Cottonwood Creek	1.53	0.80	0.47	0.59
CCGR-4	Cottonwood Creek	2.33	0.40	0.00	0.00
CCGR-5	Cottonwood Creek	2.73	0.50	0.19	0.37
CC-1	Cougar Creek	0.00	0.67	0.17	0.25
CC-2	Cougar Creek	0.67	0.49	0.19	0.38
CC-3	Cougar Creek	1.16	0.31	0.04	0.13
MC-1	Menatchee Creek	0.00	0.34	0.11	0.34
MC-2	Menatchee Creek	0.34	0.42	0.19	0.44

1.2.3 Mainstem

Table C-9 presents similar channel statistics for the four mainstem reaches while Table C-10 shows levee and encroachment data for the mainstem. No bank incision segments were delineated in the mainstem because the mainstem is naturally systemically incised. Reaches MS-1 and MS-4 have more influences from roads and levees while MS-2 and MS-3 are more remote.

Table C-9
Mainstem Channel Data

Mainstem Reach	RM Start	River Length (mi)	Valley Length (mi)	Sinuosity	Average Channel Slope
MS-1	0.00	4.83	4.56	1.06	0.30%
MS-2	4.83	11.03	10.37	1.06	0.30%
MS-3	15.86	10.69	10.16	1.05	0.30%
MS-4	26.55	12.64	12.01	1.05	0.33%

Table C-10
Mainstem Levees and Road Encroachments

Mainstem Reach	RM Start	Length (RM)	Levee Length (mi)	Levee Length per RM (mi/rm)	Road Encroachment Length (mi)	Road Encroachment Length per RM (mi/rm)
MS-1	0.00	4.83	0.44	0.09	2.64	0.55
MS-2	4.83	11.03	0.00	0.00	1.75	0.16
MS-3	15.86	10.69	0.22	0.02	2.05	0.19
MS-4	26.55	12.64	1.56	0.12	5.22	0.41

Tables C-11 and C-12 show results from the inundation analysis on the mainstem. Because the mainstem project areas are so large, utility of this data is limited since the mainstem was prioritized based on individual restoration sites. The data shows that available floodplain tends to increase with downstream distance, and the MS-3 reach has the least potential floodplain connectivity.

Table C-11
Modeled Inundation at 1-year to 25-year Flow Events

Mainstem Reach	RM Start	Length (RM)	Inundated Area per RM (ac/rm)				
			1-year	2-year	5-year	10-year	25-year
MS-1	0.00	4.83	31.1	38.9	43.1	46.2	50.0
MS-2	4.83	11.03	32.8	38.2	40.7	42.4	44.4
MS-3	15.86	10.69	29.9	34.3	36.3	37.8	39.9
MS-4	26.55	12.64	28.6	34.0	36.6	38.3	41.2

Table C-12
Increase in Inundated Area from the 1-year inundated Area

Mainstem Reach	RM Start	Length (RM)	Increase in Inundated Area per RM (ac/rm)			
			2-year	5-year	10-year	25-year
MS-1	0.00	4.83	7.8	12.0	15.2	18.9
MS-2	4.83	11.03	5.3	7.8	9.6	11.6
MS-3	15.86	10.69	4.5	6.4	7.9	10.1
MS-4	26.55	12.64	5.4	8.0	9.7	12.6

Appendix D
Mainstem Reaches

LIST OF MAINSTEM REACHES

Mainstem Grande Ronde 1

Mouth to Narrows

Tier 1 Sites: Island Complex RM 3.6-3.9
Tier 2 Sites: Island Complex RM 3.2-3.3,
Wild Steelhead Coalition Property,
Island RM 1.6-1.7
Tier 3 Sites: Island RM 0.9-1.0,
Joseph Creek Beach

Mainstem Grande Ronde 2

Narrows to Shumaker Creek

Tier 1 Sites: N/A
Tier 2 Sites: Island RM 6.6-6.9,
Myers Creek Site
Tier 3 Sites: Island RM 8.2-8.4,
Beach RM 11.9-12.1

Mainstem Grande Ronde 3

Shumaker Creek to Rattlesnake Creek

Tier 1 Sites: Buford Creek Mouth and Island,
Island Complex RM 24.5-24.6,
Island Complex RM 25.1-25.4
Tier 2 Sites: N/A
Tier 3 Sites: Island RM 17.0-17.2,
Shumaker Take Out Gravel Bar,
Deer Creek Mouth and Bar,
Shumaker Creek Mouth,
Gravel Bar RM 23.9-24.1

Mainstem Grande Ronde 4

Rattlesnake Creek to Oregon Border

Tier 1 Sites: Gravel Bar RM 36.7-36.9,
4-0 Land and Livestock Ranch and Island,
Cottonwood Creek Mouth,
Island RM 29.9-30.1,
Beach RM 31.9-32.1,
McNeill Island RM 33.5-33.6
Tier 2 Sites: Cougar Creek Mouth,
Beach RM 27.0-27.3,
Menatchee Creek Mouth
Tier 3 Sites: N/A

ABBREVIATIONS

LWM	large woody material
mi	mile
RM	river mile

Mainstem Grande Ronde 1 Reach

Reach Description

The Mainstem Grande Ronde 1 reach runs from the confluence with the Snake River 4.83 river miles upstream past the confluence with Joseph Creek to just above the rapids known as the "Narrows." Joseph Creek is the major tributary in this project area and enters at river mile (RM) 4.4 on the right bank. This reach is bordered by roads and is surrounded by a residential area near the river's mouth. The entire reach was surveyed by vehicle and foot.

Floodplain and Riparian Area

Primary land use in the reach is residential and agricultural, and there are also multiple recreational fishing access lots in the floodplain. The river is unconfined for most of the project area, but the channel is essentially locked in place due to the surrounding bedrock geology. Roads, a bridge, and a single agricultural levee are the major encroachments on the floodplain. Riparian vegetation is sparse to non-existent throughout the floodplain. This is due to the large open valley, which sees full sun in the summertime. The floodplain is entirely basaltic bedrock at the upstream end by the Narrows. Further downstream, the floodplain is dominated by large unvegetated bars composed of large cobble-sized substrate. Residences are scattered along the left bank further downstream but appear to be outside the active floodplain.

Mainstem Grande Ronde 1

Vicinity Map

Reach Characteristics

River	Grande Ronde River
Parent River	Snake River
River Distance to Confluence (mi)	0.00
Valley Distance to Confluence (mi)	0.00
River Length (mi)	4.83
Valley Length (mi)	4.56
Sinuosity	1.06
Average Slope	0.30%
Delineated Restoration Sites	6
Total Levee/Road Encroachment (mi)	3.08
Notable Tributaries	Joseph Creek

Channel Conditions

Channel complexity is moderate in this project area, and there are at least six low-lying island or gravel bar sites within the reach. Stream power is extremely high through the Narrows as the entire discharge is conveyed through a channel no more than 10 to 20 feet wide. This entire bedrock portion is scoured clean of sediment, and there are a couple of very deep bedrock pools at the foot of the Narrows. All sediment transported through the Narrows and exiting the Joseph Creek basin is deposited in large gravel bars and islands downstream. These islands are sparsely vegetated by willows and other shrubs. There is another rapid emptying into a pool just upstream of the Joseph Creek Road bridge. The remainder of the project area downstream follows a run-riffle sequence before the river's confluence with the Snake River. No wood accumulation was observed within the reach.

Influencing Anthropogenic Features

Anthropogenic features in this reach include roads and residences in or near the floodplain, an agricultural field and its associated levee, and one major bridge. Of these features, the agricultural levee at RM 3.7 has the most significant impact on floodplain connectivity, isolating a substantial piece of disconnected left bank floodplain. Joseph Creek Road is well above the floodplain, but Snake River Road and Rogersburg Road function as floodplain encroachments in multiple locations. While these sections of road are not acting as levees by disconnecting low-lying floodplain from the river, the road surface and associated riprap banks constrict the available channel width of the river. There are no significant residential levees, but a small wall or levee on the left bank at RM 0.8 acts as the boundary between the channel migration area and private residences. The only bridge is on the Snake River Road at RM 2.8 and likely influences geomorphic processes through floodplain constriction, hydraulic backwater, and sediment transport continuity.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. The following restoration actions will be prioritized for the reaches in the mainstem. Details and specific sites where these restoration actions might be applied are provided in the next section.

Stabilize Existing Islands and Beaches

Many low-lying islands and gravel bars or "beaches" are scattered throughout the mainstem Grande Ronde. The entire mainstem tends to follow a pattern of alternating riffles and deep runs or pools, often spaced at half-mile or greater intervals due to the large meander length of the river. While the deeper pools and runs lack complexity, islands and gravel bars are present in the riffles promoting split flow and complexity. Few of these islands are occupied by mature trees due to their frequent inundation during floods, and by the destructive forces of winter ice flows. Some exemplary islands exist, such as McNeill Island in the Mainstem Grande Ronde 4 reach that is a few feet higher than the other islands and has established ponderosa pines. Stable islands like these are critical to salmonid habitat because trees within the channel can help provide some shade and cover. Stable islands also provide hydraulic refuge and ideal feeding locations for salmonids and increase the percent of shallow edge habitat per river mile, benefiting juveniles.

Log structures such as pile fields could be placed at the head of existing low-lying islands and gravel bars to promote aggradation and establish mature vegetation. Installed wood features will need to be robust to withstand the destructive forces of floods and ice flows on these exposed islands with no existing hard points. In the Mainstem Grande Ronde 1 reach where summer water temperatures allow invasive bass and other predatory warmwater species to thrive, the primary benefit of the pile fields to salmonids would be during the short migration period. The costs and benefits should be considered for constructing projects on this section of the mainstem when projects further upstream could benefit more life stages of salmonids.

Collect Large Wood

Instream wood in the mainstem Grande Ronde is limited because the surrounding hillsides are mostly vegetated with grasses and shrubs. There is also very little floodplain area due to the surrounding basaltic geology. As a result, trees that rely on periodic floodplain inundation such as alders and cottonwoods scarcely exist along the mainstem. Despite this, some accumulations of wood were observed during the survey of the mainstem. Large wood in the mainstem was often trapped along cliffs and in rocky outcroppings, and the wood was often 5 to 10 feet above the low-flow water surface, indicating the magnitude of the flow event needed to transport significant wood in the Grande Ronde basin.

One possible remedy for the lack of wood in the mainstem Grande Ronde is to build pile fields on islands that are designed to trap smaller woody material and develop large log jams. These structures would need to be tall enough to interact with wood during the large flood events that transport it. Piles would need to be driven deep enough to withstand these floods.

Establish Riparian Vegetation

Very little mature vegetation inhabits the banks of the mainstem. Riparian vegetation has been shown to be critical to ecological and geomorphic processes. Vegetation is critically needed to provide a renewable and constant source of instream wood, as well as to provide overhanging cover and shade. Little suitable habitat for trees exists in the mainstem that is out of the path of destructive floods and ice flows but low enough to be periodically inundated and allow roots to tap into the floodplain aquifer.

Establishing mature stands of vegetation in the immediate riparian area and channel migration areas should be a restoration target for the mainstem. Restoration actions should target establishing vegetated gravel bars and may require stabilizing features pile fields or wood collecting features. Additionally, riparian planting efforts should seek to establish stands of riparian species in locations of low-lying floodplain. Finally, some agricultural grazing is present in the mainstem and is likely detrimental to the establishment of riparian vegetation. Grazing exclusions should be considered as part of any vegetation-focused restoration actions.

Tier 1

Restoration Sites in the Mainstem Grande Ronde 1

Island Complex RM 3.6-3.9

River Mile Start	3.6
River Mile Stop	3.9
River Length (mi)	0.3
Est. Vegetation and Large Wood	4/5
Promote Complexity/Connectivity	5/5
Summer Water Temperature	1/5
Fish Life Stage Benefit	2/5
Ease of Access	4/5

Recommended Restoration Actions

- Wood collecting features to stabilize islands
- Riparian planting on islands

Tier 2

Restoration Sites in the Mainstem Grande Ronde 1

Island Complex RM 3.2-3.3

River Mile Start	3.2
River Mile Stop	3.3
River Length (mi)	0.1
Est. Vegetation and Large Wood	4/5
Promote Complexity/Connectivity	3/5
Summer Water Temperature	1/5
Fish Life Stage Benefit	2/5
Ease of Access	4/5

Recommended Restoration Actions

- Pile field and wood collecting features to stabilize islands and promote split flow
- Riparian planting on islands

Wild Steelhead Coalition Property

Source: Google Earth 2020

River Mile Start	1.9
River Mile Stop	2.3
River Length (mi)	0.4
Est. Vegetation and Large Wood	3/5
Promote Complexity/Connectivity	2/5
Summer Water Temperature	1/5
Fish Life Stage Benefit	2/5
Ease of Access	5/5

Recommended Restoration Actions

- Wood collecting features to stabilize island and promote split flow
- Riparian planting on islands and left bank

Island RM 1.6-1.7

Source: Google Earth 2020

River Mile Start	1.6
River Mile Stop	1.7
River Length (mi)	0.1
Est. Vegetation and Large Wood	3/5
Promote Complexity/Connectivity	2/5
Summer Water Temperature	1/5
Fish Life Stage Benefit	2/5
Ease of Access	4/5

Recommended Restoration Actions

- Wood collecting features to promote split flow and habitat in right side channel
- Riparian planting on island

Tier 3

Restoration Sites in the Mainstem Grande Ronde 1

Island RM 0.9-1.0

Source: Google Earth 2020

River Mile Start	0.9
River Mile Stop	1.0
River Length (mi)	0.1
Est. Vegetation and Large Wood	3/5
Promote Complexity/Connectivity	2/5
Summer Water Temperature	1/5
Fish Life Stage Benefit	2/5
Ease of Access	3/5

Recommended Restoration Actions

- Wood collecting features to stabilize and help vegetate island
- LWM to establish channel migration boundary between residences and floodplain

Joseph Creek Beach

Source: Google Earth 2020

River Mile Start	4.0
River Mile Stop	4.4
River Length (mi)	0.4
Est. Vegetation and Large Wood	1/5
Promote Complexity/Connectivity	2/5
Summer Water Temperature	1/5
Fish Life Stage Benefit	2/5
Ease of Access	4/5

Recommended Restoration Actions

- Wood collecting features to promote split flow into right floodplain
- Riparian planting

Mainstem Grande Ronde 2 Reach

Reach Description

The Mainstem Grande Ronde 2 reach runs from just upstream of the rapids known as the "Narrows" 11.03 river miles upstream to the mouth of Shumaker Creek. Slippery Creek and Myers Creek are the only tributaries in this reach and enter the mainstem on the left bank at RM 10.1 and 13.8, respectively. These creeks are not a part of the assessment. Some dirt roads border the river in this reach, and it flows through a remote section of the valley with only a few agricultural fields at the downstream end. The entire reach was surveyed by boat. Ease of access presents a primary challenge to restoration in this reach.

Floodplain and Riparian Area

The only land use in this reach is an estate and its associated agricultural fields on the right bank in the lower portion of the reach. Some dirt roads border the river in the upper and lower portions of the reach, but the river is unconfined for most of the reach. Pockets of riparian vegetation are observed near the confluence with Myers Creek, but floodplain vegetation is generally scarce. Typically, more vegetation can be observed along the north-facing right bank, especially where steep cliffs provide some shade for scattered ponderosa pines. Gradually sloping hillsides on both banks are more exposed to sun and exhibit a savanna-like biome. There are several floodplain

Mainstem Grande Ronde 2
Vicinity Map

Reach Characteristics

River	Grande Ronde River
Parent River	Snake River
River Distance to Confluence (mi)	4.83
Valley Distance to Confluence (mi)	4.56
River Length (mi)	11.03
Valley Length (mi)	10.37
Sinuosity	1.06
Average Slope	0.30%
Delineated Restoration Sites	4
Total Levee/Road Encroachment (mi)	1.75
Notable Tributaries	Slippery Creek Myers Creek

beaches in the lower half of the reach that provide opportunities to help establish more riparian vegetation.

Channel Conditions

Channel complexity is low in this reach, and there are four low-lying gravel bar sites that may act as islands at high flow. This entire section is characterized by shallow riffles and rapids that empty into deep pools formed at the base of sheer cliffs on the outer edge of bends. These pools can be up to 25 feet deep in sections. Each pool is typically followed by a long, deep run. In multiple occasions, flow velocity was so low in these runs that they behaved as lakes. Predatory warmwater species such as smallmouth bass and northern pikeminnow abounded in these stagnant sections. Some wood accumulation was observed in the project area, especially wedged into cliffs and outcroppings, but no observed wood was interacting with the river during summer low flow. High summer water temperatures are likely a primary limiting factor in this reach.

Influencing Anthropogenic Features

A dirt access road follows the river on the right bank for the lower 4 river miles of the reach, but the access road remains above the floodplain for most of its length. This road provides access to a single estate on a property with both irrigated and dry agricultural fields. Another dirt access road at the upstream end connects Shumaker Road to a gravel fishing access lot within the floodplain near the mouth of Myers Creek. This gravel lot is located within one of the only pockets of riparian vegetation in the reach. There are no other levees or structures interacting with the river in this reach.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. The following restoration actions will be prioritized for the reaches in the mainstem. Details and specific sites where these restoration actions might be applied are provided in the next section.

Stabilize Existing Islands and Beaches

Many low-lying islands and gravel bars or “beaches” are scattered throughout the mainstem Grande Ronde. In the Mainstem Grande Ronde 2 reach, there are four primary gravel bar sites that act as islands during high flow events. While the deeper pools and runs in this reach lack complexity, gravel bars are present in the riffles and can be stabilized to promote split flow and side channel development. Few of these islands are occupied by mature trees due to their frequent inundation during floods, and by the destructive forces of winter ice flows. Two islands in the Mainstem Grande Ronde 2 reach have begun to establish vegetation, including ponderosa pines, but remain connected to the banks by a gravel bar during low flow. Restoration could help develop the side channels and promote year-round split flow. Stabilizing these islands would help provide shade and cover to the channel. Stable islands also provide hydraulic refuge and ideal feeding locations for salmonids and increase the percent of shallow edge habitat per river mile, benefiting juveniles.

Log structures such as pile fields could be placed at the head of existing low-lying islands and gravel bars to promote aggradation and establish mature vegetation. Installed wood features will need to be robust to withstand the destructive forces of floods and ice flows on these exposed islands with no existing hard points. In the Mainstem Grande Ronde 2 reach where summer water temperatures allow invasive bass and other predatory warmwater species to thrive, the primary benefit of the pile fields to salmonids would be during the short migration period. The costs and benefits should be considered for constructing projects on this section of the mainstem when projects further upstream could benefit more life stages of salmonids. Ease of access also presents a major challenge to implementing any projects in this reach.

Collect Large Wood

Instream wood in the mainstem Grande Ronde is limited because the surrounding hillsides are mostly vegetated with grasses and shrubs. There is also very little floodplain area due to the surrounding basaltic geology. As a result, trees that rely on periodic floodplain inundation such as alders and cottonwoods scarcely exist along the mainstem. Despite this, some accumulations of wood were observed in the Mainstem Grande Ronde 2 reach. Large wood was trapped along cliffs and in rocky outcroppings, and the wood was often 5 to 10 feet above the low-flow water surface, indicating the magnitude of the flow event needed to transport significant wood in the Grande Ronde basin.

One possible remedy for the lack of wood in the mainstem Grande Ronde is to build pile fields on islands that are designed to trap smaller woody material and develop large log jams. As with island stabilization, these structures would need to be extremely robust, and would need to be tall enough to interact with wood during the large flood events that transport it. These structures should be strategically placed in flow paths where wood could accumulate, and in areas where alluvium depth is adequate for pile driving.

Establish Riparian Vegetation

Very little mature vegetation inhabits the banks of the mainstem. Riparian vegetation has been shown to be critical to ecological and geomorphic processes. Vegetation is critically needed to provide a renewable and constant source of instream wood, as well as to provide overhanging cover and shade. Little suitable habitat for trees exists in the mainstem that is out of the path of destructive floods and ice flows but low enough to be periodically inundated and allow roots to tap into the floodplain aquifer.

Establishing mature stands of vegetation in the immediate riparian area and channel migration areas should be a restoration target for this reach. Restoration actions should target establishing vegetated gravel bars and may require stabilizing features such as wood collecting features. Riparian planting efforts should seek to establish stands of riparian species in locations of low-lying floodplain in conjunction with gravel bar stabilization efforts. Finally, some agricultural grazing is present within this reach and is likely detrimental to the establishment of riparian vegetation. Grazing exclusions should be considered as part of any vegetation-focused restoration actions.

Tier 2

Restoration Sites in the Mainstem Grande Ronde 2

Island RM 6.6-6.9

Source: Google Earth 2020

River Mile Start	6.6
River Mile Stop	6.9
River Length (mi)	0.3
Est. Vegetation and Large Wood	4/5
Promote Complexity/Connectivity	4/5
Summer Water Temperature	1/5
Fish Life Stage Benefit	2/5
Ease of Access	1/5

Recommended Restoration Actions

- Wood collecting feature to promote split flow and stabilize island
- Riparian planting on island
- LWM additions to side channel

Myers Creek Site

River Mile Start	14.0
River Mile Stop	14.6
River Length (mi)	0.6
Est. Vegetation and Large Wood	3/5
Promote Complexity/Connectivity	3/5
Summer Water Temperature	2/5
Fish Life Stage Benefit	2/5
Ease of Access	3/5

Recommended Restoration Actions

- Pile field to collect wood and create large jam
- Riparian planting

Tier 3

Restoration Sites in the Mainstem Grande Ronde 2

Island RM 8.2-8.4

River Mile Start	8.2
River Mile Stop	8.4
River Length (mi)	0.2
Est. Vegetation and Large Wood	4/5
Promote Complexity/Connectivity	3/5
Summer Water Temperature	1/5
Fish Life Stage Benefit	2/5
Ease of Access	1/5

Recommended Restoration Actions

- Wood collecting features to stabilize island
- Riparian planting on island
- LWM additions to side channel

Beach RM 11.9-12.1

Source: Google Earth 2020

River Mile Start	11.9
River Mile Stop	12.1
River Length (mi)	0.2
Est. Vegetation and Large Wood	2/5
Promote Complexity/Connectivity	2/5
Summer Water Temperature	1/5
Fish Life Stage Benefit	2/5
Ease of Access	1/5

Recommended Restoration Actions

- Wood collecting feature on gravel bar
- Riparian planting

Mainstem Grande Ronde 3 Reach

Reach Description

The Mainstem Grande Ronde 3 reach runs from the mouth of Shumaker Creek 10.69 river miles upstream to the Highway 129 bridge at Rattlesnake Creek. Four main tributaries enter the mainstem in this reach. In addition to Shumaker and Rattlesnake creeks at the downstream and upstream boundaries, Deer Creek enters on the right bank at RM 19.5, and Buford Creek enters at RM 25.9 on the right bank. The reach is bordered by dirt roads at the upstream and downstream ends, but most of the reach is remote, making access for restoration projects limited. The entire reach was surveyed by boat.

Floodplain and Riparian Area

The floodplain and surrounding area in this reach is either ranchland or open public land. Some dirt roads encroach on the floodplain in this reach, but the majority of the reach is unconfined. Riparian vegetation is sparse through this reach, and congregated in pockets along steep cliffs on the north-facing right bank. Few gravel bars and islands within this reach have established vegetation. Outside of barren gravel bars, the floodplain is limited as the river flows through a narrow, steeper-walled canyon than the other mainstem reaches. Large alluvial fans were present at the mouths of Buford and Deer creeks, and about 10 feet of gravel bar separated the creek bed

Mainstem Grande Ronde 3
Vicinity Map

Reach Characteristics

River	Grande Ronde River
Parent River	Snake River
River Distance to Confluence (mi)	15.86
Valley Distance to Confluence (mi)	14.92
River Length (mi)	10.69
Valley Length (mi)	10.16
Sinuosity	1.05
Average Slope	0.30%
Delineated Restoration Sites	8
Total Levee/Road Encroachment (mi)	2.27
Notable Tributaries	
Shumaker Creek	Buford Creek
Deer Creek	Rattlesnake Creek

from the mainstem water surface at low flow. These gravel bars were composed of very large cobble-sized to small boulder-sized substrate.

Channel Conditions

Channel complexity is moderate in this project area, and there are at least eight low-lying island or gravel bar sites within the reach. Multiple island complexes are located in the vicinity of the Buford Creek mouth at the upstream end of the reach. Split flow was observed during low-flow conditions through these island features. The same pattern of rapids emptying into deep pools forced by sheer cliffs continues in this reach. The frequency of rapids and riffles is greater in this reach compared to the Mainstem Grande Ronde 2 reach, and fewer low velocity runs exist. Two large woody material jams were lodged in bedrock outcroppings in this reach. The largest jam was just downstream of Deer Creek on river right and spanned the entrance to a high-flow channel in a bedrock opening. The observed jams were both a few feet above the low-flow water surface.

Influencing Anthropogenic Features

Anthropogenic features in this reach include dirt roads and recreational access lots, a livestock operation in floodplain, and the Highway 129 road and bridge. Shumaker Road borders the left bank for about 2.5 miles upstream of Shumaker Creek, and represents an encroachment on the floodplain for most of this length. There is a livestock operation in the left floodplain just downstream of Buford Creek, and a bank stabilization project composed of logs and boulders lines the left bank protecting this property. The only bridge in the reach is the Highway 129 bridge at the downstream boundary and has some effect on floodplain constriction.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. The following restoration actions will be prioritized for the reaches in the mainstem. Details and specific sites where these restoration actions might be applied are provided in the next section.

Stabilize Existing Islands and Beaches

Low-lying islands and gravel bars or "beaches" are prevalent in the upper and lower sections of the Mainstem Grande Ronde 3 reach. These islands and gravel bars are present in the riffles promoting split flow and complexity. Few of these islands are occupied by mature trees due to their frequent inundation during floods, and by the destructive forces of winter ice flows. A few of the islands observed in the Mainstem Grande Ronde 3 reach had mature vegetation, while some were completely barren and barely above the low-flow water surface. Stabilizing these islands and promoting aggradation can help establish vegetation to provide some shade and cover. Stable islands also provide hydraulic refuge and ideal feeding locations for salmonids and increase the percent of shallow edge habitat per river mile, benefiting juveniles.

Log structures such as pile fields could be placed at the head of existing low-lying islands and gravel bars to promote aggradation and establish mature vegetation. Installed wood features will need to be robust to withstand the destructive forces of floods and ice flows on these exposed islands with no existing hard points. The Mainstem Grande Ronde 3 reach is the transition where summer water temperatures are at the tolerable limit for salmonids. Invasive warmwater species like smallmouth bass and common carp were abundant in this reach. The primary benefit of restoration to salmonids in this reach would be during the short migration period. The middle section and the Deer Creek tributary are difficult to access for potential restoration projects.

Collect Large Wood

Instream wood in the mainstem Grande Ronde is limited because the surrounding hillsides are mostly vegetated with grasses and shrubs. There is also very little floodplain area due to the surrounding basaltic geology. As a result, trees that rely on periodic floodplain inundation such as alders and cottonwoods scarcely exist along the mainstem. The Mainstem Grande Ronde 3 reach had the largest naturally occurring jams in the mainstem. Large wood jams were wedged into bedrock, and the wood was 3 to 4 feet above the low-flow water surface. These wood accumulations occurred in hard points at the outside of bends, and future wood accumulation projects should be targeted in similar areas.

One possible remedy for the lack of wood in the mainstem Grande Ronde is to build pile fields on islands that are designed to trap smaller woody material and develop large log jams. As with island stabilization, these structures would need to be extremely robust, and would need to be tall enough to interact with wood during the large flood events that transport it.

Improve Fish Passage Connection from Mainstem to Tributaries

One impediment to fish use of mainstem tributaries is the large change in bed elevation between the tributary mouths and the mainstem. This was observed in several tributaries in this reach, most notably at the mouths of Buford and Deer creeks. These smaller tributaries were either dry or scarcely flowing during the summer survey. There were dry gravel bars with about 10 feet in elevation between the creek bed and the mainstem water surface. These smaller tributaries seemed to only be accessible by returning spawners during high-flow events. Because spring spawning steelhead are the primary targeted species in the basin, it is likely that the connection to the tributaries is made during the spring freshet. Prolonging the duration of this connection would help diversify run timing and provide juveniles a longer window to grow in the tributaries before outmigration.

Possible solutions to this problem include placing wood structures at the creek mouth to develop a more passable flow path and restoration actions in the tributaries to try to increase baseflow. Logs could be used to construct a natural fish ladder analog, forming step pools or weir like structures that would allow fish to ascend these gravel bars. The challenge with this would be designing a lasting structure in a zone of high sediment transport. Additionally, an increase in base discharge in the tributaries would help maintain a more defined channel through these gravel bars. Restoration actions like engineered log jams and beaver dam analogs in the tributaries could help store more water in the tributary floodplains to provide more consistent flow during the dry months.

Establish Riparian Vegetation

Very little mature vegetation inhabits the banks of the mainstem. Riparian vegetation has been shown to be critical to ecological and geomorphic processes. Vegetation is critically needed to provide a renewable and constant source of instream wood, as well as to provide overhanging cover and shade. Little suitable habitat for trees exists in the mainstem that is out of the path of destructive floods and ice flows but low enough to be periodically inundated and allow roots to tap into the floodplain aquifer.

Establishing mature stands of vegetation in the immediate riparian area and channel migration areas should be a restoration target for the mainstem. Restoration actions should target establishing vegetated gravel bars and may require stabilizing features such as wood collecting features. Additionally, riparian planting efforts should seek to establish stands of riparian species in locations of low-lying floodplain. Finally, some agricultural grazing is present in the mainstem and is likely detrimental to the establishment of riparian vegetation. Grazing exclusions should be considered as part of any vegetation-focused restoration actions.

Tier 1

Restoration Sites in the Mainstem Grande Ronde 3

Buford Creek Mouth and Island

River Mile Start	25.9
River Mile Stop	26.3
River Length (mi)	0.4
Est. Vegetation and Large Wood	4/5
Promote Complexity/Connectivity	4/5
Summer Water Temperature	3/5
Fish Life Stage Benefit	3/5
Ease of Access	4/5

Recommended Restoration Actions

- Wood collecting features to stabilize island and promote split flow
- Improve tributary fish passage connection
- Riparian planting on islands

Island Complex RM 24.5-24.6

River Mile Start	24.5
River Mile Stop	24.6
River Length (mi)	0.1
Est. Vegetation and Large Wood	4/5
Promote Complexity/Connectivity	4/5
Summer Water Temperature	3/5
Fish Life Stage Benefit	3/5
Ease of Access	3/5

Recommended Restoration Actions

- Pile field to stabilize islands and promote establishment of vegetation
- Riparian planting on islands

Island Complex RM 25.1-25.4

River Mile Start	25.1
River Mile Stop	25.4
River Length (mi)	0.3
Est. Vegetation and Large Wood	3/5
Promote Complexity/Connectivity	4/5
Summer Water Temperature	3/5
Fish Life Stage Benefit	3/5
Ease of Access	4/5

Recommended Restoration Actions

- Pile field to stabilize islands and promote aggradation
- Riparian planting on islands and left floodplain

Tier 3

Restoration Sites in the Mainstem Grande Ronde 3

Island RM 17.0-17.2

River Mile Start	17.0
River Mile Stop	17.2
River Length (mi)	0.2
Est. Vegetation and Large Wood	2/5
Promote Complexity/Connectivity	2/5
Summer Water Temperature	2/5
Fish Life Stage Benefit	2/5
Ease of Access	3/5

Recommended Restoration Actions

- Wood collection feature on island
- Riparian planting on island
- LWM along road bank to provide cover

Shumaker Take Out Gravel Bar

River Mile Start	17.7
River Mile Stop	18.0
River Length (mi)	0.3
Est. Vegetation and Large Wood	2/5
Promote Complexity/Connectivity	2/5
Summer Water Temperature	2/5
Fish Life Stage Benefit	2/5
Ease of Access	3/5

Recommended Restoration Actions

- Wood collecting features to promote split flow and help vegetate gravel bars
- Riparian planting

Deer Creek Mouth and Bar

River Mile Start	19.5
River Mile Stop	19.7
River Length (mi)	0.2
Est. Vegetation and Large Wood	3/5
Promote Complexity/Connectivity	3/5
Summer Water Temperature	2/5
Fish Life Stage Benefit	2/5
Ease of Access	1/5

Recommended Restoration Actions

- Improve tributary fish passage connection
- Wood collecting features to promote split flow into right floodplain

Tier 3

Restoration Sites in the Mainstem Grande Ronde 3

Shumaker Creek Mouth

Source: Google Earth 2020

River Mile Start	15.8
River Mile Stop	15.9
River Length (mi)	0.1
Est. Vegetation and Large Wood	2/5
Promote Complexity/Connectivity	1/5
Summer Water Temperature	2/5
Fish Life Stage Benefit	2/5
Ease of Access	3/5

Recommended Restoration Actions

- Improve tributary fish passage connection
- Wood collecting features along left bank to promote flow structure complexity

Gravel Bar RM 23.9-24.1

River Mile Start	23.9
River Mile Stop	24.1
River Length (mi)	0.2
Est. Vegetation and Large Wood	2/5
Promote Complexity/Connectivity	1/5
Summer Water Temperature	3/5
Fish Life Stage Benefit	3/5
Ease of Access	1/5

Recommended Restoration Actions

- Wood collecting features to promote split flow into floodplain
- Riparian planting

Mainstem Grande Ronde 4 Reach

Reach Description

The Mainstem Grande Ronde 4 reach runs from the Highway 129 bridge 12.64 river miles upstream to the Oregon border. Three main tributaries enter on the left bank in the reach. Cottonwood Creek, Cougar Creek, and Menatchee Creek enter the mainstem at RM 28.9, 30.9, and 36.2, respectively. The entire reach is bordered by the Grande Ronde Road on the left bank. Some private residences and ranches are scattered throughout the reach. The entire reach was surveyed by vehicle and foot.

Floodplain and Riparian Area

Primary land use in the reach is residential and agricultural, and there are several residences and homesteads located in the floodplain vicinity. Grande Ronde Road is the primary confining feature and at times acts as a levee disconnecting potential left bank floodplain. Minor levees also protect residences on the right bank just upstream of Boggan's Oasis. Like the rest of the mainstem reaches, the Mainstem Grande Ronde 4 reach has limited floodplain area to enable any channel migration, and dense riparian vegetation is confined to a few islands, gravel bars, and shaded north-facing steep right banks. Riparian planting of ponderosa pines is evident across from the mouth of Cottonwood Creek in the right bank floodplain.

Mainstem Grande Ronde 4

Vicinity Map

Reach Characteristics

River	Grande Ronde River
Parent River	Snake River
River Distance to Confluence (mi)	26.55
Valley Distance to Confluence (mi)	25.08
River Length (mi)	12.64
Valley Length (mi)	12.01
Sinuosity	1.05
Average Slope	0.33%
Delineated Restoration Sites	9
Total Levee/Road Encroachment (mi)	6.79
Notable Tributaries	Cottonwood Creek Cougar Creek Menatchee Creek

Channel Conditions

Channel complexity is moderate in this project area, and there are at least nine low-lying island or gravel bar sites within the reach. The reach followed the same riffle-run pattern as the remainder of the mainstem with deep pools forced by bedrock cliffs. Runs in this reach were shallower than the lower mainstem, and water was cold enough to support salmonids, as mature adult salmonids were observed during the survey. Islands with sustained split flow during summer low flow were observed, and McNeill Island was noted as a model island that was high enough to have established mature ponderosa pines. Expansive exposed gravel bars just upstream of Menatchee Creek represented potential sites to establish an anastomosing channel character by promoting aggradation. Little wood accumulation was observed within the reach.

Influencing Anthropogenic Features

Primary anthropogenic features in the Mainstem Grande Ronde 4 reach include roads, a hatchery acclimation pond, and agricultural infrastructure and residences. The Grande Ronde Road functions as an encroachment that constricts total floodplain width. The road is also lined with riprap in locations where it directly borders the channel. The Cottonwood Creek acclimation pond where hatchery steelhead are released also acts as an encroachment on the floodplain. Houses throughout the reach are largely set back enough to have limited effect on floodplain confinement. A steep bank or levee bordering the ranch at RM 35.1 acts as the channel migration boundary and represents a potential target for bank stabilization in conjunction with potential restoration on the adjacent island. Culverts also pass under the road at each of the tributaries in the reach and likely influence sediment transport and fish passage at the mouths of these tributaries.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. The following restoration actions will be prioritized for the reaches in the mainstem. Details and specific sites where these restoration actions might be applied are provided in the next section.

Stabilize Existing Islands and Beaches

Many low-lying islands and gravel bars or “beaches” are scattered throughout this reach. Islands and gravel bars are present in the riffles and are critical in promoting split flow and complexity. Many large exposed gravel bars were observed in this reach during low flow, and these areas could be targeted to promote aggradation and development of mature vegetation. McNeill Island was a few feet higher than the other islands and has established ponderosa pines. Stable islands like these are critical to salmonid habitat because trees within the channel can help provide some shade and cover. Stable islands also provide hydraulic refuge and ideal feeding locations for salmonids and increase the percent of shallow edge habitat per river mile, benefiting juveniles.

Log structures such as pile fields could be placed at the head of existing low-lying islands and gravel bars to promote aggradation and establish mature vegetation. Installed wood features will need to be robust to withstand the destructive forces of floods and ice flows on these exposed islands with no existing hard points. Restoration projects in the Mainstem 4 reach have the potential to benefit multiple life stages of salmonid because water in this reach is cool enough to support foraging juveniles and holding adults through the summer.

Collect Large Wood

Instream wood in the mainstem Grande Ronde is limited because the surrounding hillsides are mostly vegetated with grasses and shrubs. There is also very little floodplain area due to the surrounding basaltic geology. As a result, trees that rely on periodic floodplain inundation such as alders and cottonwoods scarcely exist along the mainstem. Despite this, some accumulations of wood were observed during the survey of the mainstem. Large wood in the mainstem was often trapped along cliffs and in rocky outcroppings, and the wood was often 5 to 10 feet above the low-flow water surface, indicating the magnitude of the flow event needed to transport significant wood in the Grande Ronde basin.

One possible remedy for the lack of wood in the mainstem Grande Ronde is to build pile fields on islands that are designed to trap smaller woody material and develop large log jams. As with island stabilization, these structures would need to be extremely robust, and would need to be tall enough to interact with wood during the large flood events that transport it.

Improve Fish Passage Connection from Mainstem to Tributaries

Culverts are primary impediments to upstream passage in the three major tributaries in the Mainstem Grande Ronde 4 reach. Culverts influence sediment transport from these tributaries to the mainstem as well. Culvert replacement projects may be already planned for these tributaries. Additionally, an increase in base discharge in the tributaries would help maintain a greater baseflow to allow for a longer fish passage window. Restoration actions like engineered log jams and beaver dam analogs in the tributaries could help store more water in the tributary floodplains to provide more consistent flow for fish passage.

Establish Riparian Vegetation

Very little mature vegetation inhabits the banks of the mainstem. Riparian vegetation has been shown to be critical to ecological and geomorphic processes. Vegetation is critically needed to provide a renewable and constant source of instream wood, as well as to provide overhanging cover and shade. Little suitable habitat for trees exists in the mainstem that is out of the path of destructive floods and ice flows but low enough to be periodically inundated and allow roots to tap into the floodplain aquifer.

Establishing mature stands of vegetation in the immediate riparian area and channel migration areas should be a restoration target for the mainstem. Restoration actions should target establishing vegetated gravel bars and may require stabilizing features such as wood collecting pile fields. Additionally, riparian planting efforts should seek to establish stands of riparian species in locations of low-lying floodplain. Finally, some agricultural grazing is present in this reach and is likely detrimental to the establishment of riparian vegetation. Grazing exclusions should be considered as part of any vegetation-focused restoration actions.

Tier 1

Restoration Sites in the Mainstem Grande Ronde 4

Gravel Bar RM 36.7-36.9

River Mile Start	36.7
River Mile Stop	36.9
River Length (mi)	0.2
Est. Vegetation and Large Wood	3/5
Promote Complexity/Connectivity	4/5
Summer Water Temperature	4/5
Fish Life Stage Benefit	5/5
Ease of Access	4/5

Recommended Restoration Actions

- Wood collecting features to promote aggradation and develop a vegetated island
- Riparian planting

4-0 Land and Livestock Ranch and Island

River Mile Start	34.9
River Mile Stop	35.2
River Length (mi)	0.3
Est. Vegetation and Large Wood	3/5
Promote Complexity/Connectivity	4/5
Summer Water Temperature	4/5
Fish Life Stage Benefit	5/5
Ease of Access	3/5

Recommended Restoration Actions

- Wood collecting feature to promote island aggradation and help develop vegetation
- LWM for bank stabilization along left bank and establishment of channel migration boundary

Cottonwood Creek Mouth

River Mile Start	28.9
River Mile Stop	29.2
River Length (mi)	0.3
Est. Vegetation and Large Wood	3/5
Promote Complexity/Connectivity	3/5
Summer Water Temperature	4/5
Fish Life Stage Benefit	4/5
Ease of Access	4/5

Recommended Restoration Actions

- Pile field to help vegetate islands
- Wood collecting features in side channel to help engage left floodplain
- Culvert replacement at creek mouth

Tier 1

Restoration Sites in the Mainstem Grande Ronde 4

Island RM 29.9-30.1

Source: Google Earth 2020

River Mile Start	29.9
River Mile Stop	30.1
River Length (mi)	0.2
Est. Vegetation and Large Wood	2/5
Promote Complexity/Connectivity	3/5
Summer Water Temperature	4/5
Fish Life Stage Benefit	4/5
Ease of Access	4/5

Recommended Restoration Actions

- Wood collecting feature to promote aggradation and establishment of riparian trees
- LWM along left bank road to provide stabilization and habitat structure

Beach RM 31.9-32.1

River Mile Start	31.9
River Mile Stop	32.1
River Length (mi)	0.2
Est. Vegetation and Large Wood	2/5
Promote Complexity/Connectivity	2/5
Summer Water Temperature	4/5
Fish Life Stage Benefit	4/5
Ease of Access	4/5

Recommended Restoration Actions

- Wood collecting features to promote split flow into right high flow channel
- Riparian planting

McNeill Island RM 33.5-33.6

River Mile Start	33.5
River Mile Stop	33.6
River Length (mi)	0.1
Est. Vegetation and Large Wood	2/5
Promote Complexity/Connectivity	2/5
Summer Water Temperature	4/5
Fish Life Stage Benefit	4/5
Ease of Access	4/5

Recommended Restoration Actions

- Wood collecting features to promote jam development
- LWM along left bank road to provide habitat structure

Tier 2

Restoration Sites in the Mainstem Grande Ronde 4

Cougar Creek Mouth

River Mile Start	30.9
River Mile Stop	31.0
River Length (mi)	0.1
Est. Vegetation and Large Wood	2/5
Promote Complexity/Connectivity	1/5
Summer Water Temperature	4/5
Fish Life Stage Benefit	4/5
Ease of Access	4/5

Recommended Restoration Actions

- Replace culvert to improve fish passage
- LWM to help engage floodplain on both banks

Beach RM 27.0-27.3

Source: Google Earth 2020

River Mile Start	27.0
River Mile Stop	27.3
River Length (mi)	0.3
Est. Vegetation and Large Wood	2/5
Promote Complexity/Connectivity	2/5
Summer Water Temperature	3/5
Fish Life Stage Benefit	4/5
Ease of Access	3/5

Recommended Restoration Actions

- LWM along right bank to establish channel migration boundary between residences and floodplain
- Remove or set back levees where applicable

Menatchee Creek Mouth

Source: Google Earth 2020

River Mile Start	36.2
River Mile Stop	36.3
River Length (mi)	0.1
Est. Vegetation and Large Wood	2/5
Promote Complexity/Connectivity	1/5
Summer Water Temperature	4/5
Fish Life Stage Benefit	4/5
Ease of Access	4/5

Recommended Restoration Actions

- Wood collecting features to help engage right floodplain
- LWM along left bank road to provide habitat structure

Appendix E
Tributary Reaches

LIST OF TRIBUTARY REACHES

Joseph Creek

Mouth to Oregon Border

Project Areas: JC-1 to JC-8

Tier 1 Projects:
Tier 2 Projects:
Tier 3 Projects:

Cottonwood Creek — Joseph

Mouth to Oregon Border

Project Areas: CJC-1 to CJC-2

Tier 1 Projects:
Tier 2 Projects:
Tier 3 Projects:

Shumaker Creek

Mouth to end of LiDAR Extent 0.32 River Miles Upstream

Project Area: SC-1

Tier 1 Projects:
Tier 2 Projects:
Tier 3 Projects:

Deer Creek

Mouth to end of LiDAR Extent 0.97 River Miles Upstream

Project Areas: DC-1 to DC-2

Tier 1 Projects:
Tier 2 Projects:
Tier 3 Projects:

Buford Creek

Mouth to Oregon Border

Project Areas: BC-1 to BC-4

Tier 1 Projects:
Tier 2 Projects:
Tier 3 Projects:

West Fork Rattlesnake Creek

Rattlesnake Creek Confluence to end of LiDAR Extent 2.35 River Miles Upstream

Project Areas: WFRC-1 to WFRC-5

Tier 1 Projects:
Tier 2 Projects:
Tier 3 Projects:

Cottonwood Creek — Grande Ronde

Mouth to end of LiDAR Extent 3.23 River Miles Upstream

Project Areas: CCGR-1 to CCGR-5

Tier 1 Projects:
Tier 2 Projects:
Tier 3 Projects:

Cougar Creek

Mouth to end of LiDAR Extent 1.46 River Miles Upstream

Project Areas: CC-1 to CC-3

Tier 1 Projects:
Tier 2 Projects:
Tier 3 Projects:

Menatchee Creek

Mouth to end of LiDAR Extent 0.75 River Miles Upstream

Project Areas: MC-1 to MC-2

Tier 1 Projects:
Tier 2 Projects:
Tier 3 Projects:

ABBREVIATIONS

BDA	beaver dam analog
ELJ	engineered log jam
LiDAR	Light Detection and Ranging
LWM	large woody material
mi	mile
PALS	post-assisted log structure
RM	river mile

Joseph Creek Reach

Reach Description

The Joseph Creek reach runs from the confluence with the mainstem Grande Ronde 8.44 river miles upstream to the Oregon border. This reach includes eight project areas from JC-1 to JC-8. Cottonwood Creek is the only major tributary in the reach and enters Joseph Creek at river mile (RM) 4.4 on the right bank. Joseph Creek is the largest tributary in this assessment and drains a large, arid 549-square-mile basin. A field survey was conducted by vehicle and by foot in project areas JC-1 to JC-6.

Floodplain and Riparian Area

Land use throughout this reach includes irrigated and dry agricultural fields, ranches, and roads. The creek can be divided into two sections with respect to geomorphic conditions. The lower section below Cottonwood Creek has been highly confined by agriculture, residences, and roads. Many reaches have been linearized, and incision of 6 to 8 feet below the floodplain is common. Riparian vegetation in the lower reach is sparse, and many unvegetated gravel bars exist. Areas of geomorphic change were observed where the floodplain was wider, with evidence of gravel bar building, avulsions, and a more densely vegetated riparian zone. The furthest downstream project areas particularly suffer from blackberry invasion in the riparian zone, with tall walls of blackberry on

Joseph Creek

Vicinity Map

Reach Characteristics

River	Joseph Creek
Parent River	Grande Ronde River
River Length (mi)	8.44
Valley Length (mi)	7.97
Sinuosity	1.07
Average Slope	1.01%
Delineated project areas	JC-1 to JC-8 (8)
Total Levee Length (mi)	2.21
Road/Encroachment Length (mi)	1.64
Bank Incision Length (mi)	5.67
Notable Tributaries	Cottonwood Creek

both banks precluding the growth of beneficial riparian trees that can contribute woody material.

The upstream part of the reach above Cottonwood Creek has an entirely different character with mostly unconfined channel and wider channel migration area. The channel is better connected with its floodplain, and side channels and avulsions were observed. Riparian vegetation was much denser in the upper portion but could be improved by restoration actions that promote further bed aggradation.

Channel Conditions

Channel planform also varied between the upper and lower sections of the reach. The lower part of the reach was less complex and sinuous, and substrate was predominantly large cobble to boulder sized indicating the high stream power linked to incision and channel straightening. Some pools and avulsions were observed but almost no woody material was observed in the reach. Incised sections had steep eroding banks and lacked sinuosity. Thick algae was observed on the rocks indicating high nutrient concentrations and warm water temperatures. Much of the reach was exposed to direct sunlight, promoting warm water temperatures except in occasional deep pools.

The upper portion of the reach began with a linear plane bed reach, but further upstream the floodplain widened and channel complexity increased. Evidence of a major avulsion was found at RM 5.0, and multiple natural log jams occurred in this portion of project area JC-6. These jams were contributing to pool formation. Most of this section was shaded by trees, and pool density was much greater than in the lower section. Evidence of flood water levels in the form of woody material and twigs was observed in floodplain high-flow channels, but these channels were dry during low flow.

Influencing Anthropogenic Features

Roads, bridges, and levees protecting residential and agricultural infrastructure are the primary influencing features in this reach. Joseph Creek Road parallels the creek for the lower five project areas and acts as a levee for portions of project areas JC-1 to JC-3. Agricultural levees border some parts of the lower creek. The creek is extremely linear in places where it is confined by these levees and the floodplain has been replaced by agricultural fields, indicating past channelization was likely. Three bridges cross the road in this creek and likely influence the geomorphic processes through floodplain constriction, hydraulic backwater, and sediment transport continuity. These bridges include:

- Joseph Creole Road at RM 0.2
- Joseph Creek Road at RM 2.0
- Joseph Creek Road at RM 4.5

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. While other restoration actions should be considered at a project implementation level, the following should all be considered for any project in this reach. Details on how these restoration actions might be applied on a project area level are provided in the next section.

Remove Confinement (Encroachments and Incision)

Confining structures are prevalent in the lower six project areas of Joseph Creek causing incision and loss of channel complexity. Incision is a critical problem in the lower portion of Joseph Creek. Incision forced by linear confinements has increased transport capacity, reduced sinuosity and pool frequency, and reduced the potential for riparian vegetation by disconnecting the channel from its floodplain. Confining features in the reach include agricultural levees and roads and should be removed or set back where possible.

Providing room for the creek to actively migrate and inundate the floodplain is vital to restoring geomorphic complexity, sinuosity, and hyporheic exchange. Where possible, levees and encroachments should be moved or set back to reconnect low-lying floodplain and relic side channels. This restoration strategy will be bolstered by further restoration measures to install large woody material to help promote aggradation and reverse detrimental incision. The first step in reversing incision is to remove confining structures that limit channel migration.

Add Instream Wood and Complexity

This reach lacks instream wood due to poor riparian vegetation caused by a lack of available floodplain and intrusion of invasive blackberries. Log jams are needed to address the pool deficit, promote aggradation, and initiate beneficial geomorphic complexity. Minor woody material was observed downstream of areas with greater floodplain width and more geomorphic change. More large wood should be added as a secondary step to reversing incision.

Adding large woody material in strategic locations that will cause beneficial geomorphic change should be a primary restoration action in this reach. The warm summer water temperature and lack of shade and complexity in Joseph Creek make establishing pools a critical goal for expanding suitable salmonid habitat. Pools provide energy-efficient holding habitats and cold water refugia, and the associated log jams provide cover from predators. A primary function of engineered log jams in this reach should be to help store sediment, promote aggradation, and develop riparian vegetation that will establish a self-sustaining source of future instream wood. These processes also contribute to channel complexity by enabling increased channel migration and side channel development. Finally, large wood can be used to provide hardpoints to prevent erosion where critical infrastructure must be protected.

Establish Channel Migration Area

The channel migration area has been minimized in many locations within this reach due to agricultural and residential land use. The channel migration area is confined by levees and other encroachments, limiting the natural geomorphic and ecological processes. While these areas often require additional restoration due to lack of instream complexity and established vegetation, an established channel migration area provides an excellent first step for restoration of natural processes.

Restoration should target protection against further confinement in areas with large channel migration areas and expansion of compromised channel migration areas. These actions can involve the establishment of setback levees to protect against future migration or flooding outside of this channel migration area along with legal protections and easements against further development. Limiting bank erosion and avulsions with placement of large woody material can help to establish these boundaries and represent a compromise between restoration objectives and landowner objectives.

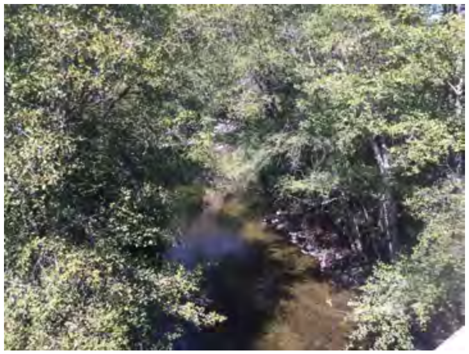
Establish Riparian Vegetation

Project areas JC-6 to JC-8 have functional riparian vegetation, but establishment of native riparian vegetation is necessary in the lower project areas of Joseph Creek. Riparian vegetation will help provide shade in exposed reaches and develop a source of woody material to promote beneficial geomorphic processes.

Establishing mature stands of vegetation in the immediate riparian area and channel migration areas should be a restoration target for this reach. Restoration actions should target establishing vegetation in barren floodplain and gravel bars and may require stabilizing features such as large apex engineered log jams. Additionally, restoration actions should seek to establish stands of riparian species in locations where the floodplain has been reconnected through restoration and active channel migration. Finally, some agricultural grazing was observed through this reach and is likely detrimental to establishment of riparian vegetation. Grazing exclusions should be considered as part of any vegetation focused restoration actions.

Tier 1
Project Areas in Joseph Creek

Project Area JC-2



River Length (mi)	0.75
Valley Length (mi)	0.73
Sinuosity	1.02
Average Slope	0.92%
Total Levee Length (mi)	0.94
Road/Encroachment Length (mi)	0.09
Bank Incision Length (mi)	0.61
Restore Connectivity Score	5/5
Add Complexity Score	5/5

Recommended Restoration Actions
- Remove or breach levees through RM 1.4 to 2.0
- Pilot cuts to reconnect right side channels
- ELJs to promote split flow and deposition

Project Area JC-3

River Length (mi)	1.07
Valley Length (mi)	1.02
Sinuosity	1.04
Average Slope	0.90%
Total Levee Length (mi)	0.59
Road/Encroachment Length (mi)	0.59
Bank Incision Length (mi)	1.46
Restore Connectivity Score	4/5
Add Complexity Score	5/5

Recommended Restoration Actions
- Remove or breach levees through RM 2.1 to 2.6
- ELJs to promote floodplain connectivity and help vegetate large gravel bars

Project Area JC-5

River Length (mi)	0.56
Valley Length (mi)	0.54
Sinuosity	1.04
Average Slope	0.91%
Total Levee Length (mi)	0.08
Road/Encroachment Length (mi)	0.19
Bank Incision Length (mi)	0.66
Restore Connectivity Score	4/5
Add Complexity Score	3/5

Recommended Restoration Actions
- ELJs to store sediment and promote complexity and pools in incised reach

Tier 2

Project Areas in Joseph Creek

Project Area JC-4

River Length (mi)	0.84
Valley Length (mi)	0.66
Sinuosity	1.27
Average Slope	0.83%
Total Levee Length (mi)	0.06
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.73
Restore Connectivity Score	4/5
Add Complexity Score	2/5

Recommended Restoration Actions

- ELJs to promote split flow and help vegetate large gravel bars
- Remove levees RM 3.4 to 3.6

Project Area JC-6

River Length (mi)	1.07
Valley Length (mi)	1.05
Sinuosity	1.01
Average Slope	1.12%
Total Levee Length (mi)	0.04
Road/Encroachment Length (mi)	0.38
Bank Incision Length (mi)	0.66
Restore Connectivity Score	2/5
Add Complexity Score	3/5

Recommended Restoration Actions

- ELJs to promote split flow in location of recent avulsion
- ELJs to promote sediment storage

Tier 3
Project Areas in Joseph Creek

Project Area JC-7

Source: Google Earth 2020

River Length (mi)	1.38
Valley Length (mi)	1.31
Sinuosity	1.05
Average Slope	1.08%
Total Levee Length (mi)	0.00
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.36
Restore Connectivity Score	1/5
Add Complexity Score	2/5

Recommended Restoration Actions

- ELJs to promote complexity and sediment deposition

Project Area JC-1

Source: Google Earth 2020

River Length (mi)	1.20
Valley Length (mi)	1.16
Sinuosity	1.03
Average Slope	1.23%
Total Levee Length (mi)	0.50
Road/Encroachment Length (mi)	0.40
Bank Incision Length (mi)	0.90
Restore Connectivity Score	1/5
Add Complexity Score	1/5

Recommended Restoration Actions

- ELJs to promote sinuosity and pool formation
- Remove or breach levees through RM 0.6 to 0.8
- Blackberry removal and riparian planting

Project Area JC-8

Source: Google Earth 2020

River Length (mi)	1.59
Valley Length (mi)	1.49
Sinuosity	1.06
Average Slope	1.10%
Total Levee Length (mi)	0.00
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.29
Restore Connectivity Score	1/5
Add Complexity Score	1/5

Recommended Restoration Actions

- ELJs to promote complexity and increase size and density of pools

Cottonwood Creek — Joseph Reach

Reach Description

The Cottonwood Creek — Joseph reach runs from the confluence with Joseph Creek 0.93 river miles upstream to the Oregon border. This reach includes two project areas from CJC-1 to CJC-2. Horse Creek and other smaller tributaries enter the creek upstream of this assessment. A field survey was conducted on the entire reach by foot.

Floodplain and Riparian Area

Land use in this reach is limited to the Joseph Creek Road. For much of this reach, a wide channel migration corridor exists, and the road is cut into the hillside above the floodplain. In a few areas, the road is level with the floodplain and large riprap armors the right bank, confining the channel. Bank incision was observed in CJC-1 where the road bordered the channel. Outside this section, the channel was well connected with the floodplain and the floodplain appeared to be accessible during a 1-year flood event. A dense canopy of riparian vegetation shaded most of the reach and was composed of mature alders and cottonwoods.

Channel Conditions

Channel complexity and geomorphic change was high in this reach due to the high connectivity with the floodplain. The channel was able to meander throughout most of the

Cottonwood Creek — Joseph
Vicinity Map

Cottonwood Creek — Joseph Reach Characteristics

River	Cottonwood Creek
Parent River	Joseph Creek
River Length (mi)	0.93
Valley Length (mi)	0.84
Sinuosity	1.11
Average Slope	2.44%
Delineated project areas	CJC-1 to CJC-2 (2)
Total Levee Length (mi)	0.22
Road/Encroachment Length (mi)	0.37
Bank Incision Length (mi)	0.40
Notable Tributaries	Horse Creek

floodplain, supporting geomorphic processes. Several avulsions were observed in conjunction with large natural log jams. Gravel-sized substrate was abundant, which allowed scour pools to form in locations of instream wood. Side channel frequency was low despite the multitude of potential high-flow channels. Placement of a few key pieces of wood could promote side channel formation.

Influencing Anthropogenic Features

Joseph Creek Road and its associated bank protection are the only anthropogenic influences in this reach. The road represents an encroachment on the floodplain for most of CJC-1. The road is well above the floodplain for project area CJC-2 and the floodplain is unconfined for this reach. The bridge crossing Joseph Creek just below the mouth of Cottonwood Creek forms a deep pool at the mouth and likely influences sediment transport dynamics at the mouth of Cottonwood Creek.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. While other restoration actions should be considered at a project implementation level, the following should all be considered for any project in this reach. Details on how these restoration actions might be applied on a project area level are provided in the next section.

Remove Confinement (Encroachments and Incision)

The road acts as both a levee and encroachment on the floodplain within project area CJC-1. The ideal solution would be to shift the road upslope to where it no longer interacts with the floodplain. While this solution could be costly, an alternative could include using large woody material along the riprap banks to provide habitat.

Providing room for the creek to actively migrate and inundate the floodplain is vital to restoring geomorphic complexity, sinuosity, and hyporheic exchange. Where possible, levees and encroachments should be moved or set back to reconnect low-lying floodplain and relic side channels. This restoration strategy will be bolstered by further restoration measures to install large woody material to help promote aggradation and reverse incision. Together these actions can help restore the creek's interaction with the floodplain and re-initiate side channel formation.

Add Instream Wood and Complexity

Instream wood is prevalent in this reach and is often observed contributing to geomorphic change. The abundance of gravel in the reach increases the effectiveness of wood addition in initiating geomorphic change. Where wood was observed, scour pools were almost always present. Large log jams were also observed near areas of avulsions, indicating a cause and effect relationship between wood and channel migration. Additional large wood should be added to promote side channel formation.

Adding large woody material in strategic locations that will cause beneficial geomorphic change should be a primary restoration action in this reach. Wood structures should be placed at junctions between the main channel and high-flow channels to encourage split flow. Wood structures such as beaver dam analogs (BDAs) and post-assisted log structures (PALS) are potential low-cost structures that can provide numerous benefits in small tributaries such as Cottonwood Creek. BDAs and PALS both help store sediment and promote aggradation, which raises the water table, supporting nutrient exchange and aquifer recharge. These processes help increase water storage in the floodplain, which can augment summer baseflow. Finally, large wood can be used to provide hardpoints to prevent erosion along riprap banks to provide cover and structure in reaches that lack complexity.

Establish Channel Migration Area

Much of this reach already has a large channel migration area, which provides room for natural geomorphic processes as well as room for flood inundation and the establishment of riparian vegetation. While these areas often require additional restoration due to lack of instream complexity, an established channel migration area provides an excellent first step for restoration of natural processes. In other areas within the reach, the channel migration area is confined by the road, limiting the natural geomorphic and ecological processes.

Restoration should target protection against further confinement in areas with large channel migration areas. Areas where the road confines the channel should also be targeted for road setback. Actions can involve legal protections and easements against further development as well as projects to set back the road or reduce its negative impact on the channel. Limiting bank erosion and avulsions with placement of large woody material can help to establish these boundaries.

Tier 2

Project Areas in Cottonwood Creek — Joseph

Project Area CJC-1

River Length (mi)	0.62
Valley Length (mi)	0.57
Sinuosity	1.09
Average Slope	2.82%
Total Levee Length (mi)	0.22
Road/Encroachment Length (mi)	0.37
Bank Incision Length (mi)	0.37
Road Setback Score	3/5
Levee Setback Score	2/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	3/5

Recommended Restoration Actions

- ELJs or BDAs to promote floodplain inundation
- LWM along riprap bank to provide habitat and erosion protection

Tier 3

Project Areas in Cottonwood Creek — Joseph

Project Area CJC-2

River Length (mi)	0.31
Valley Length (mi)	0.27
Sinuosity	1.14
Average Slope	2.06%
Total Levee Length (mi)	0.00
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.03
Road Setback Score	0/5
Levee Setback Score	0/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	3/5

Recommended Restoration Actions

- ELJs to promote side channel and pool formation

Shumaker Creek Reach

Reach Description

The Shumaker Creek reach runs from the confluence with the mainstem Grande Ronde 0.32 river mile upstream to the end of the Light Detection and Ranging (LiDAR) extent. This reach has a single project area SC-1. This is a small tributary to the mainstem and parallels Shumaker Road for most of the creek. A field survey was conducted on the entire reach by foot.

Floodplain and Riparian Area

Land use in this reach includes the gravel Shumaker Road. The Shumaker Creek basin includes a couple of cattle ranches. The floodplain in the 0.32-mile reach is sparsely vegetated with drought tolerant hackberry and occasional willows. The creek was dry during the summer survey, but flow was observed in the upper reaches of the creek outside the assessment. This section of the creek is managed within the Conservation Reserve Enhancement Program, which oversaw planting of the native juniper and chokecherry at the creek mouth. Some levees and confining features exist in the reach and limit the creek's access to the low-lying right floodplain.

Channel Conditions

The channel was dry during the field survey indicating the flow goes subsurface before reaching the Grande Ronde River during low-flow conditions. This reach is steep, and substrate

Shumaker Creek

Vicinity Map

Reach Characteristics

River	Shumaker Creek
Parent River	Grande Ronde River
River Length (mi)	0.32
Valley Length (mi)	0.31
Sinuosity	1.03
Average Slope	7.00%
Delineated project areas	SC-1 (1)
Total Levee Length (mi)	0.31
Road/Encroachment Length (mi)	0.20
Bank Incision Length (mi)	0.30
Notable Tributaries	N/A

size ranged from large boulders to large cobbles with occasional gravel. The steep slope of the creek likely forces a step-pool morphology when the creek is flowing. Channel complexity and pool formation are limited in this reach due to steep slope and large substrate size that does not appear to mobilize easily. No accumulations of large wood were observed.

Influencing Anthropogenic Features

Shumaker Road, a culvert at the creek mouth, and some remnant levees are the only anthropogenic features in the reach. Shumaker Road is a minor encroachment in the right floodplain throughout the reach but is largely outside the creek's small migration area. A culvert was installed at the dirt road crossing at RM 0.1 in a location where a ford previously existed. Adult steelhead observed crossing the ford provided the impetus for culvert installation. The culvert appeared to have some impact on sediment transport but appeared to support fish passage. There was some evidence of remnant levees on both banks, and there is an old rock wall in the right floodplain downstream of the culvert. The gravel Shumaker Road parallels the creek for its entire length and likely influences the creek by encroaching on the floodplain in places and providing minor additions of fine sediment.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. While other restoration actions should be considered at a project implementation level, the following should all be considered for any project in this reach. Details on how these restoration actions might be applied on a project area level are provided in the next section.

Remove Confinement (Encroachments and Incision)

Shumaker Creek has some minor levees along the banks that contribute to incision throughout the assessed reach. In a small, steep tributary creek, these structures channelize flood flows, increasing transport capacity and scouring out any beneficial gravel. Providing room for the creek to actively migrate and inundate the floodplain is vital to restoring geomorphic complexity, sinuosity, and hyporheic exchange. Where possible, levees and encroachments should be removed or set back to reconnect floodplain and relic side channels. This restoration strategy will be bolstered by further restoration measures to install large woody material to help promote aggradation and reverse detrimental incision. Together these actions can help restore the creek's interaction with the floodplain and re-initiate side channel formation.

Add Instream Wood and Complexity

There were no accumulations of instream wood in this reach, and no available source of mature vegetation to naturally supply wood. Wood is needed to support pool habitats in this steep reach to provide rearing areas for juveniles and pockets of spawning gravel. Because the creek dries up, addition of BDAs should be considered to help increase summer low flows.

Adding large woody material in strategic locations that will cause beneficial geomorphic change should be a primary restoration action in this reach. The steep slope of this tributary makes establishing pools a critical goal for expanding suitable salmonid habitat. Pools provide energy-efficient holding habitats and cold water refugia, and the associated log jams provide cover from predators. Wood structures such as BDAs and PALS are potential low-cost structures that have numerous benefits in small tributaries such as Cottonwood Creek. BDAs and PALS both help store sediment and promote aggradation, which raises the water table and supports riparian revegetation, nutrient exchange, and aquifer recharge. These processes help increase water storage in the floodplain, which can augment summer baseflow in tributaries where low summer flows and high temperatures are a limiting factor. These processes also contribute to channel complexity by enabling increased channel migration and side channel development.

Establish Channel Migration Area

This reach has a small channel migration area that could be expanded through restoration. While these areas often require additional restoration due to lack of instream complexity and established vegetation, an established channel migration area provides an excellent first step for restoration of natural processes. In most of the reach, the channel migration area is confined by levees and other encroachments protecting key infrastructure and limiting the natural geomorphic and ecological processes.

Therefore, establishment of a wider channel migration area should be targeted in areas that are affected by encroachments. These actions can involve the establishment of setback levees to protect against future migration or flooding outside of this channel migration area along with legal protections and easements against further development. Limiting bank erosion and avulsions with placement of large woody material can help to establish these boundaries.

Establish Riparian Vegetation

Establishment of riparian vegetation to provide shade and woody material is critical in this section of Shumaker Creek. Most of this reach has very little riparian vegetation. Riparian vegetation has been shown to be critical to ecological and geomorphic processes. For this reach, riparian vegetation is critically needed to provide a renewable and constant source of instream wood, as well as to provide overhanging cover and shade.

Establishing mature stands of vegetation in the immediate riparian area and channel migration areas should be a restoration target for this reach. Restoration should target reconnecting the creek with its floodplain and may require structures such as BDAs and PALS. Additionally, restoration actions should seek to establish stands of riparian species in locations where the floodplain has been reconnected through restoration and active channel migration. Finally, some agricultural grazing was observed through this reach and is likely detrimental to establishment of riparian vegetation. Grazing exclusions should be considered as part of any vegetation-focused restoration actions.

Tier 2

Project Areas in Shumaker Creek

Project Area SC-1

River Length (mi)	0.32
Valley Length (mi)	0.31
Sinuosity	1.03
Average Slope	7.00%
Total Levee Length (mi)	0.31
Road/Encroachment Length (mi)	0.20
Bank Incision Length (mi)	0.30
Road Setback Score	1/5
Levee Setback Score	2/5
Establish Vegetation Score	4/5
In-Channel Complexity Score	3/5

Recommended Restoration Actions

- Remove or breach levees through RM 0.0 to 0.3
- BDAs or PALS to promote complexity and floodplain inundation

Deer Creek Reach

Reach Description

The Deer Creek reach runs from the confluence with the mainstem 0.97 river mile upstream to the end of the LiDAR extent. This reach includes two project areas from DC-1 to DC-2. The creek is very isolated and only small dirt roads provide access. Limited access poses challenges for restoration efforts. Only the mouth of Deer Creek was surveyed during the boat survey of the mainstem and the tributary was dry during this summer visit.

Floodplain and Riparian Area

Land use throughout this reach includes dirt access roads, a lone residence, and cattle grazing. The creek is unconfined and meanders throughout the floodplain for most of the reach. The dirt road crosses the creek in at least one location and acts as a levee or encroachment at a few points in the reach. The creek gulley is densely vegetated with riparian trees for most of the reach, but vegetation is sparser on the alluvial fan. Multiple side channels and high-flow channels can be observed using the LiDAR data.

Channel Conditions

Channel complexity observed in the LiDAR data appears to be high relative to other similar-sized tributaries in the assessment. The channel is very sinuous for a steeply sloped tributary, and

Deer Creek

Vicinity Map

Reach Characteristics

River	Deer Creek
Parent River	Grande Ronde River
River Length (mi)	0.97
Valley Length (mi)	0.87
Sinuosity	1.11
Average Slope	5.87%
Delineated project areas	DC-1 to DC-2 (2)
Total Levee Length (mi)	0.16
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.28
Notable Tributaries	N/A

the abundance of mature riparian vegetation indicates there is a sustainable supply of natural woody material in the reach. The mouth of the creek was notably perched at least 10 feet above the mainstem water surface during the summer field survey and Deer Creek's flow was entirely subsurface. Sediment size of the creek mouth gravel bar ranged from large cobbles to small boulders. This large difference in bed elevation indicates the tributary is only accessible to salmonids during high flows.

Influencing Anthropogenic Features

The dirt road is the primary anthropogenic feature influencing the reach. The ford crossing acts as a confinement on the floodplain and likely contributes fine sediment to the creek. A building at RM 0.9 is the only structure in the floodplain. The surrounding hillsides are used as ranchland, and cattle may have access to the creek in places.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. While other restoration actions should be considered at a project implementation level, the following should all be considered for any project in this reach. Details on how these restoration actions might be applied on a project area level are provided in the next section.

Remove Confinement (Encroachments and Incision)

There are few areas of confinement in the Deer Creek reach, and dirt access roads are the primary confining features. The dirt road ford likely has a negative impact on the stream and could be improved with a culvert or minor bridge.

Providing room for the creek to actively migrate and inundate the floodplain is vital to maintaining geomorphic complexity, sinuosity, and hyporheic exchange. Deer Creek already appears to meander throughout the floodplain for most of this reach. Where possible, dirt roads should be set back out of the floodplain to contribute additional connectivity. This restoration strategy will be bolstered by further restoration measures to install large woody material to help promote aggradation in a few areas of bank incision.

Add Instream Wood and Complexity

Although no survey was completed in this tributary, the abundance of vegetation suggests some instream wood is present in this reach. Because the creek was dry, large wood additions should aim to restore year-round flow to the tributary by storing more spring runoff in the floodplain. Additionally, the steep slope of this tributary and large sediment size at the mouth indicates establishment of holding pools where gravel can deposit should be a key to improving salmonid habitat in the reach.

Due to the isolated nature of the reach, low technology restoration options such as BDAs and PALS would be ideal because they can be installed without construction equipment. BDAs and PALS both help store sediment and promote aggradation, which raises the water table and supports riparian revegetation, nutrient exchange, and aquifer recharge. These processes help increase water storage in the floodplain, which can augment summer baseflow in tributaries where low summer flows and high temperatures are likely a limiting factor. These processes also contribute to channel complexity by enabling increased channel migration and side channel development.

Establish Channel Migration Area

Much of this reach already has a large channel migration area, which provides room for natural geomorphic processes as well as room for flood inundation and the establishment of riparian vegetation. An established channel migration area provides an excellent first step for restoration of natural processes. In other areas within the reach, the channel migration area is confined by dirt roads, limiting the natural geomorphic and ecological processes.

Restoration should also target protection against further confinement and development in the floodplain. The entire creek is within private ownership, and restoration actions should involve considering legal protections and easements against further development within the floodplain.

Establish Riparian Vegetation

Most of the creek has a dense canopy of riparian trees, but vegetation in the creek mouth decreases as the water table drops well below the bed throughout the alluvial fan. Revegetation actions should target expanding riparian vegetation at the creek mouth and in various unvegetated gravel bars in the lower portion of the reach.

Large wood structures and BDAs can be useful in raising the water table to revegetate arid portions of the floodplain. Restoration efforts should target revegetation where the water table has been elevated. Additionally, promoting channel migration and avulsions will benefit riparian vegetation as the channel migrates back and forth through the floodplain, irrigating the trees in its vicinity. Cattle may also have access to parts of this reach so grazing exclusions should be considered as part of any vegetation-focused restoration actions.

Tier 3

Project Areas in Deer Creek

Project Area DC-1

River Length (mi)	0.27
Valley Length (mi)	0.24
Sinuosity	1.11
Average Slope	6.17%
Total Levee Length (mi)	0.03
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.15
Road Setback Score	0/5
Levee Setback Score	0/5
Establish Vegetation Score	3/5
In-Channel Complexity Score	3/5

Recommended Restoration Actions

- BDAs or PALS to promote aggradation, complexity, and floodplain water storage
- Create protected inlet to improve fish passage connectivity to mainstem

Project Area DC-2

Source: Google Earth 2020

River Length (mi)	0.70
Valley Length (mi)	0.63
Sinuosity	1.11
Average Slope	5.57%
Total Levee Length (mi)	0.12
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.13
Road Setback Score	0/5
Levee Setback Score	0/5
Establish Vegetation Score	3/5
In-Channel Complexity Score	3/5

Recommended Restoration Actions

- BDAs or PALS to promote complexity and increase floodplain water storage
- Culvert or basic bridge to reduce impact of dirt road ford crossing

Buford Creek Reach

Reach Description

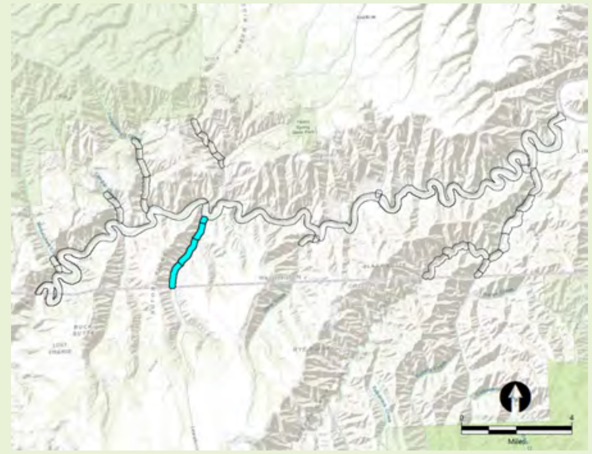
The Buford Creek reach runs from the confluence with the mainstem Grande Ronde 3.16 river miles upstream just past the culvert under Highway 129 to the Oregon border. This reach includes four project areas from BC-1 to BC-4. The lower portion of the reach is under private ownership while the upper portion of the reach, including parts of BC-3 and all of BC-4, is owned by the Nez Perce Tribe as part of their Precious Lands Wildlife Area. The entire reach was surveyed by road and foot, and the creek was dry with only a few isolated pools during the survey.

Floodplain and Riparian Area

Land use in the reach includes Highway 129, which acts as a confining feature for most of the reach. The available floodplain is narrow, and floodplain width ranges from a single channel width confined between the road and the valley wall to two to three channel widths where the road is set back from the floodplain. The floodplain is confined by large riprap along the road on the left bank, and the steep valley wall on the right bank. Riparian vegetation is present for most of the reach and dominated by alders and cottonwoods. The density of riparian trees decreases with downstream distance and the water table likely drops further below the bed with downstream distance. The channel appears less confined in project areas BC-1 and

Buford Creek

Vicinity Map



Buford Creek Reach Characteristics

River	Buford Creek
Parent River	Grande Ronde River
River Length (mi)	3.16
Valley Length (mi)	3.03
Sinuosity	1.04
Average Slope	4.40%
Delineated project areas	BC-1 to BC-4 (4)
Total Levee Length (mi)	0.45
Road/Encroachment Length (mi)	1.90
Bank Incision Length (mi)	2.49
Notable Tributaries	N/A

BC-4, while project areas BC-2 and BC-3 have narrow, confined floodplains.

Channel Conditions

The channel was dry during the field survey, though some isolated pools were observed and appeared to be connected to subsurface flow. Like other dry tributaries such as Shumaker Creek, Buford Creek is known to follow the pattern of drying from the mouth upstream, and upstream portions of Buford Creek are known to flow year-round. The channel was steep and lacked sinuosity and complexity for most of the reach. Some areas of recent bar formation were observed, and these areas lacked dense riparian vegetation. Substrate size within the reach ranged from large cobbles to boulders and very little gravel accumulation was observed. Little instream wood was noted throughout the reach despite the abundance of riparian trees. The lack of wood and gravel are indicators of the high transport capacity in this steeply sloped reach that can quickly transport wood out of the system during floods. The confinement of the road magnifies this excess transport capacity causing further degradation and scouring of sediment. Incision was prevalent throughout the reach, especially in sections where the creek was confined by the road.

A large alluvial fan composed of similarly large substrate was observed at the mouth of Buford Creek. There was an 8- to 10-foot elevation drop between the creek bed and the mainstem water surface providing an impediment to fish passage, and passage into Buford Creek is likely only possible during high-flow conditions.

Influencing Anthropogenic Features

Highway 129 and the recently constructed culvert under the highway at the upstream end of BC-4 are the primary anthropogenic features in the reach. The riprap along the highway is a primary encroachment throughout the reach. The highway prism occupies a large portion of the floodplain for much of the reach, forcing a narrower floodplain and contributing to incision. Field staff also observed sections of unused or abandoned riprap levee that extended into the floodplain and was not directly protecting the road. These extra levees should be targeted for removal. A culvert was recently completed under Highway 129 at the Oregon border to improve fish passage. Until the culvert was completed, this road crossing likely reduced sediment supply to the downstream reach further contributing to incision. After installation, this culvert represents an improvement for fish passage and sediment transport. The culvert will likely still act as a partial impediment to sediment transport continuity. The large road embankment at the crossing will also cause hydraulic backwater conditions during flood events.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. While other restoration actions should be considered at a project implementation level, the following should all be considered for any project in this reach. Details on how these restoration actions might be applied on a project area level are provided in the next section.

Remove Confinement (Encroachments and Incision)

The primary confining feature in the reach is the Highway 129 road deck, which will be difficult to reroute. Relocating the road further up the hillside would be the ideal restoration action, but is likely not financially feasible. The most effective feasible action would be to remove extraneous pieces of riprap levee in the floodplain.

Providing room for the creek to actively migrate and inundate the floodplain is vital to restoring geomorphic complexity, sinuosity, and hyporheic exchange. Where possible, levees and encroachments should be moved or set back to reconnect low-lying floodplain and relic side channels. This restoration strategy is the first step in reversing detrimental incision and will be bolstered by further restoration measures to install large woody material to help promote aggradation. Together these actions can help restore the creek's interaction with the floodplain.

Add Instream Wood and Complexity

Some instream wood is prevalent in this reach, but the reach lacks natural log jams that create large pools, store gravel, and initiate beneficial geomorphic complexity. Where wood was observed, accumulations were not significant enough to force large pools or contribute to side channel development. Installations of large wood should also be targeted to help raise the water table and increase floodplain water storage.

Adding large woody material in strategic locations that will cause beneficial geomorphic change should be a primary restoration action in this reach. The steep slope of this tributary makes establishing pools a critical goal for expanding suitable salmonid habitat. Pools provide energy-efficient holding habitats and cold water refugia, and the associated log jams provide cover from predators. Wood structures such as BDAs and PALS are potential low-cost structures that have numerous benefits in small tributaries. BDAs and PALS both help store sediment and promote aggradation, which raises the water table and supports riparian revegetation, nutrient exchange, and aquifer recharge. These processes help increase water storage in the floodplain, which can augment summer baseflow. These structures also serve the purpose of collecting natural woody material to increase its residence time in the basin. Finally, large wood can be used to line riprap banks and provide some beneficial habitat while helping protect infrastructure.

Establish Riparian Vegetation

Much of this reach has a developed canopy of riparian vegetation. Some patches of gravel bars support fewer trees, and riparian vegetation density decreases in the lower part of the reach. Restoration should target raising the water table to revegetate the entire width of the floodplain. Revegetation efforts may require structures such as BDAs to help store sediment and elevate the water table. Riparian planting efforts should seek to establish stands of riparian species in locations where the floodplain has been reconnected through restoration and active channel migration. Together these efforts will help develop a sustainable source of natural woody material to maintain these beneficial processes.

Tier 1

Project Areas in Buford Creek

Project Area BC-3

River Length (mi)	1.13
Valley Length (mi)	1.08
Sinuosity	1.05
Average Slope	4.45%
Total Levee Length (mi)	0.30
Road/Encroachment Length (mi)	1.01
Bank Incision Length (mi)	0.87
Road Setback Score	4/5
Levee Setback Score	3/5
Establish Vegetation Score	3/5
In-Channel Complexity Score	4/5

Recommended Restoration Actions

- Remove or breach levees and road through RM 1.5 to 1.6
- ELJs to promote complexity, sediment storage, and pool formation

Project Area BC-1

River Length (mi)	0.29
Valley Length (mi)	0.29
Sinuosity	1.02
Average Slope	4.48%
Total Levee Length (mi)	0.06
Road/Encroachment Length (mi)	0.05
Bank Incision Length (mi)	0.20
Road Setback Score	1/5
Levee Setback Score	4/5
Establish Vegetation Score	4/5
In-Channel Complexity Score	3/5

Recommended Restoration Actions

- ELJs to promote aggradation and increase floodplain water storage
- Remove or breach levee through RM 0.2 to 0.3
- Improve fish passage connection to mainstem

Tier 2

Project Areas in Buford Creek

Project Area BC-2

Source: Google Earth 2020

River Length (mi)	0.68
Valley Length (mi)	0.66
Sinuosity	1.03
Average Slope	4.09%
Total Levee Length (mi)	0.00
Road/Encroachment Length (mi)	0.66
Bank Incision Length (mi)	0.39
Road Setback Score	5/5
Levee Setback Score	0/5
Establish Vegetation Score	3/5
In-Channel Complexity Score	4/5

Recommended Restoration Actions

- ELJs to promote aggradation and complexity in incised areas
- Riparian planting in reconnected floodplain

Project Area BC-4

River Length (mi)	1.06
Valley Length (mi)	1.00
Sinuosity	1.06
Average Slope	4.58%
Total Levee Length (mi)	0.09
Road/Encroachment Length (mi)	0.19
Bank Incision Length (mi)	1.03
Road Setback Score	0/5
Levee Setback Score	0/5
Establish Vegetation Score	3/5
In-Channel Complexity Score	5/5

Recommended Restoration Actions

- ELJs to promote aggradation and protect vegetated islands
- Remove or breach levee through RM 2.8 to 2.9

West Fork Rattlesnake Creek Reach

Reach Description

The West Fork Rattlesnake Creek reach runs from the confluence with Rattlesnake Creek 2.35 river miles upstream to the U.S. Forest Service boundary. This reach includes five project areas from WFRC-1 to WFRC-5. This reach is a tributary to Rattlesnake Creek where a catastrophic dam break recently released a deluge destroying most vegetation and scouring the streambed. West Fork Rattlesnake Creek was relatively unaffected by the event. This steep, well-vegetated tributary travels through private ranchland. All project areas except WFRC-5 were surveyed by foot.

Floodplain and Riparian Area

The land in this reach is devoted to cattle ranching and the reach is bordered by a dirt access road. The access road acts as an encroachment on the floodplain for the first part of the reach including WFRC-1 and WFRC-2. There are several fords throughout the reach bordered both upstream and downstream by rock berms that confine the channel. After the first ford in WFRC-1, the road ascends the hillside, reducing its impact on the floodplain for most of the reach upstream. For the remainder of the reach, the creek is well connected with its floodplain and many side channels and backwaters were observed. Multiple remnant rock levees were also observed disconnecting available floodplain. The riparian area in the

West Fork Rattlesnake Creek

Vicinity Map

Reach Characteristics

River	West Fork Rattlesnake Creek
Parent River	Rattlesnake Creek
River Length (mi)	2.35
Valley Length (mi)	2.27
Sinuosity	1.03
Average Slope	8.47%
Delineated project areas	WFRC-1 to WFRC-5 (5)
Total Levee Length (mi)	0.24
Road/Encroachment Length (mi)	1.49
Bank Incision Length (mi)	0.50
Notable Tributaries	N/A

reach is heavily vegetated with both broadleaf species such as cottonwoods and alders, and conifers including ponderosa pines and grand and Douglas firs. Some of the Conservation Reserve Enhancement Program's riparian plantings were observed in the reach.

Channel Conditions

West Fork Rattlesnake Creek is a small, high-gradient tributary, but continuous flow was observed during the summer field survey. Relative to other tributaries of similar slope, this reach had high complexity and a large channel migration area. Side channels and backwaters were observed despite the large boulder-sized substrate and high gradient. Minor incision is present in the creek, especially in locations where remnant levees and the road act as confining features. Large wood was prevalent in the active channel and contributed to pool and side channel formation. An abundance of woody material was deposited at the mouth of the creek from the dam break flood on the mainstem Rattlesnake Creek. In steep sections the creek is naturally confined by large boulders and steep valley walls, and low-lying floodplain is limited. However, floodplain is accessible for most of the reach, and active side channels were observed even during low-flow conditions.

Influencing Anthropogenic Features

The dirt road and its associated fords, a culvert, and remnant levees are the primary anthropogenic features in the reach. The reach is also within a cattle ranch, and cattle grazing may impact riparian vegetation. The impact of the dirt road is felt most in project area WFRC-1 where the road occupies the floodplain and narrows the channel migration area. Outside of this reach, the road fords are the primary influencing features. Rock berms placed at the fords channelize flow and act as a bottleneck on the floodplain. In other locations, remnant levees and earth berms prevented the creek from accessing low-lying floodplain. These levees should be targeted for removal. A culvert at the boundary between WFRC-2 and WFRC-3 is another bottleneck on the floodplain. At the culvert, a steep 5-foot riprap wall confines the creek on the left bank. This culvert under the road may affect sediment transport continuity but appears to be sized appropriately for the tributary.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. While other restoration actions should be considered at a project implementation level, the following should all be considered for any project in this reach. Details on how these restoration actions might be applied on a project area level are provided in the next section.

Remove Confinement (Encroachments and Incision)

WFRC-1 is the most confined project area in this reach due to the road, but all project areas have some confining features such as levees and fords. These structures reduce the channel migration area, reducing sinuosity and increasing sediment transport capacity. Rock abutments at fords and remnant levees should specifically be targeted for removal within this reach.

Providing room for the creek to actively migrate and inundate the floodplain is vital to restoring geomorphic complexity. Complexity is high in this reach when the creek is unconfined except in the steepest sections. Where possible, levees should be removed and roads should be set back to expand the available floodplain and reconnect side channels. This restoration strategy will be bolstered by further restoration measures to install large woody material to help promote aggradation and reverse detrimental incision. Together these actions can help restore the creek's interaction with the floodplain and re-initiate side channel formation in places where it has been compromised.

Add Instream Wood and Complexity

Instream wood is prevalent in this reach, but large wood additions should be targeted in incised areas. Wood was observed contributing to complexity in this reach. Due to the steep nature of this creek, establishing large pools that can support salmonid feeding and spawning is critical. Large wood will also help retain spawning gravel and maintain summer flow.

Adding large woody material in strategic locations that will cause beneficial geomorphic change should be a primary restoration action in this reach. The steep slope of this tributary makes establishing pools a critical goal for expanding suitable salmonid habitat. Pools provide energy-efficient holding habitats and cold water refugia, and the associated log jams provide cover from predators. Engineered log jams specifically designed to create pools could be implemented.

Wood structures such as BDAs and PALS are potential low-cost structures that could also have numerous benefits in this reach. BDAs and PALS both help store sediment and promote aggradation, which raises the water table and supports riparian revegetation, nutrient exchange, and aquifer recharge. These processes help increase water storage in the floodplain, which can augment summer baseflow where low summer flows and high temperatures are likely a limiting factor. These structures should be installed in incised sections to promote aggradation. Finally, large wood can be used along the armored road embankment to prevent erosion while providing habitat structure.

Establish Channel Migration Area

Much of this reach already has a large channel migration area, which provides room for natural geomorphic processes as well as room for flood inundation and the establishment of riparian vegetation. While these areas often require additional restoration due to lack of instream complexity and established vegetation, an established channel migration area provides an excellent first step for restoration of natural processes. In other areas within the reach, the channel migration area is confined by levees and other encroachments, limiting the natural geomorphic and ecological processes.

Therefore, establishment of a wider channel migration area should be targeted in areas that are affected by encroachments. Restoration should also target protection against further confinement in areas with large channel migration areas. These actions can involve the establishment of setback levees to protect against future migration or flooding outside of this channel migration area along with legal protections and easements against further development. Limiting bank erosion and avulsions with placement of large woody material can help to establish these boundaries.

Tier 1

Project Areas in West Fork Rattlesnake Creek

Project Area WFRC-3

River Length (mi)	0.46
Valley Length (mi)	0.45
Sinuosity	1.03
Average Slope	7.67%
Total Levee Length (mi)	0.11
Road/Encroachment Length (mi)	0.09
Bank Incision Length (mi)	0.06
Road Setback Score	3/5
Levee Setback Score	3/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	3/5

Recommended Restoration Actions

- Remove or breach levees through RM 0.85 to 0.95
- BDAs or PALS to promote aggradation and increase floodplain water storage

Tier 2

Project Areas in West Fork Rattlesnake Creek

Project Area WFRC-4

River Length (mi)	0.56
Valley Length (mi)	0.54
Sinuosity	1.03
Average Slope	9.72%
Total Levee Length (mi)	0.09
Road/Encroachment Length (mi)	0.45
Bank Incision Length (mi)	0.16
Road Setback Score	5/5
Levee Setback Score	1/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	3/5

Recommended Restoration Actions

- Remove or breach levees through RM 1.3 to 1.4
- BDAs or PALS to promote aggradation and increase floodplain water storage

Project Area WFRC-5

Source: Google Earth 2020

River Length (mi)	0.61
Valley Length (mi)	0.58
Sinuosity	1.06
Average Slope	9.34%
Total Levee Length (mi)	0.04
Road/Encroachment Length (mi)	0.36
Bank Incision Length (mi)	0.13
Road Setback Score	3/5
Levee Setback Score	2/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	2/5

Recommended Restoration Actions

- Remove or breach levee through RM 2.0 to 2.1
- BDAs and PALS to promote complexity and floodplain inundation

Project Area WFRC-2

River Length (mi)	0.38
Valley Length (mi)	0.37
Sinuosity	1.05
Average Slope	7.17%
Total Levee Length (mi)	0.00
Road/Encroachment Length (mi)	0.29
Bank Incision Length (mi)	0.05
Road Setback Score	4/5
Levee Setback Score	1/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	3/5

Recommended Restoration Actions

- BDAs and PALS to promote pool formation and floodplain inundation
- LWM along road embankment to provide habitat structure and erosion protection

Tier 3

Project Areas in West Fork Rattlesnake Creek

Project Area WFRC-1

River Length (mi)	0.33
Valley Length (mi)	0.33
Sinuosity	1.00
Average Slope	8.45%
Total Levee Length (mi)	0.00
Road/Encroachment Length (mi)	0.30
Bank Incision Length (mi)	0.10
Road Setback Score	5/5
Levee Setback Score	0/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	2/5

Recommended Restoration Actions

- Remove rock berm at ford
- LWM along road riprap to provide habitat structure and erosion protection
- Set back road outside floodplain

Cottonwood Creek — Grande Ronde Reach

Reach Description

The Cottonwood Creek — Grande Ronde reach runs from the confluence with the mainstem Grande Ronde 3.22 river miles upstream past the confluence with East Fork Cottonwood Creek. This reach includes five project areas from CCGR-1 to CCGR-5. East Fork Cottonwood Creek is the only tributary in this reach and enters Cottonwood Creek at RM 2.9 on the left bank. This creek is notable for being the destination for hatchery steelhead returning to the Cottonwood Creek Acclimation Pond at the creek's mouth. A field survey was conducted where landowner permissions were granted on the lower part of the creek including project area CCGR-1 and the lower half of CCGR-2.

Floodplain and Riparian Area

Land use throughout this reach includes cattle ranching and a quarry, and most of the reach is bordered by a dirt access road. For much of this reach, a moderately wide channel migration corridor exists, and the access road is set back far enough from the creek. There is a ford crossing at the upstream boundary of CCGR-1 and the road becomes more of a confining feature in the vicinity of the ford. In project area CCGR-1 below the ford to the mouth, floodplain connectivity is reduced by old levees and a rock levee associated with the quarry on the left bank. This section is within the jurisdiction of the Conservation

Cottonwood Creek — Grande Ronde

Vicinity Map

Reach Characteristics

River	Cottonwood Creek
Parent River	Grande Ronde River
River Length (mi)	3.23
Valley Length (mi)	2.96
Sinuosity	1.09
Average Slope	5.48%
Delineated project areas	CCGR-1 to CCGR-5 (5)
Total Levee Length (mi)	1.54
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	1.04
Notable Tributaries	East Fork Cottonwood Creek

Reserve Enhancement Program. Upstream of the road ford, the floodplain is more accessible to the creek, but the creek's steep slope and associated large cobble-sized to boulder-sized substrate contributes to a natural bank armoring effect that limits floodplain connectivity. A mature and dense riparian canopy exists throughout most of the reach. Among the project areas, CCGR-1 and CCGR-2 are more confined by levees while CCGR-3 to CCGR-5 are less confined and have a larger channel migration area.

Channel Conditions

Channel complexity and pool formation is limited in this reach due to steep slope and large substrate size that does not appear to mobilize easily. Large wood is abundant in the reach, but the effectiveness of wood in forming pools is limited due to the immobility of the substrate. Small pools were observed where the creek plunged over woody material, but pool length was no more than a meter. The creek is a single thread channel with few pools for most of the reach. A few side channels were observed, and the number of side channels increased upstream of the quarry and other levees. In general, planform complexity is low, and the high-flow channels that were observed were left high and dry and are likely inundated only during large flood events.

Influencing Anthropogenic Features

The dirt road, quarry levee, and the fish acclimation pond are the primary anthropogenic features influencing the reach. The dirt road remains far enough away through most of CCGR-1 to provide a channel migration area on the right bank. A ford exists at approximately RM 0.7 near the upstream boundary of CCGR-1 and acts as a significant encroachment to the floodplain in this vicinity. There is a large rock levee on the left bank for the first quarter mile of CCGR-1, and additional natural or remnant levees continue upstream through the end of CCGR-2. Over 1.5 miles of levee line the banks in this reach. At the creek mouth, a major diversion routes flow to the Cottonwood Creek Acclimation Pond. The creek passes through a culvert under Grande Ronde Road before it empties into the mainstem Grande Ronde. Culvert replacement is currently being contemplated as part of a fish passage improvement program. This culvert is the only structure crossing the creek in the reach and likely influences the geomorphic processes through floodplain constriction, hydraulic backwater, and sediment transport continuity.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. While other restoration actions should be considered at a project implementation level, the following should all be considered for any project in this reach. Details on how these restoration actions might be applied on a project area level are provided in the next section.

Remove Confinement (Encroachments and Incision)

Project areas CCGR-1 and CCGR-2 are most afflicted by levees and encroachments within this reach. These structures reduce the channel migration area, reducing sinuosity and increasing sediment transport capacity. This results in scouring of all but large substrate during flood events, which contributes to the reach's lack of pools and complexity.

Providing room for the creek to actively migrate and inundate the floodplain is vital to restoring geomorphic complexity, sinuosity, and hyporheic exchange. Where possible, levees and encroachments should be moved or set back to reconnect low-lying floodplain and relic side channels. This restoration strategy will be bolstered by further restoration measures to install large woody material to help promote aggradation and reverse detrimental incision. Together these actions can help restore the creek's interaction with the floodplain and re-initiate side channel formation.

Add Instream Wood and Complexity

Instream wood is prevalent in this reach, but the reach lacks natural log jams that create large pools, promote aggradation, and initiate beneficial geomorphic complexity. Where wood was observed, accumulations were not significant enough to force large pools or contribute to side channel development. There is an abundance of woody material in the creek already, and addition of large wood will help collect the existing wood and form more robust jams.

Adding large woody material in strategic locations that will cause beneficial geomorphic change should be a primary restoration action in this reach. The steep slope of this tributary makes establishing pools a critical goal for expanding suitable salmonid habitat. Pools provide energy-efficient holding habitats and cold water refugia, and the associated log jams provide cover from predators. Wood structures such as BDAs and PALS are potential low-cost structures that have numerous benefits in small tributaries such as Cottonwood Creek. BDAs and PALS both help store sediment and promote aggradation, which raises the water table and supports riparian revegetation, nutrient exchange, and aquifer recharge. These processes help increase water storage in the floodplain, which can augment summer baseflow in tributaries where low summer flows and high temperatures are likely a limiting factor. These processes also contribute to channel complexity by enabling increased channel migration and side channel development. Finally, large wood can be used to provide hardpoints to prevent erosion where critical infrastructure must be protected.

Establish Channel Migration Area

Much of this reach already has a large channel migration area, which provides room for natural geomorphic processes as well as room for flood inundation and the establishment of riparian vegetation. While these areas often require additional restoration due to lack of instream complexity and established vegetation, an established channel migration area provides an excellent first step for restoration of natural processes. In other areas within the reach, the channel migration area is confined by levees and other encroachments protecting key infrastructure and limiting the natural geomorphic and ecological processes.

Therefore, establishment of a wider channel migration area should be targeted in areas that are affected by encroachments. Restoration should also target protection against further confinement in areas with large channel migration areas. These actions can involve the establishment of setback levees to protect against future migration or flooding outside of this channel migration area along with legal protections and easements against further development. Limiting bank erosion and avulsions with placement of large woody material can help to establish these boundaries.

Tier 1

Project Areas in Cottonwood Creek — Grande Ronde

Project Area CCGR-1

River Length (mi)	0.61
Valley Length (mi)	0.57
Sinuosity	1.07
Average Slope	5.28%
Total Levee Length (mi)	0.73
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.07
Road Setback Score	0/5
Levee Setback Score	5/5
Establish Vegetation Score	2/5
In-Channel Complexity Score	5/5

Recommended Restoration Actions

- Remove or breach levees through RM 0.2 to 0.6
- ELJs to promote sediment storage and pool formation

Project Area CCGR-2

River Length (mi)	0.92
Valley Length (mi)	0.82
Sinuosity	1.12
Average Slope	5.10%
Total Levee Length (mi)	0.51
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.31
Road Setback Score	0/5
Levee Setback Score	5/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	5/5

Recommended Restoration Actions

- Remove or breach levees through RM 0.6 to 1.0 and RM 1.1 to 1.4
- ELJs to promote floodplain connectivity

Project Area CCGR-3

Source: Google Earth 2020

River Length (mi)	0.80
Valley Length (mi)	0.73
Sinuosity	1.10
Average Slope	4.95%
Total Levee Length (mi)	0.15
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.47
Road Setback Score	0/5
Levee Setback Score	3/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	5/5

Recommended Restoration Actions

- ELJs to promote sediment storage and pool formation
- Remove or breach levees through RM 1.5 to 1.6 and 1.9 to 2.0

Tier 2

Project Areas in Cottonwood Creek — Grande Ronde

Project Area CCGR-5

Source: Google Earth 2020

River Length (mi)	0.50
Valley Length (mi)	0.48
Sinuosity	1.04
Average Slope	6.67%
Total Levee Length (mi)	0.15
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.19
Road Setback Score	0/5
Levee Setback Score	3/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	4/5

Recommended Restoration Actions

- Remove or breach levees through RM 2.75 to 2.85
- ELJs to promote floodplain connectivity

Tier 3

Project Areas in Cottonwood Creek — Grande Ronde

Project Area CCGR-4

Source: Google Earth 2020

River Length (mi)	0.40
Valley Length (mi)	0.37
Sinuosity	1.09
Average Slope	5.40%
Total Levee Length (mi)	0.00
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.00
Road Setback Score	0/5
Levee Setback Score	1/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	3/5

Recommended Restoration Actions

- ELJs to promote sediment storage, split flow, and pool formation

Cougar Creek Reach

Reach Description

The Cougar Creek reach runs from the confluence with the mainstem Grande Ronde 1.46 river miles upstream to the confluence with Medicine Creek. This reach includes three project areas from CC-1 to CC-3. Medicine Creek is a small tributary that enters on the right bank and is not included in the assessment. The Cougar Creek reach is the steepest reach in this assessment and is bordered by the gravel Cougar Creek Road for the entire reach. The entire reach was surveyed by vehicle and by foot.

Floodplain and Riparian Area

Cougar Creek Road is the dominant feature in the floodplain of this reach. The road parallels the creek on the left bank and the road prism acts as a floodplain encroachment for all of project areas CC-1 and CC-2. The creek has very little floodplain in project area CC-3 and is naturally a steep step pool channel. The road is perched on the hillside out of the floodplain in CC-3 and the creek is naturally confined to this narrow channel. Further downstream in project area CC-2, the floodplain alternates between sections that are very confined by the road and valley wall and pockets of wider floodplain where large wood has forced some deposition of sediment. In project area CC-1, a culvert causes a floodplain bottleneck, and the creek is very confined by the road just upstream of the culvert. An

Cougar Creek

Vicinity Map

Reach Characteristics

River	Cougar Creek
Parent River	Grande Ronde River
River Length (mi)	1.46
Valley Length (mi)	1.42
Sinuosity	1.03
Average Slope	11.14%
Delineated project areas	CC-1 to CC-3 (3)
Total Levee Length (mi)	0.41
Road/Encroachment Length (mi)	0.66
Bank Incision Length (mi)	0.39
Notable Tributaries	Medicine Creek

elevated bench between the road and the channel provides an opportunity for floodplain benching to expand the confined channel. Further upstream in project area CC-1, floodplain width increases, and some side channels and instream wood were observed. Incision is present in project areas CC-1 and CC-2 where the road acts as a confining feature. Riparian vegetation was dense throughout the reach and both mature deciduous and coniferous trees were present.

Channel Conditions

The dominant channel types throughout the reach are step-pool and cascade due to the high gradient of the stream. Cascades and small waterfalls were observed in the CC-3 project area and may impede fish passage. Substrate is predominantly boulder sized due to the high stream power, but some pockets of smaller substrate exist where deposition has been forced by large wood. In the upper section of the reach, substrate is large and immobile, and instream wood was observed perched above the channel and unable to contribute to geomorphic change. The channel is confined between steep riprap along the road on the left bank and steep valley walls on the right bank. Some small pools were observed to hold small juvenile fish, which appeared to be salmonids. Cougar Creek was dry upstream of Medicine Creek at the time of the field survey, but Medicine Creek provided some flow and flow was continuous from here to the mouth. The channel was well shaded by riparian trees for the entire reach.

Influencing Anthropogenic Features

The road, culvert, and some old levees are the anthropogenic features influencing the reach. The road prism acts as a confining feature for most of project areas CC-1 and CC-2 by narrowing the floodplain width. The road ascends the hillside in CC-3, but the channel naturally remains narrow. A large rock levee at RM 0.9 occupies the left floodplain and should be targeted for removal. The culvert at the creek mouth was perched a foot above the channel on the downstream end, impeding fish passage. A culvert replacement project is already planned.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. While other restoration actions should be considered at a project implementation level, the following should all be considered for any project in this reach. Details on how these restoration actions might be applied on a project area level are provided in the next section.

Remove Confinement (Encroachments and Incision)

Project areas CC-1 and CC-2 are confined by the road, and the road should be rerouted further up the hillside to diminish floodplain constriction where possible. Several old levees besides the road in these project areas prevent access to low-lying floodplain and should be removed.

Providing room for the creek to actively migrate and inundate the floodplain is vital to restoring geomorphic complexity, sinuosity, and hyporheic exchange. This restoration strategy will be bolstered by further restoration measures to install large woody material to help promote aggradation and reverse detrimental incision. Together these actions can help restore the creek's interaction with the floodplain and re-initiate side channel formation in pockets of available floodplain.

Add Instream Wood and Complexity

Instream wood is prevalent in this reach, but wood is incapable of forcing pools and storing sediment in steep and confined sections where substrate is too large. Natural jams in less steep sections have contributed to sediment storage and floodplain connectivity. Low technology restoration structures such as PALS and BDAs would be effective in these floodplain pockets to help collect wood and develop large jams that contribute to beneficial geomorphic change.

Adding large woody material in strategic locations that will cause beneficial geomorphic change should be a primary restoration action in this reach. The steep slope of this tributary makes establishing larger pools a critical goal for expanding suitable salmonid habitat. Pools provide energy-efficient holding habitats and cold water refugia, and the associated log jams provide cover from predators. Wood structures such as BDAs and PALS are potential low-cost structures that have numerous benefits in small tributaries such as Cougar Creek. BDAs and PALS both help store sediment and promote aggradation, which raises the water table and supports riparian revegetation, nutrient exchange, and aquifer recharge. These processes help increase water storage in the floodplain, which can augment summer baseflow in tributaries where low summer flows are likely a limiting factor. These processes also contribute to channel complexity by enabling increased channel migration and side channel development. Finally, large wood can be used to provide hardpoints to prevent erosion while providing beneficial habitat structure along the road riprap.

Establish Channel Migration Area

Much of this reach has a small channel migration area with only a few pockets of low-lying floodplain. Expanding the channel migration area in places where the creek is confined will allow flood energy to dissipate throughout the floodplain rather than contributing to incision. In most of the reach, the channel migration area is confined by the road and levees limiting the natural geomorphic and ecological processes. The channel migration area naturally would not be very wide in Cougar Creek, and restoration measures should target less steep sections where the floodplain could expand if allowed to.

Establishment of a wider channel migration area should be targeted in areas that are affected by encroachments. These actions can involve road setback, levee removal, and floodplain benching.

Tier 2

Project Areas in Cougar Creek

Project Area CC-1

River Length (mi)	0.67
Valley Length (mi)	0.66
Sinuosity	1.01
Average Slope	9.37%
Total Levee Length (mi)	0.31
Road/Encroachment Length (mi)	0.35
Bank Incision Length (mi)	0.17
Road Setback Score	3/5
Levee Setback Score	2/5
Establish Vegetation Score	2/5
In-Channel Complexity Score	3/5

Recommended Restoration Actions

- Floodplain benching to expand floodplain just upstream of culvert
- Culvert replacement
- BDAs and PALS to store sediment and wood in floodplain pockets

Tier 3

Project Areas in Cougar Creek

Project Area CC-2

River Length (mi)	0.49
Valley Length (mi)	0.46
Sinuosity	1.06
Average Slope	10.54%
Total Levee Length (mi)	0.10
Road/Encroachment Length (mi)	0.32
Bank Incision Length (mi)	0.19
Road Setback Score	4/5
Levee Setback Score	0/5
Establish Vegetation Score	2/5
In-Channel Complexity Score	2/5

Recommended Restoration Actions

- Remove levee through RM 0.85 to 0.95
- ELJs to promote sediment storage and pool formation and help reconnect side channels

Project Area CC-3

River Length (mi)	0.31
Valley Length (mi)	0.30
Sinuosity	1.03
Average Slope	13.50%
Total Levee Length (mi)	0.00
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.04
Road Setback Score	0/5
Levee Setback Score	0/5
Establish Vegetation Score	1/5
In-Channel Complexity Score	1/5

Recommended Restoration Actions

- Install LWM in low gradient sections to promote complexity, gravel deposition, and pool formation

Menatchee Creek Reach

Reach Description

The Menatchee Creek reach runs from the confluence with the mainstem Grande Ronde 0.75 river mile upstream to the end of the LiDAR extent. This reach includes two project areas from MC-1 to MC-2. All listed tributaries enter the creek upstream of the assessment reach. By discharge, Menatchee Creek is the second largest tributary in the assessment behind Joseph Creek and drains a high-elevation, 33-square-mile basin on the southern slope of the Blue Mountains. The assessment reach was surveyed by foot.

Floodplain and Riparian Area

Land use in the floodplain is limited to a dirt access road along the left bank for the lower quarter mile of the reach. Low-lying floodplain and side channels are abundant throughout the reach. In some areas, old levees restrict access to the floodplain and should be targeted for removal. In other areas, side channels were blocked by woody material jams. The banks are densely vegetated with mature alders and cottonwoods, and ponderosa pines occupy higher areas within the floodplain. Portions of disconnected floodplain are more open and only vegetated with grasses. Removal of encroachments in conjunction with large wood jams to promote sediment storage would help reconnect and re-establish riparian vegetation in these areas.

Menatchee Creek

Vicinity Map

Reach Characteristics

River		Menatchee Creek
Parent River		Grande Ronde River
River Length (mi)		0.75
Valley Length (mi)		0.69
Sinuosity		1.09
Average Slope		2.82%
Delineated project areas		MC-1 to MC-2 (2)
Total Levee Length (mi)		0.72
Road/Encroachment Length (mi)		0.00
Bank Incision Length (mi)		0.30
Notable Tributaries		
	Brushy Creek	Indian Tom Creek
	W. Fork Menatchee	Ranger Creek

Channel Conditions

Channel complexity is high throughout the reach with multiple side channels and high-flow paths. Sediment size throughout the reach ranges from large boulders to gravel, with abundant gravel promoting areas of active geomorphic change throughout the reach. Scour pools formed by large natural log jams were observed. Planform diversity was also rich throughout the reach with gravel riffles, boulder riffles, and step-pool sections all observed. Incised sections were observed where old levees had constricted the floodplain. Bar building and pool formation was observed in several sections of the reach. Restoration efforts should seek to augment these processes with additional engineered log jams that will help reconnect disconnected side channels and increase pool density.

Influencing Anthropogenic Features

Anthropogenic features influencing the reach include a short dirt access road and multiple old levees along both banks. Most of the basin drains remote forest service land with the exception of a few agricultural operations on the surrounding Grouse Flat plateau. The bridge on Grande Ronde Road at the creek mouth is another influencing feature, but the bridge appears to be sized appropriately for the creek. Fish passage into the creek should not be inhibited by this crossing. The gradual slope and abundant supply of cold water combined with minimal anthropogenic impacts in the floodplain for most of the watershed make Menatchee Creek a promising tributary to support healthy populations of wild salmonids.

Summary of Restoration Strategies

The following restoration actions are recommended based on the above information, as well as field observations and the desktop analysis and prioritization results. While other restoration actions should be considered at a project implementation level, the following should all be considered for any project in this reach. Details on how these restoration actions might be applied on a project area level are provided in the next section.

Remove Confinement (Encroachments and Incision)

Old levees serving no apparent purpose are found in both project areas MC-1 and MC-2 and should be removed to help reconnect the channel to its floodplain. These structures are contributing to incision and preventing access to potential side channels. Removal of these levees will help reduce incision and contribute to sinuosity and complexity throughout the reach.

Providing room for the creek to actively migrate and inundate the floodplain is vital to restoring geomorphic complexity, sinuosity, and hyporheic exchange. In this reach, levee removal will help revegetate open fields within the floodplain by allowing greater inundation during floods. Levee removal will also reduce scour and promote sediment storage in a reach where beneficial gravel is already abundant.

Add Instream Wood and Complexity

Instream wood is prevalent in this reach and wood is observed serving a critical role in beneficial geomorphic processes. Wood accumulations were observed forcing scour pools in places where a gravel bed enabled pool development. In other steeper sections with coarser substrate, wood was perched above the channel and could not influence geomorphic processes. The addition of a few robust engineered log jams will help initiate beneficial geomorphic change where these processes have been impaired by confinement.

Adding large woody material in strategic locations that will cause beneficial geomorphic change should be a primary restoration action in this reach. Wood additions should aim to help reconnect abandoned side channels and break up plane bed reaches with deep scour pools. Engineered log jams placed in the reach will also help store sediment in sections with coarser substrate and collect the abundant natural wood within the reach.

Establish Riparian Vegetation

Most of the reach has excellent riparian vegetation, but some areas of disconnected floodplain are devoid of riparian trees. Restoration actions that remove confinement and aim to reconnect these areas will naturally help revegetate these open meadows. Riparian planting efforts should target these reconnected areas to establish species that can thrive with roots near the water table.

Tier 1

Project Areas in Menatchee Creek

Project Area MC-1

River Length (mi)	0.34
Valley Length (mi)	0.30
Sinuosity	1.12
Average Slope	2.95%
Total Levee Length (mi)	0.33
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.11
Road Setback Score	0/5
Levee Setback Score	5/5
Establish Vegetation Score	2/5
In-Channel Complexity Score	5/5

Recommended Restoration Actions

- Remove levees through RM 0.0 to 0.35
- ELJs to promote floodplain connectivity and pool formation
- Riparian planting in reconnected floodplain

Project Area MC-2

River Length (mi)	0.42
Valley Length (mi)	0.39
Sinuosity	1.07
Average Slope	2.69%
Total Levee Length (mi)	0.40
Road/Encroachment Length (mi)	0.00
Bank Incision Length (mi)	0.19
Road Setback Score	0/5
Levee Setback Score	5/5
Establish Vegetation Score	2/5
In-Channel Complexity Score	5/5

Recommended Restoration Actions

- Remove or breach levees through RM 0.35 to 0.75
- ELJs to promote floodplain connectivity and pool formation

Appendix F
Project Area Maps