LOWER LIBBY CREEK
REACH ASSESSMENT

Prepared for **YAKAMA NATION FISHERIES** | PO BOX 15, FORT ROAD | TOPPENISH, WA 98948

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1 INTRODUCTION

1.1 Purpose

This assessment evaluates geomorphic processes and aquatic habitat conditions in the lower 1.4 miles of Libby Creek and identifies strategies to restore and preserve salmonid habitat and natural river processes. Libby Creek supports populations of salmonids that are currently listed under the Endangered Species Act (ESA), including Upper Columbia River summer steelhead and a small population of spring Chinook salmon. Habitat for these species has been impacted by anthropogenic activities throughout the basin.

Specific goals of this assessment include:

- Identify actions that address critical aquatic habitat impairments limiting the productivity of local salmonid populations
- Identify actions that protect and restore the dynamic landscape processes that support sustainable riparian and salmonid habitat
- Identify actions that improve and protect water quality to promote salmonid recovery
- Coordinate efforts with local landowners, resource managers, and other stakeholders in order to establish collaborative efforts that contribute to the success of restoration strategies

1.2 Study Area

Libby Creek is a tributary of the Methow River, joining the Methow River at River Mile (RM) 26.5 near the town of Carlton, WA. Libby Creek is a third-order stream that drains a watershed of approximately 40 square miles. The headwaters of Libby Creek are found in adjacent lakes on Hoodoo Peak in the Lake Chelan-Sawtooth Wilderness. See Figure 1 for a locator map of the basin and the study area for this reach assessment.

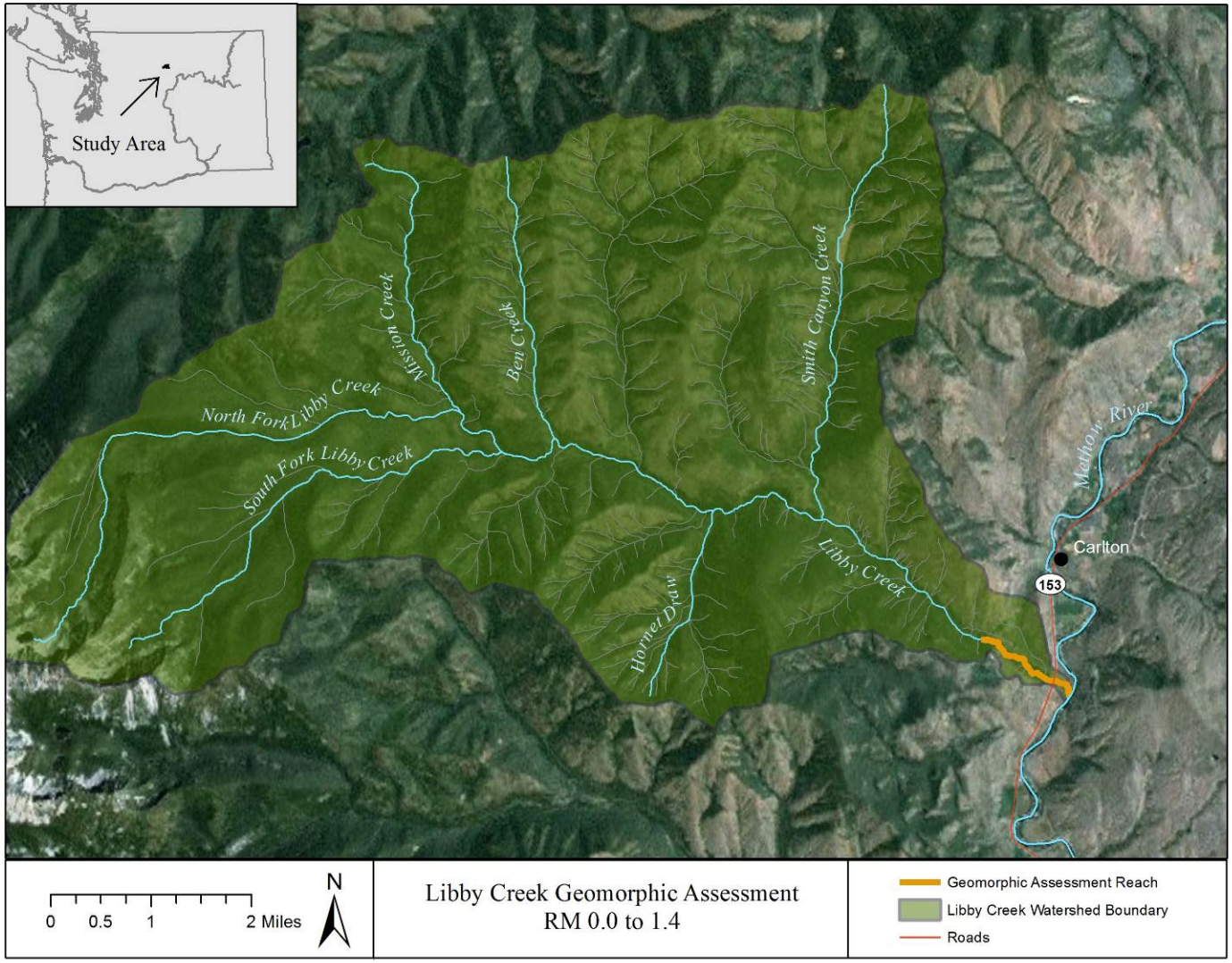

Figure 1. Lower Libby Creek Study Area. The Reach Assessment study area extends from RM 0.0 to RM 1.4.

1.3 Recovery Planning Context

Upper Columbia spring Chinook salmon are listed as Endangered and upper Columbia River steelhead and bull trout are listed as Threatened under the ESA. The Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (Recovery Plan, UCSRB 2007) states that recovery of species viability will require reducing threats to the long-term persistence of fish populations, maintaining widely distributed and connected fish populations across diverse habitats of their native ranges, and preserving genetic diversity and life-history characteristics. The Recovery Plan calls for recovery actions within all of the "H" categories that affect salmon throughout their life history; namely Harvest, Hatchery, Hydropower, and Habitat. This Libby Creek Reach Assessment and its restoration strategies help to address the Habitat component of the Recovery Plan, with a focus on the lower 1.4 miles of the Libby Creek corridor.

The following habitat restoration and preservation objectives were set forth in the Recovery Plan. These objectives apply to spring Chinook, steelhead, and bull trout habitat and are consistent with the Methow Subbasin Plan (KWA 2004) and the Biological Strategy (UCRTT 2008). The objectives are intended to reduce threats to the habitat needs of the listed species. Objectives that apply to areas outside the study area or that are outside the scope of this plan are not included. A list of regional objectives (applicable to all streams in the Recovery Planning area) is followed by a list of specific Habitat Recovery Actions for the Libby Creek/Gold Creek Basins (UCSRB 2007). These objectives and actions provided a framework and guidance for this Reach Assessment.

Short-Term Regional Objectives

- Protect existing areas where high ecological integrity and natural ecosystem processes persist.
- Restore connectivity (access) throughout the historical range where feasible and practical for each listed species.
- Protect and restore water quality where feasible and practical within natural constraints.
- Increase habitat diversity in the short term by adding instream structures (e.g. large wood, boulders) where appropriate.
- Protect and restore riparian habitat along spawning and rearing streams and identify long-term opportunities for riparian habitat enhancement.
- Protect and restore floodplain function and reconnection, off-channel habitat, and channel migration processes where appropriate and identify long-term opportunities for enhancing these conditions.
- Restore natural sediment delivery processes by improving road networks, restoring natural floodplain connectivity, riparian health, natural bank erosion, and wood recruitment.

Long-Term Regional Objectives

- Protect areas with high ecological integrity and natural ecosystem processes.
- Maintain connectivity through the range of the listed species where feasible and practical.

Habitat Recovery Actions Specific to the Gold and Libby Creek Basins

- Increase habitat diversity and quantity by restoring riparian habitat, reconnecting side channels and floodplains (where feasible), and adding large wood within the streams.
- Use practical and feasible means to increase stream flows (within the natural hydrologic regime and existing water rights) in the streams.
- Re-establish connectivity throughout the assessment unit by removing, replacing, or fixing artificial barriers (culverts and diversions).

2 METHODS

2.1 Geomorphic Assessment

The geomorphic assessment included the mapping of geomorphic features and the characterization of channel and floodplain processes throughout the study area. The geomorphic assessment utilized a combination of field surveys, aerial photographs, topographic maps, and existing data, where available. Human alterations affecting habitat conditions, channel dynamics, and floodplain processes were identified and mapped. The following were evaluated as part of the geomorphic assessment: 1) sediment transport and response conditions, 2) channel incision and channel evolution trends (erosion and stability), 3) substrate types, distribution, and availability, 4) influence and role of large woody debris, 5) floodplain, channel migration zone, and habitat connectivity, 6) surface and subsurface flow interactions, 7) influence of past and current human structures and activities, and 8) interaction of the stream with riparian ecological processes.

Geomorphic conditions were characterized at the reach as well as subunit scales. Reaches were delineated based on dominant underlying geology, channel gradient, valley confinement, and channel type. Reaches were initially delineated using aerial photographs and topographical maps; appropriate reach divisions were confirmed during the field surveys.

The reaches were further divided into “subunits”, which consist of distinct channel or floodplain units such as an individual floodplain terrace. This scale of analysis is useful for understanding the influence of specific human alterations on geomorphic processes and provides a basis for the identification of site-specific restoration opportunities. Each subunit is mapped and is given a designation based on whether it is located within a segment of active channel, referred to as an “inner zone (IZ),” or if it is located within the floodplain, referred to as an “outer zone (OZ)”.

The patterns and processes at work at the subunit scale are described, and are used to inform the project identification and prioritization process.

An inner zone subunit is defined as the wetted low-flow channel and all related areas that annually experience ground-disturbing flow (e.g. secondary channels and active bars). An outer zone subunit is defined as the low-lying area adjacent to the channel that may become inundated at higher flow but does not normally experience ground disturbing flow (USBR 2009a). Inner zone subunits were delineated using breaks in geomorphic control such as bedrock constrictions, changes in geomorphic patterns (e.g. step-pool to riffle-run), or roadways that result in variations in channel pattern and channel type. Outer zone subunits were delineated as discrete floodplain areas separated by natural breaks, variation in the dominant ecology, or anthropogenic barriers.

Inner and outer zones may further be designated as "disconnected", denoted with a "D" before the IZ (inner zone) or OZ (outer zone) identifier. A designation of "disconnected" indicates that a zone's historical pattern and processes have been severed due to anthropogenic alterations. An example of a disconnected inner zone is an area of active channel that has been blocked by a levee. Inner and outer zones may become disconnected through channel or floodplain manipulations including straightening, ditching, filling, and rip-rap, and through construction of levees, road embankments, or bridges. In addition, outer zones may be disconnected via indirect alterations that affect channel migration and flood inundation processes. These may include upstream or downstream bridge crossings that limit channel migration or land-use induced channel incision that reduces the extent of floodplain inundation.

2.2 Stream Habitat Assessment

A habitat assessment was conducted on lower Libby Creek in 2011 using the US Forest Service (USFS) Level II stream habitat survey protocol. Results of this assessment are included in Appendix A. The habitat assessment included measurements of habitat unit type, channel dimensions, bed substrate, large wood, and riparian conditions. See Appendix A for complete methods and results of this assessment.

2.3 Identification of Project Opportunities

Potential project opportunities were identified through a combination of methods, including: 1) assessment of existing geomorphic conditions, 2) field surveys of project opportunities, and 3) remote sensing using aerial photography. Location information, general site conditions, and photographs were acquired for each project opportunity area. A summary of project opportunities for the entire study area is presented in Section 4. Project locations and types by reach are provided in the tables and maps for each reach description, in Section 5. Detailed project descriptions and site photos are included in the list of project opportunities (Appendix B).

2.4 Process-based Restoration Strategy

Restoration and preservation activities are identified and prioritized according to a process-based hierarchical framework, similar to those presented by Roni et al. (2002), Roni et al. (2005), and

utilized by the USBR for other reach assessments in the region (e.g. Lyon and Maguire 2008). As illustrated by Figure 2, the framework used in this assessment emphasizes preservation and process-based restoration as the highest priority, followed by habitat enhancement and stabilization.

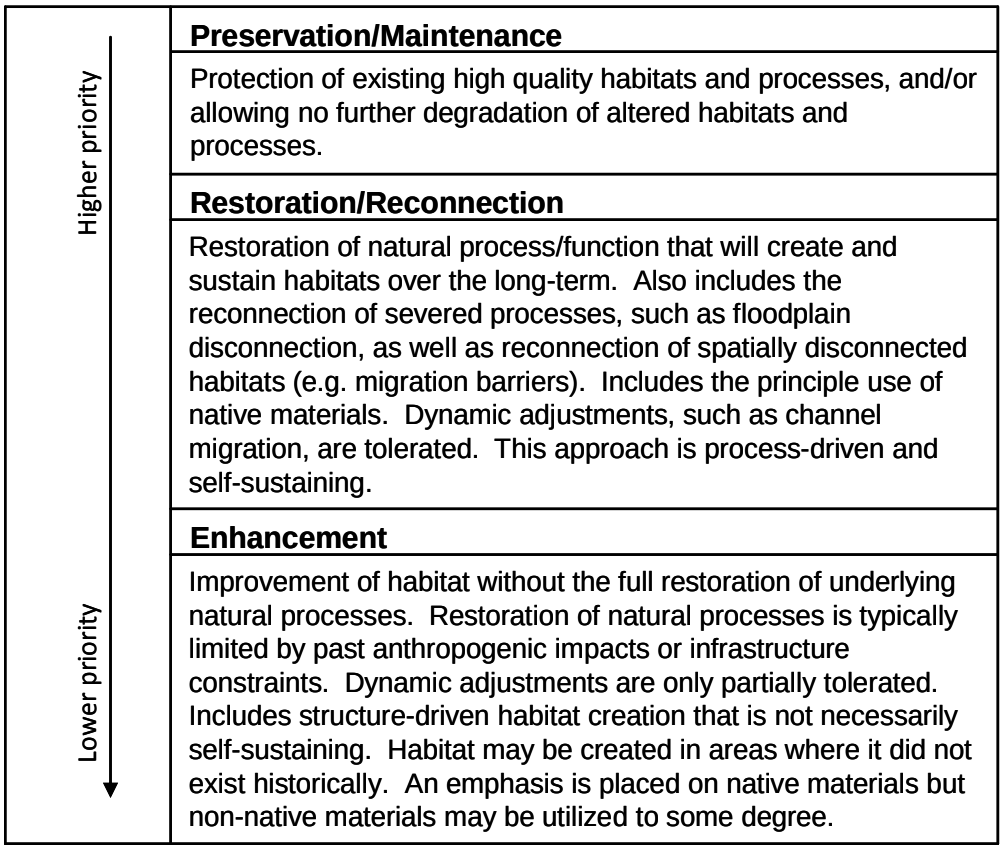

Figure 2. Hierarchical framework, prioritization, and terminology used to categorize and prioritize projects. Adapted from Gilliland et al. (2005) and Skidmore et al. (2010).

All of the projects identified within this assessment are categorized by project type. The project types are included below with a brief description and examples for each type. Each project type is explained in detail below and is listed in priority order based on the hierarchical strategy described in Figure 2. Project priorities are based on geomorphic analysis and do not account for feasibility considerations (e.g. landowner permissions, access).

Protect and Maintain. Protection projects are located in areas that are presently in a connected and functional state, as well as in impacted areas that should be preserved against further degradation. These actions should be considered obligatory when the opportunity arises, and are inherent in all potential actions. In many cases, adequate protection may already be in place through existing laws and regulations. The adequacy and enforcement of these regulations needs to be considered when planning for protection activities

Examples:

- Direct purchase (fee acquisition) of an area of functioning habitat and physical processes, or of an area at risk of further degradation through development.
- Obtaining a conservation easement from a landowner in order to eliminate agricultural uses or grazing within a riparian buffer zone.

Reconnect Stream Channel Processes. Stream channel reconnection projects are located in areas where stream bio-physical processes have been disconnected due to anthropogenic activities. These are areas that have the potential for an increase in habitat quality and a reestablishment of dynamic processes through their reconnection. Restoration actions are focused on reclaiming a component of the system that has been lost, thus regaining habitat and process that was previously a functional part of the river system.

Examples:

- Removal of riprap in order to eliminate bank hardening and channelization that restricts channel migration, simplifies the channel, and compromises instream aquatic habitat quality and quantity.
- Removal of a road embankment or levee that has cut-off an older channel alignment in order to reconnect a side-channel or mainstem channel.
- Placement of a large wood jam where wood recruitment rates have been reduced to promote active lateral channel dynamics, such as development of a multi-thread channel system.

Reconnect Floodplain Processes. Floodplain reconnection projects are located in areas where floodplain and channel migration processes have been disconnected due to anthropogenic activities. These are areas that have the potential for an increase in habitat quality and a reestablishment of dynamic processes through their reconnection. Restoration actions are focused on reclaiming a component of the system that has been lost, thus regaining habitat and process that was previously a functional part of the river system.

Examples:

- Removal of a levee that limits floodplain connectivity.
- Selective bridging or breaching of road embankments or levees to enhance floodplain connectivity.
- Removal of floodplain infrastructure or fill that limits floodplain connectivity.

Riparian Restoration. Riparian restoration projects are located in areas where native riparian vegetation communities have been significantly impacted by anthropogenic activities such that riparian functions and connections with the stream are compromised. Restoration actions are focused on restoring native riparian vegetation communities in order to reestablish natural stream stability, stream shading, nutrient exchange, and large wood recruitment. Even though it is not explicitly stated, riparian restoration is a recommended component of most restoration projects,

particularly within the disturbance limits of the project.

Examples:

- Replanting a riparian buffer area with native forest vegetation.
- Eliminating invasive plant species that are preventing the reestablishment of a native riparian forest community.
- Fencing livestock out of a riparian zone in order to recover natural vegetation and streambank stability conditions.

Instream Habitat Enhancement. Instream habitat enhancement projects are located in active channel areas where there is the potential to increase stream habitat quantity and quality. Instream enhancement projects typically involve active restoration measures that either directly increase key habitat components or indirectly improve habitat through structural enhancements that restore habitat-forming processes (e.g. pool scour from a large wood jam).

Examples:

- Construction of a log-jam to increase in-channel habitat complexity.
- Placement of boulders or individual logs to increase cover and hiding habitat for juvenile salmonid rearing..

Off-Channel Habitat Enhancement. Off-channel habitat enhancement projects are located in off-channel areas (e.g. floodplains) where there is the potential to increase the quantity and quality of off-channel habitat. In some cases, the location may not have historically provided this habitat, but has the potential to support the habitat under current hydrologic and geomorphic conditions. Given limited opportunities and constraints in other parts of a reach, this may sometimes be the best option to achieve restoration objectives.

Examples:

- Improving fish connectivity to an existing off-channel habitat area.
- Construction of off-channel features such as alcoves, backwaters, or beaver ponds that are connected to the main channel.
- Addition of large wood cover and complexity in an existing off-channel area.

3 STUDY AREA CHARACTERIZATION

3.1 Setting

Libby Creek is a tributary to the Methow River and drains a watershed of approximately 40 square miles (25,000 acres). Libby Creek is located in Okanogan County in Northern Washington State, on the east side of the Cascade Mountains. Although the majority of the Libby Creek subbasin is within the Okanogan National Forest (~85%), the lower reach of the mainstem and the majority of streamside areas in the lower basin are privately owned.

Libby Creek is approximately 14 miles long and flows into the Lower Methow River along the right bank at Methow RM 26.5. The headwaters of the north and south forks of Libby Creek are found in adjacent lakes on Hoodoo Peak in the Lake Chelan-Sawtooth Wilderness. Libby Creek has six tributaries, three fish-bearing, and three that are non-fish-bearing. Fish-bearing streams include Smith Canyon (entering at the left bank at RM 3.33), Ben Creek (left bank at RM 6.5), and Mission Creek (left bank at RM 7.93). Non fish-bearing tributaries of Libby Creek include Hornet Draw (right bank at RM 4.6), Chicamun Canyon (left bank at RM 5.6), and Nickel Canyon (right bank at RM 7.2).

3.2 Salmonid Use and Population Status

Salmonid use of Lower Libby Creek includes spawning and rearing for Upper Columbia River summer steelhead and spring Chinook salmon. A single bull trout has been documented in Libby Creek (USFS 2010). Brook trout are also present in the basin; their removal is listed as a Tier 4 recommended habitat action in the Biological Strategy (UCRTT 2008). Life-stage usage and ESA status for each species relevant to Libby creek are summarized in Table 1.

Table 1. Species usage in Libby Creek. Adapted from the USFS Libby Creek Stream Survey Report (2010).

Species	ESA Status	Life Stages	
		High density or abundant use	General use
Summer steelhead	Threatened	Migration	Spawning Rearing
Spring Chinook	Endangered	Migration	Spawning Rearing
Bull trout*	Threatened	Unknown	Unknown
Brook trout	None	Stocked	Spawning, Rearing

* Only one Bull trout has been recorded in Libby Creek (captured by the USGS in 2005 (USFS 2010))

3.3 Habitat Conditions

*See Appendix A for a full description of habitat conditions in lower Libby Creek.

Habitat in Lower Libby Creek has been impacted by a number of historical and on-going land-use activities within the subbasin. These land use activities have directly impacted Libby Creek's instream habitat, riparian areas, floodplains, and the physical processes that create and maintain the habitat conditions to which aquatic species have adapted to over time.

Timber harvesting has reduced hydrologic regulation and increased fine sediment loads within the subbasin. Since 1963, eleven timber sales over a total area of 16,670 acres were harvested and sold. Approximately 10,000 of these acres were tractor logged which has led to soil compaction (USFS 1999c, Andonaegui 2000). A majority of the sediment in Libby Creek has been linked to the creation/presence of logging roads and slope failures induced by timber harvesting. The increase in sediment load was evidenced by a 1999 pebble count above this study area which found that 27% of stream substrate was fine sediments (USFS 1999a). Increases in fine sediments to a system can alter stream temperatures, diminish water quality, and make it difficult for juvenile salmonid species to find food.

Road building has altered the river corridor through bank armoring, vegetation clearing, installation of undersized culverts, and accelerated sediment delivery. Road density in the watershed is 2.1 miles/square mile and 4.6 miles/square mile in the riparian area. Nearly every stream in the Libby Creek basin is paralleled by a road. Riparian areas have been cleared along streams as part of residential development or agricultural land use.

Agricultural uses appear to have impacted floodplains and wetlands through grazing and vegetation clearing. Water withdrawals (see Section 3.5) from Libby Creek also may be impacting the stream's natural processes. Modeling of Libby Creek suggests that withdrawal rates may exceed late summer baseflows (August, September), but local residents indicate that the stream has remained wet year round for at least the past 10 years (USFS 2010, Methow Valley Water Pilot Planning Project Committee 1994). Three small riparian planting projects and a riparian fencing project to reduce livestock grazing were completed in 2010 on private property. Projects such as these are beneficial to habitat conservation.

Trapping and removal of beaver has had a major impact on the pattern and process of low gradient streams throughout the Methow Basin, including Libby Creek. Historically, beaver built numerous dams throughout streams in the Methow Basin (Methow Basin Planning Unit 2005, Knudsen 1962; Parker 1986). In addition to mimicking a step-pool geomorphic structure, these dams retain sediment, impound organic material, establish wetlands and bogs, alter nutrient cycling, and slow the hydrograph by storing water as groundwater, which is then slowly released back into the stream throughout the year (Naiman et al. 1988). Although some beaver activity was observed as part of this assessment, this activity is a fraction of historical beaver activity in the system. Areas where beaver activity was observed exhibited the most complex habitat, including gravel recruitment, deep pools, large wood for cover, and the development of point and mid-channel bars.

Specific conditions with respect to hydrology, geomorphology, and human alterations are discussed in the individual reach profile summaries in Section 5.

3.4 Hydrology

Hydrology in the Libby Creek watershed is driven by snowmelt, groundwater seeps, and precipitation. The high elevation headwaters of Libby Creek's North Fork provides consistent flows from snowpack for much of the spring and summer season. Flow from Libby Creek is also augmented by the entry of significant tributaries that include Smith Canyon (entering at RM 3.33), Hornet Draw (right bank at RM 4.6), Chicamun Canyon (left bank at RM 5.6), Ben Creek (left bank at RM 6.5), Mission Creek (left bank at RM 7.93), and Nickel Canyon (right bank at RM 7.2). There are also multiple unnamed ephemeral drainages that contribute to Libby Creek's flow.

Libby Creek's mean annual discharge is estimated at 15 cfs (Mullan et al. 1992). Summer baseflows in Libby Creek are estimated at 3 cfs (Mullan et al. 1992).

Table 2. Available Libby Creek Flow Measurements. Flow Data from 1992, 1998, and 2010 (adapted from USFS 2010)

Measurement Location	Date of Discharge Measurement	Flow	Corresponding flow at Methow River at Twisp Gage (USGS 12449500)
RM 0.1	September 10, 1992	2.4 cfs	238 cfs
RM 6.4	August 08, 1998	9.8 cfs	568 cfs
RM 6.4	July 30, 2010	11.2 cfs	1,050 cfs

At the time of the survey (September 2011), a scour line was observed at the low flow water surface elevation (i.e. an ordinary low water line). This indicates that Libby Creek's summer baseflow is very consistent between years, and suggests hydrology is driven by springs and/or snowpack. This was further supported by a secondary vegetation line (primarily mosses) and a well-defined cross-sectional area set within the channel's ordinary high water geometry.

3.5 Water Rights

The Libby Creek Watershed was adjudicated in the 1920s and has 776 acres listed as 'acres under rights' with monthly water rights listed as 17.37 cfs (USFS 1999b). This flow could potentially exceed modeled baseflows in August and September, but observations by local residents indicate that over the past 10 years Libby Creek stays wet all year round.

3.6 Geomorphology overview

Libby Creek flows through a semi-confined valley, incising into andesite, schist and historical alluvial terraces. The valley-wall confinement of Libby Creek increases in the upstream direction. Holocene-aged alluvium deposited by both Libby Creek and the Methow River frame much of lower Libby Creek. Initial reworking by Libby Creek of these deposits resulted in the

Holocene-aged alluvial fan that borders the lower 0.3 miles of the channel. Incision into the Holocene deposits has resulted in diverse sets of historical floodplain surfaces throughout the study area.

Evidence of channelization exists throughout the study area, although the creek increases in complexity in the upstream direction. Evidence of human-induced channelization is most prevalent in Reach 1. Within this portion of the study area, field observations indicate that natural incision has been accelerated by human activities. The accelerated incision throughout Libby Creek results from a combination of logging Libby Creek and its subbasins, building of roads along almost every major tributary, channelization through excavation and bank hardening, and the removal of beaver. In Reach 2, visible bedrock indicates that the creek has reached its grade control elevation. Localized accumulations of large wood and evidence of beaver activity have slowed the rate of incision by promoting gravel recruitment in Reach 2.

A summary of geomorphic and habitat conditions in Libby Creek can be found in Table 3, along with an overview map in Figure 3.

Table 3. Summary of geomorphic and habitat conditions among reaches in Lower Libby Creek.

	Metric	Reach One	Reach Two
Channel	River Miles	0.0 to 0.58	0.58 to 1.4
	Gradient	2.11%	2.95%
	Sinuosity	1.30	1.42
	Dominant Channel Morphology	Pool-riffle	Pool-riffle
	Average Bankful Width (ft)	22.6	31.6
Floodplain	Average Floodprone Width (ft)	174	205.7
	% Floodplain Disconnected*	95.8%	79.7%
	% Floodplain Connected*	4.2%	20.3%
% Habitat Area	Pool	12%	11%
	Riffle	80%	80%
	Glide	8%	8%
	Side Channel	0%	1%

*for an explanation of what constitute a disconnected or connected floodplain see Section 2.1.

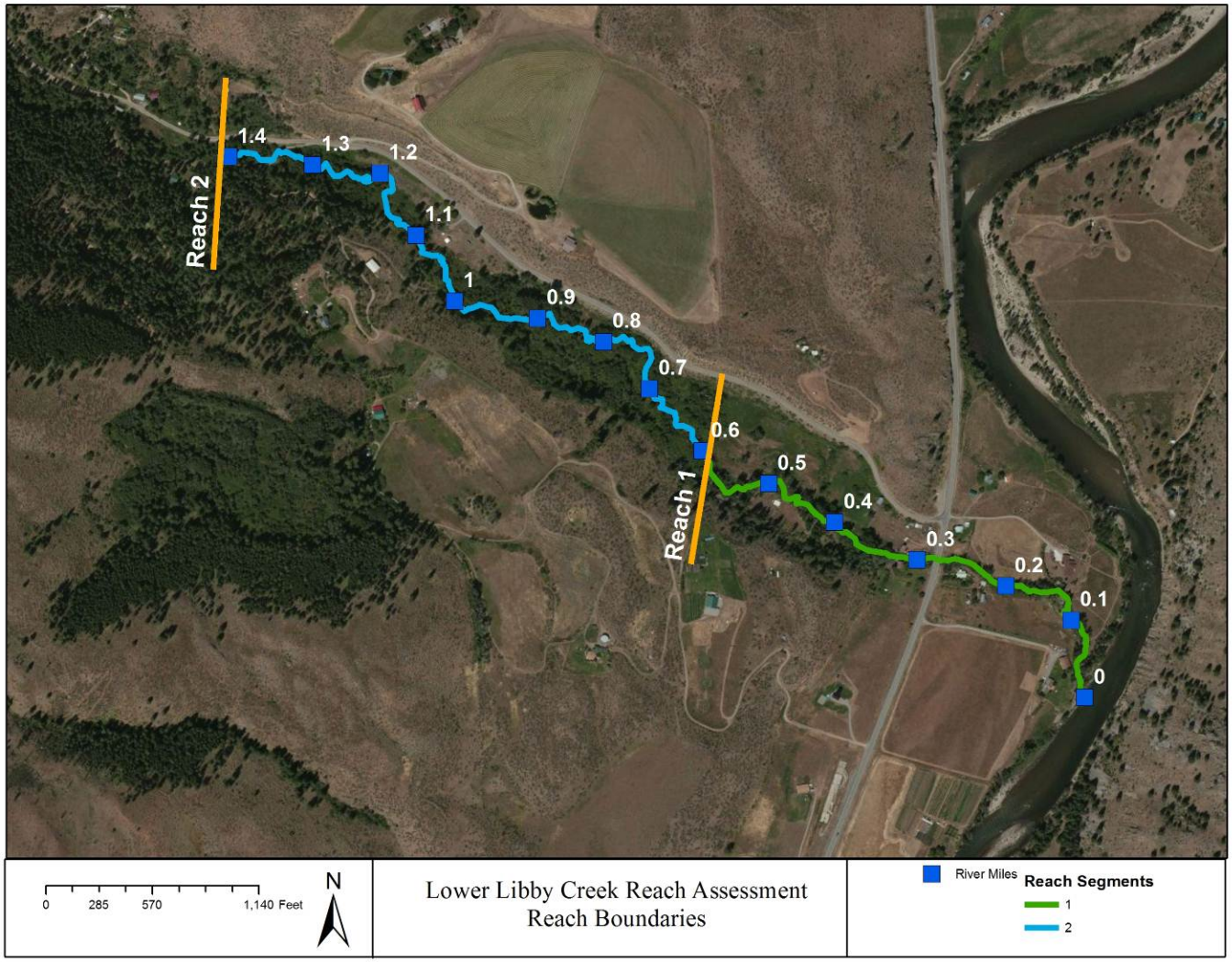

Figure 3. Reach delineation map for Libby Creek Study Area.

4 SUMMARY OF PROJECT OPPORTUNITIES

The restoration strategy and project opportunities for each reach are presented in Section 5 and in Appendix B. This section presents an overview and summary of the project opportunities for the entire study area.

This reach assessment identified twenty-three project opportunities in the lower 1.4 miles of Libby Creek. The spatial distribution and types of projects in the study area are dependent on the condition of biophysical processes, the level of human disturbance, and specific opportunities that are available for restoration. The Protect and Maintain category is applied to any existing and connected floodplain, as functioning floodplain is extremely limited throughout the reach, and preventing any further degradation of current conditions should be prioritized. Further, all opportunities to protect, conserve, and monitor the river corridor should be investigated. The highest priority action, reconnecting stream channel processes, has the highest proportion of potential projects with eight potential opportunities. For Libby Creek, these projects primarily involve the removal of riprap or bridge abutments and the placement of complex large wood projects to promote floodplain development and aggradation. Instream habitat enhancement comprises the second largest proportion of project opportunities with seven potential projects. All of these projects involve placing smaller large wood complexes in the system. Re-establishing natural wood loading patterns will enhance the entire ecosystem over time through sustained formation of a wide variety of instream and off-channel habitats. Riparian restoration was the third ranking project type at four total projects. Reestablishing native riparian cover will reduce stream temperatures, provide future sources of large wood material, and increase channel roughness to regulate channel hydraulics. Two project opportunities are focused on reconnecting floodplain processes. This low number is due to the significant disconnection of Libby Creek from historical floodplain surfaces and limited opportunities for floodplain reconnection projects due to residential development.

Table 4 . Summary of projects identified for each reach in the study area.

Reach	Reconnect Stream Channel Processes	Reconnect Floodplain Processes	Riparian Restoration	Instream Habitat Enhancement	Off-Channel Habitat Enhancement	Totals
1	6	2	1	4	0	13
2	2	0	3	3	0	10

5 REACH DESCRIPTIONS

This section of the report is organized on a reach basis with information presented for each individual reach in separate sections. Reach numbers increase in the upstream direction and are presented in numerical order. Thus, the farthest downstream reach (Reach 1 in this study) is presented first, followed by the most upstream reach, Reach 2. Reach descriptions include an overview of geomorphology, floodplain condition, and anthropogenic influences operating within the reach. This information is followed by the reach-scale restoration strategy, which presents the bulk of the information in tabular format. Unlike reaches, subunits are numbered in the downstream direction. Thus, the furthest upstream subunits are presented first in alphabetical order by subunit type (DOZ, IZ, OZ) and subsequent summaries proceed in the downstream direction within a given reach. The subunit tables include a subunit description, the restoration strategy within the subunit, and a list of the project opportunities that fall within the subunit. Projects are named using their river mile location, with the approximate midpoint used for long projects. An “R” (right bank), “L” (left bank), or “C” (Channel) designation may also be included if a location has multiple distinct projects. Reference to river-left or river-right is always oriented facing the downstream direction.

A comprehensive project opportunity list for the study area, which includes project descriptions and photos, is included as Appendix B.

Libby Creek was broken into two distinct reaches based on underlying geology and geomorphic observation. Reaches are designated from the downstream to upstream direction, with Reach 1 extending from the confluence of the Methow River (RM 0.0) to RM 0.58 and Reach 2 extending from RM 0.58 to RM 1.4. Figure 4 shows the reaches in the study area. The defining characteristics of each reach, and their geomorphology, floodplain condition, and extent of human alteration are described in detail in the subsequent sections.

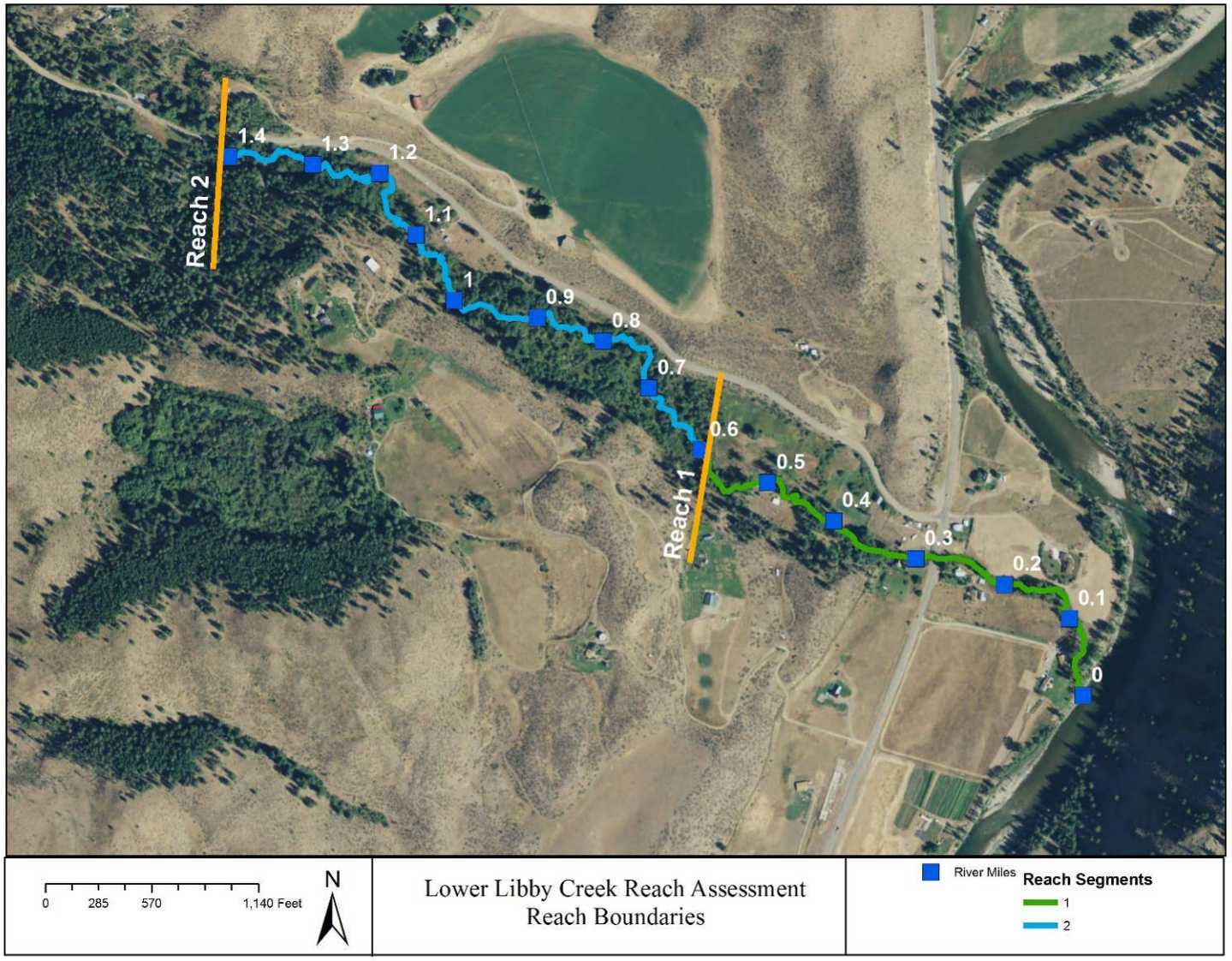

Figure 4. Libby Creek reaches and river mile stationing (RM 0.0 to RM 1.4)

5.1 Reach 1

Reach Overview

Reach 1 is a semi-confined reach that extends 0.58 RM from the confluence of the Methow River. This reach is mostly inset into Holocene-aged alluvial deposits of the Methow River and Libby Creek. Field observation and historical information indicate that Libby Creek's entrenchment into the Holocene alluvial deposits is a natural geomorphic process that has been accelerated by anthropogenic activities. Incision into the historic alluvial fan and further human-induced channelization limits channel processes and mobility. Residential and agricultural development have further accelerated rates of incision. The bed morphology is largely riffle-glide and step-pool. Access to off-channel habitats is limited in Reach 1.

Geomorphology

Bed morphology throughout Reach 1 shifts between riffle-glide and step-pool. Bed substrate is dominated by gravels and cobbles with boulders scattered throughout the reach. The reach has a sinuosity of 1.30 and a gradient of 2.11%. Libby Creek has a modern steep small alluvial fan at its mouth where it enters the Methow River.

Modern channel form and substrate are greatly influenced by the historical alluvial terraces that Libby Creek is entrenched into. Natural incision into the terraces likely began as a result of changes in climate, hydraulic regime, and sediment supply of the early Holocene. Since that time Libby Creek has gradually and naturally lowered its bed elevation by incising into the historical alluvial deposits. Over the last 150 years Lower Libby Creek has been ditched and straightened (USDA 1999a, Andonaegui 2000), riparian vegetation has been altered, roads have been built adjacent to stream channels, and banks have been armored. Further, timber harvest of over 16,000 acres since the early 1960s (Andonaegui 2000) has likely altered the hydrologic regime by increasing flashy flows. Each of these alterations have reduced channel length, removed hydraulic roughness and increased bed shear -- all of which promote incision. Evidence of incision is based on field investigations of the modern geomorphic processes of the channel. The exact influence of anthropogenic activities on incision rates is not known for this reach. Determining modern incision rates will require an analysis of sediment transport competence and effective discharge.

Despite anthropogenic influences on the study area localized rates of incision have appeared to have slowed enough for development of small modern floodplain surfaces at the current base elevation. In the lower portion of Libby Creek reduced incision rates may be influenced by the abundance of relatively large sized substrate (cobbles and boulders) on the channel bed.

In Reach 1, channel gradient, lack of large wood, and anthropogenic channelization all prevent the recruitment of finer-grained sediment. This has led to excessive sediment transport, and although the rate of incision appears to have slowed, further bed incision remains a concern.

Lateral channel dynamics have been inhibited by the entrenchment of lower Libby Creek but not

stopped, especially in the upper portion of Reach 1. The rate at which lateral migration occurs is dependent upon the bed and bank composition as well as riparian roughness. In areas were bank materials are easily erodible (e.g. unarmored gravels, lacking mature riparian vegetation) lateral migration will likely continue.

A short section of partial channel aggradation occurs at mid-reach. This is an expected result of upstream incision processes transporting scoured bed material downstream and depositing it. This process commonly occurs in degrading systems as a cyclic channel response.

Only minor wood inputs and accumulations were observed in this reach. Where these accumulations are present, the channel has responded with localized pool development, some sediment retention, reduced gradient, increased sinuosity, and increased complexity.

Floodplain

Connected modern floodplain areas account for 4.2% percent of the total Reach 1 subunit area. The connected floodplains that do exist are found in small, discrete pockets with the largest floodplain subunit spanning just 0.21 acres and the majority being below 0.05 acres. Floodplains and terraces near the river are mostly vegetated, with the exception of some areas along the left bank. Vegetation is dominated by cottonwood, willow, dogwood, and rose. Both the active floodplain and historical floodplain surface as well as the bordering terrace surfaces have been altered by human land use practices.

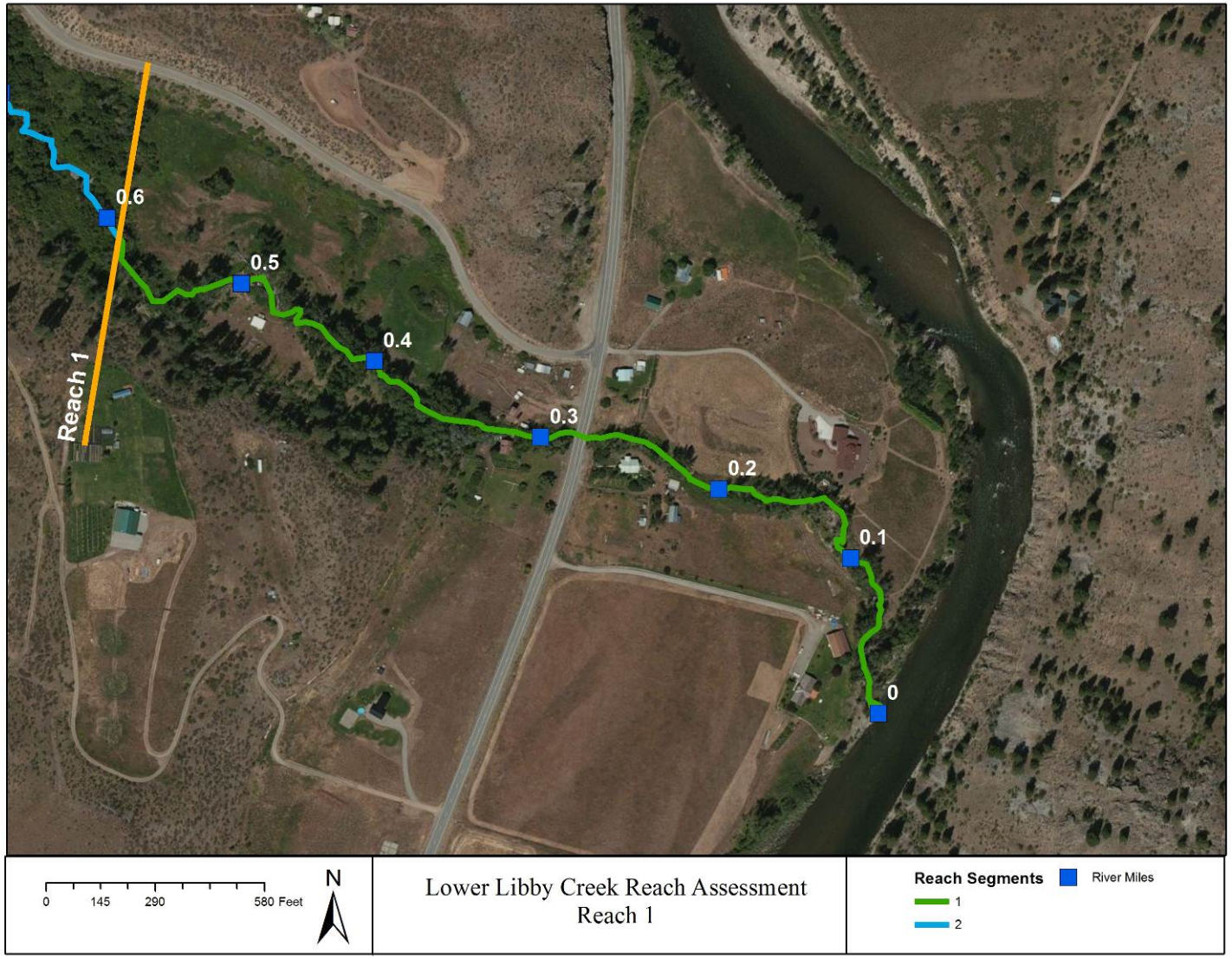

Figure 5. Reach 1 overview. Reach 1 extends from the confluence of Libby Creek and the Methow River (RM 0.0) upstream to RM 0.6.

Human Alterations

Anthropogenic influence on the river corridor is extensive throughout Reach 1. Limited residential development and agriculture is present throughout the reach along both banks, but historically the Creek has been channelized and basin-scale activities have accelerated incision processes. This development has resulted in floodplain alterations, instream alterations, and modifications to the riparian corridor. Each category is expanded upon below and distribution of these features is presented in Figure 8.

Floodplain Alterations

The most notable floodplain alteration is the lack of accessible floodplain surfaces, due to accelerated incision processes. Moderate residential development has taken place along both banks throughout the reach. This is low-density rural development and there have been limited additions of impervious surfaces. The development includes some grading of lawns and structures on historical floodplain surfaces.

Riparian Alterations

Riparian vegetation has been cleared or altered at multiple points throughout the reach. Metal mesh fencing has been placed around the base of larger trees (mostly cottonwood) throughout the lower portion of the reach, presumably to prevent beaver activity. This has prevented beaver from using riparian vegetation to build dams, which would provide valuable habitat complexity, recruit gravel substrate, and provide pool habitat.

Instream Alterations

There are multiple instream alterations present throughout Reach 1. Two of the most significant alterations within Reach 1 are a 42-ft long riprap wall that has been installed along the river left bank at RM 0.11 (Figure 6) and the Highway 153 bridge (Figure 7).

Figure 6. Riprap wall near RM 0.11. The top elevation is approximately 5.5 ft above OWH.

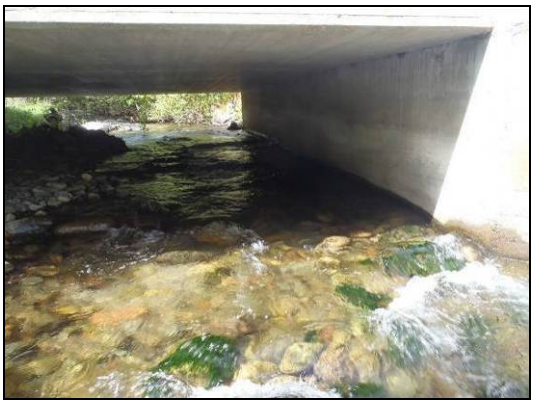

Figure 7. Highway 153 bridge facing upstream.

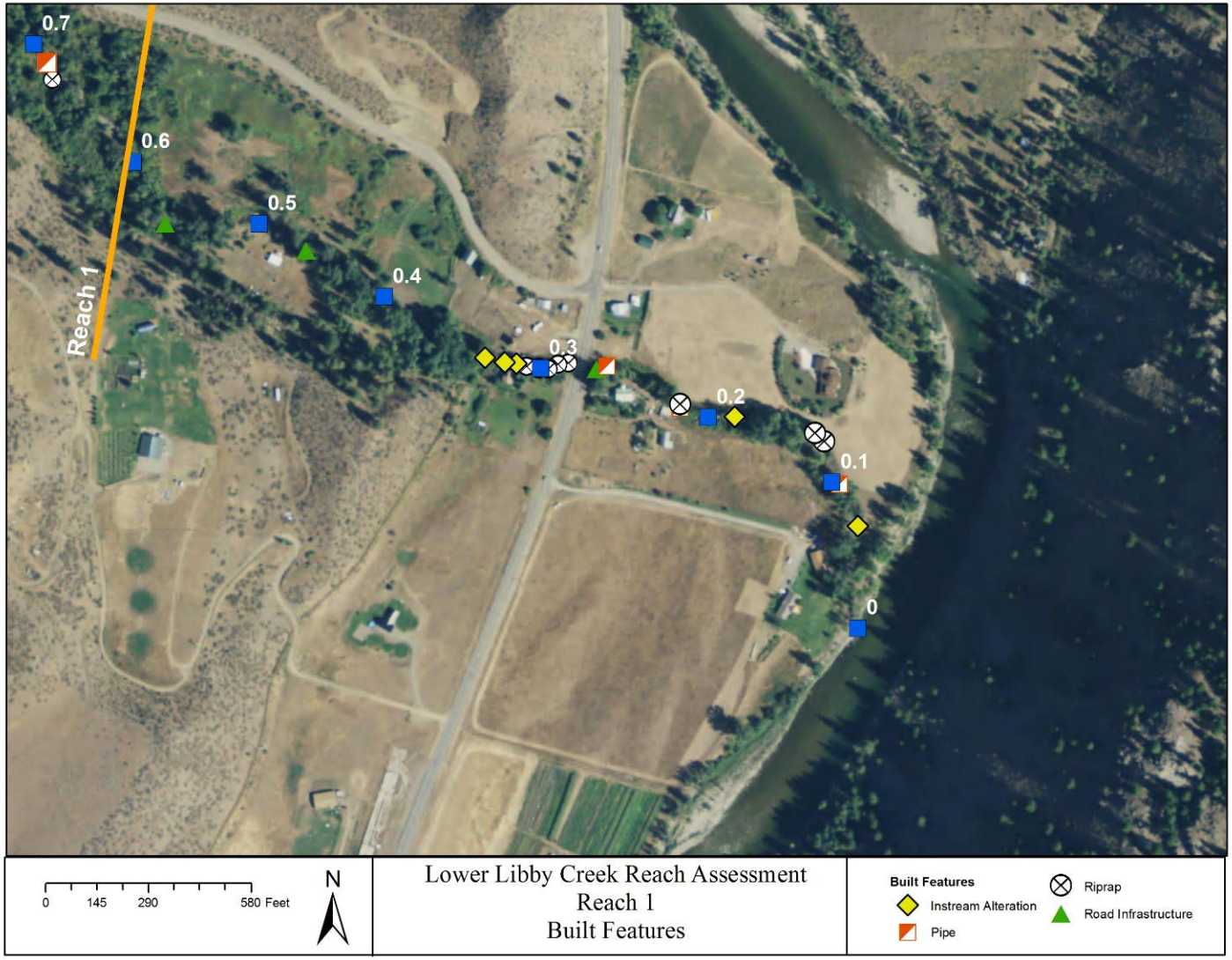

Figure 8. Human alterations in Reach 1.

Restoration Strategy Overview

This reach is largely confined, lacks access to the floodplain, and has minimal off-channel habitat. Opportunities to reduce incision processes and reconnect the channel with modern floodplain surfaces should be prioritized. Riprap should be removed throughout the reach and vegetated riparian buffers along developed areas should be restored and/or widened. Further, the lack of wood throughout the reach should be alleviated by the addition of small wood jams wherever possible. The addition of large wood will promote the development of pool habitat, provide hydraulic complexity, and will recruit spawning gravels.

Thirty six subunits were identified in Reach 1, including seven disconnected outer zones, sixteen inner zones, and thirteen outer zones (Table 5, Figure 9, and Figure 10). The majority (95.8%) of the river's historical floodplain surfaces have become disconnected through a combination of natural and human-accelerated incision of Libby Creek and riprap channelization. Connected outer zones are small, discrete floodplain pockets (less than 0.2 acres) that provide space for overland flow.

The restoration strategy for each subunit is presented in Table 5. Thirteen specific project opportunities that are included in Table 5 have been identified in this reach and are mapped in Figure 11 and Figure 12. Additional project detail is provided in Appendix B.

Table 5. Subunit scale restoration strategy for Reach 1. Individual projects are listed under their respective restoration strategy category. Additional detail on projects is included in Appendix B.

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
01-DOZ-01	DOZ	6.26	• This is an historical floodplain surface that has become abandoned from incision • Surface is mostly pasture used for grazing; Vegetation has been cleared and fencing has been installed • Surface extends from the top of bank to Libby Creek Road • Contains spring and small wetland pockets with patches of aspen groves and willow.	Reconnect Floodplain Processes • Project RM 0.41 - Floodplain Reconnection • Project RM 0.41 - Floodplain Reconnection
01-DOZ-02	DOZ	0.36	• This is a well-vegetated surface along the right bank • This is an historical floodplain surface that has become abandoned from incision • surface extends from the top of bank to the valley's confining hillslope • The DOZ is bisected by an ephemeral tributary that connects to Libby Creek	
01-DOZ-03	DOZ	1.85	• This is an historical floodplain surface that has become abandoned from incision • A residential trailer is located on river right at the upstream end • The boundaries of this subunit are marked by aspen and cottonwood	Reconnect Stream Channel Processes • Project RM 0.41 - Floodplain Reconnection • Project RM 0.41 - Floodplain Reconnection
01-DOZ-04	DOZ	0.37	• This is an historical floodplain surface that has become abandoned from incision • Banks are steeply sloping • Composed of cobble to sands • The land has been cleared for pasture and residential development • The downstream end of this unit is bounded by Highway 153	
01-DOZ-05	DOZ	0.63	• This is an historical floodplain surface that has become abandoned from incision • Alluvium of cobbles to sands are expansive along this DOZ	
01-DOZ-06	DOZ	2.89	• This is an alluvial terrace that has become abandoned from incision • Surface is a well-vegetate near channel margins; including aspen, rose, alder, and cottonwood	Riparian Restoration • Project RM 0.06 (Left Bank) - Riparian Restoration

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• The floodplain has been cleared for pasture • The surface appears to be inundated very rarely • Large rounded boulders and minor racked material are scattered across the surface	
01-DOZ-07	DOZ	3.74	• This is an alluvial terrace that has become abandoned from incision • Surface is a well-vegetate; including aspen, rose, alder, and cottonwood near the channel margins • The floodplain has been cleared for pasture • The surface appears to be inundated very rarely • Contains multiple homesites, and is bisected by a private road	
01-IZ-01	IZ	0.08	• Step-pool channel morphology • Steps are been made of large boulders • Banks are well vegetated with a dense mix of cottonwood, alder, and willow • Small wood accumulations are evident on the channel margins, but are absent on floodplain surfaces • An ephemeral drainage joins the right bank but was not wetted on the date of the survey • One channel-spanning Large Wood jam was evident on the date of the survey and was accumulating gravels	
01-IZ-02	IZ	0.11	• a long straight riffle • minimal lateral migrating, but still maintains a gully-like appearance • The banks are largely cobbles at the base with gravel and sand at the top	
01-IZ-03	IZ	0.09	• This subunit is defined by a series of channel-spanning Large Wood jams that create a step-pool sequence • Inadequate riparian cover • Large Wood jams reduce channel gradient, add complexity, and raise the water table • Noticeably more gravel and sand throughout • Evidence of beaver activity throughout	Instream Habitat Enhancement • Project RM 0.15 - Large Wood Enhancement
01-IZ-04	IZ	0.05	• steep-pool sequence morphology with large boulder steps • Substrate ranges from large boulders to sands in pool	

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• Right bank vegetation is altered and has been thinned • Large Wood jam creates mid-channel complexity • Right bank is vertical; </= eight feet above channe l	
01-IZ-05	IZ	0.24	• Long extended riffles with short, small pools • Substrate is cobble to gravel • The banks are vertical but have dense riparian cover that offer good canopy cover • Channel is incised	
01-IZ-06	IZ	0.06	• A constructed step-pool sequence near a homesite • Right bank vegetation has been altered for residential development • One galvanized 4'' pipe and one 3'' plastic pipe spans the channel	Reconnect Stream Channel Processes • Project RM 0.33 - Transverse Bar Construction
01-IZ-07	IZ	0.11	• Step-pool morphology with boulder substrate • Confined by large boulder riprap and vertical banks • Downstream end is confined by Highway 153 Bridge	Reconnect Stream Channel Processes • Project RM 0.3 - Riprap removal & grade control
01-IZ-08	IZ	0.07	• Step-pool morphology with boulder steps • Upstream end is laterally confined by Highway 153 Bridge • Banks are composed of partially cemented conglomerate alluvium • Substrate has become armored throughout this IZ. This condition is likely caused by scour from the bridge constriction	Reconnect Stream Channel Processes • Project RM 0.29 - Replace Highway 153 Bridge
01-IZ-09	IZ	0.03	• Pool-riffle channel morphology • Substrate is dominated by sand ; less gravels as compared with upstream unit (IZ-08) • Thick overhanging vegetation throughout	Reconnect Stream Channel Processes • Project RM 0.21-C - Remove Channel Spanning Wood Bridge and Replace with Channel-spanning jam
01-IZ-10	IZ	0.07	• Riffle-glide channel morphology • Substrate is gravel to cobbles • Dense riparian canopy continues throughout • Floodplain connectivity has increased; some aggradation is visible throughout the left bank	Reconnect Stream Channel Processes • Project RM 0.12 – Remove Riprap
01-IZ-11	IZ	0.02	• This subunit is made up of a short cascade and step-pool sequence	

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• Steps are approximately 1- to 2-feet high • Substrate ranges from cobbles to very coarse sands • Limited connectivity to floodplain	
01-IZ-12	IZ	0.05	• Channel is narrow and flume-like through this stretch • High gradient riffle morphology • Banks are vertical and range from 1 to 2 feet • A deep pool is associated with a large downed cottonwood root wad, which is accumulating Large Wood material	
01-IZ-13	IZ	0.03	• Riffle-glide channel morphology • Lower gradient IZ than IZ-12 • Substrate ranges from cobbles to very coarse sands • The right bank is gradually sloping away from vertical	
01-IZ-14	IZ	0.07	• Step-pool channel morphology • Substrate is cobbles to small gravels • The channel lacks sinuosity through this IZ • Vertical banks (approximately 2' high) line the channel on both sides of the channel	
01-IZ-15	IZ	0.07	• Low gradient riffle-glide unit • Substrate is cobble to coarse sand • Gradual sloping banks	Instream Habitat Enhancement • Project RM 0.04 – Large wood enhancement
01-IZ-16	IZ	0.03	• Confluence of Libby Creek and Methow River • Channel flow has split into two short, steep riffles that flow out of an area dammed by beaver activity • Sediment (sand to cobble) is accumulating at the mouth and the toe of the fan is steeply sloped and drops 2 to 3 feet at approximately a 10% grade at the confluence • Willows have established along the toe of the fan	Instream Habitat Enhancement • Project RM 0.0 - Monitor and maintain fish passage at low flow
01-OZ-01	OZ	0.04	• This floodplain pocket appears to be regularly inundated • Evidence of fresh deposits of large wood and sand • Surface is composed of cobbles to sand	Protect & Maintain

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• Thick vegetative cover of cottonwood and alder	
01-OZ-02	OZ	0.01	• Small area of active floodplain • Surface is approximately 3 ft above channel invert • Dense vegetation that includes cottonwood and alder • Fresh sand deposits on the surface indicate recent deposition on this surface	Protect & Maintain
01-OZ-03	OZ	0.05	• Along the right bank of the channel this floodplain pocket appears to be regularly inundated • Evidence of fresh deposits of large wood and sand • Surface is composed of cobbles to sand • Thick vegetative cover of cottonwood and alder	Protect & Maintain Reconnect Floodplain Processes • Project RM 0.38 – Floodplain excavation and restoration
01-OZ-04	OZ	0.02	• Surface is composed of cobbles to sand • Thick vegetative cover of cottonwood and alder but inland portion has a small patch of blackberry and reed canary grass	Protect & Maintain
01-OZ-05	OZ	0.14	• Vegetated with horsetail, cottonwood, and dogwood • Evidence of fresh deposits of large wood and sand • Surface is composed of cobbles to sand • Wire fencing around base of larger trees to prevent beaver chewing • This unit is more aggradational than the units downstream	Protect & Maintain
01-OZ-06	OZ	0.21	• This is a low elevation surface • Evidence of fresh deposits of large wood and sand	Protect & Maintain
01-OZ-07	OZ	0.01	• Evidence of fresh deposits of large wood and sand • Surface is composed of cobbles to sand • Vegetation dominated by dogwood	Protect & Maintain
01-OZ-08	OZ	0.01	• This floodplain pocket appears to be regularly inundated • Evidence of fresh deposits of large wood and sand • Surface is composed of cobbles to boulders • Thick vegetative cover of cottonwood and alder	Protect & Maintain
01-OZ-09	OZ	0.03	• This is a low elevation surface (approximately 2 feet off of the channel) • Single log bridge lying across the floodplain that is accumulating wood	Protect & Maintain

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
01-OZ-10	OZ	0.03	• Deposition of cobbles to sands • Minor areas of gravel and cobble accumulation present • Recent scour evident on alluvial fan • Vegetation is primarily alder and cottonwood	Protect & Maintain
01-OZ-11	OZ	0.13	• Scouring evident • Riparian area vegetated with cottonwood • Entire area could not be surveyed because of landowner access restrictions	Protect & Maintain
01-OZ-12	OZ	0.02	• This is an alluvial fan near the confluence with the Methow River • Substrate is cobble to sand • Sparsely vegetated with willow • Dynamic surface evidenced by recent scouring flows (deposition of sands and large wood material)	Protect & Maintain

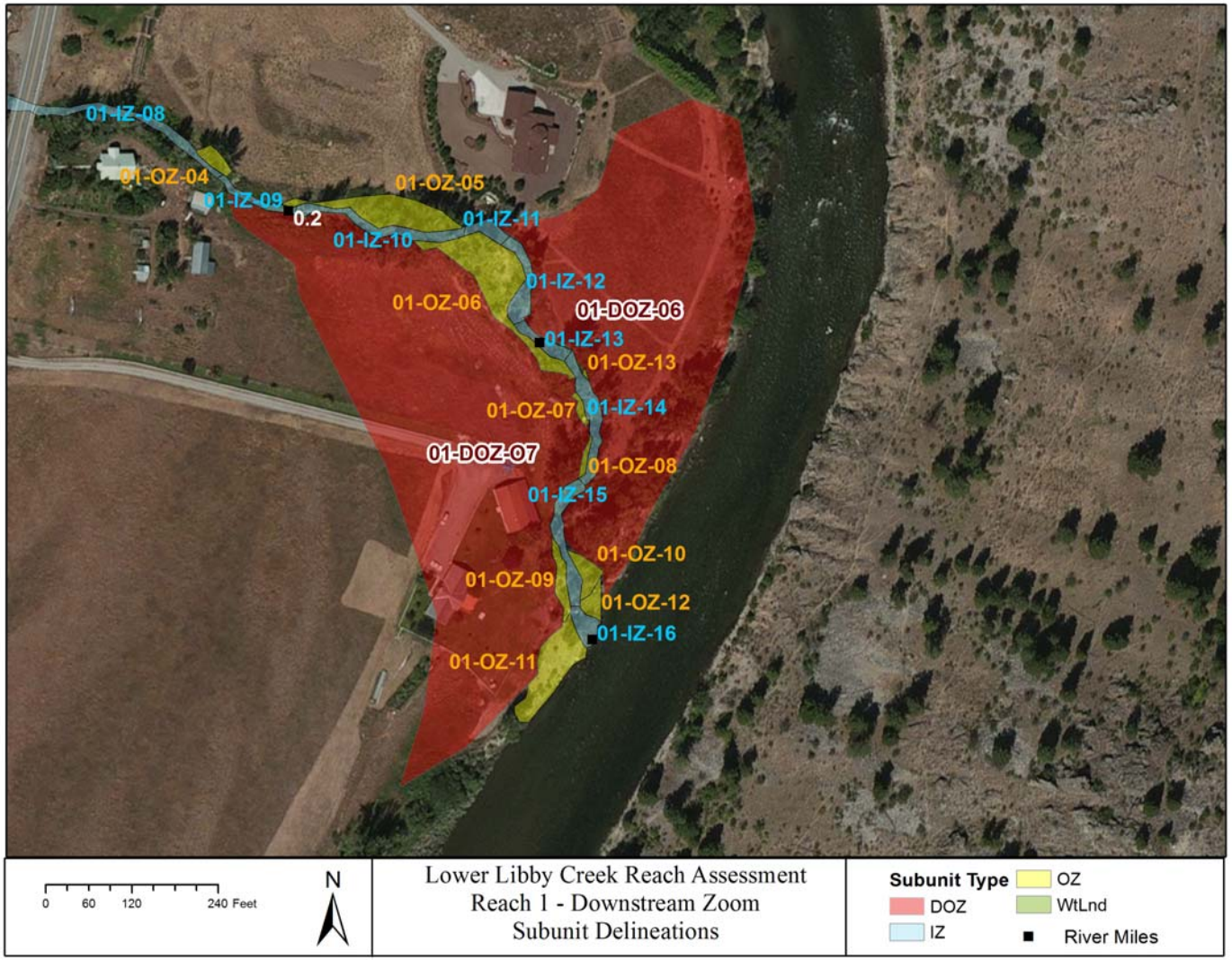

Figure 9. Subunit delineations in the downstream portion of Reach 1. Flow is from northwest to southeast.

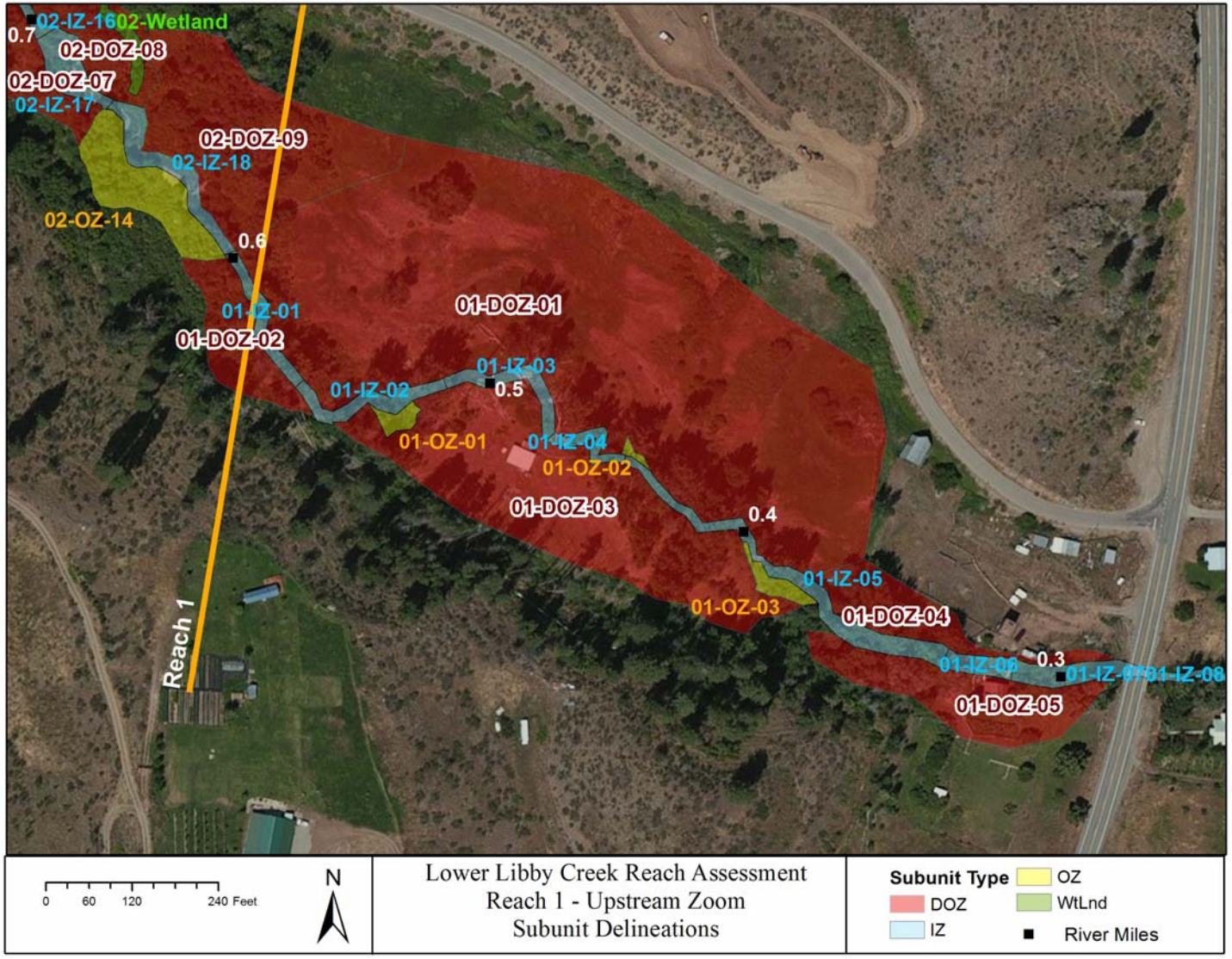

Figure 10. Subunit delineations in the upstream portion of Reach 1. Flow is from northwest to southeast.

Figure 11. Potential project locations in the downstream portion of Reach 1. Project photographs are provided for selected sites to illustrate the types of project opportunities that are available throughout the reach. Additional project detail is included in Appendix B.

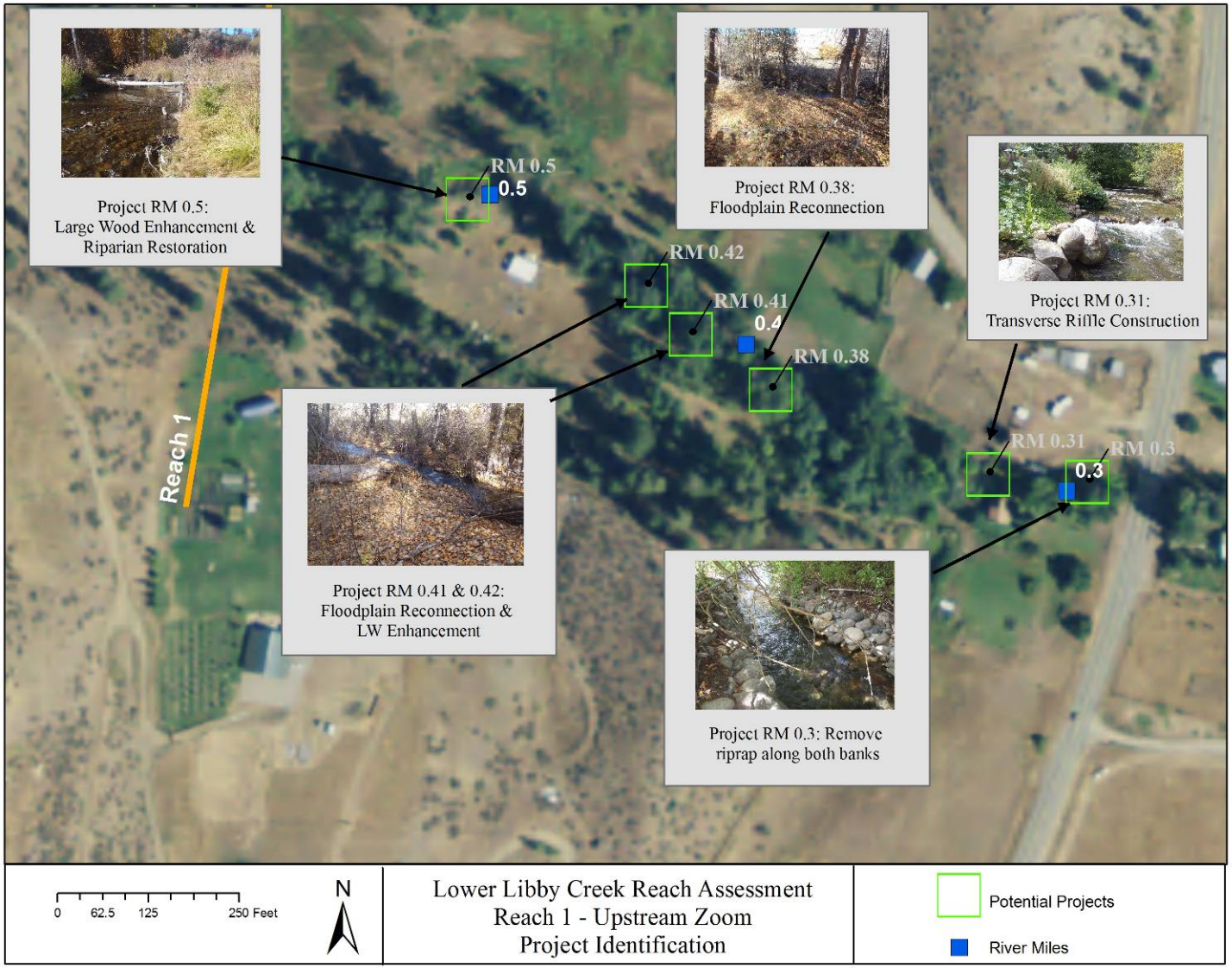

Figure 12. Potential project locations in the upstream portion of Reach 1. Additional project detail is included in Appendix B.

5.2 Reach 2

Reach Overview

Reach 2 begins at RM 0.58 and extends upstream to the end of the survey reach at River Mile 1.42 (RM 1.4). This section of Libby Creek has a slightly steeper gradient (increasing from 2.11% to 2.95%) than Reach 1 and enters into a semi-confined valley between Libby Creek Road (to the north of the channel) and a hillslope terrace (to the south of the channel). The sinuosity increased from 1.30 to 1.42, and the overall canopy cover increased compared to Reach 1.

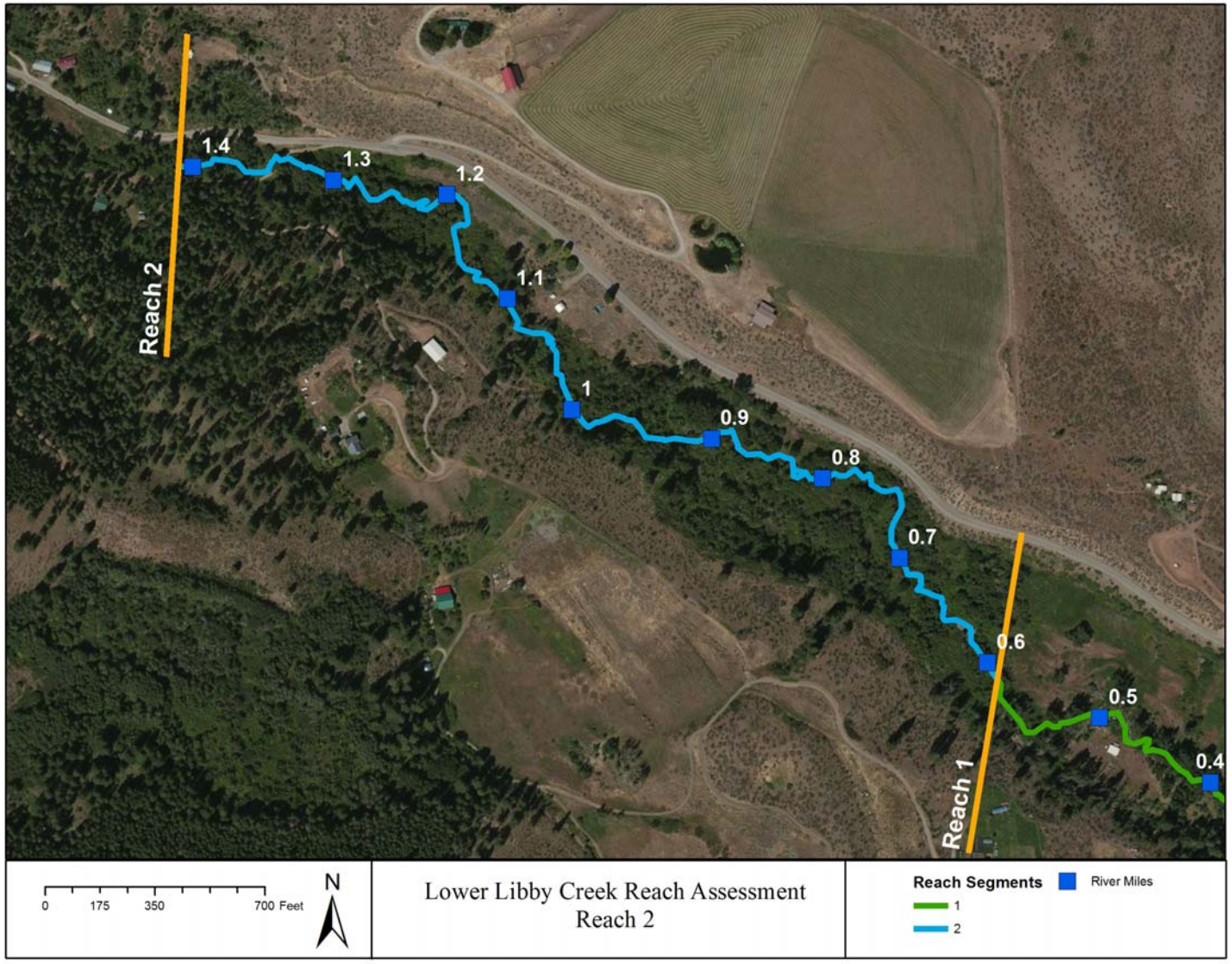

Figure 13. Reach 2 overview. Reach 2 extends from RM 0.58 upstream to RM 1.4.

Geomorphology

The channel through this reach is dominated by sequences of steep, extended riffles and pools. Smaller sequences of step-pools are interspersed throughout the reach. The lateral migration of the creek is constrained by Libby Creek Road to the north and the hillslope to the south. Bed substrate throughout this reach was predominantly gravels and cobbles, although boulders and sand were prevalent in the step-pool sequences.

The channel becomes increasingly complex throughout this reach. The channel transitions from incising to alternating sequences of aggradation and incision. This is evident from the development of point bars and mid-channel bars at aggradation sequences within the reach. This aggradation is most dominant in areas of beaver activity and large wood accumulation and is promoting localized areas of lateral migration within the channel. Large wood accumulations create complex step-pool sequences and reduce stream gradient, promote aggradation, increase complexity (both habitat and geomorphic), increase floodplain connections, and minimize incision.

Floodplain

As Libby Creek works to reestablish lateral migration inset within historical alluvial surfaces, it has formed new floodplain surfaces at its current incised channel elevation. These modern floodplain surfaces range from six to twelve feet below the historical floodplain surface at the creek's current baseflow elevation. Development of modern floodplain surfaces appears to be in areas of large wood accumulations. These large wood accumulations induce recruitment of gravels upon which vegetation establishes and a floodplain develops. In other locations, large wood has led to channel avulsion and the historical channel locations have subsequently become floodplain. This is evident in areas where even-aged alder stands have developed on inset floodplains in the upstream portions of Reach 2.

Floodplains and terraces near the river are mostly vegetated and vegetation is dominated by alder, cottonwood, willow, dogwood, and rose. Historical floodplain surfaces alternate between well-vegetated to pasture. A county owned property extends from RM 0.6 to RM 1.0 and provides forest cover along this abandoned terrace for 200 feet along the left and right banks. Conversely, segments of the historical floodplain surface up and downstream of this preserve have been cleared for residential development. This includes the removal of riparian canopy and apparent streamside grazing.

A 0.06-acre area of a perched spring bisects an historical floodplain surface (02-DOZ-01). This wetland complex runs along the base of the hillslope on river-left and is likely fed by groundwater and/or spring seeps. This is a functioning wetland system with cool standing water and a diverse mix of vegetation. The shape and inland terrace boundary of the wetland indicates that it is located in an abandoned channel.

Human Alterations

The current state of anthropogenic influence on the river corridor throughout Reach 2 is moderate. Large wood accumulations, bedrock control, and limited bank armoring have allowed the creek to generate increased complexity as compared with Reach 1. However, limited residential development and agriculture is present throughout the reach along both banks below RM 0.6 and upstream of RM 1.0. This development has resulted in floodplain alterations, instream alterations, and modifications to the riparian corridor. Each category is expanded upon below and distribution of these features is presented in Figure 14.

Floodplain

Similar to Reach 1, the most notable floodplain alteration is the disconnection of historical floodplain surfaces throughout the reach. Natural incision processes have been accelerated by human-induced activities such a timber harvest, road building, and beaver removal. As previously mentioned, upstream of RM 1.0 and downstream of RM 0.6, historical floodplain surfaces have been cleared and altered. These areas are primarily being used for grazing or low density rural development.

Riparian

Similar to Reach 1, riparian vegetation has been cleared or altered at multiple points throughout the reach. There are small segments where the riparian canopy has been completely removed.

Instream

At the downstream end of the reach, Libby Creek has been channelized and confined through riprap bank protection. This has accelerated incision throughout this portion of the channel. Humans have further modified the channel bed by constructing step-pools and digging out of areas of the channel bed. At the upstream end of the reach, riprap and bridge abutments confine the channel and there is evidence of channel incision. A private road continues from Libby Creek Road, over the bridge, and then along the right bank. The road fill confines the channel by limiting lateral migration.

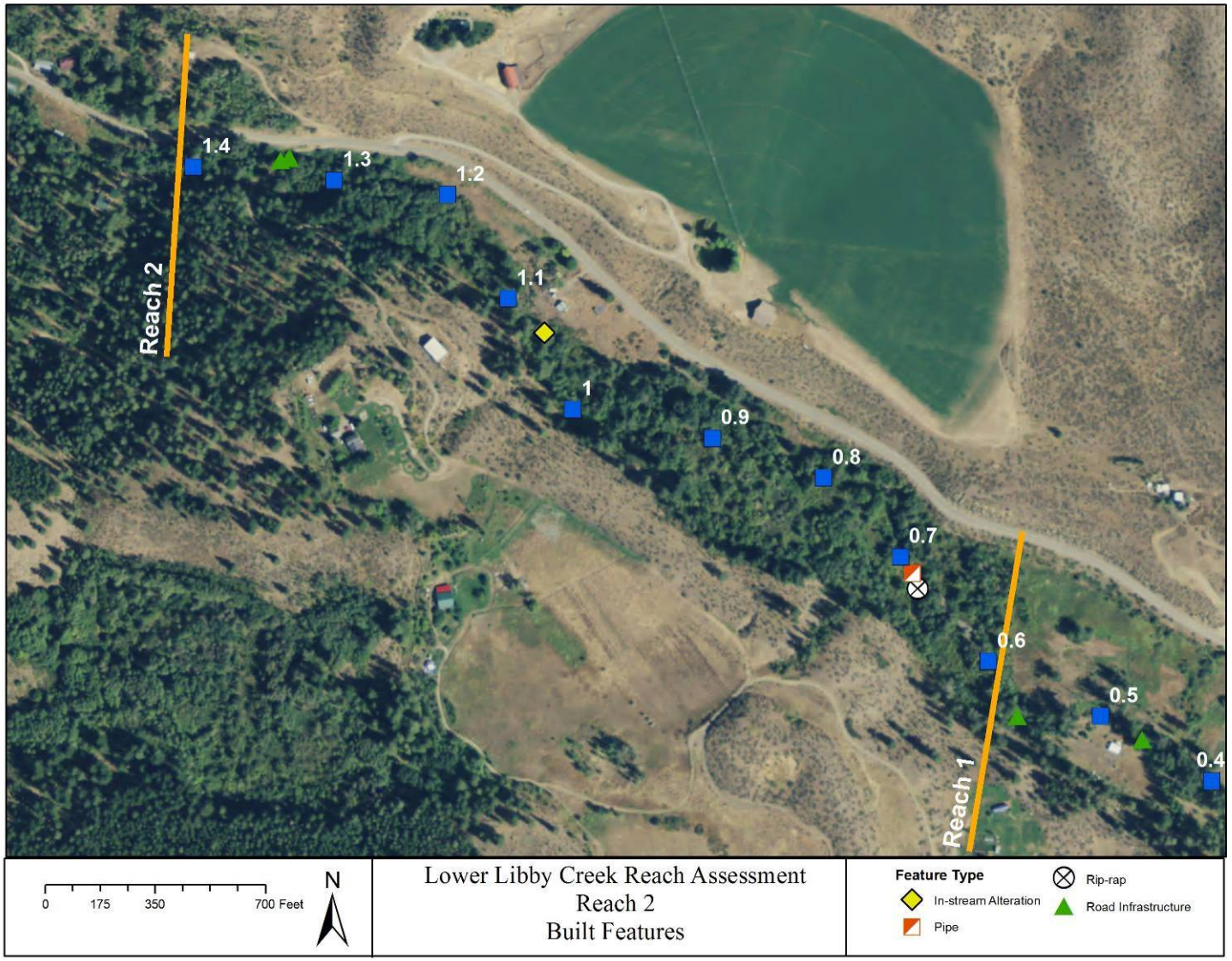

Figure 14. Aerial photo showing human features in Reach 2.

Restoration Strategy Overview

Overall, the geomorphic and habitat complexity is improved from Reach 1. Large wood accumulations are promoting lateral channel dynamics, pool scour, recruitment of gravels, and development of new floodplains at the creek's current baseflow elevation. Locations that lack large wood and habitat diversity within the reach should be alleviated through the addition of large wood to further encourage floodplain development and habitat diversity within the channel.

Forty-two subunits were identified in Reach 2, including nine disconnected outer zones, eighteen inner zones, and fourteen outer zones (Table 6, Figure 15, Figure 16). The majority of the historical floodplain is disconnected (80%), with only small, discrete active floodplain areas remaining. This current condition provides substantial opportunity for restoration and enhancement. The lack of active floodplain and off-channel habitat should be mitigated wherever possible.

The restoration strategy for each subunit is presented in Table 6. Eight specific project opportunities have been identified in this reach and these are included in the table and are mapped in Figure 17 and Figure 18. Additional project detail is provided in Appendix B.

Table 6. Subunit scale restoration strategy for Reach 2. Individual projects are listed under their respective restoration strategy category. Additional detail on projects is included in Appendix B.

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
02-DOZ-01	DOZ	0.12	• An historical floodplain surface that has become abandoned from incision and road construction • Vegetation has been altered by the construction of a gravel road; dust from the road is adding fines to the stream	Riparian Restoration • Project RM 0.62 - Riparian restoration (right bank)
02-DOZ-02	DOZ	0.37	• An historical floodplain surface that has become abandoned from incision • Very well vegetated	
02-DOZ-03	DOZ	0.44	• An historical floodplain surface that has become abandoned from incision • Very well vegetated	
02-DOZ-04	DOZ	0.80	• An historical floodplain surface that has become abandoned from incision and home construction • Anthropogenic activities have altered the streambank and riparian vegetation	
02-DOZ-05	DOZ	0.07	• An historical floodplain surface that has become abandoned from incision • Very well vegetated	
02-DOZ-06	DOZ	2.55	• An historical floodplain surface that has become abandoned from incision • Very well vegetated • Provides vegetated buffers to perched wetland	Protect & Maintain
02-DOZ-07	DOZ	2.99	• An historical floodplain surface that has become abandoned from incision • Very well vegetated	Riparian Restoration • Project RM 0.7 - Riparian Restoration
02-DOZ-08	DOZ	0.43	• Dominated by a well-functioning, but perched, spring-fed wetland complex. • Located in an abandoned channel on an historical floodplain surface • There is no evidence of recent inundation • No evidence of connection to the channel and the complex	Protect & Maintain

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			is perched ~ 8 feet above the channel's surface at its downstream end • The water is cool and clear • Evidence of some beaver activity • Some fill has been deposited at the upstream end of the unit • Evidence of an old berm connected to a derelict culvert exists, likely used to drain the wetland historically • Dense vegetation exists throughout the unit including alder, dogwood, willow, aspen and emergent wetland vegetation • Provides vegetated buffer to perched wetland	
02-DOZ-09	DOZ	1.31	• An historical floodplain surface that has become abandoned from incision • Unit extends from top of bank to Libby Creek Road • Includes additional areas of perched wetland complex, which has become disconnected from the channel due to incision • The upstream portion of the unit has wetted areas that appear to be spring fed • Area has been cleared and leveled to be used as pasture	
02-IZ-01	IZ	0.05	• Subtle step-pool morphology • Substrate is small boulders and large cobbles • Vegetation is removed for a gravel road	
02-IZ-02	IZ	0.05	• Riffle-pool morphology • Sparse boulders to cobbles • Banks are well-vegetated • A few undercut banks are present throughout, providing small amounts of cover	Reconnect Stream Channel Processes • Project RM 1.35 - Bridge Replacement
02-IZ-03	IZ	0.07	• Riffle-pool morphology; with one cascade over large boulders • Substrate is cobbles with sparse boulders • Both banks through are well-vegetated and offer good canopy cover	Reconnect Stream Channel Processes • Project RM 1.35 - Bridge Replacement

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
02-IZ-04	IZ	0.04	• Riffle-pool morphology • Substrate is cobble to gravels • The right bank has been disconnected from incision • Two large wood material jams were present at the time of survey	
02-IZ-05	IZ	0.03	• Step-pool morphology; steps are defined by boulders • Substrate is boulders (steps) to sands (located in pools) • Small point bars are forming on the inside of meander bends, which is expanding the connected floodplain OZs (OZ-04, OZ-05) along both banks	
02-IZ-06	IZ	0.16	• Riffle-pool morphology • Substrate is cobbles with sparse gravels and sand • The right bank floodplain is connected, and the left bank slopes up sharply to an abandoned alluvial terrace approximately 3 feet above the channel's elevation • Both banks are well vegetated and provide excellent canopy cover • Deposition (of cobbles, gravels) on the inside of meander bends is more subtle than in IZ-05	Reconnect Stream Channel Processes • Project RM 1.18 - Large Wood Enhancement
02-IZ-07	IZ	0.07	• Cascade-pool morphology • Substrate of pools is cobles and gravels, banks are composed of cobbles and sand • Left bank (DOZ 04) has had vegetation cleared for residential development	
02-IZ-08	IZ	0.07	• Step-pool morphology; steps are a mix of cobbles and boulders • Canopy cover throughout is >90% • A secondary high-flow channel has formed through this IZ, at the time of survey it was not wetted, and was disconnected from a large material jam forming at divergence	
02-IZ-09	IZ	0.04	• Step-pools morphology created by Large Wood jams • Substrate is primarily sand, with large cobbles and sparse	

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			gravels • Both banks throughout are well-vegetated with dense overhanging vegetation that offers good canopy cover	
02-IZ-10	IZ	0.05	• High gradient riffles morphology with short, intermittent glides • Dense vegetation along both banks • Intermittent undercut banks throughout	
02-IZ-11	IZ	0.10	• Riffle-pool morphology • Substrate is cobble to sand, with a few sparse boulders • A cool spring seep source enters the channel here • Bedrock exposure is evident at spring seep location • Channel-spanning overhanging vegetation is present (primarily dogwood)	
02-IZ-12	IZ	0.14	• Riffle-pool morphology • Substrate is cobble to gravel • Point bars deposits of gravel are forming on the inside of meander bends • Occasional mid-channel bars are forming	
02-IZ-13	IZ	0.06	• Riffle pool morphology • Substrate is cobbles to coarse sand, sparse boulders are present • Channel has access to smaller connected floodplains (OZ-09, 0Z-10), which are inset below higher, disconnected alluvial terraces	
02-IZ-14	IZ	0.09	• Riffle-pool morphology • Substrate is cobbles to coarse sand, sparse boulders are present • Channel has access to smaller connected floodplains (OZ-09, 0Z-10), which are inset below higher, disconnected alluvial terraces	Instream Habitat Enhancement • Project RM 0.9- Large Wood Enhancement
02-IZ-15	IZ	0.06	• Riffle-run-pool morphology • Substrate is cobble to sand	Instream Habitat Enhancement • Project RM 0.75 - Large Wood Enhancement

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• Gravel accumulations on the inside of meander bends forms point bars • Riffle is lower gradient than upstream (IZ-14) • Three channel-spanning jams are accumulating gravel and sands	
02-IZ-16	IZ	0.02	• Long riffles with short pool morphology • Substrate is cobble to sand with a few small boulders • No point bars forming on the margins • Banks are well vegetated	Instream Habitat Enhancement • Project RM 0.71 - Large Wood Enhancement
02-IZ-17	IZ	0.12	• Step-pool morphology • Substrate is cobbles to very coarse sand • Large Wood accumulations are present • Small gravels to small cobbles are accumulating along the inside of meander bends • Dense vegetation along both banks • Banks are cobbles to sand at base, with sandy loam along the tops of banks	Instream Habitat Enhancement • Project RM 0.7 - Large Wood Enhancement
02-IZ-18	IZ	0.15	• Riffle-pool braided morphology • Channel is aggrading • Substrate is cobble to sand • Mid-channel point bars are dominated by gravels and sands, and some vegetation has established on them	
02-OZ-01	OZ	0.03	• Evidence of overland flow (sand deposition, Large Wood racked in vegetation) • Well-vegetated with thick shrubs and trees	Protect & Maintain
02-OZ-02	OZ	0.05	• Evidence of overland flow (sand deposition, Large Wood racked in vegetation) • Well-vegetated with thick shrubs and trees	Protect & Maintain
02-OZ-03	OZ	0.07	• Well-vegetated with mostly alder	Protect & Maintain
02-OZ-04	OZ	0.30	• Vegetation has been cleared along bank for residential development	Protect & Maintain Riparian Restoration

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
				• Project RM 1.07 - Riparian Restoration
02-OZ-05	OZ	0.06	• Dense stand of even-aged alders- indicates channel has realigned through avulsion, or human induced realignment	Protect & Maintain
02-OZ-06	OZ	0.23	• Low elevation surface- seems to be inundated regularly throughout the high-flow season • Point bar is developing at downstream end	Protect & Maintain Reconnect Floodplain Processes • Project RM 1.18 - Large Wood Enhancement
02-OZ-07	OZ	0.13	• Well-vegetated floodplain surface (largely dogwood, cottonwood, and horsetail) • Surface is sand to cobbles	Protect & Maintain Reconnect Stream Channel Processes • Project RM 0.9- Large Wood Enhancement & Fill Removal
02-OZ-08	OZ	0.19	• Sparse vegetation (alders, horsetails) • This modern floodplain has multiple terrace levels, which have been created from episodic incision of Libby Creek	Protect & Maintain
02-OZ-09	OZ	0.04	• Connected floodplain that has formed inset to historical disconnected floodplain surface • Large wood jam at upstream end is orienting flow over the surface. This has created a secondary channel that is wetted at the downstream end. Flow at the upstream end is hyporheic.	Protect & Maintain
02-OZ-10	OZ	0.30	• Extremely dense vegetation (dominated by dogwood) • North/northeast boundary of surface abuts area that has been altered by road fill and becomes DOZ-06	Protect & Maintain
02-OZ-11	OZ	0.11	• Extends from channel to road fill boundary (north/northeast boundary of OZ) • Well vegetated with dogwood, alder, and horsetail • Piles of trash along north/northeast boundary where trash is thrown from road	Protect & Maintain
02-OZ-12	OZ	0.04	• Evidence of recent inundation (sand, debris) • Well-vegetated	Protect & Maintain
02-OZ-13	OZ	0.16	• Connected to DOZ-08; channel appears to be incising, which has disconnected DOZ-08	Protect & Maintain

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• A wetland complex (02-Wetland) spans DOZ-08 and OZ-13. • Downstream boundary is altered by road grade and an old abandoned culvert runs from the road grade into the channel. The culvert is plugged with sediment.	
02-OZ-14	OZ	0.36	• Large wood accumulations along the bank • Very well vegetated with a mix of trees and shrubs • Area appears to receive more inundation than other OZs	Protect & Maintain
02-Wetland	Wetland Area	0.06	• A large complex of small, interconnected wetlands • Water surface elevation is approximately 8 feet above the water Surface elevation of Libby Creek • There may be hyporheic connection between Libby Creek and the wetland complex • Wetlands are likely sourced from hillslope seeps • Evidence of beaver activity throughout the wetland	Protect & Maintain

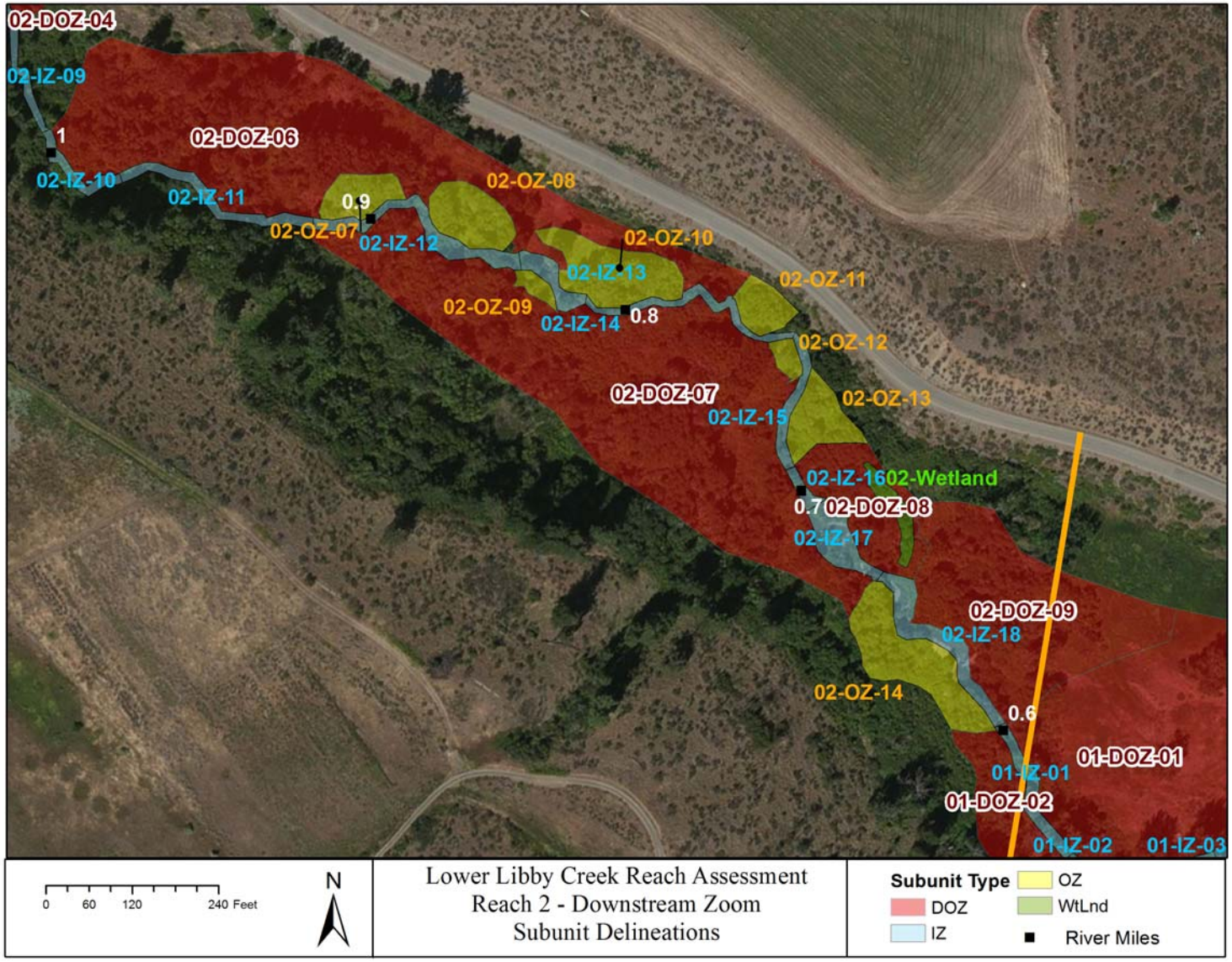

Figure 15. Subunit delineations in the downstream portion of Reach 2. Flow is from northwest to southeast.

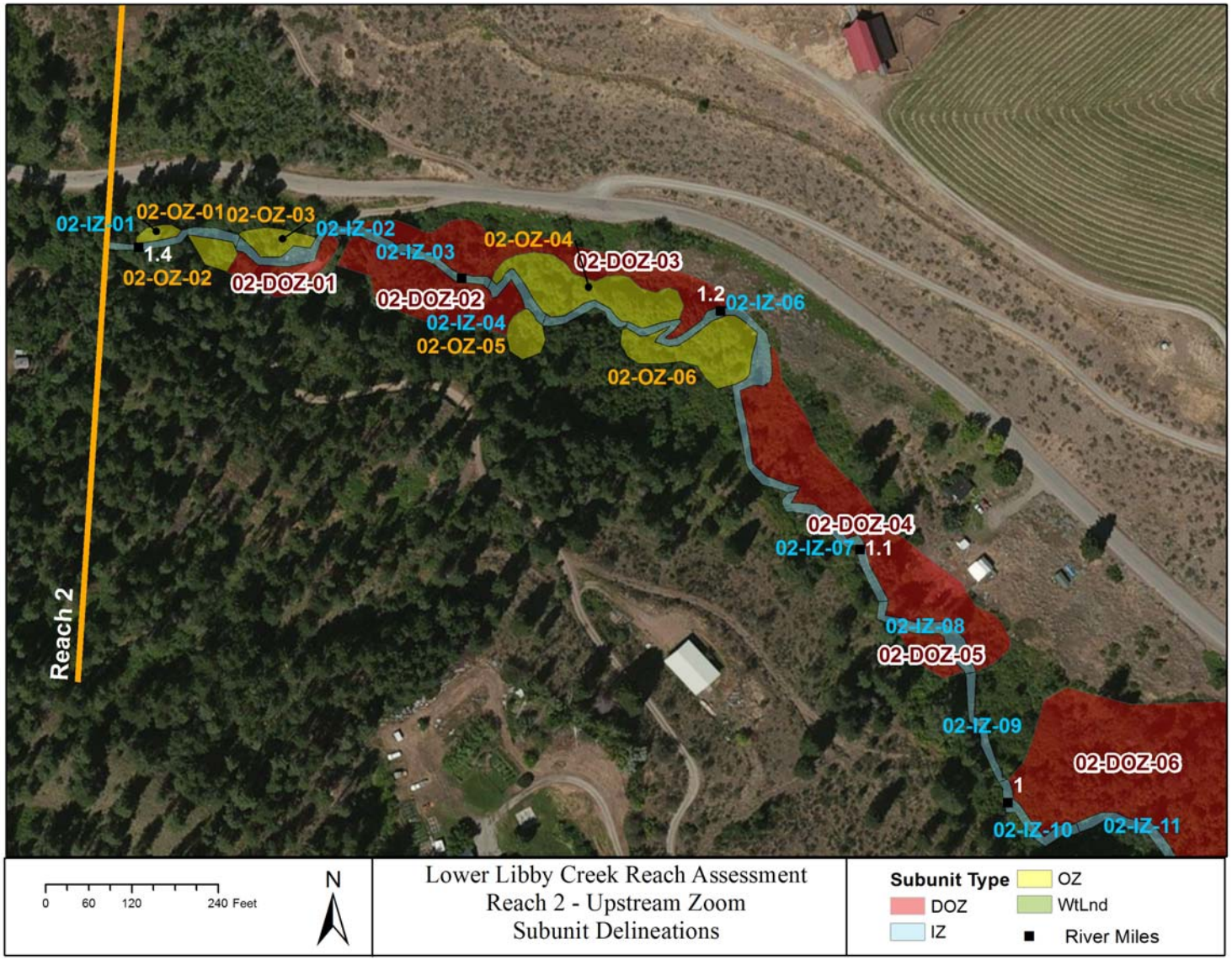

Figure 16. Subunit delineations in the upstream portion of Reach 2. Flow is from northwest to southeast.

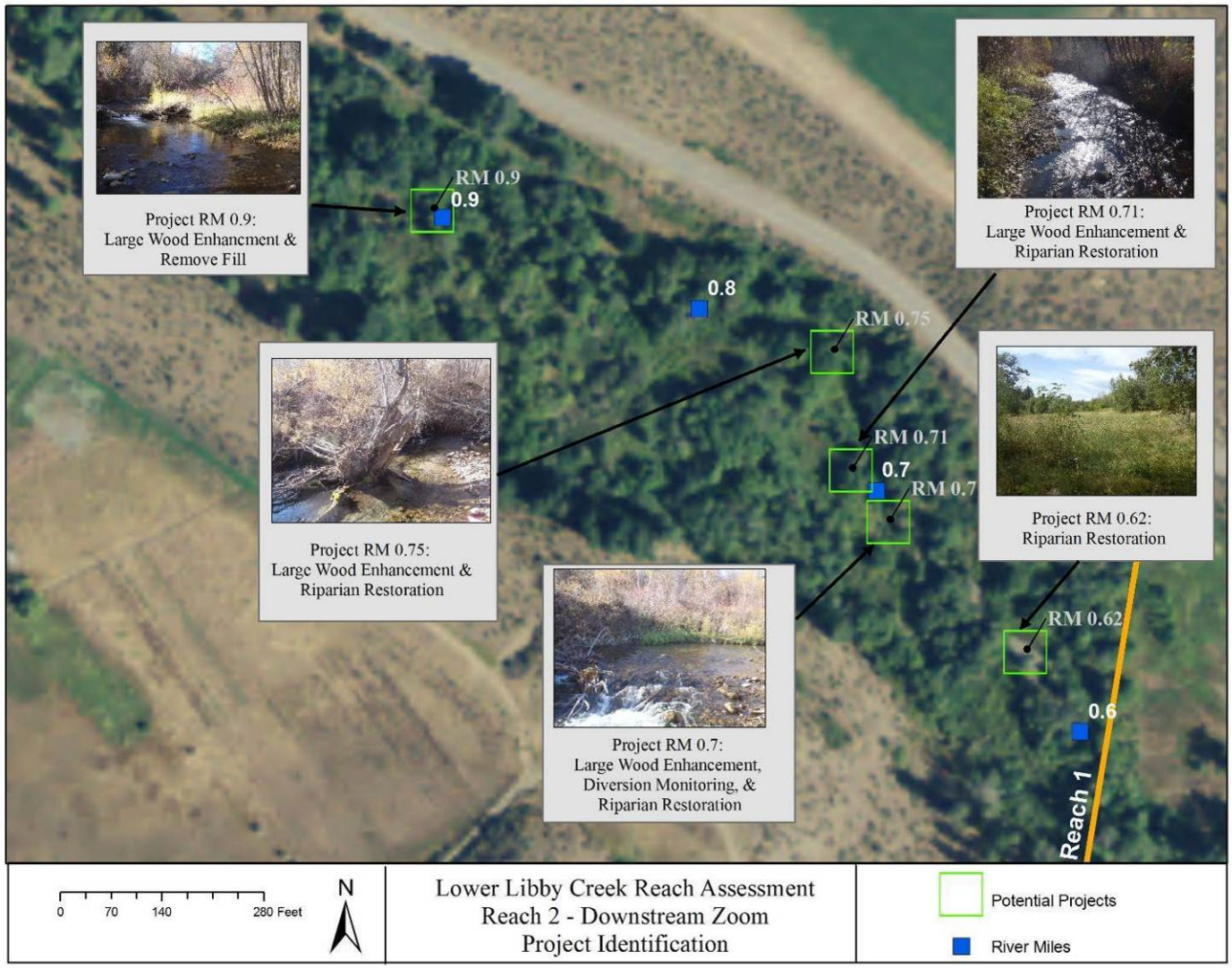

Figure 17. Potential project locations in the downstream portion of Reach 2. Project photographs are provided for selected sites to illustrate the types of project opportunities that are available throughout the reach. Additional project detail is included in Appendix B.

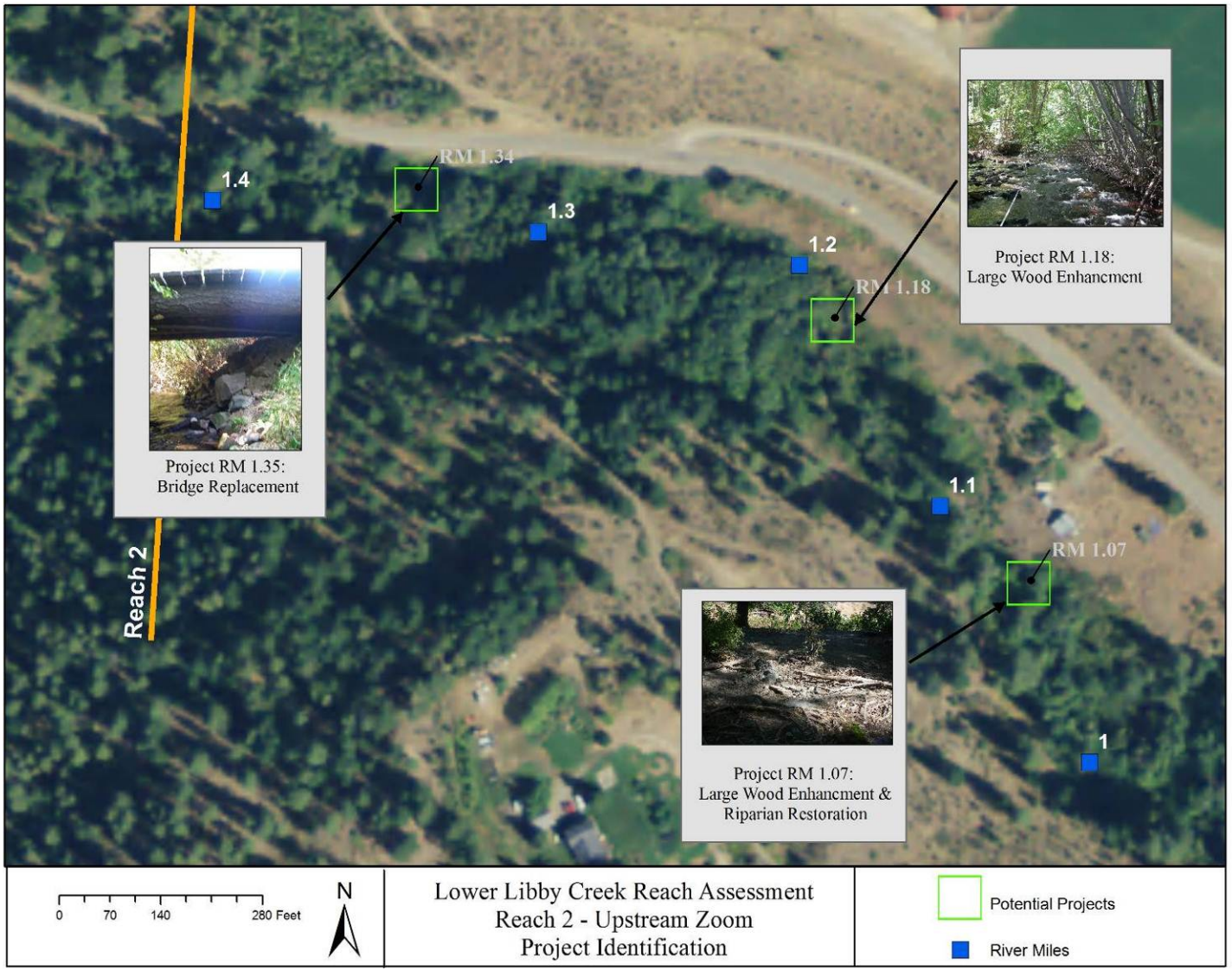

Figure 18. Potential project locations in the upstream portion of Reach 2. Flow is from northwest to southeast. Additional project detail is included in Appendix B.

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