RECLAMATION

Managing Water in the West

MIDDLE FORK AND UPPER JOHN DAY RIVER TRIBUTARY ASSESSMENTS GRANT COUNTY, OREGON

BUREAU OF RECLAMATION

TECHNICAL SERVICE CENTER, DENVER, CO

AND

PACIFIC NORTHWEST REGIONAL OFFICE, BOISE, ID

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

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Executive Summary

The Bureau of Reclamation completed these assessments of physical river processes and associated habitat for spring Chinook and ESA-listed steelhead for approximately 23 river miles (RM) of the Middle Fork John Day River (Middle Fork) and 3 miles of the Upper John Day River (Upper Mainstem), located in Grant County, Oregon. The purpose of this report is to develop restoration and protection strategies based on a sound assessment of channel processes. This report includes both a strategy that resource managers can use to sequence and prioritize opportunities for protecting or restoring channel and floodplain connectivity and complexity in the Middle Fork and Upper Mainstem John Day Rivers and detailed technical results from geomorphic assessments of two areas within the John Day River subbasin.

Within this document, Reclamation describes a tributary reach-based approach to conduct geomorphic assessments and informs how this approach provides a platform that can be integrated with monitoring and adaptive management activities. The tributary reach-based approach employs a sequence of steps to focus funding and technical resources at telescoping geographic scales and to provide insight on the identification of potential project areas with the greatest biological benefits. This systematic, reproducible, and scientific approach includes stakeholder involvement to guide progress. Definition of discrete geographic areas (reaches) and the use of a modified Matrix of Pathways and Indicators (NOAA, 1996) provide an objective basis to integrate project implementation with implementation, status and trend, and effectiveness monitoring, and adaptive management at comparable geographic scales. Connections between project implementation, monitoring, and adaptive management can be potentially "rolled up" from smaller to larger scales to measure progress toward the Federal Columbia Power System Biological Opinion and recovery plan goals.

Projects implemented with a clear understanding of the existing physical processes are more likely to provide both short- and long-term benefits to the ESA-listed and other culturally important fish species. The proposed strategy provides spatial linkages within the assessment areas so that potential restoration activities can be conducted to expand and reconnect areas that are already functioning. Spatial linkages also ensure there are no critical limiting factors that need to be addressed before newly improved habitat can be accessed and utilized (e.g., barriers, flow limitations). In addition, understanding the existing physical processes will help minimize unanticipated impacts to presently functioning habitat, other potential restoration projects, infrastructure, and property, as well as maximize the sustainability of potential restoration projects.

Reclamation evaluated trends in physical processes over the last century and delineated reaches with similar geomorphic and habitat characteristics. Prioritization of identified reaches is based on current habitat quality and potential habitat improvements through integration of results of the geomorphic assessments with established objectives from the *Middle Columbia River Draft Steelhead Recovery Plan* (Carmichael 2006), the *Draft John*

Day River Subbasin Plan (NPCC 2005), and other biological guidance documents [(*Upper Columbia Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan* (UCSRB 2007)].

Reaches were characterized into three general types—confined, moderately confined, and unconfined. The reach types are based on differences in geomorphic conditions and the potential to provide habitat features associated with multiple life stages and species use, particularly complexity habitat for spring Chinook and ESA-listed steelhead.

River morphology is determined by the flow regime, sediment regime, and topographic features within the channel and floodplain. Each element was evaluated with respect to historic changes to the channel to assess the habitat restoration potential of this system. Minimal historic impacts to the flow regime were identified, which is generally the most difficult element to correct with restoration actions. Some minor impacts to the sediment regime were detected, including short-term increases in fine sediments from anthropogenic activities, localized changes in channel slopes resulting from channelization, and possibly mild localized degradation or bed coarsening in small portions of a few reaches. The greatest impacts on channel processes in the assessment areas result from changes in topographic features due to constructed features and to vegetation-related factors. This increases the chance for success of habitat restoration projects on the river since channel processes affected by these topographic changes are typically reversible.

Key topographic factors that limit habitat function in the assessment areas include:

- Clearing of riparian vegetation.
- Reduced floodplain function and connectivity.
- Reduced side channel access.
- Reduced lateral migration potential.
- Altered rates of large woody debris (LWD) inputs and vegetation recruitment.

There are no large man-made dams and reservoirs in the assessment areas or upstream watersheds that have significantly reduced sediment loads or incoming water discharge (peak floods) over the last century. No significant trends in the occurrence or magnitude of peak floods were detected from the USGS gaging station data that could imply a change to stream energy over time.

Sediment supplies to the systems have remained relatively stable over the last century, with the exception of interceptions of flow for irrigation from tributaries contributing small coarse sediment supplies. Grazing, logging, and dredge mining led to short-term increases in fine sediments and reduced channel complexity. Anthropogenic channelization of sections of the rivers has resulted in increased slopes in some reaches. Higher erosive forces resulting from increased channel slopes has led to localized mild incision, channel widening, and possibly bed coarsening in a few reaches.

In the Middle Fork assessment area (Report Map 1), investigation of the hydraulics and sediment transport indicated that substantial incision has not occurred in most reaches, despite considerable modifications to stream energy. Following development in the basin and significant changes to land use primarily between 1860 and 1970, the river appears to have reached a new equilibrium within its boundaries. The new equilibrium is defined by fewer active overbank and side channels, and possibly less frequently inundated floodplains, than historic conditions. Although active channel aggradation or degradation was not evidenced during field visits, a slight tendency for degradation in the downstream direction may be present during flood events. Any modifications to the system that disrupt the present equilibrium (e.g., removal of artificial topographic features) may result in channel adjustments through increased lateral channel migration in locations where the channel is competent to rework floodplain deposits. Potential channel adjustments have implications for long-term stability of restoration actions, such as LWD placements, and will require additional investigations at a more refined scale.

Within the Upper Mainstem assessment area (Report Map 2), substantial vertical channel degradation was not evidenced from the channel stability analyses. Extensive bank erosion was noted in localized areas during field visits. Some bank erosion is expected to occur as part of natural bend migration processes; however, erosion at these sites could be occurring as a response to historic channel straightening. A slight tendency for degradation exists in Reach UJD2 under flood conditions. The extent of further degradation may be limited by vertical and/or lateral geologic controls that are actively confining reach transitions.

Within the floodplain (low surface), a range of constructed features are present that impact channel and floodplain processes to varying degrees. Levees, bridges, and roads typically disconnect floodplain access by preventing flow inundation of the geologic low surface and side channels. Rock spurs, riprap, and other bank armoring techniques may not restrict flow to the floodplain, but they do prevent channel migration and active reworking of floodplain deposits. Anthropogenic activities that impact topography, in addition to sediment regime, include dredge mining, grazing, timber harvest within the floodplain, and removal of LWD for flood control. The modified topography reduces access to off-channel habitat and impacts the formation of habitat features within the channel that depend on channel migration, recruitment of LWD, and reworking of the stream bed.

Floodplain function and connectivity to the main channel has been impacted in both assessment areas. This is particularly apparent in unconfined and moderately confined reaches. Side channels are no longer inundated at historic rates and riparian vegetation cover, LWD inputs, and off-channel habitat are limited. Disruption of floodplain connectivity has resulted in a loss of habitat complexity features within the floodplain and channel, and in turn, has reduced the availability of high flow and thermal refugia.

A vegetation mapping effort was completed as part of these assessments. Historical clearing and the lack of floodplain reworking had the largest impact on the condition and regeneration of riparian vegetation. Many locations that historically supported woody vegetation have been converted to shrubs or open areas as noted from historical aerial photographs. In both assessment areas, access to LWD is greatest in confined reaches. In moderately confined and unconfined reaches, denudation of riparian vegetation and historic removal of woody debris for flood control has substantially altered LWD recruitment potential.

Floodplains of the Middle Fork are comprised of 6 percent LWD-sized trees, 14 percent small trees and shrubs, and 80 percent low vegetation or open areas. Vegetated areas are concentrated in reaches MF4, MF9, MF10, and MF11, and appear to be primarily conifer-dominated in the upper reaches with some cottonwoods present in the lower reaches. The loss of vegetation within the floodplain since 1939 varies between 0 percent and 100 percent in each reach, with the greatest impacts noted in the upper portion of the assessment area.

Within the assessment area of the Upper Mainstem, 19 percent of the floodplain area is dominated by LWD sized-trees. These cottonwood-dominated areas are concentrated in reaches UJD1 and UJD3. Shrubs comprise 15 percent of the floodplain area, persisting primarily along the river channel and adjacent irrigation channels. Between 37 percent and 66 percent of the floodplain area within each reach has been converted from trees and shrubs to open areas or low vegetation between 1939 and the present day.

Results of the geomorphic assessment were used to determine the potential for recovering channel processes that support desired habitat. Actions with the greatest potential to create habitat are those that work to restore river processes that generate habitat complexity, particularly in dynamic reaches that typically have frequent channel migration and floodplain interaction. Short-term actions, such as LWD placements, may be needed to supplement long-term riparian vegetation recovery.

In moderately confined and unconfined reaches, primary restoration concepts recommended for long-term recovery of habitat complexity are twofold. First, a major revegetation effort would work to restore healthy riparian processes, provide shade and cover to the channel, recruit LWD, and moderate lateral channel migration and bank erosion. A second important restoration concept includes the setback or removal of topographic features that negatively impact channel processes, including floodplain connectivity, lateral channel migration and floodplain reworking, and the availability of off-channel and main channel complexity features. In geologically confined reaches, the largest impacts to habitat function result from the loss of riparian vegetation and the installation of bank armoring. Modification or removal of these features in conjunction with riparian planting offers the best opportunity for improving long-term habitat viability in these reaches.

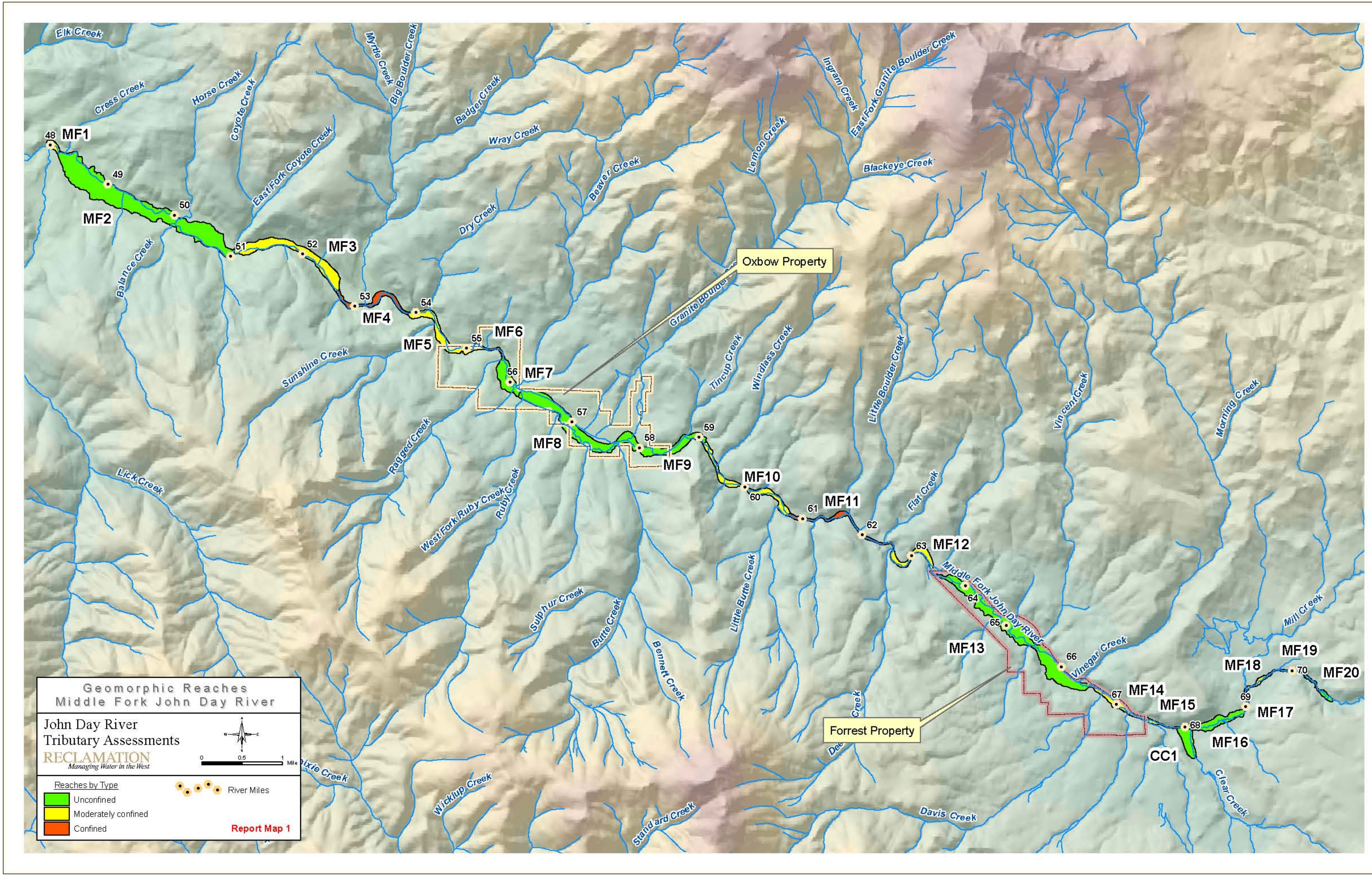
Protection and monitoring opportunities were identified as part of a restoration strategy to maximize beneficial effects of restoration projects in adjacent areas. Protection areas can provide a connection among otherwise separated restoration areas. However, less than 2.6 percent of the Middle Fork and just over 1 percent of the Upper Mainstem were considered functioning floodplains with few or no topographic features or anthropogenic activities that negatively influence channel processes. A summary of the restoration and protection potential for each assessment areas is summarized in Table 1.

A technical ranking of reaches was developed to provide planners, managers, and stakeholders with a way to identify, sequence, and prioritize opportunities for protecting or restoring channel and floodplain connectivity and channel complexity at the reach-scale. The ranking was structured following recommended procedures identified by UCSRB (2007) and UCRTT (2007). On the Middle Fork, reaches MF2, MF13, and MF8 are the top three ranked reaches, and UJD3 is the top ranked reach in the Upper Mainstem. All but MF2 have a higher than average number of Chinook spawning use when compared with other reaches in the assessment areas.

Data collected from the assessment activities were processed into a geographic information system (GIS) database to allow the information to be spatially related and readily transferred to other design engineers, cooperators, and stakeholders. Once a reach is chosen for implementation of proposed protection and restoration actions, a more detailed technical analysis, including a modified Matrix of Diagnostics/Pathways and Indicators (NMFS 1996; USFWS 1998) and a relevant data collection effort referred to as a “reach assessment,” may be conducted to refine restoration project possibilities. This effort is a cooperative process with project sponsors, stakeholders, regulatory and permitting entities, and technical groups involved in recovery planning and implementation in the John Day River.

Table 1 – Summary of Potential Opportunities for Protection and Restoration in Each Assessment Area.

Potential for Restoration and/or Protection	Percent of 23-Mile Long Assessment Area on the Middle Fork, including Clear Creek Reach	Percent of 3-Mile Long Assessment Are on the Mainstem
Generally functioning floodplain area with riparian vegetation	2%	0.20%
Accessible floodplain requiring heavy revegetation	16%	0%
Opportunities for restoration of high-complexity or channel network area, including reforestation of the floodplain	61%	3%
Side channel(s) with some floodplain reconnection and revegetation	16%	79%
Reconnection of overbank surfaces with few or no side channels	4%	18%
Heavy development with little opportunity for protection or restoration	1%	0%


Geomorphic Reaches
Middle Fork John Day River
John Day River
Tributary Assessments
RECLAMATION
Managing Water in the West
Reaches by Type
Unconfined
Moderately confined
Confined
River Miles
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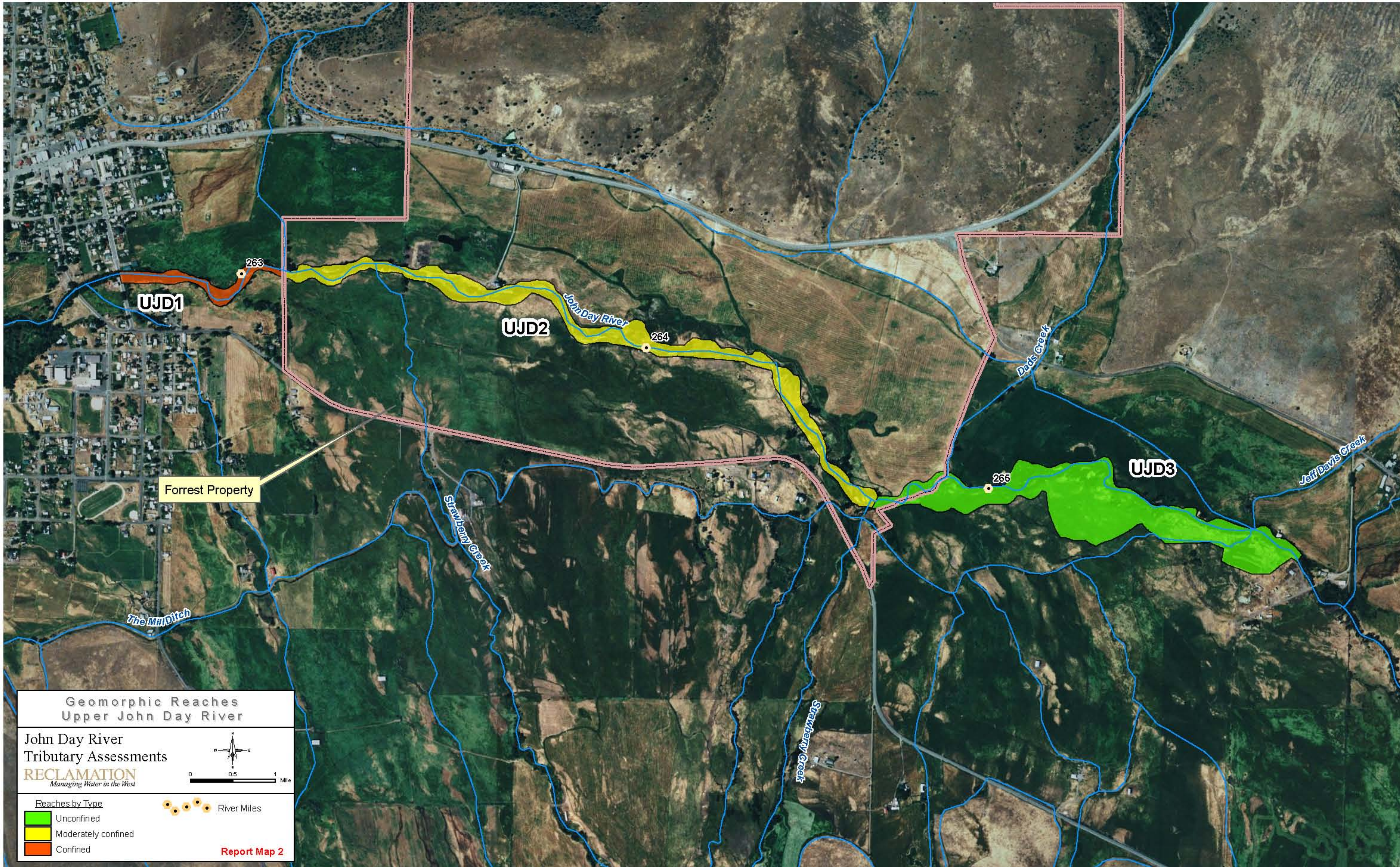
Forrest Property
MF1
MF2
MF3
MF4
MF5
MF6
MF7
MF8
MF9
MF10
MF11
MF12
MF13
MF14
MF15
MF16
MF17
MF18
MF19
MF20
CC1
Elk Creek
Cress Creek
Horse Creek
Coyote Creek
East Fork Coyote Creek
Myrtle Creek
Big Boulder Creek
Badger Creek
Wray Creek
Beaver Creek
Dry Creek
Granite Boulder Creek
Lemon Creek
Ingram Creek
East Fork Granite Boulder Creek
Blackeye Creek
Balance Creek
Sunshine Creek
Ragged Creek
Lick Creek
West Fork Ruby Creek
Ruby Creek
Tincup Creek
Windlass Creek
Little Boulder Creek
Little Butte Creek
Flat Creek
Vincent Creek
Morning Creek
Middle Fork John Day River
Vinegar Creek
Mill Creek
Sulphur Creek
Butte Creek
Bennett Creek
Wickiup Creek
Standard Creek
Davis Creek
Clear Creek
Dixie Creek



263
264
265
UJD1
UJD2
UJD3
John Day River
Dads Creek
Jeff Davis Creek
Strawberry Creek
The Mill Ditch
Forrest Property
Geomorphic Reaches
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0
0.5
1
Mile
Reaches by Type
Unconfined
Moderately confined
Confined
River Miles
Report Map 2

1.0 INTRODUCTION

The John Day River is a tributary to the Columbia River and drains nearly 8,000 square miles. Its diverse landscape covers parts of the Deschutes-Umatilla Plateau through the Blue Mountains, with elevations ranging from 150 to 9,000 feet. Two subbasins within the John Day River include the Middle Fork and Upper John Day (also referred to as the Upper Mainstem) Rivers. A detailed description of regional characteristics of the John Day River and the timeline of basin development are presented in Appendix A.

The Middle Fork subbasin originates in the Blue Mountains of the Malheur National Forest and flows 75 miles to its confluence with the North Fork John Day River north of Monument, Oregon. The drainage area of the watershed is approximately 806 square miles with elevations ranging from 2,200 feet at its mouth to over 8,100 feet in the headwaters (Young 1986). The landscape within the assessment area of the Middle Fork is a range of private ownership and federally-owned national forest lands. Within the assessment area, multiple properties are owned by the Confederated Tribes of the Warm Springs Reservation of Oregon and by The Nature Conservancy. This assessment area also covers the lower 0.5 mile of Clear Creek, a tributary at the upstream end of the assessment area, near the historic town of Bates.

The Upper John Day River originates in the Blue Mountains and generally flows in a northwesterly direction to its confluence with the North Fork John Day River at Kimberly, Oregon. The Upper Mainstem watershed drains 1,070 square miles with elevations ranging between 2,000 feet to 9,000 feet in the Strawberry Mountain Range. A major tributary, the South Fork John Day River, joins the Upper Mainstem in Dayville, Oregon. The Upper Mainstem of the John Day River extends from RM 262.67 to RM 265.85 and is contained within private property. Within the assessment area, portions of reach UJD2 and all of reach UJD3 are properties owned by the Confederated Tribes of the Warm Springs Reservation of Oregon. This property is the Mainstem Forrest Conservation Area.

Within both subbasins, substantial changes to channel processes and resulting habitat have occurred over the last century. As a result, populations of several important fish species have considerably decreased, and some species have been listed under the Endangered Species Act (ESA). Protection of existing aquatic habitat and restoration of altered habitat are generally accepted methods that benefit important fish species. In order to make good decisions about where and how to implement projects aimed at preserving and restoring physical processes that provide suitable aquatic habitat, a strong scientific foundation is necessary. This report includes state of the art science and introduces preliminary project implementation opportunities.

1.1 Background and Need

In the Middle Fork and Upper John Day subbasins, changes in channel processes have resulted in limited access to side channels, lateral channel migration potential, floodplain connectivity, and recruitment of LWD. In turn, these changes have reduced the quality and availability of habitat for Chinook salmon, steelhead, and bull trout in the John Day River and tributaries. These impacts have affected the abundance, productivity, spatial structure, and diversity of spring Chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*Oncorhynchus mykiss*), and bull trout (*Salvelinus confluentus*) to such a degree that populations within the basin have markedly decreased over the last century. Mid-Columbia River steelhead trout (*Oncorhynchus mykiss*) were listed as threatened in 1999 by the National Marine Fisheries Act, and bull trout were listed as threatened by the U.S. Fish and Wildlife Service in 1998. Spring Chinook and summer steelhead are of particular importance to the local area and region because the John Day River is managed exclusively for wild fish production (NPCC 2005).

Recovery of the salmonid species to viable populations requires reducing or eliminating threats to the long-term persistence of fish populations, maintaining widely distributed and connected fish populations across diverse habitats within their native ranges, and preserving genetic diversity and life-history characteristics. Successful recovery of listed species means that populations have met certain measurable criteria (i.e., abundance, productivity, spatial structure, diversity), referred to as viable salmonid population (VSP) parameters (ICBTRT 2007; UCSRB 2007).

To achieve recovery, four sectors need to be addressed: harvest, hatchery, hydropower, and habitat (ICBTRT 2007; UCSRB 2007). The following biological guidance documents include recommendations for the John Day Subbasin on developing implementation frameworks, and types and prioritization of restoration activities needed to achieve recovery in these four sectors:

- Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs, Interior Columbia Basin Technical Recovery Team (ICTRT 2007)
- Draft Recovery Plan for Oregon’s Middle Columbia River Steelhead, Progress Report (Carmichael 2006).
- John Day Subbasin Revised Draft Plan (NPCC 2005).

In addition to the above documents directly related to the recovery of salmonid species in Oregon, documents relating to salmon and steelhead recovery in the Upper Columbia Region also were referenced. Although the documents focus on the Upper Columbia River, the methodology presented for recovery of listed species has broad application to other basins and can be tailored to meet specific basin objectives. The additional biological guidance documents include:

- Upper Columbia Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan (Upper Columbia Salmon Recovery Board (UCSRB 2007); referred to as Upper Columbia Recovery Plan (2007) in this document.

- A Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region (Draft) (UCRTT 2007).

Most biological guidance documents identify potential protection and restoration strategies that were based on available information and the professional judgment of a panel of scientists. Further technical investigation was necessary to refine protection and restoration strategies to the level of detail needed to implement projects, and to determine if the recommendations are sustainable and compatible with the geomorphic conditions in the river.

Biological Opinions (BiOps) on the operation and maintenance of the Federal Columbia River Power System[1] (FCRPS) issued by National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries Service) to the Bonneville Power Administration, US Army Corps of Engineers, and Bureau of Reclamation (Reclamation), collectively referred to as the "Action Agencies," include measures to improve tributary habitat for salmon and steelhead listed under the Endangered Species Act (ESA). These measures are addressed by the Action Agencies consistent with subbasin plans developed through the Northwest Planning and Conservation Council (NPCC) and State recovery plans approved by NOAA Fisheries Service.

1.2 Purpose and Scope

The purpose of this report is to describe technical results from the geomorphic assessments of parts of the Middle Fork and Upper John Day Rivers and to describe a strategy that resource managers can use to sequence and prioritize opportunities for protecting and restoring channel and floodplain connectivity and complexity in the assessment areas. The report addresses approximately 26 miles of Category 2 river valley segments in the John Day subbasin (Figure 1 and Table 2). These areas are contained within the region addressed by the Middle Columbia River Draft Steelhead Recovery Plan (Carmichael 2006). The assessment areas were investigated concurrently to compare and prioritize potential habitat protection and restoration areas within 21 delineated geomorphic reaches of the Middle Fork and 3 geomorphic reaches of the Upper Mainstem. The assessments were conducted by Reclamation with input from the Confederated Tribes of the Warm Springs Reservation of Oregon.

[1] The FCRPS comprises 14 mainstem Federal hydroelectric dams in the Columbia River Basin. The Army Corps of Engineers and Reclamation operate and maintain the dams, and the Bonneville Power Administration markets the power.

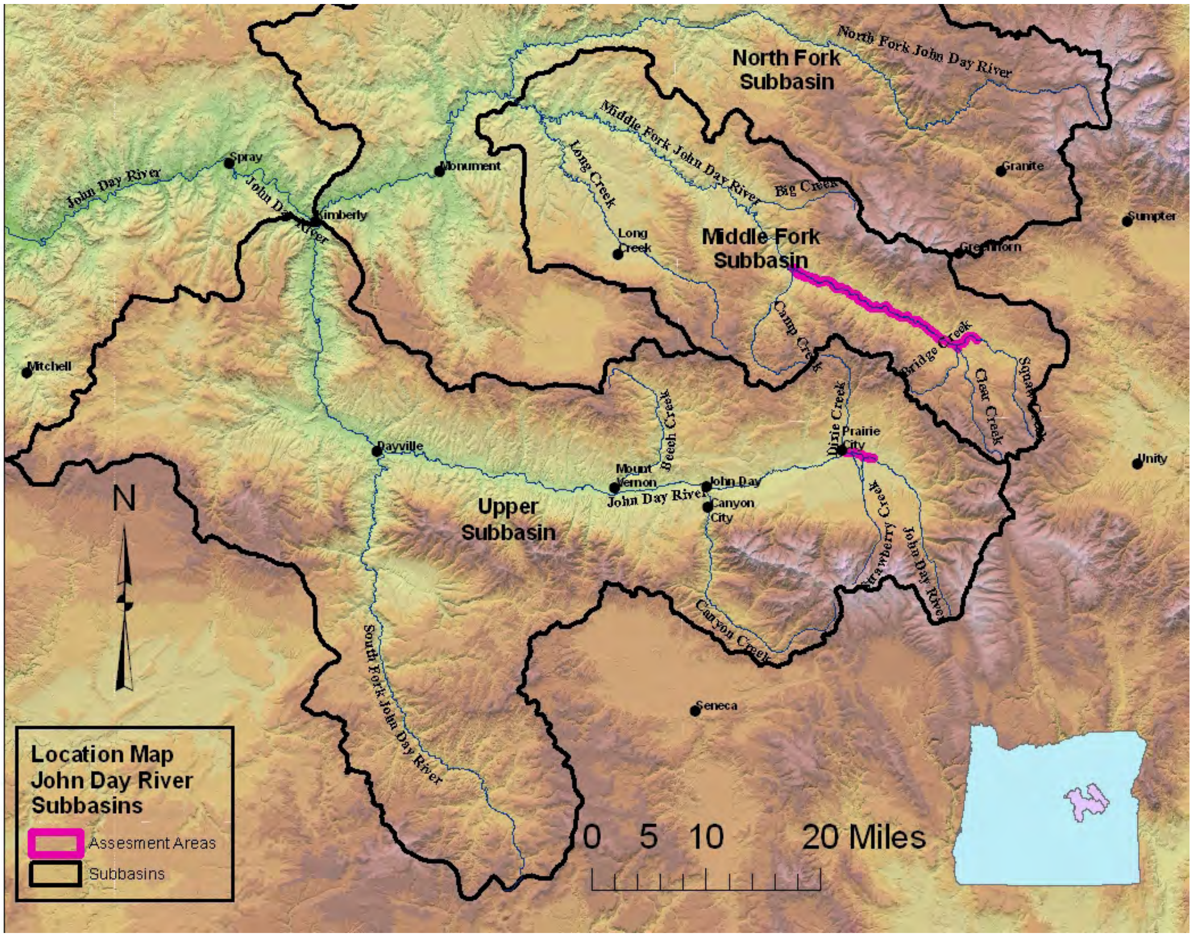

Figure 1 –Location Map of Assessment Areas in the John Day River.

Table 2 – Assessment Areas Within the John Day Subbasin.

Valley Stream Segment	Downstream Boundary	Upstream Boundary	River Mile (RM) Length
Middle Fork John Day River	RM 47.95 (confluence with Camp Creek)	RM 70.81 (near Forest Service Boundary)	22.9
Clear Creek	RM 0 (confluence with Middle Fork)	RM 0.5 (County Road 20 Bridge)	0.5
Upper Mainstem John Day River	RM 262.67 (Prairie City Bridge)	RM 265.85 (confluence with Jeff Davis Creek)	3.2
TOTAL LENGTH			26.6

1.3 Authority

Reclamation established a Tributary Habitat Program to address tributary habitat improvement commitments for the Federal Columbia River Power System Biological Opinions. Objectives of the Tributary Habitat Program are to improve the survival of Columbia River Basin salmon and steelhead listed under the ESA by ensuring fish screens meet current criteria, artificial fish passage barriers are replaced or removed to provide access to spawning and rearing areas, and instream flow and spawning and rearing habitat are improved in selected Columbia River tributary subbasins, including the John Day. Working closely with local partners and willing private landowners, Reclamation provides engineering and related technical assistance to meet mutual tributary habitat improvement objectives. Reclamation conducts the Tributary Habitat Program under authorities contained in the ESA, Fish and Wildlife Coordination Act, and Fish and Wildlife Act as delegated from the Secretary of the Interior in Secretarial Order No. 3274 dated September 11, 2007.

1.4 Federal Columbia River Power System (FCRPS) Biological Opinion

Reclamation's commitment to tributary habitat improvement for the FCRPS Biological Opinion (2008) began in 2000 and has operated in nine Interior Columbia River tributary subbasins with over 50 on-going project activities in various stages of development, implementation, or completion at any one time. Considering the necessary interactions among partners for any given project—including local, State, Federal, and tribal resources; oversight, regulating, and funding entities and private landowners—this program is a challenging endeavor for Reclamation and the many partners with whom it works. While there are scores of people with these partners throughout the Columbia River Basin that see habitat projects through to completion, there are also dozens of Reclamation people that participate in a wide assortment of technical, administrative, and management capacities needed to deliver the services and products provided by Reclamation.

The tributary reach-based approach was applied in these tributary assessments as a mechanism that can improve the delivery of services and products within schedule and budget for our partners and for Reclamation. In addition to features described in more detail later in this report, this approach provides:

- A planning tool that can be used collectively by all partners within a subbasin to focus their resources in a systematic and scientifically reproducible way to identify and prioritize floodplain connectivity and channel complexity restoration/protection projects.
- A method that will help Reclamation managers anticipate upcoming near-term and long-term workloads, assign people and allocate funding for that workload, and keep partners informed on the extent of available Reclamation near- and long-term resources for their planning purposes.

1.5 Report Organization and Methodology

Section 2 of this report summarizes the approach applied in conducting these assessments and describes the general direction of future assessments at refined spatial scales. This section also discusses linkages to monitoring and adaptive management. Section 3 describes background information on the present use of each subbasin by focal fish species, on delineation of geomorphic reaches, and on typical channel processes for different types of reaches. Section 4 presents an investigation of historical changes to geomorphic conditions based on changes in the flow regime, sediment regime, and topography of the channel and floodplain. In Section 5, existing geomorphic conditions relevant to restoration and protection actions are summarized by reach. Based on findings from the tributary assessments and biological guidance documents, a protection and restoration strategy is presented in Section 6. This section includes a prioritization tool of these reaches in terms of the potential to restore habitat. Section 7 presents a summary of the major conclusions of the assessments.

Existing and new information was synthesized into a GIS database, so that the information could be viewed spatially and readily transferred to other design engineers, cooperators, and stakeholders. Detailed methods and findings of the work described are contained in the appendices, which are provided on a DVD at the back of this report. An atlas that includes a series of maps showing the spatial relationships of the data compiled for these assessments accompanies this report, and is also provided on the attached DVD.

Work described in this report was accomplished by a multidisciplinary team from Reclamation consisting of expertise in hydraulic and sedimentation engineering, geology and geomorphology, and vegetation.

The scope, analyses, and protection and restoration strategies described in this report were created in conjunction with those developed in the biological guidance documents. Variations in channel and floodplain processes were used to delineate and evaluate potential project areas in the assessment areas where habitat for focal fish species might be protected, enhanced, or restored. Prioritization of reaches were made based on the current habitat quality, potential habitat improvements, and how well proposed restoration actions meet established habitat objectives from recovery plan documents (see Section 1.1). At key milestones in this report, presentations of completed and on-going work were made to the technical staff of local Reclamation partners so they could provide input to this process.

The information from this report also provides a current description of river processes operating within the assessment areas, so that subsequent, more detailed assessments for smaller river sections can build upon and refine this information to successfully implement proposed actions. Restoration projects implemented with a clear understanding of the associated physical processes have a greater potential for sustainable short- and long-term habitat benefits for spring Chinook and steelhead.

Methodology used to produce this report and the accompanying map atlas is described in detail in Appendices B, C, D, and E. Key steps were to:

- Delineate and characterize river valley segments and channel reaches on the basis of their geomorphic characteristics and biological opportunities, and develop potential restoration strategies organized by a reach-based approach.
- Identify a technical sequencing of the reaches that can be used to prioritize the potential habitat protection and restoration areas within the assessment areas based on linkage to primary limiting factors for salmon recovery.
- Identify the recurrence intervals of natural and human-induced disturbances and how they affect understanding of and impose controls on channel processes and planform within the assessment areas.
- Identify the habitat-forming physical processes and disturbance regimes working at the subbasin and reach scales from both historical and contemporary context.

For these assessments, methods included a mixture of quantitative and qualitative analyses to provide an acceptable level of certainty consistent with assessments' objectives. Quantitative methods provide more certainty to results than qualitative methods, but cannot be used in all areas because they are more costly and time consuming to employ. Qualitative methods are faster and less costly, but can be difficult to repeat in a scientific manner and therefore, have less certainty. The approach taken was to meld multiple independent analysis tools that could be overlaid and compared to determine conclusions regarding channel processes within the scope described in this report. Quantitative data were collected to characterize and compare reach-level trends within the assessment areas. Refinement of this information with additional data and analysis can then occur at a smaller scale of the channel reach selected by stakeholders and project partners in which to implement restoration actions.

2.0 LINKAGE TO IMPLEMENTATION AND MONITORING

The scope of this report originated in May 2006, based on input from local stakeholders and documents that provided both technical guidance on recovery strategies and legal authority to accomplish this work. The approach taken in the assessments, in particular the identification and preliminary prioritization of restoration and protection opportunities, evolved to incorporate new information as it became available. This report documents one stage of the tributary reach-based approach, a scaled assessment approach being utilized by Reclamation. The entire approach is described in section 2.1, to provide the reader a background of how this report fits in with the larger process.

2.1 Tributary Reach-Based Approach

The tributary reach-based approach developed from discussions among participating scientists, managers, and local recovery planners who recognized a process-based geomorphic assessment would align well with the objectives and guidance expressed in NPCC subbasin plans and recent recovery planning documents.

The tributary reach-based approach includes the following stages:

- A “tributary assessment” of a valley segment is made at a relatively coarse scale. A tributary assessment focuses on a length of river up to a few tens of miles long. The purpose of the tributary assessment is to identify major geologic and hydraulic processes active within the valley segment, explore whether geomorphic and hydraulic conditions upstream and downstream from the valley segment affect conditions within the segment, and identify “geomorphic reaches” within the segment that share common geologic and hydraulic physical attributes.

- Near the conclusion of the tributary assessment, stakeholders review the results and include relevant social, political, and biological information, and prioritize which of the geomorphic reaches identified from the assessment possesses the greatest potential to implement projects that will obtain successful, sustainable, biological benefits and warrant a more detailed “reach assessment.” A few project locations and concepts may be identified at this stage that do not require a reach assessment, particularly when the processes associated with the project are fairly localized and isolated.

- A “reach assessment” focuses on an individual reach identified in a tributary assessment, which is preferably less than 10 miles in length. The purpose of the reach assessment is to further refine understanding of the predominant processes that affect the reach, to establish a baseline of environmental habitat conditions, and to provide technical recommendation of sequenced habitat actions. Analysis obtained previously from the tributary assessment provides information on upstream and downstream geomorphic and hydraulic conditions that could affect those physical conditions within the assessed reach. A reach assessment identifies project areas that are based on factors negatively impacting channel processes and establishes a baseline of environmental habitat conditions using a modified "Matrix of Diagnostics/Pathways and Indicators" (NOAA, 1996).

- At the conclusion of a reach assessment, stakeholders review results; include more detailed social, political, and biological information; and prioritize project areas and specific projects with the greatest potential to obtain successful and sustainable biological benefits. After projects are identified and prioritized, partners typically take the next steps to design and implement alternatives, including landowner discussions, and secure funding for construction.

The tributary reach-based approach described above is used to identify potential habitat protection and restoration opportunities. The purpose of nesting reach assessments within a tributary assessment is to ensure the appropriate geomorphic and hydraulic information is obtained at the appropriate scale and timeframe for answering relevant questions or problems being investigated. In turn, this supports a decision process with others to seek ways to prioritize funding and resources as effectively as possible. The decision process further allows partners to systematically identify and prioritize areas with the greatest potential to implement protection or restoration projects that obtain successful, sustainable biological benefits, postpone investment in areas with less potential, and avoid investing in areas with little potential. This is a flexible approach and can be modified to accommodate smaller areas or the availability of pre-existing information. The approach may not be needed at all when partners conclude that biological benefits of protection or restoration projects are already clearly defined.

Use of the tributary reach-based approach could contribute to obtaining funds for project implementation. Funding proposals that conform to a systematic scientifically-based approach that identifies and prioritizes channel-complexity and floodplain-reconnection protection and restoration projects potentially could be more open to consideration for grants from entities that require sound justification for the proposals they choose to fund.

2.2 Potential for Linking the Tributary Reach-Based Approach with Monitoring and Adaptive Management

Tributary habitat actions demand a strong understanding of the regional and watershed context. Three ultimate controlling factors at these coarser levels: physiography (geology and topography), vegetation, and climate, play an important role in assessing and identifying tributary habitat actions. These factors and their influences on rivers are essential in further understanding the effects of human disturbances on physical processes at the local level. When physical processes and their controlling factors are not well understood or considered, habitat restoration has greater potential for failure.

Monitoring efforts serve as a foundation for scientists, managers, and stakeholders to refine and improve upon future management decisions, restoration activities, and practices. Monitoring provides feedback on how individual projects are performing immediately after construction and over time, by helping determine what changes occur after project implementation as compared to baseline conditions before initiating project implementation. Given that most habitat restoration occurs at the site and reach scale (Fausch et al. 2002; Montgomery and Bolton, 2003), implementation and monitoring strategies need to be geared accordingly within an adaptive management framework

Within the Interior Columbia Basin, Upper Columbia subbasins are developing strategies for monitoring and adaptive management, which could be transferred as a model for monitoring efforts in other subbasins. Many different organizations, including Federal, State, Tribal, local, and private entities, implement tributary actions and have drafted integrated monitoring strategies intended to assess the effectiveness of restoration projects and management actions on tributary habitat and fish populations (Hillman 2006). Because of a multitude of ongoing activities in the Interior Columbia Basin, the *Monitoring Strategy for the Upper Columbia Basin* (Hillman 2006) includes recommendations for a monitoring plan that captures the needs of all entities, avoids duplication of sampling efforts, increases monitoring efficiency, and reduces overall monitoring costs. This same approach was adopted in the John Day Basin Research Monitoring and Evaluation Pilot Project (USBR 2004) and could be implemented across the basin for improved efficiency in monitoring habitat actions in the assessment areas of the John Day River.

The plan[2] described in the *Monitoring Strategy* (Hillman 2006) is aimed at answering the following basic questions:

- Status monitoring—What are the current habitat conditions and abundance, distribution, life-stage survival, and age-composition of fish?
- Trend monitoring—How do these factors change over time?
- Effectiveness monitoring—What effects do tributary habitat actions have on fish populations and habitat conditions?

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[2] Although this plan targets ESA-listed fish species (i.e., spring Chinook, summer steelhead, and bull trout), it is also applicable to other non-listed species (Hillman, 2006).

In the *Upper Columbia Biological Strategy* (UCRTT 2007), further guidance is provided on implementing monitoring activities specific to habitat restoration actions. Monitoring strategies are generally described in three categories:

- Implementation monitoring.
- Level 1 effectiveness monitoring.
- Level 2 and 3 effectiveness monitoring.

Implementation monitoring provides proof that the action was carried out as planned. Level 1 (extensive methods) is the next step up from implementation monitoring; it involves fast and easy methods that can be completed at multiple sites. Level 2 and 3 (intensive methods) includes additional methods beyond Level 1 that increase accuracy and precision but require more sampling time (Hillman 2006).

Information presented in this report is intended to complement the monitoring protocols described above by providing historic and contemporary information on channel and floodplain functions. Subsequent reach assessments will provide a finer resolution diagnostic investigation on present biological use and habitat conditions, which are integrated with an understanding of local physical processes. Reclamation, their partners, and project sponsors are conducting implementation monitoring to document restoration actions accomplished in the John Day subbasin. This information provides for near-term future assessment and monitoring efforts, which can be used by entities working on status, trend, and effectiveness monitoring plans to test whether the river and habitat function responded as anticipated to implemented projects. Additionally, each restoration project implemented will have documented predictions based on hypotheses as to how processes and complexity are to improve (restore) as an outcome of the project(s).

This kind of overall framework is consistent with an “adaptive management framework” as described in *Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance* (NMFS 2007a). Organizing implementation, monitoring, and adaptive management at a reach scale provides a “building block” structure that could be explored for meeting FCRPS BiOp and recovery goals at the population, Major Population Group (MPG), Evolutionary Significant Unit (ESU) and Discrete Population Segment (DPS) levels. Project implementation and monitoring proposals that conform to a framework able to connect project implementation with monitoring and adaptive management, could potentially also be more open to consideration for grants from entities that require sound scientific justification for the proposals they choose to fund.

3.0 Background Information on Fish Use and Typical Channel Processes

3.1 Present Fish Use

The John Day subbasin is characterized as a Category 2 watershed using criteria described in the *Upper Columbia Recovery Plan* (UCSRB 2007). This means that it has significant subwatersheds that support important aquatic resources for one or more ESA-listed fish species, and is considered to have medium habitat fragmentation (UCSRB 2007). Both spring Chinook and ESA-listed steelhead utilize the assessment areas for migration, holding, spawning, and rearing. Reductions in steelhead abundance are of particular regional importance due to large populations of naturally spawning steelhead in the recent past (NOAA 2003).

In the Middle Fork, surveys conducted since the mid-1950s indicate a generally increasing trend in spring Chinook in the basin. Increased escapement populations may result from improvements to fish passage and diversion screening, management practices, riparian vegetation, and irrigation efficiency (NPCC 2005). However, Ruzycki et al. (2007) contend that smolt production remains limited, despite increases in redd densities, due to summer rearing temperatures. Long-term trends in steelhead populations indicate a general decline, with a substantial reduction of 13.7 percent between 1987 and 1997 (NMFS 1999).

In the Upper Mainstem, Oregon Department of Fish and Wildlife redd surveys illustrate an increasing trend in spring Chinook abundance. Steelhead abundance has been generally declining in the Upper John Day River since 1958, with short-term trends between 1987 and 1997 showing a 15.2 percent decrease.

Detailed descriptions of habitat conditions for salmonids on the Oxbow and Forrest Conservation Areas are provided in a draft biological report (CTWSRO 2007). These properties cover at least part of the following reaches: UJD2, UJD3, MF5, MF6, MF7, MF8, MF9, MF13, and MF14.

3.2 Delineation of Geomorphic Reaches

Process-based reaches were defined primarily by physical characteristics that dominate channel function and shape and maintain habitat features. Initially, geologic controls, such as alluvial fans and bedrock outcrops, were identified through field evaluation of the assessment areas. Other physical characteristics used in identifying the reaches included valley confinement, tributary inputs of flow and sediment, and riparian vegetation. Geomorphic processes that result from the physical characteristics of the river were evaluated to further define reach characteristics. Examples of geomorphic processes include changes in channel form and position, channel slope, sediment transport capacity, and notable areas of erosion or deposition.

Longitudinal boundaries of the reaches are generally located at geologic constriction points, such as bedrock or large alluvial-fan deposits that impart lateral and vertical limits on channel position. These geologic controls may influence the transition of channel processes between adjacent reaches. For example, channel position in one reach may be controlled by a downstream constriction point through which the channel must travel. Other processes, such as sediment transport, may not be constricted at these points and depend more on the ability of the downstream reach to transport incoming sediment.

Figure 2 – Alluvial Bank Showing Bedrock Exposure. This material acts as a lateral control on the channel position in the Middle Fork, above Big Boulder Creek

Lateral boundaries of each reach are defined by the extent of the floodplain, referred to as the "low surface" in this report. The low surface is composed of the active channel (unvegetated main channel and sediment bars), side channels, vegetated islands, and the adjacent floodplain. The floodplain boundary consists of bedrock outcrops and alluvial fans that are difficult to erode on a decadal time scale and limit or at least slow lateral expansion (Figure 2).

3.3 Floodplain Types

As a result of geologic influences, the floodplain within the assessment areas ranges from reaches that are geologically confined and relatively narrow to floodplain areas that are unconfined with the greatest potential for dynamic lateral channel migration over a wider floodplain (Figure 3 and Figure 4; Table 3). Three floodplain types were identified that help group geomorphic reaches based on their potential to develop and sustain features of habitat complexity:

- Wide, Unconfined Floodplain with High Complexity
- Moderately Confined Floodplain with Medium Complexity
- Narrow, Confined Floodplain with Low Complexity

The degree of complexity within the floodplain refers to the availability of off-channel habitat due to large woody debris (LWD), side channels, wide-ranging vegetation, groundwater inputs, and diverse patterns of hydraulics (velocities and depths) and sediment deposition. The relative degrees of complexity described in this document vary substantially between basins. For example, a highly complex, wide, and unconfined floodplain within the Upper Mainstem is relative to the floodplains in that assessment area, which differ considerably from the same terminology used to describe the floodplain of the Middle Fork due to large-scale controlling factors of hydrology, geology, and topography.

Although the level of complexity may vary between each floodplain type, each has valuable habitat components that are essential to sustaining the variety of aquatic life stages and species within the John Day River ecosystems. Areas with higher rates of floodplain reworking and interaction between the channel, side channels, and riparian vegetation offer the most opportunity for providing habitat complexity.

More than 90 percent of the assessment area in each subbasin is composed of moderately confined and unconfined reaches. These reaches have measurable floodplain areas adjacent to the main channel that consist of islands, overbank flooding areas, side, and overflow channels and contain a considerable number of opportunities for protecting and restoring habitat complexity (Figure 5). The 2006 main channel length in moderately confined and unconfined reaches that offer opportunities for restoring channel and floodplain connectivity accounts for 18.6 river miles in the Middle Fork assessment area (81 percent of total length) and 2.7 river miles in the Upper Mainstem assessment area (86 percent of total length). Additional details related to the floodplain types are provided in Appendices D and E.

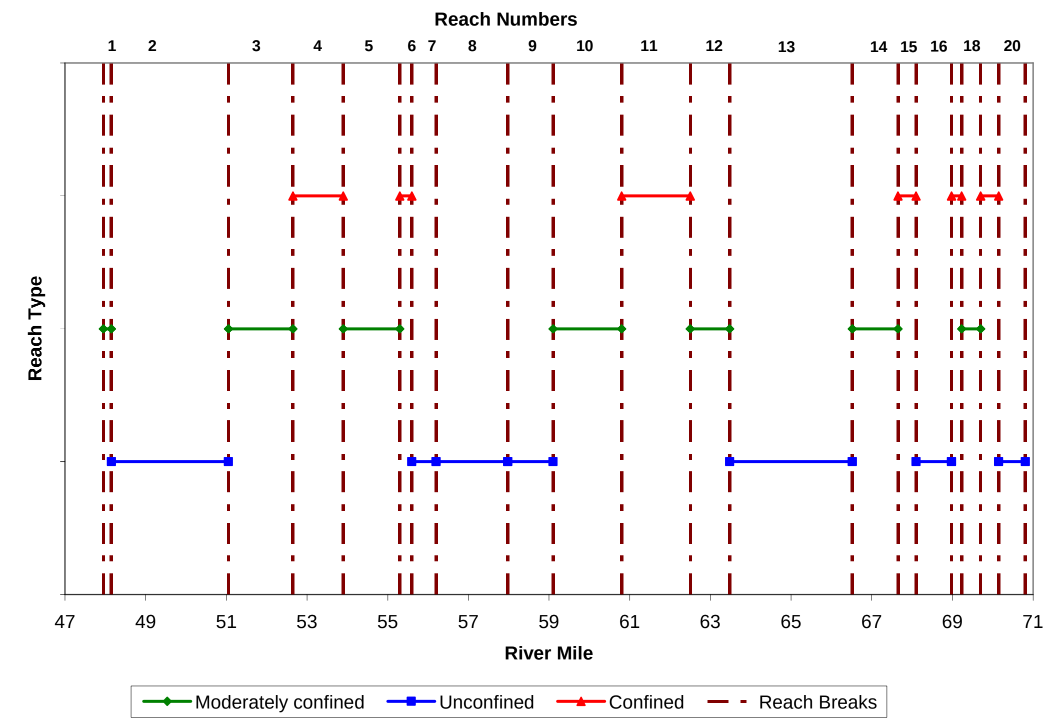

Figure 3 – Distribution of Floodplain Types in the Middle Fork Assessment Area. Note the alternating pattern of confined to unconfined floodplain, from upstream to downstream.

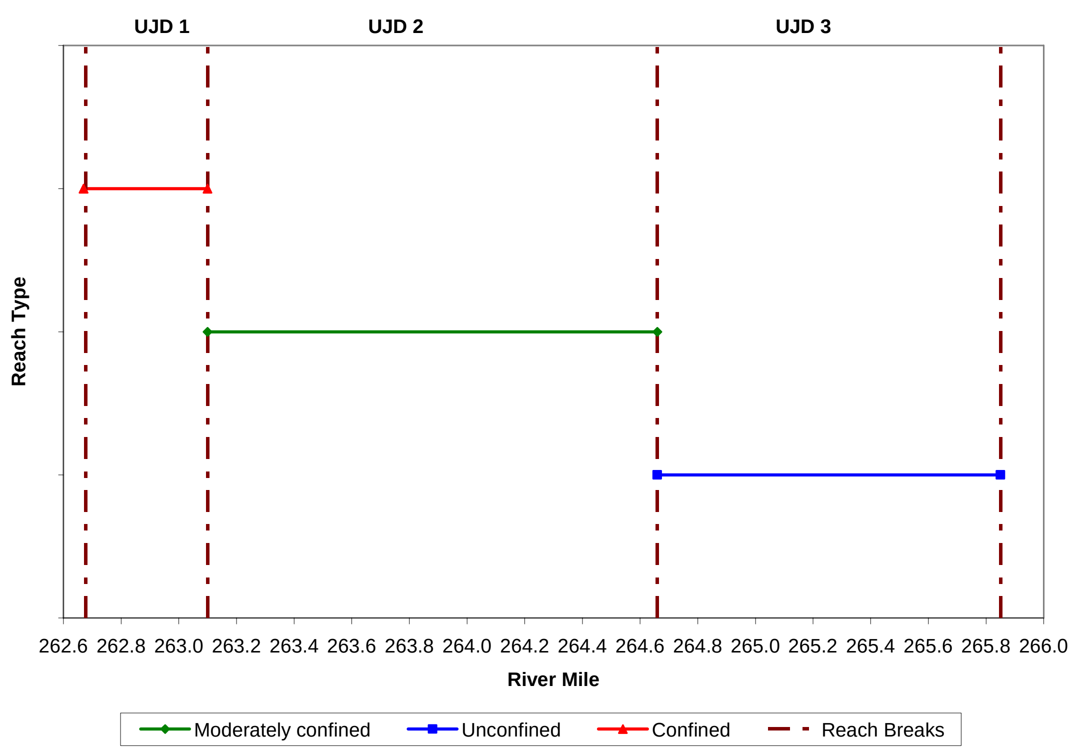

Figure 4 - Distribution of Floodplain Types in the Upper Mainstem Assessment Area.

Table 3 – Location and Floodplain Type of Geomorphic Reaches

Floodplain Type	Reach*	Downstream River Mile	Upstream River Mile
Middle Fork Assessment Area			
Moderately confined	MF1	48.0	48.2
Unconfined	MF2	48.2	51.1
Moderately confined	MF3	51.1	52.7
Confined	MF4	52.7	53.9
Moderately confined	MF5	53.9	55.3
Confined	MF6	55.3	55.6
Unconfined	MF7	55.6	56.2
Unconfined	MF8	56.2	58.0
Unconfined	MF9	58.0	59.1
Moderately confined	MF10	59.1	60.8
Confined	MF11	60.8	62.5
Moderately confined	MF12	62.5	63.5
Unconfined	MF13	63.5	66.5
Moderately confined	MF14	66.5	67.7
Confined	MF15	67.7	68.1
Unconfined	MF16	68.1	69.0
Confined	MF17	69.0	69.2
Moderately confined	MF18	69.2	69.7
Confined	MF19	69.7	70.2
Unconfined	MF20	70.2	70.8
Unconfined	CC1	0.0	0.5
Upper Mainstem Assessment Area			
Confined	UJD1	262.7	263.1
Moderately confined	UJD2	263.1	264.7
Unconfined	UJD3	264.7	265.9

* MF = Middle Fork John Day River; UJD = Upper Mainstem John Day River; CC – Clear Creek

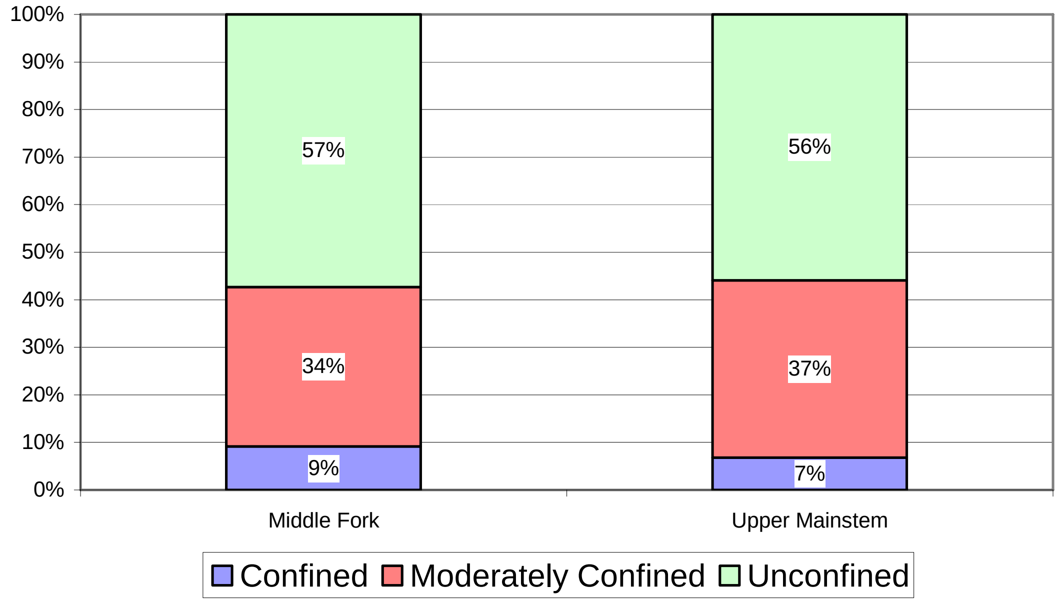

Figure 5 – Distribution of Reach Types and Floodplain Availability within Assessment Areas.

3.4 Typical Channel Processes

The following discussion describes typical characteristics and channel processes that are generally associated with each of the floodplain types. Based on physical attributes of each system, historical trend analyses, and anecdotal information, these typical channel processes provide a conceptual framework for how the channel could ideally function.

3.4.1 Wide, Unconfined Floodplain with High Complexity

In general, this floodplain type consists of relatively wide, unconfined valleys with flatter slopes than more confined floodplains (Figure 6). Channels have greater potential to be more sinuous than other floodplain types and frequently interact with their floodplains. The wide alluvial nature of the floodplain results in large supplies of sediment in storage. The frequency and rate of lateral channel migration and reworking of the floodplain could be greater than other floodplain types. The dynamic process of the conversion of channel to floodplain, and vice versa, can support the continual regeneration of healthy riparian forests, which add shade, organic material, and complexity to the channel.

The presence of LWD combined with healthy riparian vegetation can moderate rates of lateral migration and floodplain reworking. LWD inputs from adjacent banks or upstream reaches encourage the development of point bars and subsequent establishment of vegetation. The persistence of the bars and islands promote continued vegetation growth, which add to channel roughness and to the future contribution of LWD. Within the channel and adjacent floodplain, LWD leads to unique patterns of hydraulics and sediment, creates backwater habitats, and increases the overall complexity of the channel.

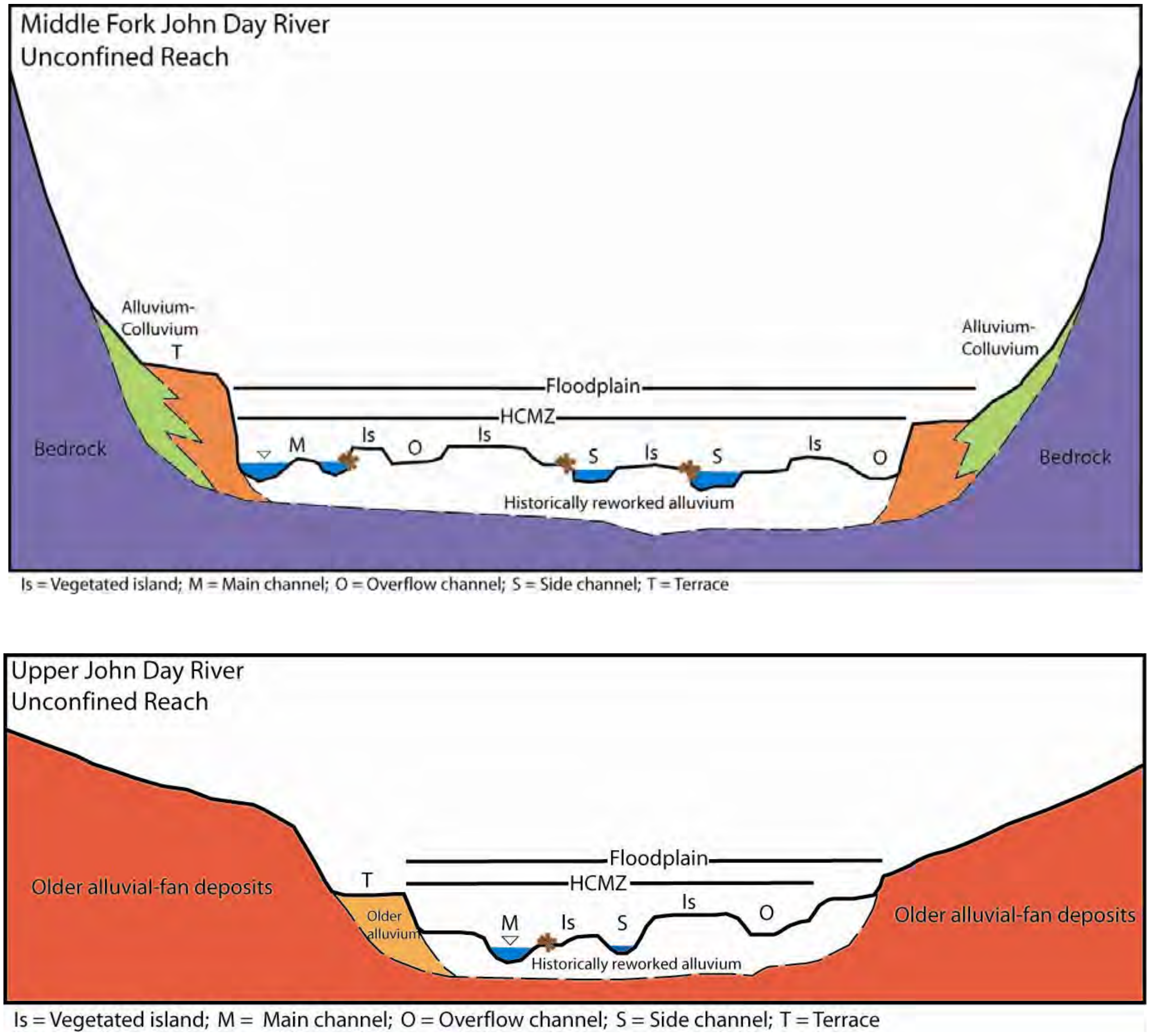

Figure 6 – Schematic Cross Sections of a Wide, Unconfined Floodplain in the Middle Fork (top) and Upper Mainstem (bottom) Assessment Areas. Note differences in the degree of complexity.

Channel avulsions can occur commonly during flood events due to the formation of a channel plug from a sediment wave or log jam. The channel in this floodplain type has the ability to dynamically equilibrate following natural episodic events, such as fire or flooding. Despite lateral channel movement and recurrent working of floodplain sediments, no net change in the total volume of sediment stored in the reach is expected over the long term.

The dynamic and often complex processes occurring in this floodplain type can result in more diverse sediment deposition patterns, typically smaller sediment gradations, and inputs of LWD. These critical habitat elements can create ideal spawning and rearing habitats. The presence of springs, tributaries, and subsurface flows can provide cold water recharge areas that are important attributes of thermal refugia.

The Middle Fork unconfined floodplains differ from those of the Upper Mainstem in their relative degrees of complexity. Unconfined floodplains of the Middle Fork typically have much wider floodplain surfaces and flatter slopes than those of the Upper Mainstem and have greater potential for a complex network of multiple side and overbank channels. In the Middle Fork, there is evidence of a dynamic interaction between the river and the groundwater table. Springs and wet meadows may have historically contributed to base flows and temperature regulation. During low flow conditions, unconfined floodplains of the Middle Fork could consist of multiple wetted channels due to seeps, springs, and groundwater storage. Although beaver populations were documented as having historical significance in both assessment areas, their influence on channel processes may have the potential to play a larger role in adding to the complexity of wet meadows in the assessment area of the Middle Fork. Beaver dams could add to base flows in both systems.

3.4.2 Moderately Confined Floodplain with Medium Complexity

The topography of this floodplain type consists of a more defined main channel and fewer side and overbank channels than the unconfined floodplain (Figure 7). Floodplain widths are generally narrower than those of the unconfined floodplain and older, higher surfaces contribute to increased stability of floodplain surfaces. Most water and sediment is conveyed through the main channel, but some side channels could have sufficient flow to support habitat on a seasonal and possibly year-round basis.

A healthy riparian corridor in the moderately confined floodplain could supply organic leaf litter and LWD to the system, shading the channels, reducing bank velocities, and hence, moderating rates of lateral migration and bank erosion. LWD inputs from the floodplain and upstream reaches could add complexity to the channel and floodplain similar to the unconfined reaches. However, the duration of time that log jams remain within the channel of this floodplain type may be shorter than that of unconfined floodplains due to increased energy. In the Middle Fork, there is a lesser tendency towards the development of wet meadows in moderately confined floodplains compared with unconfined floodplains.

Lateral channel migration and floodplain reworking occurs less frequently than in unconfined floodplains due to a higher percentage of older surfaces. Channel avulsions may occur in the main channel and possibly within a few defined side channels, but are typically not prevalent across the entire floodplain. The main channel generally remains within the same location over a decadal scale with slight adjustments in channel position due to the natural evolution of meander bends and localized channel avulsions.

Off-channel habitat complexity may not be as abundant as in unconfined floodplains. However, these floodplains can still contain a wide variety of habitat components and complexity, and support a range of fish species and life cycles. Within the main channel, conditions could provide suitable spawning habitat for Chinook and steelhead. Some large pools could provide holding habitat with good shade and predation cover. High winter and spring flows contribute to the potential storage of water in the alluvium that enhances base flows and maintains adequate temperatures to support salmonid habitat. Tributary inputs and groundwater flows further moderate temperatures through cold water additions during warm summer months. This process is of particular importance on the Middle Fork, where small variations in summer water temperatures greatly influence the survival of salmonids.

Spawner escapement in these reaches is dependent on hydrologic conditions. In lower flow years, redds that are established in riffles and in higher velocity areas could be successful since major flooding does not mobilize and disrupt the nests. However, redds embedded at the edge of the wetted channel or in higher side channels may be subject to desiccation. In higher flow years, redds in high velocity zones may be washed out, but redds at the edges of the channel or in side channel habitats are more successful.

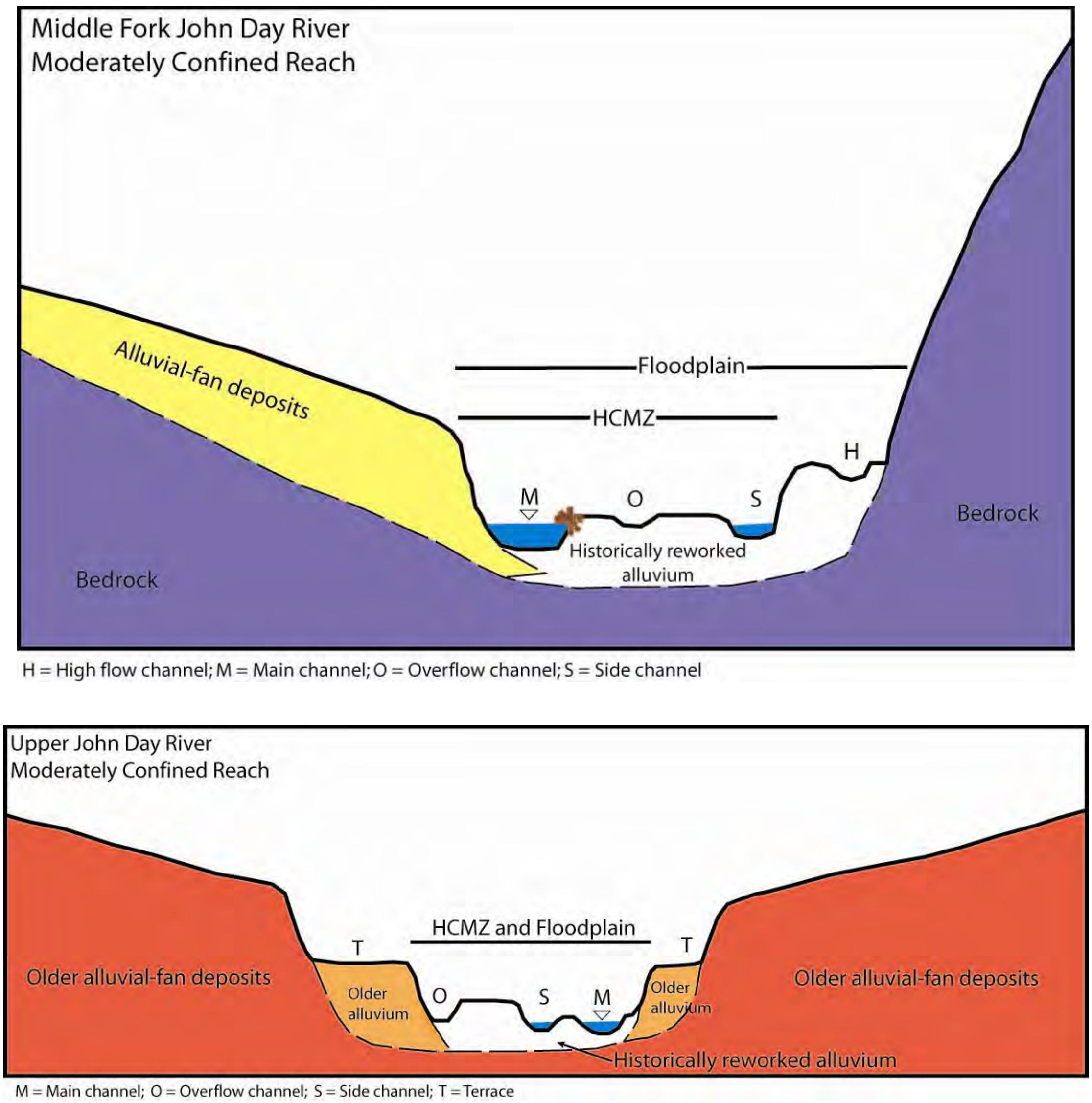

Figure 7 – Schematic Cross Sections of a Narrower, Moderately Confined Floodplain in the Middle Fork (top) and Upper Mainstem (bottom) Assessment Areas.

3.4.3 Narrow, Confined Floodplain with Low Complexity

Confined reaches typically offer less potential for off-channel habitat due to narrow floodplains, steep slopes, and greater energy than unconfined and moderately confined reaches (Figure 8). In confined floodplains of the Middle Fork, surfaces adjacent to the floodplains experience dramatic increases in slopes and are generally comprised of steep alluvium and resistant bedrock. Confined floodplains in the Upper Mainstem are surrounded by older alluvial surfaces with much more gentle slopes predominantly consisting of alluvium. Surfaces bounding the floodplains in these reaches are typically only inundated during events of high magnitude, and in some locations may have historically been inundated only during paleofloods.

Sediment sizes comprising the bed and bars of the channel are generally larger than those of other floodplain types. Confined reaches are typically supply-limited, transporting most of the smaller material through to downstream reaches. Lateral channel migration and channel avulsions are limited due to the inability of the channel to erode through larger sediments and bedrock, although some lateral channel evolution could occur in stretches with a wider floodplain. In the Middle Fork, bedrock, alluvial fans, and boulders provide substantial vertical and lateral controls on channel position in confined reaches.

Most of the complexity within this floodplain type consists of in-channel habitat complexity, which can result from LWD, organic inputs from adjacent hillslopes, and variability in sediment sizes. Interactions between the floodplain and groundwater may be limited by floodplain storage; however, groundwater inputs to these reaches from alluvial features and bedrock aquifers may be present. Riparian vegetation is generally restricted to the narrow floodplain and on some bars, potentially providing LWD to downstream reaches. Other woody vegetation from hillslopes could further contribute to LWD within the system, particularly in the Middle Fork. Mass wasting events and alluvial material from adjacent hillslopes of the Middle Fork could add to complexity features within the channel. Due to the high energy of these floodplains and the subsequent ability to transport sediment and wood, the potential for LWD within the channel may be limited. In the Middle Fork, LWD could fall across the valley and possibly remain for several years until a large enough flood event is capable of dislodgement.

Despite limited off-channel habitat, these reaches could have important habitat functions. While some species may have success spawning in confined reaches, spring Chinook and steelhead probably use these reaches as holding and migration corridors to upstream or downstream reaches. Pockets of slower-velocity flows behind occasional boulders may provide resting areas. In-channel LWD and dense riparian vegetation could also provide canopy cover and predation protection to younger age classes.

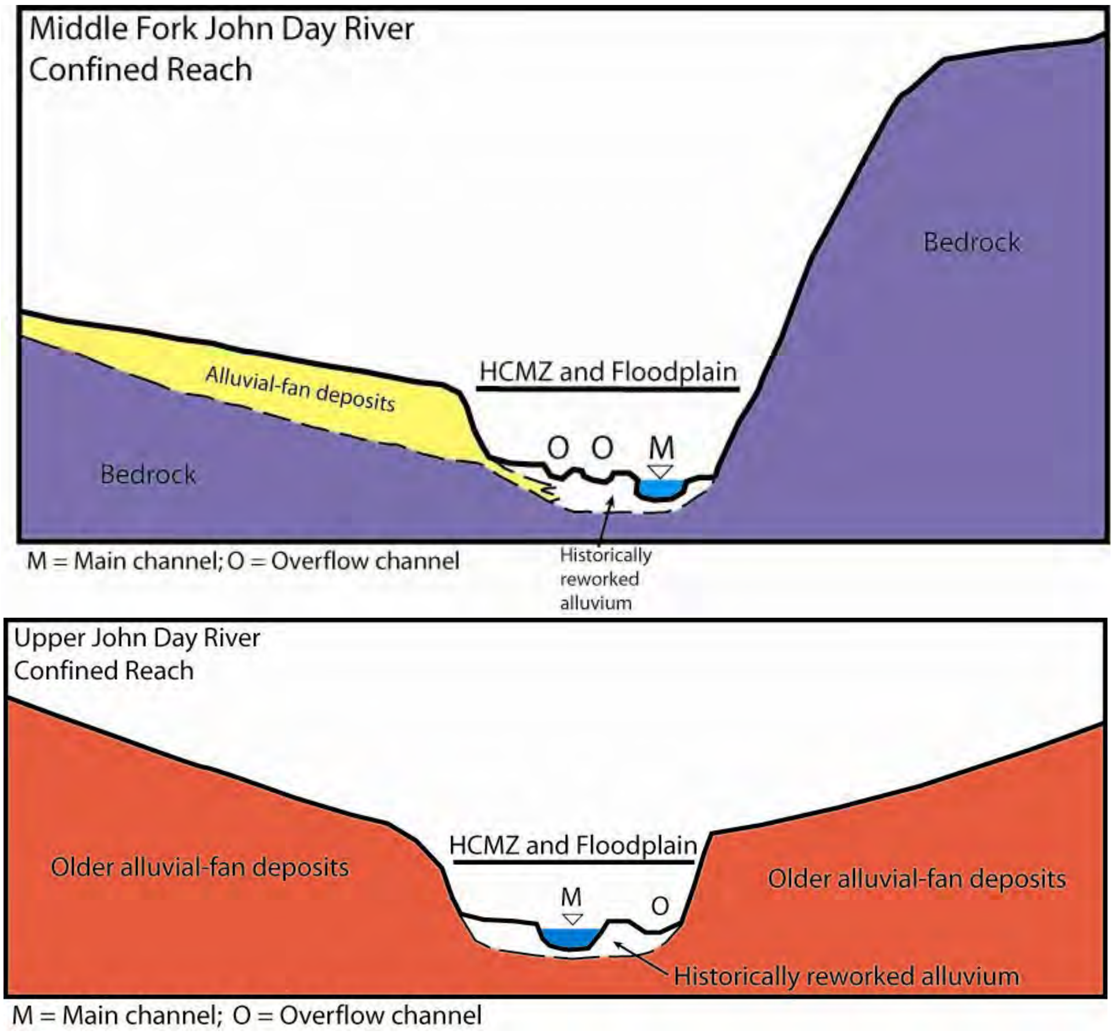

Figure 8 – Schematic Cross Sections of a Narrow, Confined Floodplain within Middle Fork (top) and Upper Mainstem (bottom) Assessment Areas.

4.0 HISTORICAL CHANGES IN GEOMORPHIC CONDITIONS

The geomorphic portion of this report focused on physical processes that drive creation and sustained habitat features important to spring Chinook and steelhead. River morphology and channel processes, and subsequently habitat, are dominated by the flow regime, the sediment regime, and the geologic and constructed topography. Topographic features, including riparian vegetation, also affect channel morphology. Disturbance to any of the three main elements can alter the form of the river and associated channel processes. Changes to temporal or spatial distributions in flow, changes in sediment sources or the sediment budget, changes to channel slope, vertical controls or channel energy, and changes to channel planform, channel bed elevation, riparian condition, channel and floodplain connectivity can alter the availability of and the potential to restore salmonid habitat. Habitat features that were considered include development of pools, quality of and access to side channel areas, LWD, spawning gravels, and refuge areas during high- and low-flow periods.

Of particular focus are changes in the three key elements of flow regime, sediment regime, and topography in the nineteenth and twentieth centuries that could impair habitat restoration today. Detailed descriptions of the methods and findings are provided in Appendices D and E. The typical channel processes described in Chapter 3 provide a conceptual model to help identify process-based opportunities for habitat improvement. A review of historic change and comparison of the present river setting to the conceptual model helps determine which processes may not be functioning at their fullest potential today. Trends based on historical change in the river system were evaluated to identify the rate and extent of changes. Looking at historical trends of river processes provides an understanding of how changes relate to historical floods and human activities, and whether the changes can be anticipated to continue in the future.

4.1 Historical Changes in Flood Hydrology

Flow volume and timing is arguably the dominant control over channel processes that determines the shape and planform of the river. In the nineteenth and twentieth centuries, many rivers were altered by the construction of water development projects. Restoring habitat in the face of major changes to the flow regime of a river is one of the greatest challenges of a habitat restoration project. Habitat restoration in the John Day River assessment areas has an advantage in that the flow regime persists relatively intact from predevelopment time for both the Middle Fork and the Upper Mainstem.

There are no large man-made dams and reservoirs in the assessment areas or upstream watersheds that have significantly reduced sediment loads or incoming water discharge (peak floods) over the last century. No significant trends in the occurrence or magnitude of peak floods were detected from the USGS gaging station data that could imply a change to stream energy over time. The longest gage record at any one location in the Middle Fork subbasin is

76 years, and in the Upper Mainstem, the longest flow record is 42 years (Appendix C). Table 4 shows the range of discharge and slopes present in the Middle Fork and Upper Mainstem Assessment Areas.

Table 4 – Range of Discharges and Channel Slopes Along Each River within the Assessment Areas.

John Day River Assessment Area	2-Year Flood Peak (cubic feet per second)	100-Year Flood Peak (cubic feet per second)	Slope (Percent)
Middle Fork	330 - 1,130	1,080 - 3,500	0.33 – 2.3
Upper Mainstem	780 - 1,000	2,480 - 3,210	0.5 - 0.87

There is a range of flow for each assessment area to account for tributary inputs and increasing drainage area from upstream to downstream. Additional stream flow from tributaries and overland flow provides more potential energy to transport sediment and LWD.

Floods have an important function in the maintenance of complexity habitat for anadromous salmon. Flood processes are responsible for complex geomorphic features that exist in rivers and within their floodplains. Although the magnitude, timing, duration, and spatial extent of an individual flood will influence system impacts, floods are generally important to:

- Channel avulsion and lateral migration (e.g. Figure 9).
- Recruitment and transport of LWD.
- Recruitment and establishment of riparian vegetation.
- Scour of floodplain deposits.
- Maintenance of vegetation-free gravel bars.
- Replenishment of groundwater aquifers and maintenance of water table elevations.
- Creation of in-stream geomorphic features, such as pools and riffles.

Major flow events in the John Day Basin were recorded in 1894, 1955/56, and 1964/65 (Table 5). Impacts of each flood event resulted in the development and implementation of management strategies for the protection of property and infrastructure. Management strategies consisted of channel straightening, riprap bank installations, levees, and clearing of channel blockages, including the removal of LWD and other gravel and debris plugs.

Table 5 – Annual Peak Flow in Cubic Feet per Second Recorded during Flood Events on the Mainstem and Middle Fork of the John Day River. The instantaneous peak was likely higher than the flows presented here.

Gauge Location	1894	1955/1956	1964/1965
John Day River at McDonald's Ferry	39,100	24,900	42,800
Upper Mainstem John Day River at Prairie City	NA	962	2,400
Middle Fork John Day River at Ritter	NA	3,330	4,730

Results of a paleoflood study on the John Day River indicate that historical floods occurring in the past 2,000 years were similar in magnitude to flood events of the past 73 years (Orth 1998). Only 2 floods in the past 2,000 years were determined to be greater than the discharge recorded at this site for the 1964 flood.

Figure 9 – John Day River near Dayville during 1964 Flood Event. This photo exemplifies typical channel avulsion occurring on a rancher's property. The river eventually formed a new channel and straightened out the river bend. Photo compliments of Grant County.

4.2 Historical Changes in the Sediment Regime

Sediment also plays a large role in river form and channel processes. The conveyance of sediment and the erosive power of rivers are controlled by the grain size of transported material, the sediment supply, and the energy in the system, which is a function of slope, flow, and valley confinement. Studying historical changes to these factors is helpful for assessing the rate of past trends and determining the degree to which restoration of habitat is possible under present conditions.

Over time, streams move towards an equilibrium condition to balance energy available with energy needed to convey and transport the incoming sediment. Changes to the system can alter the supply of sediment or can change the ability of the stream to transport sediment, potentially disrupting the equilibrium of the system. Consequences of modifications to the sediment regime can be incision, aggradation, or a change in channel planform (e.g. braided to meandering or meandering to braided). Disruption to the sediment regime can also cause reductions in gravel transport or increases in the transport of fine sediment, which can reduce the quality of spawning habitat.

Floodplain confinement resulting from constructed features restricts water to a smaller conveyance area during floods. Reduced flood conveyance area may cause increased velocities in the main channel compared to unrestricted floodplains where water inundates the surfaces and side channels surrounding the main channel. Increased stream energy in the main channel may cause channel adjustment through increased sinuosity, incision, or widening. However, lateral and vertical geologic controls along the channel margins limit the ability of the river to significantly adjust its geometry. Although local bed elevations may change in response to a change in channel position, system-wide trends in aggradation or incision were not detected in either basin. Evidence of past adjustment to the installation of constructed features and floodplain disconnection was noted through possible channel widening in the Upper Mainstem and localized areas of degradation in the Middle Fork.

The sediment regime for the Middle Fork and the Upper Mainstem are treated separately in this section. More detailed discussion of channel stability and sediment transport capacity characteristics of each assessment area are provided in Appendices D and E.

4.2.1 Historical Changes in the Sediment Regime of the Middle Fork Assessment Area

4.2.1.1 Anthropogenic Activities

The Middle Fork has experienced historical adjustments to the sediment regime as a result of watershed changes such as grazing and logging. The system has also experienced localized adjustments due to mechanical changes from dredge mining and logging operations.

Grazing

Within the Middle Fork John Day River, grazing has influenced channel morphology and riparian conditions in most moderately confined and unconfined reaches. Sheep grazing was prevalent in the basin from the late 1800s to the middle 1900s. By the 1940s, domestic grazing was dominated by cattle and continues to be today (USFS 1998). Streamside vegetation and bank stability within most of the unconfined and moderately confined reaches has been altered by cattle grazing and trampling. In several locations where cattle grazing was persistent for decades, the channel is wider, shallower, and less complex than ungrazed reaches. Bar, bed, and bank trampling contributes increased amounts of fine sediment. Degraded riparian vegetation and reduced canopy cover have lead to decreased stream shading and increased potential for solar heating (USFS 1998).

Dredge Mining

Following the turn of the century, dredge mining was initiated on the Middle Fork and continued into the 1940s (Figure 10). Dredge mining activities modified the channel and the valley floors in reaches MF8 and MF11. Within the meadow, dredging operations would turn over floodplain deposits, bringing coarse alluvial substrate from the deep subsurface and freeing up finer sediments for down stream transport (McDowell 2000). When dredging operations were complete, floodplains were transformed to piles of coarse alluvium (Figure 10), and the adjacent river beds and banks were dominated by much coarser material than the river was competent to rework.

Logging Impacts

Logging was once a major source of income for towns within and surrounding the Middle Fork subbasin. Rates of timber harvest increased following development of the railroad. The town of Bates and several temporary camps were developed throughout the Middle Fork basin to assist in hauling lumber to local mills. As a result of development in the town of Bates, Clear Creek was channelized and relocated approximately 200 meters to the east of the original channel position. In order to create one of the two mill ponds, a dam was constructed across Bridge Creek. Significant impacts from timber harvest in the assessment area include:

- Modifications to river morphology to accommodate mill construction and development of the town of Bates.
- Removal of potential sources of LWD.
- Construction of railroads and roads within the floodplain to transport logs to adjacent mills.
- Increased pollution from the milling operations (Grant 1993).
- Increased fine sediment delivery to the river resulting from increased surface runoff.

Figure 10 – Example of Dredge Mining Impacts on the John Day River and Adjacent Floodplain in Reach MF8. The top photograph shows the river conditions in 1939, just prior to the start of dredging operations in this reach. The bottom photograph was taken in 1956, almost 15 years following the end of dredge mining in the basin.

4.2.1.2 Vertical and Horizontal Controls and Channel Slope

Geomorphic mapping of the river system (see *Map Atlas)* was conducted to identify geologic and constructed constraints on the vertical position of the river system and geologic constraints on the horizontal position. Both geologic and man-made controls can limit the degree of channel response and adjustment to changed conditions in the flood plain.

River slope is strongly influenced by vertical controls, which can prevent or limit slope adjustments, such as channel degradation. Vertical controls and their rate of change can also play a large role on the development of the valley width. When a vertical control is more erosion resistant than the channel banks and valley walls (horizontal controls), wider valleys can form over geologic time. In general, reaches in the Middle Fork Assessment Area alternate in patterns of wide, unconfined valleys and narrow valleys constricted by alluvial fans and bedrock. McDowell (2001) suggests that the alternating valley types occur as a result of abrupt transitions in valley width, which are likely due to lithologic change and fault structures.

Geologic constriction points formed by opposing resistant surfaces, such as bedrock and alluvial fans, result in flow restrictions which control channel position through transitional reaches (unconfined to confined and vice versa). Bedrock present in the channel can limit the degree of vertical channel adjustment. Coarse materials from an alluvial fan or large boulders from an adjacent hill slope can harden the channel bed and impose both a steeper slope and a vertical control on the river. Locations of vertical geologic controls, geologic constrictions and major alluvial fans are illustrated in Figure 11 relative to channel bed elevations.

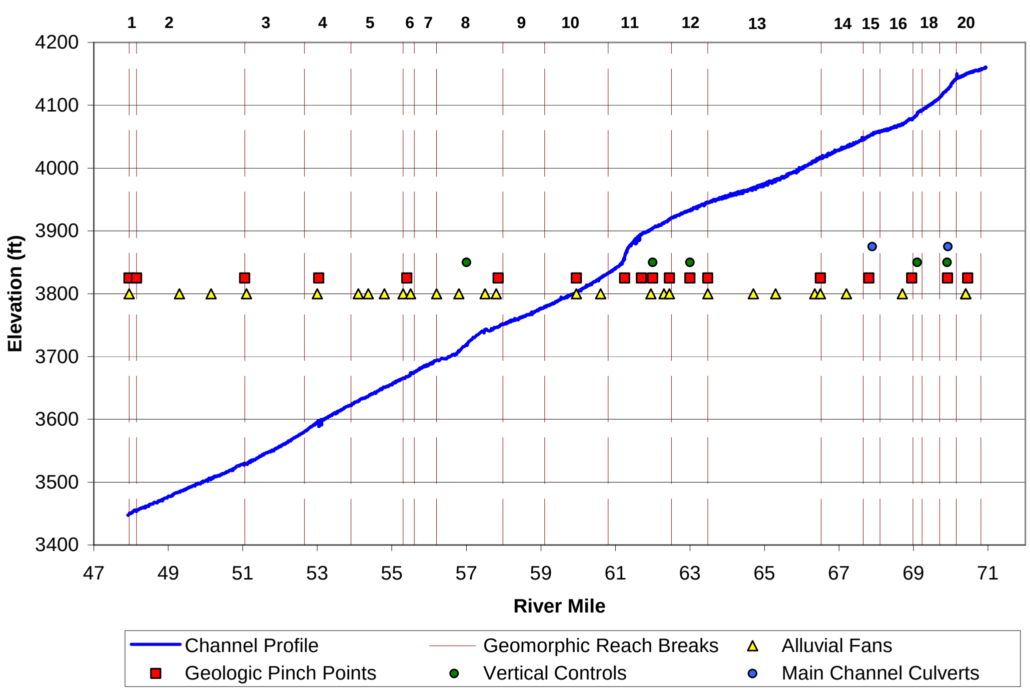

Figure 11 – Location of Alluvial Fans, Geologic Constrictions, and Vertical Controls in the Middle Fork Assessment Area.

In general, vertical controls have not changed substantially in the last 100 years, with the exception of some additional constructed controls. The exact number and locations of man-made vertical controls have not been mapped, but known locations include most diversion structures and culverts (see Figure 30), log and rock structures on Forest Service properties, and a rock grade control structures in MF16 (Figure 12 and Figure 13). These structures are discussed further in sections of Chapter 4.3. Like vertical geologic controls, constructed features can cause upstream aggradation, or if they are removed, can instigate headcuts.

Historical dredge mining in MF8 and MF12 has created another type of vertical geologic control by effectively inverting the stratigraphic column of the floodplain. During the dredging process, fine sediments were frequently buried at depth with coarse-grained sediment overlying them, or fine sediments were winnowed out of the remaining tailings by river flows and transported to downstream reaches. The channel is no longer capable of reworking the more coarse bed and bank materials that remain near the surface in dredged areas over a decadal time scale.

Figure 12 – Rock Structure in MF15. It may provide a vertical control on the extent of erosion.

Figure 13 – Rock Diversion. It exerts some vertical control on the channel position in reach MF20.

Geologic surfaces bounding the floodplain of each reach are illustrated in Figure 14. These surfaces are generally difficult to erode on a decadal time-scale and restrict the lateral position of the channel. Major alluvial fans are less resistant than bedrock but supply a large volume of material that can shift the channel to the opposite side of the floodplain surface. A more detailed description of the influence of each alluvial fan on channel position is provided in Appendices D.

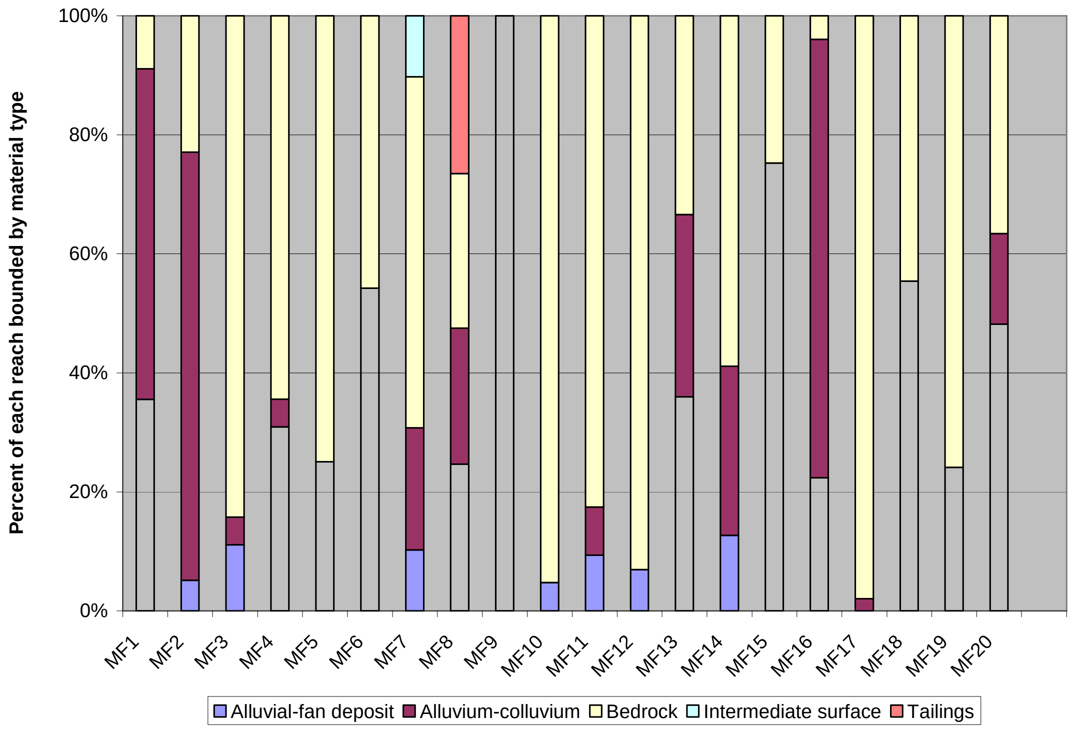

Figure 14 - Geologic Surface Bounding the Floodplain Throughout the Middle Fork Assessment Area.

The range in slopes is much more variable for the Middle Fork Assessment Area than for the Upper Mainstem. The channel profile was used to identify significant geologic and anthropogenic vertical channel controls. In general, the channel slope of the Middle Fork coincides with the relative degree of floodplain confinement (Figure 15). Confined reaches tend to illustrate relatively high slopes when compared with moderately confined and unconfined reaches and generally have a greater capacity to transport sediment and LWD due to their high slopes. For example, reach MF11 is heavily confined and contains a sharp drop in grade as the channel travels over large boulder and bedrock controls (Figure 16). Unconfined reaches of the Middle Fork tend to have the lowest slopes.

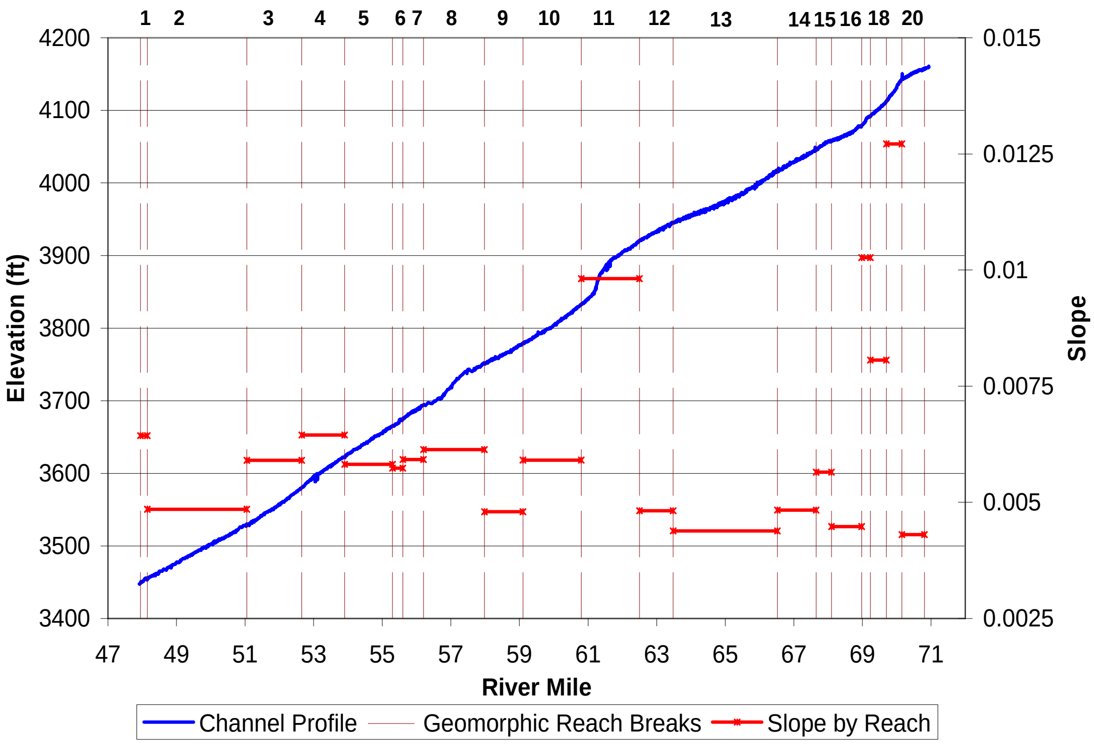

Figure 15 – Bed Elevations and Reach Average Slope of the Middle Fork Assessment Area.

Figure 16 – Major Slope Break Near RM 62. The large boulders act as a vertical geologic control to channel the adjustment.

4.2.1.3 Sediment Sources

Fine sediment is supplied through sheet and rill erosion occurring in subdrainages that have been disturbed by timber harvest, road construction and wildland fires. These sediments are being transported downslope to perennial and ephemeral streams and then to the Middle Fork by entrainment and saltation.

Coarse sediment is supplied through bank erosion along the Middle Fork and sediment pulses entering the Middle Fork from several perennial tributaries. Removal of riparian vegetation along the Middle Fork may have destabilized the riverbanks. Following major flood events, bank erosion control measures were installed and primarily consisted of bank armoring that prevents lateral channel migration, and rock spurs that were intended to restrict lateral movement. These measures can also increase flow velocity, deepen the channel and reduce sediment supply.

Tributaries with the greatest potential to contribute coarse sediment to the Middle Fork include Clear Creek, Vinegar Creek, Granite Boulder Creek and Big Boulder Creek. The most significant contributions appear to be coming from the Big Boulder Creek subdrainage. In 1996, the Big Boulder Creek subdrainage was burned by a moderate-to-high intensity wildland fire that removed much of the groundcover exposing the soil to erosion. Shallow landslides and debris flows are prevalent throughout the Boulder Creek watershed and provide sediment pulses to the perennial stream and eventually to the Middle Fork. Big Boulder Creek has been a coarse sediment source to the Middle Fork throughout the Holocene epoch, based on the large alluvial fan that has developed where the creek flows across the valley floor. In addition, a relatively large gravel bar at the mouth of the creek suggests coarse sediment is continually being delivered to the Middle Fork. Sediment deposits at the downstream end of Granite Boulder Creek also indicate coarse sediment loading to the artificial north channel of reach MF8.

At the present time, Clear Creek and Vinegar Creek do not appear to be providing significant amounts of coarse sediment to the Middle Fork. There is a small gravel bar at the mouth of Clear Creek that formed between the 1976 and 2005 aerial photograph sets, following the creek's realignment due to the construction of the town of Bates. The gravel bar presence suggests that the creek provides a relatively small amount of coarse sediment to the Middle Fork. Vinegar Creek also provides an episodic supply of coarse sediment as interpreted from historic aerial photography that shows shallow landslides along the creek and some channel migration across its alluvial fan on the valley floor.

Other potential coarse sediment supplies may be contributed from disturbed areas associated with historic placer mining. These areas include the Middle Fork downstream of Caribou Creek and Granite Boulder Creek, and also the Vincent Creek subdrainage.

4.2.1.4 Assessment of Middle Fork Channel Stability

Various methods were used to evaluate the stability of the Middle Fork Assessment Area and are discussed in detail in Appendix D. These methods included a one-dimensional hydraulic model, evaluation of sediment samples, incipient motion computations, longitudinal comparison of stream power, and sediment transport capacity analyses. Results from the efforts are summarized below.

Water surface elevations for the 2-year flow are close to or overtopping the channel banks in almost all reaches. Within confined reaches, water surface elevations are typically just at or only slight overtopping the channel banks for the 2-year event. Water surface elevations for the 2-year event in moderately and unconfined reaches tend to overtop the channel banks in a greater number of cross sections than in the confined reaches. In general, unconfined and moderately confined reaches have a greater percentage of overbank flow under the 2- through 100-year flood events than confined reaches. In unconfined reaches, as the flows and channel area increase in the downstream direction, the amount of overbank flow tends to decrease.

Three separate sediment transport capacity formulae were used to assess trends in sediment transport capacity under flood flow conditions. Sediment transport capacity patterns tend to coincide with the planform attributes of each reach and/or slope breaks. Unconfined, low gradient sections of the channel are typically characterized by low sediment transport capacity, while highly confined, high gradient sections have much higher sediment transport capacity. Reach breaks are often located at transitions zones or geologic constriction points, where variable sediment transport patterns are noted.

Results of the assessment suggest that substantial incision has not occurred in most reaches. Segments of river channel containing artificial channelization, such as the lower portions of reaches MF8 and MF15, typically do not access the floodplain as frequently as segments without channelization. While the 2-year event slightly overtops the bank in most unconfined reaches, substantial floodplain connectivity does not occur without flow conditions on the order of a 5- to 10-year event. In most reaches, both the channel and bar sediments are mobilized by flows less than the 2-year flood event. Exceptions include samples from reaches MF2, MF3, MF5, MF8, MF12, MF14, and MF16, where greater flow events are required to mobilize bed and bar materials. Mild localized incision or bed coarsening may have occurred in small portions of a few reaches as evidenced by the frequency of bed material mobilization and floodplain inundation. However, differentiation between localized incision and artificial channelization is difficult to decipher.

Potential for aggradation or degradation were assessed by comparing general trends in stream power across the assessment area. River systems with high rates of change in downstream slope tend to be characterized by a peak in stream power near the headwaters and greater concavity in the downstream direction (Knighton 1998). Local variations in stream power patterns may be related to geologic constraints in valley confinement and slope, such as those present in the confined reaches of the Middle Fork. Evaluating trends in unconfined reaches indicates increasing stream power in the downstream direction, which suggests a tendency for degradation in the downstream direction during flood flow events (Figure 17). Further degradation may be limited to some extent by vertical and/or lateral geologic controls at several reach transitions.

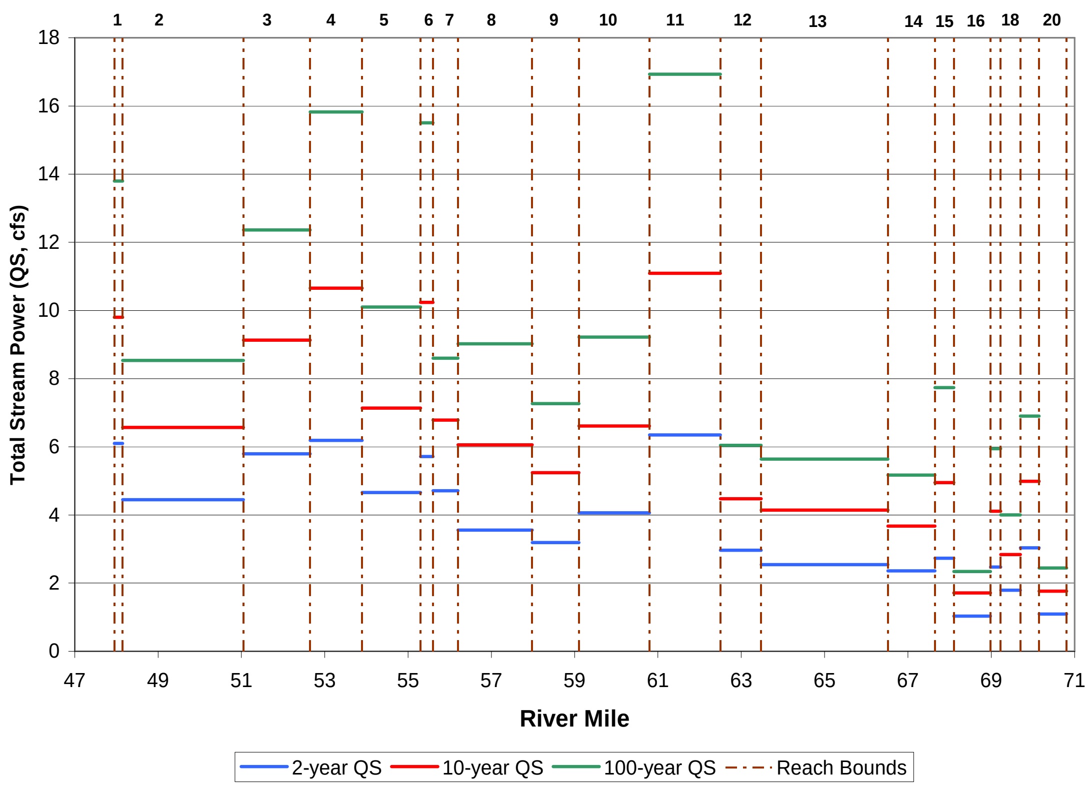

Figure 17 – Total Stream Power in Each Geomorphic Reach. Reach numbers are shown at the top of the graph.

Despite historical development and changes to the valley since the 1800s, the river appears to have reached a new dynamic equilibrium. The new equilibrium is defined by fewer active overbank and side channels and possibly a less frequently inundated floodplain than under historic conditions. Although active channel aggradation or degradation was not evidenced during field visits, a slight tendency for degradation in the downstream direction may be present during flood events. Any modifications to the system that disrupt the present equilibrium (e.g., removal of artificial topographic features) may result in channel adjustments through increased lateral channel migration where the channel is competent to rework floodplain deposits. Potential channel adjustments have implications for long-term stability of restoration actions, such as LWD placements, and will require additional investigations at a more refined scale.

4.2.2 Historical Changes in the Sediment Regime of the Upper Mainstem

4.2.2.1 Ranching, Grazing, and Timber Harvest

Within the Upper John Day River, ranching and grazing have considerably influenced channel morphology and riparian conditions. Sheep were more prevalent than cattle throughout the basin from the late 1800s to the middle 1900s. By the 1940s, as transportation routes improved and cattle were hauled with greater ease, domestic grazing became dominated by cattle and continues to be today. Ranching and grazing often required land clearing within meadows and along the river banks. This maximized the area of land that could be seeded with grass or hay for cattle grazing, which became increasingly important when the fenced cattle ranging practices were initiated. Oliver (1962) describes the importance of land clearing as a first step in homesteading along the John Day River between Prairie City and John Day, Oregon:

> "One of the first jobs on the Clark homestead was to clear off brush and trees. Big cottonwoods grew all along the river and the meadows were covered by wild thornbushes, to be chopped out by hand."

Streamside vegetation and bank stability within reaches UJD2 and UJD3 have been notably altered by cattle grazing and trampling. Where cattle grazing was persistent for decades, the channel is wider, shallower, and less complex than ungrazed segments (Figure 18). Erosion of unvegetated banks contributes increased amounts of fine sediment, while degraded riparian vegetation and reduced canopy cover have lead to decreased stream shading and increased potential for solar heating.

Timber harvest was likely more prevalent in upstream reaches of the Upper John Day River than in the assessment area. Vegetation that was removed from the floodplain may have been sold to local mills or used for fire wood. A large log mill was built near Prairie City in the 1960s for the production of lumber, but has not operated in several years. A stud mill was constructed in the same area and operates today at a capacity of 300,000 board feet per day (ODEQ 2007).

While the mechanism is not entirely clear, a substantial portion of riparian vegetation was removed within the floodplain due to anthropogenic activities. Comparison of historic aerial photographs indicate that 37 percent of woody vegetation in reach UJD1, 66 percent of woody vegetation in reach UJD2, and 50 percent of woody vegetation in reach UJD3 was converted to low vegetation or open areas since 1939. However, a substantial amount of woody vegetation was probably removed prior to the earliest 1939 photographs.

Figure 18 - Wide, Shallow River Devoid of Woody Vegetation in Reach UJD2.

4.2.2.2 Vertical and Horizontal Controls and Channel Slope

Geomorphic mapping of the river system (see *Map Atlas*) was conducted to identify geologic constraints on the river system. Vertical geologic controls within the assessment area are difficult to document due to the lack of bedrock; however, alluvial fans are present that impart both lateral and vertical controls. Due to the large supply of coarse sediment comprising the alluvial fans, these geologic surfaces are generally difficult to erode on a decadal time-scale. Opposing alluvial fans near the transition of reach UJD2 and reach UJD3 constrict lateral channel position by forcing flow between the geologic features. A substantial change in channel grade at this location indicates that the opposing fans may be protecting the bed of the river and imparting a vertical control.

The main geologic surfaces bounding the floodplain include older alluvial materials and an intermediate surface comprised of alluvium (Figure 19). Alluvial fans impacting the Upper Mainstem Assessment Area include fans at Strawberry Creek, Dad's Creek, and Jeff Davis Creek. Their locations within the assessment area are shown in Figure 20. These geologic controls have generally remained intact; however, some localized lateral erosion of accessible alluvial materials may have occurred in locations where the river flows against the alluvium.

Constructed features also provide local vertical controls on the system that generally persist over much shorter time scales than geologic controls. Several continuous grade control structures are present in reach UJD3 (Figure 21) to provide sufficient head for an upstream diversion. Four diversions are located in the assessment area and combined with bank protection features may impart some degree of vertical and lateral control on channel position. A major irrigation diversion, installed between 1976 and 1994, is located just downstream of the boundary between reaches UJD2 and UJD3. No culverts were documented as being present within the Upper John Day assessment area.

Channel slopes in the Upper Mainstem Assessment Area range between 0.5 percent and 0.87 percent. Slopes in reaches UJD1 and UJD2 are relatively consistent, with greater variability in reach UJD3. The longitudinal profile on the Upper Mainstem shows a considerable change in grade at the transition between reaches UJD2 and UJD3. The slopes in reach UJD3, however, have likely departed from historic conditions due to substantial channel straightening and grade controls structures. The slope break just downstream from Jeff Davis Creek is the location of a series of rock grade control structures. Historic slopes in reach UJD3 were probably more similar to the lower end of the reach, which is characterized by slopes of approximately 0.5 percent. Reach UJD2 has also experienced a high degree of channel straightening, and slopes may presently be greater than historic conditions.

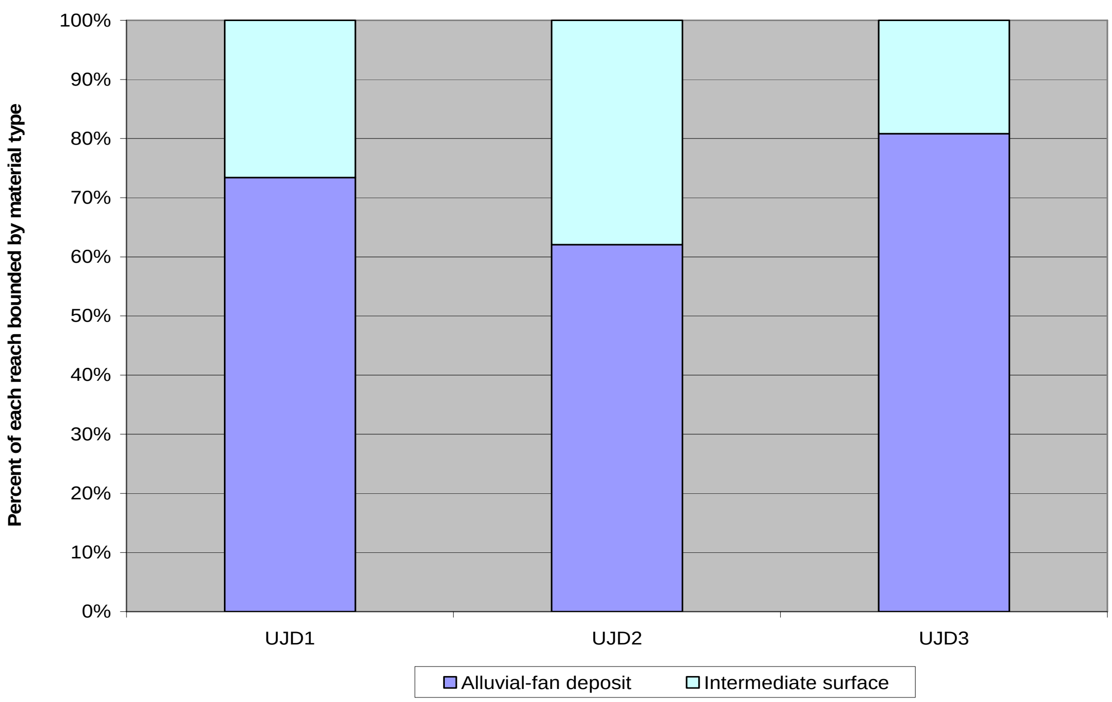

Figure 19 – Geologic Surface Bounding the Floodplain Throughout the Upper Mainstem Assessment Area.

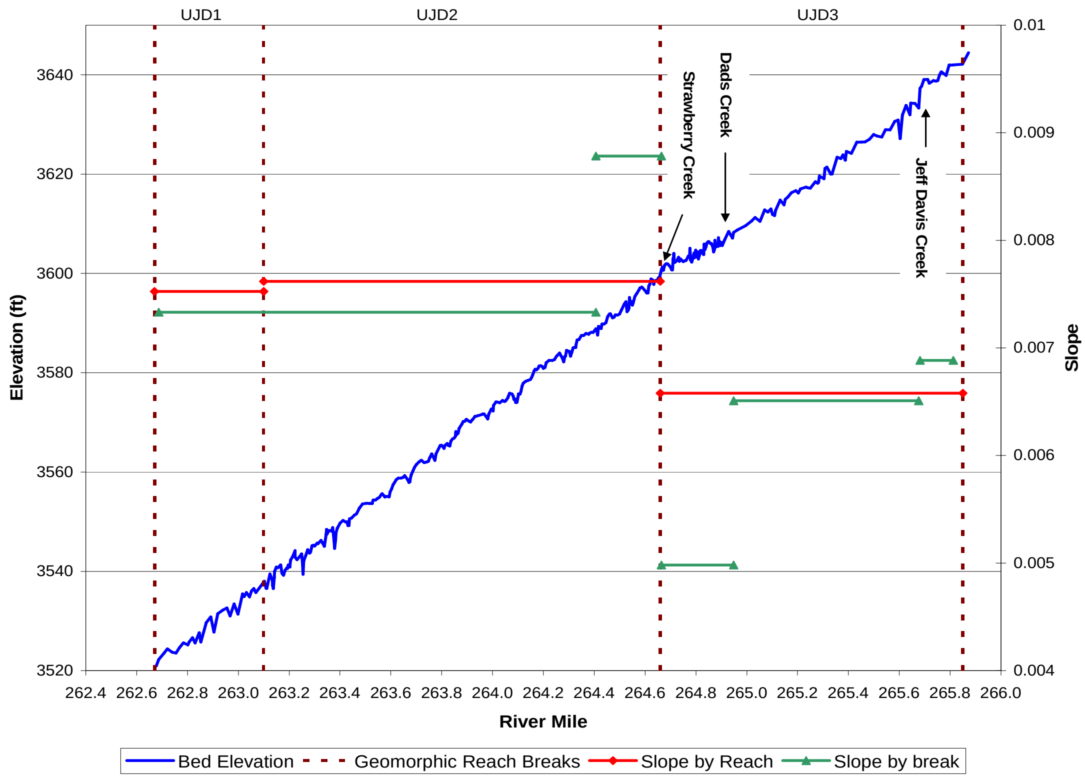

Figure 20 – Bed Elevations and Slopes in Upper Mainstem Assessment Area.

Figure 21 – Photograph of Grade Control Structure along Reach UJD3. A series of structures is present in the reach to support the required head for an upstream diversion.

4.2.2.3 Sediment Sources

Fine sediment is supplied through sheet and rill erosion from croplands, pediments, and subdrainages that have been disturbed by timber harvest, road construction, and agriculture. The fine sediments are being transported downslope to the Upper John Day River during spring runoff and also by agricultural practices (i.e., flood irrigation). Other fine sediments are supplied from ephemeral streams and perennial streams during spring runoff, although many of the perennial streams are partially diverted for irrigation purposes.

Coarse sediment is primarily supplied from bank erosion along the mainstem and possibly episodic "sediment slugs" entering the Upper John Day River upstream of the assessment area. Some loading of coarse sediment may also be supplied by Dad's Creek and Strawberry Creek based on the presence of bars immediately downstream of their confluences with the John Day River. Removal of riparian vegetation along the river may have destabilized the riverbanks, and bank erosion appears to have been a chronic problem based on interpretations of historic aerial photographs. Bank protection and river channelization methods were used to reduce bank erosion and to restrict lateral channel migration.

Other potential sediment sources include disturbed areas associated with historical placer mining. Placer mining was conducted along Dixie Creek and on the Upper John Day River downstream of Dixie Creek. Both of these areas are downstream from the current assessment area.

4.2.2.4 Assessment of Upper Mainstem Channel Stability

Various methods were used to evaluate the stability of the Upper Mainstem Assessment Area. These included a one-dimensional hydraulic model, evaluation of sediment samples, incipient motion computations, longitudinal comparison of stream power, and sediment transport capacity equations. Results from the assessments are summarized below. In general, the results suggest that substantial incision has not occurred in the assessment area.

Water surface elevations for the 2-year flow are close to or overtopping the channel banks in all reaches. In general, the 2-year flow was close to or overtopping the banks at a fewer number of cross sections and in lesser quantity in the confined reach (UJD1) when compared to the unconfined reach (UJD3). The percent of overbank flow in moderately confined reach UJD2 is close in value to that of the confined reach.

Three formulae were used to assess trends in sediment transport capacity under flood flow conditions. Moderately confined reach UJD2 had the greatest capacity to transport sediment of all three reaches and was generally close in value to the capacity of confined reach UJD1.

Although most of the channel in the assessment area does not appear incised, segments of river channel that have been artificially channelized, such as reach UJD2, typically do not access the floodplain as frequently as under historic conditions. While the 2-year event does slightly overtop the bank in the unconfined reach, substantial inundation of the floodplain does not occur without flow conditions on the order of a 5- to 10-year event. In reaches UJD2 and UJD3, both the channel and bar sediments are mobilized by flows less than the 2-year flood event. No samples were obtained in reach UJD1.

Evaluation of the 2-year modeled width-to-depth ratios indicates that the depth of flow is close enough to unity in most cross sections that the width and width-to-depth ratios are close in value. Comparison of the width-to-depth ratios for the 2-year flow on the Upper Mainstem with published values for properly functioning conditions (NMFS 1996; USFWS 1998) suggests that the channel geometry may not be functioning at levels consistent with providing high-quality habitat. These results indicate that there is insufficient depth in the channel when compared with width, which may be negatively influencing habitat value through reduced complexity and greater exposure to solar warming.

Due to historic alterations to the sediment regime, the river may be continuing a trend of adjustment through attempts at lateral channel migration where possible (Figure 22). Reach UJD2 has an increased erosive capacity compared to both upstream and downstream reaches under flood flow events. These results suggest that there is a trend toward lateral and/or vertical channel degradation in this reach, but no vertical degradation was noted during field visits. Opposing alluvial fans at the transition of reach UJD2 and UJD3 may impart some control on vertical channel adjustment. Considerable bank erosion was noted in localized areas during field visits. Some bank erosion and lateral channel shifts should be associated with the natural process of bend migration; however, it is not known whether the erosion noted was part of natural bend migration processes, or a response to historic channel straightening. Flood flows have caused alterations in channel position during the limited time period of this study. Overall, the channel may be eroding banks and making lateral adjustments, but is not degrading the bed.

Figure 22 – Example Location of Lateral Channel Migration Processes. Note the lack of woody vegetation that could slow bank erosion rates.

4.3 Historical Changes in Topography

4.3.1 Topographic Impacts to Physical Processes

Common topographic impacts to channel processes include the constriction of channel alignments, reductions in floodplain widths, disconnection of the historic channel migration zone (HCMZ) and floodplain, channel straightening, and reduction in channel complexity. Within the floodplain (low surface), a range of constructed features are present that impact channel and floodplain processes. Features, such as rock spur, riprap, and levees, were likely installed for flood protection following major events, like the 1964 floods. Development of transportation routes in the basin led to floodplain constrictions at bridges and general reductions in floodplain width. Bridge abutments impinged on channel widths and created increased velocities through smaller areas than were historically present. Logging roads were typically constructed within the level terrain offered by floodplains and meadows (USFS 1998). The railroad and other local roads were constructed on top of levees or berms through the floodplain, in some cases reducing floodplain width by 50 percent or more. In reach MJ13 of the Middle Fork, railroad construction disconnected several meander bends, causing channel straightening and increased slopes (e.g., Figure 23). A comparison of historical and current aerial photographs provides evidence that a substantial amount of artificial channel straightening occurred by repeated excavations to limit the extent of lateral channel migration through landowner properties.

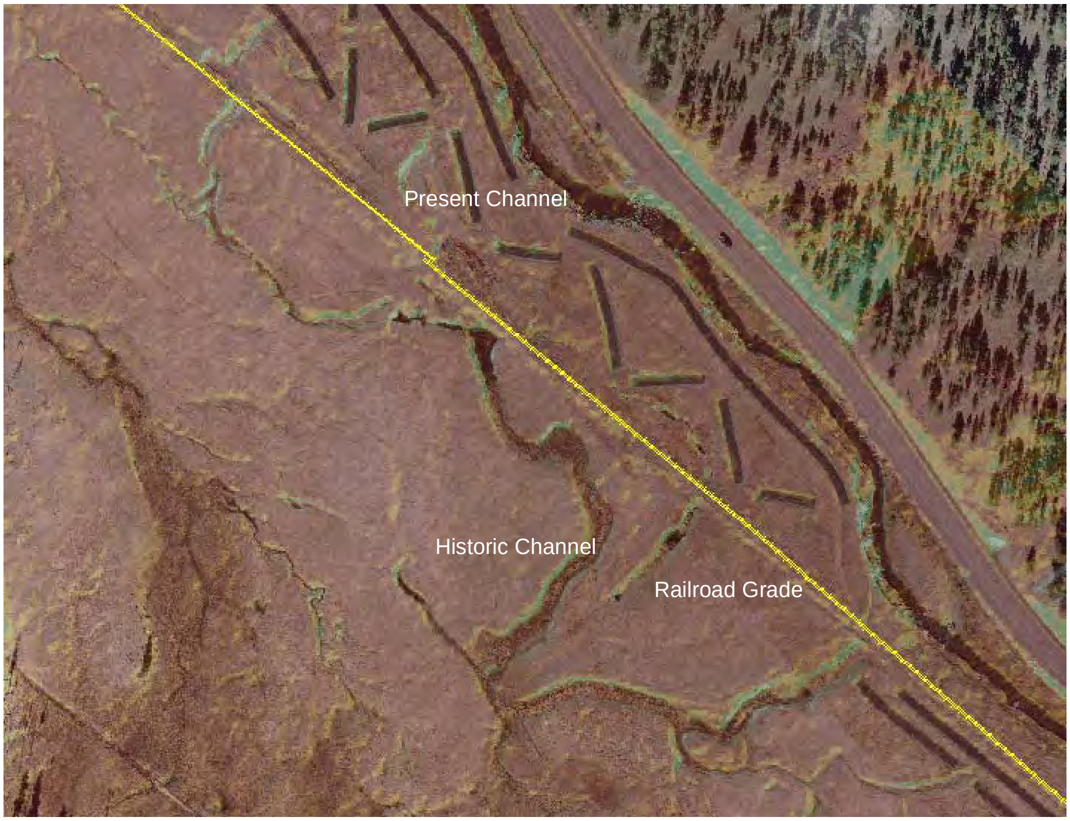

Figure 23 – Aerial View of Impacts of the Historic Railroad Grade on the Middle Fork. The railroad disconnects over 70 percent of the historic floodplain in some locations.

Constructed features impact channel conditions and floodplain complexity and connectivity to varying degrees. Levees, bridges, and roads typically disconnect floodplain access by preventing flow inundation of the surface and side channels. Rock spurs, riprap, and other bank armoring techniques may not restrict flow to the floodplain, but can often prevent channel migration and active reworking of floodplain deposits. Anthropogenic activities addressed in previous sections that also impact topography, such as dredge mining, grazing, timber harvest within the floodplain, and removal of LWD for flood control, may create channel instability and reduce channel complexity. These changes in channel form can translate to impaired access to floodplain habitat by fish and to a reduction in habitat features that depend on channel migration, recruitment of LWD, and reworking of the stream bed to form.

Although general impacts of structures were considered, the value of removing specific structures was not evaluated as part of this assessment. In some cases, individual structures may not notably affect channel processes and may even provide beneficial habitat, depending on their location with respect to current river conditions. The next stage of analysis should include a site specific geomorphic analysis of individual structures to assess the habitat restoration potential for each removal.

Table 6 summarizes the constructed features within each reach. (Within the *Map Atlas* that accompanies this report, constructed features are referred to as human features.) Reaches are numbered from downstream to upstream. Constructed features were broken into three categories (point, linear, or area) based on how they were mapped in a Geographic Information System (GIS) and based on their impacts on the floodplain. Point features impact specific locations in the channel, including rock spurs, bridges, diversions, culverts, filled or blocked channel locations, grade controls, weirs, or other structures. Linear features are features that impact a measurable length of channel, including armored banks (riprap and steel), levees, railroad grade, improved roads (highway), unimproved roads, irrigation ditches, and spoil piles. Constructed features evaluated by areal extent include dredge tailings, embankments, buildings, and other disturbed areas. Documentation on constructed features within each reach is provided in Section 4.3.4.2 and Section 4.3.5.2., and also Appendices D and E. GIS mapping of modified topography (see *Map Atlas*), as identified from historical aerial photographs and LiDAR data, was used to determine the percentage of artificially straightened or confined channels in each reach. The percentage indicates the degree of impact to the main channel in each reach.

Results in Table 6 indicate that unconfined reaches typically have the greatest length of impacted channel from constructed features. Exceptions to this include confined reaches MF15 and UJD1. The majority of MF15 was straightened and armored following the construction of the town of Bates in the mid 1900s. Reach UJD1 has been almost completely lined with riprap. Since the greatest impacts on channel processes results from topographic features, reaches with the greatest number, length, and area of constructed features generally offer the greatest opportunity for habitat restoration. However, future reach analysis should include more detailed geomorphic assessments of individual structures to determine if removal or modification of the structure could be anticipated to produce improvements in the desired habitat.

Table 6– Summary of Constructed Features Mapped in GIS for Each Reach. These features are referred to as human features in the *Map Atlas*.

Floodplain Type	Reach*	Down-Stream River Mile	Up-Stream River Mile	Total Number of Point Features	Total Length of Linear Features (feet)	Total Area of Area Features (acres)	Percent of 2006 Channel That is Artificially Straightened	Percent of 2006 Channel That is Artificially Confined
Middle Fork Assessment Area								
Moderately confined	MF1	48.0	48.2	2	251	0.42	34.5%	0.0%
Unconfined	MF2	48.2	51.1	37	6,972	1.81	5.9%	32.1%
Moderately confined	MF3	51.1	52.7	16	5,750	0.03	22.3%	9.3%
Confined	MF4	52.7	53.9	10	1,465	0.00	23.2%	0.0%
Moderately confined	MF5	53.9	55.3	11	2,263	0.00	8.4%	2.6%
Confined	MF6	55.3	55.6	2	1,632	0.00	0.0%	0.0%
Unconfined	MF7	55.6	56.2	50	1,385	5.70	28.9%	58.6%
Unconfined	MF8	56.2	58.0	5	2,804	141.06	100%	0.0%
Unconfined	MF9	58.0	59.1	14	5,035	4.43	35.8%	0.0%
Moderately confined	MF10	59.1	60.8	9	6,554	2.24	17.1%	17.2%
Confined	MF11	60.8	62.5	4	1,317	0.09	3.1%	14.6%
Moderately confined	MF12	62.5	63.5	2	1,894	18.20	61.8%	19.3%
Unconfined	MF13	63.5	66.5	284	1,8571	0.02	13.5%	77.2%
Moderately confined	MF14	66.5	67.7	109	2,280	3.66	16.0%	48.1%
Confined	MF15	67.7	68.1	5	434	3.56	100%	0.0%
Unconfined	MF16	68.1	69.0	6	3,631	0.44	9.2%	0.0%
Confined	MF17	69.0	69.2	2	0	0.00	3.0%	0.0%
Moderately confined	MF18	69.2	69.7	4	436	0.00	0.0%	0.0%
Confined	MF19	69.7	70.2	5	1,922	0.19	10.0%	0.0%
Unconfined	MF20	70.2	70.8	2	3,350	0.00	0.0%	4.2%
Unconfined	CC1	0.0	0.5	2	0	25.49	100%	0
Upper Mainstem Assessment Area								
Confined	UJD1	262.7	263.1	0	3,768	0.00	64.6%	0.0%
Moderately confined	UJD2	263.1	264.7	25	4,306	0.11	4.1%	45.1%
Unconfined	UJD3	264.7	265.9	27	4,807	0.00	5.9%	86.6%

* MF: Middle Fork UJD: Upper Mainstem CC: Clear Creek

4.3.2 Changes in Channel Planform

Historical aerial photographs within the assessment areas indicate some evidence of change in channel planform in localized sections of the Middle Fork and Upper Mainstem (Figure 24). For the most part, reaches that were single-thread main channels have remained single-thread channels. Reaches historically comprised of a complex network of multiple channels and a vegetated floodplain have been converted to single-thread channels with little or no side channel connectivity.

Figure 24 presents findings from comparisons of historical channel mapping (see *Map Atlas*) conducted in both assessment areas. In general, increases in main channel length and sinuosity can be attributed to meander bend evolution (both natural and in response to constructed features or anthropogenic activities), georectification errors in channel position, and errors in identifying the channel in the aerial photographs. Decreases in channel length may also be partially attributed to accuracies in channel mapping, but are in large part due to channel straightening and disconnection of meander bends. In many reaches, channel straightening occurred prior to the earliest photoset. One key example is the disconnection of more than 3,000 feet in MF13 due to construction of the railroad in the late 1800s. Descriptions of changes in channel length and sinuosity of each reach are provided in Appendices D and E.

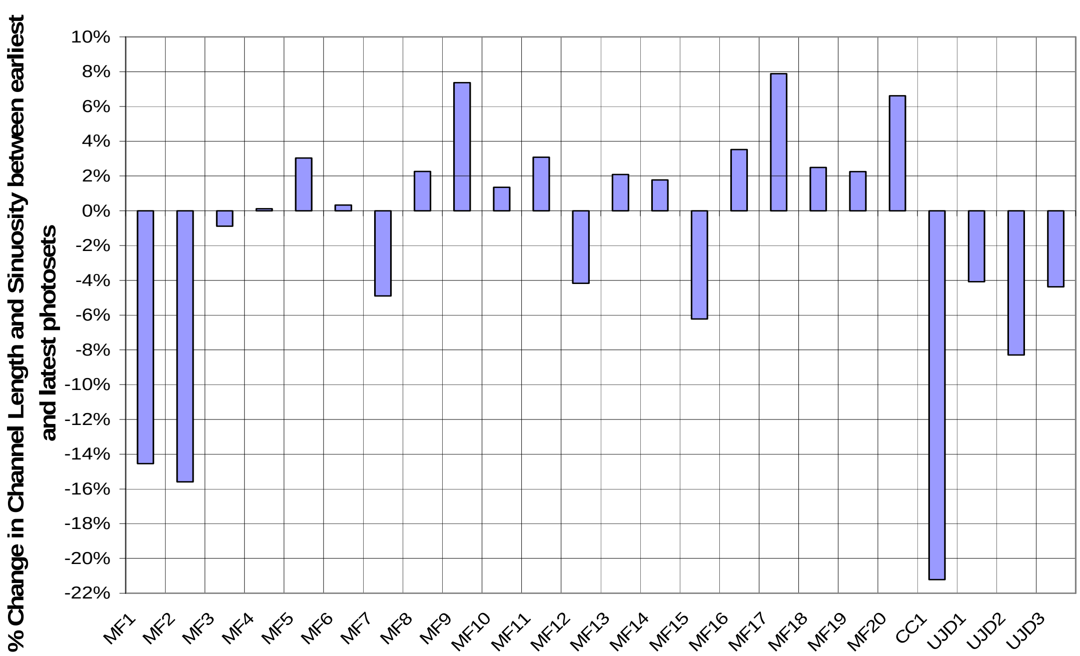

Figure 24 – Graph of Measured Changes in Channel Length from Historical Aerial Photosets. The earliest available aerial photographs range from 1939 to 1976.

Many sections of the Middle Fork and Upper Mainstem floodplains are laterally bounded by either alluvial fans or bedrock outcrops that are not easily eroded. These features cause local constrictions in the floodplain (Figure 25) and often influence the channel position, slope, and resulting planform.

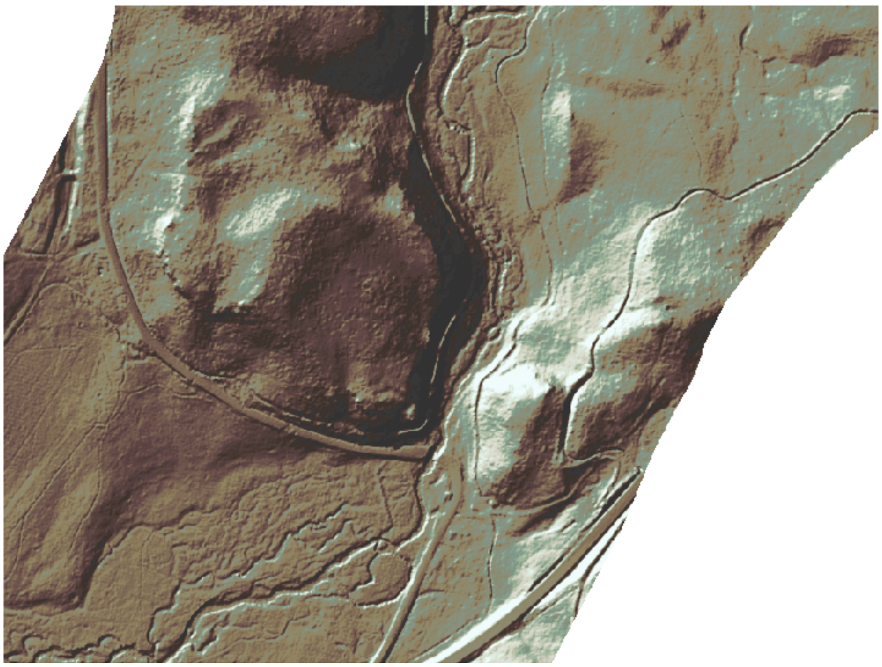

Figure 25 – Geologic Constriction Formed by Bedrock at the Boundary of MF16 and MF17.

4.3.3 Modifications to Floodplain Function and Connectivity

The impacts of constructed features on channel processes can be captured through examination of the impacted area of the historical channel migration zone (HCMZ) and the area of the floodplain disconnected from the channel. The area of HCMZ impacted provides an indication of the floodplain area that can not be accessed through lateral channel migration and/or inundated during high flow events due to constructed features or anthropogenic activities. Disconnected floodplain represents the floodplain area that was historically flooded, including side channels, but can no longer be accessed due to constructed features. In many cases, there is overlap between the disconnected floodplain and the impacted HCMZ areas. As such, disconnected floodplain area outside of the HCMZ can be used in conjunction with the impacted HCMZ to best capture modifications to floodplain function and connectivity. Because the HCMZ incorporates side channels and potential areas of lateral channel migration, its habitat value is greater than the area of disconnected floodplain outside of the HCMZ. Figure 26 illustrates the percentage of assessment areas impacted by constructed features. Reach-scale descriptions of topographic impacts on channel processes are discussed in further detail in subsequent sections and in Appendices D and E.

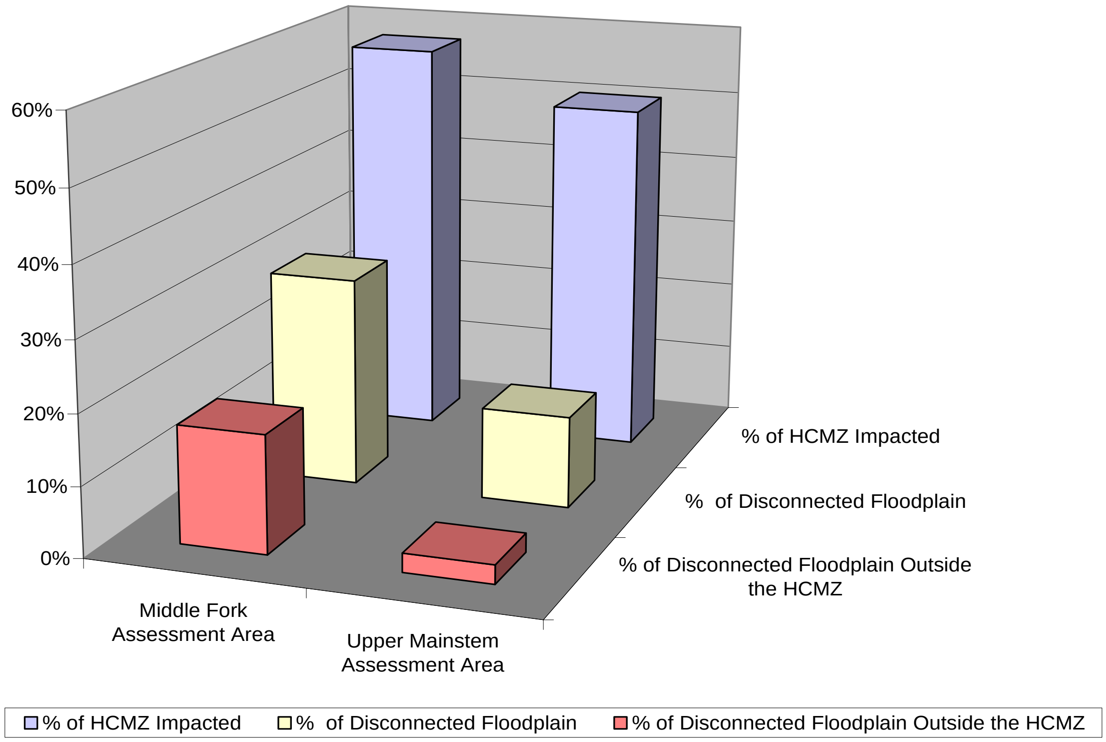

Figure 26 - Indicators of Impacts to Channel Processes from Constructed Features and Anthropogenic Activities.

4.3.4 Topographic Changes Specific to the Middle Fork John Day River

The geologic floodplain width of the Middle Fork Assessment Area ranges from approximately 60 feet to almost 1,800 feet (Figure 27). The widest geologic floodplain areas are present in unconfined reaches, particularly in reach MF2 between RM 48 and RM 51 and in reach MF13 between RM 63.5 and RM 66.5. The narrowest floodplain areas occur in confined reaches, such as reaches MF6, MF11, MF17, and MF19. Reductions in the width and area of the floodplain were mapped based on the locations of known constructed features.

The present width of the floodplain represents the width of the floodplain that is currently accessible given the installation of constructed features. In general, bridges and the historic railroad grade caused the greatest impact to floodplain width. The greatest reductions in floodplain width occurred in:

- Reach MF2, generally throughout the reach due to bridge and highway embankments and riprap placements through side channel entrances.
- Reach MF3, due to railroad grade.
- Reach MF8, due to tailings and historic road crossing.

- Reach MF9, due to highway embankment and bridge crossing.
- Reach MF12, due to tailings.
- Reach MF13, due to historic railroad embankment crossings.

It is important to differentiate the function of the HCMZ from that of the floodplain. The HCMZ lies within the floodplain, but is the portion where the main channel and primary side channels are hypothesized to have historically flowed. In some cases, the HCMZ may be inundated under flood flow events, but if constructed features have constrained the ability of the channel to laterally migrate and rework floodplain deposits, the HCMZ has essentially been impacted. The HCMZ is also considered impacted if the ability for inundation of the HCMZ is limited due to constructed features. Because the HCMZ is a corridor within the floodplain, the disconnected floodplain outside of the HCMZ is generally important for overbank flows, but less important for off-channel habitat and habitat complexity. Figure 28 and Figure 29 summarize impacts from constructed features on both lateral channel migration potential and overbank inundation of floodplain surfaces. In general, the HCMZ has been most impacted in unconfined and moderately confined reaches. One exception is confined reach MF15, which has experienced substantial impacts due to armored banks along the entire reach length. Figure 29 illustrates the difference in types of impacts to the HCMZ within each reach.

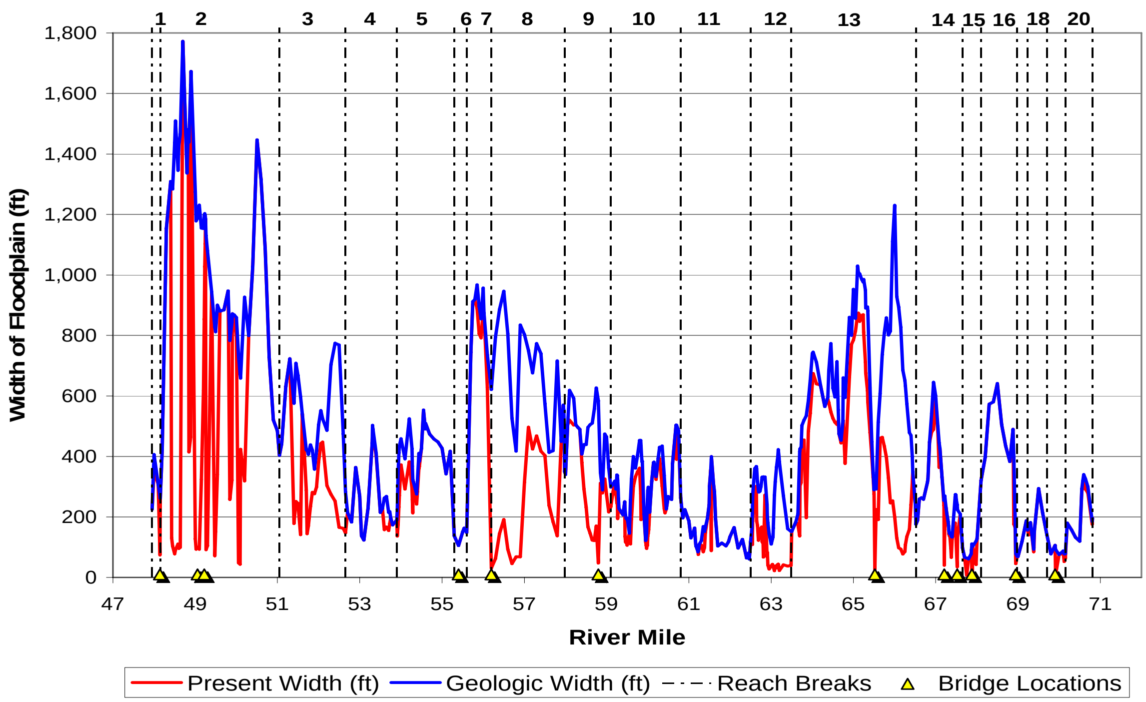

Figure 27 – Reduction in Middle Fork Floodplain Widths Due to Constructed Features. Reach numbers are shown at the top of the graph.

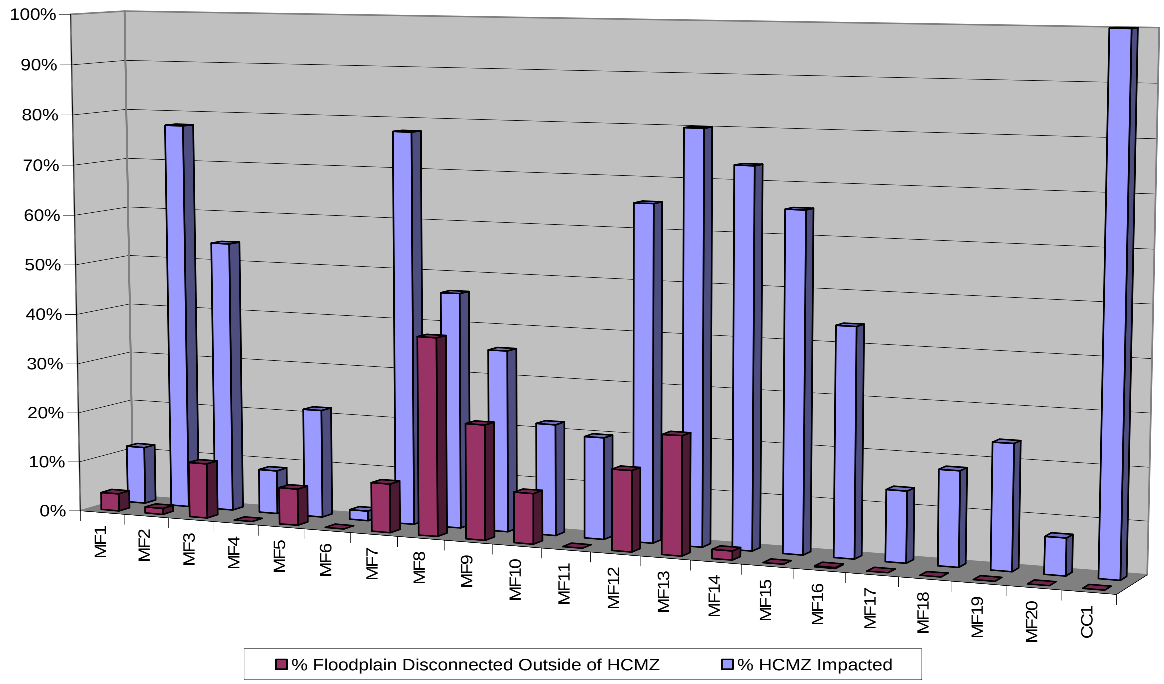

Figure 28 – Impacts of Constructed Features and Anthropogenic Activities on the Middle Fork HCMZ and Floodplain Surfaces Outside of the HCMZ.

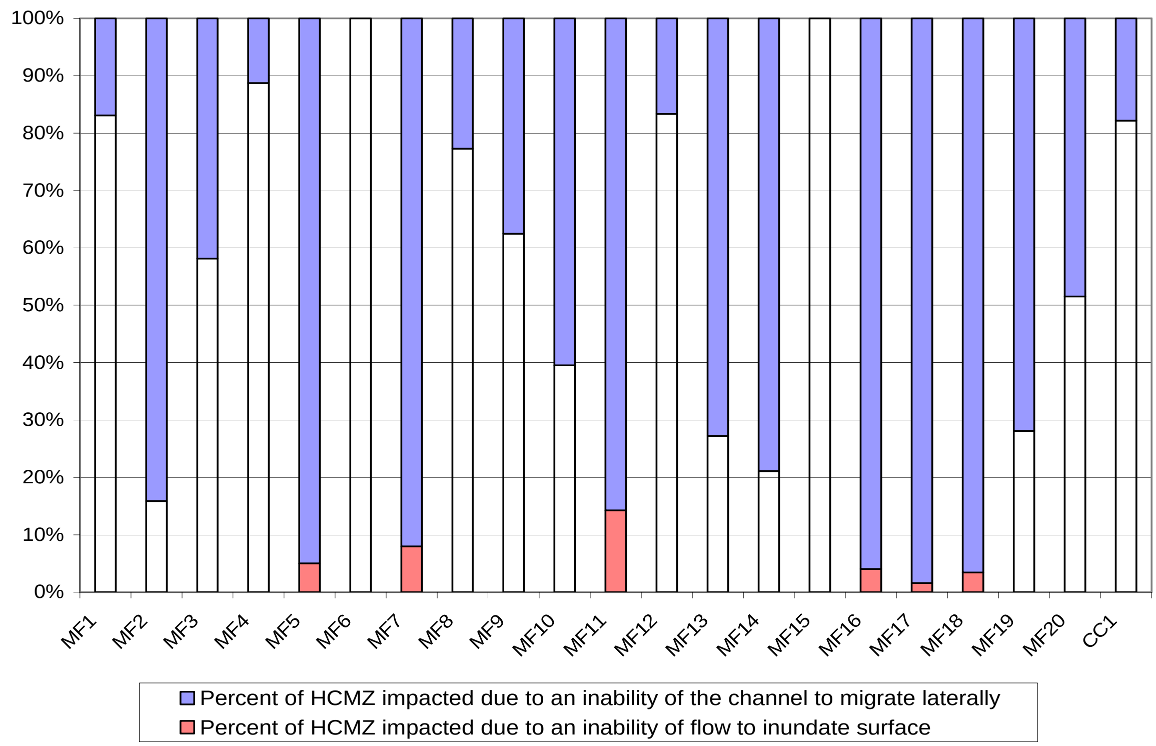

Figure 29 - Type of Impacts to the HCMZ for Each Reach.

Constructed features were mapped in GIS as points (Figure 30), lines (Figure 31), and areas, (Figure 32) depending on their type, extents, and impacts to physical processes. Features within the floodplain predominantly consisting of levees, rock spurs, riprap, roads, railroads, and bridges limit lateral migration of the channel and access to side and overflow channels. These features have had the largest impact on habitat complexity in unconfined and moderately confined reaches (Table 6).

Within the assessment area, the largest number of constructed features identified by points lie within MF13, which has 247 rock spurs and over 18 channel disconnections due to the railroad. Reaches MF14 and MF 7 also have a large number of rock spurs, 86 and 47 respectively. The greatest length of linear features that negatively impact channel processes is also in MF13, with substantial impacts from the historic railroad grade, irrigation ditches, and riprap. By area, the tailings have the greatest influence in MF8 and MF12. However, the historic town site of Bates has impacted a substantial area in CC1, MF14, and MF15.

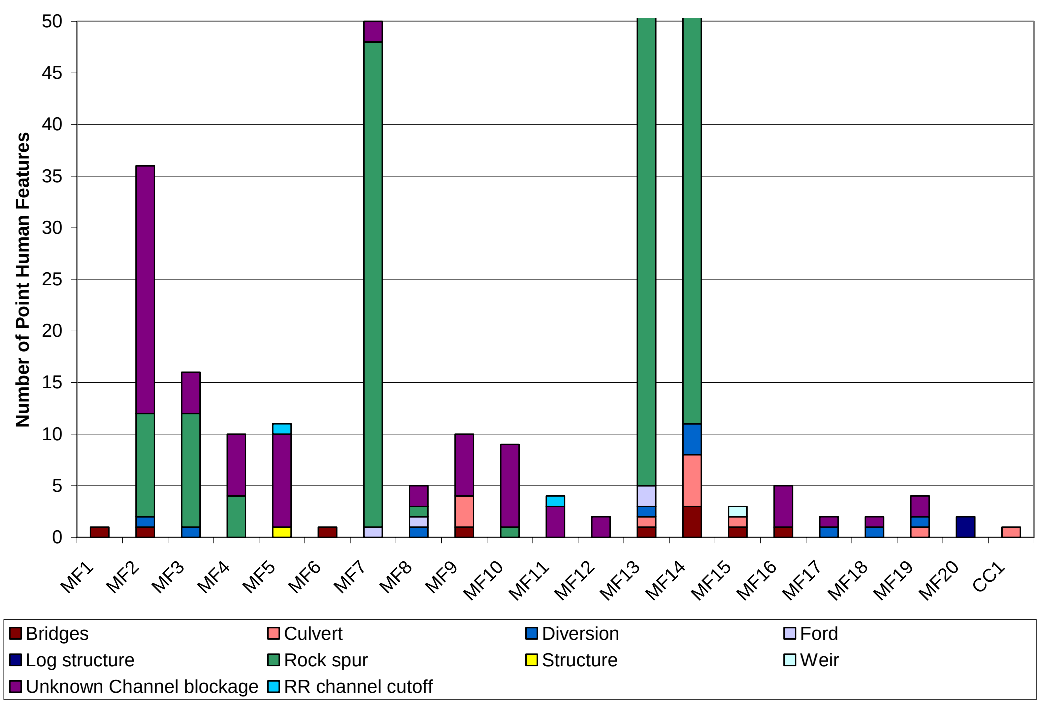

Figure 30 – Number of Constructed Feature Points. The scale was reduced to show values in all reaches. Reaches MF7, MF13, and MF14 can be reviewed in greater detail in Appendix D.

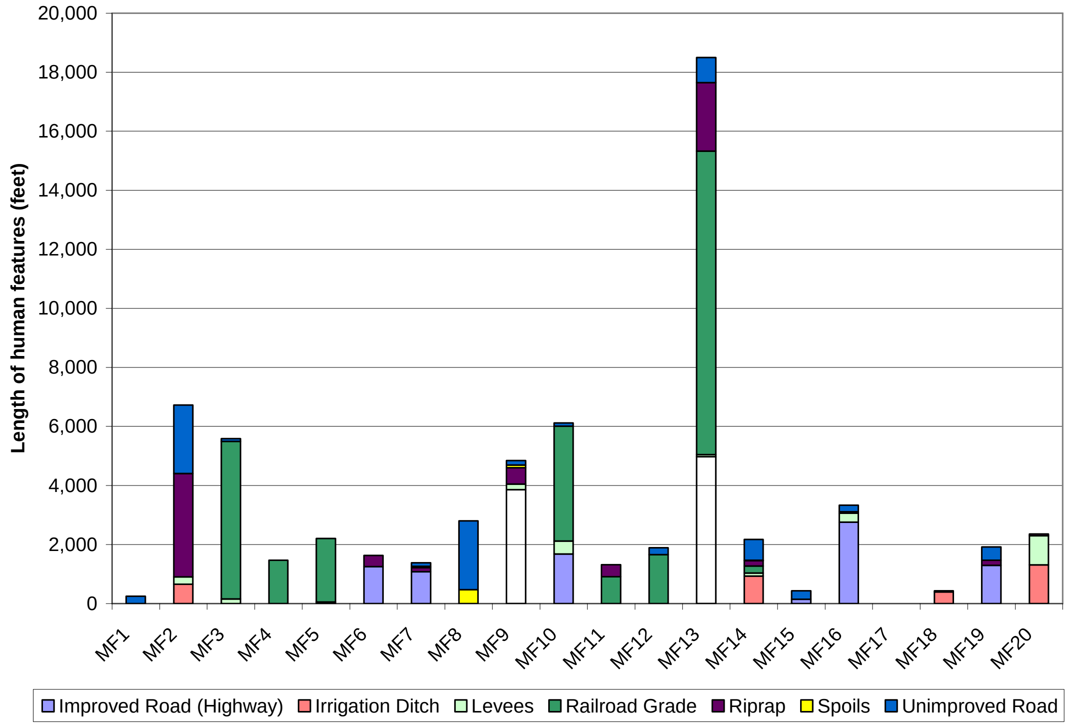

Figure 31 – Types of Constructed Features Measured by Length Within the Floodplain on the Middle Fork John Day River by Reach.

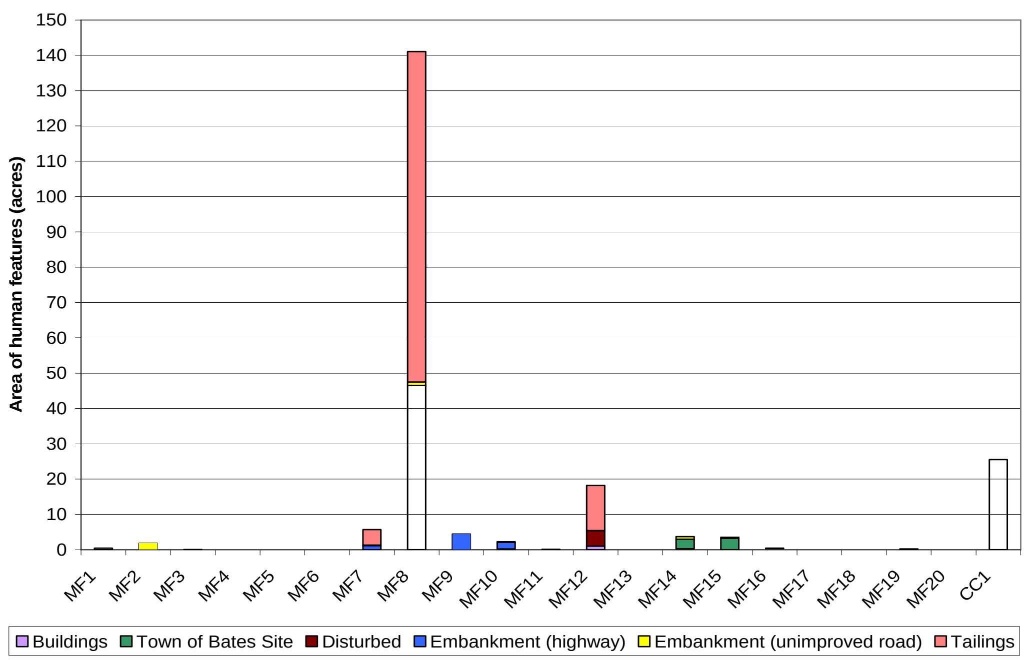

Figure 32 – Types of Constructed Features Measured by Area Within the Floodplain of the Middle Fork John Day River.

4.3.5 Topographic Changes Specific to the Upper Mainstem

The geologic floodplain widths of the Upper Mainstem Assessment Area range from 70 feet to 900 feet (Figure 33). The geologic floodplain widths are greatest in unconfined reach UJD3 and least in confined reach UJD1. The present day floodplain width reflects disconnected floodplain resulting from constructed features and anthropogenic activities. Greatest impacts to floodplain widths are in reach UJD3 and result from levees and riprap.

The HCMZ is the portion of the floodplain where the main channel and primary side channels are hypothesized to have historically transported flow. While some topographic features block inundation of the floodplain in some instances, others constrain lateral channel migration. Despite differences in the mechanism, both types of features impact the HCMZ. Floodplain area outside of the HCMZ is not as important as the floodplain area within the HCMZ to the creation of off-channel habitat features, such as side channels, off-channel ponds, and LWD inputs. Figure 34 and Figure 35 summarize impacts from constructed features on both lateral channel migration potential and overbank inundation of floodplain surfaces. Similar to the Middle Fork assessment area, the HCMZ has been most impacted in unconfined portions of the assessment area (reach UJD3) and least impacted in confined portions (reach UJD1). Major impacts on the HCMZ include rock spurs, blocked channels, riprap, levees and irrigation ditches. Figure 35 illustrates the difference in types of impacts to the HCMZ within each reach.

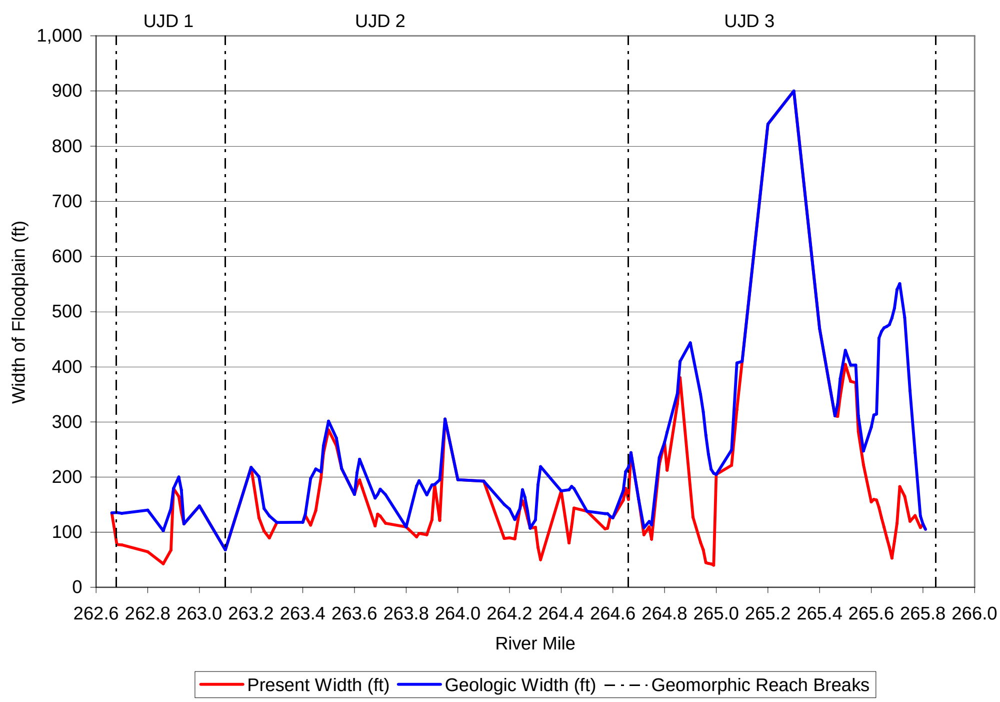

Figure 33 – Comparison of Geologic Floodplain Widths with Presently Accessible Floodplain Widths on the Upper Mainstem Assessment Area.

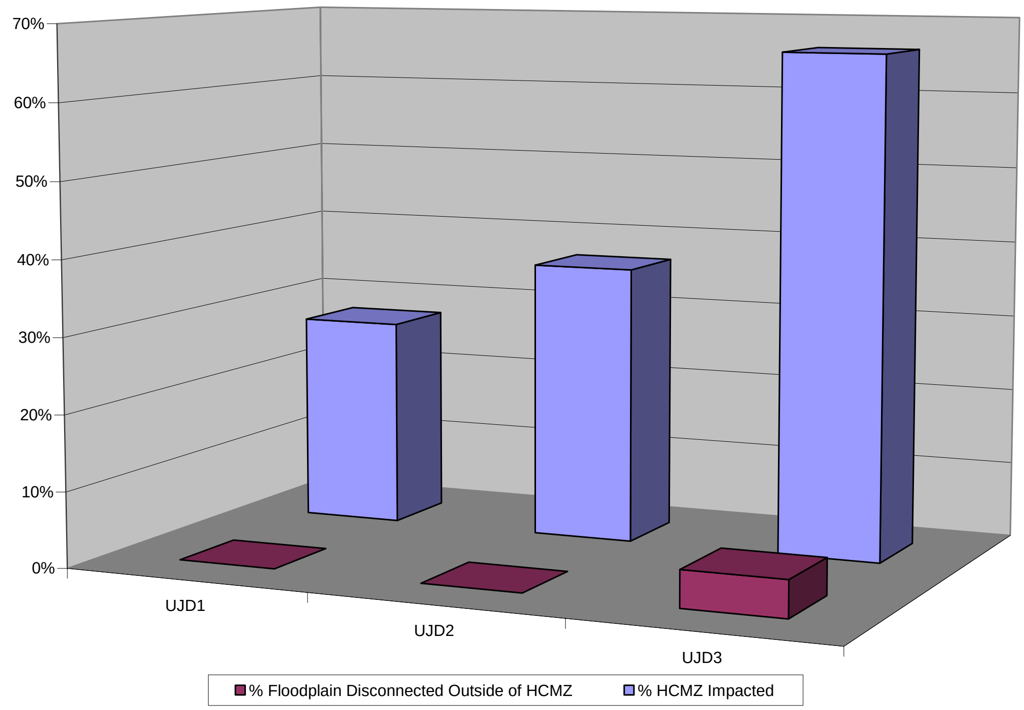

Figure 34 – Impacts of Constructed Features and Anthropogenic Activities on the Upper Mainstem HCMZ and Floodplain Surfaces Outside of the HCMZ.

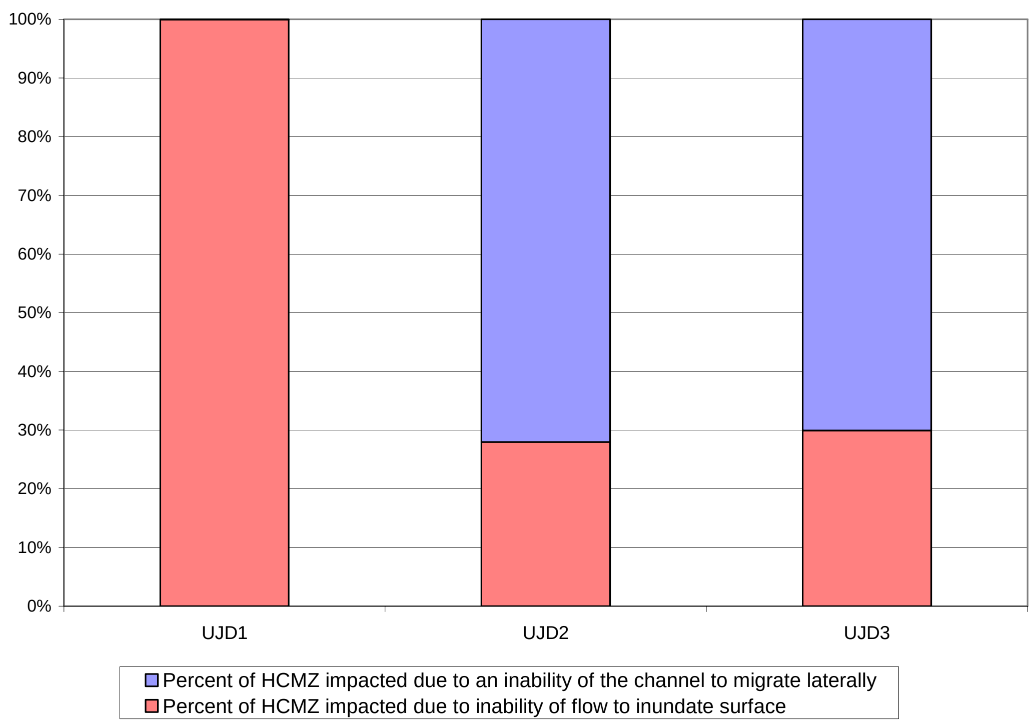

Figure 35 – Types of Impacts to HCMZ for Each Reach

Within the Upper Mainstem Assessment Area, constructed features were mapped in GIS as points (Figure 36), lines (Figure 37), and areas, depending on their type, extents, and impacts to physical processes. Features within the floodplain predominantly consisting of levees, rock spurs, riprap, and roads limit lateral migration of the channel and access to side and overflow channels. These features have had the largest impact on habitat complexity in moderately-confined reach UJD2 and unconfined reach UJD3.

Constructed features documented as points are similar in number in reaches UJD2 and UJD3 (Table 6). However, reach UJD3 also contains grade control structures that are not present in reach UJD2. No constructed features were recorded as points in reach UJD1. The length of features that negatively impact channel processes is also greatest in reach UJD3, with a similar total length in reach UJD2. The majority of constructed features in these two reaches consisted of levees, roads, riprap, and irrigation ditches. Reach UJD1 was dominated by riprap as almost the entire length of the reach is lined with this form of bank protection. Constructed features measured by area were only present in reach UJD2 and consisted of approximately 1.1 acres of road and bridge embankment.

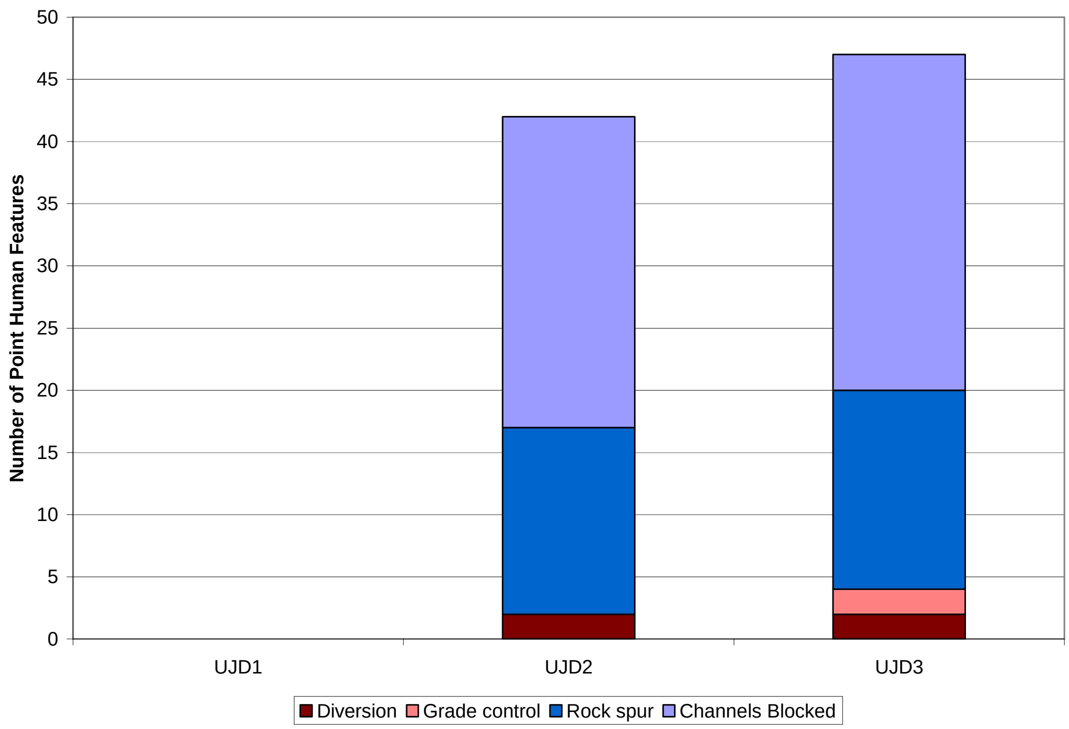

Figure 36 – Number of Constructed Features by Point and Reach in the Upper Mainstem Assessment Area.

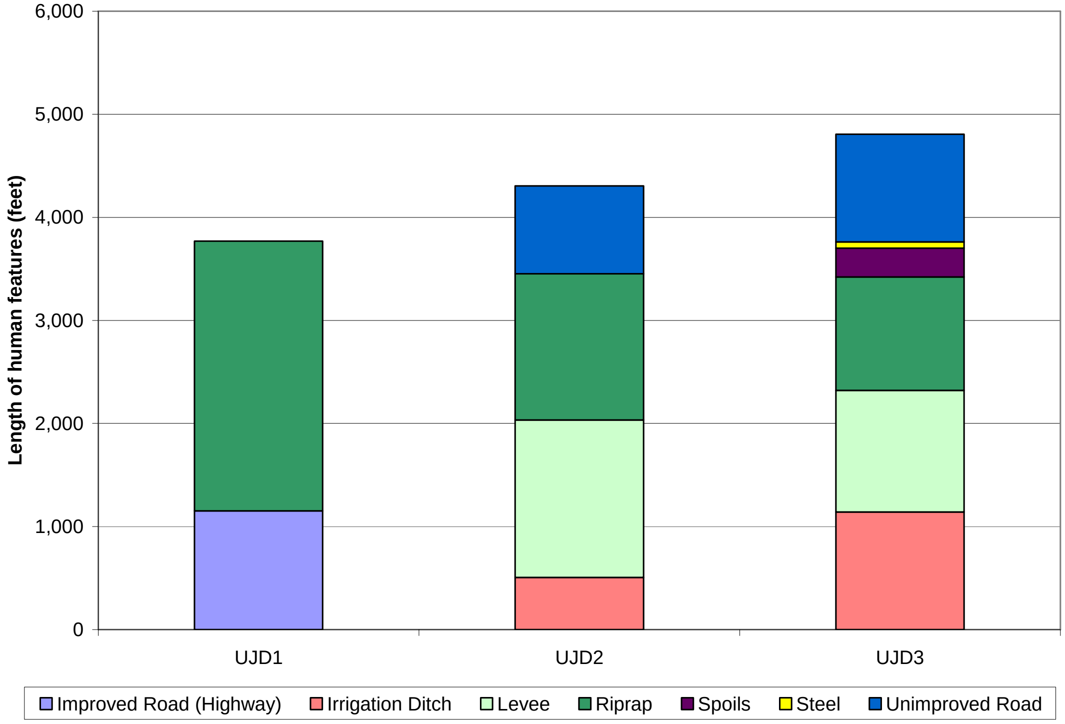

Figure 37 – Length of Constructed Features Within the Floodplain of the Upper Mainstem Assessment Area.

4.3.6 Historical Changes in Riparian Vegetation and LWD

4.3.6.1 Riparian Vegetation

Riparian vegetation is an important component of the aquatic ecosystem and can be used as an indicator as to whether river and floodplain processes are functioning at their fullest potential. As part of the geomorphic assessment, riparian vegetation classes were mapped using aerial photography and LiDAR data. Changes in vegetation between 1939 and present day were calculated and mapped in GIS. This report found that historical clearing and the lack of floodplain reworking has had the largest impact on condition and regeneration of riparian vegetation. Many locations that historically supported woody vegetation have been converted to shrubs or open areas. In the Middle Fork, wet meadows were likely present in some of the unconfined reaches under historic conditions. These wet meadow communities may have been impacted by drainage for conversion to crop fields and cattle grazing.

The percent of the floodplain that has changed from trees and shrubs to open areas or low vegetation between 1939 and present day is shown in Figure 38. Results from the vegetation mapping suggest that loss of vegetation is ubiquitous throughout the assessment areas. In general, reaches in the upstream portions of the Middle Fork have experienced the greatest loss of vegetation since 1939. However, reaches in the lower section may have lost a substantial amount of vegetation prior to 1939 through timber harvest, ranching and grazing practices, or natural episodic events (e.g., wildfires).

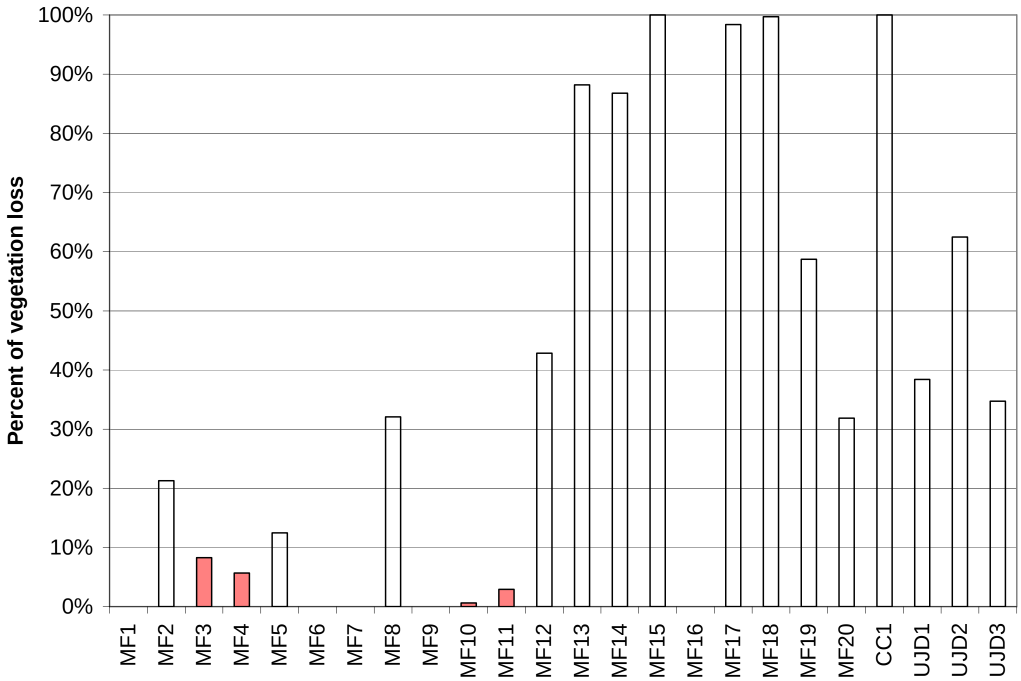

Figure 38 – Percentage of Floodplain Changed from Trees and Shrubs to Low Vegetation and Open Areas.

4.3.6.2 Large Woody Debris (LWD)

A properly functioning riparian corridor in this region is essential for providing large trees for shade, LWD recruitment, bank stability, floodplain structure, and roughness. Leaf litter and insects falling into the river from riparian areas provide nutrients for aquatic food chains. Larger pieces of wood trap smaller pieces of wood, organic debris, and fine sediment. This creates bars, log complexes, deep pools, complex aquatic habitat, and a growing medium for riparian vegetation.

Accumulations of large wood also facilitate channel migration, forming new channels that often excavate new gravel for spawning and provide extremely productive habitat for salmonids (USFS 2002). LWD helps to form nutrient reservoirs by creating slow water areas where organic litter can accumulate and by providing a medium on which algae, zooplankton, and insects can grow. Shade from LWD may help regulate stream temperatures during warm summer months.

Evaluation of the presence of and accessibility to potential LWD was accomplished as part of the technical ranking of the reaches (Appendix F). The analysis used LWD as a surrogate for the ability of the reach to provide shade and complexity to habitat. Within each reach, GIS analyses were conducted to characterize the percentage of the floodplain comprised of LWD-sized trees, the percentage of a 25-meter buffer capable of providing shade to the river, and the percentage of a 25-meter buffer comprised of LWD trees.

Within the assessment areas, reaches with the most potential for LWD recruitment are confined reaches that have experienced less forest clearing in recent decades. However, the duration of time that a log jam will actually remain in more confined reaches may be limited due to high stream energy, especially in confined reaches of the Middle Fork. Once recruited, LWD would most likely deposit within channel eddies, entrances to side channels, and at the heads of islands, where it may create stable hard points that slow the rate of river migration and allow formation of vegetated islands.

4.4 Summary of Geomorphic Changes and Impacts to Habitat

The form of the river and channel processes can be affected by changes in flow regime, sediment regime, and topography. The flow regime in the John Day River is relatively unaffected by the historical development in the basin with the exception of minor flow diversions. The sediment regime is mainly affected by short-term increases in fine sediments from anthropogenic activities, localized changes in channel slopes resulting from channelization, and possibly some rare occurrences of localized degradation or bed coarsening. The greatest impacts to river form and habitat result from historical changes to the topography due to constructed features in this basin and to vegetation-related factors. Constructed features have reduced the length of the channel, have reduced floodplain connectivity, and reduced both the river and habitat complexity. Changes to topography, in contrast to changes in flow and sediment factors, are more easily reversed.

Changes to topography and the river form that impact the availability and quality of habitat for spring Chinook and steelhead include:

- Reduced channel and floodplain connectivity due to bridges, roads, levees, and push-up dikes that disconnect the channel from the historical channel migration zone and floodplain area.
- Reduced access to side channels due to placement of riprap, sediment plugs, levees, roads, and other constructed features.
- Reduced access to the historical channel migration zone through increased channel slope and decreased sinuosity due to confinement of high flow events, manual channel straightening, and bank protection measures.
- Reduced quantity of large trees available for recruitment to the river due to timber harvest and conversion of riparian forests to agricultural fields.
- Alteration in the rates of regeneration of the riparian vegetation caused by a lack of lateral reworking of the channel and floodplain.
- Reduced habitat complexity within the channel due to alterations in habitat cover, shading, LWD inputs, and hydraulic and sediment diversity.

- Reduced habitat complexity features along boundaries of the channel and floodplain caused by conversion of banks to rock protection.

- Reduced competency of the channel to rework floodplain materials due to historic dredge mining activities.

- Increased water temperatures resulting from alterations in channel complexity, increased width-to-depth ratios, disconnected floodplains, and reduced shade.

- Reduced off-channel habitat that provides thermal refugia (e.g., beaver ponds and wetlands).

5.0 EXISTING GEOMORPHIC CONDITIONS RELEVANT TO RESTORATION AND PROTECTION ACTIONS

The previous chapter focused on reviewing historic changes to the flow regime, sediment regime and topography. This chapter is intended to provide a brief description of the geomorphic condition of each reach as it exists today, and relevant geomorphic factors of flow, sediment, and topography that could influence the selection of restoration actions or protection areas. Within this section, factors are identified that may require further consideration in the selection of restoration actions and in project design and implementation. Reach descriptions are presented from the upstream reach to the downstream reach. Detailed discussions of the present geomorphic conditions of each reach are provided in Appendices D and E.

5.1 Overview of Tributary Inputs

Flow and sediment inputs from tributaries can influence the geomorphic characteristics of the main channel. The relative degrees of their contributions to the system should be considered in evaluating potential restoration actions. A qualitative description of the flow and sediment contributions from major tributaries in the assessment areas is provided in Table 7 and in the subsequent sections of this chapter. Definitions for the qualitative descriptors are provided below the table. Descriptions for the Upper Mainstem (UJD) follow the descriptions for the Middle Fork (MF).

Table 7 – Qualitative Descriptions of the Contributions of Flow and Sediment from Major Tributaries in the Middle Fork and Upper Mainstem Assessment Areas.

Reach	Tributary Name	River Mile	Flow Contribution	Coarse Sediment Contribution
MF18	Mill Creek	69.3	Large	Some loading
MF15	Clear Creek	68.1	Large	Unknown
MF14	Bridge Creek	67.5	Large	Some loading
MF14	Placer Creek	67.2	Small	None Detectible
MF14	Davis Creek	66.7	Moderate	None Detectible
MF13	Vinegar Creek	66.3	Large	Large Loading
MF13	Dead Cow Gulch	65.5	Small	None Detectible
MF13	Vincent Creek	65.5	Moderate	None Detectible
MF12	Caribou Creek	63.3	Small	None Detectible
MF11	Deerhorn Creek	62.5	Small	Unknown
MF11	Flat Creek	62.3	Small	Unknown
MF11	Little Boulder Creek	61.9	Small	Unknown
MF11	Murdock Creek	61.7	Small	Unknown
MF11	Gorge Creek	61.1	Small	Unknown
MF10	Little Butte Creek	60.6	Small	None Detectible
MF10	Windlass Creek	59.4	Small	None Detectible
MF9	Tincup Creek	58.8	Small	None Detectible
MF8	Granite Boulder Creek	57.4	Large	Large Loading
MF8	Ruby Creek	56.8	Moderate	Unknown
MF7	Beaver Creek	56.1	Moderate	Some loading
MF6	Ragged Creek	55.6	Small	None Detectible
MF5	Sunshine Creek	54.4	Small	None Detectible
MF5	Dry Creek	54.2	Small	None Detectible
MF4	Big Boulder Creek	53.1	Large	Large Loading
MF2	Coyote Creek	51.0	Small	Some loading
MF2	Dunstan Creek	50.8	Small	Some loading
MF2	Balance Creek	50.1	Small	Unknown
MF2	Horse Creek	50.1	Small	None Detectible
MF1	Cress Creek	48.2	Small	None Detectible
MF1	Camp Creek	47.9	Large	Large Loading
UJD3	Jeff Davis Creek	265.7	Moderate	None Detectible
UJD3	Dad's Creek	264.9	Large	Some loading
UJD2	Strawberry Creek	264.7/263.4	Moderate	Some loading

- Flow contribution
  - Small- The drainage area for the channel is less than 5 square miles or high flows increase main channel flow volume by less than 5 percent.
  - Moderate- The drainage area is between 5 and 10 square miles and high flows increase main channel flow volume by 5 percent to 15 percent.
  - Large- The drainage area is greater than 10 square miles or high flows increase main channel flow volume by more than 15 percent.

- Coarse sediment contribution
    - None detectible- no deposits present at tributary mouth and no bars in river immediately downstream despite relatively flat grade.
    - Unknown- The presence of a steep grade in tributary or in the river at the tributary confluence would cause a small or large load to transport downstream, and qualitative measurements are not discernible; or substantial modification to the tributary or channel produces uncertainty in the amount of sediment supplied from the tributary.
    - Some loading- small deposits are detectable at the mouth and/or small exposed gravel bars are present in the tributary near the mouth or immediately downstream from confluence with main channel.
    - Large loading- large quantities of deposits are present at the mouth despite average channel slope; possible braiding or rapid channel relocation noted in tributary or in downstream channel near confluence.

5.2 Middle Fork John Day River Geomorphic Conditions

5.2.1 Reach MF20

Reach MF20 is an unconfined to moderately unconfined valley and is characterized by relatively low sediment transport under the 2- through 100- year flood events. Half of the geologic floodplain is bounded by alluvial-fan deposits. The scalloped edges of the alluvium-colluvium and alluvial-fan deposits indicate that the Middle Fork has eroded these deposits, and still may be able to erode them. Opposing alluvial fans in the mid-section of the reach limit the lateral migration on both sides of the low surface; however, some active channel migration is occurring within the floodplain boundaries. Although minimal riparian vegetation is present to add bank stability and moderate lateral channel migration, no evidence of channel instability was detected. Analyses suggest that the bed and bar materials are mobilized during a 2-year flow event, and that the river is inundating its floodplain during this same event. This indicates a normally functioning system that has not experienced significant incision. The denudation of woody vegetation in this reach has reduced stream shading and LWD recruitment, which in turn, has impacted in-channel and floodplain complexity. LWD placements could provide a short-term strategy to enhance habitat quality.

Bedrock may impose a vertical control in the channel at the upstream reach boundary where the river appears to be running again a bedrock surface. Further investigation is necessary to determine if bedrock is present in the bed of the channel.

5.2.2 Reach MF19

Confined reach MF19 is a short transitional zone between two less confined reaches. MF19 is confined primarily by bedrock on both sides of the river, limiting the lateral migration potential. Channel slopes approach 1.3 percent and high flow velocities are extremely high. A sharp rise in sediment transport capacity corresponds to the high degree of confinement in this reach. Sediment contributed from upstream reaches is likely transported through MF19 to downstream reaches.

Minimal lateral channel migration is active through this reach due to geologic constraints combined with localized areas of bank armoring and levee presence. Highway embankments impact lateral channel position near the center of the reach, and a culvert impacts both vertical and lateral channel position. Bedrock is present in the channel at the location of the culvert, moderating extents of vertical degradation from the constructed features. Upstream from the culvert, an irrigation diversion routes flow to the right side of the valley. The diversion is created through the use of a rock structure, which may provide some local vertical control on channel position.

5.2.3 Reach MF18

Moderately confined reach MF18 is characterized by a highly sinuous meandering planform, a slope of 0.74 percent, and a low sediment transport capacity compared with upstream and downstream reaches. Only a few small localized areas of lateral migration are evident in this reach despite high sinuosity, the lack of riparian vegetation, and few bank armoring features. An apparent balance in sediment inflows and outflows may maintain channel stability in this reach.

The reach is bounded by alluvium-colluvium on the right side of the valley and bedrock on the left. The alluvium-colluvium has been eroded by the Middle Fork in the past, and may still be erodible by the river. The sinuous boundary of the bedrock along the left floodplain boundary suggests that the bedrock may also be somewhat erodible by the Middle Fork. Bedrock outcrops may influence the vertical channel position just upstream from Mill Creek, where the channel is aligned against bedrock. An irrigation diversion is present near the middle of the reach and routes flow through a canal that runs along the left boundary of the floodplain. The diversion imparts minimal horizontal control on channel position and diverts only a small percent of total flow from the river.

5.2.4 Reach MF17

Heavily confined reach MF17 is characterized by a slope of 1.1 percent and a two-fold increase in sediment transport capacity compared with upstream reach MF18. No sediment samples were collected in this reach due to the lack of gravel bars and the presence of bedrock in the bed. A tributary enters the Middle Fork just upstream of the reach boundary with

MF18. A portion of Mill Creek was historically intercepted by irrigation diversions and a flume (probably used for mining purposes). Diversion of flow from Mill Creek through historic irrigation canals may continue today as evidenced through LiDAR and aerial photography. This tributary does not provide a significant source of coarse sediment to the system but may provide some sediment through floodplain reworking processes under higher flows. Any sediment contributed to MF17 from upstream reaches and Mill Creek is likely transported through the system to downstream reaches.

The floodplain of this reach is confined between bedrock on both sides of the river, which limits potential for lateral migration. Bedrock outcrops in the bed of the channel were identified in the downstream portion of this reach and provide vertical controls on channel position in this reach. Aside from a short segment at the downstream end of this reach where channel position is controlled by highway embankments, the river through this reach has a meandering planform and appears to be stable.

5.2.5 Reach MF16

Within reach MF16, the valley is wide and unconfined with multiple visible historical channel scars. Some of these channels appear to have been cut-off through anthropogenic modification, but additional field verification of LiDAR and aerial photographs is needed. The slope through this river segment is less than 0.35 percent, and sediment transport capacity is the lowest of the entire assessment area. MF16 has large quantities of sediment in storage and acts as a supply reach for downstream reaches under high flow conditions. A volumetric sample collected in MF16 suggests that a 10-year flow event may be required to mobilize sediment stored in the channel bed and bars. In contrast, pebble count data, which are typically less reliable than volumetric samples, suggest that most material can be mobilized during a 2-year event. Low velocities and slopes in this reach are partially responsible for the apparent inability of the sediment to be mobilized. However, unrestricted cattle grazing may have exposed a higher percentage of fines to downstream transport, thereby increasing the D_{50} of the bed and bar materials in the reach. ODFW redd surveys indicate a high number of Chinooks redds per mile in this reach compared with most other unconfined reaches.

Some localized areas of lateral channel migration are noted in this reach, but the degree is fairly minimal despite high sinuosity, the lack of riparian vegetation, and few constructed features. Sediment delivered from upstream appears to be in balance with the sediment transported through the reach. Restoration strategies should consider how decreased channel slopes and velocities may impact channel stability and sediment balance.

No substantial tributaries are contributing surface flow to this reach. Wet floodplain conditions notable in aerial photographs indicate that groundwater may be supplied to the reach through springs and seepage from surrounding hill slopes. An unnamed drainage mid-way through the reach is intercepted by an irrigation diversion on the left side of the river. Seepage from the irrigation canal may be supplementing the apparent wet meadow conditions; however, water adjudication maps from 1926 categorize the floodplain as meadow and also identify the locations of several springs. Revegetation efforts should evaluate the ability of the soils and hydrologic conditions to sustain different types of vegetation.

5.2.6 Reach CC1

Due to the construction of the town of Bates and facilities for the operation of a sawmill, historical impacts to the Clear Creek channel and the adjacent floodplain areas were so great that the pre-development characteristics of the creek, the HCMZ, and floodplain can only be speculated. Today, Clear Creek flows are routed through a constructed channel with a slope of 1.4 percent, and the floodplain appears to be relatively unconfined. The upstream reach boundary is at a bedrock constriction, where a culvert and highway embankments are present, imposing additional controls on channel position. Lateral channel migration has been negligible over the last 30 years. The lateral stability could be due to disturbance of floodplain deposits and possibly the construction of an oversized channel. The culvert at the upstream boundary imparts a vertical control on the system. Restoration strategies that impact channel length and slope should consider potential future impacts from changes to the culvert elevation. Restoration of a meandering planform in this reach would require active excavation since the current hydraulic conditions do not appear competent to mobilize and rework floodplain deposits through natural processes. This reach has a very low number of Chinook redds per mile compared with other unconfined reaches.

5.2.7 Reach MF15

Reach MF15 acts as a narrow transition zone between less confined reaches MF16 and MF14. The reach is very confined between bedrock on river right and alluvial-fan deposits from Bridge Creek and Clear Creek on river left. This segment of the river was heavily channelized and armored during the construction of the town of Bates, and the floodplain was markedly altered. The channel is also confined by a culvert and highway embankments approximately mid-way through the reach. Sediment transport capacity is significantly greater than the adjacent upstream and downstream reaches. Downstream from the culvert, the 100-year flood is contained within the channel banks and sediment transport capacity is extremely high. A large tributary, Clear Creek, enters the Middle Fork at the upstream end of this reach, nearly doubling flows in the Middle Fork. Clear Creek likely provides coarse sediment to the system, particularly during high flows. Due to the high capacity of MF15 compared with upstream and downstream reaches, most sediment delivered from Clear Creek is probably transported to downstream reaches. Some temporary storage may occur in a gravel bar at the mouth of the tributary. Compared with other confined reaches, MF15 has a very high number of Chinook redds per mile, which is likely related to cold water inputs from Clear Creek.

Lateral channel migration is negligible due to bank armoring combined with geologic controls. The culvert provides a lateral and vertical control on channel position. Just upstream from the culvert, a river-spanning rock control structure is present that provides a vertical control. Restoration strategies that aim to reconnect floodplain access or lateral channel migration should consider impacts to the culvert's conveyance capacity and also impacts from potential future modifications in the base elevation of the culvert. Downstream from the culvert, the channel is devoid of in-channel complexity and could benefit from the addition of LWD as a short-term means of enhancing habitat quality.

5.2.8 Reach MF14

Moderately confined reach MF14 appears to be stable under current conditions, with little evidence of active incision or channel widening. Rock spurs and rip rap along the channel banks were placed throughout most of the reach to constrain lateral movement. Several side channels appear to have been disconnected from the main channel. As a result, the channel may be slightly incised from historic conditions. Multiple rock spurs were installed along the right bank to protect against erosion of the highway embankment. In any effort to restore lateral channel migration processes, the removal of rock spurs should be evaluated individually to determine if the rock spurs are in fact restricting lateral movement so that some benefit from removal could be expected. Secondly, the individual removal should be examined to determine if the benefits of removal outweigh any loss of existing habitat. Concurrently, risks to roads and other infrastructure resulting from structure removal should be investigated. MF14 lacks substantial in-channel complexity and could benefit from LWD placements as a short-term means of enhancing habitat quality.

Compared to sediment transport capacity throughout the rest of the assessment area, reach MF14 is characterized by an average ability to transport sediment, with a slightly higher transport capacity upstream of Placer Creek. Pebble counts suggest that bed material of the river through the channelized segment is much greater than in the downstream portion of the reach. A surface and subsurface sample conducted in the reach indicates that the reach is not substantially armored downstream from Placer Creek. Incipient motion computations demonstrate that the bed and bar material in the downstream portion of the reach are mobilized under a 2-year event, while larger material comprising the bed of the upstream portion of the river is initially mobilized during 5- to 10-year flood events. High erosive forces upstream from Placer Creek may result from channel straightening associated with the construction of the historic town of Bates. Hydraulic model results reveal that water surface elevations during the 2-year event are generally close to or overtopping the channel banks throughout the entire reach. This indicates a normally functioning system that has not experienced significant incision.

In MF14, Davis Creek, Placer Creek, and Bridge Creek all contribute flows to the system. At the upstream end of the reach, Bridge Creek flows into the Middle Fork; although, Bridge Creek historically likely entered the Middle Fork further upstream in reach MF15. Development of the town of Bates and damming of Bridge Creek for saw mill purposes substantially altered the channel alignment. Today, a small reservoir is still present nearly 0.5

miles upstream from its mouth due to backwater impacts from the dam. Downstream from the dam, Bridge Creek is being fed from a remnant spillway located on the left abutment of the dam. A substantial amount of sediment is likely in storage in the pool and could be contributed to the Middle Fork under high flow events. Potential sediment inputs from the reservoir should be considered if modifications are made to the tributary or reservoir. Placer Creek supplies a minimal amount of sediment to the system through fluvial processes. Currently, gravel mining of alluvial fan deposits occurs near the mouth of Placer Creek. A culvert is located at the mouth of Placer Creek to convey flow under an unimproved road embankment. Just downstream from Placer Creek, an irrigation diversion removes a portion of flow to the left bank of the river through another culvert. Davis Creek is located at the very downstream end of this reach and is discussed in the following section.

5.2.9 Reach MF13

Unconfined reach MF13 is characterized by two distinct regions of sediment transport. The break in the sediment transport through this reach coincides with a change in the degree of channelization and floodplain disconnection. The upstream section was modified from a highly sinuous channel to a straight river, and the railroad cuts off access to approximately 80 percent of the floodplain. Sediment transport through this section is high relative to similarly unconfined reaches. The downstream section of reach MF13 is much less channelized, and a single-thread meandering planform is present. Sediment transport capacity through the downstream segment is much lower than upstream and downstream reaches. Incipient motion computations show that the material present in the bed and bars of the study areas will generally be mobilized under a 2-year event. A surface and subsurface sample collected at the downstream end of the reach indicates mild channel armoring with the surface material median grain size (D_{50}) three times greater than the subsurface D_{50}.

Lateral channel migration is limited in this reach due to the installation of riprap, levees, and also possibly by rock spurs. Rock spurs are designed to prevent bank erosion, but minor changes in approach flow patterns over time can make them non-functional. A few localized areas were noted where the channel flanked the rock spurs and migrated behind the rock piles. Although non-native, the rock piles that have been flanked add complexity and pocket pool habitat to the channel. In a few other locations, rock spurs are present, but do not impact channel migration under the present channel planform. If rock spurs are identified for removal, each structure should be assessed independently to determine if the structure is currently functional, and to assess the expected benefits and possible negative impacts to habitat resulting from removal.

Water surface elevations for the 2-year event are close to the bank height for most cross-sections in the reach, which indicates conditions consistent with a normally functioning system. Upstream from the confluence with Vincent Creek, flows generally do not overtop the railroad levee and are unable to access a large portion of the floodplain for events as large as the 100-year event. Despite installations of river-training structures and other constructed features, the channel does not appear to be notably incised. Comparison of the geometry of the present channel with the historic channel on the south side of the railroad embankment indicates that the present channel is slightly deeper and has a greater area than the historic channel. Differences in the channel geometries may be the result of the channel design of the present channel and natural adjustment to the transport of higher flow events resulting from floodplain disconnection. If reconnections of historic flow paths that have been cut off by the railroad grade are considered, the analysis should assess how changes in slope will impact sediment transport processes. In addition, plugs may be required in the existing path to force flow into the historic channels.

Several tributaries contribute flow and sediment to this reach. The most significant tributaries include Dead Cow Gulch, Vincent Creek, Vinegar Creek, and Davis Creek (at the boundary with MF14). Each of these is comprised of alluvial fan deposits that impact the position of the channel to some degree. Vinegar Creek may be a substantial contributor of coarse sediment to the system through erosion processes combined with episodic shallow landslides. Historic placer mining occurred in Vincent Creek, which could have some impact on the current sediment supply to the system. At least a portion of flow from Vincent Creek and Davis Creek was historically intercepted by irrigation ditches. Culverts are located at confluences of Vinegar Creek and Dead Cow Gulch with the Middle Fork through the highway embankment or railroad grade. Vinegar Creek exhibits evidence of incision, possibly due to straightening and relocation of the Middle Fork, road and culvert construction near the mouth of the confluence, and documented modifications to the mouth of the channel for recreational use (Johns 1997). Restoration strategies that modify current channel geometry and planform should consider potential changes in sediment inputs from the tributaries and possible alterations in channel planform of the tributaries near their confluence with the main channel.

Although this reach has a greater number of Chinook redds per mile than any other reach assessed, the channel appears to be lacking in channel complexity and could benefit from LWD placements. Alluvial inputs from tributaries should be considered when locating or designing LWD structures.

5.2.10 Reach MF12

Moderately confined reach MF12 has varying widths of geologic floodplain with alluvial fan deposits constricting the upstream and downstream ends of the reach against bedrock. Periodic changes in floodplain width suggest that the erodibility of confining bedrock is variable. Slopes through the reach are around 0.5 percent with a sharp change in slope at the downstream transition to MF11.

Minimal lateral channel migration is occurring in this reach and is probably related to historic dredge mining and changes to the channel planform and alignment. The channel is incapable of reworking floodplain deposits through dredge tailings similar to MF8. Large cobbles from the tailings may also impose a vertical control on channel stability. Reconnection of historic channels will require excavation and creation of meander bends that would otherwise form through typical channel processes. Caribou Creek is the only substantial tributary in the reach. Historic placer mining in Caribou Creek may have altered the sediment supply to the system compared with pre-development conditions.

Sediment transport capacity rates in this reach are similar to the incoming capacity from the lower section of MF13, despite the channelization due to dredge mining of a portion of this reach. This results from sediment size differences between the two reaches. The surface D_{50} of reach MF12 is twice as large as that of reach MF13 based on volumetric bar samples, but the stream power is greater in reach MF12. Incoming sediment from MF13 is likely transported through MF12 to downstream reaches. Incipient motion calculations applied to a volumetric sample at the downstream end of the dredge tailings indicate that a 10-year flow event may be required to mobilize sediments. Differences between pebble counts and volumetric samples complicate concrete interpretation of sediment transport processes.

5.2.11 Reach MF11

The reach is very confined between bedrock, primarily, a large landslide on the left side of the river, and small alluvial-fan deposits. Tributaries present in the reach include Deerhorn Creek, Flat Creek, Little Boulder Creek, Murdock Creek, and Gorge Creek. Of these, Deerhorn Creek and Little Boulder Creek may contribute the most significant amounts of sediment to the system based on drainage size. Because most of the sediment transported to this reach is likely conveyed downstream, the degree of sediment contribution from each of the tributaries is unclear. Alluvial-fan deposits from Deerhorn Creek impose a substantial lateral control on channel position. Lateral migration of the channel is minimal and primarily limited by geologic controls on channel position.

The sediment sizes of the bed material in this reach range from coarse gravels to large boulders. A considerable change in the slope of the longitudinal profile is present where a landslide created a chute in the channel. Large boulders from the adjacent hill slope may provide a vertical control at the change in grade. MF11 is characterized as a transport reach with extremely high sediment transport capacity compared with the rest of the assessment area. The high transport capacity through this reach combined with a maximum slope of 2.4 percent suggests that any coarse gravels and small cobbles entering this segment will be moved through efficiently.

5.2.12 Reach MF10

Moderately confined reach MF10 is characterized by reach-averaged slopes, velocities, and stream power consistent with other moderately confined reaches. The reach can be divided into two regions of sediment transport capacity. Although both zones have similar magnitudes of sediment transport capacity (slightly lower than assessment area average), the upstream segment is marked by a short spike, likely related to side channel disconnection and railroad and highway construction. The difference in magnitude between the two segments is more pronounced under higher flow events. Two notable tributaries in MF10 include Windlass Creek and Little Butte Creek, neither of which contributes large amounts of coarse sediment. The lack of exposed gravel bars in the reach suggests that material contributed from the tributaries is transported through the reach.

Despite notable historic channel avulsions and lateral meander migrations since 1939, little notable change in channel position has occurred over the past 10 years. A gradual trend of increasing channel length is notable, and may be occurring in response to historic alignment changes and the disconnection of side channels due to the construction of the railroad nearly 100 years earlier. Most of the floodplain boundary in MF10 appears to be unerodable due to the bedrock confines. Periodic changes in floodplain width suggest that the erodibility of the bedrock is variable, and that in some places, the river can more readily erode the bedrock boundaries than in others.

5.2.13 Reach MF9

Unconfined reach MF9 has similar velocities, slopes, and sediment transport capacity to the downstream section of moderately confined reach MF10. Lateral channel migration in MF9 is minimal and only notable in a few localized areas. The lateral stability of the channel is likely due to bank armoring, levees, and roadway embankments. Sediment sizes in this reach are consistent with those measured in other unconfined reaches and mobilization of bed and bank material occurs during flows that are considerably less than a 2-year event. Tincup Creek is a minor tributary to the reach and contributes very little coarse sediment to the system. This reach has greater potential to provide channel complexity than is currently available and could benefit from LWD placements as a short-term complexity enhancement strategy.

5.2.14 Reach MF8

MF8 begins just upstream of the flow bifurcation of the north and south channels of the Oxbow Conservation Property and was greatly modified by dredge mining in the 1940s. Mine tailings on the valley floor serve to confine the channel and inhibit lateral and vertical migration where the channel is located within or against the mine tailings. The tailings are likely responsible for a significant break in slope in the channel profile.

From the upstream end of the reach to the confluence of the north and south channels, sediment transport capacity is close to the average of the assessment area. Under high flow conditions, most of the flow is routed through the south channel, and only a small portion travels through the north channel. In contrast, under lower flow conditions, more flow was measured as entering the north channel than the south channel. This difference results from the entrance condition of the north channel and the conveyance capacity of the south channel.

Under geomorphically significant flows, most flow and sediment is actually transported through the historical south channel.

At the confluence of the north and south channels, the sediment transport capacity increases distinctly with a high magnitude relative to the entire assessment area. Most of the flow is contained within the channelized river with little access to the surrounding floodplain. Resulting high shear stresses cause this segment to act as a transport zone, although historically this was unlikely the case.

Due to dredge mining, the reach is now confined by coarse sediment sizes that the channel is incapable of mobilizing. An in-channel pebble count collected in the north channel is considerably larger than all other sediment sizes measured in the assessment area. Increasing the sinuosity in this reach through dredge tailings will require active construction or realignment of the channel. The addition of off-channel complexity, such as side channels, may also require excavation through the dredge deposits. Unlike the rest of this reach, the south channel is located in unmodified floodplain deposits and appears to be continuing lateral channel migration and reworking of floodplain deposits. Sediment samples collected in the south channel and at the confluence of the north and south channels were comprised of material that was smaller than almost all other samples collected in the assessment area.

Two significant tributaries to this reach include Granite Boulder Creek near the upstream end and Ruby Creek, close to the confluence of the north and south channels. Alluvial fans from each creek are juxtaposed to the left and right of the floodplain, respectively. Historically, the fans would have had a high impact on lateral channel migration, but the toe of each fan has been dredged, and the streams have been diverted into artificial channels, leaving the remaining fan structures with no impact on the channel. Reconnection of flows to the main channel should consider potential increases in flow and sediment, particularly to the south channel, where mobilization of channel and floodplain deposits during more frequent flood events is likely. These additional flow and sediment inputs could impact the designs and selection of locations for LWD placements. An additional tributary is located at the upstream end of the reach on the left side of the valley; however, flow and sediment contributions from this creek are likely small relative to other larger tributaries in the assessment area.

Vegetation planting efforts are underway in this reach. Additional revegetation efforts should consider the potential for wet meadow conditions and the impacts of tailings deposits and seasonal fluctuations in the groundwater table on the sustainability of the plantings.

5.2.15 Reach MF7

Reach MF7 is downstream from the historic dredge activities and is an unconfined reach situated between a channelized reach and a geologically confined reach. Reach MF7 is characterized by relatively high sediment transport capacity compared with other unconfined reaches, although magnitudes are much lower than the transport zone of reach MF8. Slopes in reach MF7 are consistent with the slopes measured in confined reach 6, but velocities are considerably lower. Channel migration through this reach is minimal due to riprap and rock spurs lining every meander bend. Sediment comprising gravel bars is mobilized under flow events substantially lower than a 2-year event. However, based on redd surveys, Chinook usage of this reach for spawning is low compared to most unconfined reaches. Beaver Creek is located at the upstream end of MF7 and may be a moderate contributor of sediment to the system. The lack of a large number of exposed gravels bars in the reach suggests that most of the sediment contributed to the reach from upstream and Beaver Creek is transported to downstream reaches. Modifications to channel slope should consider evaluation of changes in channel stability related to decreased sediment transport capacity.

The entire floodplain in this reach is shown as meadow in a 1926 water adjudication map. Today, the floodplain consists almost entirely of open grassland. Revegetation efforts in MF7 have been initiated by the Confederated Tribes of the Warm Springs Reservation of Oregon. Additional investigation may be required to determine if seasonal wet meadow conditions were historically present, and how the soil and hydrologic conditions impact revegetation efforts. Short-term in-channel complexity could be gained through LWD placements while riparian vegetation matures.

5.2.16 Reach MF6

Reach MF6 is a highly confined reach bounded by bedrock and alluvial fan deposits. Velocities and stream power are extremely high in this reach during flood events. Sediment transport capacity is relatively high compared to upstream and downstream reaches. No sediment samples were obtained in this reach due to the lack of unvegetated gravel bars; however, a 2-year flow event could mobilize sediments as great as 62 mm, which is greater than sediments comprising gravels bars in upstream reach MF7. MF6 likely acts as a transport zone under high flow events. Ragged Creek alluvial fan has a high influence on channel position, forcing the channel to the right side of the valley. The lack of erodible floodplain deposits prevents substantial channel migration through this reach. The drainage area of Ragged Creek, which enters at the boundary of MF7, is fairly small and likely only contributes small amounts of coarse sediment to the system under high flows (e.g., 2-year flood event is estimated to contribute 32 cfs).

5.2.17 Reach MF5

Reach MF5 is moderately confined bounded by confined reaches both upstream and downstream. Both the upstream and downstream boundaries of the reach are bedrock constrictions that control channel position. The reach is characterized by low sediment transport capacity and a slope of 0.6 percent. A short peak in sediment transport capacity occurs at the transition zone between reaches MF4 and MF5, where the historic railroad grade disconnects a portion of the floodplain. In the lower portion of the reach, Dry Creek and Sunshine Creek contribute to increased flows and transport capacity. Surface topography from

LiDAR indicates that a portion of Dry Creek may have been historically routed to an irrigation diversion.

Well-defined channels that are visible on the LiDAR hillshade appear to have been main channels, or perhaps side channels, that were abandoned by the river before the oldest set of historical aerial photographs (1939). Field verification of several of the side channels suggests that some of the channels are currently connected under higher flow conditions. At the upstream end of this reach, active channel widths and width to depth ratios begin to noticeably increase in the downstream direction compared with upstream reaches. Flows close to a 5-year event may be required to mobilize bed and bar material in the reach. These findings suggest that localized channel degradation (possibly vertical or lateral) may be limiting the ability of the channel to access the floodplain and adjacent side channels at historic frequencies. Revegetation of the riparian corridor may aid efforts to reduce impacts of lateral channel degradation.

5.2.18 Reach MF4

Reach 4 is a narrow, confined reach that has less opportunity for restoration of off-channel habitat due to the availability of floodplain. Big Boulder Creek alluvial fan controls channel position throughout most of the reach. Channel bed elevations are likely also controlled by alluvial inputs from Big Boulder Creek as evidenced from a change in slope at the downstream end of the reach. The reach is characterized by high total stream power compared with other reaches due to the ability of the channel to transport high flows without substantial energy dissipation on floodplains. Upstream of the confluence of Big Boulder Creek, sediment transport capacity is relatively low compared to other confined reaches. Downstream of Big Boulder Creek, transport capacity increases due to increased slope, increased flow, and decreased sediment gradation due to the sediment supply from Big Boulder Creek.

The presence of a well defined channel along the north side of the floodplain and the concave configuration of the alluvial-fan deposits from Big Boulder Creek suggest that the main channel of the Middle Fork once flowed on the north side and eroded the alluvial-fan deposits. This channel currently appears to be blocked to protect against bank erosion of the historic railroad and highway road embankment. Reconnection of this channel as a secondary channel should consider potential for avulsion and impacts to sediment transport capacity.

Other side channels in this reach may require some construction efforts since the topography appears to be heavily modified, and channels may be filled or blocked. Placements of LWD in this reach should consider active deposition from Big Boulder Creek and high erosive forces in steeper portions of the reach.

5.2.19 Reach MF3

Reach 3 lies within a moderately confined geologic low surface. Sediment transport capacity is high in the upstream portion of this reach and gradually decreases in the downstream direction. This pattern may partially result from changes in the degree of channel confinement of the reach due to construction of the railroad on the right side of the river and bedrock confinement on the left side. A high percentage of the reach has been disconnected from its floodplain and based on aerial photos, channel migration is minimal. This stability is likely a result of bank armoring and artificial channel straightening combined with geologic confinement. Stream power is higher than other moderately confined reaches and is close in magnitude to stream power in some confined reaches. Incipient motion analyses indicate that a flood event with a recurrence interval between 2 and 5 years would be required to mobilize bed material at the upstream end of this reach. Results suggest that high erosive forces related to increased channel slopes may have reduced the availability of spawning-sized gravels.

A large alluvial fan created by Big Boulder Creek creates the upstream boundary of this reach and imparts a control on lateral channel position. Restoration actions should consider alluvial inputs from Big Boulder Creek to ensure that changes in sinuosity do not instigate channel instability. This reach is lacking in channel complexity. LWD could provide a short-term strategy to enhance complexity features in the channel. Some of the open areas in this reach appear to be wet meadows, and therefore, will require vegetation consistent with these seasonal conditions.

5.2.20 Reach MF2

The upstream boundary of unconfined reach MF2 is an alluvial fan created by Coyote Creek. Other tributaries in the reach include Horse Creek, Dunstan Creek and Balance Creek. A portion of flow from Horse Creek and Balance Creek was historically intercepted by drainage ditches. Coyote Creek and Dunstan Creek may supply some coarse sediment based on the presence of gravel bars at their mouths, but contributions from the other tributaries does not appear substantial. MF2 is characterized by a slope of less than 0.5 percent and consistently low sediment transport capacity. Sediment sizes and total stream power in this reach are larger than those of other unconfined reaches. Incipient motion results suggest that a flood event with a recurrence interval between 2 and 5 years may be required to mobilize the bed material in this reach under current conditions. Results indicate that high erosive forces related to increased channel slopes. Compared with other unconfined reaches, ODFW surveyed a very low number of Chinook redds per mile in MF2. Further investigation is needed to determine if the lack of surveyed redds in this reach is related to channel access. Evaluation of potential habitat actions in this reach should consider reconnection of flow from tributaries, and possible modifications to sediment transport capacity resulting from increased sinuosities and reduced slopes.

The majority of this reach is depicted as meadow in the 1926 water adjudication maps, and small areas of trees and shrubs are visible on historical aerial photographs (1939, 1956, and 1976). Additional investigation may be required to determine if seasonal wet meadow conditions were historically present, and how the soil and hydrologic conditions impact revegetation efforts.

5.2.21 Reach MF1

Reach MF1 encompasses a short moderately confined segment of the study area between Cress Creek and Camp Creek. Camp Creek is a substantial contributor of sediment to the system. The downstream boundary of reach MF1 is the end of the study area and coincides with a lateral geologic control caused by Camp Creek alluvial fan. The bridge at the upstream end of the reach and Camp Creek alluvial fan at the downstream end of the reach control the channel position through this short section of river. Portions of this reach were identified as meadows on the 1926 WATER ADJUDICATION MAP maps. Today, 32 percent of the river in this reach is shaded by vegetation consisting of mixed conifers and cottonwood. Revegetation efforts should consider possible wet meadow conditions on a seasonal basis.

5.3 Upper Mainstem John Day River Geomorphic Conditions

5.3.1 Reach UJD3

Unconfined reach UJD3 is bounded by older alluvial fan deposits and terraces. Major tributaries in this reach include Jeff Davis Creek, at the upstream boundary, and Dad’s Creek, near the lower end of the reach. Both tributaries were historically diverted through irrigation canals and may continue to be today under certain flow conditions. Neither tributary is a substantial contributor of coarse sediment to the Upper Mainstem. A series of grade control structures are located at the upstream end of the reach and provide sufficient head for an irrigation diversion. These rock structures also act as a vertical control on channel position.

No major channel incision was observed or noted in the stability analyses. Active lateral channel migration was apparent downstream from Dad’s Creek. Lateral channel migration may be a secondary result of channel straightening, disconnection of side and overbank channels, and vegetation clearing through this section of the river; however, most of those impacts have had sufficient time to stabilize. The evident bank erosion may also be a response to a more recent input or simply a natural process of channel bank migration. Bank erosion resulting from lateral equilibration and channel migration is a natural process that should be occurring in this system. Without interruption, the channel has sufficient competence to continue to erode the channel banks through the reach until equilibrated channel processes have been achieved (i.e., channel slope, length, and sediment transport capacity are in balance).

Results from analysis of sediment samples suggest that materials comprising the bars of the reach are mobilized during 2-year flood events. Spawning is highest in this reach compared with both downstream reaches in the assessment area based on ODFW Chinook redd surveys. Sediment transport capacity is relatively low compared with downstream reaches. A reduction in capacity is apparent just downstream from Dad's Creek confluence and may result from a significant change in slope through opposing alluvial fans. This reduced transport capacity is not adequate to preclude channel adjustment to historical channel straightening and side channel blocking activities, recently imposed impacts, or natural channel adjustments as reflected in bank erosion from active lateral migration and downstream meander migration.

5.3.2 Reach UJD2

The reach is a moderately wide section that is constricted by older alluvial-fan deposits and terraces. Most of the floodplain boundary is at least somewhat erodible. Lateral channel migration in this reach is limited by bank armoring, bridge embankments, and levees. Some minor shifts in channel position are occurring where geologic or constructed features have minimal impacts. Reach UJD2 has greater sediment transport capacity and higher erosive forces than both the upstream and downstream reaches, probably resulting from channel straightening and increased channel slope. Bed and bar materials are consistent with those measured in UJD3 and are mobilized during flows less than 2-year events. Alluvial inputs supplied to reach UJD2 are most likely being transported to reach UJD1 during high flow events. Results of the channel stability analysis indicate a tendency for degradation in reach UJD2 during flood flow events. Opposing alluvial fans at the transition between reaches UJD2 and UJD3 may limit any further vertical degradation of reach UJD2.

Within reach UJD2, field observations did not identify the presence of active degradation or aggradation, but over-widened channels were observed in this reach. Strawberry Creek is the only substantial tributary and may provide some inputs of coarse sediment to the system. Flows from the creek have historically been intercepted by drainage ditches. Strawberry Creek travels through a large alluvial fan with flows diverging into several surface flow paths that merge with the Upper John Day River in multiple locations. UJD2 is lacking in channel complexity. Placement of LWD at strategic locations could provide a short-term enhancement to habitat quality during the reestablishment of woody vegetation along the riparian corridor.

5.3.3 Reach UJD1

Confined reach UJD1 is a narrow section that is constricted by older alluvial-fan deposits. Most of the floodplain boundary is at least somewhat erodible. The channel is not able to migrate laterally through the reach due to substantial amounts of bank armoring throughout the reach and bridge embankments at the downstream boundary of the reach. Sediment transport capacity is lower in this confined reach than in the upstream moderately confined reach, with increasingly large differences during higher flow events. This is likely related to the degree of channelization of reach UJD2. No sediment samples were obtained in this reach. Incoming sediment appears to be transported downstream based on the lack of gravel bars and coarse sediments available for transport in the bed as noted in the field. A riparian corridor is in place along most of the banks of this reach. Width-to-depth ratios are typically smaller than either of the upstream reaches, which may be related to the presence of vegetation and greater depths. No significant tributaries are located within this reach.

6.0 Reach-Based Protection and Restoration Opportunities

The goal for habitat protection and restoration strategies is to maximize availability, connectivity and complexity of habitat, including that of rearing and spawning habitat. Many reaches are geomorphically stable under present conditions. However, the current river may not utilize the full potential of the river and floodplain to maximize spawning, rearing, and migration habitat. General findings from the geomorphic assessments conclude that although topographic factors have been altered, the flow and sediment regimes of the study area have not been greatly disturbed from the late 1800s and early1900s. This conclusion supports protection and restoration opportunities that change the river to a form that more closely resembles the typical channel processes identified in Chapter 3, and more closely resembles pre-development conditions. Restoration efforts to reverse some of the topographic changes from the last century, and establish a new stable and self-sustaining form of the river appears promising. The considered changes to the river should both enhance channel processes and provide improved quantity and quality of salmonid habitat.

Currently functioning areas of the river that maximize the potential for habitat under the existing conditions can be protected through conservation or other strategies. Building upon this base, restoration areas are identified where improvements to habitat can be gained to provide continuous stretches of functioning habitat. One of the fundamental habitat objectives from the *Mid-Columbia Draft Recovery Plan* (Carmichael 2006) and the *John Day Draft Subbasin Plan* (NPCC 2005) is to protect and improve habitat diversity through connectivity between the channel and floodplain. Since floodplain connectivity is dependent upon the availability of floodplain, preliminary restoration opportunities in unconfined and moderately confined reaches with wide floodplain areas were identified separately from geologically confined, single-thread channel reaches.

6.1 Reach-Based Protection and Restoration Strategy

Two primary restoration concepts are recommended to recover long-term habitat function and complexity based on this analysis. First, a major revegetation effort is necessary to restore healthy riparian processes, provide shade and cover to the channel, recruit LWD, and moderate lateral channel migration and bank erosion. The second key restoration concept is the setback or removal of constructed features that impact floodplain connectivity, lateral channel migration and reworking processes, and the availability of off-channel and main channel complexity features, such as side channels and LWD-formed pools. These strategies will help maximize habitat improvements in moderately confined and unconfined reaches.

In geologically confined reaches, the largest impacts have been the loss of vegetation and the installation of riprap along channel banks. Modification or removal of these features in conjunction with riparian planting offers an opportunity for improving long-term habitat viability in these reaches. Removal of riprap features in locations of residential and roadway development is less feasible than in reaches without development along surrounding surfaces. Revegetation efforts along the riparian boundaries of confined reaches should consider the ability of the vegetation to provide shade and a potential source of LWD to the system.

A list of strategies that can be utilized to increase habitat function and complexity in moderately confined and unconfined reaches are identified below. All structure removal actions, floodplain reconnection actions, and channel plan form changes proposed in these strategies should be designed based on relevant geomorphic factors as presented in Chapter 5 to meet the goal of a self-sustaining river. The strategies include:

- Protection of existing riparian vegetation within the floodplain and along the channel margins to maintain canopy cover, bank stability, and LWD inputs.
- Restoration of floodplain connectivity and function through the modification, setback or removal of features that block inundation of portions of the floodplain and side channels, including levees, riprap, roads, bridges, railroad grades, etc.
- Restoration of lateral channel migration through the removal of instream structures and hardened bank protection measures.
- Reconnection of historical main, side, and overflow channels. This may entail modification to channels that are presently connected, but at reduced frequencies compared to historical conditions.
- Reforestation of cleared floodplains, prioritizing areas with the most potential for interaction with the river for maximum improvements to water temperature and habitat quality.
- Implementation of cattle grazing management within the HCMZ to limit trampling of banks, bed, and channel bar materials and to support recruitment and survival of riparian vegetation.
- Installation of LWD structures as a short-term means of enhancing habitat while the long-term processes that naturally supply LWD re-establish.
    - Placement of LWD to direct high flows into side or overflow channels, thereby promoting floodplain access.
    - Placement of LWD to promote short-term channel complexity, provide fish cover, and re-establish typical channel morphology.
- Channel relocation to promote long-term channel complexity and increase fish habitat in locations where the channel has been completely modified through dredging activities or channelization.

More confined reaches are limited in the types of restoration actions that would effectively address restoration objectives. Measures that may be feasible in more confined reaches are:

- Protection of existing riparian vegetation within the floodplain and along the channel margins to maintain canopy cover, bank stability, and LWD inputs.
- Revegetation of riparian areas.
- Restoration of lateral channel migration through the removal of instream structures and hardened bank protection measures that are currently impairing channel processes.
- Installation of LWD structures as a short-term means of enhancing habitat while the long-term processes that naturally supply LWD re-establish.
  - Placement of LWD to direct high flows into side or overflow channels, thereby promoting floodplain access.
  - Placement of LWD to promote short-term channel complexity, provide fish cover, stabilize banks, and re-establish typical channel morphology.

For each reach, floodplain areas were distinguished between those with potential to expand or improve habitat through restoration actions and those that are generally functioning from a process and riparian vegetation perspective. Protection areas were identified by evaluating changes in flow, sediment, and topography and typically consist of no constructed features or topographic impacts. Protection areas are hypothesized to be currently maximizing potential salmon habitat. Table 8 summarizes the possible protection opportunities in each reach. The results demonstrate that there are localized areas within only a few reaches where protection of functioning processes is possible. The maximum amount of potential protection area is contained within confined reach MF11.

Within each reach, mapping of constructed features, historic channels, impacted HCMZ, and disconnected floodplains (see *Map Atlas*) were used to determine which restoration actions were needed to improve habitat complexity and physical processes that have been disrupted in a given floodplain area.

Findings of the geomorphic assessments are translated into habitat action classes and associated viable salmonid population (VSP) parameters that would be addressed using available references from Table 5.9 in the *Upper Columbia Recovery Plan* (UCSRB 2007). All of the habitat actions from the recovery plan are considered except for water quality and quantity restoration and nutrient restoration. However, restoration of floodplain processes can also serve to restore water quality and quantity where impacted from levees, roads, and bridges. Temperature can be further addressed through restoration of riparian vegetation, reconnection of any known disconnected groundwater sources, and implementation of existing water quality plans.

Table 8 – Quantity of Protection Versus Restoration Floodplain Area in Each Reach.

Floodplain Type	Reach	Area of Geologic Floodplain (acres)	Floodplain Protection		Floodplain Restoration	
			Area (acres)	Percent of Total	Area (acres)	Percent of Total
Middle Fork Assessment Area						
Moderately confined	MF1	8.9	0	0%	8.9	100%
Unconfined	MF2	326.4	0	0%	326.4	100%
Moderately confined	MF3	107.3	0	0%	107.3	100%
Confined	MF4	35.4	0	0%	35.4	100%
Moderately confined	MF5	59.9	0	0%	59.9	100%
Confined	MF6	4.10	0	0%	4.1	100%
Unconfined	MF7	48.52	0	0%	48.5	100%
Unconfined	MF8	148.3	0	0%	148.3	100%
Unconfined	MF9	53.2	8.2	15%	45.0	85%
Moderately confined	MF10	58.4	4.4	7%	54.0	93%
Confined	MF11	29.9	17.3	58%	12.6	42%
Moderately confined	MF12	30.1	0	0%	30.1	100%
Unconfined	MF13	197.8	0	0%	197.8	100%
Moderately confined	MF14	34.4	0	0%	34.4	100%
Confined	MF15	6.1	0	0%	6.1	100%
Unconfined	MF16	39.4	0	0%	39.4	100%
Confined	MF17	3.7	0	0%	3.7	100%
Moderately confined	MF18	8.7	0	0%	8.7	100%
Confined	MF19	4.6	0	0%	4.6	100%
Unconfined	MF20	12.4	2.2	18%	10.2	82%
Unconfined	CC1	26.9	0	0%	26.9	100%
Upper Mainstem Assessment Area						
Confined	UJD1	5.6	0	0%	5.6	100%
Moderately confined	UJD2	30.7	0.9	3%	29.8	97%
Unconfined	UJD3	46.0	0	0%	46.0	100%

Other actions not specifically addressed in Table 5.9 of the *Upper Columbia Recovery Plan* (UCSRB 2007) include channel reconstructions. For the purposes of these assessments, side channel reconstructions are included under the habitat action class of side channel reconnection, and main channel reconstruction is included under the habitat action class of floodplain restoration. Reconstructions are recommended in reaches where the main channel has been substantially altered through complete relocation, channelized through straightening of alignments and continuous bank armoring, or where side channels were filled in or re-graded.

Habitat action classes associated with each reach are provided in Table 9. These categories indicate actions for single or multiple project areas within the reach. LWD restoration is considered a potential habitat action in all reaches due to the denuded nature of the system and opportunities for short-term, in-channel habitat complexity improvements during re-establishment of longer term fluvial processes. Road maintenance was included as a habitat action class in reaches where roads and bridges negatively impact the channel and floodplain and could be improved through the implementation of best management practices and potential road decommissioning.

Table 9 – Reach-based Habitat Action Classes to Address and Associated VSP Parameters.

		Habitat Action Class [1/]					VSP Parameters Addressed [2/]	
Floodplain Type	**Reach Name**	**Riparian restoration within low surface**	**Side-channel reconnection**	**Road Maintenance**	**Floodplain Restoration**	**LWD Restoration**	**A/P**	**D/SS**
Middle Fork John Day River								
Moderately confined	MF1	X	X	X		X	X	
Unconfined	MF2	X	X		X	X	X	X
Moderately confined	MF3	X	X		X	X	X	X
Confined	MF4	X	X	X	X	X	X	X
Moderately confined	MF5	X	X		X	X	X	X
Confined	MF6	X		X		X	X	
Unconfined	MF7	X	X		X	X	X	X
Unconfined	MF8	X	X		X	x	X	X
Unconfined	MF9	X	X	X	X	X	X	X
Moderately confined	MF10	X	X		X	X	X	X
Confined	MF11	X	X		X	x	X	X
Moderately confined	MF12	X	X		X	X	X	X
Unconfined	MF13	X	X		X	X	X	X
Moderately confined	MF14	X	X	X	X	X	X	X
Confined	MF15	X		X		X	X	
Unconfined	MF16	X	X		X	X	X	X
Confined	MF17	X		X		X	X	
Moderately confined	MF18	X	X		X	X	X	X
Confined	MF19	X		X		X	X	
Unconfined	MF20	X	X		X	X	X	X
Unconfined	CC1	X			X	X	X	X
Upper Mainstem John Day River								
Confined	UJD1		X		X	X	X	X
Moderately Confined	UJD2	X	X		X	X	X	X
Unconfined	UJD3	X	X		X	X	X	X

[1/] Habitat action classes and associated VSP parameters addressed referenced from Table 5.9 in *Upper Columbia Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan* (UCSRB, 2007)

[2/] A/P = abundance and productivity; D/SS = diversity and spatial structure as described in *Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs* (ICBTRT, 2007)

6.2 Technical Prioritization of Restoration for Geomorphic Reaches

One objective of this report is to provide planners, managers, and stakeholders with decision making tools for prioritization of reaches. The prioritization technique presented in this report is based on the potential of each reach to be protected or restored. Additional ranking schemes are provided in Appendix F for management consideration.

Many reaches of the existing river are stable and have functioning channel processes. Restoration/protection potential describes the potential for the channel and floodplain to be adjusted to more closely resemble typical channel processes described in Chapter 3 and the pre-development river form for the enhancement of salmonid habitat. This category was structured after recommendations from *Upper Columbia Recovery Plan* (UCSRB 2007) and *Upper Columbia Biological Strategy* (UCRTT 2007), which suggest prioritizing areas that are currently functioning (protection), followed by areas in which processes can be restored that improve salmonid habitat.

Since the Middle Fork and Upper Mainstem John Day River are two different river systems with potentially different stakeholders, separate rankings are developed for each system. There are 21 process-based reaches in the Middle Fork Assessment Area, including the Clear Creek reach, and 3 process-based reaches in the Upper Mainstem Assessment Area. The reaches are characterized and ranked so they can be relatively compared within each basin to help resource managers sequence restoration efforts at a reach scale. Based on the *Upper Columbia Recovery Plan* and *Biological Strategy* recommendations, the ranking method gives more weight to areas with greater amounts of existing habitat complexity than to reaches with a greater departure from ideal (fully functioning) conditions. The ranking focuses on the lateral connectivity of the floodplain and channel that allows development of habitat features associated with complexity.

Within each reach, project actions are identified to protect and enhance physical processes responsible for shaping desired habitat. Project areas are grouped within each reach by project actions, and are assigned a restoration/protection potential. Project areas received rankings from 1 to 8, with 8 being the best potential and 1 being the worst (Table 10). The ranking was structured such that the highest ranked areas (8s) are protection areas that have no known topographic changes since pre-development conditions and no known impacts from previous anthropogenic activities that may have altered river form. The ranking assigns higher values to areas that provide habitat features associated with complexity and lower values to areas that serve mainly as overflow surfaces and are only inundated during higher magnitude flows.

Table 10 – Scoring Values for Restoration/Protection Potential.

Score [1]	Restoration/Protection Potential	Percent of 23-Mile Long Assessment Area on the Middle Fork, including Clear Creek Reach	Percent of 3-Mile Long Assessment Area on the Upper John Day River
8	Functioning floodplain area with healthy riparian vegetation	1%	0.2%
7	Functioning floodplain area needing additional riparian vegetation	1%	0%
6	Accessible floodplain requiring heavy revegetation	16%	0%
5	Full restoration of high-complexity floodplain or channel network area, including reforestation of low surface	43%	3%
4	Partial restoration of high-complexity floodplain or channel network area, including partial reforestation of low surface	18%	0%
3	Side channel(s) with floodplain reconnection and revegetation	13%	69%
2	Side channel(s) with partial or little floodplain reconnection and revegetation	3%	10%
1	Low surface reconnection with few or no side channels and revegetation	4%	18%
0	Project area has heavy development in present setting	1%	0%

[1] Rank: 8 = “(Highest or Best)”; 0 = Lowest or Worst

After assigning all project areas within a reach a score for restoration/ protection potential, an area-averaged reach score can be computed. The final ranking for the restoration/protection potential is determined by multiplying the reach-weighted score by the ratio of the area of the reach to the total assessment area. This methodology gives greater weight to reaches with greater floodplain areas. Results of the ranking are provided in Table 11.

Both assessment areas are used by spring Chinook and steelhead for spawning. Data on the spatial distribution of spring Chinook redd counts are used to evaluate the current significance of each reach for spawning habitat. The average number of redds per mile measured between 2002 and 2006 in each reach are provided in the table as an indicator of present fish use.

Table 11 – Ranking of Reaches by Restoration/Protection Potential. (An indicator of present fish use is provided to evaluate with the ranking results.)

Floodplain Type	Reach	Area-Averaged Restoration/ Protection Potential for Reach	Normalized Area (Area of Reach / Total Area of Assessment)	Final Rank (Reach weighted Restoration Potential * Normalized Area*100)	Actual Rank Out of Total Number of Reaches	Average Number of Chinook Redds per Mile (2002-2006)
Middle Fork Assessment Area						
Moderately confined	MF1	3.01	1%	2.2	17	0
Unconfined	MF2	5.53	26%	145	1	3.9
Moderately confined	MF3	3.69	9%	31.8	4	5.1
Confined	MF4	3.17	3%	9	13	2.7
Moderately confined	MF5	4.69	5%	22.6	5	5.8
Confined	MF6	0.99	0%	0.3	21	3.3
Unconfined	MF7	4.74	4%	18.5	6	3.3
Unconfined	MF8	3.69	12%	44	3	9.4
Unconfined	MF9	3.73	4%	16	8	10.5
Moderately confined	MF10	3.7	5%	17.3	7	4
Confined	MF11	5.23	2%	12.6	10	5.4
Moderately confined	MF12	1.91	2%	4.6	15	12.7
Unconfined	MF13	4.85	16%	77.1	2	27.1
Moderately confined	MF14	4.07	3%	11.3	11	13.8
Confined	MF15	1	0%	0.5	20	13.7
Unconfined	MF16	5	3%	15.8	9	14.6
Confined	MF17	3	0%	0.9	19	4.5
Moderately confined	MF18	3	1%	2.1	18	4.7
Confined	MF19	6	0%	2.2	16	0
Unconfined	MF20	4.9	1%	4.9	14	9.6
Unconfined	CC1	4.45	2%	9.6	12	2
Upper Mainstem Assessment Area						
Confined	UJD1	2	7%	13.6	3	1.9
Moderately confined	UJD2	3.12	37%	116.3	2	8.8
Unconfined	UJD3	2.36	56%	131.9	1	11.7

Based on physical processes, reaches MF2, MF13, and MF8 are the top three ranked reaches in the Middle Fork, and Reach UJD3 is the top ranked reach in the Upper Mainstem, followed closely by UJD2. All but MF2 have a higher than average number of Chinook redds per mile compared with other reaches in the assessment areas. Reaches MF13 and MF8 are the Forrest and Oxbow Conservation Areas on the Middle Fork, respectively.

Additional rankings are developed based on the amount of human impact, accessibility to potential LWD, and the relative degree of vegetation loss. The information is intended to be cumulatively evaluated to guide informed decision-making and can be modified in the future by incorporating new information as it becomes available. The combined results of the different ranking schemes for the top 3 highest ranks in each category are provided in Table 12. Greater detail on these additional rankings is provided in Appendix F. The rankings show that reaches with the greatest degree of impacts to habitat quantity and quality and to the typical channel processes occurring in the HCMZ and the floodplain are the same reaches as those having the greatest potential for restoration and protection.

Table 12 - Top 3 ranking reaches for each of the 4 different ranking schemes. More detailed results are included in Appendix F.

Rank Number	Restoration/ Protection Potential	Most impacted HCMZ and floodplain	Greatest Access to Potential LWD	Greatest Loss of Vegetation
Middle Fork Assessment Area				
1	MF2	MF2	MF11	MF15/CC1
2	MF13	MF13	MF10	MF18
3	MF8	MF8	MF4	MF17
Upper Mainstem Assessment Area				
1	UJD3	UJD3	UJD1	UJD2
2	UJD2	UJD2	UJD3	UJD1
3	UJD1	UJD1	UJD2	UJD3

All reaches provide important habitat for a variety of life stages for spring Chinook, steelhead, and other fish species. The relative need for protection and restoration in any given reach may be based upon the natural resiliency of the floodplain type to morphologic disturbances, potential threats to channel processes and habitat availability in the reach, current level of impairment to river processes that maximize habitat in a reach, and the use of the reach by provide information to local stakeholders, planners, and technical teams that can be used to aid prioritization of habitat restoration efforts within each assessment area.

Once a reach has been prioritized for implementing restoration activities, there are several combinations and sequencing of project alternatives that may be undertaken. A sequencing of habitat actions was developed for the reaches owned by the Confederated Tribes of the Warm Springs Reservation of Oregon and is presented in Appendix F. Future reach assessments will develop a scientifically supported and geomorphically sound implementation strategy at a more detailed scale. Other factors, such as constructability of projects, cost, landowner willingness, funding availability, and permitting acceptance, will guide the types, localities, and sequencing of projects within a given reach.

6.3 Breakout of Potential Protection and Restoration Project Areas

A total of 97 potential project areas were identified within the Middle Fork Assessment Area, and 40 potential project areas were identified in the Upper Mainstem based on findings from the geomorphic assessment. Within each project area, restoration concepts were identified to address the recovery of typical physical processes for the benefit of salmonid habitat. For the technical ranking presented above, the project areas were categorized according to their restoration/ protection potential as described by Table 13. These general categories can be used to view the relative opportunities of each reach for protection, floodplain connectivity, and side channel reconnection. Identification of protection areas as part of a restoration strategy is needed to provide spatial information for linking restoration areas.

Figure 39 illustrates the percentage of restoration/ protection categories assigned in each reach. Generally, revegetation of the floodplain is an important part of restoration in every reach. In addition, LWD could be beneficial for aiding floodplain connectivity and habitat complexity in all reaches by deflecting high flows into side channels, creating backwater habitat, providing cover, and moderating bank erosion. Further evaluation to determine project benefits, feasibility, sustainability, and potential sequencing within each reach will be accomplished in subsequent assessments.

Table 13 – Categories for Potential Protection and Restoration

Category	**General Description of Restoration/ Protection Opportunity**
8	Functioning floodplain area with healthy riparian vegetation
7	Functioning floodplain area needing additional riparian vegetation
6	Accessible floodplain requiring heavy revegetation
5	Full restoration of high-complexity floodplain or channel network area, including reforestation of low surface
4	Partial restoration of high-complexity floodplain or channel network area, including partial reforestation of low surface
3	Side channel(s) with floodplain reconnection and revegetation
2	Side channel(s) with partial or little floodplain reconnection and revegetation
1	Low surface reconnection with few or no side channels and revegetation
0	Project area has heavy development in present setting

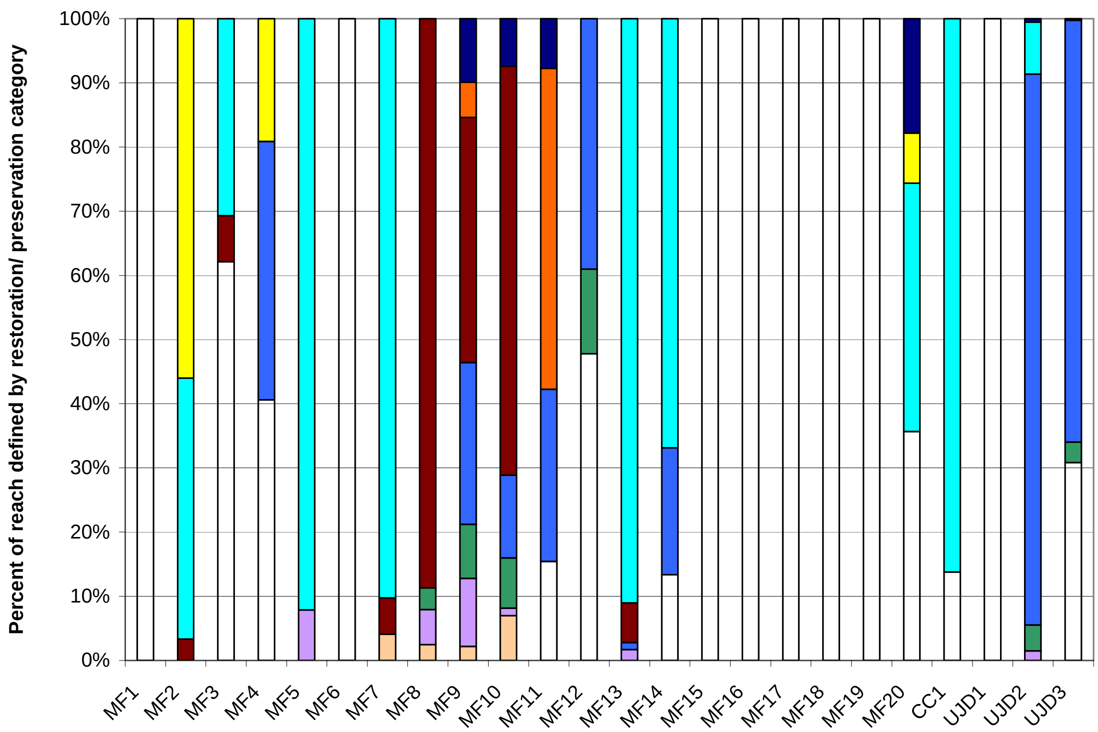

Figure 39 – Distribution of General Restoration/Protection Categories in Assessment Areas.

Project areas with a designation of category 7 or 8 (protection and monitoring) are sites with no known topographic features that impair floodplain connectivity or complexity. However, the lack of vegetation in some reaches may be related to historic anthropogenic activities. These sites only make up approximately 2.6 percent of the Middle Fork Assessment Area and just over 1 percent of sites in the Upper Mainstem Assessment Area. Additional field verification may find geologic or constructed features in these areas that were not known or located at the time of this assessment. Undetected geologic features could be expected to have a greater impact on channel processes than unmapped constructed features. High percentages of category 6 typically indicate areas where the floodplain is accessible and few constructed features block floodplain inundation, but riparian vegetation is limited or non-existent. Reaches with a high percentage of categories 4 and 5 projects offer the greatest opportunity for reconnection of floodplain processes and are generally located in moderately confined and unconfined reaches. Categories 2 and 3 are common in locations where a single or multiple side channels have potential for reconnection, but the opportunity for improving connectivity to surrounding floodplain is less than areas with high-complexity channel networks. Reaches with a high percentage of category 1 floodplain, such as MF6, MF12, and MF15, contain constructed features that block access to the floodplain but do not contain off-channel habitat complexity features, such as side channels. Areas with substantial development within the floodplain were assigned a value of 0 due to risks associated with habitat restoration actions. In these cases, the possible risks to infrastructure outweigh implementation benefits.

Each of the potential restoration areas represents a section of floodplain that has been altered by constructed features or anthropogenic activities. Constructed features that disconnect a portion of the floodplain from the active channel are components of potential projects within each floodplain area. Areas containing potential for complex networks of channels and side channels provide the most direct benefit to increasing available habitat area and floodplain connectivity. Restoration of overbank floodplain areas provides some relief during floods by allowing flow to spill out onto the floodplain surface, thus reducing energy in the main channel. While these surfaces are important to include in a reach-based habitat restoration strategy, they are generally small relative to the entire reach, do not contain any low elevation channels, and are infrequently inundated.

6.4 Restoration Success and Sustainability

The success and sustainability of habitat restoration actions is an important consideration when evaluating opportunities. Actions with the most potential to create habitat are those that work to restore river processes that generate habitat complexity, particularly in dynamic reaches that typically have frequent channel migration and floodplain interaction. Anthropogenic activities have not caused substantial changes in the flow and sediment regimes, and a large amount of floodplain area is free of major infrastructure development.

Geologic controls have helped keep the overarching river morphology intact in both assessment areas, despite human activities; however, a large number of topographic impacts resulting from human features and anthropogenic activities are present, and these impacts are generally reversible. Therefore, potential for recovering floodplain and channel connectivity by removing features that negatively impact channel processes is high. In addition to removal of features that negatively impact channel processes, enhancement of floodplain function may require the strategic placement of flow deflection structures (e.g., log jams) and/or reconnection of historic channels that have either been filled or plugged.

Once lateral connectivity is re-established, side channels, riparian vegetation, and LWD that provide off-channel habitat and habitat complexity will begin to re-establish. Efforts may be necessary to promote restoration of habitat complexity within the short term, particularly in areas where constructed features actively degrade habitat complexity. In-channel features of habitat complexity, such as engineered log jams, may provide short-term biological benefit during the establishment of more sustainable process-based restoration strategies.

Restoration actions impose new conditions on the river, potentially disturbing equilibrium, and triggering evolution to a new form that is dynamically stable under the modified flow, sediment, and topographic conditions. The timeframe required to maximize salmonid habitat by enhancing floodplain processes will depend to some extent on the emphasis placed on mechanical methods to implement habitat recovery actions. Designing and excavating new channels to the predicted stable condition does not guarantee a stable channel, but does reduce the timeline to stability. If few mechanical methods are employed, the frequency, duration, timing, and magnitude of flood events following project implementation will be the dominant factors in controlling the period of time required for river adjustment. Channel evolution to the stable form under natural conditions and with limited mechanical intervention could take decades to occur.

Substantial loss of vegetation has degraded potential complexity within the channel and floodplain areas. Re-establishment of riparian vegetation will require active revegetation efforts. In many areas, vegetation clearing began prior to 1939 and little re-establishment has occurred in the last 65 to 70 years since initial removal. Recovery of floodplain processes is expected to promote the recruitment of riparian vegetation. However, efforts to protect new vegetation growth from ungulate browsing could increase survival rates. Cattle grazing management may also assist establishment of vegetation within the low surface. In some areas, it may take a significant flood to erode adjacent surfaces and start the decadal long process of building new surfaces and establishing riparian vegetation. Cottonwoods require a bare and moist deposit of sand or gravel and ample exposure to the sun to become established. The lack of floodplain reworking has caused a combination of limited cottonwood regeneration and a conversion of new growth to species such as shrubs. Complete restoration of riparian vegetation may require several decades. Given the present condition of vegetation in both assessment areas, LWD recruitment rates may require more than 50 years to increase.

7.0 CONCLUSIONS

Tributary assessments were conducted on approximately 23 miles of the Middle Fork John Day River and 3 miles of the Upper Mainstem John Day River to further understanding of physical processes within the basin and to develop a reach-based restoration strategy. Assessments in each subbasin were conducted to compare and prioritize potential protection and habitat restoration areas. Although the two systems have regional similarity, geomorphic characteristics and human impacts are different within each assessment area.

7.1 Geomorphic Evaluation

Variations in geomorphic processes and the occurrence of geologic floodplain constriction points were used to delineate 21 reaches in the Middle Fork and 3 reaches in the Upper Mainstem where habitat for spring Chinook and steelhead might be preserved, enhanced, or restored. Three typical floodplain types were identified that helped evaluate geomorphic reaches based on the potential for providing habitat complexity:

- Wide, Unconfined Floodplain with High Complexity
- Moderately Confined Floodplain with Medium Complexity
- Narrow, Confined Floodplain with Low Complexity

The degree of complexity within the floodplain refers to the potential for off-channel salmonid habitat due to LWD, side channels, wide-ranging vegetation, groundwater inputs, and diverse patterns of hydraulics and sediment. The descriptions are relative to the floodplain types within each assessment area.

River morphology is determined by the flow regime, sediment regime, and topographic features within the channel and floodplain. Each element was evaluated with respect to historic changes to the channel to assess the habitat restoration potential of this system. Minimal historic impacts to the flow regime were identified, which is generally the most difficult element to correct with restoration actions. Some minor impacts to the sediment regime were detected, including short-term increases in fine sediments from anthropogenic activities, localized changes in channel slopes resulting from channelization, and possibly mild localized degradation or bed coarsening in small portions of a few reaches. The greatest impacts on channel processes in the assessment areas result from changes in topographic features due to constructed features and to vegetation-related factors.

Methods used to evaluate the historic and present geomorphic conditions of the system included historical accounts and maps, aerial photographs from 1939 to 2006, LiDAR surveys, ground survey data, and geomorphic mapping. Field mapping of geologic surfaces bounding the floodplain vertical and lateral controls present in each reach. Sediment sampling, evaluation of longitudinal slopes, and hydraulic and sediment transport analyses provided a foundation for evaluating the present channel stability and geomorphic conditions in each reach.

In the Middle Fork, alternating wide and narrow valleys result from the presence of bedrock constrictions and alluvial fans. Reach-average channel slopes range between 0.4 percent and 1.25 percent with higher slopes in localized areas. Results of the assessment indicate that substantial incision has not occurred in most reaches, despite significant modifications to stream energy. Constructed features, mainly rock spurs, riprap, railroad grade, levees, roads, and bridges, have had the greatest impact on channel processes and floodplain connectivity in moderately and unconfined reaches. Denudation of riparian vegetation has resulted in vegetation losses of up to 100 percent in some reaches, which in turn limits the ability of the channel to recruit and store LWD. Following development in the basin and significant changes to land use primarily between 1860 and 1970, the river appears to have reached a new equilibrium within it boundaries. The new equilibrium is defined by fewer active overbank and side channels and possibly less frequently inundated floodplain than historic conditions. Although active channel aggradation or degradation was not evidenced during field visits, a slight tendency for degradation in the downstream direction may be present during flood events. Any modifications to the system that disrupt the present equilibrium (e.g., removal of artificial topographic features) may result in channel adjustments through increased lateral channel migration in locations where the channel is competent to rework floodplain deposits. Potential channel adjustments have implications for long-term stability of restoration actions, such as LWD placements, and will require additional investigations at a more refined scale.

The Upper Mainstem Assessment Area has substantially different geological boundaries than the Middle Fork and is comprised primarily of alluvial material from surrounding, often subtle, alluvial fans. Reach-average channel slopes in the assessment area range between approximately 0.67 percent and 0.87 percent, with localized sections of steeper and gentler slopes depending on the degree of alteration. The greatest slopes in the assessment area are within moderately confined reach UJD2 and likely result from decades of channel straightening activities. Although substantial vertical channel degradation is not evidenced in the results, considerable bank erosion was noted in localized areas during field visits. Some bank erosion is expected to occur as part of natural bend migration processes; however, erosion at these sites could be occurring as a response to historic channel straightening. Further geomorphic investigations would be needed to help identify the main cause. Evaluation of width-to-depth ratios suggests that the channel may be wider than under historic conditions. A slight tendency for degradation exists in reach UJD2 under flood conditions. The extent of further degradation may be limited by vertical and/or lateral geologic controls that are actively confining reach transitions. The most substantial topographic impacts and anthropogenic activities in the assessment area include grazing, denudation of riparian vegetation, channel straightening, and installation of grade control structures, irrigation diversions, riprap, levees, and rock spurs.

A reach-based assessment that integrates geomorphic findings relevant to salmonid habitat restoration and protection strategies was also presented to guide selection of and to aid further development of specific habitat actions at the next level of analysis.

7.2 Protection and Restoration Strategies

Findings presented in this report for each reach provide guidance for the types of protection and restoration strategies that would be most successful and beneficial to the system, based on their biologic and physical components. This report and biological guidance documents identify the need to protect and improve habitat diversity through connectivity between the channel and floodplain. Since floodplain connectivity is dependent upon the availability of floodplain, preliminary restoration opportunities in unconfined and moderately confined reaches with wide floodplain areas were identified separately from geologically confined, single-thread channel reaches.

More than 90 percent of the assessment area in each subbasin is composed of moderately confined and unconfined reaches. The 2006 main channel length in moderately confined and unconfined reaches that offer opportunities for restoring channel and floodplain connectivity accounts for 18.6 river miles in the Middle Fork Assessment Area (81 percent of total length) and 2.7 river miles in the Upper Mainstem Assessment Area (86 percent of total length). Although confined reaches comprise a smaller percentage of floodplain within each assessment area, they provide important ecological functions to anadromous salmon and offer some potential for protection and restoration of habitat.

Based on incorporation of local knowledge, biological guidance documents, and findings of these geomorphic assessments, factors most notably negatively impacting channel processes that maximize quality and availability of habitat include clearing of riparian vegetation, reduced floodplain function and connectivity, reduced side channel access, reduced lateral migration potential, and altered rates of LWD inputs and vegetation recruitment.

Two primary restoration concepts are recommended to recover long-term habitat function and complexity based on this analysis. First, a major revegetation initiative is necessary to restore healthy riparian processes, provide shade and cover to the channel, recruit LWD, and moderate lateral channel migration and bank erosion. The second crucial restoration concept is the setback or removal of artificial features that impact floodplain connectivity, lateral channel migration and reworking processes, and the availability of off-channel and main channel complexity features, such as side channels and LWD-formed pools. These strategies will provide the greatest habitat benefit in moderately confined and unconfined reaches. In geologically confined reaches, the largest impacts have been the loss of vegetation and the installation of riprap along channel banks. Modification or removal of these features in conjunction with riparian planting offers the best opportunity for improving long-term habitat viability in these reaches.

Identification of protection areas as part of a restoration strategy is important because connecting protection and restoration areas enhances the quality of the restored habitat. However, less than 2.6 percent of the Middle Fork and just over 1 percent of the Upper Mainstem were comprised of floodplains with desirable habitat conditions. In most cases, quality and availability of habitat was limited by constructed features or anthropogenic activities that impact the river topography.

Protection and restoration strategies proposed for each reach were categorized by habitat action class and associated VSP parameters as referenced from Table 5.9 in the *Upper Columbia Recovery Plan*. This organization provides a linkage between biological needs and physical processes of the river. Actions with the most potential to create habitat are those that work to enhance or restore river processes that generate habitat complexity, particularly in dynamic reaches that typically have frequent channel migration and floodplain interaction. In addition to removal of features that negatively impact habitat-related channel processes and reforestation of the floodplain, rehabilitation of floodplain function may require the strategic placement of flow deflection structures (e.g., log jams) and/or restoration of historic channels that have either been filled or plugged. Short-term actions, such as LWD placements, may be needed to supplement long-term strategies that require extended timeframes for physical processes that support salmonid habitat features to recover.

A technical ranking of reaches was developed to provide planners, managers, and stakeholders with a way to identify, sequence, and prioritize opportunities for protecting or restoring channel and floodplain connectivity and channel complexity at the reach-scale. The ranking was based on the current function of the floodplain, potential for the channel to restore physical processes that impact habitat and meet identified habitat objectives, and the degree to which the channel has departed from pre-development conditions. The rankings indicated that reaches MF2, MF13, and MF8 are the top three ranked reaches in the Middle Fork, and UJD3 is the top ranked reach in the Upper Mainstem. All but MF2 have a higher than average number of Chinook spawning use compared with other reaches in the assessment areas.

7.3 Remaining Data Gaps

This report provides an important level of technical information for resource decision makers to evaluate where to begin potential restoration actions within the assessment areas of the John Day River. Broad-scale conclusions presented in this report provide generalized characteristics and describe physical river processes at a reach scale. During this investigation, several technical areas outside of the scope of this assessment were identified. Four key areas where additional data may be incorporated to improve this report at a reach level include (1) biological interpretation of habitat value of each reach for the historic and present conditions; (2) characterization of the vegetation types and condition based on historical conditions and current potential; (3) identification of groundwater characteristics of each reach, including determination of seasonal variability in loss and gains from alluvial aquifers and contributing springs; and (4) incorporation of temperature patterns based on historical assessments, FLIR (forward-looking infrared) data, and measurements at specific locations.

On a project scale, localized features and processes may differ from the reach-scale characterizations presented in this assessment. Additional data and analysis will be needed in most cases for the subsequent reach assessments and project-scale evaluations prior to project implementation. The level of analysis needed will vary depending upon the complexity of the proposed project and adjacent land use and infrastructure. The next level of assessment (reach assessment) will incorporate more localized analyses for determinations of several tasks that are not completed at the tributary scale. Tasks identified as adding substantial value to the findings of this assessment include:

- Habitat survey of baseline conditions and limiting factors to provide a more detailed diagnosis within the reach of biological conditions to guide treatment sequencing and prioritization. This baseline information will also provide the foundation for all future monitoring efforts conducted within the reach.
- Site-specific geomorphic evaluations of constructed features to examine both positive and negative impacts to habitat that could result from the removal of the structures.
- Linkage of biological conditions with an understanding of channel and floodplain function using a modified Matrix of Pathways and Indicators (NOAA 1996).
- Two-dimensional hydraulic modeling to validate the present and potential lateral connectivity between the active floodplain and main channel, and investigate split flows between main and side channels.
- Refinement of GIS mapping of present side and overflow channels using field verification of the connectivity and definition of side and overflow channels. Connectivity of side channels and floodplain may be evaluated across a range of flows using a hydraulic model, ground photo documentation, helicopter video and/or survey of water elevations during high water, and evidence of high water marks following floods.
- Collection of new temperature or flow data during critical, low flow, and late-summer periods to understand the longitudinal variation in temperatures
- Refinement of vegetation mapping through site investigations to further evaluate the vegetation health and overlay vegetation findings with biological habitat value for each reach.
- Rectification of additional historical aerial photographs or maps if new information is found, particularly those relating to flood flow events.
- Integration of any monitoring information available to apply any lessons learned to restoration strategies being developed or implemented.

Collection of additional ground survey data where needed to refine numerical modeling used in evaluation of alternatives and development of project designs.

7.4 Future Directions

These tributary assessments considered previous work of many others to help fill large information voids and to establish a cohesive reference point for the development of protection and restoration opportunities within the assessment areas. Throughout the progression of this assessment, Reclamation and local partners obtained insight about the physical processes active in the assessment areas. Interim reports and presentations were accomplished to advance candidate projects sooner than the scheduled report completion date. Reclamation will continue to work with partners to scale, scope, and sequence the preparation of tributary assessments they conduct within acceptable reporting times and available budgets, as guided by local priorities and needs. Evaluating the 26 river miles concurrently allowed for prioritization of preliminary protection and restoration opportunities in terms of which areas provided the most habitat potential (i.e., unconfined versus confined valley segments).

A reach assessment, which follows the tributary assessment, is intended to advance local protection and restoration objectives at a scale that is amenable for all involved parties to execute and manage. Based on findings of the tributary assessment, a finer resolution diagnostic investigation of local physical processes and habitat features is conducted at the reach scale. The product of the reach assessment serves as the basis of an implementation strategy. Reach assessments include several primary goals: (a) diagnosing physical/environmental conditions at the reach scale; (b) proposing a technical sequencing recommendation of habitat actions for a cumulative biological benefit; and (c) documenting baseline environmental conditions for future effectiveness monitoring. Habitat actions are prioritized based on the number of VSP parameters and limiting factors addressed by an action and sequenced to maximize their cumulative benefits for the target species.

Based on findings in the reach assessment, project areas can then be selected for implementation by local entities according to their merit and benefit to the target species. Once a project area is selected, a design alternatives evaluation can be conducted to determine the type of habitat actions that can be implemented; and to examine construction feasibility and relative cost estimates. This nesting of spatial scales and the iterative interdisciplinary process provides an objective, scientific basis for local partners to focus discussions on project selection and development that will maximize the cumulative benefits for the target species.

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9.0 ACRONYMS

ACRONYMS	MEANING
ACOE	U.S. Army Corps of Engineers
BiOp	biological opinion (under the ***ESA***)
cfs	cubic feet per second, a measure of flow volume
D_{50}	The median particle-size diameter for a sediment sample, such that 50 percent of the sample is larger than this value.
DS	downstream
ELJ	engineered log jam
ESA	Endangered Species Act
ESUs	evolutionarily significant units
FCRPS	Federal Columbia River Power System comprises the Bonneville Power, the Army Corps of Engineers, and the Bureau of Reclamation. ACOE and Reclamation operate Federal hydroelectric dams in the Columbia River Basin and BPA markets the power.
FEMA	Federal Emergency Management Agency
ft	feet
FWS	U.S. Fish and Wildlife Service of the Department of the Interior
GIS	Geographic Information System
GLO	Government Land Office, the predecessor of the Bureau of Land Management
GPS	Water Adjudication mapbal positioning system
HCMZ	Historical Channel Migration Zone
ICBTRT	Interior Columbia Basin Technical Recovery Team
IFIM	Instream Flow Incremental Methodology
LiDAR	Light Detection and Ranging (LiDAR) is a remote-sensing system used to collect topographic data.
LWD	large woody debris
MPI	Matrix of Diagnostics/Pathways and Indicators
NAD 1983	The North American Datum of 1983 (NAD 83) is the horizontal control datum for the United States, Canada, Mexico, and Central America, based on a geocentric origin and the Geodetic Reference System 1980.
NAVD 1988	The North American Vertical Datum of 1988 (NAVD 88) is the vertical control datum established in 1991 by the minimum-constraint adjustment of the Canadian-Mexican-U.S. leveling observations
NED	National Elevation Data
NMFS	National Marine Fisheries Service of ***NOAA***

ACRONYMS	MEANING
NOAA	National Oceanic and Atmospheric Administration of the U.S. Department of Commerce
NPCC	Northwest Power and Conservation Council
Reclamation	U. S. Bureau of Reclamation, Department of the Interior
RM	river mile
RTK GPS system	real-time kinematic Water Adjudication mapbal positioning equipment utilizes a process where GPS signal corrections are transmitted in real time from a reference receiver at a known location to one or more remote rover receivers.
RTT	regional technical team
TIR	thermal-infrared photography
TRT	Technical Recovery Team
UCRTT	Upper Columbia Regional Technical Team
UCSRB	Upper Columbia Salmon Recovery Board
Upper Columbia Biological Strategy	*A Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region, A report to the Upper Columbia Salmon Recovery Board* (UCRT 2007)
Upper Columbia Recovery Plan	*Upper Columbia Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan* (UCSRB, 2007)
US	upstream
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service of the Department of Agriculture
USGS	U.S. Geological Survey of the Department of the Interior
VS	unit stream power
VSP	viable salmonid populations
WRIA	Water Resource Inventory Area

10.0 GLOSSARY

Some terms in this glossary appear in these *Tributary Assessments;* many are in the various appendices.

TERM	DEFINITION
adaptive management	A management process that applies the concept of experimentation to design and implementation of natural resource plans and policies.
aggrading stream	A stream that is actively building up its channel or floodplain by being supplied with more bedload than it is capable of transporting.
alluvial fan	A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream at the place where it issues from a narrow mountain valley upon a plain or broad valley, or where a tributary stream is near or at its junction with the main stream, or wherever a constriction in a valley abruptly ceases or the gradient of the stream suddenly decreases; it is steepest near the mouth of the valley where its apex points upstream, and it slopes gently and convexly outward with a gradually decreasing gradient (Neuendorf et al. 2005).
alluvium	A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream, as a sorted or semi-sorted sediment on the river bed and floodplain (Neuendorf et al. 2005).
anadromous (fish)	A fish, such as the Pacific salmon, that spawns and spends its early life in freshwater but moves into the ocean where it attains sexual maturity and spends most of its life span (Owen & Chiras 1995).
anthropogenic	Caused by human activities.
bar (in a river channel)	Accumulations of bed load (sand, gravel, and cobble) that are deposited along or adjacent to a river as flow velocity decreases. If the sediment is reworked frequently, the deposits will remain free of vegetation. If the surface of the bar becomes higher than the largest flows, vegetation stabilizes the surface making further movement of the sediment in the bar difficult.
bedload	The sediment that is transported intermittently along the bed of the river channel by creeping, rolling, sliding, or bouncing along the bed. Typically includes sizes of sediment ranging between coarse sand to boulders (the larger or heavier sediment).
bed-material	Sediment that is preserved along the channel bottom and in adjacent bars; it may originally have been material in the suspended load or in the bed load.

TERM	DEFINITION
bedrock	A general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material (Neuendorf et al. 2005). The bedrock is generally resistant to fluvial erosion over a span of several decades, but may erode over longer time periods.
canopy cover (of a stream)	Vegetation projecting over a stream, including crown cover (generally more than 1 meter (3.3 feet) above the water surface) and overhang cover (less than 1 meter (3.3 feet) above the water).
Category 2	Category 2 watersheds support important aquatic resources, and are strongholds for one or more listed fish species (Appendix A). Compared to Category 1 watersheds, Category 2 watersheds have a higher level of fragmentation resulting from habitat disturbance or loss. These watersheds have a substantial number of subwatersheds where native populations have been lost or are at risk for a variety of reasons. Connectivity among subwatersheds may still exist or could be restored within the watershed so that it is possible to maintain or rehabilitate life history patterns and dispersal. Restoring and protecting ecosystem functions and connectivity within these watersheds are priorities. Adapted from UCRTT (2007).
centerline	A line drawn along the center of the active or unvegetated channel; visually placed to be at the center of all channel paths.
channel morphology	The physical dimension, shape, form, pattern, profile, and structure of a stream channel.
channel planform	Characteristics of the river channel that determine its two-dimensional pattern as viewed on the ground surface, aerial photograph, or map.
channel remnant (wet)	Same as an ***old channel*** (wet) for channels on the ***USGS*** topographic maps from the middle 1980s. Mapped as a channel remnant (wet), because this is how they appear on the topographic maps.
channel sinuosity	The ratio of length of the channel or thalweg to down-valley distance. Channel with a sinuosity value of 1.5 or more are typically referenced as meandering channels (Neuendorf et al. 2005).
channel stability	The ability of a stream, over time and under the present climatic conditions, to transport the sediment and flows produced by its watershed in such a manner that the stream maintains its dimension, pattern, and profile without either aggrading or degrading.
channelization	The straightening and deepening of a stream channel to permit the water to move faster, to reduce flooding, or to drain wetlands.
concavity	Curvature in the shape of a segment of the interior of a circle. With respect to stream power, greater concavity in the downstream direction signifies that the stream power decreases in the downstream direction with an increasing tendency for curvature as the distance from the headwater increases.

TERM	DEFINITION
constructed features	Man-made features that are constructed in the river and/or floodplain areas (e.g., levees, bridges, riprap). These features are referred to as human features in the *Map Atlas*.
core habitat	Habitat that encompasses spawning and rearing habitat (resident populations), with the addition of foraging, migrating, and overwintering habitat if the population includes migratory fish. Core habitat is defined as habitat that contains, or if restored would contain, all of the essential physical elements to provide for the security of allow for the full expression of life history forms of one or more local populations of salmonids.
Cretaceous	The final period of the Mesozoic era that covered the span of time between 135 and 65 million years ago.
degradation	Wearing down of the land surface through the processes of erosion and/or weathering
depositional areas (stream)	Local zones within a stream where the energy of flowing water is reduced and sediment settles out, accumulating on the streambed.
discharge (stream)	With reference to stream flow, the quantity of water that passes a given point in a measured unit of time, such as cubic meters per second or, often, cubic feet per second (cfs).
diversity	All the genetic and phenotypic (life history traits, behavior, and morphology) variation within a population.
ecosystem	A unit in ecology consisting of the environment with its living elements, plus the non-living factors, that exist in and affect it (Neuendorf et al. 2005).
embeddedness	The degree to which large particles (boulders, gravel) are surrounded or covered by fine sediment, usually measured in classes according to percentage covered.
fine sediment (fines)	Sediment with particle sizes of 2.0 mm (0.08 inch) or less, including medium to fine sand, silt, and clay.
floodplain	The surface or strip of relatively smooth land adjacent to a river channel constructed by the present river in its existing regimen and covered with water when the river overflows its banks. It is built on alluvium, carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current. A river has one floodplain and may have one or more terraces representing abandoned floodplains (Neuendorf et al. 2005).
flow regime	The quantity, frequency, and seasonal nature of water flow.
fluvial bull trout	Bull trout that migrate from tributary streams to larger rivers to mature (one of three bull trout life histories). Fluvial bull trout migrate to tributaries to spawn.

TERM	DEFINITION
fluviolacustrine	Pertaining to sedimentation, partly in lake water and partly in streams, and to sediment deposited in alternating and overlapping lacustrine and fluvial conditions (Neuendorf et al. 2005).
Fraser glaciation	Equivalent to the Late Wisconsin Glaciation from about 30,000 to 9,500 years B.P.
Fuel Loading	Volume of material available for burning during a fire. It is usually reported in tons per acre. The higher the fuel loading, the more heat that will be generated during a fire.
geometric mean	A measure of central tendency that is applied to multiplicative processes (e.g., population growth). It is calculated as the antilogarithm of the arithmetic mean of the logarithms of the data.
geomorphic province	A geomorphic province is comprised of similar land forms that exhibit comparable hydrologic, erosional, and tectonic processes (Montgomery and Bolton, 2003); any large area or region considered as a whole, all parts of which are characterized by similar features or by a history differing significantly from that of adjacent areas (Neuendorf et al. 2005); also referred to as a basin. An example would be the Upper Columbia Basin.
geomorphic reach	A geomorphic reach, represents an area containing the active channel and its floodplain bounded by vertical and/or lateral geologic controls, such as alluvial fans or bedrock outcrops, and frequently separated from other reaches by abrupt changes in channel slope and valley confinement. Within a geomorphic reach, similar fluvial processes govern channel planform and geometry through driving variables of flow and sediment. A geomorphic reach is comprised of a relatively consistent floodplain type and degree of valley confinement. Geomorphic reaches may vary in length from 100 meters in small, headwater streams to several miles in larger systems (Frissell et al. 1986).
geomorphology	The study of the classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes caused by the actions of flowing water.
GIS	Geographical information system. An organized collection of computer hardware, software, and geographic data designed to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.
glacial deposits (undifferentiated)	Consists predominantly of till and glaciofluvial deposits of silt, sand, gravel, cobbles and boulders. These deposits were not differentiated as ice-contact, ice-proximal or ice-distal deposits (i.e., moraine versus glacial outwash). The materials are generally consolidated in the headwater areas where they were in contact with the glacier and unconsolidated in the valley bottoms where they were deposited primarily by glaciofluvial processes.

TERM	DEFINITION
glaciofluvial	Pertaining to the melt water streams flowing from wasting glacier ice and especially to the deposits produced by such streams; relating to the combined actions of glaciers and streams (Neuendorf et al. 2005).
glaciolacustrine	Pertaining to, derived from, or deposited in glacial lakes, especially a set of deposits and land forms composed of suspended material brought by melt water streams flowing into lakes bordering the glacier (Neuendorf et al. 2005)
habitat action	Proposed restoration or protection strategy to improve the potential for sustainable habitat upon which endangered species act (ESA) listed salmonids depend on. Examples of habitat actions include the removal or alteration of project features to restore floodplain connectivity to the channel, reconnection of historic side channels, placement of large woody debris, reforestation of the low surface, or implementation of management techniques.
habitat connectivity (stream)	Suitable stream conditions that allow fish and other aquatic organisms to access habitat areas needed to fulfill all life stages.
habitat unit	A habitat unit is defined as a morphologically distinct area within a geomorphic reach comprising floodplain and channel areas; typically less than several channel widths in length (Montgomery and Bolton 2003). Individual habitat units may include pools, riffles, bars, steps, cascades, rapids, floodplain features, and transitional zones characterized by relatively homogeneous substrate, water depth, and cross-sectional averaged velocities.
headwaters	The source of a river. Headwaters are typically the upland areas where there are small swales, creeks, and streams that are the origin of most rivers. These small streams join together to form larger streams and rivers or run directly into larger streams and lakes.
Holocene	The geologic time interval between about 10,000 years ago and the present.
hydrologic response	The response of a watershed to precipitation; usually refers to stream flow resulting from precipitation.
hyporheic zone	In streams, the region adjacent to and below the active channel where water movement is primarily in the downstream direction and the interstitial water is exchanged with the water in the main channel. The boundary of this zone is where 10 percent of the water has recently been in the stream (Neuendorf et al. 2005).
ICBTRT	Interior Columbia Basin Technical Recovery Team. Expert panel formed by NOAA Fisheries Service (NMFS) to work with local interests and experts and ensure that ICBTRT recommendations for delisting criteria are based on the most current and accurate technical information available.
igneous rocks	Rocks that form from the cooling and solidification of molten or partly molten material (magma) either below the surface as an intrusive (plutonic) rock or on the surface as an extrusive (volcanic) rock.

TERM	DEFINITION
incipient motion	The initiation of mobilizing a single sediment particle on the stream bed once threshold conditions are met.
incision	The process where by a downward-eroding stream deepens its channel or produces a relatively narrow, steep-walled valley (Neuendorf et al. 2005).
intermediate surface	Comprised of alluvial deposits that form a series of terrace risers and terrace treads that are elevated between 2.5 to 3.5 meters above normal water surface in the active channel. These surfaces are intermittent throughout the major drainages, but were only locally mapped where they have an influence on the rivers' morphology. This surface is rarely flooded by the river during the current climatic regime. The intermediate surface is considered stable on a decadal time scale. These materials are unconsolidated and susceptible to fluvial erosion.
landslide	Consists of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders. Occur predominantly along glacial terrace deposits and valley walls. Mass wasting along the active river channels typically result in a "self-armoring" bank in that the finer materials are transported by the fluvial system and the larger materials are retained along the toe of the slope protecting the slope except during flood events.
large woody debris (LWD)	Large downed trees that are transported by the river during high flows and are often deposited on gravel bars or at the heads of side channels as flow velocity decreases. The trees can be downed through river erosion, wind, fire, or human-induced activities. Generally refers to the woody material in the river channel and floodplain whose smallest diameter is at least 12 inches and has a length greater than 35 feet in eastern Cascade streams.
levee	A natural or artificial embankment that is built along a river channel margin; often a man-made structure constructed to protect an area from flooding or confine water to a channel. Also referred to as a dike.
limiting factor	Alternate definition: Any factor in the environment of an organism, such as radiation, excessive heat, floods, drought, disease, or lack of micronutrients, that tends to reduce the population of that organism (Owen & Chiras 1995).
low surface	Generally represents an area encompassing historic channel migration and floodplain. Consists of a mixture of reworked glacial deposits and fluviolacustrine deposits comprised of silt- to boulder-size material, but is predominantly sand, gravel, and cobbles. These deposits occur along stream channels and their active floodplains. These materials are unconsolidated and highly susceptible to fluvial erosion.
low-flow channel	A channel that carries stream flow during base flow conditions.
mass wasting	General term for the dislodgement and downslope transport of soil and rock under the influence of gravitational stress (mass movement). Often referred to as shallow-rapid landslide, deep-seated failure, or debris flow.
Mesozoic	An era of geologic time from about 225 to about 65 million years ago that includes the Triassic, Jurassic and Cretaceous periods.

TERM	DEFINITION
metamorphic rocks	Rocks derived from pre-existing rocks (sedimentary or igneous) in response to marked changes in temperature, pressure, shearing stress and chemical environment.
moraine	A mound or ridge of unstratified glacial drift deposited by direct action of glacial ice.
nonnative species	Species not indigenous to an area, such as brook trout in the western United States. Sometimes referred to as an exotic species.
Oligocene	An epoch of the Tertiary period than began about 34 million years ago and extended to about 23 million years ago.
orthorectified photograph	An aerial photograph that has been corrected for the geometries and tilt angles of the camera when the image was taken and for topographic relief using a digital elevation model, flight information, and surveyed control points on the ground.
overbank deposits	Fine sediment (medium to fine sand, silt, and clay) that is deposited outside of the channel on the floodplain or terrace by floods.
overflow channel	A channel that is expressed by no or little vegetation through a vegetated area. There is no evidence for water at low stream discharges. The channel appears to have carried water recently during a flood event. The upstream and/or downstream ends of the overflow channel usually connect to the main channel.
peak flow	Greatest stream discharge recorded over a specified period of time, usually a year, but often a season.
planform	The shape of a feature, such as a channel alignment, as seen in two dimensions, horizontally, as on an aerial photograph or map.
Pleistocene	The geologic time interval between 1.6 million years ago and 10,000 years ago.
project area	A project area is a distinct geographic location with potential implementation opportunities for habitat restoration and protection actions. Project areas are at a comparable level of organization as a habitat unit within a geomorphic reach and typically bounded by geomorphic features (e.g., river channel, floodplain, or terrace).
project feature	A project feature is an individual structure or component of an active floodplain of a project area; examples include levees, roadway embankments, bridges, or culverts.
Quaternary	The geologic time interval between 1.6 million years ago and the present. It includes both the Pleistocene and the Holocene.
redd	A nest constructed by salmonid species in the streambed where eggs are deposited and fertilized. Redds can usually be distinguished in the streambed by a cleared depression and associated mound of gravel directly downstream.

TERM	DEFINITION
riparian area	An area with distinctive soils and vegetation community/composition adjacent to a stream, wetland, or other body of water.
riprap	Large angular rocks that are placed along a river bank to prevent or slow erosion.
salmonid	Fish of the family *salmonidae*, including trout, salmon, chars, grayling, and whitefish. In general usage, the term most often refers to salmon, trout, and chars.
scour	Concentrated erosive action by flowing water, as on the outside curve of a bend in a stream; also, a place in a streambed swept clear by a swift current.
side channel	A channel that is not part of the main channel, but appears to have water during low-flow conditions and has evidence for recent higher flow (e.g., may include unvegetated areas (bars) adjacent to the channel). At least the upstream end of the channel connects to, or nearly connects to, the main channel. The downstream end may connect to the main channel or to an overflow channel. Can also be referred to as a secondary channel.
slough	A sluggish channel of water, such as a side channel of a river, in which water flows slowly through, swampy ground, such as along the Columbia River, or a section of an abandoned river channel, containing stagnant water and occurring in a floodplain (Neuendorf et al. 2005).
smolt	A juvenile salmon or steelhead migrating to the ocean and undergoing physiological and behavioral changes to adapt its body from a freshwater environment to a saltwater environment.
spawning and rearing habitat	Stream reaches and the associated watershed areas that provide all habitat components necessary for adult spawning and juvenile rearing for a local salmonid population. Spawning and rearing habitat generally supports multiple year classes of juveniles of resident and migratory fish, and may also support subadults and adults from local populations.
subbasin	A subbasin represents the drainage area upslope of any point along a channel network (Montgomery & Bolton 2003). Downstream boundaries of subbasins are typically defined in this assessment at the location of a confluence between a tributary and mainstem channel. An example would be the Twisp River Subbasin.

TERM	DEFINITION
successional stages	Progressive change in a biologic community as a result of the response of the member species to the environment over time. Distinct stages of succession from early to late are the Forbs stage (0 to 5 years, consisting of shrubs, tree seedlings, mosses, lichens, and herbaceous plants; mostly insects, small rodents, and birds); the Shrub stage (6 to 25 years, consisting of established tree seedlings and larger shrubs that shade out many of the herbaceous plants; mostly birds, rodents, small mammels, deer, and large predators); the Young Forest stage (deciduous forest canopy forms, shading out shrubs and herbaceous plants; beaver but otherwise a reduction in wildlife species); the Mature Forest stage (51 to 150 years; large evergreens, deciduous trees leave openings in canopy in fall, shrubs grow again; small birds and mammels), and the Climax Forest stage (150 to 300 years, consisting of large evergreens, fewer trees per acre; snag-dwelling species).
suspended load	The part of the total stream load that is carried for a considerable period of time in suspension, free from contact with the streambed, it consists mainly of silt, clay, and fine sand (Neuendorf et al. 2005).
suspended sediment	Solids, either organic or inorganic, found in the water column of a stream or lake. Sources of suspended sediment may be either human induced, natural, or both.
terrace	A relatively stable, planar surface formed when the river abandons the floodplain that it had previously deposited. It often parallels the river channel, but is high enough above the channel that it rarely, if ever, is covered by water and sediment. The deposits underlying the terrace surface are alluvial, either channel or overbank deposits, or both. Because a terrace represents a former floodplain, it can be used to interpret the history of the river.
terrane	A crustal block or fragment that preserves a distinctive geologic history that is different from the surrounding areas and that is usually bounded by faults.
Tertiary	The first period of the Cenozoic era thought to have covered the span of time between about 65 million and 2 million years ago. It is divided into five epochs: the Paleocene, Eocene, Oligocene, Miocene and Pliocene.
tributary	A stream feeding, joining, or flowing into a larger stream or lake (Neuendorf et al. 2005).
valley segment	A valley segment is a section of river within a subbasin. Within a valley segment, multiple floodplain types exist and may range between wide, highly complex floodplains with frequently accessed side channels to narrow and minimally complex floodplains with no side channels. Typical scales of a valley segment are on the order of a few to tens of miles in longitudinal length.

TERM	DEFINITION
watershed	The area of land from which rainfall (and/or snow melt) drains into a stream or other water body. Watersheds are also sometimes referred to as drainage basins. Ridges of higher ground form the boundaries between watersheds. At these boundaries, rain falling on one side flows toward the low point of one watershed, while rain falling on the other side of the boundary flows toward the low point of a different watershed.

Appendix A: Basin Setting

Top: Confined Reach of the Middle Fork John Day River
Bottom: Forrest Conservation Area, Upper John Day River.

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1.0 Basin Setting

1.1 Physiographic Setting

1.1.1 Upper John Day Subbasin

The Upper John Day River subbasin, located in eastern Oregon upstream of Picture Gorge, drains about 1,070 square miles. Most of the headwater areas are on public lands managed by the Malheur and Ochoco National Forests in the Blue, Aldrich, Ochoco Mountains, and the Strawberry Range. The lower portion of the Upper John Day River flows over primarily private lands that have been developed for agricultural purposes. The elevation ranges from more than 9,000 feet in the Strawberry Range to approximately 2,230 feet at Picture Gorge (Young 1986).

The subbasin is mostly forest and rangeland, with private rangeland dominating below the treeline. The primary agricultural activity is ranching, but there is a small percentage of cropland used to grow grass, hay, and alfalfa (Young 1986).

1.1.2 Middle Fork John Day Subbasin

The Middle Fork John Day subbasin is located entirely in Grant County, Oregon, and drains about 806 square miles. Most of the headwaters are on public lands in the Malheur and Umatilla National Forests in the Greenhorn and Elkhorn Ranges of the Blue Mountains. The Middle Fork flows about 75 miles from its headwaters before entering the North Fork at river mile (RM) 32.2 (Young 1986).

The subbasin has a highly variable terrain ranging from steep mountains to gentle meadows (Young 1986; USFS 1998). The elevation ranges from over 8,100 feet in the headwaters to about 2,200 feet at its mouth (Young 1986).

Rangeland and forestland are the predominant land cover in the subbasin (Young 1986). Fire plays an important role in maintaining the overall condition of the forestlands with a wide range of effects that promote diverse vegetation age classes (Agee 1990, cited in USFS 1998). Livestock grazing and past timber harvests have significantly reduced the riparian coverage along the Upper John Day River and its tributaries. Placer mining between Susanville and Bates modified the stream channel and the riparian corridor (USFS 1998).

1.2 Regional Hydrology

The John Day River is a tributary to the Columbia River, merging with it approximately 215 river miles upstream from the mouth of the Columbia. The John Day River contains a complex network of major tributaries, including the North Fork, Middle Fork, and South Fork (Figure 1). This section of the report provides a summary of key hydrologic features of each of the assessment subbasins. More detailed hydrology studies are provided in Appendix C.

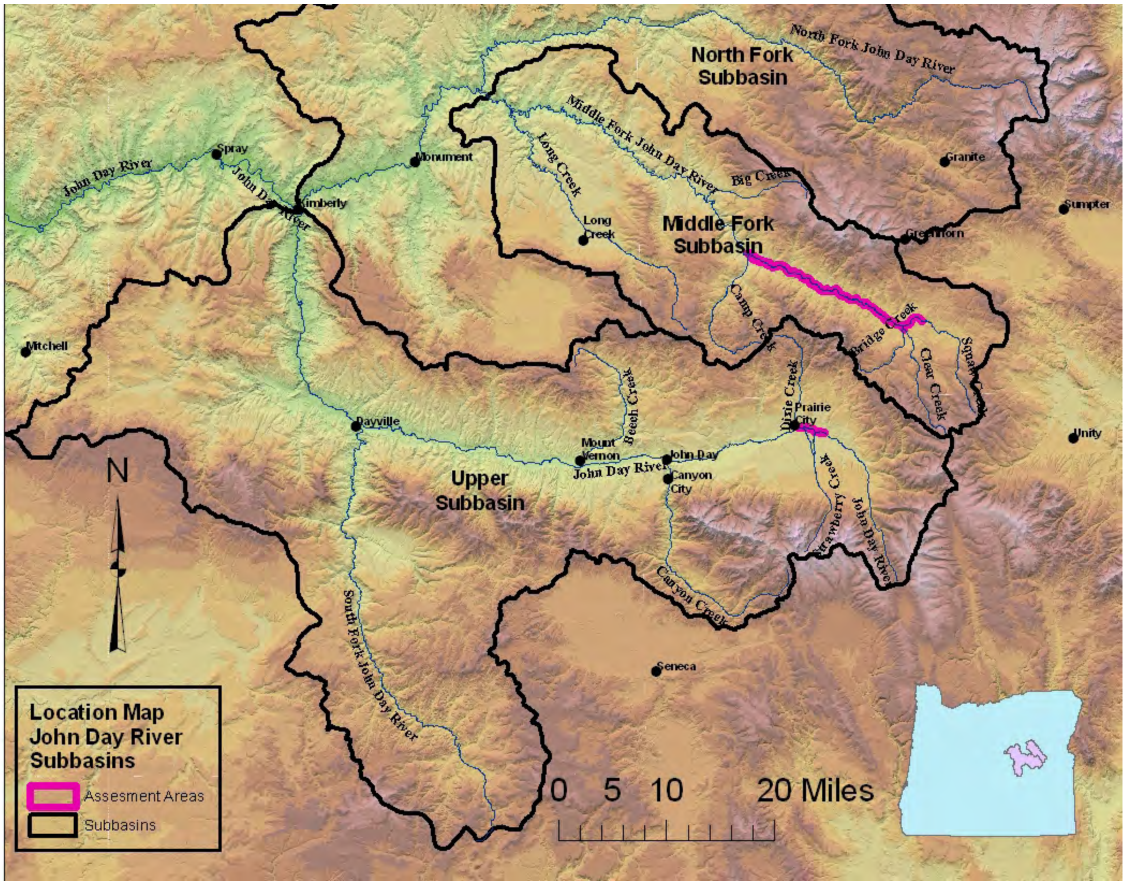

Figure 1 – Map of the Upper John Day Subbasin and the Middle Fork John Day Subbasin. The assessment areas are highlighted in pink.

1.2.1 Upper John Day Subbasin

The Upper John Day subbasin is delineated as the drainage area upstream of the confluence with the North Fork (Figure 1). Major tributaries in the subbasin include the South Fork John Day River, Beech Creek, Canyon Creek, Strawberry Creek, and Dixie Creek. The assessment area in the Upper John Day Subbasin is located within two 5th field hydrologic (HUC5) watersheds, the Upper John Day and Strawberry Creek. HUC5s represent drainage areas delineated to nest within a larger drainage system, and typically range in size from 40,000 to 250,000 acres.

The climate is classified as semi-arid, influenced by moderate prevailing westerly flows of maritime air (FEMA 1988). Average annual precipitation in the river valley typically ranges from 10 to 12 inches with as much as 40 inches in the headwater areas where the precipitation falls mostly as snow. The average annual temperature is 49 degrees Fahrenheit with about 100 frost-free days at an elevation of 3,400 feet (Young 1986).

Peak flows typically occur from March through early June following snowmelt from the higher elevations of the watershed (Figure 2). Rain-on-snow events occurring during the winter months have contributed to the largest flow events in the subbasin. Low flows generally occur from August through September.

Severe flooding in the Upper John Day River is usually the result of rainstorms combined with snowmelt. The largest recorded flood in the basin occurred on December 22, 1964, with a peak discharge of 2,400 cubic feet per second (cfs) at Prairie City, Oregon (FEMA 1988). This discharge corresponds to a flood event with a recurrence interval around 75 years. Other significant storm events in the subbasin include the storms of March 25, 1952 and January 30, 1965, with respective recurrence intervals of 45 and 30 years (FEMA 1988).

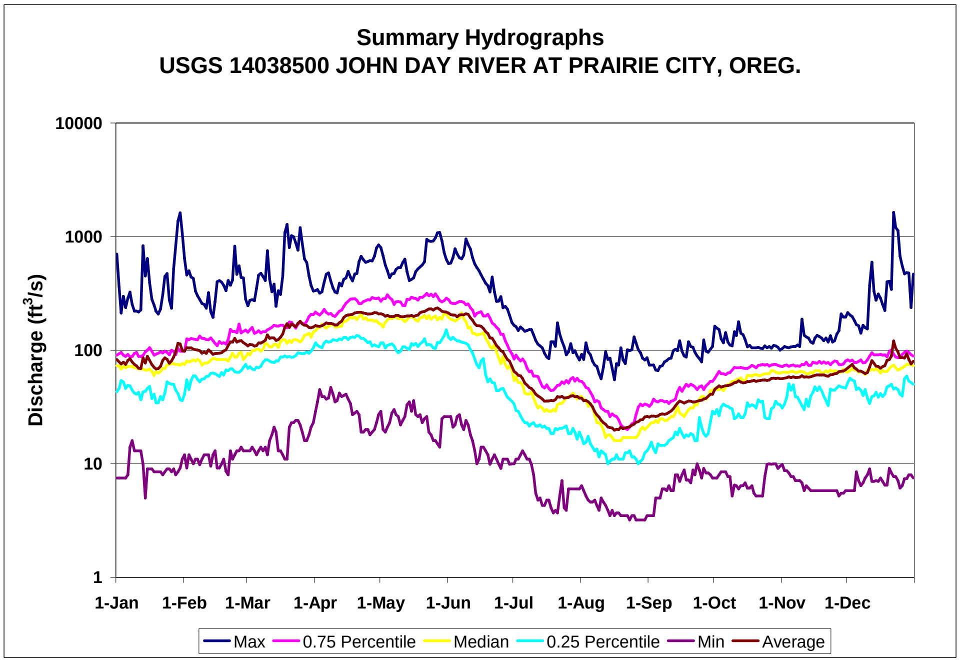

Figure 2 – Summary Hydrograph from USGS Gauge at Prairie City, Oregon (located less than 1 mile downstream from the assessment area).

1.2.2 Middle Fork Subbasin

The Middle Fork subbasin encompasses the drainage area contributing to the Middle Fork John Day River upstream of its confluence with the North Fork (Figure 1). Major tributaries to the Middle Fork include Long Creek, Big Creek, Vinegar Creek, Bridge Creek, Camp Creek, Clear Creek, and Squaw Creek. The assessment area of the Middle Fork also falls within two HUC5 watersheds, Camp Creek and the Upper Middle Fork John Day River.

The climate is generally semi-arid with a combination of maritime and continental influences. Average annual precipitation is about 10 inches at the mouth to approximately 40 inches in the headwater areas. Precipitation falls mostly as snow from October to March with occasional rain-on-snow events occurring in late winter and spring. In the summer, precipitation is typically delivered by convective thunderstorms that are of high intensity and short duration. The mean temperature ranges from 20 to 30 degrees Fahrenheit during the winter months to about 40 to 60 degrees Fahrenheit during the summer months (Young 1986; USFS 1998).

The flow regime of the Middle Fork subbasin is dominated by snowmelt runoff with peak flows typically occurring from March through early June (Figure 3). Variability of peak

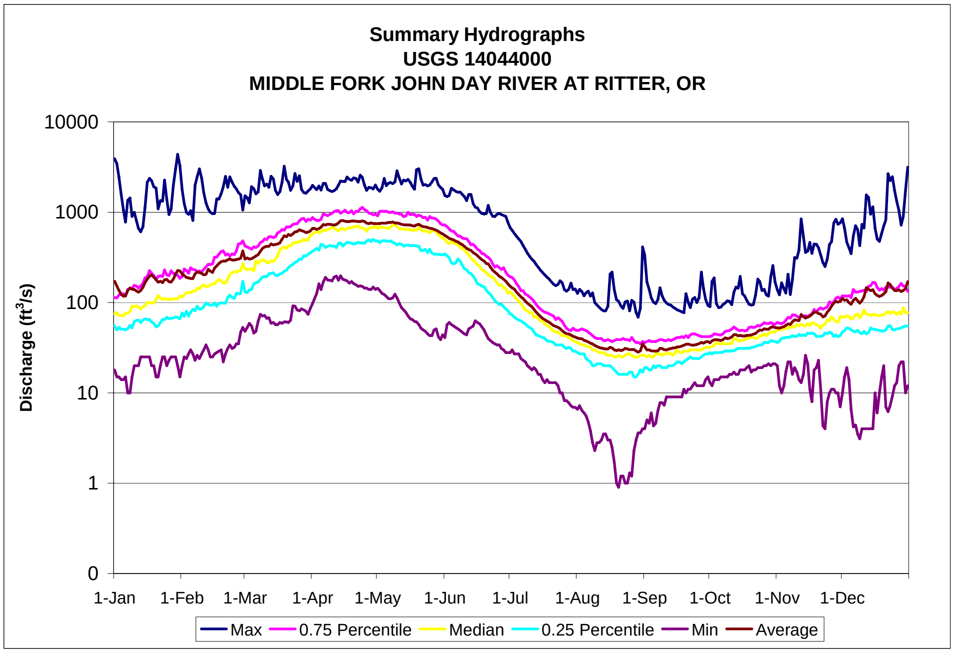

Figure 3 – Summary Hydrograph of USGS Gauge at Ritter, Oregon (Approximately 30 Miles Downstream from the Middle Fork Assessment Area).

flow from year to year is high, with the duration and magnitude depending upon the snowpack for each winter (USFS 1998). High magnitude, short duration flood surges are common during late winter and early spring due to rain-on-snow storm events. Low flow periods during the months of August through September correspond to the driest and hottest summer months. Perennial springs, groundwater effluent, and numerous wet meadows in the upper portions of the subbasin sustain base flows and deliver cool water to the surface flows (USFS 1998).

The largest recorded flood event in the basin occurred on January 30, 1965, as measured at the U.S. Geological Survey (USGS) streamflow gauge at Ritter, Oregon. Discharge at the Ritter gauge, approximately 30 miles downstream from the assessment area, measured 4,730 cfs during this event, which corresponds to a recurrence interval between a 50- and 100-year storm event. Although the December 24, 1964 flood was also a high flow event in the basin, the January 30th flood was the peak for the 1965 water year. Other major flood events in the basin occurred on March 19, 1932 and January 1, 1997, with measured streamflows at Ritter of 4,000 cfs and 4,540 cfs respectively.

1.3 Regional Characteristics of Water Quality

1.3.1 Upper John Day River

Water quality is generally satisfactory except during high-runoff events or periods of low flow. Higher turbidities have been reported during runoff events and higher water temperatures have been reported during low flow periods. Irrigated cropland is concentrated in the valley with over 80 irrigation ditches diverting water from the Upper John Day River. Irrigation return flows present a possible nutrient nonpoint source of pollution problems during summer months (Young 1986).

1.3.2 Middle Fork John Day River

Water quality is generally satisfactory except during high-runoff events or periods of low flow. The most serious water quality issue is elevated temperatures during low flow periods, which may be related to riparian habitat degradation. Turbidity is generally not serious although localized streambank erosion does occur in several areas (Young, 1986). The numerous perennial springs in the headwater areas supply cool water to the river and are important to maintaining the river's baseflow (USFS 1998).

1.4 Regional Geology

1.4.1 Introduction

The assessment areas are located within the Blue Mountains physiographic province. This province covers northeastern Oregon and parts of Washington and Idaho. It is bordered to the north by the Deschutes-Umatilla Plateau, to the east by the Joseph Upland and Columbia Intermontane, and to the south by the High Lava Plains and Owyhee Upland (Figure 4). The province is defined by a 360 kilometers by 80 kilometers area that was uplifted during the Cenozoic era.

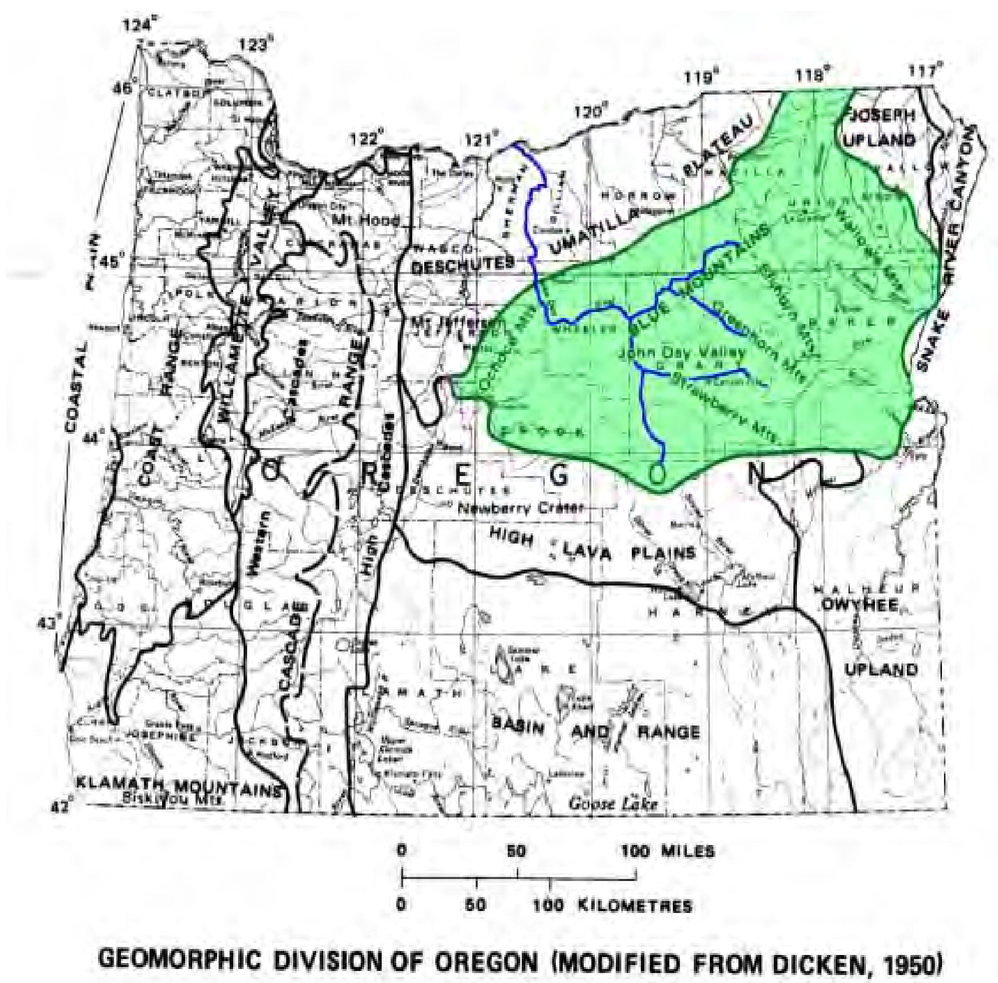

Figure 4 - Location Map of Physiographic Provinces in Oregon (modified from Walker 1977). The Blue Mountains physiographic province is shaded in green and the John Day River is shaded in blue.

1.4.2 Geologic Setting

During the Miocene epoch, between about 24 and 5 million years ago, the Blue Mountains province experienced extensional tectonic forces related to the oblique convergence of the Pacific and North American plates. This extensional deformation initiated the uplift of the Blue Mountains province and created fold and fault (i.e., John Day fault) structures across the region (Walker 1990a). In the Pliocene epoch, between about 5 and 1.8 million years ago, the Strawberry Mountain chain, comprised predominantly of the Strawberry Volcanics (Figure 5), rose 1.5 miles above the valley floor along the John Day and other faults forming the southern John Day valley margin along the Upper John Day River (Thayer 1990). Erosion ensued as these mountains uplifted and enormous amounts of sediment were transported downslope fanning out over the Upper John Day valley floor (fanglomerate deposit of the Rattlesnake Formation). As these alluvial fans built-up along the southern valley margin, the Upper John Day River was forced toward the opposing valley margin.

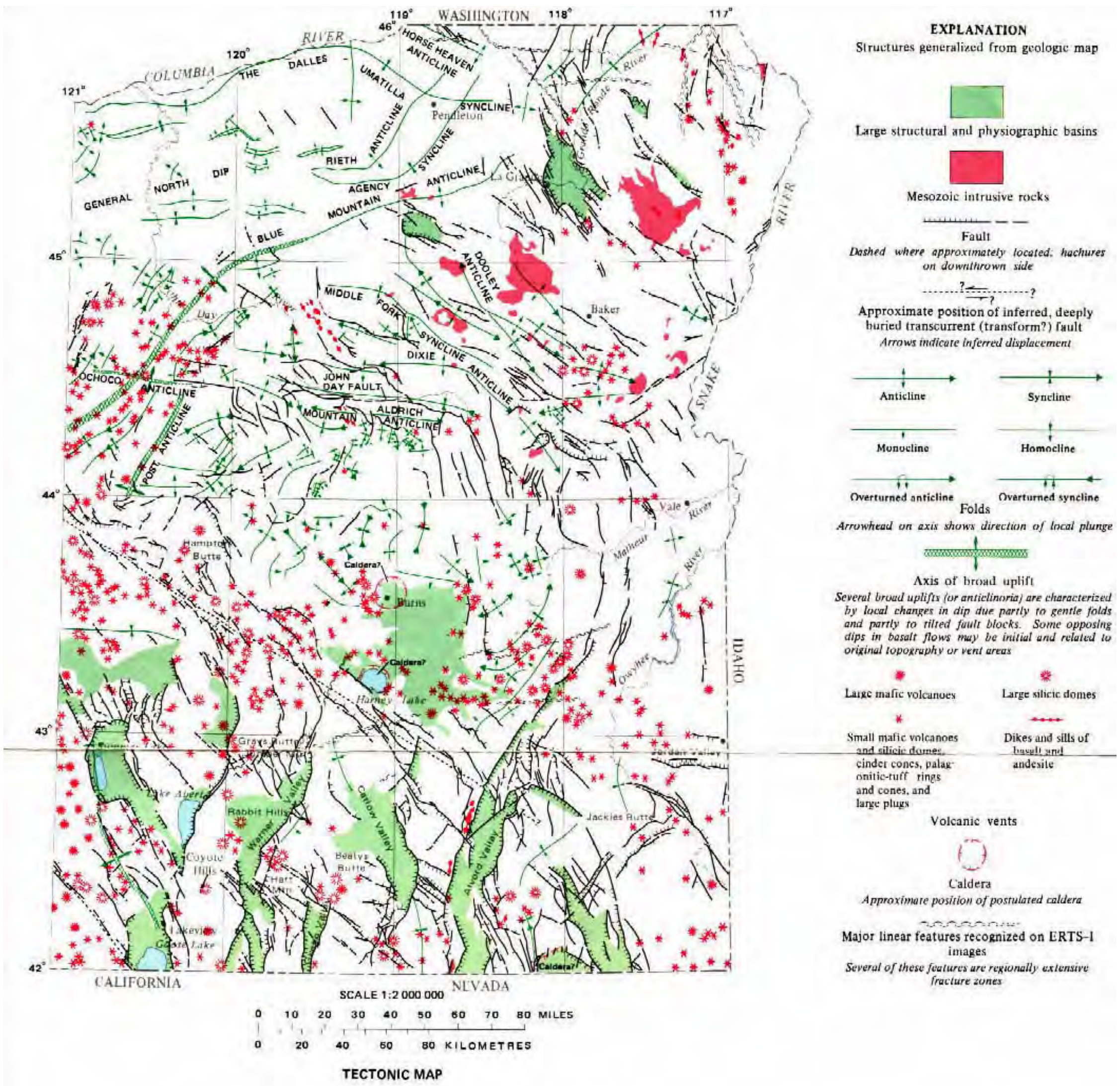

Figure 5 - Tectonic Map Showing the Locations of Mesozoic Intrusive Rocks, Structural Basins, Volcanic Vents, and Major Fold and Fault Structures (Walker 1977).

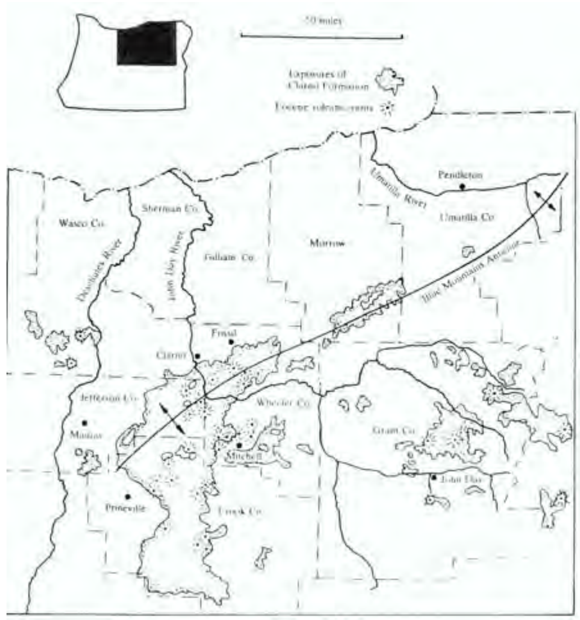

Figure 6 – Location Map of the Axis of the Blue Mountains Anticline and Distribution of the Clarno Formation (after Walker and Robinson 1990a; Orr et al. 1992).

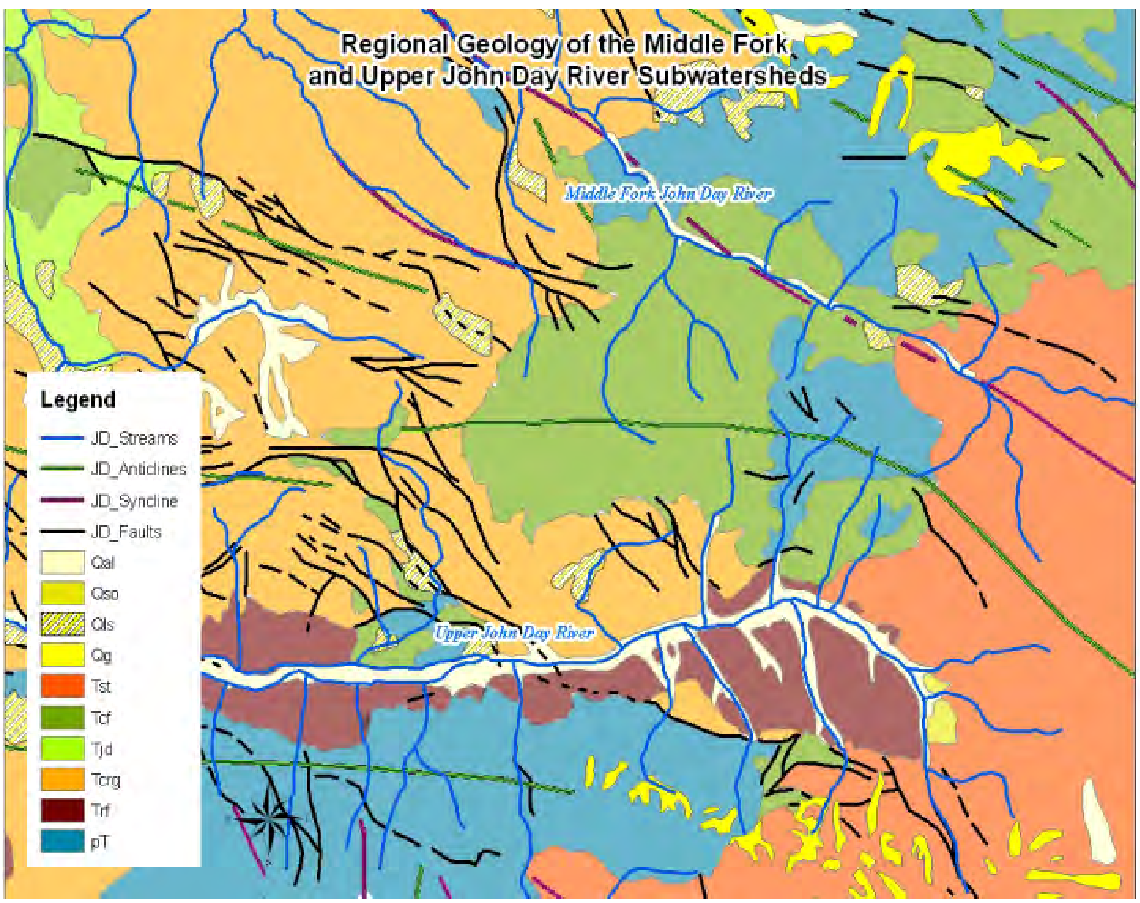

Figure 7 - Geologic Map of the Middle Fork and Upper John Day River Drainage Basins. The symbols used in the legend are as follows: Qal – Quaternary alluvium , Qso – Quaternary older sediments, Qls – Quaternary landslide, Qg – Quaternary glacial, Tst – Tertiary Strawberry Volcanics, Tcf – Tertiary Clarno Formation, Tjd – Tertiary John Day Formation, Tcrg – Tertiary Columbia River Basalt Group, Trf – Tertiary Rattlesnake Formation, and pT – pre-Tertiary rocks (modified from Walker, 1977).

During the Pleistocene epoch, between about 2 million years ago and 10,000 years before the present, alpine glaciers advanced and retreated several times in the upper valleys above elevation 5,000 feet across the region (Thayer 1990). The climate was cooler and wetter during this period, and extensive lakes developed in the southern parts of Oregon. With the increased availability of water (precipitation and ice), the Upper John Day River and its primary tributaries probably had more flow and stream power. For instance, in the Upper John Day River valley, the river was capable of eroding the fanglomerate that filled the John Day valley.

In the Holocene epoch (10,000 years ago to the present), the climate became warmer and drier across the region, and most of the extensive lakes evaporated and only a few alpine glaciers remained in the Strawberry Mountains. With the decrease in the availability of water, the John Day River and its primary tributaries had less flow and stream power. For example, the Upper John Day River has limited ability to migrate across the valley bottom through the coarser materials (boulders and cobbles) of the fanglomerate. Under the current climatic regime, the Upper John Day River now migrates within a narrow floodplain within the broader Pleistocene-age eroded surface. In the Upper John Day valley, finer sediments (sand and fines) are being eroded from the surface of the fanglomerate and are being deposited along the margins of the Pleistocene surface by sheetwash and rill erosion forming a concave-like topography along the length of the Pleistocene surface.

1.5 Focal Fish Species

1.5.1 Introduction

The John Day River is one of the most important subbasins within the Columbia River Basin due to its support of the last two remaining intact wild anadromous fish populations (NPCC 2005). Furthermore, the John Day River likely supported the largest naturally spawning, native steelhead population in the region (Carmichael 2006). The Upper and Middle Fork John Day Rivers lie within the Middle Columbia River Steelhead Evolutionarily Significant Unit (ESU). The Draft Middle Columbia Steelhead Recovery Progress Report (Carmichael 2006) and the John Day Subbasin Plan (NPCC 2005) propose the vision for the John Day Subbasin:

> *"A healthy and productive landscape where diverse stakeholders from within and outside the subbasin work together to maintain and improve fish and wildlife habitat in a manner that supports the stewardship efforts of local land managers, makes efficient use of resources and respects property rights. The result will be sustainable, resource-based activities that contribute to the social, cultural and economic well-being of the subbasin and the Pacific Northwest" (NPCC 2005).*

The *Upper Columbia River Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan* is referred to throughout this document as a framework for the recovery of listed species within the John Day Basin (UCRSRB 2007). Although the document focuses on the Upper Columbia River, the methodology presented for recovery of listed species has broad application to other basins and can be tailored to meet specific basin objectives. Within the plan, four viable salmonid population (VSP) parameters are proposed to characterize recovery, including abundance, productivity, spatial structure, and diversity.

These parameters provide a consistent measure for the long-term persistence of viable populations of listed species and are used in the biological ranking of proposed restoration projects presented in Appendices D and E.

The goal of this section is to familiarize the reader with the focal species of the analysis and provide background information to enhance understanding of the species' spatial distributions and uses of the basin.

1.5.2 Fish Species Considered: Summer Steelhead and Spring Chinook Salmon

Within the Interior Columbia River Basin, 12 salmon and steelhead populations were listed as threatened or endangered under the Endanger Species Act (ESA) in the1990s (USGAO 2002). These 12 include various populations of Chinook salmon (*Oncorhynchus tshawytscha)*, Sockeye salmon (*Oncorhynchus nerka)*, and summer steelhead (*Oncorhynchus mykiss)*. The John Day River has been designated by NOAA Fisheries as an Evolutionary Significant Unit (ESU) for one of these listed populations, the Mid-Columbia River steelhead. In addition, the 2002 Biological Opinion of the NOAA Fisheries Services assigned a priority status to the Upper John Day watershed because of its potential for habitat and migratory improvements.

The other primary species targeted by the proposed recovery actions of this report are spring Chinook salmon (*Oncorhynchus tshawytscha*). Although spring Chinook are not a listed species in the John Day River Basin, the species are recognized as rare or significant to the local area (NPCC 2005). Both the spring Chinook and summer steelhead populations of the John Day River basin have regional significance because neither is supplemented with hatchery fish (NPCC 2005).

Additional fish species that are listed or have ecological significance to the basin include the westslope cutthroat trout (*Oncorhynchus clarki lewisi)*, interior redband trout (*Oncorhynchus mykiss gairdneri*), and bull trout (*Salvelinus confluentus*). Although these species are not directly considered in the analysis, proposed recovery efforts are expected to, at a minimum, maintain or improve aquatic habitat for all ecologically significant species.

1.5.3 Recent Trends in Abundance

Since 1958, Oregon Department of Fish and Wildlife (ODFW) has collected data indicating trends in populations of summer steelhead and spring Chinook in the John Day basin. Despite periodic increases in total abundance of summer steelhead, a declining trend in total population was measured (Figure 8). Between 1997 and 2001, NOAA Fisheries Service has measured a decreasing trend of -6.7 percent in the population of summer steelhead in the Middle Fork and -2.0 percent in the Upper John Day River (NOAA 2003a).

Within both the Upper John Day and Middle Fork John Day Rivers, spawning populations of spring Chinook have increased since measurements began in 1959 (Figure 9 and Figure 10). Factors contributing to the increased escapement populations may include improvements to fish passage and diversion screening, management practices, riparian vegetation, and irrigation efficiency (NPCC 2005). Research conducted by Ruzycki et al. (2007) suggests that smolt production has remained relatively constant despite dramatic increases in redd densities. The research attributes limits in smolt production levels to summer rearing temperatures, and identifies the importance of lateral tributary inputs to the maintenance of adequate temperatures.

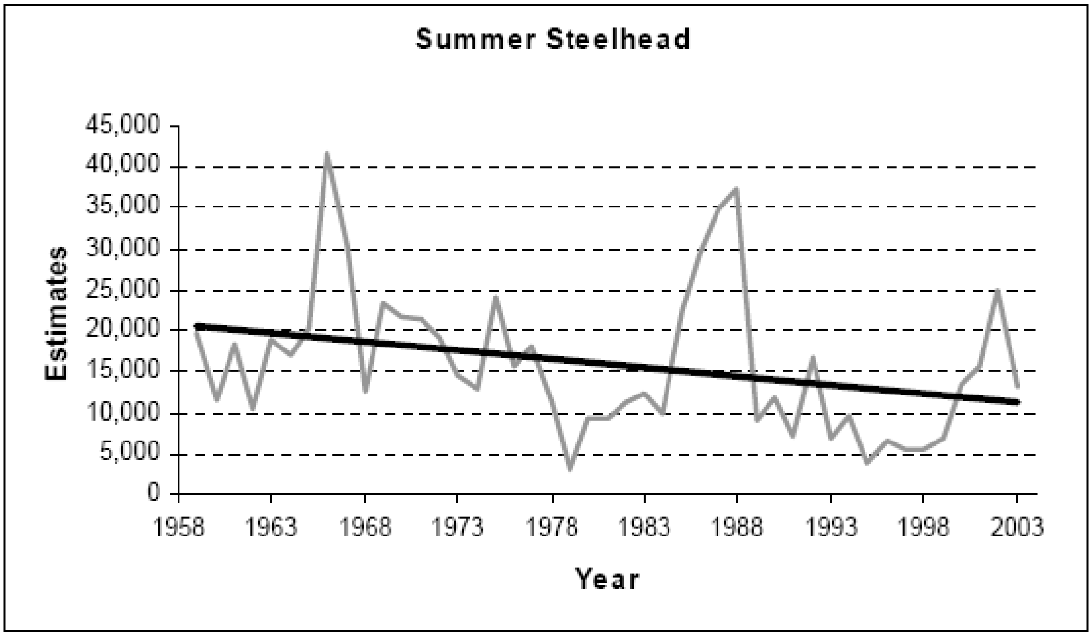

Figure 8 – Total Adult John Day Summer Steelhead, as Estimated by ODFW (NPCC 2005).

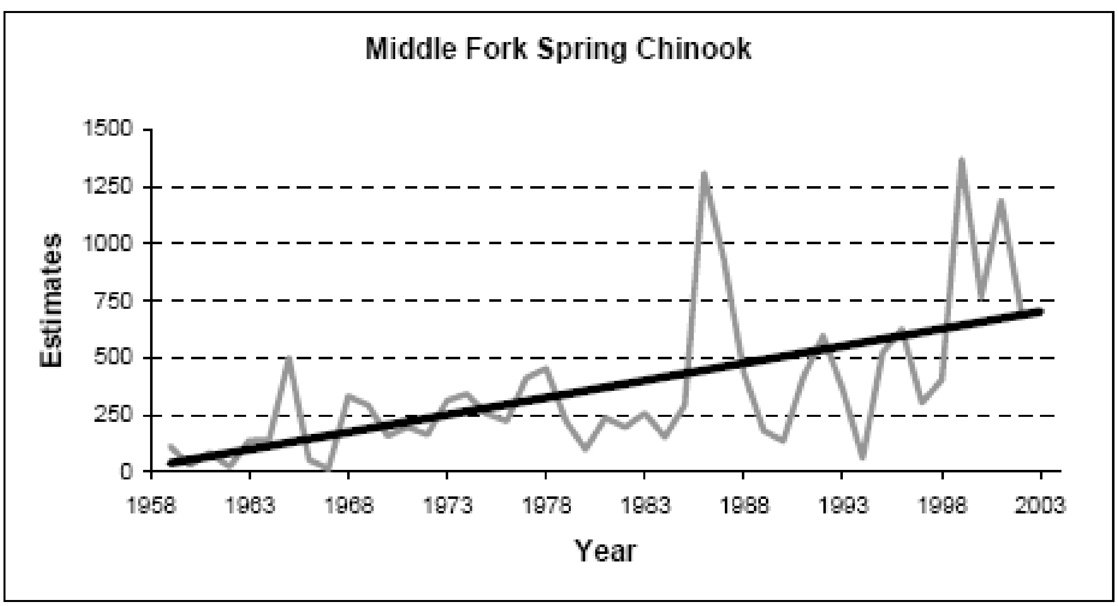

Figure 9 – Total Spring Chinook Escapement in the Middle Fork John Day River Basin, as Estimated by ODFW (NPCC 2005).

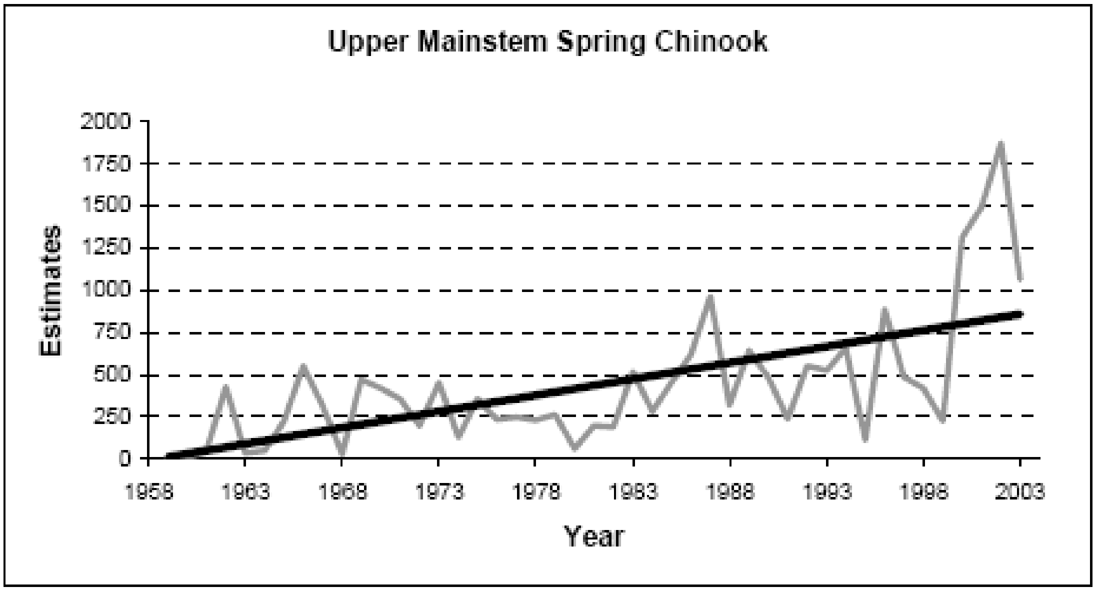

Figure 10 – Total Spring Chinook Escapement in the Upper John Day Basin, as Estimated by ODFW (NPCC 2005).

1.5.4 Spatial Distribution and Use

Summer steelhead and spring Chinook salmon use the John Day River basin for spawning, rearing, and migration (Figure 11 and Figure 12). In the John Day Basin, steelhead use is widespread. However, steelhead are not found above Izee Falls, where fish passage is impossible, or in the lower reaches of the mainstem, where high temperatures and low flows limit usage (NPCC 2005). Within the basin, 38 streams provide habitat for spring Chinook (NPCC 2005). Chinook spawning has been documented in the Upper John Day River above Prairie City, in the Middle Fork above Armstrong Creek, and in the North Fork above Camas Creek (Jonasson et al. 1998). Juvenile rearing most commonly occurs in the downstream reaches of cooler water tributaries of the mainstem of the John Day River, although rearing habitats are also available on Upper John Day reaches. Most frequently used adult holding habitat is characterized by pools with depths greater than 4.9 feet with sufficient escape cover, consisting of undercut banks, LWD, boulders, or vegetation (Lindsay et al. 1986).

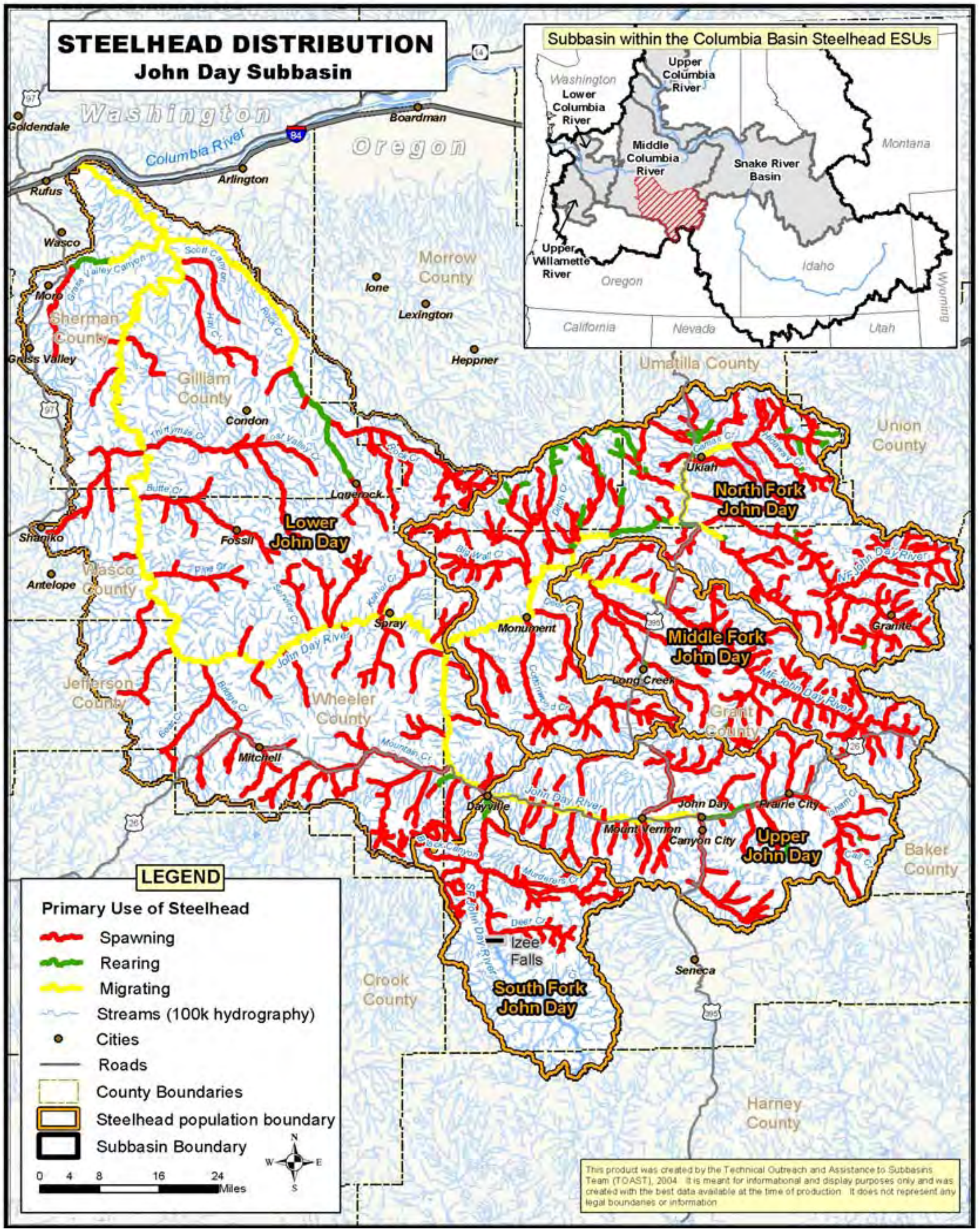

Figure 11 – Spatial Distribution of Summer Steelhead in the John Day River Basin (NPCC 2005).

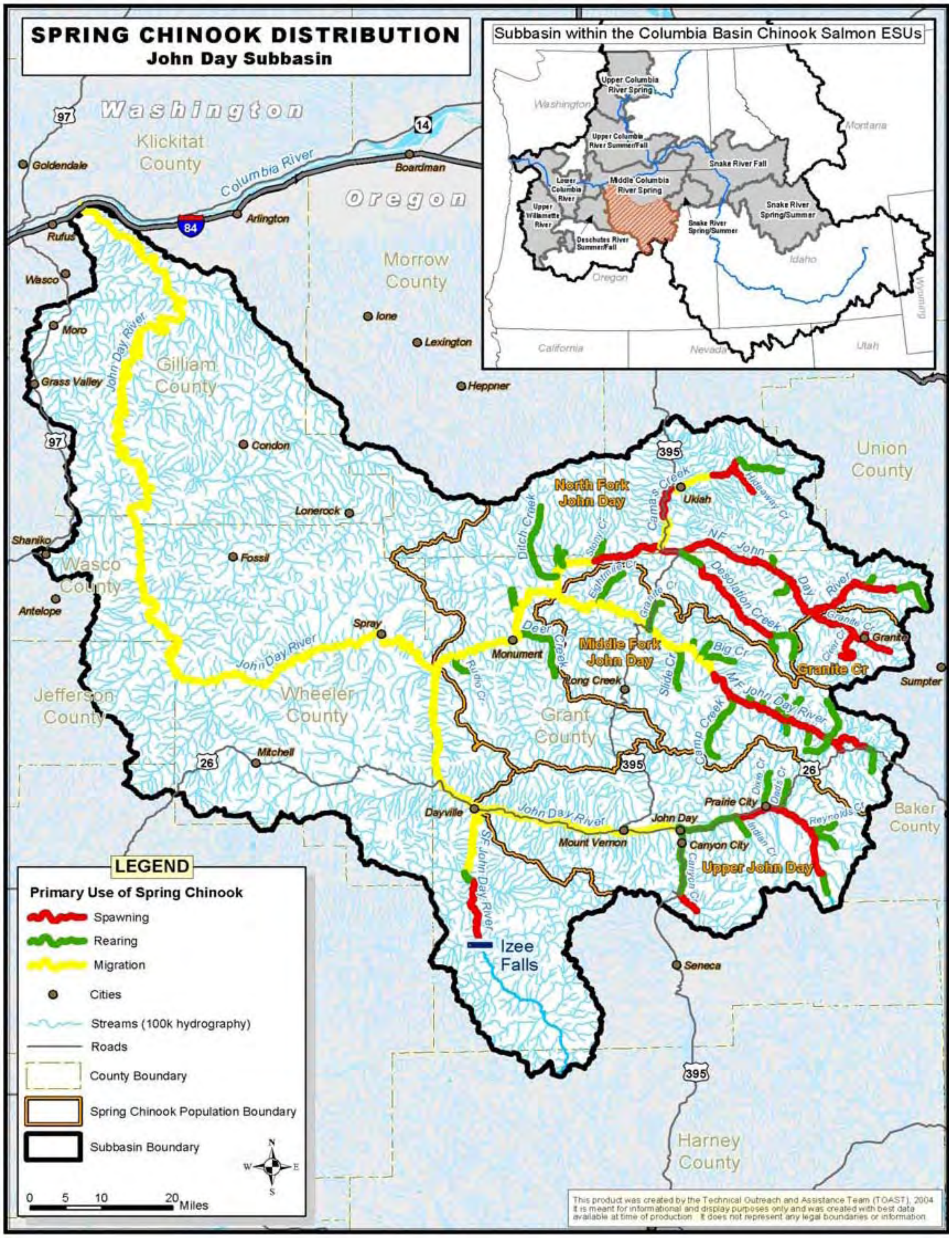

Figure 12 – Spatial Distribution of Spring Chinook Salmon in the John Day River Basin (NPCC 2005).

1.5.5 Life History of Steelhead and Chinook Salmon in John Day Basin

The John Day River populations of the summer steelhead and spring Chinook have gained considerable ecological significance because they are two of the last remaining native populations of anadromous fish species in the Columbia River (NPCC 2005). Relatively few hatchery influences are present in the basin. These anadromous populations hatch in the John Day system, spend a portion of their life maturing in ocean-water, and return to the fresh waters of the John Day River to spawn. The typical life cycle of salmon and steelhead is depicted in Figure 13. Summer steelhead require several months in freshwater to mature and spawn, and spring Chinook rear in the ocean for most of their lives before entering freshwaters to spawn (NPCC 2005). Although rare, John Day populations of summer steelhead can spawn more than once before dying; spring Chinook die within 2 weeks of spawning (ODFW 1995).

The timing of usage for various life stages of summer steelhead and spring Chinook within the John Day Basin is summarized in Figure 14. The John Day Basin provides rearing habitat for these species on a year-round basis. Summer steelhead spawn between March and June, while spring Chinook spawn between the end of July and the end of September. Although temperature and flow issues may affect all life stages of both populations, spring Chinook holding and spawning occurs during the most critical low flow periods and highest temperatures.

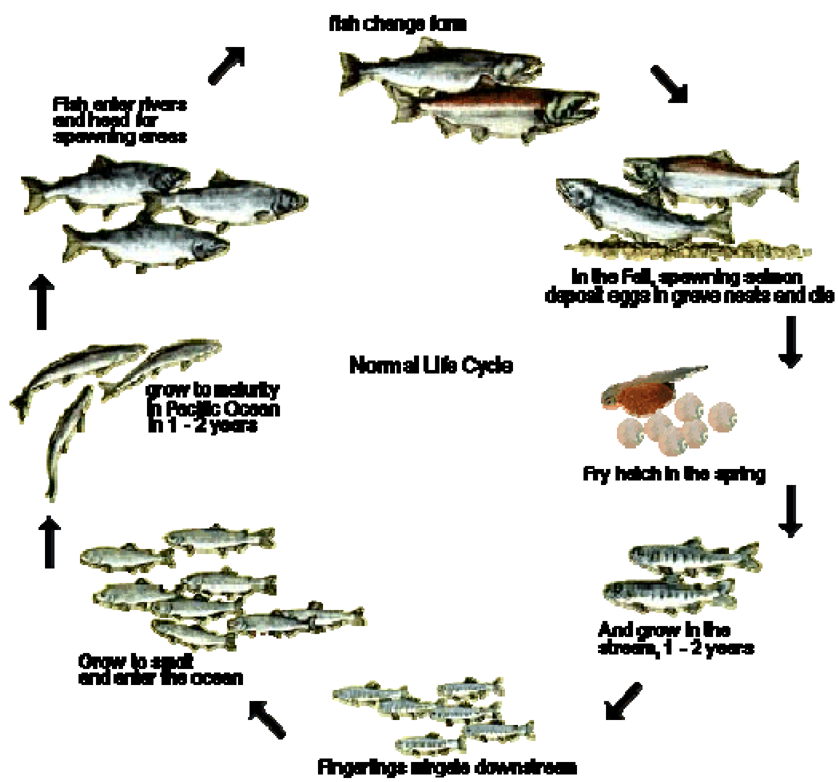

Figure 13 – Life Cycle of Salmon and Steelhead (Seymour 2008).

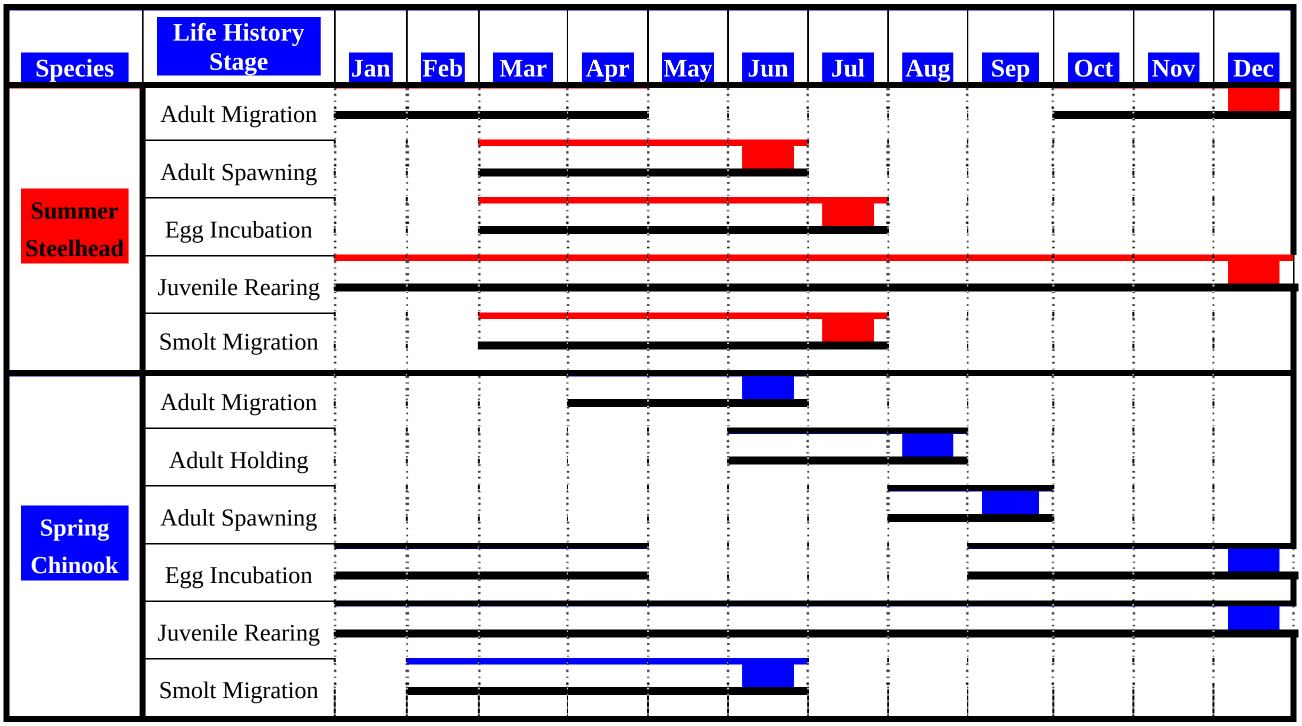

Figure 14 - Periodicity of Steelhead and Chinook Life History in the John Day River (Adapted from USDI 2000).

1.5.6 Overview of Habitat Concerns

Efforts to mitigate negative impacts to salmon and steelhead populations in the Columbia River date back to 1877, when the first fish hatchery was constructed. Despite these efforts, increasing human demands on water and land resources in the basin combined with harvesting practices in the ocean and the Columbia River have resulted in greatly reduced populations of salmon and steelhead, with some populations completely extinct. Impacts from dams, irrigation diversions, mining activities, timber harvest, cattle and sheep grazing, fire suppression, and flood management have all resulted in reduced habitat quality for steelhead and salmon.

In the John Day River, limiting factors affecting salmon and steelhead populations are related to flow, habitat diversity, fish passage barriers, modified sediment loads, water quality, temperature, and key habitat quantity (NPCC 2005). These general categories of limiting factors can be linked to anthropogenic activities and resultant habitat conditions. Examples of human influences on historic processes that created and maintained salmon and steelhead habitat are presented below:

- Natural flow patterns in the basin have been impacted by irrigation diversions during low flow periods, removal of beavers that contribute to sustained baseflows, draining of floodplain areas for maximum grazing or farming opportunity, and concentration of flows within the main channel due to disconnection of side channels.
- Habitat diversity has been influenced by the disconnection of side channels and adjacent floodplain, physical removal and harvest of potential sources of LWD,

reduced channel sinuosity for flood management, and reduced pool depth and frequency.

- Disturbances in historic rates of sediment load have resulted from increased erosion from upland areas, removal of channel stabilizing riparian vegetation, and increased velocities from levees and channelization among many other factors.
- Water quality and temperature have been modified by removal of riparian vegetation, increased width-to-depth ratios, floodplain disconnection, LWD removal, cattle grazing, and development within the floodplain.

Numerous restoration opportunities exist within the basin to improve the habitat conditions of salmon and steelhead. Habitat degradation may be at least partially mitigated by restoration of physical processes linked to the limiting factors, such as those described above. Proposed restoration actions may vary in the spatial and temporal scales of impact. For example, reforestation of the floodplain covers a large area and may take decades to completely develop, while installation of an engineered log jam affects a localized area and may only persist through one or two large storm events. The ultimate goal of restoration strategies proposed within this report is to improve the survival and recovery of anadromous fish listed under the Endangered Species Act by addressing the limiting factors preventing sustainable habitat conditions.

1.6 Historical Timeline of the John Day River Basin

The Upper John Day and the Middle Fork John Day Rivers have been impacted by development of the region for gold mining, ranching, grazing, and timber harvest. Historical accounts of the basin date back to the early 1800s. The following discussion describes the historic use of the basin and activities that may have contributed to the degradation of valuable habitat of the ESA-listed species. A notable portion of this information is derived from the Malheur National Forest Heritage Program (USFS 2006).

1.6.1 Native Americans

Prior to European settlement, higher elevation reaches of the John Day Basin were likely inhabited by Native Americans during the summer and fall. Archaeological evidence of hunting and fishing materials indicates that an extensive trade network was in operation over 500 years ago. Other than tobacco cultivation, Native Americans of the late Holocene periods did not practice agriculture. However, they were probably involved in practices that favored preferred plant species, such harvesting plants in moderation so as not to deplete their sources. Up to 500 years ago and perhaps much earlier, Native Americans burned upland meadows and travel routes to encourage the production of plant foods (USFS 2006).

Although the earliest encounters between Native Americans and Euro-Americans in this region did not occur until the early 1800s, European influences reached the Native Americans much earlier. Introduction of the horse to the region occurred in the early 1700s, more than a century before initial European settlement, bringing considerable changes in transportation and trade (USFS 2006).

1.6.2 Beaver Trapping

Historically, beavers likely played a significant role in several reaches and tributaries of the John Day River Basin. Beaver activities are an important part of the creation and maintenance of diverse aquatic and floodplain habitat due to the supply LWD to the system and to the establishment of wetlands and ponds. Beaver ponds and bordering wetlands promote healthy riparian ecosystems, locally elevate the water table, reduce sedimentation downstream of dams, improve water quality, enhance fish habitat and waterfowl nesting and brooding areas, and increase water storage (Saldi-Caromile et al. 2004).

The earliest documented accounts of European activity in the John Day Basin include the beaver trapping expeditions of Peter Skene Ogden, a Scottish trapper under the direction of the British fur trading company, Hudson Bay Company (Binns 1967). Between 1824 and 1827, Ogden led multiple trapping expeditions through the Pacific Northwest, traveling along the South Fork and Mainstem of the John Day River and his records convey moderate success in beaver trapping within the basin.

Due to the lucrative nature of fur trading, beaver and otter trapping continued throughout the John Day basin in the early 1800s, although no successes such as those achieved during Ogden's expeditions were documented (Beckham and Lentz 2000). Beaver trapping activities throughout the early 19th century likely resulted in a drastic reduction in beaver populations throughout northeastern Oregon. Today, beavers are present in several reaches of the John Day River. However, the number of beavers in the basin is greatly reduced from estimated historic numbers (USFS 1998).

1.6.3 Discovery of Gold

Discovery of gold in the John Day Basin was a leading factor responsible for initial settlement in the mid-19th century. Until the 1860s, most settlers traveled to Oregon across the Oregon Trail, but few actually remained in the John Day Country. After gold was discovered within Canyon Creek in June of 1962, nearly 5,000 miners rushed to the mouth of Canyon Creek, near present day Canyon City (Oliver 1962). After most of the first free gold along the creeks was removed, placer mining was implemented, in which water pressure was used to cut gravel and soil from a bank and into a sluice box where the heavier gold settled out (Oliver 1962).

Following the turn of the century, dredge mining was initiated and continued into the 1940s (Figure 15). Dredge mining activities drastically modified the valley floors where they operated. Within a meadow, dredging operations would essentially overturn floodplain deposits, bringing coarse alluvial substrate from the deep subsurface to the surface and freeing finer sediments for downstream transport (McDowell 2000). Some finer sediments were likely buried at depth beneath the tailings deposits during the dredging process. When dredging operations were complete, floodplain deposits were completely transformed to piles of coarse alluvium (Figure 16), and the adjacent river beds and banks were dominated by much coarser material than the river was competent to rework. Oliver (1962) portrays the dredging activities in the basin from a rancher's perspective:

"After a beautiful meadow was dredged, it was turned into a worthless, unsightly, formless pile of rocks. The good soil washed away with the water and went down the Columbia and on to the sea (p 29)."

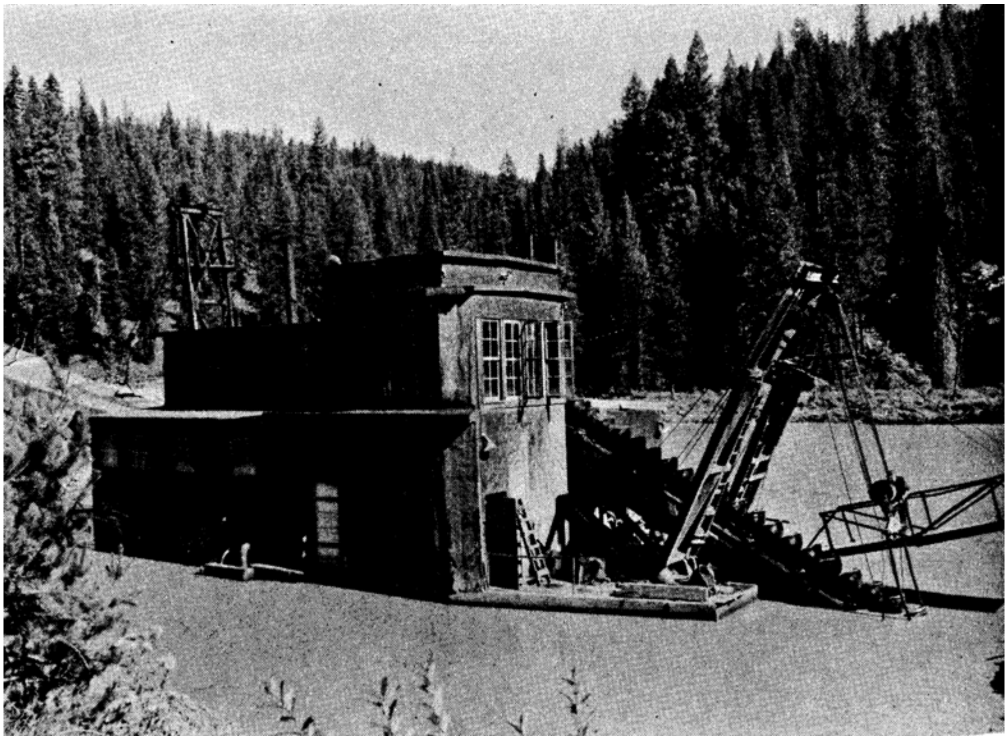

Figure 15 – Photograph of a Gold Dredge in Operation (Oliver 1962).

Figure 16 – Photograph of the Floodplain Deposits Following Dredge Mining Activities (Oliver 1962).

Stream surveys of Columbia River Tributaries conducted in 1942 and 1944 by the U.S. Fish and Wildlife Service described conditions of gold dredging downstream from Prairie City at Mount Vernon in the Upper John Day River (Nielson 1948).

> *"It [gold dredge] has torn up 10 miles of river bottom above this point, where the stream bed was transformed into numerous conical mounds of gravel tailings 8-12 feet high around which the river meandered through numerous small channels. During low water periods, as at the time of inspection, this condition would greatly impede if not entirely block the upstream passage of adult fish and also would be a hazard to downstream migrants (p 16)."*

Gold dredge mining also dramatically increased river turbidity and caused fine silts to be deposited over the stream bed (Nielson 1948). This resulted in unsuitable salmon spawning habitat downstream from the gold dredging activities. Although these impacts were typically only detectable for 2 years after gold dredging ended, gold dredging was reportedly present in the basins for 25 years. Nielson (1948) explains findings from the 1942 and 1944 surveys of the present day Oxbow Conservation Area, where dredge mining occurred between 1939 and 1942:

> *"…at the time of our first survey the stream bed was covered with silt….In 1944, following two years of no mining activity, the water was very clear and normal stream action had practically removed all silt from the stream bed (p 18)."*

During World War II, all gold mining activities were suspended. Ranchers who supplied their lands to the dredge received a royalty, but profits were generally minimal (Grant 1993). Dredge mining left lands unsuitable for farming, overturned floodplains, and temporarily damaged water quality. In addition, the physical processes that sustain adequate habitat for spawning and rearing, such as reworking of floodplain deposits, may never return to historical conditions.

1.6.4 Ranching, Grazing, and Homesteading

In conjunction with the Homestead Act of 1862 and the discovery of gold in the basin, settlers flocked to northern and eastern Oregon for the dual allure of mining and cattle raising (Beckham and Lentz 2000). Through various governmental land programs and laws passed to support the development of range industries, Congress encouraged permanent settlement of the John Day basin. Fertile bottomlands along the river and its tributaries, in addition to abundant upland areas of bluebunch wheat grass attracted ranchers to cattle, sheep, and horse raising (Beckham and Lentz 2000). After years of heavy cattle and sheep stocking and overgrazing of range lands, the open range cattle business began to decline, and the cattle industry shifted to predominantly fenced range practices.

Winter feed for cattle became a problem after harsh winters in the late 1880s. To supply a sufficient quantity of feed for the cattle in the basin, alfalfa hay and grains were grown on the irrigated bottomlands of the basin. According to Bureau of Census records, the acreage of agriculture lands in the John Day watershed steadily increased between 1870 and 1950 (Beckham and Lentz 2000). By 1950, many farmers began to reforest their properties and transformed their incomes from agriculture to timber harvest.

Ranching and grazing often required land clearing within meadows and along the river banks. This maximized the area of land that could be seeded with grass or hay for cattle grazing, which became increasingly important when the fenced cattle ranging practices were initiated. Oliver (1962) describes the importance of land clearing as a first step in homesteading along the John Day River between Prairie City and John Day, Oregon:

> *"One of the first jobs on the Clark homestead was to clear off brush and trees. Big cottonwoods grew all along the river and the meadows were covered by wild thornbushes, to be chopped out by hand."*

The influx of settlers, cattle, and sheep greatly transformed the previous land use of the basin. Between the 1860s and 1940s, the lush bottomlands and cottonwood-lined rivers were cleared, grazed, farmed, and homesteaded while upland areas became so heavily grazed that regulations and eventually permits were required to prevent depletion from overgrazing (Figure 17; Beckham and Lentz 2000).

Figure 17 - Dewitt Ranch on the Middle Fork John Day River in 1937. This ranch is currently the Oxbow Conservation Area owned by the Confederated Tribes of the Warm Springs Reservation of Oregon.

1.6.5 Timber Harvest

Once the railroad was constructed to Austin in 1905, the town became a stagecoach stop near the headwaters of the Middle Fork, and development of the region quickly accelerated. The Oregon Lumber Company initially built a sawmill in Austin next to the tracks and in 1917, the company constructed a new mill on the Middle Fork (Johns 1997). Demand for workers at this new double-sided mill resulted in the development of the town of Bates at the confluence of Clear Creek and the Middle Fork where employees of the mill and their families were housed until 1975. In the early years of logging, temporary camps were built throughout the Middle Fork basin, and provisional railroad tracks were laid to haul lumber to the mill. Logging was also conducted in the headwaters of Dixie, Dad's, and Davis Creeks (USFS 1998).

To accommodate the population growth in Bates, Clear Creek was channelized and relocated approximately 200 meters to the east of the original channel position. In order to create one of the two mill ponds, a dam was constructed across Bridge Creek.

One memory of early logging activities in the Middle Fork is recounted by a local resident (Johns 1997):

> *"In the early days there were several logging camps in the hills around Bates. The loggers lived in shacks, tents, old railroad cars, etc. Their families were out there also…At one time Hazel's parents lived at Phipps Meadows at a logging camp and walked the three miles to school at Austin…Hazel's father was a horse logger that had big work horses that he used to log with. They were always out in the woods living in one place or another. They lived in a tent and moved from camp to camp, summer and winter. It was a different life than we live today (Chapter 13)."*

As logging trucks became increasingly available for the transport of timber to the mills, many railroads were abandoned. Logging roads were typically constructed within the level terrain offered by floodplains and meadows (USFS 1998).

Adjacent to the Upper John Day River, the D.R. Johnson Lumber Company currently owns and operates a sawmill in Prairie City, known as Prairie Wood Products. The original mill, the large log mill, was built in the 1960s for the production of lumber of various sizes, but has not been operated for several years. In 1978, a stud mill was constructed for the production of standard size studs and operates today at a capacity of 300,000 board feet per day (Oregon DEQ 2007).

Although logging activities continue in the John Day watershed, most notably in national forests, the harvest is heavily monitored and controlled by the U.S. Forest Service. Significant impacts from timber harvest in the watershed include:

- Modifications to river morphology to accommodate mill construction and development of the town of Bates.
- Removal of potential sources of LWD.
- Construction of railroads and roads within the floodplain to transport logs to adjacent mills.
- Increased pollution from the milling operations (Grant 1993).
- Increased fine sediment delivery to the river resulting from increased surface runoff.

1.6.6 Transportation

Early European settlers to the region arrived by wagon and horse (Figure 18). Those that entered the region by means of the Oregon Trail encountered steep, rocky terrain and had to ford the river near present day McDonald's Ferry. The upper John Day basin remained almost inaccessible to settlers traveling by wagon until the discovery of gold in the 1860s. The first well-established trail to the upper region of the basin formed between The Dalles and Canyon City mines and later became the The Dalles-Boise Military Road (Beckham and Lentz 2000). Supplies, from mining pick axes to farm machinery, were

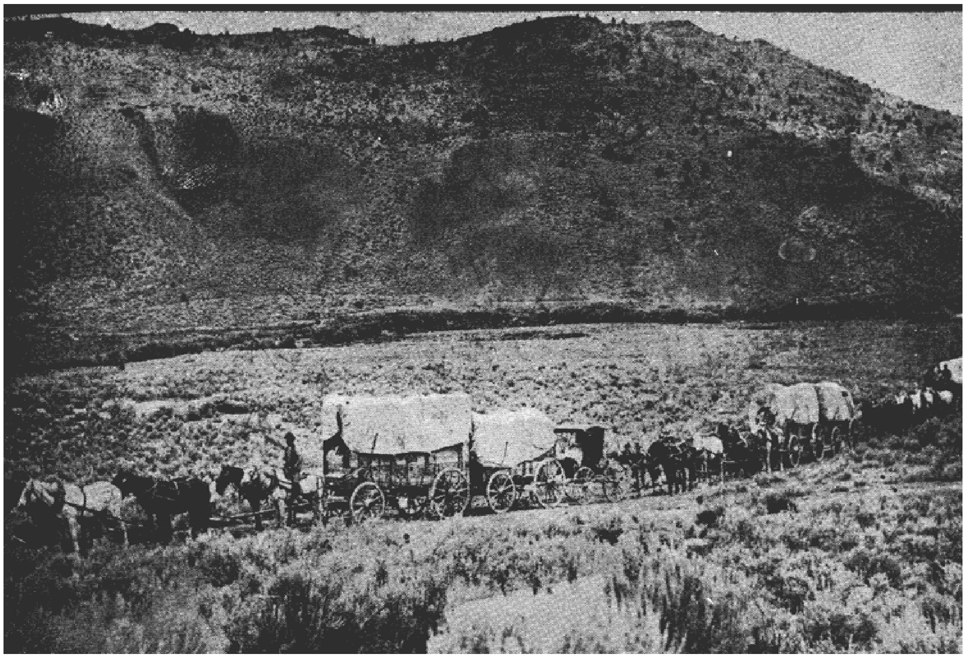

Figure 18 – Early Settlers Traveling through the John Day River Basin (Oliver 1962).

transported from The Dalles by pack animals and freight wagons (Oliver 1962). Early travel throughout higher elevations of the basin was only accomplished by foot, horse or along rugged wagon trails.

In the mid 1880s, the founder of the Oregon Lumber Company, David Eccles, realized the need for a rail line to transport lumber from the west to his mill in Baker City. In 1890, the Sumpter Valley Railroad was incorporated, and construction began from Baker City to the west. The narrow gauge line advanced slowly to the west, crossing several summits above 5,000 feet before reaching Austin in 1905 (Johns 1997). Oregon Lumber Company built railroad tracks down the Middle Fork John Day River from Bates down to Camp Creek and established branch lines up the tributaries to convey logs to the sawmill in Bates (Johns 1997). These rail lines were often constructed in the wide bottomlands of the river, which subsequently disconnected portions of the river from its floodplain.

By 1910, tracks to Prairie City were complete. The Sumpter Valley Railroad greatly facilitated the transport of cattle and sheep, timber, gold ore, and supplies between Prairie City and Baker City. Passenger cars were also available for individual travel throughout the region. Shortly after the railroad tracks reached Prairie City, motorized transportation and the construction of highways arrived in John Day country. By 1933, the rail line between Prairie City and Bates could no longer compete with alternate methods of transportation and was abandoned. By 1947, the Sumpter Valley Railroad tracks were removed, and the line was officially terminated (Oliver 1962).

Beginning in 1913, highways afforded access to previously isolated areas of the John Day watershed. By 1936, almost all of the current state and county roads in the upper portion of the John Day basin had been established (Johns 1997); however, road improvements and bridge construction continued throughout the middle and late twentieth century. Due to the rugged terrain of the region, many of the heavily traveled roads were established within the more manageable floodplain terrain and often adjacent to the John Day River and its tributaries.

Overall, development of transportation in the basin led to increased constrictions in the floodplain and in the river upstream and downstream of bridges. The railroad and other local roads were constructed on top of levees or berms through the floodplain, in some cases reducing floodplain width by more than 50 percent. On one reach of the Middle Fork, construction of the railroad entailed the disconnection of several meander bends and re-positioning and straightening of the channel. At bridge locations that were not geologically constrained by bedrock, bridge abutments impinged on channel widths and created increased velocities through smaller areas than were historically present. Railroads and bridges may have partially modified the physical processes responsible for creating habitat complexity within the river and floodplain.

1.6.7 Historic Flood Events and Management Activities

Floods have an important function in the maintenance of complexity habitat for anadromous salmon. Flood processes are responsible for complex geomorphic features that exist in the river and within their floodplains. Although the magnitude, timing, duration, and spatial extent of an individual flood will influence system impacts, floods are generally important to:

- Channel avulsion and lateral migration.
- Recruitment and transport of LWD.
- Recruitment and establishment of riparian vegetation.
- Scour of floodplain deposits.
- Maintenance of vegetation-free gravel bars.
- Replenishment of groundwater aquifers and maintenance of water table elevations.
- Creation of in-stream geomorphic features, such as pools and riffles.

Paleoflood hydrology research was conducted on the John Day River near Service Creek. Results of the study indicate that historical floods occurring in the past 2,000 years were similar in magnitude to flood events of the past 73 years (Orth 1998). Major flow events in the John Day Basin were recorded in 1894, 1955/56 and 1964/65 (Table 1). Only 2 floods in the past 2000 years were determined to be greater than the discharge recorded at this site for the 1964 flood. Impacts of each flood event resulted in the development and implementation of management strategies for the protection of property and infrastructure.

Table 1 – Annual Peak Flow in CFS Recorded During Flood Events on the Upper John Day and Middle Fork John Day Rivers. (The instantaneous peak was likely higher than the flows presented here.)

Gauge Location	1894	1955/ 1956	1964/ 1965
John Day River at McDonald's Ferry	39,100	24,900	42,800
John Day River at Prairie City	NA	962	2,400
Middle Fork John Day River at Ritter	NA	3,330	4,730

Little information is available regarding the first recorded flood event on the John Day River in 1894. However, the 1894 flood on the Columbia River was the greatest recorded flood in history at several locations of the Columbia River (Willingham 1983), and was instigated by snowmelt from heavy snowpack. Prior to this flood on the John Day River, some flood management practices were likely in operation. Oliver (1962) describes his early memories of flooding and flood management near the town of John Day:

> *"In the early days there were deep snows…The deep snow would sometimes go off with a rush when a Chinook hit. Then the John Day would change from a narrow, meandering stream to a big wide river, tearing holes in the banks, changing its course and ruining a meadow, and perhaps destroying in a night a season's patient, hard work of land clearing.*
>
> *Father took out the big bends, straightened the channel, rip-rapped the banks and made each meadow safe. He dried up the wet places (p 8)."*

The Corps of Engineers reported flood damage on the John Day River during December of 1955 and May of 1956 (USACOE 1957). Floods in the Columbia River and several of its tributaries in May and June of 1956 were caused by considerable snowmelt. Although irrigation diversions and storage facilities were available for flood relief, the John Day floods still caused bank erosion and damage to stream protection measures. Damages in the John Day River Basin totaled $150,000 (USACOE 1957). Existing bank protection measures were largely destroyed during the sustained bankfull flows accompanying this flood. Federal agencies were responsible for some of the flood management activities in the basin following the Flood Control Act of 1950. However, small scale efforts by local

Figure 19 – John Day River Following the 1964 Flood Event. Channel blockage caused high water to overflow the banks and spill onto the floodplain. (Photo compliments of Grant County)

Figure 20 – John Day River near Dayville During 1964 Flood Event. This photograph exemplifies typical channel avulsion occurring on a rancher's property. The river eventually formed a new channel and straightened out the river bend. Photo compliments of Grant County.

residents probably resulted in additional bank protection and river channelization activities following these flood events.

Emergency services provided by the Army Corps of Engineers consisted of channel straightening, riprap bank installations, and clearing of channel blockages, including the removal of LWD and other gravel and debris plugs. Several years after the 1964/1965 floods, the Soil Conservation Service further quelled ranchers' fears of property loss through the installation of bank protection measures, such as riprap and rock spurs (Figure 21; Grant 1997). The goal of their efforts was to deflect flow away from eroding

Figure 21 – Photograph of Rock Spurs on the Middle Fork Forrest Conservation Area. (Photograph by R. McAffee, July 20, 2007)

banks. Previous decades of LWD removal and riparian vegetation may have disrupted

channel stability. In addition to these documented flood management practices, local residents who were unable to secure federal assistance may have constructed their own levees and added bank protection through private funding.

1.7 Fire History

Though a natural part of western ecosystems, fire is one of the most feared, fought, and controversial components of our physical environment. The landscapes of the west have been shaped by frequent wildfires for thousands of years. The role of fire in these ecosystems is evident from studies of past vegetation, charcoal layers in the soil, fire scars on trees, the even-aged character of most forests, and records of explorers. Until the beginning of the last century, fire burned through the forests of the west at fairly regular intervals and was a natural component of fire-based or fire-dependent ecosystems. Fire-dependent ecosystems and plant communities depend on periodic fires to maintain their structure and function (Barkley et al. 2005).

Fire varies in how often it occurs (frequency), when it occurs (season), and how fiercely it burns (intensity). Combinations of these elements define an area’s fire regime. A fire regime is a generalized description of the role fire plays in an ecosystem. It can be described by the characteristics of the disturbance, the dominant or potential vegetation of the ecosystem in which ecological effects are being summarized, or the fire severity based on the effects of fire on dominant vegetation.

Natural fire regimes help species that are best suited to an ecosystem maintain a competitive advantage over less suited species. Less competition reduces stress, which in turn reduces insect and disease outbreaks. Fire stimulates understory vegetation, which is important to wildlife and biodiversity, and helps maintain or provide opportunities for species that depend on it. Natural fire regimes also stimulate reproductive cycles of many plants while preparing suitable seedbeds for new seedlings.

Two general fire regimes are commonly recognized. A stand-maintenance fire regime consists of low- to moderate-intensity surface fires at short intervals (2 to 50 years) (Barkley et al. 2005). This type of fire regime maintains an ecosystem of essentially uniform stands of dominant tree species and is typical of long-needled conifer forests dominated by ponderosa pine. Stand maintenance fires kill competing vegetation including shade tolerant trees in the understory, consume small to moderate amounts of surface fuels, and reduce fuel loads.

A stand-replacing fire regime has moderate- to high-intensity fires that occur at longer intervals (50 to 500 years) and is typical of short-needled coniferous forests dominated by species such as lodgepole pine (Barkley et al. 2005). With stand-replacing fires, most or all of the above ground vegetation is killed, and surface fuels and portions of crowns are consumed. A common result of stand-replacing fires is a mosaic of stands of different species’ composition and age across the landscape.

Historically, drier sites were dominated by stand-maintenance fire regimes and moist sites were dominated by stand-replacing fire regimes. The areas between these two types had a mixture of both types of fire regimes.

Fire occurrence is primarily a result of natural ignitions caused by lightning. Between 1970 and 1996, there were 193 fires within the Malheur National Forest. Based on the data available, one fire per thousand acres per decade can be expected (USFS, 1998).

1.7.1 Cool/Moist Biophysical Environment

Detailed information on fire disturbance in the Upper Middle Fork HUC5 was available from the USFS 1998. The Upper Middle Fork HUC5 encompasses the subbasin upstream from the confluence with Bridge Creek, near RM 67.5. These conditions may be similar to those present in the headwater areas of the Upper John Day River. Further investigation is necessary to determine the regional similarity of the biophysical environments of these watersheds.

The forested vegetation of the Upper Middle Fork John Day watershed reflects the diverse topography, climate, soil characteristics, and disturbance processes of a cool/moist biophysical environment (USFS 1998).

The fire regime in the cool/moist biophysical environment is characterized by moderate-severity fires every 25 to 100 years and high-severity stand replacement fires every 100 to 250 years (Agee 1990). Stand-replacement, fire-disturbance patch sizes typically ranged between 50 and 500 acres. Cool/moist sites have the widest range of expected natural fuel volumes, because fires occur less frequently. Fuel loading can range from incidental, immediately following a fire disturbance, to extremely high during late successional stages, just prior to a stand replacement fire.

1.7.2 Warm/Dry and Warm/Hot Biophysical Environment

Warm/Dry and Hot/Dry forests occupy 68 percent (53 percent and 15 percent, respectively) of the Upper Middle Fork John Day watershed, occurring across a wide range of aspects, soil types, and elevations (USFS 1998). Within this biophysical environment, the fire regime is characterized by low- to moderate- severity fire. In Warm/Dry biophysical environments, fires burned in ponderosa pine plant associations on an average of every 7 to 15 years in a mosaic pattern, resulting in light underburns. Because fires occur in these areas more frequently and with lower intensity, fuel loads are typically low throughout stand succession.

In the Hot/Dry biophysical environments, moderately severe fire regimes are the most difficult to characterize. Fire frequencies usually range from 25 to 100 years and individual fire often show a wide range of effects, from high to low severity. The overall effect is a patchiness over the landscape as a whole, and individual stands will often consist of two or more age classes (Agee 1990). Higher fuel loads are expected on Hot/Dry and Juniper areas just prior to fire disturbance. The natural role of fire within the analysis area would have created a mosaic pattern in the vegetation and fuel loading consistent with fire return intervals. Stand-replacement, fire-disturbance patch sizes typically ranged between 50 and 500 acres (USFS 1998).

1.7.3 Subbasin Fires

Within the John Day River subbasin, a total of 131 fires were recorded from the 1890s to 2006 (**Error! Reference source not found.**; Umatilla, Malheur, and Wallowa-Whitman National Forests 2006). It should be noted that any fire that intersected any part of a subbasin was added to the database even if the majority of the fire area was outside of the subbasin boundary. Also, some fires occurred within more than one subbasin. These fires were included in each subbasin and counted more than once.

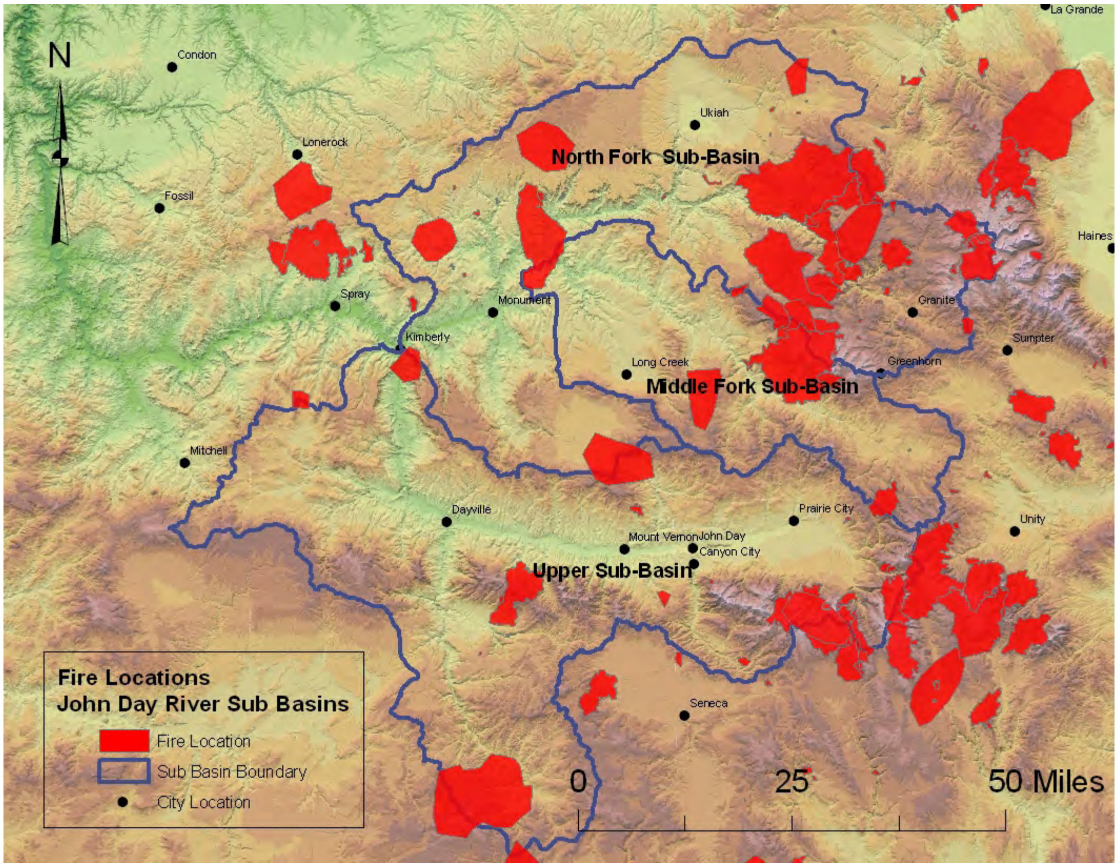

Figure 22 – Fires in the John Day River Subbasin (USFS 2006a).

Within the Middle Fork subbasin there have been 14 fires recorded between 1893 and 2006. The size of the fires ranged from about 12 to 37,985 acres with an average burn area of about 8,300 acres (Table 2).

Within the Upper John Day subbasin there have been 33 fires recorded between 1893 and 2006. The size of the fires ranged from 8 to 76,723 acres, with an average burn area of just over 9,000 acres (Table 3).

Table 2– Middle Fork Subbasin Fires (USFS 2006a).

Year	Name	Area (Acres)	Perimeter (ft)
1910	1910 Fire 23	13,647	103,016
1910	1910 Fire 20	19,197	111,484
1961	Ditch Creek	27,269	181,570
1981	Buck Fire	460	22,503

Year	Name	Area (Acres)	Perimeter (ft)
1986	Grouse Knob	23	4,101
1986	Jumpoff	1,355	37,770
1988	Road Creek	12	3,365
1994	Indian Rock	1,411	59,526
1994	Reed	2,338	59,169
1996	Phipps	43	6,100
1996	Summit	37,986	274,105
2002	Easy	5,842	95,128
2003	Bull Spring 2	1,268	63,738
2006	Sharps Ridge	5,466	82,749
	Average Acreage of Middle Fork Fires	**8,308**	
	Maximum Acreage of Middle Fork Fires	**37,986**	
	Minimum Acreage of Middle Fork Fires	**12**	

Table 3 – Upper John Day Subbasin Fires. (USFS 2006a)

Year	Name	Area (Acres)	Perimeter (ft)
19??	Dixie Creek	8	5,088
1910	1910 Fire 22	6,578	65,265
1910	1910 Fire 24	2,390	40,004
1910	1910 Fire 25	22,134	121,234
1910	1910 Fire 26	1,056	29,111
1910	1910 Fire 29	52,802	199,152
1910	1910 Fire 27	19,294	114,973
1910	1910 Fire 30	76,724	232,010
1939	Widows Creek	1,125	28,638
1939	Big Cow	31,116	333,340
1939	Roberts Creek	1,806	74,749
1986	Deardorff	945	39,225
1987	Little Canyon	131	13,254
1988	Table Mountain	637	21,675
1989	Glacier	9,323	126,650
1990	Snowshoe	11,836	151,374
1990	1990009	16	4,065
1990	Corral Basin	1,135	41,694
1990	Sheep Mountain	10,981	147,672
1994	Timber Cat	64	6,808
1995	Overholt	194	17,877
1996	Graham	558	26,171
1996	Wildcat	10,642	155,871
1997	Incident 029	161	17,423
2000	Slide Mtn Fire	412	23,508
2002	Trout Farm	167	26,407
2002	OR-MAF-284	36	5,515
2002	High Roberts	13,540	159,189
2002	Easy	5,842	95,128
2003	Jenkins Cabin	773	37,676

Year	Name	Area (Acres)	Perimeter (ft)
2003	Big Ridge	71	11,059
2005	Dry Cabin	260	21,822
2006	Thorn Creek	14,527	160,844
	Average Acreage of Upper John Day Fires	**9,009**	
	Maximum Acreage of Upper John Day Fires	**76,724**	
	Minimum Acreage of Upper John Day Fires	**8**	

2.0 Glossary

TERM	DEFINITION
aggradation	Gradual deposition of sediment within the bed of the river due to water action, sediment transport, or alluvial deposits. An aggrading condition occurs when more sediment is transported to a section of river than is transported through to a downstream section of river.
alluvial fan	A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream at the place where it issues from a narrow mountain valley upon a plain or broad valley, or where a tributary stream is near or at its junction with the main stream, or wherever a constriction in a valley abruptly ceases or the gradient of the stream suddenly decreases; it is steepest near the mouth of the valley where its apex points upstream, and it slopes gently and convexly outward with a gradually decreasing gradient (Neuendorf et al. 2005).
alluvium	A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream, as a sorted or semi-sorted sediment on the river bed and floodplain (Neuendorf et al. 2005).
alpine glacier	A glacier in mountainous terrain.
anadromous (fish)	A fish, such as the Pacific salmon, that spawns and spends its early life in freshwater but moves into the ocean where it attains sexual maturity and spends most of its life span (Owen & Chiras 1995).
andesite	A fine-grained, gray volcanic rock, mainly plagioclase and feldspar.
anthropogenic	Caused by human activities.
anticline	A fold, generally convex upward, whose core contains the stratigraphically older rocks.
bar (in a river channel)	Accumulations of bed load (sand, gravel, and cobble) that are deposited along or adjacent to a river as flow velocity decreases. If the sediment is reworked frequently, the deposits will remain free of vegetation. If the surface of the bar becomes higher than the largest flows, vegetation stabilizes the surface making further movement of the sediment in the bar difficult.
basalt	A dark-colored igneous rock, commonly extrusive, composed primarily of calcic plagioclase and pyroxene.
bed-material	Sediment that is preserved along the channel bottom and in adjacent bars; it may originally have been material in the suspended load or in the bed load.

TERM	DEFINITION
bedrock	A general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material (Neuendorf et al. 2005). The bedrock is generally resistant to fluvial erosion over a span of several decades, but may erode over longer time periods.
breccia	A coarse-grained clastic rock, composed of angular broken rock fragments held together by a mineral cement or a fine-grained matrix.
Cenozoic era	An era of geologic time from about 65 million years ago to present that includes the Tertiary and Quaternary periods.
channel morphology	The physical dimension, shape, form, pattern, profile, and structure of a stream channel.
channel planform	Characteristics of the river channel that determine its two-dimensional pattern as viewed on the ground surface, aerial photograph, or map.
channel sinuosity	The ratio of length of the channel or thalweg to down-valley distance. Channel with a sinuosity value of 1.5 or more are typically referenced as meandering channels (Neuendorf et al. 2005).
channel stability	The ability of a stream, over time and under the present climatic conditions, to transport the sediment and flows produced by its watershed in such a manner that the stream maintains its dimension, pattern, and profile without either aggrading or degrading.
channelization	The straightening and deepening of a stream channel to permit the water to move faster, to reduce flooding, or to drain wetlands.
colluvium	A general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity.
concavity	Curvature in the shape of a segment of the interior of a circle. With respect to stream power, greater concavity in the downstream direction signifies that the stream power decreases in the downstream direction with an increasing tendency for curvature as the distance from the headwaters increases.
Cretaceous period	The final period of the Mesozoic era that covered the span of time between 135 and 65 million years ago.
deformation	A general term for the processes of folding, faulting, shearing, compression, or extension of rocks as a result of various earth forces.
degradation	Wearing down of the land surface through the processes of erosion and/or weathering
Devonian period	A period during the Paleozoic era thought to have covered the span of time between 410 and 355 million years ago.

TERM	DEFINITION
discharge (stream)	With reference to stream flow, the quantity of water that passes a given point in a measured unit of time, such as cubic meters per second or, often, cubic feet per second (cfs).
diversity	All the genetic and phenotypic (life history traits, behavior, and morphology) variation within a population.
ecosystem	A unit in ecology consisting of the environment with its living elements, plus the non-living factors, that exist in and affect it (Neuendorf et al. 2005).
entrainment	The process of picking up and carrying along, as the collecting and movement of sediment by currents.
ephemeral stream	A stream or portion of a stream which flows briefly in direct response to precipitation in the immediate vicinity, and whose channel is at all times above the water table.
extrusion	The emission of relatively viscous lava onto the earth's crust.
fine sediment (fines)	Sediment with particle sizes of 2.0 mm (0.08 inch) or less, including medium to fine sand, silt, and clay.
floodplain	The surface or strip of relatively smooth land adjacent to a river channel constructed by the present river in its existing regimen and covered with water when the river overflows its banks. It is built on alluvium, carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current. A river has one floodplain and may have one or more terraces representing abandoned floodplains (Neuendorf et al. 2005).
GIS	Geographical information system. An organized collection of computer hardware, software, and geographic data designed to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.
Holocene epoch	The geologic time interval between about 10,000 years ago and the present.
HUC5	5^{th} field Hydrologic Unit Code: Watersheds consist of subwatersheds that are delineated and arranged in nested hydrologic units, ranging from smallest (HUC8) to largest (HUC1). HUCs provide a uniquely identified and uniform method of subdividing large drainage areas. HUC5s represent 40,000- to 250,000-acre drainage areas that are nested within a larger drainage system. Several 5^{th} field hydrologic units comprise a HUC4, while several 6^{th} field hydrologic units are contained within a HUC5.

TERM	DEFINITION
ICBTRT	Interior Columbia Basin Technical Recovery Team. Expert panel formed by NOAA Fisheries Service (NMFS) to work with local interests and experts and ensure that ICBTRT recommendations for delisting criteria are based on the most current and accurate technical information available.
igneous rocks	Rocks that form from the cooling and solidification of molten or partly molten material (magma) either below the surface as an intrusive (plutonic) rock or on the surface as an extrusive (volcanic) rock.
Jurassic period	A period during the Mesozoic era thought to have covered the span of time between 203 and 135 million years ago.
landslide	Consists of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders. Occur predominantly along glacial terrace deposits and valley walls. Mass wasting along the active river channels typically result in a “self-armoring” bank in that the finer materials are transported by the fluvial system and the larger materials are retained along the toe of the slope protecting the slope except during flood events.
large woody debris (LWD)	Large downed trees that are transported by the river during high flows and are often deposited on gravel bars or at the heads of side channels as flow velocity decreases. The trees can be downed through river erosion, wind, fire, or human-induced activities. Generally refers to the woody material in the river channel and floodplain whose smallest diameter is at least 12 inches and has a length greater than 35 feet in eastern Cascade streams.
levee	A natural or artificial embankment that is built along a river channel margin; often a man-made structure constructed to protect an area from flooding or confine water to a channel. Also referred to as a dike.
limiting factor	Alternate definition: Any factor in the environment of an organism, such as radiation, excessive heat, floods, drought, disease, or lack of micronutrients, that tends to reduce the population of that organism (Owen & Chiras 1995).
low surface	Generally represents an area encompassing historic channel migration and floodplain. Consists of a mixture of reworked glacial deposits and fluviolacustrine deposits comprised of silt- to boulder-size material, but is predominantly sand, gravel, and cobbles. These deposits occur along stream channels and their active floodplains. These materials are unconsolidated and highly susceptible to fluvial erosion.

TERM	DEFINITION
low-flow channel	A channel that carries stream flow during base flow conditions.
mass wasting	General term for the dislodgement and downslope transport of soil and rock under the influence of gravitational stress (mass movement). Often referred to as shallow-rapid landslide, deep-seated failure, or debris flow.
Mesozoic era	An era of geologic time from about 225 to about 65 million years ago that includes the Triassic, Jurassic and Cretaceous periods.
metamorphic rocks	Rocks derived from pre-existing rocks (sedimentary or igneous) in response to marked changes in temperature, pressure, shearing stress and chemical environment.
Miocene epoch	An epoch of the early Tertiary period, after the Oligocene and before the Pliocene.
nonnative species	Species not indigenous to an area, such as brook trout in the western United States. Sometimes referred to as an exotic species.
Oligocene epoch	An epoch of the Tertiary period than began about 34 million years ago and extended to about 23 million years ago.
ophiolite	An assemblage of mafic and ultramafic igneous rocks whose origin is associated with an early phase development of a geosycline.
orthorectified photograph	An aerial photograph that has been corrected for the geometries and tilt angles of the camera when the image was taken and for topographic relief using a digital elevation model, flight information, and surveyed control points on the ground.
overflow channel	A channel that is expressed by no or little vegetation through a vegetated area. There is no evidence for water at low stream discharges. The channel appears to have carried water recently during a flood event. The upstream and/or downstream ends of the overflow channel usually connect to the main channel.
Paleiozoic era	An era of geologic time from about 570 to about 225 million years ago that includes the Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian periods.
peak flow	Greatest stream discharge recorded over a specified period of time, usually a year, but often a season.
perennial stream	A stream that flows throughout the year; a permanent stream.
planform	The shape of a feature, such as a channel alignment, as seen in two dimensions, horizontally, as on an aerial photograph or map.
Pleistocene epoch	The geologic time interval between 1.6 million years ago and 10,000 years ago.

TERM	DEFINITION
Pliocene epoch	An epoch of the Tertiary period that began about 5 million years ago and lasted until the start of the Pleistocene epoch about 2 million years ago.
project area	A project area is a distinct geographic location with potential implementation opportunities for habitat restoration and protection actions. Project areas are at a comparable level of organization as a habitat unit within a geomorphic reach and typically bounded by geomorphic features (e.g., river channel, floodplain, or terrace).
project feature	A project feature is an individual structure or component of an active floodplain of a project area; examples include levees, roadway embankments, bridges, or culverts.
Quaternary period	The geologic time interval between 1.6 million years ago and the present. It includes both the Pleistocene and the Holocene.
redd	A nest constructed by salmonid species in the streambed where eggs are deposited and fertilized. Redds can usually be distinguished in the streambed by a cleared depression and associated mound of gravel directly downstream.
rhyolite	A group of extrusive igneous rocks, typically porphyritic and commonly exhibiting flow texture, with phenocrysts of quartz and alkali feldspar in a glassy to cryptocrystalline groundmass; the extrusive equivalent of granite.
rill	A small channel that is caused by erosive runoff. The term rill is limited to small channels that are only a few centimeters deep.
riparian area	An area with distinctive soils and vegetation community/composition adjacent to a stream, wetland, or other body of water.
riprap	Large angular rocks that are placed along a river bank to prevent or slow erosion.
salmonid	Fish of the family *salmonidae*, including trout, salmon, chars, grayling, and whitefish. In general usage, the term most often refers to salmon, trout, and chars.
side channel	A channel that is not part of the main channel, but appears to have water during low-flow conditions and has evidence for recent higher flow (e.g., may include unvegetated areas (bars) adjacent to the channel). At least the upstream end of the channel connects to, or nearly connects to, the main channel. The downstream end may connect to the main channel or to an overflow channel. Can also be referred to as a secondary channel.

TERM	DEFINITION
slip-plane fault	The relative displacement across a flat surface of formerly adjacent points on opposite sides of a fault.
spawning and rearing habitat	Stream reaches and the associated watershed areas that provide all habitat components necessary for adult spawning and juvenile rearing for a local salmonid population. Spawning and rearing habitat generally supports multiple year classes of juveniles of resident and migratory fish, and may also support subadults and adults from local populations.
subbasin	A subbasin represents the drainage area upslope of any point along a channel network (Montgomery & Bolton 2003). Downstream boundaries of subbasins are typically defined in this assessment at the location of a confluence between a tributary and mainstem channel. An example would be the Twisp River Subbasin.
tectonism	A general term for all movement of the crust produced by tectonic processes, including the formation of ocean basins, continents, plateaus, and mountain ranges.
terrace	A relatively stable, planar surface formed when the river abandons the floodplain that it had previously deposited. It often parallels the river channel, but is high enough above the channel that it rarely, if ever, is covered by water and sediment. The deposits underlying the terrace surface are alluvial, either channel or overbank deposits, or both. Because a terrace represents a former floodplain, it can be used to interpret the history of the river.
terrane	A crustal block or fragment that preserves a distinctive geologic history that is different from the surrounding areas and that is usually bounded by faults.
Tertiary period	The first period of the Cenozoic era thought to have covered the span of time between about 65 million and 2 million years ago. It is divided into five epochs: the Paleocene, Eocene, Oligocene, Miocene and Pliocene.
tributary	A stream feeding, joining, or flowing into a larger stream or lake (Neuendorf et al. 2005).
uplift	A structurally high area in the crust, produced by movements that raise the rocks, as in a broad dome or arch.

TERM	**DEFINITION**
watershed	The area of land from which rainfall (and/or snow melt) drains into a stream or other water body. Watersheds are also sometimes referred to as drainage basins. Ridges of higher ground form the boundaries between watersheds. At these boundaries, rain falling on one side flows toward the low point of one watershed, while rain falling on the other side of the boundary flows toward the low point of a different watershed.

Appendix B: Study Methods

Table of Contents

1.0 Introduction

This assessment focuses on approximately 23 miles of the Middle Fork John Day River (Middle Fork) from Camp Creek to just below Crawford Creek and 3 miles of the Upper Mainstem John Day River (Upper Mainstem) from Prairie City to Jeff Davis Creek. The Middle Fork Assessment Area also includes a 0.5 mile reach of Clear Creek, a tributary that enters the Middle Fork near the upstream end of the assessment area.

The objectives of the assessment are to improve our knowledge of the physical processes within each river system and to generate restoration and protection strategies for salmonid habitat. Projects implemented with a clear understanding of the existing physical processes are more likely to provide both short- and long-term benefits to the ESA-listed and other culturally important fish species. Therefore, proposed project concepts are developed from a baseline understanding of the river system processes, how those processes typically functioned prior to development in the basin, and how current processes may continue to function in the future.

To evaluate geomorphic processes, a conceptual model was developed to characterize typical channel processes and ideal river function that may have occurred prior to anthropogenic influence. Not all river reaches can support the same level of floodplain complexity due to variations in geologic controls, such as floodplain width, sediment sizes, channel slope, and access to riparian vegetation zones. Comparison of the present river setting to the conceptual model of the pre-development setting helps determine which processes may have been altered and to what degree. Not all processes may be fully returned to pre-development conditions due to changes in vegetation, climate, or land use. Project concepts must also anticipate how river processes may or may not change in the future. Historical trends of morphological river features throughout the last 100 years help define the rate of change from pre-development conditions, how the changes relate to historical floods and anthropogenic activities, and whether the changes are continuing or have stabilized.

The assessment takes into account physical river processes that can change laterally, vertically, or longitudinally along the valley length. Connectivity within the river system is an important consideration for habitat function for these reasons:

- Longitudinal connectivity (along river channel) is critical for salmon and steelhead migration, genetic exchange between populations, and re-establishment of populations following major events.
- Lateral connectivity (across the river channel) is critical for access and viability of off-stream habitat.
- Vertical connectivity is critical for water quality and quantity in habitat areas (e.g., flow, water temperature).

For this assessment, methods included a mixture of quantitative and qualitative analyses to provide an acceptable level of certainty consistent with the assessment objectives. Quantitative methods provide more certainty to results than qualitative methods, but cannot be used in all areas because they are more costly and time consuming to employ. Qualitative methods are faster and less costly, but can be difficult to repeat in a scientific manner and therefore, have less certainty. The approach taken was to meld multiple independent analysis tools that could be overlaid and compared to determine conclusions regarding channel processes within the scope described in this report. Quantitative data were collected to characterize and compare reach-level trends within the assessment areas. Refinement of this information with additional data and analysis can then occur at a smaller scale of the channel reach selected by stakeholders and project partners in which to implement restoration actions.

2.0 Literature and Data Utilized

Previous research efforts and evaluations of the John Day River completed by other groups were very beneficial to this assessment. These reports were utilized wherever possible to avoid duplication of efforts and supplement existing information.

2.1 Available Literature

Key reports utilized in this investigation included:

- Anderson, J., and S. Leonard, 2004. Forrest and Oxbow Conservation Areas, PFC Assessment for the Confederated Tribes of the Warm Springs Reservation of Oregon, Department of Natural Resources, John Day Basin Office: National Riparian Service Team, Prineville, Oregon, 30 p.
- Bandow, J.R., 2003. Holocene alluvial history of the Middle Fork John Day River, Oregon [M.A. thesis]: University of Oregon, 3 appendices, 106 p.
- Grant, K.R., 1993. Historic Changes in River Channel and Riparian Woody Vegetation on the Middle Fork John Day Preserve. Report submitted to Oregon Office of The Nature Conservancy. University of Washington.
- Johns, S., 1997. Bates-Austin Remembered (a brief history). Excerpts available online at http://www.precious-testimonies.com/TestimonyLivesOn/Bates.htm. Accessed October 11, 2007.
- McDowell, P., 2001. Spatial Variations in Channel Morphology at Segment and Reach Scales, Middle Fork John Day River, Northeastern Oregon, Geomorphic Processes and Riverine Habitat, Water Science and Application, Volume 4, Pp. 159-172.
- ODFW reports on the status of spring Chinook and summer steelhead.
- U.S. Army Corps of Engineers (USCOE) flood reports and historical photographs.
- U.S. Forest Service (USFS), 1998. Upper Middle Fork John Day Watershed Analysis Report, Malheur National Forest, Grant County, Oregon, Long Creek and Prairie City Ranger Districts.
- Young, W., 1986. John Day River Basin, State of Oregon Water Resources Department, Salem, Oregon, 263 pp.

To achieve recovery, the four sectors that need to be addressed are harvest, hatchery, hydropower, and habitat (ICBTRT 2007; UCSRB 2007). The following biological guidance documents include recommendations for the John Day Subbasin on developing implementation frameworks, and types and prioritization of restoration activities needed to achieve recovery in these four sectors:

- *John Day Subbasin Revised Draft Plan* (NPCC 2005)
- *Draft Recovery Plan for Oregon's Middle Columbia River Steelhead* (Carmichael 2006).
- *Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs* (ICTRT 2007)

In addition to the above documents directly related to the recovery of salmonid species in Oregon, documents relating to salmon and steelhead recovery in the Upper Columbia Region also were referenced. Although the documents focus on the Upper Columbia River, the methodology presented for recovery of listed species has broad application to other basins and can be tailored to meet specific basin objectives. The additional biological guidance documents include:

- *Upper Columbia Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan* (UCSRB 2007)
- *A Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region (Draft)* (UCRTT 2007)

Regarding physical processes associated with habitat, *The Upper Columbia Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan* (UCSRB 2007) recommends conducting additional studies to identify priority locations for protection and restoration, and to examine fluvial geomorphic processes in order to assess how these processes affect habitat creation and loss.

2.2 Available Data

Historical maps and aerial photographs were available for the geomorphic assessment of channel changes over time. Aerial photographs from 1939, 1956, 1976, and 2002 were acquired and rectified for use in this investigation. USGS digital orthorectified quadrangle aerial photos and USDA National Agricultural Imagery Program 2005 aerials photos were also used for evaluation of the present setting. Government Land Office maps from the late 1800s and water adjudication maps from 1926 were also used to help define conditions prior to major development in the basin.

In November of 2006, aerial photographs and LiDAR (Light Detection and Ranging) data were acquired and used for mapping and modeling purposes. Other ground surveys were conducted between 2005 and 2006, and consisted of channel cross-sections, longitudinal profiles, and limited areas of 2-foot contour development. No historic stream survey data were located for evaluation of vertical changes in the river channel.

Biological data from Oregon Department of Fish and Wildlife redd surveys dates back as early as the 1950s. Spatial data related to more recent surveys were put into GIS and used to identify spatial spawning patterns. Within the Forrest and Oxbow Conservation Areas, additional biological information has been collected in recent years, including stream flow data, floodplain water surface elevations, and water temperatures. These data were incorporated into these analyses where appropriate and can be further applied for development of restoration designs on these properties.

3.0 Spatial Scale of Findings

Within the John Day Subbasin, a 23-mile stretch of the Middle Fork and a 3-mile stretch of the Upper Mainstem were analyzed for improvements to habitat conditions. However, larger-scale processes were evaluated at a regional-level and for the watershed encompassing the assessment areas. Processes such as hydrology were investigated from the downstream-most point of the assessment areas to the headwaters of the basin. Locations and timing of human impacts to upland vegetation, sediment loads, and discharge were qualitatively linked to the processes within the assessment areas.

For each assessment area, the findings were characterized and averaged by reach. Twenty reaches were delineated within the Middle Fork Assessment Area, and three reaches were defined on the Upper Mainstem Assessment Area. Within each reach, geomorphic processes are generally similar and are distinguished from other reaches by longitudinal geologic controls. However, localized areas within each reach may differ from the reach-averaged results. Subsequent assessments at finer scales are necessary prior to implementation of protection or restoration actions at project sites within any given reach.

4.0 Rate of Change

River systems are naturally dynamic and the duration and rate of change must be considered in a geomorphic assessment. Habitat use is often viewed over long time periods to account for this variability. In this assessment, temporal scales of processes forming the present conditions ranged from thousands of years or longer (e.g., geologic controls) to a single flood event (e.g., channel avulsion). Results from this assessment are focused on identifying long-term benefits from improving river processes that can be detected on a decadal scale or longer. However, some short-term biological benefits can be gained through implementation of specific restoration strategies [(e.g., installation of large woody debris (LWD)] in the interim period until long-term processes evolve (e.g., revegetation efforts).

Channel change as a result of floods is a natural process. Floods resulting in channel changes may occur on an annual basis or may take several years to occur, depending upon variations in runoff and precipitation. Extreme floods occur infrequently at intervals of tens of years to one hundred years or longer, and can result in “resetting” the river due to their powerful energy. The infrequent flood events can counteract the effects of negative impacts on channel processes when stream energies are large enough to mobilize bed sediments, overtop and possibly destabilize topographic features, rework floodplain deposits, and modify channel slopes, planform, and geometry.

Land use changes, created by human development, have occurred in the John Day River system since the late 1800s, but river responses to these changes varies both in timescale and spatial extent. Some effects to river processes are only localized and temporary, where as others affect larger reaches and can take decades to fully develop.

Many natural processes within the watershed, such as the frequency of fires and floods, will continue to fluctuate. This assessment accounts for some level of variability, but portions of the analysis should be repeated in the future to update findings and predictions. For example, future efforts could involve repeating LiDAR and aerial photograph acquisition to determine whether conditions most affected by geomorphic controls have significantly changed (e.g., channel planform and geometry).

5.0 Assessment Tasks

A multidisciplinary team consisting of local biologists, hydraulic engineers, geologists, geomorphologists, and vegetation specialists performed the following steps as part of the assessment:

5.1 Assessment plan development

a) Scope Development: Assessment team met with clients and local stakeholders to develop assessment area boundaries, objectives, timeline, and funding constraints.

b) Literature Review: Assessment team gathered and reviewed available data and literature to determine data gaps in addressing physical processes.

c) Conceptual Model: Assessment team developed hypotheses of river processes and trends to guide development of the assessment plan; hypotheses were based on existing literature, field reconnaissance, and local stakeholder observations.

d) Assessment Plan: Assessment team identified new data collections and analyses that were needed in order to develop a complete picture of the geomorphic setting at a reach-level scale and to identify potential protection and restoration projects.

5.2 Developed conceptual model of typical channel processes prior to basin development

e) Acquired historical ground photographs, maps, journal accounts, books, and anecdotal information to document human activities in basin and river setting prior to earliest aerial photography.

f) Mapped historical river channels to document the natural (geologic) floodplain area that defines the boundary of the interaction between channel and floodplain processes where habitat projects may be proposed.

g) Mapped geologic units that bind the low surface and any geologic controls present in the channel bed (e.g., bedrock, large boulders, alluvial fans).

h) Identified geologic lateral and vertical controls on river processes based on stereo-pair aerial photographs, 2006 LiDAR surveys, regional geology maps, geologic mapping, and field reconnaissance.

i) Subdivided the assessment area into reaches with similar geomorphic processes that offer unique habitat opportunities.

5.3 Assessed present setting and compared it to conceptual model of fully functioning conditions

j) Assessed available biologic information to understand present habitat use and opportunities for improvement.

k) Analyzed hydrologic data to develop a flood frequency for gauged and non-gauged locations.

l) Analyzed hydraulic and sediment data to provide additional information for evaluating the balance between water and sediment loads and how this impacts channel form.

m) Mapped historical channel migration to evaluate lateral channel change and to verify active floodplain reworking areas; based on historical aerial photographs (1939, 1956, 1976, and 2000) and maps (late 1800s to early 1900s) that were acquired, rectified, and put into a GIS database.

n) Mapped constructed features to identify locations and extent of areas within active floodplains that have been disconnected from the river channels and areas along boundary of active floodplains that have been altered.

o) Mapped vegetation in the riparian corridors of the Upper Mainstem and Middle Fork using recent aerial photography to assess the present condition of vegetation, compare present vegetation with historic quantities, and identify potential LWD recruitment areas.

p) Integrated information to hypothesize pre-development conditions of the rivers, to determine the present degree of departure from these conditions, and to identify trends that may persist into the future.

5.4 Identified project concepts and reaches

q) Grouped sections of the river that have similar physical processes and offer unique habitat opportunities in process-based reaches; this step separated areas of river that are naturally confined from areas with unconfined floodplains (off-channel habitat); this step also distinguished the degree of complexity in reaches based on the rate of lateral reworking, the presence of LWD, and the wetland complexes in the natural setting.

r) Synthesized data and analyses from above tasks to determine reach-based restoration concepts based on the knowledge of typical channel processes, the present conditions of the river, the types of disturbances, and the stability of river system.

s) Identified floodplain areas that are potential protection areas that do not have constructed features but need to be protected and monitored as part of a reach-based strategy.

t) Identified restoration opportunities within the low surface of each reach based on a comparison of present conditions and the hypothesized pre-development conditions. Conceptual restoration strategies were determined by disruption of typical channel processes, which were most notably impacted by constructed features (e.g., levees, riprap, bridge embankments) and anthropogenic activities (e.g., grazing, timber harvest, draining of wetlands).

u) Developed a ranking criteria for process-based reaches based on results from the geomorphic assessment and biological benefits.

v) Sequenced projects identified as “Tier-1” on the Forrest and Oxbow Conservation Areas.

5.5 Documented assessment findings

w) Generated report.

x) Generated GIS databases.

5.6 Shared information with local stakeholders

y) Shared assessment information in workgroup settings and public forums to allow comments on the process and assessment approach that can be integrated into project plans.

Appendix C

Middle Fork John Day River Drainage Basin
Hydrology Data and GIS

December 21, 2006

Prepared by: **David E. Sutley**
Hydraulic Engineer

Introduction:
This report documents hydrology data and a GIS database developed for the restoration projects in the Middle Fork John Day River drainage basin being accomplished by the Technical Service Center for the Pacific Northwest Region of the Bureau of Reclamation. The report contains the following information:

- Basin characteristics.
- Historical flood accounts.
- Flood frequency computations for peak flows at USGS gage station locations.
- Flood frequency computations with GIS integration for ungaged locations based on the regional regression equations for Northeast Oregon.

Basin Characteristics:
The selected study area of the Middle Fork John Day drainage basin is located in western Grant County, Oregon approximately 25 miles northeast of John Day, Oregon (Figure 1). The drainage basin above river mile 38.8 is 354 mi^2, which accounts for 8% of the total area of Grant County.

The entire basin falls within the Malheur National Forest. The topography of the basin varies significantly. The basin outlet of the study area is approximately 3,280 ft above sea level. The highest point at elevation 8,190 is located above Granite Boulder Creek along the north-central watershed boundary.

The USGS maintains stream gage stations throughout the Middle Fork John Day River drainage basin which provide mean daily flow data and instantaneous annual peak flow data. Within the selected study area of the Middle Fork John Day drainage basin, there are two gages that have greater than 15 years of record. The nearest downstream gage on the Middle Fork is located at Ritter, OR and has 76 years of peak flow data. The Ritter gage is approximately 16 miles northwest of the outlet of the selected study area. Table 1 contains the gage number and description, date of peak discharge, years of record, and drainage area for these three gages.

Figure 1 – Middle Fork John Day drainage basin.

Table 1 – USGS stream gage information.

USGS Gage No.	Description	Date of Peak Discharge	Years of Record	Drainage Area (mi^2)
14043800	BRIDGE CREEK NR PRAIRIE CITY OREG.	5/15/1975	16	6.9
14043850	COTTONWOOD CREEK NEAR GALENA OREG.	4/1/1978	15	3.9
14044000	MIDDLE FORK JOHN DAY RIVER AT RITTER, OR	1/30/1965	76	515

Historical Flood Accounts:
Figures 2 and 3 show the annual peak discharges for each year of record at the two gages within the selected study area of the Middle Fork John Day River drainage basin.

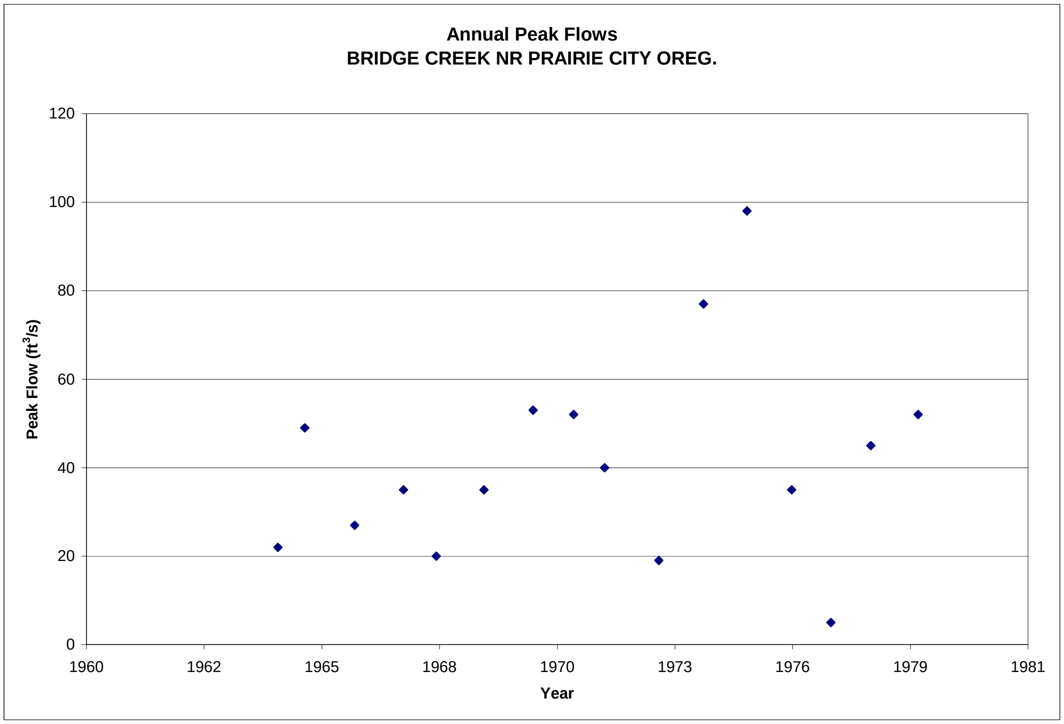

Figure 2 – Annual peak flow data for USGS gage 14043800.

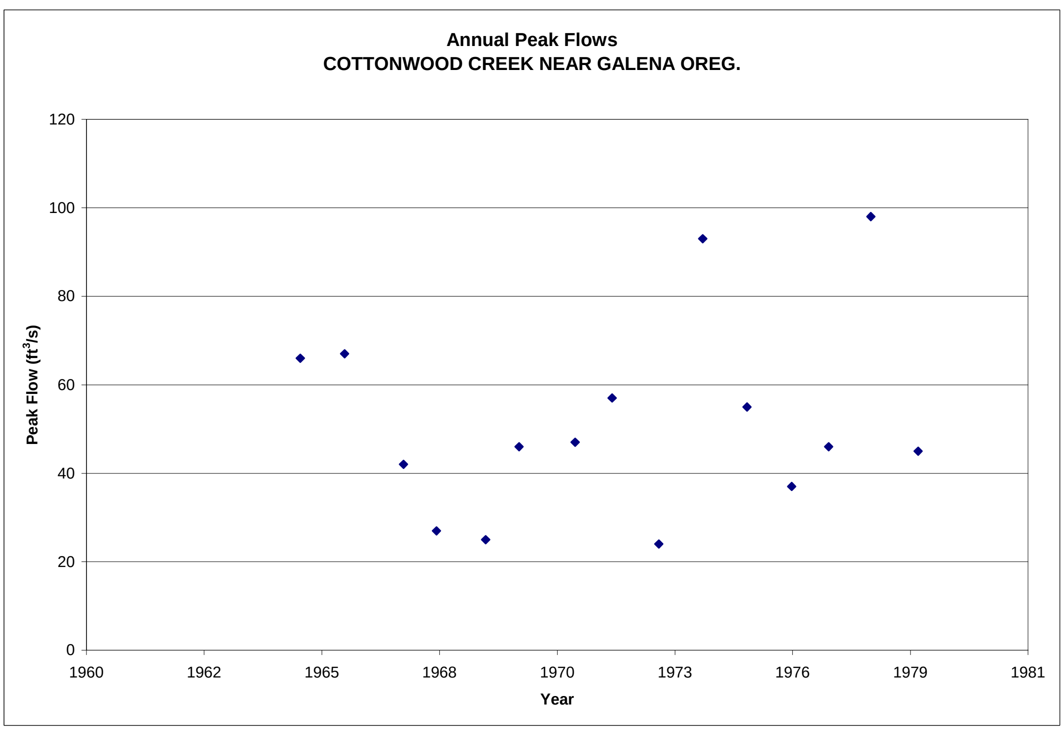

Figure 3 – Annual peak flow data for USGS gage 14043850.

Peak Flow Calculations at USGS Gage Station Locations:
The annual flow data for the three selected USGS stream gages were sought from the USGS NWIS web site. A Log-Pearson III distribution was fit to the gaged record of peak flows using the method of moments to develop the 2-, 5-, 10-, 25-, 50-, and 100-year flood frequency values. This process is consistent with the procedure described in the Guidelines for Determining Flood Flow Frequency, *Bulletin 17B* [1]. Figure 4 is a frequency plot of the peak discharge versus annual exceedance probability (AEP) for the Bridge Creek gage. The peak discharge value for 1977 was removed from the analysis because the actual discharge was higher than indicated in the gage record. Table 2 provides the results of the statistical analysis for all gages. The ranked data statistics and flood frequency results for each gage are shown in more detail in the Appendix.

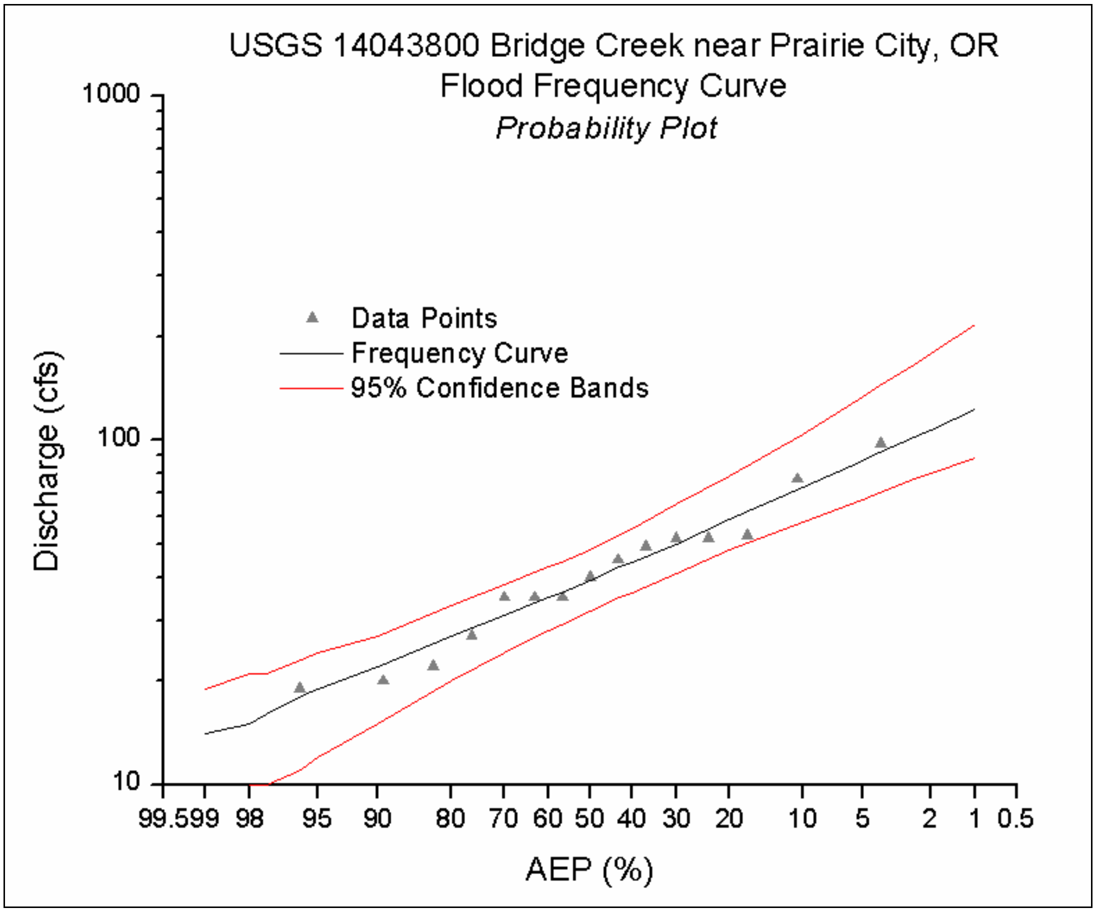

Figure 4 – Middle Fork John Day Flood Frequency Curve

Table 2 – Peak flow data computed for USGS stream gages in the Middle Fork basin.

USGS Gage No.	Description	Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)
14043800	BRIDGE CREEK NR PRAIRIE CITY OREG.	39	59	73	92	107	123
14043850	COTTONWOOD CREEK NEAR GALENA OREG.	48	68	82	100	113	127
14044000	MIDDLE FORK JOHN DAY RIVER AT RITTER, OR	1746	2599	3165	3873	4394	4908

Peak Flow Calculations at Ungaged Sites with GIS Integration:
Because a stream channel restoration project site could potentially be located along any reach within the Middle Fork John Day basin, peak flow calculations were also computed over the entire basin and incorporated into a geographic information system. The user of the Middle Fork John Day GIS database can easily acquire the desired peak flow information by simply clicking on a potential project site within the basin. This system was created using the watershed processing tools in ESRI's ArcHydro and the USGS publication: *Magnitude and Frequency of Floods in Eastern Oregon, 1983* [2]. The results can vary at individual sites and should be considered tools to represent a range of possible flood frequency values.

A geographic information system was created to quickly access specific peak flow information associated with potential project sites. This system incorporates digital elevation models (DEM's) of the topography, forest cover, mean annual precipitation (MAP), aerial photography, existing stream networks, existing project locations, and a graphical database that contains the peak flow information for the Middle Fork John Day drainage basin's individual sub-watersheds or sub-basins. Once the DEM of the basin is imported into the GIS, ArcHydro delineated all of the sub-basins. For this system, a minimum sub-basin size of 2 mi^2 was selected because most stream channel restoration projects have watersheds greater than this size. After the watershed processing was complete, ArcHydro had created 109 sub-basins within the entire Middle Fork John Day basin. For each of these sub-basins peak flows for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals were calculated based on the regional regression equations for Northeastern Oregon developed by the USGS [2].

Peak Flows at Ungaged Locations in the Middle Fork John Day Basin
Due to the limited amount of available streamflow data within the Middle Fork John Day basin, the regional regression equations developed by the USGS for Northeastern Oregon were used to compute peak flows. The equations listed in *Magnitude and Frequency of Floods in Eastern Oregon, 1983* [2] were developed based on data from 60 stations. Table 3 presents the regression equations developed for Northeast Oregon and the inherent error associated with their results. The equations are a function of basin area, mean annual precipitation, and forest cover, where Q_x is the peak discharge for the x recurrence interval, A is the basin area in mi^2, P is the mean annual precipitation in inches from the NRCS National Water and Climate Center (Figure 5), and F is percent forest cover (Figure 6). According to the National Land Cover Dataset's (NLCD 2001) land cover definitions, forest is considered to have a canopy that covers over 20 percent of the ground. Once the computations for all of the sub-basins were completed, they were integrated in the GIS.

Table 3 – USGS regional regression equations for Northeast Oregon [2].

Recurrence Interval	Equation	Standard Error		
			Percent	
		Log Units	Plus	Minus
Q_2	$0.508A^{0.82}P^{1.36}(1+F)^{-0.27}$	0.259	82	45
Q_5	$2.44A^{0.79}P^{1.09}(1+F)^{-0.30}$	0.254	79	44
Q_{10}	$5.28A^{0.78}P^{0.96}(1+F)^{-0.32}$	0.262	83	45
Q_{25}	$11.8A^{0.77}P^{0.83}(1+F)^{-0.35}$	0.277	89	47
Q_{50}	$19.8A^{0.76}P^{0.75}(1+F)^{-0.36}$	0.280	90	48
Q_{100}	$30.7A^{0.76}P^{0.68}(1+F)^{-0.38}$	0.303	101	50

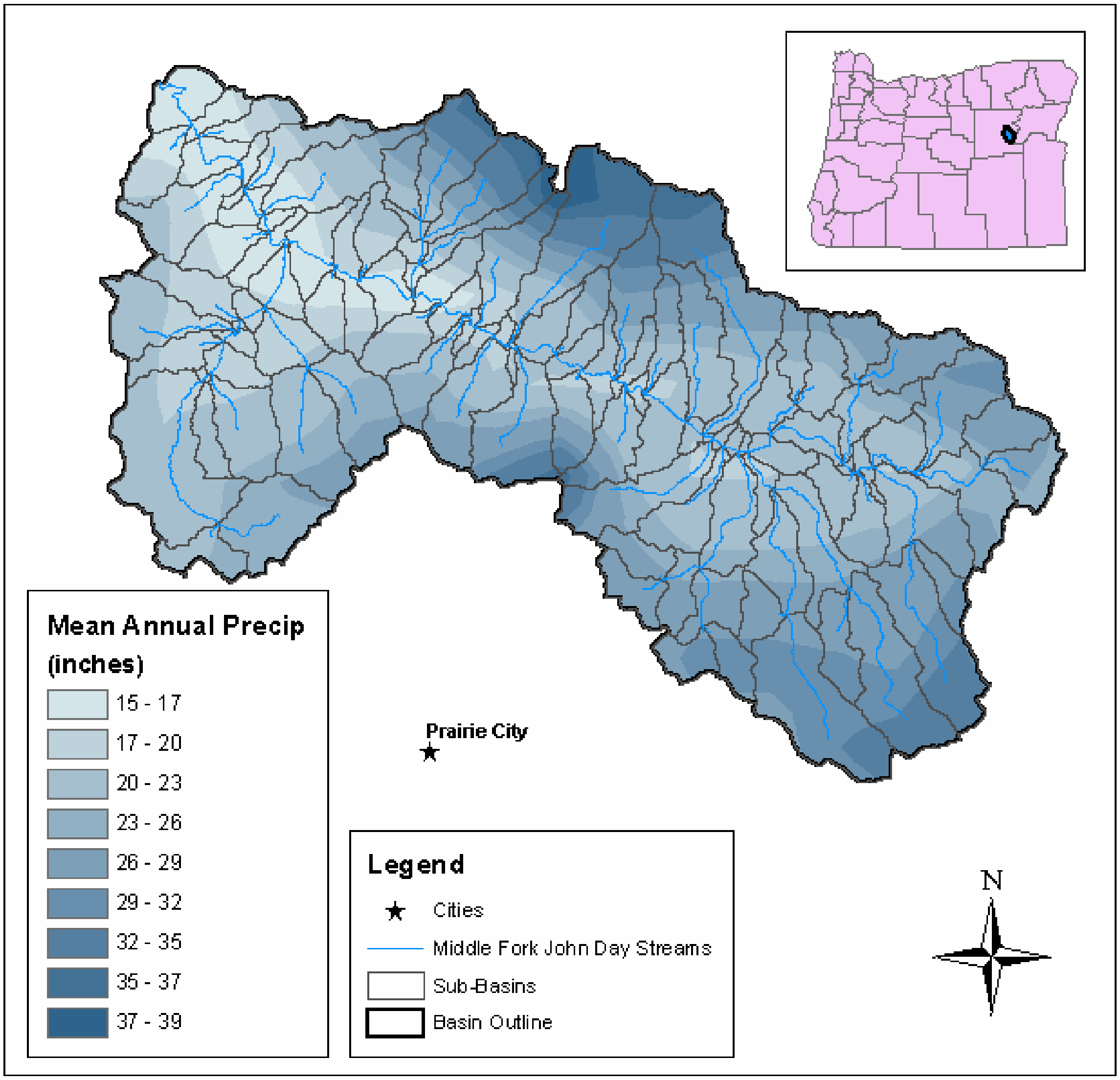

Figure 5 – Middle Fork John Day Mean Annual Precipitation (NRCS).

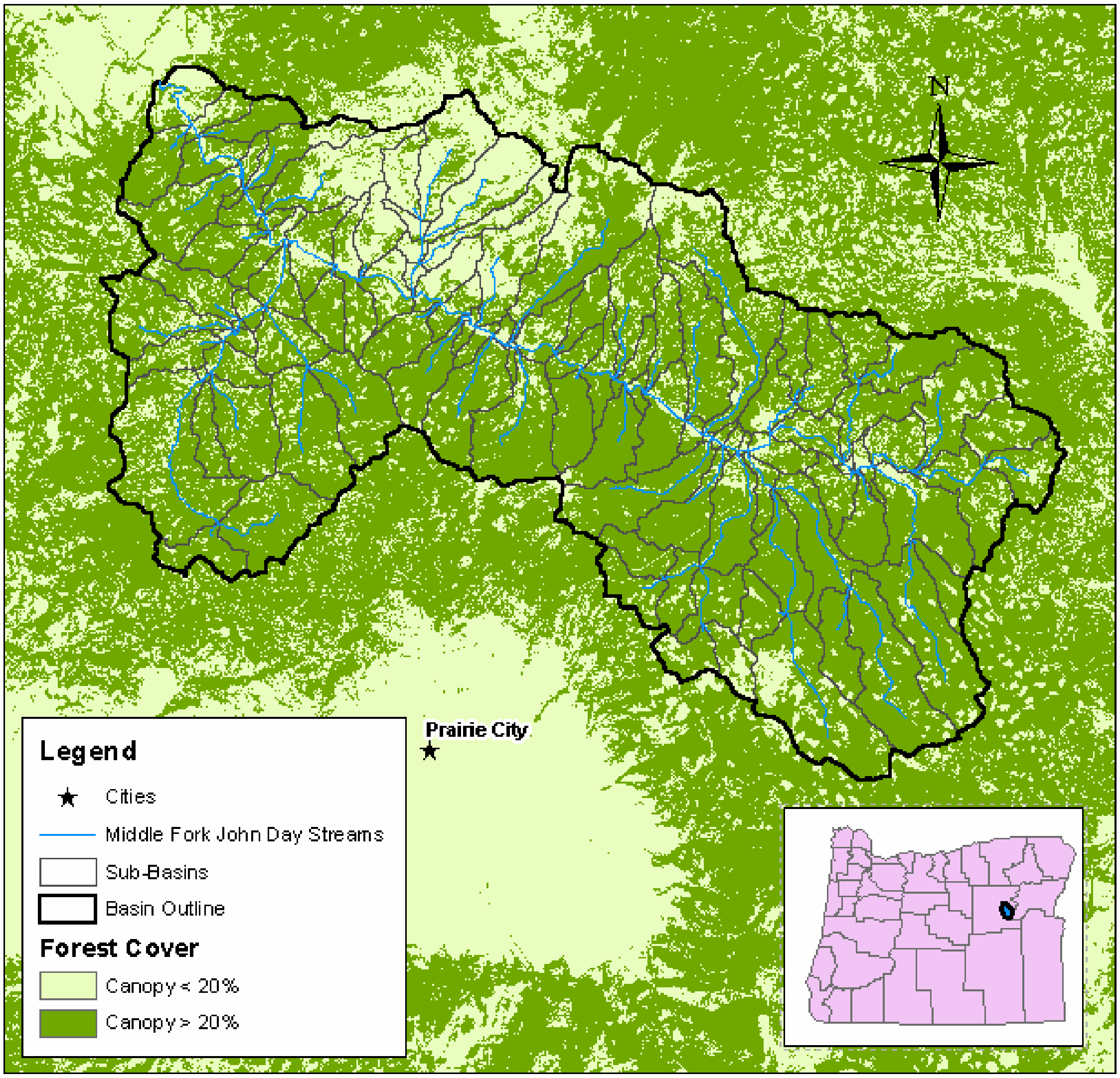

Figure 6 – Middle Fork John Day Forest Cover (NLCD 2001).

Comparison of Peak Flows

The peak flows computed at USGS gages 14043800 and 14043850 were compared to the corresponding sets of peak flows computed using the USGS regional regression equations as shown in Table 4. The flows from the regional regression equations have been selected for this report because they are based on data from 60 gage stations and provide more conservative estimates of the peak flows in the Middle Fork John Day basin. The main reasons for not using the gage data analysis is because it does not represent runoff conditions for the entire basin and the two gages within the selected study area have very short periods of record.

Table 4 – Comparison of Peak Flows at USGS Gage Stations.

Peak Flow	USGS Gage Station 14043800				USGS Gage Station 14043850				USGS Gage Station 14044000			
	Gage Data Analysis		Regional Regresion Equations	% Out of Gage Range	Gage Data Analysis		Regional Regresion Equations	% Out of Gage Range	Gage Data Analysis		Regional Regresion Equations	% Out of Gage Range
	Low	High			Low	High			Low	High		
Q2 (ft^3/s)	32	48	64	33%	39	58	38	3%	1591	1918	1648	0%
Q5 (ft^3/s)	48	79	105	33%	56	89	67	0%	2348	2922	2584	0%
Q10 (ft^3/s)	58	104	133	28%	66	113	88	0%	2823	3630	3277	0%
Q25 (ft^3/s)	70	144	166	15%	79	149	115	0%	3399	4548	4121	0%
Q50 (ft^3/s)	80	178	201	13%	87	178	142	0%	3813	5242	4906	0%
Q100 (ft^3/s)	89	216	226	5%	96	209	164	0%	4214	5941	5681	0%

Using the GIS Database

Once the computations for all of the sub-basins were completed, they were integrated into the GIS. The information tool is used to access the data by simply clicking on the sub-basin of interest (Figure 7). Figure 8 is a close up of the attributes displayed for a specific sub-basin. Table 5 lists the descriptions of each attribute in the GIS database.

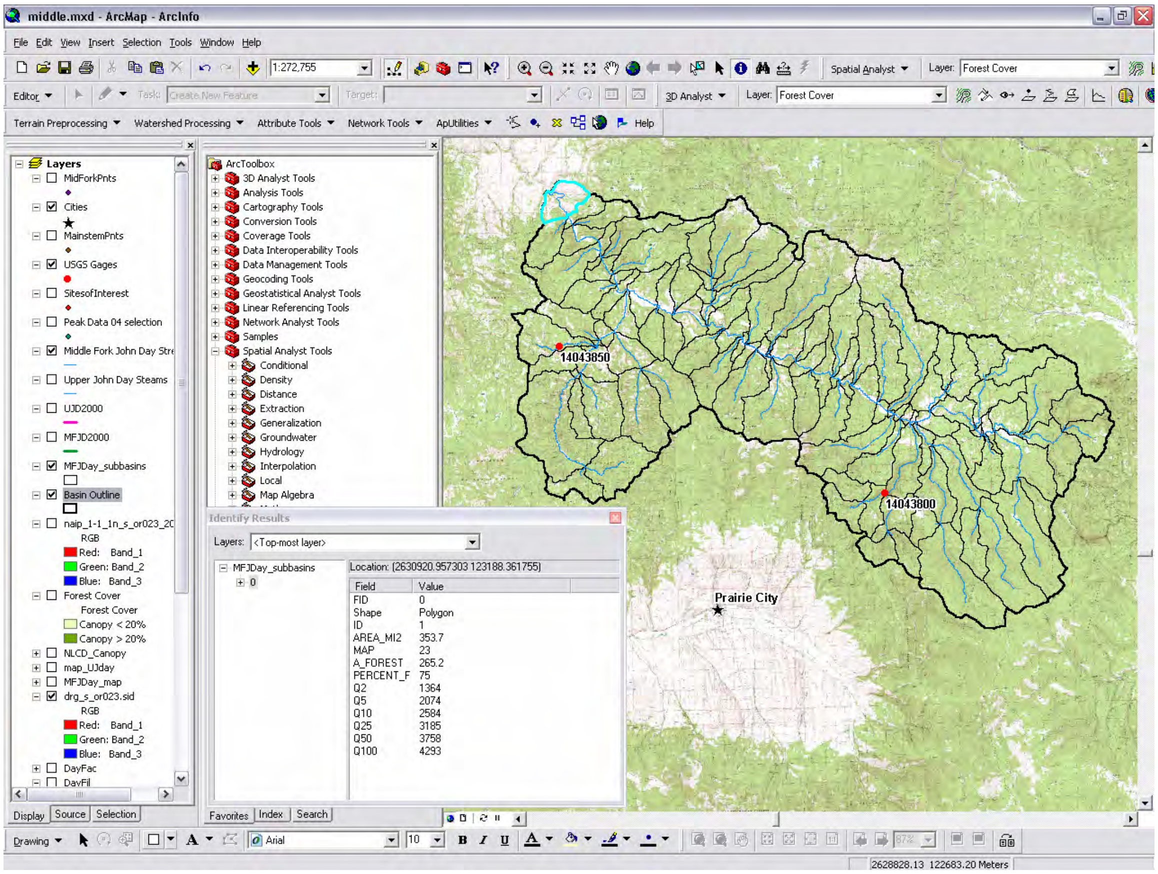

Figure 7 – Accessing the peak flow data in ArcGIS.

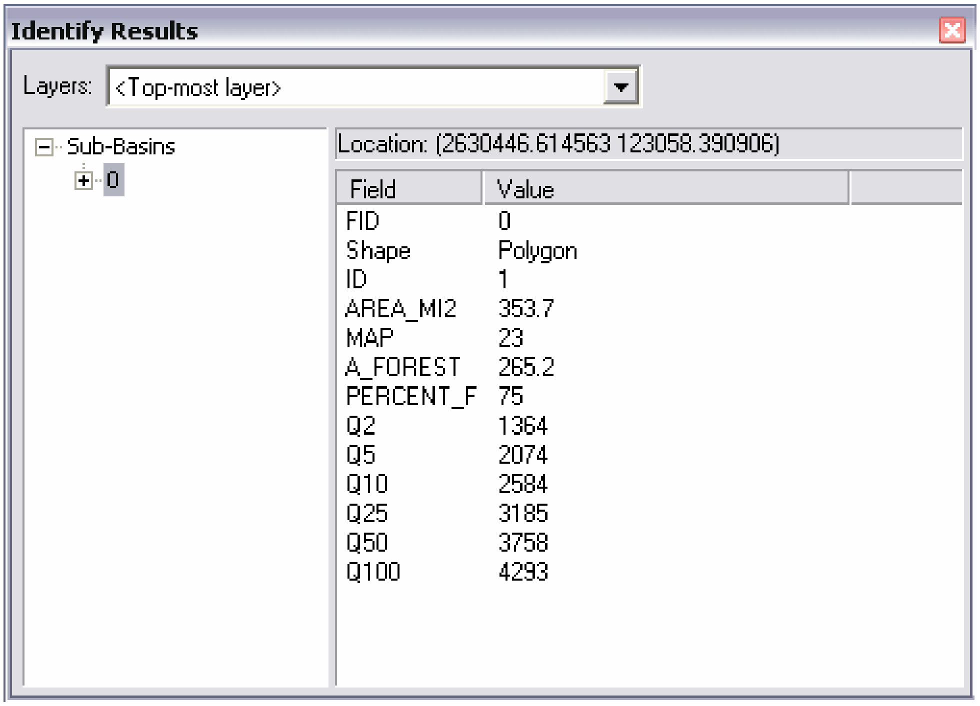

Figure 8 – Output summary example for an ungaged sub-basin.

Table 5 – GIS output description.

Field	Description
AREA_MI2	Sub-basin area in square miles
MAP	Mean annual precipitation in inches
A_FOREST	Area of forest cover in square miles (canopy > 20%)
PERCENT_F	Percent of subbasin that is covered by forest (canopy > 20%)
Q2	2 year peak flow in cubic feet per second
Q5	5 year peak flow in cubic feet per second
Q10	10 year peak flow in cubic feet per second
Q25	25 year peak flow in cubic feet per second
Q50	50 year peak flow in cubic feet per second
Q100	100 year peak flow in cubic feet per second

References:

[1] Guidelines for Determining Flood Flow Frequency, *Bulletin #17B of the Hydrology Committee*, U.S. Department of the Interior, United States Water Resources Council, 1981.

[2] USGS, 1983. *Magnitude and Frequency of Floods in Eastern Oregon, 1983*, U.S. Geological Survey, Water Resources Investigations Report 82-4078.

Middle Fork John Day River Drainage Basin
Hydrology Data and GIS

Prepared by
David E. Sutley
Hydraulic Engineer

1/9/2007
Date

Peer Reviewed by
Robert E. Swain, P.E.
Flood Hydrology Technical Specialist

1/9/07
Date

APPENDIX

USGS Gage Station 14043800 – Frequency Analysis

Mean of Logs	Std.Dev	Data Skew	Reg. Skew	Final Skew
1.5977	0.2044	0.1071	0	0.1071

RANK	PlotPos	YEAR	Q	EXCEED.	FREQ.Q	LOW	HIGH
1	0.03947	1975	98	0.99	14	8	19
2	0.10526	1974	77	0.98	15	10	21
3	0.17105	1970	53	0.975	16	10	21
4	0.23684	1979	52	0.96	18	11	23
5	0.30263	1971	52	0.95	19	12	24
6	0.36842	1965	49	0.9	22	15	27
7	0.43421	1978	45	0.8	27	20	33
8	0.5	1972	40	0.7	31	24	38
9	0.56579	1969	35	0.6	35	28	43
10	0.63158	1976	35	0.5704	36	29	44
11	0.69737	1967	35	0.5	39	32	48
12	0.76316	1966	27	0.4296	43	35	53
13	0.82895	1964	22	0.4	44	36	55
14	0.89474	1968	20	0.3	50	41	65
15	0.96053	1973	19	0.2	59	48	79
				0.1	73	58	104
				0.05	87	67	134
				0.04	92	70	144
				0.025	102	77	166
				0.02	107	80	178
				0.01	123	89	216
				0.005	140	99	259
				0.002	163	112	323
				0.001	182	122	378
				0.0005	203	132	439
				0.0001	254	158	608

USGS Gage Station 14043850 – Frequency Analysis

Mean of Logs	Std.Dev	Data Skew	Reg. Skew	Final Skew
1.6769	0.1849	-0.0164	0	-0.0164

RANK	PlotPos	YEAR	Q	EXCEED.	FREQ.Q	LOW	HIGH
1	0.03947	1978	98	0.99	18	11	23
2	0.10526	1974	93	0.98	20	13	26
3	0.17105	1966	67	0.975	21	13	27
4	0.23684	1964	66	0.96	23	15	29
5	0.30263	1972	57	0.95	24	16	30
6	0.36842	1975	55	0.9	28	20	34
7	0.43421	1971	47	0.8	33	25	40
8	0.5	1970	46	0.7	38	30	46
9	0.56579	1977	46	0.6	43	35	51
10	0.63158	1979	45	0.5704	44	36	53
11	0.69737	1967	42	0.5	48	39	58
12	0.76316	1976	37	0.4296	51	43	63
13	0.82895	1968	27	0.4	53	44	65
14	0.89474	1969	25	0.3	59	50	75
15	0.96053	1973	24	0.2	68	56	89
				0.1	82	66	113
				0.05	96	76	140
				0.04	100	79	149
				0.025	109	85	168
				0.02	113	87	178
				0.01	127	96	209
				0.005	141	104	242
				0.002	160	115	289
				0.001	175	124	328
				0.0005	191	132	370
				0.0001	228	152	478

Upper John Day River Drainage Basin

Hydrology Data and GIS

December 21, 2006

Prepared by: **David E. Sutley**
Hydraulic Engineer

Introduction:

This report documents hydrology data and a GIS database developed for the restoration projects in the Upper John Day River drainage basin being accomplished by the Technical Service Center for the Pacific Northwest Region of the Bureau of Reclamation. The report contains the following information:

- Basin characteristics.
- Historical flood accounts.
- Flood frequency computations for peak flows at USGS gage station locations.
- Flood frequency computations with GIS integration for ungaged locations based on the regional regression equations for Northeast Oregon.

Basin Characteristics:

The selected study area of the Upper John Day drainage basin is located in western Grant County, Oregon approximately 10 miles east of John Day, Oregon (Figure 1). The drainage basin above river mile 258.15 is 259 mi^2, which accounts for 6% of the total area of Grant County.

The topography of the basin varies significantly. The basin outlet of the study area is approximately 3,370 ft above sea level. The highest point at elevation 9,050 is located above Shaw Gulch in the southwest corner of the basin.

The USGS maintains stream gage stations throughout the Upper John Day River drainage basin which provide mean daily flow data and instantaneous annual peak flow data. Within the selected study area of the Upper John Day drainage basin, there are two gages that have greater than 20 years of record. There is also a significant gage downstream of the basin outlet near John Day, OR. Table 1 contains the gage number and description, date of peak discharge, years of record, and drainage area for these three gages. The gages shown in Figure 1 that do not appear in Table 1 have insufficient data records and will not be considered in the flood frequency analysis.

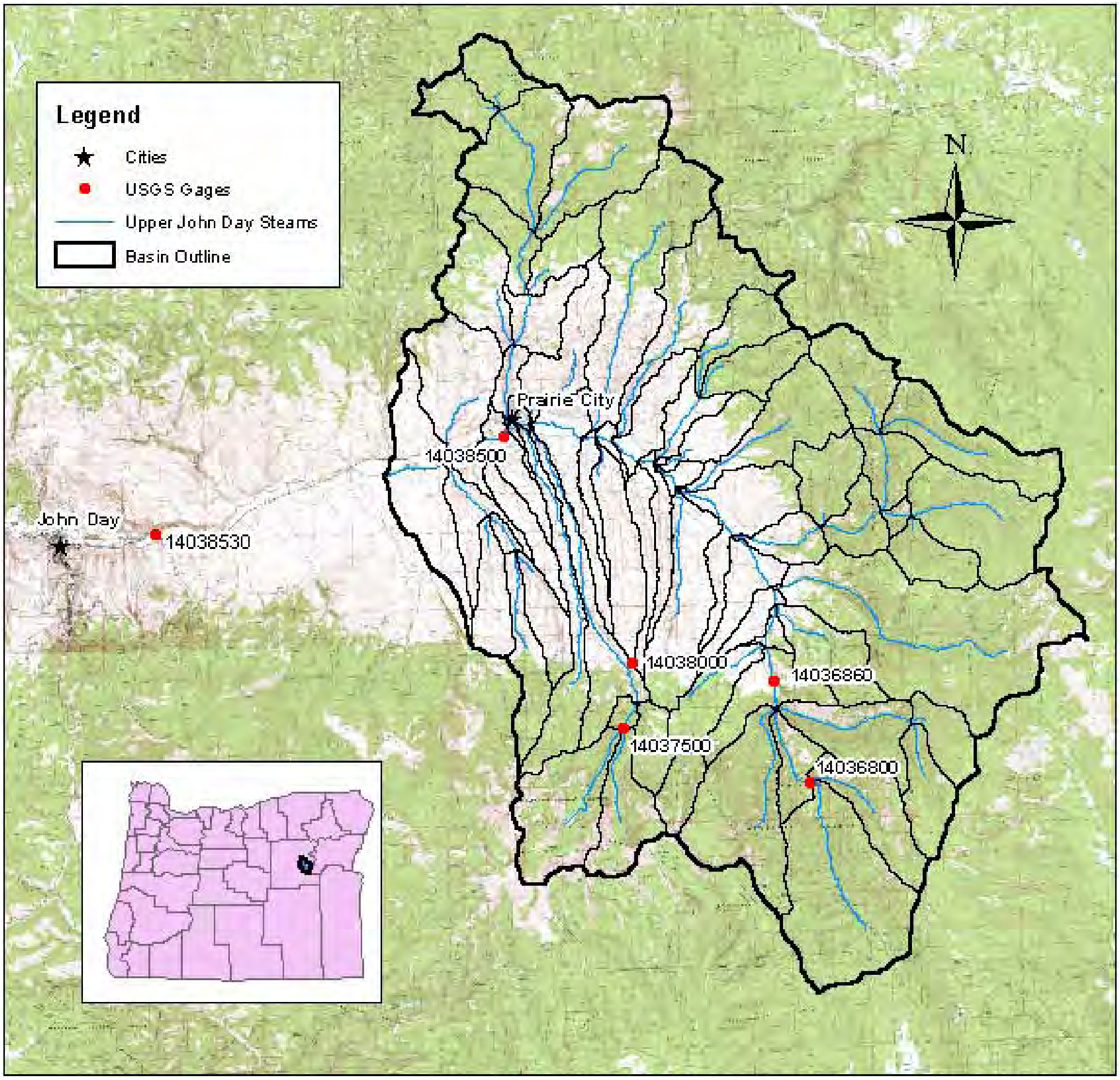

Figure 1 – Upper John Day drainage basin.

Table 1 – USGS stream gage information for gages used in the flood frequency analysis.

USGS Gage No.	Description	Date of Peak Discharge	Years of Record	Drainage Area (mi^2)
14037500	STRAWBERRY CR AB SLIDE CR NR PRAIRIE CITY,OREG.	5/31/1983	61	7
14038500	JOHN DAY RIVER AT PRAIRIE CITY, OREG.	12/22/1965	42	231
14038530	JOHN DAY RIVER NEAR JOHN DAY, OREG.	6/9/1969	32	386

Historical Flood Accounts:
Figures 2 and 3 show the annual peak discharges for each year of record at the two gages within the selected study area of the Upper John Day River drainage basin.

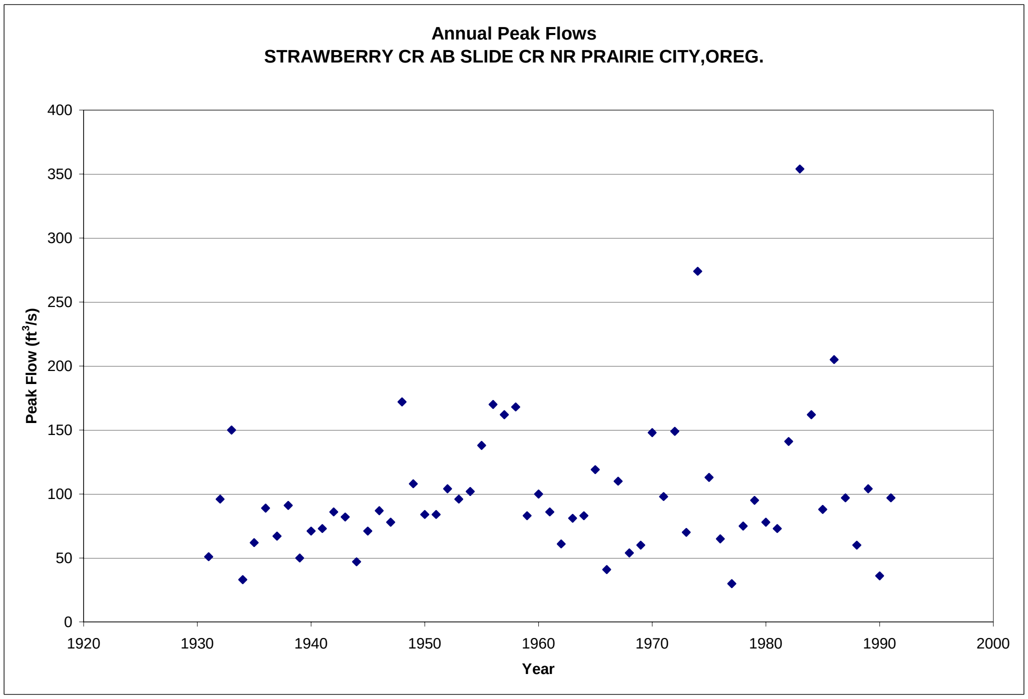

Figure 2 – Annual peak flow data for USGS gage 14037500.

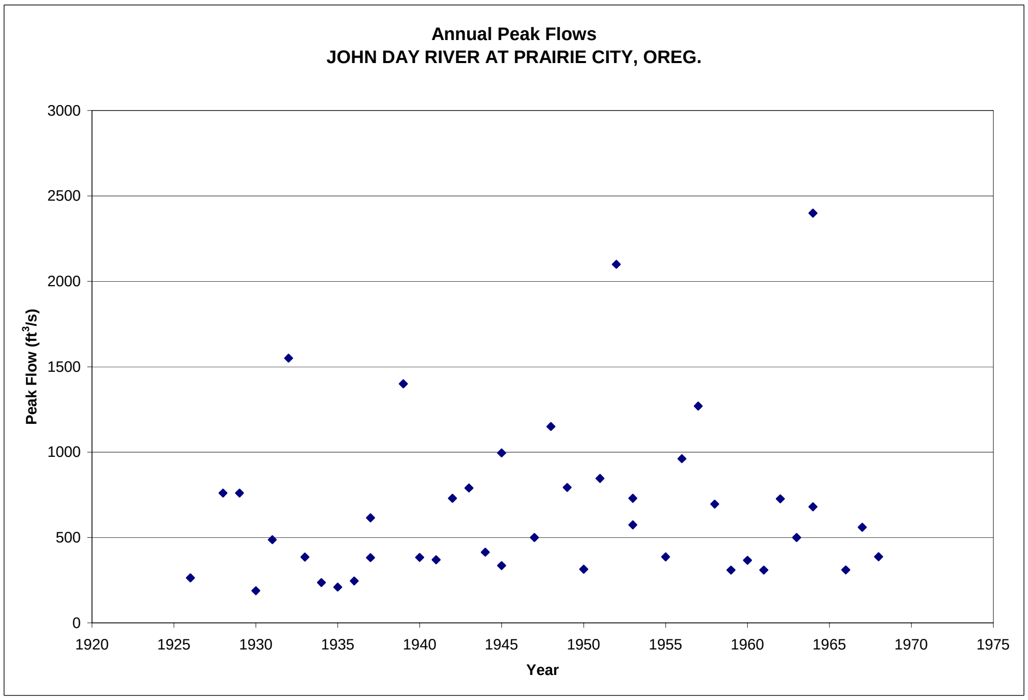

Figure 3 – Annual peak flow data for USGS gage 14038500.

Peak Flow Calculations at USGS Gage Station Locations:
The annual flow data for the three selected USGS stream gages were sought from the USGS NWIS web site. A Log-Pearson III distribution was fit to the gaged record of peak flows using the method of moments to develop the 2-, 5-, 10-, 25-, 50-, and 100-year flood frequency values. This process is consistent with the procedure described in the Guidelines for Determining Flood Flow Frequency, *Bulletin 17B* [1]. Figure 4 is a frequency plot of the peak discharge versus annual exceedance probability (AEP) for the Prairie City gage. Table 2 provides the results of the statistical analysis for all gages. The ranked data statistics and flood frequency results for each gage are shown in more detail in the Appendix.

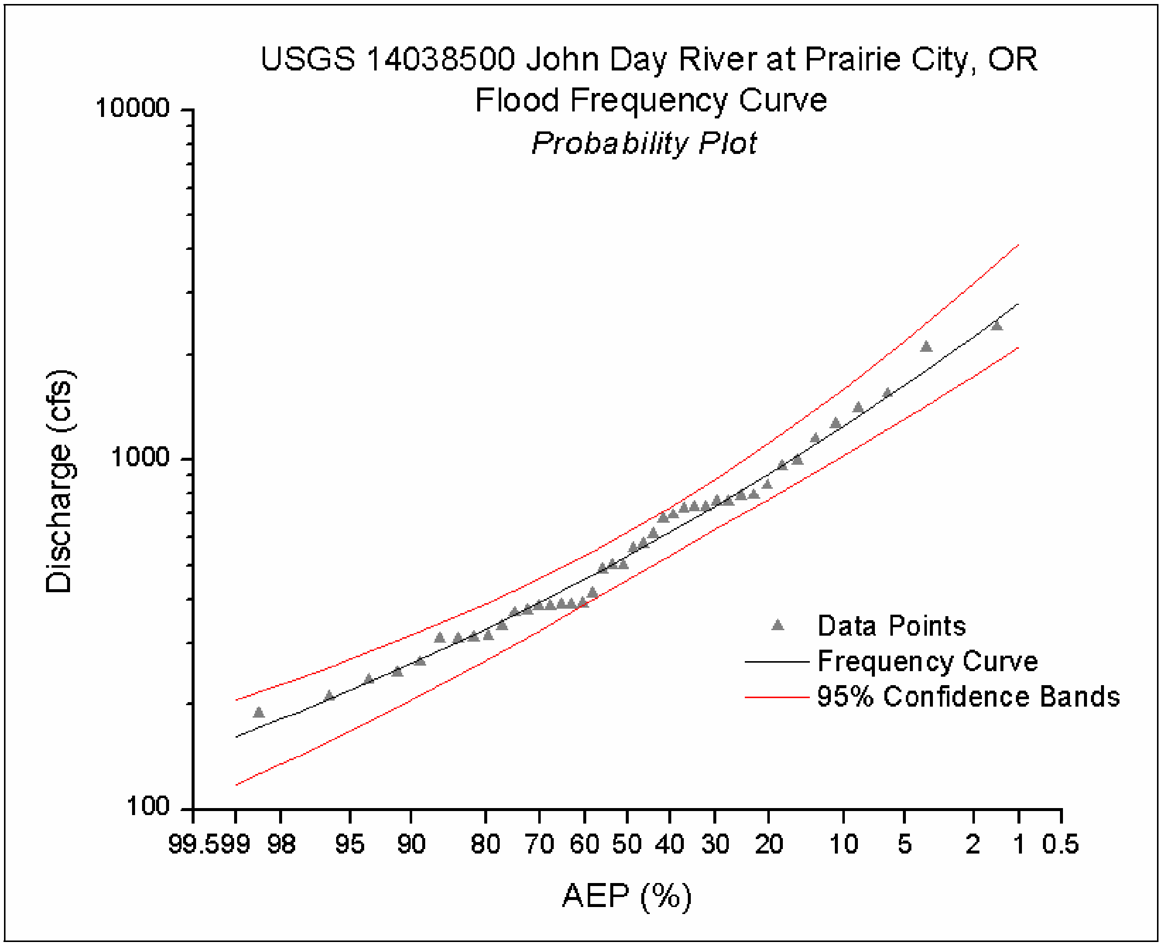

Figure 4 – Upper John Day Flood Frequency Curve

Table 2 – Peak flow data computed for USGS stream gages in the Upper John Day basin.

USGS Gage No.	Description	Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)
14037500	STRAWBERRY CR AB SLIDE CR NR PRAIRIE CITY,OREG.	88	133	167	214	252	294
14038500	JOHN DAY RIVER AT PRAIRIE CITY, OREG.	531	915	1250	1770	2250	2800
14038530	JOHN DAY RIVER NEAR JOHN DAY, OREG.	1324	2504	3464	4867	6042	7324

Peak Flow Calculations at Ungaged Sites with GIS Integration:
Because a stream channel restoration project site could potentially be located along any reach within the Upper John Day basin, peak flow calculations were also computed over the entire basin and incorporated into a geographic information system. The user of the Upper John Day GIS database can easily acquire the desired peak flow information by simply clicking on a potential project site within the basin. This system was created using the watershed processing tools in ESRI's ArcHydro and the USGS publication: *Magnitude and Frequency of Floods in Eastern Oregon, 1983* [2]. The results can vary at individual sites and should be considered tools to represent a range of possible flood frequency values.

A geographic information system was created to quickly access specific peak flow information associated with potential project sites. This system incorporates digital elevation models (DEM's) of the topography, forest cover, mean annual precipitation (MAP), aerial photography, existing stream networks, existing project locations, and a graphical database that contains the peak flow information for the Upper John Day drainage basin's individual sub-watersheds or sub-basins. Once the DEM of the basin is imported into the GIS, ArcHydro delineated all of the sub-basins. For this system, a minimum sub-basin size of 2 mi^2 was selected because most stream channel restoration projects have watersheds greater than this size. After the watershed processing was complete, ArcHydro had created 73 sub-basins within the entire Upper John Day basin. For each of these sub-basins peak flows for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals were calculated based on the regional regression equations for Northeastern Oregon developed by the USGS [2].

Peak Flows at Ungaged Locations in the Upper John Day Basin
Due to the limited amount of available streamflow data within the Upper John Day basin, the regional regression equations developed by the USGS for Northeastern Oregon were used to compute peak flows. The equations listed in *Magnitude and Frequency of Floods in Eastern Oregon, 1983* [2] were developed based on data from 60 stations. Table 3 presents the regression equations developed for Northeast Oregon and the inherent error associated with their results. The equations are a function of basin area, mean annual precipitation, and forest cover, where Q_x is the peak discharge for the x recurrence interval, A is the basin area in mi^2, P is the mean annual precipitation in inches from the NRCS National Water and Climate Center (Figure 5), and F is percent forest cover (Figure 6). According to the National Land Cover Dataset's (NLCD 2001) land cover definitions, forest is considered to have a canopy that covers over 20 percent of the ground. Once the computations for all of the sub-basins were completed, they were integrated in the GIS.

Table 3 – USGS regional regression equations for Northeast Oregon [2].

Recurrence Interval	Equation	Standard Error		
		Log Units	Percent	
			Plus	Minus
Q_2	$0.508A^{0.82}P^{1.36}(1+F)^{-0.27}$	0.259	82	45
Q_5	$2.44A^{0.79}P^{1.09}(1+F)^{-0.30}$	0.254	79	44
Q_{10}	$5.28A^{0.78}P^{0.96}(1+F)^{-0.32}$	0.262	83	45
Q_{25}	$11.8A^{0.77}P^{0.83}(1+F)^{-0.35}$	0.277	89	47
Q_{50}	$19.8A^{0.76}P^{0.75}(1+F)^{-0.36}$	0.280	90	48
Q_{100}	$30.7A^{0.76}P^{0.68}(1+F)^{-0.38}$	0.303	101	50

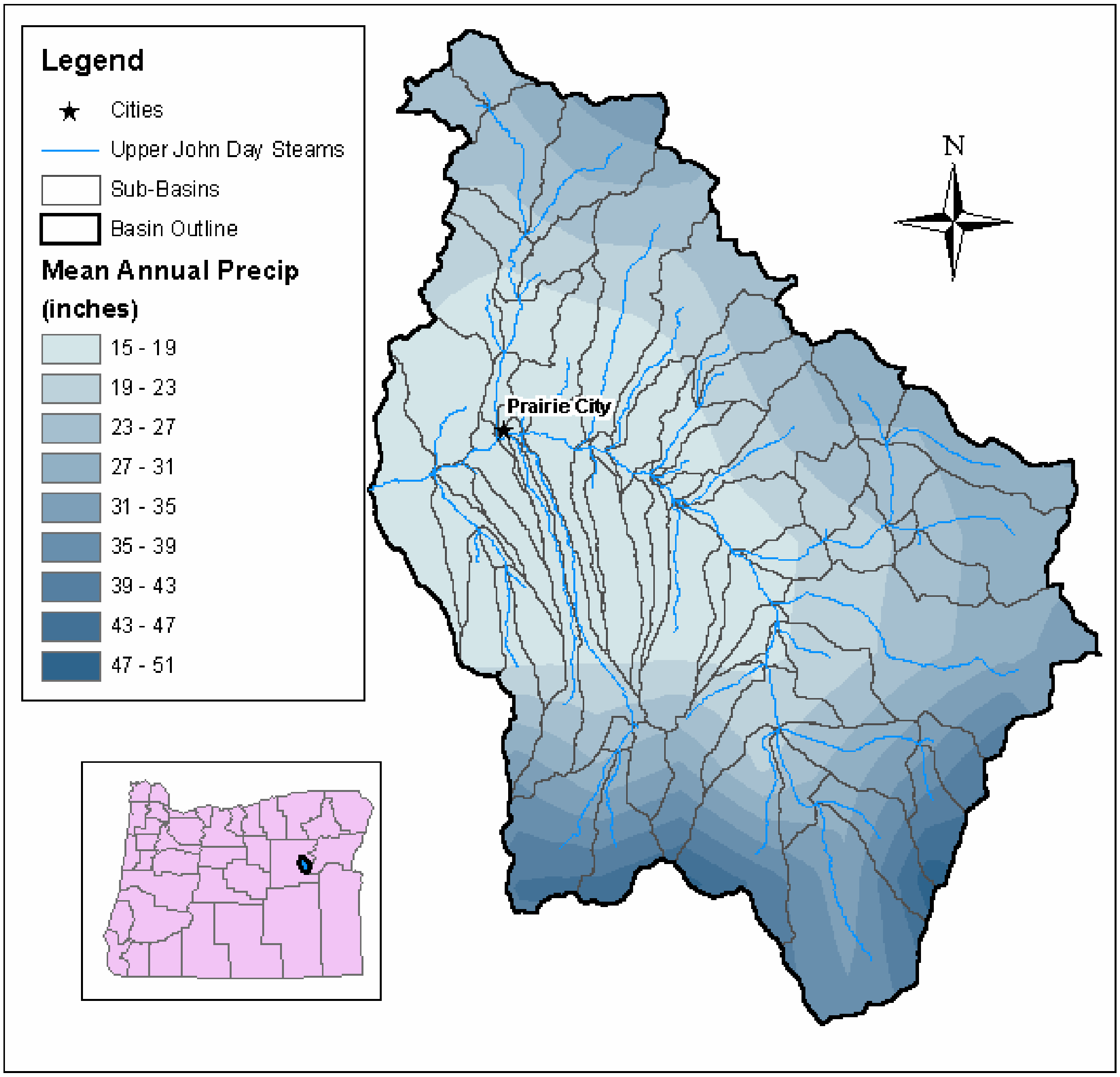

Figure 5 – Upper John Day Mean Annual Precipitation (NRCS).

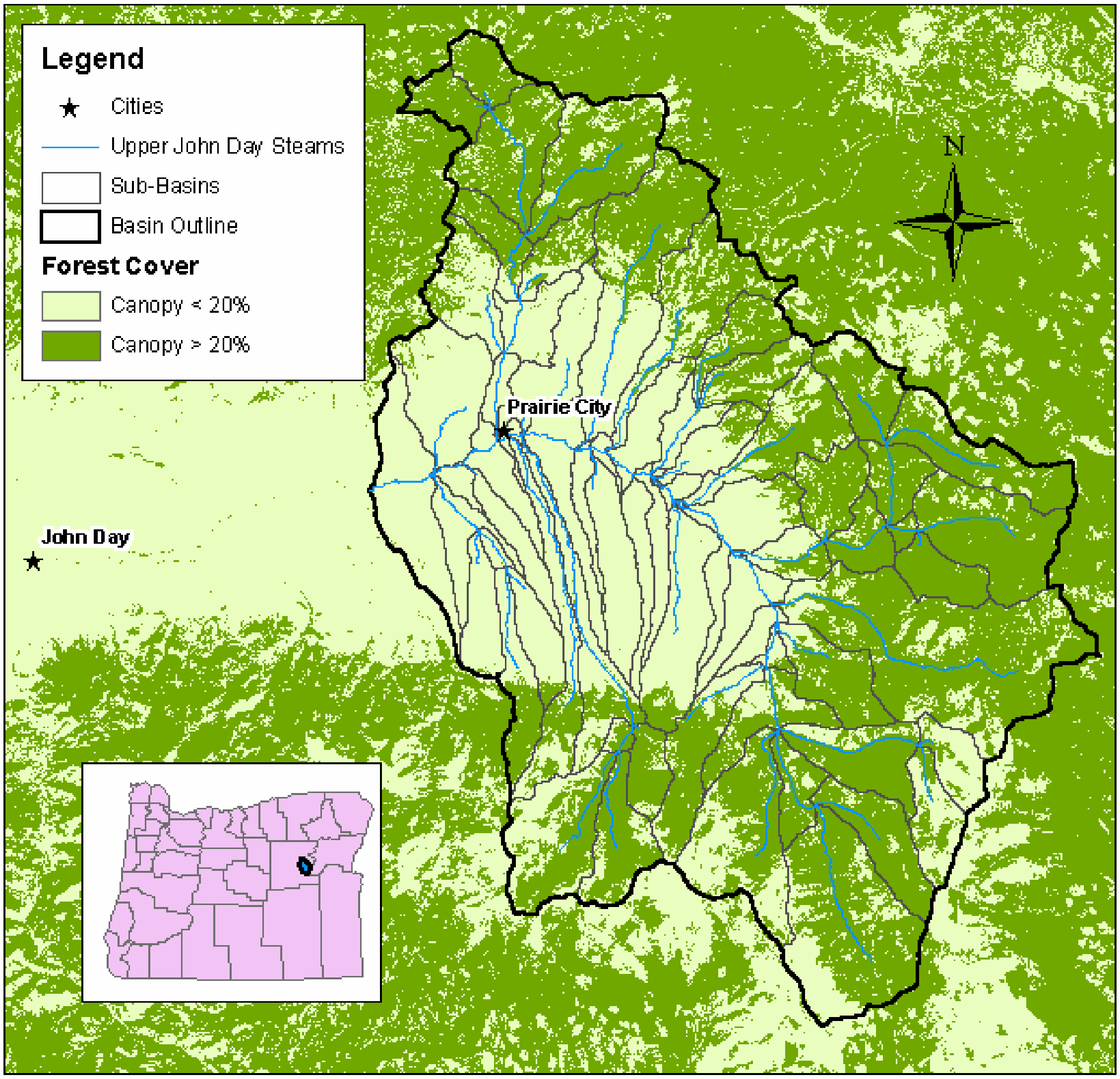

Figure 6 – Upper John Day Forest Cover (NLCD 2001).

Comparison of Peak Flows

The peak flows computed at USGS gages 14037500, 14038500, and 14038530 were compared to the corresponding sets of peak flows computed using the USGS regional regression equations as shown in Table 4. The flows from the regional regression equations have been selected for this report because they are based on data from 60 gage stations and provide more conservative estimates of the peak flows in the Upper John Day basin. The main reason for not using the gage data analysis is because it does not represent runoff conditions for the entire basin. However, if a project location is located immediately upstream or downstream of either gage, then the appropriate gage analysis should be considered. In a previous study entitled *Extension of Natural Flow Data in the Upper John Day River Basin*, an analysis of existing data was completed to produce a seasonal distribution of runoff in order to reduce seasonal water shortages in the basin [3]. Because peak flows were not calculated in this study, a comparison of the results of both reports could not be completed.

Table 4 – Comparison of Peak Flows at USGS Gage Stations.

Peak Flow	USGS Gage Station 14037500				USGS Gage Station 14038500				USGS Gage Station 14038530			
	Gage Data Analysis		Regional Regresion Equations	% Out of Gage Range	Gage Data Analysis		Regional Regresion Equations	% Out of Gage Range	Gage Data Analysis		Regional Regresion Equations	% Out of Gage Range
	Low	High			Low	High			Low	High		
Q2 (ft^3/s)	80	98	122	24%	453	622	1120	80%	1065	1649	1500	0%
Q5 (ft^3/s)	119	151	182	21%	774	1118	1720	54%	1989	3326	2410	0%
Q10 (ft^3/s)	147	194	222	14%	1029	1596	2160	35%	2677	4859	3098	0%
Q25 (ft^3/s)	185	258	268	4%	1407	2411	2680	11%	3622	7293	3969	0%
Q50 (ft^3/s)	214	312	317	2%	1733	3200	3170	0%	4377	9472	4764	0%
Q100 (ft^3/s)	245	372	351	0%	2101	4171	3630	0%	5171	11968	5575	0%

Using the GIS Database

Once the computations for all of the sub-basins were completed, they were integrated into the GIS. The information tool is used to access the data by simply clicking on the sub-basin of interest (Figure 7). Figure 8 is a close up of the attributes displayed for a specific sub-basin. Table 5 lists the descriptions of each attribute in the GIS database.

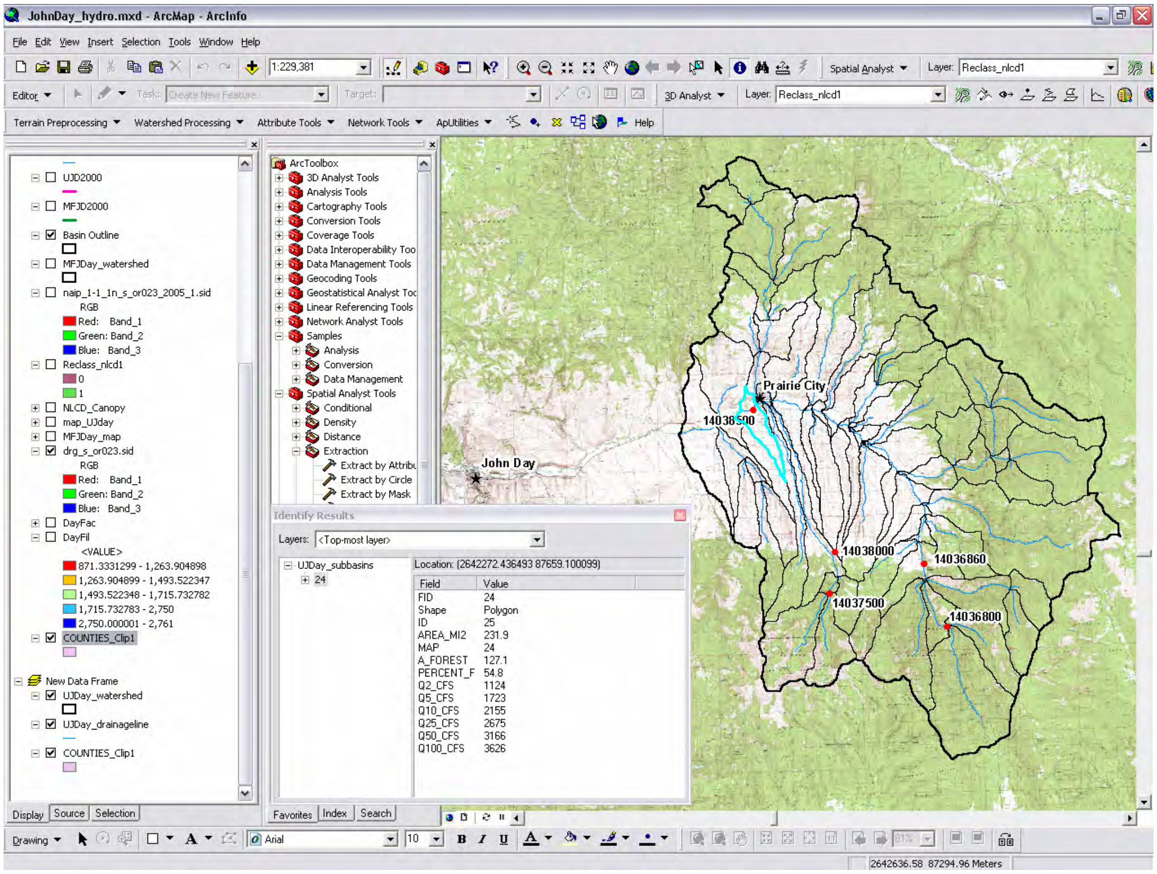

Figure 7 – Accessing the peak flow data in ArcGIS.

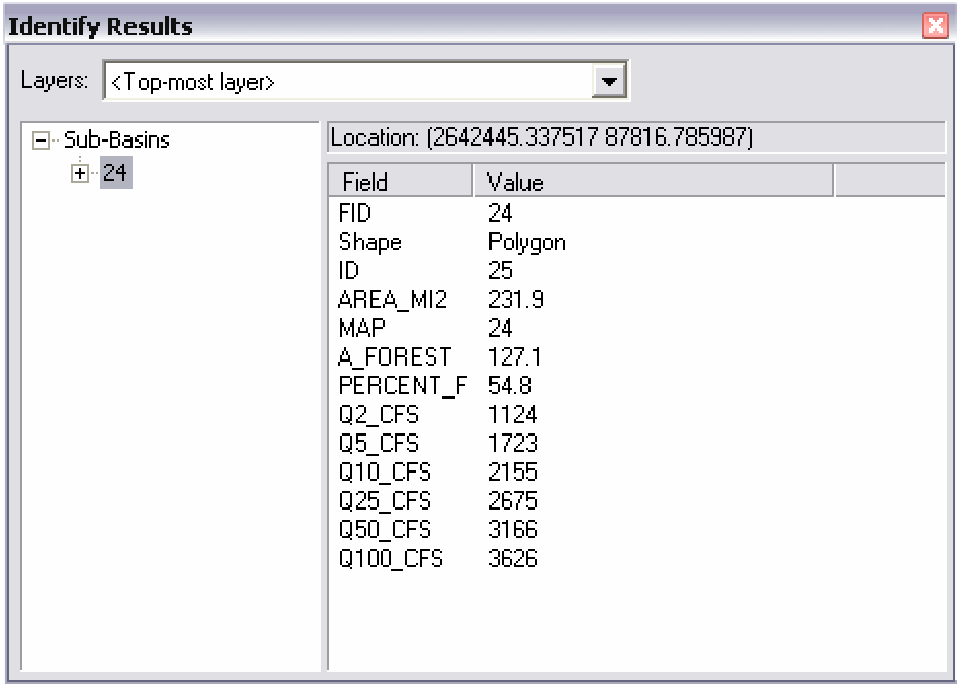

Figure 8 – Output summary example for an ungaged sub-basin.

Table 5 – GIS output description.

Field	Description
AREA_MI2	Sub-basin area in square miles
MAP	Mean annual precipitation in inches
A_FOREST	Area of forest cover in square miles (canopy > 20%)
PERCENT_F	Percent of subbasin that is covered by forest (canopy > 20%)
Q2_CFS	2 year peak flow in cubic feet per second
Q5_CFS	5 year peak flow in cubic feet per second
Q10_CFS	10 year peak flow in cubic feet per second
Q25_CFS	25 year peak flow in cubic feet per second
Q50_CFS	50 year peak flow in cubic feet per second
Q100_CFS	100 year peak flow in cubic feet per second

References:

[1] Guidelines for Determining Flood Flow Frequency, *Bulletin #17B of the Hydrology Committee*, U.S. Department of the Interior, United States Water Resources Council, 1981.

[2] USGS, 1983. *Magnitude and Frequency of Floods in Eastern Oregon, 1983*, U.S. Geological Survey, Water Resources Investigations Report 82-4078.

[3] Belinger, Tom, 2005. *Extension of Natural Flow Data in the Upper John Day River Basin*. U.S. Department of the Interior, Bureau of Reclamation, Lower Columbia Area Office, Portland, Oregon.

Upper John Day River Drainage Basin
Hydrology Data and GIS

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APPENDIX

USGS Gage Station 14038530 – Frequency Analysis

Mean of Logs	Std.Dev	Data Skew	Reg.Skew	Final Skew
3.1156	0.3342	-0.1147	0	-0.1147

RANK	PlotPos	YEAR	Q	EXCEED.	FREQ.Q	LOW	HIGH
1	0.01705	1969	5830	0.99	204	121	295
2	0.04545	1997	4810	0.98	256	160	358
3	0.07386	1971	4000	0.975	277	176	384
4	0.10227	1991	3740	0.96	329	217	446
5	0.13068	1982	3620	0.95	359	241	481
6	0.15909	1986	2680	0.9	483	343	625
7	0.1875	1979	2600	0.8	686	517	863
8	0.21591	1989	2530	0.7	881	687	1095
9	0.24432	1983	2220	0.6	1089	866	1349
10	0.27273	1984	2030	0.5704	1155	922	1432
11	0.30114	1970	1910	0.5	1324	1065	1649
12	0.32955	2005	1770	0.4296	1517	1225	1904
13	0.35795	1993	1680	0.4	1608	1298	2026
14	0.38636	1972	1640	0.3	1974	1588	2540
15	0.41477	1974	1530	0.2	2504	1989	3326
16	0.44318	1998	1530	0.1	3464	2677	4859
17	0.47159	2003	1400	0.05	4510	3387	6655
18	0.5	1981	1360	0.04	4867	3622	7293
19	0.52841	1977	1340	0.025	5653	4130	8737
20	0.55682	1980	1270	0.02	6042	4377	9472
21	0.58523	1975	1200	0.01	7324	5171	11968
22	0.61364	1975	1120	0.005	8718	6008	14805
23	0.64205	1985	941	0.002	10741	7186	19121
24	0.67045	1999	923	0.001	12416	8133	22847
25	0.69886	2004	870	0.0005	14221	9130	26999
26	0.72727	1990	853	0.0001	18940	11647	38445
27	0.75568	2002	773				
28	0.78409	1973	720				
29	0.8125	2000	641				
30	0.84091	1987	603				
31	0.86932	1991	450				
32	0.89773	2001	440				
33	0.92614	1988	380				
34	0.95455	1994	372				
35	0.98295	1977	251				

USGS Gage Station 14038500 – Frequency Analysis

Mean of Logs	Std.Dev	Data Skew	Reg.Skew	Final Skew
2.7445	0.2664	0.4325	0	0.4325

RANK	PlotPos	YEAR	Q	EXCEED.	FREQ.Q	LOW	HIGH
1	0.01422	1964	2400	0.99	162	118	206
2	0.03791	1952	2100	0.98	182	135	228
3	0.06161	1932	1550	0.975	190	142	237
4	0.08531	1939	1400	0.96	209	159	257
5	0.109	1957	1270	0.95	219	168	269
6	0.1327	1948	1150	0.9	262	206	315
7	0.1564	1945	995	0.8	328	268	389
8	0.18009	1956	962	0.7	391	325	459
9	0.20379	1951	846	0.6	457	386	534
10	0.22749	1949	793	0.5704	478	405	558
11	0.25118	1943	790	0.5	531	453	622
12	0.27488	1928	760	0.4296	593	507	696
13	0.29858	1929	760	0.4	621	532	732
14	0.32227	1953	730	0.3	740	632	883
15	0.34597	1942	730	0.2	915	774	1118
16	0.36967	1962	726	0.1	1247	1029	1596
17	0.39336	1958	696	0.05	1633	1310	2191
18	0.41706	1964	680	0.04	1770	1407	2411
19	0.44076	1937	615	0.025	2084	1624	2927
20	0.46445	1953	574	0.02	2245	1733	3200
21	0.48815	1967	560	0.01	2801	2101	4171
22	0.51185	1947	500	0.005	3453	2518	5363
23	0.53555	1963	500	0.002	4485	3154	7353
24	0.55924	1931	487	0.001	5417	3710	9241
25	0.58294	1944	414	0.0005	6502	4339	11528
26	0.60664	1968	388	0.0001	9743	6130	18827
27	0.63033	1955	386				
28	0.65403	1933	385				
29	0.67773	1940	383				
30	0.70142	1937	382				
31	0.72512	1941	370				
32	0.74882	1960	366				
33	0.77251	1945	336				
34	0.79621	1950	315				
35	0.81991	1966	310				
36	0.8436	1961	309				
37	0.8673	1959	309				
38	0.891	1926	264				
39	0.91469	1936	246				
40	0.93839	1934	236				
41	0.96209	1935	210				
42	0.98578	1930	188				

USGS Gage Station 14037500 – Frequency Analysis

Mean of Logs	Std.Dev	Data Skew	Reg.Skew	Final Skew
1.9545	0.205	0.2473	0	0.2473

RANK	PlotPos	YEAR	Q	EXCEED.	FREQ.Q	LOW	HIGH
1	0.0098	1983	354	0.99	33	27	38
2	0.02614	1974	274	0.98	36	30	42
3	0.04248	1986	205	0.975	38	31	44
4	0.05882	1948	172	0.96	41	34	47
5	0.07516	1956	170	0.95	43	36	49
6	0.0915	1958	168	0.9	50	43	56
7	0.10784	1984	162	0.8	60	53	67
8	0.12418	1957	162	0.7	69	62	77
9	0.14052	1933	150	0.6	78	71	87
10	0.15686	1972	149	0.5704	81	73	90
11	0.1732	1970	148	0.5	88	80	98
12	0.18954	1982	141	0.4296	96	87	106
13	0.20588	1955	138	0.4	100	90	111
14	0.22222	1965	119	0.3	114	103	127
15	0.23856	1975	113	0.2	133	119	151
16	0.2549	1967	110	0.1	167	147	194
17	0.27124	1949	108	0.05	202	175	241
18	0.28758	1952	104	0.04	214	185	258
19	0.30392	1989	104	0.025	240	205	294
20	0.32026	1954	102	0.02	252	214	312
21	0.3366	1960	100	0.01	294	245	372
22	0.35294	1971	98	0.005	339	278	438
23	0.36928	1987	97	0.002	404	325	538
24	0.38562	1991	97	0.001	458	363	622
25	0.40196	1953	96	0.0005	516	404	716
26	0.4183	1932	96	0.0001	672	509	973
27	0.43464	1979	95				
28	0.45098	1938	91				
29	0.46732	1936	89				
30	0.48366	1985	88				
31	0.5	1946	87				
32	0.51634	1961	86				
33	0.53268	1942	86				
34	0.54902	1951	84				
35	0.56536	1950	84				
36	0.5817	1964	83				
37	0.59804	1959	83				
38	0.61438	1943	82				
39	0.63072	1963	81				
40	0.64706	1980	78				
41	0.6634	1947	78				
42	0.67974	1978	75				
43	0.69608	1981	73				
44	0.71242	1941	73				
45	0.72876	1945	71				
46	0.7451	1940	71				
47	0.76144	1973	70				
48	0.77778	1937	67				
49	0.79412	1976	65				
50	0.81046	1935	62				
51	0.8268	1962	61				
52	0.84314	1988	60				
53	0.85948	1969	60				
54	0.87582	1968	54				
55	0.89216	1931	51				
56	0.9085	1939	50				
57	0.92484	1944	47				
58	0.94118	1966	41				
59	0.95752	1990	36				
60	0.97386	1934	33				
61	0.9902	1977	30				

USGS Gage Station 14044000 – Frequency Analysis

Mean of Logs	Std.Dev	Data Skew	Reg.Skew	Final Skew
3.2335	0.213	-0.2422	0	-0.2422

RANK	PlotPos	YEAR	Q	EXCEED.	FREQ.Q	LOW	HIGH
1	0.00787	1965	4730	0.99	502	405	594
2	0.021	1997	4540	0.98	587	484	685
3	0.03412	1932	4000	0.975	620	514	719
4	0.04724	1991	3860	0.96	697	588	800
5	0.06037	1996	3370	0.95	740	628	845
6	0.07349	1989	3360	0.9	903	785	1014
7	0.08661	1955	3330	0.8	1141	1016	1262
8	0.09974	1986	3330	0.7	1344	1212	1477
9	0.11286	1974	3310	0.6	1541	1399	1690
10	0.12598	1952	3010	0.5704	1600	1455	1756
11	0.13911	1993	2940	0.5	1746	1591	1918
12	0.15223	1972	2790	0.4296	1903	1735	2096
13	0.16535	1982	2680	0.4	1974	1799	2177
14	0.17848	1971	2620	0.3	2245	2040	2494
15	0.1916	2005	2580	0.2	2599	2348	2922
16	0.20472	1978	2560	0.1	3165	2823	3630
17	0.21785	1984	2560	0.05	3704	3263	4325
18	0.23097	1948	2500	0.04	3873	3399	4548
19	0.24409	1970	2470	0.025	4227	3681	5019
20	0.25722	2002	2440	0.02	4394	3813	5242
21	0.27034	1983	2430	0.01	4908	4214	5941
22	0.28346	1975	2410	0.005	5417	4607	6645
23	0.29659	2004	2390	0.002	6088	5117	7589
24	0.30971	1957	2240	0.001	6594	5497	8312
25	0.32283	1999	2160	0.0005	7101	5874	9045
26	0.33596	1943	2110	0.0001	8281	6739	10782
27	0.34908	1936	2020				
28	0.3622	1953	1990				
29	0.37533	1998	1980				
30	0.38845	1931	1960				
31	0.40157	1958	1960				
32	0.4147	2003	1950				
33	0.42782	1939	1920				
34	0.44094	1995	1900				
35	0.45407	1946	1850				
36	0.46719	1985	1800				
37	0.48031	1979	1790				
38	0.49344	1938	1780				
39	0.50656	2000	1720				
40	0.51969	1969	1680				
41	0.53281	1976	1680				
42	0.54593	1940	1670				
43	0.55906	1937	1650				
44	0.57218	1951	1630				
45	0.5853	1933	1560				
46	0.59843	1990	1540				
47	0.61155	1981	1500				
48	0.62467	1935	1470				
49	0.6378	1942	1450				
50	0.65092	1994	1440				
51	0.66404	1949	1440				
52	0.67717	1964	1410				
53	0.69029	1960	1380				
54	0.70341	1963	1350				
55	0.71654	1962	1330				
56	0.72966	1977	1270				
57	0.74278	1945	1270				
58	0.75591	1987	1260				
59	0.76903	1967	1260				
60	0.78215	1966	1160				
61	0.79528	1950	1140				
62	0.8084	1947	1100				
63	0.82152	1958	1090				
64	0.83465	1968	1090				
65	0.84777	1980	1090				
66	0.86089	1954	1030				
67	0.87402	2001	999				
68	0.88714	1955	942				
69	0.90026	1973	865				
70	0.91339	1941	774				

Appendix D: Geomorphic Investigation of the Middle Fork John Day River

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1.0 Introduction to the Assessment Area

The assessment area on the Middle Fork John Day River is a 23-mile section of the river located between Camp Creek and Crawford Creek. In addition, the lower reach of Clear Creek (0.5 miles), a tributary to the Middle Fork, is considered in this assessment. Within the assessment area, land ownership is predominantly private, with some federal ownership by the Malheur National Forest. The assessment area offers unique opportunities for salmonid habitat restoration due to land ownership by the Nature Conservancy and the Confederated Tribes of the Warms Springs Reservation of Oregon.

The assessment area was identified by the relative opportunity to improve salmonid habitat conditions within the Middle Fork John Day River. In addition to land ownership considerations, the assessment area covers the highest biological priority area as identified in the John Day River Draft Subbasin Plan (NPCC 2005). Currently existing efforts throughout the basin are focusing on restoration of salmonid habitat through recovery programs and intensive monitoring. This geomorphic assessment presents additional management considerations and guidance to local stakeholders, planners, and managers for improving salmonid habitat in the Middle Fork John Day River.

The approach of this assessment was to first develop a conceptual model of typical channel processes that could be present under fully functioning or “ideal” conditions based on historical accounts of the basin, a current understanding of historic impacts to the systems, and knowledge of similar systems with less human disturbance. The second phase of the assessment was to evaluate the present conditions of each subbasin using geomorphic and vegetation mapping in GIS, LiDAR data, and channel stability analyses. Conditions of the present setting were compared to the conceptual model of fully functioning conditions to depict how and why physical processes that shape and maintain habitat have changed in the last 100 years. Finally, a qualitative description of how the processes may be impacted by restoration and protection actions was documented. This strategy supports the identification of restoration and protection actions that provide the best opportunities for long-term improvements to habitat for spring Chinook and steelhead.

2.0 Conceptual Model of Typical Channel Processes

2.1 *Floodplain Types and Channel Dynamics*

2.1.1 Introduction

Because limited information is available to characterize the conditions of the river in its pre-development state, a conceptual model of "ideal" or fully functioning conditions was generated through our understanding of the present system, historical accounts of the basin, and current knowledge of similar systems with less human disturbance. Within the Middle Fork John Day River, three general floodplain types were identified, including:

- Wide, unconfined floodplain with high complexity.
- Moderately confined floodplain with medium complexity.
- Narrow, confined floodplain with low complexity.

The degree of complexity within the floodplain refers to the availability of off-channel habitat due to large woody debris (LWD), side channels, wide-ranging vegetation, groundwater inputs, and diverse patterns of hydraulics and sediment. The relative degrees of complexity described in this document refer to the Middle Fork John Day River and may vary within other basins. In other words, a highly complex, wide, and unconfined floodplain within the Middle Fork may differ from the same description used to describe the floodplain of another river system due to large-scale controlling variables of hydrology, geology, and topography. Typical channel processes associated with each of the floodplain types hypothesized to represent fully functioning conditions are described in detail below.

One data gap of this assessment is our ability to characterize the vegetation types and abundance that were present prior to basin development. As such, our understanding of fully functioning vegetation configurations within the floodplain types has some uncertainty. Each of these following descriptions of floodplain types represent hypothesized fully functioning conditions that could be present in the system.

2.1.2 Wide, Unconfined Floodplain with High Complexity

2.1.2.1 Topographic Features

Highly complex floodplains could be present in wide, unconfined valleys of the Middle Fork (Figure 1). Compared with more confined floodplain types, this type generally consists of flatter slopes and larger supplies of sediment and LWD in storage in the floodplain and river channel. A highly sinuous main channel could frequently interact with the floodplain through a complex network of multiple side and overbank channels (Figure 2). This high degree of floodplain interaction would allow lateral channel migration and support the dynamic cycle of conversion from river to floodplain and vice versa. This dynamic process could maintain a healthy riparian forest that provides ample shade, complexity, and the ability to re-establish upon new floodplain deposits as others are eroded. Within the floodplain, some areas are older and slightly higher than the active channel, but these areas can be activated under repeated or high flow flooding.

Figure 1 – Present-Day Example of a Wide, Unconfined Floodplain Topographic Features, Reach 13. Historic floodplains of this type were likely much more complex.

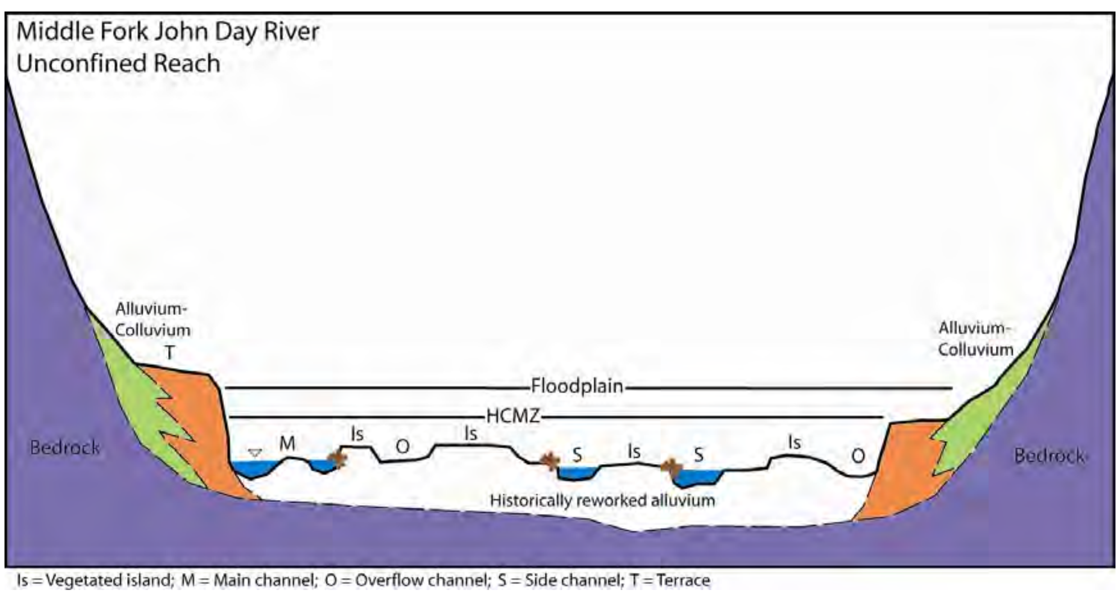

Figure 2 – Schematic Cross Section of Wide, Unconfined Floodplain in the Middle Fork Assessment Area.

2.1.2.2 Groundwater-Floodplain Interaction

The interaction between water in the river and the groundwater table has the potential to be highly dynamic and could be an important part of the aquatic habitat. This floodplain type typically consists of alluvium that allows a dynamic interaction between the river and groundwater. High winter and spring flows inundate the floodplain and can be stored within the alluvial aquifer and within wet meadow environments. Springs from adjacent alluvial aquifers could help maintain wet floodplains, at least on a seasonable basis. If present, beavers would add to floodplain and channel complexity through the addition of logs and debris dams, which help to preserve an inundated floodplain environment during part of the year and add to base flows during lower flow periods.

2.1.2.3 Lateral Migration/Channel Avulsions

In these reaches, multiple channels could become wetted during low flow conditions, part of which may result from springs and the slow seepage of groundwater stored within the floodplain. Under larger flow events or over several years, localized patterns of erosion and deposition could occur as the channel migrates laterally across the floodplain and meanders slowly migrate downstream. During a single high flood event (more than 10-year recurrence interval), a side or main channel may become plugged due to a sediment wave or a log jam and the inability of the channel to continue to transport the material downstream. This process could lead to the abandonment of the channel and possibly the creation or enlargement of an alternative path. Channel avulsions have the potential to cause localized increases in channel slopes, but the average channel bed elevations within the reach are typically unaffected over the long term, and no net changes occur in the total volume of sediment stored in the reach beyond a natural range of fluctuation. This type of floodplain is typically in a state of dynamic equilibrium. Following episodic natural events, such as a fire, flood, or landslide, the river system has the potential to adjust to changes in the balance of wood, sediment, or stream flow through alteration in channel planform, slope, and geometry until a new equilibrium condition can be reached.

2.1.2.4 LWD and Riparian Vegetation

In wide, unconfined, and highly complex floodplain reaches, erosion of functioning habitat areas could be as important as the creation of new habitat areas and could frequently add to the complexity of the new habitat areas. Riparian vegetation and LWD could moderate rates of floodplain reworking within these floodplains. Log jams may become established in the main and side channel areas and at the head of bars, promoting downstream deposition. The unique hydraulic and sediment patterns associated with the log jams cause the formation of deep scour pools that create valuable holding habitat, maintain connectivity with the hyporheic zone, and provide thermal refugia. Log jams can also promote the accumulation of deposits of fine sediment and organic materials, which form a growing medium for vegetation. LWD has the potential to create stable hard points that allow vegetated islands to persist, slow the rate of channel migration across the floodplain, and create backwater habitats. The persistence of vegetated islands and point bars formed as a result of the LWD may be vital to the continued growth of the vegetation, increased channel roughness, and ultimately to the contribution of LWD once it is eroded.

2.1.2.5 Spawning, Rearing, and Holding Habitat

From a biological perspective, the smaller sediment, complexity of channels and floodplain, and presence of LWD creates and maintains more spawning and rearing habitat for steelhead and spring Chinook than other types of reaches. Areas with cold water recharge, such as springs and tributaries, provide localized patches of high spawning and rearing use and offer the best holding pools for adult salmon. This thermal refugia can be particularly important in river reaches where water quantity is low and temperatures are high during drought years or late summer conditions. Scour holes developed by LWD and root wads could also contribute significant thermal refugia during low flow conditions.

2.1.3 Moderately Confined Floodplain with Medium Complexity

2.1.3.1 Topographic Features

Moderately confined floodplains generally consist of a more defined main channel and fewer well-defined side channels compared with the high complexity floodplains (Figure 3 and Figure 4). Although the majority of water and coarse sediment can be conveyed through the main channel, some side channels may have potential to support habitat, particularly in locations where groundwater supplements the supply during low-flow conditions. Older surfaces present within the floodplain are higher and more stable than the surfaces of the unconfined floodplain areas. These surfaces may become inundated under large magnitude floods but can not be reworked as rigorously as lower, more frequently activated floodplain surfaces. Only fine sediments, carried in suspension, can be deposited on and removed from these surfaces.

Figure 3 – Example of a Moderately Confined Floodplain in Reach MF5.

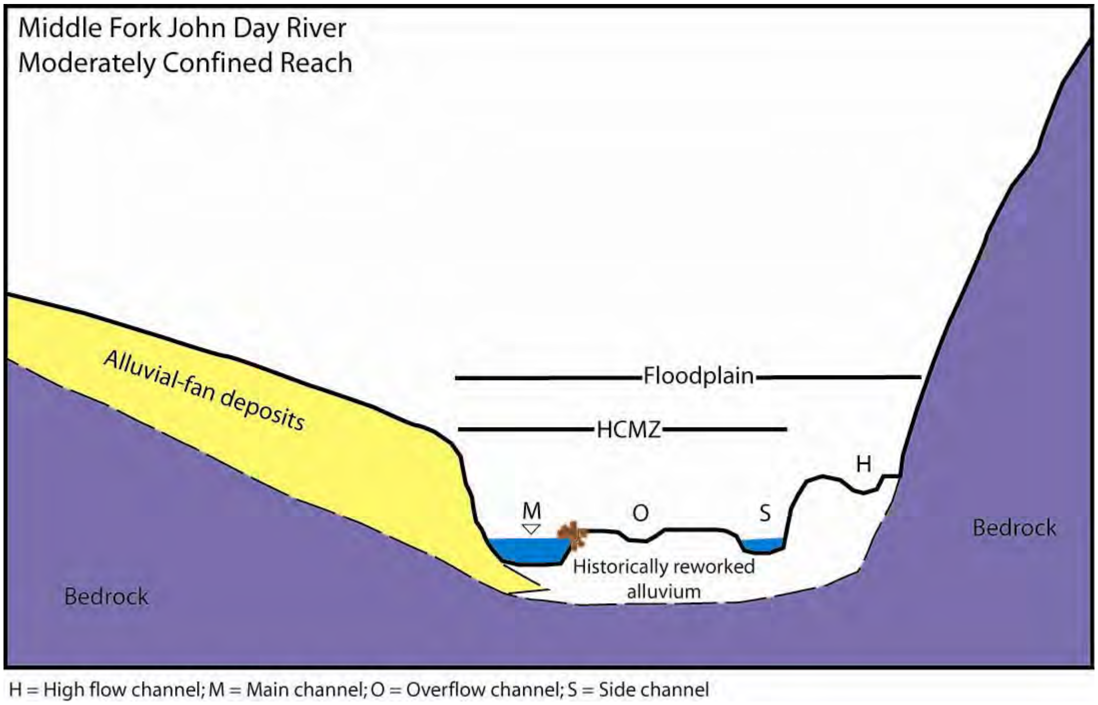

Figure 4 – Schematic Cross Section of a Narrower, Moderately Confined Floodplain in the Middle Fork Assessment Area.

2.1.3.2 Groundwater-Floodplain Interaction

Wet meadows and seasonally flooded surfaces could occasionally be present in the off-channel areas of these reaches. High winter flows and spring snowmelt probably recharge the alluvial aquifers within the moderately confined reaches. The amount of potential floodplain storage is generally less than that of the high complexity floodplains, but still aids in maintaining base flows during summer months. Beaver activity could be common, particularly within the areas with more dense riparian vegetation.

2.1.3.3 Lateral Migration/Channel Avulsions

Compared with high complexity, unconfined reaches, lateral reworking of the floodplain typically occurs less frequently in this floodplain type due to a greater percentage of older and higher surfaces. Channel avulsions could more commonly occur within the main channel and possibly within a few defined side channels rather than across the entire floodplain. The main channel probably remains in one place with only minor lateral channel adjustment for several years to decades.

2.1.3.4 LWD and Riparian Vegetation

Similar to unconfined floodplain, LWD and riparian vegetation could play an important role in creating both floodplain and off-channel complexity features. With a lesser tendency toward wet meadows, the riparian buffer zone could be been thicker than in unconfined reaches. Riparian vegetation could slow near-bank velocities, create shade, provide organic leaf litter and wood recruitment to the channel, and reduce the rate of bank erosion. LWD could most commonly be present in the slower velocity off-channel areas. Log jams could frequently occur at the head of vegetated islands as in the unconfined floodplain types.

2.1.3.5 Spawning, Rearing, and Holding Habitat

Moderately confined floodplains generally do not have as much potential for off-channel habitat complexity as unconfined floodplains, but they could still contain a wide variety of habitat components and complexity, and could support a range of fish species and life cycles. Off-channel areas could likely support spawning and rearing of spring Chinook and steelhead. Within the main channel, spawning grounds could be suitable for steelhead and spring Chinook, and some holding pools could provide adequate shade and predation cover for adults. Spawner escapement can be dynamic due to the variability of hydrologic conditions. In lower flow years, redds that establish in riffles and in higher velocity areas have greater potential for success as high freshets can not mobilize and disrupt the nests. However, redds embedded at the edge of the wetted channel may be subject to desiccation. In higher flow years, redds in the riffles could be washed out, but redds at the edges of the channel may have greater success. Within these reaches, local recharge areas, such as locations surrounding groundwater and tributary inputs, provide refuge during low-flow conditions.

2.1.4 Narrow, Confined Floodplain with Low Complexity

2.1.4.1 Topographic Features

The third typical floodplain type consists of confined, straight channel reaches with little to no off-channel habitat (Figure 5 and Figure 6). In most confined reaches, adjacent hillslopes dramatically increase above the floodplain surface. These surfaces are likely inundated only during paleoflood events. In a few of the confined reaches, alluvial fans and terraces may not have quite as dramatic hillslopes and may be inundated during 50- to 100-year flood events. Bedrock provides vertical and lateral geologic controls on channel position. Chanel slopes within confined floodplains are typically substantially greater than slopes in moderately confined and unconfined floodplains.

Figure 5 – Example of a Confined Floodplain, Reach MF4, at Big Boulder Creek Confluence.

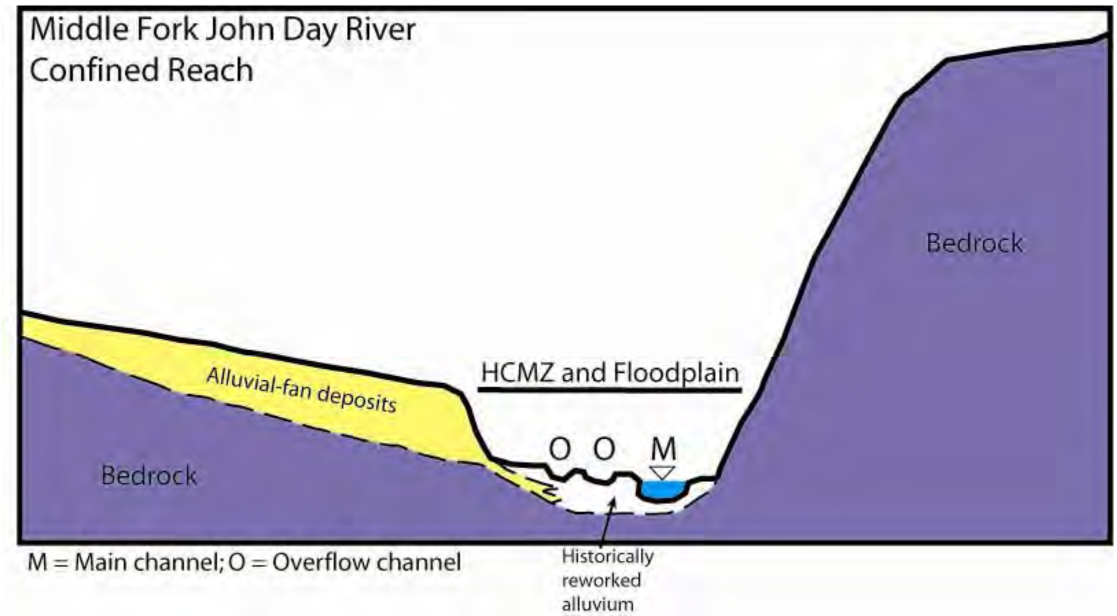

Figure 6 – Schematic Cross Section of a Narrow, Confined Floodplain Section in the Middle Fork Assessment Area.

2.1.4.2 Groundwater-Floodplain Interaction

The interaction between the groundwater and the floodplain within the confined reaches is much more limited than in moderately confined and unconfined reaches as potential for floodplain storage capacity is low. However, groundwater input to these reaches from alluvial features and bedrock aquifers may be present. Inputs from springs or groundwater upwellings through the hyporheic zone may augment base flows and provided thermal refugia.

2.1.4.3 Lateral Channel Migration/Channel Avulsions

Within the confined reaches, sediment sizes range from coarse gravel to large boulders, with most of the smaller material being transported through the reach. These reaches are primarily supply limited and contain small quantities of sediment in storage for reworking. Potential for lateral channel migration is limited within a small migration zone due to the inability of the channel to mobilize large boulders and erode bedrock. Channel migration and avulsions are generally limited and could only occur in small stretches of wider floodplain.

2.1.4.4 LWD and Riparian Vegetation

Most of the potential for habitat complexity within these floodplain types is in-channel habitat complexity, which could result from LWD, organic inputs from adjacent hillslopes, and variability in sediment sizes. Riparian vegetation could be present on narrow floodplain surface and on some established sediment bars. This vegetation could be a LWD recruitment source for downstream reaches. Furthermore, the steep sloping valley walls may provide additional LWD inputs and occasional mass wasting of portions of hillsides. LWD in the channel is generally limited due to the high ability of the channel to transport wood, but could occasionally be present on bars or on the upstream sides of exposed boulders in the bed. During floods, river stage increases faster than the wetted width, and the same area is consistently reworked during each flood; however, riparian vegetation requires fresh, bare soil to establish. Riparian vegetation cycles in these reaches as a function of the hydrologic regime. During a period of dryer years, the riparian vegetation can establish. Once in a while, a rare large flood occurs that erodes the vegetation and restarts the cycle by providing a fresh surface on which new vegetation could potentially establish.

2.1.4.5 Spawning, Rearing, and Holding Habitat

Despite limited off-channel habitat, these reaches could have important habitat functions. While some species may have success spawning in confined reaches, spring Chinook and steelhead probably use these reaches as holding and migration corridors to upstream or downstream reaches. Pockets of slower-velocity flows behind occasional boulders provide resting areas and cold water inputs from tributaries provide thermal refugia. In-channel LWD and dense riparian vegetation could provide canopy cover and predation protection to younger age classes.

2.2 Pre-Development Habitat Conditions

Although little data is available to document pre-development aquatic habitat, anecdotal accounts during the early years of settlement and land use changes throughout the basin since the late 1800s indicate that habitat conditions were likely different than today. The John Day Subbasin Plan (NPCC 2005) describes the historical condition of the river as being relatively stable with substantial riparian cover, good summer streamflows, and high water quality. Historical accounts portray the streambanks as having dense growths of aspen, poplar, and willow (Wismmar et al. 1994). Early explorations of the region indicate that summer flows and beaver populations were greater than they are today (Binns 1967).

Under fully functioning conditions, channel erosion rates could be moderated by healthy streambank vegetation, LWD, and stream energy dissipation due to floodplain connectivity. Flow and sediment could be transported through the system in a manner that maintains channel planform and geometry without substantial rates of aggradation and degradation over the long term. USFS (1998) hypothesized that highly sinuous channels historically existed in wide valleys of the Middle Fork and were dominated by classic wet meadow systems. Both beaver activity and frequent fires could contribute to the vitality of riparian hardwood forests (USFS 1998). The abundance of beaver dams could create pools and wet meadow/hardwood floodplain. The presence of greater quantities of woody debris could result in high-quality pool habitat, side channel connectivity, and overall increased habitat diversity (USFS 1998).

Prior to development, patterns of streamflow were likely different than those of present day. Beaver dams have the potential to significantly impact the storage of water in the floodplain, the subsequent slow release of stored water during base flow conditions, and energy dissipation characteristics during flood flows. The lack of roads in a watershed reduces the opportunity for channelization of runoff and increases interception of flows into the ground. Pre-development streamflow patterns were not affected by water diversions during critical times of the year, which likely increased water quantity and quality required for healthy anadromous fish runs. Year-to-year fluctuations in fish runs may partially depend upon the hydrologic conditions. According to the USFS (1998), frequent low intensity fires thinned the forests, increased the percentage of precipitation entering the streams, and reduced conifer encroachment into the wet meadows.

The earliest documented habitat surveys in the Middle Fork were conducted in the 1940s by the U.S. Fish and Wildlife Service. At the time of the initial surveys in fall of 1942, the surveyors identified numerous shallow riffles and adequate resting pools in the lower 25 miles of the river. They also suggest that the Middle Fork contained extensive areas of potential spawning habitat that were not useable because gold dredge mining on the Dewitt Ranch had covered the stream bed with silt. A repeat survey conducted in late spring of 1944 (following two years without mining) found very little remaining silt on the stream bed. These early surveyors described the historic value of the Middle Fork of the John Day River:

> *"The Middle Fork at one time was an excellent producer of Chinook salmon and steelhead trout, and at the present time it has good potential fisheries value."*

Most anecdotal reports suggest that fish populations were much greater near the turn of 20th century (Grant 1993; Neal et al. 1998). Some reports describe salmon runs with such ubiquity that you could not ride a horse through the river without stepping on them (Grant 1993). Table 1 shows estimated historic populations of summer steelhead and spring Chinook. ODFW estimates current populations in the Middle Fork and Upper Mainstem between 2,500 and 3,000 for summer steelhead and between 900 and 1,400 for spring Chinook. A historic run of fall Chinook has become almost entirely extinct (Wissmar et al. 1994).

The present lack of habitat diversity, high water temperatures, and poor water quality within the stream may in large part be attributed to degradation of the riparian corridor, channel straightening, disconnection of the floodplain and side channels, reduction in beaver populations, mechanical removal of LWD, and reduction in LWD recruitment potential. Although natural disturbance regimes (e.g., fires and floods) likely caused episodic disruptions in habitat quality, the level and persistence of the impacts were not sufficient to result in long-term degradation of habitat conditions in the Middle Fork.

Table 1 – Professional Judgment Estimated Historic Average Adult Populations (NPCC 2005).

	Summer Steelhead	Spring Chinook
Middle Fork John Day	10,934	7,680
Upper John Day*	10,164	6,280
Total John Day	70,000	40,000

* Upper/Lower John Day split occurs at the confluence of the South Fork John Day

2.2.1 Potential Natural Vegetation Community

The potential natural community is a biotic community that could be established if all successional sequences were completed without the interference of human activities (Winward 2000). This healthy riparian area is important for maintaining the structure and function of aquatic ecosystems (Platts 1991). The potential community in the Middle Fork Assessment Area may consist of similar reaches of wet meadow and forested reaches; however, little information is available to determine the potential natural community with certainty. Wet meadows could be present in wide, flat and unconfined floodplains, but some woody species, such as alders, willows, and cottonwoods, could likely persist in these areas as well. Based on the currently available information, it is difficult to determine which areas may have contained wet-meadows prior to land use changes. Some of the areas which are now grass meadows have potential to contain more sedge species. Because of possible floodplain draining and livestock grazing, these areas may have changed to grass-dominated species. The total amount of trees and shrubs within the floodplain was probably greatly reduced following the introduction of sheep and then cattle grazing.

3.0 Delineation of Process-Based Reaches

Process-based reaches were defined primarily by physical characteristics that dominate channel function, and shape and maintain habitat features. Initially, geologic controls, such as alluvial fans and bedrock outcrops, were identified through field evaluation of the assessment area. Other physical characteristics used in identifying the reaches included valley confinement, tributary inputs of flow and sediment, and present riparian vegetation. Geomorphic processes that result from the physical characteristics of the river were evaluated to further define reach characteristics. Examples of geomorphic processes include changes in channel form and position, channel slope, sediment transport capacity, and notable areas of erosion or deposition.

Within some reaches, small sections are present that have different characteristics than those of the rest of the reach. However, these sections are not separated into unique reaches because they do not affect the overall character of the longer reach. These short sections are significant locally, and could affect habitat and potential project alternatives in that area.

Longitudinal boundaries of the reaches are generally located at geologic constriction points, such as bedrock or large alluvial-fan deposits that impart lateral and often vertical limits to channel change. Geologic controls may influence the transition of channel processes between adjacent reaches. For example, channel position in one reach may be controlled by a downstream constriction point through which the channel must travel. Other processes, such as sediment transport, may not be constricted at these points and depend more on the ability of the downstream reach to transport incoming sediment. These processes are discussed in more detail in the following chapter. Figure 7 illustrates the delineation of 20 reaches in the Middle Fork by floodplain type. The Clear Creek reach (CC1) is not shown on the graph, but is an unconfined reach that flows into the Middle Fork between reaches MF15 and MF16.

The lateral boundaries of each reach are defined by the extent of the floodplain, referred to as the “low surface” in this assessment. The low surface is composed of the active channel (unvegetated main channel and sediment bars), side channels, vegetated islands, and the adjacent floodplain.

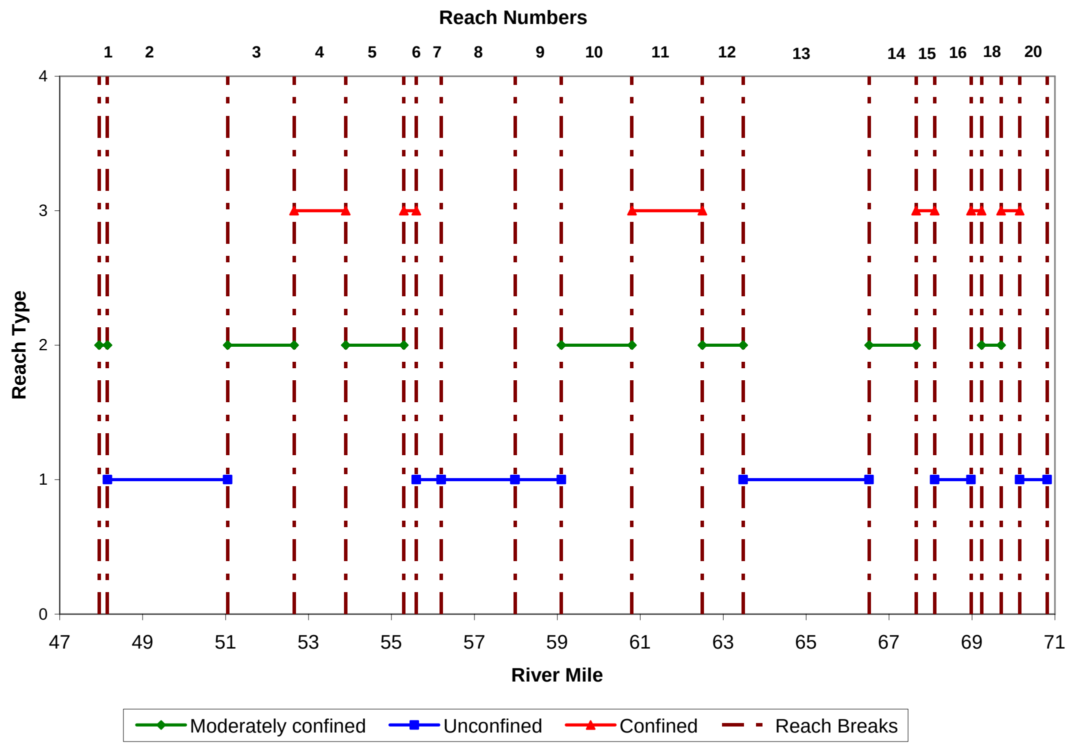

Figure 7 – Middle Fork Assessment Area Delineation of Reaches by Floodplain Type.

4.0 Geologic and Geomorphic Characterizations of the Assessment Area

4.1 Formation of the Middle Fork Geology

Throughout the Cenozoic era, the Blue Mountains province has experienced a stress regime of extension with localized compression related to the convergence of the Pacific and North American plates. This stress regime is the result of the direction of subduction as the Pacific plate converged northeast (oblique) beneath the North American plate (Walker, 1990a). This extensional deformation structurally raised (uplifted) the Blue Mountains province and created fold (e.g., anticlines and synclines) and fault structures across the region (Walker 1990). The Middle Fork of the John Day River (Middle Fork) is structurally controlled in that it has been constrained since at least the Miocene epoch within the Middle Fork syncline bordered to the north by the Dooley anticline and to the south by the Dixie anticline (Figure 8).

In the Middle Fork valley, the river flows over four distinct bedrock types. These bedrock types include the Miocene epoch Columbia River Group downstream of Bear Creek, Mesozoic era metasedimentary and metavolcanic rocks between Bear Creek and Gibbs Creek, Eocene to Oligocene epochs Clarno Formation between Gibbs Creek and Deerhorn Creek, and Miocene epoch Strawberry Volcanics upstream of Deerhorn Creek. The competency of these rock types vary from very hard extrusive igneous rocks to soft metasedimentary and metavolcanic rocks. In general, the more competent rocks are resistant to fluvial erosion resulting in narrower valley widths caused by incision. Conversely, the less competent rocks are not very resistant to fluvial erosion resulting in wider valley widths developed by lateral channel erosion (channel migration).

Based on our interpretation of the geologic map of the Middle Fork (Walker 1990), there are other additional confounding geologic events that have shaped the Middle Fork valley. The river has been impounded, at least twice, by geologic events that temporally impacted the river's baselevel. First, during the Miocene epoch, the Columbia River flood basalts filled the valley near Bear Creek, causing alluviation upstream of the blockage. Second, during the Quaternary period a deep-seated landslide between RM 61.35 and 62.4 in the Clarno Formation temporarily impounded the river resulting in alluviation upstream that was followed by incision through the landslide deposit. Lastly, alpine glaciers and perennial ice fields present in the upper drainage basins (i.e., Vinegar Creek, Granite Boulder Creek, possibly Camp Creek, and possibly Big Boulder Creek) during the Pleistocene epoch supplied copious amounts of sediment to the fluvial system accompanied by an increase in discharges.

Additional geologic mapping in the assessment area illustrate the effects of alluvial fans on the river's planform. Some of the tributaries are undersized (underfit) for developing the larger alluvial fans (i.e., Granite Boulder Creek), suggesting they were primarily built-up during the Pleistocene epoch when alpine glaciers and perennial ice fields were present in their drainage basins. A different process built up the relatively large Big Boulder Creek alluvial fan that was primarily deposited sometime during the Quaternary period as a result of the creek's impoundment by a deep-seated landslide followed by incision through the landslide deposit. However, most of the alluvial fans have been built-up during the Pleistocene to Holocene epochs by mass wasting (i.e., debris flows) and fluvial processes. In general, these alluvial fan deposits contain higher percentages of boulders and large cobbles that are more resistant to fluvial transport under the current climatic regime. These alluvial fans provide natural constraints, restricting lateral channel migration.

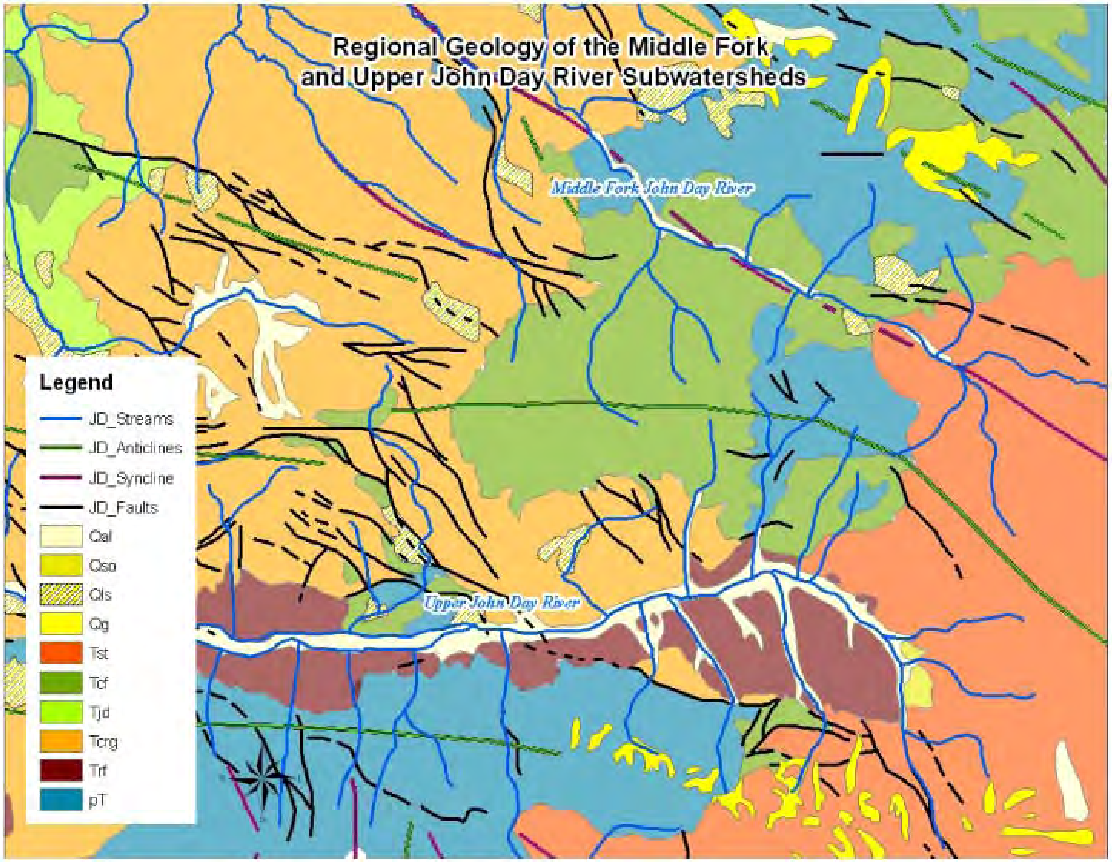

Figure 8 - Regional Geologic Map for the Middle Fork and Upper John Day Drainage Basins. The symbols used in the legend are as follows: Qal – Quaternary alluvium, Qso – Quaternary older sediments, Qls – Quaternary landslide, Qg – Quaternary glacial, Tst – Tertiary Strawberry Volcanics, Tcf – Tertiary Clarno Formation, Tjd – Tertiary John Day Formation, Tcrg – Tertiary Columbia River Basalt Group, Trf – Tertiary Rattlesnake Formation, and pT – pre-Tertiary rocks (modified from Walker 1977).

4.2 Geologic Unit Descriptions

Geologic mapping was done to distinguish various surfaces along the river corridor. Mapping was accomplished using Light and Distancing Infra-red Radar (LiDAR) data, stereo-pair aerial photographs from 2002, and then rectifying the mapping into ARC GIS on 2005 color aerial photographs. Historical aerial photography from 1939, 1956, and 1976 was also used to validate and refine mapping boundaries. Field checking was done by driving and walking along the course of the river within the study reach. This section describes the geologic units that were mapped. Units are broken out by the geologic time period during which they were formed.

4.2.1 Quaternary Deposits

4.2.1.1 Holocene Nonglacial Deposits

Lower Surface – The lower surface consists of a mixture of reworked older alluvial deposits comprised of silt- to boulder-size material, but is predominantly sand, gravel, and cobbles. These deposits occur along stream channels and their active floodplains. These materials are unconsolidated and highly susceptible to fluvial erosion.

The lower surface is frequently reworked and inundated by floods. The lower surface generally includes areas with an elevation of less than 1.5 meters above the normal water surface in the active channel.

4.2.1.2 Holocene to Pleistocene Deposits

Landslides – Landslides consist of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders. The landslides occur predominantly along valley walls. Mass wasting along the active river channels typically result in a “self-armoring” bank in that the finer materials are transported by the fluvial system and the larger materials are retained along the toe of the slope protecting the slope except during flood events.

Alluvial Fan – An alluvial fan is comprised of Pleistocene eopoch glaciofluvial and Holocene epoch fluvial deposits that form fans on the valley floors. Excessively large fans are interpreted to be glacially generated in that their headwater areas show signs of alpine glaciation and the glacier would have provided the mechanism to transport the amount of sediment necessary to form these fans. Smaller fans, sometimes inset within the much larger fans, are generated by fluvial processes related to ephemeral and perennial streams under the current climatic regime. These materials are unconsolidated and susceptible to fluvial erosion.

Intermediate Surface – An intermediate surface is comprised of alluvial deposits that form a series of terrace risers and terrace treads that are elevated between 2.5 to 3.5 meters above normal water surface in the active channel. These surfaces are intermittent throughout the major drainages, but were only locally mapped where they have an influence on the river’s morphology. This surface is rarely flooded by the river during the current climatic regime. The intermediate surface is considered stable on a decadal time scale. These materials are unconsolidated and susceptible to fluvial erosion.

Alluvium/colluvium – This feature is comprised of alluvial and colluvial deposits that form subtle slopes similar to alluvial fans that could not be differentiated. The alluvial components include rill and sheet erosion, and the transport and deposition of the sediment is primarily by water. The colluvial components include soil creep and landslides, and the transport and deposition of the sediment is primarily by gravity. These deposits are intermittent throughout the Middle Fork John Day River. These materials are unconsolidated and susceptible to fluvial erosion.

4.2.2 Pre-Jurassic to Tertiary Deposits

Bedrock – The bedrock is comprised of pre-Jurassic to Tertiary sedimentary, volcanic, metamorphic and igneous rocks, undifferentiated. The unit includes the Baker Terrane, Clarno Formation, Columbia River Basalt Group, and Strawberry Volcanics. The bedrock is generally competent, but also includes zones of ash, silt and other deposits that provide slip-planes resulting in localized mass wasting of the overburden.

4.3 Geomorphology of Process-Based Reaches

Geological processes occurring over the past several thousand to tens of thousands of years impose controls on present channel position and morphology. Throughout the Middle Fork of the John Day River study area, geologic controls generally consist of bedrock, alluvial fans, and large cobbles and boulders. These materials are difficult to erode on a decadal time scale under current climate conditions, limit the valley width, provide lateral constraints on the width of meander bends and lateral channel migration, and restrict vertical channel adjustment. Geologic controls were mapped for each reach and are shown in Figure 9 and Table 2 through Table 4. A description of geologic controls by reach is provided below.

Geomorphic mapping of the river system was conducted to identify geomorphic patterns within each reach of the river (see *Middle Fork John Day River Atlas).* In general, the assessment area reaches alternate in patterns of wide, unconfined valleys and narrow valleys constricted by alluvial fans and bedrock (see Figure 10).

The HCMZ and geologic floodplain areas were mapped for each reach to identify the historic extents of flooding and lateral channel migration. Figure 11 illustrates how the HCMZ and floodplain areas differ in each reach. The total floodplain area is represented by the sum of the HCMZ and the geologic floodplain outside of the HCMZ. The geologic floodplain is differentiated from the current floodplain based on the ability of the channel to inundate its surface. The geologic floodplain represents the lateral extent of the low surface prior to development within the basin.

The following sections describe geologic and geomorphic characteristics of each reach including a description of the reach boundaries, lateral and vertical geologic constraints on the river, composition of the floodplain boundary, and the historical channel migration zone (HCMZ) and geologic floodplain. In addition, bank erosion was field mapped in 8 out of 20 of the reaches. A general description of vegetation is provided within each reach. However, greater detail on the present conditions of and historic changes to riparian vegetation can be found in Chapter 5.4 of this appendix. A compilation of the measured attributes is also provided in Appendix G.

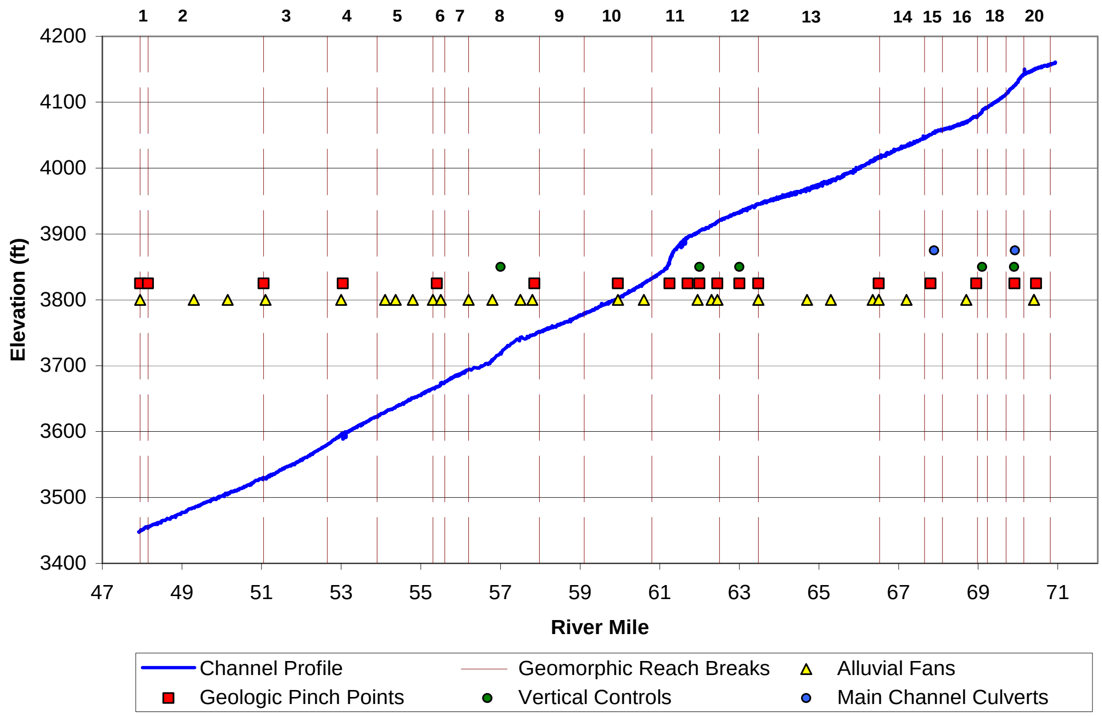

Figure 9 – Summary of Major Geologic Controls and Their Locations with Respect to Channel Slope.

Table 2 – Alluvial Fans Present in the Middle Fork Assessment Area and Their Influence on Channel Position. LB indicates left bank and RB indicates right bank.

Reach	Drainage/stream	Bank	River Mile	Influence
MF1	Camp Creek	LB	47.95	High; forces the channel to the right.
MF2	Un-named Stream	LB	49.30	None
	Balance Creek	LB	50.15	None
MF3	Coyote Creek	RB	51.10	None
MF4	Big Boulder Creek	RB	53.00	High; forces the channel to the left.
MF5	Dry Creek	RB	54.10	Low
	Sunshine Creek	LB	54.37	None
	Un-named Stream	LB	54.80	None
MF6	Un-named Stream	RB	55.30	Low
	Ragged Creek	LB	55.50	Possibly high; forces channel to the right.
MF7	Beaver Creek	RB	56.20	None
MF8	Ruby Creek	LB	56.80	Probably high prior to dredging, now low
	Granite Boulder Creek	RB	57.50	Probably high prior to dredging, now low
	Butte Creek	LB	57.80	Low
MF10	Un-named Stream	LB	59.95	Low
	Little Butte Creek	LB	60.60	None
MF11	Little Boulder Creek	RB	61.95	None
	Flat Creek	LB	62.30	Possibly low
	Deerhorn Creek	LB	62.45	High; forces channel to the right
MF12/13	Caribou Creek	RB	63.48	High; forces channel to the left
MF13	Un-named Stream	LB	64.70	None
	Un-named Stream/Vincent Creek	RB	65.30	None
	Vinegar Creek	RB	66.35	High; forces the channel to the left
	Davis Creek	LB	66.50	High; forces the channel to the right
MF14	Un-named Stream	RB	67.20	High; forces the channel to the left
MF16	Un-named Stream	RB	68.70	None
MF20	Un-named Stream	RB	70.40	High; forces the channel to the left
	Un-named Stream	LB	70.40	High; stops the river from continuing to the right

Table 3 – Geologic Constructions in Channel Positions (Constrictions Causing Abrupt Changes in Channel Widths).

Reach	Geologic material/Bank	River Mile
MF1	Bedrock on RB; alluvial fan on LB	47.95
MF-1/2	Alluvium/colluvium on RB; bedrock on LB	48.15
MF3	Alluvium/colluvium on RB; bedrock on LB	51.05
MF4	Alluvial fan on the RB; bedrock on LB	53.04
MF6	Bedrock/alluvial fan on RB; bedrock/alluvial fan on LB	55.40
MF8	Alluvial fan on RB; alluvial fan on LB	57.85
MF10	Bedrock on RB; alluvial fan/bedrock on LB	59.95
MF11	Bedrock on both banks	61.25
	Bedrock on RB; alluvium/collivium on LB	61.70
	Bedrock on RB; landslide on LB	62.00
	Bedrock on RB; alluvial fan on LB	62.45
MF12	Bedrock on both banks	63.00
	Bedrock R; alluvial fan on LB	63.48
MF13	Alluvial fan on RB alluvial fan on the LB	66.50
MF15	Bedrock on RB; alluvium/colluvium on LB	67.80
MF17	Bedrock on both sides	68.95
MF19	Bedrock on both sides	69.91
MF20	Opposing alluvial fans	70.45

Table 4 – Vertical Geologic Controls.

Reach	Material	River Mile
MF8	Mine tailings	56.2-57.8
MF11	Landslide/ large boulders in channel bed	61.4 -62.4
MF12	Mine tailings	62.8-63.5
MF15	Culvert in channel	67.89
MF17	Bedrock in channel	69.1

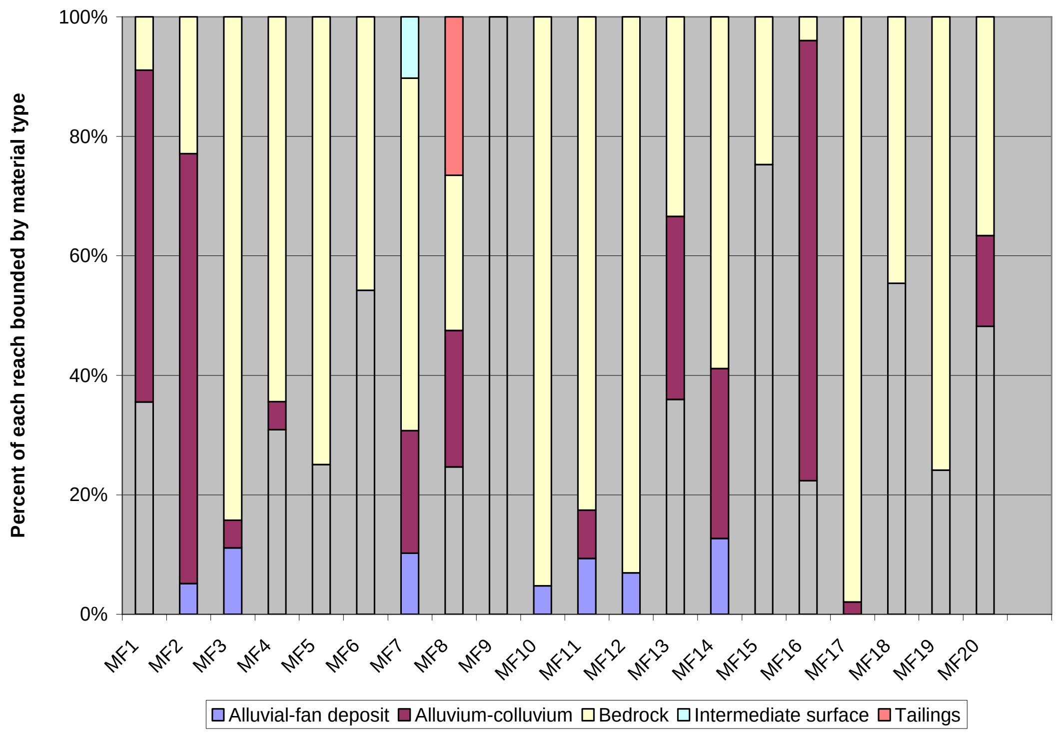

Figure 10 – Geologic Surface Bounding the Floodplain in Each Reach.

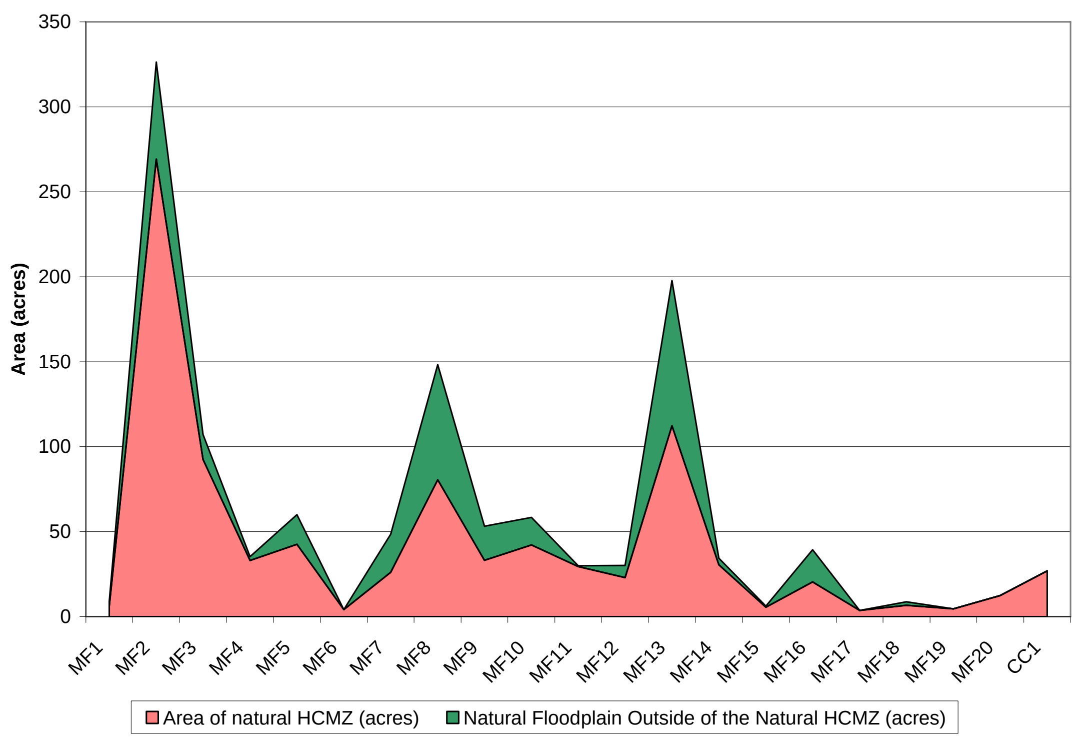

Figure 11 – Total Area of HCMZ and Floodplain Area Outside of the HCMZ. The cumulative value represents the total floodplain area for each reach.

4.3.1 Geomorphic Reach Characteristics

4.3.1.1 Reach MF20

Reach MF20 is a 0.7-mile long, unconfined reach that extends from RM 68.1 to RM 68.95.

Reach Boundaries-- The downstream boundary is at the point where the floodplain begins to narrow. The upstream boundary is at a point where the floodplain width narrows slightly (about 55 feet versus less than 90 feet downstream). The floodplain is bounded by bedrock, which provides some constriction to both lateral and vertical changes.

Lateral and Vertical Geologic Constraints-- The reach is a wide or moderately wide section upstream of a very narrow, confined section. The geologic floodplain width ranges between about 120 and 340 feet and has an average of about 230 feet. The section downstream of about RM 70.5 is generally narrower than the section upstream of this point. In the downstream section, floodplain widths range between 120 and 180 feet, with an average width of about 145 feet. In the upstream section, floodplain widths range between 295 and 340 feet, with an average width of about 315 feet. The geologic floodplain is narrowest near downstream boundary of the reach. Another narrow point is between RM 70.45 and RM 70.5, where alluvial-fan deposits from opposite sides of the valley are preserved within the floodplain. The widest point is near RM 70.6, where the alluvial-fan deposits that bound the north side of the geologic floodplain have been eroded.

Half of the geologic floodplain is bounded by alluvial-fan deposits. About 35 percent of the floodplain boundary is bedrock and about 15 percent of the boundary is alluvium/colluvium. The scalloped edges of the alluvium/colluvium and alluvial-fan deposits indicate that the Middle Fork has eroded these deposits, and still may be able to erode them. The bedrock bounding both sides of the floodplain in the upstream portion of the reach may be more resistant to erosion.

Between RM 70.16 and RM 70.73, the right bank alternates between running against floodplain deposits and alluvial fan deposits. At RM 70.73, the right bank runs against bedrock. The left bank of the channel runs against alluvium/colluvium and alluvial fan material throughout the majority of the reach. The channel may be controlled vertically by possible bedrock in the channel at the upstream reach boundary at RM 70.81.

Channel Migration (HCMZ) and Floodplain**—**Historical main channel paths were likely meandering (in the wider, upstream section) or slightly meandering (in the narrower, downstream section). The main channel paths observed on the historical aerial photographs generally overlap. Major changes in the channel paths are not apparent. Moderately well defined channel paths visible on the LiDAR hillshade between RM 70.2 and RM 70.5 both north and south of the river may be older main and/or secondary channel paths. These observations suggest that the pre-development channel had a meandering path. Upstream of RM 70.5, the LiDAR hillshade is difficult to interpret for channel history. The HCMZ is interpreted to coincide with the geologic floodplain, although there is not evidence to confirm this.

Vegetation—This reach is not shown on the 1926 water adjudication map. Two areas of trees and shrubs are visible on the historical aerial photographs (1939, 1956, and 1976): one south of the river between RM 70.2 and RM 70.3 and one north and along the channel between RM 70.45 and RM 70.65. In 2006, most of the floodplain was open grassland. Upstream of RM 70.65, areas of larger trees were present within the floodplain. Areas of larger trees also were present just outside of the floodplain both south and north of the river upstream of RM 70.45.

4.3.1.2 Reach MF19

Reach MF19 is a 0.5-mile long, confined, nearly straight reach that extends from RM 69.7 to RM 70.15.

Reach Boundaries-- The downstream boundary is the downstream extent of a narrower section. The upstream boundary is at the point where the floodplain begins to widen.

Lateral and Vertical Geologic Constraints—The reach is confined between bedrock mostly on both sides of the river. The section on the north side (river right) downstream of RM 69.85 is bounded the alluvium/colluvium. The width of the geologic floodplain ranges between about 76 feet and about 105 feet. The average width is about 85 feet. Bedrock may be present in the channel near the center of the reach near RM 69.9, and may provide a vertical control on channel adjustment in this reach.

Bedrock and alluvium/colluvium provide some influence on the position of the channel in this reach. Between RM 69.75 and 69.82, the right bank runs against bedrock and alluvium/colluvium. Bedrock bounds the left bank of the channel between RM 69.92 and RM 69.96, RM 70.01 and RM 70.02, and between RM 70.09 and RM 70.14.

Channel Migration (HCMZ) and Floodplain— Reach MF19 is so narrow that little change has occurred in the paths of the historical main channels and possible older main and secondary channels are not visible on the LiDAR hillshade. The pre-development channel was confined by bedrock in this reach and likely only experienced slight meandering and migration. The HCMZ is coincident with the geologic floodplain.

Vegetation—The area immediately north of the geologic floodplain downstream of RM 69.85 is shown as brush and trees on the 1926 water adjudication map. Most of the floodplain downstream of RM 69.95 and some of the adjacent area have trees and/or shrubs visible on the historical aerial photographs (1939, 1956, and 1976). In 2006, most of the floodplain downstream of RM 69.85 was open grassland. The floodplain upstream of this point was a mixture of open grassland, small trees and shrubs, and larger trees.

4.3.1.3 Reach MF18

Reach MF18 is 0.5-mile long moderately confined, nearly straight reach that extends from RM 69.23 to RM 69.7. A large tributary enters the Middle Fork from the north near RM 69.25, near the downstream reach boundary.

Reach Boundaries-- The downstream is at a slight constriction by bedrock and at the point where the floodplain begins to widen. The upstream boundary is the downstream extent of a narrower section.

Lateral and Vertical Geologic Constraints**—**The reach is a moderately wide section between the narrower sections both downstream and upstream. The geologic floodplain width varies between about 95 feet near RM 69.38 and about 295 feet near RM 69.5. Changes in floodplain width appear to be primarily the result of erosion of the unconsolidated alluvial/colluvial deposits along the north side (river right) of the reach.

The floodplain is bounded primarily by bedrock on the south side (55 percent of the boundary), and by alluvium/colluvium on the north side (45 percent of the boundary). The alluvium/colluvium includes alluvium from Mill Creek, a large tributary that enters the valley from the north near the downstream reach boundary. The alluvium/colluvium on the north boundary has been eroded by the Middle Fork in the past, and may still be erodible by the river. The sinuous boundary of the bedrock along the south floodplain boundary suggests that the bedrock may be somewhat erodible by the Middle Fork also.

Alluvium/colluvium likely influences the lateral channel position between RM 69.25 and RM 69.26, RM 69.32 and RM 69.38, RM 69.41 and RM 69.42, and between RM 69.64 and RM 69.65, where the lateral extent of the low surface is narrow. Bedrock may influence channel position along the left bank of the river at RM 69.3.

Channel Migration (HCMZ) and Floodplain**—**The historical main channels probably had meandering to slightly meandering paths. Moderately well defined channels that are visible on the LiDAR hillshade south of the historical main channel paths suggest that the pre-development main channel or secondary channels may have extended to the south edge of the geologic floodplain. Moderately well defined channels north of the historical main channel could be related to Mill Creek or smaller tributaries and so are not included within the HCMZ. However, these channels may have been formed or used by the Middle Fork at some time in the past. On the basis of the historical channel paths and channels visible on the LiDAR hillshade, the pre-development channel in reach MF18 is interpreted to have been a single or multiple meandering channel, with some secondary and overflow channels.

The HCMZ covers about 7 acres, which is 75 percent of the geologic floodplain (about 9 acres). The area with channels that appear to be related to tributaries north of the river is not included within the HCMZ.

Vegetation**—**The portion of this reach north of the HCMZ, but within the floodplain between RM 69.45 and RM 69.55, was shown as brush and trees on the 1926 water adjudication map. The entire floodplain south of the active channel had trees and/or shrubs that are visible on the historical aerial photographs (1939, 1956, and 1976). Part of the area north of the river that was shown as brush and trees in 1926, also had trees and/or shrubs visible on the historical aerial photographs. In 2006, the entire floodplain was open grassland.

4.3.1.4 Reach MF17

Reach MF 17 is a 0.3-mile long, confined, slightly sinuous reach that extends from RM 68.95 to RM 69.23.

Reach Boundaries**--** The downstream boundary is at a bedrock constriction that marks the downstream end of a very narrow section. The upstream boundary is at a slight constriction by bedrock and at the point where the floodplain begins to widen.

Lateral and Vertical Geologic Constraints**—**The reach is confined between bedrock on both sides of the river. The section downstream of RM 69.05 is narrower than the reach is upstream of that point. The width of the geologic floodplain in the downstream section is about 70 feet. Upstream of RM 69.05, the floodplain gradually widens to about 185 feet near the upstream reach boundary.

Bedrock inhibits lateral channel migration throughout the reach, and is particularly influential along the right bank between RM 68.96 and RM 69.15 and along the left bank between RM 68.99 and RM 69.1. Bedrock in the bed of the channel acts to limit vertical channel adjustment as well.

Channel Migration (HCMZ) and Floodplain**—** The downstream section (downstream of RM 69.05) is so narrow that the main Middle Fork channel was likely a single path that could meander only slightly prior to substantial land use changes. Historical main channels essentially overlap. In the slightly wider, upstream section, the historical main channels show some meandering. Moderately defined channels suggest that secondary, or possibly main, channels have extended outside of the historical main channel paths. Because of the narrowness of the reach, the HCMZ is interpreted to cover most of the geologic floodplain.

Vegetation**—**This reach is not shown on the 1926 water adjudication map. The geologic floodplain and HCMZ, except for the active channel, have trees and/or shrubs visible on the historical aerial photographs (1939, 1956, and 1976). In 2006, the entire floodplain was open grassland, except for a small area of small trees and shrubs and a small area of larger trees, both near RM 69.1.

4.3.1.5 Reach MF16

Reach MF16 is a 0.9-mile-long, unconfined, nearly straight reach that extends from RM 68.1 to RM 68.95.

Reach Boundaries**--** The downstream boundary is at the point where the floodplain begins to widen at the upstream end of the alluvial-fan deposit from Clear Creek on river left. The upstream boundary is at a bedrock constriction that marks the downstream end of a very narrow section.

Lateral and Vertical Geologic Constraints-- The reach is a wide section between two very narrow, confined reaches. The geologic floodplain width ranges between about 80 and 640 feet, and has an average of about 425 feet. The floodplain is narrowest near upstream boundary of the reach. The widest point is near RM 68.5, where the alluvial fan deposits and alluvial/colluvial deposits that bound the geologic floodplain have been eroded.

The floodplain is bounded primarily (about 75 percent of the total boundary length) by alluvium/colluvium, which includes some alluvial-fan deposits. A large alluvial-fan deposit on river right between RM 68.5 and RM 68.9 comprises about 25 percent of the floodplain boundary. Bedrock only accounts for about 5 percent of the floodplain boundary, but is present in the valley-bounding ridges. The scalloped edges of the alluvium/colluvium and alluvial-fan deposits indicate that the Middle Fork has eroded these deposits and still may be able to erode them. The upstream boundary is confined by bedrock on both sides of the floodplain. None of the surfaces bounding the floodplain appear to influence or prohibit lateral migration of the channel.

Channel Migration (HCMZ) and Floodplain—Because of the great width of this reach, the channel likely had a very meandering path. The main channels on the historical aerial photographs between 1939 and 2006 all have a meandering to slightly meandering pattern, depending upon location within the reach. Well-defined channels south of the river between RM 68.1 (downstream reach boundary) and RM 68.5 and north of the river between RM 68.7 and RM 68.9 are visible on the LiDAR hillshade and indicate that the pre-development main channel likely flowed in this area. Well-defined to poorly defined channels north of the river along the entire reach appear to be related to the large tributary with the alluvial-fan deposit. Although some of these channels may have been formed or modified by the Middle Fork, these processes are probably older than those represented by the now-visible channels. Consequently, these channels are not included in the HCMZ.

Because of the width of the floodplain, it is conjectured that the pre-development channel was meandering and/or braided with several channel paths active simultaneously. Shifting of the channel was likely common. The pre-development main channel likely migrated over the south half of the floodplain. Sediment deposited from the large tributary on river right at the upstream end of the reach may have kept the main channel on the south side of the floodplain in the geologically recent past. The HCMZ (about 20 acres) is interpreted to cover at least 50 percent the floodplain area (about 40 acres). The north half of the floodplain is not included within the HCMZ. It may be that a slope to the south extends from the alluvial-fan deposits from the unnamed tributary that enters from the north near the upstream reach boundary.

Vegetation—The entire floodplain in this reach and the lower portion of the large alluvial fan to the north are shown as meadow in a 1926 water adjudication map. No areas of trees and shrubs are visible on the historical aerial photographs (1939, 1956, and 1976). In 2006, the entire floodplain and immediately surrounding area were open grassland.

4.3.1.6 Reach CC1

Reach CC1 is a 0.5-mile-long, unconfined, nearly straight reach. The geologic floodplain in this section of Clear Creek and the surrounding area were markedly altered by the former town of Bates. The channel of Clear Creek was moved and straightened, and the floodplain was modified as the town was established. Consequently, the boundaries of the geologic floodplain and HCMZ, and the natural processes that operated within them, are difficult to interpret. The boundaries shown are interpreted based on the geology and 1926 water adjudication map. Clear Creek enters the Middle Fork in Reach MF15.

Reach Boundaries-- The downstream boundary is the junction of Clear Creek with the Middle Fork John Day River. The upstream boundary is located at a bedrock constriction.

Lateral and Vertical Geologic Constraints-- The reach is interpreted to have a wide geologic floodplain. Upstream, about two-thirds of the reach is bounded by bedrock, which somewhat constrains the location of the channel. The downstream one-third is bounded by alluvium/colluvium related to the Middle Fork. In this section, deposits from both drainages likely interfinger and the area probably included the channels from both drainages at different times. In this section, the location and planform of Clear Creek would have been constrained only by the location and processes on the Middle Fork.

***Channel Migration (HCMZ) and Floodplain*—**If the geologic floodplain is as wide as interpreted, then the channel of Clear Creek likely had a meandering path. The upstream section of the 1939 main channel had a more meandering path than later, totally constrained historical channel paths. The pre-development channel may have had a single, or multiple simultaneously active channels that shifted frequently, especially in the downstream one-third of the reach, where the channels of Clear Creek and the Middle Fork interacted. Because interpretation in this area is so difficult due to site disturbance, the HCMZ is shown as coincident with the geologic floodplain, but this may not actually reflect pre-development conditions.

***Vegetation*—**Most of the floodplain in this reach is shown as meadow in a 1926 water adjudication map. Three areas of trees and shrubs are visible on the historical aerial photographs (1939, 1956, and 1976) at the downstream end of the reach. In 2006, the downstream end of the floodplain (the only area that was studied) was open grassland.

4.3.1.7 Reach MF15

Reach MF15 is a 0.5-mile-long, confined, nearly straight reach that extends from RM 67.65 to RM 69.1. A large tributary, Clear Creek, enters the Middle Fork in this reach.

***Reach Boundaries*--** The downstream boundary is the downstream extent of a narrow section formed by bedrock on river right and by alluvial-fan deposits (mapped as alluvium/colluvium) from Bridge Creek on river left. The upstream boundary is at the point where the floodplain begins to widen at the upstream end of the alluvial-fan deposit from Clear Creek on river left.

***Lateral and Vertical Geologic Constraints*—**The reach is very confined between bedrock on river right and alluvial-fan deposits (mapped as alluvium/colluvium) from Bridge Creek and Clear Creek on river left. The section downstream of RM 67.88 is extremely narrow. Geologic floodplain widths range between about 60 and 90 feet, and average about 70 feet. The section upstream of RM 66.88 is slightly wider. Geologic floodplain width ranges between about 105 and 125 feet and averages about 115 feet. The geologic floodplain in the very narrow, downstream section is bounded by bedrock on river right and by alluvial-fan deposits from Bridge Creek on river left. The floodplain in the wider, upstream section is bounded by either bedrock or alluvium/colluvium on river right and by alluvial-fan deposits from Clear Creek on river left. Erosion of the unconsolidated deposits may account for the slightly greater widths in the upstream section. The floodplain is well constrained or fairly well constrained laterally by these geologic controls. The change in geologic floodplain may coincide with bedrock in the channel which would provide vertical control on the channel in this reach. Overall, most of the geologic floodplain (75 percent) is bounded by alluvial-fan deposits or alluvium/colluvium. The rest of the floodplain is bounded by bedrock.

***Channel Migration (HCMZ) and Floodplain*—** The downstream section (downstream of RM 67.88) is so narrow that the main Middle Fork channel was likely a single path that could meander very slightly. In the slightly wider upstream section, the 1939 main channel was slightly more sinuous than the later historical main channels. The geologic floodplains of the Middle Fork, Clear Creek, and Bridge Creek and the surrounding area were markedly altered by the former town of Bates. The channels of all of these drainages were moved and straightened when the town was established. Consequently, interpretation of the boundaries of the geologic floodplain and HCMZ is difficult. The very narrow width of reach MF15 suggests that the pre-development main channel of the Middle Fork was likely a single path that could meander only slightly. Because of the narrowness of the reach, the HCMZ is interpreted to cover most of the geologic floodplain.

Vegetation—The portion of the reach upstream of RM 68 and most of the lower Clear Creek floodplain are shown as meadow on the 1926 water adjudication map. Several areas upstream of RM 67.8 have trees and/or shrubs visible on the historical aerial photographs (1939, 1956, and 1976). Except for one area upstream of RM 68 and south of the river, all of these areas are outside of the floodplain of the Middle Fork. In 2006, the entire floodplain was open grassland.

4.3.1.8 Reach MF14

Reach MF14 is a 1.13-mile-long, moderately confined, nearly straight reach that extends from RM 66.52 to RM 67.65. The reach downstream of RM 67.45 is within the Tribe's Forrest property.

Reach Boundaries-- The downstream boundary is a narrow point that is bounded by bedrock on river right and by an alluvial fan from Davis Creek on river left. The upstream boundary is the downstream extent of a narrow section formed by bedrock on river right and by alluvial-fan deposits (mapped as alluvium/colluvium) from Bridge Creek on river left.

Lateral and Vertical Geologic Constraints—The reach is a moderately wide section between a wider, unconfined reach downstream (MF13) and a very confined reach upstream (MF15). The geologic floodplain width is moderately wide at the downstream and upstream ends (downstream of RM 66.7 and upstream of RM 67.4). The downstream section is confined by the large alluvial fan from Davis Creek and the geologic floodplain width averages about 240 feet. The upstream section is confined by alluvial/colluvial deposits, and the geologic floodplain width is about 250 feet. In the rest of the reach, the geologic floodplain width is wider than this (average of about 385 feet), except for a short section between RM 67.3 and RM 67.4, where the floodplain width is only about 150 feet. This narrow section is confined by bedrock.

The floodplain is bounded primarily by bedrock (50 percent of the boundary). Alluvial/colluvial deposits make up nearly 30 percent of the boundary. The large alluvial fan at Davis Creek and a smaller fan from an unnamed drainage compose about 15 percent of the floodplain boundary. The scalloped edges of the alluvial/colluvial deposits in the upstream third of the reach suggest that these deposits have been, and likely can be, eroded by the Middle Fork. The configuration of the large alluvial fan from Davis Creek suggests that it is at least somewhat difficult for the Middle Fork to erode. The bedrock in this reach is likely nearly unerodible.

The Davis Creek alluvial fan does not influence lateral migration or form a constriction until the downstream reach boundary. In the middle section of the reach, small alluvial fan from an unnamed stream redirects the channel to the right toward the center of the floodplain. The channel runs against bedrock along the right bank between RM 66.55 and RM 66.65 and RM 66.73 and RM 66.80. Alluvium/colluvium bounds the channel along its right bank between RM 67.54 and 67.65. The left bank of the channel runs against alluvial fan material from RM 67.2 to RM 67.3.

Channel Migration (HCMZ) and Floodplain—The main channel in 1939 was slightly more meandering than the historical main channels observed in later years. Meanders that were present in 1939 near RM 66.6 and RM 67.5 were no longer part of the main channel by 1956. In other areas, the historical main channel paths have changed position only slightly between 1939 and 2006. Plantings on Tribal land adjacent to the main channel downstream of RM 67.45 have markedly altered the ground surface and make interpretation of pre-development channel paths difficult on the LiDAR hillshade. Additional human activities and structures upstream of this point have modified the ground surface to the upstream reach boundary. Thus, the pre-development channel conditions can only be hypothesized from other reaches of similar widths. The pre-development channel in the narrow section between RM 67.3 to RM 67.4 could probably meander and migrate only slightly. Downstream of the narrow section, the pre-development main channel likely was very sinuous, and may have migrated across a large portion of the floodplain. The HCMZ covers about 31 acres, which is nearly 90 percent of the geologic floodplain (about 34 acres).

Vegetation—This reach is not shown the 1926 water adjudication map. Areas of trees and/or shrubs that are visible on the historical aerial photographs (1939, 1976) are common throughout the reach. In 2006, much of the floodplain was open grassland. The exceptions are the areas near RM 67.2 and between RM 67.4 and RM 67.5, where the floodplain included areas of small trees and shrubs and a couple of small areas of larger trees (north of the river near RM 67.5). Larger trees were present along and just outside of the floodplain south of the river between RM 66.9 and RM 67.6, and north of the river between RM 67.2 and RM 67.5.

4.3.1.9 Reach MF13

Reach MF13 is a 3-mile-long, unconfined, nearly straight reach that extends from RM 63.48 to RM 66.52. The largest alluvial-fan deposits are from Vincent Creek and Vinegar Creek on river right and from Davis Creek on river left at the upstream reach boundary. This reach is entirely within the boundaries of the tribe's Forrest property.

Reach Boundaries-- The downstream boundary is at a narrow point where an alluvial-fan deposit from an unnamed tributary enters the valley from the north (river right). The upstream boundary is at a narrow point that is bounded by bedrock on river right and by an alluvial fan from Davis Creek on river left.

Lateral and Vertical Geologic Constraints-- The reach is a wide section between two narrower, moderately confined reaches (MF12 downstream and MF14 upstream). The floodplain is consistently wide, but has three narrower sections between RM 63.48 (downstream reach boundary) and RM 63.7, between RM 65.5 and RM 65.55, and near the upstream reach boundary at RM 66.52. In the downstream narrow section, the average geologic floodplain width is about 180 feet. In the central narrow section, which includes the narrowest point in the reach (about 150 feet), the floodplain width is about 315 feet. In the upstream narrow section, the average geologic floodplain width is about 300 feet. The downstream wider section has a maximum width of greater than 1,000 feet between RM 65.1 and RM 65.2, where alluvial-fan deposits and alluvium/colluvium bound the geologic floodplain and appear to have been eroded by the Middle Fork. The upstream wider section has a maximum width of about 1,230 feet near RM 66, where alluvial-fan deposits from an unnamed tributary on river left have been eroded.

The floodplain is bounded in nearly equal portions by alluvial-fan deposits (about 35 percent of the total floodplain boundary), by bedrock (about 35 percent of the boundary), and by alluvium/colluvium (about 30 percent of the boundary). The three narrower sections are all at locations of alluvial-fan deposits from one side of the valley. The two widest areas of the reach also are at locations where alluvial-fan deposits are preserved. The scalloped edges of these unconsolidated deposits, along with the widest widths, suggest that these units have been, and likely could be, eroded by the Middle Fork. The alluvial-fan deposits at the narrowest points appear to be relatively unerodible by the Middle Fork. These deposits may contain larger or more consolidated material, or these may be the localities where the tributaries are periodically adding sediment to the valley. The sections of the floodplain that are bounded by bedrock are essentially unerodible.

Alluvial fans present in this reach impart some influence on channel position. At the upstream end of the reach on the right side, Vincent Creek alluvial fan forces the channel toward the center of the low surface. In the middle section of the reach, Vincent Creek and another unnamed stream on the right and two unnamed streams on the left have alluvial fan structures, but these fans do not influence the lateral position of the channel. At the upstream reach boundary, there is a constriction between the upstream end of the Vincent Creek alluvial fan on the left and the downstream end of the Davis Creek alluvial fan on the right. At the downstream end, the Caribou Creek alluvial fan forces the channel to the left against bedrock, forming a constriction at the downstream reach boundary.

Bedrock exposures in some locations also impart a lateral and possibly vertical constraint on channel position. The channel runs against bedrock on river right between RM 64.09 and 64.11, 64.32 and 64.38, 64.56 and 64.62, 65.83 and 66.02, and between 66.10 and 66.15. The left side of the river appears to run against bedrock at the downstream boundary between 63.48 and 63.52.

Channel Migration (HCMZ) and Floodplain—Early human activities and manipulations of the channel completed prior to the oldest aerial photographs of 1939, make interpretation of the pre-development channel pattern difficult. The meandering main channels have been present since 1939 in the downstream wider section. Several well-defined channels that appear to have been former main channels of the Middle Fork are visible on the LiDAR hillshade in the upstream wider section. These observations, along with the width of the reach, suggest that the pre-development channel likely had channel characteristics similar to those hypothesized for unconfined reach MF2.

It may be that the historic channel and floodplain in reach MF13 included a wide zone of main and secondary channels within an even wider zone of flooding. The pre-development channel in reach MF13 may have been meandering and/or braided with several channel paths active simultaneously. Shifting of the channel may have been common. The alluvial-fan deposits that are common this reach likely influenced the location of the main channel by adding sediment to the floodplain. The HCMZ has been drawn to reflect the possible influence of the alluvial-fan deposits on channel migration. Thus, the HCMZ (about 110 acres) in reach MF13 covers a smaller percentage (56 percent) of the total geologic floodplain area (about 198 acres) than it does in reach MF2 (82 percent).

Vegetation—The entire floodplain in this reach is shown as meadow in a 1926 water adjudication map. Several small areas of trees and/or shrubs are visible within the floodplain between RM 64.6 and RM 66.8 and upstream of RM 66.3 on the historical aerial photographs (1939, 1956, and 1976). In 2006, the floodplain was entirely open grassland. Areas of larger trees are preserved along and outside of the floodplain primarily downstream of RM 64, between RM 65.4 to RM 65.7, and between RM 65.8 and RM 66.3.

4.3.1.10 Reach MF12

Reach MF12 is a 0.98-mile-long, moderately confined, very sinuous reach that extends from RM 62.5 to RM 63.48.

Reach Boundaries-- The downstream boundary is at a narrow point that is bounded by bedrock. The upstream boundary is at a narrow point where an alluvial-fan deposit from an unnamed tributary enters the valley from the north (river right).

Lateral and Vertical Geologic Constraints—The reach is moderately wide between a very confined reach downstream (MF11) and a wider, unconfined reach upstream (MF13). Reach MF12 has two wider sections: between RM 62.5 (downstream reach boundary) and RM 62.9 and between RM 63.05 and RM 63.35. The section between these two wider ones is very narrow and naturally constrained by bedrock. The section upstream of RM 63.35 to the upstream reach boundary at RM 63.48 also is narrow, and it is constrained by bedrock on river left and by an alluvial fan from an unnamed tributary on river right. In the two wider sections, average geologic floodplain widths are about 315 feet between RM 62.5 and RM 62.9 and about 355 feet between RM 63.05 and RM 63.35. The maximum geologic floodplain width for the reach is about 425 feet at RM 63.17 in the upstream wider reach. In the two narrower sections, average geologic floodplain widths are about 145 feet between RM 62.9 and RM 63.05 and about 150 feet upstream of RM 63.35. The minimum geologic floodplain width for the reach is about 110 feet at RM 63, where bedrock along both banks forms a tight constriction. The average floodplain width for the entire reach is about 280 feet.

The floodplain is bounded almost entirely by bedrock (93 percent of the boundary). The Caribou Creek alluvial-fan deposit on river right near the upstream reach boundary composes 7 percent of the floodplain boundary. Thus, most of the floodplain boundary is essentially unerodible. However, the periodic changes in floodplain width suggest that the erodibility of the bedrock is variable and that in some places, the river can more readily erode it than in others. The downstream end of the Caribou Creek alluvial fan begins to force the channel to the left against bedrock, forming a constriction.

The downstream section of the channel has an extremely steep slope. The channel position is influenced by alluvial fan materials and bedrock in some locations. The channel runs against bedrock on river right between RM 62.93 and 63.01 and on river left between RM 62.53 and 62.57, 62.61 and 62.72, 62.82 and 62.83, and between 63.15 and 63.48.

Channel Migration (HCMZ) and Floodplain—The 1939 main channel is slightly more sinuous than later main channels that are visible on the historical aerial photographs. One meander that was present in 1956 near RM 62.8 had shifted position by 1976. However, dredge mining and manipulation of the channel have left very little record of the pre-development channel pattern. Well-defined and moderately defined channels are visible on the LiDAR hillshade in three localities: south of the river between RM 62.7 and RM 62.8, north of the river between RM 62.75 and RM 62.9, and north of the river between RM 63 and RM 63.1. It is possible that this last channel is related to a tributary, at least in part, rather than the Middle Fork. On the basis of some evidence of meandering and channel migration from the aerial photographs and LiDAR hillshade, it is hypothesized that the pre-development main channel in the two wider sections had a meandering pattern that shifted periodically. The channel in the two narrower sections must have had a single, straighter path that shifted only slightly, because the restricted widths of these sections would not have allowed channel meandering and migration. The constraint on the channel position in these two sections would have influenced somewhat the positions of the channel in the intervening wider sections. The area of the HCMZ (about 23 acres) is about 76 percent of the geologic floodplain (about 30 acres). This is because the geologic floodplain is thought to extend outside of the HCMZ in the two wider sections; whereas, the floodplain and HCMZ coincide in the narrower sections.

Vegetation—This reach is not shown the 1926 water adjudication map. Two areas of trees and/or shrubs are visible on the historical aerial photographs (1939, 1956, and 1976) north of the river within the floodplain between RM 63.1 and RM 63.35 in the upstream wider section of the reach. In 2006, much of the floodplain was open grassland. The exception is the area between RM 62.6 and RM 62.8, which contained a mosaic of open grassland, small trees, shrubs, and larger trees. Larger trees are nearly continuous along and just outside of the south (river left) floodplain boundary.

4.3.1.11 Reach MF11

Reach MF11 is a 1.7-mile-long, confined, sinuous reach that extends from RM 55.3 to RM 55.6.

Reach Boundaries-- The downstream and upstream boundaries are both at narrow points that are bounded by bedrock.

Lateral and Vertical Geologic Constraints—The reach is very confined between bedrock, primarily, a large landslide south of the river upstream of RM 61.3, and small alluvial-fan deposits mostly upstream of RM 61.8. The valley has a sinuous to slightly sinuous pattern. The alluvial-fan deposits are from three drainages: Little Boulder Creek and Flat Creek on river right, and Deerhorn Creek on river left.

The floodplain ranges between about 60 and 400 feet wide and has an average width of about 170 feet. The narrowest point is upstream of RM 61.4, where an alluvial fan from an unnamed tributary from the south enters the valley. The floodplain also is narrow near RM 61.2, where bedrock confines the floodplain. A slightly wider section is present between RM 61.7 and RM 61.9, which is bounded on the north by bedrock and a small alluvial fan from Little Boulder Creek, and on the south by the landslide. The widest floodplain is between RM 61.5 and RM 61.6, where the valley makes a near-90-degree bend to the left.

Nearly two-thirds (65 percent) of the floodplain is bounded by bedrock and 20 percent is bounded by the landslide. Alluvial-fan deposits and alluvium/colluvium make up about 15 percent of the boundary. Although the alluvial and colluvium may be erodible by the Middle Fork, their limited distribution means that for the most part, the floodplain boundary is essentially unerodible. However, the widest section of the reach (RM 61.7 to RM 61.9) coincides with the location of a deposit of alluvium/colluvium.

On the right side in the middle of the reach, the Little Boulder Creek alluvial fan does not influence the channel. However, upstream on the right side, the Little Boulder Creek alluvial fan does push the channel to the left, against the landslide, forming a slight constriction. The left bank is made up of a landslide for most of the reach. The landslide inhibits lateral channel migration to the left of the low surface. At the top of the reach on the left bank, the Deerhorn Creek alluvial fan pushes the channel to the right against bedrock, forming a constriction.

A change in the slope of the longitudinal profile is present at RM 61.16, where the floodplain is relatively narrow (about 120 feet). Large boulders from the adjacent slope provide a vertical control at this point.

Channel Migration (HCMZ) and Floodplain— Reach MF11 is so narrow that the main Middle Fork channel was likely a single path that could meander only slightly naturally. Historical paths for the main channel nearly overlap. Well defined and moderately defined channels are visible on the LiDAR hillshade in the widest section of the reach (RM 61.7 to RM 61.9) and suggest a pre-development path that was more meandering than the historical channel paths. Because the reach is so narrow, the HCMZ (about 29.5 acres) is interpreted to cover the entire geologic floodplain (30 acres), except at the downstream end of the reach downstream of RM 60.9.

Vegetation—This reach is not shown the 1926 water adjudication map. The only areas where trees and/or shrubs are visible on the historical aerial photographs (1939, 1956, and 1976) are outside of the floodplain between RM 61.1 and RM 61.5 and within the floodplain between RM 61.4 and RM 61.5. In 2006, much of the floodplain upstream of RM 61.7 was open grassland. The floodplain downstream of this point was a mixture of small trees and shrubs (mostly) with areas of open grassland and larger trees. A fairly broad area of larger trees was present between RM 61.5 and 61.7 in 2006. About half of the floodplain downstream of RM 61.2, especially north (river right) of the channel, also had larger trees in 2006.

4.3.1.12 Reach MF10

Reach MF10 is a 1.7-mile-long, moderately confined reach that extends from RM 59.1 to RM 60.8. The reach is nearly straight downstream of RM 59.6 and slightly sinuous upstream of this point.

Reach Boundaries-- The downstream and upstream boundaries are both at narrow points that are bounded by bedrock.

Lateral and Vertical Geologic Constraints—The reach is a moderately wide transitional section between a wider reach downstream (MF9) and a narrow, confined reach upstream (MF11). The floodplain ranges between about 120 and 500 feet wide and has an average width of just less than 300 feet. The nearly straight section downstream of RM 59.55 is slightly narrower (average width of about 250 feet) than the reach upstream of that point (average width of about 335 feet). The reach upstream of RM 59.55, which is more sinuous, has alternating narrower (125 to 250 feet) and wider (350 to 500 feet) sections.

The floodplain is bounded almost entirely by bedrock (95 percent of the boundary). Small alluvial-fan deposits bound the floodplain at two localities south of the river near RM 59.9 and RM 60.6. Small alluvial-fan deposits (not mapped) also may be present in two localities north of the river near RM 59.4 and RM 60.3. Thus, most of the floodplain boundary is essentially unerodible. However, the periodic changes in floodplain width suggest that the erodibility of the bedrock is variable and that in some places the river can more readily erode it than in others.

The un-named alluvial fan at RM 59.95 forms a constriction of the low surface against bedrock on the right side to RM 59.99. At the upstream end of the reach, the Little Butte Creek alluvial fan on the left side of the low surface does not impact the channel position. The channel alternates between running against bedrock and running within the low surface and underlying floodplain deposits throughout the reach.

Channel Migration (HCMZ) and Floodplain—Historical main channels have been slightly meandering with little marked change in the channel paths. The exception is between RM 60.6 and RM 60.7, where a meander present in 1939 changed position by 1956. In the narrow section of the reach downstream of RM 59.55, the pre-development main channel had less room to meander than it did in the section upstream of this point. In the narrower section, the HCMZ is nearly coincident with the floodplain. In the wider section upstream of RM 59.55, well-defined and moderately defined channels (e.g., between RM 59.7 and RM 58 and between RM 60.1 and RM 60.4) suggest that the pre-development channel may have migrated across a larger portion of the floodplain than has the historical main channel since 1939, but that some floodplain was present outside of the HCMZ. Overall, the HCMZ is interpreted to cover an area of about 42 acres and the geologic floodplain covers an area of approximately 58 acres, about 25 percent larger than the HCMZ.

Vegetation—This reach is not shown the 1926 water adjudication map. A small area of trees and/or shrubs is visible on the historical aerial photographs (1939, 1956, and 1976) north of the river just outside of the floodplain near RM 59.9. A larger area of trees and/or shrubs is present within the floodplain south of the river between RM 60.4 and RM 60.6. In 2006, much of the floodplain was small trees and shrubs. Small areas of

larger trees are present in the floodplain upstream of RM 59.55, where wider sections are present. Some areas of open grassland were present in the floodplain, especially upstream of RM 60.3.

4.3.1.13 Reach MF9

Reach MF9 is a 1.1-mile-long, unconfined, slightly sinuous reach that extends from RM 57.98 to RM 59.1. The downstream portion of the reach, to RM 58.5, is within the Tribe's Oxbow property.

Reach Boundaries—The downstream and upstream boundaries are both at narrow points that are bounded by bedrock.

Lateral and Vertical Geologic Constraints-- Reach MF9 is a transitional reach, between a wider, unconfined reach downstream (MF8) and a narrower, moderately confined reach upstream (MF10). The floodplain ranges between about 290 and 625 feet wide and has an average width of about 480 feet. The floodplain is narrowest at a bedrock constriction at RM 58.9, where the valley makes a near 90-degree turn to the left. The floodplain is widest just downstream of this point, at RM 58.75.

The floodplain is bounded entirely by bedrock, although an unmapped alluvial-fan deposit may be present at the mouth of Tincup Creek near RM 58.8. Between RM 58.1 and RM 58.5, the floodplain width appears to be controlled by the bedrock that is present on both sides of the floodplain. The floodplain boundaries are nearly straight in this section. Thus, the boundaries of the floodplain in this reach are nearly unerodible.

The channel is runs against bedrock along the right bank between RM 58.05 and RM 58.07, RM 58.13 and RM 58.15, and between RM 58.65 and RM 58.7. The left bank runs against bedrock between RM 58.89 and RM 58.95. A possible bedrock influence is located at RM 58.35 due to the narrow lateral extent of the low surface.

Channel Migration (HCMZ) and Floodplain—The pre-development main channel was likely meandering, as indicated by the main channel paths that are visible on historical aerial photographs. A meander between RM 58 and RM 58.1 in 1939 is not seen in subsequent years. A meander between RM 58.4 and RM 58.5 in 1939 and 1956 also was not seen in later photo sets; however, meanders between RM 58.1 and RM 58.3, and upstream of RM 59 are present in all available years of photographs. Sections of well-defined channels upstream of RM 58.7 may have been main channels or side channels that were abandoned, and suggest that the pre-development channel meandered. Poorly defined channels south of the river between RM 58.5 and RM 58.7 are interpreted as overflow channels and, thus, part of the floodplain and not the HCMZ. If this is true, then the HCMZ for the section is very narrow, relative to the geologic floodplain width. Downstream of RM 58.5, plantings on Tribal land adjacent to the main channel have markedly altered the ground surface and make interpretation of channel paths difficult on the LiDAR hillshade in this part of the reach.

As interpreted, the HCMZ (about 33 acres) covers about 62 percent of the geologic floodplain area (about 53 acres). Because of the lack of well-defined channels on the LiDAR hillshade, areas south and north of the river are excluded from the HCMZ upstream of RM 58.5. The HCMZ is totally interpretative downstream of this point, because of the surface modifications.

Vegetation— This reach is not shown in the 1926 water adjudication map. No areas of trees and shrubs are visible on the historical aerial photographs (1939, 1956, and 1976). In 2006, the floodplain was a mixture of open grassland and small trees and shrubs. The areas of open grassland were more continuous downstream of RM 58.4; the areas of small trees and shrubs were more continuous upstream of this point. A large area of larger trees was preserved in the floodplain south of the river between RM 58.5 and RM 58.8. Small areas of larger trees were preserved north of the river upstream RM 58.9.

4.3.1.14 Reach MF8

Reach MF8 is a 1.8-mile-long, unconfined, slightly sinuous reach that extends from RM 56.2 to RM 57.98. This reach is mostly within the boundaries of the Tribe's Oxbow property. An artificial channel that was constructed to the north of the pre-development channel will not be discussed in this section, but in Section 5.2.

***Reach Boundaries*--** The downstream boundary is at the upstream end of the alluvial-fan deposit from Beaver Creek on river right. The upstream boundary is at a narrow point that is bounded by bedrock.

***Lateral and Vertical Geologic Constraints*--** The reach is a wide section upstream of a wider unconfined reach downstream (MF7) and a narrower unconfined reach upstream (MF9). The floodplain ranges between about 415 and 945 feet wide and has an average width of about 655 feet. The floodplain is narrowest near RM 57.6, where alluvial-fan deposits from opposite sides of the valley, from Granite Boulder Creek to the north and from Butte Creek to the south, bound the floodplain. The floodplain is widest near RM 56.5, in the downstream half of the reach

The floodplain is bounded primarily by alluvial-fan deposits, but also by bedrock (about 25 percent of the boundary) and by alluvium/colluvium (about 25 percent of the boundary). The scalloped upstream edge of the large alluvial fan from Granite Boulder Creek suggests that the alluvial-fan deposits have been eroded by the Middle Fork. The concave patterns of the smaller alluvial-fan deposits from tributaries on the south side of the river suggest that they have built out into the valley and are mostly uneroded. The bedrock that bounds the floodplain north of the river downstream of RM 56.9 creates a nearly unerodible boundary. The unconsolidated alluvial and colluvial deposits south of the river may be eroded.

Although the floodplain is considered unconfined, mine tailings on the valley floor serve to confine the channel and inhibit lateral and vertical migration where the channel is located within or adjacent to the tailings. The mine tailings are likely responsible for a break in slope in the channel profile. The Ruby Creek and Granite Boulder Creek alluvial fans are juxtaposed to the left and right of the low surface, respectively. Historically, the fans would have imparted a control on lateral channel migration, but the toe of each fan has been dredged, and the streams have been diverted, leaving the remaining fan structures with no impact on the channel. At the upstream end of the reach, the Butte Creek alluvial fan comes in from the left. The fan forces the channel to the right forming a constriction with the upstream end of the Granite Boulder Creek Fan.

Dredge mining has split into two channels, although the south channel represents the pre-development channel. The north channel runs almost entirely through tailings material. The south channel is located within the geologic low surface, but the surface and underlying deposits have likely been somewhat disturbed due to the adjacent tailings.

Channel Migration (HCMZ) and Floodplain—Because of the great width of this reach, the pre-development channel (south channel) likely had a very meandering path. In 1939, the main channel was more meandering than channels appearing on later historical aerial photographs. By 1956, much of the channel and floodplain had been modified drastically by dredge mining and resulting channel manipulation. The surface of the floodplain upstream of RM 56.8 adjacent to the channel has been further modified by plantings. Consequently, no evidence of pre-development channels remains in this area. It may be that the pre-development channel and floodplain here were similar to that hypothesized for the unconfined reach MF2, where numerous channel paths, some well defined and others poorly defined, suggest a wide zone of main and secondary channels within an even wider zone of flooding. The pre-development channel in reach MF8 may have been meandering and/or braided with several channel paths active simultaneously. Shifting of the channel may have been common. The main channel may have migrated over a large percentage of the floodplain.

In reach MF8, the large alluvial fan from Granite Boulder Creek may have influenced the channel position and planform, so that the pre-development main channel of the Middle Fork could not access such a large portion of the geologic floodplain as it apparently did in reach MF2. Because migration of the channel in reach MF8 appears to have been limited, the HCMZ is drawn to encompass only the south side of the floodplain between RM 57 and RM 57.6. Alluvial-fan deposits and colluvium from small tributaries and slopes south of the river may have had a similar effect downstream of RM 56.8, keeping the main channel on the north side of the floodplain. Thus, the HCMZ as mapped covers about 80 acres and the geologic floodplain covers about 148 acres.

Vegetation—The entire floodplain in this reach is shown as meadow in a 1926 water adjudication map. Several areas of pines are indicated along Granite Boulder Creek just upstream of its mouth. Three small areas of trees and/or shrubs are visible in the floodplain between RM 57.2 and RM 57.6 on the historical aerial photographs (1939, 1956, and 1976). In 2006, the floodplain was nearly all open grassland. A few small areas of small trees and shrubs were present, mainly near the downstream and upstream reach boundaries. A small area of larger trees is preserved north of the river in the eroded area at the upstream end of the Granite Boulder Creek alluvial fan.

4.3.1.15 Reach MF7

Reach MF7 is a 0.6-mile-long, unconfined, slightly sinuous reach that extends from RM 55.6 to RM 56.2.

Reach Boundaries-- The downstream boundary is at the point where the floodplain begins to widen at the upstream end of the alluvial-fan deposit from Ragged Creek on river left. The upstream boundary is at the upstream end of the alluvial-fan deposit from Beaver Creek on river right.

Lateral and Vertical Geologic Constraints-- The reach is a wide section upstream of the very narrow, confined reach (MF6) and downstream of a wide, unconfined reach (MF8). The floodplain ranges between about 735 and 965 feet wide and has an average width of about 875 feet. The floodplain is narrowest at the downstream and upstream ends of the reach and widest at the mid point, near RM 55.85. At the upstream end, alluvial-fan deposits from an unnamed tributary on river left narrow the floodplain upstream of RM 56.

The floodplain is bounded primarily by bedrock, which makes up about 60 percent of the reach boundary. Unconsolidated deposits bound the floodplain in three sections: alluvial-fan deposits from an unnamed tributary south of the river upstream of RM 56, alluvial-fan deposits from Beaver Creek north of the river upstream of RM 56.1, and alluvium preserved north of the river between RM 55.75 and RM 55.9. The scalloped pattern of the boundaries of these unconsolidated deposits suggests that the Middle Fork has, and may still be able to, eroded the floodplain boundary in these areas.

At the downstream end, the Ragged Creek alluvial fan forces the channel to the right against bedrock. At the upstream end, the Beaver Creek alluvial fan is juxtaposed to the right of low surface boundary and is thought to have no impact on the channel.

The right bank of the channel runs along bedrock between RM 55.6 and RM 55.63, and then runs through floodplain deposits from RM 55.63 to the upstream end of the reach at RM 56.20. The left bank runs through floodplain deposits the entire length of the reach with no exposure to bedrock or alluvial fans.

Channel Migration (HCMZ) and Floodplain—Because of the great width of this reach, the channel likely had a very meandering path. In the 1939 and 1956 aerial photos, the main channel has a slightly more meandering path than later historical main channels, especially upstream of RM 56. One meander between RM 56 and RM 56.1 was present in 1939, 1956, and 1976, but was abandoned by 2000. Plantings on Tribal land adjacent to the main channel throughout this reach have markedly altered the ground surface and make interpretation of channel paths difficult on the LiDAR hillshade. The historical meanders suggest a naturally, more meandering channel pattern than the present one. Because of the width of the floodplain, it is conjectured that the pre-development channel was meandering andor braided with several channel paths active simultaneously. The main channel likely migrated over a large percentage of the floodplain. The HCMZ (about 26 acres) is interpreted to cover at least 54 percent of the floodplain area (about 49 acres). The south portion of the floodplain is not included within the HCMZ. It may be that a slope to the north extends from the alluvial-fan deposits from the unnamed tributary that enters from the south near the upstream reach boundary. However, the surface of the floodplain has been markedly altered so that the presence or absence of former channels of the Middle Fork cannot be evaluated.

Vegetation—The entire floodplain in this reach is shown as meadow in a 1926 water adjudication map. No areas of trees and shrubs are visible on the historical aerial photographs (1939, 1956, and 1976). In 2006, the floodplain was nearly all open grassland. A few small areas of small trees and shrubs were scattered throughout the reach.

4.3.1.16 Reach MF6

Reach MF6 is a 0.3-mile-long, confined, curving reach that extends from RM 55.3 to RM 55.6.

Reach Boundaries-- The downstream boundary is at a geologic constriction between an alluvial-fan deposit from an unnamed tributary on river right and bedrock on river left. The upstream boundary is at the point where the floodplain begins to widen at the upstream end of the alluvial-fan deposit from Ragged Creek on river left.

Lateral and Vertical Geologic Constraints—The reach is very confined between bedrock and two large alluvial-fan deposits from opposite sides of the valley. The floodplain ranges between about 105 and 165 feet wide and has an average width of about 140 feet. The narrowest point is at RM 55.4, where the opposing alluvial-fan deposits bound the floodplain. From this point upstream, the floodplain gets progressively wider to the reach boundary, where it narrows.

About half (54 percent) of the floodplain is bounded by bedrock and about half (46 percent) is bounded by alluvial-fan deposits. Although the upstream edge of the alluvial-fan deposits from Ragged Creek is slightly sinuous, suggesting some erosion of these deposits by the Middle Fork, the generally convex form of the alluvial fans suggests that the most of the deposits have not been eroded. Thus, most of the floodplain may be prone to erode or essentially so.

On the right side, an unnamed alluvial fan forms a constriction first with bedrock at the downstream end, and then with the opposing Ragged Creek alluvial fan on the left bank near the upstream end of the reach. The Ragged Creek alluvial fan forces the channel to the right and forms a constriction with the bedrock on the right side of the low surface.

Between RM 55.42 and RM 55.60, the right bank runs against bedrock. Sections of the low surface with narrow lateral extent between the channel and adjacent surfaces are at RM 55.32 and 55.44, allowing bedrock and alluvial fan influence, respectively.

Channel Migration (HCMZ) and Floodplain— Reach MF6 is so narrow that the main Middle Fork channel was likely a single path that could meander only slightly prior to development. Plantings on Tribal land in this reach have markedly altered the ground surface and make interpretation of channel paths difficult, especially in the slightly wider section of the reach upstream of RM 55.45. Historical paths for the main channel nearly overlap. Because the reach is so narrow, the HCMZ is interpreted to cover the entire floodplain, about 4 acres in area.

Vegetation—This reach is not shown the 1926 water adjudication map. The only areas where trees and/or shrubs are visible on the historical aerial photographs (1939, 1956, and 1976) are outside of the floodplain north of the river and downstream of RM 54.4. In 2006, much of the floodplain was covered by water. At a slightly wider section between RM 55.45 and RM 55.5, the floodplain was a mixture of open grassland and small trees and shrubs. Some small areas of larger trees were present north of the river downstream of RM 55.4 and south of the river upstream of that point.

4.3.1.17 Reach MF5

Reach MF5 is a 1.4-mile-long, moderately confined, Z-shaped reach that extends from RM 53.9 to RM 55.3.

Reach Boundaries-- The downstream boundary is where the valley narrows into the bedrock-confined section that makes up the upstream half of reach MF4. The upstream boundary is at a geologic constriction between an alluvial-fan deposit from an unnamed tributary on river right and bedrock on river left.

Lateral and Vertical Geologic Constraints—The reach is moderately confined between bedrock mostly, and alluvial-fan deposits of variable size from two tributaries on river right and two on river left.

The floodplain ranges between about 225 and 555 feet wide and has an average width of about 400 feet. The narrowest sections are near the downstream and upstream reach boundaries, where the floodplain width is about 190 feet (downstream) and about 140 feet (upstream). One of the two widest sections is where the valley bends to the left near RM 54.2 and the floodplain is about 525 feet wide. The other wide section (about 510 feet) is between RM 54.5 and RM 54.6, which is a straight section bounded by bedrock and just downstream of the bend to the right near RM 54.7.

Three-fourths of the floodplain is bounded by bedrock. Alluvial-fan deposits compose the other one fourth of the boundary. The scalloped boundaries of the alluvial-fan deposits suggest that these deposits have been, and may still be, eroded by the Middle Fork. However, bedrock makes up most of the floodplain boundary and periodic additions of sediment to the alluvial-fan deposits means that the boundary is not readily erodible.

At the downstream end of the reach, the Dry Creek alluvial fan on the right bank has a low influence on the river position. In the upstream section of the reach, there are two alluvial fans from unnamed streams in this reach. One is located at RM 54.8 on the left side of the low surface and is thought to have no impact on the channel. The second has its downstream end at RM 55.25 on the right side of the low surface and continues upstream into the next reach. This alluvial fan is thought to have no impact on the channel in this reach.

The lateral extent of the low surface between the right bank of the channel and adjacent deposits is narrow, allowing for bedrock influence on lateral migration to the right at RM 54.6 and 54.91, and alluvial fan influence on lateral migration at RM 53.98 and 55.19. There are sections of narrow lateral extent with bedrock behind that influences lateral migration to the left at RM 55.35 and fan influence at RM 55.44.

Channel Migration (HCMZ) and Floodplain—The pre-development main channel in reach MF5 was likely a single path that could meander except in the narrowest section of the reach, upstream of RM 55.2. A historical change in meander path occurred between 1956 and 1976 between RM 54.7 and RM 54.8. Well-defined channels that are visible on the LiDAR hillshade appear to have been main channels, or perhaps side channels, that similarly were abandoned by the river before our oldest set of historical aerial photographs (1939) (e.g., north of the river between RM 54.35 and RM 54.5, south of the river between RM 54.65 and RM 54.7, and south of the river between RM 55 and RM

55.l). Remnants of poorly defined channels outside of the HCMZ are interpreted as overflow channels. A fairly well defined channel south of the river between RM 54.5 and RM 54.6 may have originally been a main or secondary channel of the Middle Fork, but appears to have carried tributary flow since that time. Plantings on Tribal land upstream of RM 54.7 have markedly altered the ground surface, and make interpretation of channel paths difficult.

Because of the apparently abandoned main channel paths that are visible on the LiDAR hillshade, the HCMZ is interpreted to cover about 43 acres and the geologic floodplain about 60 acres. Approximately 35 percent of the geologic floodplain is estimated to extend beyond the HCMZ. These areas are all on the south side of the valley. Between RM 54.8 and RM 55, the alluvial-fan deposits from an unnamed tributary to the south may naturally restrict the main channel to the north side of the floodplain. Small, unmapped alluvial-fan deposits and colluvium from other drainages along the south side may act similarly downstream of RM 54.6. Historically (since 1939), it appears that the main channel has been at the mouth of Sunshine Creek, in contradiction to this pattern. However, a possible main channel path to the north may have been the pre-development location of the main channel.

Vegetation—This reach is not shown the 1926 water adjudication map. Several areas within the floodplain upstream of RM 54.6 had trees and/or shrubs that are visible on the historical aerial photographs (1939, 1956, and 1976). Most of these areas are at meanders or abandoned meanders. In 2006, the reach downstream of RM 54.65 (approximately downstream of the right bend in the valley) was a mixture of small trees, shrubs, and open grassland, with a few small areas of larger trees. Upstream of this point, the floodplain was primarily open grassland with small areas of small trees and shrubs or larger trees.

4.3.1.18 Reach MF4

Reach MF4 is a 1.25-mile-long, confined, sinuous reach that extends from RM 52.65 to RM 53.9.

Reach Boundaries-- The downstream boundary is at the downstream narrowing created by the very large alluvial-fan deposit from Big Boulder Creek on river right and bedrock on river left. The upstream boundary is where the valley widens from the narrow, bedrock-confined section that contains the upstream half of the reach.

Lateral and Vertical Geologic Constraints—The reach is confined by the large alluvial-fan deposit from Big Boulder Creek on river right between RM 52.5 (downstream of reach MF4) and RM 53.4, and by bedrock elsewhere. The reach is confined by bedrock on the left side for its entire length. The 0.5-mile-long section upstream of the Big Boulder Creek alluvial-fan deposit is very narrow, consistently less than about 260 feet wide.

The floodplain ranges between about 125 and 500 feet wide, and has an average width of about 270 feet. The narrowest point is at the apex of the Big Boulder Creek alluvial fan. The widest section is the upstream side of the alluvial-fan deposit, which appears to have been eroded at some time by the Middle Fork. The floodplain widens both downstream and upstream of the reach boundaries.

More than half (64 percent) of the floodplain is bounded by bedrock. The alluvial-fan deposits from Big Boulder Creek bound about 30 percent of the floodplain. The concave boundary of the alluvial-fan deposits between RM 53.3 and RM 53.4 suggests that the deposits have been eroded by the Middle Fork, and could likely still be eroded. However, additional sediment that is periodically deposited by the creek into the Middle Fork valley would limit extensive erosion of the alluvial-fan deposits. All of the south floodplain boundary and the north boundary upstream of the alluvial-fan deposits are not prone to erosion.

In this reach, the left bank alternates between running against bedrock and through the floodplain deposits in the downstream half of the reach. Bedrock is present along the left bank of the channel between RM 53.62 and RM 53.88. Alluvial fan material bounds the channel is several locations within the middle of the reach. Between 53.49 and RM 53.54, the right bank runs against bedrock.

Channel Migration (HCMZ) and Floodplain—Reach MF4 is so narrow that the main Middle Fork channel was likely a single path that could meander only slightly prior to development. Between RM 53.3 and RM 53.4, the presence of a well defined channel along the north side of the floodplain and the concave configuration of the alluvial-fan deposits from Big Boulder Creek suggest that the main channel of the Middle Fork once flowed on the north side and eroded the alluvial-fan deposits. The channel has been geologically constricted in the very narrow section between RM 53 and RM 53.1. In the area north of the river between RM 53.3 and RM 53.4, one well-defined channel and a few poorer defined channels are present. The ground surface within the floodplain has been modified to the extent that interpretation of the pre-development channel pattern is not possible.

Because of the narrowness of the reach, the HCMZ (about 33 acres) is thought to encompass the entire floodplain area (about 35 acres), except north of the river between RM 52.8 and RM 53. In this area, a slope toward the river created by alluvial-fan deposits and the deflection of the channel from the narrowest point at the fan apex may have kept the main channel to the south, allowing only flood flows to access this part of the floodplain.

Vegetation—This reach is not shown in the 1926 water adjudication map, although the downstream half of the Big Boulder Creek alluvial fan (north of the floodplain of the Middle Fork) is shown as brush and pasture or meadow. The areas just outside of the floodplain downstream of RM 52.8, near RM 53.1, and within the floodplain near RM 53.3 had trees and/or shrubs that are visible on the historical aerial photographs (1939, 1956, and 1976). In 2006, the reach downstream of RM 53.1 (approximately the apex of the Big Boulder Creek alluvial fan) was open grassland. Upstream of this point, the reach had a mixture of open grassland, small trees and shrubs, and larger trees. One relatively large area of larger trees was present north of the river between RM 53.3 and RM 53.4, in the area between the old main channel path and the present main channel path.

4.3.1.19 Reach MF3

Reach MF3 is a 1.6-mile-long, moderately confined, slightly curving reach that extends from RM 51.05 to RM 52.65.

Reach Boundaries-- The downstream boundary is at a geologic constriction between the alluvial-fan deposit from Coyote Creek on river right and bedrock on river left. The upstream boundary is at the downstream narrowing created by the very large alluvial-fan deposit from Big Boulder Creek on river right and bedrock on river left.

Lateral and Vertical Geologic Constraints—The reach is a moderately wide section between a very wide reach downstream (MF2) and a very narrow reach upstream (MF4). The floodplain ranges between about 350 and 775 feet wide and has an average width of slightly less than 550 feet. The floodplain width is fairly consistent throughout the reach.

The floodplain narrows to about 400 feet at the downstream boundary and narrows markedly to about 280 feet at the upstream reach boundary. The floodplain is bounded almost entirely by bedrock (84 percent of the boundary). Alluvial-fan deposits bound the floodplain near the reach boundaries. Thus, most of the floodplain boundary is not or only slightly erodible.

At the downstream end of the reach, the extent of lateral migration to the left is influenced by bedrock. Through most of the reach, the current channel boundary alternates between floodplain deposits and bedrock on the left side of the valley.

Channel Migration (HCMZ) and Floodplain—Historical main channels in 1939 and 1956 had a few short (less than 0.1 mile), broad meanders (e.g., near RM 52.2 and RM 51.6). Surface modifications make interpretation of the pre-development channel pattern difficult. A few well and moderately well defined channels are present, for example, north of the river between RM 52.1 and RM 52.3, and downstream of RM 51.6. However, some of the channels in the downstream area appear to trend from the valley edge downstream and toward the Middle Fork, and may all be, or partially be, old tributary channels. Because of the width of the floodplain, it is likely that the pre-development channel pattern was meandering. On the basis of the channel paths visible on the LiDAR hillshade, it appears that the main channel has been primarily along the south side of the floodplain, although older paths to the north may have been destroyed. The channel paths that are visible north of the river suggest a slope to the south, so that the main channel may not have migrated much to the north in recent times.

Because the channel paths that are visible on the LiDAR hillshade, the HCMZ is interpreted to cover about 94 acres and the geologic floodplain about 105 acres. Only about 14 percent of the geologic floodplain is estimated beyond the HCMZ. These areas are on the north side of the valley, where the local slope may be to the south, possibly from alluvium/colluvium deposited from tributaries or bedrock slopes bounding the valley. These are areas where alluvial-fan deposits slope upward toward the edges of the valley and do not appear to have been accessed by the main Middle Fork channel in some time.

Vegetation—This reach is shown as meadow or brush and pasture on a 1926 water adjudication map. Small areas of trees and/or shrubs are visible on the historical aerial photographs (1939, 1956, and 1976) north of the river between RM 51.9 and RM 52.4.

In 2006, most of the reach upstream of about RM 51.9 was open grassland, whereas the reach downstream of this point contained a mosaic of open grassland and small trees and shrubs. Some small areas of larger trees were present also.

4.3.1.20 Reach MF2

Reach MF2 is a 2.9-mile-long, unconfined, nearly straight reach that extends from RM 48.15 to RM 51.05.

Reach Boundaries-- The downstream boundary is at a geologic constriction between alluvium/colluvium, in part formed by deposits from Cress Creek on river right and by bedrock on river left. The upstream boundary is at a geologic constriction between the alluvial-fan deposit from Coyote Creek on river right and bedrock on river left.

Lateral and Vertical Geologic Constraints-- The reach is a very wide section between narrower, moderately confined reaches downstream (MF1) and upstream (MF3). The floodplain ranges between about 425 and 1,775 feet wide, and has an average width of slightly greater than 1,000 feet. The floodplain is narrower where tributaries of various sizes have deposited alluvial fans (sometimes mapped as alluvium/colluvium) in the valley. The narrowest section of the reach is between RM 49.6 and RM 50.2, where alluvial-fan deposits are present on both sides of the valley.

The floodplain is bounded primarily by alluvium/colluvium, alluvial-fan deposits, or bedrock. The scalloped pattern of the boundary in the alluvium/colluvium and alluvial-fan deposits suggests that these units were at some time, and may be still are, erodible by the river. Thus, these units may provide less lateral control to channel migration than bedrock, which is present along 23 percent of the reach boundary and along the valley margin.

Moving from downstream to upstream, the left bank runs within floodplain deposits for the downstream two-thirds of the reach, then crosses the valley at RM 50.1, and runs along alluvium/colluvium and bedrock to the top of the reach at RM 51.05. The right bank runs mostly along alluvium/colluvium in the downstream half of the reach. Between RM 49.24 and RM 49.46, bedrock bounds most of the right bank.

Channel Migration (HCMZ) and Floodplain—Because of the great width of this reach, the channel likely had a very meandering path. The 1939 channel had many meanders, some across nearly the entire HCMZ, that were not present in later years, especially by 1976. The remnants of these abandoned channels are still visible. Channel paths are visible on the LiDAR hillshade. Some of these are still well or moderately well defined, and are probably abandoned main or side channels. Channels with poorer definition may have been overflow channels. The channel naturally may have been meandering and/or braided with several channel paths active simultaneously. Shifting of the channel may have been common. The main channel likely migrated over most of the floodplain, and because of the numerous, fairly well defined channel paths, the HCMZ (about 270 acres) is interpreted to cover most of the floodplain area about 325 acres). About 18 percent of the floodplain extends beyond the HCMZ. These are areas where alluvial-fan deposits slope upward toward the edges of the valley and do not appear to have been accessed by the main Middle Fork channel in some time.

Vegetation—Except for two small areas of brush, this entire reach is shown as meadow in a 1926 water adjudication map. Small areas of trees and shrubs are visible on the historical aerial photographs (1939, 1956, and 1976), mainly downstream of RM 48.8, and at the upstream end of the reach between RM 50.1 and 50.8. These areas were mostly cleared of vegetation (grass only) in 2006, although some small trees and shrubs remain in these areas.

4.3.1.21 Reach MF1

Reach MF1 is a 0.2-mile-long, moderately confined reach that extends from RM 47.95 to RM 48.15.

Reach Boundaries-- The downstream boundary is at a constriction formed by bedrock on river right and an alluvial-fan deposit from Camp Creek on river left. The upstream boundary is at a geologic constriction between alluvium/colluvium, in part formed by deposits from Cress Creek on river right and by bedrock on river left.

Lateral and Vertical Geologic Constraints-- The reach is a slightly wider section just upstream of a very narrow section bounded by bedrock (outside of our study area) and a very wide section upstream (reach MF2). The floodplain is about 300 to 400 feet wide in this reach, about 225 feet wide at the downstream boundary, and about 260 feet wide at the upstream boundary. The floodplain is bounded by alluvial-fan deposits from Camp Creek on river left and by alluvium/colluvium on river right. Bedrock is present at the reach boundaries and along the valley margins. The Camp Creek alluvial fan at the downstream end forces the river to the right, against bedrock. The channel runs mostly against floodplain deposits along both banks. However, at RM 47.95 the left bank runs against alluvial fan material, and the right bank runs against bedrock at RM 47.93 in the downstream end of the reach.

Channel Migration (HCMZ) and Floodplain--The floodplain is wide enough that the main channel had a meandering pattern in 1939, 1956, and 1976, but was markedly straighter in 2000 and 2006 as a result of channel avulsions and abandonment of the older meanders. The channels visible on the historical aerial photographs suggest that flow has been primarily in a single path (main channel). Only one prehistoric channel path, possibly an overflow channel, is visible on the north side of the floodplain. Since 1939, the main channel appears to have been in the central and south portion of the reach. South of the river, the floodplain coincides with the HCMZ. North of the river, the floodplain (about 2.7 acres) extends beyond the HCMZ. Poorly defined channels are visible on this surface and were likely overflow channels.

Vegetation—The area on the south side of the river and the upstream half of the area north of the river are shown as meadow in a 1926 water adjudication map.

4.4 Sediment Sources

Fine sediment sources include sheet and rill erosion occurring in subdrainages that have been disturbed by timber harvest, road construction and wildland fires. These sediments are being transported downslope to perennial and ephemeral streams and then to the Middle Fork by entrainment and saltation.

Coarse sediment sources include bank erosion along the Middle Fork and sediment pulses entering the Middle Fork from several perennial tributaries. Removal of riparian vegetation along the Middle Fork may have destabilized the riverbanks, and bank erosion appears to have been a chronic problem based on aerial photographs following major flood events. Bank erosion control measures were installed and primarily consisted of bank armoring (i.e., rock spurs, riprap, etc.) that restricts lateral channel migration.

Tributaries with the greatest potential to contribute coarse sediment to the Middle Fork include Clear Creek, Vinegar Creek, Granite Boulder Creek, and Big Boulder Creek. The most significant contributions appear to be coming from the Big Boulder Creek subdrainage. In 1996, the Big Boulder Creek subdrainage was burned by a moderate-to-high intensity wildland fire that removed much of the groundcover, exposing the soil to erosion. Shallow landslides and debris flows are episodic throughout the Boulder Creek watershed and provide sediment pulses to the perennial stream and eventually to the Middle Fork. Big Boulder Creek has been a coarse sediment source to the Middle Fork throughout the Holocene based on the large alluvial fan that has developed where the creek flows across the valley floor. In addition, a relatively large gravel bar at the mouth of the creek suggests coarse sediment is continually being delivered to the Middle Fork. Sediment deposits at the downstream end of Granite Boulder Creek indicate some loading to the artificial north channel of reach MF8.

At the present time, Clear Creek and Vinegar Creek do not appear to be providing significant amounts of coarse sediment to the Middle Fork. There is a small gravel bar at the mouth of Clear Creek that formed between the 1976 and 2005 aerial photograph sets, following the creek's realignment due to the construction of the town of Bates. The gravel bar presence suggests that the creek provides a relatively small amount of coarse sediment to the Middle Fork. Vinegar Creek also provides an episodic supply of coarse sediment as interpreted from historic aerial photography that shows shallow landslides along the creek and some channel migration across its alluvial fan on the valley floor.

Other potential coarse sediment sources include disturbed areas associated with historic placer mining. These areas include the Middle Fork downstream of Caribou Creek and Granite Boulder Creek and also the Vincent Creek subdrainage.

5.0 Present Setting

This section describes the present river setting and how current processes may have been altered from the conceptual model of the pre-settlement (natural) hypothetical condition as described earlier in this appendix. The discussion focuses on trends in physical river processes that are tied to channel morphology and habitat complexity. Channel morphology can change over time as a result of natural or human-induced alteration to upstream reaches or due to local impacts within the reach itself. Key factors determining the channel morphology in each reach include geologic controls, hydrologic regime, sediment inputs and transport, riparian vegetation, and LWD recruitment. Processes can also change due to localized alterations in the hydraulic capacity (channel geometry and floodplain accessibility) due to human influences, such as bridges, levees, and riprap. The following discussion presents a brief overview of channel dynamics, a detailed investigation of the current hydraulics and sediment transport of the assessment area, a description of how human impacts have impacted each reach, and finally an assessment of the present state of vegetation.

5.1 Brief Overview of River Processes

Over time, streams attempt to move toward an equilibrium condition to balance energy available with energy needed to transport incoming sediment. Dynamic equilibrium is often referred to as the condition where the net incoming sediment supply approximately equals the sediment transported out of a reach over a given period of time. In this scenario, incoming discharge may alternate between wet and dry cycles, but there is no definitive trend in flow peaks or duration over a decadal time period. Additionally, short-term changes in the channel bed position and elevation can still occur, but net change in channel form or bed elevations for a given reach cannot be detected over years to decades. For example, a channel may migrate across its floodplain causing the existing channel to at least partially fill with sediment as the channel is abandoned. Concurrently, a new channel is eroded or converted from floodplain to channel area. At any one location in the floodplain during this process, an observer could note erosion or aggradation, but the overall sediment in storage within the reach would not have significantly changed.

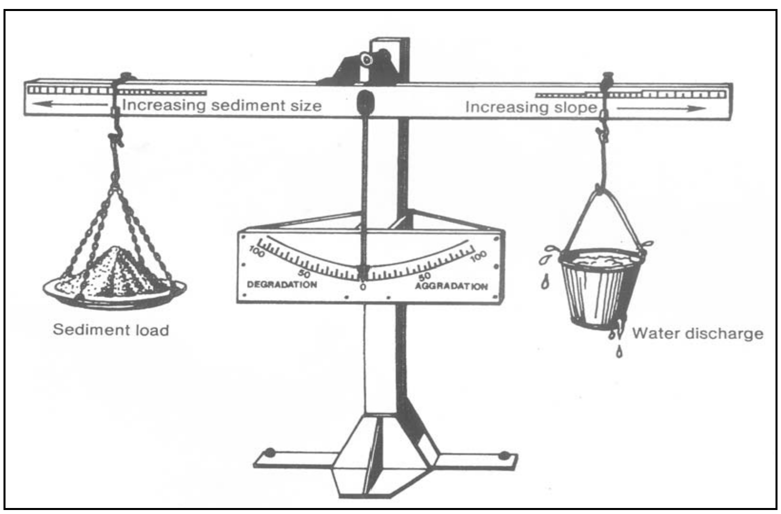

Figure 12 - Illustration of Channel Response to Varying Incoming Sediment Load and Water Based on Sediment Transport Capacity Within the Reach (Lane 1955).

A simplified version of this concept can be described using Lane's balance of water and sediment (Lane 1955; Figure 12). In Lane's conceptual figure, the river's ability to remain in equilibrium is dependent on the ability to transport incoming sediment supply given a quantity of water.

According to Lane's balance, water discharge and sediment load are inversely related as a function of channel slope and sediment size:

$$QS \sim Q_s D_{50}$$

Where:

Q = water discharge,

S = channel slope,

Q_s = sediment load, and

D_{50} = sediment size.

A change in any one of these four variables will result in a change in the others in order to restore equilibrium to the system. Once a channel has reached a state of equilibrium, sediment is transported through the reach without substantial aggradation or degradation. However, this equilibrium is dynamic in that a channel has the potential to migrate laterally through erosion of one bank and accretion of the opposite bank at a similar rate. Natural or man-induced changes in the incoming sediment load, water discharge, slope, or sediment size can offset the balance and result in changes in channel morphology. Channels can respond to changes through lateral (widening or narrowing) or vertical adjustment (incision or aggradation) or through modified rates of channel migration and floodplain reworking.

5.2 Anthropogenic Impacts on Reach Conditions

Anthropogenic activities have been occurring for over a century in the basin. Appendix A provides a timeline of anthropogenic activities in the basin and their general impacts to river conditions. This section is intended to provide a detailed look at how constructed features and anthropogenic activities have directly impacted the geomorphology of each of the reaches. This discussion is followed by a description of cattle grazing in the general vicinity of the assessment area since cattle grazing activities are hypothesized to have historically impacted riparian vegetation and possibly in-channel habitat complexity features. A compilation of the measured human impacts is provided in Appendix G.

In the Middle Fork assessment area, the greatest impacts to channel processes have been topographic in nature and result primarily from grazing, logging, dredge mining, development of transportation routes, and flood control measures. The locations and types of constructed features are presented in Chapter 4 of the main report. In general, constructed features along the channel and within the floodplain predominantly consist of rock spurs, riprap, levees, roads, railroads and bridges. These constructed features limit floodplain connectivity, lateral migration of the channel, and access to side and overflow channels. The greatest impacts to habitat complexity from constructed features and human activities occurred in unconfined and moderately confined reaches. Reaches with the greatest number, length, and area of constructed features include reaches MF2, MF7, MF8, MF9, MF12, MF13, and CC1.

5.2.1 Reach Descriptions

Mapping of constructed features, also termed human features, was conducted throughout the assessment area using field observations, aerial photography, and LiDAR data. Although attempts were made to document every constructed feature present in a reach, time and physical access to each reach precluded detailed ground truthing of every feature. In some locations, aerial photographs and LiDAR data were the only methods available to identify potential constructed features.

5.2.1.1 Reach MF20 (RM 68.1 to RM 68.95)

Summary

Most of reach MF20 is not impacted by constructed features. Only about 0.9 acres, or approximately 7 percent, of the 12-acre HCMZ is impacted in three areas. An irrigation ditch on river left between RM 70.6 and RM 70.81 impacts about 0.63 acres of HCMZ. An unimproved road on river right between RM 70.55 and RM 70.65 impacts about 0.23 acres of HCMZ. Both the irrigation ditch and unimproved road are near the HCMZ boundary, so that their impact is likely minimal and channel migration is essentially unaffected. Riprap extends upstream from the unimproved road on river right downstream of the reach boundary in reach MF19. This riprap impacts about 0.02 acres of HCMZ between the reach boundary at RM 70.15 and RM 70.17. The reach between RM 70.17 and RM 70.48 does not have mapped constructed features. The channel meanders in this section and none of the HCMZ appears to be impacted. This section may be properly functioning.

Constructed Features

- **Irrigation Ditch:** About 1,310 feet of irrigation parallels the left boundary of the HCMZ between RM 70.6 and 70.81 and impacts about 0.63 acres of HCMZ. This area is at the edge of the HCMZ and channel migration is essentially unaffected.
- **Unimproved Road:** About 990 feet of an unimproved road parallels the right boundary of the HCMZ between RM 70.55 and RM 70.65 and impacts about 0.23 acres of HCMZ. This area is at the edge of the HCMZ and channel migration is essentially unaffected.
- **Bank Armoring:** About 60 feet of riprap is present along the right bank near the downstream reach boundary and impacts about 0.02 acres of the HCMZ between RM 70.15 (downstream reach boundary) and RM 70.17. It likely limits channel migration.
- **Log Structures:** Two log structures are present in the channel at RM 70.7 and RM 70.74.

HCMZ and Channel Migration

The section between RM 70.17 and RM 70.48 does not appear to have constructed features and the HCMZ and channel migration is this section may be properly functioning. Three areas that make up less than 10 percent of the HCMZ in reach MF20 are impacted by constructed features. Between RM 70.17 and the downstream reach boundary at RM 70.15, riprap is present along about 60 feet of the right bank as a continuation of riprap that protects an unimproved road in reach MF19. The riprap appears to limit channel migration. Between RM 70.55 and RM 70.65, an unimproved road on river right impacts about 0.23 acres of HCMZ. Between RM 70.6 and RM 70.81, an irrigation ditch on river left impacts about 0.63 acres of HCMZ. For the unimproved road and irrigation ditch, the impacted areas are near the edges of the HCMZ, so their impacts likely are minimal and channel migration is not limited significantly.

Channel Planform

Between 1939 and 1956, no change in channel length was measured. However, channel migration and avulsions are evident. An increase in the channel length was measured in the subsequent years from 1956 to 1976. Although the measured change was almost 170 feet, a large portion of this may be due to an improved ability to track channel location in 1976 resulting from a reduction in vegetation. Some of the increase is due to lateral channel migration and increased meander amplitude. Between 1976 and 2000, a very small reduction in channel length was measured (60 feet) and little lateral channel migration is evident. The channel increased a length of 80 feet between 2000 and 2006 due to 2 locations of minor channel migration. The net change in channel length from 1939 to 2006 was an increase of 220 feet (6.6 percent increase in total length and sinuosity), most of which is related to the capability of the digitizer to accurately identify the channel location.

Floodplain Access

The floodplain is coincident with the HCMZ and off-channel areas (e.g., overflow channels) are impacted in the areas where the HCMZ is impacted.

5.2.1.2 Reach MF19 (RM 69.7 to RM 70.15)

Summary

The main constructed features that impact reach MF19 are a culvert in the highway embankment at RM 69.92 near the middle of the reach and the adjacent highway embankments. Of the 1.1 acres (24 percent) of the HCMZ that is impacted in this reach, about 0.6 acres of this acreage is from the culvert through the highway embankment. The culvert and embankment impose about 240 feet of straightened and confined channel. Downstream of RM 69.72, two possible artificially blocked channels, one on each side of the channel, impact about 0.23 acres of HCMZ in reach MF 19. About 450 feet of unimproved road and about 175 feet of riprap along the bank protecting the road impact about 0.23 acres of HCMZ on river right between RM 70.07 and the upstream reach boundary at RM 70.15. A diversion at RM 70.04 impacts a small area (0.02 acres) of HCMZ on river right.

Constructed Features

- **Culvert and Highway Embankment:** A culvert at RM 69.92 and highway embankment across the HCMZ impacts about 0.6 acres of HCMZ and result in about 240 feet of straightened and confined channel.
- **Possible Artificially Blocked/Filled Channels:** Possible artificially blocked channels at RM 69.7 on river left (just upstream of the reach boundary) and at RM 69.72 on river right impact about 0.23 acres of HCMZ. These areas need to be checked in the field.
- **Unimproved Road and Bank Armoring:** About 450 feet of unimproved road and about 175 feet of riprap placed for road protection along the river's right bank. These features impact about 0.23 acres of the HCMZ and limit channel migration between RM 70.07 and RM 70.15, the upstream reach boundary.
- **Diversion:** A diversion is present at RM 70.04 that impacts about 0.02 acres of HCMZ on river right.

HCMZ and Channel Migration

A culvert and a highway embankment at RM 69.92 limit the HCMZ (about 0.6 acres impacted) and channel migration between RM 69.88 and RM 69.95. About 240 feet of the channel appear to be straightened and confined near the culvert. About 0.23 acres of HCMZ are impacted downstream of RM 69.72, the downstream reach boundary, by two possible artificially blocked channels. Riprap along about 450 feet of the right bank that protects an unimproved road impacts about 0.23 acres of HCMZ and limits channel migration.

Channel Planform

Very little change has occurred over the last 70 years in reach MF19. An increase of approximately 50 feet was measured between 1939 and 1956. However, the difference is likely related to an inability to accurately track channel location in the 1939 photoset. The net measured change in channel length between 1939 and 2006 was an increase of 50 feet.

Floodplain Access

The floodplain is coincident with the HCMZ. Off-channel areas (e.g., overflow channels) are impacted in the areas where the HCMZ is impacted.

5.2.1.3 Reach MF18 (RM 69.23 to RM69.7)

Summary

Possible artificially blocked or filled channels have the greatest impact in reach MF18, with about 1 acre, or 15 percent, of the HCMZ are impacted. Downstream of RM 69.28, the HCMZ on both sides of the channel is impacted. A channel on river left at RM 69.28 appears to be artificially blocked and impacts about 0.46 acres of HCMZ. A 40-foot-long section of bank on river right has riprap between RM 69.26 and RM 69.27, at the confluence of Mill Creek, which impacts about 0.1 acre of HCMZ. A diversion at RM 69.39 and an irrigation ditch between there and RM 69.3 impacts about 0.13 acres of the

HCMZ on river left. Between RM 69.39 and RM 69.62, no constructed features have been mapped. The channel is meandering and may be mostly properly functioning. Upstream of RM 69.62, about 0.53 acres of HCMZ area are impacted by possible artificially blocked channels in reach MF19.

Constructed Features

- **Possible Artificially Blocked/Filled Channels:** A possible artificially blocked channel at RM 69.28 impacts about 0.46 acres of HCMZ on river left. Possible artificially blocked channels on both sides of the channel in reach MF19 impact about 0.53 acres of HCMZ in reach MF18 upstream of RM 69.62. These areas need to be checked in the field.
- **Bank Armoring:** Riprap on a 40-foot-long section of bank on river right near the confluence of Mill Creek impacts about 0.1 acre of HCMZ downstream of RM 69.27.
- **Diversion and Irrigation Ditch:** A diversion at RM 69.39 and an irrigation ditch extending nearly 400 feet downstream of that point to RM 69.3 impact about 0.13 acres of HCMZ on river left.

HCMZ and Channel Migration

About 1.2 acres, or 18 percent, of the HCMZ is impacted in reach MF18. About 0.5 acres of this total is created by possible artificially blocked channels on both sides of the channel in reach MF19. A possible artificially blocked channel on river left at RM 69.28 and riprap along a 40-foot-long section of bank on river right between RM 69.26 and RM 69.27 impact 0.56 acres of HCMZ and limit channel migration downstream of RM 69.3. Between RM 69.3 and RM 69.39, a diversion and irrigation ditch limit about 0.13 acres of HCMZ on river left. Between RM 69.4 and RM 69.62, no constructed features have been mapped and the HCMZ and channel migration may be functioning. The channel planform throughout the reach is meandering, except at the culvert at the upstream reach boundary, where the channel appears to have been straightened and is confined.

Channel Planform

See the discussion for Reach MF17.

Floodplain Access

The floodplain is coincident with the HCMZ. Off-channel areas (e.g., overflow channels) are impacted in the areas where the HCMZ is impacted.

5.2.1.4 Reach MF17 (RM 68.95 to RM 69.23)

Summary

Most of reach MF17 is not impacted by constructed features. A possible artificially blocked channel on river right at RM 69.2 impacts about 0.4 acres of HCMZ and limits channel migration. A 50-foot-long section of the bank on river right that may be protected by riprap impacts about 0.07 acres of HCMZ. A bridge for the highway at RM 68.95, just downstream of the reach boundary, impacts about 0.05 acres of HCMZ and creates about 40 feet of straightened channel in reach MF17.

Constructed Features

- **Possible Artificially Blocked or Filled Channel:** One channel on river right may be artificially blocked at RM 69.2. The blockage impacts about 0.4 acres of HCMZ and limits channel migration. These areas need to checked in the field.
- **Bank Armoring:** A 50-foot-long section of bank on river right between RM 69.09 and RM 69.1 may be armored with riprap. The section impacts about 0.07 acres of HCMZ.
- **Bridge and Highway Embankments:** A highway bridge at RM 68.95, just downstream of the reach boundary, impacts about 0.05 acres of HCMZ in reach MF 17.
- **Diversion:** A diversion is present at RM 69.3, but does not appear to affect the HCMZ.
- **Flume and Irrigation Ditches:** A 1926 water adjudication map shows a flume near RM 69 and irrigation ditches across and along the south edge of the HCMZ.

HCMZ and Channel Migration

About 0.5 acres, or about 14 percent, of HCMZ are impacted in reach MF17. Most of this (0.4 acres) is from a possible artificially blocked channel on river right at RM 69.2. The rest of the area is impacted by a 50-foot-long section of bank that may be covered by riprap, and by a highway bridge at RM 68.95, just downstream of this reach. Channel migration is limited in these sections, especially at the downstream end, where about 40 feet of the channel has been straightened and is confined by the highway bridge. The remainder of the reach has a meandering path and may be properly functioning.

Channel Planform

Although an effort was made to digitize the 1939 channel in reaches MF17 and MF18, the difference in ability to track channel location between the 1939 and later photosets resulted in a misrepresentation of the true channel length changes. Further, historical aerial photographs of the 1956 channel were unavailable for the majority of these two reaches.

Comparison of channel lengths in this reach was accomplished for years 1976, 2000, and 2006. Between 1976 and 2000, almost no change in channel length occurred in either of the reaches. Between 2000 and 2006, the channel length was measured as having increased slightly (less than 100 feet in each reach). These increases may be due in part to meander evolution, but are likely influenced by differences in the resolution of each photoset. Constructed features noted in reaches MF17 and MF18 include one location of riprap near the Mill Creek confluence, a bridge at the downstream end of reach MF17, and a bridge at the upstream end of reach MF18. These channel modifications may have resulted in temporary reductions in channel length. LiDAR data indicate that additional human activities (i.e., levees, channelization) may have modified channel planform in other locations of reaches MF17 and MF18, but field verification is necessary.

Floodplain Access

The floodplain is coincident with the HCMZ. Off-channel areas (e.g., overflow channels) are impacted in the areas where the HCMZ is impacted.

5.2.1.5 Reach MF16 (RM 68.1 to RM 68.95)

Summary

Reach MF16 downstream of RM 68.45 is impacted primarily by possible artificially blocked or filled channels that disconnect about 6 acres (30 percent) of the HCMZ and at least 600 feet of channel. Upstream of RM 68.7, the main constructed features affecting the HCMZ are an unimproved road on river right that impacts about 2.3 acres of HCMZ and a highway bridge at RM 68.95, which confines about 75 feet of the channel. Off-channel areas (e.g., side and overflow channels and areas) also are impacted.

Reach MF16 downstream of RM 68.46 is impacted by four possible artificially blocked/filled channels on river left at RM 68.15, RM 68.35, RM 68.45, and RM 68.46. The blockage of these channels, possibly former main channels, impacts the HCMZ, limits channel migration, and disconnects off-channel areas from the channel. The section of the reach between RM 68.5 and RM 68.7 does not have mapped constructed features. Upstream of RM 68.5 to RM 68.93, the HCMZ on river right is impacted by an unimproved road that cuts across the valley. At RM 68.95, a bridge for the highway impacts about 0.3 acres of HCMZ and straightens and confines 75 feet of channel. Downstream of RM 68.17 on river right, the impacted area of HCMZ created by the Bates townsite continues upstream from reach MF15 and impacts about 0.3 acres of the HCMZ in reach MF16. About 340 feet of channel have been straightened and are confined.

Constructed Features

- **Possible Artificially Blocked/Filled Channels:** Four channels on river left at RM 68.15, RM 68.35, RM 68.45, and RM 68.46 appear to be artificially blocked. The channels are well expressed on the LiDAR hillshade and may have been former main channels. The possible artificially blocked channels impact about 6 acres of HCMZ and limit channel migration. These areas need to be checked in the field.
- **Unimproved Road:** About 225 feet of unimproved road cuts across the valley between RM 6.89 and RM 68.93. It impacts about 2.3 acres of HCMZ on river right downstream of the road.
- **Bates Townsite:** Modifications from the Bates townsite are mainly in reach MF15, but a small area appears to extend into reach MF16. The modifications are on river right downstream of RM 68.46 and impact about 0.3 acres of the HCMZ. About 340 feet of channel have been artificially straightened and are confined. A 1926 water adjudication map shows two springs and several irrigation ditches south of the HCMZ in this reach.
- **Bridge and Highway Embankments:** The highway crosses the valley at a bridge at RM 68.95 near the upstream reach boundary. About 2,760 feet of highway is present within the HCMZ. These features impact about 0.3 acres of HCMZ on both sides of the channel, and they straighten and confine about 75 feet of channel.

HCMZ and Channel Migration

The channel in this reach mostly has a meandering planform. The exceptions are the two sections that have been straightened and are now confined. One of these sections is at the downstream end of the reach (downstream of RM 68.17), where about 340 feet of channel was straightened by activities in the Bates townsite. The other is near the upstream reach boundary (upstream of RM 68.95), where the channel was straightened for about 75feet to flow under a highway bridge. This straightened section continues upstream approximately 40 feet. The HCMZ and channel migration have been impacted in this reach on river left downstream of RM 68.46, where four possibly former main channel paths appear to have been artificially filled. Channel migration has also been impacted on river right between RM 68.9 and RM 68.93. A total of about 9 acres, or 44 percent, of the HCMZ and channel migration is impacted.

Channel Planform

According to LiDAR data, historical photographs, and historical accounts of this area, reach MF16 may have once been a highly active, multi-thread channel that was modified through installation of constructed structures (e.g., levees, roads) and unrestricted cattle grazing. By the 1939 photographs, the channel was largely single-thread with only a few short segments of spit flow. Between 1939 and 1956, the channel length decreased very minimally. By 1976, the channel had self-adjusted, gaining 120 feet of channel length through increased meander amplitudes. Although lateral channel migration continued from 1976 to 2006, the channel length remained relatively stable, and the net change from 1939 to 2006 amounted to a gain of 150 feet or 3.5 percent.

Floodplain Access

The floodplain is coincident with the HCMZ. Off-channel areas (e.g., overflow channels) are impacted in the areas where the HCMZ is impacted.

5.2.1.6 Reach CC1

Summary

Reach CC1 has been totally impacted by the town of Bates which was built beside Clear Creek, the Middle Fork, and Bridge Creek. Impacts to the Clear Creek channel and the adjacent area were so great that the original characteristics of the creek, the HCMZ, and floodplain can only be speculated. The HCMZ and floodplain boundaries that are delineated for reach CC1 have been inferred from the geology and depictions of the channel and vegetation on the 1881 GLO map and on the 1926 water adjudication map. The town existed in 1926. The mill at Bates was built in 1917, but by the mid-1970s, the town became less productive, and the buildings were relocated away from the townsite.

Based on available information, essentially the entire area of the HCMZ in CC1, consisting of 25.5 acres as mapped, was impacted by the town. The entire length of the channel downstream from the upstream reach boundary (about 2,125 feet) has been channelized and thus, straightened and confined. Channel migration has been greatly limited, but some channel adjustment has occurred. The downstream end of the Clear Creek channel is shown to the west (left) of its present position on the 1881 GLO map.

The channel was initially rerouted to the west of the present channel, as indicated in the 1939 and 1956 aerial photos. Its position did not appear to coincide with the channel location in 1881. By 1976, the channel was in it present location.

Constructed Features

- **Bates Townsite:** The entire HCMZ surrounding reach CC1 was impacted by the townsite of Bates which occupied the entire area from 1917 until the middle 1970s. The channel was channelized, straightened, and confined. Between 1956 and 1976, the channel was moved between about 315 and 395 feet to the east, where it has remained since that time. The 1926 water adjudication map shows a pipeline that crossed Clear Creek near the upstream reach boundary. The pipeline went from a spring on river right just upstream of the boundary to a hotel and mill pond at the mouth of Bridge Creek, west of Clear Creek. The map also shows the railroad crossing diagonally across the toe of reach CC1 from the Middle Fork to the mill at the mouth of Bridge Creek.
- **Culvert and Highway Embankment:** A culvert and highway embankment mark the upstream reach boundary and limit channel migration and flow.

HCMZ and Channel Migration

The entire HCMZ has been impacted by the townsite of Bates. Because the channel has been straightened and the ground surface regraded, nothing of the natural planform remains through the reach. A culvert at a highway embankment locks in the channel location at the upstream reach boundary and confines the channel at this point. The present channel location is about 315 to 395 feet east of a constructed channel that was present in 1939 and 1956. Channel migration is severely limited to the width of the constructed channel.

Channel Planform

This reach was completely modified from its original planform and location due to construction of Bates and the Bates Mill. Prior to human impacts, reach CC1 may have been a sinuous channel, which appeared to have flowed through Bates. With the construction of Bates came the partial channelization of the reach where the river encroached on residential property. As the town continued to expand, channelization likely increased. Between 1939 and 1956, the channel length decreased by 445 feet, which accounted for a 16.4 percent reduction in the total channel length and sinuosity. By 1976, the channel had been entirely channelized and relocated approximately 370 feet to the east of its previous location, resulting in an additional 100-foot reduction in channel length. Between 1976 and 2006, the channel length remained stable, with a measured reduction of 31 feet. The net change in channel length between 1939 and 2006 was a reduction of 570 feet for a total loss of 21 percent of the channel length and sinuosity.

Floodplain Access

As mapped the floodplain is coincident with the HCMZ; however, the natural extent of the HCMZ and floodplain is unknown because of the drastic modifications for the construction and demolition of the town of Bates. Any off-channel areas (e.g., overflow channels) that would have been present naturally have been destroyed and essentially no properly functioning floodplain exists at this time.

5.2.1.7 Reach MF15 (RM 67.65 to RM 69.1)

Summary

The entire reach has been impacted by the townsite of Bates, which was active between 1917 and about 1975. It had a peak population of approximately 400 people. The town extended downstream into reach MF14 and upstream into reach MF16, and to the toes of the alluvial fans from Clear Creek and Bridge Creek. Bates was a mill town that included the mill, mill pond, hotel, dance hall, grocery store, post office, tavern, office building, maintenance shop, school, and houses. The railroad was used to transport timber and lumber to and from the mill until about 1946 or 1947, when transportation methods shifted to highway trucking. Most of the town was in reach MF15 upstream of RM 67.9 and in the lower reach of Clear Creek (CC1). The exact changes that the town brought to the HCMZ and floodplain in this reach are not known. The ground surface throughout the reach has been heavily modified. The channel throughout the reach has been straightened and is confined so that the channel cannot migrate. The channel also is confined by a culvert under the highway at RM 67.89 and the highway embankments and by a bridge at RM 67.75. All flow is confined to the constructed channel. Off-channel areas have been eliminated.

Constructed Features

- **Bates Townsite:** The entire reach was impacted by the mill town that was built there and in the downstream reach of Clear Creek (CC1). Although all of the constructed features were removed from the Middle Fork and Clear Creek in the middle 1970s, the ground surface throughout the reach has been modified. The entire length of channel has been straightened and can no longer migrate. Off-channel areas have been eliminated. A 1926 water adjudication map shows the mill pond within the HCMZ and along its boundary between RM 67.78 and RM 67.88. It also shows the railroad from the mill, which was located at the mouth of Bridge Creek, crossing reach MF15 between RM 67.68 and the downstream reach boundary.
- **Culvert and Highway:** A culvert through the highway embankments at RM 67.89 directs all flows.
- **Bridge:** A bridge at RM 67.75 for an unimproved road directs flow at this point.
- **Weir:** A weir is present in the channel at RM 67.91.

HCMZ and Channel Migration

About 3.2 acres, or 59 percent, of the HCMZ has been disconnected in this reach. The only active portion is directly along the present channel. Channel migration has been eliminated from most of this HCMZ area by the Bates townsite. Smaller areas are impacted by a culvert and embankments for the highway at RM 67.89 and by a bridge on an unimproved road at RM 67.75. The entire length of the channel, about 2,382 feet, has been straightened for the Bates townsite, the culvert, and the bridge. The present channel path has been modified from its natural planform. The entire length of the channel is confined and cannot migrate.

Channel Planform

Considerable channelization of reach MF15 occurred near the historic townsite of Bates, most likely to protect the town from flooding. The only detectable changes in channel length occurred between 1939 and 1956, with a reduction of approximately 160 feet or 6.2 percent of total channel length and sinuosity. Almost no change was measured between 1956 and 2006. Today, several sections of this reach are similar to a wide, deep canal.

Floodplain Access

The extent of the natural HCMZ and floodplain are difficult to interpret because of the modifications that were imposed by the construction and removal of Bates. The alluvial-fan deposits from Clear Creek and Bridge Creek on river left would have likely confined the Middle Fork against the bedrock on river right. The extent of this natural confinement is unknown. At present, there is no floodplain outside of the impacted HCMZ area. No overflow channels exist.

5.2.1.8 Reach MF14 (RM 66.52 to RM 67.65)

Summary

Most of the reach MF14, especially the section downstream of RM 67.4, is impacted by rock spurs that were placed along a meandering channel path. The bank armoring impacts the HCMZ and channel migration. Upstream of RM 67.4, the reach is impacted by a bridge at RM 67.51, the road embankments leading to the bridge, and by modifications in the floodplain and channel that resulted from the town of Bates.

About 15.6 acres, or 51 percent, of the natural HCMZ is impacted by rock spurs. This is mostly downstream of RM 66.8, where rock spurs are nearly continuous along the meandering channel. These rock spurs confine the channel to its meandering path and impact the HCMZ function. Two bridges and their associated embankments, riprap, rock spurs, and levees impact about 2.3 acres of HCMZ and straighten and confine about 1,300 feet of channel. Upstream of RM 67.52, about 2.8 acres of HCMZ have been modified and about 500 feet of channel were straightened and confined by the Bates townsite. Two diversions and associated irrigation ditches and rock spurs impact about 0.6 acres of HCMZ and confine about 227 feet of channel (4 percent of the 2006 channel length). The railroad grade is primarily outside of the floodplain, but about 230 feet cross the floodplain between RM 66.87 and RM 66.95, disconnecting about 0.6 acres of the floodplain outside of the HCMZ. Other than a small area (less than 0.1 acre) that is disconnected by an irrigation ditch, the remainder of the floodplain outside of the HCMZ is intact.

Constructed Features

- **Bank Armoring:** Eighty-six rock spurs and about 200 feet of riprap have been placed to armor the banks in reach MF14. Most of the rock spurs are downstream of RM 66.8, where they are nearly continuous along the channel. Other rocks spurs and the riprap are at or near the two bridges and the two diversions. The bank armoring prohibits channel migration and impacts the HCMZ.
- **Bridges:** Two bridges are present in the reach at RM 67.2 and RM 67.51. The downstream bridge impacts about 1.8 acres of HCMZ, with road embankments, riprap, rock spurs, and a levee confining the channel to a meandering path directing flow toward the bridge. The upstream bridge impacts about 1.5 acres of HCMZ and extends downstream from the confined section of channel through the Bates townsite.
- **Bates Townsite:** Upstream of RM 67.52, the town of Bates occupied the HCMZ and floodplain. The channel was straightened in this section; about 945 feet of channel were affected. The townsite changed the ground surface and valley enough that it is difficult to interpret the natural conditions so that the impacts cannot be judged. A 1926 water adjudication map shows the railroad on river right within the HCMZ between the upstream reach boundary at RM 67.65 and RM 67.45 and diagonally crossing the HCMZ and floodplain between RM 66.82 and RM 67.15, although no evidence of the railroad is present now.
- **Diversions and Irrigation Ditches:** Two diversions, at RM 67.07 and RM 67.38, are present in the reach along with about 930 feet of irrigation ditches. Rock spurs at the diversions to direct stream flow impact the HCMZ and confine a few hundred feet of channel. The irrigation ditches impact about 0.4 acres of HCMZ and disconnect a small area (less than 0.1 acres) of floodplain outside of the HCMZ.
- **Railroad Grade:** About 230 feet of railroad grade is present between RM 66.87 and RM 66.95. The railroad grade disconnects about 0.6 acres of floodplain outside of the HCMZ. It does not impact the HCMZ in this reach.
- **Buildings:** About 0.25 acres of the HCMZ has buildings. This area is on river right between RM 67.47 and RM 67.52. Along with the bridge and embankment for an unimproved road immediately upstream, the buildings impact about 1 acre of the HCMZ and contribute to straightening and confinement of the channel downstream of the bridge.

HCMZ and Channel Migration

Channel migration has been eliminated from much of this reach, primarily by bank armoring (rock spurs and riprap) throughout the reach and by straightening and confining the channel at the Bates townsite upstream of RM 67.52. Two bridges and two diversions, along with associated embankments and bank armoring, contribute to the channel confinement and lack of channel migration. Two short sections of the reach between RM 67.1 and RM 67.17 and between RM 67.43 and RM 67.45 do not have mapped bank armoring. Channel migration is limited to the short, unconfined sections that alternate with the longer confined sections. Except for the section upstream of RM 67.45, where the channel has been straightened for a bridge and the Bates townsite, the channel is confined in a meandering planform with short straight sections.

Channel Planform

The greatest change in channel length and sinuosity in reach MF14 occurred between 1939 and 1956 for a loss of 230 feet, which represents a decrease of 4.0 percent of the total channel length and sinuosity. Natural channel avulsions and human-induced channelization are responsible for this decrease. Between RM 66.8 and 67.2, the channel had a multi-thread planform in 1939 that was changed to a single thread planform by 1956. In the subsequent years, the channel length increased 60 feet from 1956 to 1976, 170 feet from 1976 to 2000, and another 100 feet between 2000 and 2006. Increases in channel length are attributable to self-adjustment of the channel through increases in meander amplitude. The net change in channel length between 1939 and 2006 was an increase of 100 feet, which equates to a 1.8 percent increase in total channel length and sinuosity.

Floodplain Access

Floodplain access outside of the HCMZ is curtailed by about 0.6 acres by the railroad grade between RM 66.87 and RM 66.95. Irrigation ditches disconnect a small area (less than 0.1 acre) of floodplain outside of the HCMZ.

5.2.1.9 Reach MF13 (RM 63.48 to RM 66.52)

Summary

Bank armoring by rock spurs and riprap and remnants of the railroad grade are the two greatest impacts on the HCMZ and channel migration in reach MF13. The railroad grade has the greatest impact on the floodplain outside of the HCMZ.

About 90 acres, nearly 80 percent, of the natural HCMZ is impacted by bank armoring and the railroad grade. About 65 acres (57 percent) of the 90 acres is from 247 rock spurs and about 2,216 feet of riprap that have been placed along the channel throughout the reach. This results in about 12,380 feet of channel (77 percent of the 2006 channel length) that is confined in a meandering or slightly meandering planform and an additional about 2,165 feet of channel (13 percent of the 2006 channel length) that has been artificially straightened and confined. The rock spurs and riprap also disconnect about 1,122 feet of former main channel paths. Channel migration and channel planform are markedly impacted. Remnants of the railroad grade that cut through the valley on river left impact an additional 24.5 acres of HCMZ and contribute to channel straightening and confinement. The railroad grade disconnects about 2,418 feet of former main channel paths. Nearly 5,000 feet of irrigation ditch impacts about 0.2 acres of HCMZ. Remnants of the railroad grade have the biggest impact on the floodplain by disconnecting nearly 45 acres, or about 52 percent, of the floodplain outside of the HCMZ. Another 0.7 acres of floodplain outside of the HCMZ are disconnected by irrigation ditches. In these areas, the floodplain is disconnected from the channel, and off-channel areas are eliminated. About 5,500 feet (cumulative) of bank has evidence of erosion. Most of this length is at the outsides of meander bends and involves erosion of alluvium within the floodplain (reworking).

Constructed Features

- **Bank Armoring:** Rock spurs (247) and riprap (2,216 feet) are present throughout reach MF13 and prevent channel migration and impact the functioning of the HCMZ. Along with the railroad grade, the rock spurs and riprap account for nearly 2,165 feet of artificially straightened and confined channel and nearly 12,380 feet of meandering, but artificially confined channel. The rock spurs and riprap also disconnect about 1,122 feet of former main channel paths.
- **Railroad Grade:** About 10,280 feet of railroad grade are preserved within reach RM13. These remnants impact 24.5 feet of HCMZ, and about 45 acres of floodplain outside of the HCMZ. The remnants cut off about 2,418 feet of former main channel paths in 18 localities.
- **Irrigation Ditches:** Nearly 5,000 feet of irrigation ditches impact about 0.2 acres of HCZM and disconnect about 0.7 acres of floodplain outside of the HCMZ.
- **Possible Artificial Blocked or Filled Channels:** In 12 localities, channels appear to be blocked or filled artificially (other than those blocked by the railroad grade or bank armoring). In addition, about 75 feet of levees block channels. These possible artificially blocked or filled channels impact about 0.4 acres of the HCMZ. These areas need to be checked in the field.
- **Bridge:** The bridge at RM 65.52 on an unimproved road confines the channel at this location. Riprap was placed on both sides of the channel at the bridge. Riprap that directs flow under the bridge has been placed upstream to RM 65.6.

HCMZ and Channel Migration

The HCMZ and channel migration are impacted throughout reach MF13. Between the downstream reach boundary at RM 63.48 and RM 63.8, the HCMZ is impacted by remnants of the railroad grade, possible artificially blocked or filled channels, a few rock spurs, and riprap. The channel meanders in this section, but is confined. Erosion occurs at the outsides of meanders. Between RM 63.8 and RM 65.08, mostly rock spurs and some riprap are nearly continuous along the channel. The railroad grade does not impact the HCMZ in this section, although it cuts off part of the floodplain outside of the HCMZ. The channel meanders, but is confined by the armored banks. Erosion occurs at the outsides of meander bends. Between RM 65.08 and RM 66.05, the HCMZ is impacted by the railroad grade, rock spurs, and riprap. The channel is meandering to slightly meandering, but is locked into its path by the railroad grade, rock spurs, and riprap. Erosion occurs along the outsides of meanders. Between RM 66.05 and RM 66.3, the present channel path is very straight. The railroad grade has significantly narrowed the HCMZ in this section. The channel is further confined by rock spurs. No erosion was noted along the channel in this section. Between RM 66.3 and the upstream reach boundary at RM 55.62, the railroad grade leaves a wider portion of the HCMZ active. The channel is confined by rock spurs and riprap in a meandering path. Erosion occurs at the outsides of meanders.

Channel Planform

With the construction of the railroad in the late 1800s, the river through this reach was channelized. Through the channelization process, a minimum of 3,900 feet of meandering channel was reduced to a 2,600-foot straightened channel. The railroad was constructed through the center of the floodplain, disconnecting access to over half of the geologic low surface. Between 1939 and 1956, the channel was further reduced by 340 feet due to either natural channel avulsions or additional channel straightening. Within the next twenty years, the channel length increased by 260 feet through self-adjustment of the channel and meander evolution upstream and downstream of the heavily channelized segment. Between 1976 and 2000, the channel length increased by another 180 feet by the same mechanisms of the previous two decades. Meander evolution following the implementation of the rock spurs led to flanking of several of the structures. The spurs were largely successful in eliminating natural patterns of channel migration. Between 2000 and 2006, an increase of approximate 230 feet was measured, but no substantial changes in channel position are detected between the two photosets. The net change in channel length between 1939 and 2006 was an increase of approximately 330 feet which amounts to a 2.1 percent increase in total channel length and sinuosity. The channel length through this reach remains significantly reduced from its undisturbed channel length due to the impacts of the historic railroad grade.

Floodplain Access

Floodplain access is most impacted by the railroad, which disconnects nearly 45 acres, about 52 percent, of the floodplain outside of the HCMZ. This occurs on river left between RM 63.7 and RM 65.1 and between RM 65.6 and RM 66.5. A portion of this area, mostly between RM 65.6 and RM 66.5, is adjacent to the HCMZ and may have the most impact by eliminating off-channel areas and disconnecting the channel and floodplain. The section of floodplain that is disconnected between RM 63.95 and RM 65.1 is at the edge of the floodplain and separated from the HCMZ. Part of the floodplain in these areas may still be connected to the channel and, although impacted, may provide some off-channel areas.

5.2.1.10 Reach MF12 (RM 62.5 to RM 63.48)

Summary

Tailings left from dredge mining and the associated disturbed area around the tailings are the biggest human impacts in reach MF12. The tailings cover about 12.8 acres; the disturbed area covers an additional 4.3 acres. These features impact about 12.5 acres of the HCMZ between RM 62.77 and RM 63.48. The tailings alter channel location, channel migration, channel geometry, and floodplain characteristics. They eliminate off-channel areas and disconnect the channel and floodplain. Because of the large size of the tailings, the channel is unable to adjust its bed or to migrate laterally. The present channel was dug through the tailings once mining was completed, so that the location, planform, and geometry of the channel were produced artificially and are not the result of fluvial processes. About 3,178 feet of channel, 62 percent of the 2006 channel length, were constructed through the tailings and are artificially straightened; consequently, the river cannot migrate laterally or adjust bed characteristics (e.g., pool location and depth).

The tailings and disturbed areas cut off about 1.5 acres of the floodplain outside of the HCMZ. A more detailed discussion of the effects of dredge mining is presented in the section on reach MF8.

Three remnants of the railroad grade are preserved in the reach. The total length of these remnants is 1,660 feet, and all but 85 feet are in the areas that are impacted by dredge mining and tailings. The additional impacts of the railroad grade are minimal. The remnants of railroad grade that are not in the area of the tailings are near the downstream reach boundary, where they impact about 0.2 acres of the HCMZ. About 0.8 acres of floodplain outside of the HCMZ are disconnected by the railroad grade.

Several buildings are present on river right between RM 62.65 and RM 62.8. They block a portion of the HCMZ, confine about 500 feet of channel, and disconnect about 1.4 acres of the floodplain outside of the HCMZ.

Constructed Features

- **Tailings and Disturbed Areas from Dredge Mining:** Tailings cover about 12.8 acres of reach MF12, and disturbed areas adjacent to the tailings cover an additional about 4.3 acres. These features impact about 12.5 acres of the HCMZ between RM 62.77 and RM 63.48 and result in about 3,178 feet of channel that has been artificially located and straightened so that the river channel cannot migrate. The tailings and disturbed areas cut off about 1.5 acres of the floodplain outside of the HCMZ.
- **Railroad Grade:** Three remnants of the railroad grade are preserved in the reach. The total length of these remnants is 1,660 feet, of which all but 85 feet are located within the areas impacted by the tailings and dredge mining. The 85 feet of railroad grade near the downstream reach boundary impact about 0.2 acres of HCZM and disconnect about 0.8 acres of floodplain outside of the HCZM.
- **Buildings and Unimproved Roads:** Several buildings and roads are present on river right between RM 62.65 and RM 62.8. Along with the tailings that are upstream and across the channel, they confine about 995 feet of channel. The buildings and roads cut off about 1.4 acres of floodplain outside of the HCMZ.

HCMZ and Channel Migration

Dredge mining with its tailings and disturbed ground that are left behind have markedly and permanently altered channel migration, channel planform, and channel characteristics (e.g., location, number of flow paths, and depth of pools). The tailings are much larger than the surface alluvium that is replaced, so that the channel that was dug after mining ceased cannot adjust its bed properties or migrate laterally. About 12.5 acres of HCMZ is affected, and about 3,178 feet of channel are immobile at present. A more detailed discussion of the effects of dredge mining is presented in the section on reach MF8.

An additional 0.2 acres of HCMZ are impacted near the downstream reach boundary. Short remnants of the railroad grade cross the HCZM and confine the channel. An additional about 500 feet of channel are confined between RM 62.66 and RM 62.88 by buildings and roads on river right. Channel migration is limited in this section.

Channel Planform

The greatest change in channel length in this reach occurred between 1939 and 1956 with the reconstruction and shortening of the channel between RM 63 and RM63.4. The decrease in channel length between 1939 and 1956 was approximately 250 feet which accounts for 4.6 percent of the total channel length and sinuosity. Minimal increases in channel length were measured in the last 50 years resulting from lateral channel migration in one location. The net change between 1939 and 2006 was a reduction of 225 feet or 4.2 percent of the total channel length and sinuosity.

Floodplain Access

Dredge mining and adjacent disturbed ground disconnected about 1.5 acres of floodplain outside of the HCMZ between RM 63.15 and RM 63.4. Mining activities and the resulting tailings have destroyed off-channel areas (e.g., overflow channels) in the floodplain and have disconnected the channel and floodplain. Because of the size of the sediment in the tailings, the river cannot migrate and modify the floodplain areas so that new off-channel areas (e.g., overflow channels) cannot be created.

Floodplain access also is compromised on river right between RM 62.55 and RM 63.67 by a remnant of the railroad grade that disconnects about 0.8 acres of the floodplain outside of the HCMZ. Another about 1.4 acres of floodplain is disconnected on river right between RM 62.66 and RM 62.88 by buildings and roads.

5.2.1.11 Reach MF11 (RM 55.3 to RM 55.6)

Summary

Reach MF11 is mostly a naturally confined reach that is very narrow. The exception is the section between RM 61.4 and RM 61.6 where buildings and access routes impact about 3.4 acres of HCMZ and 1,015 feet of channel. In another slightly wider section, a remnant of the railroad grade on river left between RM 61.25 and RM 61.4 disconnects about 0.8 acres of HCMZ and confines about 290 feet of channel.

In reach MF11, impacts of constructed features have been minimal due to the narrow character of the reach. In the wider section between RM 61.43 and RM 61.63, buildings and probably artificially blocked channels on river right impact about 3.4 acres of HCMZ. Blocked channels are inferred from the sharp (greater than 90 degree) bend in the channel at RM 61.62 at the upstream end of this section. An embankment for an unimproved road at RM 62.16 impacts about 0.53 acres of HCMZ on river right. Adjacent to this section, it appears that about 280 feet of channel have been excavated, resulting in a straight planform. This impacts an additional 0.3 acres of HCMZ on river left. About 910 feet of railroad grade are preserved on river left between RM 61.23 and RM 61.42, which impact about 0.8 acres of HCMZ and confine nearly 290 feet of channel. Between these constructed features, the HCMZ may be properly functioning. The channel is fairly straight, but the reach is very narrow and the channel is naturally confined.

Constructed Features

- **Buildings and Possible Artificially Blocked/Filled Channels:** Between RM 61.43 and RM 61.63, the reach is somewhat wider. The HCMZ on river right is impacted by buildings that cover about 0.07 acres and channels that are likely artificially blocked. The channel makes an abrupt bend at RM 61.62, suggesting that it cannot access channels on river right. An unimproved road from the highway to the buildings crosses the HCMZ at the upstream end of this section and just downstream of the abrupt bend in the channel, affecting about 3.4 acres of HCMZ. About 1,015 feet of channel are confined.
- **Embankment for Unimproved Road and Artificially Straightened Channel:** Between RM 62.05 and RM 62.16, about 0.5 acres of HCMZ on river right are impacted by a road embankment, and by about 280 feet of channel that appears to have been excavated between RM 62.09 and RM 62.15. An additional 0.3 acres of HCMZ on river left are impacted adjacent to the excavated section of channel.
- **Railroad Grade:** About 910 feet of railroad grade are preserved within the HCMZ on river left between RM 61.23 and RM 61.42. This impacts about 0.8 acres of HCMZ. Nearly 290 feet of channel are confined by the railroad grade.
- **Possible Artificially Blocked/Filled Channel:** A possible artificially blocked/filled channel on river left at RM 61 impacts about 0.9 acres of HCMZ between RM 60.87 and RM 61.02. These areas need to be checked in the field.

HCZM and Channel Migration

Reach MF11 is naturally narrow and confined. The HCMZ in most of the reach is not impacted by constructed features and may be properly functioning. Between the downstream reach boundary at RM 60.8 and RM 60.87, no constructed features were mapped, although the channel is straight in this section. Between RM 66.87 and RM 61.02, a blocked channel on river left impacts about 0.9 acres of HCMZ and limits channel migration. Between RM 61.02 and RM 61.23, no constructed features were mapped and the HCMZ may be properly functioning. Between RM 61.23 and RM 61.63, the HCMZ is impacted by the railroad grade on river left (about 0.8 acres) and by buildings and probable artificially blocked channels on river right (3.4 acres). About 1,015 feet of channel are confined in this section. Between RM 61.63 and RM 62.5 (the upstream reach boundary), the HCMZ is very narrow and channel migration is limited naturally. The only impacts to the HCMZ in this section are an embankment for an unimproved road at RM 62.16 and an apparently excavated section of straight channel about 280 feet long. In this area, about 0.83 acres of HCMZ are impacted on both sides of the channel.

Channel Planform

The majority of Reach MR11 is laterally confined by bedrock. Very little change has occurred in this reach between 1939 and 2006. The noted increase in channel length may be in part due to some lateral channel movement near RM 61.6. A considerable portion of the measured change is probably attributable to imprecision in georectification and channel mapping, as this reach is heavily vegetated and the actual channel position was often difficult to decipher. The net measured change between 1936 and 2006 is an increase in 270 feet or 3 percent.

Floodplain Access

The floodplain boundary is coincident with the HCMZ boundary. Off-channel areas (e.g., overflow channels) are impacted within the HCMZ in the areas where the HCMZ is impacted. In this naturally narrow, confined reach, this is primarily between RM 61.43 and RM 62.63, where the HCMZ is somewhat wider.

5.2.1.12 Reach MF10 (RM 59.1 to RM 60.8)

Summary

The HCMZ is primarily impacted by remnants of the railroad grade that are preserved throughout the reach. Nearly 6 acres of the HCMZ are impacted by the railroad grade, and nearly 2,700 feet of channel have been straightened or are confined. Channel migration is impacted in these areas. The highway, which is along river right, disconnects about 3.2 acres of the floodplain outside of the HCZM in four places. The railroad grade disconnects an additional nearly 2 acres of the floodplain outside of the HCMZ. Floodplain access and off-channel areas have been eliminated in these areas.

Nearly 3,900 feet of railroad grade remnants are preserved throughout this reach on both sides of the present channel. These remnants impact 7.5 acres of the HCMZ and disconnect about 2 acres of floodplain outside of the HCMZ. Buildings and levees on river right between RM 59.7 and RM 59.9 impact another 1.7 acres of the HCMZ and disconnect 0.6 acres of floodplain outside of the HCMZ. The highway is along and mostly just outside of the floodplain on the north (river right) side of the valley. It impacts 0.2 acres of the HCMZ at a single locality between RM 59.97 and RM 60.05. However, the highway intersects the floodplain outside of the HCMZ at four localities and disconnects 3.2 acres of floodplain. Levees, possible artificially blocked or filled channels, and rock spurs in several locations also impact the HCMZ. A total area of 9.2 acres of the HCMZ (22 percent) is impacted and a total area of 5.8 acres of floodplain outside of the HCMZ (36 percent) is disconnected. The railroads grade, buildings, levees, and blocked or filled channels confine and, in places, straighten more than 3,000 feet of channel. Of this length, the railroad grade influences 1,970 feet, the railroad grade, buildings, and levee influence 760 feet, and a disturbed area influences 340 feet.

Constructed Features

- **Railroad Grade:** Six remnants of a railroad grade with a total length of nearly 3,900 feet are preserved on both sides of the channel and throughout reach MF10. These remnants impact nearly 6 acres of HCMZ and disconnect about 3 acres of floodplain outside of the HCMZ. Where the railroad once crossed the channel in this reach (two places), remnants are preserved on both sides of the channel and confine or straighten channel migration over a length of about 2,700 feet.
- **Highway and Embankment:** The highway is present along the north (river right) side of the valley. It is mostly outside of the HCMZ and floodplain, but does cross the edge of the floodplain in four localities, where it disconnects 3.2 acres of floodplain outside of the HCMZ. The highway impacts a small area of HCMZ (0.2 acres).
- **Buildings/Levee:** Buildings and a levee on river right between RM 59.7 and RM 59.9 impact 1.7 acres of HCMZ and, along with the railroad grade on the opposite bank, straighten and confine about 760 feet of channel.
- **Disturbed Area:** A disturbed area on river right between RM 59.15 and RM 59.21 impacts about 1.2 acres of HCMZ and about 340 feet of channel. In this area, the ground surface has been disturbed. The disturbed area covers about 0.5 acres between the highway and the Middle Fork between RM 59.15 and RM 59.23. It appears to be an area where vehicles have repeated driven. Some movement of surface sediment may have occurred also. Vegetation has been cleared or partially cleared.

HCMZ and Channel Migration

The HCMZ and channel migration are impacted intermittently throughout reach MF10. Most of the impacted area is from remnants of the railroad grade, which are located throughout the reach between RM 59.43 and RM 60.73. These remnants impact nearly 6 acres of the HCMZ. In two localities near RM 59.55 and RM 60.65, the railroad crossed the Middle Fork and the remnants of the railroad grade on both sides of the channel confine about 2,700 feet of channel and limit channel migration. In addition to the railroad grade, levee and buildings on river right between RM 59.66 and RM 59.91 impact about 1.7 acres of HCMZ and contribute to about 760 feet of channel straightening and confinement. Short sections (less than 0.2 mile) of the channel in this reach do not have mapped constructed features, but these sections are probably impacted by the constructed features in adjacent sections.

Channel Planform

Despite minimal measured changes in channel length of reach MF10 throughout the last 70 years, localized regions of channel adjustment are notable. Multiple locations of channel avulsions and lateral meander migrations are detectable, but the net change in channel length between 1939 and 2006 is only an increase of approximately 120 feet or 1.3 percent. A gradual trend of increasing channel length may be related to channelization due to the railroad construction and possibly the disconnection of side channels.

Floodplain Access

Floodplain access is disconnected in four localities by the highway embankment along the north (right) side of the valley, by remnants of the railroad grade in four localities, by buildings on river right between RM 59.83 and RM 59.89, and by an embankment for an unimproved road on river right between RM 59.27 and RM 59.28. The total area of the floodplain outside of the HCMZ that is disconnected is about 5.8 acres, or 36 percent, of the floodplain outside of the HCMZ.

5.2.1.13 Reach MF9 (RM 57.98 to RM 59.1)

Summary

The greatest impact on the HCMZ and floodplain in reach MF9 is the highway, which bisects the reach between RM 58.4 and RM 58.85. The highway embankment, about 3,860 feet long in the reach, disconnects about 7.5 acres of HCMZ and nearly 12 acres of floodplain outside of the HCMZ. A bridge at RM 58.8 restricts the channel location and contributes to about 1,330 feet of channel that has been artificially straightened and confined.

A possible artificially blocked or filled channel at RM 58.22 and bank armoring (riprap, levees) downstream of RM 58.1 impact an additional 2 acres of the HCMZ. The bank armoring also straightens and confines 490 feet of channel. Possible artificially blocked or filled channels on river right between RM 58.45 and RM 58.55 and on river left at RM 59.05 impact another 1.2 acres of HCMZ.

Constructed Features

- **Highway Embankment and Bridg**e: About 3,860 feet of highway embankment that bisects the valley between RM 58.35 and RM 58.86 and a highway bridge at RM 58.8 disconnect about 7.5 acres of HCMZ, or nearly 25 percent of the total HCMZ area. Levees near the both upstream and downstream of the bridge contribute to the restriction of the HCMZ. The highway, bridge, and levees also disconnect about 12 acres of floodplain outside of the HCMZ, which is nearly 60 percent of the total floodplain area outside of the HCMZ in this reach. In addition, these features straighten and confine about 2,000 feet of channel which is about 36 percent of the total length of the 2006 channel.
- **Possible Artificially Blocked or Filled Channels:** Six channels appear to be artificially blocked or filled, which impact 3.8 acres of HCMZ in three localities delineated by river left between RM 57.98 and RM 58.23, on river right between RM 58.46 and RM 58.57, and on river left between RM 58.97 and RM 59.09. The impacted HCMZ area is about 11 percent of the total HCMZ. These areas need to be checked in the field.
- **Bank Armoring:** Riprap and a levee downstream of RM 58.16 create a straightened, confined section of channel about 490 feet long and contribute to the impacted portion of the HCMZ.

HCMZ and Channel Migration

The highway embankment and bridge that bisect the HCMZ and floodplain impact 7.5 acres of the HCMZ and 12 acres of floodplain outside of the HCMZ. Channel migration is impacted along the embankment and at the bridge, with about 2,000 feet of the channel affected. Additional HCMZ areas are impacted by six possible artificially blocked or filled channels in three localities. Bank armoring contributes to the impacted areas of the HCMZ areas and creates 490 feet of straightened and confined channel downstream of RM 58.1.

Channel Planform

Human impacts to reach MF9 include one bridge crossing, encroachment of the floodplain by road construction and channel straightening. Notable changes in channel length throughout the last 70 years are only apparent between 1976 and 2000, when the channel length increased by 7.4 percent. During this time period, the highway and bridge crossing appear to have been greatly improved and possibly widened. The measured increase in channel length is related to localized areas of lateral channel movement and meander evolution. The net change in channel length between 1939 and 2006 was an increase of 400 feet.

Floodplain Access

About 12 acres of the floodplain outside of the HCMZ on river left between RM 58.5 and RM 58.8 are disconnected by the highway embankment and bank armoring near the highway bridge near RM 58.8.

5.2.1.14 Reach MF8 (RM 56.2 to RM 57.98)

Summary

Geomorphic processes along all of reach MF8 have been drastically and permanently modified by dredge mining that occurred in the early 1940s. The following discussion about the effects is based on work by Pierce (2000) about dredge mining in Granite Creek, a tributary to the North Fork of the John Day River.

Constructed Features

- **Dredge mining:** Dredge mining began in reach MF8 when the Timms Gold Dredge was moved from Galena to the Dewitt Ranch some time in 1939 (Norman Johnson, undated). On the 1939 aerial photographs, a small area of tailings are visible. By 1956, most of the HCMZ and floodplain in reach MF8 was covered with tailings or disturbed by mining activities, and the mining appears to have ceased. Norman Johnson reported that the mining went on for a few years.

  Dredge mining was utilized to obtain small pieces of gold that tributaries, like Granite Boulder Creek, eroded from gold-bearing veins in volcanic rocks that form the hills in the area. The tributaries transported the gold to the Middle Fork, where it was deposited as part of the alluvium that eventually filled the valley. Because of its high density, gold tends to be found in the lower part of the alluvium, often at the alluvium-bedrock contact under the valley. In order to reach the gold, the dredge overturns the gravel fill in the valley to a depth of about

10 feet, or to bedrock if it is shallower. In doing this, there is massive disturbance of the large cobbles and boulders that were deposited and buried below finer sediment tens of thousands of years ago when discharges on the Middle Fork were larger. The larger sediment is left at the ground surface when mining is finished. The dredge left piles of this large material (tailings) over much of the valley in reach MF8. The tailings are mainly in rows that are parallel to the axis of the valley, but in some areas (e.g., between RM 56.8 and RM 57.1), the tailings are in poorly formed rows nearly perpendicular to the valley. Poorly formed channel-like areas are left between the rows of tailings. When mining was completed, the dredge may have dug a more continuous channel for the river through the tailings piles.

In reach MF8, tailings are easily visible from RM 56.15 to 57.8 on the 1956 and later aerial photographs. Between RM 56.15 and RM 56.9, the tailings cover the entire HCMZ and floodplain. Between RM 56.9 and RM 57.6, the tailings cover about half of the floodplain on the north (river right) and extend outside of the floodplain to along the toe of the alluvial fan from Granite Boulder Creek. Between about RM 57 and RM 57.5, the natural HCMZ appears to have been on the south (river left) side of the floodplain, and is not covered by tailings. Between about RM 57.6 and RM 57.8, the tailings are entirely within the natural floodplain, and cover about half of the HCMZ upstream of RM 57.5. About 37.5 acres of the HCMZ in the reach are covered with tailings. About 32.6 acres of the floodplain outside of the HCMZ are covered with tailings. The tailings continue another 0.05 miles downstream into reach MF7.

- **Constructed Channels:** After mining ceased, the flow was left in two channels upstream of RM 57. One channel was the remnant of the natural channel to the south of the tailings (referred to as the south channel). The other channel was constructed through the tailings and is partly (RM 57.1 to RM 57.6) outside of the natural floodplain along the toe of the alluvial fan from Granite Boulder Creek. This channel is referred to as the north channel. Near RM 57, most of the flow in the south channel joins the north channel. Between RM 56.2 (the downstream reach boundary) and RM 57, most flow is in a continuation of the north channel, a constructed, very straight, very narrow channel that appears to be within the natural floodplain. Some flow continues along the south side of the tailings in a channel that was constructed after mining ceased. A middle channel constructed in this section (seen on the 1956 aerial photographs) no longer carries flow.
- **Disturbed Area:** Nearly all of the HCMZ and floodplain in reach MF8 not covered by tailings appear to have been heavily modified, probably by mining activities. The disturbed area covers about 46.5 acres.

Changes Caused By the Dredge Mining

The dredge mining altered or destroyed the natural channel and floodplain characteristics; changed the location, number of flow paths, and planform of the channel; changed the size of the channel bed and floodplain sediment; and modified the channel geometry. The dredging operations turned over floodplain deposits, winnowed out the available fines, and resulted in channel and floodplain materials that constrain lateral channel migration.

***Changes in Channel Bed and Bank Sediment*:** In removing the upper layers of alluvium to reach the gold-bearing layers that are usually buried beneath the valley, the dredge left piles of large cobbles and boulders across the HCMZ and floodplain. The previously buried alluvium is usually considerably coarser than the younger surface alluvium that it replaces. The larger sediment cannot be transported by the present flows in the Middle Fork. Because the sediment in the channel bed and banks is essentially immobile, the channel cannot adjust its bed characteristics or migrate laterally. At best, some of the bed and bank sediment can be moved, but the smaller material that is removed may be replaced by larger sediment from the adjacent tailings piles. Bank erosion on the outsides of meanders along the south channel, most of which is through disturbed areas but not tailings, suggests that the channel is trying to adjust. The sediment here is likely finer than in the areas covered by tailings.

***Changes in Channel Characteristics and Planform*:** The channels through the tailings were excavated by the dredge after mining was completed. Consequently, the morphology and planform of these channels were not created by fluvial processes, but were artificially created. The excavated channels are nearly straight and dissimilar to the naturally meandering channel that was previously present in this reach prior to mining. All flow is confined within these two channels. No secondary or overflow channels (e.g., potential off-channel areas) existed after mining. Channel characteristics, such as pools, riffles, and channel cross sections, were created by the dredge directly or are the result of the tailings piles and intervening low areas left by the mining. The pools that exist were formed in places where the dredge dug deeper and are not at the outside of meanders where they would occur naturally. Riffles formed when the dredge dug less deeply or where an immobile tailings pile was intersected. The channel cross section mirrored the form of the rectangular dredge bucket. Because of the size and distribution of the tailings, the channel cannot adjust these post-mining characteristics.

***Other Post-Mining Changes*:** The conditions left by the dredge resulted in a disconnected channel and floodplain. Overflow channels have been lost. Channel migration, which created abandoned channels that might carry slower flows, cannot occur. Connection between surface and ground water may have been altered. Vegetation that was demolished by the mining cannot be easily restored because of the coarse size of the surface sediment.

Channel Characteristics

Major dredge mining occurred throughout most of this reach between 1939 and 1942. The floodplain was completely overturned and now primarily consists of large cobbles with little opportunity for vegetation recruitment. The south channel in this reach is considered the main channel since it was the historic flow route. The north channel, a constructed route, only consists of the segment of river between the north-south channel bifurcation and the Ruby Creek confluence with the Middle Fork. The remnant ditch on the south side of the floodplain that diverts a portion of Ruby Creek is not considered for this assessment.

North Channel: The north channel is an artificial channel created during dredge mining. Although the north channel carries the majority of flow under base flow conditions, the south channel transports the majority of flood flows. Flow dynamics between the two channels result from unique entrance conditions at the point of the flow split. The north channel was not established until after the 1939 photographs were taken. Therefore, changes in the channel lengths were evaluated between 1956 and 2000. Between 1956 and 1976, the length of the north channel decreased by approximately 12 percent due to human alteration of the channel path at the confluence of the north and south channels. Minimal change has occurred in the subsequent years. Very little natural channel adjustment has occurred in this reach due to the inability of the channel to rework the bed and bank materials deposited by the dredging activities.

South Channel (main channel): Between 1939 and 1956, the main channel of reach MF8 decreased in length by over 500 feet, which is a 4.4 percent reduction in total channel length and sinuosity. During this time period, the channel was completely channelized and rerouted through the floodplain to accommodate dredge mining activities. The 1939 photographs do not indicate the presence of a considerable riparian corridor and the 1939 channel is bounded by several unvegetated bars. Channel length increased in the two ensuing time periods evaluated, with a gain of almost 400 feet between 1956 and 1976 and an additional gain of just under 300 feet between 1976 and 2000. Between 2000 and 2006, the channel length increased an additional 90 feet. Increases in channel length were accomplished through the growth of meanders between the north-south channel bifurcation and the confluence of Ruby Creek. Channel adjustment likely occurred in response to the channelization of the other sections of the main channel and was limited to this segment due to the ability of the stream to rework the bed and bank material. Outside of this segment, self-adjustment is restricted by tailings from the dredging operations.

5.2.1.15 Reach MF7 (RM 55.6 to RM 56.2)

Summary

Reach MF7 is downstream from a major area of dredge mining. Riprap and rock spurs that are nearly continuous along the meandering channel impact about 18.5 acres of HCMZ and confine or straighten about 2,385 feet of channel (about 75 percent of the length of the 2006 main channel). The HCMZ and channel migration are impacted throughout the entire reach. Off-channel areas (e.g., overflow channels and adjacent areas) are impacted also. Tailings upstream of RM 56.15 and embankments for an unimproved road at RM 56.2 (reach boundary) also impact the HCMZ and channel migration.

Forty-seven rock spurs have been placed nearly continuously between RM 55.7 and RM 56 and intermittently between RM 56 and RM 56.15. They armor the banks of the channel and confine or straighten about 2,385 feet of the channel (about 75 percent of the length of the 2006 channel) in a slightly meandering path. The rock spurs impact 18.5 acres of HCMZ on both sides of the channel, or about 71 percent of the total HCMZ area. Riprap on river right between RM 56.09 and RM 56.11 contributes to the impacted area of HCMZ. Upstream of RM 56.15, an artificial straight channel about 385 feet long has been created through tailings left from dredge mining. The tailings impact an additional 1.6 acres of the HCMZ. The tailings, along with an embankment for an unimproved road, disconnect about 3 acres of the floodplain on river left outside of the HCMZ. About 1,000 feet of highway embankment disconnect about 1.8 acres of the floodplain outside of the HCMZ along the left boundary of the floodplain. The location of this disconnected area along the edge of the floodplain means that the disconnected area likely has minimal impact on floodplain access, except at higher flood flows.

Constructed Features

- **Bank Armoring:** Forty-seven rock spurs have been place along the channel between RM 55.7 and RM 56.15. The rock spurs impact 18.5 acres of the HCMZ on both sides of the channel, confine or straighten 2,385 feet of channel to a slightly meandering path, and eliminate channel migration. Riprap armors 143 feet of the right bank between RM 56.09 and RM 56.11 and contributes to the HCMZ area that is impacted by the rock spurs.
- **Tailings:** Tailings from dredge mining primarily in reach MF8 cover the HCMZ and floodplain upstream of RM 56.15. An artificial straight channel, about 385 feet long, was constructed through the tailings. This channel has an unnatural form and cannot migrate through the tailings, which consist of material too large in diameter to be transported by the present flows on the Middle Fork.
- **Embankment for Unimproved Road:** Embankments that cross the HCMZ and floodplain near the upstream reach boundary at RM 56.2 disconnect about 3 acres of floodplain outside of the HCMZ.
- **Embankment of Highway:** About 1,000 feet of highway embankment disconnect about 1.7 acres of floodplain outside of the HCMZ, but the disconnected area likely has minimal impact on floodplain access.

Effects of Dredge Mining

The changes in the channel and floodplain that are discussed for reach MF8 would apply to the short section of reach MF7 with tailings (RM 56.15 to RM 56.2).

Most of reach MF7 is immediately downstream of the dredge mining. Tailings from the mining are limited to the very upstream end of the reach. Reach MF7 would have received an increased amount of sediment when mining was done upstream, as the sediment in the floodplain was excavated, sorted, and returned to the channel. Most of the sediment that was transported downstream to reach MF7 would have been finer sizes. The larger sediment remained upstream in the tailings piles along the channel and in the floodplain in reach MF8. Aggradation may have occurred in reach MF7 as mining-related sediment choked the channel. Deposition of bars along the channel may have resulted in channel migration and bank erosion. Once mining ceased, the sediment supply would have sharply decreased, which may have caused bank erosion in reach MF7. Pierce (2000) reported bank erosion downstream of mined reaches as meanders migrated into new floodplain areas. Later human activities (e.g., development, grazing) may have contributed to bank instability. Although we have not documented this sequence of events in reach MF7, bank erosion, which may have been initiated by the dredge mining upstream, may explain why the rock spurs were added to the banks.

HCMZ and Channel Migration

Channel migration has essentially been eliminated in this reach by the placement of rock spurs and riprap along the channel and by the dredge mine tailings upstream of RM 56.15. The channel is locked into a slightly meandering planform.

Channel Planform

Between 1939 and 1956, the channel length decreased by more than 200 feet, equivalent to a 6.5 percent reduction in total channel length and sinuosity. This decrease can be attributed to one channel avulsion near the upstream reach boundary and a few other shifts in channel position. However, qualitative comparison indicates that by 1956, the channel had begun to adjust laterally to increased energy inputs from upstream channelization. Also visible in the 1956 photoset are altered channel banks, possibly riprap or temporary levees; however, the bank protection in 1956 was not sufficient to preclude channel adjustment. In the following years between 1956 and 1976, the channel increased by the same amount that it had decreased in the previous two decades. This increase is appears to be due to continued lateral movement and increases in meander bend amplitudes. Between 1976 and 2000, the channel length decreased again by approximately 180 feet, or 5.4 percent. This reduction in length is likely a result of the installation of rock spurs and one major channel avulsion at the upstream end of the reach. The net change in channel length between 1939 and 2006 was a reduction of about 165 feet, which is a 5 percent decrease in total channel length and sinuosity.

Floodplain Access

About 3 acres of the floodplain outside of the HCMZ near the upstream reach boundary are disconnected by tailing and an embankment of an unimproved road. The floodplain cannot be accessed in this area. An additional 1.7 acres of the floodplain outside of the HCMZ are disconnected by about 1,000 feet of embankment along the left edge of the floodplain between RM 55.75 and RM 56.02. Because the disconnected areas are near the edge of the floodplain, the highway embankment has little impact on floodplain access.

5.2.1.16 Reach MF6 (RM 55.3 to RM 55.6)

Summary

Reach MF6 is naturally confined and the impact of constructed features on geomorphic processes has been minimal. A bridge at RM 55.4 may restrict flow somewhat, but the reach is naturally narrow. The embankments for the highway leading to the bridge and embankments for an unimproved road about 0.5 miles upstream disconnect less than 0.1 acre of the HCMZ. Riprap along these embankments is along the HCMZ/floodplain boundary; therefore, it has limited impact on channel migration.

Reach MF6 is naturally confined by bedrock and alluvial fans. Both units are present on both sides of the valley. The highway bridge that crosses the channel at RM 55.4 does not appear to markedly affect the HCMZ or floodplain. About 377 feet of riprap has been placed at this bridge and along embankments for an unimproved road near RM 55.45. The riprap is along the HCMZ/floodplain boundary, and has limited impact on bank erosion or channel migration.

Constructed Features

- **Riprap:** About 377 feet of riprap has been placed along embankments for a highway bridge at RM 55.4 and along embankments for an unimproved road near RM 55.45. Because the riprap is along the boundaries of the HCMZ and floodplain, it probably has little effect on channel migration.
- **Bridge at Highway Crossing:** A highway bridge crosses the channel at RM 55.4. Because the river is naturally confined at this point, the effect of the bridge on the HCMZ and floodplain appears to be minimal.

HCMZ and Channel Migration

Reach MF6 is naturally confined, so that channel migration is naturally limited. The constructed features in the reach, riprap and a highway bridge, probably have little impact on the HCMZ or channel migration. The channel curves with shallow meanders.

Channel Planform

Reach MF6 is a short reach laterally confined by bedrock and alluvial deposits. Measured changes in the channel length in this reach are minimal, despite percentage results. Channel changes in this reach are more attributable to mapping imprecision than to actual channel adjustment. Noted channel position differences between photosets appear to result from the identified position of the channel thalweg, which varied slightly between photosets. Because of the narrowness of the reach, this planform is likely unchanged from natural conditions

Floodplain Access

Constructed features do not disconnect the floodplain in this reach.

5.2.1.17 Reach MF5 (RM 53.9 to RM 55.3)

Summary

The HCMZ is primarily affected by possible artificially blocked or filled channels throughout the reach. Nearly 8 acres (18 percent) of the HCMZ and about 1,260 feet (17 percent of the 2006 channel length) of the main channel are impacted. A remnant of railroad grade on river left between RM 53.9 to RM 54.3 cuts off about 4 acres (25 percent) of the floodplain outside of the HCMZ, eliminating off-channel areas.

Nine channels that may be artificially blocked or filled and impact about 8 acres of HCMZ on both river right and river left primarily between RM 54.3 and RM 54.7 and between RM 55 and RM 55.2. Remnants of the railroad grade disconnect about 0.5 acres of the HCMZ in three localities delineated as RM 53.9 to RM 53.92, RM 54.27 to RM 54.31, and RM 54.37 to RM 54.43. These areas of the HCMZ that are disconnected are primarily only one side of the channel, except between RM 54.35 and RM 54.4 and between RM 55 and RM 55.2, where channel migration is limited on both sides. About 625 feet of channel appears to have been straightened along two of the remnants of railroad grade, between RM 54.29 and RM 54.4. The railroad grade between RM 53.92 and RM 54.31, at the downstream end of the reach, disconnects 4.1 acres of floodplain outside of the HCMZ. One possible overflow channel at RM 53.95 appears to be artificially blocked by the remnant of railroad grade on river left.

Constructed Features

- **Possible Artificially Blocked or Filled Channels:** Nine channels between RM 54.3 and RM 54.7 and between RM 55 and RM 55.2 appear to be artificially blocked or filled. They impact nearly 8 acres of the HCMZ and about 1,260 feet of the main channel, and, thus, affect channel migration. These areas need to be checked in the field.
- **Railroad Grade:** Three remnants of the railroad grade (RM 53.9 to RM 53.92; RM 54.27 to RM 54.31; and RM 54.37 to RM 54.43) with a total length of about 2,160 feet disconnect about 0.5 acres of HCMZ. Two of the remnants, along with possible artificially blocked channels on the opposite side of the river, result in about 625 feet of straightened channel. The railroad grade disconnects a large area (4.1 acres) of floodplain outside of the HCMZ between RM 53.92 and RM 54.31 and at least one probable overflow channel.
- **Levee:** A 52-foot-long levee between RM 54.12 and RM 54.13 impacts 0.17 acres of HCMZ on river right.
- **Excavations:** Excavations between RM 54.12 and RM 54.05 impact about 0.5 acres of the HCMZ on river left. The excavated area is between the railroad grade and the Middle Fork. It includes three or four pits, some sharply defined and others poorly defined, and their associated piles of sediment. The area is unvegetated, which suggests that the area has been worked recently.
- **Structure:** A small structure near RM 53.92 cuts off 0.1 acre of HCMZ and, along with a remnant of the railroad grade, confines about 195 feet of the channel between RM 53.9 and RM 53.93.

HCMZ and Channel Migration

About 8 acres, or 18 percent, of the HCMZ is impacted in reach MF5, primarily by possible artificially blocked or filled channels, but also by remnants of the railroad grade. Nearly 820 feet of channel have been straightened or are confined by the railroad grade. Although the constructed features are discontinuous in this reach, it appears that most of the channel experiences some constraint on lateral migration.

Channel Planform

Reach MF5 is bounded both upstream and downstream by confined reaches. Between 1936 and 2006, minor increases in channel length have occurred, amounting to a 3 percent increase in channel sinuosity. The small increases are due to elongation of one meander bend and change in main channel position around an island. The channel adjustment may be the result of historical channel straightening due to the installation of the railroad and flood control measures.

Floodplain Access

One large area (4 acres) of floodplain outside of the HCMZ is disconnected by the railroad grade between RM 53.92 and RM 54.31 on river left. This area is about 25 percent of the floodplain outside of the HCMZ, and limits floodplain access in this section of the reach.

5.2.1.18 Reach MF4 (RM 52.65 to RM 53.9)

Summary

Reach MF4 is naturally confined and the impact of constructed features on geomorphic processes is limited primarily to an 825-foot-long remnant of railroad grade on river right between RM 53.57 and RM 53.73. This remnant disconnects about 1.8 acres of HCMZ from the main channel and straightens and confines about 1,443 feet of the main channel.

Two other remnants of the railroad grade are preserved within the HCMZ and floodplain on river right. One remnant, 645 feet long, is between RM 53.3 and RM 53.4. The other remnant, only about 30 feet long in reach MF4, is the upstream extension of a remnant in reach MF3. These two remnants disconnect less than 1 acre of the HCMZ.

Possible artificially blocked or filled channels have some affect on the HCMZ between RM 53.47 and RM 53.57, but may do not disconnect the HCMZ. Three possible artificially blocked channels between RM 53.06 and RM 53.08 are probably at the downstream ends of channels from Big Boulder Creek. They would limit the flow from the creek into the Middle Fork. The reach between RM 52.7 and RM 53.05 is naturally confined by bedrock and the large alluvial fan from Big Boulder Creek. Constructed features have not been identified in this section, so that channel and floodplain processes may be operating in near-natural conditions.

Constructed Features

- **Railroad Grade:** Three remnants of the railroad grade are preserved along river right from RM 52.65 to RM 52.7, RM 53.3 to RM 53.4, and RM 53.57 to RM 53.73. The upstream reach disconnects the largest area of HCMZ, has the most impact on HCMZ width, and results in a straight, confined main channel. The HCMZ and channel migration are impacted, despite the reach being naturally confined by bedrock. The downstream remnant of railroad grade is an extension of a remnant preserved in reach MF3. The middle remnant only impinges on a small area along the edge of the HCMZ, so that its impacts are minimal.
- **Possible Artificially Blocked or Filled Channels:** Six possible artificially blocked or filled channels have been mapped in this reach. Three appear to be channels of Big Boulder Creek near their confluence with the Middle Fork. These blockages would concentrate the flow of Big Boulder Creek at its mouth, or would limit flow into the Middle Fork. Three of the possible artificially blocked/filled channels are related to the Middle Fork, but may have had minimum impact on the HCMZ. These areas need to be checked in the field.
- **Bank Armoring:** Four rock spurs are present in the reach. Two cut off 0.2 acres (less than 1 percent) of the HCMZ and limit channel migration between RM 53.67 and RM 53.68. The other two, on at RM 52.73 and the other near RM 53.48, are near the HCMZ boundary and have no or limited impact on processes within the HCMZ.

HCMZ and Channel Migration

Reach MF4 is naturally confined downstream of RM 53.2 between a large alluvial fan from Big Boulder Creek and bedrock and upstream of RM 53.55 by bedrock. The narrowness of this reach means that the constructed features are limited. Two remnants of the railroad grade (RM 52.65 to RM 52.7 and RM 53.33 to RM 53.81) disconnect about 2.3 acres of the HCMZ, limit HCMZ widths, and result in about 1,443 feet of artificially straightened main channel. A third remnant (RM 53.3 to RM 53.4) disconnects only about 0.2 acres of HCMZ at the edge of the HCMZ and has minimal impact.

Channel Planform

Within confined reach MF4, only small changes in channel length occurred between the photosets and appear to be due to minor adjustments in channel position combined with imprecision in georectification of the photographs through this heavily vegetated reach. The net measured change in channel length and sinuosity between 1936 and 2006 is approximately 0.1 percent.

Floodplain Access

Because the reach is so narrow, little floodplain extends outside of the HCMZ. None of this area is disconnected.

5.2.1.19 Reach MF3 (RM 51.05 to RM 52.65)

Summary

The railroad grade is preserved in three sections along the right side of the valley between RM 51.4 and RM 51.57, RM 51.73 to RM 52.11, and RM 52.18 to RM 52.65. The total length of railroad grade is greater than 1 mile (5,588 feet). Between these remnants, the banks are armored by 11 rock spurs, 160 feet of levees, and 4 possible artificially blocked/filled channels. The entire right side of the HCMZ is presently impacted or disconnected from the main channel. The total area of the HCMZ that is impacted or disconnected is about 50 acres, which is just greater than half (54 percent) of the total HCMZ area. Channel migration is limited. About 2,660 feet of channel, or 32 percent of the total 2006 channel length, have been straightened or are confined by 1,875 feet of railroad grade and 785 feet of rock spurs that armor the banks. The straightening and confinement caused by the railroad grade occurs along the upstream remnant between RM 52.18 and RM 52.65. The remnants of railroad grade also disconnect about 12 acres of floodplain outside of the HCMZ, or about 80 percent of the total floodplain area outside of the HCMZ. These disconnected floodplain areas outside of the HCMZ are near the north edge of the floodplain between RM 51.4 to RM 51.56 and between RM 52.21 and RM 52.6. Because of these locations, access to the floodplain in these areas would be affected only at higher flood flows.

Constructed Features

- **Railroad Grade:** More than 1 mile (5,588 feet) of railroad grade is preserved in three remnants within the floodplain on river right near the middle of the valley. These remnants are embankments constructed primarily of unconsolidated sand and silt, and in most places, could be easily eroded by the Middle Fork. The remnants that remain severely decrease the widths of the HCMZ and floodplain. The greatest restrictions in floodplain widths by the railroad grade are between RM 52.3 and RM 52.6 and between RM 51.5 and RM 51.8. Along with bank armoring and possible artificially blocked/filled channels, the remnants of railroad grade impact or disconnect more than half of the HCMZ area and restrict lateral channel migration. The upstream railroad grade remnant straightens and confines 1,875 feet of channel which is about 22 percent of the 2006 channel length. The remnants of railroad grade also disconnect an additional 12 acres (about 80 percent) of the floodplain outside of the HCMZ. Because these areas are near the edges of the floodplain, accessibility to the floodplain in these areas is affected only during higher flood flows.
- **Bank Armoring:** Eleven rock spurs and 160 feet of levee, which are present along the right bank between RM 51.8 and RM 52.1, impact or disconnect the HCMZ, decrease the width of the HCMZ, and restrict channel migration in this section. These features increase the impact of the remnant of the railroad grade that is preserved farther away from the channel in this section. The rock spurs between RM 51.8 and RM 51.85 may be related to a diversion that is just upstream at RM 51.88. In this section, the railroad grade disconnects 7.2 acres of the HCMZ and the rock spurs impact an additional 6.5 acres of the HCMZ.
- **Possible Artificially Blocked or Filled Channels:** Four channels appear to be blocked or filled artificially, although it is possible that they were filled during natural channel migration. The channels are all on river right at RM 51.3, RM 51.58, RM 51.87, and RM 52.3. In addition to these four channels, a 160-foot-long levee between RM 51.25 and RM 51.29 blocks at least one channel. About 14 acres of HCMZ is impacted or disconnected from the main channel by possible artificially blocked/filled channels or the levee. Channel migration also is restricted by the blocked/filled channels. These areas need to be checked in the field.

HCMZ and Channel Migration

A combination of remnants of the railroad grade, rock spurs, levees, and possible artificially blocked/filled channels impact or disconnect more than 50 percent of the HCMZ, decrease the width of the HCMZ, and limit channel migration. The HCMZ is affected throughout the entire reach.

Channel Planform

Channel length changes in reach MF3 were never greater than 50 feet between any of the available photosets. However, considerable channelization prior to 1939 is apparent, particularly where the railroad grade was constructed through the floodplain and disconnected several oxbows. Constructed features have resulted in straightening of the channel planform, especially upstream of RM 52.2.

Floodplain Access

The floodplain is cut off from the main channel by the remnants of the railroad grade. The total length of these remnants is 5,588 feet, which are preserved in three sections along river right. About 12 acres (about 80 percent) of floodplain outside of the HCMZ are disconnected by the remnants of railroad grade. All of these areas are near the edge of the floodplain and would affect accessibility to the floodplain only during higher flood flows.

5.2.1.20 Reach MF2 (RM 48.15 to RM 51.05)

Summary

Reach MF2 is a naturally unconfined reach. Many channels throughout the reach appear to have been artificially blocked or filled. About 7 acres of the HCMZ are impacted directly by the blocked/filled channels. Another 163 acres of the HCMZ are impacted by blocked/filled channels along with riprap, levees, irrigation ditches, or spoil. Channel migration is limited in these areas. A bridge at RM 49.08 and the approach embankment on river left, short levees across channels, a diversion and irrigation ditch, and bank armoring all contribute to limiting the HCMZ area and channel migration. About 38 acres of the HCMZ are affected. In addition, off-channel areas (e.g., overflow channels and adjacent areas) within the HCMZ have been eliminated or modified through most of the reach.

Bank armoring, especially riprap, and possible artificially blocked or filled channels do not allow the channel to migrate and restrict flow to a single, straight-to-slightly meandering path. Historical channels since 1939 have been markedly straighter than they were in that year. The width of reach MF2 and well-defined channels that are visible on the LiDAR hillshades are interpreted as indicating that the natural channel was sinuous, shifted location frequently, and may have included several channels that carried flow simultaneously. If these were the natural channel conditions, the blocked/filled channels and bank armoring have significantly diminished the HCMZ and possible channel migration. Presently, the channel is restricted to the north side of the valley between RM 48.15 and RM 49.5 and to the south side between RM 50.2 and RM 51.05. A bridge at RM 49.08 and the associated embankment on river left restrict the channel and disconnect about 38 acres of the HCMZ.

Constructed Features

- **Possible Artificially Blocked or Filled Channels and Levees:** In 24 localities, the upstream (usually) or downstream ends of channels appear to have been blocked artificially, either with fill or short levees, and are no longer accessible to the main channel. It is possible that some of these channels were filled naturally as part of channel migration. The blocked or filled channels that have been mapped are those that are blocked or filled by features that appear to have been constructed. The features are very sharp and short and some appear to be levees. Other blocked or filled channels are associated with or near riprap or other constructed features. Some channels are mapped as artificially blocked or filled. Others are mapped as possible artificially blocked or filled channels. This category depends upon the certainty based on expression on the LiDAR hillshades or aerial photographs. All of these blocked or filled channels need to checked in the field to determine if the blockage or filling is the result of natural processes or constructed features. Many of the disconnected channels are well expressed on the LiDAR hillshades, which suggests that they were once main or secondary channels. Five of the blocked or filled channels (RM 48.5; RM 48.8; RM 49.05; RM 50.4; and RM 50.75) were active main channel meanders in 1939. Many of the disconnected channels may have been secondary channels in 1939 and 1956. Thus, the channels that are disconnected probably carried significant flow under pre-development conditions. About 11,610 feet (greater than 2 miles) of channel have been blocked. The blocked channels, along with bank armoring, significantly limit the HCMZ and channel migration. At least one significant channel is blocked by the road embankment near RM 49.1. Nearly 170 acres, or about 60 percent, of the HCMZ are impacted at least in part by the blocked or filled channels in this reach.

- **Bank Armoring:** About 3,500 feet of riprap, 245 feet of levees, and 10 rock spurs restrict the HCMZ and channel migration. In some localities, the bank armoring has disconnected channels, which limits the HCMZ if they were main or secondary channels, and limits floodplain accessibility if they were overflow channels. Between RM 50 and RM 50.3, nearly continuous riprap along one or both sides of the channel restricts the channel to a very narrow, slightly sinuous path. The riprap may be maintained to direct flow into a diversion and irrigation ditch at RM 50.1. Between RM 48.15 and RM 48.2, rock spurs on the right bank direct flow to the bridge at RM 48.13, just downstream of the reach boundary, and result in about 230 feet of straightened channel and limited channel migration.
- **Bridge and Associated Embankment:** A bridge at RM 49.08 and the embankment that leads to it from the south side of the valley (river left) restrict the position of the channel, disconnect the HCMZ, restrict channel migration, and reduce floodplain accessibility. The 1,760-foot-long embankment blocks a well-defined channel and several poorly defined ones on river left. The embankments to the bridge and riprap near them not only confine the channel, but also decrease channel complexity by decreasing channel roughness and bank vegetation.

HCMZ and Channel Migration

Nearly 170 acres of the HCMZ are diconnected at least in part by filled channels or levees, by banks that are armored by riprap and rock spurs, and by a bridge and associated embankment near RM 49.08. A more sinuous channel present in 1939 and other well-defined channels that are visible on the LiDAR hillshades suggest that the present channel is much straighter than in the past, and that the HCMZ was much more extensive prior to development. All of these constructed features severely limit the HCMZ and channel migration. An especially restricted section is located between RM 50 and RM 50.2, where riprap is nearly continuous on one or both banks and directs flow into a diversion and irrigation ditch at RM 50.1. More than a mile (5,794 feet) of channel has been straightened or is confined by the bridge, riprap, and rock spurs (related to the bridge downstream at RM 48.13), so that lateral migration is markedly limited.

Channel Planform

Overall, channel length and sinuosity have decreased greatly in reach MF2 since 1939, with the greatest change occurring between 1939 and 1956. Between 1939 and 1956, the channel length decreased by approximately 2,800 feet and the sinuosity decreased by 15 percent. These changes were primarily caused by substantial channelization of the river through the installation of riprap along the channel banks. Only minor changes were noted in channel length between 1956 and 2006 due to the artificial confinement of the channel. By 2006, the channel appears to have been restricted within its lateral constraints. This reach of the Middle Fork showed the greatest decrease in channel length and sinuosity within the assessment area.

Floodplain Access

About 4 acres (7 percent) of the floodplain outside of the HCMZ have been disconnected. The two largest disconnected areas, which are disconnected by riprap, are near RM 48.5. A small area (0.2 acres) of floodplain outside of the HCMZ is disconnected by the bridge embankment near RM 49.08, where channels have been blocked. All of these areas are near the edges of the floodplain and would only affect the floodplain at higher flood flows.

5.2.1.21 Reach MF1 (RM 47.95 to RM 48.15)

Summary

The main constructed features that impact the HCMZ in reach MF1 are a bridge at RM 48.13, near the upstream reach boundary and the associated embankments for an unimproved road leading to the bridge. The bridge is visible on the 1939 aerial photographs but its exact construction date is not known. The bridge and embankments disconnect about 0.72 acres (12 percent) of the HCMZ and straighten and confine about 373 feet of channel near the bridge. Flow is restricted to a single channel in this area and off-channel areas (e.g., overflow channels and adjacent areas) of the floodplain have been heavily impacted by construction of the bridge.

Downstream of about RM 48.1, the channel includes two broad meanders, but the channel has been straighter since 1976 than it was in 1939 and 1956. Although no constructed features have been mapped along this section of channel, some may be present. Alternatively, the channel in this section may have straightened naturally. An embankment for an unimproved road cuts off 0.3 acres, or 12 percent, of the floodplain outside of the HCMZ. Because this area is small and located near the edge of the floodplain, its impact is minimal. It would affect the floodplain at higher flows only.

Constructed Features

- **Bridge and Embankments for Unimproved Road:** A bridge and associated embankments at RM 48.13, which were built before 1939, restrict channel migration by cutting off 0.72 acres (12 percent) of the HCMZ, by narrowing the HCMZ by 174 feet (about 70 percent of the natural width), and by forcing flow into a single, straight channel at the bridge and both upstream and downstream of it. About 373 feet (34 percent of the 1,091 feet of the 2006 channel length) of the channel has been straightened near the bridge. The effects of the bridge extend upstream into reach MF2, which was discussed in the previous section.
- **Embankment and Unimproved Road:** A 270-foot-long section of embankment and unimproved road between RM 47.97 and RM 48.05 cuts off 0.31 acres (12 percent) of floodplain outside of the HCMZ. Because of the location of this area near the edge of the floodplain, this embankment would affect floodplain accessibility only at the highest flood flows.

HCMZ and Channel Migration

The HCMZ and channel migration are limited upstream of RM 48.1, because the channel is restricted by a bridge and the associated embankments at RM 48.13. The channel has been straightened both upstream and downstream of the bridge and is not allowed to migrate. Meanders that were present in both the 1939 and 1956 downstream of RM 48.1 have not been occupied since at least 1976. Constructed features that would restrict flow and straighten the channel in this section have not been identified, but may be present.

Channel Planform

Reach MF1 encompasses a short moderately confined segment of the study area between Cress Creek and Camp Creek. Between 1936 and 1976, the channel length increased by approximately 12 percent. No 1956 data were available for this reach to determine the change between 1939 and 1956. The increase appears to be related to the evolution of a few meander bends within the reach; however, the channel length decreased drastically by 2000, owing in large part to multiple channel avulsions and abandonment of meander bends. This may be related to bridge improvements at the upstream end of the reach, which caused an increase in flow constriction and also increased erosive forces through the bridge embankments. Very little change occurred between 2000 and 2006. The total channel length and sinuosity between 1936 and 2006 was reduced by approximately 15 percent with the greatest change occurring between 1976 and 2000.

Floodplain Access

The floodplain on both sides of the channel is disconnected near the bridge at RM 48.13. The bridge and associated embankments restrict flow to a single channel, and do not allow any flood flows to spread into the floodplain. A road embankment between RM 47.97 and RM 48.05 disconnects the floodplain outside of the HCMZ, but only for the highest flood flows, and so has minimal impact on floodplain accessibility.

5.2.2 Cattle Grazing

Throughout the United States, channel erosion and degradation of the riparian zone have been linked to cattle grazing. These impacts directly affect water quality, water temperature, channel morphology, streamside vegetation, and debris inputs, which have a substantial influence on habitat for anadromous fish and other aquatic species (McDowell and Magilligan 1997). In the past 2 decades, management practices have been employed to effectively reduce the impacts of grazing on stream habitat. However, these practices are not ubiquitous, and many streams continue to degrade or remain in a degraded state as a result of continued cattle grazing.

A study of eight streams in eastern Oregon found that grazed reaches were typically characterized by greater widths, greater width to depth ratios, decreased low flow depths, and decreased pool area compared with reaches with cattle exclosure practices (McDowell and Magilligan 1997). Cattle exclosures also tended to have narrower bankfull channels, increased riparian vegetation, and greater bank stability.

Within the Middle Fork John Day River, grazing may have considerably influenced channel morphology and riparian conditions. Sheep grazing was prevalent in the basin from the late 1800s to the middle 1900s. By the 1940s, domestic grazing was dominated by cattle which continues today (USFS 1998). Streamside vegetation and bank stability within most of the unconfined and moderately confined reaches have been altered by cattle grazing and trampling. In several locations where cattle grazing has been persistent for decades, the channel is wider, shallower, and less complex than ungrazed reaches. Bar, bed, and bank trampling contributes increased amounts of fine sediment. Degraded riparian vegetation and reduced canopy cover have lead to decreased stream shading and increased potential for solar heating (USFS 1998).

Today, cattle grazing is moderated in many reaches of the Middle Fork. On the Oxbow and Forrest Conservation Areas, exclosure fencing prevents cattle from entering the channel and grazing within the riparian corridor. Within a few reaches of the assessment area, uncontained cattle grazing continues (Figure 13).

Figure 13 – Cattle Grazing in Reaches MF15 and MF 16.

5.3 Hydraulic and Sediment Transport Analysis

An integral step in defining sustainable restoration strategies is to develop an understanding of the hydraulics and sediment transport dynamics of a system. Evaluation of a river's flood hydraulic and sediment transport regimes was completed in this study as a foundation for future assessments and project implementation. Results from the hydraulic and sediment transport analyses will help address several of the existing hypotheses related to channel stability. At the beginning of the study, the multi-disciplinary channel assessment team, combined with local stakeholders, identified multiple hypotheses related to how hydraulics and sediment are currently functioning in the Middle Fork John Day River. First, the group hypothesized that the river is no longer accessing its floodplain and side channels at historic rates due to constructed features located within the floodplain, historic management activities, and substantial changes in land use from pre-settled conditions. A second hypothesis was that several sections of the channel have incised and become armored due to human impacts. Analyses were conducted to address these hypotheses through the following tasks:

- Evaluate the frequency that the channel is accessing its floodplain.
- Evaluate the frequency that bar and bed material are being reworked.
- Characterize how sediment is transported through the system.
- Determine locations where historic rates of sediment transport may have been altered.
- Characterize the present channel stability and determine if the channel is significantly incised.
- Identify potential for degradation or aggradation within the system.

5.3.1 Methods

5.3.1.1 Hydrology

The hydrology study in Appendix C provided the information used in modeling the 2- through 100-year flood events. A geographical information system (GIS) was developed based on regional regression equations for northeastern Oregon because insufficient gauged data were available to characterize the peak flows throughout the basin. Within the GIS, subbasins were delineated with a minimum area of 2 square miles. For each subbasin, the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals were calculated. These flows were imported into the one-dimensional hydraulic model for steady flow analysis. Flows due to groundwater and irrigation diversions were not considered in this analysis and are not expected to markedly influence the magnitude of flood flows.

5.3.1.2 Topographic Data

Surveys have been conducted over multiple years on the Middle Fork of the John Day River. Although each survey was not necessarily performed for the present investigation, all available survey data were incorporated into this analysis.

Ground Surveys

Between August and December of 2005, topographic surveys were collected on the Oxbow and Forrest Conservation Areas of the Middle Fork of the John Day River. These surveys entailed detailed cross sectional surveys through the river and into the floodplain and sufficient points between cross sections to generate breaklines and 2-foot contours in the areas of specific project locations. The north channel of the Middle Fork on the Oxbow Conservation Area was not surveyed at this time due to scheduled recontouring of dredge tailings within the floodplain.

Following identification of the need for a larger-scale geomorphic assessment in early 2006, additional ground surveys were requested to develop a longitudinal profile through the extents of the assessment area. The assessment area encompasses the specific project sites on the Oxbow and Forrest Conservation Areas and several miles upstream and downstream of each of the sites. Selection of the extents of profile survey was also dependent on land owner access and potential land owner involvement in future project locations. In October 2006, longitudinal profile surveys were collected along the active channel thalweg spaced such that the bottom of each pool and the top of each riffle were identified with a maximum distance of 100 feet between points.

A substantial flow event occurred during spring runoff in 2006, potentially modifying previously existing ground surface features as surveyed in the 2005 surveys. As a result, several cross sections needed to be resurveyed to record changes that may have occurred. On each of the Oxbow and Forrest Conservation Areas, a minimum of two cross sections across the river were resurveyed.

Cross sectional surveys through the north channel of the Middle Fork on the Oxbow Conservation Area were also collected in October 2006 for the anticipated project designs on the property. Sufficient survey data were obtained between the cross sections such that breaklines of channel features (e.g., top of bank, toe of slope, edge of water, thalweg) could be generated.

LiDAR

Light Detection and Ranging (LiDAR) data were acquired in October 2006 to identify ground surface elevations, infrastructure, and vegetation within the floodplain of the study area (Watershed Sciences 2006). Quality control data were collected within the project area using a ground-based real-time kinematic (RTK) survey and were compared to the processed LiDAR data to evaluate LiDAR accuracy across the project area. The root mean square error was reported as 0.069 meters based on a comparison of the LiDAR and RTK surveys.

TIN Development

Both the ground survey data and the LiDAR were combined to create the triangulated irregular networks (TIN) used for the one-dimensional hydraulic model. Because of the size of the assessment area and the number of LiDAR points, three TINs were created for input into the model. LiDAR points within the wetted channel area were removed due to the inability of the technology to collect underwater data; however, sufficient ground survey data were available to develop the necessary geometry of the channel for one-dimensional modeling. The channel geometry within the Oxbow and Forrest

Conservation Areas has greater accuracy than areas outside of the properties due to the large amount of ground survey data collected. Channel geometries outside of the conservation areas are based on interpolated points between the channel banks, the edge of the water surface, and the thalweg. Since LiDAR was acquired during low flows, the conveyance area based on the interpolated points is sufficient for modeling high flows. Modeling of low flows or two-dimensional modeling may require additional survey data, particularly outside of the Oxbow and Forrest Conservation Areas.

Cross Sections

Cross section geometry was developed based on three separate TINs of the Upper, Middle, and Lower reaches of the assessment area. Within ArcGIS, HEC-GeoRAS was utilized to convert two-dimensional line files to cross sections having elevation values. Cross sections were spaced approximately every 200 to 300 feet longitudinally along the channel. To capture the hydraulic controls of the channel, at least one cross section was located across every known riffle. Widths of the cross sections varied depending on the width of the valley, but all cross sections covered the extents of a 100-year flow event. The cross sections were imported into a one-dimensional HecRAS model and then filtered to reduce the number of points to 500 (maximum allowable). This was completed within HecRAS using a filtering methodology that minimized the change in the area of the channel geometry.

5.3.1.3 Slope Analysis

An analysis of river profile was conducted to evaluate substantial vertical geologic controls and identify potential changes in sediment transport through the system. The surveyed longitudinal profile of the channel thalweg was used to evaluate the channel slopes. Slope data were processed in Excel after extrapolation using ArcGIS. Slopes were computed first by visual breaks in grade. Slopes breaks were determined based on notable changes in grade along the longitudinal profile. Slopes were also computed for each reach for comparison with the visual breaks in grade.

5.3.1.4 Sediment Sampling

In order to address specific study questions related to sediment transport, sediment samples were collected by both surface sampling and volumetric sampling methods (Bunte and Abt 2001). Surface sampling entails measurement of surface particles, while volumetric sampling entails measurements of bed material layers (e.g., armor layer, subarmor layer, surface layer, subsurface layer). Pebble counts were selected as the most appropriate surface sampling technique for this study based on study questions, time and budgets constraints. Volumetric sampling included collection of surface and subsurface layers at select locations.

Pebble Counts

Channel bed and bar sediments were sampled using pebble counts at 32 locations along the Middle Fork. For in-channel pebble counts, Wolman (1954) sampling methods were applied, in which the pebble counter selects a particle from beneath the tip of his or her boot while looking away. This method is most appropriate for in-channel measurements where laying out a systematic grid would be difficult. Pebble counts performed on gravel bars were performed using systematic sampling at even spaced marks along a measuring tape. In most areas, the spacing was 0.5 feet. Bars that were relatively small in length often required multiple transects to complete a minimum of 100 counts.

A US SAH-97 gravelometer (Potyondy and Bunte, 2002) was used in the measurement of each particle size. Research indicates that template measurements are expedient, provide higher accuracy than measurements with rulers and reduce variability between pebble counters (Bunte and Apt 2001).

Surface and Subsurface Layer Samples

Surface and subsurface layer sediment samples were collected at nine locations on the Middle Fork for use in sediment transport capacity modeling. Where possible, one sample was collected between each known major geologic control. Between reaches MF17, MF18, and MF19, no sediment sample was obtained due to the high percentage of bedrock in the channel bed and the lack of gravel bars. In general, samples were collected from gravel bars that appeared to be the most representative of the material within the river between the geologic controls. Sampling locations were also influenced by land owner access and the distance to vehicle staging locations.

Once a site was selected for volumetric sampling, equipment was carried to the site for field-sieving of particles greater than 32 millimeters. On the selected bar, a 1-meter by 1-meter area was framed that appeared consistent with the material noted throughout the section of river. Shovels were used to first remove the surface or armor layer down to the bottom side of the largest particle or until a substantial change in sediment material was noted. A rocker sieve was used to sieve material smaller than 32 millimeters and the remaining sediment particles were segregated by size class and weighed on site. The subsurface sample followed a similar procedure, but the depth was greater than the surface sample, typically extending to a depth equal to the maximum surface particle size. The combined weights of the surface and subsurface samples ranged between 150 and 330 pounds. All material finer than 32 millimeters was carried off-site to a lab for further sieve analyses. Photographs were taken to document each surface and subsurface sample.

5.3.1.5 Hydraulics

The hydraulic analysis consisted of a one-dimensional, steady flow HecRAS model. The purpose of the model was primarily to approximate water surface elevations, extents of inundation, and channel velocities for flood flow events. One-dimensional hydraulic models are capable of illustrating average water surface elevations, velocities, and shear stresses across a series of cross sections. For the large-scale evaluation of channel processes presented in this geomorphic assessment, the one-dimensional model was sufficient. However, the model was not developed to analyze two- or three-dimensional hydraulic patterns associated with multiple and substantial flow splits, river meandering, point bar formation, pool-riffle formation, or alterations to planform.

Geometry was imported into HecRAS using HecGeoRAS 4.1 within ArcGIS 9.1. Once the hydrology and geometry data were set up in the model, bank stations were verified and values of roughness were defined for various types of land use. Within the channel, Manning’s Roughness coefficients varied between 0.04 and 0.05, depending on the size of sediment and the amount of in-channel vegetation and debris. Several measured water surface elevations at lower flows were compared with modeled water surface elevations to validate the use of the assigned roughness values for each cross section. In general, the measured water surface elevations were within 0.2 feet of the modeled water surface elevations at lower flows. Within the floodplain, roughness values varied between 0.055 and 0.09 and were dependent on the vegetation cover and land use within the floodplain. These values were obtained from guidance presented by Chow (1959). Due to the lack of measured water surface elevations during flood flow conditions, floodplain roughness values were not validated by measured values.

The Middle Fork HecRAS model consisted of 638 cross sections covering 23 miles of river. Within the model, levees were installed only at locations where known dikes, roads, or levees prevent flow from accessing adjacent side channels and floodplain. Flow obstructions were used to prevent flow in irrigation ditches from conveying portions of the flood flows. This was based on the assumption that irrigation ditches will not be used to convey high flows and are not expected to reduce in-channel flows during major flooding events. Ineffective flow areas were used to all other areas that are expected to be wet but are not expected to convey flood flows from upstream cross sections, such as historic stock ponds and tributaries.

Several attempts were made to capture the flow split between the north and south channels in reach MF8. Due to the flood plain geometry and entrance conditions of the north channel, the looped network option within HecRAS would not accurately depict flow splits. Instead, various flows were only routed down the north channel until flow began to overtop the banks near the channel bifurcation. This occurred when flow in the north channel reached 300 cubic feet per second (cfs). A value of 300 cfs was therefore determined to be the capacity of the north channel. All remaining flood flows were conveyed through the south channel. Although flow splits were estimated for use in the one-dimensional model of flood events, a two-dimensional model will more accurately represent both low flow and flood flow conditions in this reach.

Results of the hydraulic analysis were used to validate low surface mapping, to perform sediment transport investigations, and to evaluate channel stability.

5.3.1.6 Sediment Analysis

Various surrogates were used to evaluate how sediment moves through the John Day system under flood flow events. Sediment transported during the 2- through 100-year flow events were considered in this analysis as these events tend to be geomorphically significant in the ability of the channel to mobilize bed and bar material. While surrogates do not provide the exact quantity of sediment being transported during the flow events of interest, they offer an improved understanding of the relative degree to which channel forming processing vary throughout the system and of the relative capacity of reaches to transport sediment under transport-limited conditions. The surrogates investigated include incipient motion, unit stream power, total stream power, and sediment transport capacity.

Incipient Motion

Incipient motion is described as the threshold condition between erosion and deposition (Julien 1998). When particles of sediment resisting motion are in balance with hydraulic forces acting on the particles, the particles are at incipient motion. Hydrodynamic forces exceeding the resisting forces cause sediment to become mobilized. Calculations of incipient motion examine the ability of varying flow conditions to mobilize and rework the sediment present in the bed and bars within the river. Incipient motion does not consider the supply of sediment or identify the quantity of sediment moved through a given cross section of the river; however, incipient motion does explain if the material present in channel bed and bars are reworked under specific flow events. The results can also be used to hypothesize if the bed material has coarsened, become armored, or if the channel has incised.

Incipient motion was calculated for each cross section under 2-, 5-, 10-, 25, 50-, and 100-year flow conditions using Yang's criteria (1973) for flood conditions in gravel-bed rivers in combination with Rubey's criteria (1933) for particle fall velocity. The equation used to determine the critical diameter at which incipient motion occurs is shown below.

$$D_c = 0.0216 v_{cr}^2$$

Where:

v_{cr} = critical average velocity at incipient motion (m/s); and

D_c= grain size diameter at which incipient motion occurs (m).

Grain sizes smaller than the calculated critical diameter are expected to be mobilized for flow velocity assessed. Grain sizes greater than the critical diameter are stable.

Incipient motion can also be used to better understand the bed coarsening, degree of channel armoring, and potential degradation that may have occurred in each reach. During the process of channel armoring, the balance of sediment load is offset and the channel bed becomes the sediment source. This is followed by degradation of the channel bed. As finer materials are transported through the system, the bed material becomes coarser until a complete layer of coarse material covers the channel bed, thereby blocking transport of finer underlying materials (Yang 1996). When a channel is substantially armored and the thickness of the armoring layer is known, the depth of the degradation can be estimated.

Stream Power

Total Stream Power

Stream power influences river systems through impacts on channel form, pattern, and channel forming processes, such as sediment transport and channel migration (Knighton 1998). Total stream power per unit length of channel is defined by:

$$\Omega = \gamma Q S$$

Where:

γ = the specific weight of water (N/m^3)

Q = water discharge (m^3/s)

S = energy gradient (m/m)

Because γ is a constant, total stream power was evaluated in this investigation as the product of discharge and friction slope (QS with units of cfs). Stream power was calculated for each cross section and flow event and averaged across each geomorphic reach.

Discharge tends to increase in the downstream direction in most river systems as tributaries and runoff augment river flows. As discharge and slope change, the ability of the river to transport sediment also changes. Hence, their product, total stream power, is directly related to the sediment transport capacity within a system. Total stream power may be used to compare the relative magnitude of sediment loads a stream is capable of transporting between reaches. This surrogate does not consider or evaluate the supply of incoming sediment, the quantity of sediment loads, or the size of sediment transported. Interpretation of total stream power can suggest where aggradation or degradation might occur in the system assuming a uniform supply of sediment. Only in-channel flow was considered in the assessment.

Unit Stream Power

Unit stream power is defined as the rate of potential energy expenditure per unit weight of water available for transporting water and sediment in an open channel (Yang 1996). This sediment transport surrogate is an indicator of the relative amount of energy required to transport a given sediment load. For each cross section of the hydraulic model, unit stream power was computed as the product of the friction slope and channel velocity (VS with units of feet per second). Unit stream power differs from total stream power in that velocity incorporates the impact of channel geometry on sediment transport. Unit stream power can be used in a relative comparison of the ability of the stream to transport a given sediment load through each cross-section. Within each geomorphic reach, cross sections represent a range of hydraulic conditions. Unit stream power was averaged across all cross sections in a reach to compare relative sediment transport capacity between reaches. While unit stream power is appropriate for relative comparisons of transport capacity, this surrogate does not indicate the quantity or sizes of sediment transported through each cross section or reach. Similar to total stream power, unit stream power can provide information as to where aggradation or degradation might be expected based on a uniform supply of sediment. Computations of unit stream power only considered flow transported through the main channel. Overbank flows were not included in this assessment.

5.3.1.7 Sediment Transport Capacity

Sediment transport capacity analyses were conducted for the 2- through 100-year flow events. Using the one-dimensional hydraulic model results, SRH-1D sediment transport capacity routines were run through the interface program, MoNet. Three different methods for calculating sediment transport were applied, including: Meyer-Peter and Müller's formula (1948) modified by Wong and Parker (2006), Yang's sand (1973) and gravel (1984) transport formulas, and Parker's method (1990). Sediment transport was calculated for each cross section based on the representative volumetric surface, subsurface, and combined sediment gradations for the reach. Results of the analysis were centrally averaged across multiple cross sections to reduce variability from cross section to cross section and to facilitate interpretation.

5.3.2 Results

5.3.2.1 Hydrology

Along the channel within the assessment area, flow was augmented at 22 locations due to increasing drainage area and tributary inputs (Figure 14). Tributaries contributing substantial flow and their locations are defined in Table 5. Some tributaries had sufficiently small drainage areas or were within a close distance with other contributing drainages that their inputs were combined with one or more other tributaries. At the upper end of the assessment area, flood flows are relatively small. Once flows from Clear Creek enter the Middle Fork, mainstem flows increase dramatically and continue to gradually increase in the downstream direction. A considerable decrease in flood flows is noted near RM 57, where flow splits between the north and south channel. Figure 14 illustrates flow through the south channel at this location. For the purposes of modeling, a flow of 300 cfs was determined to be routed through the north channel for all flood events based on entrance conditions of the north and south channels at the bifurcation. A flow of 300 cfs represents the capacity of the north channel without flow spilling into the south channel.

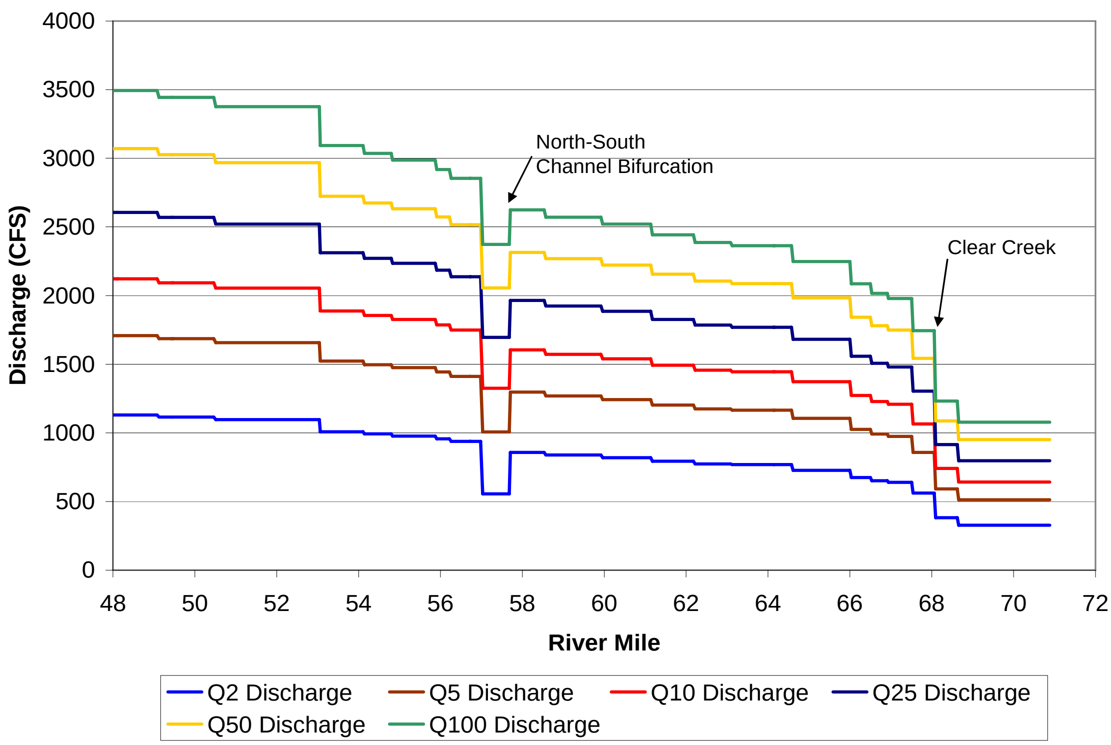

Figure 14 – Discharge Used in Modeling the Middle Fork of the John Day River.

Table 5 – Major Tributaries Contributing Flows to the Middle Fork.

Tributary	Approx. River Mile	Tributary	Approx. River Mile
Mill Creek	69.25	Butte Creek	57.70
Clear Creek	68.10	Granite Boulder Creek	57.35
Bridge Creek	67.50	Ruby Creek	56.80
Davis Creek	66.70	Beaver Creek	56.10
Vinegar Creek	66.30	Ragged Creek	55.65
Vincent Creek	65.50	Sunshine Creek	54.35
Flat Creek	62.30	Dry Creek	54.20
Little Boulder Creek	61.90	Big Boulder Creek	53.10
Murdock Creek	61.70	Coyote Creek	51.00
Gorge Creek	61.15	Dunston Creek	50.80
Little Butte Creek	60.80	Balance Creek	50.15
Windlass Creek	59.45	Horse Creek	50.00
Tincup Creek	58.80	Cress Creek	48.20
		Camp Creek	47.90

5.3.2.2 Slopes

The channel bed profile and the computed bed slopes are presented in Figure 15. Slope breaks identified visually only coincided with the reach breaks in a few instances. Within one geomorphic reach, multiple visual slope breaks may have been due to the relative degree of valley confinement. This was particularly noticeable in reaches where valley width was transitioning to or from a confined reach. In general, reach average slopes correlated with the degree of valley confinement. Confined reaches tended to illustrate relatively high slopes compared with moderately confined and unconfined reaches. Unconfined reaches tended to have the lowest slopes. The channel profile was also used to identify and/or validate significant natural and human-placed vertical channel controls. For example, reach MF11 is heavily confined and contains a sharp drop in grade as the channel travels over large boulder and bedrock controls. Within unconfined reach MF8, the channel has been substantially modified due dredge mining activities. The channelization in this reach has notably increased the channel slope from its historic condition.

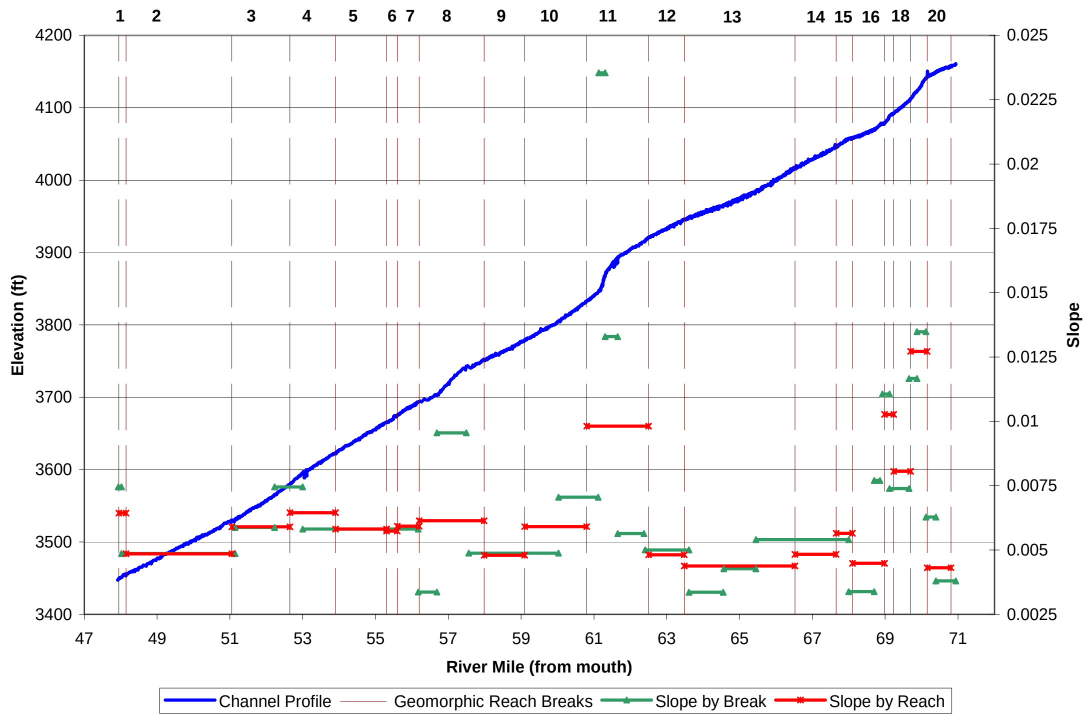

Figure 15 – Profile of the Middle Fork John Day River. Bed elevations are denoted on the primary Y-axis, and slopes are denoted on the secondary Y-axis.

5.3.2.3 Velocity

The hydraulic model computes the channel velocity at each cross section based on the flow event, channel roughness, hydraulic geometry, and specific energy. As Figure 17 shows, high flow channel velocities are highly variable from one cross section to the next as a result of variation in the channel capacity and friction slope. Velocities of the Middle Fork correlate with the degree of channel confinement and the bed slope of the channel. Higher velocities correspond to high confinement and high bed slope. In general, velocities increase slightly from upstream to downstream with some variations due to highly confined reaches characterized by steep slopes.

For a clearer depiction of how the velocities change throughout the system, the velocities were averaged across each geomorphic reach, as depicted in Figure 16. Across the 23-mile stretch of the Middle Fork, reach-averaged channel velocities vary between 3.5 and 8.5 feet per second.

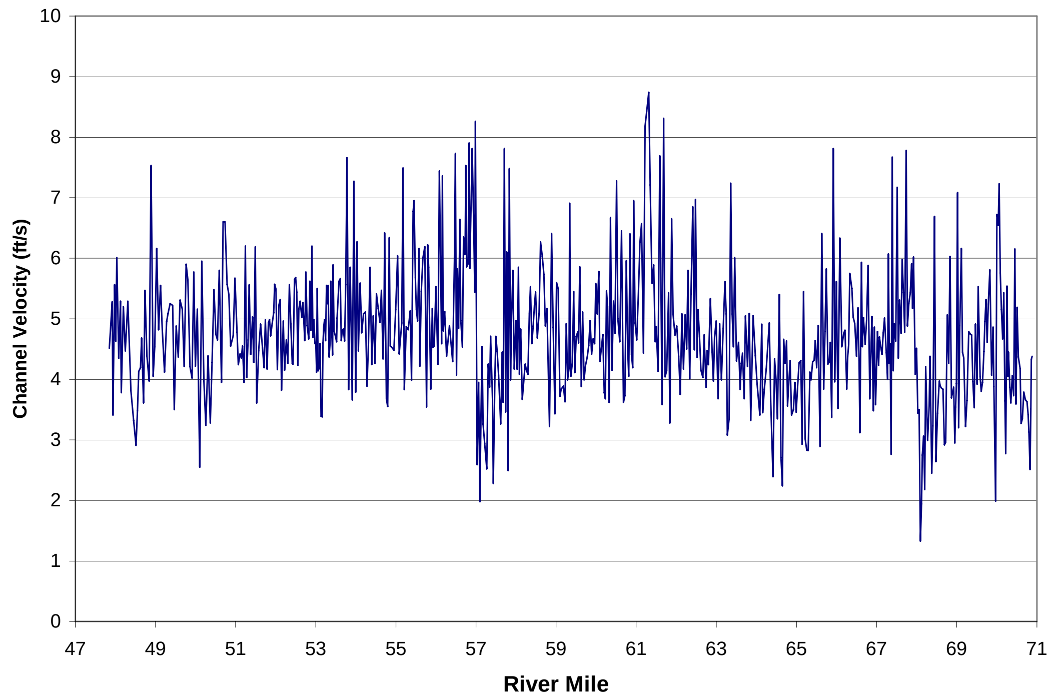

Figure 17 – 2-Year Flood Flows in Channel Velocities as Computed from 638 Cross Sections in HecRas.

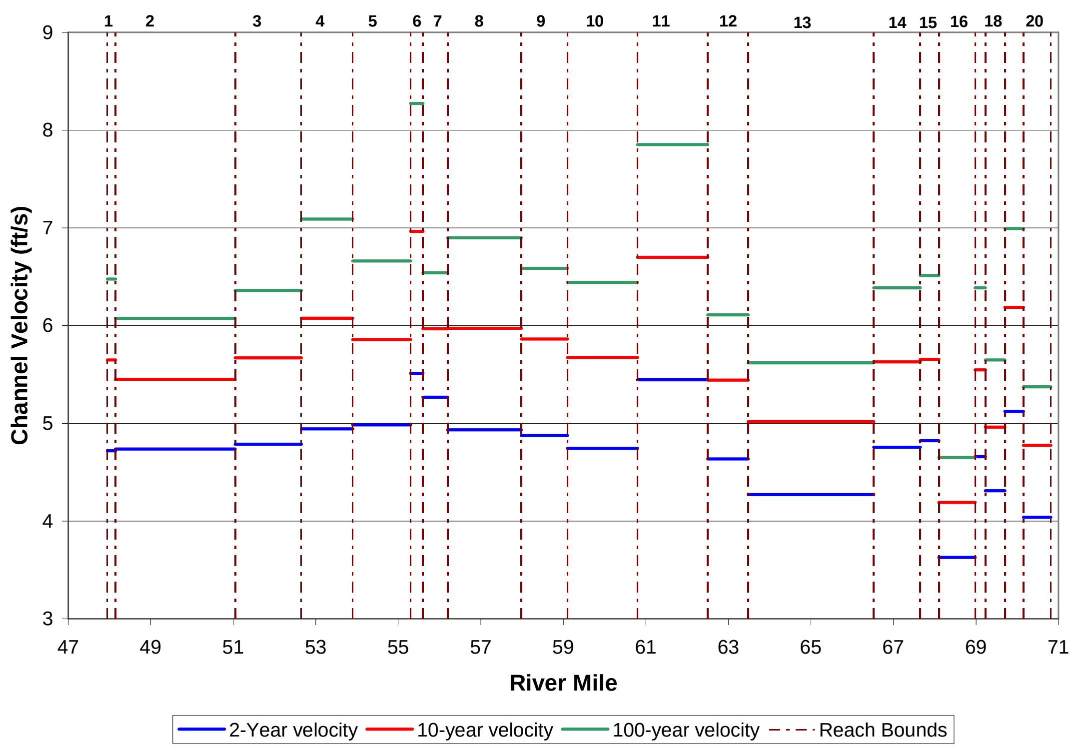

Figure 16 - Reach-Averaged Channel Velocities for the 2-, 10-, and 100-Year Flow Events. Reach numbers are shown across the top of the graph

5.3.2.4 Width-to-Depth Ratio

The active channel width-to-depth ratios for the 2-year flood event are illustrated in Figure 18. Within the Middle Fork, width-to-depth ratios range from 3.2 and 82, while active channel widths range from 12 to 160 feet. The graph suggests that the dominant variable in determining the width-to-depth ratio is the active channel width. While depths remain relatively constant (ranging between 1 and 5 feet), channel widths have a much greater amount of variation. In general, widths tend to increase in the downstream direction, which defines the similar pattern in width-to-depth ratio.

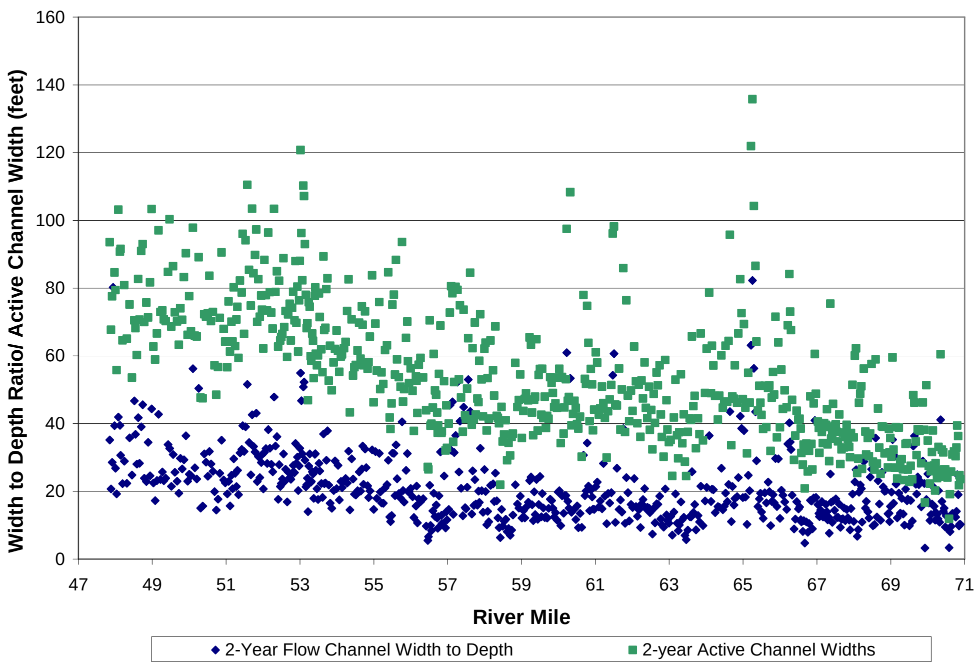

Figure 18 – Width-to-Depth Ratio and Active Channel Widths for the 2-Year Flow Event on the Middle Fork John Day River.

5.3.2.5 Floodplain Inundation

The frequency of floodplain inundation under present conditions was assessed to determine if significant incision has occurred, potentially disconnecting the floodplain from its channel. This task was accomplished by evaluating the water surface elevations in each cross section of the hydraulic model and qualitatively comparing them with the elevations of the channel banks. An additional parameter examined to evaluate potential flood inundation was the percentage of total flow in each cross section that was not contained within the channel. Figure 19 illustrates the reach-averaged percent of flow that is conveyed overbank during varying flood events. Both methods contain uncertainty due to the assumptions of equivalent water surface elevations in the one-dimensional model. A two-dimensional model that incorporates lateral flow between cross sections would more accurately assess floodplain inundation. The following discussion provides a broad picture of anticipated floodplain inundation in the assessment area and the spatial variation in the degree of inundation.

In general, unconfined and moderately confined reaches have a greater percentage of overbank flow under the 2- through 100-year flood events than confined reaches. In the unconfined channel reaches, as the flows and channel area increase in the downstream direction, the amount of overbank flow tends to decrease. Results from the hydraulic model indicate that the 2-year flow does flow out of bank in all reaches. However, the one-dimensional model does not require that flow overtops channel banks before flowing out of bank unless a levee, road, or other constructed feature is present preventing flow from entering side channels. The percentage of overbank flow presented in the graphs may be higher than what actually occurs under the varied flow conditions. Better representations of floodplain and side channel flows can be gained through a two-dimensional model analysis.

A review of the modeled cross sections indicates that water surface elevations for the 2-year flow are close to or overtopping the channel banks in almost all reaches. Within confined reaches, water surface elevations are typically just at or only slight overtopping the channel banks for the 2-year event. Water surface elevations for the 2-year event in moderately and unconfined reaches tend to overtop the channel banks in a greater number of cross sections than in the confined reaches. A few additional notes of interest related to the inundation of the assessment areas are:

- Most cross sections indicate substantial floodplain connectivity during the 5- to 10- year flood events.
- In reach MF8 (Oxbow Conservation Area), even with the north channel transporting a portion of the flow, water surface elevations in the south channel are close to or overtopping channel banks under a 2-year event.
- Within reach MF9, cross sections clearly illustrate that the road embankment through the floodplain restricts access to potentially valuable floodplain and side-channel habitat.
- In reach MF13 (Forrest Conservation Area), the historic railroad embankment eliminates access to a large portion of the floodplain. Water surface elevations for the 2-year event are close to the bank height for most cross-sections in the reach. Upstream from RM 65.5, flows generally do not overtop the railroad levee and are unable to access a large portion of the floodplain for events as large as the 100-year event.
- Within a channelized portion of reach MF15, just downstream from the historic town of Bates, the 100-year flood is contained within the channel banks.

Because the 2-year flow event is close to or just overtopping the channel banks in most reaches, substantial channel incision is not expected to have occurred. Reaches containing some artificial channelization typically do not access the floodplain as frequently as reaches without channelization. While the 2-year event does slightly overtop the bank in most unconfined reaches, substantial floodplain connectivity does not occur without flow conditions on the order of a 5- to 10-year event. If the unconfined reaches were historically wet meadows, the historic frequency of inundation and floodplain connectivity may have been greater than the present conditions.

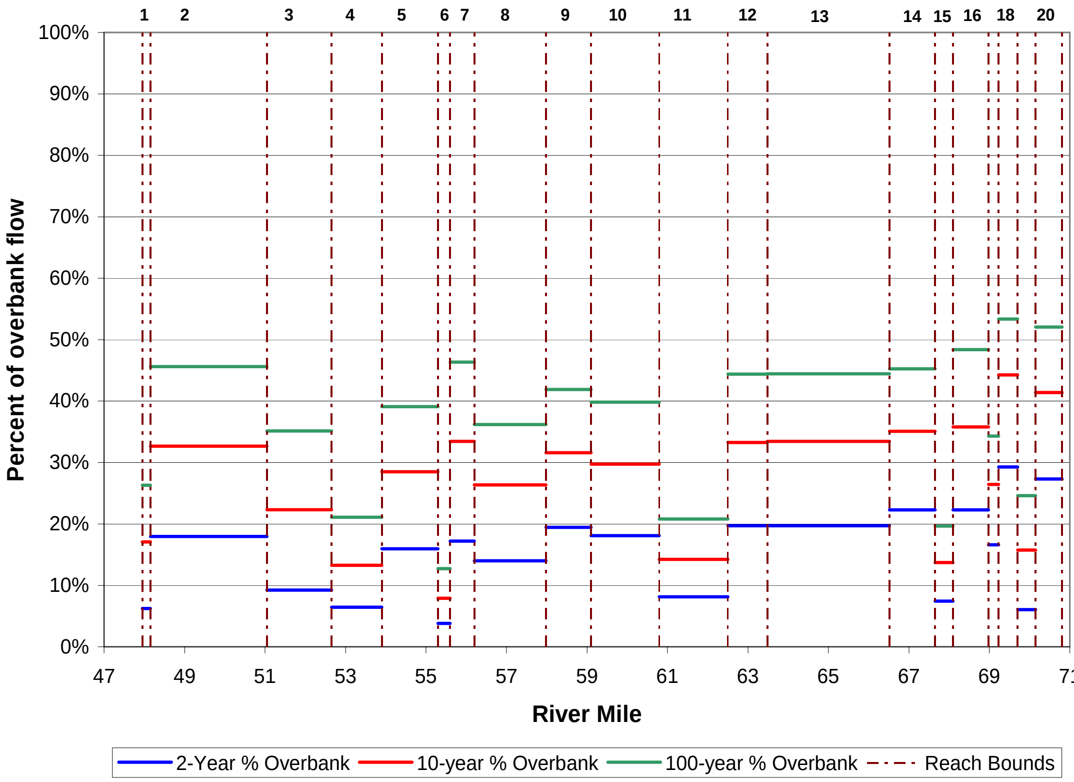

Figure 19 - Percentage of Total Flow That is Not Contained Within the Channel for the 2-, 10-, and 100-Year Flow Events. Reach numbers are shown at the top of the graph.

5.3.2.6 Sediment Sampling

Figure 20 illustrates how surface sediment sizes vary throughout the Middle Fork system. Both pebble count data and volumetric samples are displayed on the graph. In general, sediment sizes vary with the degree of channel confinement and the amount of human impacts. Where natural geologic controls substantially confine the width of valley and where constructed features disconnect access with considerable portions of the floodplain, sediment sizes are typically larger than unconfined reaches.

Pebble count data were collected within gravel bars and within the channel bed. In-channel sediment sizes were usually slightly larger than the material comprising the gravel bars. Of particular note, the channel pebble count in reach MF8 is considerably larger than all other sediment sizes in the assessment area. This pebble count was collected from the north channel of the river on the Oxbow Conservation Area, which was constructed as part of historic dredging operations.

Bars in the graph illustrate the range in sediment sizes between the 16th and 84th percentiles of the pebble count data. A comparison of the median grain size (D_{50}) from the volumetric surface samples and the D_{50} from subsurface samples indicates the degree of channel armoring. In locations where only pebble count data were obtained, the degree of armoring can be qualitatively evaluated by the range in the 16th and 84th percentile. Evaluation of the volumetric samples shows that the D_{50} of the surface sample is typically 1.5 to 3 times greater than D_{50} of the subsurface sample. This range is typical in mountainous streams and indicates very mild armoring.

The degree of channel armoring does not indicate if the sediment sizes have coarsened or become finer than historic sediment sizes. Data on historic sediment gradations were not available for this evaluation.

In typical river systems, sediment tends to become finer in the downstream direction due to selective sorting and abrasion; however, the process of downstream fining can be interrupted by tributary inputs, landslides, and mass wasting. This concept does not account for confined reaches composed of large boulders or bedrock as found in the Middle Fork John Day River. Each category of sediment sampling suggests that a coarsening of bed material is present in the segment of the Middle Fork considered in this assessment. This coarsening may be due to lateral inputs in the stream and may, in part, result from a degraded condition increasing in the downstream direction due to substantial modifications to the river system.

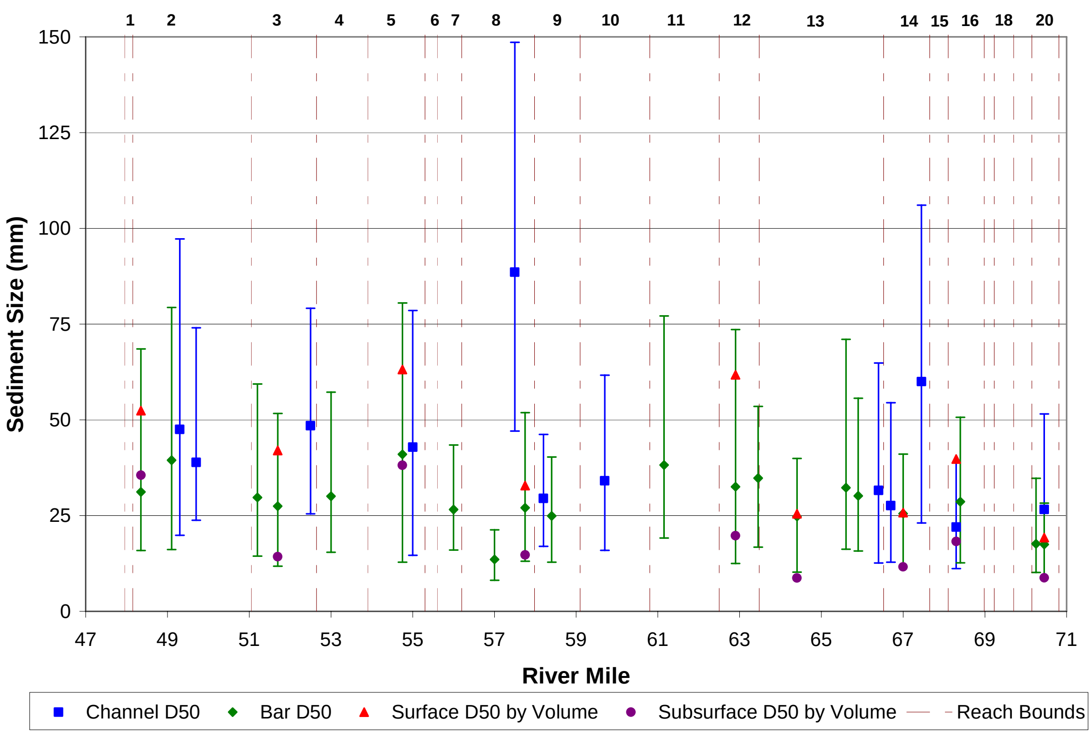

Figure 20 - Measured Sediment Sizes of the Middle Fork John Day River. Bars indicate the range of sizes between the 16th and 84th percentiles of the pebble count data. Reach numbers are displayed at the top of the graph.

5.3.2.7 Incipient Motion

At each cross section, the critical sediment diameter at which incipient motion occurs was calculated. Sediment sizes above these diameters are not expected to be mobilized. The critical diameters were averaged for each reach, as illustrated in Figure 21. A comparison of the measured sediment sizes in each reach with the critical diameters of incipient motion provides an indication of the flow event required to mobilize the bed and bar material in each reach. In most reaches, both the channel and bar sediments are mobilized by flows less than the 2-year flood event. Exceptions include samples from reaches MF2, MF3, MF5, MF12, MF14, MF16, and the north channel of reach MF8. Results suggest that a flood event with a recurrence interval between 2 and 5 years would be required to mobilize the samples in reaches MF2, MF3, and MF5. However, a flow event with a recurrence interval between 5 and 10 years would be needed for mobilization of some material sampled in at the upstream end of reach MF14. This reach is located just downstream of channelized reach MF15 and may have experienced some bed coarsening as a result of increased erosive forces. Samples collected in reaches MF12, MF16, and the north channel of reach MF8 would require flows at or above a 10-year event to become mobile. Reaches MF12 and the north channel of reach MF8 are comprised of tailings materials following substantial dredging activities in the mid-1900s.

Reach MF16 results are more complicated because pebble count data, which are typically less reliable than volumetric samples, suggest that most material can be mobilized during a 2-year event. Low velocities and slopes in this reach are partially responsible for the apparent inability of the sediment to be mobilized. However, unrestricted cattle grazing may have exposed a higher percentage of fines to downstream transport, thereby increasing the D_{50} of the bed and bar materials in the reach.

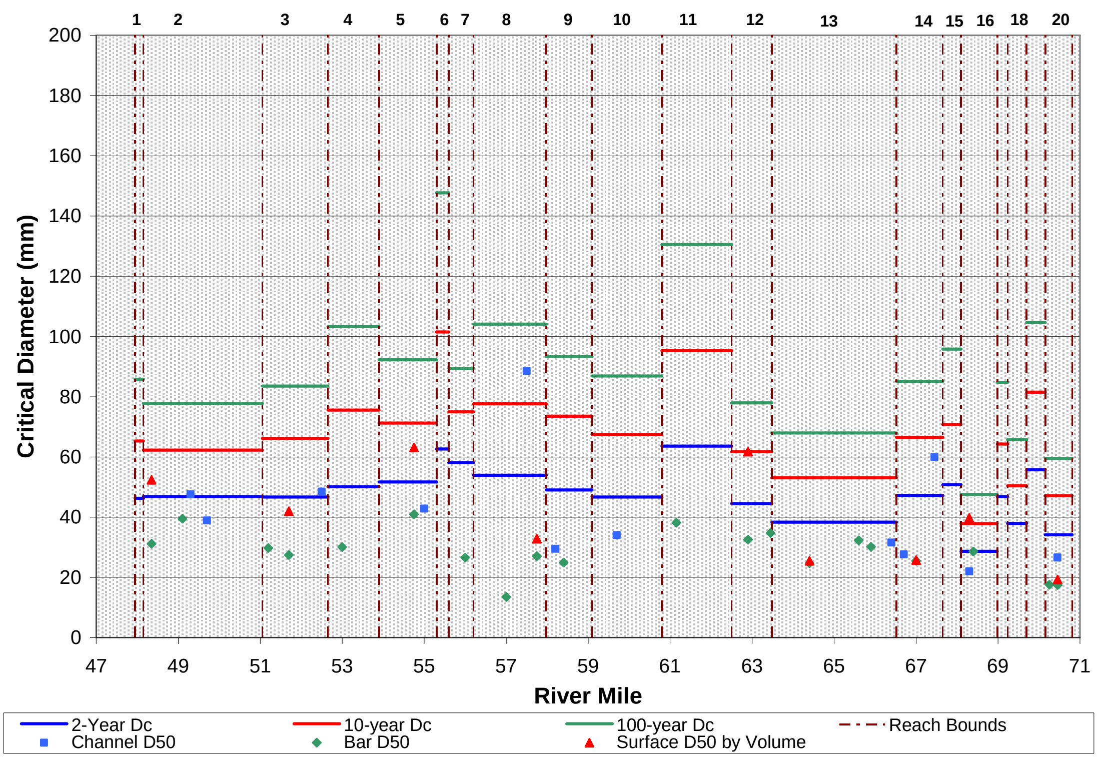

Figure 21 - Results of Incipient Motion Analysis. The critical diameter represents the size of material that is expected to be mobilized in each reach for corresponding flow events. The points indicate the measured sediment $\mathbf{D_{50}}$.

5.3.2.8 Stream Power

Figure 22 illustrates the average total stream power computed in each geomorphic reach. Within the mildly increasing trend of stream power in the downstream direction, several oscillations occur as a function of friction slope. Total stream power is the largest where friction slopes are the greatest. For the 2-year event, reach-averaged total stream power ranges between 1 and 7 cfs and for the 100-year event ranges between 2.5 and 17 cfs. The fluctuations in total stream power also appear to be a function of valley confinement. Total stream power is the greatest in reaches MF4, MF6, and MF11, all of which are confined reaches. Upstream of reach MF11, the confined reaches transport much lower flows at all events, and as a result are not characterized by as great total stream power as the downstream confined reaches.

Unit stream power stems from the general concept that the rate of energy dissipation used in transporting material should be related to the rate of material being transported. This parameter is used as an indicator of the relative ability of each reach to transport a given sediment load despite differences in channel areas. According to Figure 23, the unit stream power correlates with the valley confinement. Confined reaches (e.g., MF4, MF6, MF11, MF15, MF17, and MF19) tend to have higher unit stream power than moderately confined and unconfined reaches. The lowest unit stream power in the system occurs in unconfined reaches.

These results imply that confined reaches tend to act as transport reaches and unconfined reaches are typically supply reaches. Confined reaches are not expected to degrade because they have the highest stream power. Confined reaches have coarser sediment material and can generally transport sediment supplied from upstream reaches.

Potential for aggradation or degradation may be assessed by comparing general trends in stream power across the assessment area. Recent research indicates that total stream power tends to peak at some intermediate location along a river as a function of the rate of change in discharge and slope (Knighton 1998). River systems with high rates of change in downstream slope tend to be characterized by a peak in stream power near the headwaters and greater concavity in the downstream direction. Local variations in stream power patterns may be related to geologic constraints in valley confinement and slope, such as those present in the confined reaches of the Middle Fork.

Comparison of trends in total stream power in unconfined reaches may offer a clearer depiction of potential patterns in aggradation and degradation in the Middle Fork John Day River. In general, total stream power of the unconfined reaches increase in the downstream direction, which is inconsistent with river systems in “dynamic equilibrium.” These results indicate a tendency for degradation in the downstream direction during flood flow events. If vertical and/or lateral geologic controls are actively confining reach transitions (often between transitions of unconfined to confined reaches), further degradation of the channel may be limited.

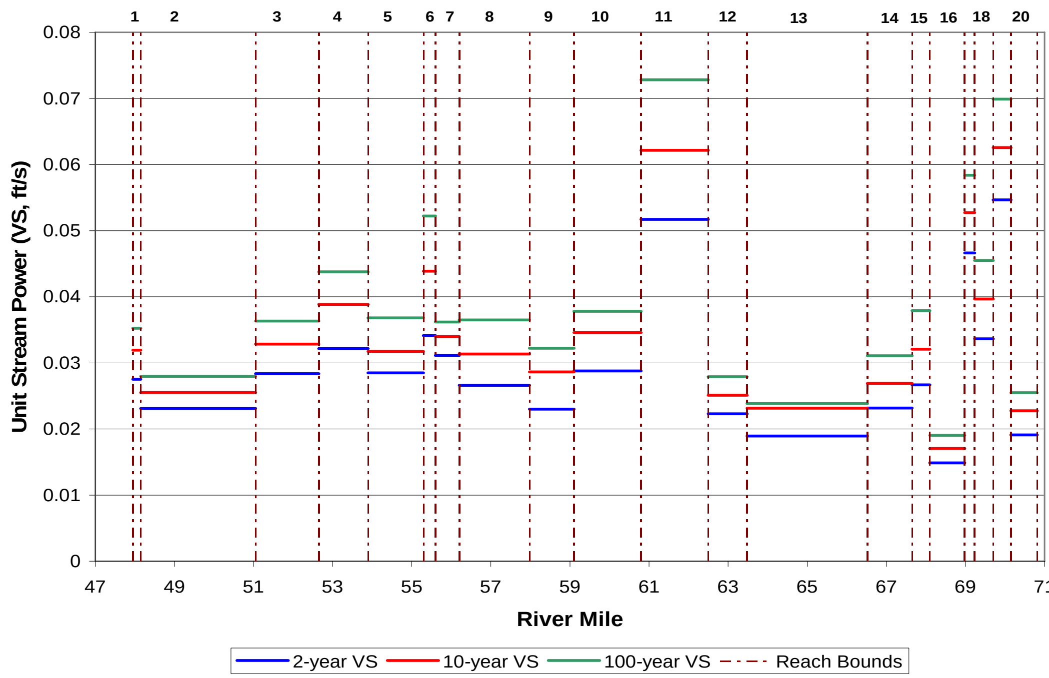

Figure 22 – Unit Stream Power in Each Geomorphic Reach. Reach numbers are shown at the top of the graph.

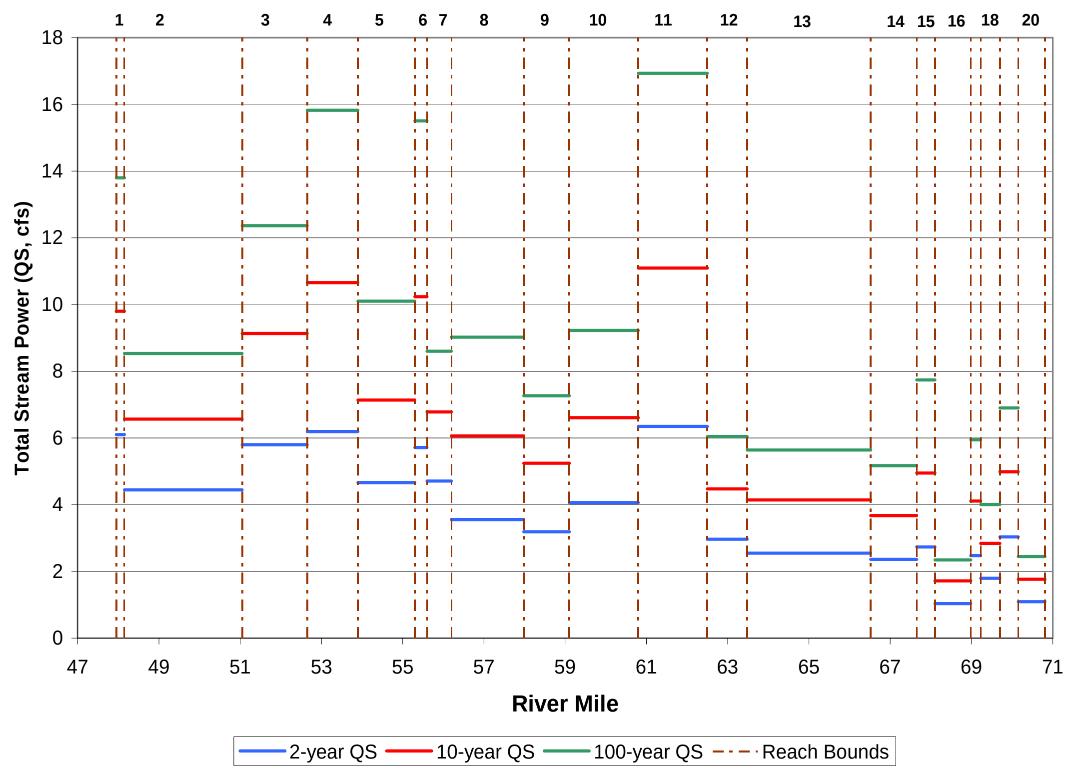

Figure 23 – Total Stream Power in Each Geomorphic Reach. Reach numbers are shown at the top of the graph.

5.3.2.9 Sediment Transport Capacity

The capacity of each reach to transport sediment provides an indication of the relative amount of sediment that would be expected to be transported in each reach and is dependent on the sediment sizes making up the bed and banks of the reach. Sediment transport capacity patterns tend to coincide with the planform attributes of each reach and/or slope breaks. Unconfined, low gradient sections of the channel are typically characterized by low sediment transport while highly confined, high gradient sections have much higher sediment transport rates. Reach breaks are often located at transitions zones or geologic constrictions, where variable sediment transport patterns are noted.

Three separate sediment transport capacity formulae were used to assess trends in sediment transport capacity under flood flow conditions. Although differences are noted in the quantities of transport capacity calculated by each equation, the patterns are similar. Differences among the sediment transport capacity equations are due to the approach of the development of the equations. Yang's equations are based on unit stream power while Meyer-Peter Mueller's and Parker's equations are derived from excess shear stress. Results for each equation under the 2-, 10-, and 100-year flow events are displayed in Figure 24 through Figure 32. A summary of the results is described below.

Reaches MF20 to MF16

Each reach is separated by a major change in valley confinement and with substantial variations in slope. Reach MF20 is a moderately wide valley and is characterized by relatively low sediment transport under the 2- through 100- year flood events.

Reach MF19 is a short transition zone between reaches MF20 and MF18 and laterally confined by bedrock walls. Within reach MF19, channel slope increases to greater than 1 percent, and a sharp rise in the sediment transport capacity is noted. Downstream of the transition zone, the valley in reach MF18 widens to a moderately confined planform, slope decreases to 0.74 percent, and the capacity of the channel to transport sediment decreases.

At the Mill Creek confluence with the Middle Fork, the valley transitions to a bedrock-confined planform down to the State Highway 7 Bridge. Reach MF17 is highly confined and is characterized by a slope of 1.1 percent and a two-fold increase in sediment transport capacity.

A drastic decrease in sediment transport is noted in reach MF16 between the State Highway 7 Bridge and the confluence of Clear Creek. Within reach MF16, the valley becomes wide and unconfined with multiple visible historical channel scars. Some of these channels appear to have been cut-off through constructed modification. The slope through this river segment is less than 0.4 percent, and sediment transport capacity is the lowest of the entire study area. Prior to human impacts, this reach may have been laterally active with a high frequency of floodplain reworking. Restoration strategies should consider how decreased channel slopes and velocities may impact channel stability and sediment balance.

Reaches MF15 to MF10

Just downstream of the confluence of Clear Creek, reach MF15 acts as a transition zone between reaches MF16 and MF14. This segment of the river was heavily channelized with the construction of the town of Bates, and the low surface is highly confined. Sediment transport capacity through this section is significantly greater than the adjacent upstream and downstream planform reaches. Downstream of reach MF15, the valley in reach MF14 is considered moderately confined. However, the placement of rock spurs along the channel banks constrains lateral movement throughout most of the reach, and several side channels appear to have been disconnected from the main channel. As a result, the channel may be slightly incised from historical conditions. Compared to sediment transport capacity throughout the rest of the study area, reach MF14 is characterized by an average ability to transport sediment.

Two distinct regions of sediment transport are noted throughout reach MF13. Although the entire reach has a wide, unconfined valley, channelization and floodplain disconnection have occurred due to the construction of the railroad. The break in the sediment transport through this reach coincides with a change in the degree of channelization and floodplain disconnection. The upstream section was modified from a highly sinuous channel to a straight, channelized river, and the railroad cuts off access to approximately 80 percent of the floodplain. As a result, sediment transport through this section is high relative to similarly unconfined reaches. The downstream section of reach MF13 is much less channelized, and a single-thread meandering planform is present. However, lateral channel migration through this section is confined by rock spurs. Sediment transport capacity through this segment is much lower than upstream and downstream reaches.

Reach MF12 has sediment transport rates similar to the lower segment of reach MF13, despite the channelization due to dredge mining of a portion of this reach. This results from the change in sediment size differences between the two reaches. The surface D_{50} of reach MF12 is twice as large as that of reach MF13, but the stream power is considerably greater in reach MF12. The combination of these two factors results in similar sediment transport between the two segments of the river.

At the transition zone between reaches MF11 and MF12, a small spike in sediment transport capacity is notable. This is likely due to an increased slope caused by channelization of the river from the historic railroad embankment and the highway. Downstream of the channelization, the floodplain remains geologically confined and reach MF11 is characterized as a transport section with extremely high sediment transport capacity compared with the rest of the study area. This does not represent the capacity of the channel to transport the material that comprises the bed of this entire reach because no samples were obtained in the boulder and bedrock portion of this reach. The high transport capacity through this reach combined with a maximum slope of 2.4 percent suggests that any sediment entering this segment will be moved through efficiently.

Reach MF10 to MF6

Reach MF10 can be divided into two regions of sediment transport capacity. Although both zones have similar magnitudes of sediment transport capacity (slightly lower than study area average), the upstream segment is marked by a short spike, likely related to side channel disconnection and railroad and highway construction. The difference in magnitude between the two segments is more pronounced under higher flow events.

Reach MF9 begins just upstream of the Oxbow Conservation Area. It is unconfined and has a similar sediment transport capacity to the downstream section of moderately confined reach MF10. While the sediment transport capacity of an unconfined reach would be expected to be lower than an adjacent moderately confined reach, reach MF9 has been substantially straightened and the highway disconnects a large portion of its floodplain.

Reach MF8 begins just upstream of the flow bifurcation of the north and south channels of the Oxbow Conservation Area and was severely modified by dredge activities in the 1940s. From the upstream end of reach MF9 to the confluence of the north and south channels, sediment transport capacity is close to the study area average. Under high flow conditions, most of the flow is routed through the south channel, and only a small portion travels through the north channel. Conversely, under lower flows, more flow was measured as entering the north channel than the south channel. This difference results from the entrance condition of the north channel and the channel capacity of the south channel. Under geomorphically significant flows, most flow and sediment is actually transported through the historical south channel. At the confluence of the north and south channels, the sediment transport capacity increases dramatically with a high magnitude relative to the entire study area. This section was also dredged and channelized, but almost all of the flow is contained within the channelized river. Resulting high shear stresses cause this segment to act as a transport zone, although historically, this was unlikely the case. Although reach MF8 was historically unconfined, the dredge mining and channel straightening have resulted in a reach that is confined by human impacts.

Reach MF7 is downstream from the historic dredge activities and is an unconfined reach situated between a channelized reach and a geologically confined reach. Reach MF7 is characterized by relatively high sediment transport capacity, although magnitudes are much lower than the transport zone of reach MF8. At the upstream end of the reach, a bridge was removed, but bridge embankments remain, which disconnect the floodplain and constrict high flows. Reach MF7 has a fairly short length (less than 0.5 miles), is comprised of numerous rock spurs, and appears to have been disconnected from multiple side channels. As a result, sediment transport capacity at higher flow events is similar in magnitude to the adjacent reaches.

A peak in transport capacity occurs at the transition between confined reach MF6 and unconfined reach MF7. This location corresponds to the site of a bridge, but is also a geological constriction formed from opposing bedrock outcrops. From this point, sediment transport capacity decreases in the downstream direction until the floodplain widens and transport capacity begins to level out in reach MF5.

Reach MF5 to MF1

Reach MF5 is moderately confined and characterized by low sediment transport with a gradient of 0.6 percent. A short peak in sediment transport capacity occurs at the transition zone between reaches MF4 and MF5, where the historic railroad grade disconnects a portion of the floodplain. Reach MF4 consists of two regions of sediment transport, separated by a geologic control caused by the Big Boulder Creek alluvial fan.

Upstream of the confluence of Big Boulder Creek, sediment transport capacity is relatively low compared to other confined reaches. However, the slope through the upstream section is only 0.6 percent while the downstream section's slope is approximately 0.75 percent. Downstream of Big Boulder Creek, transport capacity increases due to increase slope, increased flow, and decreased sediment gradation due to the sediment supply from Big Boulder Creek.

Reach MF3 lies within a moderately confined geologic low surface. The sediment transport capacity within reach MF3 peaks at the transition with reach MF4 and gradually decreases in the downstream direction. The gradual decrease and the high capacity in reach MF3 may result from channelization of the upper half due to construction of the railroad. A large percentage of the upstream portion of reach MF3 has been disconnected from its floodplain and appears to have been straightened prior to the 1939 photographs. The downstream segment has also been modified due to railroad construction, but the sinuosity is slightly greater than the upstream section producing a slightly lower gradient (0.59 percent versus 0.74 percent).

Reach MF2 is characterized by consistently low sediment transport capacity. This wide, unconfined reach has a slope less than 0.5 percent, and several historical channel scars are visible in the LiDAR hillshade output and historical aerial photographs. This reach was likely laterally active with frequently inundated floodplains prior to human influence.

Downstream from the highway bridge, sediment transport capacity through reach MF1 increases as slope and valley confinement also increase. The downstream boundary of reach MF1 is the end of the study area and coincides with a lateral geologic control caused by Camp Creek alluvial fan.

2-Year Flow Sediment Transport Capacity

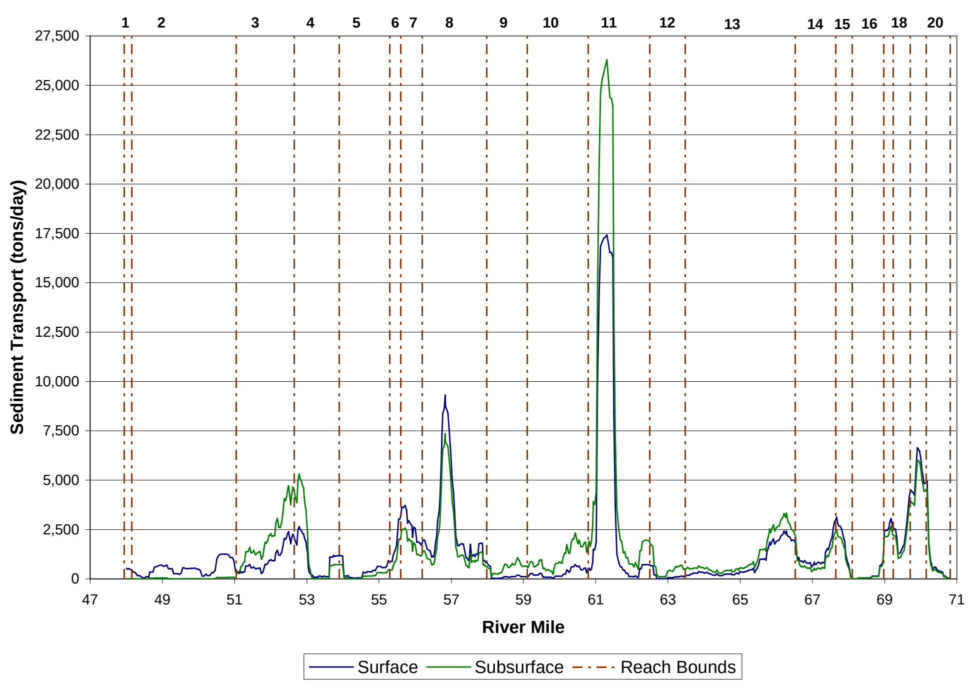

Figure 24 - Parker (1990) Sediment Transport Capacity for the 2-Year Flow.

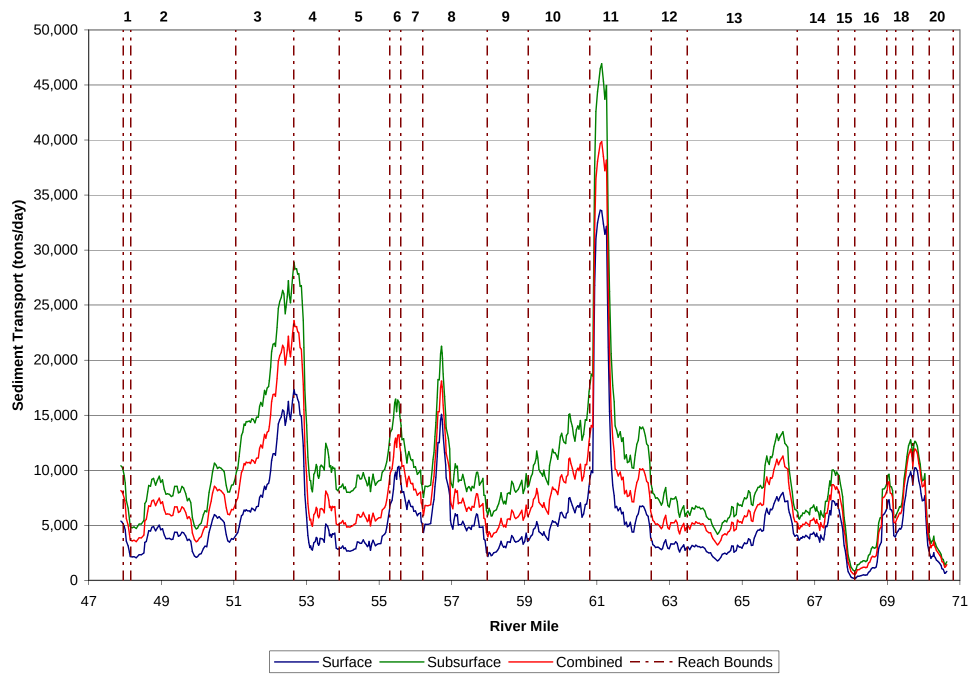

Figure 25 - Meyer-Peter and Müller (1948) Modified by Wong and Parker (2006) Sediment Transport Capacity for the 2-Year Flow.

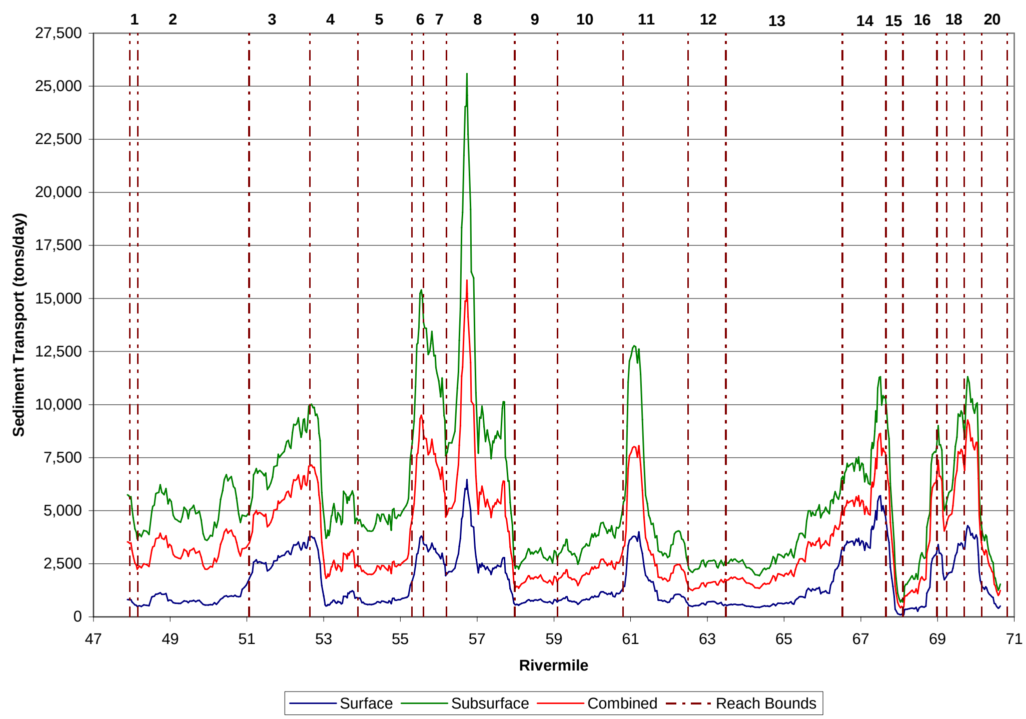

Figure 26 - Yang's Sand (1973) and Gravel (1984) Sediment Transport Capacity for the 2-Year Flow.

10-Year Flow Sediment Transport Capacity

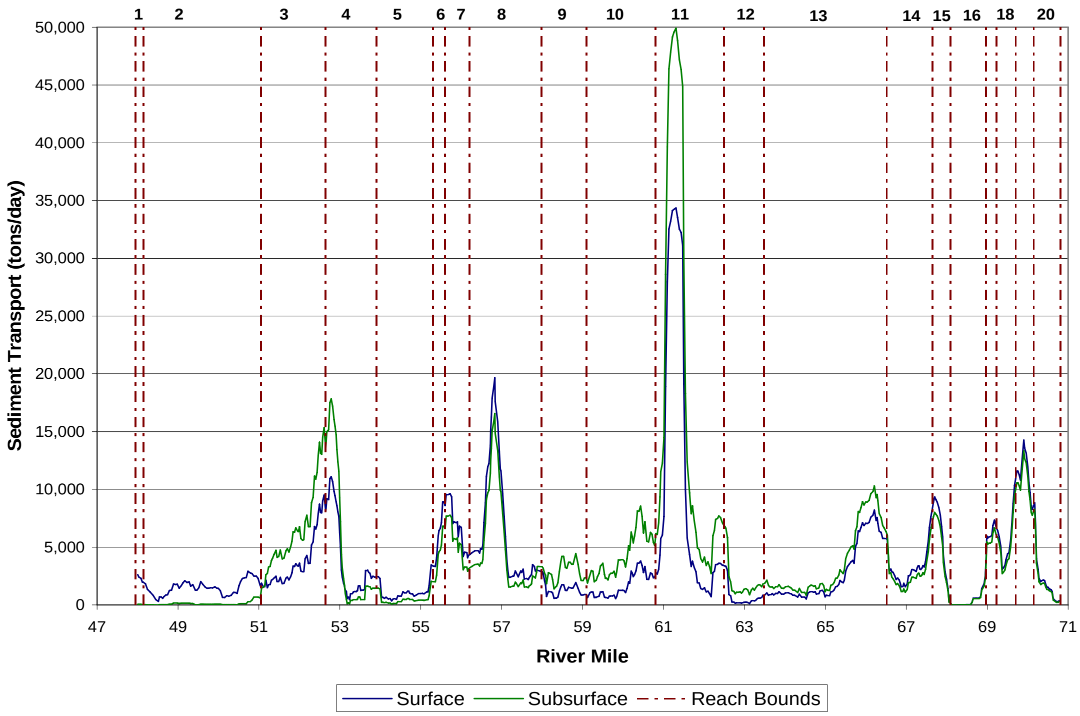

Figure 27 - Parker (1990) Sediment Transport Capacity for the 10-Year Flow.

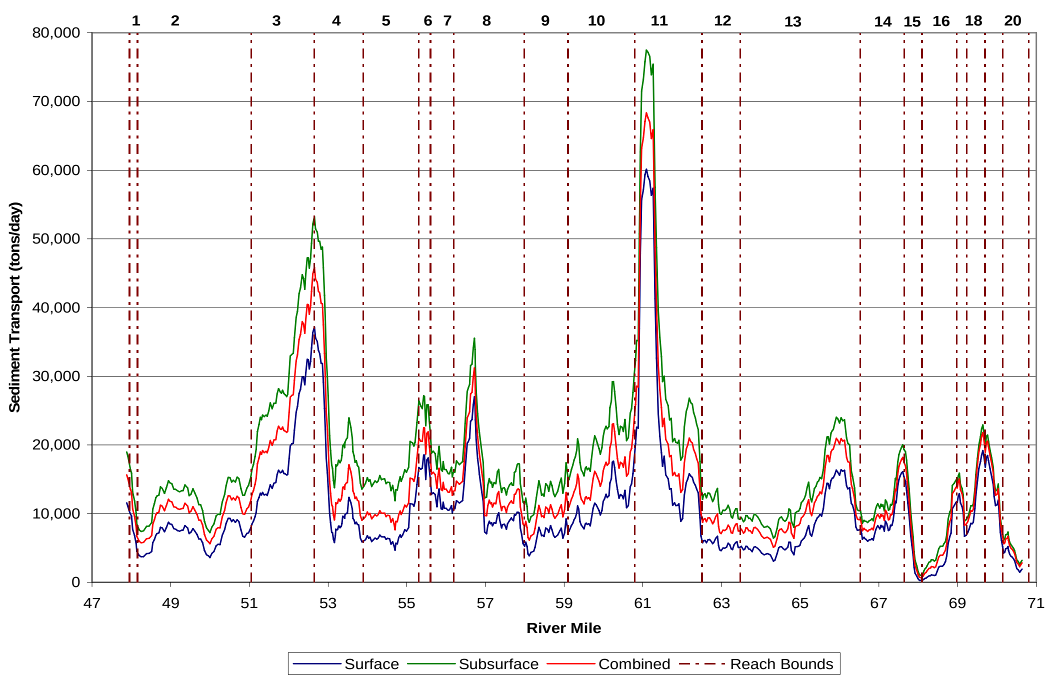

Figure 28 - Meyer-Peter and Müller (1948) Modified by Wong and Parker (2006) Sediment Transport Capacity for the 10-Year Flow.

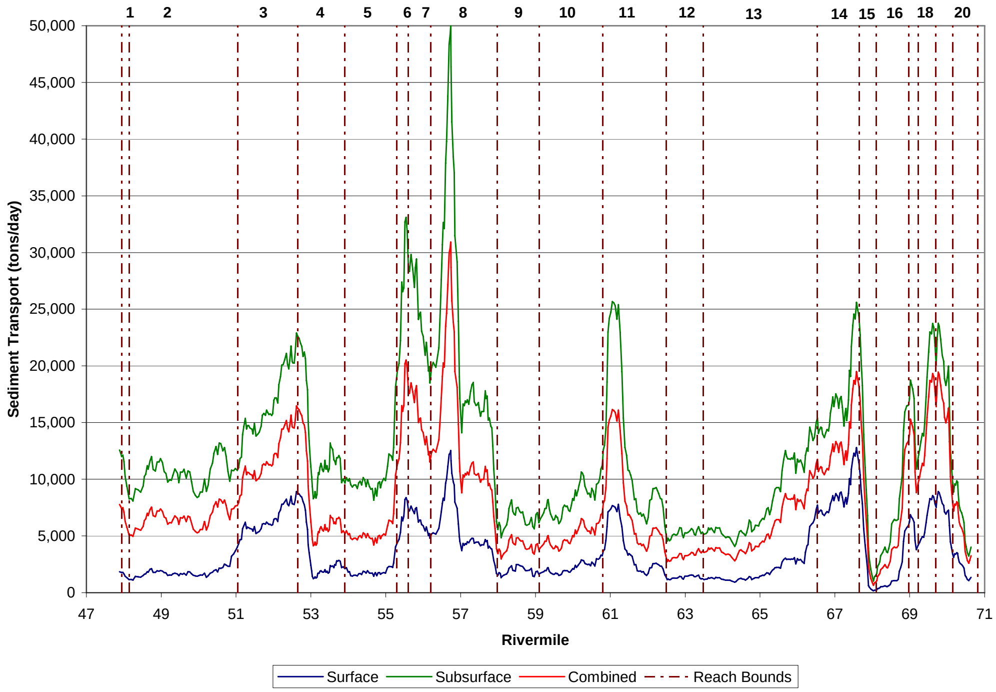

Figure 29 - Yang's Sand (1973) and Gravel (1984) Sediment Transport Capacity for the 10-Year Flow.

100-Year Flow Sediment Transport Capacity

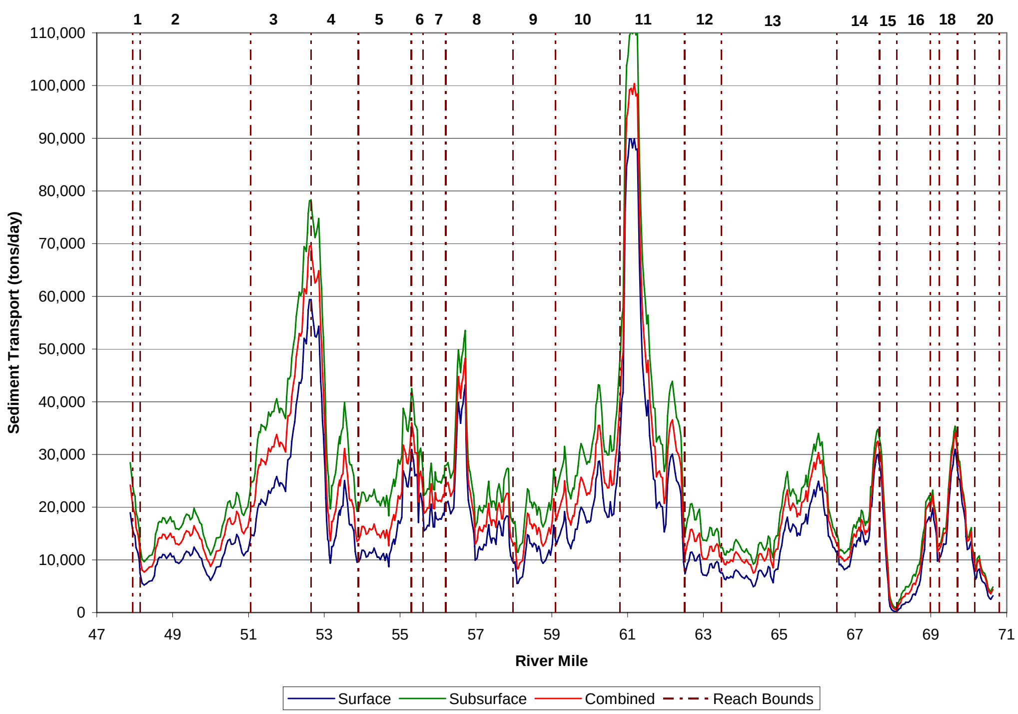

Figure 30 - Meyer-Peter and Müller (1948) Modified by Wong and Parker (2006) Sediment Transport Capacity for the 100-Year Flow.

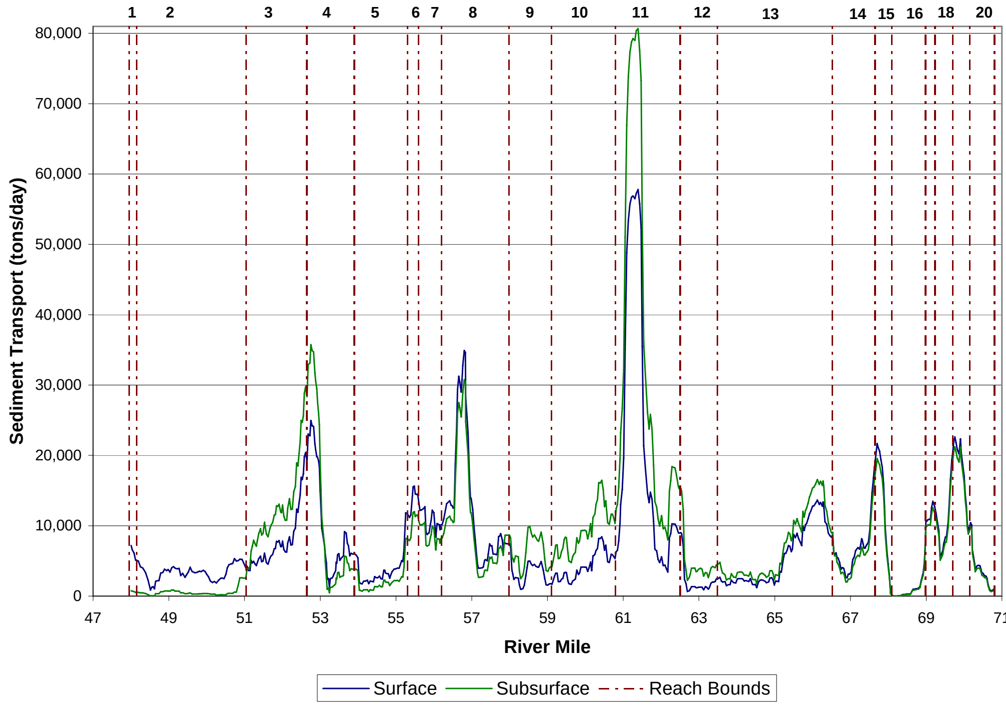

Figure 31 - Parker (1990) Sediment Transport Capacity for the 100-Year Flow.

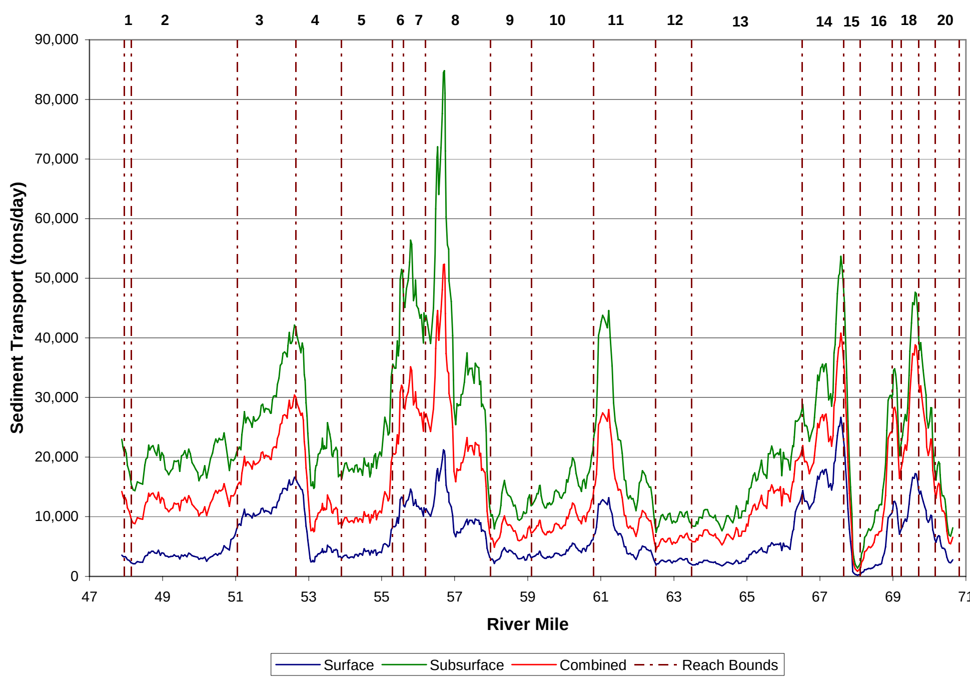

Figure 32 - Yang's Sand (1973) and Gravel (1984) Sediment Transport Capacity for the 100-Year Flow.

5.3.3 Conclusions

Various methods were used to evaluate the present stability of the Middle Fork assessment area. These included a one-dimensional hydraulic model, evaluation of sediment samples, incipient motion computations, longitudinal comparison of stream power, and sediment transport capacity equations. Results from the efforts are summarized below.

Water surface elevations for the 2-year flow are close to or overtopping the channel banks in almost all reaches. Within confined reaches, water surface elevations are typically just at or slightly overtopping the channel banks for the 2-year event. Water surface elevations for the 2-year event in moderately and unconfined reaches tend to overtop the channel banks in a greater number of cross sections than in the confined reaches. In general, unconfined and moderately confined reaches have a greater percentage of overbank flow under the 2- through 100-year flood events than confined reaches. In unconfined reaches, as the flows and channel area increase in the downstream direction, the amount of overbank flow tends to decrease.

Three separate sediment transport capacity formulae were used to assess trends in sediment transport capacity under flood flow conditions. Sediment transport capacity patterns tend to coincide with the planform attributes of each reach and/or slope breaks. Unconfined, low gradient sections of the channel are typically characterized by low sediment transport, while confined, high gradient sections have much higher sediment transport rates. Reach breaks are often located at transitions zones or geologic constrictions, where variable sediment transport patterns are noted.

Results of the assessment suggest that substantial incision has not occurred in most reaches. Segments of river channel containing artificial channelization, such as the lower portions of reaches MF8 and MF15, typically do not access the floodplain as frequently as segments without channelization. While the 2-year event does slightly overtop the bank in most unconfined reaches, substantial floodplain connectivity does not occur without flow conditions on the order of a 5- to 10-year event. In most reaches, both the channel and bar sediments are mobilized by flows less than the 2-year flood event. Exceptions include samples from reaches MF2, MF3, MF5, MF8, MF12, MF14, and MF16, where greater flow events are required to mobilize bed and bar materials. Mild localized incision or bed coarsening may have occurred in small portions of a few reaches as evidenced by the frequency of bed material mobilization and floodplain inundation. However, differentiation between localized incision and artificial channelization is difficult to decipher.

Despite historical development and changes to the valley since the 1800s, the river appears to have reached a new dynamic equilibrium. The new equilibrium is defined by fewer active overbank and side channels and possibly a less frequently inundated floodplain than under historic conditions. Although active channel aggradation or degradation was not evidenced during field visits, a slight tendency for degradation in the downstream direction may be present during flood events. The extent of further degradation may be limited by vertical and/or lateral geologic controls that are actively confining reach transitions. Any modifications to the system that disrupt the present equilibrium (e.g., removal of artificial topographic features) may result in channel adjustments through increased lateral channel migration where the channel is competent to rework floodplain deposits. Potential channel adjustments have implications for long-term stability of restoration actions, such as LWD placements, and will require additional investigations at a more refined scale.

5.4 Riparian Vegetation Assessment

5.4.1 Background and Objectives

The assessment area on the Middle Fork of the John Day River lies between Susanville and Austin, Oregon. Austin, located at the upstream end of the assessment area has an elevation of 4,200 feet and an annual precipitation average of 18.6 inches (Anderson et al. 1997).

The objectives of the riparian vegetation assessment are to fill in gaps on Reclamation's John Day Reach Assessment for salominid recovery. These objectives are to:

- Visually interpret canopy vegetation community classes such as conifer, hardwoods, shrub, or meadows; with species interpretation as possible from aerial photography and LiDAR data.
- Create digital polygons in GIS representing vegetation communities within the low surface boundary or within a buffer extending out 300 feet from the river, whichever is the greater of the two.
- Calculate acreages for each vegetation community class.
- Compare acreages from year to year to discover trends and theoretical past conditions for the assessment. (years 1939, 1956, and 1976).
- Quantify large woody debris (LWD) potential and shading by trees in the riparian areas as indicators for potential salominid habitat.

5.4.2 Methods

Aerial photography was flown for the project in October 2006, and orthorectified for the project. Aerial photography from 1939, 1956, and 1976 was also provided, which was georeferenced and mosaicked for the project. LiDAR data were captured in October 2006, and first and second returns were used to create a grid containing tree height values. The LiDAR data and color aerial photography were used to visually interpret the photographs.

An attempt was made to identify canopy species, but it was found to be difficult, especially on the historical photography. Without field checking to assist in the interpretation, species were classified using primarily the LiDAR vegetation height classifications overlaid on aerial photography. Areas dominated by trees, small trees, shrubs or low vegetation, and openings were identified. Low vegetation and openings may include agricultural use, meadows, or bare ground. This maintained consistency between reaches and drainages. These data could be further refined in the future based on a field assessment of species present. During interpretation of the historical aerial photos, an attempt was made to differentiate tree and shrub cover, but differences in resolution and accuracy of the spatial overlay of the photos made interpretation to this level unreliable.

In order to estimate shading, short-term shading, and LWD contribution of the riparian vegetation, a buffer of 82 feet (25 meters) was selected. This distance is used to represent one site potential tree height. One site potential tree height is the height of a mature tree under potential natural conditions. At this distance from the river channel, trees could potentially shade the river. LWD could also be recruited in the short term (decades), into the river.

5.4.2.1 Final GIS Methods

In ArcGIS 9.2, a 300-foot buffer from river center was created and merged with the geologic low surface to create the polygon for the evaluation of vegetation. Existing vegetation mapping performed by CTWSRO on the Forrest and Oxbow Conservation Areas was incorporated. LiDAR data were grouped into height classifications, made semi-transparent, and overlain on 2006 aerial photography (Figure 33). Polygons of dominate canopy cover were created using heads-up digitizing. Polygons were classified into three types: (1) trees, (2) small trees and shrubs, and (3) low vegetation and openings (Figure 34).

The 2006 vegetation polygons were overlain on the historical aerial photography, and changes in the vegetation were analyzed. Polygons were split into areas that remained as openings between 1939 and 2006, and areas that at some time between 1939 and 2006 were converted to low vegetation/openings. In almost all cases, areas that showed change were areas of trees and/or shrubs on the historical photos that had changed to low vegetation/open areas on the 2006 photos. An attribute was created to indicate change or no change for the polygon (Figure 36). This information was used to calculate tree/shrub change between 1939 and 2006.

An 82-foot buffer was created in GIS and intersected with the vegetation classification for analysis of streamside conditions for shade and LWD analysis (Figure 35). Areas were calculated for all polygons and added as an attribute. The summary reports were exported to a Microsoft Excel spreadsheet for distribution and formatting for reports.

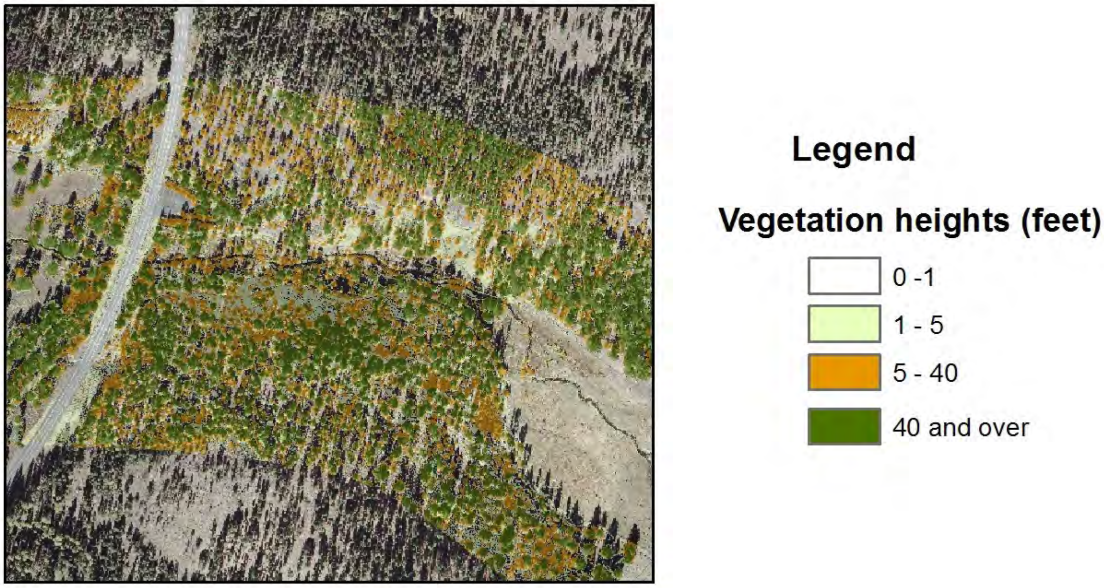

Figure 33 - LiDAR vegetation height data overlain on aerial photography.

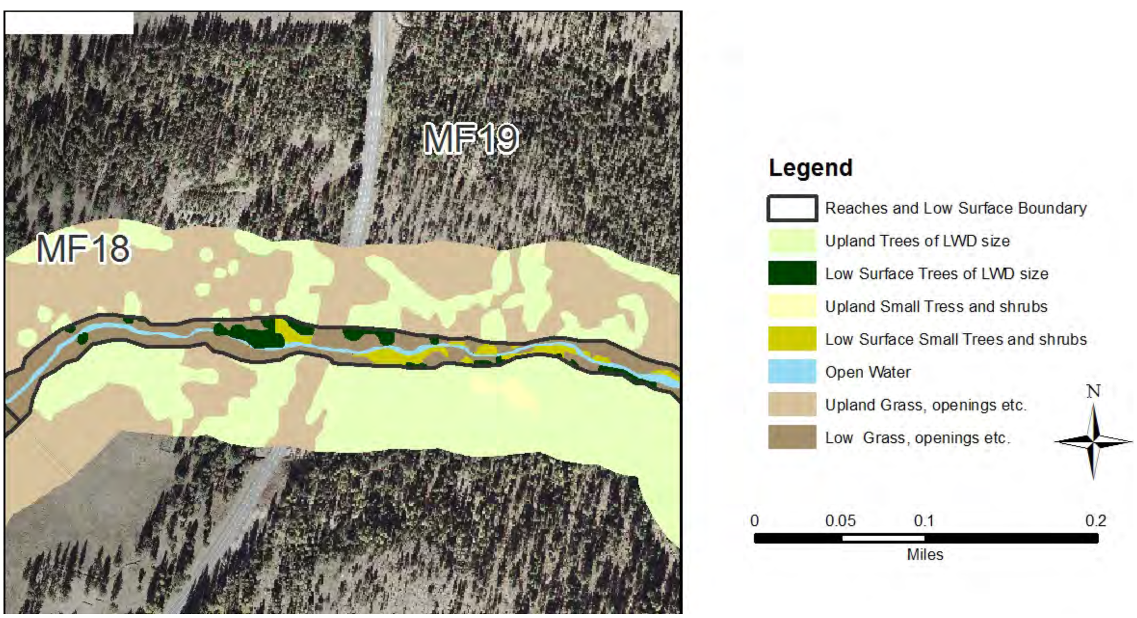

Figure 34 - LWD Vegetation Polygons Overlain on Aerial Photography.

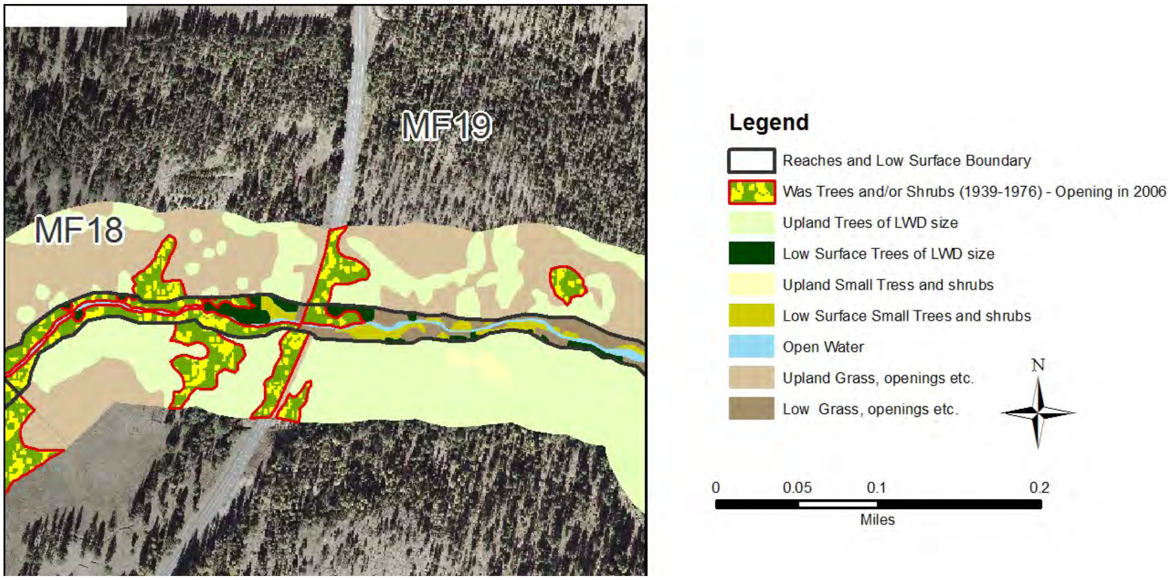

Figure 36 - LWD Vegetation and Historical Change Polygons Overlain on Aerial Photography.

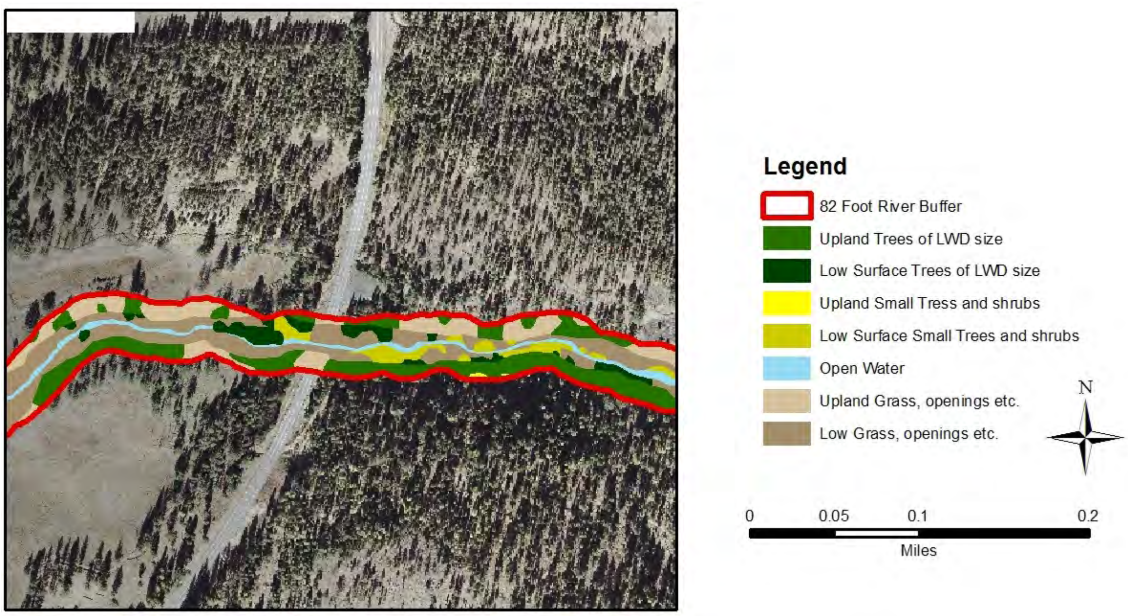

Figure 35 – 82-Foot Buffer Polygons Overlain on Aerial Photography.

5.4.3 Riparian Vegetation Summary of the Assessment Area

Six percent of the assessment area has polygons which are dominated by LWD sized-trees. The treed areas are concentrated in reaches MF4, MF9, MF10, and MF11. These areas appear to be primarily conifers in the upper reaches and mainly cottonwood in the lower reaches. Shrub-dominated areas make up 14 percent of the assessment area, mainly along the river channel and side channels off the river.

Eighty percent of the assessment area was classified as low vegetation and openings, and has surface textures on aerial photos which indicate a wet meadow or dry meadow community. The dry meadows may have been created by draining the wet meadows to create grazing forage. Drain structures are observed on the aerial photos. Dry meadows contain predominantly grasses and forbs, while wet meadows are dominated by sedge species. Wet meadows commonly contain few if any trees and shrubs. The meadow classifications need to be verified by field observations of indicator plants. In reaches MF2, MF3, and MF7, the area classified as low vegetation has surface textures on aerial photos which indicate a wet meadow community. This classification needs to be verified by field observations of indicator plants. Drains for reducing the water level for livestock grazing are noticeable on the photography, but require field validation.

Placer mining and grazing practices have most likely impacted vegetation in the assessment area. The river and wetlands have been altered to support grazing to the detriment of the riparian vegetation.

Table 6 - Summary of Vegetation Classification in the Assessment Area.

LWD Trees	Small Trees/ Shrubs	Low Vegetation/ Openings	Sum of Acres*
70.21 acres	159.48 acres	905.63 acres	1,135.32 acres
6.18%	14.05%	79.77%	100.00%

*Wetted areas, including the river, were not included in the acreages.

5.4.4 LWD Contribution and Shading

Riparian vegetation contributes at least two important components to salmon habitat, LWD and shading for the river channel. LWD provides salmon habitat, and shading of the river channel reduces water temperatures during hot summer months. The desired riparian vegetation would be that which is consistent with its Potential Natural Community, a biotic community that could be established if all successional vegetation sequences were completed without the interference of human activities (Winward 2000). This healthy riparian area is important for maintaining the structure and function of aquatic ecosystems (Platts 1991).

These data were generated from the GIS analysis:

- LWD trees which could be potentially recruited into the stream by river meanders accessing the trees (acres of polygons classified as dominated by trees within the low surface).
- LWD which is available to the stream in the short-term, which are within one site potential tree height from the current channel on the date of the aerial photo which was interpreted (acreages of trees within 82 feet of the wetted river on 2006 aerial photography).
- Shading by trees and shrubs adjacent to the river (acreages of trees within 82 feet of the wetted river on 2006 aerial photography).

5.4.4.1 LWD GIS Methods

Thirty-foot long logs are the generally accepted minimum-sized logs for LWD in the river. For this assessment, forty feet was used as a minimum size that would provide LWD. This conservative size was used to account for some breakage of the tree and for the small diameter of the top 5 feet of the trees.

LiDAR data were symbolized to group vegetation into areas with greater than 50 percent canopy cover of trees to potential LWD tree size (over 40 feet tall), small trees 5 to 40 feet tall, and low vegetation 1 to 5 feet tall (crops, herbaceous, low shrubs and open areas). Polygons classified as LWD trees contain an average of 18 trees per acre.

5.4.5 Results

5.4.5.1 LWD-Sized Trees in Low Surface

Limited LWD is available only along short reaches of the river that are dominated by conifers. Most LWD is probably contributed by reaches upstream or by tributaries to the assessment area. Roads may cut off contributions from the tributaries. Additional investigations could identify LWD sources outside the floodplain area.

Trees of LWD-size in this assessment area may be limited by wildlife grazing in the natural wet meadow riparian habitat (elk and deer), livestock grazing, and water draining and diversion for livestock (present and past). Table 7 shows acreages of LWD trees within the low surface for each reach. This represents the number of acres of LWD-sized trees that could be recruited if the river accessed them either through lateral erosion or flood flow overtopping.

Table 7 – Acreages of LWD-Sized Trees within the Low Surface by Reach.

Reach	LWD Trees	Reach	LWD Trees
MF01	1.19	MF12	1.41
MF02	12.20	MF13	0.73
MF03	6.66	MF14	0.25
MF04	9.25	MF15	0.00
MF05	6.33	MF16	0.02
MF06	0.31	MF17	0.02
MF07	0.07	MF18	0.00
MF08	2.82	MF19	0.67
MF09	6.74	MF20	1.50
MF10	10.71	CC1	0.0
MF11	9.33		

5.4.5.2 Accessible LWD

This analysis includes vegetation within 82 feet of the river and includes both the low surface and area outside the low surface. These areas could provide LWD-sized trees adjacent to the river which could be recruited into the stream in the short-term. Table 8 shows acreages for each reach.

Table 8 - Acres of LWD-Sized Trees Within 82 Feet of the River by Reach. Some acreage is larger than the low surface area because of treed areas outside the low surface, but within 82 feet of the river.

Reach	LWD Trees	Reach	LWD Trees
MF01	0.5	MF12	5.8
MF02	10.9	MF13	1.9
MF03	10.2	MF14	0.9
MF04	9.6	MF15	0.6
MF05	2.2	MF16	0.0
MF06	1.7	MF17	0.8
MF07	0.2	MF18	0.0
MF08	0.7	MF19	3.5
MF09	1.2	MF20	2.0
MF10	6.4	CC1	0.0
MF11	15.7		

5.4.5.3 Shading

Table 9 shows the percent of the strip 82 feet wide along both sides of the river which contains trees and/or shrubs and could provide shade to the river. Trees and shrubs outside the low surface, but within 82 feet are included.

Streamside trees and shrubs may have been historically limited in some reaches of the study area by wet meadow habitat. Short reaches of the river contain well shaded portions and provide adequate thermal refugia for salominid species during hot summer months (Nelson 2008).

Table 9 - Percent of Stream Shaded by Trees or Shrubs by Reach.

Reach	Percent of stream shaded	Reach	Percent of stream shaded
MF01	31.9%	MF12	37.8%
MF02	37.4%	MF13	3.3%
MF03	67.2%	MF14	8.9%
MF04	55.8%	MF15	6.8%
MF05	37.2%	MF16	0.2%
MF06	44.6%	MF17	16.7%
MF07	3.9%	MF18	0.1%
MF08	8.0%	MF19	47.1%
MF09	52.5%	MF20	17.7%
MF10	62.9%	CC1	0.0%
MF11	67.8%		

5.4.5.4 Historical Changes

Aerial photography revealed that many of the human impacts on vegetation had already occurred by 1939. Historic livestock grazing, fire exclusion, increased big game numbers, and timber harvests are cited as reasons for the significant reduction in riparian vegetation and overall reduction in coverage. Sheep grazing has existed in the area since the late 1860s, and cattle grazing has dominated the area since the late 1940s. The timber industry brought railroad lines to the area in 1905 to support mills in Bates and Austin. Loss of beavers has also probably contributed to the loss of riparian vegetation recruitment. Beavers benefit riparian areas by stimulating growth and by damming up areas which raise the water table and trap sediments (USFS 1998). The percentage of area historically dominated by trees and shrubs that was converted to low vegetation or open areas based on 2006 aerial photography is summarized by reach in Table 10.

Table 10 - Percent Negative Change of Trees and Shrubs From 1939 to 2006, by Reach.

Reach	Tree or Shrubs – Negative Percent Change	Reach	Tree or Shrubs – Negative Percent Change
MF01	0.0%	MF12	42.9%
MF02	21.3%	MF13	88.2%
MF03	8.3%	MF14	86.8%
MF04	5.7%	MF15	100.0%
MF05	12.5%	MF16	0.0%
MF06	0.0%	MF17	98.4%
MF07	0.0%	MF18	99.7%
MF08	16.1%	MF19	58.7%
MF09	0.0%	MF20	31.8%
MF10	0.6%	CC1	100%
MF11	2.9%		

5.4.6 Reach Summaries

5.4.6.1 Reach MF20

Aerial photos show that between 1939 and 1956 irrigation canals were built north and south of the river in this reach. Vegetation between the canals and the river was significantly reduced.

5.4.6.2 Reach MF19

Between 1956 and 1976, a highway was built across this reach and consequently, reduced vegetation. Logging impacts probably had the greatest impact in this reach. In the adjacent area extending 300 feet from the river, there are areas dominated by conifer trees.

5.4.6.3 Reach MF18

This is a narrow reach with no trees or shrub showing on the 2006 photography. Logging and the impacts of logging upstream may have impacted this area.

5.4.6.4 Reach MF17

This is a narrow reach with few trees or shrubs. Logging operations may have impacted this area.

5.4.6.5 Reach MF16

This reach contains a broad riparian zone and may have contained wet meadows similar to those downstream. The 2006 aerial photographs show patterns that suggest that wet meadows may exist in this reach today and may have been impacted less than the wet meadows immediately downstream. The 1939 photographs show an area that is obviously modified from the natural state, mostly likely due to timber harvest and livestock grazing. There is no shade provided by trees or shrubs in this reach, but this may be the natural state for a wet meadow in this location. Additional field work is necessary to confirm this hypothesis.

5.4.6.6 Clear Creek Reach 1

Most of the floodplain in this reach is shown as meadow in a 1926 GLO map. Three areas of trees and shrubs are visible on the historical aerial photographs (1939, 1956, and 1976) at the downstream end of the reach. In 2006, the floodplain of this reach was open grassland.

5.4.6.7 Reach MF15

This is a very narrow reach which lies just down stream from the old timber mill. It has contained little vegetation since 1939 and was most likely impacted by the development in this area. There is no shade provided by trees or shrubs in this reach.

5.4.6.8 Reach MF14

This reach is similar in vegetation characteristics to reaches MF12 and MF13. It probably contained wet meadows which were drained for cattle grazing.

5.4.6.9 Reach MF13

This reach is similar in vegetation characteristics to reach MF12. It probably contained wet meadows which appear to have been drained for livestock grazing.

5.4.6.10 Reach MF12

This reach contains significantly lower tree and shrub vegetation as compared to the downstream reaches to the west. The 1939 photographs show what appear to be wet meadows. In this area, 1956 photographs show what appear to be drainage ditches, which may have been used to dry the area and promote grasses for cattle grazing. On the 2006 aerial photographs, the ditches are no longer visible and very little vegetation is discernable. The cause may be overgrazing. Major historic changes may have been affects of livestock management.

5.4.6.11 Reach MF11

This reach has a very narrow riparian zone. Conifers are probably the dominant LWD tree in this reach with some hardwoods on the larger meander areas which should be preserved.

5.4.6.12 Reach MF10

This reach has a very narrow riparian zone that is well shaded. The low surface contains 67.5 percent of the trees and shrubs. This area should be preserved for its potential thermal refugia. Conifers are probably the dominant LWD tree in this reach.

5.4.6.13 Reach MF9

This area contains a mix of hardwood and conifer trees. This is adequately shaded by the riparian vegetation. No change in vegetation cover was detected from aerial photographs; however, on the west end, drying may have occurred possibly by lowering of the water table resulting in a loss of wetland vegetation.

5.4.6.14 Reach MF8

The vegetation in this reach was removed by dredge mining between 1939 and 1956. Much of the wet meadows that may have existed, were most likely destroyed by mining and are now probably dry-grass meadows. Areas south of the south channel were not mined and still appear to contain wet meadows.

5.4.6.15 Reach MF7

Texture on the aerial photographs suggests that significant wet meadows occupy the area classified as low vegetation. The far west end of the reach was dredge mined between 1939 and 1956 which probably destroyed any wet meadow in that area. Sparse hardwoods and conifers make up the trees of LWD-size.

5.4.6.16 Reach MF6

This is a very narrow, short reach. LWD-sized trees appear to be a mix of hardwoods and conifers.

5.4.6.17 Reach MF5

The LWD tree cover in this area appears to be a mix of hardwoods and conifers. The downstream portion contains some significant of tree dominated patches which should be protected.

5.4.6.18 Reach MF4

This reach has a narrow riparian zone. There are some significant patches of treed areas which should be preserved. The LWD trees appear to be a mix of conifers and hardwoods.

5.4.6.19 Reach MF3

Reach MF3 contains some areas of open areas which appear to be wet meadows. The dominant LWD trees are most likely black cottonwood, with a few conifers in some areas.

5.4.6.20 Reach MF2

Sparse cover of trees in this reach appears to be mixed conifers and cottonwood. The majority of the area classified as low vegetation has surface textures on aerial photographs which indicate a wet meadow community. This classification needs to be verified by field observations of indicator plants.

5.4.6.21 Reach MF1

Tree canopy cover in this reach appears to be mixed conifers and cottonwood.

5.4.7 Potential Future Improvements to Assessment

This analysis was limited by working only from aerial photos because time and budget did not allow field work at this stage. The riparian assessment would improve with these additions from field work:

- Species verification and identification of tree, shrub, forbs, and grasses at selected sites and interpretation expansion in GIS to non-visited sites; size/age classifications.
- Addition of structural components to vegetation communities: canopy (overstory), understory, forb/grass/littler, snags and downed wood (LWD) at selected sites, and interpretation in a GIS of non-visited sites.
- Noxious weeds mapping and assessment.
- Field assessment of riparian vegetation health (seral stage, invasive weed colonization, grazing, and logging impacts) from observations of selected sites.
- Assessment of overbank flooding at selected sites.
- Assessment of LWD sources outside the assessment area.

5.5 Present Fish Use

5.5.1 Spring Chinook

Oregon Department of Fish and Wildlife (ODFW) surveys illustrate an increasing trend in spring Chinook abundance in the Middle Fork John Day River (Figure 37). The Middle Fork assessment area appears to be one of the most productive spawning areas for spring Chinook in the entire John Day Basin. Spring Chinook rearing occurs within the mainstem and its tributaries.

Table 11 indicates the distribution of Chinook redds surveyed by ODFW between 2002 and 2006. Because some of the coordinates were missing from the 2002 dataset, 2002 surveyed redd counts may be slightly greater than those depicted in the table.

In the Middle Fork assessment area, reach MF13 in the Forrest Conservation Area has the greatest number of redds per mile. All reaches shaded in green had greater than average redds per mile between 2002 and 2006.

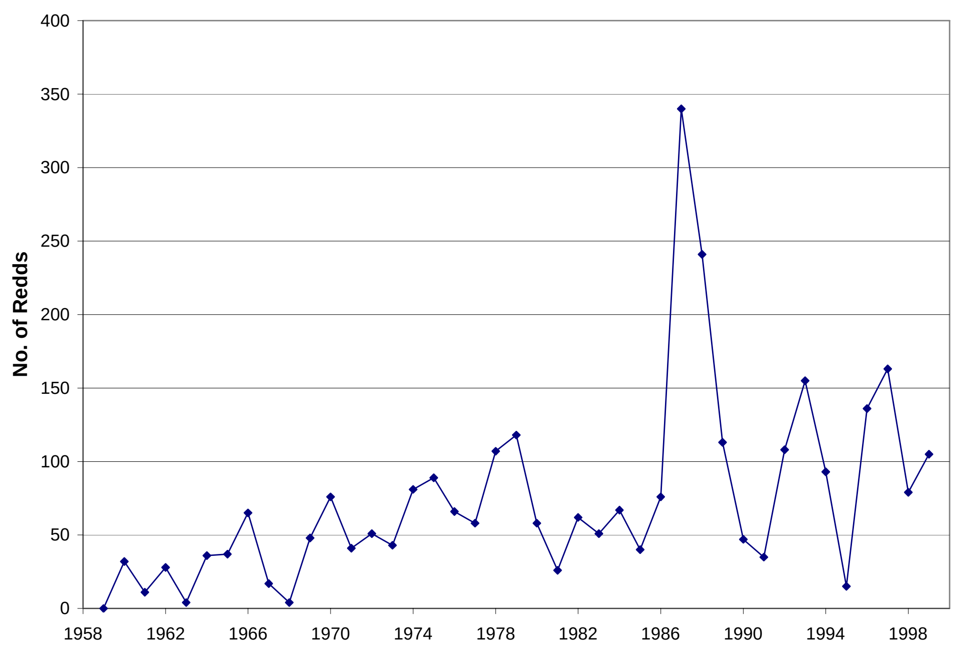

Figure 37 – Historic Redd Surveys in the 12-Mile Index Area of the Middle Fork John Day River, From Highway 7 to Beaver Creek (Ruzycki et al. 2002)

Table 11 - Distribution of Chinook Redds Surveyed by ODFW Between 2002 and 2006.

Reach	Type	Length (miles)	2002	2003	2004	2005	2006	Average per year	Average per mile
Reach MF1	Moderately Confined	0.21	0	0	0	0	0	0	0.0
Reach MF2	Unconfined	2.90	0	4	41	9	3	11.4	3.9
Reach MF3	Moderately Confined	1.60	2	2	25	6	6	8.2	5.1
Reach MF4	Confined	1.24	0	5	7	4	1	3.4	2.7
Reach MF5	Moderately Confined	1.40	4	9	14	5	9	8.2	5.8
Reach MF6	Confined	0.30	1	2	1	0	1	1	3.3
Reach MF7	Unconfined	0.60	2	2	3	2	1	2	3.3
Reach MF8N	Unconfined	0.68	11	5	5	6	5	6.4	9.4
Reach MF8S	Unconfined	2.24	7	17	17	5	4	10	4.5
Reach MF9	Unconfined	1.11	24	8	8	10	8	11.6	10.5
Reach MF10	Moderately Confined	1.70	7	4	6	6	11	6.8	4.0
Reach MF11	Confined	1.70	14	6	12	3	11	9.2	5.4
Reach MF12	Moderately Confined	0.98	13	8	17	5	19	12.4	12.7
Reach MF13	Unconfined	3.04	122	90	67	62	71	82.4	27.1
Reach MF14	Moderately Confined	1.13	30	19	11	4	14	15.6	13.8
Reach MF15	Confined	0.45	11	9	4	3	4	6.2	13.7
Reach MF16	Unconfined	0.87	22	20	9	9	3	12.6	14.6
Reach MF17	Confined	0.27	2	2	2	0	0	1.2	4.5
Reach MF18	Moderately Confined	0.47	6	4	1	0	0	2.2	4.7
Reach MF19	Confined	0.45	0	0	0	0	0	0	0.0
Reach MF20	Unconfined	0.66	17	6	3	1	5	6.4	9.6
Reach CC1	Unconfined	0.40	1	1	1	1	0	0.8	2.0
Total		**24.40**	**296**	**223**	**254**	**141**	**176**	**218**	**8.9**

5.5.2 Summer Steelhead

Steelhead primarily use the assessment area for spawning and rearing. Steelhead abundance has been generally declining slightly in the Middle Fork since 1958. NOAA Fisheries Service (1999) calculated the long-term trend in steelhead abundance for the Middle Fork as a 3.7 percent decrease, while the more recent short-term trend, calculated between 1987 and 1997, was a 13.7 percent decrease. The decline of steelhead abundance in the John Day Basin is particularly important due to large populations of naturally spawning steelhead in the recent past (WCSBRT 2003).

The spatial distribution of steelhead redd count data in the Middle Fork was not available for inclusion into this report. However, surveys completed by ODFW illustrate that summer steelhead redds were in greater abundance in the late 1970s and mid 1980s than they were in the early 2000s (Figure 38). Carmichael (2006) developed spawner abundance estimates for steelhead based on redd count expansions (Figure 39).

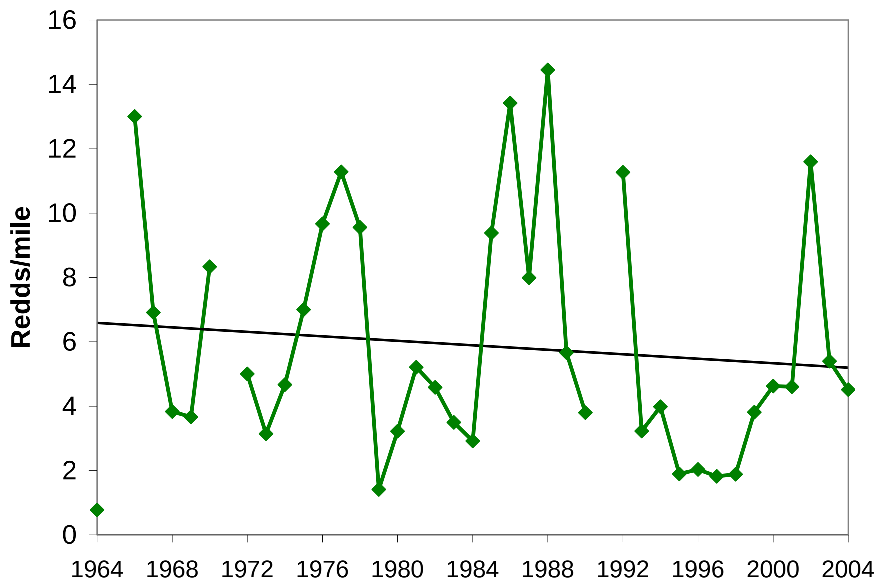

Figure 38 - Middle Fork John Day River Steelhead Spawning Surveys (Chilcote 2008).

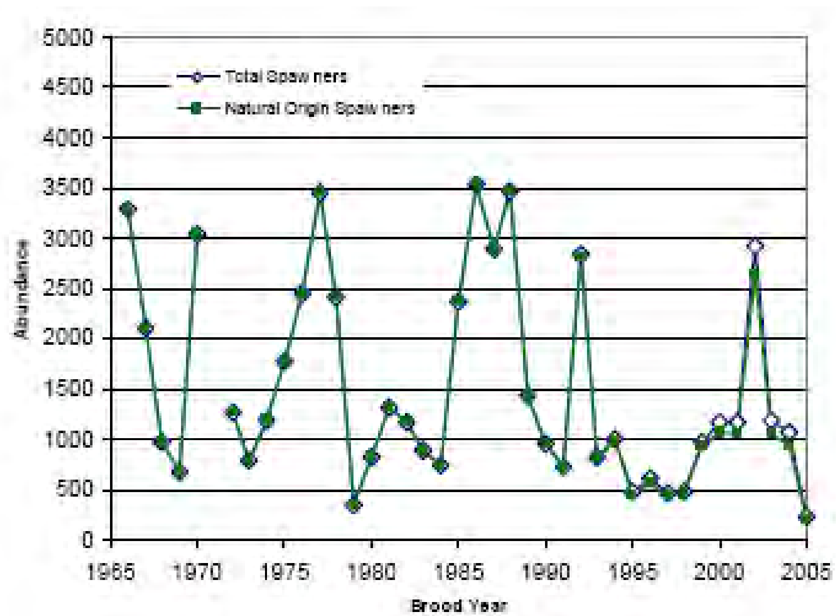

Figure 39 - Steelhead Spawner Abundance Estimates, Based on Redd Count Expansion. (Carmichael 2006).

6.0 General Impacts of Restoration and Protection Strategies

This section describes the conceptual interpretation of how restoration and protection strategies could impact physical processes. The discussion relates to physical processes within the next several years to decades; beyond this timeframe, major changes in large-scale controlling variables (e.g., climate, land use) could substantially alter river processes.

Comparison of the fully functioning conditions with the present setting helped identify substantial impacts to lateral floodplain connectivity, localized areas of vertical floodplain connectivity, and regeneration of vegetation within the floodplain. These impacts, primarily topographic in nature, have resulted in significant loss of off-channel habitat, instream complexity, and likely degraded water quality. Historical removal of LWD, deforestation of the low surface, channelization, and disconnection of side and overbank channels has resulted in increased channel energy and modification of channel geometry and planform (i.e., increased slopes, erosion of banks). Vertical channel degradation appears have occurred in localized areas, but the further extent of degradation may be limited by vertical geologic controls and large sediment sizes. Alluvial fans and bedrock also constrain lateral channel position and expansion of the floodplain.

The present channel appears to have adjusted to impacts on the topography and has reached a new state of channel equilibrium. Results of the assessment indicate that under significant flooding events, lateral or vertical degradation may occur in downstream reaches of the assessment area. However, potential future degradation will be limited by the lateral and vertical controls. Following implementation of proposed protection and restoration efforts (e.g., removal of constructed features, re-establishment of vegetation in the riparian corridor, and reconnection of side and over bank channels), lateral floodplain connectivity with the active channel is anticipated to improve, which in turn should dissipate channel energy and promote regeneration of riparian vegetation. A quantitative understanding of benefits gained through implementation of specific actions requires additional analyses to determine the degree to which off-channel habitat and habitat complexity can be restored by each action. Reach- and project-level assessments can be performed to evaluate the frequency and degree of connectivity that will occur. If proposed restoration and protection actions are not completed in full (e.g., culvert installed through a levee), additional analyses would be needed to understand if floodplain function can be fully or only partly restored.

In areas where the channel has been vertically disconnected with its floodplain, proposed protection and restoration efforts may assist in local rises in bed elevation. Areas where the channel has been completely disconnected from the floodplain, such as locations of dredge mining activities and channelization, active reconnection of the channel with the floodplain may require reconstruction of the main and/or side channels.

River processes within the low surface are currently functioning in some areas. Restoration activities can be conducted to expand and reconnect areas that are already functioning to maximize cumulative benefits for salmonid populations. Reworking of the channel bed and floodplain through sediment transport processes and channel migration is a healthy part of the fluvial system. Localized degradation and aggradation of the channel bed may result from functioning river processes, but a long-term net change in the channel or floodplain elevations is unlikely to occur if a dynamic state of equilibrium is restored.

7.0 Restoration and Protection Concepts

7.1 Greatest Departures from Typical Channel Processes

Historical research, aerial photographs, hydraulic modeling, geologic and geomorphic mapping were integrated to identify significant departures from "ideal" or fully functioning conditions within the assessment areas. Because historical data were not available prior to major human settlement, hypothesized typical channel processes were developed from the earliest documented accounts, anecdotal information, ground and aerial photographs from the early 20th century, and an understanding of similar system processes with less impacts within the region.

Greatest departures from fully functioning conditions of the Middle Fork John Day River assessment area included:

1. Reduced floodplain function
    a. Reduced floodplain connectivity due to construction of roads, levees, push-up dikes, and rock spurs.
    b. Reduced lateral migration potential due to hardened bank protection measures.
    c. Localized elimination of floodplain connectivity due to dredge mining of floodplain and construction of railroad embankment.
2. Reduced habitat complexity within the channel and floodplain due to clearing of riparian and upland vegetation, cattle and sheep grazing, and removal of LWD sources.
3. Localized reductions in channel length caused by channel relocations, straightening, and cut-off of natural meanders.

Recognizing the greatest departures, biological hypotheses were developed, including:

1. If we preserve areas where the fluvial system is "properly functioning," then we will protect core areas of the riverine ecosystem upon which multiple species depend.
2. If we restore/rehabilitate the fluvial system where it is "not properly functioning" using a hierarchal (or nested) approach to achieve a cumulative ecological benefit, then we will improve the abundance and productivity, and spatial structure and diversity of multiple species that are dependent on the riverine ecosystem.
3. By using a holistic approach to preserving and restoring/rehabilitating natural processes and function of the fluvial system across different temporal and spatial scales, the fluvial system will maintain a "properly functioning" riverine ecosystem and sustain a viable salmonid population.

7.2 VSP Parameters and Limiting Factors

In addition to biological guidance documents directly related to the recovery of salmonid species in Oregon, documents relating to salmon and steelhead recovery in the Upper Columbia Region also were referenced. Although the documents focus on the Upper

Columbia River, the methodology presented for recovery of listed species has broad application to other basins and can be tailored to meet specific basin objectives. Within the *Biological Strategy* (UCRTT 2007), four viable salmonid population (VSP) parameters are proposed to characterize recovery, including abundance, productivity, spatial structure, and diversity. These parameters provide a consistent measure for the long-term persistence of viable populations of listed species.

As part of the development of the John Day Subbasin Plan (NPCC 2005), limiting factors were evaluated through an Ecosystem Diagnostic and Treatment Model (EDT). For both the Upper Mainstem and Middle Fork John Day River assessment areas, limiting factors for Summer Steelhead and Spring Chinook included habitat diversity, sediment load, temperature, key habitat quantity, and flow.

The Draft Middle Columbia River Steelhead Recovery Progress Report (Carmichael, 2006) provides a synopsis of biological statistics for the Middle Fork John Day River Basin, including:

Middle Fork John Day

- Drainage Area: 2,052 km^2
- Number of major spawning areas (MaSAs) 4
- Number of minor spawning areas (MiSAs) 2
- Population is at moderate risk.
- ICTRT overall rating is the population does not currently meet viability criteria.
- Limiting Factors: key habitat quantity, habitat diversity, flow, sediment load, and water temperature.
- Anthropogenic Threats: riparian disturbance, stream channelization and relocation, grazing, timber harvest, road building, passage barriers, irrigation withdrawals, mining, and dredging (NMFS 2004).

7.3 Habitat and Restoration Objectives

To address each limiting factor, the John Day Subbasin Plan and Middle Columbia River Steelhead Progress Report (Carmichael 2006) established habitat objectives:

Habitat diversity/ Key habitat quantity

- Maintain riparian management objectives.
- Provide adequate habitat components necessary for focal species.
- Increase role and abundance of wood and large organic debris in streambeds.
- Increase pool habitat (e.g. beaver ponds).
- Maintain and improve quality and quantity of spawning grounds.
- Decrease gradient; restore sinuosity.
- Restore channel and floodplain connectivity.
- Restore off-channel areas for high flow refugia.

Flow

- Enhance base flows.
- Moderate peak flows where appropriate.
- Restore natural hydrographic conditions where appropriate.

Sediment Load

- Minimize unnatural rates of erosion from upland areas.
- Trap sediment on the floodplain as appropriate.
- Bring the stream channel in balance with the water and sediment as supplied by the watershed.

Temperature

- Moderate extreme stream temperatures through improvement of width-to-depth ratio, increased shade and floodplain connectivity.

Specific restoration objectives within the assessment areas were derived from the habitat objectives presented in the John Day Subbasin Plan and Middle Columbia River Steelhead Progress Report integrated with findings from the geomorphic assessment and biological objectives identified by the Confederated Tribes of Warm Springs Reservation of Oregon (2007). Because the width of the valley often defines restoration opportunities and floodplain complexity, the river was partitioned into reaches by the relative degree of valley confinement: confined, moderately confined, and unconfined. One paramount objective common to all types of reaches is the protection of properly functioning habitat. The restoration objectives for differing reach types are presented below.

Unconfined and Moderately Confined Reaches

1. Protection of existing functioning habitat.
2. Re-establish riparian vegetation in areas that have been denuded due to clearing, timber harvest, or disconnection from water table.
3. Promote river interaction with the floodplain to rehabilitate the natural function of the floodplain.
4. Restore a more natural channel gradient through increased sinuosity.
5. Restore habitat complexity features and processes within the channel and surrounding floodplain.

Confined Reaches

1. Protection of existing functioning habitat.
2. Re-establish riparian vegetation in areas that have been denuded due to clearing, timber harvest, or disconnection from water table.
3. Renew in-channel habitat complexity.

7.4 Development of Restoration Strategies

The Middle Fork John Day Rivers is considered a Category 2 (Restoration/Protection) watershed based on descriptions provided by the UCRTT (2007). The Draft Middle Columbia Steelhead Recovery Progress Report (Carmichael 2006) imparts prioritization considerations as guidance for management and restoration actions. Actions with the highest priority include:

- Actions that provide long-term protection for the major life history strategies (i.e., summer and winter run timing) that currently exist at the major population grouping (MPG) level.
- Actions that provide long-term protection of habitat conditions that support the viability of priority extant populations and their primary life history strategies throughout their entire life cycle. A population is considered a priority if it is critical for MPG or evolutionary significant unit (ESU) viability.
- Actions that enhance the viability of priority extant populations.
- Actions that protect or enhance viability of multiple listed populations.
- Actions that enhance habitat and restore natural processes to increase survival, connectivity, and reproductive success of priority extant populations.
- Actions that target the key limiting factors and that contribute the most to closing the gap between current status and desired future status of priority populations.
- Actions that are required to protect and enhance habitats for populations that are not critical for MPG or ESU viability but must be maintained.

As part of the John Day Subbasin Plan effort, three geographic areas were divided for development and ranking of restoration strategies based on the EDT and then "based on professional opinion" (NPCC 2005, p6.). The Middle Fork John Day River assessment area lies within the geographic region identified as "Middle Fork and North Fork John Day River."

The assessment area on the Middle Fork is located within two HUC5s, Camp Creek and the Upper Middle Fork John Day River. The Camp Creek HUC5 encompasses the study area from the downstream boundary at RM 47.95 to the upstream boundary of the Forrest Conservation Property at RM 67.5. Both the Oxbow and Forrest Conservation Areas lie within the Camp Creek HUC5, which is the top ranking HUC5 in its geographic region. The assessment area upstream of RM 67.5 is contained within the Upper Middle Fork John Day River HUC5 and is ranked as the second highest priority in the geographic region.

In the Camp Creek HUC5, five restoration strategies were assigned the "very high" priority ranking by the Subbasin Plan. These restoration strategies and their specific types of actions included:

1. Protection of Existing Habitat

a. Acquisition and management of land

b. Acquisition and management of conservation easements

c. Adoption and management of cooperative agreements

d. Implementation of special management designation on public lands

2. Riparian Habitat Improvements
    a. Management of riparian grazing
    b. Riparian vegetation management
    c. Floodplain restoration
    d. Beaver management
3. Fish Passage
    a. Replacing or removing culverts
    b. Improving irrigation diversion
    c. Addressing other artificial passage barriers
4. Flow Restoration
    a. In-stream water right leases and acquisitions
    b. Irrigation efficiency projects
    c. Floodplain aquifer recharge projects
    d. Off-stream storage basins
    e. Efforts to improve hydrologic connectivity between springs and streams
5. In-stream Activities
    a. Large woody debris placement
    b. Channel restoration
    c. Bank protection/stabilization
    d. Weirs and other structures

In the Upper Middle Fork John Day River HUC5, three restoration strategies received a "very high" priority ranking by the Subbasin Plan. These restoration strategies and associated habitat actions included:

1. Protection of Existing Habitat
    a. Acquisition and management of land
    b. Acquisition and management of conservation easements
    c. Adoption and management of cooperative agreements
    d. Implementation of special management designation on public lands
2. Fish Passage
    a. Replacing or removing culverts
    b. Improving irrigation diversion
    c. Addressing other artificial passage barriers

3. Flow Restoration
    a. In-stream water right leases and acquisitions
    b. Irrigation efficiency projects
    c. Floodplain aquifer recharge projects
    d. Off-stream storage basins
    e. Efforts to improve hydrologic connectivity between springs and streams

7.4.1 Restoration Strategies by Valley Width

Priority restoration actions identified through the Subbasin Plan (NPCC 2005) combined with findings from geomorphic investigations were the foundation for the development of specific restoration actions within the assessment areas. The restoration actions are structured to satisfy the habitat and restoration objectives, and are divided as to the relative confinement of the reach. Opportunities for restoration are generally much greater within unconfined and moderately confined reaches than within confined reaches.

For moderately confined and unconfined reaches, the following actions were recognized as addressing specific biological and restoration objectives.

- Preservation and protection of existing riparian vegetation within the floodplain and along the channel margins to maintain canopy cover, bank stability, and LWD inputs.
- Restoration of floodplain connectivity and function.
- Reconnection of historical main, side, and overflow channels.
- Restoration of lateral channel migration through the removal of instream structures and hardened bank protection measures.
- Re-vegetation of the low surface and installation of cattle exclusion fencing around the low surface.
- Installation of LWD structures as a short-term means of enhancing habitat while the long-term processes that naturally supply LWD re-establish.
    - Placement of LWD to direct high flows into side or overflow channels, thereby promoting floodplain access.
    - Placement of LWD to promote short term channel complexity, provide fish cover, and re-establish natural channel morphology
- Channel relocation to promote long-term channel complexity and increase fish habitat

More confined reaches are limited in the types of restoration actions that would effectively address restoration objectives. Measures that may be feasible in more confined reaches are:

- Preservation and protection of existing riparian vegetation within the floodplain and along the channel margins to maintain canopy cover, bank stability, and LWD inputs.
- Recruitment of riparian vegetation.
- Restoration of lateral channel migration through the removal of instream structures and hardened bank protection measures.
- Installation of LWD structures as a short-term means of enhancing habitat while the long-term processes that naturally supply LWD re-establish.
    - Placement of LWD to direct high flows into side or overflow channels, thereby promoting floodplain access.
    - Placement of LWD to promote short-term channel complexity, provide fish cover, stabilize banks, and re-establish natural channel morphology

7.4.2 Adaptive Management and Project Monitoring

An important aspect of each restoration strategy will be the ability to modify the project design as necessary to meet project goals. Adaptive management is often defined as a "reliance on scientific methods to test the results of actions taken so that the management and related policy can be changed promptly and appropriately" (UCSRB 2007). In some locations, an adaptive management approach will be an essential component to project success, while in others locations, little to no adaptive management may be required. Adaptive management works well with the dynamic nature of rivers and may impart some flexibility in the design of each project and in the maintenance of a successful effort. The Upper Columbia Salmon Recovery Board (UCSRB) recommends that adaptive management be framed in the sequence of developing a hypothesis, monitoring the project, evaluating results, and responding to the results.

The measurement of project success and a key component of adaptive management is often driven by monitoring efforts. The USCRB (2007) recommends the use of two monitoring strategies for determining the level of project success, implementation monitoring and level 1 effectiveness monitoring. Implementation monitoring demonstrates proof that the restoration action occurred and measures the qualitative success of the project through photo documentation and written descriptions before and after project implementation. Level 1 effectiveness monitoring is used as a tool to evaluate if the restoration action actually met targeted environmental parameters. Level 1 effectiveness monitoring is conducted through photograph, counts, and presence/absence surveys (Hillman 2006) at defined temporal intervals. Steps for development of a monitoring plan for each project are provided by the Upper Columbia Salmon Recovery Board (2006).

8.0 Glossary

TERM	DEFINITION
adaptive management	A management process that applies the concept of experimentation to design and implementation of natural resource plans and policies.
aggradation	Gradual buildup of land along a stream bank due to water action, sediment transport, or alluvial deposits
alluvial fan	A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream at the place where it issues from a narrow mountain valley upon a plain or broad valley, or where a tributary stream is near or at its junction with the main stream, or wherever a constriction in a valley abruptly ceases or the gradient of the stream suddenly decreases; it is steepest near the mouth of the valley where its apex points upstream, and it slopes gently and convexly outward with a gradually decreasing gradient (Neuendorf et al. 2005).
alluvium	A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream, as a sorted or semi-sorted sediment on the river bed and floodplain (Neuendorf et al. 2005).
anadromous (fish)	A fish, such as the Pacific salmon, that spawns and spends its early life in freshwater but moves into the ocean where it attains sexual maturity and spends most of its life span (Owen & Chiras 1995).
anthropogenic	Caused by human activities.
bar (in a river channel)	Accumulations of bed load (sand, gravel, and cobble) that are deposited along or adjacent to a river as flow velocity decreases. If the sediment is reworked frequently, the deposits will remain free of vegetation. If the surface of the bar becomes higher than the largest flows, vegetation stabilizes the surface making further movement of the sediment in the bar difficult.
bed-material	Sediment that is preserved along the channel bottom and in adjacent bars; it may originally have been material in the suspended load or in the bed load.
bedrock	A general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material (Neuendorf et al. 2005). The bedrock is generally resistant to fluvial erosion over a span of several decades, but may erode over longer time periods.
canopy cover (of a stream)	Vegetation projecting over a stream, including crown cover (generally more than 1 meter (3.3 feet) above the water surface) and overhang cover (less than 1 meter (3.3 feet) above the water).

TERM	DEFINITION
Category 2	Category 2 watersheds support important aquatic resources, and are strongholds for one or more listed fish species (Appendix A). Compared to Category 1 watersheds, Category 2 watersheds have a higher level of fragmentation resulting from habitat disturbance or loss. These watersheds have a substantial number of subwatersheds where native populations have been lost or are at risk for a variety of reasons. Connectivity among subwatersheds may still exist or could be restored within the watershed so that it is possible to maintain or rehabilitate life history patterns and dispersal. Restoring and protecting ecosystem functions and connectivity within these watersheds are priorities. Adapted from UCRTT (2007).
channel morphology	The physical dimension, shape, form, pattern, profile, and structure of a stream channel.
channel planform	Characteristics of the river channel that determine its two-dimensional pattern as viewed on the ground surface, aerial photograph, or map.
channel remnant (wet)	Same as an old channel (wet) for channels on the USGS topographic maps from the middle 1980s. Mapped as a channel remnant (wet), because this is how they appear on the topographic maps.
channel sinuosity	The ratio of length of the channel or thalweg to down-valley distance. Channel with a sinuosity value of 1.5 or more are typically referenced as meandering channels (Neuendorf et al. 2005).
channel stability	The ability of a stream, over time and under the present climatic conditions, to transport the sediment and flows produced by its watershed in such a manner that the stream maintains its dimension, pattern, and profile without either aggrading or degrading.
channelization	The straightening and deepening of a stream channel to permit the water to move faster, to reduce flooding, or to drain wetlands.
concavity	Curvature in the shape of a segment of the interior of a circle. With respect to stream power, greater concavity in the downstream direction signifies that the stream power decreases in the downstream direction with an increasing tendency for curvature as the distance from the headwater increases.
core habitat	Habitat that encompasses spawning and rearing habitat (resident populations), with the addition of foraging, migrating, and overwintering habitat if the population includes migratory fish. Core habitat is defined as habitat that contains, or if restored would contain, all of the essential physical elements to provide for the security of allow for the full expression of life history forms of one or more local populations of salmonids.
Cretaceous	The final period of the Mesozoic era that covered the span of time between 135 and 65 million years ago.

TERM	DEFINITION
degradation	Wearing down of the land surface through the processes of erosion and/or weathering
discharge (stream)	With reference to stream flow, the quantity of water that passes a given point in a measured unit of time, such as cubic meters per second or, often, cubic feet per second (cfs).
diversity	All the genetic and phenotypic (life history traits, behavior, and morphology) variation within a population.
dynamic equilibrium	Condition where on-going opposing processes proceed at the same rate, resulting in little change in the state of the environment.
ecosystem	A unit in ecology consisting of the environment with its living elements, plus the non-living factors, that exist in and affect it (Neuendorf et al. 2005).
embeddedness	The degree to which large particles (boulders, gravel) are surrounded or covered by fine sediment, usually measured in classes according to percentage covered.
fine sediment (fines)	Sediment with particle sizes of 2.0 mm (0.08 inch) or less, including medium to fine sand, silt, and clay.
floodplain	The surface or strip of relatively smooth land adjacent to a river channel constructed by the present river in its existing regimen and covered with water when the river overflows its banks. It is built on alluvium, carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current. A river has one floodplain and may have one or more terraces representing abandoned floodplains (Neuendorf et al. 2005).
geomorphic reach	A geomorphic reach, represents an area containing the active channel and its floodplain bounded by vertical and/or lateral geologic controls, such as alluvial fans or bedrock outcrops, and frequently separated from other reaches by abrupt changes in channel slope and valley confinement. Within a geomorphic reach, similar fluvial processes govern channel planform and geometry through driving variables of flow and sediment. A geomorphic reach is comprised of a relatively consistent floodplain type and degree of valley confinement. Geomorphic reaches may vary in length from 100 meters in small, headwater streams to several miles in larger systems (Frissell et al. 1986).
geomorphology	The study of the classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes caused by the actions of flowing water.
GIS	Geographical information system. An organized collection of computer hardware, software, and geographic data designed to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.

TERM	DEFINITION
glacial deposits (undifferentiated)	Consists predominantly of till and glaciofluvial deposits of silt, sand, gravel, cobbles and boulders. These deposits were not differentiated as ice-contact, ice-proximal or ice-distal deposits (i.e., moraine versus glacial outwash). The materials are generally consolidated in the headwater areas where they were in contact with the glacier and unconsolidated in the valley bottoms where they were deposited primarily by glaciofluvial processes.
glaciofluvial	Pertaining to the melt water streams flowing from wasting glacier ice and especially to the deposits produced by such streams; relating to the combined actions of glaciers and streams (Neuendorf et al. 2005).
habitat action	Proposed restoration or protection strategy to improve the potential for sustainable habitat upon which endangered species act (ESA) listed salmonids depend on. Examples of habitat actions include the removal or alteration of project features to restore floodplain connectivity to the channel, reconnection of historic side channels, placement of large woody debris, reforestation of the low surface, or implementation of management techniques.
habitat connectivity (stream)	Suitable stream conditions that allow fish and other aquatic organisms to access habitat areas needed to fulfill all life stages.
hardwood forest	A large area of deciduous trees (broad, flat leaves).
Holocene	The geologic time interval between about 10,000 years ago and the present.
human features	Man-made features that are constructed in the river and/or floodplain areas (e.g., levees, bridges, riprap).
HUC5	5th field Hydrologic Unit Code: Watersheds consist of subwatersheds that are delineated and arranged in nested hydrologic units, ranging from smallest (HUC8) to largest (HUC1). HUCs provide a uniquely identified and uniform method of subdividing large drainage areas. HUC5s represent 40,000- to 250,000-acre drainage areas that are nested within a larger drainage system. Several 5th field hydrologic units comprise a HUC4, while several 6th field hydrologic units are contained within a HUC5.
hyporheic zone	In streams, the region adjacent to and below the active channel where water movement is primarily in the downstream direction and the interstitial water is exchanged with the water in the main channel. The boundary of this zone is where 10 percent of the water has recently been in the stream (Neuendorf et al. 2005).
ICBTRT	Interior Columbia Basin Technical Recovery Team. Expert panel formed by NOAA Fisheries Service (NMFS) to work with local interests and experts and ensure that ICBTRT recommendations for delisting criteria are based on the most current and accurate technical information available.

TERM	DEFINITION
igneous rocks	Rocks that form from the cooling and solidification of molten or partly molten material (magma) either below the surface as an intrusive (plutonic) rock or on the surface as an extrusive (volcanic) rock
incipient motion	The initiation of mobilizing a single sediment particle on the stream bed once threshold conditions are met.
incision	The process where by a downward-eroding stream deepens its channel or produces a relatively narrow, steep-walled valley (Neuendorf et al. 2005).
intermediate surface	Comprised of alluvial deposits that form a series of terrace risers and terrace treads that are elevated between 2.5 to 3.5 meters above normal water surface in the active channel. These surfaces are intermittent throughout the major drainages, but were only locally mapped where they have an influence on the rivers' morphology. This surface is rarely flooded by the river during the current climatic regime. The intermediate surface is considered stable on a decadal time scale. These materials are unconsolidated and susceptible to fluvial erosion.
landslide	Consists of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders. Occur predominantly along glacial terrace deposits and valley walls. Mass wasting along the active river channels typically result in a "self-armoring" bank in that the finer materials are transported by the fluvial system and the larger materials are retained along the toe of the slope protecting the slope except during flood events.
large woody debris (LWD)	Large downed trees that are transported by the river during high flows and are often deposited on gravel bars or at the heads of side channels as flow velocity decreases. The trees can be downed through river erosion, wind, fire, or human-induced activities. Generally refers to the woody material in the river channel and floodplain whose smallest diameter is at least 12 inches and has a length greater than 35 feet in eastern Cascade streams.
levee	A natural or artificial embankment that is built along a river channel margin; often a man-made structure constructed to protect an area from flooding or confine water to a channel. Also referred to as a dike.
limiting factor	Alternate definition: Any factor in the environment of an organism, such as radiation, excessive heat, floods, drought, disease, or lack of micronutrients, that tends to reduce the population of that organism (Owen & Chiras 1995).

TERM	DEFINITION
low surface	Generally represents an area encompassing historic channel migration and floodplain. Consists of a mixture of reworked glacial deposits and fluviolacustrine deposits comprised of silt- to boulder-size material, but is predominantly sand, gravel, and cobbles. These deposits occur along stream channels and their active floodplains. These materials are unconsolidated and highly susceptible to fluvial erosion.
low-flow channel	A channel that carries stream flow during base flow conditions.
mass wasting	General term for the dislodgement and downslope transport of soil and rock under the influence of gravitational stress (mass movement). Often referred to as shallow-rapid landslide, deep-seated failure, or debris flow.
Mesozoic	An era of geologic time from about 225 to about 65 million years ago that includes the Triassic, Jurassic, and Cretaceous periods.
Metamorphic rocks	Rocks derived from pre-existing rocks (sedimentary or igneous) in response to marked changes in temperature, pressure, shearing stress, and chemical environment.
nonnative species	Species not indigenous to an area, such as brook trout in the western United States. Sometimes referred to as an exotic species.
Oligocene	An epoch of the Tertiary period that began about 34 million years ago and extended to about 23 million years ago.
orthorectified photograph	An aerial photograph that has been corrected for the geometries and tilt angles of the camera when the image was taken and for topographic relief using a digital elevation model, flight information, and surveyed control points on the ground.
overflow channel	A channel that is expressed by no or little vegetation through a vegetated area. There is no evidence for water at low stream discharges. The channel appears to have carried water recently during a flood event. The upstream and/or downstream ends of the overflow channel usually connect to the main channel.
peak flow	Greatest stream discharge recorded over a specified period of time, usually a year, but often a season.
planform	The shape of a feature, such as a channel alignment, as seen in two dimensions, horizontally, as on an aerial photograph or map.
Pleistocene	The geologic time interval between 1.6 million years ago and 10,000 years ago.
project area	A project area is a distinct geographic location with potential implementation opportunities for habitat restoration and protection actions. Project areas are at a comparable level of organization as a habitat unit within a geomorphic reach and typically bounded by geomorphic features (e.g., river channel, floodplain, or terrace).

TERM	DEFINITION
project feature	A project feature is an individual structure or component of an active floodplain of a project area; examples include levees, roadway embankments, bridges, or culverts.
Quaternary	The geologic time interval between 1.6 million years ago and the present. It includes both the Pleistocene and the Holocene.
redd	A nest constructed by salmonid species in the streambed where eggs are deposited and fertilized. Redds can usually be distinguished in the streambed by a cleared depression and associated mound of gravel directly downstream.
riparian area	An area with distinctive soils and vegetation community/composition adjacent to a stream, wetland, or other body of water.
riprap	Large angular rocks that are placed along a river bank to prevent or slow erosion.
salmonid	Fish of the family *salmonidae*, including trout, salmon, chars, grayling, and whitefish. In general usage, the term most often refers to salmon, trout, and chars.
side channel	A channel that is not part of the main channel, but appears to have water during low-flow conditions and has evidence for recent higher flow (e.g., may include unvegetated areas (bars) adjacent to the channel). At least the upstream end of the channel connects to, or nearly connects to, the main channel. The downstream end may connect to the main channel or to an overflow channel. Can also be referred to as a secondary channel.
spawning and rearing habitat	Stream reaches and the associated watershed areas that provide all habitat components necessary for adult spawning and juvenile rearing for a local salmonid population. Spawning and rearing habitat generally supports multiple year classes of juveniles of resident and migratory fish, and may also support subadults and adults from local populations.
subbasin	A subbasin represents the drainage area upslope of any point along a channel network (Montgomery & Bolton 2003). Downstream boundaries of subbasins are typically defined in this assessment at the location of a confluence between a tributary and mainstem channel. An example would be the Twisp River Subbasin.
terrace	A relatively stable, planar surface formed when the river abandons the floodplain that it had previously deposited. It often parallels the river channel, but is high enough above the channel that it rarely, if ever, is covered by water and sediment. The deposits underlying the terrace surface are alluvial, either channel or overbank deposits, or both. Because a terrace represents a former floodplain, it can be used to interpret the history of the river.

TERM	DEFINITION
terrane	A crustal block or fragment that preserves a distinctive geologic history that is different from the surrounding areas that is usually bounded by faults.
Tertiary	The first period of the Cenozoic era thought to have covered the span of time between about 65 million and 2 million years ago. It is divided into five epochs: the Paleocene, Eocene, Oligocene, Miocene and Pliocene.
tributary	A stream feeding, joining, or flowing into a larger stream or lake (Neuendorf et al. 2005).
watershed	The area of land from which rainfall (and/or snow melt) drains into a stream or other water body. Watersheds are also sometimes referred to as drainage basins. Ridges of higher ground form the boundaries between watersheds. At these boundaries, rain falling on one side flows toward the low point of one watershed, while rain falling on the other side of the boundary flows toward the low point of a different watershed.

Appendix E: Geomorphic Assessment of the Upper Mainstem John Day River

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1.0 Introduction to the Assessment Area

The assessment area on the Upper John Day River (Upper Mainstem) is a 3-mile long section of the river located upstream of the Prairie City Bridge and Jeff Davis Creek (see *Upper John Day River Map Atlas*). Within the assessment area, land ownership is private. The assessment area offers unique opportunities for salmonid habitat restoration due to the high percentage of land owned and managed by the Confederated Tribes of the Warms Springs Reservation of Oregon (CTWSRO).

The assessment area was identified by the opportunity to improve salmonid habitat conditions within the Upper Mainstem John Day River. In addition to land ownership considerations, the assessment area covers the highest biological priority area within the geographic area identified as the “Upper Mainstem and South Fork John Day River” in the John Day River Draft Subbasin Plan (NPCC 2005). This tributary assessment presents additional management considerations and guidance to local stakeholders, planners, and managers for improving salmonid habitat in the river.

The approach of this assessment was to first develop a conceptual model of typical channel processes that could be present under fully functioning or “ideal” conditions based on historical accounts of the basin, a current understanding of historic impacts to the systems, and knowledge of similar systems with less human disturbance. The second phase of the assessment was to evaluate the present conditions of each subbasin using geomorphic and vegetation mapping in a geographic information system (GIS), Light Detecting and Ranging (LiDAR) data, and channel stability analyses. Conditions of the present setting were compared to the conceptual model of fully functioning conditions to depict how and why physical processes that shape and maintain habitat have changed in the last 100 years. Finally, a qualitative description of how processes may be impacted by restoration and protection actions was documented. This strategy supports the identification of restoration and protection actions that provide the best opportunities for long-term improvements to habitat for spring Chinook and steelhead.

2.0 Conceptual Model of Typical Channel Processes

2.1 Floodplain Types and Channel Dynamics

2.1.1 Introduction

Because limited information is available to characterize the conditions of the river in its pre-development state, a conceptual model of "ideal" or fully functioning conditions was generated through our understanding of the present system, historical accounts of the basin, and current knowledge of similar systems with less human disturbance. Within the Upper John Day River, three general floodplain types were identified, including:

- Wide, unconfined floodplain with high complexity.
- Moderately confined floodplain with medium complexity.
- Narrow, confined floodplain with low complexity.

The degree of complexity within the floodplain refers to the availability of off-channel habitat due to large woody debris (LWD), side channels, wide-ranging vegetation, groundwater inputs, and diverse patterns of hydraulics and sediment. The relative degrees of complexity described in this document refer to the Upper Mainstem John Day River and vary substantially in other basins. For example, a highly complex, wide, and unconfined floodplain within the Upper Mainstem is relative to the floodplains in the assessment area, which differs considerably from the same terminology used to describe the floodplain of the Middle Fork due to large-scale controlling variables of hydrology, geology, and topography.

One data gap of this assessment is our ability to characterize the natural vegetation types and abundance. As such, our understanding of the natural vegetation within the floodplain types has some uncertainty. Each of these following descriptions of floodplain types represent hypothesized fully functioning conditions that could be present in the system.

2.1.2 Wide, Unconfined Floodplain with High Complexity

2.1.2.1 Topographic Features

As described in the geologic characterization of the Upper Mainstem (Section 4.0 of this appendix), the topography over the low surface was defined by glacial movement and development of alluvial fans, which ultimately led to the formation of a "bowl-shaped" valley in the assessment area. Unconfined floodplain areas in this assessment have wide floodplains relative to moderately confined and narrow floodplains (Figure 1). Compared with more confined floodplain types, this type generally consists of flatter slopes and larger supplies of sediment and LWD in storage in the floodplain and river channel (Figure 2). A sinuous main channel could frequently interact with the floodplain through side and overbank channels. This high degree of floodplain interaction provides potential for lateral channel migration and could support the dynamic cycle of conversion from river to floodplain and vice versa. This dynamic process is what could maintain a healthy riparian forest that provides ample shade, complexity, and the ability to re-establish upon new floodplain deposits as others are eroded. Within the floodplains, some areas are older and slightly higher than the active channel, but these areas could likely be activated under repeated or high flow flooding.

Figure 1 – Present Day Photograph near Upstream End of Unconfined Reach UJD3.

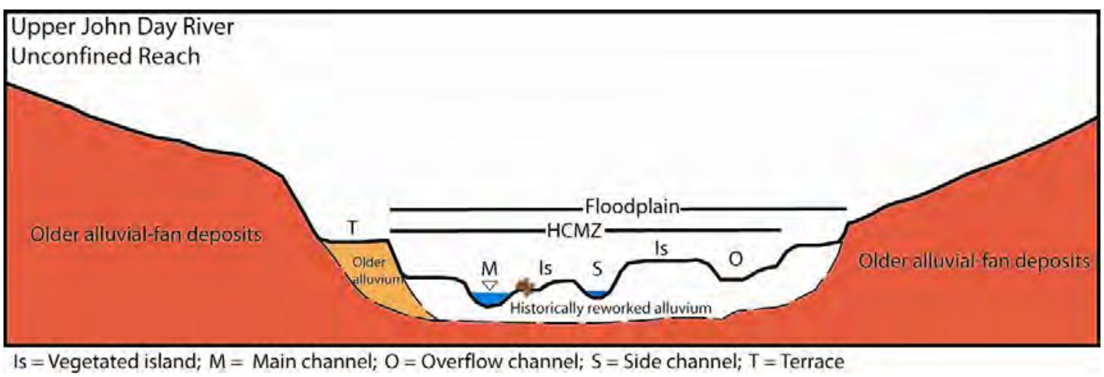

Figure 2 – Schematic Cross Section of a Wide, Unconfined Floodplain in the Upper Mainstem Assessment Area.

2.1.2.2 Groundwater-Floodplain Interaction

The interaction between water in the river and the groundwater table can be an important part of the aquatic habitat. This floodplain type typically consists of alluvium that allows a dynamic interaction between the river and groundwater. High winter and spring flows can inundate the floodplain and become stored within an alluvial aquifer. Beavers can add to the floodplain and channel complexity through the addition of logs and debris dams, which help preserve an inundated floodplain environment during part of the year and add to base flows during lower flow periods.

2.1.2.3 Lateral Migration/Channel Avulsions

Typically, one main channel is probably wetted during low flow conditions, with the potential for connectivity of several side channels. Under larger flow events or over several years, localized patterns of erosion and deposition could occur as the channel migrates laterally across the floodplain. During a single high flood event (greater than a 10-year recurrence interval), a side or main channel could become plugged due the inability of the channel to continue to transport a sediment wave or log jam material downstream. This process could lead to the abandonment of the channel and possibly the creation or enlargement of an alternative path. Channel avulsions have the potential to cause localized changes in channel slopes, but the average channel bed elevations within the reach are typically unaffected over the long term, and no net changes occurs in the total volume of sediment stored in the reach beyond a natural range of fluctuation. This type of floodplain can be in a state of dynamic equilibrium. Following episodic natural events, such as a fire, flood, or mass wasting inputs, the river system adjusts to changes in the balance of wood, sediment, or stream flow through alteration in channel planform, slope, and geometry until a new equilibrium condition is reached.

2.1.2.4 LWD and Riparian Vegetation

In wide, unconfined floodplain areas, erosion of functioning habitat can be as important as the creation of new habitat and could add to the complexity of the new habitat areas. Riparian vegetation and LWD could moderate rates of floodplain reworking within these floodplains. Log jams may become established in the main and side channel areas and at the head of bars, promoting downstream deposition. The unique hydraulic and sediment patterns associated with the log jams cause the formation of deep scour pools that create valuable holding habitat, maintain connectivity with the hyporheic zone, and provide thermal refugia for aquatic species. Log jams can also promote the accumulation of deposits of fine sediment and organic materials, which form a growing medium for vegetation. LWD has the potential to create stable hard points that allow vegetated islands to persist, slow the rate of channel migration across the floodplain, and create backwater habitats. The persistence of vegetated islands and point bars formed as a result of the LWD may be vital to the continued growth of the vegetation, increased channel roughness, and ultimately to the contribution of LWD once it is eroded.

2.1.2.5 Spawning, Rearing, and Holding Habitat

From a biological perspective, the smaller sediment, complexity of channels and floodplain, and presence of LWD creates and maintains more spawning and rearing habitat for steelhead and spring Chinook than other types of reaches. Tributaries and flow through alluvial material (Dad’s and Strawberry Creeks) provide cold water recharge, providing localized patches of high spawning and rearing use. This thermal refugia can be particularly important in river reaches where water quantity is low and temperatures are high during drought years or late summer conditions. Scour holes developed by LWD and root wads can also contribute significant thermal refugia during low flow conditions.

2.1.3 Moderately Confined Floodplain with Medium Complexity

2.1.3.1 Topographic Features

Moderately confined floodplains generally consist of a single main channel and fewer well-defined side channels as compared with the unconfined floodplains (Figure 3). Although the majority of water and coarse sediment can be conveyed through the main channel, some side channels can have enough incoming flow to support habitat. Older surfaces present within the floodplain are slightly higher than the surfaces of the unconfined floodplain (Figure 4). These surfaces may be inundated at a similar frequency as unconfined floodplains due to backwater impacts from downstream geological constrictions, but the floodplain deposits do not have as much potential for reworking as lower, more frequently activated floodplain deposits. Fine sediments, carried in suspension, can be deposited on and transported from floodplain surfaces during different stages of a flood event.

Figure 3 – Present Day Photograph of Moderately Confined Reach UJD2. Note proximity of terrace on the left side of the photograph.

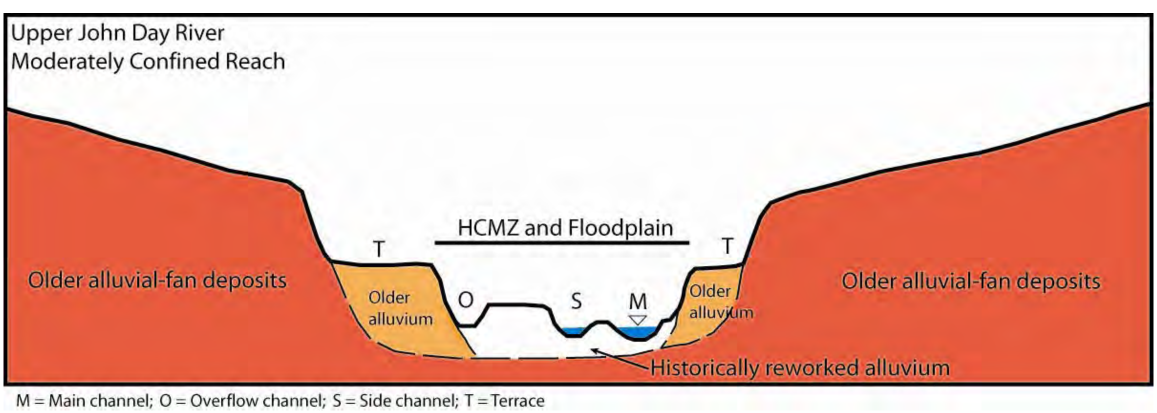

Figure 4 – Schematic Cross Section of a Narrower, Moderately Confined Floodplain in the Upper Mainstem Assessment Area.

2.1.3.2 Groundwater-Floodplain Interaction

Seasonally flooded surfaces can occasionally be present in the off-channel areas of these reaches. High winter flows and spring snowmelt recharge the alluvial aquifers within the moderately confined reaches. Base flows could be supplemented by subsurface flow through Strawberry Creek alluvial fans. The amount of floodplain storage is typically less than that of the unconfined floodplains, but could still aid in maintaining base flows during summer months. The potential for beaver activity exists within the dense riparian areas.

2.1.3.3 Lateral Migration/Channel Avulsions

Compared with unconfined floodplain areas, lateral reworking of the floodplain occurs less frequently in this floodplain type due to a greater percentage of older and higher surfaces and a more limited low surface width. Channel avulsions could more commonly occur within the main channel and possibly within a few defined side channels rather than across the entire floodplain. The main channel probably remains in one place with minor lateral channel adjustment for several years to decades.

2.1.3.4 LWD and Riparian Vegetation

Similar to the unconfined floodplain, LWD and riparian vegetation play an important role in creating both floodplain and off-channel complexity features. With less frequent floodplain reworking, the riparian buffer zone may be thicker than in unconfined reaches. Riparian vegetation slows near-bank velocities, creates shade, provides organic leaf litter and wood recruitment to the channel, and reduces the rate of bank erosion. LWD is most commonly present in the slower velocity off-channel areas. Log jams can frequently occur at the head of vegetated islands as in the unconfined floodplain types.

2.1.3.5 Spawning, Rearing, and Holding Habitat

Moderately confined floodplains generally do not have as much potential for off-channel habitat complexity as unconfined floodplains, but they still contain a wide variety of habitat components and complexity, and support a range of fish species and life cycles. Off-channel areas likely support spawning and rearing of spring Chinook and steelhead. Within the main channel, spawning grounds are suitable for steelhead and spring Chinook and some holding pools provide adequate shade and predation cover for adults. Spawner escapement can be dynamic due to the variability of hydrologic conditions. In lower flow years, redds that establish in riffles and in higher velocity areas have greater potential for success as high freshets can not mobilize and disrupt the nests. However, redds embedded at the edge of the wetted channel may be subject to desiccation. In higher flow years, redds in the riffles could be washed out, but redds at the edges of the channel may have greater success. Holding pools provide thermal refuge during high summer temperatures due to local subsurface inputs from Strawberry Creek alluvium.

2.1.4 Narrow, Confined Floodplain with Low Complexity

2.1.4.1 Topographic Features

The third historic floodplain type consists of confined, straight channel reaches with little to no off-channel habitat (Figure 5). In most confined reaches, adjacent terraces are more pronounced above the floodplain surface than in less confined reaches (Figure 6). These surfaces are likely inundated only during floods that pool in the valley due to backwater impacts from geologic channel constrictions. Channel slopes within confined floodplains are typically higher than slopes in moderately confined and unconfined floodplains, partially due to the inability of the channel to develop meanders through higher, more resistant surfaces.

Figure 5 – Picture of Confined Reach UJD1. Note the houses adjacent to the river surface lie at a higher elevation.

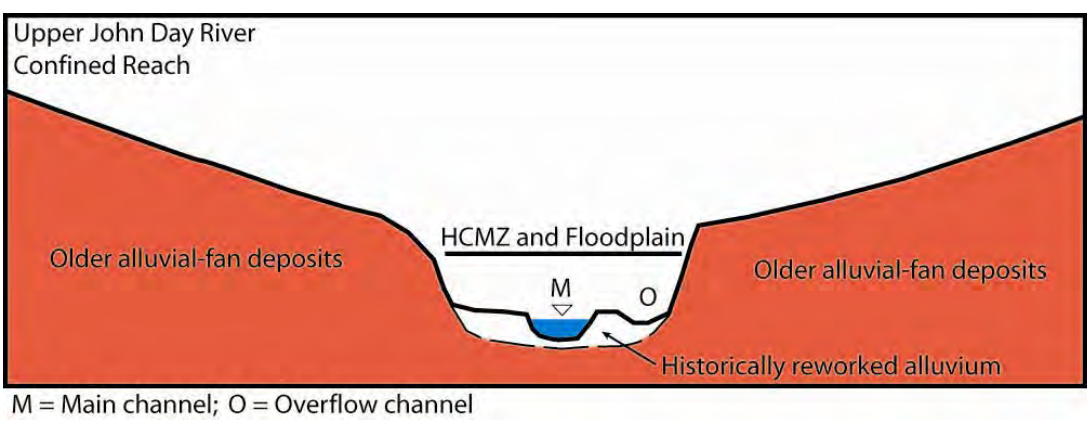

Figure 6 – Schematic Cross Section of a Narrow, Confined Floodplain Section in the Upper Mainstem Assessment area.

2.1.4.2 Groundwater-Floodplain Interaction

The interaction between groundwater and the floodplain within the confined reaches is less pronounced than moderately confined and unconfined floodplain areas due to limited floodplain storage capacity. However, subsurface input to confined floodplain areas from alluvial features could be present. Inputs from groundwater upwellings through the hyporheic zone could augment base flows and provide thermal refugia.

2.1.4.3 Lateral Channel Migration/Channel Avulsions

Within the confined reach, sediment sizes are typically larger than those of moderately confined and unconfined reaches. This reach is likely supply limited and only contains small quantities of sediment in storage for reworking. Potential for lateral channel migration is limited within a small migration zone due to the inability of the channel to mobilize sediments in higher surfaces. Channel migration and avulsions are generally limited and can only occur in localized areas of wider floodplain.

2.1.4.4 LWD and Riparian Vegetation

Most of the complexity within this floodplain type is in-channel habitat complexity, which results from LWD, organic inputs, and variability in sediment sizes. Riparian vegetation may be present along the narrow floodplain surface and on some established sediment bars, providing substantial shade, and moderating bank erosion. This vegetation can be a LWD recruitment source for downstream reaches. LWD could be temporarily present in the channel between larger flood events.

2.1.4.5 Spawning, Rearing, and Holding Habitat

Despite limited off-channel habitat, the confined reach has important habitat functions. While spring Chinook and steelhead may have success spawning in the confined reach, the reach is probably more frequently used as holding and migration corridors to upstream or downstream reaches. Pockets of slower-velocity flows behind occasional boulders provide resting areas. In-channel LWD and dense riparian vegetation provide canopy cover and predation protection to younger age classes.

2.2 Historic Habitat Conditions

Although little data are available to document pre-development aquatic habitat, anecdotal accounts during the early years of settlement and land use changes throughout the basin since the late 1800s indicate that habitat conditions were likely different than today. The John Day Subbasin Plan (NPCC 2005) describes the historical condition of the river as being relatively stable with substantial riparian cover, good summer streamflows, and high water quality. Historical accounts portray the streambanks as having dense growths of aspen, poplar, and willow (Wismmar et al. 1994). Early explorations of the region indicate that summer flows and beaver populations were greater than they are today (Binns 1967).

Under fully functioning conditions, channel erosion rates are moderated by healthy streambank vegetation, large woody debris, and stream energy dissipation due to floodplain connectivity. Flow and sediment transport through the system in a manner that maintains channel planform and geometry without substantial rates of aggradation and degradation over the long term. Beaver may be present in the Upper Mainstem watershed, increasing the availability of LWD for transport and for increased habitat diversity. Similar to the Middle Fork John Day River, the presence of greater quantities of woody debris could result in high-quality pool habitat, side channel connectivity, and overall increased habitat diversity (USFS 1998).

Prior to development, patterns of streamflow were likely different than those of present day. Beaver dams have the potential to significantly impact the storage of water in the floodplain, the subsequent slow release of stored water during base flow conditions, and energy dissipation characteristics during flood flows. The lack of roads in a watershed reduces the opportunity for channelization of runoff and increases interception of flows into the ground. Pre-development streamflow patterns were not affected by water diversions during critical times of the year, which likely increased water quantity and quality required for healthy anadromous fish runs. Year-to-year fluctuations in fish runs may partially depend upon the hydrologic conditions.

The earliest documented habitat surveys on the Upper Mainstem were conducted in the 1940s by the Fish and Wildlife Service. Within the area of this assessment, the surveyors identified numerous spawning riffles of “excellent nature, at least 75 percent of the total bottom area being suitable for spawning.” However, dredge mining activities and temporary irrigation diversion structures in downstream reaches greatly impeded upstream migration of adult fish and acted as passage barriers under low flows. Interviews conducted by the surveyors indicated that salmon had not been seen in the Upper Mainstem for many years, but large runs of both salmon and steelhead were present 25 to 30 years prior.

Most anecdotal reports suggest that fish populations were much greater near the turn of 20th century (Grant 1993; Neal et al. 1999). Some reports describe salmon runs with such ubiquity that a person could not ford the river on horseback without stepping on them (Grant 1993). Table 1 shows estimated historic populations of summer steelhead and spring Chinook. In the Middle Fork and Upper Mainstem, Oregon Department of Fish and Wildlife (ODFW) estimates current fish populations range between 2,500 and 3,000 for summer steelhead and between 900 and 1,400 for spring Chinook. A historic run of fall Chinook has become almost entirely extinct (Wissmar et al. 1994).

The present lack of habitat diversity, high water temperatures, and poor water quality within the stream may in large part be attributed to degradation of the riparian corridor, channel straightening, disconnection of the floodplain and side channels, reduction in beaver populations, mechanical removal of LWD, and reduction in LWD recruitment potential. Although natural disturbance regimes (e.g., fires and floods) likely caused episodic disruptions in habitat quality, the level and persistence of the impacts were not sufficient to result in long-term degradation of habitat conditions in the Upper John Day River.

Table 1 – Professional Judgment Estimated Historic Average Adult Populations (NPCC 2005).

	Summer Steelhead	Spring Chinook
Middle Fork John Day	10,934	7,680
Upper John Day*	10,164	6,280
Total John Day	70,000	40,000

* Upper/Lower John Day split occurs at the confluence of the South Fork John Day

3.0 Delineation of Process-Based Reaches

Process-based reaches were defined primarily by physical characteristics that dominate channel function and shape and maintain habitat features. Initially, geologic controls, such as alluvial fans, were identified through field evaluation of the assessment area. Other physical characteristics used in identifying the reaches included valley confinement, tributary inputs of flow and sediment, and present riparian vegetation. Geomorphic processes that result from the physical characteristics of the river were evaluated to further define reach characteristics. Examples of geomorphic processes include changes in channel form and position, channel slope, sediment transport capacity, and notable areas of erosion or deposition.

Within some reaches, small sections are present that have different characteristics than those of the rest of the reach. These sections are not separated into unique reaches because they do not affect the overall character of the longer reach. These short sections are significant locally, and could affect habitat and potential project alternatives in that area.

Longitudinal boundaries of the reaches are generally located at geologic constriction points, such as large alluvial-fan deposits that impart lateral and often vertical limits to channel change. Geologic controls may influence the transition of channel processes between adjacent reaches. For example, channel position in one reach may be controlled by a downstream constriction point through which the channel must travel. Other processes, such as sediment transport, may not be constricted at these points and depend more on the ability of the downstream reach to transport incoming sediment. Figure 7 illustrates the delineation of three reaches by floodplain type in the Upper Mainstem.

The lateral boundaries of each reach are defined by the extent of the floodplain, often referred to as the “low surface” in this assessment. The low surface is composed of the active channel (unvegetated main channel and sediment bars), side channels, vegetated islands, and the adjacent floodplain.

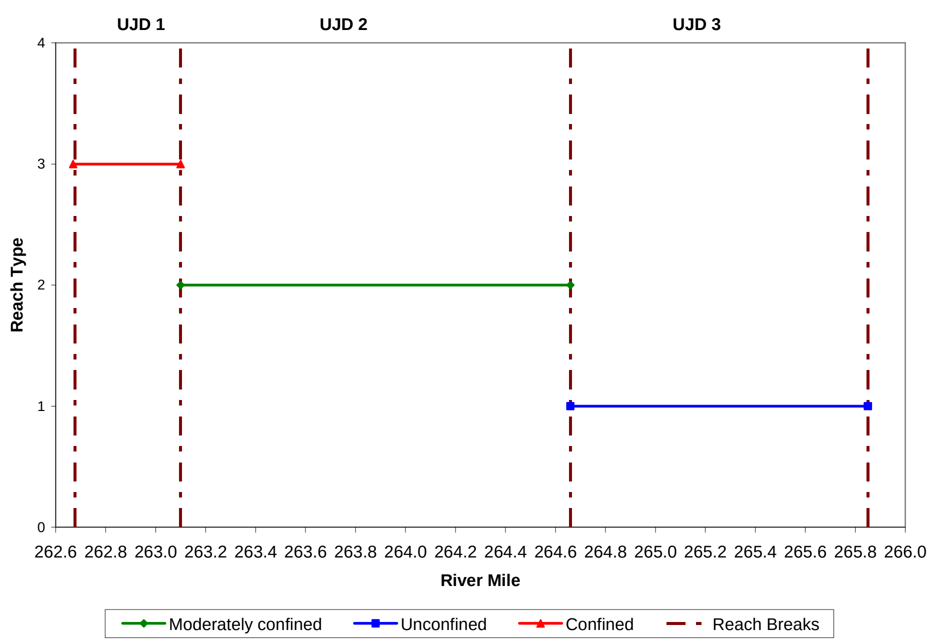

Figure 7 – Delineation of Reaches by Floodplain Type.

4.0 Geologic and Geomorphic Characterizations of the Assessment Area

4.1 Formation of the Upper Mainstem Geology

As previously noted, the Blue Mountains province has experienced extensional tectonic forces related to the oblique convergence of the Pacific and North American plates throughout the Cenozoic era. This extensional deformation initiated the uplift of the Blue Mountains province and created fold and fault (i.e., John Day fault) structures across the region (Walker 1990a). During the late Miocene era and into the Pliocene era, the Strawberry Mountain chain, comprised predominantly of the Strawberry Volcanics (Figure 8), rose 1.5 miles above the valley floor along the John Day and other faults forming the southern John Day valley margin (Thayer 1990). Erosion ensued as the mountains uplifted and enormous amounts of sediment were transported downslope fanning out over the valley floor (fanglomerate deposit of the Rattlesnake Formation). As these alluvial fans built-up along the southern valley margin, the Upper John Day River was forced toward the opposing valley margin.

During the Pleistocene era, alpine glaciers advanced and retreated several times in the upper valleys (above elevation 5,000 feet) along the Strawberry Mountain chain (Thayer 1990). The climate was cooler and wetter during this period, and extensive lakes developed in the southern parts of Oregon. With the increased availability of water (precipitation and ice) the Upper John Day River was probably much larger with more stream power and capable of eroding the fanglomerate that filled the John Day valley.

In the Holocene era, the climate became warmer and drier, and most of the extensive lakes evaporated and only a few alpine glaciers remained in the Strawberry Mountains. With a decrease in the availability of water, the Upper John Day River’s stream power was reduced, limiting the river’s ability to migrate across the valley bottom through the coarser materials (boulders and cobbles) of the fanglomerate. Under the current climatic regime, the river migrates within a narrow floodplain within the broader Pleistocene-age eroded surface. Additionally, finer sediments (sand and fines) are being eroded from the surface of the fanglomerate and are being deposited along the margins of the Pleistocene surface by sheetwash forming a concave-like topography along the length of the Pleistocene surface.

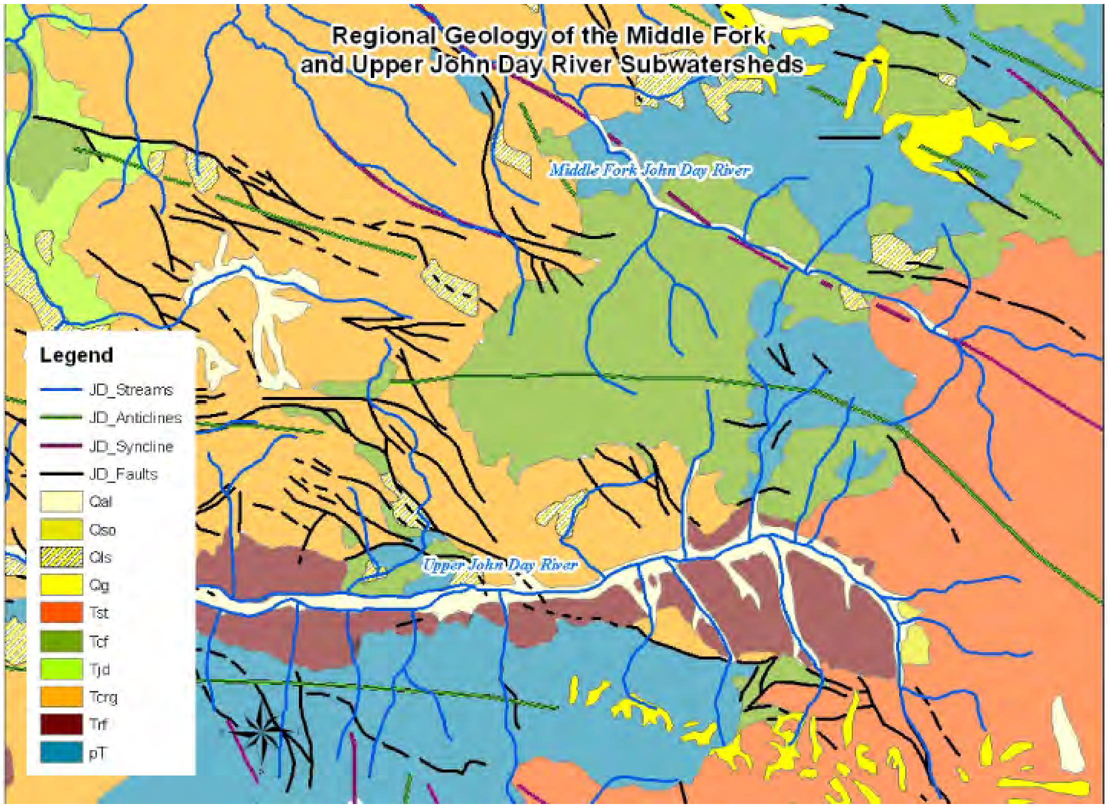

Figure 8 - Regional Geologic Map for the Middle Fork and Upper John Day Drainage Basins. The symbols used in the legend are as follows: Qal – Quaternary alluvium, Qso – Quaternary older sediments, Qls – Quaternary landslide, Qg – Quaternary glacial, Tst – Tertiary Strawberry Volcanics, Tcf – Tertiary Clarno Formation, Tjd – Tertiary John Day Formation, Tcrg – Tertiary Columbia River Basalt Group, Trf – Tertiary Rattlesnake Formation, and pT – pre-Tertiary rocks (modified from Walker 1977).

4.2 Geologic Unit Descriptions

Geologic mapping was done to distinguish various surfaces along the river corridor. Mapping was accomplished using Light and Distancing Infra-red Radar (LiDAR) data, stereo-pair aerial photographs from 2002, and then rectifying the mapping into ARC GIS on 2005 color aerial photographs. Historical aerial photography from 1939, 1956, and 1976 was also used to validate and refine mapping boundaries. Field checking was done by driving and walking along the course of the river within the study reach. This section describes the geologic units that were mapped. Units are broken out by the geologic time period during which they were formed.

4.2.1 Quaternary Deposits

4.2.1.1 Holocene Nonglacial Deposits

Lower Surface – Consists of a mixture of reworked older alluvial deposits comprised of silt- to boulder-size material, but is predominantly sand, gravel, and cobbles. These deposits occur along stream channels and their active floodplains. These materials are unconsolidated and highly susceptible to fluvial erosion.

The lower surface is frequently reworked and inundated by floods. The lower surface generally includes areas with an elevation of less than 1.5 meters above the normal water surface in the active channel.

4.2.1.2 Holocene to Pleistocene Deposits

Alluvial Fan – Comprised of Pleistocene glaciofluvial and Holocene fluvial deposits that form fans on the valley floors. Excessively large fans are interpreted to be glacially generated in that their headwater areas show signs of alpine glaciation and the glacier would have provided the mechanism to transport the amount of sediment necessary to form these fans. Smaller fans, sometimes inset within the much larger fans, are generated by fluvial processes related to ephemeral and perennial streams under the current climatic regime. These materials are unconsolidated and susceptible to fluvial erosion.

Intermediate Surface/ Terrace – Comprised of alluvial deposits that form a series of terrace risers and terrace treads that are elevated between 2.5 to 3.5 meters above normal water surface in the active channel. These surfaces are intermittent throughout the major drainages, but were only locally mapped where they have an influence on the rivers' morphology. This surface is rarely flooded by the river during the current climatic regime. The intermediate surface is considered stable on a decadal time scale. These materials are unconsolidated and susceptible to fluvial erosion.

4.3 Geomorphology of Process-Based Reaches

Geomorphic mapping of the river system was conducted to identify geomorphic patterns within each reach of the river (see *Upper John Day River Map Atlas*). In general, the assessment area transitions from a wide, unconfined floodplain at the upstream end to a narrow floodplain with greater constriction imposed by alluvial fans and intermediate surfaces (Figure 9).

Geological processes that occurred over the past several thousand to tens of thousands of years impose controls on the present channel position and morphology. Throughout the Upper John Day River Assessment Area, geologic controls generally difficult to erode on a decadal time-scale, limit the valley width, provide lateral constraints on the width of meander bends and lateral channel migration, and restrict vertical channel adjustment.

Three geologic controls are present throughout the assessment area. The upstream boundary of the assessment area is located at a geologic constriction in the river induced by an alluvial fan from Jeff Davis Creek. Opposing alluvial fans from Strawberry Creek and Dad's Creek create a lateral control and possibly vertical controls on the channel near the transition between reaches UJD2 and UJD3. Another less pronounced lateral geologic constriction is present at River Mile (RM) 263.1.

The historic channel migration zone (HCMZ) and geologic floodplain areas were mapped for each reach to identify the historic extents of flooding and lateral channel migration. Figure 10 illustrates how the HCMZ and floodplain areas differ in each reach. The total floodplain area is represented by the sum of the HCMZ and the geologic floodplain outside of the HCMZ. The geologic floodplain is differentiated from the current floodplain based on the ability of the channel to inundate its surface. The geologic floodplain represents the lateral extent of the low surface prior to development within the basin.

A description of the general geomorphic characteristics is provided for each reach in the following paragraphs. A general description of vegetation is provided within each reach. Greater detail on the present conditions of and historic changes to riparian vegetation can be found in Chapter 5.4 of this appendix. A compilation of the measured attributes is also provided in Appendix G.

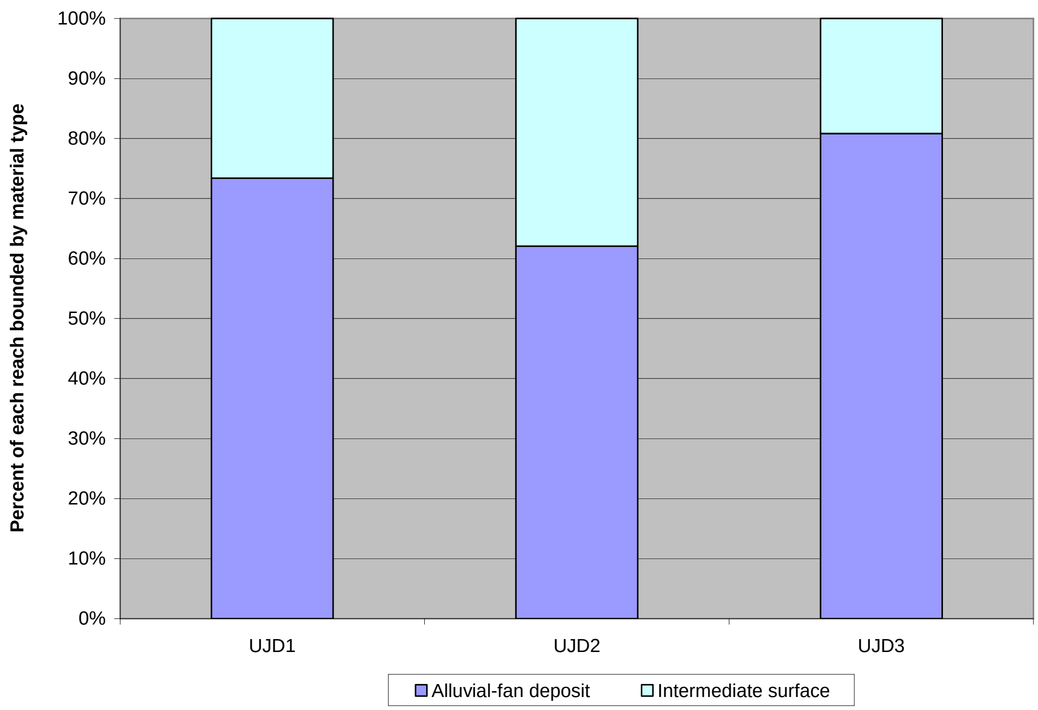

Figure 9 – Geologic Surfaces Bounding the Floodplain in Each Reach.

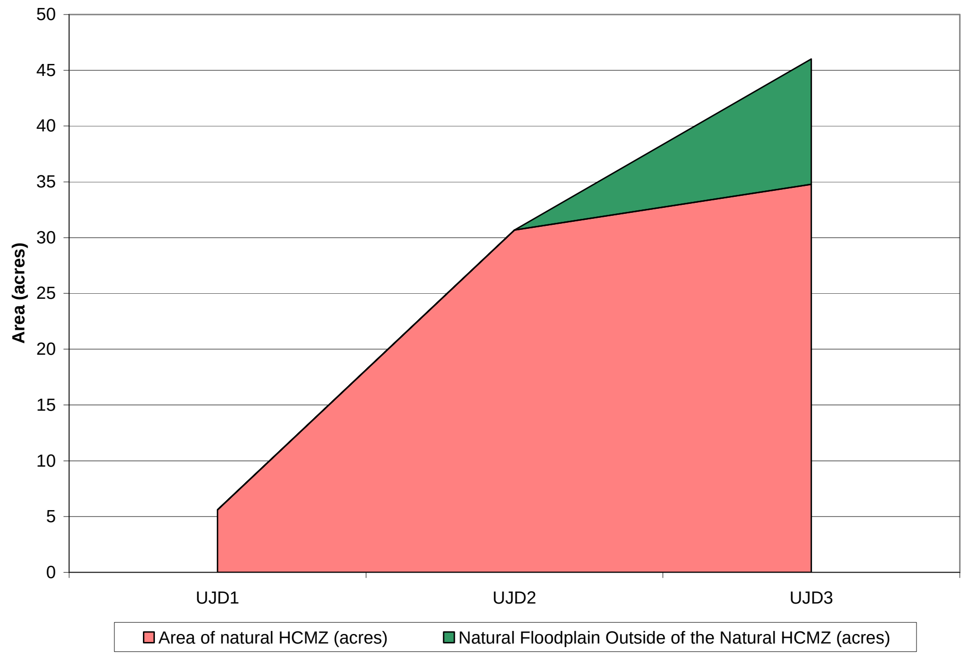

Figure 10 – Total Area of HCMZ and Floodplain Area Outside of the HCMZ. The cumulative value represents the total floodplain area for each reach.

4.3.1 Geomorphic Reach Characteristics

4.3.1.1 Reach UJD3

Reach UJD3 is a 1.1-mile-long, unconfined reach that extends from RM 264.7 to RM 265.81. The very downstream portion of the reach, downstream of RM 264.9, is within the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO) Forrest Conservation Area.

***Reach Boundaries*--** The downstream boundary is at the point where the floodplain width increases. The upstream boundary is at the point where the floodplain width narrows.

***Lateral and Vertical Geologic Constraints*—**The reach is a wide section that is bounded by older alluvial-fan deposits and terraces.

The width of the natural floodplain varies considerably, ranging between about 105 feet and 900 feet wide, with an average width of about 350 feet. The widest sections are between RM 264.85 and RM 264.95 (350 to 445 feet), RM 265.08 to RM 265.1 (405 to 410 feet), RM 265.2 to RM 265.3 (850 to 900 feet), near RM 265.4 (470 feet), RM 265.5 to RM 265.54 (400 to 430 feet), and RM 265.6 to RM 265.73 (450 to 550 feet). Differences in the floodplain widths are probably the result of differential erosion of the unconsolidated deposits bounding the floodplain.

About 80 percent of the natural floodplain is bounded by older alluvial-fan deposits. The remaining about 20 percent of the floodplain is bounded by terraces. Thus, most of the floodplain boundary is erodible to at least somewhat erodible.

Channel Migration (HCMZ) and Floodplain—In the 1939 aerial photographs, the historical main channel was markedly more meandering than the later historical main channels. In the 1956 aerial photographs, the main channel was slightly more meandering than later main channels. Well defined and moderately defined channels are visible on the LiDAR hillshade both north and south of the historical channel path. The natural main channel was probably meandering, and may have had secondary channels. This reach is wide enough in places that the natural HCMZ does not extend to the edge of the natural floodplain in three places on the south side of the floodplain. The natural HCMZ covers about 35 acres, and is about 75 percent of the natural floodplain area (about 46 acres).

Vegetation—Areas of trees and/or shrubs within and adjacent to much of the natural floodplain are visible on the historical aerial photographs (1939, 1956, and 1976). In 2006, the floodplain area south of the river was nearly all open grassland. The floodplain north of the river was either small trees and shrubs or larger trees. Areas of larger trees are prevalent near the channel upstream of RM 265.

4.3.1.2 Reach UJD2

Reach UJD2 is a 1.6-mile-long, moderately confined, slightly sinuous and curving reach that extends from RM 263.1 to RM 264.7. The entire reach is within the CTWSRO's Forrest Conservation Area.

Reach Boundaries-- The downstream boundary is at the upstream end of a narrow section (reach UJD1), where the floodplain begins to widen upstream of this point. The upstream boundary is at the point where the floodplain width increases again.

Lateral and Vertical Geologic Constraints—The reach is a moderately wide section that is constricted by older alluvial-fan deposits and terraces.

The width of the natural floodplain ranges between about 70 feet and 305 feet wide, and has an average width of about 175 feet. The floodplain width varies somewhat within the reach. The narrowest sections are near the downstream reach boundary, and near RM 263.8 in a northwest-trending straight section of the valley. The widest sections (305 feet) are near RM 263.5 and near RM 263.95, where the river has eroded laterally into the older alluvial-fan deposits or terraces.

About 60 percent of the natural floodplain is bounded by older alluvial-fan deposits. The remaining about 40 percent of the floodplain is bounded by terraces. Thus, most of the floodplain boundary is at least somewhat erodible.

Channel Migration (HCMZ) and Floodplain—In the 1939 aerial photographs, the historical main channel was markedly more meandering than the later historical main channels. In the 1956 aerial photographs, the main channel was slightly more meandering than later main channels. One likely older main channel is visible on the LiDAR hillshade south of the river between RM 263.15 and RM 263.25. This reach is narrow enough that the natural channel is interpreted to have had a single, slightly meandering path, perhaps similar to the channel in 1939. The natural HCMZ is interpreted as being coincident with the natural floodplain.

***Vegetation*—**Areas of trees and/or shrubs are visible on the historical aerial photographs (1939, 1956, and 1976) within and adjacent to the natural floodplain along much of the reach. In 2006, the floodplain area was primarily open grassland. Small areas with larger trees were present near the downstream and upstream ends of the reach. Areas of small trees and shrubs were present near RM 263.8, at the center part of the reach.

4.3.1.3 Reach UJD1

Reach UJD1 is a 0.4-mile-long, confined, somewhat sinuous reach that extends from RM 262.67 to RM 263.1.

Reach Boundaries-- The downstream boundary is located at the upstream Prairie City Bridge. The upstream boundary is at the upstream end of the narrow section, where the floodplain begins to widen upstream of this point.

***Lateral and Vertical Geologic Constraints*—**The reach is a narrow section that is constricted by older alluvial-fan deposits. The width of the natural floodplain ranges between about 105 feet and 200 feet wide, and has an average width of about 145 feet. The floodplain width is fairly consistent throughout the reach, except for the section between RM 262.9 and RM 262.93, where the floodplain width is between about 175 and 200 feet.

About 75 percent of the natural floodplain is bounded by older alluvial-fan deposits. The remaining 25 percent of the floodplain is bounded by terraces. Thus, most of the floodplain boundary is at least somewhat erodible.

The right bank of the channel runs against alluvial deposits for most of the reach, except at RM 262.76 and 262.85. The left bank of the channel runs against older alluvial fan deposits at two locations delineated by RM 262.90 and 263.05.

***Channel Migration (HCMZ) and Floodplain*—**In the 1939 aerial photographs, the historical main channel meandered more than the main channel in later years. Additional possible main and secondary channels are not visible on the LiDAR hillshade. Because this reach is so narrow, the natural main channel is interpreted to have had a single, slightly meandering path, perhaps similar to the main channel in 1939. The natural HCMZ is interpreted as being coincident with the natural floodplain.

***Vegetation*—**Areas of trees and/or shrubs are visible on the historical aerial photographs (1939, 1956, and 1976) north of the river and partially within the floodplain upstream of RM 262.85, and south of the river and partially within the floodplain upstream of RM 263. In 2006, the floodplain area was covered primarily with large and small trees and shrubs. Areas of open grassland were present upstream of 262.85.

4.4 Sediment Sources

Fine sediment is supplied to the system through sheet and rill erosion from croplands, pediments, and subdrainages that have been disturbed by timber harvest, road construction, and agriculture. The fine sediments are being transported downslope to the Upper John Day River during spring runoff and also by agricultural practices (i.e., flood irrigation). Other fine sediment sources include ephemeral and perennial streams during spring runoff. Many of the perennial streams are diverted for irrigation purposes for a portion of the year.

Coarse sediment is primarily supplied from bank erosion along the mainstem and possibly episodic “sediment slugs” entering the Upper John Day River upstream of the assessment area. Some loading of coarse sediment may also be supplied by Dad’s Creek and Strawberry Creek based on the presence of bars immediately downstream of their confluences with the John Day River. Removal of riparian vegetation along the river may have destabilized the riverbanks, and bank erosion appears to have been a chronic problem based on interpretations of historic aerial photographs. Bank protection and river channelization methods were used to reduce bank erosion and to restrict lateral channel migration.

Other potential sediment sources include disturbed areas associated with historical placer mining. Placer mining was conducted along Dixie Creek and on the Upper John Day River downstream of Dixie Creek.

In general, the groundcover and riparian corridors on private lands do not appear to be recovering from historical timber harvests, mining, and grazing practices. Implementation of best management practices could significantly reduce erosion rates.

5.0 Present Setting

This section describes the present river setting and how current processes may have been altered from the conceptual model of the fully-functioning conditions as described earlier in this appendix. The discussion focuses on trends in physical river processes that are tied to channel morphology and habitat complexity. Channel morphology can change over time as a result of natural or human-induced alteration to upstream reaches, or due to local impacts within the reach itself. Key factors determining the channel morphology in each reach include geologic controls, hydrologic regime, sediment inputs and transport, riparian vegetation, and LWD recruitment. Processes can also change due to localized alterations in the hydraulic capacity (channel geometry and floodplain accessibility) due to human influences, such as bridges, levees, and riprap. The following discussion presents a brief overview of channel dynamics followed by a detailed investigation of the current hydraulics and sediment transport of the assessment area, a description of how anthropogenic activities have impacted the conditions of each reach, and finally an assessment of the current state of vegetation.

5.1 Brief Overview of River Processes

Over time, streams attempt to move toward an equilibrium condition to balance energy available with energy needed to transport incoming sediment. Dynamic equilibrium is often referred to as the condition where the net incoming sediment supply approximately equals the sediment transported out of a reach over a given period of time. In this scenario, incoming discharge may alternate between wet and dry cycles, but there is no definitive trend in flow peaks or duration over a decadal time period. Additionally, short-term changes in the channel bed position and elevation can still occur, but net change in channel form or bed elevations for a given reach cannot be detected over years to decades. For example, a channel may migrate across its floodplain causing the existing channel to at least partially fill with sediment as the channel is abandoned. Concurrently, a new channel is eroded or converted from floodplain to channel area. At any one location in the floodplain during this process, an observer could note erosion or aggradation, but the overall sediment in storage within the reach would not have significantly changed.

A simplified version of this concept can be described using Lane's balance of water and sediment (Lane 1955; Figure 11). In Lane's conceptual figure, the river's ability to remain in equilibrium is dependent on the ability to transport incoming sediment supply given a quantity of water.

According to Lane's balance, water discharge and sediment load are inversely related as a function of channel slope and sediment size:

$$QS \sim Q_s D_{50}$$

Where:

Q = water discharge,

S = channel slope,

Q_s = sediment load, and

D_{50} = sediment size.

A change in any one of these four variables will result in a change in the others in order to restore equilibrium to the system. Once a channel has reached a state of equilibrium, sediment is transported through the reach without substantial aggradation or degradation. However, this equilibrium is dynamic in that a channel has the potential to migrate laterally through erosion of one bank and accretion of the opposite bank at a similar rate. Natural or man-induced changes in the incoming sediment load, water discharge, slope, or sediment size can offset the balance and result in changes in channel morphology. Channels can respond to changes through lateral (widening or narrowing) or vertical adjustment (incision or aggradation) or through modified rates of channel migration and floodplain reworking.

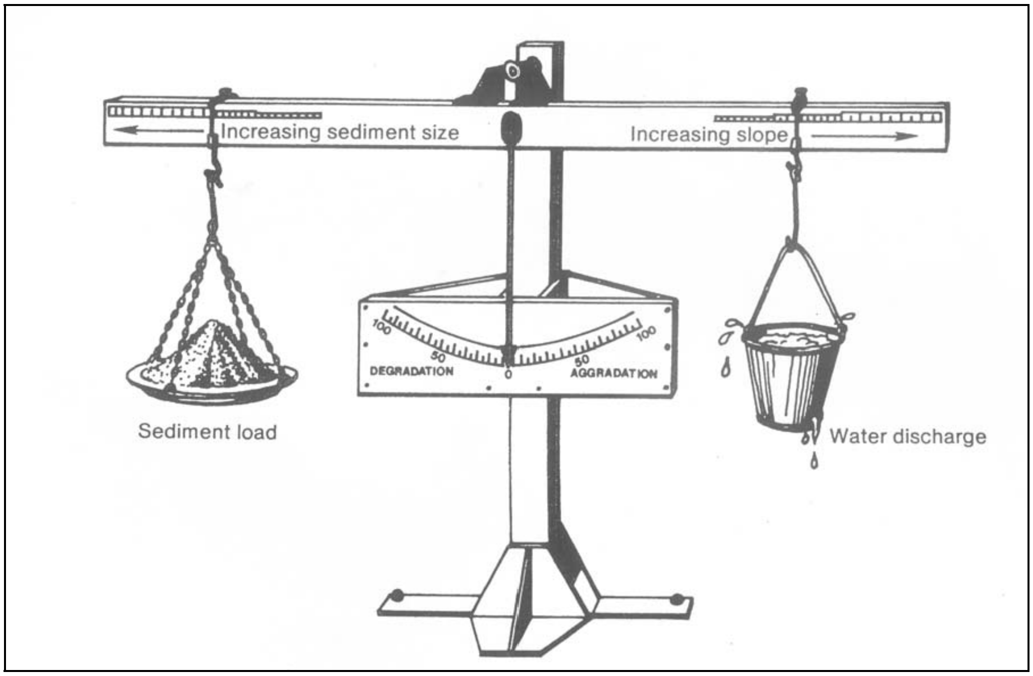

Figure 11 – Illustration of Channel Response to Varying Incoming Sediment Load and Water Based on Sediment Transport Capacity Within the Reach (Lane 1955).

5.2 Anthropogenic Impacts on Reach Conditions

Anthropogenic activities have been occurring for over a century in the basin. Appendix A provides a timeline of human activities in the basin and their general impacts to river conditions. This section is intended to provide a detailed look at how constructed features and anthropogenic activities have directly impacted the geomorphology of each of the reaches. This discussion is followed by a description of cattle grazing in the general vicinity of the assessment area since cattle grazing activities are hypothesized to have historically impacted riparian vegetation and possibly in-channel habitat complexity features. A compilation of the measured human impacts is provided in Appendix G.

In the Upper Mainstem Assessment Area, the greatest impacts to channel processes have been topographic in nature and result primarily from ranching, grazing, timber harvest, and flood control measures. The locations and types of constructed features are presented in Chapter 4 of the main report. In general, constructed features within the floodplain, predominantly consisting of levees, rock spurs, riprap, roads, railroads, and bridges, limit lateral migration of the channel and access to side and overflow channels. These features have had the largest impact on habitat complexity in moderately confined reach UJD2 and unconfined reach UJD3.

5.2.1 Reach Descriptions

Mapping of constructed features, also termed human features, was conducted throughout the assessment area using field observations, aerial photography, and LiDAR. Although attempts were made to document every constructed feature present in a reach, time and physical access to each reach precluded detailed ground truthing of every feature. In some locations, aerial photographs and LiDAR were the only methods available to identify potential human features.

5.2.1.1 Reach UJD3 - RM 264.7 to RM 265.81

Summary

Possible artificially blocked or filled channels and levees, along with bank armoring, have the most impact on the HCMZ and channel migration in reach UJD3. Nearly 23 acres of the HCMZ (66 percent) are impacted. About 600 feet of former channel paths are disconnected by levees and about 5,000 feet of channel has been straightened and/or are confined. Off-channel areas (e.g., overflow channels and areas) also are disconnected.

Several types of constructed features are present along the entire length of reach UJD3. These features include levees, two diversions and irrigation ditches, riprap, rock spurs, blocked or filled channels, and unimproved roads. The constructed features, often in combinations, impact about 23 acres of HCMZ. The impacted areas are on both sides of the present channel, and are nearly continuous along the reach. The constructed features disconnect about 610 feet of former main channel paths. About 5,073 feet of channel is confined and cannot migrate naturally. The constructed features also disconnect about 2.2 acres (20 percent) of floodplain outside of the HCMZ.

Constructed Features

- **Bank Armoring:** Channel banks are armored by about 1,100 feet of riprap and by 16 rock spurs. These are present intermittently along the entire reach. Bank armoring impacts the HCMZ and decreases channel complexity.
- **Levees:** About 1,180 feet of levees are present in the reach. They are often along or near the present channel. They disconnect former main channels or contribute to bank armoring, impacting the HCMZ and channel migration. They create a straighter channel by cutting off former meanders.
- **Blocked or Filled Channels:** Possible artificially blocked or filled channels appear to be present in seven localities in the reach. These channels were former main channels that are no longer connected to the present main channel. By disconnecting the channels, the artificially blocked channels impact the HCMZ and channel migration. They create a straighter channel by cutting off former meanders. These areas need to be checked in the field.

- **Diversions and Irrigation Ditches:** In two places (RM 264.74; RM 265.66), diversions and about 1,140 feet of irrigation ditches, usually along with riprap or levees, impact the HCMZ and channel migration.
- **Unimproved Road:** Upstream of RM 265.6, an unimproved road is on river left near the present channel. It crosses blocked channel paths. Sections of the road are protected by riprap, levees, or rock spurs. The unimproved road (about 1,050 feet total length) and associated bank armoring impact the HCMZ. Channel migration also is impacted by confining the channel.

HCMZ and Channel Migration

About 23 acres of HCMZ are impacted by the constructed features, which is about 65 percent of the total HCMZ area. Bank armoring, diversions and irrigation ditches, and channels that are disconnected from the present main channel either by possible artificial fill or levees limit channel migration and modify the natural meandering planform by restricting the location of the channel. About 5,073 feet of channel are confined which is 86 percent of the total 2006 channel length. Two meanders that were part of the main channel in 1939 have been blocked, and one meander of the 1956 channel path has been blocked.

Channel Planform

Moderate changes were noted in channel length and sinuosity in the reach. Between 1939 and 1956, no change was detected in channel length despite considerable differences in channel positions. Between 1956 and 1976, the channel length decreased by 325 feet, which is a 5.3 percent decrease in total channel length and sinuosity. This reduction may be attributed to the installation of rock spurs, levees, and riprap that was installed following the 1964 flood event. These constructed features are present at a greater density in reach UJD3 than in reach UJD2. Between 1976 and 2000, the channel increased in channel length by 200 feet, possibly resulting from adjustment to previous channel straightening. Channel adjustment likely entailed lateral movement of meander bends in unrestricted locations. The channel decreased by 165 feet between 2000 and 2006 due to an apparent avulsion near RM 265.25. Qualitative assessment of the two photosets indicates continued meander evolution and migration in several locations. The net decrease is channel length between 1939 and 2006 was 270 feet, which equates to a 4.4 percent decrease in total channel length and sinuosity.

Floodplain Access

The constructed features disconnect about 2.2 acres of floodplain outside of the HCMZ. The total acreage is split between two areas, both on river left, consisting of 1.5 acres between RM 265.6 and RM 265.8 and 0.75 acres between RM 264.88 and RM 265.

Bank Erosion

Two areas of erosion along a total length of about 375 feet of bank are present downstream of RM 264.9. One area that is about 180 feet long is on river left between RM 264.8 and RM 264.83. The other area that is nearly 200 feet long is on river right between RM 264.87 and RM 264.9 at the mouth of Old Dad’s Creek and downstream. The erosion is occurring in a section downstream of RM 265, where levees block access to two former main channels, one that was active main channel in 1939.

5.2.1.2 Reach UJD2 - RM 263.1 to RM 264.7

Summary

Possible artificially blocked or filled channels and levees, along with bank armoring, have the most impact on the HCMZ and channel migration in reach UJD2. Nearly 10 acres of the HCMZ are impacted and nearly 3,200 feet of former channel paths are disconnected. About 4,500 feet of channel has been straightened and/or are confined. Off-channel areas (e.g., overflow channels and areas) are also disconnected.

Constructed features in this reach include riprap, levees, rock spurs, possible artificially blocked or filled channels, two diversions and irrigation ditches, embankments, a bridge, and unimproved roads. Three short sections, which are geologically narrow compared to the rest of the reach, have no known constructed features (RM 263.27 to RM 263.4, RM 263.73 to RM 263.8, RM 264.03 to RM 264.09). In the intervening slightly wider sections (RM 263.4 to RM 263.73, RM 263.8 to RM 264.03, RM 264.09 to RM 264.7), constructed features are present on both sides of the present channel. The downstream section has riprap, rock spurs, levees, and a bridge where an unimproved road crosses the river. The middle section has levees, possible artificially blocked or filled channels, riprap, and small embankments. The upstream section has levees, two diversions and irrigation ditches, riprap, rock spurs, and possible artificially blocked or filled channels. The constructed features, often in combinations, disconnect 11.3 acres of the HCMZ and floodplain and about 3,150 feet of former main channel paths. Nearly 4,500 feet of channel is confined and cannot migrate naturally. Of this length, about 690 feet of channel has been straightened.

Constructed Features

- **Bank Armoring:** Channel banks are armored by about 1,420 feet of riprap and by 16 rock spurs. These are present intermittently along the entire reach. Bank armoring impacts the HCMZ and decreases channel complexity.
- **Levees:** About 1,525 feet of levees are present in the reach. They are often along or near the present channel. They disconnect former main channels or contribute to bank armoring, impacting the HCMZ and channel migration. They create a straighter channel by cutting off former meanders.
- **Possible Artificially Blocked or Filled Channels:** Possible artificially blocked or filled channels appear to be present in eight localities in the reach. These channels were former main channels that are no longer connected to the present main channel. The artificially blocked channels impact the HCMZ and channel migration and create a straighter present channel by cutting off former meanders. These areas need to checked in the field.
- **Diversions and Irrigation Ditches:** In two places (RM 264.23 to RM 264.29; RM 264.54 to RM 264.61), diversions and about 500 feet of irrigation ditches, usually along with riprap or levees, impact the HCMZ and channel migration.
- **Bridge and Embankments for Unimproved Road:** At RM 264.43, an unimproved road crosses the channel. Embankments leading to the bridge are protected by riprap. The bridge and embankments (about 850 feet total length) impact the HCMZ. Channel migration also is impacted by restricting all flow to the bridge, and confining the channel in this position.

HCMZ and Channel Migration

About 11.3 acres of HCMZ in this reach are impacted by the constructed features. This is about 37 percent of the total HCMZ area. Bank armoring, a bridge and embankments, and channels that are cut off from the present main channel either by artificial fill or levees limit channel migration and modify the natural meandering planform by restricting the location of the channel.

Channel Planform

Reach UJD2 is the most impacted reach of the assessment area. Between 1939 and 1956, substantial constructed alterations to the channel occurred, including apparent denudation of riparian vegetation combined with channel straightening. During this 20-year period, the channel length decreased by 1,200 feet. Between 1956 and 1976, the channel length increased slightly, although continued channelization activities were present. Between 2000 and 2006, the channel length has continued to increase 330 feet through the elongation of several meander bends. The net change in channel length and sinuosity is a reduction of 760 feet or 8.3 percent.

Floodplain Access

Because the reach is so narrow, the floodplain coincides with the HCMZ. In areas where former main channels are disconnected, adjacent surfaces and overflow channels that may have received flood flows also are disconnected.

5.2.1.3 Reach UJD1 - RM 262.67 to RM 263.1

Summary

The main impact to geomorphic processes in reach UJD1 is the riprap that armors the banks downstream of RM 262.95. The riprap disconnects about 1.5 acres of the HCMZ and floodplain, disconnects about 1,320 feet of former main channels, and straightens and confines about 1,460 feet of channel.

Downstream of RM 262.96, at least one bank has been armored with riprap. Between RM 262.96 and RM 262.89, riprap is along the left bank only. Downstream of RM 262.89 to the downstream reach boundary at RM 262.67, riprap is along both banks. The riprap cuts off about 1.5 acres of HCMZ and floodplain. The channel cannot migrate where the riprap has been placed. About 1,460 feet of the channel has been artificially straightened and channel position is confined by the riprap. A highway bridge at the downstream reach boundary also restricts channel position. The upstream 0.14 miles of reach UJD1 (RM 262.96 to 263.1) do not include any mapped constructed features, and except for alteration of the vegetation, this section of the reach may be functioning.

Constructed Features

- **Bank Armoring:** About 2,615 feet of riprap has been placed along both sides of the channel downstream of RM 262.67, and along the left bank between RM 262.67 and RM 262.89. The 451-foot-long section of riprap on the right bank downstream of RM 262.89 is along the HCMZ and floodplain boundary, so may have minimal impact on channel migration. The remainder of the riprap disconnects about 1.5 acres of HCMZ and floodplain. As shown in the 1939 and 1956 aerial photograph sets, the main channel previously meandered into these areas. The riprap disconnects nine former channel meanders with a total length of 1,322 feet. About 1,460 feet of channel downstream of RM 262.96 has been straightened and is confined. The present channel in this section cannot migrate.
- **Highway Bridge:** The highway crosses the channel at the downstream reach boundary at RM 262.67. Its primary influence on reach UJD1 is that is confines the channel at this point. It may be that the riprap in reach UJD1 was placed to direct the channel toward the bridge and ensure that this channel position is maintained.

HCMZ and Channel Migration

The riprap that lines one or both banks downstream of RM 262.96 has disconnected about 1.5 acres of the HCMZ and adjacent floodplain. Of this disconnected area, 1.1 acres is on the left side of the river (looking downstream), and 0.4 acres is on the right side. The disconnected area is 27 percent of the entire HCMZ area in the reach. Nearly all of the HCMZ is disconnected downstream of RM 262.96. About 1,460 feet of channel has been straightened and is now confined by riprap, which disconnects nine historical meander bends from the present channel.

Channel Planform

Reach UJD1 was significantly impacted by constructed modification over the last century. Between 1939 and 1956, the channel length was reduced by over 200 feet, which amounts to a 9 percent decrease in channel length and sinuosity. This decrease appears to be related to channelization activities along the channel banks. Between 1956 and 1976, the channel length increased by 145 feet, due to adjustment to channel straightening and regeneration of mild channel meanders. Very small changes in channel length occurred between 1976 and 2006. Today, a large portion of this reach is lined with riprap along both banks. The net change in channel length between 1939 and 2006 was a reduction of 100 feet, which is a 4 percent decrease in length and sinuosity.

Floodplain Access

The riprap disconnects 1.5 acres of floodplain downstream of RM 262.96. This area includes several disconnected main channel paths and is entirely within the HCMZ. Areas near the disconnected main channel paths that flooded during higher flows are no longer accessible, and all flow is constrained to the present main channel.

5.2.2 Cattle Grazing

Throughout the United States, channel erosion and degradation of the riparian zone have been linked to cattle grazing. These impacts directly affect water quality, water temperature, channel morphology and streamside vegetation and debris inputs, which have a substantial influence on habitat for anadromous fish and other aquatic species (McDowell and Magilligan 1997). In the past two decades, management practices have been employed to effectively reduce the impacts of grazing on stream habitat. These practices are not ubiquitous, and many streams continue to degrade or remain in a degraded state as a result of continued cattle grazing.

A study of eight streams in Eastern Oregon found that grazed reaches were typically characterized by greater widths, greater width to depth ratios, decreased low flow depths, and decreased pool area compared with reaches with cattle exclosure practices (McDowell and Magilligan 1997). Cattle exclosures also tended to have narrower bankfull channels, increased riparian vegetation, and greater bank stability.

Within the Upper John Day River, grazing may have considerably influenced channel morphology and riparian conditions. Sheep were more prevalent than cattle throughout the basin from the late 1800s to the middle 1900s. By the 1940s, as transportation routes improved and cattle were hauled with greater ease, domestic grazing became dominated by cattle and continues to be today (Figure 12; USFS 1998). Streamside vegetation and bank stability within Reaches UJD2 and UJD3 have been notably altered by cattle grazing and trampling. Where cattle grazing was persistent for decades, the channel is wider, shallower, and less complex than ungrazed segments (Figure 13). Erosion of unvegetated banks contributes increased amounts of fine sediment, while degraded riparian vegetation and reduced canopy cover have lead to decreased stream shading and increased potential for solar heating.

Today, cattle grazing is moderated within the assessment area. Fences are present that prevent cattle from entering the stream, but the riparian corridor remains open to grazing and little woody vegetation is present to protect. The complexity of the grazed reaches is diminished from historic conditions and pool habitat is limited. Unvegetated banks, vulnerable to erosive fluvial forces, are degrading at rates that are likely increased from historic conditions (Figure 14). While these impacts are not the sole result of cattle grazing, land use and management has influenced current channel conditions.

Year	Sheep	Cattle	Horses/Mules	AUMs
1895(1)	119,926	18,013	9,299	53,622
1965(2)	6,500	59,700	2,500	64,125
2001(2)	400	54,000	2,500	57,205

(1) Grant County News 1895 as reported in the *History of Baker, Grant, Malheur and Harney County*.
(2) *OSU Extension Reports*

Figure 12 – Estimated Historic Numbers of Livestock in Grant County. AUMs represent animals units months. (From UJDLAC 2002)

Figure 13 – Wide, Shallow River Devoid of Woody Vegetation in Reach UJD2. This condition may result from historic grazing impacts.

Figure 14 – Example Showing How Unvegetated Banks are More Susceptible to Erosion.

5.3 Hydraulic and Sediment Transport Analysis

An integral step in defining sustainable restoration strategies is to develop an understanding of the hydraulics and sediment transport dynamics of a system. Evaluation of a river's flood hydraulic and sediment transport regimes was completed in this geomorphic investigation as a foundation for future assessments and project implementation. Results from the hydraulic and sediment transport analyses will help address several of the existing hypotheses related to channel stability. At the beginning of the study, the multi-disciplinary channel assessment team, combined with local stakeholders, identified multiple hypotheses related to how hydraulics and sediment are currently functioning in the Upper Mainstem John Day River. The group hypothesized that the river has become wider and straighter than historical conditions due to constructed features located within the floodplain, historical management activities, and substantial changes in land use from pre-development conditions. Analyses were conducted to further define the flood hydraulics and sediment transport of the system through the following tasks:

- Evaluate the frequency that the channel is accessing its floodplain.
- Evaluate the frequency that bar and bed material are being reworked.
- Characterize how sediment is transported through the system.
- Determine locations where historical rates of sediment transport may have been altered.
- Characterize the present channel stability and determine if the channel is significantly incised.
- Identify potential for degradation or aggradation within the assessment area.

5.3.1 Methods

5.3.1.1 Hydrology

The hydrology study in Appendix C provided the information used in modeling the 2- through 100-year flood events. A geographical information system (GIS) was developed based on regional regression equations for northeastern Oregon because insufficient gage data were available to characterize the peak flows throughout the basin. Within the GIS, subbasins were delineated with a minimum area of 2 square miles. For each subbasin, the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals were calculated. These flows were imported into the one-dimensional hydraulic model for steady flow analysis. Flows due to groundwater and irrigation diversions were not considered in this analysis and are not expected to markedly influence the magnitude of flood flows.

5.3.1.2 Topographic Data

Surveys have been conducted over multiple years on the Upper Mainstem John Day River. Although each survey was not necessarily performed for the present investigation, all available survey data were incorporated into this analysis.

Ground Surveys

Between August and December of 2005, topographic surveys were collected on the Forrest Conservation Area on the Upper Mainstem. These surveys entailed detailed cross sectional surveys through the river into the floodplain and sufficient points between cross sections to generate breaklines and 2-foot contours in the areas of specific project locations.

Following identification of the need for a larger-scale geomorphic assessment in early 2006, additional ground surveys were requested to develop a longitudinal profile through the extents of the geomorphic assessment area. The geomorphic assessment area encompasses the specific project sites on the Forrest Conservation Area and approximately one mile upstream and downstream of the property. Selection of the extents of profile survey was also dependent on land owner access and potential land owner involvement in future project locations. In October 2006, longitudinal profile surveys were collected along the active channel thalweg spaced such that the bottom of each pool and the top of each riffle were identified, with a maximum distance of 100 feet between points.

A substantial flow event occurred during spring runoff in 2006, potentially modifying previously existing ground surface features as surveyed in the 2005 surveys. As a result, several cross sections needed to be resurveyed to record changes that may have occurred. On the Forrest Conservation Area, several cross sections of the river were resurveyed.

LiDAR

Light Detection and Ranging (LiDAR) data were acquired in October 2006 to identify ground surface elevations, infrastructure, and vegetation within the floodplain of the study area (Watershed Sciences 2006). Quality control data were collected within the project area using a ground-based real-time kinematic (RTK) survey and were compared to the processed LiDAR data to evaluate LiDAR accuracy across the project area. The root mean square error was reported as 0.069 meters based on a comparison of the LiDAR and RTK surveys.

5.3.1.3 Triangulated Irregular Networks (TIN) Development

Both the ground survey data and the LiDAR were combined to create the triangulated irregular networks (TIN) used for the one-dimensional hydraulic model. LiDAR points within the wetted channel area were removed due to the inability of the technology to collect underwater data; however, sufficient ground survey data were available to develop the necessary geometry of the channel for one-dimensional modeling. The channel geometry within the Forrest Conservation Area has greater accuracy than upstream and downstream areas due to the large amount of ground survey data collected. Channel geometries outside of the conservation area are based on interpolated points between the channel banks, the edge of the water surface, and the thalweg. Since LiDAR was acquired during low flows, the conveyance area based on the interpolated points is sufficient for modeling high flows. Modeling of low flows or two-dimensional modeling may require additional survey data, particularly outside of the Forrest Conservation Area.

Within the upstream end of the assessment area, the geometry of the channel and LiDAR were problematic with the one-dimensional modeling due to the TIN producing equal or lower ground surface elevations within the floodplain than in the channel. Further investigation of the ground surface in this location is recommended to identify if the channel is slightly perched or if the LiDAR's ability to accurately represent the ground surface in this area was limited.

5.3.1.4 Cross Sections

Cross section geometry was developed from a TIN of the assessment area. Within ArcGIS, HEC-GeoRAS was utilized to convert two-dimensional line files to cross sections having elevation values. Cross sections were approximately spaced every 200 to 300 feet longitudinally along the channel. To capture the hydraulic controls of the channel, at least one cross section was located across every known riffle. Widths of the cross sections varied slightly, but all cross sections were intended to cover the extents of a 100-year flow event. The cross sections were imported into a one-dimensional HecRAS model and then filtered to reduce the number of points to 500 (maximum allowable). This was completed within HecRAS using a filtering methodology that minimized the change in the area of the channel geometry.

5.3.1.5 Slope Analysis

An analysis of river profile was conducted to evaluate substantial vertical geologic controls and identify potential changes in sediment transport through the system. The surveyed longitudinal profile of the channel thalweg was used to evaluate the channel slopes. Slope data were processed in Microsoft Excel after extrapolation using ArcGIS. Slopes were computed first by visual breaks in grade. Slopes breaks were determined based on notable changes in grade along the longitudinal profile. Slopes were also computed for each reach for comparison with the visual breaks in grade.

5.3.1.6 Sediment Sampling

In order to address specific study questions related to sediment transport, sediment samples were collected by both surface sampling and volumetric sampling methods (Bunte and Abt 2001). Surface sampling entails measurement of surface particles, while volumetric sampling entails measurements of bed material layers (e.g., armor layer, subarmor layer, surface layer, subsurface layer). Pebble counts were selected as the most appropriate surface sampling technique for this study based on study questions, time and budgets constraints. Volumetric sampling included collection of surface and subsurface layers at select locations.

Pebble Counts

Channel bed and bar sediments were sampled using pebble counts at seven locations along the Upper Mainstem Assessment Area. For in-channel pebble counts, Wolman (1954) sampling methods were applied, in which the pebble counter selects a particle from beneath the tip of his or her boot while looking away. This method is most appropriate for in-channel measurements where laying out a systematic grid would be difficult. Pebble counts performed on gravel bars were performed using systematic sampling at even spaced marks along a measuring tape. In most areas, the spacing was 0.5 feet. Bars that were relatively small in length often required multiple transects to complete a minimum of 100 counts.

A US SAH-97 gravelometer (Potyondy and Bunte, 2002) was used in the measurement of each particle size. Research indicates that template measurements are expedient, provide higher accuracy than measurements with rulers and reduce variability between pebble counters (Bunte and Apt 2001).

Surface and Subsurface Layer Samples

Surface and subsurface layer sediment samples were collected at two locations on the Upper Mainstem for use in sediment transport capacity modeling. Where possible, one sample was collected between each known major geologic control. In general, samples were collected from gravel bars that appeared to be the most representative of the material within the river between the geologic controls. Sampling locations were also influenced by land owner access and the distance to vehicle staging locations.

Once a site was selected for volumetric sampling, equipment was carried to the site for field-sieving of particles greater than 32 millimeters. On the selected bar, a 1-meter by 1-meter area was framed that appeared consistent with the material noted throughout the section of river. Shovels were used to first remove the surface or armor layer down to the bottom side of the largest particle or until a substantial change in sediment material was noted. A rocker sieve was used to sieve material smaller than 32 millimeter, and the remaining sediment particles were segregated by size class and weighed on site. The subsurface sample followed a similar procedure, but the depth was greater than the surface sample, typically extending to a depth equal to the maximum surface particle size. The combined weights of the surface and subsurface samples ranged between 150 and 330 pounds. All material finer than 32 millimeters was carried off-site to a lab for further sieve analyses. Photographs were taken to document each surface and subsurface sample.

5.3.1.7 Hydraulics

The hydraulic analysis consisted of a one dimensional, steady flow HecRAS model. The purpose of the model was primarily to approximate water surface elevations, extents of inundation, and channel velocities for flood flow events. One-dimensional hydraulic models are capable of illustrating average water surface elevations, velocities, and shear stresses across a series of cross sections. For the large scale evaluation of channel processes presented in this assessment, the one-dimensional model was sufficient; however, the model was not developed to analyze two or three dimensional hydraulic patterns associated with multiple and substantial flow splits, river meandering, point bar formation, pool-riffle formation, or alterations to planform.

Geometry was imported into HecRAS using HecGeoRAS 4.1 within ArcGIS 9.1. Once the hydrology and geometry data were set up in the model, bank stations were verified and values of roughness were defined for various types of land use. Within the channel, Manning’s Roughness coefficient was determined to be 0.04 based on sediment size and channel roughness characteristics. Several measured water surface elevations at lower flows were compared with modeled water surface elevations to validate the use of the assigned roughness values for each cross section. In general, the measured water surface elevations were within 0.2 feet of the modeled water surface elevations at lower flows. Within the floodplain, roughness values were typically 0.05, due to consistent vegetation cover and land use within the floodplain. These values were obtained from guidance presented by Chow (1959). Due to the lack of measured water surface elevations during flood flow conditions, floodplain roughness values were not validated by measured values.

The Upper Mainstem HecRAS model consisted of 94 cross sections covering 3.2 miles of river. Within the model, levees were installed where known dikes, roads, or levees prevent flow from accessing adjacent side channels and floodplain. Flow obstructions were used to prevent flow in irrigation ditches from conveying portions of the flood flows. This was based on the assumption that irrigation ditches will not be used to convey high flows and are not expected to reduce in-channel flows during major flooding events. Ineffective flow areas were used to all other areas that are expected to be wet but are not expected to convey flood flows from upstream cross sections, such as historical stock ponds and tributaries.

Because of the short length of the model, a new geometry file was developed for each high flow event to most accurately represent flow dynamics between cross sections. For every flow event, each cross section was evaluated to determine if flow should be overtopping channel banks based on upstream cross sections. Flow was not permitted to access overbank areas unless upstream cross sections indicated overtopping of channel banks. This methodology improves the accuracy in anticipated water surface elevations but does not account for lateral floodplain access between cross sections.

Results of the hydraulic analysis were used to validate low surface mapping, to perform sediment transport investigations, and to evaluate channel stability.

5.3.1.8 Sediment Analysis

Various surrogates were used to evaluate how sediment moves through the assessment area under flood flow events. Sediment transported during the 2- through 100-year flow events were considered in this analysis as these events tend to be geomorphically significant in the ability of the channel to mobilize bed and bar material. While surrogates do not provide the exact quantity of sediment being transported during the flow events of interest, they offer an improved understanding of the relative degree to which channel forming processes vary throughout the assessment area and of the relative capacity of reaches to transport sediment under transport-limited conditions. The surrogates investigated include incipient motion, unit stream power, total stream power, and sediment transport capacity.

Incipient Motion

Incipient motion is described as the threshold condition between erosion and deposition (Julien 1998). When particles of sediment resisting motion are in balance with hydraulic forces acting on the particles, the particles are at incipient motion. Hydrodynamic forces exceeding the resisting forces cause sediment to become mobilized. Calculations of incipient motion examine the ability of varying flow conditions to mobilize and rework the sediment present in the bed and bars within the river. Incipient motion does not consider the supply of sediment or identify the quantity of sediment moved through a given cross section of the river. However, incipient motion does explain if the material present in the channel bed and bars is reworked under specific flow events. The results can also be used to hypothesize if the bed material has coarsened, become armored, or possibly if the channel has incised.

Incipient motion was calculated for each cross section under 2-, 5-, 10-, 25, 50-, and 100-year flow conditions using Yang's criteria (1973) for flood conditions in gravel bed rivers in combination with Rubey's criteria (1933) for particle fall velocity. The equation used to determine the critical diameter at which incipient motion occurs is shown below.

$$D_c = 0.0216 v_{cr}^2$$

Where:

v_{cr} = critical average velocity at incipient motion (m/s); and

D_c= grain size diameter at which incipient motion occurs (m).

Grain sizes smaller than the calculated critical diameter are expected to be mobilized for flow velocity assessed. Grain sizes greater than the critical diameter are stable.

Incipient motion can also be used to better understand the bed coarsening, degree of channel armoring, and potential degradation that may have occurred in each reach. During the process of channel armoring, the balance of sediment load is offset and the channel bed becomes the sediment source. This is followed by degradation of the channel bed. As finer materials are transported through the system, the bed material becomes coarser until a complete layer of coarse material covers the channel bed, thereby blocking transport of finer underlying materials (Yang 1996). When a channel is substantially armored and the thickness of the armoring layer is known, the depth of the degradation can be estimated.

Stream Power

Total Stream Power

Stream power influences river systems through impacts on channel form, pattern, and channel forming processes, such as sediment transport and channel migration (Knighton 1998). Total stream power per unit length of channel is defined by:

$$\Omega = \gamma QS$$

Where:

γ = the specific weight of water (N/m^3)

Q = water discharge (m^3/s)

S = energy gradient (m/m)

Because γ is a constant, total stream power was evaluated in this investigation as the product of discharge and friction slope (QS with units of cubic feet per second). Stream power was calculated for each cross section and flow event and averaged across each geomorphic reach.

Discharge tends to increase in the downstream direction in most river systems as tributaries and runoff augment river flows. As discharge and slope change, the ability of the river to transport sediment also changes. Hence, their product, total stream power, is directly related to the sediment transport capacity within a system. Total stream power may be used to compare the relative magnitude of sediment loads a stream is capable of transporting between reaches. This surrogate does not consider or evaluate the supply of incoming sediment, the quantity of sediment loads, or the size of sediment transported. Interpretation of total stream power can suggest where aggradation or degradation might occur in the system assuming a uniform supply of sediment. Only in-channel flow was considered in the assessment.

Unit Stream Power

Unit stream power is defined as the rate of potential energy expenditure per unit weight of water available for transporting water and sediment in an open channel (Yang 1996). This sediment transport surrogate is an indicator of the relative amount of energy required to transport a given sediment load. For each cross section of the hydraulic model, unit stream power was computed as the product of the friction slope and channel velocity (VS with units of feet per second). Unit stream power differs from total stream power in that velocity incorporates the impact of channel geometry on sediment transport. Unit stream power can be used in a relative comparison of the ability of the stream to transport a given sediment load through each cross-section. Within each geomorphic reach, cross sections represent a range of hydraulic conditions. Unit stream power was averaged across all cross sections in a reach to compare relative sediment transport capacity between reaches. While unit stream power is appropriate for relative comparisons of transport capacity, this surrogate does not indicate the quantity or sizes of sediment transported through each cross section or reach. Similar to total stream power, unit stream power can provide information as to where aggradation or degradation might be expected based on a uniform supply of sediment. Computations of unit stream power only considered flow transported through the main channel. Overbank flows were not included in this assessment.

5.3.1.9 Sediment Transport Capacity

Sediment transport capacity analyses were conducted for the 2- through 100-year flow events. Using the one-dimensional hydraulic model results, SRH-1D sediment transport capacity routines were run through the interface program, MoNet. Three different methods for calculating sediment transport were applied, including Meyer-Peter and Müller's Formula (1948) modified by Wong and Parker (2006), Yang's Sand (1973) and Gravel (1984) Transport Formulas, and Parker's Method (1990). Sediment transport was calculated for each cross section based on the representative volumetric surface, subsurface, and combined sediment gradations for the reach. Results of the analysis were centrally averaged across multiple cross sections to reduce variability from cross-section to cross-section and to facilitate interpretation.

5.3.2 Results

5.3.2.1 Hydrology

Along the channel within the assessment area, flow was augmented at five locations due to increasing drainage area and tributary inputs (Figure 15). Tributaries contributing substantial flow and their locations are defined in Table 2. Strawberry Creek has several fingers contributing flow from a large alluvial fan. Although much of the contributing flow from Strawberry Creek is intercepted by irrigation ditches, concentrated surface flow from the Strawberry Creek drainage enters the main channel at several locations along the south side.

Table 2 – Major Tributaries Contributing Flow to the Upper Mainstem Assessment Area. Strawberry Creek has several fingers contributing flow from a large alluvial fan.

Tributary	Approximate River Mile
Jeff Davis Creek	265.7
Dad's Creek	264.9
Strawberry Creek	263.3, 264.7

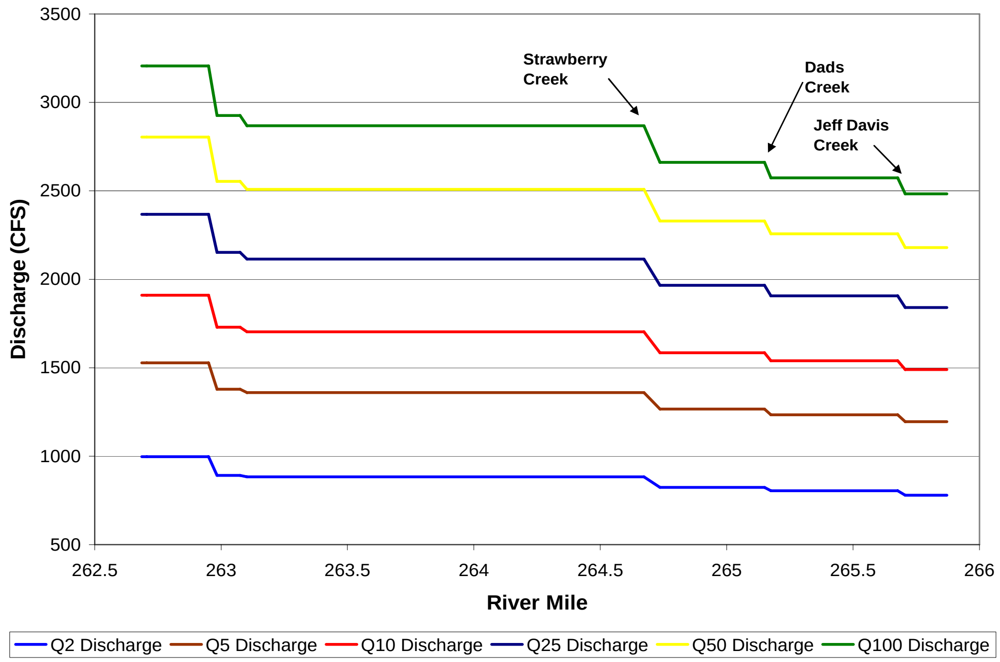

Figure 15 – Discharge Used in Modeling the Upper Mainstem John Day River Assessment Area.

5.3.2.2 Slopes

The channel bed profile and the computed bed slopes are presented in Figure 16. Slope breaks identified visually did not coincide with the reach breaks in most cases. Within one geomorphic reach, multiple visual slope breaks are likely due to constructed features or geologic influences. This is particularly noticeable in Reach UJD3, where opposing alluvial fans act as a geologic control on the slope. Confined reaches are typically characterized by relatively high slopes compared with moderately confined and unconfined reaches. Unconfined reaches tend to have the lowest slopes. However, moderately confined Reach UJD2 has the highest slope of all three reaches. The channelization in this reach has notably increased the channel slope from its historic condition. The channel profile was also used to identify and/or validate significant natural and anthropogenic vertical channel controls.

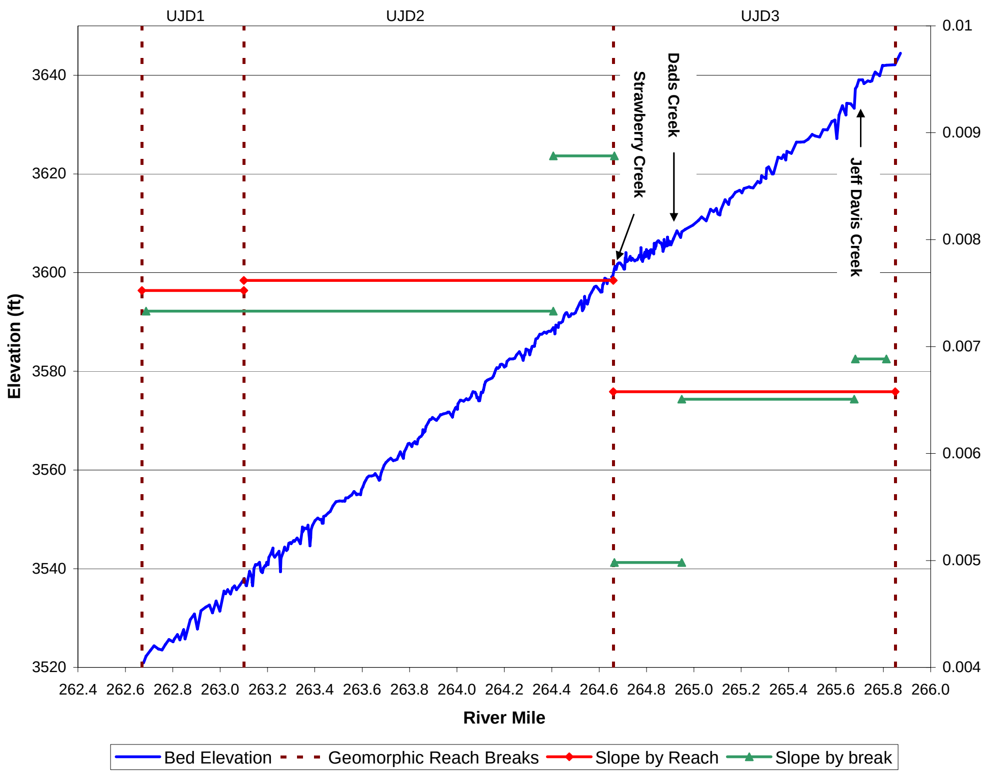

Figure 16 – Profile of the Upper Mainstem John Day River Assessment Area. Bed elevations are denoted on the primary y-axis. Slopes are denoted on the secondary Y-axis.

5.3.2.3 Hydraulics and Sediment Transport Limitations

The smaller size of the Upper Mainstem Assessment Area allowed for increased investigation of the hydraulics. A different HecRas geometry file was developed for each flow event to account for the need for levees, flow obstructions, and ineffective flow areas under differing hydraulic conditions. Flow was not permitted to access overbank areas unless upstream cross sections indicated overtopping of channel banks. The upstream one-fourth mile of the assessment area was fairly problematic due to the floodplain geometry. Between RM 265.6 and 265.85, the floodplain is lower than the channel bed elevations. This accuracy of the surface in this area should be field checked. Due to the geometry in this segment, techniques were applied to maintain flow in the channel.

Flow for the 2-year event was forced to stay within the channel between RM 265.56 and 265.85 because one-dimensional water surface elevations did not reach a sufficient height to overtop the bank at the cross section locations that were modeled. This caused high velocity flow to be routed through small channel areas. In reality, flow would likely access the floodplain through a low point in the channel, subsequently reducing velocities and sediment transport. Modeled hydraulic and sediment transport within this short segment of the model are unreliable for the 2-year event. However, the 5- through 100-year events overtopped the banks and were not forced to remain within the channel area. Due to surrounding channel geometry, this resulted in most of the flow being routed in the floodplain, which is also unlikely. Some flow may be conveyed overbank if there is an access point at some upstream location that allows some flow to access the floodplain. Caution should still be used with application of hydraulic results between RM 265.6 and 265.85 for any flow event. A two-dimensional model should be considered for projects within this vicinity to accurately depict the water surface elevations, velocities, and locations of bank overtopping.

Because of the lack of confidence in the model results in the upstream one-fourth mile of the assessment area, cross sections within this segment were removed from the investigation and not included in the averaging of the results by reach. Reach UJD3 averages only include the hydraulic results for cross sections between RM 264.7 to RM 265.6.

5.3.2.4 Velocity

The hydraulic model computes the channel velocity at each cross section based on the flow event, channel roughness, hydraulic geometry, and specific energy. As Figure 17 shows, high flow channel velocities are highly variable from one cross section to the next as a result of variation in the channel capacity and friction slope. In general, velocities remain relatively consistent from upstream to downstream, despite substantial changes in reach confinement. Velocities in confined reach UJD1 would be expected to be the greatest due to the high degree of channel confinement. However, artificially increased slopes and channel constrictions in reaches UJD2 and UJD3 may have led to increased channel velocities.

To evaluate general trends in velocities within the assessment area, the velocities were averaged across each geomorphic reach, as depicted in Figure 18. Across the 3-mile stretch of the Upper Mainstem, reach-averaged channel velocities vary between 5 and 7 feet per second.

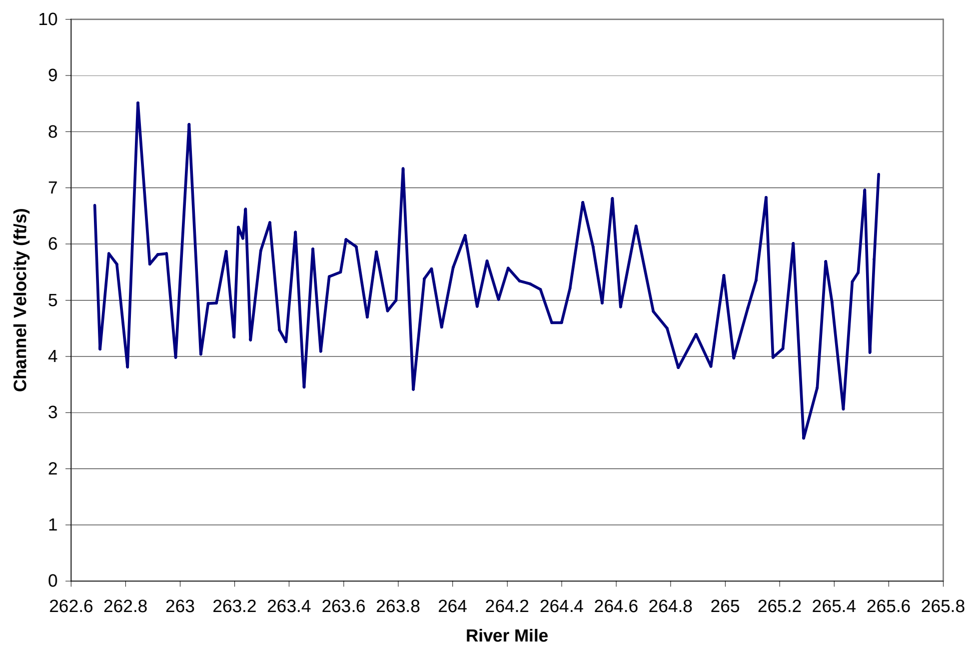

Figure 17 – 2-Year Flood Flow in Channel Velocities as Computed From 94 Cross Sections in HecRas.

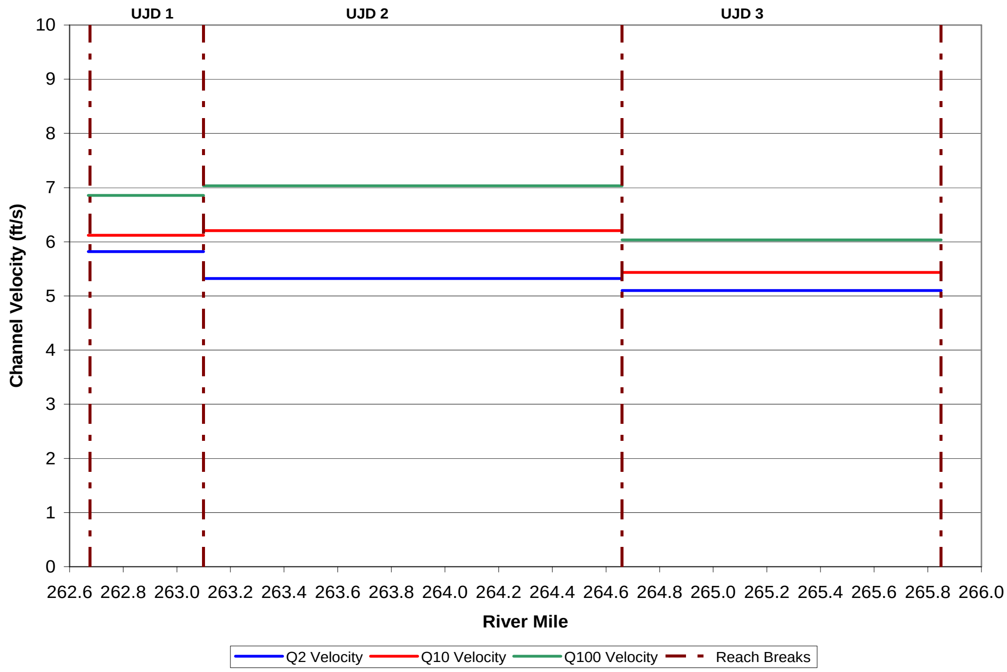

Figure 18 – Reach-averaged Channel Velocities for the 2-, 10-, and 100-Year Flow Events. Reach numbers are shown across the top of the graph.

5.3.2.5 Width to Depth Ratio

The active channel width-to-depth ratio for the 2-year flood event is illustrated in Figure 19. Within the Upper Mainstem Assessment Area, width-to-depth ratios range from 17 to 130, while active channel widths range from 37 to 123 feet. The graph illustrates that the width-to-depth ratios are close in value to the active channel widths due to depths close to 1 foot. Cross-section average depths in the assessment area range between 0.50 and 3 feet, and have a mean depth of 1.44 feet. Due to the short length of the assessment area, no trend in widths and width-to-depth ratios is detectable; however, the proximity in values of the widths and width-to-depth ratios for a 2-year flow event suggests that the active channel may be overwidened, particularly in reaches UJD2 and UJD3.

NMFS (1996) proposed that mean wetted width-to-depth ratios less than 10 are considered properly functioning for streams east of the Cascades, while values greater than 12 are considered functioning at an unacceptable risk (Hillman and Giorgi 2002). USFWS (1998) used criteria associated with width-to-depth ratios in scours pools for bull trout habitat, and considers values less than 10 as properly functioning and values greater than 20 as functioning at an unacceptable risk. Comparison of the width-to-depth ratios for the 2-year flow on the Upper Mainstem with these published values suggests that the channel geometry may not be functioning at levels consistent with providing high-quality habitat. This could be an indication that shallow depths are limiting the ability of the channel to maximize habitat conditions and are increasing the potential for solar warming.

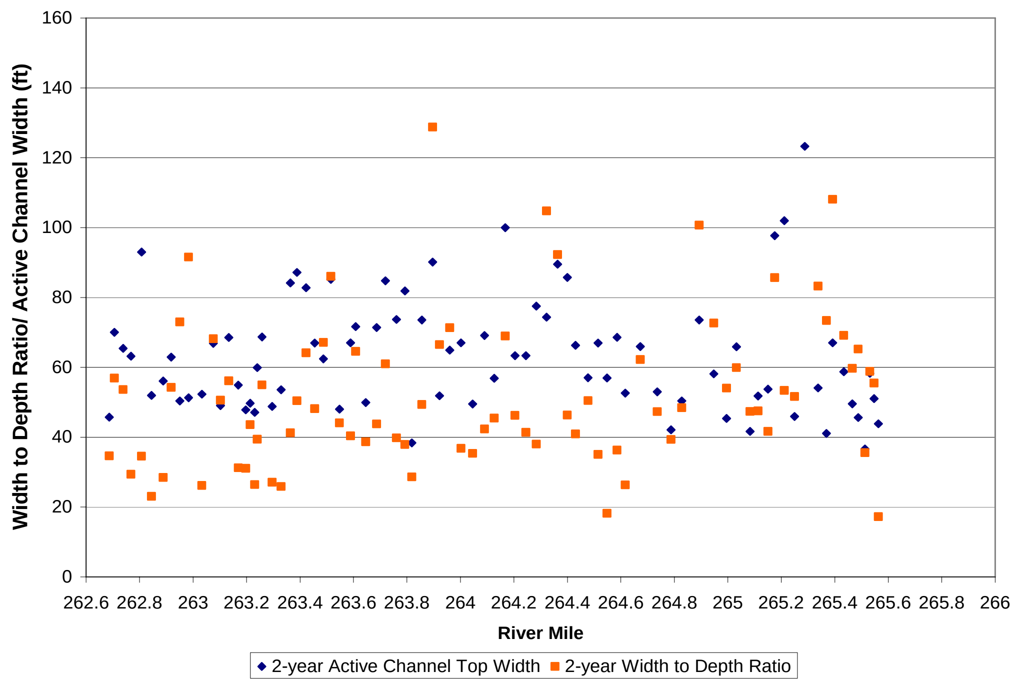

Figure 19 – Width-to-Depth Ratios and Active Channel Widths for the 2-Year Flow Event on the Upper Mainstem John Day River.

5.3.2.6 Floodplain Inundation

The frequency of floodplain inundation under present conditions was assessed to determine if significant incision has occurred, potentially disconnecting the floodplain from its channel. This task was accomplished by evaluating the water surface elevations in each cross section of the hydraulic model and qualitatively comparing them with the channel banks. The percentage of total flow in each cross section that was not contained within the channel was also used to examine potential flood inundation. Figure 20 illustrates the reach-averaged percent of flow that is overbank. Both methods are limited due to the assumptions of equivalent water surface elevations in the one-dimensional model. A two-dimensional model that incorporates lateral flow between cross sections will more accurately assess floodplain inundation. The following discussion provides a broad picture of anticipated floodplain inundation in the assessment area and the spatial variation in the degree of inundation.

Using a framework of typical channel processes, unconfined and moderately confined reaches tend to have a greater percentage of overbank flow under the 2- through 100-year flood events than confined reaches. Results from the hydraulic model indicate that the 2-year flow does flow out of bank in all reaches; however, the percent of overbank flow in moderately confined UDJ2 is close in value to that of confined reach UJD1. In general, the 2-year flow was close to or overtopping the banks at a fewer number of cross sections and in lesser quantity in the confined reach when compared to the unconfined reach.

Cross section geometries for the one-dimensional model on the Upper Mainstem model were defined such that flow was allowed to overtop channel banks and inundate the floodplain only if the upstream cross section indicated flow overtopping. Review of the modeled cross sections indicates that water surface elevations for the 2-year flow are close to or overtopping the channel banks in most cross sections. Water surface elevations for the 2-year event in unconfined UDJ3 tend to overtop the channel banks in a greater number of cross sections than in the more confined reaches. Most cross sections indicate substantial floodplain connectivity during the 5- to 10- year flood events. Because the 2-year flow event is close to or just overtopping the channel banks in most reaches, substantial channel incision is not expected to have occurred.

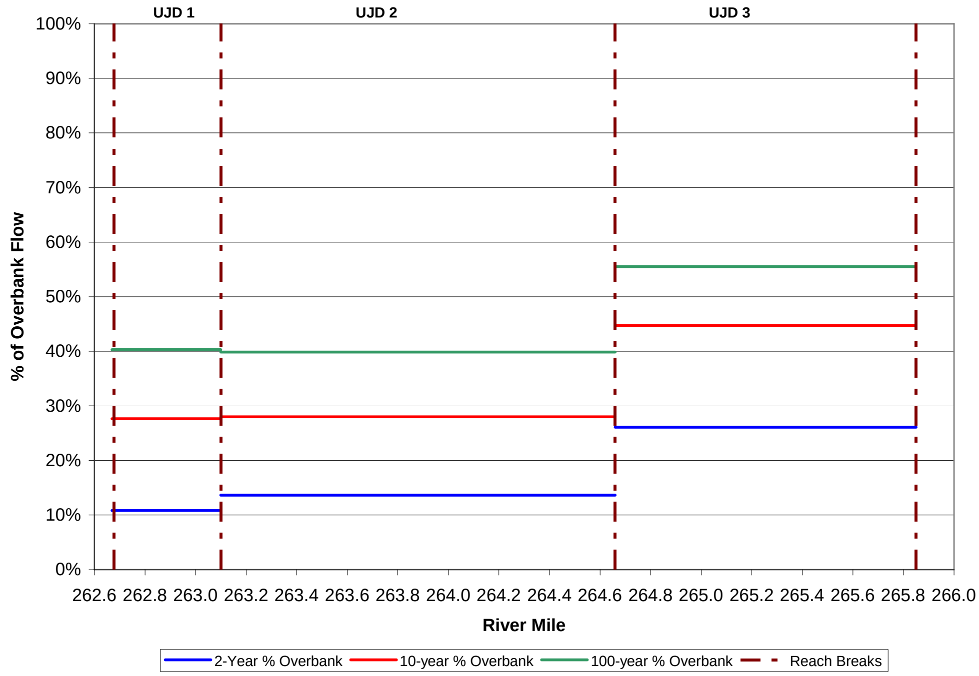

Figure 20 – Percentage of Total Flow That is Not Contained Within the Channel for the 2-, 10-, and 100-Year Flow Events.

5.3.2.7 Sediment Sampling

Figure 21 illustrates how surface sediment sizes vary in the assessment area. Both pebble count data and volumetric samples are displayed on the graph. No sediment samples were collected from the confined reach due to the lack of exposed gravel bars. Six pebble counts were performed within gravel bars, and one was collected in the channel bed. Sediment samples in UJD2 and UJD3 were relatively consistent. The in-channel median grain size (D_{50}) was slightly larger than the D_{50} comprising the gravel bars. Both volumetric samples indicated larger median grain sizes than the pebble counts.

A comparison of the D_{50} from the volumetric surface samples and the D_{50} from subsurface samples indicates the degree of channel armoring. Evaluation of the volumetric samples shows that the D_{50} of the surface sample is 2 to 3 times greater than D_{50} of the subsurface. This range is typical in mountainous streams and indicates very mild armoring. Bars in the graph illustrate the range in sediment sizes between the 16th and 84th percentiles of the pebble count data. In locations where only pebble count data were obtained, the degree of armoring can be qualitatively evaluated using the range in the 16th and 84th percentile.

The degree of channel armoring does not indicate if the sediment sizes have coarsened or become finer than historic sediment sizes. Data on historic sediment gradations were not available for this evaluation.

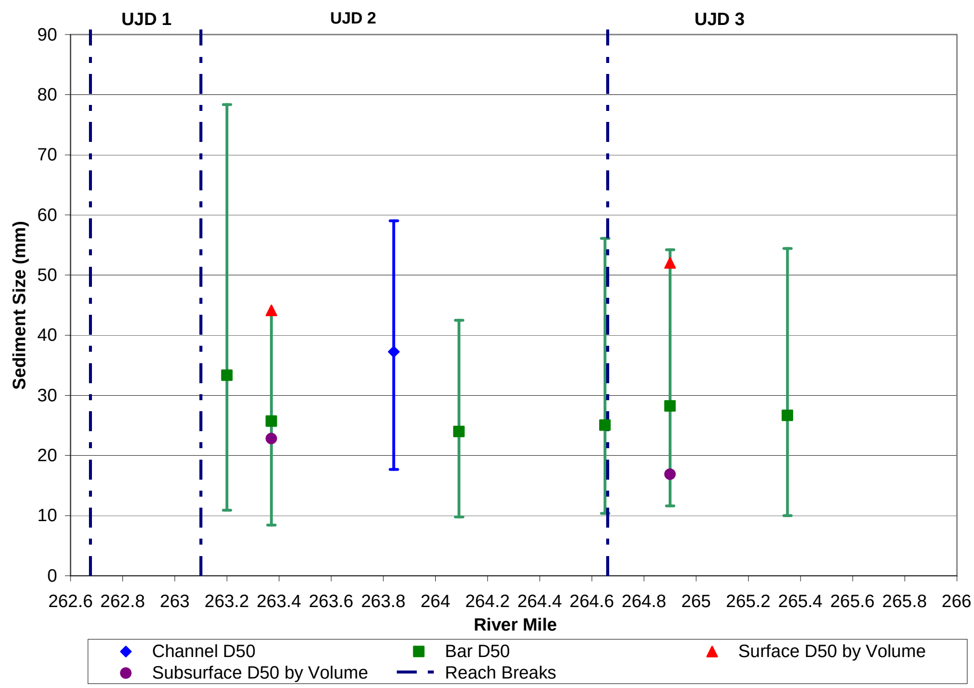

Figure 21 – Measured Sediment Sizes in the Upper Mainstem Assessment Areas. Bars indicate the range of sizes between the 16th and 84th percentiles of the pebble count data.

5.3.2.8 Incipient Motion

At each cross section, the critical sediment diameter at which incipient motion occurs was calculated. Sediment sizes above these diameters are not expected to be mobilized. The critical diameters were averaged for each reach, as illustrated in Figure 22. A comparison of the measured sediment sizes in each reach with the critical diameters of incipient motion provides an indication of the flow event required to mobilize the bed and bar material in each reach. In reaches UJD2 and UJD3, both the channel and bar sediments are mobilized by flows less than the 2-year flood event. No sediment samples were obtained in reach UJD1.

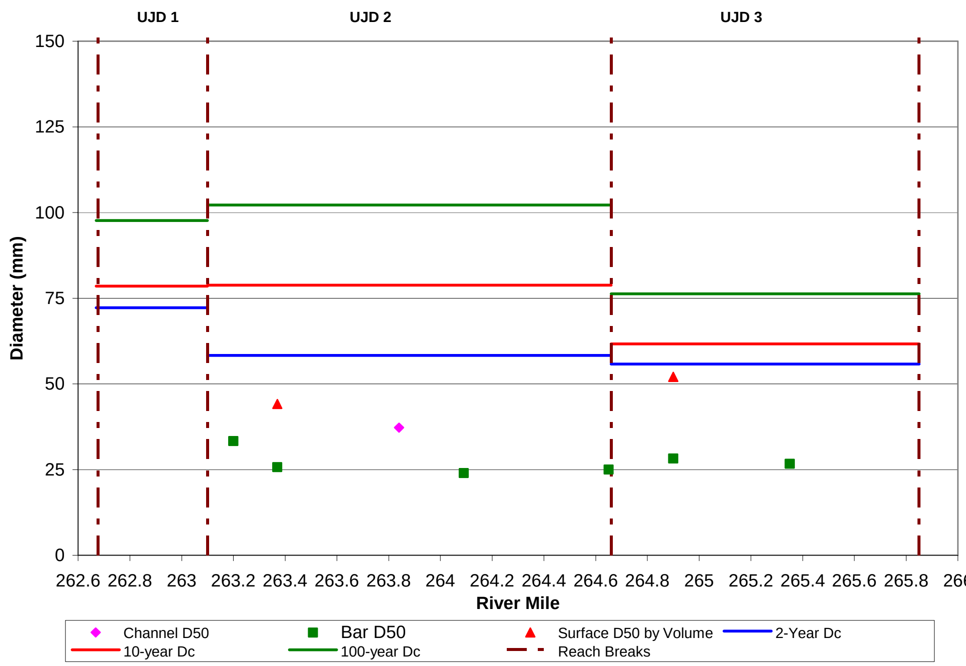

Figure 22 – Results of Incipient Motion Analysis. The critical diameter represents the size of material that is expected to be mobilized in each reach for corresponding flow events. The points indicate the measured sediment D_{50}.

5.3.2.9 Stream Power

Figure 23 illustrates the average total stream power computed in each geomorphic reach. For the 2-year event, reach-averaged total stream power ranges between 5.5 and 6.5 cubic feet per second (cfs); total stream power for the 100-year event ranges between 16 and 20 cfs. Total stream power is the greatest in moderately confined reach UJD2 and close in value for the confined and unconfined reaches. These results indicate that stream energy and erosive forces in UJD2 and UJD3 vary from hypothesized typical channel processes and are likely greater than historic conditions

Unit stream power stems from the general concept that the rate of energy dissipation used in transporting material should be related to the rate of material being transported. This parameter is used as an indicator of the relative ability of each reach to transport a given sediment load despite differences in channel areas. According to Figure 24, the unit stream power is greatest in the moderately confined channel with similar values in the unconfined and confined reach. These results are at least partially due to constructed features and anthropogenic impacts on reaches UJD2 and UJD3.

As explained in the methods section, unit stream power is a function of velocity and friction slope. In the mainstem, flood flows create substantial backwater due to geologic concavity of the basin and lateral geologic controls. As a greater percentage of flow inundates the floodplain at higher flow events, friction slope varies as a function of geometric controls on the channel, such as changes in channel or floodplain width or elevation. In all reaches, the 100-year unit stream power is the greatest of all flows due to high channel velocities, which range on average between 6 and 7 feet per second. However, in reaches UJD1 and UJD3, the 10-year unit stream power is slightly less than the 2-year unit stream power due to backwater impacts determined by changes in channel geometry, such as the lateral constriction of alluvial fans between reaches UJD2 and UJD3, and a decreased friction slope.

Potential for aggradation or degradation may be assessed by comparing general trends in stream power across a river system; however, the assessment area of the Upper Mainstem only represents a short segment of the river system. Without a clear understanding of the supply entering the system, a comparison of the stream power can only provide the ability of the channel to transport sediment through the reach relative to upstream and downstream reaches. The results imply that reach UJD2 has more erosive capacity than both the upstream and downstream reaches. Therefore, all of the material moving into reach UJD2 is most likely being transported to reach UJD1. The results indicate a tendency for degradation in reach UJD2 during flood flow events. The presence of opposing alluvial fans at the transition between reaches UJD2 and UJD3 may limit further degradation of reach UJD2.

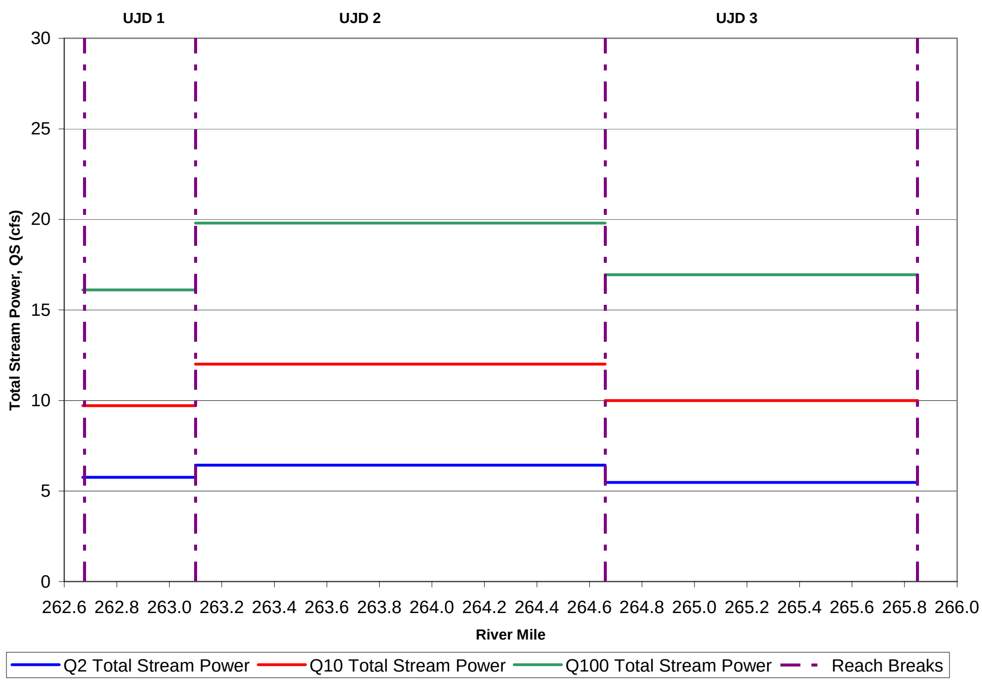

Figure 23 – Total Stream Power in Each Geomorphic Reach.

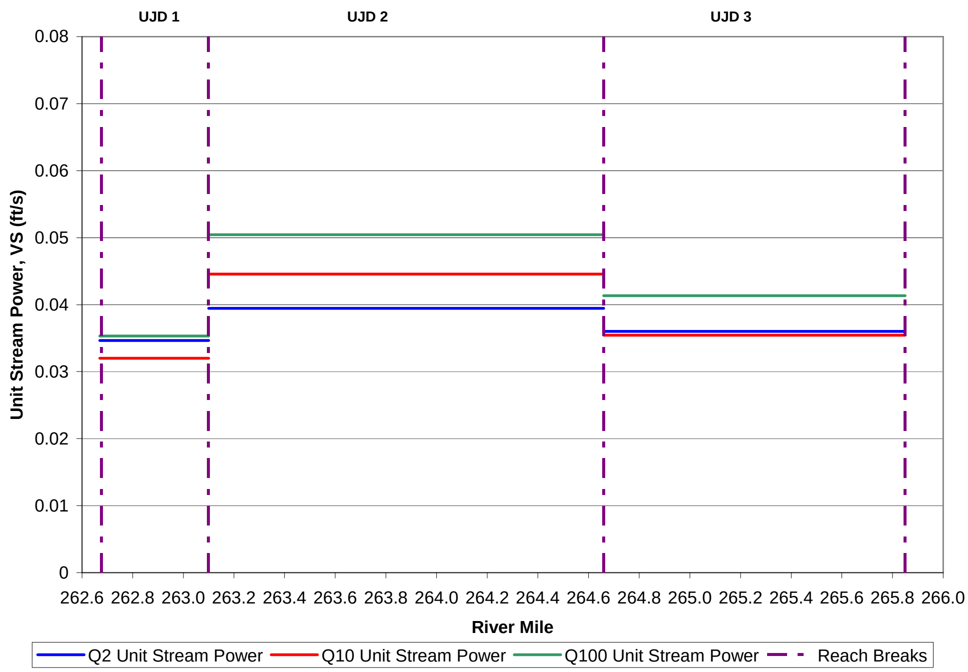

Figure 24 – Units Stream Power in Each Geomorphic Reach.

5.3.2.10 Sediment Transport Capacity

The capacity of each reach to transport sediment provides an indication of the relative amount of sediment that would be expected to be transported in each reach and is dependent on the sediment sizes making up the bed and banks of the reach. In typical mountainous streams, sediment transport capacity patterns tend to coincide with the planform attributes of each reach and/or slope breaks. Unconfined, low gradient sections of the channel are typically characterized by low sediment transport, while highly confined, high gradient sections have much higher sediment transport rates. At transitions zones or geologic pinch points, variable sediment transport patterns often occur. These patterns do coincide with the sediment transport capacity of the three reaches evaluated on the Upper Mainstem. In general, sediment transport capacity of the assessment area indicates the highest sediment transport capacity in the moderately confined reach with relatively close values of sediment transport capacity in the unconfined and confined reaches.

Three separate sediment transport capacity formulae were used to assess trends in sediment transport capacity under flood flow conditions. Although differences are noted in the quantities of transport capacity calculated by each equation, the patterns are similar. Differences among the sediment transport capacity equations are due to the approach of the development of the equations. Yang’s equations are based on unit stream power, while Meyer-Peter Mueller’s (MPM) and Parker’s equations are derived from excess shear stress. Reach-average sediment transport capacity using MPM equations are illustrated in Figure 25. Cross section results for each equation under the 2-, 10-, and 100-year flow events are displayed in Figure 26 through Figure 34. A summary of the results is described below.

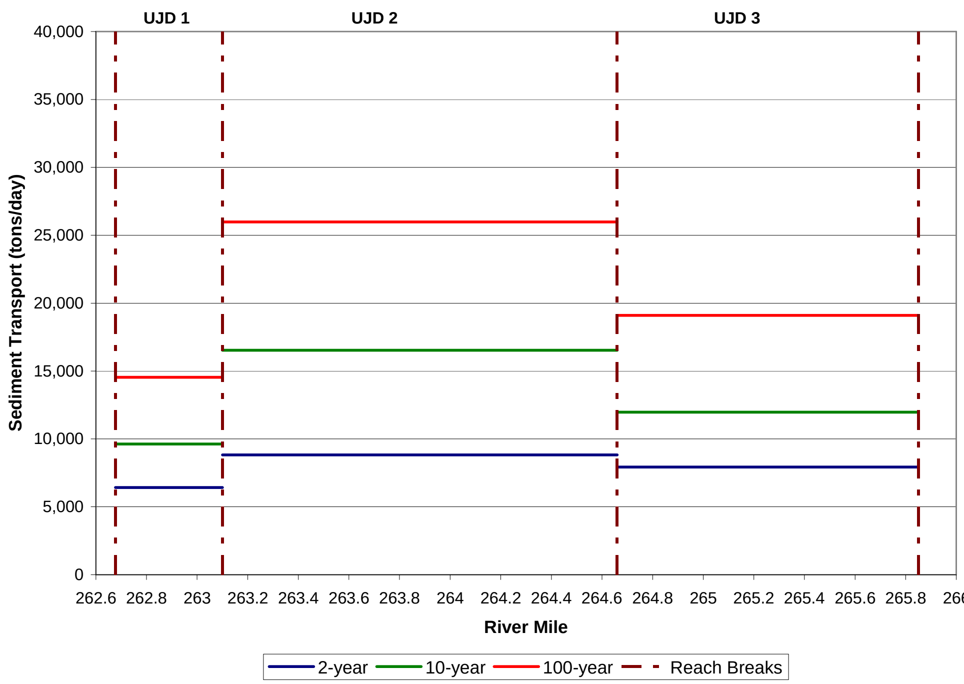

Figure 25 – Reach-Average Sediment Transport Capacity Calculated using Meyer-Peter and Müller (1948) Modified by Wong and Parker (2006) Based on a Combined Gradation of Surface and Subsurface Sediments.

Reach UJD3

Sediment transport capacities at the upstream end of this reach were not calculated due to a low confidence in the hydraulics between RM 265.6 and 265.85. Sediment transport capacity is relatively low for the 10- and 100-year flow events when compared with reach UJD2. A significant change in slope is primarily responsible for the reduction in sediment transport at the Dad's Creek confluence.

Reach UJD2

Reach UJD2 has the highest transport capacity of all three reaches. In general, the sediment transport through the reach is relatively consistent with a few peaks and troughs associated with changes in channel geometry and friction slope. A pronounced increase is noted at RM 263.5 in the results of the Parker equation for the 2-year flow event. Several factors responsible for the sharp rise include an increase in channel area, a reduction in friction slope and velocities, and a slight change in bed slope. Transport capacity in this reach is likely higher than historic conditions due to channel straightening. Sediment supplied to this reach is likely going to be transported to the next downstream reach.

Reach UJD1

The capacity of this reach was initially expected to be the greatest of all reaches due to the confined nature of the floodplain. However, sediment transport capacity is substantially lower in the confined reach than in the upstream moderately confined reach. Transport capacity in reach UJD1 is characterized by a rise in sediment transport in the middle of the reach. The peak in capacity at RM 262.8 results from close to critical flow and high velocities in one cross-section.

2-Year Flow Sediment Transport Capacity

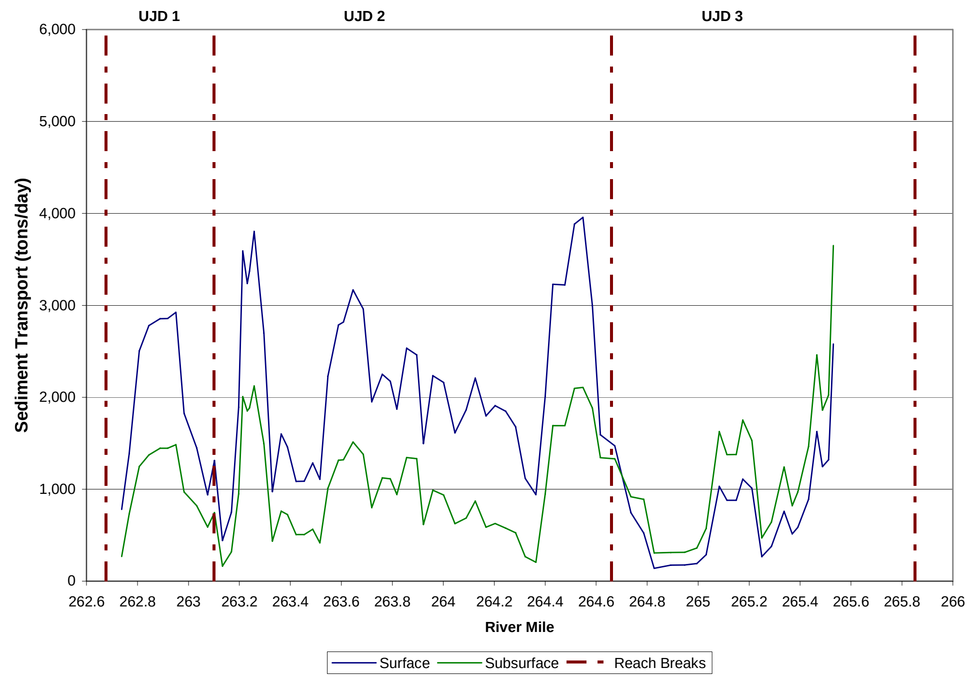

Figure 26 - Parker (1990) Sediment Transport Capacity for the 2-Year Flow.

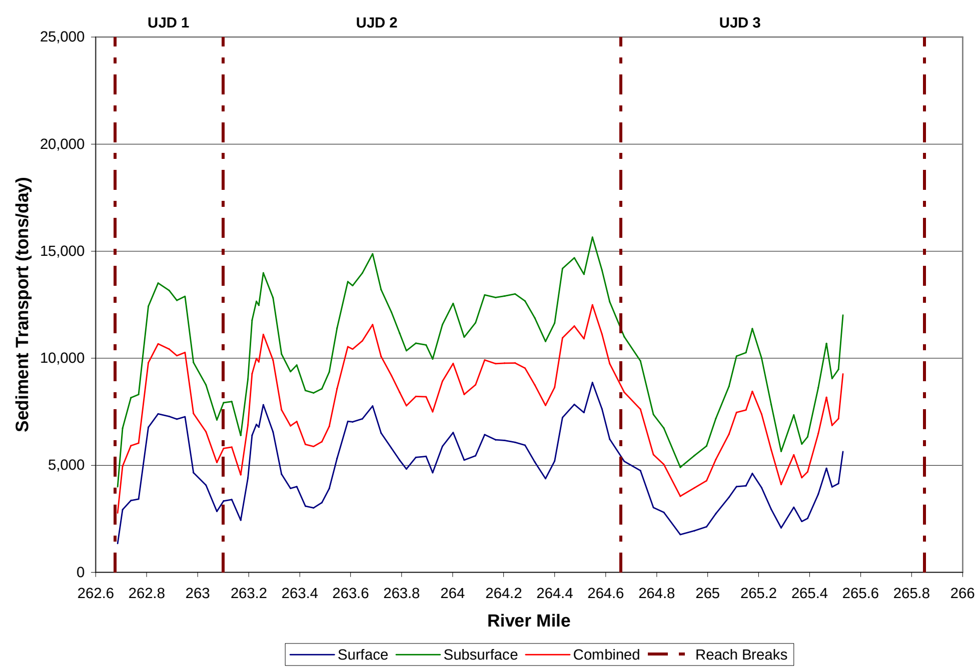

Figure 27 - Meyer-Peter and Müller (1948) Modified by Wong and Parker (2006) Transport Capacity for the 2-Year Flow.

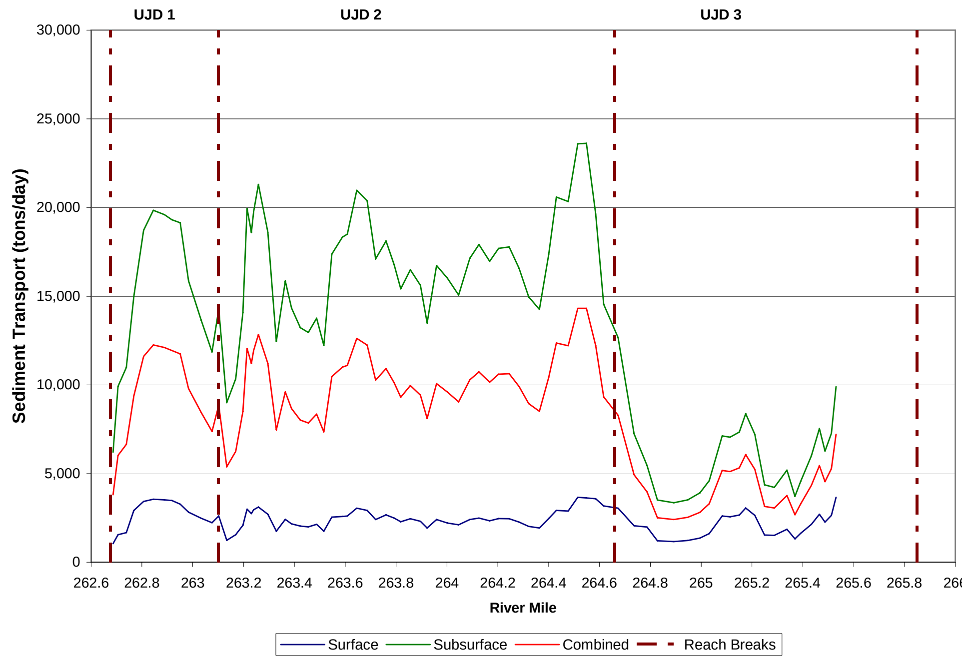

Figure 28 - Yang's Sand (1973) and Gravel (1984) Sediment Transport Capacity for the 2-Year Flow.

10-Year Flow Sediment Transport Capacity

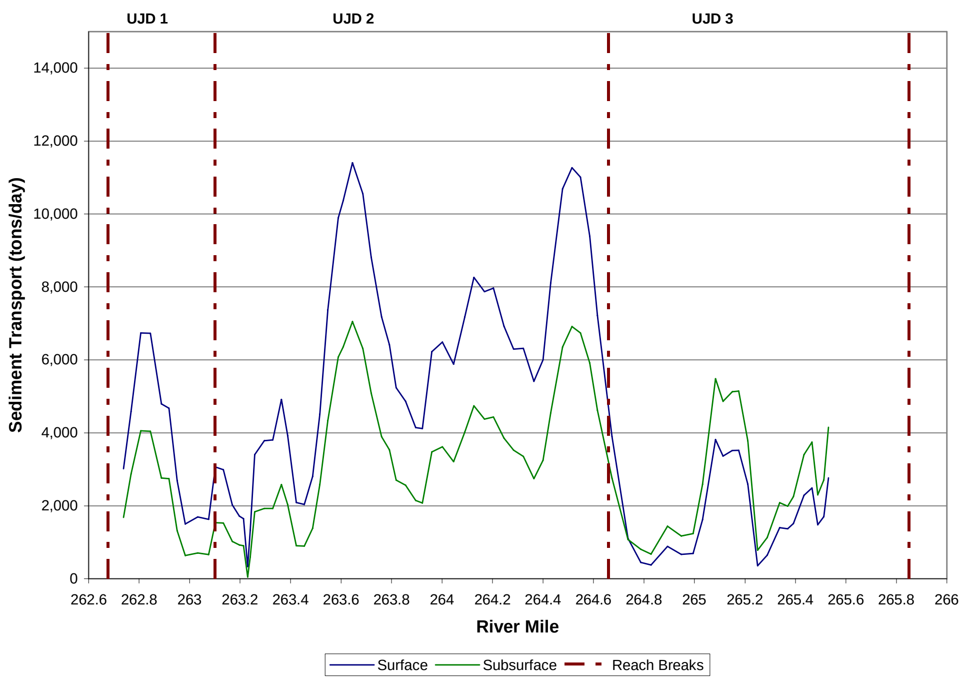

Figure 29 – Parker (1990) Sediment Transport Capacity for the 10-Year Flow.

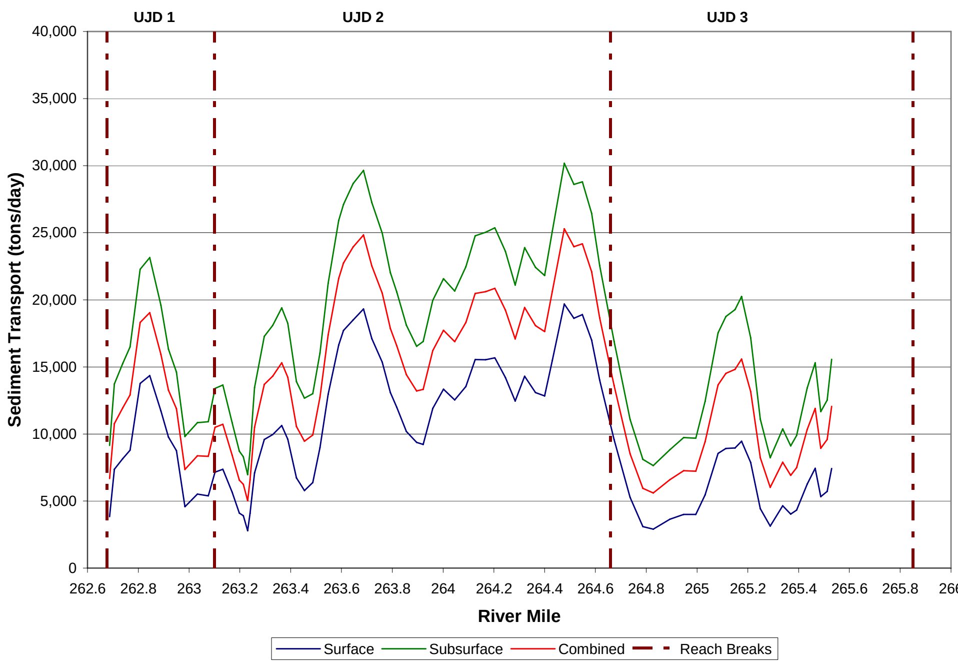

Figure 30 - Meyer-Peter and Müller (1948) Modified by Wong and Parker (2006) Sediment Transport Capacity for the 10-Year Flow.

Figure 31 - Yang's Sand (1973) and Gravel (1984) Sediment Transport Capacity for the 10-Year Flow.

100-Year Flow Sediment Transport Capacity

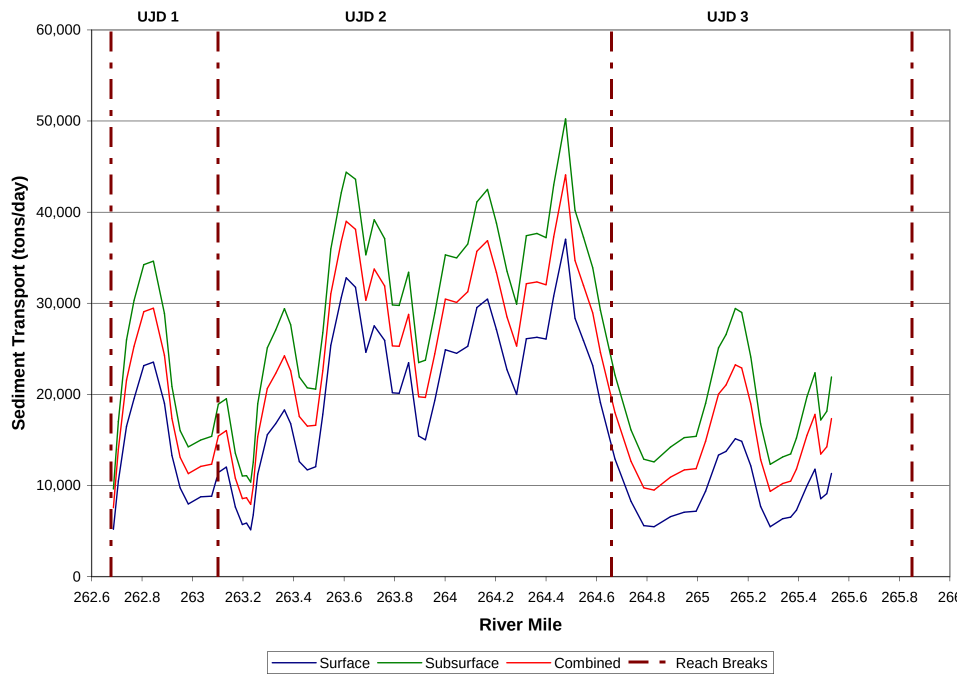

Figure 32 - Meyer-Peter and Müller (1948) Modified by Wong and Parker (2006) Sediment Transport Capacity for the 100-Year Flow.

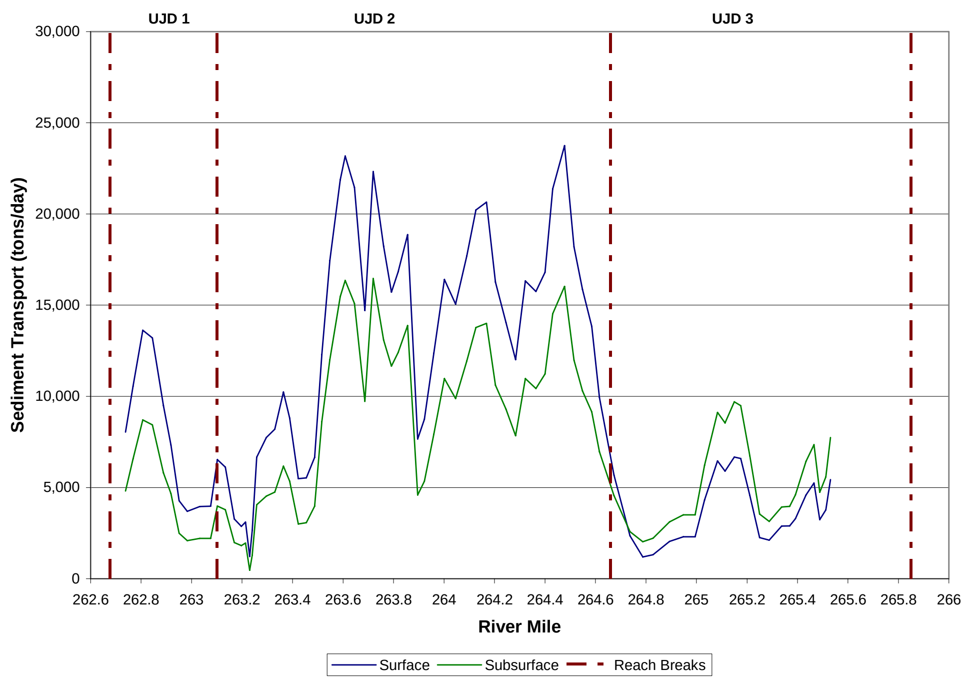

Figure 33 – Parker (1990) Sediment Transport Capacity for a 100-Year Flow.

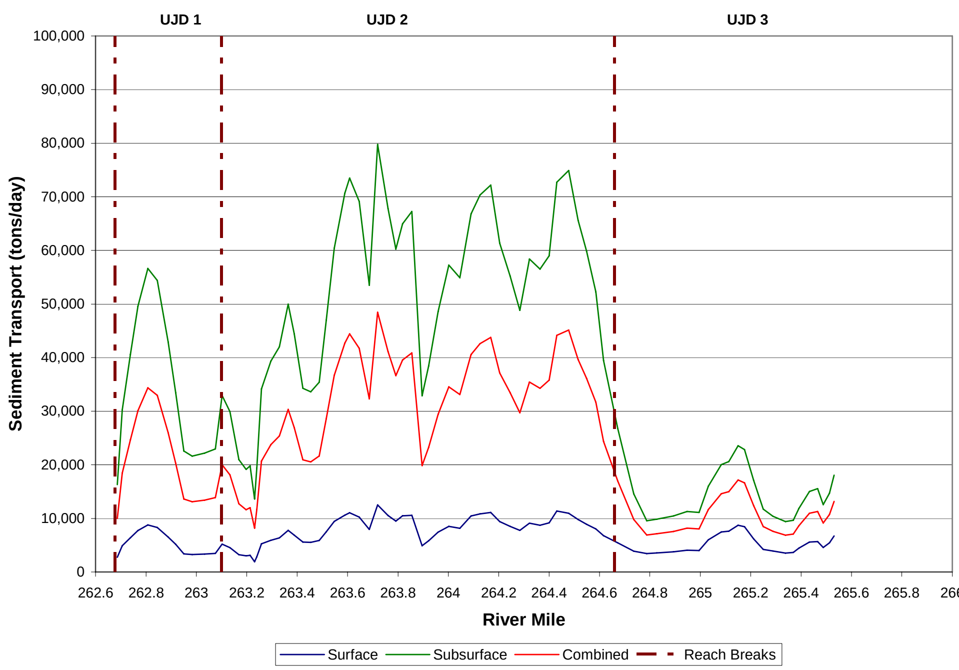

Figure 34 - Yang's Sand (1973) and Gravel (1984) Sediment Transport Capacity for the 100-Year Flow.

5.3.3 Conclusions

Various methods were used to evaluate the present stability of the Upper Mainstem Assessment Area. These included a one-dimensional hydraulic model, evaluation of sediment samples, incipient motion computations, longitudinal comparison of stream power, and sediment transport capacity equations. Results from the efforts are summarized below. In general, the results suggest that substantial incision has not occurred in the assessment area.

Water surface elevations for the 2-year flow are close to or overtopping the channel banks in all reaches. In general, the 2-year flow was close to or overtopping the banks at a fewer number of cross sections and in lesser quantity in the confined reach (UJD1) when compared to the unconfined reach (UJD3). The percent of overbank flow in moderately confined reach UJD2 is close in value to that of the confined reach.

Three separate sediment transport capacity formulae were used to assess trends in sediment transport capacity under flood flow conditions. Moderately confined reach UJD2 had the greatest capacity to transport sediment of all three reaches, and reaches UJD1 and UJD2 were generally close in their ability to transport sediment under high flow events.

Although most of the channel in the assessment area does not appear incised, segments of river channel that have been artificially channelized, such as reach UJD2, typically do not access the floodplain as frequently as under historic conditions. While the 2-year event slightly overtops the bank in the unconfined reach, substantial inundation of the floodplain does not occur without flow conditions on the order of a 5- to 10-year event.

In reaches UJD2 and UJD3, both the channel and bar sediments are mobilized by flows less than the 2-year flood event. No samples were obtained in reach UJD1.

Evaluation of the 2-year modeled width-to-depth ratios indicates that the depth of flow is close enough to unity in most cross sections that the width and width-to-depth ratios are close in value. Comparison of the width-to-depth ratios for the 2-year flow on the Upper Mainstem with published values for properly functioning conditions (NMFS 1996; USFWS 1998) suggests that the channel geometry may not be functioning at levels consistent with providing high-quality habitat. These results indicate that there is insufficient depth in the channel when compared with width, which may be negatively influencing habitat value through reduced complexity and greater exposure to solar warming.

Due to historic alterations to the sediment regime, the river may be continuing a trend of adjustment through attempts at lateral channel migration where possible (Figure 22). Reach UJD2 has an increased erosive capacity compared to both upstream and downstream reaches under flood flow events. These results suggest that there is a trend toward lateral and/or vertical channel degradation in this reach, but no vertical degradation was noted during field visits. Opposing alluvial fans at the transition of reach UJD2 and UJD3 may impart some control on vertical channel adjustment. Considerable bank erosion was noted in localized areas during field visits. Some bank erosion and lateral channel shifts should be associated with the natural process of bend migration; however, it is not known whether the erosion noted was part of natural bend migration processes, or a response to historic channel straightening. Flood flows have caused alterations in channel position during the limited time period of this study. Overall, the channel may be eroding banks and making lateral adjustments, but is not degrading the bed.

5.4 Riparian Vegetation Assessment

5.4.1 Background and Objectives

The study area on the Upper John Day River lies upstream of Prairie City, Oregon. Prairie City lies at an elevation of 3,425 feet and receives an average annual precipitation amount of 14.1 inches (Anderson et al. 1997).

The objectives of the riparian vegetation assessment are to fill in gaps on Reclamation's John Day River Geomorphic Assessment for salmonid recovery. These objectives are to:

- Visually interpret canopy vegetation community classes such as conifer, hardwoods, shrub, or meadows, with species interpretation as possible from aerial photography and LiDAR data.
- Create polygons in GIS representing vegetation communities within the low surface boundary or within a buffer extending out 300 feet from the river, whichever is the greater of the two.
- Calculate the number of acres for each vegetation community class.
- Compare number of acres from year to year – trends and theoretical past conditions assessment for years 1939, 1956 and 1976.
- Quantify LWD potential and shading by trees in the riparian as indicators for potential salmonid habitat.

5.4.2 Methods

Aerial photography was flown for the project in October 2006, and orthorectified for the project. Aerial photography from 1939, 1956, and 1976 was also available in the project vicinity. LiDAR data were captured in October 2006, and first and second returns were used to create a grid containing tree height values. The LiDAR data and color aerial photography were used to visually interpret the photographs.

An attempt was made to identify canopy species, but it was found to be difficult, especially using the historical photography. Without field checking to assist in the interpretation, species were classified primarily using the LiDAR vegetation height classifications overlaid on aerial photography. Areas dominated by trees, small trees, and shrubs or low vegetation/openings were identified. Low vegetation/openings may include agricultural use, meadows, or bare ground. This maintained consistency between reaches and drainages.

During interpretation of the historical aerial photos, an attempt was made to differentiate tree and shrub cover. Differences in resolution and accuracy of the spatial overlay of the photos made interpretation to this level unreliable.

One site potential tree height represents the height of a mature tree under pre-development conditions. In order to estimate shading and short-term LWD contribution of the riparian vegetation, a buffer of 82 feet (25 meters) was chosen as the height that best describes one site potential tree height. At this distance to the river channel, trees could potentially shade the river and provide a potential source of LWD in the short term (decades).

5.4.2.1 GIS Methods

In ArcGIS 9.2, a 300-foot buffer from the river center was created and merged with the geologic low surface to create the study area polygon. Existing vegetation information on CTWSRO properties was incorporated. LiDAR data were grouped into height classifications, made semi-transparent, and overlain on 2006 aerial photography (Figure 35). Polygons of dominate canopy cover were created using heads-up digitizing. Polygons were assigned one of three vegetation classification: (1) LWD- sized trees, (2) small trees and shrubs, and (3) low vegetation/openings (Figure 36).

The 2006 vegetation polygons were overlain on the historical aerial photography, and changes in the vegetation were analyzed. Polygons were split into areas that remained as openings between 1939 and 2006, and areas that at some time between 1939 and 2006 were converted to low vegetation/openings. In almost all cases, areas that showed change were areas of trees and/or shrubs on the historical photos that had changed to low vegetation/open areas on the 2006 photos. An attribute was created to indicate change or no change for the polygon (Figure 37). This information was used to calculate tree/shrub change between 1939 and 2006.

An 82-foot buffer was created in GIS and intersected with the vegetation classification for analysis of streamside conditions for shade and LWD (Figure 38). Areas were calculated for all of the polygons and added as an attribute. The summary reports were provided in a Microsoft Excel spreadsheet for distribution and formatting for reports (Table 3).

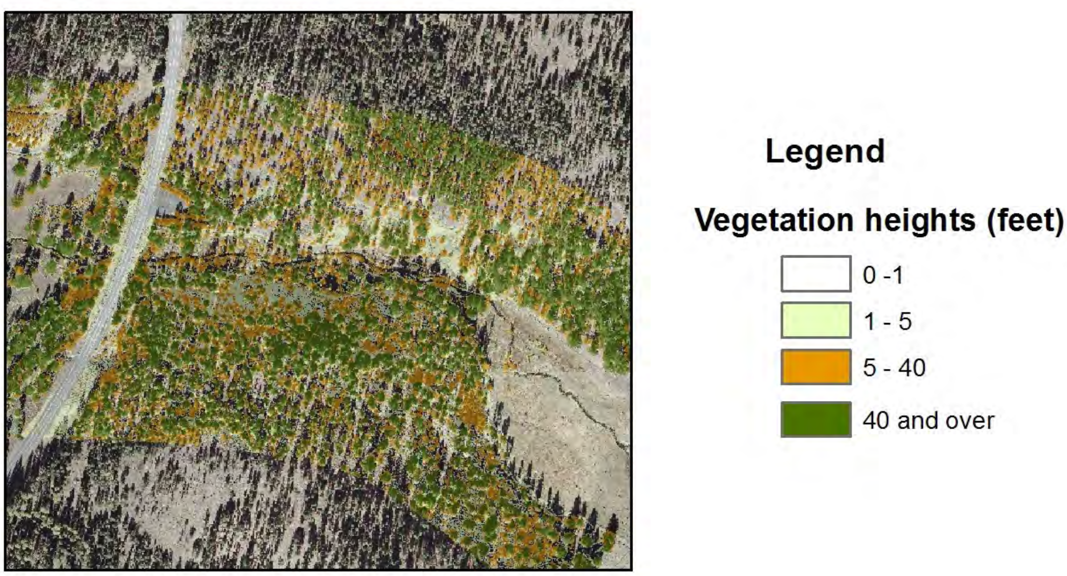

Figure 35 – LiDAR Vegetation Height Data Overlain on Aerial Photographs.

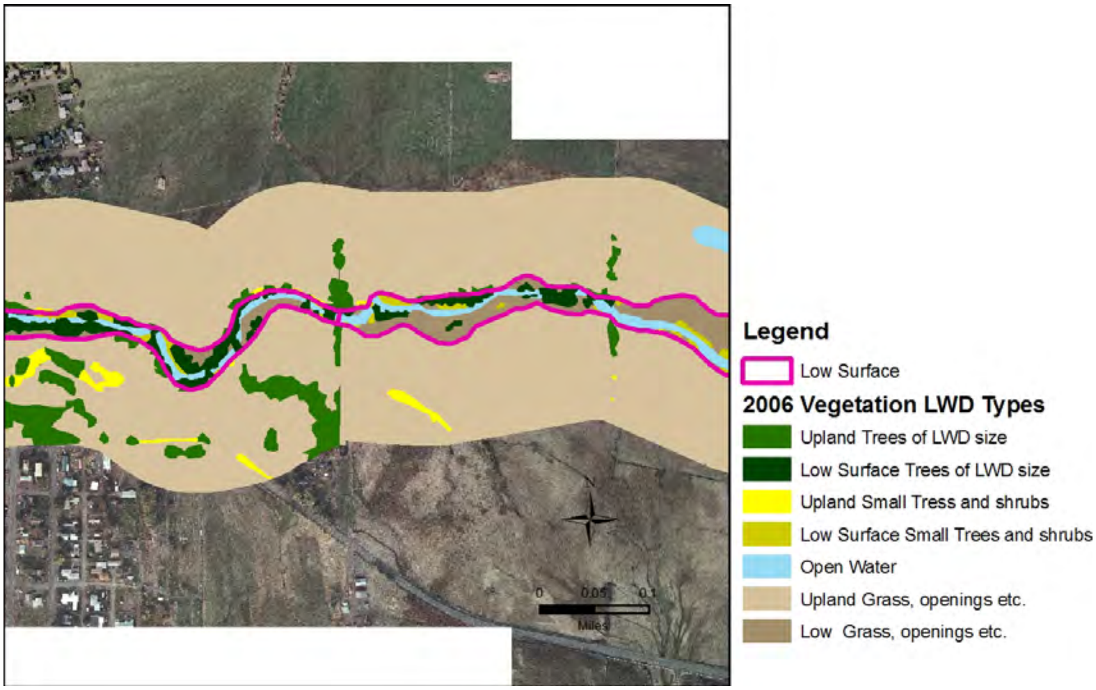

Figure 36 – LWD Vegetation Polygons Overlain on Aerial Photography.

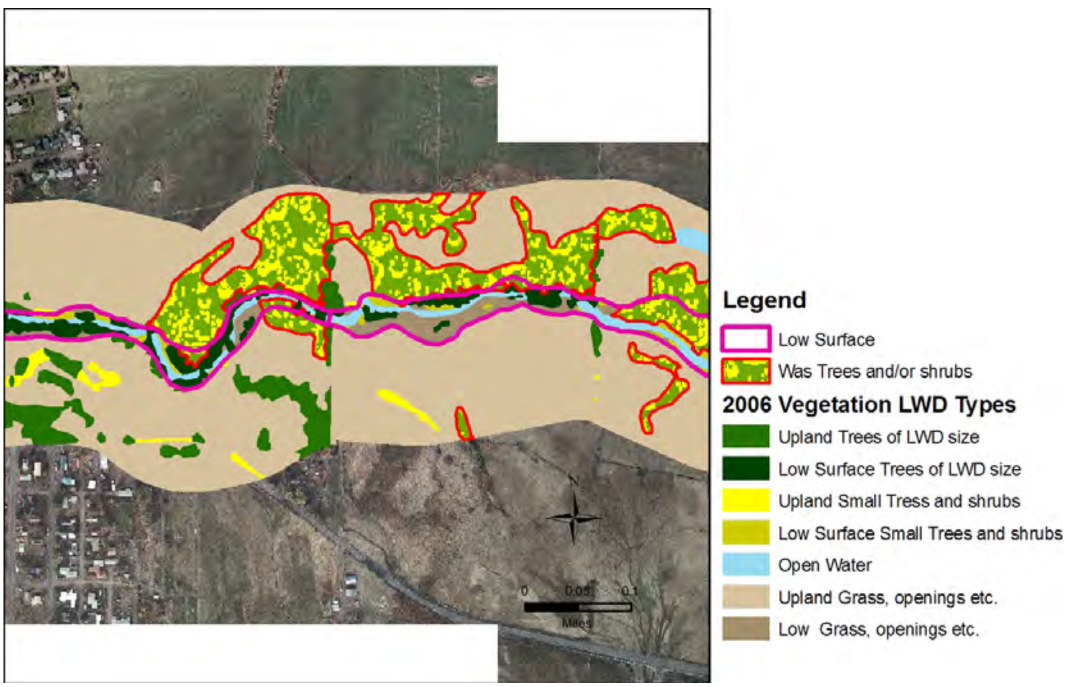

Figure 37 – LWD Vegetation and Historical Change Polygons Overlain on Aerial Photography.

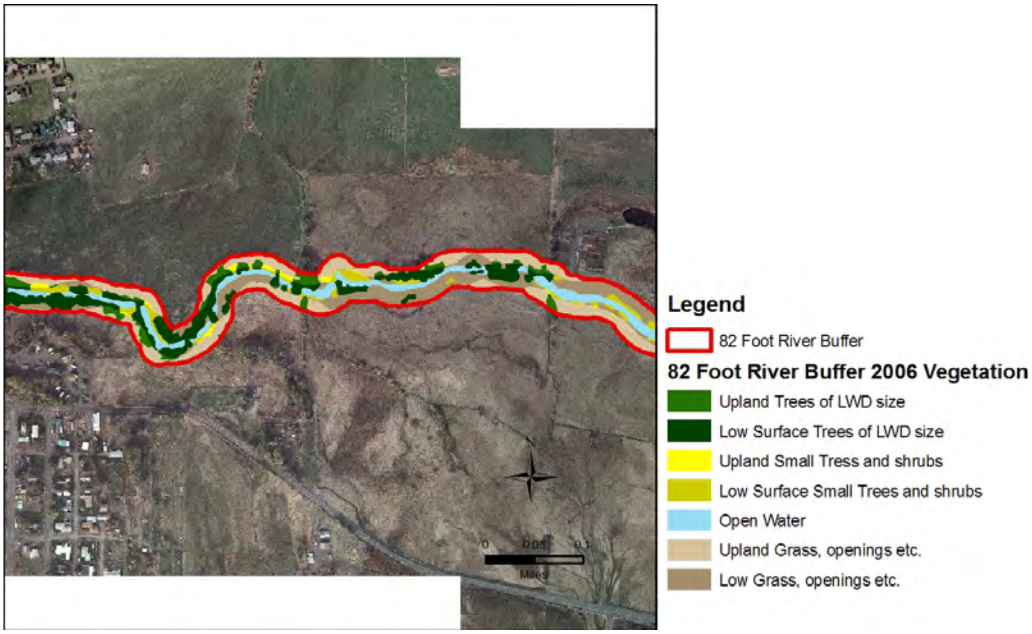

Figure 38 – 82-Foot Buffer Polygons Overlain on Aerial Photography.

Table 3 – Summary of Vegetation Classification for Assessment Area (In Acres).

LWD Trees	Small Trees/ Shrubs	Low Vegetation/ Openings	Total Acres*
13.2	10.2	46.3	69.7
18.90%	14.66%	66.44%	100.00%

* Wetted areas, including the river, were not included in the total number of acres.

5.4.3 Riparian Vegetation Summary of the Assessment Area

In the assessment area, 18.90 percent of the polygons are dominated by LWD-sized trees. The treed areas appear to be primarily cottonwoods and are concentrated in reaches UJD1 and UJD3. Shrub-dominated areas make up 14.66 percent of the assessment area and are located mainly along the river channel and side channels off the river.

Surface textures on the aerial photos indicated agricultural use in 66.44 percent of the assessment area, which was classified as low vegetation/openings. Textures on the 2006 aerial photography suggest that if the area was not cultivated, it may function as a wet meadow, as do other areas in the basin.

Today, agricultural development dominates the area, with farming up to the river banks in most places. Agriculture use has dominated the area since 1939 and may have contributed to the continued loss of forest cover within the riparian. The riparian buffer has not been functioning at its greatest capacity along this reach of the river since 1939.

5.4.4 LWD Contribution and Shading

Riparian vegetation contributes at least two important components to salmon habitat: LWD and shading for the river channel. LWD is an important contribution from the riparian corridor to the stream for salmon habitat. Shading of the river channel reduces water temperatures during hot summer months. The desired riparian vegetation would be that which is consistent with its Potential Natural Community, a biotic community that could be established if all successional vegetation sequences were completed without the interference of human activities (Winward 2000). This healthy riparian area is important for maintaining the structure and function of aquatic ecosystems (Platts 1991).

These data were generated from the GIS analysis:

- LWD trees which could be potentially recruited into the stream by river meanders accessing the trees (acres of polygons classified as dominated by trees within the low surface).
- LWD which is available to the stream in the short-term, which are within one site potential tree height from the current (on the date of the aerial photo which was interpreted).
- Shading by trees and shrubs adjacent to the river (acres of trees within 82 feet of the wetted river on 2006 aerial photography).

5.4.4.1 LWD GIS Methods

Thirty-foot long logs are the generally accepted minimum-sized logs for LWD in the stream. Forty feet was used as a minimum size that would provide LWD to the river. This conservative size was used to account for some breakage of the tree and for the small diameter of the top 5 feet of the trees.

LiDAR data were symbolized to group vegetation into areas with greater than 50 percent canopy cover of:

- Trees of potential LWD tree size (over 40 feet tall).
- Small trees 5 to 40 feet tall.
- Low vegetation (crops, herbaceous, low shrubs, and open areas) 1 to 5 feet tall.

Polygons classified as LWD trees contain an average of 18 trees per acre.

5.4.5 Results

5.4.5.1 LWD-Sized Trees in Low Surface

Limited LWD is available only along short reaches of the river that are dominated by cottonwoods. Most LWD is probably contributed by reaches upstream or by tributaries to the assessment area. Roads may cutoff contributions from the tributaries. Additional investigations could identify LWD sources outside the floodplain area.

Trees of LWD-size in this reach may be limited by:

- Natural wet meadow riparian habitat.
- Wildlife grazing (elk and deer).
- Livestock grazing and water draining and diversion for livestock (present and past).

Table 4 shows the number of acres of LWD trees within the low surface for each reach. This represents the acres of LWD-sized trees that could be recruited if the river accessed them either through lateral erosion or flood flow overtopping.

Table 4 – Acreage of LWD Trees within the Low Surface of Each Reach.

Reach	LWD Trees (in acres)
UJD1	2.8
UJD2	3.2
UJD3	7.1

5.4.5.2 Accessible LWD

This analysis includes vegetation within 82 feet of the river and includes both the low surface and area outside the low surface. LWD-sized trees adjacent to the river in these areas could be recruited into the river in the short-term. Table 5 shows acreages for each reach. Some acres are larger than the low surface LWD trees because of the area outside of the low surface, but within 82 feet of the river.

Table 5 – Acreages of LWD-Sized Trees within 82 Feet of the River.

Reach	LWD Trees (in acres)
UJD1	3.5
UJD2	4.2
UJD3	6.2

5.4.5.3 Shading

In the assessment area, trees and shrubs within the 82-foot wide buffer that provide shade to the river comprise 37.2 acres or 36.1 percent of the total buffer area. Table 6 shows the percent of the 82-feet wide strip along both sides of the river which contain trees and/or shrubs which could provide shade to the river. Trees and shrubs outside the low surface, but within 82 feet are included. Streamside trees and shrubs may have been historically limited in some reaches of the study area by wet meadow habitat.

Table 6 – Percent of Stream Shaded by Trees or Shrubs by Reach.

Reach	Percent of Stream Shaded
UJD1	56.0
UJD2	31.2
UJD3	47.2

5.4.5.4 Historical Changes

Significant losses of Tree/Shrub cover have occurred since 1939, with largest impact appearing to be from agricultural use. Major restoration work would be needed in this assessment area to restore the riparian buffer. Further work is required to make recommendations.

Table 7 – Percent Negative Change from 1939 to 2006 of Trees and Shrubs by Reach.

Reach	Tree/Shrub Percent Negative Change
UJD1	37.1
UJD2	66.3
UJD3	49.5

5.4.6 Potential Future Improvements to Assessment

This analysis was limited by working only from aerial photos because time and budget did not allow field work at this stage. The riparian assessment would improve with these additions from field work:

- Species verification and identification of tree, shrub, forb, and grasses at selected sites and interpretation expansion in GIS to non-visited sites; size/age classifications.
- Addition of structural components to vegetation communities - canopy (overstory), understory, forb/grass/litter, snags and downed wood (LWD) at selected sites and interpretation in a GIS of non-visited sites.
- Noxious weeds mapping and assessment.
- Field assessment of riparian vegetation health (seral stage, invasive weed colonization, grazing, and logging impacts) from observations of selected sites.
- Assessment of overbank flooding at selected sites.
- Assessment of LWD sources outside the assessment area.

5.5 Present Fish Use

5.5.1 Spring Chinook

Oregon Department of Fish and Wildlife (ODFW) surveys illustrate an increasing trend in spring Chinook abundance in the Upper Mainstem John Day River (Figure 39). Although the Upper Mainstem Assessment Area appears to be a productive spawning area for spring Chinook, the historic redd surveys were only conducted on the assessment area upstream of Dad’s Creek (Index Area). However, redd surveys conducted since 1998 have covered the entire assessment area. Spring Chinook spawning occurs within the mainstem of the assessment area with rearing in the mainstem and its tributaries.

Table 8 indicates the distribution of Chinook Redds surveyed by ODFW between 2002 and 2006. Because some of the coordinates were missing from the 2002 dataset, 2002 surveyed redd counts may be slightly greater than those depicted in the table.

In the Upper Mainstem Assessment Area, reach UJD3 has the greatest number of redds per mile, followed by reach UJD2. Reaches UJD2 and UJD3 cover the Forrest Conservation Area and are the moderately confined and unconfined reaches, respectively.

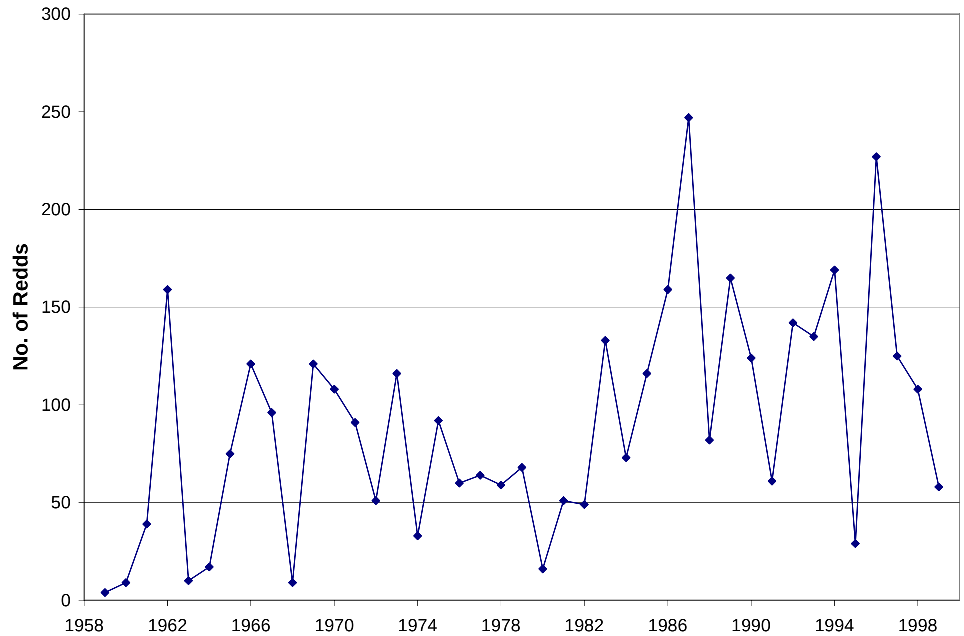

Figure 39 – Redd Counts for Spring Chinook, 1959 to 1999, Within 13 Miles of the Upper John Day River from Dad's Creek to Highway 62 Road Culvert (Ruzycki et al. 2002).

Table 8 – Distribution of Chinook Redds Surveyed by ODFW Between 2002 and 2006.

Reach	Type	Length (mi)	2002	2003	2004	2005	2006	Average per year	Average per mile
Reach UJD1	Confined	0.43	0	0	1	0	3	0.8	1.9
Reach UJD2	Moderately Confined	1.60	12	11	13	14	20	14	8.8
Reach UJD3	Unconfined	1.11	16	10	NA	NA	13	13	11.7
Total		3.14	28	21	14	14	36	22.6	7.20

*2002 data may be incomplete as several points were missing spatial data

*2006 data in reach UJD3 only cover Forrest Conservation Area

5.5.2 Summer Steelhead

Summer steelhead primarily use the assessment area for spawning and rearing. Steelhead abundance has been generally declining in the Upper John Day since 1958. NMFS (1999) calculated the long-term trend in steelhead abundance for the Upper Mainstem as a 2.9 percent decrease, while the more recent short-term trend, calculated between 1987 and 1997, was a 15.2 percent decrease. The decline of steelhead abundance in the John Day Basin is particularly important due to large populations of naturally spawning steelhead in the recent past (WCSBRT 2003).

The spatial distribution of steelhead redd count data in the Upper Mainstem was not available for inclusion into this report. However, surveys completed by ODFW illustrate that redds were in much greater abundance in the late 1980s than they were in the early 2000s (Figure 41). Carmichael (2006) developed spawner abundance estimates for steelhead based on redd count expansions (Figure 40).

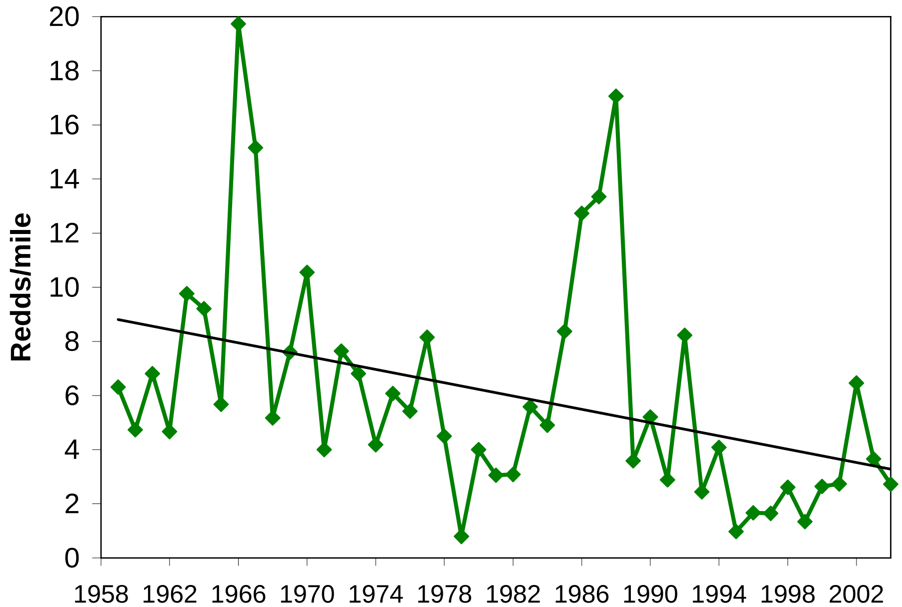

Figure 41 – Upper Mainstem John Day River Spawning Surveys, 1959 – 2004 (Chilcote 2008).

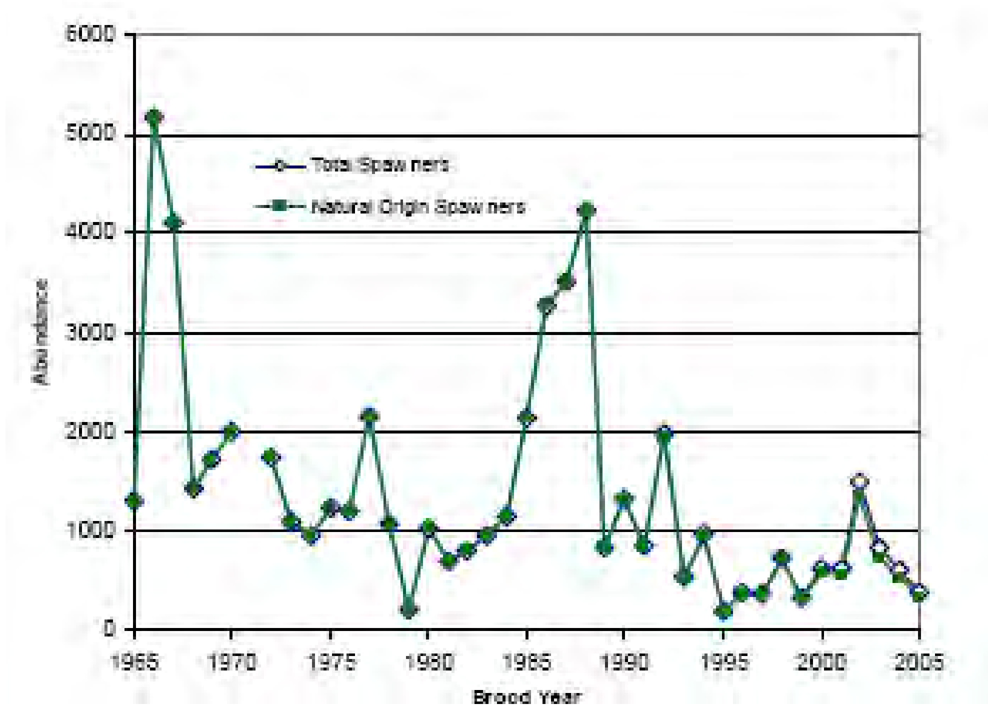

Figure 40 – Historic Steelhead Spawner Abundance in the Upper Mainstem as Calculated from Redd Count Expansions (Carmichael 2006).

6.0 General Impacts of Restoration and Protection Strategies

This section describes the conceptual interpretation of how restoration and protection strategies could impact physical processes. The discussion relates to physical processes within the next several years to decades; beyond this timeframe, major changes in large-scale controlling variables (e.g., climate, land use) could substantially alter river processes.

Comparison of the fully functioning conditions with the present setting helped identify substantial impacts to lateral floodplain connectivity, changes in channel planform and geometry, and a general lack of regeneration of vegetation within the floodplain. These impacts have resulted in significant loss of off-channel habitat, instream complexity, and likely degraded water quality. Historical removal of LWD, deforestation of the low surface, grazing activities, channelization, confinement, and disconnection of side and overbank channels has resulted in increased channel energy and modification of channel geometry and planform (i.e., increased slopes, erosion of banks). Channel degradation may be present in localized areas under flood flows, but is limited by geologic controls and possibly vertical grade control structures. Alluvial fans and terraces further constrain lateral channel position and expansion of the floodplain.

The present channel appears to have adjusted to constructed impacts and is not undergoing system-wide aggradation or degradation. The adjustments have created a less sinuous, steeper, and possibly wider channel than existed historically. Results of the assessment indicate that under significant flooding events, lateral or vertical degradation may occur in reach UJD2 of the assessment area. Any potential future degradation will be limited by the opposing alluvial fans at the upstream end of reach UJD2. The channel may continue to develop meander bends in accessible floodplain areas if channel straightening activities are not conducted. The extent of floodplain access remains limited without removal of physical barriers and reconnection of historic side channels. Following implementation of proposed protection and restoration efforts (e.g., removal of constructed features, re-establishment of vegetation in the riparian corridor, and reconnection of side and over bank channels), lateral floodplain connectivity with the active channel is anticipated to improve, which in turn should dissipate channel energy and promote regeneration of riparian vegetation. A quantitative understanding of benefits gained through implementation of specific actions requires additional analyses to determine the degree to which off-channel habitat and habitat complexity can be restored by each action. Reach- and project-level assessments can be performed to evaluate the frequency and degree of connectivity that will occur. If proposed restoration and protection actions are not completed in full (e.g., culvert installed through a levee), additional analysis would be needed to understand if floodplain function can be fully or only partly restored.

To promote increased vertical connectivity with the floodplain, proposed protection and restoration efforts may assist in local rises in bed elevation. Areas where the channel has been completely disconnected from the floodplain, such as locations of substantial channelization, active reconnection of the channel with the floodplain may require reconstruction of the main and/or side channels.

River processes within the low surface are currently functioning in a few small areas where vegetation is present. Restoration activities can be conducted to expand and reconnect areas that are already functioning to maximize cumulative benefits for salmonid populations. Reworking of the channel bed and floodplain through sediment transport processes and channel migration is a healthy part of the fluvial system. Localized degradation and aggradation of the channel bed may result from functioning river processes, but a long-term net change in the channel or floodplain elevations is unlikely to occur if a dynamic state of equilibrium is restored.

7.0 Restoration and Protection Concepts

7.1 Greatest Departures from Typical Channel Processes

Historical research, aerial photographs, hydraulic modeling, geologic and geomorphic mapping were integrated to identify significant departures from "ideal" or fully functioning conditions within the assessment areas. Because historical data were not available prior to major human settlement, hypothesized typical channel processes were developed from the earliest documented accounts, anecdotal information, ground and aerial photographs from the early 20th century, and an understanding of similar system processes with less impacts within the region.

Within the Upper Mainstem Assessment Area, the greatest departures from fully functioning conditions include:

- Widespread reductions in channel length caused by repeated channel straightening and meander cut-offs.
    - Reduced floodplain function.
    - Reduced floodplain connectivity due to construction of roads, levees, push-up dikes, and rock spurs.
- Reduced lateral migration potential due to hardened bank protection measures.
- Reduced habitat complexity within the channel and floodplain due to clearing of riparian and upland vegetation, cattle and sheep grazing, and removal of LWD sources.

Recognizing the greatest departures, biological hypotheses were developed, including:

- If we preserve areas where the fluvial system is "properly functioning," then we will protect core areas of the riverine ecosystem upon which multiple species depend.
- If we restore/rehabilitate the fluvial system where it is "not properly functioning" using a hierarchal (or nested) approach to achieve a cumulative ecological benefit, then we will improve the abundance and productivity, and the spatial structure and diversity of multiple species that are dependent on the riverine ecosystem.
- By using a holistic approach to preserving and restoring/rehabilitating natural processes and function of the fluvial system across different temporal and spatial scales, the fluvial system will maintain a "properly functioning" riverine ecosystem and sustain a viable salmonid population.

7.2 VSP Parameters and Limiting Factors

In addition to biological guidance documents directly related to the recovery of salmonid species in Oregon, documents relating to salmon and steelhead recovery in the Upper Columbia Region also were referenced. Although the documents focus on the Upper Columbia River, the methodology presented for recovery of listed species has broad application to other basins and can be tailored to meet specific basin objectives. Within the *Biological Strategy* (UCRTT 2007), four viable salmonid population (VSP) parameters are proposed to characterize recovery, including abundance, productivity, spatial structure, and diversity. These parameters provide a consistent measure for the long-term persistence of viable populations of listed species.

As part of the development of the John Day Subbasin Plan (NPCC 2005), limiting factors were evaluated through an Ecosystem Diagnostic and Treatment Model (EDT). For both the Upper Mainstem and Middle Fork John Day River Assessment Areas, limiting factors for summer steelhead and spring Chinook included habitat diversity, sediment load, temperature, key habitat quantity, and flow.

The Draft Middle Columbia River Steelhead Recovery Progress Report (Carmichael, 2006) provides a synopsis of biological statistics for the Upper John Day River basins, including:

Upper John Day

- Drainage Area - square kilometers
- Number of MaSAs 3
- Number of MiSAs 4
- Population is at moderate risk.
- ICTRT overall rating is the population does not currently meet viability criteria.
- Limiting Factors - key habitat quantity, habitat diversity, flow, sediment load, and water temperature.
- Anthropogenic Threats - agricultural practices, overgrazing by livestock, removal of large trees from riparian corridor, wetland draining and conversion, stream channelization and diking, mining, and dredging (NMFS 2004).

7.3 Habitat and Restoration Objectives

To address each limiting factor, the John Day Subbasin Plan and Middle Columbia River Steelhead Progress Report (Carmichael 2006) established habitat objectives:

Habitat diversity/Key habitat quantity

- Maintain riparian management objectives.
- Provide adequate habitat components necessary for focal species.
- Increase role and abundance of wood and large organic debris in streambeds.
- Increase pool habitat (e.g., beaver ponds).
- Maintain and improve quality and quantity of spawning grounds.
- Decrease gradient; restore sinuosity.
- Restore channel and floodplain connectivity.
- Restore off-channel areas for high flow refugia.

Flow

- Enhance base flows.
- Moderate peak flows where appropriate.
- Restore natural hydrographic conditions where appropriate.

Sediment Load

- Minimize unnatural rates of erosion from upland areas.
- Trap sediment on the floodplain as appropriate.
- Bring the stream channel in balance with the water and sediment as supplied by the watershed.

Temperature

- Moderate extreme stream temperatures through improvement of width-to-depth ratio, increased shade and floodplain connectivity.

Specific restoration objectives within the assessment areas were derived from the habitat objectives presented in the *John Day Subbasin Plan and Middle Columbia River Steelhead Progress Report* integrated with findings from the geomorphic assessment and biological objectives identified by the Confederated Tribes of Warm Springs Reservation of Oregon (2007). Because the width of the valley often defines restoration opportunities and floodplain complexity, the river was partitioned into reaches by the relative degree of valley confinement: confined, moderately confined, and unconfined. One paramount objective common to all types of reaches is the protection of properly functioning habitat. The restoration objectives for differing reach types are presented below.

Unconfined and Moderately Confined Reaches

- Protection of existing functioning habitat.
- Re-establish riparian vegetation in areas that have been denuded due to clearing, timber harvest, or disconnection from water table.
- Promote river interaction with the floodplain to rehabilitate the natural function of the floodplain.
- Restore a more natural channel gradient through increased sinuosity.
- Restore habitat complexity features and processes within the channel and surrounding floodplain.

Confined Reaches

- Protection of existing functioning habitat.
- Re-establish riparian vegetation in areas that have been denuded due to clearing, timber harvest, or disconnection from water table.
- Renew in-channel habitat complexity.

7.4 Development of Restoration Strategies

The Upper Mainstem John Day River is considered a Category 2 (Restoration/Protection) watershed using criteria described in the *Upper Columbia Salmon Recovery Plan* (UCSRB 2007). The Draft Middle Columbia Steelhead Recovery Progress Report (Carmichael 2006) imparts prioritization considerations as guidance for management and restoration actions. Actions with the highest priority include:

- Actions that provide long-term protection for the major life history strategies (i.e., summer and winter run timing) that currently exist at the major population grouping (MPG) level.
- Actions that provide long-term protection of habitat conditions that support the viability of priority extant populations and their primary life history strategies throughout their entire life cycle. A population is considered a priority if it is critical for MPG or evolutionary significant unit (ESU) viability.
- Actions that enhance the viability of priority extant populations.
- Actions that protect or enhance viability of multiple listed populations.
- Actions that enhance habitat and restore natural processes to increase survival, connectivity, and reproductive success of priority extant populations.
- Actions that target the key limiting factors and that contribute the most to closing the gap between current status and desired future status of priority populations.
- Actions that are required to protect and enhance habitats for populations that are not critical for MPG or ESU viability but must be maintained.

As part of the John Day Subbasin Plan effort, three geographic areas were divided for development and ranking of restoration strategies based on the EDT and then "based on professional opinion" (NPCC 2005, p. 6). The Upper Mainstem Assessment Area lies within the geographic area identified as "Upper Mainstem and South Fork John Day River."

Within each geographic area defined in the Subbasin Plan, restoration strategies for each 5th field hydrologic watershed (HUC5) were prioritized, and priority rankings between the HUC5s were established. The assessment area on the Upper Mainstem of the John Day River is located within two HUC5s, the Upper John Day and the Strawberry Creek. All of the Forrest Conservation Area lies in the Strawberry Creek HUC5, which is the top ranking HUC5 in its geographic area. In the Strawberry Creek HUC5, nine restoration strategies were assigned as having a "very high" rank. These restoration strategies and their specific types of actions included:

1. Protection of Existing Habitat
    a. Acquisition and management of land
    b. Acquisition and management of conservation easements
    c. Adoption and management of cooperative agreements
    d. Implementation of special management designation on public lands

2. Riparian Habitat Improvements
    a. Management of riparian grazing
    b. Riparian vegetation management
    c. Floodplain restoration
    d. Beaver management
3. Fish Passage
    a. Replacing or removing culverts
    b. Improving irrigation diversion
    c. Addressing other artificial passage barriers
4. Fish Screening
    a. Install fish screens on irrigation diversion
    b. Explore potential to screen mining diversion
5. Flow Restoration
    a. In-stream water right leases and acquisitions
    b. Irrigation efficiency projects
    c. Floodplain aquifer recharge projects
    d. Off-stream storage basins
    e. Efforts to improve hydrologic connectivity between springs and streams
6. In-stream Activities
    a. Large woody debris placement
    b. Channel restoration
    c. Bank protection/stabilization
    d. Weirs and other structures
7. Upland Improvements
    a. Appropriate livestock grazing management
    b. Minimize sediment and erosion impacts from forest harvest activities
    c. Wet meadow restoration
    d. Vegetation management
    e. Road system management
    f. Erosion and runoff control in agricultural areas
    g. Developed area runoff management

8. Education and Outreach
    a. Outreach to resource users and managers
    b. Use of demonstration projects
    c. Outreach to government officials
    d. Outreach to general public
    e. Support of regional outreach efforts
9. Manage Recreation & Tribal Fisheries

The downstream boundary of the Upper John Day HUC5 is the Dad's Creek confluence, which corresponds closely with the upstream boundary of the Forrest Conservation Area. The Upper John Day HUC5 has a restoration priority ranking of 5 out of 9. In the Upper John Day HUC5, five restoration strategies received a "very high" rank. These restoration strategies and their specific types of actions included:

1. Protection of Existing Habitat
    a. Acquisition and management of land
    b. Acquisition and management of conservation easements
    c. Adoption and management of cooperative agreements
    d. Implementation of special management designation on public lands
2. Fish Passage
    a. Replacing or removing culverts
    b. Improving irrigation diversion
    c. Addressing other artificial passage barriers
3. Fish Screening
    a. Install fish screens on irrigation diversion
    b. Explore potential to screen mining diversion
4. Flow Restoration
    a. In-stream water right leases and acquisitions
    b. Irrigation efficiency projects
    c. Floodplain aquifer recharge projects
    d. Off-stream storage basins
    e. Efforts to improve hydrologic connectivity between springs and streams
5. Manage Recreation & Tribal Fisheries

7.4.1 Restoration Strategies by Valley Width

Priority restoration actions identified through the Subbasin Plan (NPCC 2005) combined with findings from geomorphic investigations were the foundation for the development of specific restoration actions within the assessment areas. The restoration actions are structured to satisfy the habitat and restoration objectives, and are divided as to the relative confinement of the reach. Opportunities for restoration are generally much greater within unconfined and moderately confined reaches than within confined reaches.

For moderately confined and unconfined reaches, the following actions were recognized as addressing specific biological and restoration objectives.

- Preservation and protection of existing riparian vegetation within the floodplain and along the channel margins to maintain canopy cover, bank stability, and LWD inputs.
- Restoration of floodplain connectivity and function.
- Reconnection of historical main, side, and overflow channels.
- Restoration of lateral channel migration through the removal of instream structures and hardened bank protection measures.
- Re-vegetation of the low surface and installation of cattle exclusion fencing around the low surface.
- Installation of LWD structures as a short-term means of enhancing habitat while the long-term processes that naturally supply LWD re-establish.
    - Placement of LWD to direct high flows into side or overflow channels, thereby promoting floodplain access.
    - Placement of LWD to promote short term channel complexity, provide fish cover, and re-establish natural channel morphology.
- Channel relocation to promote long-term channel complexity and increase fish habitat

More confined reaches are limited in the types of restoration actions that would effectively address restoration objectives. Measures that may be feasible in more confined reaches are:

- Preservation and protection of existing riparian vegetation within the floodplain and along the channel margins to maintain canopy cover, bank stability, and LWD inputs.
- Reforestation of riparian vegetation.
- Restoration of lateral channel migration through the removal of instream structures and hardened bank protection measures.
- Installation of LWD structures as a short-term means of enhancing habitat while the long-term processes that naturally supply LWD re-establish.
    - Placement of LWD to direct high flows into side or overflow channels, thereby promoting floodplain access.
    - Placement of LWD to promote short-term channel complexity, provide fish cover, stabilize banks, and re-establish natural channel morphology.

7.4.2 Adaptive Management and Project Monitoring

An important aspect of each restoration strategy will be the ability to modify the project design as necessary to meet project goals. Adaptive management is often defined as a "reliance on scientific methods to test the results of actions taken so that the management and related policy can be changed promptly and appropriately" (UCSRB 2007). In some locations, an adaptive management approach will be an essential component to project success, while in others locations, little to no adaptive management may be required. Adaptive management works well with the dynamic nature of rivers and may impart some flexibility in the design of each project and in the maintenance of a successful effort. The Upper Columbia Salmon Recovery Board (UCSRB) recommends that adaptive management be framed in the sequence of developing a hypothesis, monitoring the project, evaluating results, and responding to the results.

The measurement of project success, and a key component of adaptive management, is often driven by monitoring efforts. The UCSRB (2007) recommends the use of two monitoring strategies for determining the level of project success: implementation monitoring and level 1 effectiveness monitoring. Implementation monitoring demonstrates proof that the restoration action occurred and measures the qualitative success of the project through photo documentation and written descriptions before and after project implementation. Level 1 effectiveness monitoring is used as a tool to evaluate if the restoration action actually met targeted environmental parameters. Level 1 effectiveness monitoring is conducted through photograph, counts, and presence/absence surveys (Hillman 2006) at defined temporal intervals. Steps for development of a monitoring plan for each project are provided by the Upper Columbia Salmon Recovery Board (2006)

8.0 Glossary

TERM	DEFINITION
adaptive management	A management process that applies the concept of experimentation to design and implementation of natural resource plans and policies.
aggradation	Gradual buildup of land along a stream bank due to water action, sediment transport, or alluvial deposits
alluvial fan	A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream at the place where it issues from a narrow mountain valley upon a plain or broad valley, or where a tributary stream is near or at its junction with the main stream, or wherever a constriction in a valley abruptly ceases or the gradient of the stream suddenly decreases; it is steepest near the mouth of the valley where its apex points upstream, and it slopes gently and convexly outward with a gradually decreasing gradient (Neuendorf et al. 2005).
alluvium	A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream, as a sorted or semi-sorted sediment on the river bed and floodplain (Neuendorf et al. 2005).
alpine glacier	A glacier in mountainous terrain.
anadromous (fish)	A fish, such as the Pacific salmon, that spawns and spends its early life in freshwater but moves into the ocean where it attains sexual maturity and spends most of its life span (Owen & Chiras 1995).
andesite	A fine-grained, gray volcanic rock, mainly plagioclase and feldspar.
anthropogenic	Caused by human activities.
anticline	A fold, generally convex upward, whose core contains the stratigraphically older rocks.
bar (in a river channel)	Accumulations of bed load (sand, gravel, and cobble) that are deposited along or adjacent to a river as flow velocity decreases. If the sediment is reworked frequently, the deposits will remain free of vegetation. If the surface of the bar becomes higher than the largest flows, vegetation stabilizes the surface making further movement of the sediment in the bar difficult.
basalt	A dark-colored igneous rock, commonly extrusive, composed primarily of calcic plagioclase and pyroxene.

TERM	DEFINITION
bed-material	Sediment that is preserved along the channel bottom and in adjacent bars; it may originally have been material in the suspended load or in the bed load.
bedrock	A general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material (Neuendorf et al. 2005). The bedrock is generally resistant to fluvial erosion over a span of several decades, but may erode over longer time periods.
breccia	A coarse-grained clastic rock, composed of angular broken rock fragments held together by a mineral cement or a fine-grained matrix.
canopy cover (of a stream)	Vegetation projecting over a stream, including crown cover (generally more than 1 meter (3.3 feet) above the water surface) and overhang cover (less than 1 meter (3.3 feet) above the water).
Category 2	Category 2 watersheds support important aquatic resources, and are strongholds for one or more listed fish species (Appendix A). Compared to Category 1 watersheds, Category 2 watersheds have a higher level of fragmentation resulting from habitat disturbance or loss. These watersheds have a substantial number of subwatersheds where native populations have been lost or are at risk for a variety of reasons. Connectivity among subwatersheds may still exist or could be restored within the watershed so that it is possible to maintain or rehabilitate life history patterns and dispersal. Restoring and protecting ecosystem functions and connectivity within these watersheds are priorities. Adapted from UCRTT (2007).
Cenozoic era	An era of geologic time from about 65 million years ago to present that includes the Tertiary and Quaternary periods.
channel morphology	The physical dimension, shape, form, pattern, profile, and structure of a stream channel.
channel planform	Characteristics of the river channel that determine its two-dimensional pattern as viewed on the ground surface, aerial photograph, or map.
channel remnant (wet)	Same as an old channel (wet) for channels on the USGS topographic maps from the middle 1980s. Mapped as a channel remnant (wet), because this is how they appear on the topographic maps.
channel sinuosity	The ratio of length of the channel or thalweg to down-valley distance. Channel with a sinuosity value of 1.5 or more are typically referenced as meandering channels (Neuendorf et al. 2005).

TERM	DEFINITION
channel stability	The ability of a stream, over time and under the present climatic conditions, to transport the sediment and flows produced by its watershed in such a manner that the stream maintains its dimension, pattern, and profile without either aggrading or degrading.
channelization	The straightening and deepening of a stream channel to permit the water to move faster, to reduce flooding, or to drain wetlands.
colluvium	A general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity.
constructed features	Man-made features that are constructed in the river and/or floodplain areas (e.g., levees, bridges, riprap).
core habitat	Habitat that encompasses spawning and rearing habitat (resident populations), with the addition of foraging, migrating, and overwintering habitat if the population includes migratory fish. Core habitat is defined as habitat that contains, or if restored would contain, all of the essential physical elements to provide for the security of allow for the full expression of life history forms of one or more local populations of salmonids.
Cretaceous period	The final period of the Mesozoic era that covered the span of time between 135 and 65 million years ago.
deformation	A general term for the processes of folding, faulting, shearing, compression, or extension of rocks as a result of various earth forces.
degradation	Wearing down of the land surface through the processes of erosion and/or weathering
Devonian period	A period during the Paleozoic era thought to have covered the span of time between 410 and 355 million years ago.
discharge (stream)	With reference to stream flow, the quantity of water that passes a given point in a measured unit of time, such as cubic meters per second or, often, cubic feet per second (cfs).
diversity	All the genetic and phenotypic (life history traits, behavior, and morphology) variation within a population.
drift	A general term for all rock material transported by glaciers and deposited directly from the ice or through the agency of meltwater.
dynamic equilibrium	Condition where on-going opposing processes proceed at the same rate, resulting in little change in the state of the environment.
ecosystem	A unit in ecology consisting of the environment with its living elements, plus the non-living factors, that exist in and affect it (Neuendorf et al. 2005).

TERM	DEFINITION
embeddedness	The degree to which large particles (boulders, gravel) are surrounded or covered by fine sediment, usually measured in classes according to percentage covered.
entrenched	A stream that flows in a narrow trench or valley cut into a plain or relatively level upland.
entrainment	The process of picking up and carrying along, as the collecting and movement of sediment by currents.
ephemeral stream	A stream or portion of a stream which flows briefly in direct response to precipitation in the immediate vicinity, and whose channel is at all times above the water table.
extrusion	The emission of relatively viscous lava onto the earth's crust.
fine sediment (fines)	Sediment with particle sizes of 2.0 mm (0.08 inch) or less, including medium to fine sand, silt, and clay.
floodplain	The surface or strip of relatively smooth land adjacent to a river channel constructed by the present river in its existing regimen and covered with water when the river overflows its banks. It is built on alluvium, carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current. A river has one floodplain and may have one or more terraces representing abandoned floodplains (Neuendorf et al. 2005).
geomorphic reach	A geomorphic reach, represents an area containing the active channel and its floodplain bounded by vertical and/or lateral geologic controls, such as alluvial fans or bedrock outcrops, and frequently separated from other reaches by abrupt changes in channel slope and valley confinement. Within a geomorphic reach, similar fluvial processes govern channel planform and geometry through driving variables of flow and sediment. A geomorphic reach is comprised of a relatively consistent floodplain type and degree of valley confinement. Geomorphic reaches may vary in length from 100 meters in small, headwater streams to several miles in larger systems (Frissell et al. 1986).
geomorphology	The study of the classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes caused by the actions of flowing water.
geosycline	A large troughlike or basinlike downwarping of the earth's crust, in which a thick succession of sedimentary and volcanic rocks accumulated. A geosyncline may form in part of a tectonic cycle in which orogeny follows.

TERM	DEFINITION
GIS	Geographical information system. An organized collection of computer hardware, software, and geographic data designed to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.
glacial deposits (undifferentiated)	Consists predominantly of till and glaciofluvial deposits of silt, sand, gravel, cobbles and boulders. These deposits were not differentiated as ice-contact, ice-proximal or ice-distal deposits (i.e., moraine versus glacial outwash). The materials are generally consolidated in the headwater areas where they were in contact with the glacier and unconsolidated in the valley bottoms where they were deposited primarily by glaciofluvial processes.
glaciofluvial	Pertaining to the melt water streams flowing from wasting glacier ice and especially to the deposits produced by such streams; relating to the combined actions of glaciers and streams (Neuendorf et al. 2005).
habitat action	Proposed restoration or protection strategy to improve the potential for sustainable habitat upon which endangered species act (ESA) listed salmonids depend on. Examples of habitat actions include the removal or alteration of project features to restore floodplain connectivity to the channel, reconnection of historic side channels, placement of large woody debris, reforestation of the low surface, or implementation of management techniques.
habitat connectivity (stream)	Suitable stream conditions that allow fish and other aquatic organisms to access habitat areas needed to fulfill all life stages.
hardwood forest	A large area of deciduous trees (broad, flat leaves).
Holocene epoch	The geologic time interval between about 10,000 years ago and the present.
HUC5	5^{th} field Hydrologic Unit Code: Watersheds consist of subwatersheds that are delineated and arranged in nested hydrologic units, ranging from smallest (HUC8) to largest (HUC1). HUCs provide a uniquely identified and uniform method of subdividing large drainage areas. HUC5s represent 40,000- to 250,000-acre drainage areas that are nested within a larger drainage system. Several 5^{th} field hydrologic units comprise a HUC4, while several 6^{th} field hydrologic units are contained within a HUC5.
hyporheic zone	In streams, the region adjacent to and below the active channel where water movement is primarily in the downstream direction and the interstitial water is exchanged with the water in the main channel. The boundary of this zone is where 10 percent of the water has recently been in the stream (Neuendorf et al. 2005).

TERM	DEFINITION
ICBTRT	Interior Columbia Basin Technical Recovery Team. Expert panel formed by NOAA Fisheries Service (NMFS) to work with local interests and experts and ensure that ICBTRT recommendations for delisting criteria are based on the most current and accurate technical information available.
igneous rocks	Rocks that form from the cooling and solidification of molten or partly molten material (magma) either below the surface as an intrusive (plutonic) rock or on the surface as an extrusive (volcanic) rock.
incipient motion	The initiation of mobilizing a single sediment particle on the stream bed once threshold conditions are met.
incision	The process where by a downward-eroding stream deepens its channel or produces a relatively narrow, steep-walled valley (Neuendorf et al. 2005).
interbedded	Said of beds lying between or alternating with others of different character.
intermediate surface	Comprised of alluvial deposits that form a series of terrace risers and terrace treads that are elevated between 2.5 to 3.5 meters above normal water surface in the active channel. These surfaces are intermittent throughout the major drainages, but were only locally mapped where they have an influence on the rivers' morphology. This surface is rarely flooded by the river during the current climatic regime. The intermediate surface is considered stable on a decadal time scale. These materials are unconsolidated and susceptible to fluvial erosion.
Jurassic period	A period during the Mesozoic era thought to have covered the span of time between 203 and 135 million years ago.
landslide	Consists of a heterogeneous mixture of silt, sand, gravel, cobbles and boulders. Occur predominantly along glacial terrace deposits and valley walls. Mass wasting along the active river channels typically result in a "self-armoring" bank in that the finer materials are transported by the fluvial system and the larger materials are retained along the toe of the slope protecting the slope except during flood events.

TERM	DEFINITION
large woody debris (LWD)	Large downed trees that are transported by the river during high flows and are often deposited on gravel bars or at the heads of side channels as flow velocity decreases. The trees can be downed through river erosion, wind, fire, or human-induced activities. Generally refers to the woody material in the river channel and floodplain whose smallest diameter is at least 12 inches and has a length greater than 35 feet in eastern Cascade streams.
levee	A natural or artificial embankment that is built along a river channel margin; often a man-made structure constructed to protect an area from flooding or confine water to a channel. Also referred to as a dike.
limiting factor	Alternate definition: Any factor in the environment of an organism, such as radiation, excessive heat, floods, drought, disease, or lack of micronutrients, that tends to reduce the population of that organism (Owen & Chiras 1995).
low surface	Generally represents an area encompassing historic channel migration and floodplain. Consists of a mixture of reworked glacial deposits and fluviolacustrine deposits comprised of silt- to boulder-size material, but is predominantly sand, gravel, and cobbles. These deposits occur along stream channels and their active floodplains. These materials are unconsolidated and highly susceptible to fluvial erosion.
low-flow channel	A channel that carries stream flow during base flow conditions.
mass wasting	General term for the dislodgement and downslope transport of soil and rock under the influence of gravitational stress (mass movement). Often referred to as shallow-rapid landslide, deep-seated failure, or debris flow.
Mesozoic era	An era of geologic time from about 225 to about 65 million years ago that includes the Triassic, Jurassic, and Cretaceous periods.
Metamorphic rocks	Rocks derived from pre-existing rocks (sedimentary or igneous in response to marked changes in temperature, pressure, shearing stress, and chemical environment.
Miocene epoch	An epoch of the early Tertiary period, after the Oligocene and before the Pliocene.
nonnative species	Species not indigenous to an area, such as brook trout in the western United States. Sometimes referred to as an exotic species.
Oligocene epoch	An epoch of the Tertiary period that began about 34 million years ago and extended to about 23 million years ago.

TERM	DEFINITION
ophiolite	An assemblage of mafic and ultramafic igneous rocks whose origin is associated with an early phase development of a geosycline.
orthorectified photograph	An aerial photograph that has been corrected for the geometries and tilt angles of the camera when the image was taken and for topographic relief using a digital elevation model, flight information, and surveyed control points on the ground.
overflow channel	A channel that is expressed by no or little vegetation through a vegetated area. There is no evidence for water at low stream discharges. The channel appears to have carried water recently during a flood event. The upstream and/or downstream ends of the overflow channel usually connect to the main channel.
Paleiozoic era	An era of geologic time from about 570 to about 225 million years ago that includes the Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian periods.
peak flow	Greatest stream discharge recorded over a specified period of time, usually a year, but often a season.
pediment	A broad, gently sloping rock-floored erosion surface or plane of low relief, typically developed by subaerial agents in an arid or semiarid region at the base of an abrupt and receding mountain front or plateau escarpment, and underlain by bedrock that may be bare but are more often partly manteled with a thin discontinuous veneer of alluvium derived from the upland masses and in transit across the surface (Glossary of Geology 1987).
perennial stream	A stream that flows throughout the year; a permanent stream.
planform	The shape of a feature, such as a channel alignment, as seen in two dimensions, horizontally, as on an aerial photograph or map.
Pleistocene epoch	The geologic time interval between 1.6 million years ago and 10,000 years ago.
Pliocene epoch	An epoch of the Tertiary period that began about 5 million years ago and lasted until the start of the Pleistocene epoch about 2 million years ago.
project area	A project area is a distinct geographic location with potential implementation opportunities for habitat restoration and protection actions. Project areas are at a comparable level of organization as a habitat unit within a geomorphic reach and typically bounded by geomorphic features (e.g., river channel, floodplain, or terrace).

TERM	DEFINITION
project feature	A project feature is an individual structure or component of an active floodplain of a project area; examples include levees, roadway embankments, bridges, or culverts.
Quaternary period	The geologic time interval between 1.6 million years ago and the present. It includes both the Pleistocene and the Holocene.
redd	A nest constructed by salmonid species in the streambed where eggs are deposited and fertilized. Redds can usually be distinguished in the streambed by a cleared depression and associated mound of gravel directly downstream.
reworked	Said of a sediment, fossil, rock fragment, or other geologic material that has been removed or displaced by natural agents from its place of origin and incorporated in recognizable form in a younger formation.
rhyolite	A group of extrusive igneous rocks, typically porphyritic and commonly exhibiting flow texture, with phenocrysts of quartz and alkali feldspar in a glassy to cryptocrystalline groundmass; the extrusive equivalent of granite.
rill	A small channel that is caused by erosive runoff. The term rill is limited to small channels that are only a few centimeters deep.
riparian area	An area with distinctive soils and vegetation community/composition adjacent to a stream, wetland, or other body of water.
riprap	Large angular rocks that are placed along a river bank to prevent or slow erosion.
salmonid	Fish of the family *salmonidae*, including trout, salmon, chars, grayling, and whitefish. In general usage, the term most often refers to salmon, trout, and chars.
side channel	A channel that is not part of the main channel, but appears to have water during low-flow conditions and has evidence for recent higher flow (e.g., may include unvegetated areas (bars) adjacent to the channel). At least the upstream end of the channel connects to, or nearly connects to, the main channel. The downstream end may connect to the main channel or to an overflow channel. Can also be referred to as a secondary channel.
slip-plane fault	The relative displacement across a flat surface of formerly adjacent points on opposite sides of a fault.

TERM	DEFINITION
spawning and rearing habitat	Stream reaches and the associated watershed areas that provide all habitat components necessary for adult spawning and juvenile rearing for a local salmonid population. Spawning and rearing habitat generally supports multiple year classes of juveniles of resident and migratory fish, and may also support subadults and adults from local populations.
stress regime	An applied force or system of forces related to plate tectonics that tends to strain or deform a crustal plate.
subbasin	A subbasin represents the drainage area upslope of any point along a channel network (Montgomery & Bolton 2003). Downstream boundaries of subbasins are typically defined in this assessment at the location of a confluence between a tributary and mainstem channel. An example would be the Twisp River Subbasin.
suspension	A mode of sediment transport in which the upward currents in eddies of turbulent flow are capable of supporting the weight of sediment particles and keeping them indefinitely held in the surrounding fluid.
tectonism	A general term for all movement of the crust produced by tectonic processes, including the formation of ocean basins, continents, plateaus, and mountain ranges.
terrace	A relatively stable, planar surface formed when the river abandons the floodplain that it had previously deposited. It often parallels the river channel, but is high enough above the channel that it rarely, if ever, is covered by water and sediment. The deposits underlying the terrace surface are alluvial, either channel or overbank deposits, or both. Because a terrace represents a former floodplain, it can be used to interpret the history of the river.
terrane	A crustal block or fragment that preserves a distinctive geologic history that is different from the surrounding areas and that is usually bounded by faults.
Tertiary period	The first period of the Cenozoic era thought to have covered the span of time between about 65 million and 2 million years ago. It is divided into five epochs: the Paleocene, Eocene, Oligocene, Miocene and Pliocene.
tributary	A stream feeding, joining, or flowing into a larger stream or lake (Neuendorf et al. 2005).
uplift	A structurally high area in the crust, produced by movements that raise the rocks, as in a broad dome or arch.

TERM	DEFINITION
watershed	The area of land from which rainfall (and/or snow melt) drains into a stream or other water body. Watersheds are also sometimes referred to as drainage basins. Ridges of higher ground form the boundaries between watersheds. At these boundaries, rain falling on one side flows toward the low point of one watershed, while rain falling on the other side of the boundary flows toward the low point of a different watershed.

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Appendix F: Technical Ranking of Protection and Restoration Opportunities

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1.0 Introduction

One of the products of this assessment is a reach-level ranking of restoration actions to help guide management actions. This ranking will help identify which reaches provide the greatest opportunity for protection of functioning habitat and restoration of degraded habitat. The proposed rankings consider potential for protection of existing habitat, restoration opportunities, degree of departure from the natural setting, and total area of potential recovery. Biological benefits of proposed actions within each reach should be further addressed by local biologists and could be overlaid with the current ranking scheme. These rankings are intended to be scientific in nature and do not incorporate political constraints, such as construction feasibility, landowner participation, existing land use, costs to implement actions, and availability of funding. Political constraints need to be considered by planners and managers as part of the implementation plan of project actions within each reach.

In addition to the reach-level ranking, a technical sequencing of project opportunities on the Forrest and Oxbow Conservation Areas was completed for all projects identified as being characteristic of Tier 1 according to descriptions provided by the Upper Columbia Salmon Recovery Board (2007). Tier 1 actions referred to in this sequencing generally require minimal additional analysis, are low cost, and highly feasible. This sequencing was completed prior to the completion of the entire assessment due to availability of funding for project design and implementation and the need for management guidance in immediate restoration actions. The sequencing of Tier 1 projects presented for the Forrest and Conservation Areas does not consider all restoration opportunities and will be expanded upon through refined assessments at the reach-scale.

2.0 Reach-Level Ranking

One objective of the *Tributary Assessments* is to provide planners, managers, and stakeholders with decision-making tools for prioritization of reaches. Following completion of the *Tributary Assessments*, more detailed analyses of specific reaches may be completed to evaluate the cumulative biological benefits of implementing restoration strategies. Variables describing reach characteristics were used to evaluate four prioritization categories. The categories and descriptive variables are provided in Table 1. The restoration/preservation potential category is the primary category for consideration of reach rankings. Additional ranking schemes are provided as additional information for management consideration. Following discussion of the reach ranking results, the biological linkages related to each proposed habitat action class are presented.

Table 1 - Prioritization Categories, Variables used to Define the Categories, and Definitions of Each Variable Where Needed.

Prioritization Category	Descriptive Variables	Detailed Definition
Restoration/ Preservation Potential	Reach-weighted restoration/preservation potential	Potential for channel to restore natural physical processes impacting habitat.
	Floodplain preservation area	Area of floodplain identified as having highly functional processes and healthy vegetation.
	Percent of floodplain preservation area in reach	Percent of reach characterized as floodplain preservation area.
Impact of Constructed Features on Channel Processes	Total potential channel reconnection length (in feet)	Total length of channels identified using LiDAR and ground photos as having the potential to be reconnected or connected as greater frequencies[1]
	Area of HCMZ impacted (area)	Total area of historical channel migration zone (HCMZ) impacted by constructed features or anthropogenic activities. This includes constructed features that constrain lateral channel position and/or block floodplain inundation.
	Percent of HCMZ impacted	Percent of HCMZ within reach that has been impacted due to constructed features or anthropogenic activities[2]
	Area of disconnected low surface (acres)	Total floodplain area in reach that has been disconnected and is no longer inundated as frequently as historic conditions due to constructed features.
	Percent low surface cutoff	Percent of floodplain/low surface that has been disconnected due to constructed features.
	Area of disconnected low surface outside of HCMZ (acres)	Total floodplain area outside of the HCMZ that can not be inundated as frequently as historic conditions due to constructed features. This area represents flooded surfaces only and not potential locations of the main or significant side channels.
	Reach average percent of 2-year flow that is overbank	Based on 1-dimensional model results, percent of 2-year flow that is flowing out of the channel and in floodplain (See Appendix D and E, Section 4.2).
	Length of main channel cut off (in feet)	The length of the main channels and possible main channels that has been disconnected due to constructed features as interpreted from LiDAR data, photos, and field mapping. This variable covers channels that may have been cut off prior to 1939 aerial photographs.
	Percent of main channel cutoff	The total length of disconnected main channels in a reach as a percentage of the total length of the 2006 main channel.
	Change in floodplain width (in feet)	Change in the average, maximum, and minimum widths of the natural and present floodplain areas; measured about every 0.1 mile and at major constructed features and anthropogenic activities.
	Total number of constructed features (points)	Total number of constructed features that impact specific points in the channel and were delineated in GIS using points, including rock spurs, bridges, diversions, culverts, points where a channel is possibly filled or blocked, grade control, weir, or other structure.
	Number of point constructed features per mile	Total number of point constructed features in a reach divided by the total length of the 2006 main channel in the reach. Ratios are used to compare the number of point constructed features among the reaches of different lengths.
	Total length of linear constructed features (in feet)	Total length of linear constructed features delineated by polylines in GIS, including connected riprap, levees, railroad grade, improved road (highway), unimproved road, irrigation ditch, spoils, and steel.

Prioritization Category	Descriptive Variables	Detailed Definition
	Ratio length constructed features to length reach	Total length of linear constructed features in a reach divided by total length of the 2006 main channel in the reach. Ratios are used to compare the total lengths of constructed features among reaches of different lengths.
	Total area of constructed features (acres)	Total area of constructed features delineated in GIS by polygons, including tailings, embankments, buildings, and other disturbed areas.
	Constructed feature areas as percent of reach area	Total area of constructed features in a reach divided by area of floodplain for the reach, expressed as a percent. Percents are used to compare the total area covered by constructed features among reaches of different sizes.
	Length of artificially straightened channel (in feet)	Total length of channel that appears to have been straightened by anthropogenic activities from LiDAR data and aerial photosets. Straightening may be from excavation in the channel and/or from placement of constructed features (e.g., riprap, levees) along the channel.
	Length of artificially confined channel (in feet)	Total length of channel that is confined by a constructed feature, such as a rock spur, riprap, levee, or tailings. In these sections, the channel has been confined as it was at the time the constructed features were placed, and usually has a meandering planform.
	Percent of 2006 channel that is artificially straightened	Length of straightened channel divided by total length of the 2006 main channel in the reach, expressed as a percentage.
	Percent of 2006 channel that is artificially confined	Length of confined channel divided by total length of the 2006 main channel in the reach, expressed as a percentage.
	Total change in channel length between earliest and latest photosets (in feet)	Change in channel length as measured from GIS mapping of historical datasets.
	Percent Change in Channel Length and Sinuosity between earliest and latest photosets	Channel length as mapped in 2006 photoset compared to channel length in earliest available and discernible photoset.
LWD accessibility and recruitment potential	Area of LWD classified trees within the low surface (in acres)	Total area of trees within each reach that are at least 40 feet tall.
	Percent of reach with LWD trees	Percent of low surface covered with trees classified as LWD.
	Percent of 25 m buffer capable of providing shade to the river	Percent of 25 meter buffer that is comprised of shrubs, small trees, or LWD.
	Percent of 25 meter buffer comprised of LWD trees	
Loss of vegetation	Percent of low surface cleared since 1939	Percent of total area within the low surface that has changed classification from vegetated to open/cleared.

[1] Ground truthing to determine the present connectivity of side channels was not performed in this analysis. In some cases, these channels may include side channels that are already connected at high flows but could be improved by allowing access at higher flows or adding complexity to the channels.

[2] The present channel migration zone only incorporated areas that the main channel could potentially migrate to under existing conditions.

2.1 Restoration/ Preservation Potential

The first prioritization category, restoration/preservation potential, describes the potential for the channel to restore typical channel processes that impact habitat and the degree to which the channel has departed from fully functioning conditions. This category was structured after recommendations from the UCSRP (2007) and biological strategy (UCRTT 2007), which suggested prioritizing areas that are currently functioning and should be preserved, followed by areas in which processes can be restored that improve habitat.

Since the Middle Fork and Upper Mainstem John Day rivers are two different river systems with many different stakeholders, separate rankings were developed for each system. Twenty-one process-based reaches in the Middle Fork Assessment Area, including the Clear Creek reach, and three process-based reaches on the Upper Mainstem were characterized and ranked so they can be relatively compared within each basin to help resource managers sequence restoration efforts at a reach scale. Utilizing the UCSRP and biological strategy recommendations, this ranking method gives more weight to areas with a high degree of functioning complexity habitat than to reaches with a greater departure from the natural setting. The ranking focuses on those physical processes associated with lateral connectivity of the floodplain and channel that are directly linked to forming habitat features associated with complexity.

Within each reach, project actions were identified to restore physical processes responsible for shaping habitat. Project areas were grouped within each reach by project actions, and were assigned a restoration/preservation potential ranking. Project areas could receive a rank of 1 to 8, with 8 having the highest potential and 1 having the least potential (Table 2). The ranking was structured such that the highest ranked areas (8s) are preservation areas that have no known constructed features and past activities that have significantly altered processes. The ranking assigns higher values to areas that provide habitat features associated with complexity. Areas that serve mainly as an overflow surface and are only inundated during higher magnitude flows were ranked lower than areas that could provide off-channel habitat. Overflow areas could still be beneficial in providing refuge and restoring floodplain function, but when compared to other sites, they seem to fall into a noticeably lower category of habitat complexity potential. Definitions used in describing the restoration/preservation potential are provided in Table 2.

Table 2 - Scoring values for Restoration/ Preservation Potential.

Rank [1/]	Restoration/Preservation Potential [2/]	Percent of 23-Mile Long Assessment Area on the Middle Fork, including Clear Creek Reach	Percent of 3-Mile Long Assessment Area on the Mainstem
8	Functioning floodplain area with healthy riparian vegetation	1%	0.2%
7	Functioning floodplain area needing additional riparian vegetation	1%	0%
6	Accessible floodplain requiring heavy revegetation	16%	0%
5	Full restoration of high-complexity floodplain or channel network area, including reforestation of low surface	43%	3%
4	Partial restoration of high-complexity floodplain or channel network area, including partial reforestation of low surface	18%	0%
3	Side channel(s) with floodplain reconnection and revegetation	13%	69%
2	Side channel(s) with partial or little floodplain reconnection and revegetation	3%	10%
1	Low surface reconnection with few or no side channels and revegetation	4%	18%
0	Project area has heavy development in present setting	1%	0%

[1/] Rank: 8 = “(Highest or Best)”; 0 = Lowest or Worst

[2/] See Table 5 for definitions of terms used in restoration/preservation potential column.

Once all project areas within a reach were assigned a score for restoration/preservation potential, a total-reach weighted score was developed by (1) multiplying the score for each project area by the ratio of the project area to the reach area; then (2) summing those values for all project areas within a single reach. This reach-weighted score represents an area-based average of the scores within that reach. The final ranking for the restoration/preservation potential was developed by multiplying the reach-weighted score by the ratio of the area of the reach to the total assessment area. This methodology gives greater weight to reaches with greater floodplain areas. Results of the ranking are provided in Table 3 and Table 4.

Table 3 - Results of Restoration/Preservation Potential for Each Reach of the Middle Fork.

Valley Width Type	Reach	Total Reach-Weighted Restoration/ Preservation Potential for Reach	Normalized Area (Area of Reach / Total Area of Assessment)	Final Rank (Reach-Weighted Restoration Potential x Normalized Area x 100)	Actual Rank out of 21
Moderately confined	MF1	3.01	1%	2.2	17
Unconfined	MF2	5.53	26%	145.0	1
Moderately confined	MF3	3.69	9%	31.8	4
Confined	MF4	3.17	3%	9.0	13
Moderately confined	MF5	4.69	5%	22.6	5
Confined	MF6	0.99	0%	0.3	21
Unconfined	MF7	4.74	4%	18.5	6
Unconfined	MF8	3.69	12%	44.0	3
Unconfined	MF9	3.73	4%	16.0	8
Moderately confined	MF10	3.70	5%	17.3	7
Confined	MF11	5.23	2%	12.6	10
Moderately confined	MF12	1.91	2%	4.6	15
Unconfined	MF13	4.85	16%	77.1	2
Moderately confined	MF14	4.07	3%	11.3	11
Confined	MF15	1.00	0%	0.5	20
Unconfined	MF16	5.00	3%	15.8	9
Confined	MF17	3.00	0%	0.9	19
Moderately confined	MF18	3.00	1%	2.1	18
Confined	MF19	6.00	0%	2.2	16
Unconfined	MF20	4.90	1%	4.9	14
Unconfined	CC1	4.45	2%	9.6	12

Table 4 - Results of Restoration/Preservation Potential for Each Reach of the Upper Mainstem.

Valley Width Type	Reach	Total Reach-weighted Restoration/ Preservation Potential for Reach	Normalized Area (Area of Reach / Total Area of Assessment)	Final Rank (Reach weighted Restoration Potential x Normalized Area x 100)	Actual Rank out of 3
Confined	UJD1	2.00	7%	13.6	3
Moderately confined	UJD2	3.12	37%	116.3	2
Unconfined	UJD3	2.36	56%	131.9	1

Table 5 - Description of Terms Used to Define the Restoration/ Preservation Scores.

Term	Brief Description
Channel network	A branching, complex network of channels, including side and overflow channels; some of the channels may be connected to the present main channel; some are not connected; some may still convey flow, especially at higher flows; some may contain water, even at low flows; the source of the water could be groundwater or tributary flow
Side channel	Defined channel that is visible on aerial photographs and typically visible in LiDAR data; channel may or may not be naturally connected to the main channel, but appears to have conveyed flow at some point between 1939 and 2006. No differentiation was made between primary and secondary channels, and therefore, the natural degree of connectivity and frequency of access varies as to the conveyance of low and high flows.
Low surface (floodplain)	Low surface is the area adjacent to the main channel and includes side and overflow channels; it includes historical channels, and the area where future channels are likely to migrate; it also includes areas between channels that have been and are most likely to experience flood flow, although water may extend beyond the low surface during very high flows; low surface includes surfaces of several relative heights (and probably several different ages), where the channel has not been in quite some time

2.2 Impact of Constructed Features

This prioritization category addresses where constructed features have had the greatest topographic impacts to the system. Constructed features identified in the assessment area were evaluated based on the number of individual features at specific location, the linear length of channel impacted, and the total area impacted within each reach. In addition, the percentage of channel straightening that has occurred was captured through comparison of historical aerial photographs and through identification of cutoff channel using LiDAR data and constructed features.

The impacts of constructed features on channel processes can be captured through examination of the impacted area of the historical channel migration zone (HCMZ) and the area of the floodplain disconnected from the channel. The impacted area of the HCMZ provides an indication of the floodplain area that can not be accessed through lateral channel migration and/or can not be not inundated during high flow events due to constructed features or anthropogenic activities. The disconnected floodplain represents the floodplain area that was historically flooded, including side channels, but can no longer be accessed due to constructed features. In many cases, there is overlap between the disconnected floodplain and the impacted HCMZ areas. As such, disconnected floodplain areas outside of the HCMZ can be used in conjunction with the impacted HCMZ to best capture modifications to floodplain function and connectivity.

Because the HCMZ incorporates side channels and potential areas of lateral channel migration, its habitat value is greater than the area of disconnected floodplain outside of the HCMZ; therefore, the impacted HCMZ was weighted more heavily in developing the final ranking. The formula used to evaluate the prioritization of impacted channel processes is shown below. This method is based on the impacted area and not expressed as a percentage of total reach. Results of the rankings (Table 6 and Table 7) indicate the total floodplain area that can be recovered following implementation of the proposed restoration actions. A final rank of 1 represents the reach with the greatest area impacted by constructed features.

$$WeightedRank = 1.5x + y$$

Where x = Area of HCMZ impacted (acres)

y = Area of disconnected low surface outside of HCMZ (acres)

Table 6 - Results of Constructed Feature Impacts Ranking for the Middle Fork Assessment Area.

Reach	Area of Disconnected Floodplain (in acres)	Area of HCMZ Impacted (in acres)	Area of Disconnected Floodplain Outside of HCMZ (in acres)	Weighted Rank	Final[1] Rank
MF1	0.91	0.72	0.31	1.39	18
MF2	37.18	208.73	4.03	317.13	1
MF3	40.90	50.11	11.76	86.93	4
MF4	2.55	2.88	0.00	4.32	15
MF5	4.81	9.16	4.35	18.09	11
MF6	0.00	0.08	0.00	0.12	21
MF7	6.29	20.18	4.67	34.94	6
MF8	86.58	37.37	57.70	113.75	3
MF9	19.38	11.84	11.98	29.75	8
MF10	9.39	9.20	5.75	19.55	10
MF11	0.84	5.85	0.00	8.78	13
MF12	17.23	15.00	4.72	27.23	9
MF13	69.91	89.88	45.44	180.26	2
MF14	5.32	22.33	0.61	34.10	7
MF15	3.57	3.57	0.00	5.35	14
MF16	0.44	8.97	0.07	13.53	12
MF17	0.01	0.50	0.00	0.75	20
MF18	0.04	1.21	0.00	1.82	16
MF19	0.31	1.09	0.00	1.64	17
MF20	0.45	0.88	0.00	1.31	19
CC1	24.66	30.01	0.00	45.02	5
[1]Greatest area impacted by constructed features is given a rank of 1.					

Table 7 - Results of Constructed Feature Impacts Ranking for the Upper Mainstem Assessment Area.

Reach	Area of Floodplain Cutoff (in acres)	Area of HCMZ Impacted (in acres)	Area of Disconnected Floodplain Outside of HCMZ (in acres)	Weighted Rank	Final[1] Rank
UJD1	1.54	1.54	0.00	2.30	3
UJD2	3.15	11.23	0.00	16.84	2
UJD3	9.09	22.99	2.22	36.70	1
[1]Greatest area impacted by constructed features is given a rank of 1.					

2.3 Accessibility of Potential Large Woody Debris (LWD)

Vegetation mapping was completed using historical and present aerial photographs (Appendices D and E). The presence and accessibility of LWD was used as a surrogate for the ability of each reach to provide shade and complexity to habitat; however, not all reaches may have provided large amounts of LWD under pre-development conditions (e.g., wet meadows). In the future, further evaluation of riparian health is recommended for improved understanding of the biological linkages between vegetation and habitat.

This prioritization category is intended to provide managers with an understanding of LWD recruitment potential in each reach and to identify which reaches are lacking LWD and stream shading. This category does not indicate the degree of vegetation departure from the historical conditions. A weighted ranking was used to prioritize the reaches in this category, in which more weight is placed on LWD and vegetation within a 25-meter buffer to the stream. A ranking of 1 indicates the greatest accessibility of LWD relative to all reaches. The formula applied to develop the weighted ranking is provided below. Results of this ranking scheme are provided in Table 8 and Table 9.

$$WeightedRank = 3x + 2y + z$$

Where x = percentage of 25-meter buffer comprised of LWD trees

y = percentage of 25-meter buffer capable of providing shade to the river

z = percentage of reach with LWD trees

Table 8 - Ranking of Middle Fork Reaches by Accessibility of Potential Large Woody Debris.

Reach	Percent of Reach with LWD trees	Percent of 25-m Buffer Capable of Providing Shade to the River	Percent of 25-m Buffer Comprised of LWD Trees	Weighted Rank of LWD Access Potential	Final[1] Rank
MF1	15.2%	29.8%	10.6%	106.5	10
MF2	3.9%	34.4%	13.4%	112.8	8
MF3	6.8%	61.5%	19.1%	187.0	4
MF4	32.4%	46.0%	22.8%	192.6	3
MF5	11.8%	39.2%	7.2%	111.9	9
MF6	15.7%	36.2%	15.8%	135.3	5
MF7	0.2%	3.0%	0.3%	7.1	15
MF8	2.0%	7.2%	0.5%	18.0	13
MF9	13.4%	54.7%	2.6%	130.8	6
MF10	20.1%	66.7%	15.5%	200.0	2
MF11	38.7%	71.6%	36.5%	291.2	1
MF12	5.3%	17.9%	6.8%	61.5	12
MF13	0.4%	0.7%	0.6%	3.5	17
MF14	0.8%	5.8%	0.3%	13.3	14
MF15	0.0%	0.0%	0.0%	0.0	20T
MF16	0.1%	0.2%	0.2%	0.9	18
MF17	0.6%	2.0%	0.9%	7.1	16
MF18	0.0%	0.1%	0.0%	0.3	19
MF19	16.8%	30.8%	16.7%	128.6	7
MF20	13.0%	11.8%	10.0%	66.6	11
CC1	0.0%	0.0%	0.0%	0.0	20T

[1] T indicates a tie. Greatest accessibility to potential LWD is given a rank of 1.

Table 9 - Ranking of Upper Mainstem Reaches by Accessibility of Potential LWD.

Reach	Percent of Reach with LWD trees	Percent of 25-m Buffer Capable of Providing Shade to the River	Percent of 25-m Buffer Comprised of LWD Trees	Weighted Rank of LWD Access Potential	Final[1] Rank
UJD1	63%	56%	47%	314.8	1
UJD2	13%	31%	13%	113.6	3
UJD3	17%	47%	29%	198.0	2

[1]Greatest accessibility to potential LWD is given a rank of 1.

2.4 Loss of Vegetation in the Low Surface

Interpretation of this last prioritization category is less complicated than previous categories. As part of the vegetation mapping, present-day vegetation was compared to historical vegetation. Although the earliest aerial photographs (1939) do not represent the pre-settlement conditions of the reaches, they were used to quantify changes in vegetation. Because human activities were present in the basin 50 years prior to the 1939 aerial photographs, the loss of vegetation is likely greater than the values shown in Table 10 and Table 11. The percent of the reach that has changed from trees and shrubs to open areas or low vegetation was used to rank the reaches. A ranking of 1 indicates the greatest loss of vegetation of all reaches.

Table 10 - Ranking of the Loss of Vegetation in Each Reach of the Middle Fork.

Reach	Percent of Low Surface Changed from Trees/Shrubs to Low Vegetation/ Openings Since 1939	Final Rank[1]
MF1	0.0%	16T
MF2	21.3%	10
MF3	8.3%	12
MF4	5.7%	13
MF5	12.5%	11
MF6	0.0%	16T
MF7	0.0%	16T
MF8	32.1%	8
MF9	0.0%	16T
MF10	0.6%	15
MF11	2.9%	14
MF12	42.9%	7
MF13	88.2%	4
MF14	86.8%	5
MF15	100.0%	1T
MF16	0.00%	16T
MF17	98.4%	3
MF18	99.7%	2
MF19	58.7%	6
MF20	31.8%	9
CC1	100.0%	1T

[1]T indicates a tie; Greatest loss of vegetation is ranked as 1.

Table 11 - Ranking of the loss of vegetation in each reach of the Upper Mainstem.

Reach	Percent of Low Surface Changed from Trees/Shrubs to Low Vegetation/ Openings Since 1939	Final Rank[1]
UJD1	38%	2
UJD2	62%	1
UJD3	35%	3

[1]Greatest loss of vegetation is ranked as 1.

2.5 Summary of Prioritizations

Reach rankings were computed based on four different prioritization categories that capture the present conditions of the streams, potential protection of existing habitat, and opportunities for restoration. Rankings based on the restoration/ preservation potential are structured after recommendations from the UCSRP (2007) and biological strategy (UCRTT 2007). Other rankings were included for management considerations and to provide insight into how each reach is functioning, superimposed with the potential for restoration. Ranking schemes based on vegetation and LWD provide an indication of the degree of alteration to historic vegetation and its potential to supply LWD to habitat. One possible future addition to the rankings may include a ranking scheme that incorporates fish use, salmonid habitat, and other biologically significant parameters.

Table 12 – Summary of Prioritization Rankings for Each Reach in the Middle Fork and Upper Mainstem John Day Rivers.

Valley Width Type	Reach	Restoration/ Preservation Potential	Impact of Constructed Features	Accessibility of Potential LWD	Loss of Vegetation in the Low Surface
Middle Fork John Day River					
Moderately confined	MF1	17	18	10	16T
Unconfined	MF2	1	1	8	10
Moderately confined	MF3	4	4	4	12
Confined	MF4	13	15	3	13
Moderately confined	MF5	5	11	9	11
Confined	MF6	21	21	5	16T
Unconfined	MF7	6	6	15	16T
Unconfined	MF8	3	3	13	8
Unconfined	MF9	8	8	6	16T
Moderately confined	MF10	7	10	2	15
Confined	MF11	10	13	1	14
Moderately confined	MF12	15	9	12	7
Unconfined	MF13	2	2	17	4
Moderately confined	MF14	11	7	14	5
Confined	MF15	20	14	20T	1T
Unconfined	MF16	9	12	18	16T
Confined	MF17	19	20	16	3
Moderately confined	MF18	18	16	19	2
Confined	MF19	16	17	7	6
Unconfined	MF20	14	19	11	9
Unconfined	CC1	12	5	20T	1T
Upper Mainstem John Day River					
Confined	UJD1	3	3	1	2
Moderately confined	UJD2	2	2	3	1
Unconfined	UJD3	1	1	2	3

2.6 Biological Linkages to Reach Rankings

Although a complete biological assessment was not completed as part of these tributary assessments, findings were translated into habitat action classes and associated viable salmonid population (VSP) parameters that would be addressed as referenced from Table 5.9 in the *Upper Columbia Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan* (UCSRB 2007). All of the habitat actions from the recovery plan were considered except for water quality and quantity restoration and nutrient restoration. Restoration of floodplain processes would serve to also restore water quality and quantity where impacted from levees, roads, and bridges. Temperature may be further addressed through restoration of riparian vegetation, reconnection of any known disconnected groundwater sources, and implementation of existing water quality plans.

Other actions not specifically addressed in Table 5.9 of the *Upper Columbia Recovery Plan* (UCSRB 2007) included channel reconstructions. For the purposes of these assessments, side channel reconstructions are included under the habitat action class of side channel reconnection, and main channel reconstruction is included under the habitat action class of floodplain restoration. Reconstructions are recommended in reaches where the main channel has been substantially altered through complete relocation, channelized through straightening of alignments and continuous bank armoring, or where side channels were filled in or re-graded.

Habitat action classes associated with proposed restoration and preservation actions in each reach are provided in Table 13. These categories indicate actions that may be taken for single or multiple project areas within the reach. LWD restoration was considered a potential habitat action in all reaches due to the denuded nature of the system and opportunities for short-term, in-channel habitat complexity improvements during re-establishment of longer term fluvial processes. Road maintenance was included as a habitat action class in reaches where roads and bridges negatively impact the channel and floodplain and could be improved through the implementation of best management practices and potential road decommissioning.

Table 13 - Habitat Action Classes Associated with Proposed Restoration and Preservation Actions in Each Reach.

		Habitat Action Class [1/]					VSP Parameters Addressed [2/]	
Floodplain Type	**Reach Name**	**Riparian restoration within low surface**	**Side-channel reconnection**	**Road Maintenance**	**Floodplain Restoration**	**LWD Restoration**	**A/P**	**D/SS**
Middle Fork John Day River								
Moderately confined	MF1	X	X	X		X	X	
Unconfined	MF2	X	X		X	X	X	X
Moderately confined	MF3	X	X		X	X	X	X
Confined	MF4	X	X	X	X	X	X	X
Moderately confined	MF5	X	X		X	X	X	X
Confined	MF6	X		X		X	X	
Unconfined	MF7	X	X		X	X	X	X
Unconfined	MF8	X	X		X	x	X	X
Unconfined	MF9	X	X	X	X	X	X	X
Moderately confined	MF10	X	X		X	X	X	X
Confined	MF11	X	X		X	x	X	X
Moderately confined	MF12	X	X		X	X	X	X
Unconfined	MF13	X	X		X	X	X	X
Moderately confined	MF14	X	X	X	X	X	X	X
Confined	MF15	X		X		X	X	
Unconfined	MF16	X	X		X	X	X	X
Confined	MF17	X		X		X	X	
Moderately confined	MF18	X	X		X	X	X	X
Confined	MF19	X		X		X	X	
Unconfined	MF20	X	X		X	X	X	X
Unconfined	CC1	X			X	X	X	X
Upper Mainstem John Day River								
Confined	UJD1		X		X	X	X	X
Moderately Confined	UJD2	X	X		X	X	X	X
Unconfined	UJD3	X	X		X	X	X	X

[1/] Habitat action classes and associated VSP parameters addressed referenced from Table 5.9 in *Upper Columbia Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan* (UCSRB 2007)

[2/] A/P = abundance and productivity; D/SS = diversity and spatial structure as described in *Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs* (ICBTRT 2007)

While the goal of the proposed restoration concepts is to improve habitat complexity associated with channel and floodplain processes, sediment transport and channel migration generally occur during bankfull and higher flows. Additional processes that occur during critical low flow periods can increase or decrease the habitat viability of a reach. The following biological parameters could be additionally considered by resource managers in developing a restoration implementation strategy for the assessment areas:

- Existing use by species and life stages.
- Presence of non-native species.
- Water temperature (limiting factor in late summer and early fall).
- Spawning gravel embeddedness (potential limiting factor downstream of burned areas or high road density areas).
- Dewatering (potential limiting factor in late summer through winter in areas where stream flow is diverted for irrigation).
- Recharge areas (provides high quality habitat and temporal refuge under extreme conditions).
- Present large wood levels in channel.

2.7 Additional Considerations for Project Implementation

This report provides an important level of baseline information for resource decision-making and future project alternative evaluations. Additional data and analysis will be needed at the reach and/or project area level prior to project implementation. The level of analysis needed for each project will likely vary depending on the complexity of the project and adjacent land use. Field verification of the information presented in this report will be needed as a first step in the process. If warranted, additional ground survey data, refinement of geomorphic and geologic mapping, and more detailed hydraulic and sedimentation modeling may also be needed to accomplish design stages. The degree of biological information available within the assessment areas is limited. Once a reach or project area is selected, additional biological surveys may be needed to better understand the existing and potential future habitat use. The biological data will also help address the biological benefit that would be gained by implementing a project.

3.0 Sequencing of Projects on Tribal Properties

This section of the report was prepared as an interim product to provide recommended actions and analysis considerations for projects initiating prior to completion of the *Tributary Assessments*. Objectives of this section are to (1) provide background information on identification of restoration actions; (2) document restoration actions on properties owned and managed by the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO) that could begin prior to completion of the *Tributary Assessments* and without substantial additional analyses; and (3) recommend a sequencing strategy for the proposed restoration actions. Information presented in this section was prepared in June 2007, but was updated in May 2008 to maintain consistency with the geomorphic assessment, such as the reach numbering system.

3.1 Introduction

The Upper Columbia Salmon Recovery Board (UCSRB 2006) proposed a general model for prioritizing, selecting, and implementing restoration actions for the recovery of Upper Columbia spring Chinook salmon, steelhead, and bull trout. While the framework was developed for the Upper Columbia Basin, the conceptual model has broad application as a guide for sequencing recovery actions in any setting where multiple objectives and competing resources require prioritization. The UCSRB presents a tiered approach to sequencing actions that accounts for three main project characteristics, including biological benefit, feasibility, and cost. Feasibility is described as a qualitative characteristic dependent on time to implement, constructability, and acceptance by local governments and stakeholders. The final ranking consists of four tiers from which to categorize each restoration action.

Tier 1: Higher biological benefit; lower cost; higher feasibility

Tier 2: Higher biological benefit; higher cost; lower feasibility

Tier 3: Lower biological benefit; lower cost; higher feasibility

Tier 4: Lower biological benefit; higher cost; lower feasibility

3.2 Initial Project Identification

This conceptual approach was applied to the assessment areas of the John Day River Basin in an effort to identify Tier 1 project actions. Upon initial categorization, all proposed restoration actions were considered to provide equal biological benefits, both from a short-term and long-term basis. No low biologically beneficial projects were identified or considered for recommendation. Initial identification of Tier 1 actions were primarily determined by (1) stakeholder acceptability; (2) time required to obtain funding and to construct; (3) cost; and (4) the amount of additional research and analyses required for implementation.

Input from stakeholders, local biologists, geologists, engineers, and managers was collectively assembled to define the initial Tier 1 projects. For the Forrest and Oxbow Conservation Areas of the John Day River (see Maps 1 and 2), specific project actions that coincide with the proposed restoration strategies were identified as Tier 1 projects. The following actions were agreed upon as being characteristic of Tier 1:

1. Preservation of existing functioning habitat.
2. Floodplain restoration.
    a. Removal of riprap, levees, rock spurs, and sediment plugs to reconnect oxbows and side channels and allow lateral channel migration.
3. Side-channel reconnection.
    a. Reconnection of side and overbank channels with limited floodplain accessibility due to the presence of constructed features protecting infrastructure.
4. Large woody debris restoration.
    a. Placement of LWD to direct high flows into historic side or overflow channels, thereby promoting floodplain access.
    b. Placement of LWD to create habitat complexity, provide fish cover, and re-establish natural channel morphology.
    c. Placement of LWD to stabilize channel banks while increasing habitat complexity.
5. Riparian Habitat Restoration.
    a. Comprehensive reforestation of the historic riparian corridor.

Additional restoration actions were acknowledged as needing further analysis and were not, upon initial categorization, identified as Tier 1 projects. The following restoration actions have high biological benefit, but more detailed analyses are necessary to examine their feasibility and costs.

1. Large-scale reconnection of floodplain processes.
2. Channel relocations to historic main channels that would convey most or all of in-channel flow.
3. Modifications of short sections of the main channel alignment to increase channel length.
4. Channel relocations in areas with bed materials composed of dredge tailings, including connection of historic tributaries.

3.3 Prioritization of Biological Benefit

After further investigation, a methodology was developed to prioritize the biological benefits of each of the initially categorized Tier 1 project actions. Primary factors included in the prioritization of the biological benefits of each action are the number of VSP parameters and limiting factors addressed. The VSP parameters and limiting factors of the study area that are addressed by each restoration action are presented in Table 14. Among similar restoration actions, additional prioritization of biological benefit can be accomplished by comparison of the total area treated for each project.

Among the project actions proposed on the Forrest and Oxbow Conservation Areas, biological prioritization is represented on a scale of 1 to 3 with 1 being of highest biological benefit and 3 being of lowest biological benefit. Habitat action classes that address all four VSP parameters and all six limiting factors are considered to have the highest biological priority of 1. Habitat action classes that address only two VSP parameters, but all six limiting factors are considered to have a biological priority of 2. Finally, habitat action classes that address only two VSP parameters and only five limiting factors have the lowest biological priority of 3.

Table 14 - VSP Parameters and Limiting Factors of the Study Area that are Addressed by Each Type of Restoration Action.

Habitat Action Class	VSP Parameters Addressed	Limiting Factors of Study Areas Addressed	Biological Priority
Preservation of Existing Habitat	Productivity, Abundance, Diversity, and Structure	Habitat Diversity, Key Habitat Quantity, Sediment, Temperature, Flow	1
Floodplain Restoration	Productivity, Abundance, Diversity, and Structure	Habitat Diversity, Key Habitat Quantity, Sediment, Temperature, Flow	1
Side-Channel Reconnection	Productivity and Abundance	Habitat Diversity, Key Habitat Quantity, Sediment, Temperature, Flow	2
Riparian Habitat Restoration	Productivity and Abundance	Habitat Diversity, Key Habitat Quantity, Sediment, Temperature, Flow	2
Large Woody Debris Restoration	Productivity and Abundance	Habitat Diversity, Key Habitat Quantity, Sediment, Temperature	3

3.4 Sequencing of Restoration Actions

River processes controlling the system, such as flow and sediment transport, influence energy translation in both the upstream and downstream direction. Impacts to the river system from restoration activities may occur both upstream and downstream from the location of a specific action. For example, removal of a dam may release sediment trapped behind the dam while the change in elevation resulting from dam removal may cause headcut propagation upstream until the river adjusts to a stable profile. At a more localized scale, placement of LWD may induce unique patterns of sediment deposition and erosion both upstream and downstream from the initial location.

Analyses conducted at a reach level assist in understanding cumulative effects of restoration actions performed within a close proximity and in evaluating possible channel adjustments resulting from the actions. When construction and funding limitations require multiple years between restoration efforts within the same reach of river, restoration actions are generally recommended to be sequenced from upstream to downstream. This sequence provides an opportunity for the river to adjust in the downstream direction before initiating a subsequent action and allows for modification to a downstream action to account for the river adjustment.

The subsequent downstream action must consider and design according to possible upstream river adjustments. Furthermore, sequencing projects in this manner should minimize equipment mobilization and transfer, damage to riparian vegetation, and construction costs.

For Tier 1 actions, an upstream-to-downstream sequencing strategy should be coupled with consideration for biological benefit, floodplain and side channel accessibility, proximity to infrastructure, and practicality of analysis. For the initially identified Tier 1 projects, each of these factors was defined to determine the most appropriate sequencing strategy. The following questions were addressed for each project area:

- What is the biological priority of the restoration action?
- What is the treatment area impacted by the restoration action?
- Does the restoration action correspond with full or partial restoration of the floodplain?
- What is the potential for floodplain and side channel connectivity based on hydraulic models and LiDAR data (low, moderate, or high)?
- Are there any infrastructure considerations within or near project area? If so, what are they?
- From an analysis standpoint, should the Tier 1 action be evaluated as part of a more detailed analysis, such as a reach assessment, for technical efficiency and cost savings?

After these questions were defined for each Tier 1 project action, projects were arranged by location and connectivity to one another and categorized into three separate groupings for sequencing: Sequence Group 1, Sequence Group 2, and Sequence Group 3. Since all Tier 1 project actions are anticipated to be implemented in the future, the most important factors determining initial categorization were practicality in analysis methodology and consideration of river processes. Tier 1 project areas differ from the project areas discussed in Section 2.1 in that they only encompass the area immediately impacted by a Tier 1 project action. Further sequencing of projects actions and biological prioritization beyond that proposed in Table 15 through Table 17 is provided in Section 3.5 of this appendix.

Sequence Group 1 represents projects that can be initiated immediately to meet funding limitations and construction timeframes for next fiscal year. Group 1 projects require minimal additional analyses, are sufficiently independent from other projects or are located at the upstream end of the reach, and can be evaluated and designed separately from a larger-scale evaluation of physical processes. In some cases, additional field verification is needed to validate the project as being characteristic of Sequence Group 1. Needed validation is addressed in the last column of Table 15. Not all Sequence Group 1 projects have the highest biological priority. In general, projects having the highest biological priority (floodplain restoration) may require more analyses and are highly connected with upstream and downstream project actions.

Sequence Group 2 represents projects that could be evaluated independently from a larger-scale evaluation, but may be more efficiently integrated into a reach-assessment that is recommended across the area of the projects (Table 16). For example, constructed feature removal and side and overbank channel reconnections on the Upper Mainstem of the John Day River could be evaluated independently from the larger-scale analysis of main channel lengthening. Since almost all of the side and overbank channel reconnections are historic main channels, some of them may be proposed to convey all of the flow through a reach-level investigation. From an analysis and design standpoint, it seems more efficient to evaluate the side and overbank channel reconnections as a part of the overall channel lengthening effort. If time and funding constraints limit that possibility, removal of the constructed features and side and overbank channel reconnections may be completed prior to the reach-level investigation. Sequence Group 2 projects are intended to be implemented after Group 1 projects and only if they can not be integrated into the larger-scale reach assessment due to funding and time constraints.

Sequence Group 3 consists of those Tier 1 restoration actions that could be completed without a larger-scale evaluation; however, proposed restoration actions resulting from the reach-assessment may either modify the need for or design of the restoration action (Table 17). One example of a Sequence Group 3 project is the removal of rock spurs within the Middle Fork Forrest Conservation Area, between Vincent and Vinegar Creeks. One alternative proposed for future analysis within this reach is the reconnection of historic oxbows and possible abandonment of portions of the current channel. While rock spur removal is recommended to be delayed until the new channel design is established, the delay may avoid implementing restoration actions that could potentially be deemed unnecessary in the future.

Maps showing the locations of the Tier 1 project areas and groups are provided as an attachment to this appendix.

Table 15 - Projects within Sequence Group 1.

Tier-1 Project Areas	Projects identifiers within Area	Biological Priority	Total Treatment Area (acres)	Project Location	Description of Projects	Needed Validation
UJD3_prj1	UJD_prj_264.86_R	2	2.745	Mainstem Forrest Conservation Area, downstream from Dad's Creek	Removal of levee blocking access to historic oxbow. Placement of LWD structures for improved bank stability and habitat complexity. Monitor and evaluate channel response to restoration actions and manage as needed.	None, field verification completed by Ed Lyon, May 2007
	UJD_prj_265.03_R	3				
	UJD_prj_264.82_R	3				
	UJD_prj_264.91_R	3				
MF5_prj1	MF_prj_55.30_R	3	4.157	Middle Fork Oxbow Conservation Area, downstream from highway bridge at RM 55.4	Installation of LWD structures for habitat complexity and localized channel narrowing. Live willow plantings along bank will assist long-term channel narrowing, fish cover effort.	None, field verification completed by Mark Croghan, May 2007
MF7_prj1	MF_prj_56.205_R	1	43.800	Middle Fork Oxbow Conservation Area, upstream from highway bridge at RM 55.4, downstream from dredge tailings	Removal of rock spurs combined with strategic placement of LWD for habitat complexity. Potential to reconnect historic side and overbank channels.	Field verification of possible constructed features and historic side channels to determine additional analysis needs. If multiple constructed features are present that block side channels, may want to incorporate into reach assessment.
MF9_prj1	MF_prj_58.51_R	1 or 3, depending on field verification	2.002	Middle Fork Oxbow Conservation Area, downstream from highway bridge at RM 58.8, upstream from dredge tailings	Strategic placement of LWD to deflect high flows into side channels, create backwater habitat, and enhance in-channel complexity. Potential to reconnect historic side and overbank channels.	Field verification of possible constructed features and historic side channels to determine additional analysis needs. If multiple constructed features are present that block side channels, may want to incorporate into reach assessment. If consideration of accessing floodplain on southeast side of river is a potential, may want to incorporate into reach assessment.
MF14_prj1	MF_prj_66.73_R	1	6.068	Middle Fork Forrest Conservation Area, Upstream from Vinegar Creek	Removal of rock spurs on river left combined with strategic placement of LWD for habitat complexity. Potential to reconnect historic side and overbank channels.	None
	MF_prj_67.47_R	3				

Table 16 - Projects within Sequence Group 2.

Tier-1 Project Areas	Projects identifiers within Area	Biological Priority	Total Treatment Area (acres)	Project Location	Description of Projects	Other Considerations
UJD2_prj1	UJD_prj_264.70_R	2	1.051	Mainstem Forrest Conservation Area, just downstream from Reach UJD3 break	Removal of 2 rock spurs and riprap; reconnection of historic side channels, and strategic placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity.	Incorporate with reach-scale evaluation, or direct portion of flow into historic channels now with consideration for conveyance of greater flows in future.
	UJD_prj_264.71_R	1				
UJD2_prj2	UJD_prj_264.45_R	1	1.006	Mainstem Forrest Conservation Area, between RM 264.4 and 264.51	Removal of 1 rock spur and levee; Reconnection of historic side channels, and strategic placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity.	Incorporate with reach-scale evaluation, or direct portion of flow into historic channels now with consideration for conveyance of greater flows in future.
	UJD_prj_264.51_R	1				
UJD2_prj3	UJD_prj_264.17_R	1	1.491	Mainstem Forrest Conservation Area, between RM 264.09 and 264.30	Removal of riprap and levee; reconnection of historic side channels, and strategic placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity.	Incorporate with reach-scale evaluation, or direct portion of flow into historic channels now with consideration for conveyance of greater flows in future. May need to investigate removing riprap at upstream end without disturbing irrigation canal.
	UJD_prj_264.24_R	1				
	UJD_prj_264.28_R	2				
UJD2_prj4	UJD_prj_263.82_R	1	1.356	Mainstem Forrest Conservation Area, between RM 263.75 and 263.96	Removal of riprap, levees, and embankment material; reconnection of historic side channels, and strategic placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity. Potential to reconnect historic side and overbank channels.	Incorporate with reach-scale evaluation, or direct portion of flow into historic channels now with consideration for conveyance of greater flows in future. Some riprap may need to remain for irrigation canal protection.
	UJD_prj_263.9_R	1				
	UJD_prj_263.96_R	1				
UJD2_prj5	UJD_prj_263.73_R	1	0.760	Mainstem Forrest Conservation Area, just upstream from silos on right bank	Removal of riprap; reconnection of historic side channels, and strategic placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity. Potential to reconnect historic side and overbank channels.	Incorporate with reach-scale evaluation, or direct portion of flow into historic channels now with consideration for conveyance of greater flows in future.

Table 16 continued

Tier-1 Project Areas	Projects identifiers within Area	Biological Priority	Total Treatment Area (acres)	Project Location	Description of Projects	Other Considerations
UJD2_prj6	UJD_prj_263.57_R	1	0.179	Mainstem Forrest Conservation Area, just downstream from silos on left bank	Removal of riprap and strategic placement of LWD to enhance in-channel habitat complexity	Could incorporate with reach-scale evaluation, no side channels connected as result of actions
UJD2_prj7	UJD_prj_263.29_R	1	1.497	Mainstem Forrest Conservation Area, just upstream from UJD2 reach break	Removal of levee; reconnection of historic side channels, and strategic placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity.	This project is underway. Consideration for conveyance of greater flows than its current overbank channel design could be incorporated with reach-scale evaluation.
MF13_prj1	MF_prj_66.46_R	1	2.595	Middle Fork Forrest Conservation Area, upstream from Vinegar Creek, but just downstream from MF14 reach break.	Removal of rock spurs and riprap; reconnection of historic side channels, and strategic placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity.	Incorporate with MF13 reach assessment, need field verification of historic side channels
	MF_prj_66.41_R	1				
	MF_prj_66.48_R	1				
MF13_prj4	MF_prj_64.7_R	1	19.050	Middle Fork Forrest Conservation Area, between RM 64.6 and Vincent Creek	Removal of rock spurs and riprap; reconnection of historic side channels, and strategic placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity.	Incorporate with MF13 reach assessment, need field verification of historic side channels
	MF_prj_64.86_R	1				
	MF_prj_65.05_R	1				
	MF_prj_65.32_R	1				
	MF_prj_65.46_R	1				
MF13_prj5	MF_prj_63.71_R	1	30.327	Middle Fork Forrest Conservation Area, between downstream property boundary and RM 64.6.	Removal of rock spurs and riprap; reconnection of historic side channels, and strategic placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity.	Incorporate with MF13 reach assessment, need field verification of historic side channels
	MF_prj_63.93_R	1				
	MF_prj_64.04_R	1				
	MF_prj_64.25_R	1				
	MF_prj_64.29_R	1				
	MF_prj_64.53_R	1				

Table 17. - Projects within Sequence Group 3.

Tier-1 Project Areas	Projects identifiers within Area	Biological Priority		Project Location	Description of Projects	Other Considerations
MF8_prj1	MF_prj_57.91_R	3	1.181	Middle Fork Oxbow Conservation Area, through dredge tailings	Placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity through maintenance of pools and riffles	Design and placement of LWD within this reach should be coordinated with the larger-scale channel reconstruction through dredge tailings.
MF13_prj2	MF_prj_66.13_R	1	5.275	Middle Fork Forrest Conservation Area, between Vincent and Vinegar Creeks	Removal of rock spurs to allow lateral channel migration and restore floodplain function. Strategic placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity	Removal of rock spurs and placement of LWD would most effectively be designed in conjunction with historic channel reconnections and railroad grade breaching.
	MF_prj_66.29_R	1				
MF13_prj3	MF_prj_65.53_R	1	4.691	Middle Fork Forrest Conservation Area, near confluence with Vincent Creek	Removal of rock spurs, riprap, and bridge to allow lateral channel migration and restore floodplain function. Strategic placement of LWD to deflect flow into side channels, create backwater habitat, and enhance in-channel habitat complexity	Removal of in-channel structures and placement of LWD would be most effectively designed in conjunction with historic channel reconnections.
	MF_prj_65.61_R	1				
	MF_prj_65.64_R	1				

3.5 Project Area Assessment

3.5.1 Sequence Group 1 Projects

Tier 1 project areas are listed by sequence class. Habitat actions (referred to as projects) within each Tier 1 project area are listed from upstream to downstream.

Upper John Day Project Tier-1 Area UJD3_prj1

Project area is located in reach UJD3 within the Mainstem Forrest Conservation Area downstream of Dad's Creek between RM 265.03 and RM 264.66.

Metrics:

- Project Area: 2.7 acres

Management Considerations

- **Project UJD_prj_265.03_R:** Place LWD to promote floodplain access and to provide habitat complexity.
    - *Habitat Action Class*: LWD Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity and abundance VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, habitat quantity, sediment, and water temperature.
    - *Biological Priority*: Considered a priority 3
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based Considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project UJD_prj_264.91_R:** Place LWD to protect bank and to provide habitat complexity.
    - *Habitat Action Class*: LWD Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity and abundance VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, habitat quantity, sediment, and water temperature.
    - *Biological Priority*: Considered a priority 3
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based Consid*erations: Reduces stream power to limit bank erosion

- **Project UJD_prj_264.86_R:** Reconnect an old channel that is blocked by a levee constructed of large boulders to function as an overflow channel.
    - *Habitat Action Class*: Side-Channel Reconnection
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity and abundance VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, habitat quantity, sediment, flow, and water temperature.
    - *Biological Priority*: Considered a priority 2
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based Considerations*: Reconnects a channel as an overflow channel

- **Project UJD_prj_264.82_R:** Placement of LWD to protect bank and to provide habitat complexity.
    - *Habitat Action Class*: LWD Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity and abundance VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, habitat quantity, sediment, and water temperature.
    - *Biological Priority*: Considered a priority 3
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based Considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

Middle Fork John Day Tier-1 Project Area MF5_prj1

Project area is located in reach MF5 within the Middle Fork Oxbow Conservation Area downstream of the highway bridge at RM 55.4 and between RM 54.64 and RM 55.3.

Metrics:

- Project Area: 4.2 acres

Management Considerations

- **Project MF_prj_55.30_R:** Place LWD or other structures to promote floodplain access and provide habitat complexity.
    - *Habitat Action Class*: LWD Restoration
    - Relationship with VSP and Limiting Factors: Actions generally apply to productivity and abundance VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, habitat quantity, sediment, and water temperature.
    - *Biological Priority*: Considered a priority 3
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes and lateral river migration.

Middle Fork John Day Tier-1 Project Area MF7_prj1

Project area is located in reach MF7 within the Middle Fork Oxbow Conservation Area downstream from the highway bridge at RM 55.4 and between RM 56.2 and RM 55.6.

Metrics:

- Project Area: 43.8 acres

Management Considerations

- **Project MF_prj_56.205_R:** Remove rock spurs to promote floodplain function.
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes

Middle Fork John Day Tier-1 Project Area MF9_prj1

Project area is located in reach MF9 within the Middle Fork Oxbow Conservation Area downstream from the highway bridge at RM 58.8 and between RM 57.9 and RM 58.51.

Metrics:

- Project Area: 2.0 acres

Management Considerations

- **Project MF_prj_58.51_R:** Place LWD or other structures to promote floodplain access and provide habitat complexity.
  - *Habitat Action Class*: LWD Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity and abundance VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, habitat quantity, sediment, and water temperature.
  - *Biological Priority*: Considered a priority 3
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes and lateral river migration.

Middle Fork John Day Tier-1 Project Area MF14_prj1

Project area is located in reach MF14 within the Middle Fork Forrest Conservation Area upstream of Vinegar Creek and between RM 66.52 and RM 67.47.

Metrics:

- Project Area: 6.1 acres

Management Considerations

- **Project MF_prj_67.47_R:** Remove rock spurs to promote floodplain function, place LWD to promote floodplain access and provide habitat complexity.
    - *Habitat Action Class*: LWD Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity and abundance VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, habitat quantity, sediment, and water temperature, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 3
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes and lateral river migration.

- **Project MF_prj_66.73_R:** Remove rock spurs to promote floodplain function
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes and lateral river migration.

3.5.2 Sequence Group 2 Projects

Upper John Day Tier-1 Project Area UJD2_prj1

Project area is located within the Mainstem Forrest Conservation Area near the upstream boundary of reach UJD2 and between RM 264.62 and RM 264.71.

Metrics:

- Project Area: 1.1 acres

Management Considerations

- **Project UJD_prj_264.71_R:** Remove rock spur to promote floodplain access.
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes and lateral river migration.

- **Project UJD_prj_264.70_R:** Remove rock spur and riprap to reconnect old channel path.
    - *Habitat Action Class*: Side-Channel Reconnection
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity and abundance VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, habitat quantity, sediment, flow, and water temperature.
    - *Biological Priority*: Considered a priority 2
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Reconnects a channel as an overflow channel.

Upper John Day Tier-1 Project Area UJD2_prj2

Project area is located in reach UJD2 within the Mainstem Forrest Conservation Area and between RM 264.43 and RM 264.51.

Metrics:

- Project Area: 1.0 acres

Management Considerations

- **Project UJD_prj_264.51_R:** Remove rock spur to reconnect historic main channel path.
  - *Habitat Action Class*: Side-Channel Reconnection
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity and abundance VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, habitat quantity, sediment, flow, and water temperature.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Reconnects a channel as an overflow channel

- **Project UJD_prj_264.45_R:** Remove levee to promote floodplain function.
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes.

Upper John Day Tier-1 Project Area PUJD2_prj3

Project area is located in reach UJD2 within the Mainstem Forrest Conservation Area and between RM 264.09 and RM 264.28.

Metrics:

- Project Area: 1.5 acres

Management Considerations

- **Project UJD_prj_264.28_R:** Remove riprap to reconnect historic main channel path.
    - *Habitat Action Class*: Side-Channel Reconnection
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity and abundance VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, habitat quantity, sediment, flow, and water temperature.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Reconnects a channel as an overflow channel

- **Project UJD_prj_264.24_R:** Remove levee to promote floodplain function, including reconnection of an old channel path.
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project UJD_prj_264.17_R:** Remove levee to promote floodplain function, including reconnection of two old channel paths.
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

Upper John Day Tier-1 Project Area UJD2_prj4

Project area is located in reach UJD2 within the Mainstem Forrest Conservation Area and between RM 263.75 and RM 263.96.

Metrics:

- Project Area: 1.4 acres

Management Considerations

- **Project UJD_prj_263.96_R:** Remove levee and embankment to promote floodplain function, including reconnection of an old channel path
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project UJD_prj_263.9_R:** Remove levee and embankment to promote floodplain function, including reconnection of an old channel path
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat

refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project UJD_prj_263.82_R:** Remove riprap to promote floodplain function
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

Upper John Day Tier-1 Project Area UJD2_prj5

Project area is located in reach UJD2 within the Mainstem Forrest Conservation Area just upstream of the silos on river right, and between RM 263.6 and RM 263.73.

Metrics:

- Project Area: 0.8 acres

Management Considerations

- **Project UJD_prj_263.73_R:** Remove riprap to promote floodplain function, including reconnection of an old channel path
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

Upper John Day Tier-1 Project Area UJD2_prj6

Project area is located in reach UJD2 within the Mainstem Forrest Conservation Area just downstream of the silos on river right, and between RM 263.49 and RM 263.57.

Metrics:

- Project Area: 0.2 acres

Management Considerations

- **Project UJD_prj_263.57_R:** Remove riprap to promote floodplain function
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

Upper John Day Tier-1 Project Area PUJD2_prj7

Project area is located within the Mainstem Forrest Conservation Area just upstream of the boundary at the downstream end of reach UJD1b, and between RM 263.1 and RM 263.29.

Metrics:

- Project Area: 1.5 acres

Management Considerations

- **Project UJD_prj_263.29_R:** Remove levee to promote floodplain function, including reconnection of an old channel path
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

Middle Fork John Day Tier-1 Project Area MF13_prj1

Project area is located within the Middle Fork Forrest Conservation Area upstream of Vinegar Creek and just downstream of the boundary of reach MF14, and between RM 66.32 and RM 66.48.

Metrics:

- Project Area: 2.6 acres

Management Considerations

- **Project MF_prj_66.48_R:** Remove rock spurs to promote floodplain access and function.
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes and lateral river migration.

- **Project MF_prj_66.46_R:** Remove rock spurs and riprap to promote floodplain access and function.
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes and lateral river migration.

- **Project MF_prj_66.41_R:** Remove rock spurs to promote floodplain access and function.
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes and lateral river migration.

Middle Fork John Day Tier-1 Project Area MF13_prj4

Project area is located in reach MF13 within the Middle Fork Forrest Conservation Area between RM 64.6 and Vincent Creek, near RM 65.46.

Metrics:

- Project Area: 19.1 acres

Management Considerations

- **Project MF_prj_65.46_R:** Remove rock spurs and riprap to promote floodplain access and function.
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes and lateral river migration.

- **Project MF_prj_65.32_R:** Remove rock spurs and riprap to promote floodplain access and function.
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes and lateral river migration (primarily).

- **Project MF_prj_65.05_R:** Remove rock spurs to promote floodplain function, including reconnection of an old channel path
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project MF_prj_64.86_R:** Remove rock spurs to promote floodplain function, including reconnection of an old channel path
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project MF_prj_64.7_R:** Remove rock spurs to promote floodplain function
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

Middle Fork John Day Tier-1 Project Area MF13_prj5

Project area is located in reach MF13 within the Middle Fork Forrest Conservation Area between RM 63.68, near the downstream property boundary, and RM 64.53

Metrics:
- Project Area: 30.3 acres

Management Considerations

- **Project MF_prj_64.53_R:** Remove rock spurs and riprap to promote floodplain function, including reconnection of an old channel path
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project MF_prj_64.29_R:** Remove rock spurs and riprap to promote floodplain function
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project MF_prj_64.25_R:** Remove rock spurs and riprap to promote floodplain function, including reconnection of old channel paths
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project MF_prj_64.04_R:** Remove rock spurs and riprap to promote floodplain function
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project MF_prj_63.93_R:** Remove rock spurs and riprap to promote floodplain function
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project MF_prj_63.71_R:** Remove rock spurs and riprap to promote floodplain function
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

3.5.3 Sequence Group 3 Projects

Middle Fork John Day Tier-1 Project Area MF8_prj1

Project area is located in reach MF8 within the Middle Fork Oxbow Conservation Area through the dredge-mining tailings and between RM 57.7 and RM 57.91.

Metrics:

- Project Area: 1.2 acres

Management Considerations

- **Project UJD_prj_57.91_R:** Place LWD to promote floodplain access and to provide habitat complexity.
  - *Habitat Action Class*: LWD Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity and abundance VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, habitat quantity, sediment, and water temperature.
  - *Biological Priority*: Considered a priority 3
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based Considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

Middle Fork John Day Tier-1 Project Area MF13_prj2

Project area is located within the Middle Fork Forrest Conservation Area between Vincent and Vinegar Creeks and between RM 65.85 and RM 66.29.

Metrics:

- Project Area: 5.3 acres

Management Considerations

- **Project MF_prj_66.29_R:** Remove rock spurs and riprap to promote floodplain function
  - *Habitat Action Class*: Floodplain Restoration
  - Relationship with VSP and Limiting Factors: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project MF_prj_66.13_R:** Remove rock spurs and riprap to promote floodplain function
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

Middle Fork John Day Tier-1 Project Area MF13_prj3

Project area is located in reach MF13 within the Middle Fork Forrest Conservation Area near the confluence with Vincent Creek and between RM 65.46 and RM 65.64.

Metrics:

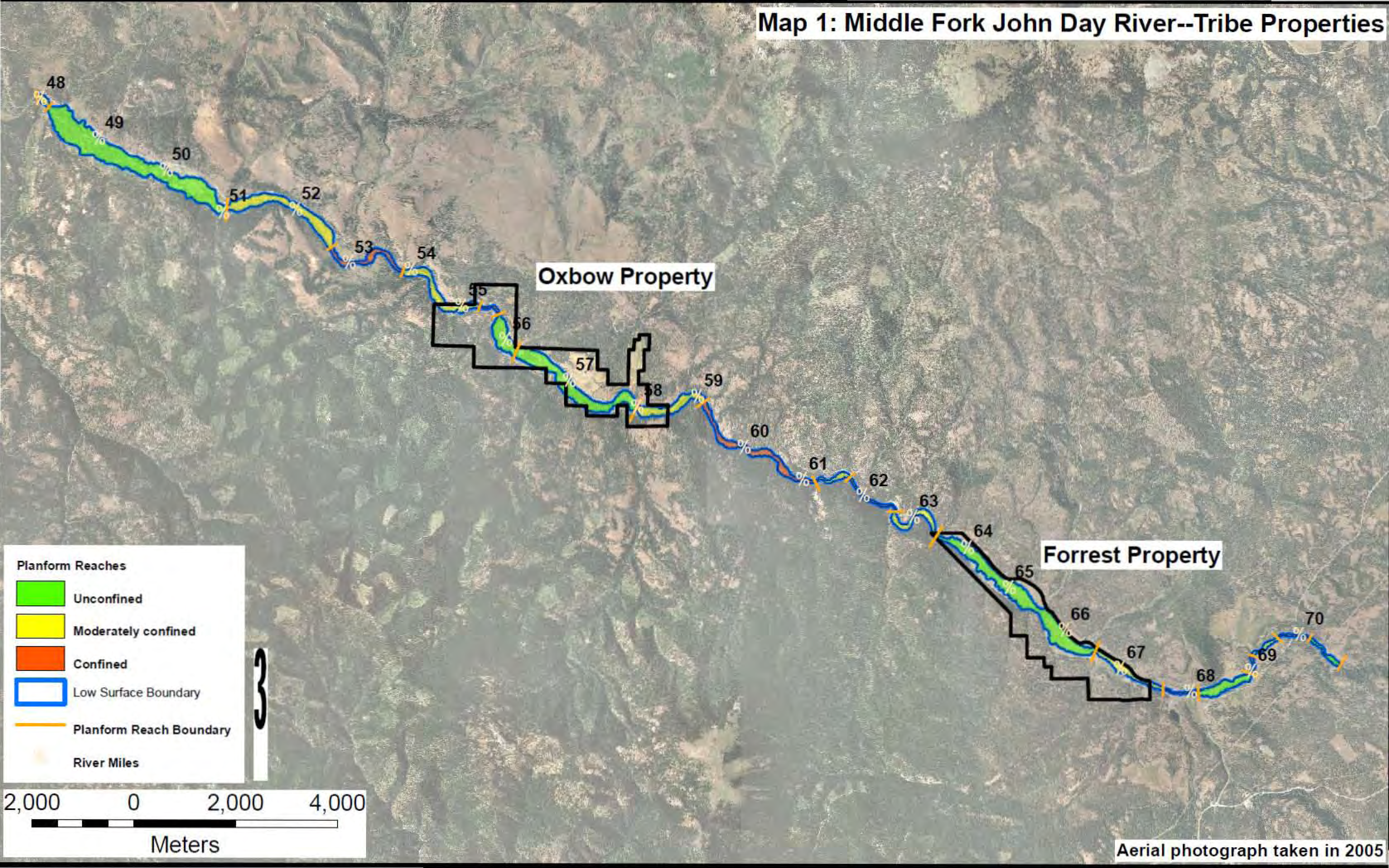
- Project Area: 4.7 acres

Management Considerations

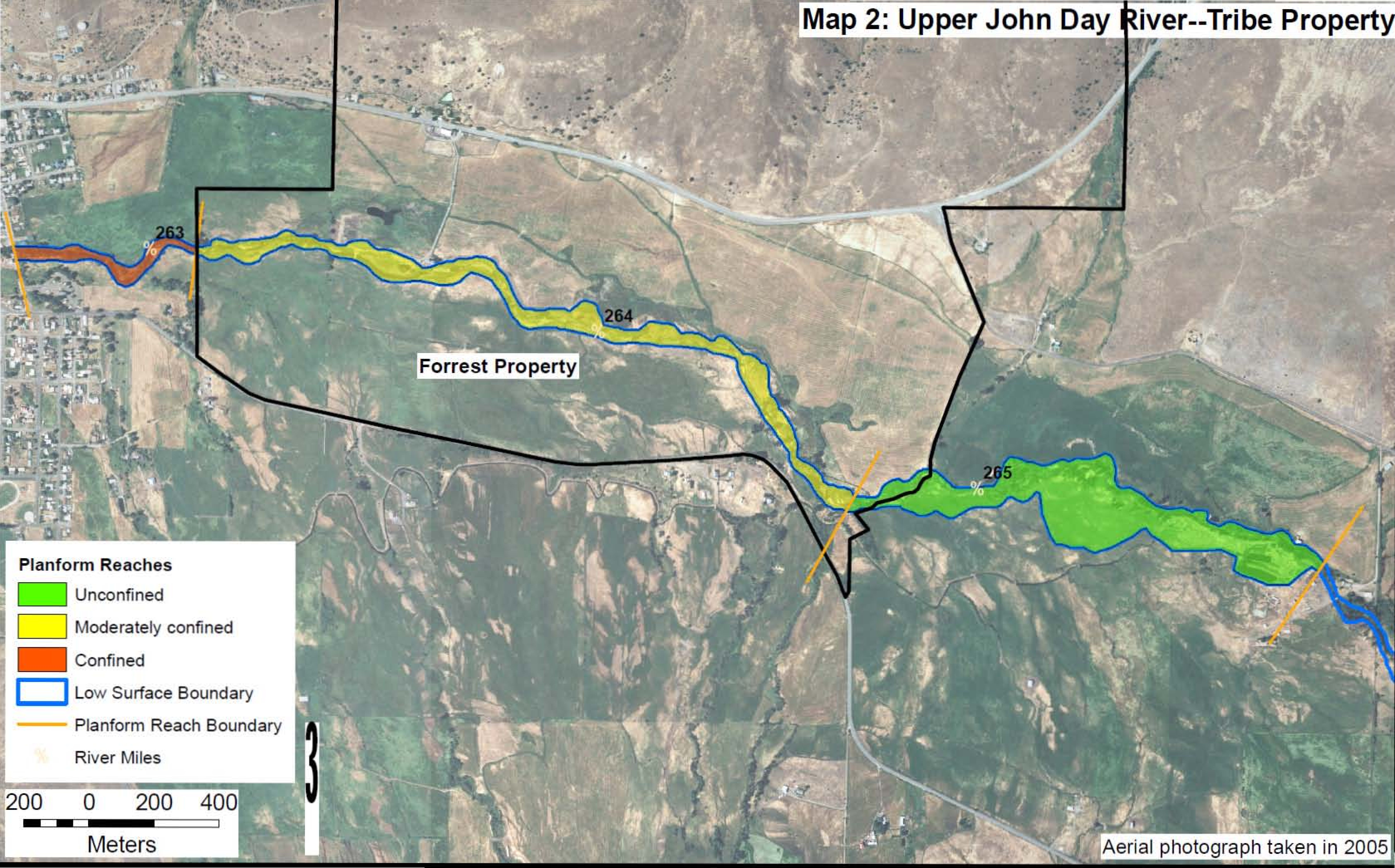
- **Project MF_prj_65.64_R:** Remove rock spurs and riprap to promote floodplain function, including reconnection of old channel paths
    - *Habitat Action Class*: Floodplain Restoration
    - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
    - *Biological Priority*: Considered a priority 1
    - *Construction Feasibility*: Considered a Tier 1
    - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project MF_prj_65.61_R:** Remove rock spurs and riprap to promote floodplain function, including reconnection of old channel paths
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion

- **Project MF_prj_65.53_R:** Remove rock spurs and riprap to promote floodplain function, including reconnection of an old channel path
  - *Habitat Action Class*: Floodplain Restoration
  - *Relationship with VSP and Limiting Factors*: Actions generally apply to productivity, abundance, diversity, and structure VSP parameters. These actions address limiting factors and causal factors including habitat refugia and diversity, hyporheic function, bed scour, channel incision, water temperature, water quality, width to depth ratios, bank stability, macroinvertebrate production, groundwater recharge, beaver populations, and spawning gravel and large woody debris recruitment.
  - *Biological Priority*: Considered a priority 1
  - *Construction Feasibility*: Considered a Tier 1
  - *Process-based considerations*: Re-establishes floodplain/river processes, lateral river migration, and reduces stream power to limit bank erosion



Map 1: Middle Fork John Day River--Tribe Properties
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
Oxbow Property
Forrest Property
Planform Reaches
Unconfined
Moderately confined
Confined
Low Surface Boundary
Planform Reach Boundary
River Miles
2,000 0 2,000 4,000
Meters
Aerial photograph taken in 2005



Map 2: Upper John Day River--Tribe Property
263
264
265
Forrest Property
Planform Reaches
Unconfined
Moderately confined
Confined
Low Surface Boundary
Planform Reach Boundary
River Miles
200 0 200 400
Meters
Aerial photograph taken in 2005

Appendix G: Geomorphic and Human Impacts Datasheets

Table of Contents

1.0 Datasheets of Middle Fork Assessment Area

1.1 Entire Assessment Area

1.1.1 Geomorphic characteristics

Downstream Boundary: RM 47.95

Upstream Boundary: RM 70.81

Type: Unconfined, Moderately confined, Confined

Main Tributaries: None

Length of Reach (2006 channel): 11 miles (43 percent) unconfined, 7 miles (33 percent) moderately confined, 4 miles (19 percent) confined; total 22.82 miles (120,464 feet)

Area of Natural Floodplain: 825.9 acres (68 percent) unconfined, 307.7 acres (25 percent) moderately confined, 83.7 acres (7 percent) confined; total 1,217 acres

> **Area of Natural HCMZ**: 877.83 acres; 553.93 acres (63 percent) unconfined, 243.60 acres (28 percent) moderately confined, 80.30 acres (9 percent) confined
>
> **Natural HCMZ Area as Percent of Total Reach Area**: 72 percent for entire assessment reach; 66 percent average for unconfined reaches, 77 percent average for moderately confined reaches, 97 percent average for confined reaches

Area of Natural Floodplain Outside of the Natural HCMZ: 399.5 acres for entire assessment reach; 38.85 acres average for unconfined reaches, 9.18 acres average for moderately confined reaches, 0.57 acres average for confined reaches

> **Percent of Natural Floodplain Outside of the Natural HCMZ**: 28 percent for entire assessment reach; 34 percent average for unconfined reaches, 23 percent average for moderately confined reaches, 3 percent average for confined reaches

Width of Natural Floodplain:

> **Average Natural Floodplain Width**: 631 feet average for unconfined reaches, 329 feet average for moderately confined reaches, 145 feet average for confined reaches
>
> **Minimum Natural Floodplain Width**: 316 feet average for unconfined reaches, 181 feet average for moderately confined reaches, 83 feet average for confined reaches
>
> **Maximum Natural Floodplain Width**: 932 feet average for unconfined reaches, 514 feet average for moderately confined reaches, 248 feet average for confined reaches

HCMZ Width:

Average Natural HCMZ Width: 398 feet average for unconfined reaches, 272 feet average for moderately confined reaches, 122 feet average for confined reaches

Minimum Natural HCMZ Width: 200 feet average for unconfined reaches, 159 feet average for moderately confined reaches, 75 feet average for confined reaches

Maximum Natural HCMZ Width: 623 feet average for unconfined reaches, 429 feet average for moderately confined reaches, 195 feet average for confined reaches

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 43.35 mile length boundary

Bedrock: 24.02 miles (55 percent of boundary)

Alluvium/Colluvium: 10.94 miles (25 percent of boundary)

Alluvial-Fan Deposits: 7.25 miles (17 percent of boundary)

Tailings: 1.01 miles (2 percent of boundary)

Terrace: 0.12 miles (0.3 percent of boundary)

Bank Erosion: Note that bank erosion was evaluated in only 8 reaches out of the 20.

Total Length Observed: 1.95 miles (10,296 feet) total length. Of this length, 9,761 feet (95 percent) involve floodplain reworking, 283 feet (3 percent) involve erosion along the floodplain boundary, and 253 feet (2 percent) involve both.

1.1.2 Human Impacts

Human Features (points):

Number of Point Human Features: 568

Number of Point Human Features/Mile: 24.9

Type of Human Features: Rock spurs (407), blocked/filled channels (87), channel cutoffs by railroad grade (19), culverts (13), diversions (11), bridges (9), straightened/channelized sections (8), fords (5), structures (4), log structures (2), foot bridges (2), weir (1)

Human Features (linear):

Total Length of Human Features: 65,815 feet (12.46 miles)

Length of Features as Percent of 2006 Channel Length: 55 percent

Type of Human Features (Percent 2005 Channel Length): 25,881 feet (21 percent) railroad grade (39 percent), 12,073 feet (10 percent) improved road (highway), 9,701 feet (8 percent) unimproved road, 8,263 feet (7 percent) irrigation ditch, 7,717 feet (6 percent) riprap, 1,562 feet (1 percent) levee, 619 feet (0.5 percent) mining spoils

Human Features (areas):

Total Area of Human Features: 188.42 acres

Percent Human Features of Total Reach Area: 16 percent

Type of Human Features (Percent Total Reach Area): 110.67 acres (9 percent) tailings, 51.34 acres (4 percent) disturbed, 11.90 acres (1 percent) Bates townsite, 8.64 acres (0.7 percent) embankment (highway), 4.31 acres (0.4 percent) embankment (unimproved road), 1.56 acres (0.13 percent) buildings

Impacted Areas of Natural HCMZ:

Total Area Impacted: 503.51 acres for assessment reach; 54.54 acres average for unconfined reaches, 15.39 acres average for moderately confined reaches, 2.33 acres average for confined reaches

Percent of Natural HCMZ Impacted: 41 percent for assessment reach; 33 percent average for unconfined reaches, 31 percent average for moderately confined reaches, 21 percent average for confined reaches

Impacted Areas of HCMZ by Human Features (Percent of Natural HCMZ):

195.75 acres (22 percent) Blocked channels, levees, riprap, rock spurs, irrigation ditches

63.57 acres (7 percent) Railroad grade

60.39 acres (7 percent) Rock spurs, riprap

46.87 acres (5 percent) Tailings

41.93 acres (5 percent) Bridge and embankments (unimproved roads)

31.12 acres (4 percent) Blocked channels

27.16 acres (3 percent) Rock spurs

7.84 acres (1 percent) Bridge and embankments (highway)

6.29 acres (1 percent) Bates townsite

5.85 acres (1 percent) Tailings, railroad grade, embankment (unimproved roads), buildings

2.73 acres (0.3 percent) Unimproved roads

2.02 acres (0.2 percent) Possible levees

1.95 acres (0.2 percent) Embankments (highway)

1.34 acres (0.2 percent) Irrigation ditches

1.16 acres (0.1 percent) Riprap

0.92 acres (0.1 percent) Embankments (highway), culverts

0.72 acres (0.1 percent) Railroad grade, embankments (highway)

0.65 acres (0.1 percent) Embankments (unimproved road)

0.54 acres (0.1 percent) Excavations

0.34 acres (less than 0.1 percent) Spoil, disturbed, filled channels

0.3 acres (less than 0.1 percent) Channelized sections

0.02 acres (less than 0.1 percent) Diversions

Present Width of HCMZ:

Average Present HCMZ Width: 137 feet average for unconfined reaches, 143 feet average for moderately confined reaches, 107 feet average for confined reaches

Minimum Present HCMZ Width: 51 feet average for unconfined reaches, 64 feet average for moderately confined reaches, 59 feet average for confined reaches

Maximum Present HCMZ Width: 332 feet average for unconfined reaches, 325 feet average for moderately confined reaches, 181 feet average for confined reaches

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 261 feet average for unconfined reaches, 129 feet average for moderately confined reaches, 36 feet average for confined reaches

Average Percent Decrease in HCMZ Width: 55 percent average for unconfined reaches, 43 percent average for moderately confined reaches, 26 percent average for confined reaches

Decrease in Minimum HCMZ Width: 27 feet average for unconfined reaches, 11 feet average for moderately confined reaches, 2 feet average for confined reaches

Decrease in Maximum HCMZ Width: 492 feet average for unconfined reaches, 308 feet average for moderately confined reaches, 116 feet average for confined reaches

Average Width Decrease Created by Constructed Features:

1,786 feet rock spurs

1,635 feet bridges (unimproved roads)

1,619 feet blocked channels

1,060 feet riprap, levees

1,047 feet riprap

941 feet levees

921 feet rock spurs, riprap

793 feet tailings

786 feet blocked channels, levees, riprap, rock spurs

650 feet railroad grade

392 feet Bates townsite

328 feet bridges (highway)

286 feet embankments

263 feet diversions, irrigation ditches

249 feet railroad grade, levees, riprap, rock spurs, buildings

223 feet buildings, embankment

174 feet culverts (highway)

167 feet rock spurs, levee

141 feet unimproved roads

117 feet highway

78 feet structures (building)

76 feet excavations

72 feet channelized sections

55 feet buildings

55 feet disturbed areas

47 feet unimproved roads, irrigation ditch

22 feet irrigation ditches

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 151.39 acres for assessment reach; 123.90 acres average for unconfined reaches, 27.49 acres average for moderately confined reaches, none for confined reaches

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 46 percent for assessment reach; 43 percent average for unconfined reaches, none for confined reaches

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

64.08 acres (19 percent) railroad grade

58.44 acres (17 percent) tailings

17.04 acres (5 percent) embankments (highway)

3.87 acres (1 percent) riprap

3.33 acres (1 percent) embankments (unimproved roads)

1.94 acres (1 percent) buildings

1.87 acres (1 percent) disturbed

0.75 acres (0.2 percent) irrigation ditches

0.07 acres (less than 0.1 percent) bridge and embankments (highway)

Present Width of Floodplain:

Average Present Floodplain Width: 441 feet average for unconfined reaches, 236 feet average for moderately confined reaches, 130 feet average for confined reaches

Minimum Present Floodplain Width: 135 feet average for unconfined reaches, 84 feet average for moderately confined reaches, 62 feet average for confined reaches

Maximum Present Floodplain Width: 802 feet average for unconfined reaches, 474 feet average for moderately confined reaches, 242 feet average for confined reaches

Change in Width of Floodplain:

Difference in Average Floodplain Width: 143 feet average for unconfined reaches, 59 feet average for moderately confined reaches, 12 feet average for confined reaches

Percent Difference in Average Floodplain Width: 23 percent average for unconfined reaches, 18 percent average for moderately confined reaches, 8 percent average for confined reaches

Difference in Minimum Floodplain Width: 181 feet average for unconfined reaches, 97 feet average for moderately confined reaches, 20 feet average for confined reaches

Difference in Maximum Floodplain Width: 130 feet average for unconfined reaches, 41 feet average for moderately confined reaches, 6 feet average for confined reaches

Average Width Decrease Created By Constructed Features:

2,332 feet bridges

1,546 feet riprap

940 feet railroad grade

694 feet tailings

663 feet buildings

514 feet bridge and embankments (unimproved roads)

407 feet embankment (highway)

322 feet unimproved roads

279 feet Bates townsite

108 feet rock spurs

86 feet embankment (highway) with culvert

83 feet irrigation ditches

56 feet embankments (unimproved roads)

Change in Flow Characteristics:

Length of Artificially Straightened Channel: 29,046 feet (5.5 miles)

Percent of 2006 Channel that is Straightened: 24 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length):

12,237 feet (10 percent) tailings

4,448 feet (4 percent) railroad grade

1,989 feet (2 percent) Bates townsite

1,958 feet (2 percent) rock spurs, railroad grade, riprap

1,449 feet (1 percent) bridges and embankments (highway)

1,338 feet (1 percent) bridges and embankments (unimproved roads)

1,326 feet (1 percent) disturbed area

947 feet (1 percent) bridge and embankment (unimproved road), Bates townsite

761 feet (1 percent) railroad grade, buildings

665 feet (1 percent) riprap

530 feet (0.4 percent) rock spurs, riprap

490 feet (0.4 percent) riprap, levees

282 feet (0.2 percent) mechanically straightened

273 feet (0.2 percent) embankment (highway)

238 feet (0.2 percent) embankment (highway) with culverts

115 feet (0.1 percent) blocked/filled channels

Length of Artificially Confined Channel: 26,716 feet (5.1 miles)

Percent of 2006 Channel that is Confined: 22 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length):

11,656 feet (10 percent) rock spurs, railroad grade, riprap

4,101 feet (3 percent) rock spurs

2,477 feet (2 percent) bridge and embankment (unimproved road), riprap

2,422 feet (2 percent) riprap

2,025 feet (2 percent) railroad grade

1,074 feet (1 percent) bridge and embankments, riprap, rock spurs, diversion

1,015 feet (1 percent) buildings, blocked/filled channels

994 feet (1 percent) tailings, buildings

725 feet (1 percent) rock spurs, riprap

227 feet (0.2 percent) rock spurs, diversions

Total Length of Straightened/Confined Channel: 55,762 feet (10.6 miles)

Percent of 2006 Channel that is Straightened/Confined: 46 percent

Length of Possible Main Channel Cutoff: 19,844 feet (3.8 miles)

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length):

9,045 feet (7 percent) artificially blocked/filled channels

3,675 feet (3 percent) riprap

2,418 feet (2 percent) railroad grade

2,204 feet (2 percent) levees

1,544 feet 1 percent) embankment (unimproved road)

418 feet (0.3 percent) rock spurs

376 feet (0.3 percent) diversion, artificially blocked/filled channels

164 feet (0.1 percent) embankment (highway)

1.2 Reach MF20

1.2.1 Geomorphic Characteristics

Downstream Boundary: RM 70.15

Upstream Boundary: RM 70.81

Type: Unconfined

Main Tributaries: None

Length of Reach (2006 channel): 0.66 miles; 3,495 feet

Area of Natural Floodplain: 12.4 acres

Area of Natural Floodplain Outside of the Natural HCMZ: None

Area of Natural HCMZ: 12.4 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 100 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 231 feet

Minimum Natural Floodplain Width: 120 feet

Maximum Natural Floodplain Width: 340 feet

HCMZ Width:

Average Natural HCMZ Width: 201 feet

Minimum Natural HCMZ Width: 118 feet

Maximum Natural HCMZ Width: 339 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 5,987 feet (1.12 miles) length boundary

Alluvial-Fan Deposits: 2,896 feet (0.54 miles); 48 percent of boundary

Bedrock: 2,186 feet (0.41 miles); 37 percent of boundary

Alluvium/Colluvium: 905 feet (0.17 miles); 15 percent of boundary

Bank Erosion: Not evaluated

1.2.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 3

Number of Point Constructed Features/Mile: 4.5

Type of Constructed Features: Log structures (2), diversion (1)

Constructed Features (linear):

Total Length of Constructed Features: 2,360 feet (0.45 miles)

Length of Features as Percent of 2006 Channel Length: 67 percent

Type of Constructed Features (Percent 2005 Channel Length): 1,309 feet (37 percent) irrigation ditches, 990 feet (28 percent) unimproved roads, 61 feet (2 percent) riprap

Constructed Features (areas):

Total Area of Constructed Features: None

Impacted Areas of Natural HCMZ:

Total Area Impacted: 0.88 acres

Percent of Natural HCMZ Impacted: 7 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

0.63 acres (5 percent) irrigation ditches

0.23 acres (2 percent) unimproved roads

0.02 acres (0.2 percent) riprap

Present Width of HCMZ:

Average Present HCMZ Width: 188 feet

Minimum Present HCMZ Width: 118 feet

Maximum Present HCMZ Width: 292 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 13 feet

Average Percent Decrease in HCMZ Width: 4 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 47 feet

Average Width Decrease Created by Constructed Features:

47 feet unimproved roads, irrigation ditches

22 feet irrigation ditches

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: None

Present Width of Floodplain:

Average Present Floodplain Width: 221 feet

Minimum Present Floodplain Width: 120 feet

Maximum Present Floodplain Width: 317 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 11 feet

Percent Difference in Average Floodplain Width: 5 percent

Difference in Minimum Floodplain Width: None

Difference in Maximum Floodplain Width: 23 feet

Average Width Decrease Created by Constructed Features:

14 feet unimproved roads

13 feet irrigation ditch

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: None

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: None

Length of Possible Main Channel Cutoff: None

1.3 Reach MF19

1.3.1 Geomorphic Characteristics

Downstream Boundary: RM 69.7

Upstream Boundary: RM 70.15

Type: Confined

Main Tributaries: Unnamed creek on river right at RM 69.8

Length of Reach (2006 channel): 0.45 miles; 2,374 feet

Area of Natural Floodplain: 4.6 acres

Area of Natural Floodplain Outside of the Natural HCMZ: None

Area of Natural HCMZ: 4.6 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 100 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 85 feet

Minimum Natural Floodplain Width: 76 feet

Maximum Natural Floodplain Width: 106 feet

HCMZ Width:

Average Natural HCMZ Width: 87 feet

Minimum Natural HCMZ Width: 76 feet

Maximum Natural HCMZ Width: 108 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 4,594 feet (0.86 miles) length boundary

Bedrock: 3,489 feet (0.66 miles); 76 percent of boundary

Alluvium/Colluvium: 1,105 feet (0.21 miles); 24 percent of boundary

Bank Erosion: Not evaluated

1.3.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 4

Number of Point Constructed Features/Mile: 8.9

Type of Constructed Features: Blocked/filled channels (2), culvert (1), diversion (1)

Constructed Features (linear):

Total Length of Constructed Features: 1,921 feet (0.36 miles)

Length of Features as Percent of 2006 Channel Length: 81 percent

Type of Constructed Features (Percent 2005 Channel Length): 1,296 feet (55 percent) improved roads (highway), 451 feet (19 percent) unimproved roads, 174 feet (7 percent) riprap

Constructed Features (areas):

Total Area of Constructed Features: 0.19 acres

Percent Constructed Features of Total Reach Area: 4 percent

Type of Constructed Features (Percent Total Reach Area): 0.19 acres (4 percent) embankment (highway)

Impacted Areas of Natural HCMZ:

Total Area Impacted: 1.09 acres

Percent of Natural HCMZ Impacted: 24 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

0.62 acres (13 percent) embankment (highway)

0.23 acres (5 percent) blocked channel

0.23 acres (5 percent) unimproved roads

0.02 acres (0.3 percent) diversion

Present Width of HCMZ:

Average Present HCMZ Width: 51 feet

Minimum Present HCMZ Width: 9 feet

Maximum Present HCMZ Width: 78 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 36 feet

Average Percent Decrease in HCMZ Width: 39 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 80 feet

Average Width Decrease Created by Constructed Features:

80 feet culvert (highway)

69 feet embankment

50 feet blocked channels

31 feet unimproved roads

26 feet riprap

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: None

Present Width of Floodplain:

Average Present Floodplain Width: 66 feet

Minimum Present Floodplain Width: 9 feet

Maximum Present Floodplain Width: 106 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 19 feet

Percent Difference in Average Floodplain Width: 22 percent

Difference in Minimum Floodplain Width: 67 feet

Difference in Maximum Floodplain Width: None

Average Width Decrease Created by Constructed Features:

84 feet embankment (highway) with culvert

20 feet riprap

8 feet unimproved road

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 354 feet

Percent of 2006 Channel that is Straightened: 15 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length):

238 feet (10 percent) embankment (highway) with culvert

115 feet (5 percent) blocked/filled channels

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: 354 feet

Percent of 2006 Channel that is Straightened/Confined: 15 percent

Length of Possible Main Channel Cutoff: None

1.4 Reach MF18

1.4.1 Geomorphic Characteristics

Downstream Boundary: RM 69.23

Upstream Boundary: RM 69.7

Type: Moderately confined

Main Tributaries: Mill Creek on river right at RM 69.25

Length of Reach (2006 channel): 0.47 miles; 2,467 feet

Area of Natural Floodplain: 8.7 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 2.06 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 24 percent

Area of Natural HCMZ: 6.7 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 76 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 175 feet

Minimum Natural Floodplain Width: 93 feet

Maximum Natural Floodplain Width: 294 feet

HCMZ Width:

Average Natural HCMZ Width: 149 feet

Minimum Natural HCMZ Width: 98 feet

Maximum Natural HCMZ Width: 191 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 4,408 feet (0.83 miles) length boundary

Alluvium/Colluvium: 2,425 feet (0.46 miles); 55 percent of boundary

Bedrock: 1.983 feet (0.37 miles); 45 percent of boundary

Bank Erosion: Not evaluated

1.4.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 2

Number of Point Constructed Features/Mile: 4.3

Type of Constructed Features: Blocked/filled channel (1), diversion (1)

Constructed Features (linear):

Total Length of Constructed Features: 435 feet (0.08 miles)

Length of Features as Percent of 2006 Channel Length: 18 percent

Type of Constructed Features (Percent 2005 Channel Length): 394 feet (16 percent) irrigation ditches, 41 feet (2 percent) riprap

Constructed Features (areas):

Total Area of Constructed Features: None

Impacted Areas of Natural HCMZ:

Total Area Impacted: 1.21 acres

Percent of Natural HCMZ Impacted: 18 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

0.99 acres (15 percent) blocked channels

0.13 acres (2 percent) irrigation ditches

0.10 acres (1 percent) riprap

Present Width of HCMZ:

Average Present HCMZ Width: 108 feet

Minimum Present HCMZ Width: 30 feet

Maximum Present HCMZ Width: 170 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 41 feet

Average Percent Decrease in HCMZ: 24 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 161 feet

Average Width Decrease Created by Constructed Features:

161 feet blocked channels, levees, riprap, rock spurs

77 feet blocked channels

49 feet diversion, irrigation ditch

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: None

Present Width of Floodplain:

Average Present Floodplain Width: 165 feet

Minimum Present Floodplain Width: 85 feet

Maximum Present Floodplain Width: 294 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 10 feet

Percent Difference in Average Floodplain Width: 6 percent

Difference in Minimum Floodplain Width: 8 feet

Difference in Maximum Floodplain Width: None

Average Width Decrease Created by Constructed Features:

19 feet irrigation ditch

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: None

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 238 feet (10 percent) culvert and embankment (highway)

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: None

Length of Possible Main Channel Cutoff: 337 feet

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length): 337 feet (14 percent) artificially blocked/filled channels

1.5 Reach MF17

1.5.1 Geomorphic Characteristics

Downstream Boundary: RM 68.95

Upstream Boundary: RM 69.23

Type: Confined

Main Tributaries: None

Length of Reach (2006 channel): 0.27 miles; 1,401 feet

Area of Natural Floodplain: 3.7 acres

Area of Natural Floodplain Outside of the Natural HCMZ: None

Area of Natural HCMZ: 3.7 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 100 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 111 feet

Minimum Natural Floodplain Width: 69 feet

Maximum Natural Floodplain Width: 187 feet

HCMZ Width:

Average Natural HCMZ Width: 139 feet

Minimum Natural HCMZ Width: 69 feet

Maximum Natural HCMZ Width: 187 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 2,630 feet (0.49 miles) length boundary

Bedrock: 2,564 feet (0.48 miles); 98 percent of boundary

Alluvium/Colluvium: 66 feet (0.01 miles); 3 percent of boundary

Bank Erosion: Not evaluated

1.5.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 2

Number of Point Constructed Features/Mile: 7.5

Type of Constructed Features: Blocked/filled channel (1), diversion (1)

Constructed Features (linear):

Total Length of Constructed Features: 51 feet (0.01 miles)

Length of Features as Percent of 2006 Channel Length: 4 percent

Type of Constructed Features (Percent 2005 Channel Length): 51 feet (4 percent) riprap

Constructed Features (areas):

Total Area of Constructed Features: None

Impacted Areas of Natural HCMZ:

Total Area Impacted: 0.50 acres

Percent of Natural HCMZ Impacted: 14 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

0.38 acres (10 percent) blocked channels

0.07 acres (2 percent) riprap

0.05 acres (1 percent) bridge and embankments (highway)

Present Width of HCMZ:

Average Present HCMZ Width: 104 feet

Minimum Present HCMZ Width: 69 feet

Maximum Present HCMZ Width: 134 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 35 feet

Average Percent Decrease in HCMZ Width: 21 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 62 feet

Average Width Decrease Created by Constructed Features:

58 feet blocked channels

25 feet riprap

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: None

Present Width of Floodplain:

Average Present Floodplain Width: 111 feet

Minimum Present Floodplain Width: 69 feet

Maximum Present Floodplain Width: 187 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: None

Percent Difference in Average Floodplain Width: 0 percent

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 42 feet

Percent of 2006 Channel that is Straightened: 3 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 42 feet (3 percent) bridge and embankment (highway)

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: 42 feet

Percent of 2006 Channel that is Straightened/Confined: 3 percent

Length of Possible Main Channel Cutoff: None

1.6 Reach MF16

1.6.1 Geomorphic Characteristics

Downstream Boundary: RM 68.1

Upstream Boundary: RM 68.95

Type: Unconfined

Main Tributaries: Unnamed creek on river left at RM 68.55

Length of Reach (2006 channel): 0.86 miles; 4,561 feet

Area of Natural Floodplain: 39.4 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 18.97 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 48 percent

Area of Natural HCMZ: 20.38

Natural HCMZ Area as Percent of Natural Floodplain Area: 52 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 425 feet

Minimum Natural Floodplain Width: 80 feet

Maximum Natural Floodplain Width: 641 feet

HCMZ Width:

Average Natural HCMZ Width: 250 feet

Minimum Natural HCMZ Width: 178 feet

Maximum Natural HCMZ Width: 358 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 8,087 feet (1.52 miles) length boundary

Alluvium/Colluvium: 5,961 feet (1.12 miles); 74 percent of boundary

Alluvial-Fan Deposits: 1,811 feet (0.34 miles); 22 percent of boundary

Bedrock: 315 feet (0.06 miles); 4 percent of boundary

Bank Erosion: Not evaluated

1.6.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 6

Number of Point Constructed Features/Mile: 7.0

Type of Constructed Features: Blocked/filled channels (4), bridge (1), straightened/channelized section (1)

Constructed Features (linear):

Total Length of Constructed Features: 3,281 feet (0.62 miles)

Length of Features as Percent of 2006 Channel Length: 72 percent

Type of Constructed Features (Percent 2005 Channel Length): 2,760 feet (60 percent) improved road (highway), 298 feet (7 percent) levee, 223 feet (5 percent) unimproved road

Constructed Features (areas):

Total Area of Constructed Features: 0.44 acres

Percent Constructed Features of Total Reach Area: 1 percent

Type of Constructed Features (Percent Total Reach Area): 0.32 acres (0.8 percent) Bates townsite, 0.13 acres (0.3 percent) embankment (highway)

Impacted Areas of Natural HCMZ:

Total Area Impacted: 8.97 acres

Percent of Natural HCMZ Impacted: 44 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

6.12 acres (30 percent) blocked channels

2.27 acres (11 percent) unimproved road

0.32 acres (2 percent) Bates townsite

0.26 acres (1 percent) bridge and embankments (highway)

Present Width of HCMZ:

Average Present HCMZ Width: 135 feet

Minimum Present HCMZ Width: 41 feet

Maximum Present HCMZ Width: 266 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 114 feet

Average Percent Decrease in HCMZ Width: 44 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 274 feet

Average Width Decrease Created by Constructed Features:

182 feet levee

147 feet blocked channels

137 feet Bates townsite

111 feet unimproved roads

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 0.07 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 0.4 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

0.07 acres (0.4 percent) bridge and embankments (highway)

Present Width of Floodplain:

Average Present Floodplain Width: 399 feet

Minimum Present Floodplain Width: 46 feet

Maximum Present Floodplain Width: 641 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 26 feet

Percent Difference in Average Floodplain Width: 6 percent

Difference in Minimum Floodplain Width: 34 feet

Difference in Maximum Floodplain Width: None

Average Width Decrease Created by Constructed Features:

35 feet embankment (highway)

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 418 feet

Percent of 2006 Channel that is Straightened: 9 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length):

342 feet (7 percent) Bates townsite

75 feet (2 percent) bridge and embankment (highway)

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: 418 feet

Percent of 2006 Channel that is Straightened/Confined: 9 percent

Length of Possible Main Channel Cutoff: 604 feet

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length): 604 feet (13 percent) artificially blocked/filled channels

1.7 Reach CC1

1.7.1 Geomorphic Characteristics

Downstream Boundary: RM 67.95 (Middle Fork)

Upstream Boundary: RM 68.1 (Middle Fork)

Main Tributaries: None

Length of Reach (2006 channel): 0.4 miles; 2,137 feet

Area of Natural Floodplain: 26.9 acres (see note below)

Area of Natural Floodplain Outside of the Natural HCMZ: None

Area of Natural HCMZ: 27.5 acres[1]

Natural HCMZ Area as Percent of Natural Floodplain Area: 102 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 328 feet

Minimum Natural Floodplain Width: 269 feet

Maximum Natural Floodplain Width: 406 feet

HCMZ Width:

Average Natural HCMZ Width: (Not measured)

Minimum Natural HCMZ Width: (Not measured)

Maximum Natural HCMZ Width: (Not measured)

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 4,141 feet (0.78 miles) length of boundary

Bedrock: 2,982 feet (0.56 miles); 72 percent of boundary

Alluvium/Colluvium: 1.159 feet (0.22 miles); 28 percent of boundary

Bank Erosion: Not evaluated

1.7.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 1

Number of Point Constructed Features/Mile: 7

Type of Constructed Features: Culvert (1)

Constructed Features (linear):

Total Length of Constructed Features: None

Constructed Features (areas):

Total Area of Constructed Features: 25.48 acres

Percent Constructed Features of Total Reach Area: 96 percent

Type of Constructed Features (Percent Total Reach Area): 25.48 acres (96 percent) embankment

[1] The natural HCMZ area is larger than the natural floodplain area because the mapped natural HCMZ extends to the boundary of the natural HCMZ of the Middle Fork, and the mapped natural floodplain extends only to the boundary of the natural floodplain of the Middle Fork.

Impacted Areas of Natural HCMZ:

Total Area Impacted: 30.01 acres

Percent of Natural HCMZ Impacted: 100 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ): 26.48 acres (100 percent) Bates townsite

Disconnected Area of Natural Floodplain Outside of the HCMZ: None

Present Width of Floodplain:

Average Present Floodplain Width: 245 feet

Minimum Present Floodplain Width: 74 feet

Maximum Present Floodplain Width: 351 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width:

Percent Difference in Average Floodplain Width:

Difference in Minimum Floodplain Width:

Difference in Maximum Floodplain Width:

Average Width Decrease Created by Constructed Features:

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 2,172 feet

Percent of 2006 Channel That is Straightened: 100 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 2,172 feet (100 percent) Bates townsite

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: 2,125 feet

Percent of 2006 Channel that is Straightened/Confined: 99 percent

Length of Possible Main Channel Cutoff: None

1.8 Reach MF15

1.8.1 Geomorphic Characteristics

Downstream Boundary: RM 67.65

Upstream Boundary: RM 68.1

Type: Confined

Main Tributaries: Clear Creek on river left at RM 68.1

Length of Reach (2006 channel): 0.45 miles; 2,379 feet

Area of Natural Floodplain: 6.1 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 0.69 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 11 percent

Area of Natural HCMZ: 5.45 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 89 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 93 feet

Minimum Natural Floodplain Width: 61 feet

Maximum Natural Floodplain Width: 127 feet

HCMZ Width:

Average Natural HCMZ Width: 89 feet

Minimum Natural HCMZ Width: 61 feet

Maximum Natural HCMZ Width: 127 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 4,750 feet (0.89 miles) length boundary

Alluvium/Colluvium: 3,570 feet (0.67 miles); 75 percent of boundary

Bedrock: 1,180 feet (0.22 miles); 25 percent of boundary

Bank Erosion: Not evaluated

1.8.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 3

Number of Point Constructed Features/Mile: 6.7

Type of Constructed Features: Bridge (1), culvert (1), weir (1)

Constructed Features (linear):

Total Length of Constructed Features: 433 feet (0.08 miles)

Length of Features as Percent of 2006 Channel Length: 18 percent

Type of Constructed Features (Percent 2005 Channel Length): 289 feet (12 percent) unimproved road, 144 feet (6 percent) improved road (highway)

Constructed Features (areas):

Total Area of Constructed Features: 3.56 acres

Percent Constructed Features of Total Reach Area: 58 percent

Type of Constructed Features (Percent Total Reach Area): 3.21 acres (52 percent) Bates townsite, 0.29 acres (5 percent) embankment (highway), 0.07 acres (1 percent) embankment (unimproved road)

Impacted Areas of Natural HCMZ:

Total Area Impacted: 3.57 acres

Percent of Natural HCMZ Impacted: 65 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

3.21 acres (59 percent) Bates townsite

0.3 acres (6 percent) embankment (highway), culvert

0.05 acres (0.9 percent) embankment (highway)

0.01 acres (0.2 percent) bridge and embankments (unimproved road)

Present Width of HCMZ:

Average Present HCMZ Width: 35 feet

Minimum Present HCMZ Width: 19 feet

Maximum Present HCMZ Width: 56 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 55 feet

Average Percent Decrease in HCMZ Width: 57 percent

Decrease in Minimum HCMZ Width: 11 feet

Decrease in Maximum HCMZ Width: 94 feet

Average Width Decrease Created by Constructed Features:

94 feet culvert (highway)

49 feet Bates townsite

41 feet bridge (unimproved road)

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: None

Present Width of Floodplain:

Average Present Floodplain Width: 58 feet

Minimum Present Floodplain Width: 7 feet

Maximum Present Floodplain Width: 127 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 34 feet

Percent Difference in Average Floodplain Width: 37 percent

Difference in Minimum Floodplain Width: 54 feet

Difference in Maximum Floodplain Width: None

Average Width Decrease Created by Constructed Features:

78 feet unimproved road

76 feet Bates townsite

57 feet bridge and embankments (unimproved road)

16 feet embankment (highway)

2 feet embankment (highway) with culvert

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 2,382 feet

Percent of 2006 Channel that is Straightened: 100 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length):

1,647 feet (69 percent) Bates townsite

735 feet (31 percent) bridge and embankments (unimproved road)

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: 2,382 feet

Percent of 2006 Channel that is Straightened/Confined: 100 percent

Length of Possible Main Channel Cutoff: None

1.9 Reach MF14

1.9.1 Geomorphic Characteristics

Downstream Boundary: RM 66.52

Upstream Boundary: RM 67.65

Type: Moderately confined

Main Tributaries: Davis Creek on river left at RM 66.7, unnamed creek on river left at RM 67.2, Bridge Creek on river left at RM 67.5

Length of Reach (2006 channel): 1.12 miles; 5,936 feet

Area of Natural Floodplain: 34.4 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 3.94 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 11 percent

Area of Natural HCMZ: 30.46 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 89 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 286 feet

Minimum Natural Floodplain Width: 134 feet

Maximum Natural Floodplain Width: 646 feet

HCMZ Width:

Average Natural HCMZ Width: 270 feet

Minimum Natural HCMZ Width: 134 feet

Maximum Natural HCMZ Width: 480 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 10,495 feet (1.97 miles) length boundary

Bedrock: 6,167 feet (1.16 miles); 59 percent of boundary

Alluvium/Colluvium: 2,982 feet (0.56 miles); 28 percent of boundary

Alluvial-Fan Deposits: 1,346 feet (0.25 miles); 13 percent of boundary

Bank Erosion:

Total Length Observed: 0.26 miles (1,382 feet)

The entire length involves reworking of floodplain sediments

1.9.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 102

Number of Point Constructed Features/Mile: 90.7

Type of Constructed Features: Rock spurs (86), culverts (6), diversions (3), structures (3), bridges (2), blocked/filled channel (1), foot bridge (1),

Constructed Features (linear):

Total Length of Constructed Features: 2,186 feet (0.41 miles)

Length of Features as Percent of 2006 Channel Length: 37 percent

Type of Constructed Features (Percent 2005 Channel Length): 932 feet (16 percent) irrigation ditches, 705 feet (12 percent) unimproved roads, 232 feet (4 percent) railroad grade, 200 feet (3 percent) riprap, 106 feet (2 percent) levees, 12 feet (1 percent) mining spoils

Constructed Features (areas):

Total Area of Constructed Features: 3.66 acres

Percent Constructed Features of Total Reach Area: 11 percent

Type of Constructed Features (Percent Total Reach Area): 2.77 acres (8 percent) Bates townsite, 0.64 acres (2 percent) embankment (unimproved roads), 0.25 acres (0.7 percent) buildings

Impacted Areas of Natural HCMZ:

Total Area Impacted: 22.33 acres

Percent of Natural HCMZ Impacted: 73 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

14.94 acres (49 percent) rock spurs

2.77 acres (9 percent) Bates townsite

1.1 acres (0.4 percent) bridge and embankment (unimproved road), rock spurs, riprap

1 acre (3 percent) bridge and embankments (unimproved road), buildings

0.81 acres (3 percent) bridge and embankments (unimproved road), riprap, levee

0.65 acres (2 percent) rock spurs, irrigation ditch

0.5 acres (2 percent) bridge and embankments (unimproved road)

0.43 acres (1 percent) irrigation ditches

0.14 acres (0.5 percent) rock spurs, culvert

Present Width of HCMZ:

Average Present HCMZ Width: 48 feet

Minimum Present HCMZ Width: 16 feet

Maximum Present HCMZ Width: 353 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 222 feet

Average Percent Decrease in HCMZ Width: 82 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 448 feet

Average Width Decrease Created by Constructed Features:

246 feet rock spurs

223 feet buildings, embankment

215 feet diversion, irrigation ditches

211 feet bridge (unimproved road)

206 feet Bates townsite

167 feet rock spurs, levee

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 0.61 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 15 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

0.56 acres (14 percent) railroad grade

0.05 acres (1 percent) irrigation ditches

Present Width of Floodplain:

Average Present Floodplain Width: 239 feet

Minimum Present Floodplain Width: 35 feet

Maximum Present Floodplain Width: 590 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 48 feet

Percent Difference in Average Floodplain Width: 17 percent

Difference in Minimum Floodplain Width: 99 feet

Difference in Maximum Floodplain Width: 55 feet

Average Width Decrease Created by Constructed Features:

214 feet bridge

203 feet Bates townsite

116 feet buildings

109 feet railroad grade

62 feet bridge and embankments (unimproved road)

29 feet irrigation ditch

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 947 feet

> **Percent of 2006 Channel That is Straightened**: 16 percent
>
> **Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length)**: 947 feet (16 percent) bridge and embankment (unimproved road) and Bates townsite

Length of Artificially Confined Channel: 2,762 feet

> **Percent of 2006 Channel that is Confined**: 46 percent
>
> **Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length)**:
>
> > 1,461 feet (25 percent) rock spurs
> >
> > 1,074 feet (18 percent) bridge and embankment, riprap, rock spurs, and diversion
> >
> > 227 feet (4 percent) rock spurs and diversion

Total Length of Straightened/Confined Channel: 3,709 feet

> **Percent of 2006 Channel that is Straightened/Confined**: 62 percent

Length of Possible Main Channel Cutoff: 241 feet

> **Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length)**: 241 feet (4 percent) embankment (unimproved road)

1.10 Reach MF13

1.10.1 Geomorphic Characteristics

Downstream Boundary: RM 63.48

Upstream Boundary: RM 66.52

Type: Unconfined

Main Tributaries: Unnamed creek on river left at RM 64.85, unnamed creek on river right at RM 65.1, Vincent Creek on river right and unnamed creek on river left at RM 65.5, Vinegar Creek on river right at RM 66.3

Length of Reach (2006 channel): 3.04 miles; 16,035 feet

Area of Natural Floodplain: 197.8 acres

> **Area of Natural Floodplain Outside of the Natural HCMZ**: 85.49 acres
>
> **Percent of Natural Floodplain Outside of the Natural HCMZ**: 43 percent

Area of Natural HCMZ: 112.27 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 57 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 656 feet

Minimum Natural Floodplain Width: 152 feet

Maximum Natural Floodplain Width: 1,230 feet

HCMZ Width:

Average Natural HCMZ Width: 377 feet

Minimum Natural HCMZ Width: 150 feet

Maximum Natural HCMZ Width: 671 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 28,967 feet (5.44 miles) length boundary

Alluvial-Fan Deposits: 10,427 feet (1.96 miles); 36 percent of boundary

Bedrock: 9.662 feet (1.82 miles); 33 percent of boundary

Alluvium/Colluvium: 8,878 feet (1.67 miles); 31 percent of boundary

Bank Erosion:

Total Length Observed: 1.03 miles (5,459 feet)

Of this length, 5,207 feet (95 percent) involve floodplain reworking, and 253 feet (5 percent) involve floodplain reworking and erosion along the floodplain boundary

1.10.2 Constructed Impacts

Constructed Features (points):

Number of Point Constructed Features: 283

Number of Point Constructed Features/Mile: 93.2

Type of Constructed Features: Rock spurs (247), channel cutoffs by railroad (18), blocked/filled channels (12), culverts (2), fords (2), bridge (1), diversion (1)

Constructed Features (linear):

Total Length of Constructed Features: 18,390 feet (3.48 miles)

Length of Features as Percent of 2006 Channel Length: 115 percent

Type of Constructed Features (Percent 2005 Channel Length): 10,281 feet (64 percent) railroad grade, 4,972 feet (31 percent) irrigation ditches, 2,216 feet (14 percent) riprap, 849 feet (5 percent) unimproved roads, 73 feet (0.4 percent) levees

Constructed Features (areas):

Total Area of Constructed Features: 0.02 acres

Percent Constructed Features of Total Reach Area: 0.01 percent

Type of Constructed Features (Percent Total Reach Area): 0.02 acres (0.01 percent) tailings

Impacted Areas of Natural HCMZ:

Total Area Impacted: 89.88 acres

Percent of Natural HCMZ Impacted: 80 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

59.60 acres (53 percent) rock spurs, riprap

24.49 acres (22 percent) railroad grade

4.80 acres (4 percent) rock spurs

0.47 acres (0.4 percent) tailings

0.36 acres (0.3 percent) blocked channels

0.16 acres (0.1 percent) irrigation ditches

Present Width of HCMZ:

Average Present HCMZ Width: 66 feet

Minimum Present HCMZ Width: 25 feet

Maximum Present HCMZ Width: 340 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 312 feet

Average Percent Decrease in HCMZ Width: 80 percent

Decrease in Minimum HCMZ Width: 27 feet

Decrease in Maximum HCMZ Width: 594 feet

Average Width Decrease Created by Constructed Features:

394 feet rock spurs

382 feet rock spurs, riprap

249 feet railroad grade, levee, riprap, rock spurs, buildings

195 feet riprap

158 feet bridge and embankments (unimproved road)

93 feet tailings

78 feet railroad grade

73 feet blocked channels

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 45.44 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 53 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

44.73 acres (52 percent) railroad grade

0.71 acres (1 percent) irrigation ditches

Present Width of Floodplain:

Average Present Floodplain Width: 441 feet

Minimum Present Floodplain Width: 27 feet

Maximum Present Floodplain Width: 874 feet

Change in Width of Natural Floodplain:

Difference in Average Floodplain Width: 215 feet

Percent Difference in Average Floodplain Width: 33 percent

Difference in Minimum Floodplain Width: 124 feet

Difference in Maximum Floodplain Width: 356 feet

Average Width Decrease Created by Constructed Features:

299 feet bridge

238 feet railroad grade

167 feet riprap

108 feet rock spurs

23 feet irrigation ditches

13 feet embankment (highway)

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 2,165 feet

Percent of 2006 Channel That is Straightened: 13 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length):

1,958 feet (12 percent) rock spurs, railroad grade, and riprap

207 feet (1 percent) tailings

Length of Artificially Confined Channel: 12,381 feet

Percent of 2006 Channel that is Confined: 77 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length):

11,656 feet (73 percent) rock spurs, railroad grade, and riprap

725 feet (5 percent) rock spurs and riprap

Total Length of Straightened/Confined Channel: 14,547 feet

Percent of 2006 Channel that is Straightened/Confined: 91 percent

Length of Possible Main Channel Cutoff: 3,540 feet

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length):

2,418 feet (15 percent) railroad grade

1,122 feet (7 percent) riprap

1.11 Reach MF12

1.11.1 Geomorphic Characteristics

Downstream Boundary: RM 62.5

Upstream Boundary: RM 63.48

Type: Moderately confined

Main Tributaries: Unnamed creek on river right and on river left at RM 63.3

Length of Reach (2006 channel): 0.97 miles; 5,147 feet

Area of Natural Floodplain: 30.1 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 7.19 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 24 percent

Area of Natural HCMZ: 22.91 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 76 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 282 feet

Minimum Natural Floodplain Width: 110 feet

Maximum Natural Floodplain Width: 423 feet

HCMZ Width:

Average Natural HCMZ Width: 196 feet

Minimum Natural HCMZ Width: 109 feet

Maximum Natural HCMZ Width: 334 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 9,967 (1.87 miles) length boundary

Bedrock: 9,276 feet (1.74 miles); 93 percent of boundary

Alluvial-Fan Deposits: 691 feet (0.13 miles); 7 percent of boundary

Bank Erosion: Not evaluated

1.11.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 2

Number of Point Constructed Features/Mile: 2.1

Type of Constructed Features: Blocked/filled channel (2)

Constructed Features (linear):

Total Length of Constructed Features: 1,894 feet (0.36 miles)

Length of Features as Percent of 2006 Channel Length: 37 percent

Type of Constructed Features (Percent 2005 Channel Length): 1,660 feet (32 percent) railroad grade, 234 feet (5 percent) unimproved roads

Constructed Features (areas):

Total Area of Constructed Features: 24.33 acres

Percent Constructed Features of Total Reach Area: 81 percent

Type of Constructed Features (Percent Total Reach Area): 12.78 acres (42 percent) tailings, 6.14 acres (20 percent) embankment (highway), 4.33 acre (14 percent) disturbed, 1.05 acres (4 percent) buildings, 0.03 acres (0.1 percent) embankment (unimproved road)

Impacted Areas of Natural HCMZ:

Total Area Impacted: 15 acres

Percent of Natural HCMZ Impacted: 65 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

9.28 acres (40 percent) tailings

2.36 acres (10 percent) tailings, buildings

1.85 acres (8 percent) tailings, railroad grade

0.72 acres (3 percent) railroad grade, embankment (highway)

0.64 acres (3 percent) blocked channels

0.16 acres (0.7 percent) railroad grade

Present Width of HCMZ:

Average Present HCMZ Width: 64 feet

Minimum Present HCMZ Width: 41 feet

Maximum Present HCMZ Width: 191 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 132 feet

Average Percent Decrease in HCMZ Width: 63 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 286 feet

Average Width Decrease Created by Constructed Features:

154 feet tailings

68 feet railroad grade

55 feet buildings

54 feet blocked channels

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 4.72 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 66 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

1.87 acres (26 percent) disturbed

1.35 acres (19 percent) buildings

0.77 acres (11 percent) railroad grade

0.63 acres (9 percent) tailings

0.07 acres (1 percent) embankment (highway)

0.03 acres (0.5 percent) embankment (unimproved road)

Present Width of Floodplain:

Average Present Floodplain Width: 100 feet

Minimum Present Floodplain Width: 22 feet

Maximum Present Floodplain Width: 301 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 181 feet

Percent Difference in Average Floodplain Width: 64 percent

Difference in Minimum Floodplain Width: 88 feet

Difference in Maximum Floodplain Width: 122 feet

Average Width Decrease Created by Constructed Features:

221 feet tailings

169 feet unimproved roads

151 feet buildings

68 feet railroad grade

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 3,178 feet

Percent of 2006 Channel That is Straightened: 62 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 3,178 feet (62 percent) tailings

Length of Artificially Confined Channel: 994 feet

Percent of 2006 Channel that is Confined: 19 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length): 994 feet (19 percent) tailings, buildings

Total Length of Straightened/Confined Channel: 4,172 feet

Percent of 2006 Channel that is Straightened/Confined: 81 percent

Length of Possible Main Channel Cutoff: None

1.12 Reach MF11

1.12.1 Geomorphic Characteristics

Downstream Boundary: RM 60.8

Upstream Boundary: RM 62.5

Type: Confined

Main Tributaries: Gorge Creek on river left at RM 61.15, Murdock Creek on river right at RM 61.7, Little Boulder Creek on river right at RM 61.95, Flat Creek on river right at RM 62.3, Deerhorn Creek on river left at RM 62.5 (reach boundary)

Length of Reach (2006 channel): 1.7 miles; 8,953 feet

Area of Natural Floodplain: 29.9 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 0.41 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 1 percent

Area of Natural HCMZ: 29.47 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 99 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 169 feet

Minimum Natural Floodplain Width: 61 feet

Maximum Natural Floodplain Width: 400 feet

HCMZ Width:

Average Natural HCMZ Width: 170 feet

Minimum Natural HCMZ Width: 64 feet

Maximum Natural HCMZ Width: 404 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 17,065 feet (3.21 miles) length boundary

Bedrock: 14,096 feet (2.65 miles); 83 percent of boundary

Alluvial-Fan Deposits: 1,596 feet (0.3 miles); 9 percent of boundary

Alluvium/Colluvium: 1,373 feet (0.26 miles); 8 percent of boundary

Bank Erosion: Not evaluated

1.12.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 4

Number of Point Constructed Features/Mile: 2.4

Type of Constructed Features: Blocked/filled channels (3), straightened/channelized section (1)

Constructed Features (linear):

Total Length of Constructed Features: 1,317 feet (0.25 miles)

Length of Features as Percent of 2006 Channel Length: 15 percent

Type of Constructed Features (Percent 2005 Channel Length): 909 feet (10 percent) railroad grade, 408 feet (5 percent) riprap

Constructed Features (areas):

Total Area of Constructed Features: 0.09 acres

Percent Constructed Features of Total Reach Area: 0.3 percent

Type of Constructed Features (Percent Total Reach Area): 0.07 acres (0.25 percent) buildings, 0.02 acres (0.05 percent) embankment (unimproved road)

Impacted Areas of Natural HCMZ:

Total Area Impacted: 5.85 acres

Percent of Natural HCMZ Impacted: 20 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

3.35 acres (11 percent) buildings, blocked channels, unimproved roads

0.88 acres (3 percent) blocked channels

0.80 acres (3 percent) railroad grade

0.53 acres (2 percent) bridge and embankment (unimproved road)

0.30 acres (1 percent) channelized section

Present Width of HCMZ:

Average Present HCMZ Width: 122 feet

Minimum Present HCMZ Width: 64 feet

Maximum Present HCMZ Width: 215 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 48 feet

Average Percent Decrease in HCMZ Width: 20 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 307 feet

Average Width Decrease Created by Constructed Features:

142 feet buildings, blocked channels

72 feet channelized section

59 feet blocked channels

40 feet railroad grade

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: None

Present Width of Floodplain:

Average Present Floodplain Width: 155 feet

Minimum Present Floodplain Width: 61 feet

Maximum Present Floodplain Width: 400 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 13 feet

Percent Difference in Average Floodplain Width: 8 percent

Difference in Minimum Floodplain Width: None

Difference in Maximum Floodplain Width: None

Average Width Decrease Created by Constructed Features:

302 feet buildings

32 feet railroad grade

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000

Length of Artificially Straightened Channel: 282 feet

Percent of 2006 Channel That is Straightened: 3 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 282 feet (3 percent) mechanically straightened

Length of Artificially Confined Channel: 1,303 feet

Percent of 2006 Channel that is Confined: 15 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length): 1,015 feet (11 percent) buildings, blocked/filled channels, 288 feet (3 percent) railroad grade

Total Length of Straightened/Confined Channel: 1,585 feet

Percent of 2006 Channel that is Straightened/Confined: 18 percent

Length of Possible Main Channel Cutoff: 549 feet

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length): 549 feet (6 percent) artificially blocked/filled channels

1.13 Reach MF10

1.13.1 Geomorphic Characteristics

Downstream Boundary: RM 59.1

Upstream Boundary: RM 60.8

Type: Moderately confined

Main Tributaries: Windlass Creek on river right at RM 59.45, unnamed creek on river left at RM 59.7, unnamed creek on river right at RM 60.2, Little Butte Creek at RM 60.7

Length of Reach (2006 channel): 1.7 miles; 8,958 feet

Area of Natural Floodplain: 58.4 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 16.14 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 28 percent

Area of Natural HCMZ: 42.21 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 72 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 305 feet

Minimum Natural Floodplain Width: 122 feet

Maximum Natural Floodplain Width: 504 feet

HCMZ Width:

Average Natural HCMZ Width: 241 feet

Minimum Natural HCMZ Width: 142 feet

Maximum Natural HCMZ Width: 450 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 16,724 feet (3.14 miles) length boundary

Bedrock: 15,946 feet (3 miles); 95 percent of boundary

Alluvial-Fan Deposits: 779 feet (0.15 miles); 5 percent of boundary

Bank Erosion: Not evaluated

1.13.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 11

Number of Point Constructed Features/Mile: 6.5

Type of Constructed Features: Blocked/filled channels (8), straightened/channelized sections (2), rock spur (1)

Constructed Features (linear):

Total Length of Constructed Features: 6,065 feet (1.15 miles)

Length of Features as Percent of 2006 Channel Length: 68 percent

Type of Constructed Features (Percent 2005 Channel Length): 3,842 feet (43 percent) railroad grade, 1,680 feet (19 percent) improved road (highway), 437 feet (5 percent) levee, 107 feet (1 percent) unimproved road

Constructed Features (areas):

Total Area of Constructed Features: 2.75 acres

Percent Constructed Features of Total Reach Area: 5 percent

Type of Constructed Features (Percent Total Reach Area): 1.89 acres (3 percent) embankment (highway), 0.5 acres (0.9 percent) disturbed, 0.19 acres (0.3 percent) buildings, 0.16 acres (0.3 percent) embankment (unimproved road)

Impacted Areas of Natural HCMZ:

Total Area Impacted: 9.20 acres

Percent of Natural HCMZ Impacted: 22 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

5.97 acres (14 percent) railroad grade

1.71 acres (4 percent) levees, buildings

1.38 acres (3 percent) bridge and embankment (highway)

0.14 acres (0.3 percent) levees

Present Width of HCMZ:

Average Present HCMZ Width: 175 feet

Minimum Present HCMZ Width: 96 feet

Maximum Present HCMZ Width: 403 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 66 feet

Average Percent Decrease in HCMZ Width: 23 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 315 feet

Average Width Decrease Created by Constructed Features:

108 feet railroad grade

67 feet levees

59 feet buildings, blocked channels

55 feet disturbed area

52 feet embankment

Disconnected Areas of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 5.75 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 36 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

3.22 acres (20 percent) embankment (highway)

1.92 acres (12 percent) railroad grade

0.59 acres (4 percent) buildings

0.02 acres (0.1 percent) embankment (unimproved roads)

Present Width of Floodplain:

Average Present Floodplain Width: 239 feet

Minimum Present Floodplain Width: 96 feet

Maximum Present Floodplain Width: 504 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 66 feet

Percent Difference in Average Floodplain Width: 22 percent

Difference in Minimum Floodplain Width: 26 feet

Difference in Maximum Floodplain Width: None

Average Width Decrease Created by Constructed Features:

93 feet buildings

76 feet embankment (highway)

59 feet railroad grade

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 1,528 feet

Percent of 2006 Channel That is Straightened: 17 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length):

761 feet (8 percent) railroad grade and buildings

427 feet (5 percent) railroad grade

340 feet (4 percent) disturbed area

Length of Artificially Confined Channel: 1,542 feet

Percent of 2006 Channel that is Confined: 17 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length): 1,542 feet (17 percent) railroad grade

Total Length of Straightened/Confined Channel: 3,069 feet

Percent of 2006 Channel that is Straightened/Confined: 34 percent

Length of Possible Main Channel Cutoff: None

1.14 Reach MF9

1.14.1 Geomorphic Characteristics

Downstream Boundary: RM 57.98

Upstream Boundary: RM 59.1

Type: Unconfined

Main Tributaries: Tincup Creek on river right at RM 58.8

Length of Reach (2006 channel): 1.11 miles; 5,844 feet

Area of Natural Floodplain: 53.2 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 19.98 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 38 percent

Area of Natural HCMZ: 33.19 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 62 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 479 feet

Minimum Natural Floodplain Width: 289 feet

Maximum Natural Floodplain Width: 627 feet

HCMZ Width:

Average Natural HCMZ Width: 300 feet

Minimum Natural HCMZ Width: 143 feet

Maximum Natural HCMZ Width: 458 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 10,376 feet (1.95 miles) length boundary

Bedrock: 10,376 feet (1.95 miles); 100 percent of boundary

Bank Erosion:

Total Length Observed: 0.17 miles (910 feet)

The entire length involves reworking of floodplain sediments

1.14.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 10

Number of Point Constructed Features/Mile: 9.0

Type of Constructed Features: Blocked/filled channels (6), culverts (3), bridge (1)

Constructed Features (linear):

Total Length of Constructed Features: 5,424 feet (1.03 miles)

Length of Features as Percent of 2006 Channel Length: 93 percent

Type of Constructed Features (Percent 2005 Channel Length): 3,861 feet (66 percent) improved roads (highway), 731 feet (13 percent) unimproved roads, 548 feet (9 percent) riprap, 191 feet (3 percent) levees, 94 feet (2 percent) mining spoils

Constructed Features (areas):

Total Area of Constructed Features: 4.43 acres

Percent Constructed Features of Total Reach Area: 8 percent

Type of Constructed Features (Percent Total Reach Area): 4.43 acres (8 percent) Bates townsite

Impacted Areas of Natural HCMZ:

Total Area Impacted: 11.84 acres

Percent of Natural HCMZ Impacted: 36 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

7.51 acres (23 percent) bridge and embankments (highway), levees

3.81 acres (11 percent) blocked channels

0.53 acres (2 percent) embankments (highway)

Present Width of HCMZ:

Average Present HCMZ Width: 166 feet

Minimum Present HCMZ Width: 49 feet

Maximum Present HCMZ Width: 312 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 134 feet

Average Percent Decrease in HCMZ Width: 41 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 328 feet

Average Width Decrease Created by Constructed Features:

328 feet bridge (highway)

251 feet levees

117 feet highway

114 feet blocked channels

Disconnected Areas of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 11.98 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 60 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

11.98 acres (60 percent) embankment (highway)

Present Width of Floodplain:

Average Present Floodplain Width: 307 feet

Minimum Present Floodplain Width: 48 feet

Maximum Present Floodplain Width: 519 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 172 feet

Percent Difference in Average Floodplain Width: 36 percent

Difference in Minimum Floodplain Width: 242 feet

Difference in Maximum Floodplain Width: 107 feet

Average Width Decrease Created by Constructed Features:

537 feet bridge

204 feet embankment (highway)

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 2,094 feet

Percent of 2006 Channel That is Straightened: 36 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length):

1,331 feet (23 percent) bridge and embankment (highway)

490 feet (8 percent) riprap, levee

273 feet (5 percent) embankment (highway)

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: 2,094 feet

Percent of 2006 Channel that is Straightened/Confined: 36 percent

Length of Possible Main Channel Cutoff: 1,290 feet

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length):

1,125 feet (19 percent) artificially blocked/filled channels

164 feet (3 percent) embankment (highway)

1.15 Reach MF8

1.15.1 Geomorphic Characteristics

Downstream Boundary: RM 56.2

Upstream Boundary: RM 57.98

Type: Unconfined

Main Tributaries: Unnamed creek on river left at RM 56.2, Ruby Creek on river left at RM 56.8, unnamed creek on river right and on river left at RM 57.2, Granite Boulder Creek at RM 57.4, Butte Creek on river left at RM 57.6, unnamed creek on river right at RM 57.8

Length of Reach (2006 channel): 1.79 miles; 9,434 feet

Area of Natural Floodplain: 148.3 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 67.84 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 46 percent

Area of Natural HCMZ: 80.46 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 54 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 656 feet

Minimum Natural Floodplain Width: 413 feet

Maximum Natural Floodplain Width: 946 feet

HCMZ Width:

Average Natural HCMZ Width: 359 feet

Minimum Natural HCMZ Width: 190 feet

Maximum Natural HCMZ Width: 643 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 20,298 feet (3.81 miles) boundary length

Tailings: 5,287 feet (1.01 miles); 27 percent of boundary

Bedrock: 5,252 feet (0.99 miles); 26 percent of boundary

Alluvial-Fan Deposits: 5,022 feet (0.94 miles); 25 percent of boundary

Alluvium/Colluvium: 4,637 feet (0.87 miles); 23 percent of boundary

Bank Erosion:

Total Length Observed: 0.05 miles (270 feet) for the north channel; 0.27 miles (1,432 feet) for the south channel

The entire length along both channels involves reworking of floodplain sediments

1.15.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 7

Number of Point Constructed Features/Mile: 3.9

Type of Constructed Features: Blocked/filled channels (2), fords (2), foot bridge (1), diversion (1), rock spur (1)

Constructed Features (linear):

Total Length of Constructed Features: 2,803 feet (0.53 miles)

Length of **Features as Percent of 2006 Channel Length**: 30 percent

Type of Constructed Features (Percent 2005 Channel Length): 2,332 feet (25 percent) unimproved roads, 471 feet (5 percent) mining spoils

Constructed Features (areas):

Total Area of Constructed Features: 141 acres

Percent Constructed Features of Total Reach Area: 95 percent

Type of Constructed Features (Percent Total Reach Area): 93.52 acres (63 percent) tailings, 46.51 acres (31 percent) disturbed, 0.97 acres (0.7 percent) embankment (unimproved roads)

Impacted Areas of Natural HCMZ:

Total Area Impacted: 37.37 acres

Percent of Natural HCMZ Impacted: 46 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

37.12 acres (46 percent) tailings

0.24 acres (0.3 percent) spoils, disturbed area

Present Width of HCMZ:

Average Present HCMZ Width: 139 feet

Minimum Present HCMZ Width: 33 feet

Maximum Present HCMZ Width: 432 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 220 feet

Average Percent Decrease in HCMZ Width: 61 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 545 feet

Average Width Decrease Created by Constructed Features:

252 feet tailings

Disconnected Areas of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 57.70 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 85 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

56.96 acres (84 percent) tailings

0.74 acres (1 percent) embankment (unimproved roads)

Present Width of Floodplain:

Average Present Floodplain Width: 274 feet

Minimum Present Floodplain Width: 31 feet

Maximum Present Floodplain Width: 570 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 382 feet

Percent Difference in Average Floodplain: 58 percent

Difference in Minimum Floodplain Width: 382 feet

Difference in Maximum Floodplain Width: 376 feet

Average Width Decrease Created by Constructed Features:

473 feet tailings

52 feet unimproved road

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 9,452 feet

Percent of 2006 Channel that is Straightened: 100 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 8,466 feet (90 percent) tailings, 986 feet (10 percent) disturbed area

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: 9,452 feet

Percent of 2006 Channel that is Straightened/Confined: 100 percent

Length of Possible Main Channel Cutoff: None

1.16 Reach MF7

1.16.1 Geomorphic Characteristics

Downstream Boundary: RM 55.6

Upstream Boundary: RM 56.2

Type: Unconfined

Main Tributaries: Ragged Creek on river left at RM 55.65, Beaver Creek on river right and unnamed creek on river left at RM 56.1

Length of Reach (2006 channel): 0.6 miles; 3,167 feet

Area of Natural Floodplain: 48.5 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 22.53 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 46 percent

Area of Natural HCMZ: 26 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 54 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 873 feet

Minimum Natural Floodplain Width: 736 feet

Maximum Natural Floodplain Width: 967 feet

HCMZ Width:

Average Natural HCMZ Width: 446 feet

Minimum Natural HCMZ Width: 296 feet

Maximum Natural HCMZ Width: 547 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 6,284 feet (1.18 miles) total boundary length

Bedrock: 3,679 feet (0.69 miles); 59 percent of boundary

Alluvium/Colluvium: 1,302 feet (0.24 miles); 21 percent of boundary

Terrace: 653 feet (0.12 miles): 10 percent of boundary

Alluvial-Fan Deposits: 650 feet (0.12 miles); 10 percent of boundary

Bank Erosion:

Total Length Observed: 0.01 miles (51 feet)

The entire length involves reworking of floodplain sediments

1.16.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 50

Number of Point Constructed Features/Mile: 83.4

Type of Constructed Features: Rock spurs (47), blocked/filled channels (2), ford (1)

Constructed Features (linear):

Total Length of Constructed Features: 1,384 feet (0.26 miles)

Length of Features as Percent of 2006 Channel Length: 44 percent

Type of Constructed Features (Percent 2005 Channel Length): 1,078 feet (34 percent) improved road (highway), 143 feet (5 percent) riprap, 122 feet (4 percent) unimproved road, 42 feet (1 percent) mining spoils

Constructed Features (areas):

Total Area of Constructed Features: 5.7 acres

Percent Constructed Features of Total Reach Area: 12 percent

Type of Constructed Features (Percent Total Reach Area): 4.35 acres (9 percent) tailings, 1.18 acres (2 percent) Bates townsite, 0.16 acres (0.3 percent) embankment (unimproved road)

Impacted Areas of Natural HCMZ:

Total Area Impacted: 20.18 acres

Percent of Natural HCMZ Impacted: 78 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

18.53 acres (71 percent) rock spurs, blocked channels

1.65 acres (6 percent) tailings, embankment (unimproved road)

Present Width of HCMZ:

Average Present HCMZ Width: 85 feet

Minimum Present HCMZ Width: 49 feet

Maximum Present HCMZ Width: 213 feet

Change in Width of HCMZ:

Average Decrease HCMZ Width: 361 feet

Average Percent Decrease in HCMZ Width: 79 percent

Decrease in Minimum HCMZ Width: 163 feet

Decrease in Maximum HCMZ Width: 498 feet

Average Width Decrease Created by Constructed Features:

375 feet rock spurs

304 feet rock spurs, riprap

293 feet tailings

Disconnected Areas of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 4.67 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 21 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

2.06 acres (9 percent) embankment (unimproved road)

1.77 acres (8 percent) embankment (highway)

0.85 acres (4 percent) tailings

Present Width of Floodplain:

Average Present Floodplain Width: 826 feet

Minimum Present Floodplain Width: 629 feet

Maximum Present Floodplain Width: 919 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 46 feet

Percent Difference in Average Floodplain Width: 5 percent

Difference in Minimum Floodplain Width: 107 feet

Difference in Maximum Floodplain Width: 49 feet

Average Width Decrease Created by Constructed Features:

107 feet riprap

63 feet embankment (highway)

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 915 feet

Percent of 2006 Channel that is Straightened: 29 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 530 feet (17 percent) rock spurs and riprap, 386 feet (12 percent) tailings

Length of Artificially Confined Channel: 1,855 feet

Percent of 2006 Channel that is Confined: 58 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length): 1,855 feet (58 percent) rock spurs

Total Length of Straightened/Confined Channel: 2,770 feet

Percent of 2006 Channel that is Straightened/Confined: 87 percent

Length of Possible Main Channel Cutoff: 418 feet

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length): 418 feet (13 percent) rock spurs

1.17 Reach MF6

1.17.1 Geomorphic Characteristics

Downstream Boundary: RM 55.3

Upstream Boundary: RM 55.6

Type: Confined

Main Tributaries: Unnamed creek on river right at RM 55.6

Length of Reach (2006 channel): 0.3 miles; 1,581 feet

Area of Natural Floodplain: 4.1 acres

Area of Natural Floodplain Outside of the Natural HCMZ: None

Percent of Natural Floodplain Outside of the Natural HCMZ: None

Area of Natural HCMZ: 4.1 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 100 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 140 feet

Minimum Natural Floodplain Width: 106 feet

Maximum Natural Floodplain Width: 163 feet

HCMZ Width:

Average Natural HCMZ Width: 126 feet

Minimum Natural HCMZ Width: 105 feet

Maximum Natural HCMZ Width: 146 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 3,165 feet (0.59 miles) total boundary length

Alluvial-Fan Deposits: 1,703 feet (0.32 miles); 54 percent of boundary

Bedrock: 1,462 feet (0.27 miles); 46 percent of boundary

Bank Erosion:

Total Length Observed: 0.01 miles (57 feet)

The entire length involves reworking of floodplain sediments

1.17.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 1

Number of Point Constructed Features/Mile: 3.3

Type of Constructed Features: Bridge (1)

Constructed Features (linear):

Total Length of Constructed Features: 1,631 feet (0.31 miles)

Length of Features as Percent of 2006 Channel Length: 103 percent

Type of Constructed Features (Percent 2005 Channel Length): 1,254 feet (79 percent) improved road (highway), 377 feet (24 percent) riprap

Constructed Features (areas):

Total Area of Constructed Features: None

Impacted Areas of Natural HCMZ:

Total Area Impacted: 0.08 acres

Percent of Natural HCMZ Impacted: 2 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

0.06 acres (2 percent) embankments (unimproved roads)

0.02 acres (0.4 percent) bridge and embankments (highway)

Present Width of HCMZ:

Average Present HCMZ Width: 140 feet

Minimum Present HCMZ Width: 106 feet

Maximum Present HCMZ Width: 163 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: None

Average Percent Decrease in HCMZ Width: None

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: None

Disconnected Areas of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: None

Percent of the Natural Floodplain Outside of the HCMZ that is

Present Width of Floodplain:

Average Present Floodplain Width: 140 feet

Minimum Present Floodplain Width: 106 feet

Maximum Present Floodplain Width: 163 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: None

Percent Difference in Average Floodplain Width: 0 percent

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: None

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: None

Length of Possible Main Channel Cutoff: None

1.18 Reach MF5

1.18.1 Geomorphic Characteristics

Downstream Boundary: RM 53.9

Upstream Boundary: RM 55.3

Type: Moderately confined

Main Tributaries: Dry Creek on river right at RM 54.2, Sunshine Creek on river left at RM 54.4

Length of Reach (2006 channel): 1.4 miles; 7,386 feet

Area of Natural Floodplain: 59.9 acres

> **Area of Natural Floodplain Outside of the Natural HCMZ**: 17.44 acres
>
> **Percent of Natural Floodplain Outside of the Natural HCMZ**: 29 percent

Area of Natural HCMZ: 42.51 acres

> **Natural HCMZ Area as Percent of Natural Floodplain Area**: 71 percent

Width of Natural Floodplain:

> **Average Natural Floodplain Width**: 406 feet
>
> **Minimum Natural Floodplain Width**: 225 feet
>
> **Maximum Natural Floodplain Width**: 554 feet

HCMZ Width:

> **Average Natural HCMZ Width**: 302 feet
>
> **Minimum Natural HCMZ Width**: 146 feet
>
> **Maximum Natural HCMZ Width**: 499 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 13, 749 feet (2.58 miles) total length

> **Bedrock**: 10,309 feet (1.94 miles); 75 percent of boundary
>
> **Alluvial-Fan Deposits**: 3,440 feet (0.65 miles); 25 percent of boundary

Bank Erosion:

> **Total Length Observed**: 0.14 miles (736 feet)
>
> > Of this length, 453 feet (62 percent) involve floodplain reworking, and 283 feet (38 percent) involve erosion along the floodplain boundary

1.18.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 12

Number of Point Constructed Features/Mile: 8.6

Type of Constructed Features: Blocked/filled channels (9), channel cutoff by railroad (1), structure (1), straightened/channelized section (1)

Constructed Features (linear):

Total Length of Constructed Features: 2,211 feet (0.42 miles)

Length of Features as Percent of 2006 Channel Length: 30 percent

Type of Constructed Features (Percent 2005 Channel Length): 2,159 feet (29 percent) railroad grade, 52 feet (1 percent) levee

Constructed Features (areas):

Total Area of Constructed Features: None

Impacted Areas of Natural HCMZ:

Total Area Impacted: 9.16 acres

Percent of Natural HCMZ Impacted: 22 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

7.84 acres (18 percent) blocked channels

0.54 acres (1 percent) excavations

0.5 acres (1 percent) railroad grade

0.17 acres (0.4 percent) possible levee

0.1 acres (0.2 percent) structure

Present Width of HCMZ:

Average Present HCMZ Width: 204 feet

Minimum Present HCMZ Width: 83 feet

Maximum Present HCMZ Width: 457 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 97 feet

Average Percent Decrease in HCMZ Width: 30 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 336 feet

Average Width Decrease Created by Constructed Features:

148 feet blocked channels

78 feet structure (building)

76 feet excavations

54 feet levee

47 feet railroad grade

Disconnected Areas of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 4.35 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 25 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

4.35 acres (25 percent) railroad grade

Present Width of Floodplain:

Average Present Floodplain Width: 350 feet

Minimum Present Floodplain Width: 136 feet

Maximum Present Floodplain Width: 554 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 17 feet

Percent Difference in Average Floodplain Width: 4 percent

Difference in Minimum Floodplain Width: 88 feet

Difference in Maximum Floodplain Width: None

Average Width Decrease Created by Constructed Features:

101 feet railroad grade

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 624 feet

Percent of 2006 Channel That is Straightened: 8 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 624 feet (8 percent) railroad grade

Length of Artificially Confined Channel: 195 feet

Percent of 2006 Channel that is Confined: 3 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length): 195 feet (3 percent) railroad grade

Total Length of Straightened/Confined Channel: 819 feet

Percent of 2006 Channel that is Straightened/Confined: 11 percent

Length of Possible Main Channel Cutoff: 1,259 feet

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length): 1,259 feet (17 percent) artificially blocked/filled channels

1.19 Reach MF4

1.19.1 Geomorphic Characteristics

Downstream Boundary: RM 52.65

Upstream Boundary: RM 53.9

Type: Confined

Main Tributaries: Big Boulder Creek on river right at RM 53.1

Length of Reach (2006 channel): 1.24 miles; 6,555 feet

Area of Natural Floodplain: 35.4 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 2.29 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 6 percent

Area of Natural HCMZ: 33.06 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 93 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 271 feet

Minimum Natural Floodplain Width: 123 feet

Maximum Natural Floodplain Width: 503 feet

HCMZ Width:

Average Natural HCMZ Width: 245 feet

Minimum Natural HCMZ Width: 130 feet

Maximum Natural HCMZ Width: 508 feet

Flow Characteristics:

Composition of Natural Floodplain Boundary: 12,611 feet (2.37 miles) total length

Bedrock: 8,106 feet (1.52 miles); 64 percent of boundary

Alluvial-Fan Deposits: 3,900 feet (0.73 miles) 31 percent of boundary

Alluvium/Colluvium: 605 feet (0.11 miles); 5 percent of boundary

Bank Erosion: Not evaluated

1.19.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 10

Number of Point Constructed Features/Mile: 8.1

Type of Constructed Features (Percent 2005 Channel Length): Blocked/filled channels (6), rock spurs (4)

Constructed Features (linear):

Total Length of Constructed Features: 1,465 feet (0.28 miles)

Length of Features as Percent of 2006 Channel Length: 22 percent

Type of Constructed Features (Percent Total Reach Area): 1,465 feet (22 percent) railroad grade

Constructed Features (areas):

Total Area of Constructed Features: None

Impacted Areas of Natural HCMZ:

Total Area Impacted: 2.88 acres

Percent of Natural HCMZ Impacted: 9 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

2.65 acres (8 percent) railroad grade

0.23 acres (0.7 percent) rock spurs

Present Width of HCMZ:

Average Present HCMZ Width: 203 feet

Minimum Present HCMZ Width: 90 feet

Maximum Present HCMZ Width: 458 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 43 feet

Average Percent Decrease in HCMZ Width: 17 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 151 feet

Average Width Decrease Created by Constructed Features:

149 feet rock spurs

71 feet railroad grade

Disconnected Areas of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: None

Present Width of Floodplain:

Average Present Floodplain Width: 251 feet

Minimum Present Floodplain Width: 123 feet

Maximum Present Floodplain Width: 467 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 6 feet

Percent Difference in Average Floodplain Width: 2 percent

Difference in Minimum Floodplain Width: None

Difference in Maximum Floodplain Width: 36 feet

Average Width Decrease Created by Constructed Features:

54 feet railroad grade

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000

Length of Artificially Straightened Channel: 1,521 feet

Percent of 2006 Channel that is Straightened: 23 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 1,521 feet (23 percent) railroad grade

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: 1,521 feet

Percent of 2006 Channel that is Straightened/Confined: 23 percent

Length of Possible Main Channel Cutoff: None

1.20 Reach MF3

1.20.1 Geomorphic Characteristics

Downstream Boundary: RM 51.05

Upstream Boundary: RM 52.65

Type: Moderately confined

Main Tributaries: Coyote Creek on river right at RM 51.1,

Length of Reach (2006 channel): 1.6 miles; 8.428 feet

Area of Natural Floodplain: 107.3 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 14.69 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 14 percent

Area of Natural HCMZ: 92.57 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 86 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 546 feet

Minimum Natural Floodplain Width: 357 feet

Maximum Natural Floodplain Width: 774 feet

HCMZ Width:

Average Natural HCMZ Width: 499 feet

Minimum Natural HCMZ Width: 283 feet

Maximum Natural HCMZ Width: 767 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 17, 240 feet (3.24 miles) total length

Bedrock: 14,521 feet (2.73 miles); 84 percent of boundary

Alluvial-Fan Deposits: 1,908 feet (0.36 miles); 11 percent of boundary

Alluvium/Colluvium: 811 feet (0.15 miles); 5 percent of boundary

Bank Erosion: Not evaluated

1.20.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 17

Number of Point Constructed Features/Mile: 10.7

Type of Constructed Features: Blocked/filled channels (4), rock spurs (11), diversion (1), straightened/channelized section (1)

Constructed Features (linear):

Total Length of Constructed Features: 5,588 feet (1.06 miles)

Length of Features as Percent of 2006 Channel Length: 66 percent

Type of Constructed Features (Percent 2006 Channel Length): 5,334 feet (63 percent) railroad grade, 160 feet (2 percent) levees, 94 feet (1 percent) unimproved roads

Constructed Features (areas):

Total Area of Constructed Features: 0.03 acres

Percent Constructed Features of Total Reach Area: 0.03 percent

Type of Constructed Features (Percent Total Reach Area): 0.03 acres (0.03 percent) embankment (unimproved road)

Impacted Areas of Natural HCMZ:

Total Area Impacted: 50.11 acres

Percent of Natural HCMZ Impacted: 54 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

11.08 acres (12 percent) railroad grade

10.75 acres (12 percent) blocked channels, levees

7.08 acres (8 percent) rock spurs

3.22 acres (3 percent) blocked channels

0.05 acres (less than 0.1 percent) embankment (unimproved roads)

Present Width of HCMZ:

Average Present HCMZ Width: 222 feet

Minimum Present HCMZ Width: 108 feet

Maximum Present HCMZ Width: 418 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 277 feet

Average Percent Decrease in HCMZ Width: 55 percent

Decrease in Minimum HCMZ Width: 80 feet

Decrease in Maximum HCMZ Width: 434 feet

Average Width Decrease Created by Constructed Features:

386 feet levees

324 feet rock spurs

291 feet blocked channels

238 feet railroad grade

212 feet blocked channels, levees, riprap, rock spurs

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 11.76 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 80 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

11.76 acres (80 percent) railroad grade

Present Width of Floodplain:

Average Present Floodplain Width: 316 feet

Minimum Present Floodplain Width: 141 feet

Maximum Present Floodplain Width: 723 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 70 feet

Percent Difference in Average Floodplain Width: 13 percent

Difference in Minimum Floodplain Width: 216

Difference in Maximum Floodplain Width: 51 feet

Average Width Decrease Created by Constructed Features:

278 feet railroad grade

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 1,876 feet

Percent of 2006 Channel That is Straightened: 22 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 1,876 feet (22 percent) railroad grade

Length of Artificially Confined Channel: 785 feet

Percent of 2006 Channel that is Confined: 9 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length): 785 feet (9 percent) rock spurs

Total Length of Straightened/Confined Channel: 2,661 feet

Percent of 2006 Channel that is Straightened/Confined: 32 percent

Length of Possible Main Channel Cutoff: None

1.21 Reach MF2

1.21.1 Geomorphic Characteristics

Downstream Boundary: RM 48.15

Upstream Boundary: RM 51.05

Type: Unconfined

Main Tributaries: Cress Creek on river right at RM 48.2, Horse Creek on river right and Balance Creek on river left at RM 50.1, Dunston Creek on river left at RM 50.8

Length of Reach (2006 channel): 2.89 miles; 15, 280 feet

Area of Natural Floodplain: 326.4 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 57.15 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 18 percent

Area of the Natural HCMZ: 269.26 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 82 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 1,096 feet

Minimum Natural Floodplain Width: 423 feet

Maximum Natural Floodplain Width: 1,773 feet

HCMZ Width:

Average Natural HCMZ Width: 852 feet

Minimum Natural HCMZ Width: 325 feet

Maximum Natural HCMZ Width: 1,345 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 30, 937 feet (5.81 miles) total length

Alluvium/Colluvium: 22,273 feet (4.18 miles); 72 percent of boundary

Bedrock: 7,091 feet (1.33 miles); 23 percent of boundary

Alluvial-Fan Deposits: 1,573 feet (0.30 miles); 5 percent of boundary

Bank Erosion: Not evaluated

1.21.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 38

Number of Point Constructed Features/Mile: 13.1

Type of Constructed Features: Blocked/filled channels (24), rock spurs (10), straightened/channelized sections (2), bridge (1), diversion (1)

Constructed Features (linear):

Total Length of Constructed Features: 6,624 feet (1.27 miles)

Length of Features as Percent of 2006 Channel Length: 44 percent

Type of Constructed Features (Percent 2005 Channel Length): 3,497 feet (23 percent) riprap, 2,325 feet (15 percent) unimproved roads, 656 feet (4 percent) irrigation ditches, 246 feet (2 percent) levees

Constructed Features (areas):

Total Area of Constructed Features: 1.81 acres

Percent Constructed Features of Total Reach Area: 0.6 percent

Type of Constructed Features (Percent Total Reach Area): 1.81 acres (0.6 percent) embankment (unimproved road)

Impacted Areas of Natural HCMZ:

Total Area Impacted: 208.73 acres

Percent of Natural HCMZ Impacted: 78 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

89.67 acres (33 percent) blocked channels, riprap

59.72 acres (22 percent) blocked channels, levees, riprap

37.80 acres (14 percent) bridge and embankments (unimproved road)

8.51 acres (3 percent) blocked channels, riprap, irrigation ditches

6.66 acres (2 percent) blocked channels

5.21 acres (2 percent) blocked channel, levees

0.96 acres (0.4 percent) riprap

0.11 acres (less than 0.1 percent) rock spurs

0.10 acres (less than 0.1 percent) spoil, blocked channels

Present Width of HCMZ:

Average Present HCMZ Width: 177 feet

Minimum Present HCMZ Width: 41 feet

Maximum Present HCMZ Width: 467 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 675 feet

Average Percent Decrease in HCMZ Width: 74 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 1,157 feet

Average Width Decrease Created by Constructed Features:

1,060 feet riprap, levees

1,051 feet bridge (unimproved road)

802 feet riprap

549 feet blocked channels

413 feet blocked channels, levees, riprap, rock spurs

298 feet rock spurs

236 feet rock spurs, riprap

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 4.03 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 7 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

3.87 acres (7 percent) riprap

0.16 acres (0.3 percent) bridge and embankment (unimproved road)

Present Width of Floodplain:

Average Present Floodplain Width: 616 feet

Minimum Present Floodplain Width: 43 feet

Maximum Present Floodplain Width: 1,773 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 146 feet

Percent Difference in Average Floodplain Width: 13 percent

Difference in Minimum Floodplain Width: 380 feet

Difference in Maximum Floodplain Width: None

Average Width Decrease Created by Constructed Features:

1,252 feet riprap

1,088 feet bridge

396 feet bridge and embankments (unimproved road)

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 895 feet

Percent of 2006 Channel That is Straightened: 6 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length):

665 feet (4 percent) riprap

229 feet (1 percent) bridge (downstream) and embankment (unimproved road)

Length of Artificially Confined Channel: 4,899 feet

Percent of 2006 Channel that is Confined: 32 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length):

2,477 feet (16 percent) bridge and embankment (unimproved road), riprap

2,422 feet (16 percent) riprap

Total Length of Straightened/Confined Channel: 5,794 feet

Percent of 2006 Channel that is Straightened/Confined: 38 percent

Length of Possible Main Channel Cutoff: 11,608 feet

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length):

5,171 feet (34 percent) artificially blocked/filled channels

2,553 feet (17 percent) riprap

2,204 feet (14 percent) levees

1,304 feet (9 percent) embankment (unimproved road)

376 feet (2 percent) diversion, artificially blocked/filled channels

1.22 Reach MF1

1.22.1 Geomorphic characteristics

Downstream Boundary: RM 47.95

Upstream Boundary: RM 48.15

Type: Moderately confined

Main Tributaries: Camp Creek on river left at RM 47.95

Length of Reach (2006 channel): 0.2 miles; 1,082 feet

Area of Natural Floodplain: 8.9 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 2.69 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 30 percent

Area of Natural HCMZ: 6.24 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 70 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 302 feet

Minimum Natural Floodplain Width: 225 feet

Maximum Natural Floodplain Width: 406 feet

HCMZ Width:

Average Natural HCMZ Width: 247 feet

Minimum Natural HCMZ Width: 205 feet

Maximum Natural HCMZ Width: 282 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 2,381 feet (0.45 miles) total boundary length

Alluvium/Colluvium: 1,317 feet (0.25 miles); 55 percent of boundary

Alluvial-Fan Deposits: 853 feet (0.16 miles); 36 percent of boundary

Bedrock: 211 feet (0.04 miles); 9 percent of boundary

Bank Erosion: Not evaluated

1.22.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 1

Number of Point Constructed Features/Mile: 4.9

Type of Constructed Features: Bridge

Constructed Features (linear):

Total Length of Constructed Features: 251 feet (0.05 miles)

Length of Features as Percent of 2006 Channel Length: 23 percent

Type of Constructed Features (Percent 2005 Channel Length): 251 feet (23 percent) unimproved road

Constructed Features (areas):

Total Area of Constructed Features: 0.42 acres

Percent Constructed Features of Total Reach Area: 5 percent

Type of Constructed Features (Percent Total Reach Area): 0.42 acres (5 percent) embankment (unimproved road)

Impacted Areas of Natural HCMZ:

Total Area Impacted: 0.72 acres

Percent of Natural HCMZ Impacted: 12 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ): 0.72 acres (12 percent) bridge and embankments (unimproved road)

Present Width of HCMZ:

Average Present HCMZ Width: 179 feet

Minimum Present HCMZ Width: 77 feet

Maximum Present HCMZ Width: 282 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 68 feet

Average Percent Decrease in HCMZ Width: 26 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 174 feet

Average Width Decrease Created By Constructed Features:

174 feet bridge (unimproved road)

166 feet embankments

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 0.31 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 12 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

0.31 acres (12 percent) embankment (unimproved road)

Present Width of Floodplain:

Average Present Floodplain Width: 240 feet

Minimum Present Floodplain Width: 74 feet

Maximum Present Floodplain Width: 351 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 19 feet

Percent Difference in Average Floodplain Width: 6 percent

Difference in Minimum Floodplain Width: 151 feet

Difference in Maximum Floodplain Width: 56 feet

Average Width Decrease Created By Constructed Features:

195 feet bridge and embankment (unimproved road)

56 feet embankment (unimproved road)

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 373 feet

Percent of 2006 Channel That is Straightened: 34 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 373 feet (34 percent) bridge and embankment (unimproved road)

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: 373 feet

Percent of 2006 Channel that is Straightened/Confined: 34 percent

Length of Possible Main Channel Cutoff: None

Vegetation: Most of the riparian vegetation was removed by 1956

2.0 Datasheets of the Upper Mainstem Assessment Area

2.1 Entire Assessment Area

2.1.1 Geomorphic Characteristics

Downstream Boundary: RM 262.67

Upstream Boundary: RM 265.81

Type: Unconfined, Moderately confined, Confined

Main Tributaries: None

Length of Reach (2006 channel): 11 miles (43 percent) unconfined, 7 miles (33 percent) moderately confined, 4 miles (19 percent) confined; total 3.13 miles (16,541 feet)

Area of Natural Floodplain: 82.3 acres; 46.01 acres (56 percent) unconfined, 30.69 acres (37 percent) moderately confined, 5.59 acres (7 percent) confined; total 82.3 acres

> **Area of Natural Floodplain Outside of the Natural HCMZ**: 11.22 acres for the entire assessment reach; 11.22 acres for the unconfined reach, none for the moderately confined and confined reaches
>
> **Percent of Natural Floodplain Outside of the Natural HCMZ:** 14 percent for the entire assessment reach; 24 percent for the unconfined reach

Area of Natural HCMZ: 71.08 acres; 34.79 acres (49 percent) unconfined, 30.69 acres (43 percent) moderately confined, 5.60 acres (8 percent) confined

> **Natural HCMZ Area as Percent of Natural Floodplain Area:** 86 percent for assessment area; 76 percent for unconfined reach, 100 percent for moderately confined reach, 100 percent for confined reach

Width of Natural Floodplain:

> **Average Natural Floodplain Width:** 350 feet for unconfined reach, 177 feet for moderately confined reach, 146 feet for confined reach
>
> **Minimum Natural Floodplain Width:** 105 feet for unconfined reach, 68 feet for moderately confined reach, 103 feet for confined reach
>
> **Maximum Natural Floodplain Width**: 900 feet for unconfined reach, 305 feet for moderately confined reach, 200 feet for confined reach

HCMZ Width:

> **Average Natural HCMZ Width:** 302 feet average for unconfined reach, 181 feet average for moderately confined reach, 137 feet average for confined reach
>
> **Minimum Natural HCMZ Width:** 107 feet average for unconfined reach, 108 feet average for moderately confined reach, 137 feet average for confined reach

Maximum Natural HCMZ Width: 502 feet average for unconfined reach, 317 feet average for moderately confined reach, 173 feet average for confined reach

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 32 497 feet (6.11 mile) length boundary

Alluvial-Fan Deposits: 22,838 feet (4.29 miles); 70 percent of boundary

Alluvial-Fan Deposits (older): 9,659 feet (1.81 miles); 30 percent of boundary

Bank Erosion: Evaluated in reach UJD3 only.

0.07 miles (376 feet) total length. Of this length, 179 feet (47 percent) involve floodplain reworking, 198 feet (53 percent) involve erosion along the floodplain boundary.

2.1.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 56

Number of Point Constructed Features/Mile: 17.9

Type of Constructed Features: Rock spur (32), blocked/filled channel (16), diversion (4), bridge (2), grade control (2)

Constructed Features (linear):

Total Length of Constructed Features: 12,877 feet (2.44 miles)

Length of **Features** as Percent of **2006 Channel Length**: 78 percent

Type of Constructed Features (Percent 2005 Channel Length): 5,132 feet (31 percent) riprap, 2,708 feet (16 percent) levee, 1,900 feet (12 percent) unimproved road, 1,647 feet (10 percent) irrigation ditch, 1,152 feet (7 percent) improved road (highway), 280 feet (2 percent) spoil, 58 feet (0.4 percent) steel

Constructed Features (areas):

Total Area of Constructed Features: 0.11 acres

Percent Constructed Features of Total Reach Area: 0.4 percent

Type of Constructed Features (Percent Total Reach Area): 0.06 acres (0.2 percent) embankment (unimproved road), 0.05 acres (0.2 percent) embankment

Impacted Areas of Natural HCMZ:

Total Area Impacted: 35.76 acres

Percent of Natural HCMZ Impacted: 50 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

19.06 acres (27 percent) levees, blocked channels, embankment, riprap, diversions, irrigation ditches

4.81 acres (7 percent) unimproved roads, irrigation ditches, riprap, levee

3.68 (5 percent) levees, rock spurs, steel, spoil

2.67 acres (4 percent) riprap

1.64 acres (2 percent) levees

1.33 acres (2 percent) rock spurs, riprap, levee

1.07 acres (2 percent) embankment (unimproved road), riprap

0.22 acres (0.3 percent) irrigation ditches, diversions

0.58 acres (1 percent) rock spurs

0.38 acres (1 percent) irrigation ditches, riprap, steel, rock spurs

0.22 acres (0.3 percent) blocked channels

0.10 acres (0.1 percent) bridge and embankments (unimproved road), riprap

Present Width of HCMZ:

Average Present HCMZ Width: 101 feet for unconfined reach, 100 feet for moderately confined reach, 86 feet for confined reach

Minimum Present HCMZ Width: 33 feet for unconfined reach, 38 feet for moderately confined reach, 45 feet for confined reach

Maximum Present HCMZ Width: 344 feet for unconfined reach, 248 feet for moderately confined reach, 145 feet for confined reach

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 202 feet for unconfined reach, 81 feet for moderately confined reach, 51 feet for confined

Average Percent Decrease in HCMZ Width: 64 percent for unconfined reach, 41 percent for moderately confined reach, 38 percent for confined reach

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 381 feet for unconfined reach, 84 feet for moderately confined reach, 61 feet for confined reach

Average Width Decrease Created by Constructed Features:

332 feet blocked channels

306 feet unimproved road, rock spurs

300 feet possible levees

286 feet levees

265 feet irrigation ditches

228 feet rock spurs

216 feet riprap

186 feet unimproved road

164 feet bridge (unimproved road)

82 feet bridge (highway)

77 feet diversion

76 feet embankment

51 feet steel

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 2.22 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 20 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

1.46 acres (13 percent) unimproved roads, levee, riprap

0.75 acres (7 percent) levee, riprap

Present Width of Floodplain:

Average Present Floodplain Width: 214 feet for unconfined reach, 144 feet for moderately confined reach, 110 feet for confined reach

Minimum Present Floodplain Width: 40 feet for unconfined reach, 50 feet for moderately confined reach, 43 feet for confined reach

Maximum Present Floodplain Width: 900 feet for unconfined reach, 305 feet for moderately confined reach, 179 feet for confined reach

Change in Width of Floodplain:

Difference in Average Floodplain Width: 136 feet for unconfined reach, 34 feet for moderately confined reach, 37 feet for confined reach

Percent Difference in Average Floodplain Width: 39 percent for unconfined reach, 19 percent for moderately confined reach, 25 percent for confined reach

Difference in Minimum Floodplain Width: 65 feet for unconfined reach, 18 feet for moderately confined reach, 60 feet for confined reach

Difference in Maximum Floodplain Width: None for unconfined reach, none for moderately confined reach, 21 feet for confined reach

Average Width Decrease Created By Constructed Features:

330 feet riprap

248 feet levees

233 feet unimproved roads

129 feet irrigation ditches

20 feet spoil

13 feet steel

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 2,151 feet (0.4 miles)

Percent of 2006 Channel That is Straightened: 13 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length):

1,808 feet (11 percent) riprap

343 feet (2 percent) levees

Length of Artificially Confined Channel: 8,872 feet (1.7 miles)

Percent of 2006 Channel that is Confined: 54 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length):

5,073 feet (31 percent) levees, riprap, rock spurs, diversion

2,536 feet (15 percent) levees, riprap, rock spurs

630 feet (4 percent) levees, riprap

487 feet (3 percent) levees

246 feet (1 percent) bridge and embankments (unimproved road)

Total Length of Straightened/Confined Channel: 11,024 feet (2.1 miles)

Percent of 2006 Channel that is Straightened/Confined: 67 percent

Length of Possible Main Channel Cutoff: 5,086 feet (0.96 miles)

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length):

1,829 feet (11 percent) riprap

1,462 feet (9 percent) levee/irrigation ditch

1,241 feet (7 percent) levees

322 feet (2 percent) unimproved road

232 feet (1 percent) riprap/irrigation ditch

2.2 Reach UJD3

2.2.1 Geomorphic Characteristics

Downstream Boundary: RM 264.7

Upstream Boundary: RM 265.81

Type: Unconfined

Main Tributaries: Dads Creek on river left at RM 264.9, Jeff Davis Creek on river left at RM 265.7

Length of Reach (2006 channel): 1.1 miles; 5,858 feet

Area of Natural Floodplain: 46.0 acres

Area of Natural Floodplain Outside of the Natural HCMZ: 11.22 acres

Percent of Natural Floodplain Outside of the Natural HCMZ: 24 percent

Area of Natural HCMZ: 34.8 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 76 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 350 feet

Minimum Natural Floodplain Width: 105 feet

Maximum Natural Floodplain Width: 900 feet

HCMZ Width:

Average Natural HCMZ Width: 302 feet

Minimum Natural HCMZ Width: 107 feet

Maximum Natural HCMZ Width: 502 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 11,659 feet (2.19 miles) total length

Alluvial-Fan Deposits: 9,435 feet (1.77 miles); 81 percent of boundary

Alluvial-Fan Deposits (older): 2,225 feet (0.42 miles); 19 percent of boundary

Bank Erosion: Bank erosion was noted in two areas (shown here), but was not systematically evaluated for the entire reach

Total Length Observed: 0.07 miles (376 feet)

Of this length, 179 feet (47 percent) involve floodplain reworking, and 198 feet (53 percent) involve erosion along the floodplain boundary

2.2.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 27

Number of Point Constructed Features/Mile: 24.3

Type of Constructed Features: Rock spurs (16), blocked/filled channels (7), diversions (2), grade control (2)

Constructed Features (linear):

Total Length of Constructed Features: 4,806 feet (0.91 miles)

Length of **Features** as Percent of **2006 Channel Length**: 82 percent

Type of Constructed Features (Percent 2005 Channel Length): 1,181 feet (20 percent) levee, 1,141 feet (19 percent) irrigation ditch, 1,099 feet (19 percent) riprap, 1,047 feet (18 percent) unimproved road, 280 feet (5 percent) spoil, 58 feet (1 percent) steel

Constructed Features (areas):

Total Area of Constructed Features: None

Impacted Areas of Natural HCMZ:

Total Area Impacted: 22.96 acres

Percent of Natural HCMZ Impacted: 66 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

17.45 acres (50 percent) levees, riprap, spoil, rock spurs, blocked channels, steel

4.81 acres (14 percent) unimproved roads, irrigation ditches, riprap, levees

0.27 acres (1 percent) irrigation ditch, diversion, riprap, rock spurs, steel

0.22 acres (1 percent) blocked channels

0.11 acres (0.3 percent) levees

0.06 acres (0.2 percent) riprap

0.08 acres (0.2 percent) rock spurs

Present Width of HCMZ:

Average Present HCMZ Width: 101 feet

Minimum Present HCMZ Width: 33 feet

Maximum Present HCMZ Width: 344 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 202 feet

Average Percent Decrease in HCMZ Width: 64 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 381 feet

Average Width Decrease Created by Constructed Features:

306 feet unimproved roads, rock spurs

208 feet possible levees

204 feet blocked channels

195 feet levees

179 feet rock spurs

124 feet riprap

120 feet unimproved roads

51 feet steel

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: 2.22 acres

Percent of the Natural Floodplain Outside of the HCMZ that is Disconnected: 20 percent

Disconnected Floodplain Areas Outside of the HCMZ by Constructed Feature (Percent of Floodplain Outside of HCMZ):

1.46 acres (13 percent) unimproved roads, levee, riprap

0.75 acres (7 percent) levees, riprap

Present Width of Floodplain:

Average Present Floodplain Width: 214 feet

Minimum Present Floodplain Width: 40 feet

Maximum Present Floodplain Width: 900 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 136 feet

Percent Difference in Average Floodplain Width: 39 percent

Difference in Minimum Floodplain Width: 65 feet

Difference in Maximum Floodplain Width: None

Average Width Decrease Created by Constructed Features:

236 feet riprap

202 feet unimproved roads

182 feet levees

79 feet irrigation ditches

20 feet spoil

13 feet steel

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: None

Length of Artificially Confined Channel: 5,073 feet

Percent of 2006 Channel that is Confined: 86 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length): 5,073 feet (86 percent) levees, riprap, rock spurs, diversion

Total Length of Straightened/Confined Channel: 5,073 feet

Percent of 2006 Channel that is Straightened/Confined: 86 percent

Length of Possible Main Channel Cutoff: 612 feet

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length): 612 feet (10 percent) levees

2.3 Reach UJD2

2.3.1 Geomorphic Characteristics

Downstream Boundary: RM 263.1

Upstream Boundary: RM 264.7

Type: Moderately confined

Main Tributaries: Strawberry Creek on river left at RM 263.3

Length of Reach (2006 channel): 1.6 miles; 8,423 feet

Area of Natural Floodplain: 30.7 acres

Area of Natural Floodplain Outside of the Natural HCMZ: None

Percent of Natural Floodplain Outside of the Natural HCMZ: -

Area of Natural HCMZ: 30.7 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 100 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 177 feet

Minimum Natural Floodplain Width: 68 feet

Maximum Natural Floodplain Width: 305 feet

HCMZ Width:

Average Natural HCMZ Width: 181 feet

Minimum Natural HCMZ Width: 108 feet

Maximum Natural HCMZ Width: 317 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 16,590 feet (3.12 miles) total length

Alluvial-Fan Deposits: 10,298 feet (1.93 miles); 62 percent of boundary

Alluvial-Fan Deposits (older): 6,292 feet (1.18 miles); 38 percent of boundary

Bank Erosion: Not evaluated

2.3.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 28

Number of Point Constructed Features/Mile: 17.6

Type of Constructed Features: Rock spurs (16), blocked/filled channels (9), diversions (2), bridge (1)

Constructed Features (linear):

Total Length of Constructed Features: 4,305 feet (0.82 miles)

Length of **Features** as Percent of **2006 Channel Length**: 51 percent

Type of Constructed Features (Percent 2005 Channel Length): 1,527 feet (18 percent) levee, 1,418 feet (17 percent) riprap, 853 feet (10 percent) unimproved roads, 506 feet (6 percent) irrigation ditches

Constructed Features (areas):

Total Area of Constructed Features: 0.11 acres

Percent Constructed Features of Total Reach Area: 0.4 percent

Type of Constructed Features (Percent Total Reach Area): 0.06 acres (0.2 percent) embankment (unimproved road), 0.05 acres (0.2 percent) embankment

Impacted Areas of Natural HCMZ:

Total Area Impacted: 11.26 acres

Percent of Natural HCMZ Impacted: 37 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

4.71 acres (15 percent) blocked channels, levees, diversions, embankment, irrigation ditches, riprap

2.12 acres (7 percent) levees

1.23 acres (4 percent) rock spurs, riprap, levees

1.08 acres (4 percent) riprap

1.07 acres (3 percent) embankments (unimproved road), riprap

0.50 acres (2 percent) rock spurs

0.43 acres (1 percent) diversions, irrigation ditches, riprap, rock spurs

0.10 acres (0.3 percent) bridge and embankments (unimproved road), riprap

Present Width of HCMZ:

Average Present HCMZ Width: 100 feet

Minimum Present HCMZ Width: 38 feet

Maximum Present HCMZ Width: 248 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 81 feet

Average Percent Decrease in HCMZ Width: 41 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 84 feet

Average Width Decrease Created by Constructed Features:

265 feet irrigation ditches

164 feet bridge (unimproved road)

128 feet blocked channels

93 feet possible levees

91 feet levees

77 feet diversions

76 feet embankments

65 feet unimproved roads

49 feet rock spurs

38 feet riprap

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: None

Present Width of Floodplain:

Average Present Floodplain Width: 144 feet

Minimum Present Floodplain Width: 50 feet

Maximum Present Floodplain Width: 305 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 34 feet

Percent Difference in Average Floodplain Width: 19 percent

Difference in Minimum Floodplain Width: 18 feet

Difference in Maximum Floodplain Width: None

Average Width Decrease Created by Constructed Features:

66 feet levees

50 feet irrigation ditches

37 feet riprap

31 feet unimproved roads

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 690 feet

Percent of 2006 Channel That is Straightened: 8 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length):

347 feet (4 percent) riprap

343 feet (4 percent) levees

Length of Artificially Confined Channel: 3,800 feet

Percent of 2006 Channel that is Confined: 45 percent

Length of Confined Channel by Constructed Feature (Percent of 2006 Channel Length):

2,536 feet (30 percent) levees, riprap, rock spurs

630 feet (7 percent) levees, riprap

487 feet (6 percent) levees

146 feet (2 percent) bridge and embankments (unimproved road)

Total Length of Straightened/Confined Channel: 4,490 feet

Percent of 2006 Channel that is Straightened/Confined: 53 percent

Length of Possible Main Channel Cutoff: 3,153 feet

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length):

1,462 feet (17 percent) levee/irrigation ditch

629 feet (7 percent) levees

508 feet (6 percent) riprap

322 feet (4 percent) unimproved road

232 feet (3 percent) riprap/irrigation ditch

2.4 Reach UJD1

2.4.1 Geomorphic Characteristics

Downstream Boundary: RM 262.67

Upstream Boundary: RM 263.1

Type: Confined

Main Tributaries: None

Length of Reach (2006 channel): 0.43 miles; 2,260 feet

Area of Natural Floodplain: 5.6 acres

Area of Natural Floodplain Outside of the Natural HCMZ: None

Percent of Natural Floodplain Outside of the Natural HCMZ: -

Area of Natural HCMZ: 5.6 acres

Natural HCMZ Area as Percent of Natural Floodplain Area: 100 percent

Width of Natural Floodplain:

Average Natural Floodplain Width: 146 feet

Minimum Natural Floodplain Width: 103 feet

Maximum Natural Floodplain Width: 200 feet

HCMZ Width:

Average Natural HCMZ Width: 137 feet

Minimum Natural HCMZ Width: 137 feet

Maximum Natural HCMZ Width: 173 feet

Channel Pattern:

Flow Characteristics:

Composition of Natural Floodplain Boundary: 4,247 feet (0.8 miles) total length

Alluvial-Fan Deposits: 3,105 feet (0.58 miles); 73 percent of boundary

Alluvial-Fan Deposits (older): 1.142 feet (0.21 miles); 27 percent of boundary

Bank Erosion: Not evaluated

2.4.2 Human Impacts

Constructed Features (points):

Number of Point Constructed Features: 1

Number of Point Constructed Features/Mile: 2.3

Type of Constructed Features: Bridge (1)

Constructed Features (linear):

Total Length of Constructed Features: 3,767 feet (0.71 miles)

Length of Features as Percent of 2006 Channel Length: 166 percent

Type of Constructed Features (Percent 2005 Channel Length): 2,615 feet (116 percent) riprap, 1,152 feet (51 percent) improved road (highway)

Constructed Features (areas):

Total Area of Constructed Features: None

Impacted Areas of Natural HCMZ:

Total Area Impacted: 1.54 acres

Percent of Natural HCMZ Impacted: 27 percent

Impacted Areas of HCMZ by Constructed Feature (Percent of Natural HCMZ):

1.54 acres (27 percent) riprap

Present Width of HCMZ:

Average Present HCMZ Width: 86 feet

Minimum Present HCMZ Width: 45 feet

Maximum Present HCMZ Width: 145 feet

Change in Width of HCMZ:

Average Decrease in HCMZ Width: 51 feet

Average Percent Decrease in HCMZ Width: 38 percent

Decrease in Minimum HCMZ Width: None

Decrease in Maximum HCMZ Width: 61 feet

Average Width Decrease Created by Constructed Features:

82 feet bridge (highway)

54 feet riprap

Disconnected Area of Natural Floodplain Outside of the HCMZ:

Total Area Disconnected Outside of the HCMZ: None

Present Width of Floodplain:

Average Present Floodplain Width: 110 feet

Minimum Present Floodplain Width: 43 feet

Maximum Present Floodplain Width: 179 feet

Change in Width of Floodplain:

Difference in Average Floodplain Width: 37 feet

Percent Difference in Average Floodplain Width: 25 percent

Difference in Minimum Floodplain Width: 60 feet

Difference in Maximum Floodplain Width: 21 feet

Average Width Decrease Created by Constructed Features:

57 feet riprap

Change in Active Channel Width: Average change is 3.4 feet between 1956 and 2000

Change in Active Channel Length: Decreased by 1,200 feet (10.4 percent) between 1939 and 2000.

Length of Artificially Straightened Channel: 1,461 feet

Percent of 2006 Channel That is Straightened: 65 percent

Length of Straightened Channel by Constructed Feature (Percent of 2006 Channel Length): 1,461 feet (65 percent) riprap

Length of Artificially Confined Channel: None

Total Length of Straightened/Confined Channel: 1,461 feet

Percent of 2006 Channel that is Straightened/Confined: 65 percent

Length of Possible Main Channel Cutoff: 1,322 feet

Length Channel Cutoff by Constructed Feature (Percent of 2006 Channel Length): 1,322 feet (58 percent) riprap

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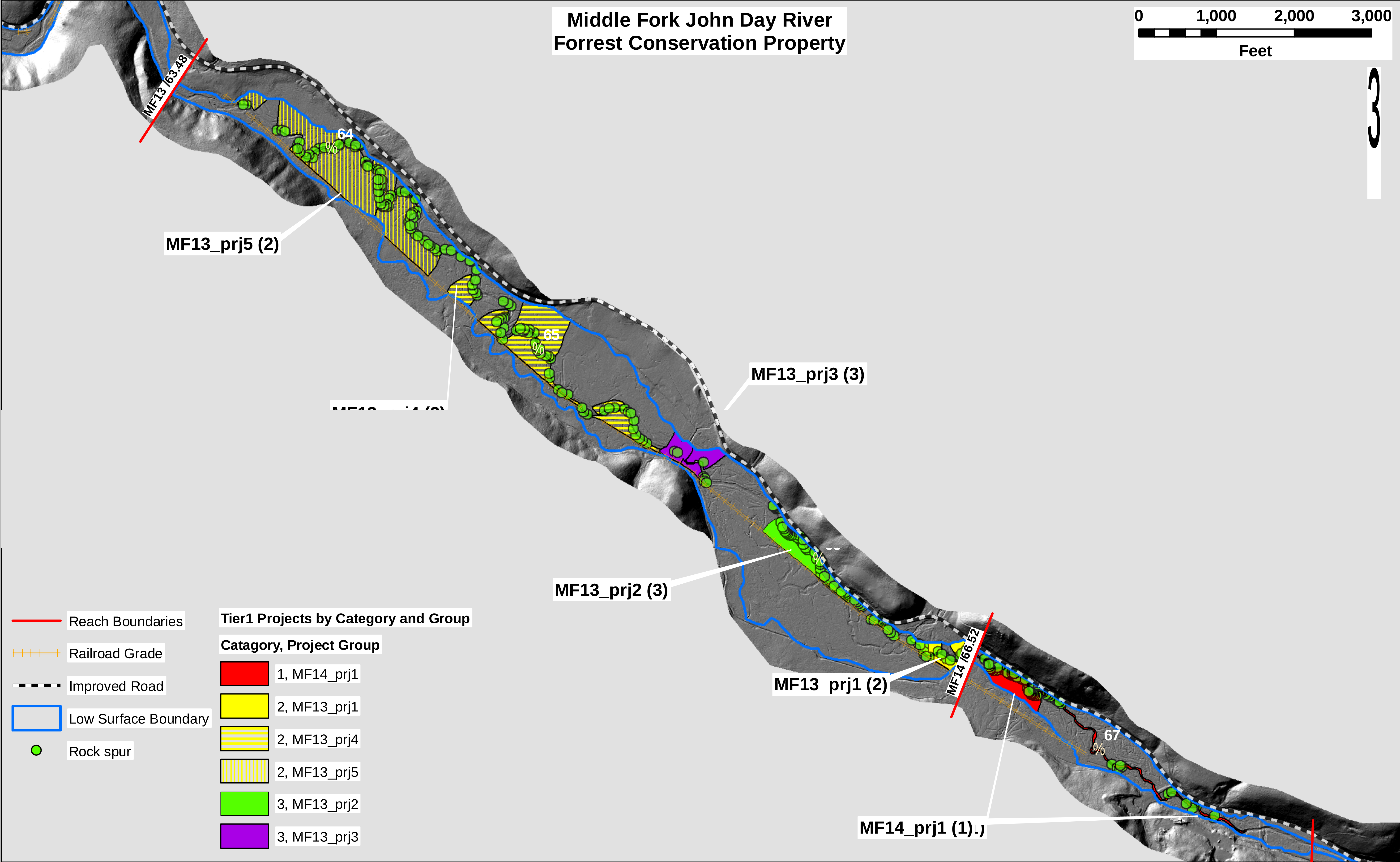
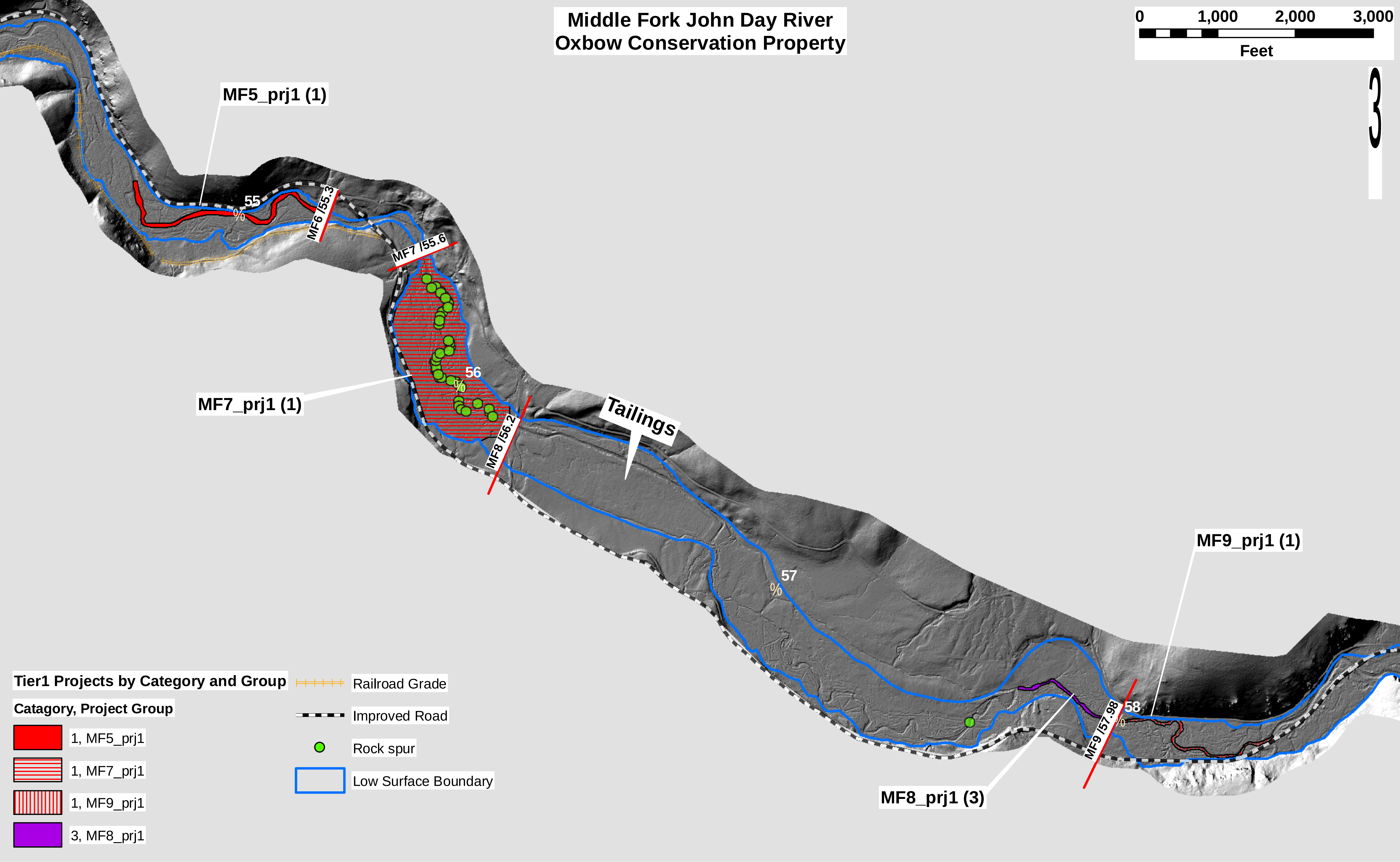
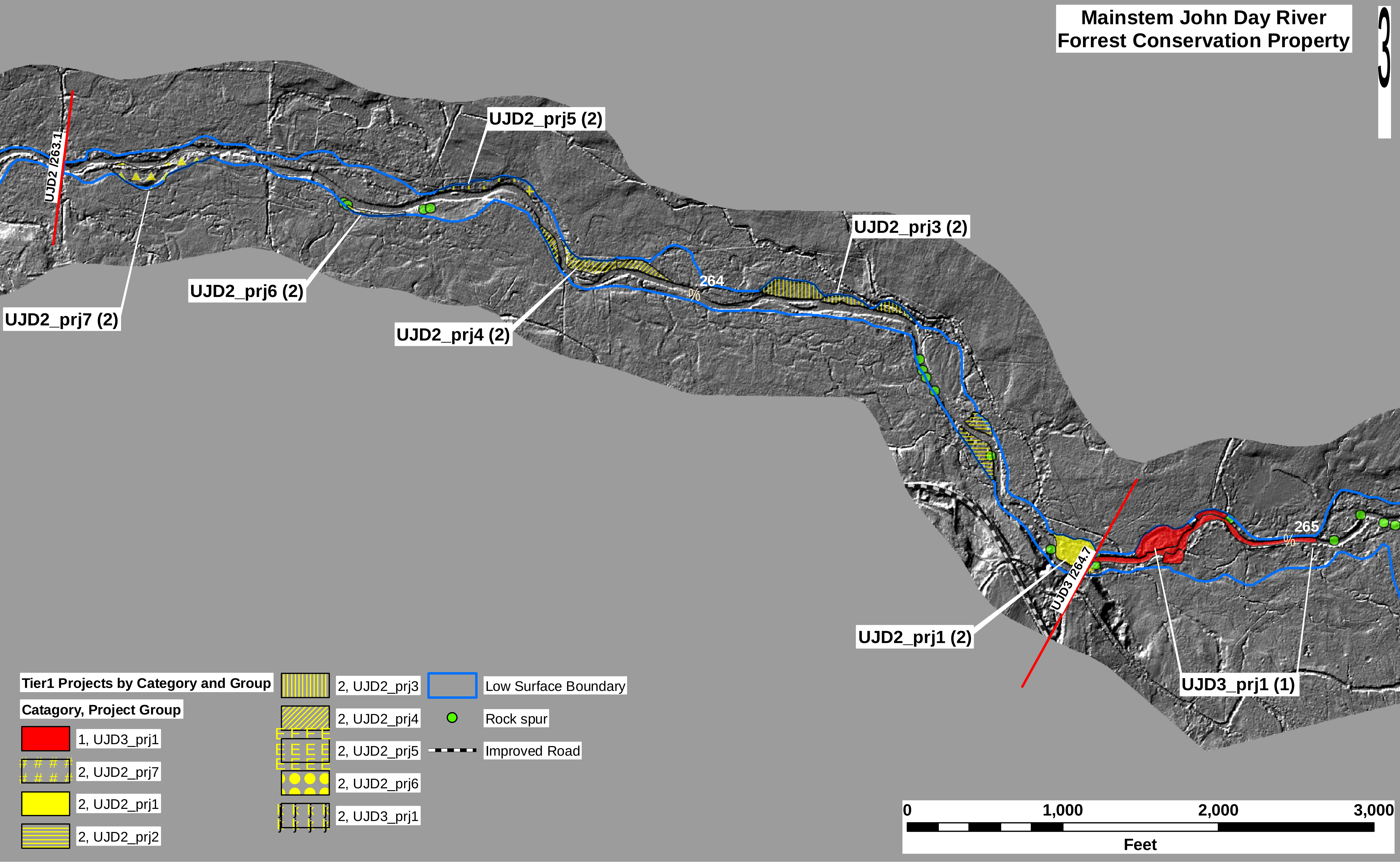
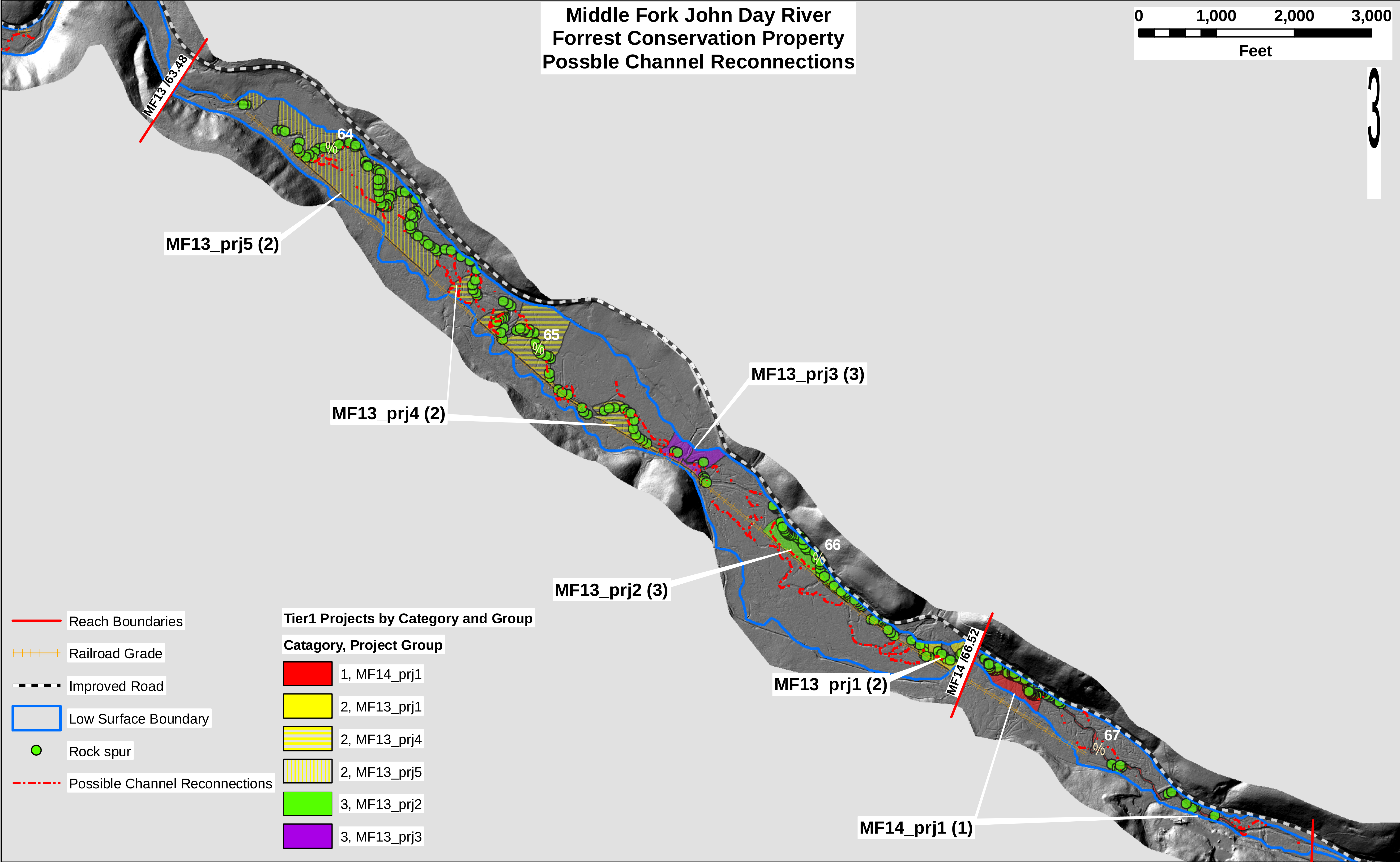
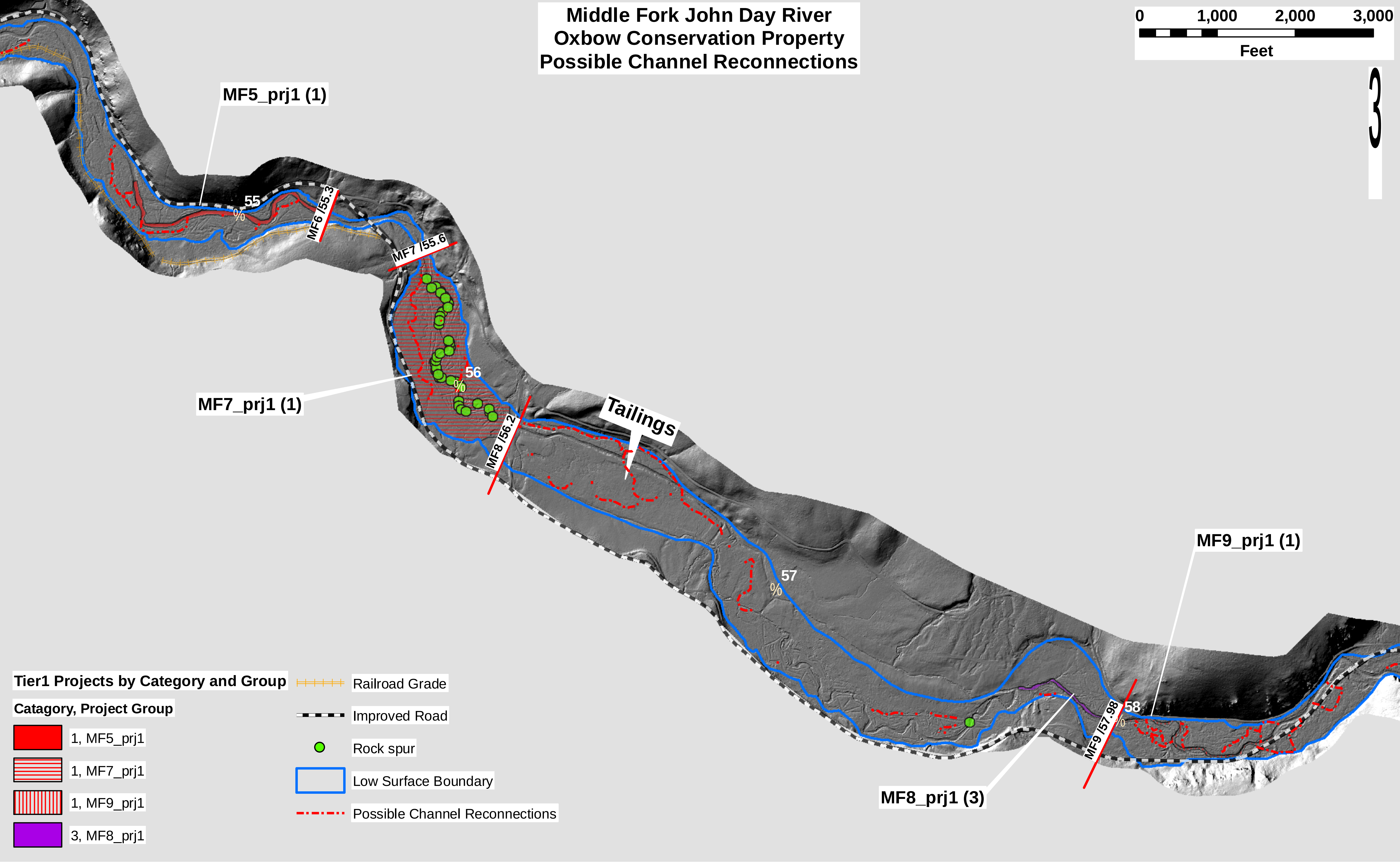

Middle Fork John Day River
Forrest Conservation Property
0
1,000
2,000
3,000
Feet
3
MF13 |63.48
MF14 |66.52
64
65
67
MF13_prj5 (2)
MF13_prj3 (3)
MF13_prj2 (3)
MF13_prj1 (2)
MF14_prj1 (1)
Reach Boundaries
Railroad Grade
Improved Road
Low Surface Boundary
Rock spur
Tier1 Projects by Category and Group
Catagory, Project Group
1, MF14_prj1
2, MF13_prj1
2, MF13_prj4
2, MF13_prj5
3, MF13_prj2
3, MF13_prj3

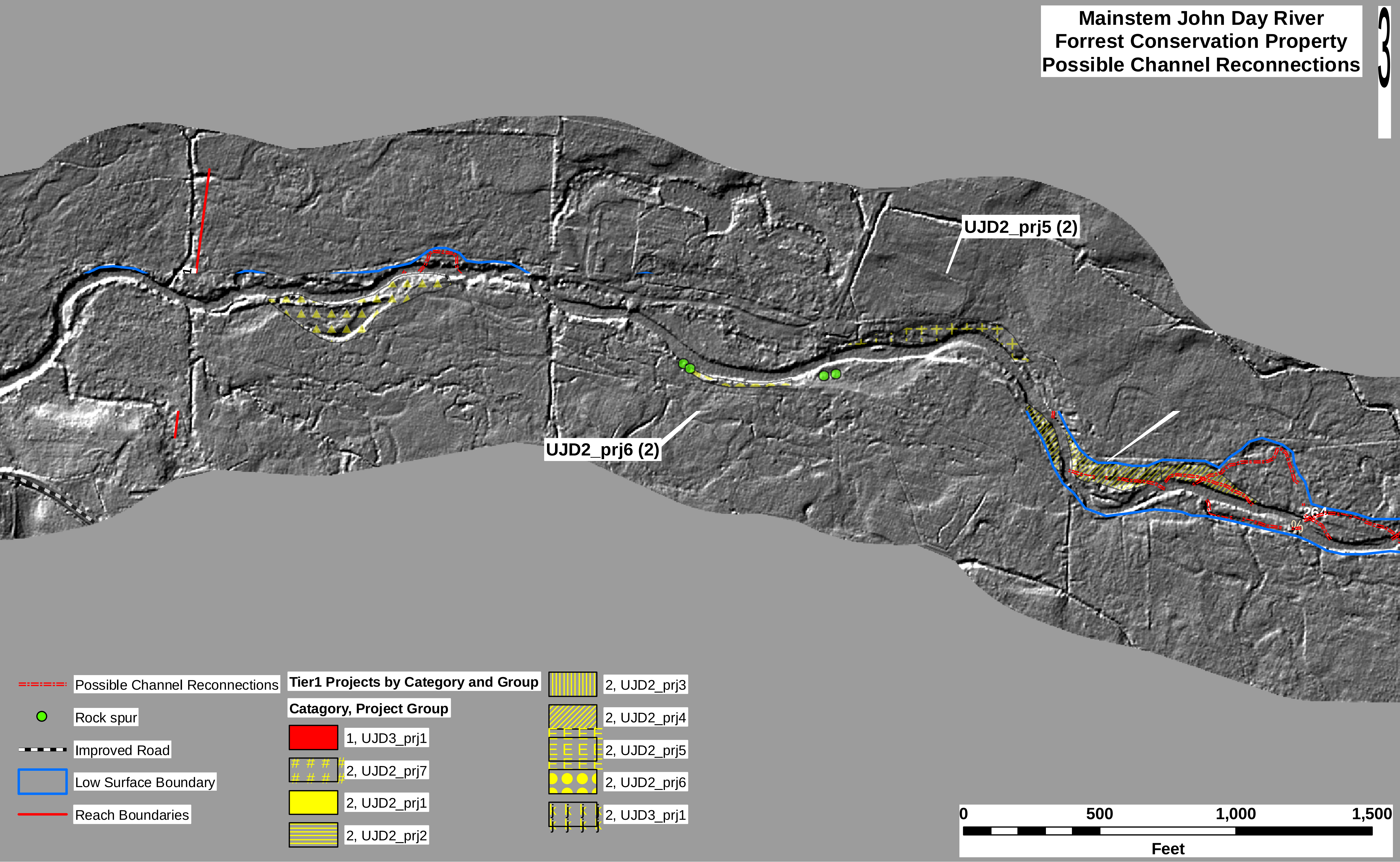


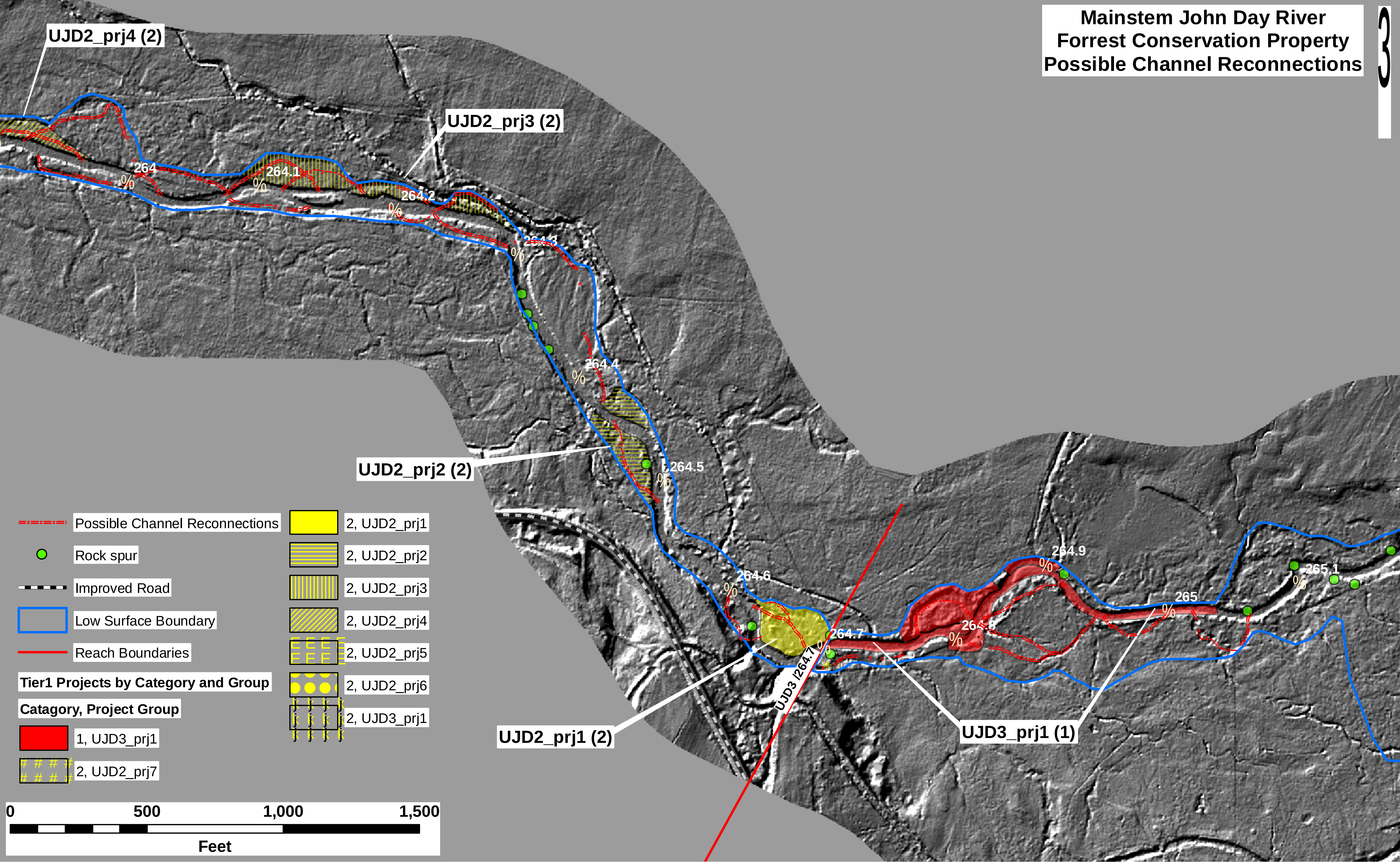
Middle Fork John Day River
Oxbow Conservation Property
0
1,000
2,000
3,000
Feet
MF5_prj1 (1)
55
MF6 /55.3
MF7 /55.6
56
MF7_prj1 (1)
MF8 /56.2
Tailings
57
MF9_prj1 (1)
58
MF9 /57.98
MF8_prj1 (3)
Tier1 Projects by Category and Group
Catagory, Project Group
1, MF5_prj1
1, MF7_prj1
1, MF9_prj1
3, MF8_prj1
Railroad Grade
Improved Road
Rock spur
Low Surface Boundary


Mainstem John Day River
Forrest Conservation Property
3
UJD2 /263.1
UJD2_prj5 (2)
UJD2_prj3 (2)
264
UJD2_prj6 (2)
UJD2_prj7 (2)
UJD2_prj4 (2)
265
UJD3 /264.7
UJD2_prj1 (2)
UJD3_prj1 (1)
Tier1 Projects by Category and Group
Catagory, Project Group
1, UJD3_prj1
2, UJD2_prj7
2, UJD2_prj1
2, UJD2_prj2
2, UJD2_prj3
2, UJD2_prj4
2, UJD2_prj5
2, UJD2_prj6
2, UJD3_prj1
Low Surface Boundary
Rock spur
Improved Road
0
1,000
2,000
3,000
Feet


Middle Fork John Day River
Forrest Conservation Property
Possble Channel Reconnections
0 1,000 2,000 3,000
Feet
3
MF13 I63.48
64
65
66
67
MF14 I66.52
MF13_prj5 (2)
MF13_prj4 (2)
MF13_prj3 (3)
MF13_prj2 (3)
MF13_prj1 (2)
MF14_prj1 (1)
Reach Boundaries
Railroad Grade
Improved Road
Low Surface Boundary
Rock spur
Possible Channel Reconnections
Tier1 Projects by Category and Group
Catagory, Project Group
1, MF14_prj1
2, MF13_prj1
2, MF13_prj4
2, MF13_prj5
3, MF13_prj2
3, MF13_prj3


Middle Fork John Day River
Oxbow Conservation Property
Possible Channel Reconnections
0
1,000
2,000
3,000
Feet
MF5_prj1 (1)
55
MF6 /55.3
MF7 /55.6
56
MF7_prj1 (1)
Tailings
MF8 /56.2
57
MF9_prj1 (1)
58
MF9 /57.98
MF8_prj1 (3)
Tier1 Projects by Category and Group
Catagory, Project Group
1, MF5_prj1
1, MF7_prj1
1, MF9_prj1
3, MF8_prj1
Railroad Grade
Improved Road
Rock spur
Low Surface Boundary
Possible Channel Reconnections


Mainstem John Day River
Forrest Conservation Property
Possible Channel Reconnections
3
UJD2_prj5 (2)
UJD2_prj6 (2)
264
Possible Channel Reconnections
Rock spur
Improved Road
Low Surface Boundary
Reach Boundaries
Tier1 Projects by Category and Group
Catagory, Project Group
1, UJD3_prj1
2, UJD2_prj7
2, UJD2_prj1
2, UJD2_prj2
2, UJD2_prj3
2, UJD2_prj4
2, UJD2_prj5
2, UJD2_prj6
2, UJD3_prj1
0
500
1,000
1,500
Feet


Mainstem John Day River
Forrest Conservation Property
Possible Channel Reconnections
3
UJD2_prj4 (2)
UJD2_prj3 (2)
UJD2_prj2 (2)
UJD2_prj1 (2)
UJD3_prj1 (1)
UJD3 / 264.7
264
264.1
264.2
264.3
264.4
264.5
264.6
264.7
264.8
264.9
265
265.1
Possible Channel Reconnections
Rock spur
Improved Road
Low Surface Boundary
Reach Boundaries
Tier1 Projects by Category and Group
Catagory, Project Group
1, UJD3_prj1
2, UJD2_prj7
2, UJD2_prj1
2, UJD2_prj2
2, UJD2_prj3
2, UJD2_prj4
2, UJD2_prj5
2, UJD2_prj6
2, UJD3_prj1
0
500
1,000
1,500
Feet