

SYCAN RIVER ASSESSMENT AND RESTORATION FEASIBILITY STUDY



Sycan River – View North to the Coyote Bucket Canyon.

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SECTION 1.0 INTRODUCTION

River Design Group, Inc. (RDG) was retained by the U.S. Fish and Wildlife Service – Klamath Basin Ecosystem Restoration Office (USFWS) to assess the Sycan River and evaluate potential restoration activities on the Sycan River from the Coyote Bucket Canyon downstream to Drews Road (project area). The project area is defined by dynamic channel conditions influenced by basin geology, land use practices, riparian vegetation conditions, and periodic high magnitude flood events. Potential restoration activities are intended to work with the underlying geologic conditions controlling the river corridor, by addressing current land uses and perceived impaired habitat conditions. The *Sycan River Assessment and Restoration Feasibility Study* (Sycan Study) serves as the culmination of field data collection and remote sensing activities that began in 2005. Additionally, this study is intended to be used as a base document for guiding restoration in the project area.

1.1 Purpose and Scope

The Sycan Study serves as a planning document for orienting restoration planning for the Sycan River from the Coyote Bucket Canyon downstream to Drews Road near Beatty, Oregon. Information included in the Sycan Study culminates data collection, analysis, and modeling efforts completed in 2006 and 2007. Field data collection, aerial photograph interpretation, and review of historical documents served five primary purposes.

- To predict or at best, characterize, the likely historical condition of the Sycan River in the project area.
- To evaluate existing river corridor conditions including riparian vegetation, channel stability, aquatic habitat, hydrology and hydraulics, and the fish community.
- To propose the desired future river corridor conditions based on likely historical conditions and reference reach characteristics.
- To provide data necessary for modeling and evaluating flood frequency, channel stability and sediment transport capacity. Hydrologic and hydraulic modeling results are incorporated with empirical data to develop and evaluate draft channel restoration designs.
- To provide a complete topography of the restoration project area including channel bathymetry. Project area topography is necessary for evaluating the existing river corridor and is recommended as a point of reference for future evaluations.

The intent of the Sycan Study document is to present a summary of these efforts in addition to presenting conceptual restoration recommendations for the project area. The Sycan Study will be submitted to USFWS for future project planning.

1.2 Project Goals and Objectives

Several goals and objectives were established for the Sycan Study. Goals are related to both the river corridor assessment and the restoration feasibility. Objectives are presented as the tasks that were or will be accomplished to achieve the presented goals.

Assessment Goal: Attain a better understanding of the Sycan River project area in the context of historical and contemporary river corridor conditions.

Objective 1: Review available information to understand the historical and contemporary river conditions.

Objective 2: Collect new data to understand river corridor processes in the project area.

Objective 3: Locate and evaluate a reference reach to compare the project area.

Objective 4: Establish a data set to provide a baseline for comparing future river corridor conditions.

Restoration Goal: Propose conceptual restoration options and determine the feasibility of implementing proposed restoration options.

Objective 1: Evaluate potential restoration strategies.

Objective 2: Restoration strategies should be cost-effective and have a high probability of positively affecting the river corridor with minimal probability of negatively affecting the river corridor.

Objective 3: Restoration options should include both passive and active strategies to improve riparian vegetation, water quality, and aquatic habitat conditions.

1.3 Project Constraints

In evaluating the project area and restoration opportunities, several constraints were realized. These constraints are not expected to limit improving river corridor conditions, but will be accounted for in developing conceptual restoration plans. The following sections present identified project constraints at the time of the assessment.

1.3.1 Land Ownership

The project area spans six private properties from the Coyote Bucket Canyon to Drews Road. The extent of restoration activities will depend on landowners' willingness to collaborate on projects. Similarly, landowners' willingness to participate may be at least partially dependent on landowners receiving compensation for lost agricultural production. Riparian vegetation recovery in the project area will depend on modifying current land use practices.

1.3.2 River Corridor Geology and Climate

The project area is strongly influenced by its geology and climate. The eruption by Mt. Mazama approximately 6,500 years ago delivered pumice and ash to the Upper Klamath Basin. The Sycan River continues to be strongly influenced by this event. Soils in the project area are very permeable and well-drained. Organic materials are generally limited to the upper foot of floodplain materials. Lower soil layers are largely devoid of organics and display varying degrees of cemented pyroclastic materials.

The project area's climate is characterized as semiarid with mild summers and cold winters. The normal annual precipitation varies with altitude, from 14.1 inches at Klamath Falls to 17.7 inches at Chioquin and more than 60 inches of precipitation in the mountain peaks (Leonard and Harris, 1974). Seventy percent of the precipitation falls between October and March. Only 9 percent of precipitation falls during the summer between July and September. The Sycan River watershed therefore receives most of its annual precipitation



The Sycan River on the Shields' property.

in the winter. Periodic summer thunderstorms deliver intense rainfall over short periods. This inconsistent and concentrated precipitation pattern creates the arid climatic patterns of the region. From a restoration perspective, the arid conditions present a constraint for revegetating disturbed areas.

1.3.3 Land Use History

There is limited documentation of historical land uses in the Sycan River watershed. However, land use patterns observed elsewhere in the Upper Klamath Basin likely also occurred in the project area. Dating to the mid 1800s, land uses in the Basin have included the fur trade, timber extraction, farming, ranching, and residential development. The fur trade and ranching are believed to have had the greatest effect on river corridor conditions in the project area. These activities are believed to have modified river processes and degraded river stability. Based on existing conditions and probable historical conditions, past land uses may have resulted in a cascade of river corridor changes that now limit the range of feasible restoration activities.

1.3.4 Recorded Archaeological Sites

Although there are only two recorded archaeological sites recognized by the State of Oregon in the project area, native peoples historically used the Sycan River as a habitation area and migratory corridor. Cultural resources sites will be avoided during future restoration activities.

In summary, potential constraints on river corridor recovery include land ownership, natural conditions, the land use history, and recorded archaeological sites. These constraints (aside from

the archaeological sites) are not expected to detract from the river corridor's recovery potential, but rather, will be accounted for in preparing restoration concepts.

1.4 How To Use This Document

The Sycan Study is structured to 1) provide the reviewer with a thorough understanding of the techniques RDG employed to characterize the project area; 2) define the historical, existing, and potential river corridor conditions; and 3) develop restoration concepts for enhancing the Sycan River in the project area.

This section includes descriptions of the systems that were employed in assessing the project area; it defines time frames for ecological recovery, explains the most probable state or reference condition concept and its application to river restoration, and provides an overview of the primary sections that comprise the remainder of the Sycan Study.

1.4.1 Technical Systems Used

The different technical systems used in our analysis were chosen because they are standard within each of their particular disciplines. Some were developed regionally, while others have been universally applied independent of geography. Systems may be delineated according to field and analytical techniques. Field techniques include methods for characterizing existing channel, aquatic habitat, and riparian conditions. Analytical techniques include remote sensing tools, and hydrologic, hydraulic, and sediment analysis models.

Key field-based technical systems include the following methods.

- River morphology and channel classification concepts developed by Rosgen (1996) and other practitioners (Montgomery and Buffington 1997). Presented methods are widely referred to in the literature and are applicable to the river systems evaluated. The classification concepts are used for describing assessed river reaches at a course level, and are primarily presented as a communication tool for conveying the general characteristics of specified stream reaches.
- The applied valley classification system focuses on the relationship of a stream system to its valley. Similar to the stream classification system, valley morphology classification is useful for conveying general information about stream valley characteristics including formative processes, dimensions, and how the valley morphology influences stream dynamics. Valley morphologies are classified according to guidelines presented in Rosgen (1996).
- Classification and Management of Montana's Riparian and Wetland Types (Hansen et al. 1995) is a vegetation-based ecological classification system centered on the dual concepts of ecological potential (habitat types) and disturbance-process-driven potential (community types). As a result, this approach provides a useful language for discussing desired future condition and understanding how restoring natural processes may influence vegetation communities on the landscape. Although this classification system was prepared in Montana, the classification system can be similarly applied in the Upper Klamath Basin.

Key analytical technical systems used in this document include the following methods.

- Flood frequency analysis produced by the Oregon Water Resources Department (OWRD) was evaluated for predicting the flood series for the streamflow gaging station on the Sycan River. Additional streamflow data collected by Graham Matthews and Associates (GMA) were also used in the hydrologic analysis.
- Aerial photograph analyses were completed for the project area as well as an upstream reference reach. Recent color aerial photographs were georeferenced in ArcGIS and served as the base imagery for field maps, river planform analysis, and valley morphology assessment. Historical and recent channel alignments were digitized to assess past channel locations and patterns.
- River corridor topographic surveys were completed using a combination of light detection and ranging data (LiDAR), RTK GPS channel bathymetry surveys, and channel habitat surveys. The LiDAR and RTK GPS channel bathymetry data were merged to create a digital terrain model (DTM) of the project area. Existing condition modeling was executed using both the DTM and the individual data components (e.g. cross-sections and channel profiles).
- Hydraulic models were developed to evaluate channel conveyance and channel hydraulics, to prepare flood inundation maps, to assess incipient motion of sediment particles and sediment transport properties, and to evaluate bed resistance. WinXSPro (Hardy et al. 2005), HEC-RAS (U.S. Army Corps of Engineers 2004), and Microsoft Excel were the primary software programs used to develop the models.
- Reference reach data describing potential channel conditions were evaluated to develop potential channel condition's concepts. Field data were stored and processed using RIVERMorph (RIVERMorph 2005).

1.4.2 The Reference Reach Concept

The reference reach concept is referred to throughout this document. A reference reach was located in Teddy Powers Meadow, approximately 7 miles upstream from the project area. The reference reach exemplifies river corridor conditions following the exclusion of livestock from the river. While conditions in the reference reach will continue to evolve as the system recovers from past land management, Teddy Powers Meadow represent the “best possible” river corridor conditions in the vicinity of the project area. Conditions exemplified by the channel’s dimensions, pattern, and profile; the distribution and characteristics of sediment and sediment loading to the channel; and the riparian condition were the primary factors in designating the Teddy Powers Meadow section as a reference reach. A non-reference reach, primarily referred to as an “existing” condition reach throughout the document, may be characterized by poorer riparian conditions, a more entrenched channel, lower streambank stability, and less frequent and simplified pools.

Ideally, a reference river reach is an integrated channel and floodplain system that is in dynamic equilibrium under the current hydrologic regime. A reference river reach may be a *hydraulic* reference reach where a channel is identified as in dynamic equilibrium under a current hydrologic regime, or it may be a *habitat* reference reach where diverse and complex habitat

features are exhibited. The Teddy Powers Reach provides a range of hydraulic and habitat conditions that will be used as a tool to help guide development of specific restoration proposals as well as to introduce project area property owners to the river benefits of livestock exclusion.

While identifying reference reaches at the present time is useful, evaluating historical conditions offers another opportunity for comparing current conditions and anticipating future channel responses to management regimes. In this document, we used information taken from the 1941 aerial photographs that captured the Sycan River in the project area. Although river-altering changes (e.g. beaver trapping and grazing) are believed to have occurred in the watershed prior to the 1941 air photo, the channel pattern and recently abandoned channel locations provide some insights to historical channel alignments. Assessing the 1941 channel pattern and recently abandoned channel locations was useful for understanding river changes over the last nearly 70 years.

Reference plant communities were formulated by combining vegetative information from the Teddy Powers Meadow reference reach and portions of the project area. Reference plant communities present a target for improving riparian conditions in the project area.

1.4.3 Summary of Sections

The Sycan Study is organized as an Executive Summary with supplemental appendices. The appendices provide more detail on assessment methods, watershed hydrology, historical and existing river corridor conditions, channel hydraulics and sediment properties, and conceptual restoration approaches. The following summarizes the contents of the Sycan Study.

Section 1 is the introduction to the Sycan Study.

Section 2 provides an overview of the project area.

Section 3 provides a framework for describing the historical, existing, and desired future conditions of the river corridor.

Section 4 provides proposed restoration strategies and techniques for restoring the Sycan River in the project area. Section 3 also provides restoration strategies for wetland and vegetative recovery. Additionally, strategies to move vegetative cover types to a desired future condition are presented.

Section 5 presents conceptual restoration plans for two reaches in the project area.

Appendix A is the hydrology appendix. The hydrology appendix provides a discussion of watershed hydrology including information on flood history, flood series, and bankfull discharge analysis techniques.

Appendix B is the geomorphic conditions appendix. Historical, existing, and desired future river corridor conditions are presented.

Appendix C includes index maps developed from recent aerial photographs. Reach breaks, field survey locations, and LIDAR/RTK GPS-derived river corridor topography are displayed.

Appendix D presents soils maps and information for the project area.

Appendix E presents the hydraulic modeling analysis.

Appendix F presents flood inundation maps for the project area. Flood inundation maps are based on the hydraulic modeling analysis.

Appendix G introduces the vegetation and wetland resources analyses for the project area. Information includes an analysis of existing conditions with emphasis placed on the description of native species, species' geographic locations, and conceptual treatments for achieving desired future conditions.

Appendix H presents an overview of the Sycan River fish community including monitoring data collected between 2003 and 2006.

Appendix I covers the restoration plan strategies.

Appendix J includes the references cited in the Executive Summary and the appendices.

SECTION 2.0 PROJECT AREA OVERVIEW

The following sections provide an overview of the Sycan River watershed and the project area.

2.1 Sycan River Watershed

The Sycan River originates in the northeastern portion of the Upper Klamath Basin in southern Oregon. From its origin in a meadow between Slide Mountain and Bald Butte (at approximately 7,500 feet m.s.l) in the Winter Ridge range (7,161 ft), the river flows northwest through several mountain meadows before entering a steep canyon. Several tributaries draining the surrounding mountains join the Sycan River before it flows into the 25,000 acre Sycan Marsh at an elevation of roughly 5,000 feet (OWRD 2000). Tributaries draining the eastern slopes of Yamsey Mountain (8,196 ft) and Booth Ridge (7,543 ft), as well as creeks and springs originating from Winter Ridge and Brattain Ridge contribute flow to Sycan Marsh. At the southern end of the marsh, the Sycan River exits, taking whatever surface and groundwater inflows not evaporated, stored in the soil matrix of the marsh, or percolated to groundwater (OWRD 2000). From the marsh, the river flows southwest gaining inflows from Merritt Creek, Torrent Springs, and several un-named tributaries before reaching Teddy Powers Meadows. Downstream of the meadow, the river enters the rugged, steep, and highly fractured basalt of Coyote Bucket Canyon. The narrow river canyon confines the channel. The channel morphology is characterized by periodic falls and rapids. Blue Creek and several small springs are the only tributaries to the river before the canyon opens into the Sycan River Valley. In the valley, the Sycan meanders within a broad flat flood plain. Spring and seeps discharging from lateral terraces contribute discharge to the river. Brown Springs Creek and Snake Creek are the final natural channels discharging to the Sycan River upstream of Drews Road. An agricultural drain captures surface and groundwater flow on the east side of the Sycan River upstream from Brown Springs Creek. Several surface water pumps are located on the Sycan River from the end of Sycan Canyon to Drews Road.

2.2 Sycan River Project Area

The project area is located from the mouth of Sycan Canyon downstream to Drews Road. The project area is entirely privately owned with six properties comprising the project area. Livestock grazing is the predominant active land use in the project area. Subordinate land uses include timber harvest, haying, and residential development. Vegetation conditions exhibit changes in soil moisture. Soils are comprised of volcanic tufts with organic mantles of varying thickness related to the location in the stream corridor. Floodplains adjacent to the channel that receiving flood deposition and organic litter, tend to have thicker organic mantles. Higher terraces that are flooded only during extreme events, and that support low densities of upland vegetation, tend to have droughty soils with limited organic content.

Project area vegetation ranges from streamside sedge/rush communities to upland Ponderosa pine forests. Intermediate vegetation communities transition from willows and silver sage at lower elevations, to big sage brush and bitterbrush transitioning to the Ponderosa pine forests.

2.2.1 Project Area Reach Break Delineations

Five reaches were delineated in the project area, plus the Teddy Powers Meadow reference reach. The project area reaches were delineated based on changes in river corridor conditions including channel slope, channel entrenchment, and vegetation. The following section summarizes

the identified reaches. Appendix C includes recent air photos with the channel alignment stationing and reach break locations.

Reach 1 – Canyon Reach Transition

Reach 1 is characterized by the transition from the lower Coyote Bucket Canyon to the beginning of the broader Sycan valley. The narrow valley bottom in the canyon confines the channel, limiting lateral channel meandering (Figure 2-1). Through Reach 1 the low sinuosity channel (Rosgen B2 stream type) transitions to a meandering planform (Rosgen C4 stream type) with a more expansive floodplain. Channel bed material characterized by boulders and cobble in the canyon, transitions to finer gravel bed. A riparian vegetation fringe comprised of mountain alder and willows is located in a narrow range between the Sycan River and the uplands in the Coyote Bucket. Through the transition, sedges/rushes vegetate backwater areas and willows have colonized depositional features. Ponderosa pine and western juniper dominate the upland forest. Reach 1 is 2,200 ft in length extending from the confined Coyote Bucket Canyon through the transition.



Figure 2-1. River corridor conditions in Reach 1 – Canyon Reach Transition are characterized by a low sinuosity, moderate gradient channel in the Coyote Bucket Canyon (left) to moderate sinuosity, broader river corridor through the river corridor transition (right).

Reach 2 – Upper Meandering Reach

Reach 2 extends from Station 22+00 to Station 76+00. The Sycan River in Reach 2 is characterized by increasing channel sinuosity, alternating pool-riffle morphology, and frequent point bars and lateral bars where sediment is stored (Figure 2-2). Channel and floodplain development is occurring between the lateral terraces. Eroding streambanks vary in the slope of the bank face. In areas where streambanks are actively eroding, large mats of vegetation and soil cleave from the bank and fall into the river. Where the eroding banks have reached an angle of repose or the bank is protected from stream energy, sedges buffer the eroding bank from the river.

Floodplain terraces maintain diverse habitats. Relict channels, springs, and signs of historical beaver activity create a range of riparian habitats. Relict channels and depressions are inundated during runoff events and hold water through the early summer. Vegetation and channel patterns suggest some of these terrace features may have been inundated more frequently in the past. The reach ends at Station 76+00 where the eastern hillslope encroaches on the channel corridor, narrowing the valley floor and channel belt width.



Figure 2-2. Reach 2 is characterized by a more sinuous channel and expanding beltwidth. Sediment is stored in point bars and lateral bars that are colonized with sediment-trapping riparian vegetation.

Reach 3 – Confined Reach

Reach 3 extends from Station 76+00 to Station 137+00. The Sycan River valley bottom narrows again in Reach 3. The river corridor necks down with the encroachment of the eastern hillslope on the river channel. The through Reach 4, channel sinuosity decreases and the channel is confined between lateral terraces. Floodplain areas are limited through the reach except between Station 90+00 and Station 102+00 where relict channel scrolls convey flow during flood events and retain spring water throughout the year (Figure 2-3). Downstream of this floodplain section, the river follows the valley's fall line and is confined between the eastern hillslope and a western high terrace. Springs and seeps arise from the western terrace and drain to the river. Developed ponds on the western terrace contribute to the subsurface discharge.



Figure 2-3. Relict channels on the floodplain in the vicinity of Station 95+00 convey water during flood events and retain water through most of the year (left). Downstream of the floodplain area, the Sycan River is confined by the eastern hill slope (right).

Reach 4 – Lower Meandering Reach

Reach 4 extends from Station 137+00 to Station 172+00. Reach 4 is characterized by a meandering planform downstream from the confined channel conditions in Reach 3 (Figure 2-4). The channel in Reach 4 is dynamic, including active lateral migration, bank erosion, and an active

chute cut-off. The channel exhibits down-valley meander migration and there is the potential for two channel avulsions that will eventually lead to further channel straightening in the reach. Relative to upstream and downstream river corridor conditions, Reach 4 maintains diverse wetland and off-channel habitats. Springs discharging at the toe of the western hillslope, form shallow wetlands and ponds that ultimately discharge to the Sycan River. These off-channel wetlands provide fish and wildlife habitat and serve as coldwater refugia. Beaver dams located at the outlets of two of the wetland control flow to the river and may limit fish access to the wetlands. Floodplain vegetation is characterized by sedges/rushes and willow thickets. Higher elevation land forms are colonized by sage brush, occasional Ponderosa pines, and juniper.



Figure 2-4. Sedges/rushes colonize point bars and confine the baseflow channel inside of the larger active channel bracketed by lateral terraces (left). A beaver dam controls the flow from an off-channel wetland to the Sycan River near Station 152+00 (right).

Reach 5 – Lower Confined Reach

Reach 4 transitions to Reach 5 when the channel Sycan River is again confined by the western hillslope and the eastern terrace. Reach 5 extends from Station 172+00 to Station 363+00 at the Drews Road Bridge. River corridor conditions are fairly consistent through Reach 5, characterized by lateral terraces confining the channel. Unique features in the reach include floodplain inclusions, spring creek tributary confluences, and off-channel wetlands occupying terrace depressions. Streambanks tend to be more stable in Reach 5 than in Reach 4 especially where vegetated surfaces have formed at the toe of sandy terraces (Figure 2-5). Eroding sites are associated with meander bends and areas of focused livestock use. Vegetation transitions from channel margin vegetated benches colonized by sedges and rushes, to a narrow elevation range where willows and silver sage are common. Sage brush and bitterbrush are located on terraces. Riparian vegetation also colonizes swales and off-channel floodplain areas that are lower than surrounding terraces.



Figure 2-5. River corridor conditions in Reach 5. The channel is confined between lateral terraces. Vegetated surfaces are emergent at base flows (left) are submerged during runoff (right).

Teddy Powers Meadow Reference Reach

The Teddy Powers Meadows reference reach is approximately 7 miles upstream of Reach 1 in the project area. Historically used as a riparian pasture, the U.S. Forest Service has excluded grazing from the reference reach area since the 1990s (Figure 2-6). Vegetation in this reach consists of a narrow fringe of perennially inundated rush/sedge communities along the channel margin transitioning to seasonally inundated sedge/rush and willow communities. Above the sedge/rush and willow communities is a relatively recent floodplain terrace dominated by silver sage similar to existing plant communities in other reaches. The old vertical eroding banks are now buffered by the riparian fringe and sediment

Since livestock have been excluded from the Sycan River through the Teddy Powers Meadow reach diverse vegetation patterns are beginning to establish along newly deposited floodplain surfaces allowing the channel to regain a more sinuous planform, narrower channel dimensions, and more moderate profile through this reach. Improved vegetation conditions have also stabilized previously eroding banks, decreasing sediment delivery to the system and improving habitat quality.

The Teddy Powers Meadows reach illustrates the potential for river corridor recovery associated with changing grazing practices. Excluding livestock from the baseflow channel improves riparian conditions both by eliminating grazing pressure on vegetation, but also by removing the source of repeated disturbance that impairs vegetation establishment.



Figure 2-6. Examples of the riparian vegetation communities in the Teddy Powers Meadow reach of the Sycan River. A sedge/rush fringe now buffers the eroding banks from the river (left). Multiple age classes of willows and other riparian vegetation have narrowed the channel and stabilized sediment.

In summary, the Sycan River exhibits diverse river corridor conditions through the project area. The width of the valley bottom has an overriding influence on channel conditions. Where the valley bottom narrows and constricts the Sycan River, the channel has a low sinuosity and limited access to floodplain areas. Where the valley is wider, in Reach 3 for example, floodplains and terraces store sediment and large wood. Vegetation communities are most diverse in these areas as the undulating land surfaces support a range of plants based on soil moisture tolerance. Relict channels dissecting the floodplain and terrace surfaces suggest the influence of the river and emergent springs on in these areas. More information regarding these features will be provided in subsequent sections of this document.

SECTION 3.0 HISTORICAL, EXISTING, AND DESIRED FUTURE CONDITIONS

The following section highlights the historical, existing, and desired future conditions for the Sycan River in the project area.

3.1 Historical Conditions

3.1.1 Channel Morphology

The current morphological state of the Sycan River is reflective of both natural processes and human-induced impacts in the river corridor. Historically, the Sycan River likely had a denser and more extensive riparian area. Over the past 60 years dating to the 1941 air photo series, the Sycan River's riparian area has become more simplified. Additionally, the river has become straighter over time due to down valley meander migration and channel meander cut-offs. The channel length reduction is most pronounced in the Reach 1 and Reach 2 where the channel in 1941 was more sinuous than it is today (Figure 3-1). Based on the location of the channel in 1941 and 2006, the channel has apparently incised approximately 2-3 ft. Relict channel locations are generally located 2-3 ft from the existing channel thalweg. In spite of this observation, it is also possible that the channel historically occupied an elevation similar to the current elevation and that the relict channel locations have filled over time and are now a low floodplain surface. Filling would also account for the current higher elevation of these features.



Figure 3-1. A comparison of the Sycan River in Reach 1 and Reach 2 in 1941 (left) and 1998 (right). The riparian community has become less dense and the river straighter over time.

Figure 3-2 illustrates the 1941 and 1998 channel alignments with the landownership boundaries. Most of the channel changes and straightening has occurred in Reach 1 and Reach 2 downstream from the Coyote Bucket Canyon. Down valley meander migration is apparent in Reach 3 and Reach 5. Channel instability is likely related to channel morphology, soils, vegetation conditions and the effect of land management on these system properties.

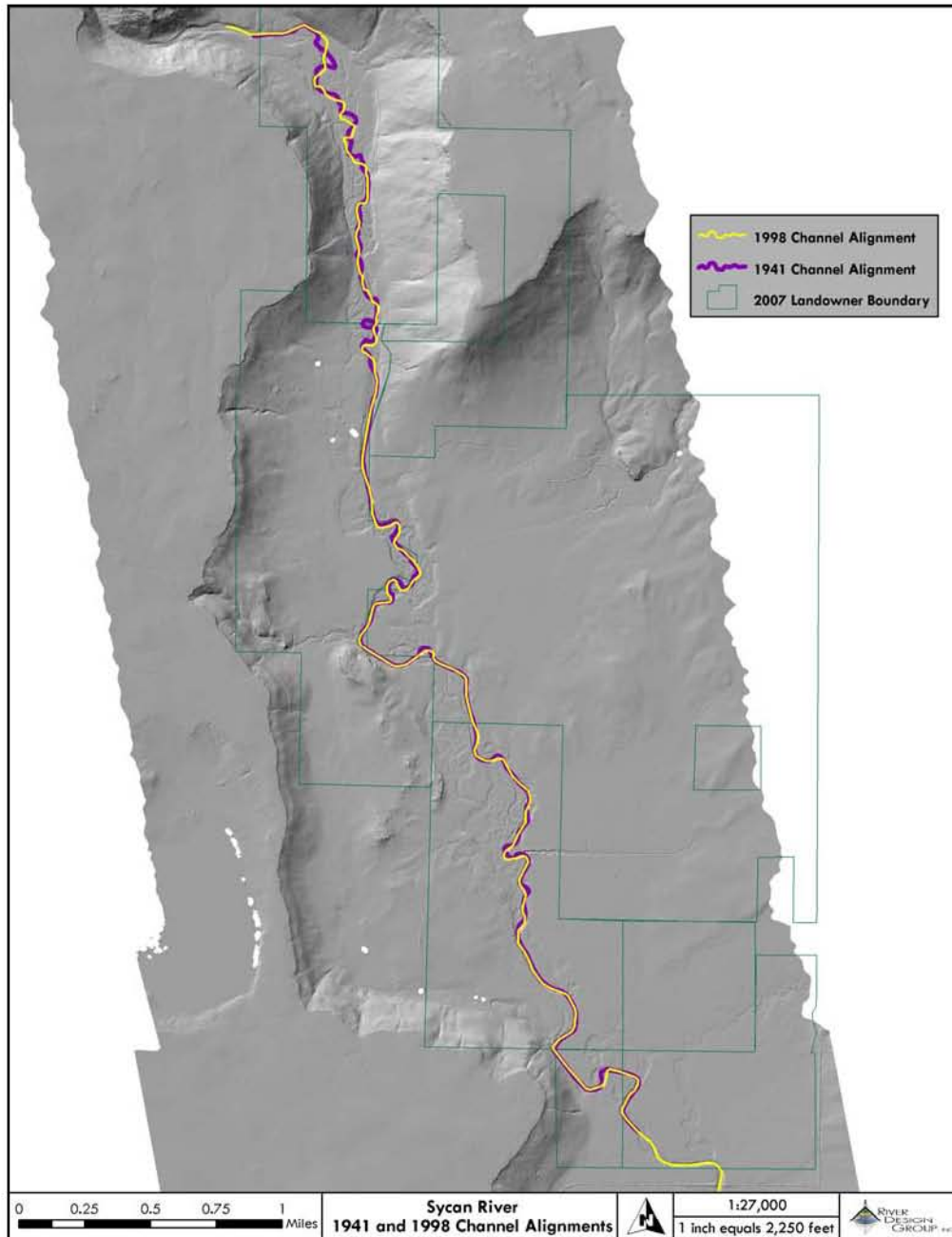


Figure 3-2. The 1941 and 1998 channel alignment locations relative to the 2007 landownership map.

The current location and bed elevation of the Sycan River appear to have deviated from historical conditions. Review of the historical air photos, soils data, field conditions, and discharge

modeling results suggest the river has downcut 2-3 ft since the 1940s. However, the data do not support the idea that the Sycan River was located on high terraces adjacent to the active river channel at least in the recent past (60 to 100 years). Terrace soils are generally lacking in clay and have high porosity; characteristics suggesting little historical interaction with the river. These characteristics do not exclude these surfaces from flooding, however, only low frequency, high magnitude floods inundate these features.

3.1.2 Vegetation Conditions

Because little information is available about vegetation prior to recent settlement of the Sycan River drainage, historical conditions are discussed based on observing riparian plant communities in the Teddy Powers Meadows reference reach, combined with our knowledge of general disturbances affecting vegetation. The existing plant communities in the project area likely resemble the historical plant communities. However, several changes to the historical plant communities including the introduction of noxious weeds, grazing effects, and reduction in the beaver population mark several changes to project area plant communities.

Introduced weed species are prominent in the project area. Bull thistle (*Cirsium vulgare*) and Canada thistle (*Cirsium arvense*) are found throughout the project area. Bull thistle grows singularly or in low density patches. Canada thistle can form dense patches. Both species are capable of displacing native vegetation and degrade forage value. These species tend to colonize drier sites and favor disturbed areas.

Livestock grazing is the primary land use in the Sycan River project area. Sheep were the earliest livestock brought to the Upper Klamath Basin. Cattle displaced sheep in the early 1900s. Reports of several hundred thousand head of livestock grazed open range in the Upper Klamath Basin in the late 1800s and early 1900s. Cattle continue to graze either open range or with limited management in the project area.

Livestock effects on the river corridor includes vegetation removal, land surface compaction, and streambank trampling. Vegetation removal is most prominent on land surfaces paralleling the low flow channel. Although these areas are submerged during high flows, sedges, rushes, and willows colonize these sites. These species provide high quality forage proximate to a water source. Grazing of this vegetation is believed to have modified the Sycan River's resistance to bank erosion and contributed to channel instability. Near-bank vegetation that would increase sediment retention and promote streambank building has been lost from much of the upper project area. Grazing on floodplain and terraces has lead to soil compaction. Compacted surfaces decrease surface permeability and promote surface water routing. Disturbed surfaces are also more susceptible to noxious weed invasion. Cattle trampling of streambanks increases bank instability and erosion (Figure 3-3). Repeated trampling related to travel routes breakdown banks and decrease vegetation diversity.



Figure 3-3. Examples of grazing impacts on the Sycan River floodplain in the project area. Repeated trampling of floodplain areas (left) and grazing vegetation within the active channel corridor have led to channel instability.

Widespread beaver trapping occurred in the mid to late 1800s. Historically, beaver were likely more abundant and may have played an important role affecting the Sycan River corridor. Similar to other areas in the Sprague River valley, beaver influenced channel morphology by harvesting vegetation, building dens, and perhaps damming the main channel and side channels. The undulating surface of floodplains and terraces parallel to the Sycan River suggest historical beaver activity. Relict beaver dams and modified channel morphology is apparent in the Teddy Powers Meadows reach of the Sycan River. Currently, there are limited signs of recent beaver activity in the project area although at least beaver home has been identified in the project area. Continued trapping over the past decades has perpetuated beaver suppression. Allowing beavers to return to the project area would be expected to result in greater riparian vegetation diversity, a wider range of aquatic habitats, and a higher local water table.

In summary, the land use practices, introduced weed species, and beaver removal have influenced the Sycan River's vegetation community. Livestock grazing and removal of beaver have increased the channel's erosion potential by creating a smoother channel network. The historical riparian vegetation community was likely more dense and more functional than the existing vegetation conditions.

3.2 Existing Conditions

3.2.1 Channel Morphology

Field data collection and remote sensing were completed to evaluate existing river corridor conditions in the Sycan River project area. Data collection included characterizing the channel cross-section, longitudinal profile, and planform dimensions at five reaches. Sediment and bank stability were also evaluated.

The Sycan River through the project area is a dynamic environment influenced by unique watershed hydrology, volcanic-derived geology and sediments, vegetation conditions, and land management activities. The Sycan Marsh, located upstream of the project area, moderates headwater flood events. The hydrology of the marsh is currently being restored through the removal of drain tiles and ditch filling. A long period of agriculture modified marsh function.

River corridor conditions vary according to the degree of channel-floodplain connectivity. Reaches were defined by the presence of a floodplain adjacent to the baseflow channel that was accessed by the river around the 2-year discharge event. Reaches with adjacent floodplain typically had diverse floodplain habitats that included flood channels, floodplain ponds, willow thickets, and large wood accumulations. Reaches lacking floodplain features tended to have fewer or more localized off-channel habitats. Relict channel segments, springs, and wetlands are unique habitats in the river corridor.

Open-range grazing throughout the project area influences riparian vegetation conditions and streambank stability. Grazing impacts the river corridor through vegetation removal, bank cleaving, and land surface compaction. Vegetation removal within the bankfull channel lowers channel roughness and reduces sediment storage. The smoother channel increases water velocities, affecting stream power and bank erosion potential.

Section 2.2.2 Project Area Reach Break Delineations, provides a summary of each of the five reaches in the project area. More detailed reach information is included in Appendix B. The following sections summarize channel planform, cross-section, and longitudinal profile information for the Sycan River project area.

Planform Summary

Table 3-1 includes the channel planform dimensions for the project area and reference reach from the 1941 and 1998 air photos. Table 3-2 includes the channel planform dimensionless ratios. Dimensionless ratios are developed by dividing the measured planform variable value by the riffle bankfull width. Dimensionless ratios allow channel width-independent comparisons.

A comparison of the 1941 and 1998 channel planform data suggests the river has become straighter over time with longer distances between meander bends (pools) and larger radius of curvature values. Higher standard deviation values for meander length (MI) and radius of curvature (Rc) also suggest the river had a more variable pattern in 1998 than in 1941. Increasing radius of curvature values may be related to less extensive and less dense bank stabilizing-riparian vegetation. Riparian vegetation losses were apparent in several reaches.

The belt width has remained fairly consistent over time suggesting that although the river channel location has changed, the width of the river corridor has on average remained consistent over time. The channel sinuosity has decreased over time.

Table 3-1. Sycan River meander geometry for the project area and the reference reach for the 1941 and 1998 air photos.

Reach	1941				1998			
	MI	Bw	Rc	Sinuosity	MI	Bw	Rc	Sinuosity
Reach 2	441 (132)	204 (72.0)	133 (45.7)	1.34	643 (121)	236 (94.0)	253 (85.7)	1.28
Reach 3	364 (176)	167 (54.8)	142 (144)	1.19	845 (570)	179 (73.6)	406 (286)	1.10
Reach 4	475 (140)	258 (100)	107 (31.4)	2.0	686 (280)	302 (121)	179 (162)	1.79
Reach 5	694 (1042)	289 (164)	258 (282)	1.44	824 (328)	299 (137)	287 (290)	1.43
Reference Reach					1257 (92.5)	509 (56.0)	265 (59.0)	1.33

Table 3-2. Sycan River meander geometry dimensionless ratios for the project area and the reference reach for the 1941 and 1998 air photos.

Reach	1941			1998		
	MI	Bw	Rc	MI	Bw	Rc
Reach 2	7.5 (2.3)	3.5 (1.2)	2.3 (0.8)	11.6 (2.2)	4.3 (1.7)	4.6 (1.6)
Reach 3	5.69 (2.7)	2.6 (0.9)	2.2 (2.2)	13.9 (9.3)	2.9 (1.2)	6.7 (4.7)
Reach 4	5.7 (1.7)	3.1 (1.2)	1.3 (0.4)	11.3 (4.6)	5.0 (2.0)	3.0 (2.7)
Reach 5	11.2 (14.7)	4.7 (5.1)	4.2 (3.4)	13.1 (5.2)	4.8 (2.2)	4.6 (4.6)
Reference Reach				14.6 (1.1)	5.9 (0.7)	3.1 (0.7)

The channel plan form dimensionless ratios exhibit the same pattern as seen with the descriptive statistics summarizing the actual channel dimensions.

Channel Dimensions

A comparison of the channel habitat dimensions for the project area and Teddy Powers Meadows Reference Reach are included below. The actual values and dimensionless ratios are included for each habitat unit type. Dimensions are based on the bankfull channel and are based on both field and remote sensing measurements.

Table 3-3 through 3-5 include the mean and standard deviation values for pool, glide, and riffle habitat units measured in the project area and Teddy Powers Meadows Reference Reach.

Table 3-3. Project area and reference reach summary data for pool habitat units. Presented data are mean values and (1 SD).

Reach	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
Reach 1	260 (132)	124 (66.9)	2.2 (0.1)	4.2 (0.9)	58.9 (33.5)
Reach 2	342 (63.5)	118 (56.4)	3.2 (0.9)	6.2 (0.8)	43.0 (32.5)
Reach 3	323 (24.8)	78.2 (15.1)	4.2 (0.5)	7.0 (1.1)	19.1 (5.9)
Reach 4	334.5 (39.3)	98.5 (2.1)	3.4 (0.3)	6.3 (0.3)	29.2 (2.2)
Reach 5	345 (35.8)	83.9 (4.5)	4.1 (0.3)	7.4 (0.6)	20.4 (0.83)
Reference Reach	157 (64.7)	68.2 (15.5)	2.30 (0.7)	3.9 (0.5)	33.0 (17.4)

Table 3-4. Project area and reference reach summary data for glide habitat units. Presented data are mean values and (1 SD).

Reach	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
Reach 1	282 (79.2)	74.3 (7.9)	3.8 (0.6)	5.5 (1.0)	19.9 (1.6)
Reach 2	N/A	N/A	N/A	N/A	N/A
Reach 3	N/A	N/A	N/A	N/A	N/A
Reach 4	N/A	N/A	N/A	N/A	N/A
Reach 5	310	71.7	4.3	5.3	16.6
Reference Reach	112 (30.6)	72.9 (15.4)	1.5 (0.4)	2.7 (0.1)	49.5 (17.3)

Table 3-5. Project area and reference reach summary data for riffle habitat units. Presented data are mean values and (1 SD).

Reach	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
Reach 1	308.5 (24.7)	143 (8.5)	2.2 (0.1)	3.3 (0.1)	66.3 (2.1)
Reach 2	191	93.9	2.0	5.1	46.3
Reach 3	242 (15.6)	70.9 (6.40)	3.4 (0.3)	4.4 (0.30)	20.9 (3.30)
Reach 4	304.3 (31.1)	74.1 (12.4)	4.2 (0.6)	6.0 (0.7)	18.4 (6.0)
Reach 5	345 (35.8)	83.9 (4.5)	4.1 (0.3)	7.4 (0.6)	20.4 (0.83)
Reference Reach	103 (34.2)	86.4 (0.6)	1.2 (0.4)	2.4 (0.4)	76.7 (26.5)

Channel Profile

A comparison of the channel profiles for the project area and Teddy Powers Meadows Reference Reach are included below (Table 3-6). Channel slopes decrease from the Coyote Bucket Canyon downstream to the Drews Road Bridge. Reach 5 has the lowest gradient slopes. The reference reach has channel slopes intermediate to Reach 1 and Reach 2.

Table 3-6. Summary channel slope information for the project area and the reference reach.

Reach	Average Bankfull Slope	Average Water Surface Slope	Riffle Bankfull Slope	Riffle Water Surface Slope	Pool Bankfull Slope	Pool Water Surface Slope
Reach 1	0.0049	0.0058	0.0146	0.0112	0.0022	0.0019
Reach 2	0.0009	0.0009	0.0032	0.0035	0.0009	0.0006
Reach 3	0.0001	0.0003	0.0003	0.0004	0.0001	0.0002
Reach 4*	N/A	N/A	N/A	N/A	N/A	N/A
Reach 5	0.00007	0.00004	0.00007	0.00011	0.00007	0.00002
Reference Reach	0.0016	0.0016	0.0045	0.0049	0.0003	0.00025

*: A channel profile was not completed in Reach 4.

3.2.2 Existing Vegetation Conditions

Existing vegetation patterns are influenced by hydrology, soils, human land uses, and natural river disturbance processes. Vegetation communities may be characterized according to their position in the river corridor. A sedge/rush community is located from the edge of the baseflow channel to approximately the bankfull elevation, a willow and silver sagebrush community that brackets the bankfull elevation (plus or minus one foot), and an upland community dominated by big sagebrush. Sedge/rush and willow communities also occupy floodplain and terrace depressions.

The sedge/rush community may be an early successional community that reflects riparian area recovery from over-widening or entrenchment. Sedges and rushes colonize sediment deposited within steep banks, often forming a stable bench between the baseflow channel and the toe of floodplain and terrace slopes. Over time, if left undisturbed, these herbaceous communities will trap sediment, thereby rebuilding streambanks. Once the sedge/rush communities are established, and have built banks to an elevation that corresponds to a hydroperiod that will support willows, the sedge/rush communities may begin to shift toward a willow community. In addition to this process, willow communities can also be early successional communities and will colonize some of the depositional features as well.

Silver sage (*Artemisia cana*) was observed in several locations growing within the active floodplain of the Sycan River, often right down to the water’s edge. Silver sage is considered a riparian shrub in dry regions such as the Columbia Basin, Great Basin, eastern Montana, Wyoming, and the western Dakotas. It is common on transitional wet to dryland sites where soils are dry by midsummer. Silver sage inhabits moister, colder soils and has superior flooding tolerance as compared to other woody species of *Artemisia*. A listing of riparian and wetland plant communities in Oregon includes various silver sage associations (Kovalchik 1987; Crowe 2004).

In some locations, silver sage is recognized as an early seral species that is later replaced by cottonwood, willow, and other riparian vegetation. It has also been noted as an increaser under grazing pressure. The presence of silver sage as the dominant species in riverbank and floodplain locations along the Sycan River suggests that the riparian vegetation here is in a state of disclimax potentially due to grazing. With heavy grazing various graminoids and forbs such as Nebraska sedge, Baltic rush, Kentucky bluegrass, yarrow, cinquefoil and pussytoes increase in cover in this riparian association and with continued overgrazing, Kentucky bluegrass becomes the dominant graminoid in the plant community (NRCS 1985; Crowe 2004). This vegetation change sequence appears to have occurred within some of the Sycan floodplain areas. A change in hydroperiod resulting from vertical channel incision and lack of diverse riparian plant communities is likely another factor that favors silver sage dominance; this species may be more tolerant to these conditions than other riparian shrub communities.

Along the Sycan River, we observed silver sage functioning much like other woody riparian vegetation: creating near-bank channel roughness, trapping sediment, building floodplain, and providing cover for willow seedlings to establish (Figure 3-4). If livestock grazing is eliminated, stands of silver sage along the riverbanks should continue to perform these functions and will likely transition to more diverse stands of woody riparian trees and shrubs.

Channel morphology influences vegetation conditions in the project area. Lateral and vertical channel instability has occurred to varying degrees in the project area. As a result of channel incision, the distance between the floodplain surface and the baseflow channel increases. Floodplain plants may be less resilient over time with a lower water table. Similarly, with an increase in channel capacity related to channel incision and widening, overbank flood events are less frequent. Nutrient and sediment delivery to floodplain surfaces is less common.

In summary, the establishment of good riparian vegetation to resist the erosive flows is necessary to trap sediments and build new streambanks and a new floodplain at the lower elevation. This process is occurring in the Teddy Powers Meadows reference reach and also locally in other assessment reaches along the Sycan River but many areas of actively eroding streambanks are also present.



Figure 3-4. Two examples of the influence of riparian vegetation on sediment trapping on the Sycan River illustrate the role of floodplain vegetation in storing fine sediment. Silver sagebrush on the floodplain creates turbulence and sediment deposition. If left undisturbed over time, these sites would be colonized by vegetation and bank building would take place.

3.3 Desired Future Conditions

The Sycan River in the project area exhibits varied channel morphology, streambank stability, riparian vegetation, and aquatic habitats. Through Reach 2, the upstream portion of Reach 3, and Reach 4, the Sycan River appears to be laterally unstable based on widespread bank erosion. Bank erosion is believed to be related to both the natural site conditions and human influences. Site conditions that contribute to the bank erosion include climatic conditions (low precipitation), hydrology (water surface elevation differences between peak flows and base flows), ash and pumice-based soils, and vegetation communities. Human-related effects include livestock grazing, historical beaver removal, and watershed modifications including the alteration of the Sycan Marsh.

The desired future condition focuses on a more stable river corridor by enhancing the riparian vegetation community. A more stable river corridor is expected to result in reduced bank erosion and sediment delivery to the Sycan River, improved riparian vegetation coverage, and enhanced aquatic habitat. Stability does not imply stopping natural processes such as bank erosion and deposition, but rather, slowing the rate of channel change through natural processes. Addressing current land management and promoting vegetation recovery is believed to be the most prudent action for achieving reach-level ecosystem recovery.

The Teddy Powers Meadows section of the Sycan River was selected as a reference reach based on the riparian vegetation community, recovery of eroding stream banks, and the diverse channel morphology. The Teddy Powers Meadows section (reference reach) provides an example of the desired future condition for the project area (Figure 3-5). The reference reach is characterized by a riparian vegetation community recovering from past season-long grazing. The reach exhibits a vegetation pattern that probably reflects a true early- to mid-seral reference condition for the majority of the Sycan River project area. The reference reach appears to be fifteen to twenty years into a period of recovery from season-long grazing, a land use pattern that is still occurring in much of the project area. Vegetation in the reference reach consists of a narrow fringe of perennially inundated rush/sedge communities along the channel margin transitioning to seasonally inundated sedge/rush and willow communities. Above the sedge/rush and willow communities is a floodplain terrace dominated by big sagebrush.

Beaver remain active in the reference reach although their activity level appears to be less than in the past. Signs of old dams on the main channel and diverse floodplain areas suggest a more active beaver community inhabited the area in the past.



Figure 3-5. Riparian vegetation in the Teddy Powers Meadows reference reach is characterized by sedges/rushes at the channel edge grading to willows at the edge of the active flood channel. Sage brush and other drier upland species occupy the low terrace.

The vertical height from the channel bed to the low terrace is less in the reference reach than in the project area. This characteristic is largely related to the geology and the depth to bedrock or a hardpan layer that resists erosion. The depth to the confining layer also influences groundwater/surface water interactions and vegetation conditions. The denser riparian community in the reference reach may be responding to both the cessation of grazing as well as better access to the water table.

Aquatic habitat conditions are more diverse in the reference reach compared to the project area. Channel edge vegetation provides protective habitat for rearing juvenile fish. Off-channel habitats including floodplain channels and ponds also contribute to habitat diversity (Figure 3-6). These features are generally connected to the base flow channel.



Figure 3-6. River corridor habitats including a floodplain pond (left) and side channels contribute to aquatic habitat diversity in the reference reach. Several features appear to have been influenced by beavers.

SECTION 4.0 RESTORATION STRATEGIES

The following section presents the four restoration alternatives that were evaluated for the Sycan River project area. Restoration goals include the following items.

- Address river corridor stability by reducing bank erosion and sediment delivery, improving riparian vegetation conditions, and enhancing habitat.
- Raise water surface elevations to increase the interaction of the river with adjacent floodplains. Enhanced river-floodplain interaction would increase floodplain storage of sediment, debris, and water. Water released from floodplain storage has the potential for increasing the magnitude of summer base flows, lowering summer water temperature, and increasing soil moisture conditions for the benefit of riparian vegetation.
- Restoration projects are to be implemented in the context of the watershed conditions. Projects should focus on re-establishing natural processes like vegetation and woody debris recruitment to the river, and habitat formation and maintenance.

4.1 Alternative 1 – Grazing Management and Bioengineering

Alternative 1 – Grazing Management and Bioengineering focuses on excluding livestock from the river corridor and implementing bioengineering projects to accelerate revegetation of disturbed areas. Alternative 1 is the preferred alternative. The foundation of this alternative is that livestock must be excluded from the river bottom in order to improve vegetation conditions. Bioengineering projects are also proposed to help accelerate vegetation colonization, stabilize eroding banks, and improve aquatic habitat.

A geographic information system (GIS) analysis was completed to estimate the exclusion acreage under the two proposed grazing exclusion alternatives. The GIS maps were produced from the hydraulic model that estimated the water surface elevations associated with the 2-year, 5-year, and 10-year flood events. The flood extents for each flood interval were mapped. The fence locations are presented in reference to the flood extents. Figure 4-1 through Figure 4-3 provide the fence locations for the two alternatives. Landownership boundaries area also presented.

Two grazing exclusion alternatives were developed. Under both alternatives, off-channel watering sites would be established. Landowner compensation and/or easements are recommended to compensate the landowners for lost livestock production. Alt. 1 would set fence lines outside of the approximate 2-year flood extent. Although livestock would be excluded from the base flow channel, livestock would have access to the majority of floodplain and terraces areas. The benefits of Alt. 1 would be that livestock would continue to have access to high quality forage. Costs associated with Alt. 1 include the cost of the longer fence, fence maintenance due to the close proximity to the channel, and maintenance of off-channel watering sites. Alt. 2 would set the fences outside of most of the 5-year/10-year flood inundation area. The benefits of Alt. 2 would include more protection of the river corridor and lower fence installation and maintenance costs. Costs associated with Alt. 2 include less grazing income for landowners as the accessible forage is lower quality forage.

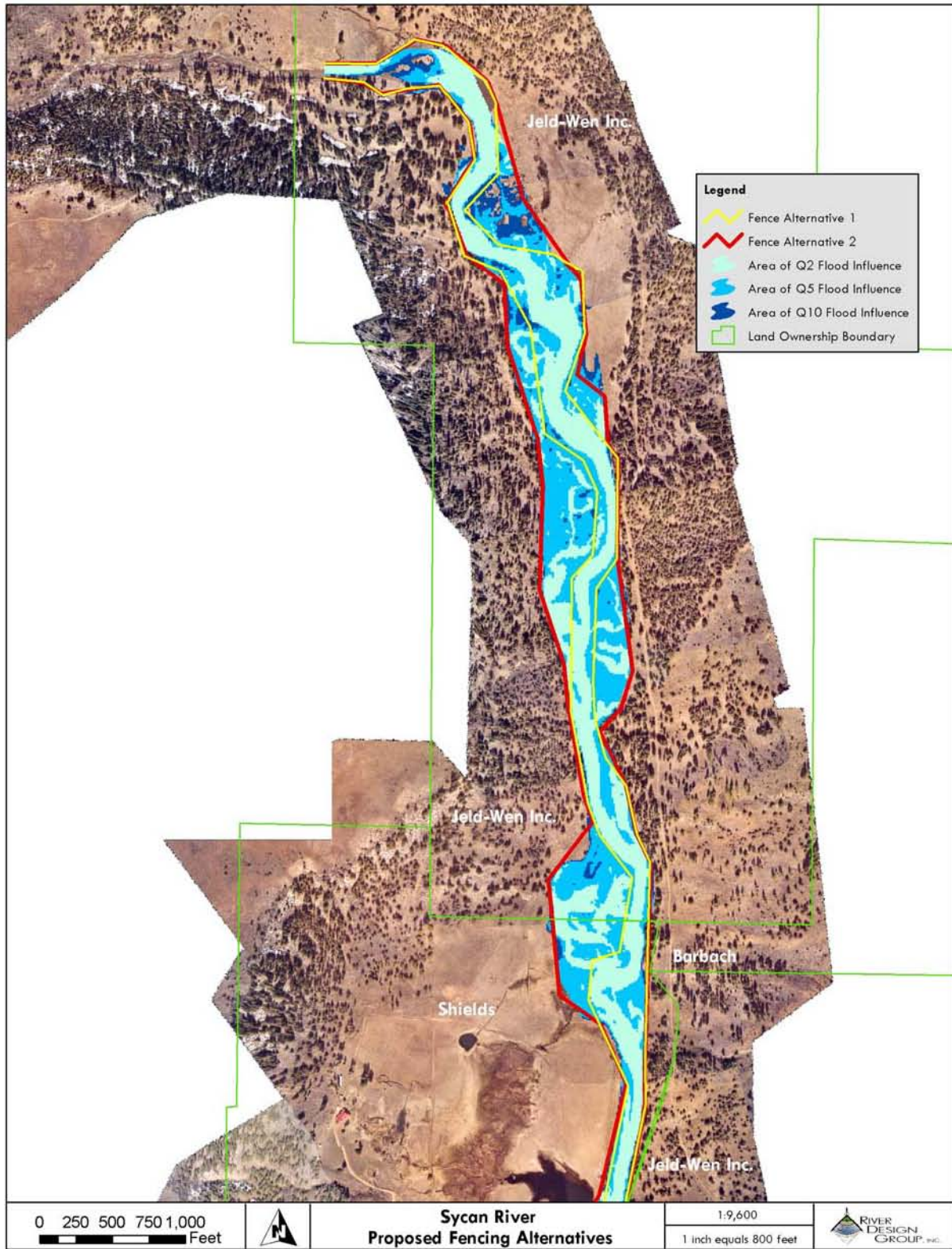


Figure 4-1. The proposed fencing alternatives map for Reach 1 through the middle of Reach 3. The flood extents, Alt. 1 and Alt. 2 fence locations, and landownership boundaries are presented.

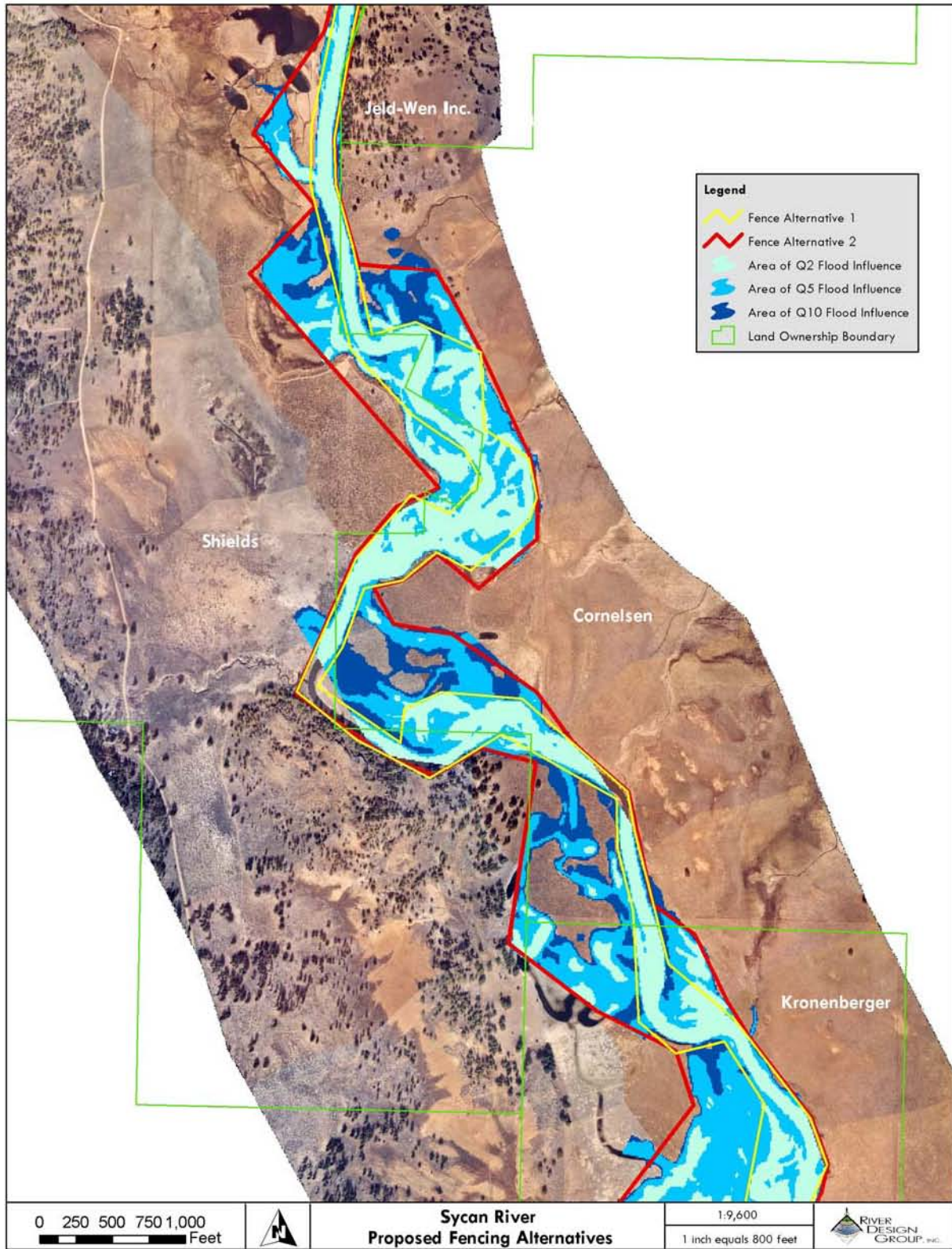


Figure 4-2. The proposed fencing alternatives map for the middle of Reach 3 through upper Reach 5. The flood extents, Alt. 1 and Alt. 2 fence locations, and landownership boundaries are presented.

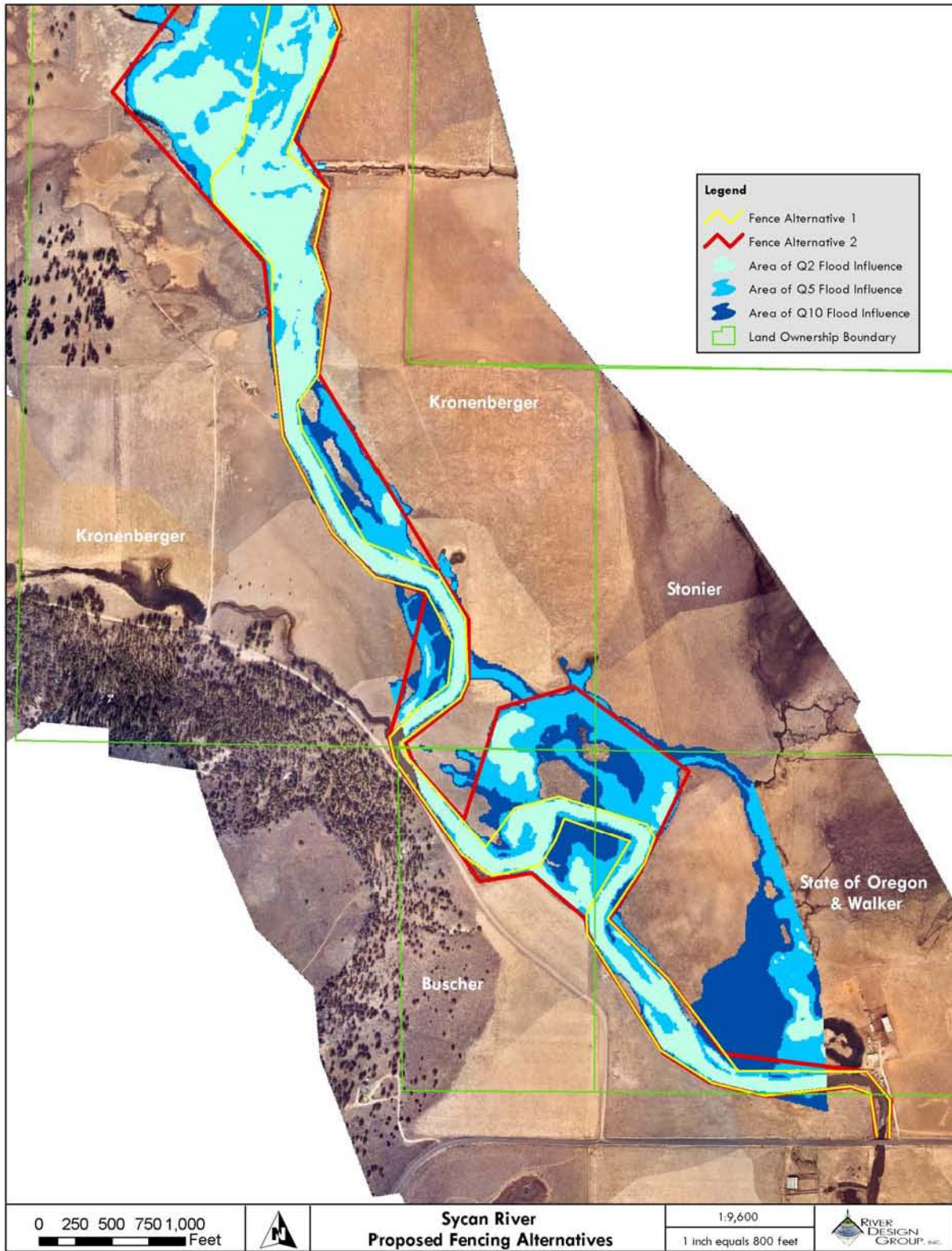


Figure 4-3. The proposed fencing alternatives map from the middle of Reach 3 to upstream of Snake Creek. The flood extents, Alt. 1 and Alt. 2 fence locations, and landownership boundaries are presented.

The area of lost livestock production by landownership was calculated by measuring the land area within the two enclosure alternatives and subtracting the area of the base flow channel (Table 4-1).

Table 4-1. Acres of livestock enclosure under Alt. 1 and Alt. 2 by landownership.

Landowner	Acres of River	Alt. 1 Enclosure Acreage	Alt. 1 Acres of Lost Livestock Production	Alt. 2 Enclosure Acreage	Alt. 2 Acres of lost livestock production
Jeld-Wen, Inc.	10.0	36.2	26.2	67.6	57.6
Shields	8.4	29.3	21.0	56.9	48.5
Cornelsen	6.3	32.8	26.4	74.1	67.7
Kronenberger	11.8	48.1	36.3	108.0	96.2
Stonier	0.0	--	--	1.7	1.7
Buscher	2.9	8.1	5.2	20.6	17.7
State of Oregon & Walker	5.3	14.7	9.4	23.0	17.7
Total	44.7	169.2	124.5	351.9	307.1

Forage values were estimated after discussions with one of the landowners in the project area. We estimated the lost livestock production by breaking forage values into three categories. Channel margin vegetation was given the highest forage value of \$130 (\$120-\$140) per acre per summer. Approximately 1 acre of channel margin vegetation supports one cow/calf pair per summer. Floodplain and terrace vegetation was given an intermediate forage value of \$70 (\$60-\$70) per acre per summer. Approximately 2 acres of terrace vegetation are necessary to support one cow/calf pair per summer. Upland vegetation (e.g. sage brush/Ponderosa pine community) typically requires considerable acreage to support livestock and was not included in the lost forage value calculations.

To estimate the area of channel margin vegetation in a reach, we multiplied the baseflow channel area by 1.5. This provides a channel margin vegetation area 50% greater than the baseflow channel area and is believed to accurately represent the channel margin vegetation area. Field verification would be necessary to improve this estimate. To estimate the terrace area, we subtracted the baseflow channel area and the channel margin fringe area from the total fenced area. The channel fringe area was multiplied by \$130 to determine the value of the excluded channel margin forage. The terrace area was multiplied by \$70 to determine the value of the excluded terrace forage. These values were added together to calculate a total lost forage value. Other costs including the fence materials and installation, maintenance, and off-channel livestock watering were not determined. These more detailed costs will be determined during final project designs. Table 4-2 estimates the cost of the lost production for Alt. 1 and Table 4-3 estimates the cost of the lost production for Alt. 2. Costs for fencing and off-channel watering were not calculated. Lost forage costs could be used as one means to secure landowner compensation.

Table 4-2. Estimated cost of lost livestock production based on the Alt. 1 livestock exclusion.

Landowner	Area Captured by Fence Alt. 1 (acres)	Baseflow Channel Area (acres)	Area of Lost Livestock Production (acres)	Estimated Cost of Lost Livestock Production		
				River Fringe Estimate (\$130/ac)	Riparian Terrace Estimate (\$70/ac)	Total Estimate
Jeld-Wen, Inc.	36.2	10.0	26.2	\$1,946	\$789	\$2,735
Shields	29.3	8.4	21.0	\$1,634	\$587	\$2,221
Cornelsen	32.8	6.3	26.4	\$1,234	\$1,185	\$2,420
Kronenberger	48.1	11.8	36.3	\$2,307	\$1,297	\$3,604
Stonier	--	--	--	--	--	--
Buscher	8.1	2.9	5.2	\$566	\$60	\$625
State of Oregon & Walker	14.7	5.3	9.4	\$1,032	\$101	\$1,133
Total	169.2	44.7	124.5	\$8,718	\$4,019	\$12,738

Table 4-3. Estimated cost of lost livestock production based on the Alt. 2 livestock exclusion.

Landowner	Area Captured by Fence Alt. 2 (acres)	Baseflow Channel Area (acres)	Area of Lost Livestock Production (acres)	Estimated Cost of Lost Livestock Production		
				River Fringe Estimate (\$130/ac)	Riparian Terrace Estimate (\$70/ac)	Total Estimate
Jeld-Wen, Inc.	67.6	10.0	57.6	\$1,946	\$2,982	\$4,928
Shields	56.9	8.4	48.5	\$1,634	\$2,516	\$4,150
Cornelsen	74.1	6.3	67.7	\$1,234	\$4,076	\$5,310
Kronenberger	108.0	11.8	96.2	\$2,307	\$5,491	\$7,798
Stonier	1.7	0.0	1.7	\$0	\$121	\$121
Buscher	20.6	2.9	17.7	\$566	\$934	\$1,499
State of Oregon & Walker	23.0	5.3	17.7	\$1,032	\$686	\$1,717
Total	351.9	44.7	307.1	\$8,718	\$16,805	\$25,524

Fencing costs were estimated for each of the landowners adjacent to the Sycan River in the project area (Table 4-4). Fencing costs are based on a \$2.25/ft cost and are marked-up from a base cost of \$1.85/ft provided by the Natural Resources Conservation Service from recent fencing projects completed in the Upper Klamath Basin. The base cost was revised to account for the remoteness of the project area and increased material prices. The fence construction cost for Alt. 2 is less than for Alt. 1 due to the shorter fencing length.

Table 4-4. Estimated fencing costs for the Alt. 1 and Alt. 2 fencing options. Costs are based on price of \$2.25 per linear foot of fence.

Landowner	Alt. 1 Fence Length (ft)	Alt. 1 Fence Cost	Alt. 2 Fence Length (ft)	Alt. 2 Fence Cost
Jeld-Wen, Inc.	15,509	\$34,896	14,831	\$33,370
Shields	11,846	\$26,653	12,947	\$29,130
Cornelsen	10,959	\$24,658	8,750	\$19,687
Kronenberger	16,089	\$36,201	16,569	\$37,281
Stonier	--	--	567	\$1,275
Buscher	4,100	\$9,226	3,160	\$7,110
State of Oregon & Walker	6,476	\$14,572	5,946	\$13,379
Total	49,471	\$146,206	47,938	\$141,231

Potential bioengineering treatments would be directed towards enhancing habitat, promoting sediment deposition, and accelerating revegetation. Example projects would include stable large wood placement in the active channel and off-channel wetlands. Planting willow cuttings would be an additional treatment to potential speed willow colonization in areas where they have been displaced by grazing. Figure 4-4 illustrates engineered log jams and bioengineering projects completed on the Sprague River.



Figure 4-6. Example bioengineering (left) and engineered log jams (right) on the Sprague River. Bioengineering and log jams provide bank stability and diverse aquatic habitat. Over time, the willows planted in the soil lift will form a dense willow thicket.

Bioengineering and ELJ projects would be implemented at select locations based on site conditions and access. Potential priority sites for bioengineering would include bare eroding banks where willow colonization would meet the restoration objectives. Potential ELJ sites would include off-channel wetlands where the trees would provide habitat for juvenile rearing. Other sites in the active channel would provide overhead cover and habitat diversity for all life history stages of fish inhabiting the Sycan River. ELJs could also be placed to deflect streamflow from unstable banks. Increasing the vegetation density and frequency of large wood in the system would increase channel roughness.

Alternative 1 Summary

Alternative 1 addresses the restoration goals. Excluding livestock from the river would improve vegetation conditions and ultimately reduce sediment loading to the river. The increased channel roughness related to the improved vegetation condition and installation of ELJs would potentially increase water surface elevations. Higher water surface elevations would increase channel-floodplain connectivity. The bioengineering and ELJs are also in the context of the watershed conditions. The bioengineering sites would accelerate willow colonization in the river corridor. ELJs would collect debris transported from the upper watershed and through the Coyote Bucket Canyon. Over time, riparian vegetation would be expected to colonize the surfaces adjacent to the baseflow channel and within the margins of the 2-year flood channel. Vegetation will improve habitat complexity, contribute wood to the stream, and slow flood water.

4.2 Alternative 2 – Grazing Exclusion/No Habitat Enhancement

Alternative 2 would include fencing the Sycan River according to the fencing options presented in Alternative 1. Bioengineering outlined in Alternative 1 would not be completed under Alternative 2. Excluding livestock from the active channel would provide the greatest long-term benefits for the system. Habitat improvements would be slower under Alternative 2 than under Alternative 1, but Alternative 3 would also be less costly and lower risk.

Alternative 2 Summary

Alternative 2 addresses the restoration goals. Excluding livestock from the river would improve vegetation conditions and ultimately reduce sediment loading to the river. The increased channel roughness related to the improved vegetation condition potentially increase water surface elevations over time. Higher water surface elevations would increase channel-floodplain connectivity. The fencing would allow vegetation to recolonize naturally. The shorter-term bank stabilization, habitat, and improved vegetation condition benefits related to bioengineering and ELJ installation would not be realized under Alternative 2. Over time, riparian vegetation would be expected to colonize the surfaces adjacent to the baseflow channel and within the margins of the 2-year flood channel. Vegetation will improve habitat complexity, contribute wood to the stream, and slow flood water. Alternative 2 would be less expensive than Alternative 1 since no habitat enhancement work would be completed.

4.3 Alternative 3 – Habitat Enhancement/No Grazing Exclusion

Alternative 3 would address aquatic and riparian habitat in the river corridor through bioengineering and large wood placement; however, the river corridor would not be fenced. Alternative 3 would improve habitat complexity but would not provide the greater watershed benefits that would be expected from the grazing exclusion. Habitat improvements would likely be short-term in nature and would be undermined by the continued grazing pressure.

Alternative 3 Summary

Alternative 3 does not entirely address the restoration goals. Excluding livestock from the river is necessary to improve vegetation conditions and ultimately reduce sediment loading to the river. Installation of ELJs would potentially increase water surface elevations, but continued grazing would reduce the potential for increasing channel roughness at the reach scale. Although the bioengineering and ELJs are also in the context of the watershed conditions, the effectiveness of these treatments would be minimal relative to the negative effects of continued grazing.

4.4 Alternative 4 - Channel Reconstruction

Under Alternative 4, portions of the Sycan River would be reconstructed to increase channel sinuosity and increase channel-floodplain connectivity. The reconstructed channel would follow the alignments of floodplain channels adjacent to the active river channel. Portions of the existing channel that were to be left in place would be modified to raise the channel invert elevation. Bioengineering, ELJs, and grade control would be used to provide channel stability and habitat.

This approach would address the original idea presented by Water Consulting, Inc. (2002) that the Sycan River was entrenched relative to the floodplain elevation and that only periodic floods accessed adjacent floodplains. The hydraulic modeling exercise suggests that the Sycan River is confined to approximately the 2-year discharge event in most of the reach upstream from the Shields' property. The lower Sycan River that is bracketed by high terraces, confines stream flows up to an exceeding the 5-year event.

This alternative was not pursued further due to the relative risk and costs associated with channel reconstruction. Channel reconstruction in the Sycan River system would have moderate risk due to periodic flood events, ice floes, fine soils, and vegetation conditions. Relocating the channel would require substantial earth moving and stabilization. Rock and gravel would be required to ensure channel stability. Because these materials are limited in the project area, materials would need to be imported into the project area.

Reducing the project risk would be exceedingly expensive due to the need for vertical and lateral channel stabilization. The remoteness of the project area would require long haul routes to import project materials if they were not available on-site.

Furthermore, the channel through most of the reach is only slightly entrenched and adjacent floodplains are inundated with moderate frequency. Higher terraces in the lower project area are infrequently inundated. High terrace soil properties suggest these landforms have not been active floodplains in the recent past.

In summary, implementing channel reconstruction through the project area is considered to be a high risk, low reward project alternative. Channel reconstruction would be expensive with questionable benefits and a moderate to considerable level of risk. For these reasons, Alternative 4 was not developed further.

Alternative 4 Summary

Alternative 4 addresses the restoration goals, however, considerable cost and risk are associated with this alternative. Channel reconstruction would include increasing the channel sinuosity, improving channel-floodplain connectivity, and stabilizing eroding banks. These efforts would be expensive due to the materials costs, remote project area, and extent of stabilization structures that would have to be installed to reduce the potential for project failure. Livestock would need to be excluded from the river corridor. Alternative 4 would be the most expensive project alternative.

4.5 Alternative 5 – Maintain Existing Land Management Practices and Existing Conditions

Alternative 5 would maintain the existing land management practices. Continuing with the current land management regime will likely result in the continuation of the existing degraded river

corridor conditions. Livestock will graze the riparian zone and bank erosion will continue. The Sycan River will continue to have stability issues, and channel roughness and channel-floodplain connectivity are not expected to improve.

No additional monetary costs would be incurred with this option. Over time if the river continues to widen, the landowners may lose property due to erosion. Environmental costs would include continued sediment delivery to the Sprague River and ultimately Upper Klamath Lake, aquatic habitat degradation, and further invasive weed colonization. The primary landowner benefit of Alternative 5 is that the existing land management regime would continue. This would not require any change in the current management costs.

Alternative 5 Summary

Alternative 5 would not achieve the restoration goals.

4.6 Restoration Strategies Summary

Proposed restoration strategies outlined in this section may be applied throughout the Sycan River project area. The preferred approach to improving the conditions of the Sycan River corridor is to exclude livestock from the river corridor for at least 5-10 years. This period of time is believed to be necessary to improve the riparian vegetation community that has been subjected to over 100 years of grazing. Using the Teddy Powers Meadow Reference Reach as an example, the riparian community is expected to rapidly respond to the livestock exclusion. An improved riparian condition will increase the channel roughness leading to more frequent flooding of adjacent floodplains.

Appendix I includes more detailed bioengineering techniques designed to accelerate riparian recovery and enhancing aquatic habitat. Techniques including engineered log jams, vegetated soil lifts, willow cuttings, and containerized plants achieve multiple project objectives. While fencing the river corridor will exclude livestock from the river margins, implementing bioengineering techniques will address near-term conditions until the river corridor naturally recovers.

SECTION 5.0 EXAMPLE CONCEPTUAL PROJECTS

Conceptual restoration strategies were prepared for three properties in the Sycan River project area. The projects vary in scale and approach although each of the sites would benefit from livestock exclusion prior to site-specific treatments. The following section presents a summary of the three conceptual projects.

5.1 Jeld-Wen, Inc. Property – Coyote Bucket Canyon Downstream to Shields Property

The following sections include proposed restoration prescriptions for the Jeld-Wen, Inc. (JWI) property in the Sycan River project area. The restoration strategy includes passive activities focused on fencing the river corridor. Fencing the river corridor and excluding livestock would promote riparian community recovery. Riparian recovery is expected to improve river corridor conditions as was illustrated in the Teddy Powers Meadows reference reach discussion. Once the vegetation has recovered, additional work could be implemented to increase aquatic and riparian habitat diversity. Examples of other potential projects include placing engineered log jams for fish habitat and pool development, willow planting to accelerate vegetation recovery, and monitoring river response.

5.1.1 Fencing Plan

Two fencing alternatives were developed for the JWI property on the Sycan River. Descriptions of the evaluation process were presented in Section 4.1. The following sections focus on the JWI property.

Alternative 1

Fencing Alternative 1 (Alt. 1) is based on placing the fence approximately 20 ft back from the edge of the terrace. The Alt. 1 fence location would exclude livestock from the flood way channel associated with the 2-year flood event. Livestock would still be allowed access to most of the terrace areas. Table 5-1 includes the area computations and value of lost livestock production under Fencing Alt. 1.

Table 5-1. Estimated cost of lost livestock production based on the Alt. 1 livestock exclusion.

	Area Captured by Fence Alt. 1 (acres)	Baseflow Channel Area (acres)	Area of Lost Livestock Production (acres)	Estimated Cost of Lost Livestock Production		
				River Fringe Estimate (\$130/ac)	Riparian Terrace Estimate (\$70/ac)	Total Estimate
Landowner						
Jeld-Wen, Inc.	36.2	10.0	26.2	\$1,946	\$789	\$2,735

Alternative 2

Fencing Alternative 2 (Alt. 2) locates the fence outside the majority of the 10-year flood inundation area and captures most of the active river corridor. Livestock would be excluded from most of the terrace areas in addition to the 2-year channel. Grazing areas outside of the fences could be uneconomical due to low forage quality. Table 5-2 includes the area computations and cost of lost livestock production under Fencing Alt. 2.

Table 5-2. Estimated cost of lost livestock production based on the Alt. 2 livestock exclusion.

Landowner	Area Captured by Fence Alt. 2 (acres)	Baseflow Channel Area (acres)	Area of Lost Livestock Production (acres)	Estimated Cost of Lost Livestock Production		
				River Fringe Estimate (\$130/ac)	Riparian Terrace Estimate (\$70/ac)	Total Estimate
Jeld-Wen, Inc.	67.6	10.0	57.6	\$1,946	\$2,982	\$4,928

Fencing costs for the two alternatives are included in Table 5-3. Table 5-4 includes the lost livestock production costs and the fencing costs for the two alternatives.

Table 5-3. Estimated fencing costs for the Alt. 1 and Alt. 2 fencing options. Costs are based on price of \$2.25 per linear foot of fence.

Landowner	Alt. 1 Fence Length (ft)	Alt. 1 Fence Cost	Alt. 2 Fence Length (ft)	Alt. 2 Fence Cost
Jeld-Wen, Inc.	15,509	\$34,896	14,831	\$33,370

Table 5-4. Project costs for implementing the grazing the two grazing exclusion alternatives on the JWI property.

Landowner	Alt. 1 Cost	Alt. 2 Cost
Jeld-Wen, Inc.	\$37,631	\$38,298

Costs and Benefits of the Alternatives

Each of the presented alternatives has costs and benefits. Alt. 1 would take less forage out of production than does the Alt. 2 plan. However, the Alt. 1 fence location is closer to the active channel and would likely require more frequent maintenance following floods. The Alt. 2 fence location is more distant from the active channel and would require less maintenance. Other fencing options that are intermediate to these alternatives could be investigated.

Our analysis of lost forage production yielded cost estimates less than originally anticipated. Excluding livestock from the 2-year flood channel (Alt. 1), would at a minimum, improve vegetation conditions between the confining terraces. This alternative would result in foregoing approximately \$3,000 per year in grazing revenue, a fairly small sum relative to the potential water quality and habitat benefits that would be provided. Alt. 2 would restrict livestock from the majority of the river corridor and improve the riparian community within the fence lines. Implementing Alt. 2 would result in a loss of approximately \$5,000 per year in grazing revenue. Because JWI leases the property for grazing, JWI is likely paid only a portion of this amount by the lessee.

Other proposed activities include managing invasive weeds, relocating beavers into the Sycan River, and placing large wood would further improve the river corridor. Large wood placement could be completed at select locations. Placing large wood to interact with the baseflow channel would provide more diverse habitat for juvenile and adult fish. Wood placement would need to consider the effects of the wood on unstable streambanks. Wood should be stabilized with ballast rock or anchored into streambanks and the stream bed. Accumulations of large wood on

floodplain surfaces suggest wood does not recruit to the river until the bankfull discharge is exceeded.

Monitoring the vegetation response is advised for determining the effectiveness of the grazing management plan. After a period of 5 to 10 years (or less as vegetation conditions permit), it would be possible to enact limited grazing within the fenced corridor. This period of time is expected to be necessary to re-establish the dense riparian vegetation that historically occupied the site. A more actively-managed grazing plan could be implemented in the future although excluding livestock from at least the 2-year channel is advised.

5.2 Kronenberger Property

RDG completed a list of 16 potential projects on the Kronenberger property. There are several issues that should be recognized when evaluating the proposed projects. The outlined projects may be organized into two groups: floodplain fill removal projects and bank erosion control projects. The following sections present the goals, potential benefits and risks, and implementation strategies for the two project groups. The project elements of foremost importance are fencing the river corridor and excluding livestock from the bankfull channel. A proper fence location would exclude livestock from the streambank edge where the river is confined by high streambanks, as well as floodplain wetland areas where the river has greater access to the floodplain. Livestock grazing would still be possible throughout the property outside of the exclusion area. Off-channel water could also be developed to provide livestock watering. If livestock are not excluded from the reach, improving the function of the Sycan River on the Kronenberger property is unlikely.

In addition to the grazing exclusion, other actions could include noxious weed management and potentially, in-stream habitat improvement. Instream habitat improvement would be achieved by placing stable whole trees and/or engineered log jams within the bankfull channel. Trees could likely be acquired from the Kronenberger's property, the Shields' property, or another source in the vicinity of the Kronenberger property. Ballast rock would also need to be acquired. Several potential rock sources are also available. The number and location of structures, structure size and material specifications, and material acquisition locations would be determined during final design. Treatment sites are included in Table 5-5.

Table 5-5. Recommended treatment sites on the Kronenberger property.

Site #	Project Type	Location	East/West Bank or Floodplain
1	Bank Treatment	225+00	West
2	Bank Treatment	228+00	West
3	Bank Treatment	232+50	West
4	Fill Removal	237+50	West
5	Fill Removal	246+00	West
6	Bank Treatment	250+00	West
7	Fill Removal	251+00	West
8	Bank Treatment	252+00	West
9	Fill Removal	261+00	West
10	Fill Removal	262+00	West
11	Bank Treatment	267+50	East
12	Fill Removal	268+00	West
13	Bank Treatment	273+50	East
14	Bank Treatment	274+00	Both
15	Bank Treatment	279+00	West

Floodplain Fill Removal Sites

The goal of the floodplain fill removal projects will be to increase the Sycan River’s access to the floodplain, improve riparian vegetation conditions, and enhance off-channel habitats. The floodplain fill removal projects entail removing fill that has been placed in the reach primarily for river access (Figure 5-1). Most of these fills are 2-3 ft high and are in the form of an unimproved road that parallels the river. The fills limit river access to floodplain areas during moderate high water and are typically colonized by sage brush, forbs, and noxious weeds. The anticipated benefits of the fill removal include increased interaction between the river and floodplain (floodplain sediment storage), increased riparian vegetation, increased opportunity for juvenile fish rearing in off-channel wetlands, and reduced in-channel stream energy (lower stream power and erosion potential). The cost of fill removal is minimal and construction would be simple to complete.



Figure 5-1. Two potential fill removal sites on the Kronenberger reach of the Sycan River. Site 6 (left) is characterized by poor vegetation conditions and floodplain confinement. Site 10 (right) separates the river from an off-channel wetland.

Implementation would be completed with a 200-class excavator and 2-3 dump trucks. The excavator would start at the upstream edge of each fill and load the fill directly to dump trucks. A travel route would be determined for each fill removal site and would be organized to minimize site disturbance. A fill stockpile area would be established out of the river corridor and would most likely be located at the shale pit where much of the fill material originated. Fill would be removed down to the floodplain elevation or tie to an appropriate topographic feature.

Following fill removal, each site would be prepared for revegetation. Due to the droughty soil conditions related to the pumice soils, the planting approach should include coir logs, willow cuttings, bare root and/or containerized plants, seeding, mulch application, and irrigation. The coir logs come in 13 ft lengths and act as a moisture-retaining sponge for improving willow survival. Willow cuttings would be bundled in fascines and buried in contact with the coir logs. The moisture from the coir logs would improve willow cutting success in the dry environment. Bare root and/or containerized sand bar willow and silver sage would also be planted in the fill removal area. A native seed mix comprised of riparian and dry species would be distributed at an appropriate application rate. Applying compost to the disturbed area would assist in limiting noxious weed invasion to the disturbed area. Weed invasion is a concern in the reach due to the prevalence of Canada thistle and bull thistle in the project area. Treating thistle for a minimum of three years following project implementation is recommended. Instituting a periodic irrigation plan is also recommended for the first two years following implementation to improve vegetation survival.

In summary, fill removal offers a low risk, high reward project alternative. Fill removal can be done moderately quickly with the revegetation approach also being fairly straight forward. However, successful implementation of the fill removal projects will require livestock exclusion, weed management, vegetation maintenance, and periodic irrigation.

Fill Removal Sites: Site 4, Site 5, Site 7, Site 9, Site 10, and Site 12.

Bank Stabilization Sites

Ten bank erosion sites were identified in the Kronenberger reach. Conditions at these sites ranged from rather short river sections approximately 50 ft in length, to more extensive areas

measuring up to 500 ft in length. Sites with the most extensive erosion included Site 1, Site 9, and Site 15. Two primary conditions relate to the bank erosion sites. First, bank erosion is related to livestock access. This process is apparent at Site 1 and Site 15 (Figure 5-2). A livestock trail at Site 1 appears to be undermining the upper bank resulting in a vertical, unstable and poorly vegetated bank. The willow community which would be expected at about the elevation of the livestock trail is absent from this site. Site 15 is located near the Kronenberger river crossing. Livestock tend to congregate on both sides of the river near the crossing. Soil compaction, vegetation removal, and surface erosion have resulted in a large eroding area.



Figure 5-2. A livestock trail at Site 1 (left) results in poor vegetation conditions and a raw bank. The Sycan River crossing (Site 15) concentrates livestock resulting in degraded riparian vegetation and stream bank conditions (right).

The second bank erosion condition relates to fluvial processes. At these locations, livestock access appears to be a secondary processes affecting bank stability. These sites are typically located where the river is interacting with a terrace or high stream bank. At these locations, the bank toe is stable but the upper bank is eroded by the river. These actions result in both incremental and acute sediment delivery to the Sycan River (Figure 5-3). Over time, the stream bank in the affected sites will reach an angle of repose and revegetate. Similarly, the failed bank material that settles at the bank toe may revegetate and become stable over time if significant flood events do not occur and livestock grazing is excluded.



Figure 5-3. Two sites characterized by vertical bank failures related more to fluvial processes than livestock access. Site 4 (left) is a short reach characterized by a vertical-to-overhanging bank. Site 9 is a more extensive reach characterized by an eroding outside bank that is contributing large blocks of soil to the river (right). Sloughed blocks may stabilize at the bank toe and revegetate as seen in the middle ground of the right photo.

The goal of treating the bank erosion sites is to reduce fine sediment delivery to the Sycan River by improving bank stability through riparian vegetation colonization of eroding sites. RDG discussed how best to achieve this goal with Tom Parker, Plant Ecologist with Geum Environmental Consulting, Inc. Our initial approach (as included in the draft project budget document) included re-grading eroding banks to achieve a bank slope more similar to stable banks found in the Kronenberger reach (Figure 5-4). Bank re-grading would be completed by excavating the eroding bank from the top of the sedge toe (if present) and day-lighting to a point on the terrace surface that would achieve the reference bank slope. Excavated material would be hauled to an appropriate stockpile area. Following bank re-grading, a bioengineering approach similar to the fill removal bioengineering concept would be completed. Coir logs and willow fascines would be placed at the inflection point located at the top of the sedge line. Willows commonly grow at this elevation throughout this section of the Sycan River. Bare root and/or containerized upland vegetation (e.g. rose, golden current, bitterbrush, and big sagebrush) would be planted. A native riparian and upland seed mix would be spread on the site. To limit noxious weed invasion, compost would be spread on the site. Irrigation would be necessary for a minimum of two years to improve revegetation success.



Figure 5-4. An example of an existing eroding bank (left) and a reference condition (right). The stream bank at the reference site has reached an angle of repose that supports vegetation.

Although the bank re-grading approach could be successful, it is questionable whether the actual re-grading is necessary, and just proceeding with the bioengineering and livestock exclusion may be a lower cost and lower risk alternative for achieving the stated goal. The bank re-grading will result in a substantial increase in the amount of exposed soils at each treated site. For example, at Site 1, the existing exposed soil surface area is approximately 3,000 ft² (500 ft long x 6 ft high). The re-graded slope could have an exposed surface area upwards of 6,000 ft² to 7,500 ft², more than doubling the existing exposed area. Due to the poor soil conditions (pumice sand) and limited soil moisture, there is a high risk of revegetation failure if the treated sites are not actively managed by landowner. Active management would include ensuring livestock exclusion, managing weeds, seasonal irrigation, and potentially periodic replanting. Additionally, other reference banks in both the Kronenberger reach and the upstream Teddy Powers Meadow reference reach illustrate the natural revegetation potential if livestock are excluded from the site (Figure 5-5).



Figure 5-5. Reference vegetation conditions on the Sycan River. A sedge/willow community in the Kronenberger reach (left) and sedges provide a buffer to a previously eroding bank on the Sycan in the Teddy Powers Meadow reach (right). Excluding livestock from the eroding bank sites in the Kronenberger reach would be expected to result in vegetation recovery.

Bioengineering for the eroding bank sites is still recommended. Coir logs and willow fascines would be installed at the toe of the eroding banks. Minimal excavation would be necessary during installation and the disturbance area would be limited. The planting work would be completed by hand labor. Irrigation would still be necessary to improve revegetation success. Combined with the livestock exclusion, this bank stabilization approach carries less risk, less cost, with a greater potential for revegetation success.

In summary, bank stabilization of eroding sites would be expected to reduce fine sediment delivery to the Sycan River. The preferred approach would include livestock exclusion and bioengineering to facilitate site revegetation. Weed management, vegetation maintenance, and periodic irrigation are suggested for ensuring revegetation success.

Bank Stabilization Sites: Site 1 – Site 3, Site 6, Site 8, Site 11, Site 13 through Site 15.

In-stream Habitat Enhancement

The Sycan River through the Kronenberger reach has limited in-stream aquatic habitat complexity. Based on results from other projects completed on the Sprague River and other river systems, placing stable large wood in the channel provides complex habitat for juvenile and adult fish. Large wood structures would be placed at locations that would promote pool scour, sediment sorting, and deflect flows from eroding banks. The structures would also provide more diverse habitat compared to the existing channel conditions.

Kronenberger Stream Crossing

A concrete stream crossing is located in the lower third of the Kronenberger property. The crossing enables Mr. Kronenberger to access the eastern portion of his property. The concrete crossing may affect fish passage during baseflow periods when shallow water depths and vertical height of the structure potentially preclude upstream fish movement (Figure 5-6). The structure is submerged during moderate and high flows. Fish passage is likely not affected during these periods. Although the structure may affect fish passage, it also provides grade control through the reach.



Figure 5-6. The Kronenberger crossing likely creates a fish passage barrier during baseflow. These picture taken in June 2007, capture the structure during the declining hydrograph.

The structure could be modified to improve fish passage. Adding rock or concrete steps to the downstream portion of the structure would provide better fish access over the structure. Building

a downstream pool tailout would also create a backwater downstream of the structure, improving the fish passage potential. Narrowing the structure width would confine the channel and increase water depths over the structure.

Agriculture Drain Channel

An agriculture drain channel was excavated in the eastern terrace between the 1940s and the 1990s. The drain captures groundwater and surface water and routes it to the Sycan River (Figure 5-7). Located on the Kronenberger and Cornelson properties, the drain was made by excavating the terrace and windrowing the soils on the terrace creating a berm. The channel at the bottom of the cut is developing a meander pattern by eroding the cut side slopes. The channel is a constant sediment source to the Sycan River, delivering fine sands.

Although further analysis is necessary, the ditch should be addressed to reduce sediment loading to the Sycan River. Potential treatments include stabilizing or filling the channel. Stabilizing the channel would improve the aquatic habitat conditions and potentially increase the ditch's habitat value. Filling the channel would treat the sediment loading and potentially raise the water table in the area. A higher water table could potentially reduce irrigation requirements. Either treatment would be relatively straightforward.

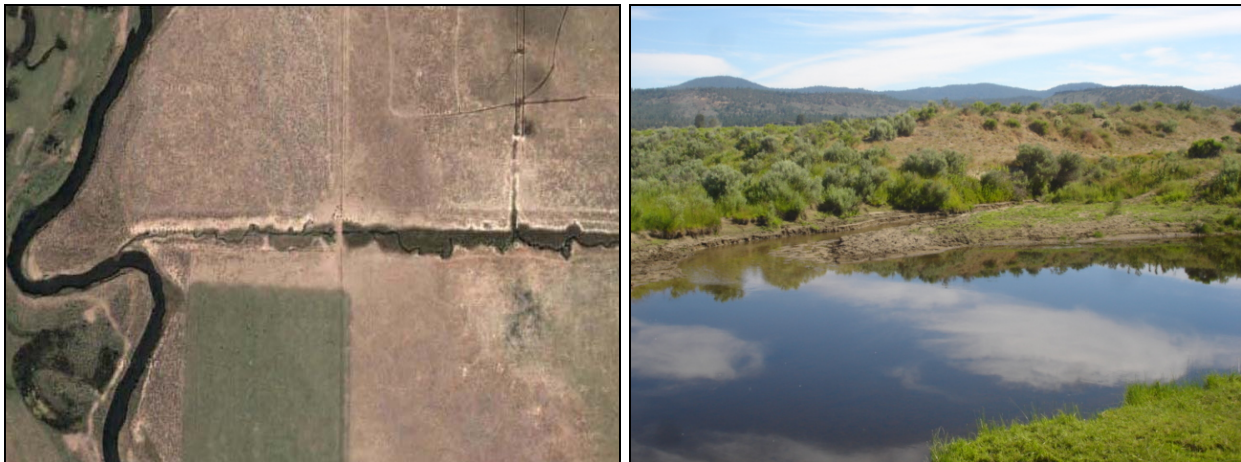


Figure 5-7. An air photo of the drainage channel (left), and a ground photo of the mouth of the drainage channel (right). The channel originates on the Cornelson property and flows through the Kronenberger property before reaching the Sycan River. The drainage channel is a persistent sediment source to the Sycan River.

The outlined project sites provide a range of options for improving river corridor conditions through the Kronenberger reach of the Sycan River. Excluding livestock from the Sycan River channel are expected to result in the greatest vegetation response. Implementing any of the planting options without complete exclusion of livestock from the river bottom is not advised. The proposed projects are also relatively straight forward and will require only moderate oversight once the operators understand the specific approaches. Building the in-stream structures will require more oversight but would be expected to result in fisheries benefits. Additionally, the vegetation response upon livestock exclusion would be expected to also result in fisheries benefits.

5.3 Conceptual Restoration Treatments Summary

The presented conceptual restoration treatments could be implemented anywhere in the Sycan River project area. The treatments rely on livestock exclusion from the bankfull channel in order to re-establish riparian vegetation. Completing structural treatments without excluding livestock from treated areas is not expected to have the same level of benefits. Restoring riparian vegetation is expected to affect sediment storage, fish habitat and floodplain diversity, and the frequency of overbank flooding.

SECTION 6.0 SYCAN RIVER ASSESSMENT SUMMARY

The Sycan River is a dynamic system influenced by its natural surroundings and human activities. As the largest tributary to the Sprague River, the Sycan River is an important contributor of flow, sediment, and wood. Although limited data are available, the Sycan River is also likely important for the Sprague River fish community. Groundwater springs, wetlands, and relict channels provide a variety of aquatic and riparian habitats.

Land management activities have influenced the watershed. Land management practices including the modification of the Sycan Marsh for agriculture, timber harvest and road construction throughout the watershed, and grazing in the river corridor have affected the Sycan River. Within the project area, grazing has impacted the riparian vegetation community. Vegetation removal, streambank trampling, soil compaction, and the spread of noxious weeds have degraded the plant community and made the Sycan River more susceptible to bank erosion.

Proposed restoration strategies focus on excluding livestock from the river corridor. To make this strategy viable, landowners will have to be compensated for lost livestock production. Setting up an easement program or pursuing existing conservation programs (e.g. Farm Services Agency's Conservation Reserve Enhancement Program) offer opportunities for compensating landowners for lost production. Implementing other habitat enhancement projects may be implemented if livestock are not excluded from the river. However, excluding livestock is expected to provide the greatest improvement in river corridor conditions. Achieving river corridor restoration goals will require re-establishing the riparian community.

SYCAN RIVER ASSESSMENT AND RESTORATION FEASIBILITY STUDY



Sycan River – View North to the Coyote Bucket Canyon.

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SECTION 1.0 INTRODUCTION

River Design Group, Inc. (RDG) was retained by the U.S. Fish and Wildlife Service – Klamath Basin Ecosystem Restoration Office (USFWS) to assess the Sycan River and evaluate potential restoration activities on the Sycan River from the Coyote Bucket Canyon downstream to Drews Road (project area). The project area is defined by dynamic channel conditions influenced by basin geology, land use practices, riparian vegetation conditions, and periodic high magnitude flood events. Potential restoration activities are intended to work with the underlying geologic conditions controlling the river corridor, by addressing current land uses and perceived impaired habitat conditions. The *Sycan River Assessment and Restoration Feasibility Study* (Sycan Study) serves as the culmination of field data collection and remote sensing activities that began in 2005. Additionally, this study is intended to be used as a base document for guiding restoration in the project area.

1.1 Purpose and Scope

The Sycan Study serves as a planning document for orienting restoration planning for the Sycan River from the Coyote Bucket Canyon downstream to Drews Road near Beatty, Oregon. Information included in the Sycan Study culminates data collection, analysis, and modeling efforts completed in 2006 and 2007. Field data collection, aerial photograph interpretation, and review of historical documents served five primary purposes.

- To predict or at best, characterize, the likely historical condition of the Sycan River in the project area.
- To evaluate existing river corridor conditions including riparian vegetation, channel stability, aquatic habitat, hydrology and hydraulics, and the fish community.
- To propose the desired future river corridor conditions based on likely historical conditions and reference reach characteristics.
- To provide data necessary for modeling and evaluating flood frequency, channel stability and sediment transport capacity. Hydrologic and hydraulic modeling results are incorporated with empirical data to develop and evaluate draft channel restoration designs.
- To provide a complete topography of the restoration project area including channel bathymetry. Project area topography is necessary for evaluating the existing river corridor and is recommended as a point of reference for future evaluations.

The intent of the Sycan Study document is to present a summary of these efforts in addition to presenting conceptual restoration recommendations for the project area. The Sycan Study will be submitted to USFWS for future project planning.

1.2 Project Goals and Objectives

Several goals and objectives were established for the Sycan Study. Goals are related to both the river corridor assessment and the restoration feasibility. Objectives are presented as the tasks that were or will be accomplished to achieve the presented goals.

Assessment Goal: Attain a better understanding of the Sycan River project area in the context of historical and contemporary river corridor conditions.

Objective 1: Review available information to understand the historical and contemporary river conditions.

Objective 2: Collect new data to understand river corridor processes in the project area.

Objective 3: Locate and evaluate a reference reach to compare the project area.

Objective 4: Establish a data set to provide a baseline for comparing future river corridor conditions.

Restoration Goal: Propose conceptual restoration options and determine the feasibility of implementing proposed restoration options.

Objective 1: Prepare a range of restoration options by landownership.

Objective 2: Restoration options should be cost-effective and have a high probability of positively affecting the river corridor with minimal probability of negatively affecting the river corridor.

Objective 3: Restoration options should include both passive and active strategies to improve riparian vegetation, water quality, and aquatic habitat conditions.

1.3 Project Constraints

In evaluating the project area and restoration opportunities, several constraints were realized. These constraints are not expected to limit improving river corridor conditions, but will be accounted for in developing conceptual restoration plans. The following sections present identified project constraints at the time of the assessment.

1.3.1 Land Ownership

The project area spans six private properties from the Coyote Bucket Canyon to Drews Road. The extent of restoration activities will depend on landowners' willingness to collaborate on projects. Similarly, landowners' willingness to participate may be at least partially dependent on landowners receiving compensation for lost agricultural production. Riparian vegetation recovery in the project area will depend on modifying current land use practices.

1.3.2 River Corridor Geology and Climate

The project area is strongly influenced by its geology and climate. The eruption by Mt. Mazama approximately 6,500 years ago delivered pumice and ash to the Upper Klamath Basin. The Sycan River continues to be strongly influenced by this event. Soils in the project area are very permeable and well-drained. Organic materials are generally limited to the upper foot of floodplain materials. Lower soil layers are largely devoid of organics and display varying degrees of cemented pyroclastic materials.

The project area's climate is characterized as semiarid with mild summers and cold winters. The normal annual precipitation varies with altitude, from 14.1 inches at Klamath Falls to 17.7 inches at Chioquin and more than 60 inches of precipitation in the mountain peaks (Leonard and Harris, 1974). Seventy percent of the precipitation falls between October and March. Only 9 percent of precipitation falls during the summer between July and September. The Sycan River watershed therefore receives most of its annual precipitation in the winter. Periodic summer thunderstorms deliver intense rainfall over short periods. This inconsistent and concentrated precipitation pattern creates the arid climatic patterns of the region. From a restoration perspective, the arid conditions present a constraint for revegetating disturbed areas.



The Sycan River on the Shields' property.

1.3.3 Land Use History

There is limited documentation of historical land uses in the Sycan River watershed. However, land use patterns observed elsewhere in the Upper Klamath Basin likely also occurred in the project area. Dating to the mid 1800s, land uses in the Basin have included the fur trade, timber extraction, farming, ranching, and residential development. The fur trade and ranching are believed to have had the greatest effect on river corridor conditions in the project area. These activities are believed to have modified river processes and degraded river stability. Based on existing conditions and probable historical conditions, past land uses may have resulted in a cascade of river corridor changes that now limit the range of feasible restoration activities.

1.3.4 Recorded Archaeological Sites

Although there are only two recorded archaeological sites recognized by the State of Oregon in the project area, native peoples historically used the Sycan River as a habitation area and migratory corridor. Cultural resources sites will be avoided during future restoration activities.

In summary, potential constraints on river corridor recovery include land ownership, natural conditions, the land use history, and recorded archaeological sites. These constraints (aside from

the archaeological sites) are not expected to detract from the river corridor's recovery potential, but rather, will be accounted for in preparing restoration concepts.

1.4 How To Use This Document

The Sycan Study is structured to 1) provide the reviewer with a thorough understanding of the techniques RDG employed to characterize the project area; 2) define the historical, existing, and potential river corridor conditions; and 3) develop restoration concepts for enhancing the Sycan River in the project area.

This section includes descriptions of the systems that were employed in assessing the project area; it defines time frames for ecological recovery, explains the most probable state or reference condition concept and its application to river restoration, and provides an overview of the primary sections that comprise the remainder of the Sycan Study.

1.4.1 Technical Systems Used

The different technical systems used in our analysis were chosen because they are standard within each of their particular disciplines. Some were developed regionally, while others have been universally applied independent of geography. Systems may be delineated according to field and analytical techniques. Field techniques include methods for characterizing existing channel, aquatic habitat, and riparian conditions. Analytical techniques include remote sensing tools, and hydrologic, hydraulic, and sediment analysis models.

Key field-based technical systems include the following methods.

- River morphology and channel classification concepts developed by Rosgen (1994; 1996) and other practitioners (Montgomery and Buffington 1997; Montgomery and MacDonald 2002). Presented methods are widely referred to in the literature and are applicable to the river systems evaluated. The classification concepts are used for describing assessed river reaches at a course level, and are primarily presented as a communication tool for conveying the general characteristics of specified stream reaches.
- The applied valley classification system focuses on the relationship of a stream system to its valley. Similar to the stream classification system, valley morphology classification is useful for conveying general information about stream valley characteristics including formative processes, dimensions, and how the valley morphology influences stream dynamics. Valley morphologies are classified according to guidelines presented in Rosgen (1996).
- Classification and Management of Montana's Riparian and Wetland Types (Hansen et al. 1995) is a vegetation-based ecological classification system centered on the dual concepts of ecological potential (habitat types) and disturbance-process-driven potential (community types). As a result, this approach provides a useful language for discussing desired future condition and understanding how restoring natural processes may influence vegetation communities on the landscape. Although this classification system was prepared in Montana, the classification system can be similarly applied in the Upper Klamath Basin.

Key analytical technical systems used in this document include the following methods.

- Flood frequency analysis produced by the Oregon Water Resources Department and Water Consulting, Inc. (2002) were evaluated for predicting the flood series for the streamflow gaging station on the Sycan River. Additional streamflow data collected by Graham Matthews and Associates (GMA) were also used in the hydrologic analysis.
- Aerial photograph analyses were completed for the project area as well as an upstream reference reach. Recent color aerial photographs were georeferenced in ArcGIS (ESRI 2006) and served as the base imagery for field maps, river planform analysis, and valley morphology assessment. Historical and recent channel alignments were digitized to assess past channel locations and patterns.
- River corridor topographic surveys were completed using a combination of light detection and ranging data (LiDAR), RTK GPS channel bathymetry surveys, and channel habitat surveys. The LiDAR and RTK GPS channel bathymetry data were merged to create a digital terrain model (DTM) of the project area. Existing condition modeling was executed using both the DTM and the individual data components (e.g. cross-sections and channel profiles).
- Hydraulic models were developed to evaluate channel conveyance and channel hydraulics, to prepare flood inundation maps, to assess incipient motion of sediment particles and sediment transport properties, and to evaluate bed resistance. WinXSPro (Hardy et al. 2005), HEC-RAS (U.S. Army Corps of Engineers 2004), and Microsoft Excel (Microsoft 2003) were the primary software programs used to develop the models.
- Reference reach data describing potential channel conditions were evaluated to develop potential channel condition's concepts. Field data were stored and processed using RIVERMorph (RIVERMorph 2005).

1.4.2 The Reference Reach Concept

The reference reach concept is referred to throughout this document. A reference reach was located in Teddy Powers Meadow, approximately 7 miles upstream from the project area. The reference reach exemplifies river corridor conditions following the exclusion of livestock from the river. While conditions in the reference reach will continue to evolve as the system recovers from past land management, Teddy Powers Meadow represent the “best possible” river corridor conditions in the vicinity of the project area. Conditions exemplified by the channel’s dimensions, pattern, and profile; the distribution and characteristics of sediment and sediment loading to the channel; and the riparian condition were the primary factors in designating the Teddy Powers Meadow section as a reference reach. A non-reference reach, primarily referred to as an “existing” condition reach throughout the document, may be characterized by poorer riparian conditions, a more entrenched channel, lower streambank stability, and less frequent and simplified pools.

Ideally, a reference river reach is an integrated channel and floodplain system that is in dynamic equilibrium under the current hydrologic regime. A reference river reach may be a *hydraulic* reference reach where a channel is identified as in dynamic equilibrium under a current hydrologic regime, or it may be a *habitat* reference reach where diverse and complex habitat

features are exhibited. The Teddy Powers Reach provides a range of hydraulic and habitat conditions that will be used as a tool to help guide development of specific restoration proposals as well as to introduce project area property owners to the river benefits of livestock exclusion.

While identifying reference reaches at the present time is useful, evaluating historical conditions offers another opportunity for comparing current conditions and anticipating future channel responses to management regimes. In this document, we used information taken from the 1941 aerial photographs that captured the Sycan River in the project area. Although river-altering changes (e.g. beaver trapping and grazing) are believed to have occurred in the watershed prior to the 1941 air photo, the channel pattern and recently abandoned channel locations provide some insights to historical channel alignments. Assessing the 1941 channel pattern and recently abandoned channel locations was useful for understanding river changes over the last nearly 70 years.

Reference plant communities were formulated by combining vegetative information from the Teddy Powers Meadow reference reach and portions of the project area. Reference plant communities present a target for improving riparian conditions in the project area.

1.4.3 Summary of Sections

The Sycan Study is organized by area of emphasis including assessment methods, watershed hydrology, historical and existing river corridor conditions, channel hydraulics and sediment properties, and conceptual restoration approaches. Each of the following sections presents summary information for a specific topic. More detailed information, air photos, and maps are included as appendices to this executive summary. The following summarizes the contents of the Sycan Study.

Section 1 is the introduction to the Sycan Study.

Section 2 provides an overview of the project area.

Section 3 provides a framework for describing the historical, existing, and desired future conditions of the river corridor.

Section 4 provides proposed restoration strategies and techniques for restoring the Sycan River in the project area. Section 3 also provides restoration strategies for wetland and vegetative recovery. Additionally, strategies to move vegetative cover types to a desired future condition are presented.

Section 5 presents conceptual restoration plans for the project area. Draft plans include fencing locations, revegetation prescription, fish habitat structures, and bank stability monitoring.

Appendix A is the hydrology appendix. The hydrology appendix provides a discussion of watershed hydrology including information on flood history, flood series, and bankfull discharge analysis techniques.

Appendix B is the geomorphic conditions appendix. Historical, existing, and desired future river corridor conditions are presented.

Appendix C includes index maps developed from recent aerial photographs. Reach breaks, field survey locations, and LIDAR/RTK GPS-derived river corridor topography are displayed.

Appendix D presents soils maps for the project area.

Appendix E presents the hydraulic modeling analysis for the project area.

Appendix F presents flood inundation maps for the project area. Flood inundation maps are based on the hydraulic modeling analysis.

Appendix G introduces the vegetation and wetland resources analyses for the project area. Information includes an analysis of existing conditions with emphasis placed on the description of native species, species' geographic locations, and conceptual treatments for achieving desired future conditions.

Appendix H presents an overview of the Sycan River fish community including monitoring data collected between 2003 and 2006.

Appendix I covers the restoration plan strategies. Information includes the process that was followed in developing the draft design dimensions and plans. Supplemental information is incorporated from the preceding appendices.

Appendix J includes the references cited in the Executive Summary and the appendices.

SECTION 2.0 PROJECT AREA OVERVIEW

The following sections provide an overview of the Sycan River watershed and the project area.

2.1 Sycan River Watershed

The Sycan River originates in the northeastern portion of the Upper Klamath Basin in southern Oregon. From its origin in a meadow between Slide Mountain and Bald Butte (at approximately 7,500 feet m.s.l) in the Winter Ridge range (7,161 ft), the river flows northwest through several mountain meadows before entering a steep canyon. Several tributaries draining the surrounding mountains join the Sycan River before it flows into the 25,000 acre Sycan Marsh at an elevation of roughly 5,000 feet (OWRD, 2000). Tributaries draining the eastern slopes of Yamsey Mountain (8,196 ft) and Booth Ridge (7,543 ft), as well as creeks and springs originating from Winter Ridge and Brattain Ridge contribute flow to Sycan Marsh. At the southern end of the marsh, the Sycan River exits, taking whatever surface and groundwater inflows not evaporated, stored in the soil matrix of the marsh, or percolated to groundwater (OWRD, 2000). From the marsh, the river flows southwest gaining inflows from Merritt Creek, Torrent Springs, and several un-named tributaries before reaching Teddy Powers Meadows. Downstream of the meadow, the river enters the rugged, steep, and highly fractured basalt of Coyote Bucket Canyon. The narrow river canyon confines the channel. The channel morphology is characterized by periodic falls and rapids. Blue Creek and several small springs are the only tributaries to the river before the canyon opens into the Sycan River Valley. In the valley, the Sycan meanders within a broad flat flood plain. Spring and seeps discharging from lateral terraces contribute discharge to the river. Brown Springs Creek and Snake Creek are the final natural channels discharging to the Sycan River upstream of Drews Road. An agricultural drain captures surface and groundwater flow on the east side of the Sycan River upstream from Brown Springs Creek. Several surface water pumps are located on the Sycan River from the end of Sycan Canyon to Drews Road.

2.2 Sycan River Project Area

The project area is located from the mouth of Sycan Canyon downstream to Drews Road. The project area is entirely privately owned with six properties comprising the project area. Livestock grazing is the predominant active land use in the project area. Subordinate land uses include timber harvest, haying, and residential development. Vegetation conditions exhibit changes in soil moisture. Soils are comprised of volcanic tufts with organic mantles of varying thickness related to the location in the stream corridor. Floodplains adjacent to the channel that receiving flood deposition and organic litter, tend to have thicker organic mantles. Higher terraces that are flooded only during extreme events, and that support low densities of upland vegetation, tend to have droughty soils with limited organic content.

Project area vegetation ranges from streamside sedge/rush communities to upland Ponderosa pine forests. Intermediate vegetation communities transition from willows and silver sage at lower elevations, to big sage brush and bitterbrush transitioning to the Ponderosa pine forests.

2.2.1 Project Area Reach Break Delineations

Five reaches were delineated in the project area, plus the Teddy Powers Meadow reference reach. The project area reaches were delineated based on changes in river corridor conditions including channel slope, channel entrenchment, and vegetation. The following section summarizes

the identified reaches. Appendix C includes recent air photos with the channel alignment stationing and reach break locations.

Reach 1 – Canyon Reach Transition

Reach 1 is characterized by the transition from the lower Coyote Bucket Canyon to the beginning of the broader Sycan valley. The narrow valley bottom in the canyon confines the channel, limiting lateral channel meandering (Figure 2-1). Through Reach 1 the low sinuosity channel (Rosgen B2 stream type) transitions to a meandering planform (Rosgen C4 stream type) with a more expansive floodplain. Channel bed material characterized by boulders and cobble in the canyon, transitions to finer gravel bed. A riparian vegetation fringe comprised of mountain alder and willows is located in a narrow range between the Sycan River and the uplands in the Coyote Bucket. Through the transition, sedges/rushes vegetate backwater areas and willows have colonized depositional features. Ponderosa pine and western juniper dominate the upland forest. Reach 1 is 2,200 ft in length extending from the confined Coyote Bucket Canyon through the transition.



Figure 2-1. River corridor conditions in Reach 1 – Canyon Reach Transition are characterized by a low sinuosity, moderate gradient channel in the Coyote Bucket Canyon (left) to moderate sinuosity, broader river corridor through the river corridor transition (right).

Reach 2 – Upper Meandering Reach

Reach 2 extends from Station 22+00 to Station 76+00. The Sycan River in Reach 2 is characterized by increasing channel sinuosity, alternating pool-riffle morphology, and frequent point bars and lateral bars where sediment is stored (Figure 2-2). Channel and floodplain development is occurring between the lateral terraces. Eroding streambanks vary in the slope of the bank face. In areas where streambanks are actively eroding, large mats of vegetation and soil cleave from the bank and fall into the river. Where the eroding banks have reached an angle of repose or the bank is protected from stream energy, sedges buffer the eroding bank from the river.

Floodplain terraces maintain diverse habitats. Relict channels, springs, and signs of historical beaver activity create a range of riparian habitats. Relict channels and depressions are inundated during runoff events and hold water through the early summer. Vegetation and channel patterns suggest some of these terrace features may have been inundated more frequently in the past. The reach ends at Station 76+00 where the eastern hillslope encroaches on the channel corridor, narrowing the valley floor and channel belt width.



Figure 2-2. Reach 2 is characterized by a more sinuous channel and expanding beltwidth. Sediment is stored in point bars and lateral bars that are colonized with sediment-trapping riparian vegetation.

Reach 3 – Confined Reach

Reach 3 extends from Station 76+00 to Station 137+00. The Sycan River valley bottom narrows again in Reach 3. The river corridor necks down with the encroachment of the eastern hillslope on the river channel. The through Reach 4, channel sinuosity decreases and the channel is confined between lateral terraces. Floodplain areas are limited through the reach except between Station 90+00 and Station 102+00 where relict channel scrolls convey flow during flood events and retain spring water throughout the year (Figure 2-3). Downstream of this floodplain section, the river follows the valley's fall line and is confined between the eastern hillslope and a western high terrace. Springs and seeps arise from the western terrace and drain to the river. Developed ponds on the western terrace contribute to the subsurface discharge.



Figure 2-3. Relict channels on the floodplain in the vicinity of Station 95+00 convey water during flood events and retain water through most of the year (left). Downstream of the floodplain area, the Sycan River is confined by the eastern hill slope (right).

Reach 4 – Lower Meandering Reach

Reach 4 extends from Station 137+00 to Station 172+00. Reach 4 is characterized by a meandering planform downstream from the confined channel conditions in Reach 3 (Figure 2-4). The channel in Reach 4 is dynamic, including active lateral migration, bank erosion, and an active

chute cut-off. The channel exhibits down-valley meander migration and there is the potential for two channel avulsions that will eventually lead to further channel straightening in the reach. Relative to upstream and downstream river corridor conditions, Reach 4 maintains diverse wetland and off-channel habitats. Springs discharging at the toe of the western hillslope, form shallow wetlands and ponds that ultimately discharge to the Sycan River. These off-channel wetlands provide fish and wildlife habitat and serve as coldwater refugia. Beaver dams located at the outlets of two of the wetland control flow to the river and may limit fish access to the wetlands. Floodplain vegetation is characterized by sedges/rushes and willow thickets. Higher elevation land forms are colonized by sage brush, occasional Ponderosa pines, and juniper.



Figure 2-4. Sedges/rushes colonize point bars and confine the baseflow channel inside of the larger active channel bracketed by lateral terraces (left). A beaver dam controls the flow from an off-channel wetland to the Sycan River near Station 152+00 (right).

Reach 5 – Lower Confined Reach

Reach 4 transitions to Reach 5 when the channel Sycan River is again confined by the western hillslope and the eastern terrace. Reach 5 extends from Station 172+00 to Station 363+00 at the Drews Road Bridge. River corridor conditions are fairly consistent through Reach 5, characterized by lateral terraces confining the channel. Unique features in the reach include floodplain inclusions, spring creek tributary confluences, and off-channel wetlands occupying terrace depressions. Streambanks tend to be more stable in Reach 5 than in Reach 4 especially where vegetated surfaces have formed at the toe of sandy terraces (Figure 2-5). Eroding sites are associated with meander bends and areas of focused livestock use. Vegetation transitions from channel margin vegetated benches colonized by sedges and rushes, to a narrow elevation range where willows and silver sage are common. Sage brush and bitterbrush are located on terraces. Riparian vegetation also colonizes swales and off-channel floodplain areas that are lower than surrounding terraces.



Figure 2-5. River corridor conditions in Reach 5. The channel is confined between lateral terraces. Vegetated surfaces are emergent at base flows (left) are submerged during runoff (right).

Teddy Powers Meadow Reference Reach

The Teddy Powers Meadows reference reach is approximately 7 miles upstream of Reach 1 in the project area. Historically used as a riparian pasture, the U.S. Forest Service has excluded grazing from the reference reach area since the 1990s (Figure 2-6). Vegetation in this reach consists of a narrow fringe of perennially inundated rush/sedge communities along the channel margin transitioning to seasonally inundated sedge/rush and willow communities. Above the sedge/rush and willow communities is a relatively recent floodplain terrace dominated by silver sage similar to existing plant communities in other reaches. The old vertical eroding banks are now buffered by the riparian fringe and sediment

Since livestock have been excluded from the Sycan River through the Teddy Powers Meadow reach diverse vegetation patterns are beginning to establish along newly deposited floodplain surfaces allowing the channel to regain a more sinuous planform, narrower channel dimensions, and more moderate profile through this reach. Improved vegetation conditions have also stabilized previously eroding banks, decreasing sediment delivery to the system and improving habitat quality.

The Teddy Powers Meadows reach illustrates the potential for river corridor recovery associated with changing grazing practices. Excluding livestock from the baseflow channel improves riparian conditions both by eliminating grazing pressure on vegetation, but also by removing the source of repeated disturbance that impairs vegetation establishment.



Figure 2-6. Examples of the riparian vegetation communities in the Teddy Powers Meadow reach of the Sycan River. A sedge/rush fringe now buffers the eroding banks from the river (left). Multiple age classes of willows and other riparian vegetation have narrowed the channel and stabilized sediment.

In summary, the Sycan River exhibits diverse river corridor conditions through the project area. The width of the valley bottom has an overriding influence on channel conditions. Where the valley bottom narrows and constricts the Sycan River, the channel has a low sinuosity and limited access to floodplain areas. Where the valley is wider, in Reach 3 for example, floodplains and terraces store sediment and large wood. Vegetation communities are most diverse in these areas as the undulating land surfaces support a range of plants based on soil moisture tolerance. Relict channels dissecting the floodplain and terrace surfaces suggest the influence of the river and emergent springs on in these areas. More information regarding these features will be provided in subsequent sections of this document.

SECTION 3.0 HISTORICAL, EXISTING, AND DESIRED FUTURE CONDITIONS

The following section highlights the historical, existing, and desired future conditions for the Sycan River in the project area.

3.1 Historical Conditions

3.1.1 Channel Morphology

The current morphological state of the Sycan River is reflective of both natural processes and human-induced impacts in the river corridor. Historically, the Sycan River likely had a denser and more extensive riparian area. Over the past 60 years dating to the 1941 air photo series, the Sycan River's riparian area has become more simplified. Additionally, the river has become straighter over time due to down valley meander migration and channel meander cut-offs. The channel length reduction is most pronounced in the Reach 1 and Reach 2 where the channel in 1941 was more sinuous than it is today (Figure 3-1). Based on the location of the channel in 1941 and 2006, the channel has apparently incised approximately 2-3 ft. Relict channel locations are generally located 2-3 ft from the existing channel thalweg. In spite of this observation, it is also possible that the channel historically occupied an elevation similar to the current elevation and that the relict channel locations have filled over time and are now a low floodplain surface. Filling would also account for the current higher elevation of these features.



Figure 3-1. A comparison of the Sycan River in Reach 1 and Reach 2 in 1941 (left) and 1998 (right). The riparian community has become less dense and the river straighter over time.

Figure 3-2 illustrates the 1941 and 1998 channel alignments with the landownership boundaries. Most of the channel changes and straightening has occurred in Reach 1 and Reach 2 downstream from the Coyote Bucket Canyon. Down valley meander migration is apparent in Reach 3 and Reach 5. Channel instability is likely related to channel morphology, soils, vegetation conditions and the effect of land management on these system properties.

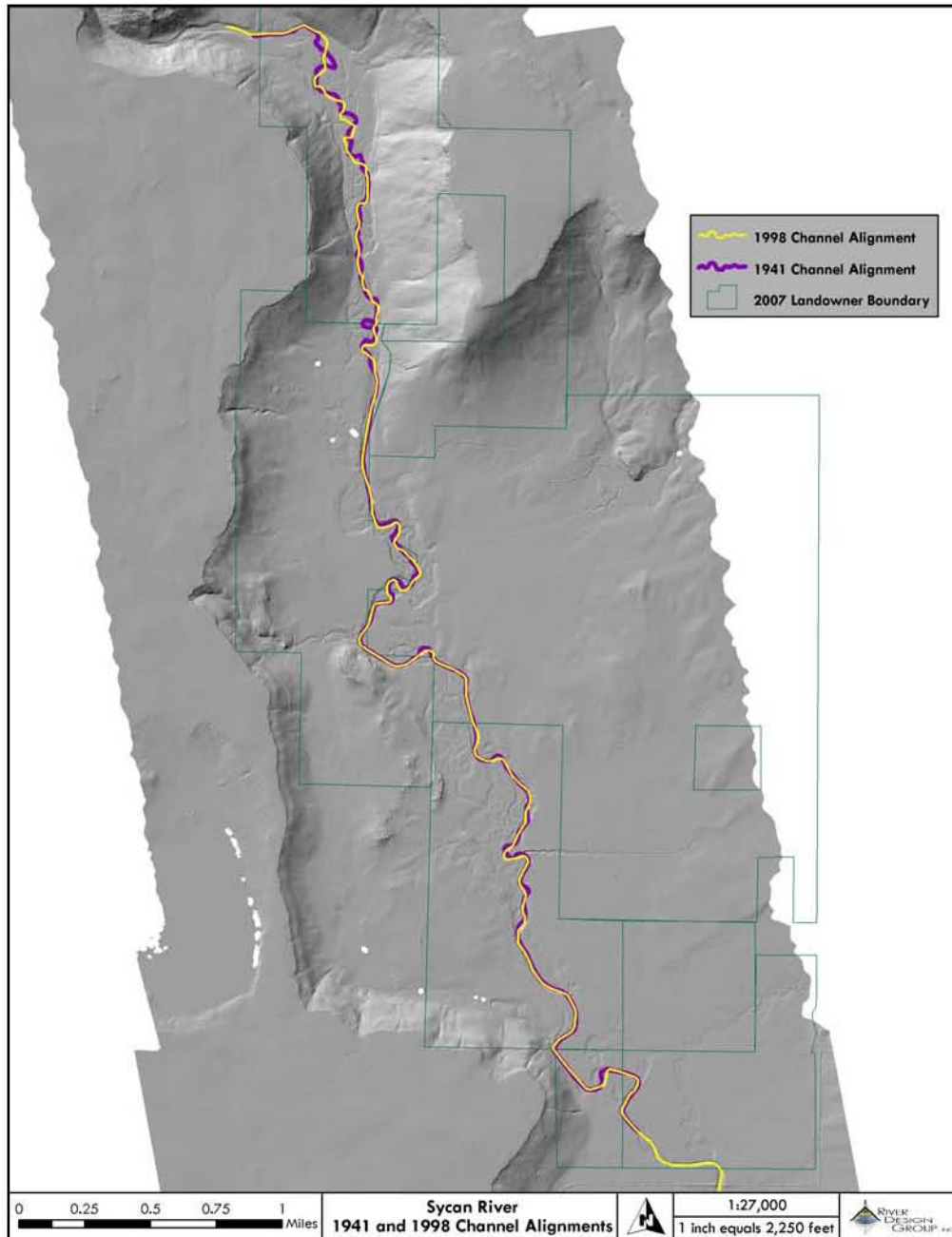


Figure 3-2. The 1941 and 1998 channel alignment locations relative to the 2007 landownership map.

The current location and bed elevation of the Sycan River appear to have deviated from historical conditions. Review of the historical air photos, soils data, field conditions, and discharge

modeling results suggest the river has downcut 2-3 ft since the 1940s. However, the data do not support the idea that the Sycan River was located on high terraces adjacent to the active river channel at least in the recent past (60 to 100 years). Terrace soils are generally lacking in clay and have high porosity; characteristics suggesting little historical interaction with the river. These characteristics do not exclude these surfaces from flooding, however, only low frequency, high magnitude floods inundate these features.

3.1.2 Vegetation Conditions

Because little information is available about vegetation prior to recent settlement of the Sycan River drainage, historical conditions are discussed based on observing riparian plant communities in the Teddy Powers Meadows reference reach, combined with our knowledge of general disturbances affecting vegetation. The existing plant communities in the project area likely resemble the historical plant communities. However, several changes to the historical plant communities including the introduction of noxious weeds, grazing effects, and reduction in the beaver population mark several changes to project area plant communities.

Introduced weed species are prominent in the project area. Bull thistle (*Cirsium vulgare*) and Canada thistle (*Cirsium arvense*) are found throughout the project area. Bull thistle grows singularly or in low density patches. Canada thistle can form dense patches. Both species are capable of displacing native vegetation and degrade forage value. These species tend to colonize drier sites and favor disturbed areas.

Livestock grazing is the primary land use in the Sycan River project area. Sheep were the earliest livestock brought to the Upper Klamath Basin. Cattle displaced sheep in the early 1900s. Reports of several hundred thousand head of livestock grazed open range in the Upper Klamath Basin in the late 1800s and early 1900s. Cattle continue to graze either open range or with limited management in the project area.

Livestock effects on the river corridor includes vegetation removal, land surface compaction, and streambank trampling. Vegetation removal is most prominent on land surfaces paralleling the low flow channel. Although these areas are submerged during high flows, sedges, rushes, and willows colonize these sites. These species provide high quality forage proximate to a water source. Grazing of this vegetation is believed to have modified the Sycan River's resistance to bank erosion and contributed to channel instability. Near-bank vegetation that would increase sediment retention and promote streambank building has been lost from much of the upper project area. Grazing on floodplain and terraces has lead to soil compaction. Compacted surfaces decrease surface permeability and promote surface water routing. Disturbed surfaces are also more susceptible to noxious weed invasion. Cattle trampling of streambanks increases bank instability and erosion (Figure 3-3). Repeated trampling related to travel routes breakdown banks and decrease vegetation diversity.



Figure 3-3. Examples of grazing impacts on the Sycan River floodplain in the project area. Repeated trampling of floodplain areas (left) and grazing vegetation within the active channel corridor have led to channel instability.

Widespread beaver trapping occurred in the mid to late 1800s. Historically, beaver were likely more abundant and may have played an important role affecting the Sycan River corridor. Similar to other areas in the Sprague River valley, beaver influenced channel morphology by harvesting vegetation, building dens, and perhaps damming the main channel and side channels. The undulating surface of floodplains and terraces parallel to the Sycan River suggest historical beaver activity. Relict beaver dams and modified channel morphology is apparent in the Teddy Powers Meadows reach of the Sycan River. Currently, there are limited signs of recent beaver activity in the project area although at least beaver home has been identified in the project area. Continued trapping over the past decades has perpetuated beaver suppression. Allowing beavers to return to the project area would be expected to result in greater riparian vegetation diversity, a wider range of aquatic habitats, and a higher local water table.

In summary, the land use practices, introduced weed species, and beaver removal have influenced the Sycan River's vegetation community. Livestock grazing and removal of beaver have increased the channel's erosion potential by creating a smoother channel network. The historical riparian vegetation community was likely more dense and more functional than the existing vegetation conditions.

3.2 Existing Conditions

3.2.1 Channel Morphology

Field data collection and remote sensing were completed to evaluate existing river corridor conditions in the Sycan River project area. Data collection included characterizing the channel cross-section, longitudinal profile, and planform dimensions at five reaches. Sediment and bank stability were also evaluated.

The Sycan River through the project area is a dynamic environment influenced by unique watershed hydrology, volcanic-derived geology and sediments, vegetation conditions, and land management activities. The Sycan Marsh, located upstream of the project area, moderates headwater flood events. The hydrology of the marsh is currently being restored through the removal of drain tiles and ditch filling. A long period of agriculture modified marsh function.

River corridor conditions vary according to the degree of channel-floodplain connectivity. Reaches were defined by the presence of a floodplain adjacent to the baseflow channel that was accessed by the river around the 2-year discharge event. Reaches with adjacent floodplain typically had diverse floodplain habitats that included flood channels, floodplain ponds, willow thickets, and large wood accumulations. Reaches lacking floodplain features tended to have fewer or more localized off-channel habitats. Relict channel segments, springs, and wetlands are unique habitats in the river corridor.

Open-range grazing throughout the project area influences riparian vegetation conditions and streambank stability. Grazing impacts the river corridor through vegetation removal, bank cleaving, and land surface compaction. Vegetation removal within the bankfull channel lowers channel roughness and reduces sediment storage. The smoother channel increases water velocities, affecting stream power and bank erosion potential.

Section 2.2.2 Project Area Reach Break Delineations, provides a summary of each of the five reaches in the project area. More detailed reach information is included in Appendix B. The following sections summarize channel planform, cross-section, and longitudinal profile information for the Sycan River project area.

Planform Summary

Table 3-1 includes the channel planform dimensions for the project area and reference reach from the 1941 and 1998 air photos. Table 3-2 includes the channel planform dimensionless ratios. Dimensionless ratios are developed by dividing the measured planform variable value by the riffle bankfull width. Dimensionless ratios allow channel width-independent comparisons.

A comparison of the 1941 and 1998 channel planform data suggests the river has become straighter over time with longer distances between meander bends (pools) and larger radius of curvature values. Higher standard deviation values for meander length (MI) and radius of curvature (Rc) also suggest the river had a more variable pattern in 1998 than in 1941. Increasing radius of curvature values may be related to less extensive and less dense bank stabilizing-riparian vegetation. Riparian vegetation losses were apparent in several reaches.

The belt width has remained fairly consistent over time suggesting that although the river channel location has changed, the width of the river corridor has on average remained consistent over time. The channel sinuosity has decreased over time.

Table 3-1. Sycan River meander geometry for the project area and the reference reach for the 1941 and 1998 air photos.

Reach	1941				1998			
	MI	Bw	Rc	Sinuosity	MI	Bw	Rc	Sinuosity
Reach 2	441 (132)	204 (72.0)	133 (45.7)	1.34	643 (121)	236 (94.0)	253 (85.7)	1.28
Reach 3	364 (176)	167 (54.8)	142 (144)	1.19	845 (570)	179 (73.6)	406 (286)	1.10
Reach 4	475 (140)	258 (100)	107 (31.4)	2.0	686 (280)	302 (121)	179 (162)	1.79
Reach 5	694 (1042)	289 (164)	258 (282)	1.44	824 (328)	299 (137)	287 (290)	1.43
Reference Reach					1257 (92.5)	509 (56.0)	265 (59.0)	1.33

Table 3-2. Sycan River meander geometry dimensionless ratios for the project area and the reference reach for the 1941 and 1998 air photos.

Reach	1941			1998		
	MI	Bw	Rc	MI	Bw	Rc
Reach 2	7.5 (2.3)	3.5 (1.2)	2.3 (0.8)	11.6 (2.2)	4.3 (1.7)	4.6 (1.6)
Reach 3	5.69 (2.7)	2.6 (0.9)	2.2 (2.2)	13.9 (9.3)	2.9 (1.2)	6.7 (4.7)
Reach 4	5.7 (1.7)	3.1 (1.2)	1.3 (0.4)	11.3 (4.6)	5.0 (2.0)	3.0 (2.7)
Reach 5	11.2 (14.7)	4.7 (5.1)	4.2 (3.4)	13.1 (5.2)	4.8 (2.2)	4.6 (4.6)
Reference Reach				14.6 (1.1)	5.9 (0.7)	3.1 (0.7)

The channel plan form dimensionless ratios exhibit the same pattern as seen with the descriptive statistics summarizing the actual channel dimensions.

Channel Dimensions

A comparison of the channel habitat dimensions for the project area and Teddy Powers Meadows Reference Reach are included below. The actual values and dimensionless ratios are included for each habitat unit type. Dimensions are based on the bankfull channel and are based on both field and remote sensing measurements.

Table 3-3 through 3-5 include the mean and standard deviation values for pool, glide, and riffle habitat units measured in the project area and Teddy Powers Meadows Reference Reach.

Table 3-3. Project area and reference reach summary data for pool habitat units. Presented data are mean values and (1 SD).

Reach	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
Reach 1	260 (132)	124 (66.9)	2.2 (0.1)	4.2 (0.9)	58.9 (33.5)
Reach 2	342 (63.5)	118 (56.4)	3.2 (0.9)	6.2 (0.8)	43.0 (32.5)
Reach 3	323 (24.8)	78.2 (15.1)	4.2 (0.5)	7.0 (1.1)	19.1 (5.9)
Reach 4	334.5 (39.3)	98.5 (2.1)	3.4 (0.3)	6.3 (0.3)	29.2 (2.2)
Reach 5	345 (35.8)	83.9 (4.5)	4.1 (0.3)	7.4 (0.6)	20.4 (0.83)
Reference Reach	157 (64.7)	68.2 (15.5)	2.30 (0.7)	3.9 (0.5)	33.0 (17.4)

Table 3-4. Project area and reference reach summary data for glide habitat units. Presented data are mean values and (1 SD).

Reach	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
Reach 1	282 (79.2)	74.3 (7.9)	3.8 (0.6)	5.5 (1.0)	19.9 (1.6)
Reach 2	N/A	N/A	N/A	N/A	N/A
Reach 3	N/A	N/A	N/A	N/A	N/A
Reach 4	N/A	N/A	N/A	N/A	N/A
Reach 5	310	71.7	4.3	5.3	16.6
Reference Reach	112 (30.6)	72.9 (15.4)	1.5 (0.4)	2.7 (0.1)	49.5 (17.3)

Table 3-5. Project area and reference reach summary data for riffle habitat units. Presented data are mean values and (1 SD).

Reach	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
Reach 1	308.5 (24.7)	143 (8.5)	2.2 (0.1)	3.3 (0.1)	66.3 (2.1)
Reach 2	191	93.9	2.0	5.1	46.3
Reach 3	242 (15.6)	70.9 (6.40)	3.4 (0.3)	4.4 (0.30)	20.9 (3.30)
Reach 4	304.3 (31.1)	74.1 (12.4)	4.2 (0.6)	6.0 (0.7)	18.4 (6.0)
Reach 5	345 (35.8)	83.9 (4.5)	4.1 (0.3)	7.4 (0.6)	20.4 (0.83)
Reference Reach	103 (34.2)	86.4 (0.6)	1.2 (0.4)	2.4 (0.4)	76.7 (26.5)

Channel Profile

A comparison of the channel profiles for the project area and Teddy Powers Meadows Reference Reach are included below (Table 3-6). Channel slopes decrease from the Coyote Bucket Canyon downstream to the Drews Road Bridge. Reach 5 has the lowest gradient slopes. The reference reach has channel slopes intermediate to Reach 1 and Reach 2.

Table 3-6. Summary channel slope information for the project area and the reference reach.

Reach	Average Bankfull Slope	Average Water Surface Slope	Riffle Bankfull Slope	Riffle Water Surface Slope	Pool Bankfull Slope	Pool Water Surface Slope
Reach 1	0.0049	0.0058	0.0146	0.0112	0.0022	0.0019
Reach 2	0.0009	0.0009	0.0032	0.0035	0.0009	0.0006
Reach 3	0.0001	0.0003	0.0003	0.0004	0.0001	0.0002
Reach 4*	N/A	N/A	N/A	N/A	N/A	N/A
Reach 5	0.00007	0.00004	0.00007	0.00011	0.00007	0.00002
Reference Reach	0.0016	0.0016	0.0045	0.0049	0.0003	0.00025

*: A channel profile was not completed in Reach 4.

3.2.2 Existing Vegetation Conditions

Existing vegetation patterns are influenced by hydrology, soils, human land uses, and natural river disturbance processes. Vegetation communities may be characterized according to their position in the river corridor. A sedge/rush community is located from the edge of the baseflow channel to approximately the bankfull elevation, a willow and silver sagebrush community that brackets the bankfull elevation (plus or minus one foot), and an upland community dominated by big sagebrush. Sedge/rush and willow communities also occupy floodplain and terrace depressions.

The sedge/rush community may be an early successional community that reflects riparian area recovery from over-widening or entrenchment. Sedges and rushes colonize sediment deposited within steep banks, often forming a stable bench between the baseflow channel and the toe of floodplain and terrace slopes. Over time, if left undisturbed, these herbaceous communities will trap sediment, thereby rebuilding streambanks. Once the sedge/rush communities are established, and have built banks to an elevation that corresponds to a hydroperiod that will support willows, the sedge/rush communities may begin to shift toward a willow community. In addition to this process, willow communities can also be early successional communities and will colonize some of the depositional features as well.

Silver sage (*Artemisia cana*) was observed in several locations growing within the active floodplain of the Sycan River, often right down to the water’s edge. Silver sage is considered a riparian shrub in dry regions such as the Columbia Basin, Great Basin, eastern Montana, Wyoming, and the western Dakotas. It is common on transitional wet to dryland sites where soils are dry by midsummer. Silver sage inhabits moister, colder soils and has superior flooding tolerance as compared to other woody species of *Artemisia*. A listing of riparian and wetland plant communities in Oregon includes various silver sage associations (Kovalchik 1987; Crowe 2004).

In some locations, silver sage is recognized as an early seral species that is later replaced by cottonwood, willow, and other riparian vegetation. It has also been noted as an increaser under grazing pressure. The presence of silver sage as the dominant species in riverbank and floodplain locations along the Sycan River suggests that the riparian vegetation here is in a state of disclimax potentially due to grazing. With heavy grazing various graminoids and forbs such as Nebraska sedge, Baltic rush, Kentucky bluegrass, yarrow, cinquefoil and pussytoes increase in cover in this riparian association and with continued overgrazing, Kentucky bluegrass becomes the dominant graminoid in the plant community (NRCS 1985; Crowe 2004). This vegetation change sequence appears to have occurred within some of the Sycan floodplain areas. A change in hydroperiod resulting from vertical channel incision and lack of diverse riparian plant communities is likely another factor that favors silver sage dominance; this species may be more tolerant to these conditions than other riparian shrub communities.

Along the Sycan River, we observed silver sage functioning much like other woody riparian vegetation: creating near-bank channel roughness, trapping sediment, building floodplain, and providing cover for willow seedlings to establish (Figure 3-4). If livestock grazing is eliminated, stands of silver sage along the riverbanks should continue to perform these functions and will likely transition to more diverse stands of woody riparian trees and shrubs.

Channel morphology influences vegetation conditions in the project area. Lateral and vertical channel instability has occurred to varying degrees in the project area. As a result of channel incision, the distance between the floodplain surface and the baseflow channel increases. Floodplain plants may be less resilient over time with a lower water table. Similarly, with an increase in channel capacity related to channel incision and widening, overbank flood events are less frequent. Nutrient and sediment delivery to floodplain surfaces is less common.

In summary, the establishment of good riparian vegetation to resist the erosive flows is necessary to trap sediments and build new streambanks and a new floodplain at the lower elevation. This process is occurring in the Teddy Powers Meadows reference reach and also locally in other assessment reaches along the Sycan River but many areas of actively eroding streambanks are also present.



Figure 3-4. Two examples of the influence of riparian vegetation on sediment trapping on the Sycan River illustrate the role of floodplain vegetation in storing fine sediment. Silver sagebrush on the floodplain creates turbulence and sediment deposition. If left undisturbed over time, these sites would be colonized by vegetation and bank building would take place.

3.3 Desired Future Conditions

The Sycan River in the project area exhibits varied channel morphology, streambank stability, riparian vegetation, and aquatic habitats. Through Reach 2, the upstream portion of Reach 3, and Reach 4, the Sycan River appears to be laterally unstable based on widespread bank erosion. Bank erosion is believed to be related to both the natural site conditions and human influences. Site conditions that contribute to the bank erosion include climatic conditions (low precipitation), hydrology (water surface elevation differences between peak flows and base flows), ash and pumice-based soils, and vegetation communities. Human-related effects include livestock grazing, historical beaver removal, and watershed modifications including the alteration of the Sycan Marsh.

The desired future condition focuses on a more stable river corridor by enhancing the riparian vegetation community. A more stable river corridor is expected to result in reduced bank erosion and sediment delivery to the Sycan River, improved riparian vegetation coverage, and enhanced aquatic habitat. Stability does not imply stopping natural processes such as bank erosion and deposition, but rather, slowing the rate of channel change through natural processes. Addressing current land management and promoting vegetation recovery is believed to be the most prudent action for achieving reach-level ecosystem recovery.

The Teddy Powers Meadows section of the Sycan River was selected as a reference reach based on the riparian vegetation community, recovery of eroding stream banks, and the diverse channel morphology. The Teddy Powers Meadows section (reference reach) provides an example of the desired future condition for the project area (Figure 3-5). The reference reach is characterized by a riparian vegetation community recovering from past season-long grazing. The reach exhibits a vegetation pattern that probably reflects a true early- to mid-seral reference condition for the majority of the Sycan River project area. The reference reach appears to be fifteen to twenty years into a period of recovery from season-long grazing, a land use pattern that is still occurring in much of the project area. Vegetation in the reference reach consists of a narrow fringe of perennially inundated rush/sedge communities along the channel margin transitioning to seasonally inundated sedge/rush and willow communities. Above the sedge/rush and willow communities is a floodplain terrace dominated by big sagebrush.

Beaver remain active in the reference reach although their activity level appears to be less than in the past. Signs of old dams on the main channel and diverse floodplain areas suggest a more active beaver community inhabited the area in the past.



Figure 3-5. Riparian vegetation in the Teddy Powers Meadows reference reach is characterized by sedges/rushes at the channel edge grading to willows at the edge of the active flood channel. Sage brush and other drier upland species occupy the low terrace.

The vertical height from the channel bed to the low terrace is less in the reference reach than in the project area. This characteristic is largely related to the geology and the depth to bedrock or a hardpan layer that resists erosion. The depth to the confining layer also influences groundwater/surface water interactions and vegetation conditions. The denser riparian community in the reference reach may be responding to both the cessation of grazing as well as better access to the water table.

Aquatic habitat conditions are more diverse in the reference reach compared to the project area. Channel edge vegetation provides protective habitat for rearing juvenile fish. Off-channel habitats including floodplain channels and ponds also contribute to habitat diversity (Figure 3-6). These features are generally connected to the base flow channel.



Figure 3-6. River corridor habitats including a floodplain pond (left) and side channels contribute to aquatic habitat diversity in the reference reach. Several features appear to have been influenced by beavers.

SECTION 4.0 RESTORATION STRATEGIES

The following section presents the four restoration alternatives that were evaluated for the Sycan River project area. Restoration goals include the following items.

- Address river corridor stability by reducing bank erosion and sediment delivery, improving riparian vegetation conditions, and enhancing habitat.
- Raise water surface elevations to increase the interaction of the river with adjacent floodplains. Enhanced river-floodplain interaction would increase floodplain storage of sediment, debris, and water. Water released from floodplain storage has the potential for increasing the magnitude of summer base flows, lowering summer water temperature, and increasing soil moisture conditions for the benefit of riparian vegetation.
- Restoration projects are to be implemented in the context of the watershed conditions. Projects should focus on re-establishing natural processes like vegetation and woody debris recruitment to the river, and habitat formation and maintenance.

4.1 Alternative 1 – Grazing Management and Bioengineering

Alternative 1 – Grazing Management and Bioengineering focuses on excluding livestock from the river corridor and implementing bioengineering projects to accelerate revegetation of disturbed areas. Alternative 1 is the preferred alternative. The foundation of this alternative is that livestock must be excluded from the river bottom in order to improve vegetation conditions. Bioengineering projects are also proposed to help accelerate vegetation colonization, stabilize eroding banks, and improve aquatic habitat.

A geographic information system (GIS) analysis was completed to estimate the exclusion acreage under the two proposed grazing exclusion alternatives. The GIS maps were produced from the hydraulic model that estimated the water surface elevations associated with the 2-year, 5-year, and 10-year flood events. The flood extents for each flood interval were mapped. The fence locations are presented in reference to the flood extents. Figure 4-1 through Figure 4-3 provide the fence locations for the two alternatives. Landownership boundaries area also presented.

Two grazing exclusion alternatives were developed. Under both alternatives, off-channel watering sites would be established. Landowner compensation and/or easements are recommended to compensate the landowners for lost livestock production. Alt. 1 would set fence lines outside of the approximate 2-year flood extent. Although livestock would be excluded from the base flow channel, livestock would have access to the majority of floodplain and terraces areas. The benefits of Alt. 1 would be that livestock would continue to have access to high quality forage. Costs associated with Alt. 1 include the cost of the longer fence, fence maintenance due to the close proximity to the channel, and maintenance of off-channel watering sites. Alt. 2 would set the fences outside of most of the 5-year/10-year flood inundation area. The benefits of Alt. 2 would include more protection of the river corridor and lower fence installation and maintenance costs. Costs associated with Alt. 2 include less grazing income for landowners as the accessible forage is lower quality forage.

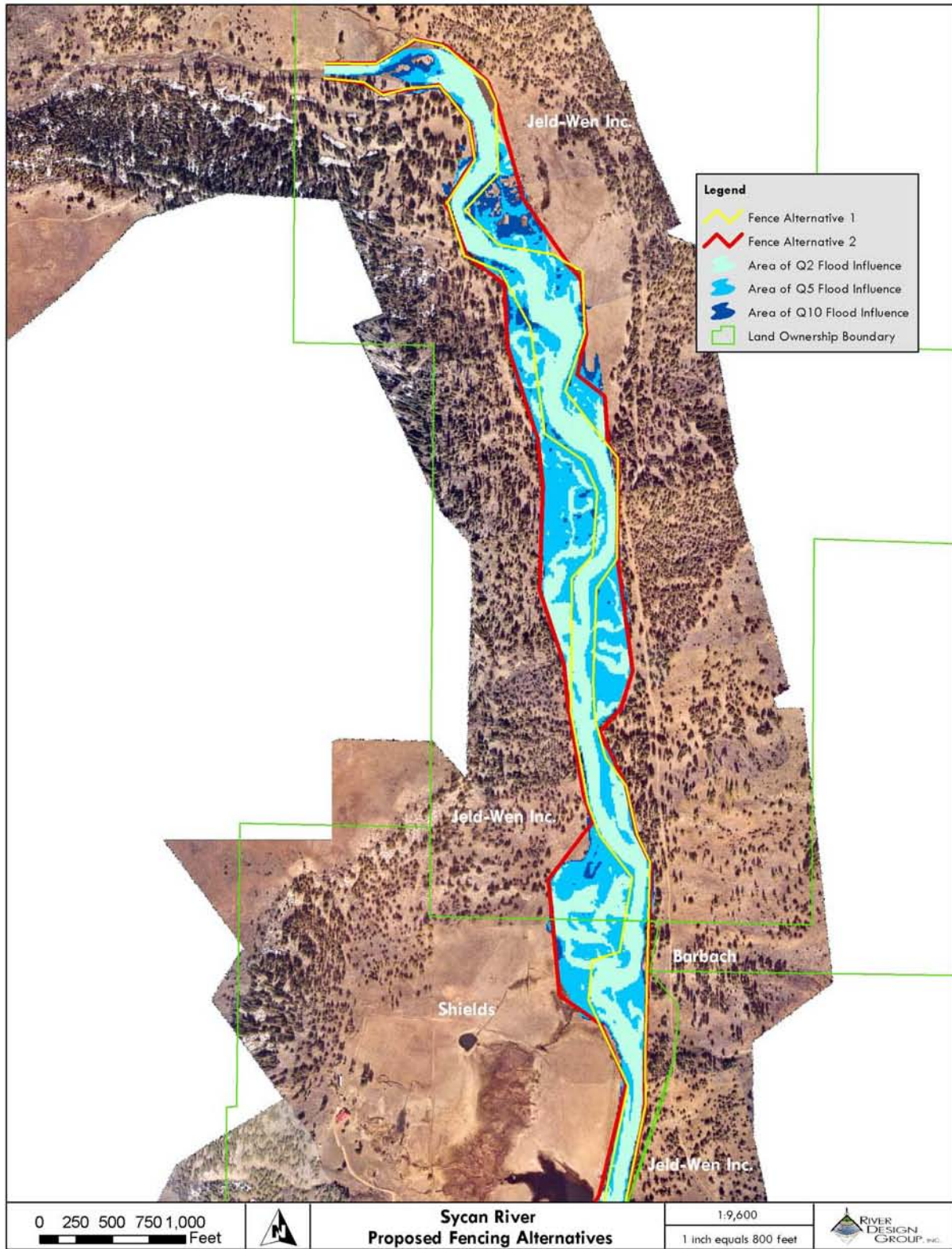


Figure 4-1. The proposed fencing alternatives map for Reach 1 through the middle of Reach 3. The flood extents, Alt. 1 and Alt. 2 fence locations, and landownership boundaries are presented.

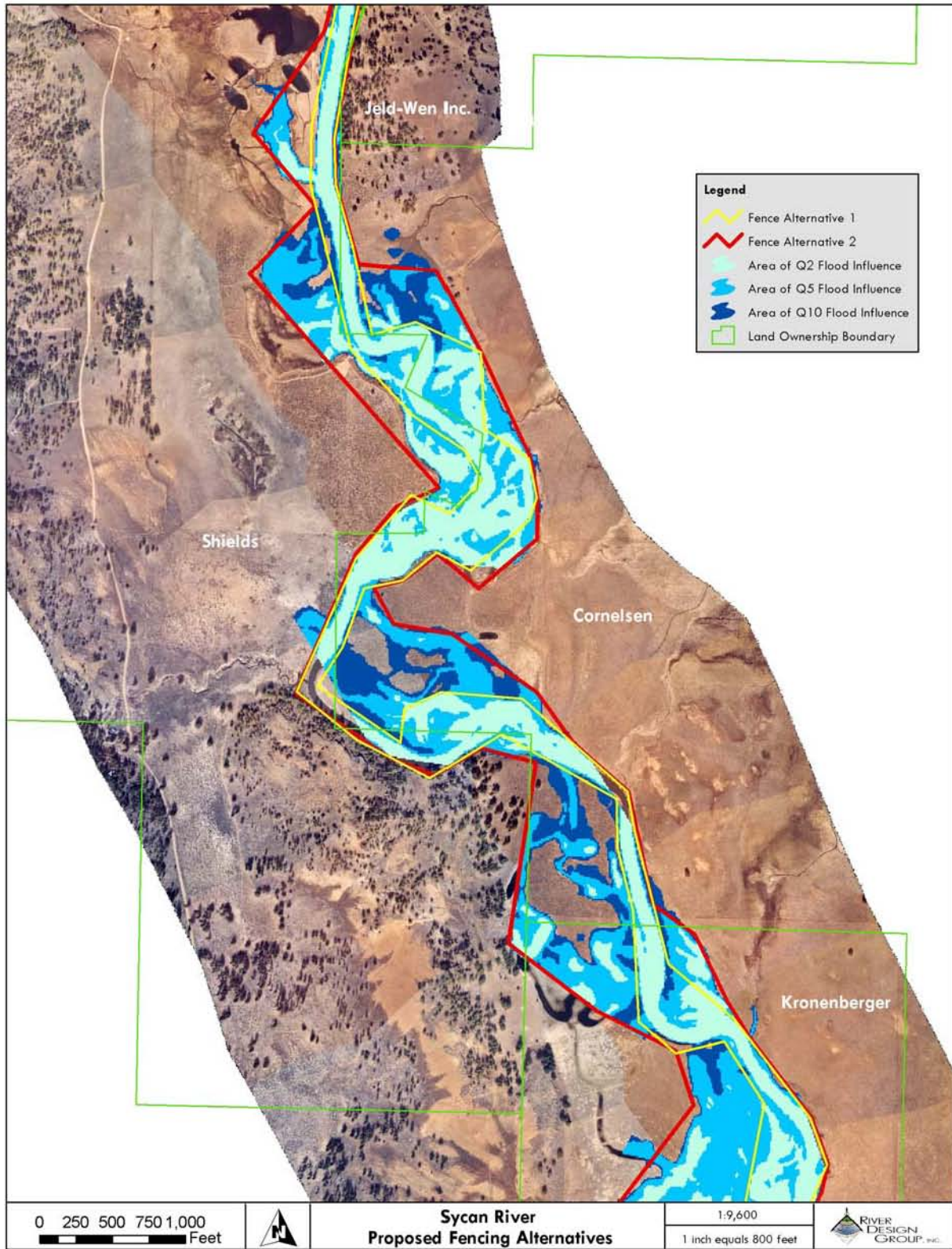


Figure 4-2. The proposed fencing alternatives map for the middle of Reach 3 through upper Reach 5. The flood extents, Alt. 1 and Alt. 2 fence locations, and landownership boundaries are presented.

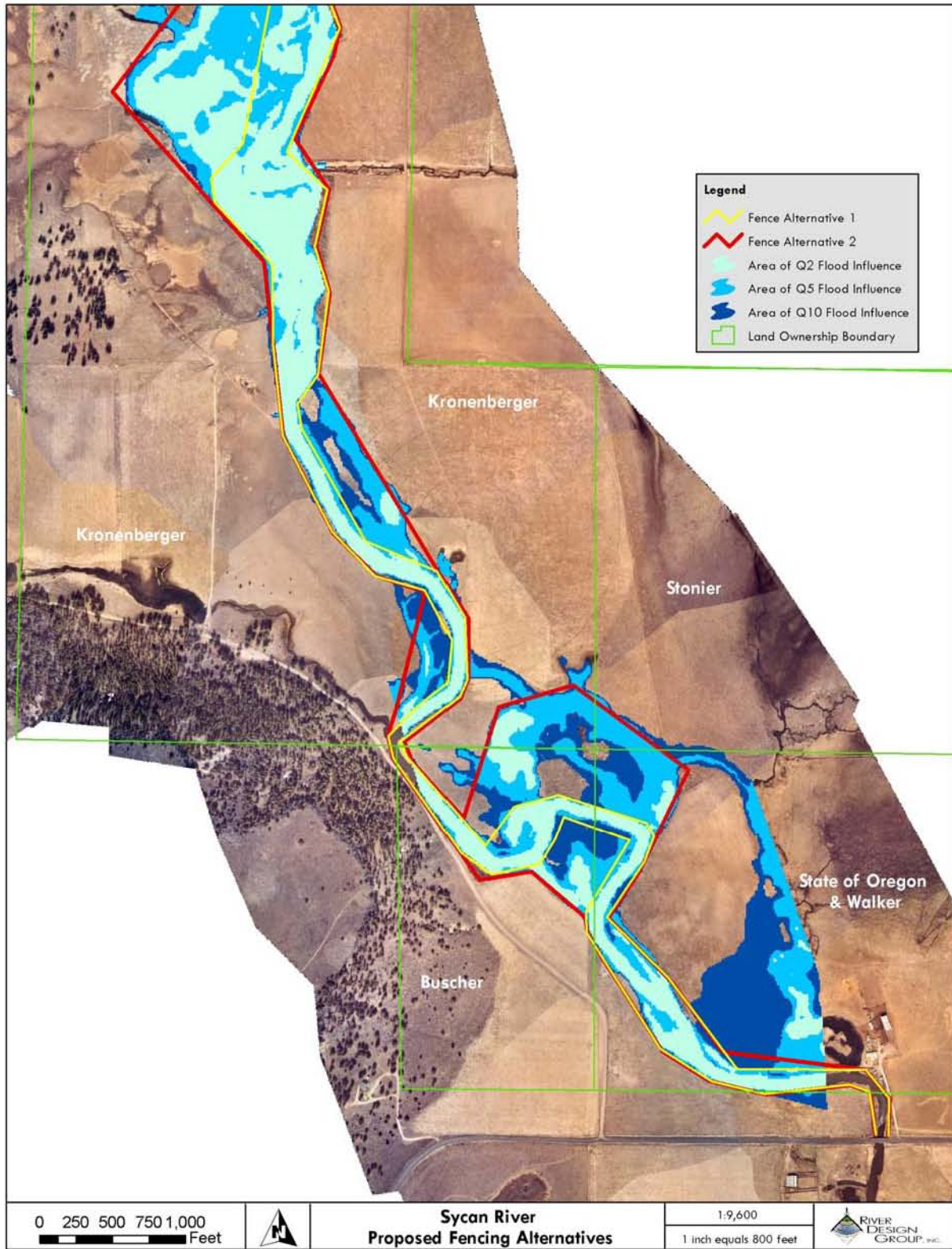


Figure 4-3. The proposed fencing alternatives map from the middle of Reach 3 to upstream of Snake Creek. The flood extents, Alt. 1 and Alt. 2 fence locations, and landownership boundaries are presented.

The area of lost livestock production by landownership was calculated by measuring the land area within the two enclosure alternatives and subtracting the area of the base flow channel (Table 4-1).

Table 4-1. Acres of livestock enclosure under Alt. 1 and Alt. 2 by landownership.

Landowner	Acres of River	Alt. 1 Enclosure Acreage	Alt. 1 Acres of Lost Livestock Production	Alt. 2 Enclosure Acreage	Alt. 2 Acres of lost livestock production
Jeld-Wen, Inc.	10.0	36.2	26.2	67.6	57.6
Shields	8.4	29.3	21.0	56.9	48.5
Cornelsen	6.3	32.8	26.4	74.1	67.7
Kronenberger	11.8	48.1	36.3	108.0	96.2
Stonier	0.0	--	--	1.7	1.7
Buscher	2.9	8.1	5.2	20.6	17.7
State of Oregon & Walker	5.3	14.7	9.4	23.0	17.7
Total	44.7	169.2	124.5	351.9	307.1

Forage values were estimated after discussions with one of the landowners in the project area. We estimated the lost livestock production by breaking forage values into three categories. Channel margin vegetation was given the highest forage value of \$130 (\$120-\$140) per acre per summer. Approximately 1 acre of channel margin vegetation supports one cow/calf pair per summer. Floodplain and terrace vegetation was given an intermediate forage value of \$70 (\$60-\$70) per acre per summer. Approximately 2 acres of terrace vegetation are necessary to support one cow/calf pair per summer. Upland vegetation (e.g. sage brush/Ponderosa pine community) typically requires considerable acreage to support livestock and was not included in the lost forage value calculations.

To estimate the area of channel margin vegetation in a reach, we multiplied the baseflow channel area by 1.5. This provides a channel margin vegetation area 50% greater than the baseflow channel area and is believed to accurately represent the channel margin vegetation area. Field verification would be necessary to improve this estimate. To estimate the terrace area, we subtracted the baseflow channel area and the channel margin fringe area from the total fenced area. The channel fringe area was multiplied by \$130 to determine the value of the excluded channel margin forage. The terrace area was multiplied by \$70 to determine the value of the excluded terrace forage. These values were added together to calculate a total lost forage value. Other costs including the fence materials and installation, maintenance, and off-channel livestock watering were not determined. These more detailed costs will be determined during final project designs. Table 4-2 estimates the cost of the lost production for Alt. 1 and Table 4-3 estimates the cost of the lost production for Alt. 2. Costs for fencing and off-channel watering were not calculated. Lost forage costs could be used as one means to secure landowner compensation.

Table 4-2. Estimated cost of lost livestock production based on the Alt. 1 livestock exclusion.

Landowner	Area Captured by Fence Alt. 1 (acres)	Baseflow Channel Area (acres)	Area of Lost Livestock Production (acres)	Estimated Cost of Lost Livestock Production		
				River Fringe Estimate (\$130/ac)	Riparian Terrace Estimate (\$70/ac)	Total Estimate
Jeld-Wen, Inc.	36.2	10.0	26.2	\$1,946	\$789	\$2,735
Shields	29.3	8.4	21.0	\$1,634	\$587	\$2,221
Cornelsen	32.8	6.3	26.4	\$1,234	\$1,185	\$2,420
Kronenberger	48.1	11.8	36.3	\$2,307	\$1,297	\$3,604
Stonier	--	--	--	--	--	--
Buscher	8.1	2.9	5.2	\$566	\$60	\$625
State of Oregon & Walker	14.7	5.3	9.4	\$1,032	\$101	\$1,133
Total	169.2	44.7	124.5	\$8,718	\$4,019	\$12,738

Table 4-3. Estimated cost of lost livestock production based on the Alt. 2 livestock exclusion.

Landowner	Area Captured by Fence Alt. 2 (acres)	Baseflow Channel Area (acres)	Area of Lost Livestock Production (acres)	Estimated Cost of Lost Livestock Production		
				River Fringe Estimate (\$130/ac)	Riparian Terrace Estimate (\$70/ac)	Total Estimate
Jeld-Wen, Inc.	67.6	10.0	57.6	\$1,946	\$2,982	\$4,928
Shields	56.9	8.4	48.5	\$1,634	\$2,516	\$4,150
Cornelsen	74.1	6.3	67.7	\$1,234	\$4,076	\$5,310
Kronenberger	108.0	11.8	96.2	\$2,307	\$5,491	\$7,798
Stonier	1.7	0.0	1.7	\$0	\$121	\$121
Buscher	20.6	2.9	17.7	\$566	\$934	\$1,499
State of Oregon & Walker	23.0	5.3	17.7	\$1,032	\$686	\$1,717
Total	351.9	44.7	307.1	\$8,718	\$16,805	\$25,524

Fencing costs were estimated for each of the landowners adjacent to the Sycan River in the project area (Table 4-4). Fencing costs are based on a \$2.25/ft cost and are marked-up from a base cost of \$1.85/ft provided by the Natural Resources Conservation Service from recent fencing projects completed in the Upper Klamath Basin. The base cost was revised to account for the remoteness of the project area and increased material prices. The fence construction cost for Alt. 2 is less than for Alt. 1 due to the shorter fencing length.

Table 4-4. Estimated fencing costs for the Alt. 1 and Alt. 2 fencing options. Costs are based on price of \$2.25 per linear foot of fence.

Landowner	Alt. 1 Fence Length (ft)	Alt. 1 Fence Cost	Alt. 2 Fence Length (ft)	Alt. 2 Fence Cost
Jeld-Wen, Inc.	15,509	\$34,896	14,831	\$33,370
Shields	11,846	\$26,653	12,947	\$29,130
Cornelsen	10,959	\$24,658	8,750	\$19,687
Kronenberger	16,089	\$36,201	16,569	\$37,281
Stonier	--	--	567	\$1,275
Buscher	4,100	\$9,226	3,160	\$7,110
State of Oregon & Walker	6,476	\$14,572	5,946	\$13,379
Total	49,471	\$146,206	47,938	\$141,231

Potential bioengineering treatments would be directed towards enhancing habitat, promoting sediment deposition, and accelerating revegetation. Example projects would include stable large wood placement in the active channel and off-channel wetlands. Planting willow cuttings would be an additional treatment to potential speed willow colonization in areas where they have been displaced by grazing. Figure 4-4 illustrates engineered log jams and bioengineering projects completed on the Sprague River.



Figure 4-6. Example bioengineering (left) and engineered log jams (right) on the Sprague River. Bioengineering and log jams provide bank stability and diverse aquatic habitat. Over time, the willows planted in the soil lift will form a dense willow thicket.

Bioengineering and ELJ projects would be implemented at select locations based on site conditions and access. Potential priority sites for bioengineering would include bare eroding banks where willow colonization would meet the restoration objectives. Potential ELJ sites would include off-channel wetlands where the trees would provide habitat for juvenile rearing. Other sites in the active channel would provide overhead cover and habitat diversity for all life history stages of fish inhabiting the Sycan River. ELJs could also be placed to deflect streamflow from unstable banks. Increasing the vegetation density and frequency of large wood in the system would increase channel roughness.

Alternative 1 Summary

Alternative 1 addresses the restoration goals. Excluding livestock from the river would improve vegetation conditions and ultimately reduce sediment loading to the river. The increased channel roughness related to the improved vegetation condition and installation of ELJs would potentially increase water surface elevations. Higher water surface elevations would increase channel-floodplain connectivity. The bioengineering and ELJs are also in the context of the watershed conditions. The bioengineering sites would accelerate willow colonization in the river corridor. ELJs would collect debris transported from the upper watershed and through the Coyote Bucket Canyon. Over time, riparian vegetation would be expected to colonize the surfaces adjacent to the baseflow channel and within the margins of the 2-year flood channel. Vegetation will improve habitat complexity, contribute wood to the stream, and slow flood water.

4.2 Alternative 2 – Grazing Exclusion/No Habitat Enhancement

Alternative 2 would include fencing the Sycan River according to the fencing options presented in Alternative 1. Bioengineering outlined in Alternative 1 would not be completed under Alternative 2. Excluding livestock from the active channel would provide the greatest long-term benefits for the system. Habitat improvements would be slower under Alternative 2 than under Alternative 1, but Alternative 3 would also be less costly and lower risk.

Alternative 2 Summary

Alternative 2 addresses the restoration goals. Excluding livestock from the river would improve vegetation conditions and ultimately reduce sediment loading to the river. The increased channel roughness related to the improved vegetation condition potentially increase water surface elevations over time. Higher water surface elevations would increase channel-floodplain connectivity. The fencing would allow vegetation to recolonize naturally. The shorter-term bank stabilization, habitat, and improved vegetation condition benefits related to bioengineering and ELJ installation would not be realized under Alternative 2. Over time, riparian vegetation would be expected to colonize the surfaces adjacent to the baseflow channel and within the margins of the 2-year flood channel. Vegetation will improve habitat complexity, contribute wood to the stream, and slow flood water. Alternative 2 would be less expensive than Alternative 1 since no habitat enhancement work would be completed.

4.3 Alternative 3 – Habitat Enhancement/No Grazing Exclusion

Alternative 3 would address aquatic and riparian habitat in the river corridor through bioengineering and large wood placement; however, the river corridor would not be fenced. Alternative 3 would improve habitat complexity but would not provide the greater watershed benefits that would be expected from the grazing exclusion. Habitat improvements would likely be short-term in nature and would be undermined by the continued grazing pressure.

Alternative 3 Summary

Alternative 3 does not entirely address the restoration goals. Excluding livestock from the river is necessary to improve vegetation conditions and ultimately reduce sediment loading to the river. Installation of ELJs would potentially increase water surface elevations, but continued grazing would reduce the potential for increasing channel roughness at the reach scale. Although the bioengineering and ELJs are also in the context of the watershed conditions, the effectiveness of these treatments would be minimal relative to the negative effects of continued grazing.

4.4 Alternative 4 - Channel Reconstruction

Under Alternative 4, portions of the Sycan River would be reconstructed to increase channel sinuosity and increase channel-floodplain connectivity. The reconstructed channel would follow the alignments of floodplain channels adjacent to the active river channel. Portions of the existing channel that were to be left in place would be modified to raise the channel invert elevation. Bioengineering, ELJs, and grade control would be used to provide channel stability and habitat.

This approach would address the original idea presented by Water Consulting, Inc. (2002) that the Sycan River was entrenched relative to the floodplain elevation and that only periodic floods accessed adjacent floodplains. The hydraulic modeling exercise suggests that the Sycan River is confined to approximately the 2-year discharge event in most of the reach upstream from the Shields' property. The lower Sycan River that is bracketed by high terraces, confines stream flows up to an exceeding the 5-year event.

This alternative was not pursued further due to the relative risk and costs associated with channel reconstruction. Channel reconstruction in the Sycan River system would have moderate risk due to periodic flood events, ice floes, fine soils, and vegetation conditions. Relocating the channel would require substantial earth moving and stabilization. Rock and gravel would be required to ensure channel stability. Because these materials are limited in the project area, materials would need to be imported into the project area.

Reducing the project risk would be exceedingly expensive due to the need for vertical and lateral channel stabilization. The remoteness of the project area would require long haul routes to import project materials if they were not available on-site.

Furthermore, the channel through most of the reach is only slightly entrenched and adjacent floodplains are inundated with moderate frequency. Higher terraces in the lower project area are infrequently inundated. High terrace soil properties suggest these landforms have not been active floodplains in the recent past.

In summary, implementing channel reconstruction through the project area is considered to be a high risk, low reward project alternative. Channel reconstruction would be expensive with questionable benefits and a moderate to considerable level of risk. For these reasons, Alternative 4 was not developed further.

Alternative 4 Summary

Alternative 4 addresses the restoration goals, however, considerable cost and risk are associated with this alternative. Channel reconstruction would include increasing the channel sinuosity, improving channel-floodplain connectivity, and stabilizing eroding banks. These efforts would be expensive due to the materials costs, remote project area, and extent of stabilization structures that would have to be installed to reduce the potential for project failure. Livestock would need to be excluded from the river corridor. Alternative 4 would be the most expensive project alternative.

4.5 Alternative 5 – Maintain Existing Land Management Practices and Existing Conditions

Alternative 5 would maintain the existing land management practices. Continuing with the current land management regime will likely result in the continuation of the existing degraded river

corridor conditions. Livestock will graze the riparian zone and bank erosion will continue. The Sycan River will continue to have stability issues, and channel roughness and channel-floodplain connectivity are not expected to improve.

No additional monetary costs would be incurred with this option. Over time if the river continues to widen, the landowners may lose property due to erosion. Environmental costs would include continued sediment delivery to the Sprague River and ultimately Upper Klamath Lake, aquatic habitat degradation, and further invasive weed colonization. The primary landowner benefit of Alternative 5 is that the existing land management regime would continue. This would not require any change in the current management costs.

Alternative 5 Summary

Alternative 5 would not achieve the restoration goals.

4.6 Restoration Strategies Summary

Proposed restoration strategies outlined in this section may be applied throughout the Sycan River project area. The preferred approach to improving the conditions of the Sycan River corridor is to exclude livestock from the river corridor for at least 5-10 years. This period of time is believed to be necessary to improve the riparian vegetation community that has been subjected to over 100 years of grazing. Using the Teddy Powers Meadow Reference Reach as an example, the riparian community is expected to rapidly respond to the livestock exclusion. An improved riparian condition will increase the channel roughness leading to more frequent flooding of adjacent floodplains.

Appendix I includes more detailed bioengineering techniques designed to accelerate riparian recovery and enhancing aquatic habitat. Techniques including engineered log jams, vegetated soil lifts, willow cuttings, and containerized plants achieve multiple project objectives. While fencing the river corridor will exclude livestock from the river margins, implementing bioengineering techniques will address near-term conditions until the river corridor naturally recovers.

SECTION 5.0 EXAMPLE CONCEPTUAL PROJECTS

Conceptual restoration strategies were prepared for three properties in the Sycan River project area. The projects vary in scale and approach although each of the sites would benefit from livestock exclusion prior to site-specific treatments. The following section presents a summary of the three conceptual projects.

5.1 Jeld-Wen, Inc. Property – Coyote Bucket Canyon Downstream to Shields Property

The following sections include proposed restoration prescriptions for the Jeld-Wen, Inc. (JWI) property in the Sycan River project area. The restoration strategy includes passive activities focused on fencing the river corridor. Fencing the river corridor and excluding livestock would promote riparian community recovery. Riparian recovery is expected to improve river corridor conditions as was illustrated in the Teddy Powers Meadows reference reach discussion. Once the vegetation has recovered, additional work could be implemented to increase aquatic and riparian habitat diversity. Examples of other potential projects include placing engineered log jams for fish habitat and pool development, willow planting to accelerate vegetation recovery, and monitoring river response.

5.1.1 Fencing Plan

Two fencing alternatives were developed for the JWI property on the Sycan River. Descriptions of the evaluation process were presented in Section 4.1. The following sections focus on the JWI property.

Alternative 1

Fencing Alternative 1 (Alt. 1) is based on placing the fence approximately 20 ft back from the edge of the terrace. The Alt. 1 fence location would exclude livestock from the flood way channel associated with the 2-year flood event. Livestock would still be allowed access to most of the terrace areas. Table 5-1 includes the area computations and value of lost livestock production under Fencing Alt. 1.

Table 5-1. Estimated cost of lost livestock production based on the Alt. 1 livestock exclusion.

	Area Captured by Fence Alt. 1 (acres)	Baseflow Channel Area (acres)	Area of Lost Livestock Production (acres)	Estimated Cost of Lost Livestock Production		
				River Fringe Estimate (\$130/ac)	Riparian Terrace Estimate (\$70/ac)	Total Estimate
Landowner						
Jeld-Wen, Inc.	36.2	10.0	26.2	\$1,946	\$789	\$2,735

Alternative 2

Fencing Alternative 2 (Alt. 2) locates the fence outside the majority of the 10-year flood inundation area and captures most of the active river corridor. Livestock would be excluded from most of the terrace areas in addition to the 2-year channel. Grazing areas outside of the fences could be uneconomical due to low forage quality. Table 5-2 includes the area computations and cost of lost livestock production under Fencing Alt. 2.

Table 5-2. Estimated cost of lost livestock production based on the Alt. 2 livestock exclusion.

Landowner	Area Captured by Fence Alt. 2 (acres)	Baseflow Channel Area (acres)	Area of Lost Livestock Production (acres)	Estimated Cost of Lost Livestock Production		
				River Fringe Estimate (\$130/ac)	Riparian Terrace Estimate (\$70/ac)	Total Estimate
Jeld-Wen, Inc.	67.6	10.0	57.6	\$1,946	\$2,982	\$4,928

Fencing costs for the two alternatives are included in Table 5-3. Table 5-4 includes the lost livestock production costs and the fencing costs for the two alternatives.

Table 5-3. Estimated fencing costs for the Alt. 1 and Alt. 2 fencing options. Costs are based on price of \$2.25 per linear foot of fence.

Landowner	Alt. 1 Fence Length (ft)	Alt. 1 Fence Cost	Alt. 2 Fence Length (ft)	Alt. 2 Fence Cost
Jeld-Wen, Inc.	15,509	\$34,896	14,831	\$33,370

Table 5-4. Project costs for implementing the grazing the two grazing exclusion alternatives on the JWI property.

Landowner	Alt. 1 Cost	Alt. 2 Cost
Jeld-Wen, Inc.	\$37,631	\$38,298

Costs and Benefits of the Alternatives

Each of the presented alternatives has costs and benefits. Alt. 1 would take less forage out of production than does the Alt. 2 plan. However, the Alt. 1 fence location is closer to the active channel and would likely require more frequent maintenance following floods. The Alt. 2 fence location is more distant from the active channel and would require less maintenance. Other fencing options that are intermediate to these alternatives could be investigated.

Our analysis of lost forage production yielded cost estimates less than originally anticipated. Excluding livestock from the 2-year flood channel (Alt. 1), would at a minimum, improve vegetation conditions between the confining terraces. This alternative would result in foregoing approximately \$3,000 per year in grazing revenue, a fairly small sum relative to the potential water quality and habitat benefits that would be provided. Alt. 2 would restrict livestock from the majority of the river corridor and improve the riparian community within the fence lines. Implementing Alt. 2 would result in a loss of approximately \$5,000 per year in grazing revenue. Because JWI leases the property for grazing, JWI is likely paid only a portion of this amount by the lessee.

Other proposed activities include managing invasive weeds, relocating beavers into the Sycan River, and placing large wood would further improve the river corridor. Large wood placement could be completed at select locations. Placing large wood to interact with the baseflow channel would provide more diverse habitat for juvenile and adult fish. Wood placement would need to consider the effects of the wood on unstable streambanks. Wood should be stabilized with ballast rock or anchored into streambanks and the stream bed. Accumulations of large wood on

floodplain surfaces suggest wood does not recruit to the river until the bankfull discharge is exceeded.

Monitoring the vegetation response is advised for determining the effectiveness of the grazing management plan. After a period of 5 to 10 years (or less as vegetation conditions permit), it would be possible to enact limited grazing within the fenced corridor. This period of time is expected to be necessary to re-establish the dense riparian vegetation that historically occupied the site. A more actively-managed grazing plan could be implemented in the future although excluding livestock from at least the 2-year channel is advised.

5.2 Kronenberger Property

RDG completed a list of 16 potential projects on the Kronenberger property. There are several issues that should be recognized when evaluating the proposed projects. The outlined projects may be organized into two groups: floodplain fill removal projects and bank erosion control projects. The following sections present the goals, potential benefits and risks, and implementation strategies for the two project groups. The project elements of foremost importance are fencing the river corridor and excluding livestock from the bankfull channel. A proper fence location would exclude livestock from the streambank edge where the river is confined by high streambanks, as well as floodplain wetland areas where the river has greater access to the floodplain. Livestock grazing would still be possible throughout the property outside of the exclusion area. Off-channel water could also be developed to provide livestock watering. If livestock are not excluded from the reach, improving the function of the Sycan River on the Kronenberger property is unlikely.

In addition to the grazing exclusion, other actions could include noxious weed management and potentially, in-stream habitat improvement. Instream habitat improvement would be achieved by placing stable whole trees and/or engineered log jams within the bankfull channel. Trees could likely be acquired from the Kronenberger's property, the Shields' property, or another source in the vicinity of the Kronenberger property. Ballast rock would also need to be acquired. Several potential rock sources are also available. The number and location of structures, structure size and material specifications, and material acquisition locations would be determined during final design. Treatment sites are included in Table 5-5.

Table 5-5. Recommended treatment sites on the Kronenberger property.

Site #	Project Type	Location	East/West Bank or Floodplain
1	Bank Treatment	225+00	West
2	Bank Treatment	228+00	West
3	Bank Treatment	232+50	West
4	Fill Removal	237+50	West
5	Fill Removal	246+00	West
6	Bank Treatment	250+00	West
7	Fill Removal	251+00	West
8	Bank Treatment	252+00	West
9	Fill Removal	261+00	West
10	Fill Removal	262+00	West
11	Bank Treatment	267+50	East
12	Fill Removal	268+00	West
13	Bank Treatment	273+50	East
14	Bank Treatment	274+00	Both
15	Bank Treatment	279+00	West

Floodplain Fill Removal Sites

The goal of the floodplain fill removal projects will be to increase the Sycan River’s access to the floodplain, improve riparian vegetation conditions, and enhance off-channel habitats. The floodplain fill removal projects entail removing fill that has been placed in the reach primarily for river access (Figure 5-1). Most of these fills are 2-3 ft high and are in the form of an unimproved road that parallels the river. The fills limit river access to floodplain areas during moderate high water and are typically colonized by sage brush, forbs, and noxious weeds. The anticipated benefits of the fill removal include increased interaction between the river and floodplain (floodplain sediment storage), increased riparian vegetation, increased opportunity for juvenile fish rearing in off-channel wetlands, and reduced in-channel stream energy (lower stream power and erosion potential). The cost of fill removal is minimal and construction would be simple to complete.



Figure 5-1. Two potential fill removal sites on the Kronenberger reach of the Sycan River. Site 6 (left) is characterized by poor vegetation conditions and floodplain confinement. Site 10 (right) separates the river from an off-channel wetland.

Implementation would be completed with a 200-class excavator and 2-3 dump trucks. The excavator would start at the upstream edge of each fill and load the fill directly to dump trucks. A travel route would be determined for each fill removal site and would be organized to minimize site disturbance. A fill stockpile area would be established out of the river corridor and would most likely be located at the shale pit where much of the fill material originated. Fill would be removed down to the floodplain elevation or tie to an appropriate topographic feature.

Following fill removal, each site would be prepared for revegetation. Due to the droughty soil conditions related to the pumice soils, the planting approach should include coir logs, willow cuttings, bare root and/or containerized plants, seeding, mulch application, and irrigation. The coir logs come in 13 ft lengths and act as a moisture-retaining sponge for improving willow survival. Willow cuttings would be bundled in fascines and buried in contact with the coir logs. The moisture from the coir logs would improve willow cutting success in the dry environment. Bare root and/or containerized sand bar willow and silver sage would also be planted in the fill removal area. A native seed mix comprised of riparian and dry species would be distributed at an appropriate application rate. Applying compost to the disturbed area would assist in limiting noxious weed invasion to the disturbed area. Weed invasion is a concern in the reach due to the prevalence of Canada thistle and bull thistle in the project area. Treating thistle for a minimum of three years following project implementation is recommended. Instituting a periodic irrigation plan is also recommended for the first two years following implementation to improve vegetation survival.

In summary, fill removal offers a low risk, high reward project alternative. Fill removal can be done moderately quickly with the revegetation approach also being fairly straight forward. However, successful implementation of the fill removal projects will require livestock exclusion, weed management, vegetation maintenance, and periodic irrigation.

Fill Removal Sites: Site 4, Site 5, Site 7, Site 9, Site 10, and Site 12.

Bank Stabilization Sites

Ten bank erosion sites were identified in the Kronenberger reach. Conditions at these sites ranged from rather short river sections approximately 50 ft in length, to more extensive areas

measuring up to 500 ft in length. Sites with the most extensive erosion included Site 1, Site 9, and Site 15. Two primary conditions relate to the bank erosion sites. First, bank erosion is related to livestock access. This process is apparent at Site 1 and Site 15 (Figure 5-2). A livestock trail at Site 1 appears to be undermining the upper bank resulting in a vertical, unstable and poorly vegetated bank. The willow community which would be expected at about the elevation of the livestock trail is absent from this site. Site 15 is located near the Kronenberger river crossing. Livestock tend to congregate on both sides of the river near the crossing. Soil compaction, vegetation removal, and surface erosion have resulted in a large eroding area.



Figure 5-2. A livestock trail at Site 1 (left) results in poor vegetation conditions and a raw bank. The Sycan River crossing (Site 15) concentrates livestock resulting in degraded riparian vegetation and stream bank conditions (right).

The second bank erosion condition relates to fluvial processes. At these locations, livestock access appears to be a secondary processes affecting bank stability. These sites are typically located where the river is interacting with a terrace or high stream bank. At these locations, the bank toe is stable but the upper bank is eroded by the river. These actions result in both incremental and acute sediment delivery to the Sycan River (Figure 5-3). Over time, the stream bank in the affected sites will reach an angle of repose and revegetate. Similarly, the failed bank material that settles at the bank toe may revegetate and become stable over time if significant flood events do not occur and livestock grazing is excluded.



Figure 5-3. Two sites characterized by vertical bank failures related more to fluvial processes than livestock access. Site 4 (left) is a short reach characterized by a vertical-to-overhanging bank. Site 9 is a more extensive reach characterized by an eroding outside bank that is contributing large blocks of soil to the river (right). Sloughed blocks may stabilize at the bank toe and revegetate as seen in the middle ground of the right photo.

The goal of treating the bank erosion sites is to reduce fine sediment delivery to the Sycan River by improving bank stability through riparian vegetation colonization of eroding sites. RDG discussed how best to achieve this goal with Tom Parker, Plant Ecologist with Geum Environmental Consulting, Inc. Our initial approach (as included in the draft project budget document) included re-grading eroding banks to achieve a bank slope more similar to stable banks found in the Kronenberger reach (Figure 5-4). Bank re-grading would be completed by excavating the eroding bank from the top of the sedge toe (if present) and day-lighting to a point on the terrace surface that would achieve the reference bank slope. Excavated material would be hauled to an appropriate stockpile area. Following bank re-grading, a bioengineering approach similar to the fill removal bioengineering concept would be completed. Coir logs and willow fascines would be placed at the inflection point located at the top of the sedge line. Willows commonly grow at this elevation throughout this section of the Sycan River. Bare root and/or containerized upland vegetation (e.g. rose, golden current, bitterbrush, and big sagebrush) would be planted. A native riparian and upland seed mix would be spread on the site. To limit noxious weed invasion, compost would be spread on the site. Irrigation would be necessary for a minimum of two years to improve revegetation success.



Figure 5-4. An example of an existing eroding bank (left) and a reference condition (right). The stream bank at the reference site has reached an angle of repose that supports vegetation.

Although the bank re-grading approach could be successful, it is questionable whether the actual re-grading is necessary, and just proceeding with the bioengineering and livestock exclusion may be a lower cost and lower risk alternative for achieving the stated goal. The bank re-grading will result in a substantial increase in the amount of exposed soils at each treated site. For example, at Site 1, the existing exposed soil surface area is approximately 3,000 ft² (500 ft long x 6 ft high). The re-graded slope could have an exposed surface area upwards of 6,000 ft² to 7,500 ft², more than doubling the existing exposed area. Due to the poor soil conditions (pumice sand) and limited soil moisture, there is a high risk of revegetation failure if the treated sites are not actively managed by landowner. Active management would include ensuring livestock exclusion, managing weeds, seasonal irrigation, and potentially periodic replanting. Additionally, other reference banks in both the Kronenberger reach and the upstream Teddy Powers Meadow reference reach illustrate the natural revegetation potential if livestock are excluded from the site (Figure 5-5).



Figure 5-5. Reference vegetation conditions on the Sycan River. A sedge/willow community in the Kronenberger reach (left) and sedges provide a buffer to a previously eroding bank on the Sycan in the Teddy Powers Meadow reach (right). Excluding livestock from the eroding bank sites in the Kronenberger reach would be expected to result in vegetation recovery.

Bioengineering for the eroding bank sites is still recommended. Coir logs and willow fascines would be installed at the toe of the eroding banks. Minimal excavation would be necessary during installation and the disturbance area would be limited. The planting work would be completed by hand labor. Irrigation would still be necessary to improve revegetation success. Combined with the livestock exclusion, this bank stabilization approach carries less risk, less cost, with a greater potential for revegetation success.

In summary, bank stabilization of eroding sites would be expected to reduce fine sediment delivery to the Sycan River. The preferred approach would include livestock exclusion and bioengineering to facilitate site revegetation. Weed management, vegetation maintenance, and periodic irrigation are suggested for ensuring revegetation success.

Bank Stabilization Sites: Site 1 – Site 3, Site 6, Site 8, Site 11, Site 13 through Site 15.

In-stream Habitat Enhancement

The Sycan River through the Kronenberger reach has limited in-stream aquatic habitat complexity. Based on results from other projects completed on the Sprague River and other river systems, placing stable large wood in the channel provides complex habitat for juvenile and adult fish. Large wood structures would be placed at locations that would promote pool scour, sediment sorting, and deflect flows from eroding banks. The structures would also provide more diverse habitat compared to the existing channel conditions.

Kronenberger Stream Crossing

A concrete stream crossing is located in the lower third of the Kronenberger property. The crossing enables Mr. Kronenberger to access the eastern portion of his property. The concrete crossing may affect fish passage during baseflow periods when shallow water depths and vertical height of the structure potentially preclude upstream fish movement (Figure 5-6). The structure is submerged during moderate and high flows. Fish passage is likely not affected during these periods. Although the structure may affect fish passage, it also provides grade control through the reach.



Figure 5-6. The Kronenberger crossing likely creates a fish passage barrier during baseflow. These picture taken in June 2007, capture the structure during the declining hydrograph.

The structure could be modified to improve fish passage. Adding rock or concrete steps to the downstream portion of the structure would provide better fish access over the structure. Building

a downstream pool tailout would also create a backwater downstream of the structure, improving the fish passage potential. Narrowing the structure width would confine the channel and increase water depths over the structure.

Agriculture Drain Channel

An agriculture drain channel was excavated in the eastern terrace between the 1940s and the 1990s. The drain captures groundwater and surface water and routes it to the Sycan River (Figure 5-7). Located on the Kronenberger and Cornelson properties, the drain was made by excavating the terrace and windrowing the soils on the terrace creating a berm. The channel at the bottom of the cut is developing a meander pattern by eroding the cut side slopes. The channel is a constant sediment source to the Sycan River, delivering fine sands.

Although further analysis is necessary, the ditch should be addressed to reduce sediment loading to the Sycan River. Potential treatments include stabilizing or filling the channel. Stabilizing the channel would improve the aquatic habitat conditions and potentially increase the ditch's habitat value. Filling the channel would treat the sediment loading and potentially raise the water table in the area. A higher water table could potentially reduce irrigation requirements. Either treatment would be relatively straightforward.

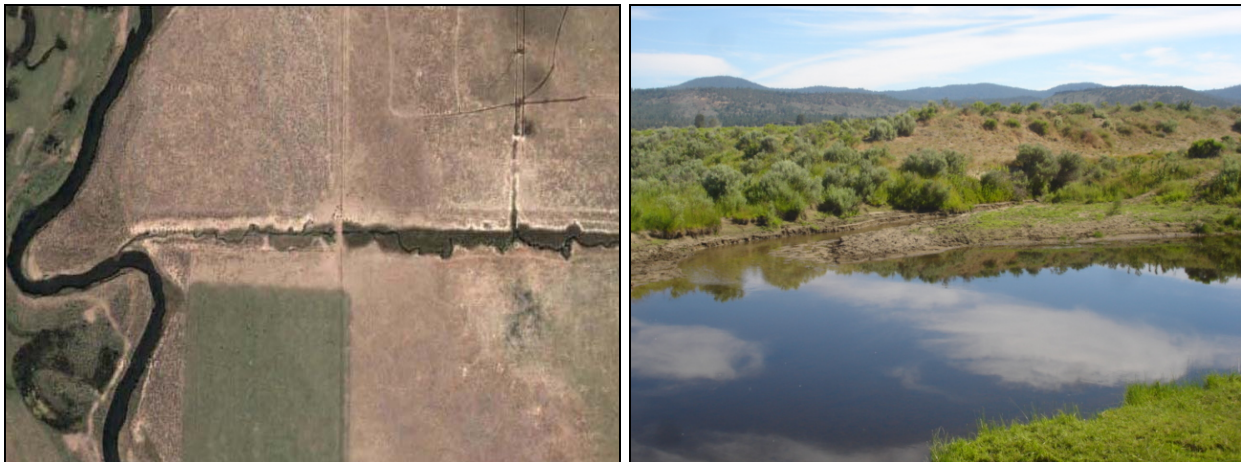


Figure 5-7. An air photo of the drainage channel (left), and a ground photo of the mouth of the drainage channel (right). The channel originates on the Cornelson property and flows through the Kronenberger property before reaching the Sycan River. The drainage channel is a persistent sediment source to the Sycan River.

The outlined project sites provide a range of options for improving river corridor conditions through the Kronenberger reach of the Sycan River. Excluding livestock from the Sycan River channel are expected to result in the greatest vegetation response. Implementing any of the planting options without complete exclusion of livestock from the river bottom is not advised. The proposed projects are also relatively straight forward and will require only moderate oversight once the operators understand the specific approaches. Building the in-stream structures will require more oversight but would be expected to result in fisheries benefits. Additionally, the vegetation response upon livestock exclusion would be expected to also result in fisheries benefits.

5.3 Conceptual Restoration Treatments Summary

The presented conceptual restoration treatments could be implemented anywhere in the Sycan River project area. The treatments rely on livestock exclusion from the bankfull channel in order to re-establish riparian vegetation. Completing structural treatments without excluding livestock from treated areas is not expected to have the same level of benefits. Restoring riparian vegetation is expected to affect sediment storage, fish habitat and floodplain diversity, and the frequency of overbank flooding.

SECTION 6.0 ASSESSMENT SUMMARY

The Sycan River is a dynamic system influenced by its natural surroundings and human activities. As the largest tributary to the Sprague River, the Sycan River is an important contributor of flow, sediment, and wood. Although limited data are available, the Sycan River is also likely important for the Sprague River fish community. Groundwater springs, wetlands, and relict channels provide a variety of aquatic and riparian habitats.

Land management activities have influenced the watershed. Land management practices including the modification of the Sycan Marsh for agriculture, timber harvest and road construction throughout the watershed, and grazing in the river corridor have affected the Sycan River. Within the project area, grazing has impacted the riparian vegetation community. Vegetation removal, streambank trampling, soil compaction, and the spread of noxious weeds have degraded the plant community and made the Sycan River more susceptible to bank erosion.

Proposed restoration strategies focus on excluding livestock from the river corridor. To make this strategy viable, landowners will have to be compensated for lost livestock production. Setting up an easement program or pursuing existing conservation programs (e.g. Farm Services Agency's Conservation Reserve Enhancement Program) offer opportunities for compensating landowners for lost production. Implementing other habitat enhancement projects may be implemented if livestock are not excluded from the river. However, excluding livestock is expected to provide the greatest improvement in river corridor conditions. Achieving river corridor restoration goals will require re-establishing the riparian community.

APPENDIX A HYDROLOGY AND FLOOD SERIES ANALYSIS

A.1 INTRODUCTION

The following section provides an introductory overview on basin hydrology, with particular emphasis on the Sycan River flood frequency analysis.

A.2 GENERAL WATERSHED HYDROLOGY

The climate of the Sprague River sub-basin is moderated by the Cascade Range and strongly influenced by post-maritime storm tracks from the Pacific Ocean to the northwest. Because of the lower mountains east of the basin, the rain shadow is less pronounced than other regions east of the Cascades (Quigley and Arbelbide 1997). Summers are typically dry with mild temperatures and moderately long growing seasons followed by wet winters and low temperatures (Akins 1970; Leonard and Harris 1974). The annual precipitation ranges from 16 inches in the valley bottoms to over 60 inches at the watershed divide (Leonard and Harris 1974; Atlas of Oregon 2001). Precipitation primarily takes the form of winter snows, spring rains, and summer thunderstorms with a steep seasonal gradient from moist winters and springs to very dry summers and fall conditions. Seventy percent of precipitation falls between October and March and only 9 percent falls from July to September (Leonard and Harris 1974).

The Sycan River watershed at Drews Road is 568 square miles. Elevations range from over 8,100 ft at Yamsey Mountain, to 4,310 ft at Drews Road. The watershed is located east of the Cascade Mountains with the headwaters originating in Winter Ridge, Brattain Ridge, and Booth Ridge areas. Yamsey Mountain and Fuego Mountain are two of the prominent mountains in the watershed. Annual water yield is approximately 116,000 acre-feet per year for the Sycan River at Drews Road.

A.3 SYCAN RIVER HYDROGRAPHY

A U.S. Geological Survey (USGS) streamflow gaging station was located on the Sycan River at the Drews Road Bridge (USGS 11499100 – Sycan River Below Snake Creek Near Beatty, Oregon). The gage was operational from October 1, 1978 through September 30, 1991. Graham Mathews and Associates (GMA) under contract with the Klamath Tribes, reactivated the USGS gage and maintained it from October 1, 2005 through June 27, 2006.

The annual hydrograph of the Sycan River generally exhibits two peak flow periods, one during mid-winter and the second during late spring (Figure A-1). The Sycan River is somewhat unique in this area as the midwinter peak (or peaks) usually provides the greatest annual flow and is generated from rain-on-snow events on frozen ground conditions. This peak tends to be of short duration, but can occur more than once during the winter. The late spring peak is usually generated by snowmelt runoff in the headwaters and is a longer duration, yet lower magnitude peak. Peak runoff in the Sycan watershed is influenced by the Sycan Marsh. Historically, the marsh tended to dampen, or reduce, the magnitude of annual floods. Although the marsh was altered for agriculture, its influence on the Sycan River may be the reason that the mid-winter peak is of greater magnitude than the snowmelt peak. Bakke et al. (2000) also suggests that the

bankfull discharge for the Sycan River may be significantly lower than nearby streams and attributes this difference to the hydrologic effects imposed on the river system by Sycan Marsh.

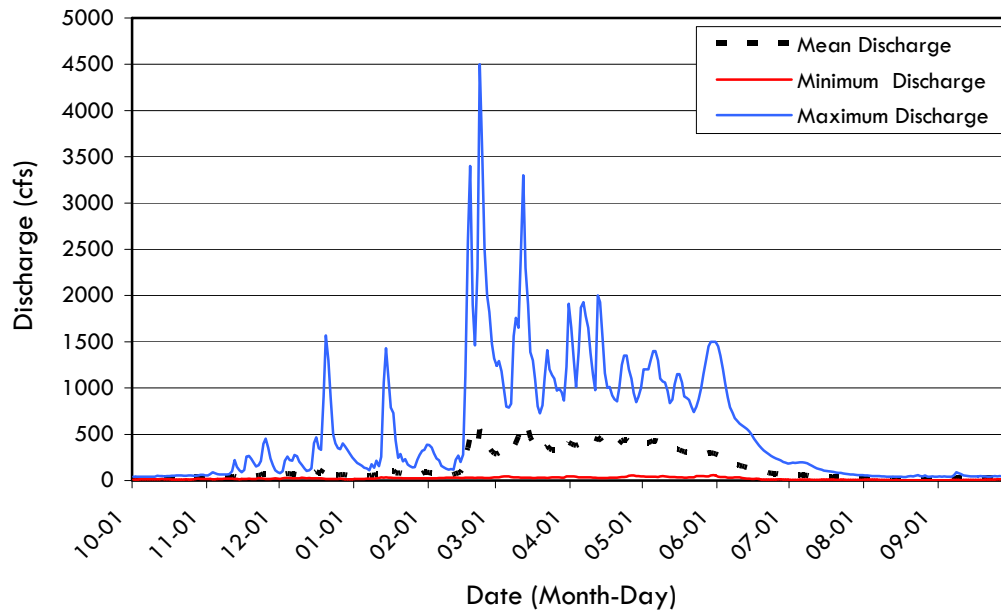


Figure A-1. The average annual hydrograph for the Sycan River at Drews Road. The period of record is from 1978 to 1990.

A hydrograph from October 1, 2005 through June 28, 2006 is presented in Figure A-2.

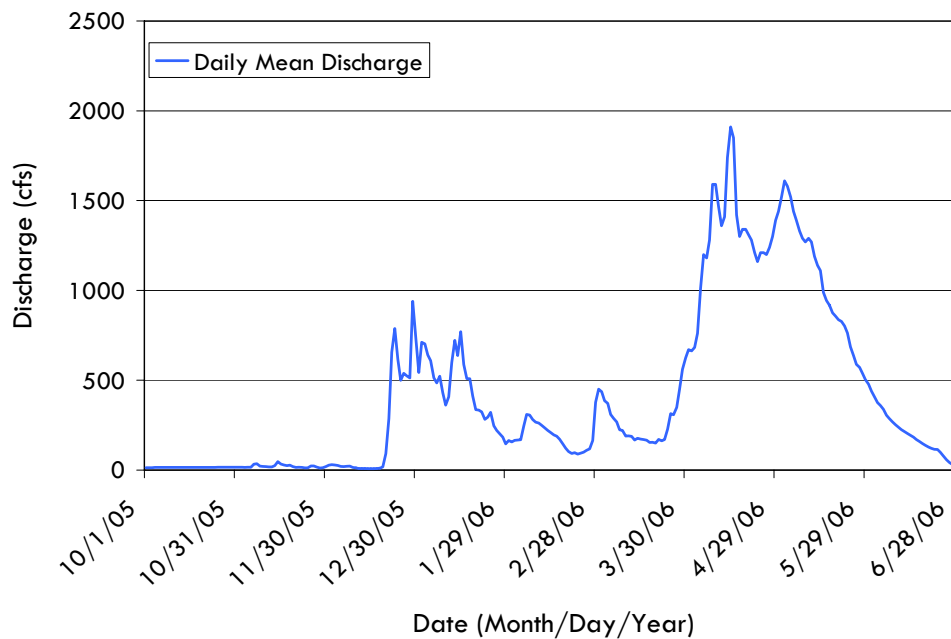


Figure A-2. The hydrograph from October 1, 2005 through June 27, 2006 (Graham Matthews and Associates, unpublished data).

A.3.1 Peak Flood History

Due to the short period of record for the Sycan River gage, few large peak flood events were documented by the gage. Table A-1 includes the peak events recorded between 1980 and 1991. The largest peak event occurred on February 21, 1982 and was greater than a 20-year event and likely associated with a rain-on-snow event. Other large events in the Sprague River watershed occurred in 1964, 1972, 1996 and 1997.

Table A-1. Sycan River peak discharge events.

Date	Annual Peak Discharge (cfs)
1/14/80	1,490
2/16/81	480
2/21/82	5,550
3/31/83	2,020
3/21/84	1,470
4/16/85	2,030
3/9/86	1,800
3/7/87	412
3/2/88	271
3/12/89	3,300
3/6/90	332
5/21/91	265
4/14/06	1,930

A.3.2 Baseflow Conditions

Summertime base flows are substantially less than annual peak runoff. Compared to the estimated 1.7-year return interval discharge of 750 cfs (see Section A.4 for analysis), base flows less than 30 cfs from July through September are not uncommon. Discharge averaged less than 5 cfs during the summer of 1981, a drought year.

The fluctuation between runoff and base flow causes extreme soil moisture conditions for vegetation on the Sycan River. Vegetation conditions in the lower reaches of the Sycan River reflect the runoff pattern. Big sagebrush and bitterbrush do not encroach into the channel due to periodic flood events. Deep-rooted sedges and rushes colonize a lower bench surface that is commonly located adjacent to the base flow channel. Figure A-3 illustrates the variation between base flows and high flows at the same reach of the river. Photos were taken during the 2006 summer base flows and the 2006 spring runoff.



Figure A-3. River corridor condition comparison between summer time base flows (left) and spring runoff (right). High water limits big sagebrush and bitterbrush encroachment into the channel.

The Sycan Marsh plays an important role in the attenuation of peak flood events and the low base flows. The Sycan watershed's average annual precipitation/runoff ratio is 0.16 indicating that for every inch of precipitation that falls in the sub-basin only 0.16 inch appears as streamflow at the USGS gage (OWRD 2000). Or alternatively, 84% of water leaves the sub-basin as evapotranspiration and deep groundwater flow (OWRD 2000). For comparison, the precipitation/runoff ratios of the upper Williamson watershed (above Rocky Ford) and the upper Sprague watershed (above Beatty), the two sub-basins closest to the Sycan River (in the Klamath drainage), are 0.20 and 0.35, respectively (OWRD 2000). The marsh therefore plays an important role in the movement of water through the Sycan River drainage.

The underlying geology of the Sycan River also influences streamflows. Fractured, highly permeable basalt underlies the majority of the Sycan River catchment (OWRD 2000). Except where springs and tributaries discharge to the Sycan River, the river is a losing system. A 2000 synoptic study found that groundwater inputs to the Sycan River at Torrent Springs and in the lower Sycan Valley, contributed roughly 95% of the flow of the Sycan River measured at the gage near Beatty (OWRD 2000). An earlier study by Newcomb and Hart (1954) suggested the Sycan River is perched approximately 200 ft above the water table below Teddy Powers Meadows, intersecting the water table in the Sycan Valley several miles below Blue Creek (cited in OWRD 2000).

A.4 FLOOD FREQUENCY ANALYSIS

Flood magnitudes for selected recurrence intervals were determined for the Sycan River from a flood frequency curve using the log-Pearson Type III distribution method as outlined in Bulletin #17B Guidelines for Determining Flood Flow Frequency (U.S. Department of the Interior Geological Survey 1982). The Oregon Water Resources Department also produced regional equations to calculate flood frequencies for ungaged streams in eastern Oregon (Cooper 2006). Due to the short period of record for the USGS gage, both the gage flood frequency and the regional equations for the ungaged streams were used to complete the Sycan River flood frequency analysis. Results are included in Table A-2 and Figure A-2. The variation in the estimates is due to the short period of record and variability associated with regional equations.

Table A-2. The log Pearson Type III flood frequency for the Sycan River developed from the 12 years of peak flow data and results from the OWRD regional equations. The percent differences of the two methods are also presented.

Method	Recurrence Interval (yrs)							
	1.5	2	5	10	20	50	100	500
Log Pearson Type III	720	1,180	2,770	3,970	5,130	6,590	7,620	9,714
OWRD Regional Equations		1,120	2,160	3,070	4,100	4,460	7,040	10,900
Percent Difference		5.1	22.0	22.7	20.1	32.3	7.6	10.9

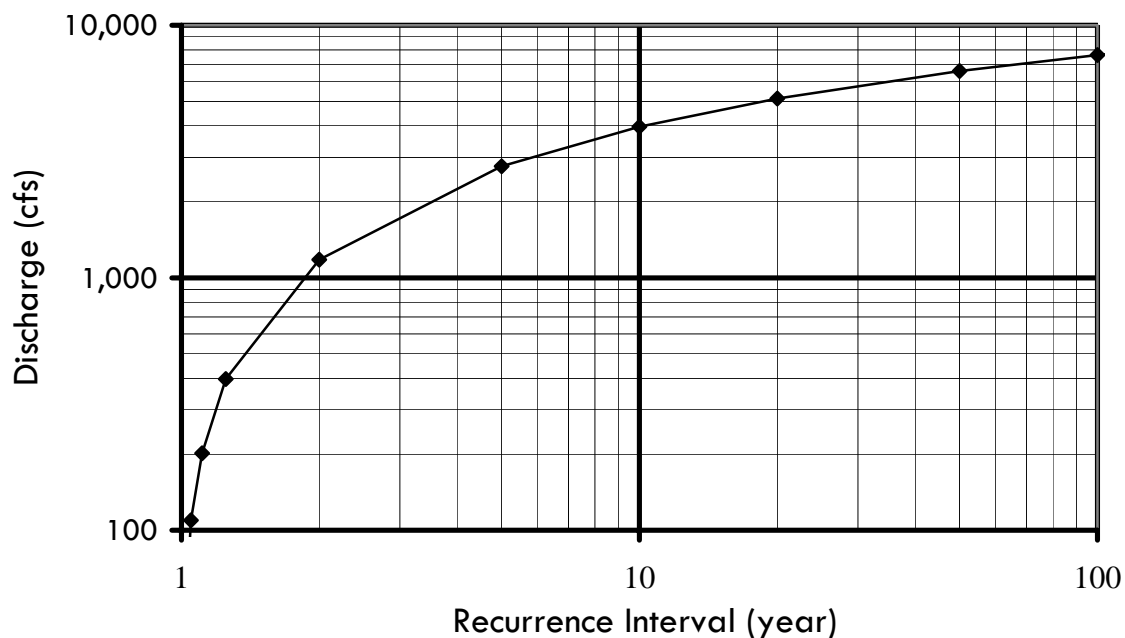


Figure A-2. The flood frequency curve for the Sycan River based on the log Pearson Type III method.

A.5 BANKFULL DISCHARGE ANALYSIS

This section presents estimates of the channel forming discharge and associated recurrence intervals for the Sycan River. The channel-forming or dominant discharge is often used as the representative value for channel design (Shields et al. 2003) and is associated with the discharge that dominates channel form and process. Dunne and Leopold associated the channel forming discharge with a momentary maximum flow, which, on average, has a recurrence interval of 1.5-1.8 years as determined using a flood frequency analysis (Dunne and Leopold 1978). Because most of the Sycan River does not access adjacent floodplain surfaces until the 2-year to 5-year discharge interval (see *Appendix E – Channel Hydraulics*), the use of bankfull throughout this report refers to the 1.7-year to 1.8-year interval discharge. Field indicators that were associated with this discharge included depositional features, changes in vegetation condition, and slope breaks.

In the project area, these features were located within the larger active channel that generally contained up to the 2-year to 5-year interval discharge (Figure A-3).

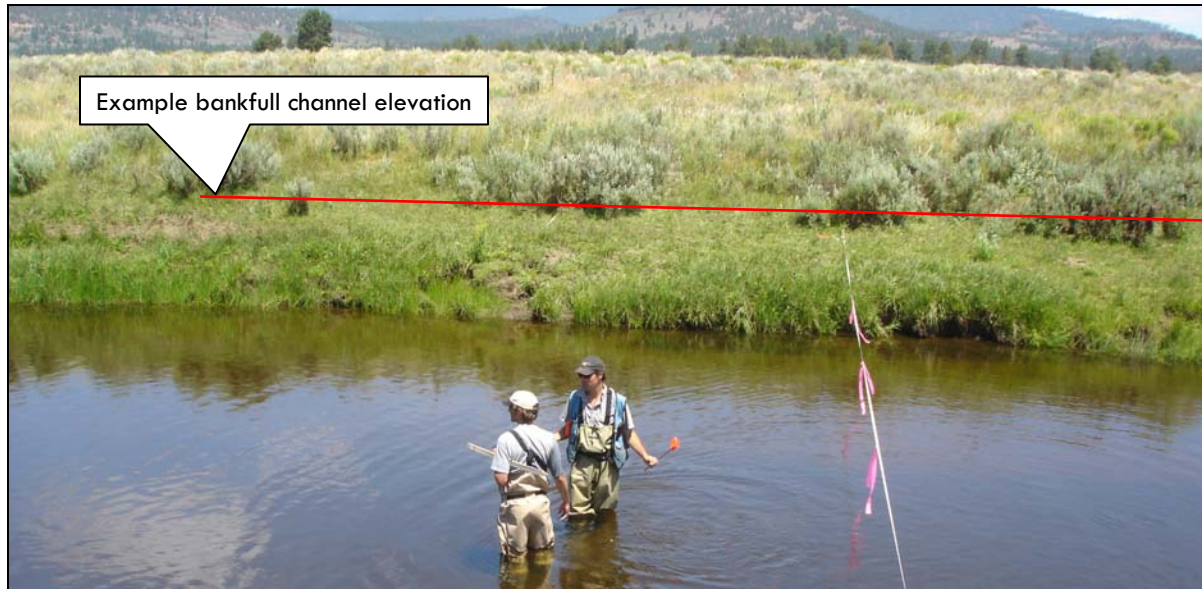


Figure A-3. A hydraulic cross-section location on the Sycan River. Features including slope breaks, vegetations transitions, and sediment deposits were typically used as bankfull discharge indicators.

Bankfull Discharge Results

Four methods were employed to estimate the bankfull discharge for the Sycan River. Computed results were evaluated and compared. Methods included:

1. Analysis of historical gage data collected at the Sycan River USGS gaging station (station #11499100),
2. USGS regional equations (Harris and Hubbard 1983),
3. USDA Forest Service regional equations (Bakke et al. 2000), and
4. Field calibration at the Sycan River USGS gaging station using field data including channel cross-sections, longitudinal profiles, water surface slopes, and bed material sampling.

The results of the bankfull discharge estimations are summarized in Table A-3.

Table A-3. Bankfull discharge analysis results for the Sycan River.

Location	Log-Pearson III (cfs)	USGS Equation (cfs)	USFS Equation (cfs)	Field Calibration (cfs)
Sycan River at Drews Road (Drainage Area: 568 mi ²) Gage #11499100	720	1,000	850	500
CSM (CFS/Drainage Area)	1.24	1.74	1.50	0.88

The methods produced a relatively wide range of values for bankfull discharge. Potential factors influencing the variation included:

- A relatively short period of record for the USGS gage,
- The effects of the Sycan Marsh are not considered or modeled in the USGS or USFS regional equations,
- The regional equations have a fairly wide margin of error, and
- Due to the high degree of channel instability, field calibration of bankfull indicators was difficult.

For the Sycan River gage, the USGS equation method generated the highest discharge, whereas the field calibration method provided the lowest values. Bakke et al. (2000) suggest that the bankfull discharge for the Sycan River may be significantly lower than nearby streams due to the effects of the Sycan Marsh dampening and altering the timing of peak flows. Field calibration of the gage identified two distinct geomorphic bankfull features present at different elevations in the channel cross-section. The lower feature, which is likely associated with the snowmelt runoff peak rather than the mid-winter peak discharge, appeared to be indicative of a discharge that is less than bankfull. The higher feature more closely corresponded to the bankfull discharge and was modeled to be approximately 780 cfs. Based on the log-Pearson type III flood frequency analysis, this result approximates the 1.7-year recurrence interval discharge.

The USGS and USFS regional equations likely over-estimate the bankfull discharge because the equations do not account for the hydrologic effects of the Sycan Marsh. For these reasons, a bankfull discharge of 750 cfs was selected.

A.6 HYDROLOGY SUMMARY

A flood frequency analysis was completed for the Sycan River using the Log Pearson Type III equation and regional equations. The Sycan River gage's short period of record and variability associated with regional equations provided similar flood frequency results for the 2-year and 5-year recurrence interval events. However, less frequent, higher magnitude event estimates were more variable. Unique watershed conditions including ground water springs and the effect of Sycan Marsh, also contribute to the variable estimates. Four methods were employed for the bankfull discharge analysis. Hydraulic modeling completed at cross-sections with consistent morphological attributes suggests the 1.7-year to 1.8-year discharge event strongly influences

channel form. However, this discharge interval is confined within the larger channel and the river does not access floodplain features until flows exceed the 2-year event.

APPENDIX B EXISTING REACH CONDITIONS AND DATA SUMMARY

B.1 INTRODUCTION

The U.S. Fish & Wildlife Service retained River Design Group, Inc. (RDG) to conduct a detailed existing conditions assessment of the Sycan River from the end of the Coyote Bucket Canyon to Drews Road. The primary goal of the project was to characterize existing river corridor conditions and evaluate the feasibility of restoration treatments. To establish a baseline data set characterizing river corridor conditions, a Sampling and Analysis Plan (SAP) was developed by RDG and USFWS. The SAP was implemented in 2006 by RDG. This report presents and summarizes the methods and results of the data collection and analysis effort.

RDG developed the SAP to address the following objectives.

1. To predict or at best, characterize, the likely historical conditions of the Sycan River from the Coyote Bucket Canyon (Canyon) downstream to the confluence with the Sprague River (Project Area) near Beatty, Oregon.
2. To characterize the existing conditions of the Sycan River within the project area (lower Canyon to Drews Road bridge).
3. To propose the desired future conditions (DFC) and morphological characteristics for restoring the Sycan River within the project area based on data collected in reference reaches. Restoration concepts will account for restoration project area constraints.
4. To provide data necessary for modeling and evaluating flood frequency, channel stability, sediment supply, and sediment transport capacity. Hydrologic and hydraulic modeling results will be incorporated with empirical data to develop and evaluate conceptual restoration designs.
5. To provide a complete topography of the Sycan River channel and floodplain by merging LIDAR data and GPS data acquired by Watershed Sciences, Inc. and RDG, respectively.

This report is organized in five main sections. Section 1 provides a general project background and lists the primary data collection objectives. Section 2 details the data collection methodologies and techniques employed in the SAP. Sections 3 and 4 present the data and reach assessments. Section 5 includes a compilation of the reference reach data developed for the Sycan River project area.

B.2 SAMPLING AND ANALYSIS PLAN

This section summarizes the field sampling methods and analysis techniques. Section B.2.1 provides a general description of the reaches and their geographic locations. Section B.2.2 describes the field sampling methodologies. Lastly, Section B.2.3 describes the data processing, analysis, and reporting methods.

B.2.1 Study Reaches

Channel reach assessments were completed in four reaches of the Sycan River project area, and a reference reach assessment was completed upstream in the Teddy Powers Meadows reach. Reach descriptions are provided in the Executive Summary. Reach maps are located in *Appendix C – Index Maps*.

B.2.2 Data Collection Methods

B.2.2.1 Remote Sensing and Field Surveys

A light detection and ranging (LiDAR) data set was developed by Watershed Sciences, Inc. under a contract with the Klamath Tribes. The LiDAR flight was completed in the fall during low water. RDG collected channel bathymetry data in the fall of 2005 to characterize the channel below the base flow water surface elevation as LiDAR does not accurately capture ground features below water. A three person survey crew using three survey grade Trimble R8 RTK GPS units was used to survey the channel topography. The GPS channel bathymetry data were integrated into the LiDAR surface to create a continuous digital terrain model (DTM). Further reference to the LiDAR data set refers to the integrated LiDAR-GPS data set.

The LiDAR data was used for several purposes including hydraulic modeling, generation of flood maps and other visualization figures, and for extracting channel cross-section and longitudinal profile data. Additional field surveys were completed to further characterize existing river corridor conditions. The Trimble R8 RTK GPS system was also used to complete the field surveys. Field survey data were also integrated into the LiDAR data base.

B.2.2.2 Level I Characterization

Prior to field surveys, a Level I coarse screen analysis was completed to stratify the assessment areas into discrete channel reaches based on several criteria including: 1) dominant landform and valley type, and (2) existing and predicted channel state and condition class. Table B-1 summarizes the general parameters used for initial stratification.

Parameter	Methods
Dominant landform and valley type	Rosgen, 1996 Montgomery and Buffington, 1993
Existing channel state and condition class	Rosgen, 1996 Montgomery and Buffington, 1993
Potential channel state and condition class	Rosgen, 1996 Montgomery and Buffington, 1993

B.2.2.3 Level II and III Existing Conditions and Departure Analysis

Level II and III surveys were completed to characterize existing channel conditions and degree of channel stability. Aerial photos from 1942, 1998, and 2004 were georeferenced and mosaiced to evaluate channel pattern changes over time.

Existing channel conditions were evaluated in terms of equilibrium state, or degree of stability. A stable river reach was defined as one in which the average channel dimensions remain more or less constant over time amidst ongoing bed and bank erosion and deposition, meander cutoffs, and lateral migration (Millar 2005). The following objectives were developed for the Level II and III analyses (Rosgen 1996):

1. Develop a quantitative basis for comparing reaches displaying similar morphologies, but which are in different conditions or geomorphic states;
2. Describe the river's potential condition, as contrasted with the existing condition;
3. Determine the departure of the river's existing condition relative to a reference baseline condition;
4. Measure field parameters that influence river state including flow regime, river size, sediment particle size distribution, sediment supply, channel stability, bank erodibility, and direct channel disturbances; and

Table B-2 summarizes the data collection parameters.

Table B-2. Summary of level II and III data collection parameters and methods.

Cross-sections (Harrelson et al. 1994)

Longitudinal profiles (Harrelson et al. 1994)

Planform Geometry (Langbein and Leopold 1966; Thorne 1997)

Substrate characterization (Wolman 1954)

Surface and subsurface particle distributions (Bunte and Abt 2001)

Bank Erodibility Hazard Index (D. Rosgen, Wildland Hydrology, Unpublished Report).

Channel cross-sections

Representative channel cross-sections were extracted from the LiDAR data set as well as surveyed using standard methods (Harrelson et al. 1994). The following section describes the field surveyed cross-sections. Cross-sections spanned the active bankfull channel, adjacent floodplain, and low terrace features. Bankfull features were identified primarily in reaches with inset floodplain surfaces located between the baseflow channel and the terrace. Identifying bankfull features in confined sections of the river was more challenging and less accurate.

Field surveyed cross-sections primarily focused on run, pool, and glide habitat units. Cross-sections for riffle habitat units were primarily extracted from the LIDAR data set. Cross-section distances and measurement frequency varied according to valley bottom and channel width, channel irregularity, and survey objective. Elevation changes (inflection points) in the channel and floodplain were detailed. Surveys detailed morphological features including terraces, floodplains, bankfull indicators, channel bed, channel thalweg, and water surface.

Longitudinal bed profiles

Longitudinal profiles were established in each surveyed reach and included a minimum channel distance equal to 20 times the average bankfull riffle width or two meander wavelengths. The

profiles included consistent measurement of left and right channel bankfull indicators, channel thalweg, and water surface elevations at select locations along the profile typically at delineated channel habitat units (e.g. riffles).

Planform geometry

Planform geometry, including radius of curvature, meander wavelength, channel belt width, and bankfull width were measured using aerial photography complemented by field survey methods described in Section B.2.1.1 (Langbein and Leopold 1966; Thorne 1997). Results were reported for actual distances as well as dimensionless ratios.

Substrate characterization

Channel materials were sampled in the project area to characterize existing bed material characteristics as well as to complement hydraulic and sediment transport modeling. Several sampling methods were employed to meet the requirements of these three goals.

The Wolman method (Wolman 1954) was used to characterize the particle size distribution of channel materials. The material sampling locations were modified to ensure various habitat units were sampled proportionally according to their percent representation in the reach. The intermediate axes of the particles were measured (Wolman 1954; Bunte and Abt 2001). Samples from habitat units were recorded separately and reported individually and as a composite.

A lateral bar or similar depositional feature was identified in close proximity to sampled riffles. The intermediate axes of the 30 largest recently deposited particles were measured and the geometric mean calculated and compared with the cumulative particle size distribution of the riffle.

Surface and subsurface particle size distributions

Volumetric sampling was completed to characterize the channel armor layer and subsurface materials (Bunte and Abt 2001). Two five gallon vinyl buckets (similar to the CSU barrel sampler presented in Bunte and Abt 2001) with their bottoms removed were nested within each other. Samples were generally collected half way between the thalweg and the bankfull channel margin in riffles. The nested buckets were swiveled into the channel bed to get below the surface armor layer. Armor layer particles were removed from inside of the bucket and placed in a holding bucket. Particles that were intercepted by the nested buckets and had more than half of the particle protruding into the bucket were removed from the bed and also placed in the holding bucket. Particle texture, color, and size were used to differentiate between surface and subsurface particles. Once the bed armor material was removed, subsurface material was removed to a depth approximately equal to twice the intermediate diameter of the largest particle in the surface armor. This depth was suggested by Rosgen (unpublished data) as a sufficient depth to characterize the subsurface particle distribution. Subsurface sediment was placed in a second holding bucket and kept apart from the surface materials.

Volumetric samples were wet sieved in the field using standard sieves and a field scale. Sieves were stacked according to sieve opening size with coarser sieves on top and the finest sieve on the bottom. The stacked sieves were placed on a drain bucket. One hole was cut in the lid of the drain bucket while a second hole was cut above the base of the drain bucket. Sediment samples were placed in the top sieve and the sieve column was agitated while water was poured over the sieve column. Sand particles that passed through all of the sieves were retained in the drain

bucket. Once the sample was completely sieved, each sieve was weighed. The weight of the sieve and the sample collected in that sieve were recorded. The weight of the sieve was then deducted from the sieve and sample weight to calculate the weight of the sample retained in the sample. Once the weight for each sieved sample was completed, a total weight was calculated for all of the samples. A relative weight for each size class was then derived by comparing the individual sieve results to the overall total weight of the sample. This process was completed for surface and subsurface samples collected in the project area. The samples were wet-sieved and weighed in the field. Weights were recorded (less tare weight) by size class and a material size-class distribution plotted using RIVERMorph version 3.1 (RIVERMorph LLC 2005).

Bank Erodibility Hazard Index

A Bank Erodibility Hazard Index (BEHI) was used to evaluate streambank erosion potential (D. Rosgen, Wildland Hydrology, unpublished report). The BEHI procedure integrates multiple factors which have a direct impact on streambank stability, including the following parameters.

- Ratio of streambank height to bankfull stage.
- Ratio of riparian vegetation rooting depth to streambank height.
- Degree of rooting density.
- Composition of streambank materials.
- Streambank angle.
- Bank material stratigraphy.
- Bank surface protection afforded by woody debris and vegetation.

The BEHI index incorporated these seven variables into a numerical reach score that was used to rank streambank erosion potential on a scale ranging from very low to extreme. Several bank sites within each reach were evaluated for bank integrity. The number of sites evaluated within each reach was based upon the variability of bank conditions within the reach. Selected sites provided a representative sample of bank conditions throughout the reach.

Table B-3. BEHI score and rating matrix (Rosgen 1996).

Parameter		Very Low	Low	Moderate	High	Very High	Extreme
Bank Height Ratio	Value	1.0 – 1.1	1.11 – 1.19	1.2 – 1.5	1.6 – 2.0	2.1 – 2.8	> 2.8
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Root Depth Ratio	Value	1.0 – 0.9	0.89 – 0.5	0.49 – 0.3	0.29 – 0.15	0.14 – 0.05	<0.05
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Weighted Root Density	Value	100 – 80	79 – 55	54 – 30	29 – 15	14 – 5	<5
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Bank Angle	Value	0 – 20	21 – 60	61 – 80	81 – 90	91 – 119	>119
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Surface Protection	Value	100 – 80	79 – 55	54 – 30	29 – 15	14 – 10	<10
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10

After evaluating the core bank integrity parameters describe in Table B-3, bank material composition factors were considered. Depending upon bank materials, BEHI score were adjusted up or down (Rosgen 1996). Banks comprised of bedrock, boulders and cobble had very low erosion potential. Banks composed of cobble and/or gravel with a high fraction of sand had

increased erosion potential. Stratified banks containing layers of unstable material also displayed greater erosion potential. After adjusting the core BEHI score for bank material composition factors, a final BEHI score and rating was derived (Table B-4).

Table B-4. BEHI score and rating following bank materials adjustment.

Rating	Very Low	Low	Moderate	High	Very High	Extreme
Score	5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

The BEHI data will be useful for comparing potential erosion hazard within a reach and among reaches. Future sampling would be necessary to estimate actual bank erosion and validate the prediction success of the BEHI method. Bank pins were installed at select sites and should be re-measured in 2006 to validate the predicted bank condition using the BEHI method.

B.2.3 Data Processing, Analysis and Reporting

B.2.3.1 Raw Data Processing and Reach Summaries

Total Station survey data was processed and analyzed in RIVERMorph version 4.0 (RIVERMorph LLC 2005). RIVERMorph, a geomorphic stream channel assessment and data storage software, merged all aspects of the surveys by transcribing the total station data from x, y, and z coordinates to station and elevation formats. The software was used to process and analyze data and produce channel reach statistics.

Cross-section data and longitudinal profile data were plotted and summary statistics generated in RIVERMorph and Microsoft Excel. Sediment data including pebble counts, RSI data, and pavement and sub-pavement samples were also analyzed. Dimensionless ratios were computed automatically for multiple variables using RIVERMorph and Microsoft Excel.

B.2.3.2 Bed Resistance and Channel Hydraulics

Streambank and channel bed characteristics are the primary parameters influencing flow resistance and ultimately the conveyance capacity of a channel. Investigating existing channel conditions in both reference and other reaches provides insights to channel resistance properties. Incorporating channel resistance variables in the design phase of this project will be necessary to investigate channel stability, conveyance capacity, and sediment transport processes. It is important to understand the flow characteristics of the existing and design condition in order to anticipate likely channel responses to a range of environmental conditions.

Two models were used to evaluate bed resistance and channel hydraulics. The U.S. Army Corps of Engineer's Hydrologic Engineering Center River Analysis System version 3.1.3 (HEC-RAS) was used to model existing channel conditions and validate bankfull discharge. HEC-RAS performs one-dimensional water surface profile calculations for steady gradually varied flow. The basic computational procedure of HEC-RAS is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by change in velocity head).

WinXSPRO (Hardy et al. 2005) was also used to analyze cross-section data for geometric and hydraulic parameters. The theoretical background for analyzing channel cross-section data is

derived from the basic continuity, momentum, and energy equations of fluid mechanics (Hardy et al. 2005). Manning's equation was used as the roughness coefficient in the model. Discharge measurements on the day of the specific surveys were used to calibrate the hydraulic models.

Bankfull channel total shear stress was calculated and compared to the Shields diagram which describes the relationship between critical shear stress and incipient motion of sediment grains along the streambed. Two curves were used including the standard Shields curve and a modified Shields curve that is based on the ratio of the D_{84} to D_{35} of the bed material (D. Rosgen, Wildland Hydrology, unpublished data).

B.3 SYCAN RIVER PROJECT AREA EXISTING CONDITIONS

B.3.1 Introduction

This section describes the existing conditions of the Sycan River in the project area. Section B.3.2 summarizes the results of a hydrology and flood series analysis performed for the Sycan River. Sections B.3.3 through Section B.3.10 include the summary data and stream reach assessments.

B.3.2 Hydrology

The climate of the Sprague River sub-basin is moderated by the Cascade Range and strongly influenced by post-maritime storm tracks from the Pacific Ocean to the northwest. Because of the lower mountains east of the basin, the rain shadow is less pronounced than other regions east of the Cascades (Quigley and Arbelbide 1997). Summers are typically dry with mild temperatures and moderately long growing seasons followed by wet winters and low temperatures (Akins 1970; Leonard and Harris 1974). The annual precipitation ranges from 16 inches in the valley bottoms to over 60 inches at the watershed divide (Leonard and Harris 1974; Atlas of Oregon 2001). Precipitation primarily takes the form of winter snows, spring rains, and summer thunderstorms with a steep seasonal gradient from moist winters and springs to very dry summers and fall conditions. Seventy percent of precipitation falls between October and March and only 9 percent falls from July to September (Leonard and Harris 1974).

The Sycan River watershed at Drews Road measures 568 square miles. Elevations range from over 8,100 ft at Yamsey Mountain, to 4,310 ft at Drews Road. The watershed is located east of the Cascade Mountains with the headwaters originating in the Winter Ridge, Brattain Ridge, and Booth Ridge ranges. Yamsey Mountain and Fuego Mountain are two of the prominent mountains in the watershed. Annual water yield is approximately 116,000 acre-feet per year for the Sycan River at Drews Road.

The Sycan Marsh is a prominent feature in the watershed. The Sycan Marsh dampens peak flows, and historically likely had a substantial effect on the timing and duration of peak events. Modification of the marsh (e.g. drainage) is believed to have modified the flows and increased the flashiness of the system. Current restoration in the marsh is reestablishing the historical hydrology through the marsh.

A hydrology and flood series analysis for the Sycan River is included in *Appendix A - Hydrology*. Flood magnitudes for selected recurrence intervals were determined from a flood frequency curve using the log-Pearson Type III distribution method as outlined in Bulletin #17B Guidelines for Determining Flood Flow Frequency (U.S. Department of the Interior Geological Survey, 1982).

Four methods were used to estimate bankfull discharge for the Sycan River: analysis of flood frequency using historical streamflow gaging records, USFS regional equations, USGS regional equations, and field calibration of bankfull discharge at the USGS gaging station. The selected bankfull (1.7-year event) and flood magnitudes for selected recurrence intervals are presented in Table B-5.

Table B-5. Selected recurrence intervals and discharge values for the Sycan River.

Recurrence Interval (years)							
Q _{1.7}	Q ₂	Q ₅	Q ₁₀	Q ₂₅	Q ₅₀	Q ₁₀₀	Q ₅₀₀
750	1,180	2,770	3,970	5,130	6,590	7,620	9,714

B.3.3 Geology

The following section is taken from the Oregon Water Resources Department document titled, “Sycan River Synoptic Measurements From Sycan Marsh to the Sprague River” (OWRD 2000).

The geology of the Sycan sub-basin is detailed in a geological map of Oregon by Walker and MacLeod (1991). The hydrologic properties of the geologic units can be generalized to a certain extent (Figure B-1). Young basalts (Quaternary) tend to be fractured and are therefore permeable with good transmissivity. These formations generally make excellent aquifers. The permeability of basalts normally decreases with age, as fractures fill with sediments. Thus Tertiary basalts (Tb) tend to be less permeable than Quaternary basalts (Qb), although both would be more permeable than tight sedimentary formations (e.g. chalk rock). Higher silica volcanic rocks such as rhyolites and dacites tend to be less fractured and less permeable than basalts. Sedimentary rocks can be very impermeable especially if they contain high amounts of clay or diatomaceous material (e.g. chalk) such as those associated with lacustrine (i.e. lake) deposits. Alluvial deposits tend to be highly permeable if they contain coarse material such as sands and gravels. With increasing silt and clays content the permeability and transmissivity of these deposits decrease.

The geological map of the Sycan basin shows that the highlands east and northeast of Sycan Marsh drain a large basalt unit (Tb) with expanses of volcanic vent deposits (QTvm). The area west of the marsh drains a mostly olivine basaltic unit (Tob) interspersed with a mixture of rhyolitic/dacitic plugs (Tvs), and silicic ash-flow tuffs (Tat) directly northwest of the Marsh. The Sycan Marsh itself consists of lacustrine and fluvial sedimentary rocks (Qs- unconsolidated to semi-consolidated clays, sands, silts, and gravels). The drainage from Sycan Marsh to Teddy Powers Meadows is on an olivine basalt unit. Progressing west of Teddy Powers Meadows towards Fuego Mountain is a thin basaltic unit (QTb), followed by olivine basalt (Tob), before reaching older (Tertiary) volcanic vent rocks (Tvm) near the mountain. From Teddy Powers Meadows to Coyote Bucket Canyon the geologic unit west of the Sycan River consists mostly of the thin basaltic unit (QTb) that caps a thicker sequence of low permeability Tuffaceous sedimentary rock (Ts) of the Yonna formation. The eastern drainage in the same reach consists of olivine basalts (Tob) and pyroclastic rocks (Tps). Lower in the basin, the Snake Creek drainage begins near the Black Hills, an area of low permeability rhyolitic, and dacitic plugs (Tvs). The drainage towards the middle of the creek consists of Tuffaceous sedimentary rocks

(Ts) and basalt. The bottom of the drainage and the Sycan River valley consists of fluvial sedimentary rocks (Qs) of clays, silts, sand, and gravels.

The surface geology described above is just part of the equation to understanding the hydrogeology and therefore surface hydrology of the basin. The location of faults as well as the underlying geologic formations also influences regional, intermediate and local groundwater flow paths, and therefore flows in the Sycan River. A detailed study of the hydrogeology of the basin has not been made. However, a general assessment of the groundwater system was made in a 1970 study of the Klamath Basin (State Water Resources Board, 1971). This study postulated that in the Sycan basin, Sycan Marsh and the Sycan/Sprague River valley act as groundwater discharge areas, while Yamsey Mountain, Winter Rim, and similar elevated areas possessing permeable soil/geology and receiving large amounts of precipitation acted as groundwater recharge areas.

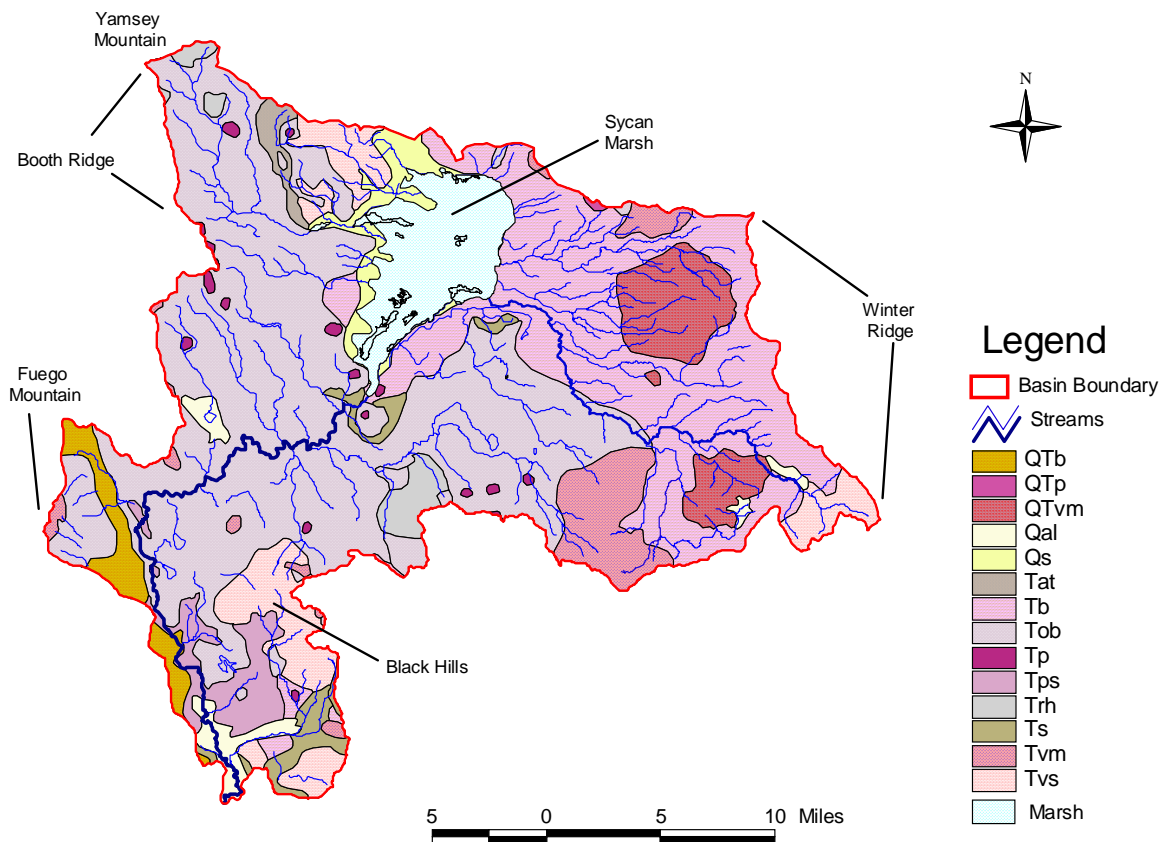


Figure B-1. A general geologic map of the Sycan basin completed by Walker and MacLeod (1991) and reproduced in OWRD (2000).

The eruption of Mount Mazama approximately 6,500 years ago delivered a large quantity of pumice to the Sycan River basin. Existing river corridor conditions suggest the Sycan may have existed at a lower base elevation prior to the eruption of Mount Mazama. Review of the soil profile at river cutbanks in the project area revealed only three sites where streambed gravels were exposed. The infrequent exposure of gravel lenses in cutbanks suggests that pumice delivered to the project area buried the valley bottom in at least 6 ft of pumice. One theory proposed by Jim O’Connor, Ph.D. of the USGS is that a pumice dam may have formed in the

Coyote Bucket Canyon. The dam would have restricted flow until the hydraulic pressure of the water behind the dam exceeded the dam's integrity. The dam material and pumice behind the dam would have rapidly eroded following dam failure. These materials then deposited in the lower Sycan River corridor and may have either formed or contributed to the lateral terraces that now confine the Sycan River.

Pumice is highly permeable and pumice plains and slopes are groundwater recharge areas for the Sycan River. Over time as flood waters deposited organic material over the pumice, the productivity and water retention of floodplains and terraces increased. Relict channels and swales located on the floodplain and terraces convey flow with the seasonal rise in the water table associated with winter or spring runoff. These channels also convey surface flows during flood events. Silt, sand, and clays that are transported during runoff are deposited in these floodplain and terrace swales. Over time, the accumulation of these fine particles has filled the interstitial spaces of coarser pumice sands, increasing the water retention capacity of off-channel swales. Pumice layers are generally located above the regional water table.



Figure B-2. Two bank profiles on the Sycan River in the project area (top) and the Teddy Powers Meadows reference reach (bottom) exhibit similar soil stratigraphy. However, the depth of pumice is substantially deeper in the project area relative to the upstream reference reach.

Pin flags located in each bank mark changes in soil composition, texture, or color. The project area bank was characterized by a thin layer of organic matter overlaying multiple layers of pumice-derived materials. The bottom pin flag notes the top of the gravel channel bed that likely marks the historical channel bed.



Pin flags note similar soil changes in the bank stratigraphy in the Teddy Powers Meadows reach. The Teddy Powers Meadows streambank had a lower bank height and less distance between the top of bank and the gravel bed. Bank materials were also more consistent with a thicker organic layer and two lower pumice layers. Bank stratigraphy differences suggest less pumice delivery occurred in the Teddy Powers Meadows reach compared to the project area.

B.3.4 Soils

Soil texture, temperature, amount and kind of organic matter, and especially water tables, have a large effect on plant species composition in riparian and wetland systems. Along the Sycan

River, soils have developed via alluvial processes. How these soils are distributed is a function of water velocity at the time of deposition and mineralogical composition of parent materials. Seasonally or permanently high water tables are necessary for a soil to support riparian and wetland vegetation (Hansen et al. 1995). Within the Sycan River floodplain, water tables are seasonally elevated in the winter and spring followed by with mid to late-summer drought. Along the lower elevation near-channel zone where diverse sedge/rush and willow communities are found in the reference reach and locally establishing in other reaches, the water tables are probably close to the surface season-long.

Soils information in this document is from the Soil Conservation Service's (SCS) *Soil Survey of Klamath County, Oregon—Southern Part* (1985). Soil characteristics and patterns indicate the geology and history of how the soil has formed. Soil units in the Sycan River project area range from frequently flooded floodplain soils, to higher elevation well-drained sandy soils. In the upper portion of the project area from the mouth of the Coyote Bucket Canyon to the lower extent of the Shields' property, Klamath-Ontko-Dilman soils (unit 34) form the floodplains and terraces adjacent to the Sycan River. High terraces bracketing the Sycan River from the lower Shields' property to Drews Road are classified as Lobert sandy loam (unit 47A), Sycan loamy sand (unit 75), and Yonna loam (unit 89). Lower elevation floodplain surfaces in this lower reach are characterized by Chilquin loam (unit 10). Because soil properties reflect the processes that have created them, understanding the soil properties is an important aspect for understanding restoration potential for the river system. The following section highlights the soils in the Sycan River project area. The descriptions are taken from Soil Conservation Service (1985) and NRCS (2007). Maps presenting soils properties are included in *Appendix D – Soils Maps*.

Klamath-Ontko-Dilman Soil Unit (34)

The Klamath-Ontko-Dilman unit is classified as a very deep, poorly drained soil that formed in alluvium derived mainly from diatomite and in ash (SCS 1985). A description of this soil unit from SCS (1985) is as follows:

Klamath and Ontko soils are neutral in the upper layers. The Klamath soils have a surface layer and subsoil of silty clay. The underlying material is silty clay and silty clay loam. Klamath soils have a water table at a depth of 0 to 3 feet. The Ontko soils have a surface layer of silty clay loam and a subsoil of clay loam. The underlying material is coarse sandy loam, loamy coarse sand and clay loam. Ontko soils have a water table at a depth of 0 to 4 feet. The Yonna soils are strongly alkaline or very strongly alkaline in the upper layers. They have a surface layer of loam and a subsoil of loam and sandy loam overlying a layer of buried clay loam and very fine sandy loam. Yonna soils have a water table at a depth of 2 to 5 feet.

The Klamath soil formed in silty alluvium weathered mainly from diatomite and is on aggrading flood plains of the Sprague River. Ontko and Dilman soils formed in stratified alluvium that includes thick layers of pumiceous ash; they are on slightly higher flood plains than Klamath soils.

This association is about 55 percent Klamath soil, 30 percent Ontko soil, and 15 percent Dilman soil. The proportions of soils vary somewhat from place to place in this association. In some mapped areas west of Sprague River, the Ontko soil is dominant. The areas on Knott Tableland dominantly are Ontko and Dilman soils. Generally, the Klamath soil is adjacent to streams or in the central part of the flood plain. The Ontko soil is adjacent to

the Klamath soil and is between the Klamath and Dilman soils. The Dilman soil is at the outer edges of the flood plain.

The climax native vegetation on this association (fig. 8) is a herbaceous plant community dominated by a variety of desirable grasses, for example, Leiberg bluegrass, Kentucky bluegrass, meadow barley, slender wheatgrass, and redtop. A variety of perennial forbs grow throughout the stand. Tufted hairgrass occurs in wet areas on the Klamath soil. If the range site deteriorates, the most desirable grasses decrease and such sod formers as sedge, redtop, and Kentucky bluegrass increase. If the site further deteriorates, forbs increase in abundance and such woody plants as green rabbitbrush and silver sagebrush invade. In this condition, much ground is left bare and is exposed to erosion. Cuts expose the infertile underlying layers in many places, particularly on the Ontko and Dilman soils.

Chiloquin Loam Soil Unit (10)

The Chiloquin loam unit is a moderately well drained soil located on narrow floodplains. In the project area, Chiloquin loam is found on the west side of the Sycan River on the Kronenberger property where several developed wetlands are located.

This moderately well drained soil is on narrow flood plains. It formed in very deep alluvium weathered mainly from lava rocks, diatomite, and a small amount of pumiceous ash. Slopes are 0 to 1 percent. Elevation ranges from 4,175 to 4,300 feet. The average annual precipitation is 15 to 18 inches, the average annual air temperature is 42 to 45 degrees F, and the frost-free season is 50 to 70 days. Typically, the surface layer is very dark brown and very dark grayish brown loam about 18 inches thick and about 15 percent pumiceous ash of coarse sand size. The subsoil is dark brown heavy loam that extends to a depth of about 28 inches. The substratum, to a depth of 60 inches or more, is dark brown and dark yellowish brown loam that is mottled below a depth of 43 inches.

Permeability is moderate. Roots commonly penetrate to a depth of more than 60 inches. Runoff is very slow. The hazard of erosion generally is slight; however, flooding can cause channeling. Available water capacity is 10 to 13 inches. A water table is at a depth of 1 foot to 3 feet in spring. The soil is subject to common flooding in spring.

Lobert Sandy Loam Soil Unit (47A)

Lobert sandy loam is found at two locations in the project area. The upstream site is located on the Shields' property downstream from the rocky outcrop on the west side of the river near the lower extent of the Shields' property. The second site is also on the west side of the river and is located between the Sycan River and the wetlands on the Kronenberger property.

This well drained soil is on terraces. It formed in alluvial and lacustrine sediment weathered from diatomaceous, tuffaceous sandstone that has a considerable amount of black sand, and a small amount of pumiceous ash. Slopes are uneven in those areas that were not leveled for irrigation. Typically, the surface layer is very dark brown sandy loam about 16 inches thick. The subsoil is very dark grayish brown, coarse sandy loam that extends to a depth of about 32 inches. The upper part of the substratum, to a depth of 42 inches, is dark brown sandy loam that has 10 percent firm and brittle nodules as much as 1/2 inch in diameter; the lower part is dark brown, firm, and brittle sandy clay loam to a depth of 60 inches or more.

Sycan Loamy Sand Soil Unit (75)

This soil unit forms the terraces on the east side of the Sycan River in the project area. Sycan soils have formed in alluvial deposits of air-deposited pumice. Sycan soils have low bulk density, very high available water capacity, and rapid or very rapid permeability.

This excessively drained soil is on low terraces. It formed in very deep alluvial deposits of pumiceous ash. Slopes are 0 to 2 percent. Typically, the surface layer is about 17 inches thick. The upper part is very dark grayish brown loamy sand about 5 inches thick, and the lower part is very dark grayish brown loamy coarse sand about 12 inches thick. The upper part of the substratum is dark brown loamy coarse sand and coarse sand that extends to a depth of about 50 inches; the lower part is brown and pale brown, mottled coarse sand to a depth of 60 inches or more. Permeability is rapid. Roots commonly penetrate to a depth of more than 60 inches. Runoff is very slow, and the hazard of erosion is slight. Available water capacity is 12 to 24 inches. A water table generally is at a depth of 5 to 7 feet. The soil is subject to occasional brief flooding from March to May in periods of exceptionally high runoff.

Yonna Loam Soil Unit (89)

This soil unit forms the terraces on the west side of the Sycan River in the project area. One site is also located on the east side of the river upstream from the Snake Creek confluence.

This poorly drained soil is on flood plains and low terraces. It formed in alluvium that has much ash in the upper part and in mixed alluvium weathered mainly from diatomite, tuff, and basalt in the lower part. This soil has sufficient sodium to interfere with the growth of most crop plants. Slopes are 0 to 2 percent. Elevation ranges from 4,200 to 4,400 feet. The average annual precipitation is 15 to 18 inches, the average annual air temperature is 42 to 45 degrees F, and the frost-free season is 50 to 70 days. Typically, the surface layer is very dark grayish brown loam about 11 inches thick. The subsoil extends to a depth of 29 inches. The upper part is very dark grayish brown loam to a depth of about 20 inches; the lower part is dark brown sandy loam to a depth of about 2'9 inches. Below this is a buried soil that is mottled, dark brown and dark grayish brown clay loam and very fine sandy loam to a depth of 60 inches or more. The surface layer and subsoil have a large amount of pumiceous ash. The surface layer is very strongly alkaline, the upper part of the subsoil is moderately alkaline, and the lower part of the subsoil and the buried soil are neutral.

The climax native plant community on this soil is dominated by basin wildrye and a variety of understory grasses, for example, alkali bluegrass, inland saltgrass, mat muhly, and sedge. Western yarrow is a common forb, and rubber rabbitbrush also occurs. If the range site deteriorates, desirable grasses decrease and rabbitbrush, low value forbs, and saltgrass increase. If it severely deteriorates, rabbitbrush dominates the range site, salts accumulate on the soil surface, and much ground is left bare.

Soils Summary

Floodplain soils along the channel are predominantly mapped as Chiloquin loam or Klamath-Ontko-Dilman association map units. Both soils occur along floodplains and are formed in deep alluvium. Water tables fluctuate in response to water levels in the channel, typical water table depths range from 0 to 3 feet in the spring, when flooding is common. Chiloquin loams are well-drained and weathered from lava rocks, diatomite and a small amount of pumiceous ash. In

uncultivated areas, silver sagebrush, big sagebrush, green rabbitbrush, sedges and annual grasses are the main natural vegetation occurring on Chiloquin loams. The Klamath-Ontko-Dilman association are silty clay soils that are poorly drained and are formed in alluvium that has varying amounts of ash. These soils are found inside meander bends along the channel and are depositional in nature.

The parent material of the pumice soils, deposited about 6,500 years ago, also has not been in place long enough for a subsoil of illuvial clay to form. Only a darkening of the upper few inches by organic matter and a slight weathering of the pumice mostly has occurred.

B.3.5 Historical Channel Regimes

The current morphological state of the Sycan River is reflective of both natural processes and human-induced impacts in the river corridor. Historically, the Sycan River likely had a denser and more extensive riparian area. Over the past 60 years dating to the 1941 air photo series, the Sycan River's riparian area has become more simplified. Additionally, the river has become straighter over time due to down valley meander migration and channel meander cut-offs. The channel length reduction is most pronounced in the Reach 1 and Reach 2 where the channel in 1941 was more sinuous than it is today (Figure B-3). Based on the location of the channel in 1941 and 2006, the channel has apparently incised approximately 2-3 ft. Relict channel locations are generally located 2-3 ft from the existing channel thalweg. In spite of this observation, it is also possible that the channel historically occupied an elevation similar to the current elevation and that the relict channel locations have filled over time and are now a low floodplain surface. Filling would also account for the current higher elevation of these features.



Figure B-3. A comparison of the Sycan River in Reach 1 and Reach 2 in 1941 (left) and 1998 (right). The riparian community has become less dense and the river straighter over time.

Figure B-4 illustrates the 1941 and 1998 channel alignments with the landownership boundaries. Most of the channel changes and straightening has occurred in Reach 1 and Reach 2 downstream from the Coyote Bucket Canyon. Down valley meander migration is apparent in Reach 3 and Reach 5. Channel instability is likely related to channel morphology, soils, vegetation conditions and the effect of land management on these system properties.

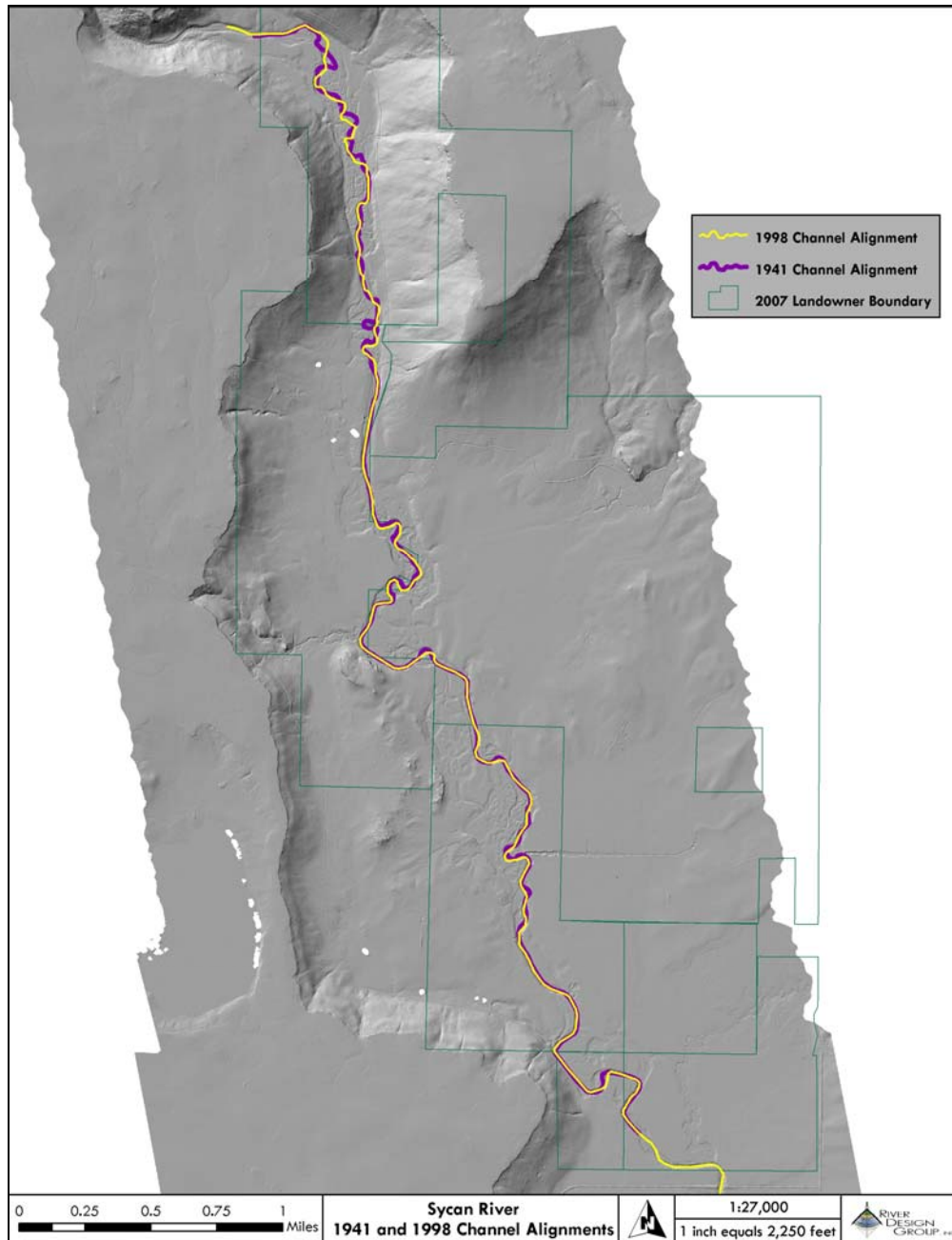


Figure B-4. The 1941 and 1998 channel alignment locations relative to the 2007 landownership map.

The current location and bed elevation of the Sycan River appear to have deviated from historical conditions. Review of the historical air photos, soils data, field conditions, and discharge modeling results suggest the river has downcut 2-3 ft since the 1940s. However, the data do not support the idea that the Sycan River was located on high terraces adjacent to the active river channel at least in the recent past (60 to 100 years). Terrace soils are generally lacking in clay and have high porosity; characteristics suggesting little historical interaction with the river. These characteristics do not exclude these surfaces from flooding, however, only low frequency, high magnitude floods inundate these features.

B.3.6 Reach 1 – Transitional Reach Existing Conditions

The following sections discuss the existing reach conditions of Reach 1 – Canyon Reach Transition.

Overview

Reach 1 is characterized by the transition from the Coyote Bucket Canyon to the Lower Sycan Valley. The river corridor transitions from a confined to a moderately confined morphology through this reach. Bed materials change from large boulders to finer gravels, revealing the change in stream energy. Livestock congregate on the floodplain and vegetated channel fringe areas in the lower portion of Reach 1.

Valley Form

Reach 1 was characterized as an Alluvial Valley (Montgomery and Buffington 1993) or Type II valley according to the Rosgen classification system (Rosgen 1996). These valley types are associated with moderately steep valleys with gentle side slopes influenced by colluvial processes. Common streams include Rosgen B stream types and Rosgen G stream types (Rosgen 1996) or cascade, pool, or plane bed channel types (Montgomery and Buffington 1993). Lateral channel migration is limited by the narrow valley bottom.

Through the reach, the Sycan River transitions to a Valley Type X (Rosgen 1996) characterized by broad and gentle slopes formed by riverine and lacustrine depositional processes. Wind-delivered sediment, related to the explosion of Mt. Mazama over 6,500 years ago, is also critical in the Sycan watershed. The Sycan River transitions from a Rosgen B stream type to a Rosgen C stream type (Rosgen 1996) through the reach. The channel morphology is referred to as a riffle-pool channel using the Montgomery and Buffington classification system (Montgomery and Buffington 1997).

Channel Planform

The Reach 1 planform morphology was assessed using field and remote sensing data including the 1941 and 1998 aerial photo series. The dominant channel classified as a single thread channel transitioning to a multiple-thread channel through the reach. In the canyon, the channel is laterally controlled. As the river emerges from the canyon, the channel meander pattern widens and a floodplain is adjacent to the right bank. Because the channel remains structurally controlled through this section, a planform analysis was not completed.

Table B-6. The existing planform channel dimensions in Reach 1. Mean values (1 SD).

Channel Type	Sinuosity	Bankfull Width (ft)	Width/Depth	Meander Belt Width (ft)	Meander Length (ft)	Radius of Curvature (ft)
B2/C3	1.14	84.6	45.7	n/a	n/a	n/a

Channel Cross-Sections

Five cross-sections were surveyed in Reach 1. Surveyed sections were located in the glide at the transition from the canyon to the meandering reach, in the riffle, and in two pools (Table B-7). Table B-8 includes channel cross-section dimensions for riffle cross-sections sampled from the LIDAR data.

Table B-7. Descriptive statistics for GPS-surveyed channel habitat features in Reach 1.

Feature	Channel Station	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
Glide XS1	0+96	226	68.7	3.3	4.8	21.0
Glide XS2	3+97	338	79.9	4.2	6.2	18.8
Riffle XS3	6+85	157	84.6	1.9	2.9	45.7
Pool XS4	9+58	166	76.4	2.2	3.6	35.2
Pool XS5	12+39	353	171.0	2.1	4.8	82.5
Average Glide Stats (1 SD)		282 (79.2)	74.3 (7.9)	3.8 (0.6)	5.5 (1.0)	19.9 (1.6)
Average Pool Stats (1 SD)		260 (132)	124 (66.9)	2.2 (0.1)	4.2 (0.9)	58.9 (33.5)

Table B-8. Descriptive statistics for LIDAR-surveyed features in Reach 1.

Feature	Channel Station (ft)	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
LID R1XS1 Riffle	7+70	326	149	2.2	3.2	67.8
LID R1XS2 Riffle	8+25	291	137	2.1	3.4	64.8
LID R1XS3 Run	10+60	308	124	2.5	3.4	50.0
LID R1XS4 Multichannel	11+25	238	227	1.1	2.8	216
LID R1XS5 Multichannel	11+75	333	244	1.4	2.7	178
Average Riffle XS Stats (1 SD)		308.5 (24.7)	143 (8.5)	2.2 (0.1)	3.3 (0.1)	66.3 (2.1)

Figures B-5 through B-7 include the channel cross-section diagrams and site photographs.

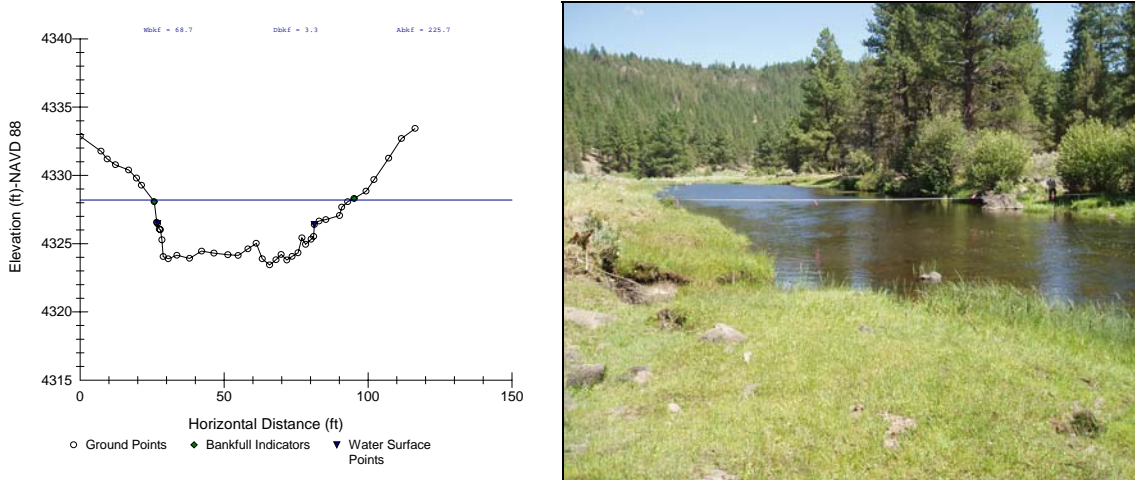


Figure B-5. The channel cross-section (left) and site photo (right) for XS1-Glide in Reach 1.

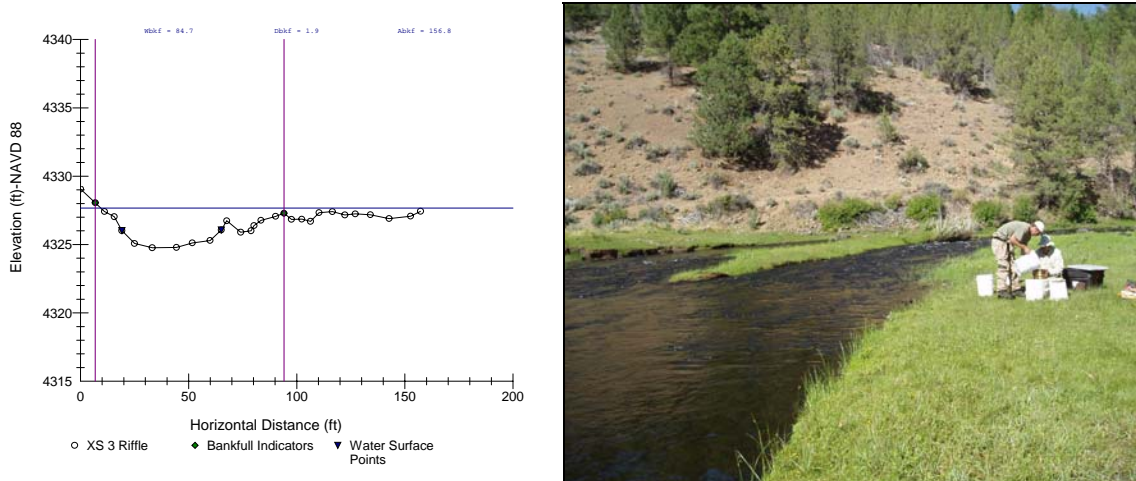


Figure B-6. The channel cross-section (left) and site photo (right) for XS3-Riffle in Reach 1.

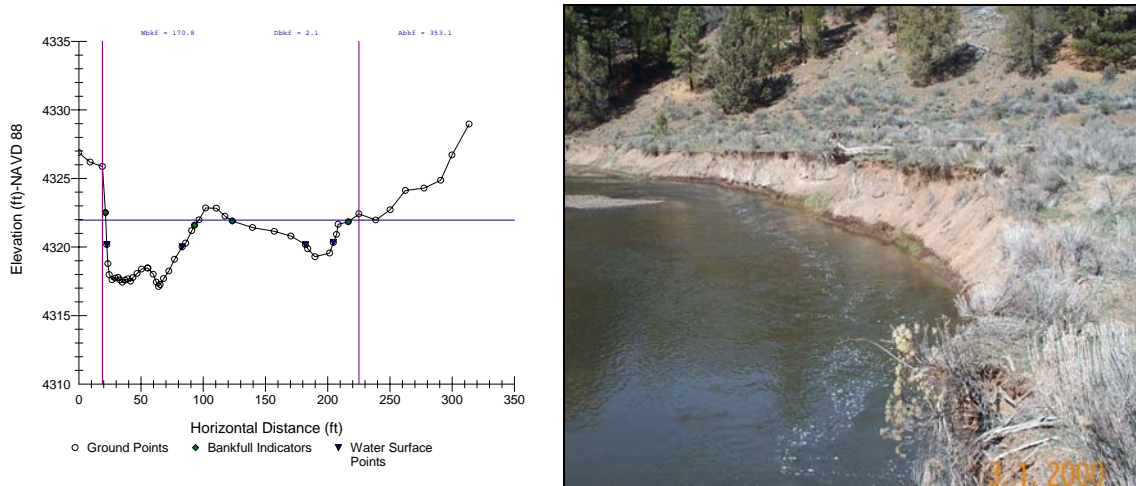


Figure B-7. The channel cross-section (left) and site photo (right) for XS5-Pool in Reach 1.

Channel Profile

A detailed longitudinal profile was surveyed along 1,350 ft of channel to characterize Reach 1 bed morphology. Figure B-8 presents the longitudinal profile graph depicting the dominant channel thalweg, water surface, bankfull feature, and other geomorphic features. Debris deposited during the 2006 runoff was also surveyed. Best-fit trend lines were applied to the water surface and bankfull data. Field survey cross-section locations are also noted. The slope break at approximately Station 7+00 denotes the end of the glide downstream from the canyon mouth.

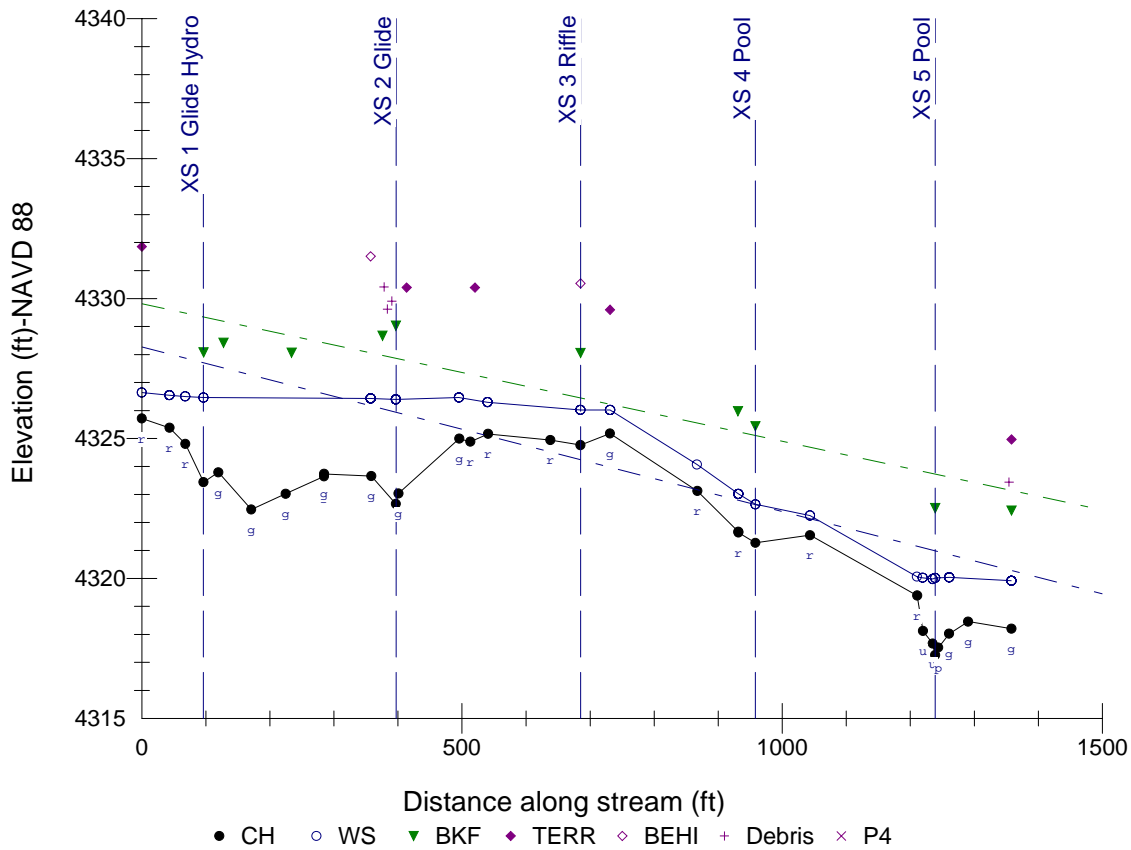


Figure B-8. The Reach 1 longitudinal channel profile graph with GPS-survey cross-section locations.

Longitudinal channel profile data results are summarized in Table B-9 and B-8.

Table B-9. Summary of Reach 1 longitudinal channel profile data (ft).

Reach	Average Bankfull Slope	Average Water Surface Slope	Riffle Bankfull Slope	Riffle Water Surface Slope	Pool Bankfull Slope	Pool Water Surface Slope
Reach 1	0.0049	0.0058	0.0146	0.0112	0.0022	0.0019

Bed morphology was dominated by the long glide at the mouth of the canyon and the moderately steep riffle transitioning from the glide to the end of Reach 1. Through the reach, changes in the bed sediment, floodplain interaction, and riparian vegetation reflected the transitioning valley morphology. The structurally-controlled glide provided the greatest maximum water surface depth. Downstream pools provided minimal cover.

Bank Integrity

The bank integrity analysis included an evaluation of two bank sites that were representative of the bank stability conditions in Reach 1 (Table B-10). Both sites were located adjacent to the glide portion of Reach 1. Sites were monumented with a rebar and bank profiles were

completed. Validation of the BEHI Score and BEHI Rating, as well as volume of sediment delivery to the Sycan River will require resurveying the BEHI cross-sections in the future.

Table B-10. Bank Erosion Hazard Index (BEHI) scores for Reach 1.

Parameter	R1 Cat 2	R1 Cat 5
Bankfull Stage (ft)	2.0	3.9
Bank Height (ft)	3.5	4.9
Root Depth (ft)	1.0	1.0
Root Density (%)	30	50
Bank Angle (degrees)	70	15
Surface Protection (%)	5.0	95
Total Bank Length (ft)	393	1,453
Total BEHI Reach Length (ft)	3,242	3,242
Percent of BEHI Reach (%)	12	45
Bank Material Adjustment	Cobble -10	Cobble -10
Bank Stratification Adjustment	None	None
BEHI Score	26.2	12.9
BEHI Rating	Moderate	Low

In general, bank height ratios (bank height/bankfull height) were less than 2.0, indicating a moderate degree of vertical entrenchment of the bankfull channel relative to the adjacent landform. Bank erosion due to cattle grazing was apparent. Further down the reach, the eastern hillslope interacts with the channel. There is limited bank erosion along the eastern valley wall due to the armored toe that has formed over time as finer particles have been winnowed from the hillslope base. There is minimal potential for accelerated bank erosion in Reach 1 due to the landforms that interact with the river. However, continued bank cleaving will likely persist if the reach continues to be managed for cattle.

Bed Resistance and Channel Hydraulic Analysis

Streambank and channel bed characteristics are the primary channel characteristics influencing flow resistance and the conveyance capacity of a channel. Riffle cross-section data were analyzed using WinXSPRO Version 3.0 (Hardy et al. 2005). Bankfull channel total shear stress was calculated and compared to the Shields diagram which describes the relationship between critical shear stress and incipient motion of grains along the streambed. Two curves were used including the standard Shields curve and a modified Shields curve that is based on the ratio of the D_{84} to D_{35} of the bed material (D. Rosgen, Wildland Hydrology, unpublished data).

Reach 1 was characterized by boulders fining to coarse gravel substrate, with particles ranging in size from 2 mm (coarse sand) to a maximum particle size of 1024 mm (large cobble). Hydraulic modeling and incipient motion results for a typical cross-section in Reach 1 are presented in Table B-11 and Table B-12.

Table B-11. Hydraulic analysis results for the measured baseflow and estimated bankfull discharge.

Discharge	Channel Area (ft ²)	Velocity (ft/sec)	Discharge (cfs)	Water Surface Slope (ft/ft)	Hydraulic Radius (ft)	Manning's N Value
Baseflow	92.5	0.41	37.5	0.0058	1.9	0.4*
Bankfull	234	3.13	735	0.0015	4.83	0.04

*: High Manning's-n value suggests low velocities outside of Price AA meter range.

Table B-15. Hydraulic and incipient motion modeling results for bankfull discharge.

Velocity (f/s)	Manning's n-value	Total shear stress (lbs/ft ²)	Grain Diameter (mm)	Size Class (% finer than)
3.13	0.04	0.3	50-70 ¹ 16-22 ²	D ₄₂₋₄₈ D ₂₅₋₃₈

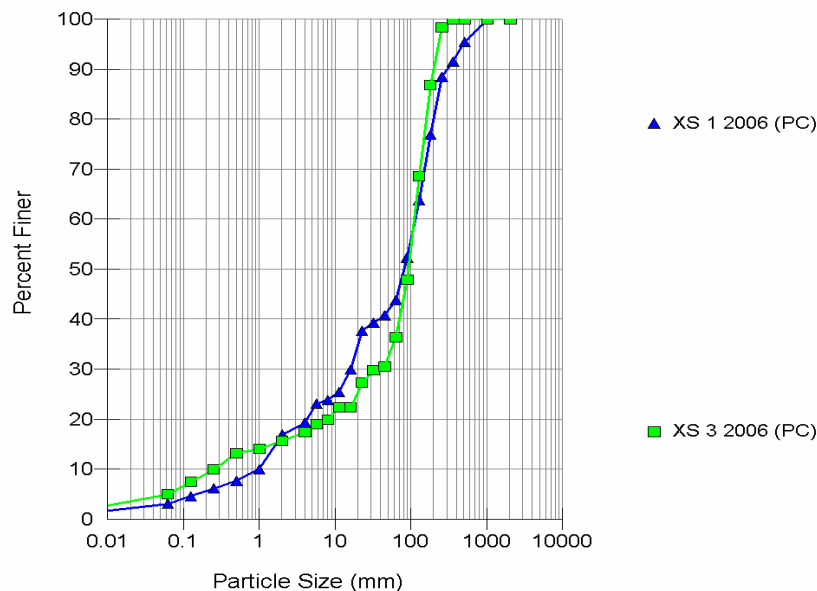
¹ Modified Shields curve (D. Rosgen, Wildland Hydrology, unpublished data)

² Shields curve

Pebble count data collected at two cross-sections in Reach 1 are presented in Table B-16. A gradation curve for the glide and riffle pebble counts is included in Figure B-9. The shear stress generated at the glide hydraulic cross-section station would be expected to mobilize slightly less than the D50 particle size.

Table B-16. Bed sediment descriptive statistics for Reach 1 (mm).

Cross-section	Feature	D16	D35	D50	D84	D95	D100
R1 XS1	Glide	2	20	83	227	497	1024
R1 XS3	Riffle	2	60	94	172	234	362

**Figure B-10.** Pebble count particle size gradation curve for R1 XS1-Glide and R1 XS3-Riffle.

B.3.7 Reach 2 – Upper Meandering Reach Existing Conditions

The following sections discuss the existing reach conditions of Reach 2 – Upper Meandering Reach.

Overview

Reach 2 is characterized by a meandering channel with adjacent floodplains. The floodplains are dissected with surface channels that convey water during flood events. Channel characteristics also suggest the influence of past beaver dams, although recent beaver activity is not apparent. Riparian vegetation occupies floodplain depressions. Big sagebrush and bunchgrasses occupy higher elevation positions on the floodplain. Noxious weeds infest areas of heavy livestock use. The river corridor through Reach 2 exhibits a number of surfaces suggesting historical channel locations. A comparison of the 1941 and 1998 air photos indicates the river's location has changed more in Reach 2 than in other reaches of the project area.

Valley Form

The Reach 2 valley is characterized as a Valley Type X (Rosgen 1996) typified by broad and gentle slopes formed by riverine and lacustrine depositional processes. Although not recognized by the Rosgen classification system for this valley type, wind-delivered sediment is also critical in the Sycaan watershed. The Sycaan River is characterized as a Rosgen C stream type (Rosgen 1996) through the reach. The channel morphology is referred to as a riffle-pool channel using the Montgomery and Buffington classification system (Montgomery and Buffington 1997).

Channel Planform

The Reach 2 planform morphology was assessed using field and remote sensing data including the 1941 and 1998 aerial photo series. The dominant channel classified as a single thread channel. Floodplains adjacent to the river support wetlands, riparian vegetation, and store sediment and debris. Reach 2 planform dimensions are included in Table B-17.

Table B-17. The existing planform channel dimensions in Reach 2. Mean values (1 SD).

Channel Type	Sinuosity	Bankfull Width (ft)	Width/Depth Ratio	Meander Belt Width (ft)	Meander Length (ft)	Radius of Curvature (ft)
C4	1.28	93.9	46.3	236 (94.0)	643 (121)	253 (85.7)

Channel planform dimensions from the 1941 and 1998 air photos are compared in Table B-18. The Sycaan River's planform dimensions have increased over time likely in response to the depleted riparian community. Because vegetation is critical for maintaining bank strength and resisting stream power, a reduction in the vegetation areal extent and density would correlate with reduced bank resistance. Lower bank resistance corresponds with greater erosion potential and a straighter channel pattern.

Table B-18. Reach 2 meander geometry summary statistics for the 1941 and 1998 air photos. Presented data include the mean and 1 standard deviation values.

Reach	1941				1998			
	Meander Length (ft)	Meander Belt Width (ft)	Radius of Curvature (ft)	Sinuosity	Meander Length (ft)	Meander Belt Width (ft)	Radius of Curvature (ft)	Sinuosity
Reach 2	441 (132)	204 (72.0)	133 (45.7)	1.34	643 (121)	236 (94.0)	253 (85.7)	1.28

Channel Cross-Sections

Four cross-sections were surveyed in Reach 2. Surveyed sections were located in pool and run habitat features (Table B-19). Table B-20 includes channel cross-section dimensions for riffle, run, and pool cross-sections sampled from the LIDAR data.

Table B-19. Descriptive statistics for GPS-surveyed channel habitat features in Reach 2.

Feature	Channel Station	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
Pool XS1	5+73	407	180.0	2.3	5.3	79.6
Run/Riffle XS2	9+00	191	93.9	2.0	5.1	46.3
Pool XS3	11+47	340	104.0	3.3	6.5	31.9
Pool XS4	20+13	280	69.8	4.0	6.7	17.4
Average Pool Stats (1 SD)		342 (63.5)	118 (56.4)	3.2 (0.9)	6.2 (0.8)	43.0 (32.5)

Table B-19. Descriptive statistics for GPS-surveyed channel habitat features in Reach 2.

Feature	Channel Station	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
LID R2XS1 Run	13+60	334	119	2.8	4.0	42.0
LID R2XS2 Pool	14+25	352	127	2.8	4.1	45.6
LID R2XS3 Pool	18+10	354	122	2.9	4.2	42.2
LID R2XS4 Pool	18+80	303	107	2.8	4.2	37.8
LID R2XS5 Riffle	23+10	348	115	3.0	4.4	38.0

Figures B-11 through B-12 include the channel cross-section diagrams and site photographs.

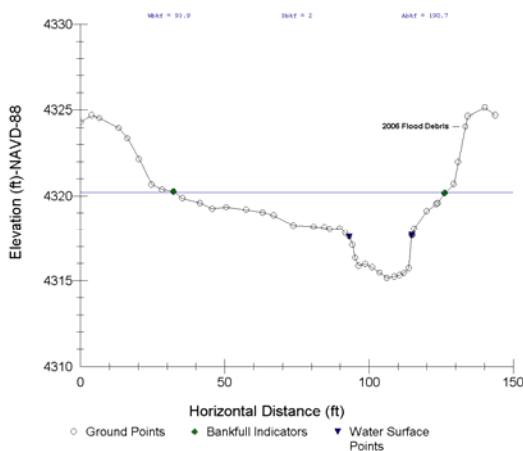


Figure B-11. The channel cross-section (left) and site photo (right) for XS2-Riffle/Run in Reach 2.

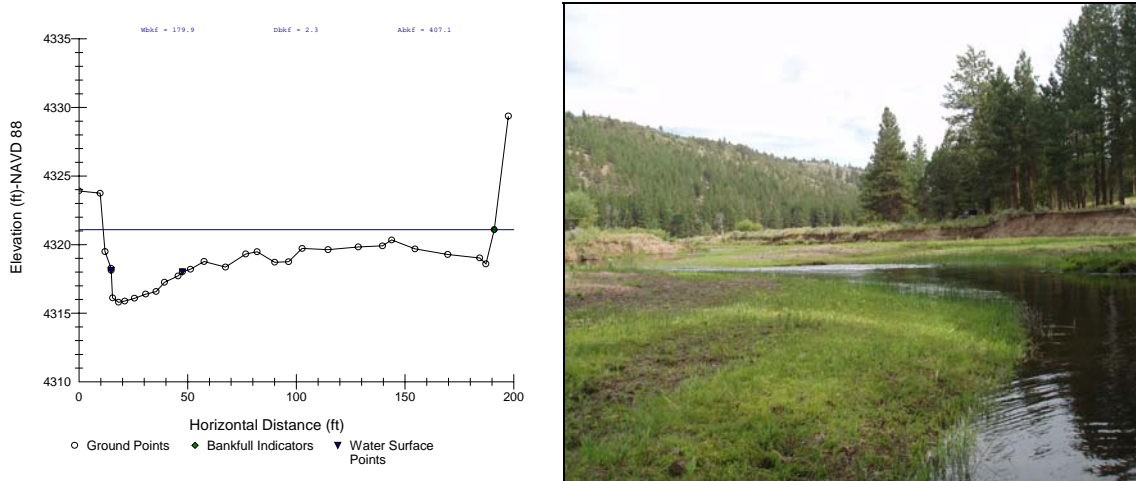


Figure B-12. The channel cross-section (left) and site photo (right) for XS1-Pool in Reach 2.

Channel Profile

A 2,300 ft longitudinal profile was surveyed to characterize Reach 2. Figure B-13 presents two photos of existing site conditions in the reach. Figure B-14 illustrates the longitudinal profile graph depicting the dominant channel thalweg, water surface, bankfull feature, and other geomorphic features. Debris deposited during the 2006 runoff was also surveyed. Best-fit trend lines were applied to the water surface and bankfull data. Field survey cross-section locations are also noted.

Compared to the Reach 1 channel profile, the Reach 2 profile exhibits a more diverse bed morphology characterized by riffle, run, pool, and glide habitat features. Pools were generally deep, greater than 4 ft at baseflow. Baseflow was maintained within a defined low flow channel. Bars paralleling the low flow channel store sediment and provide a vegetated surface. Vertical eroding banks mark the edge of the active channel. Off-channel wetlands are located on the adjacent floodplain.



Figure B-13. Project Reach 2 straight riffle section (left) and downstream meander pool sequence (right) illustrate existing channel conditions within the active channel.

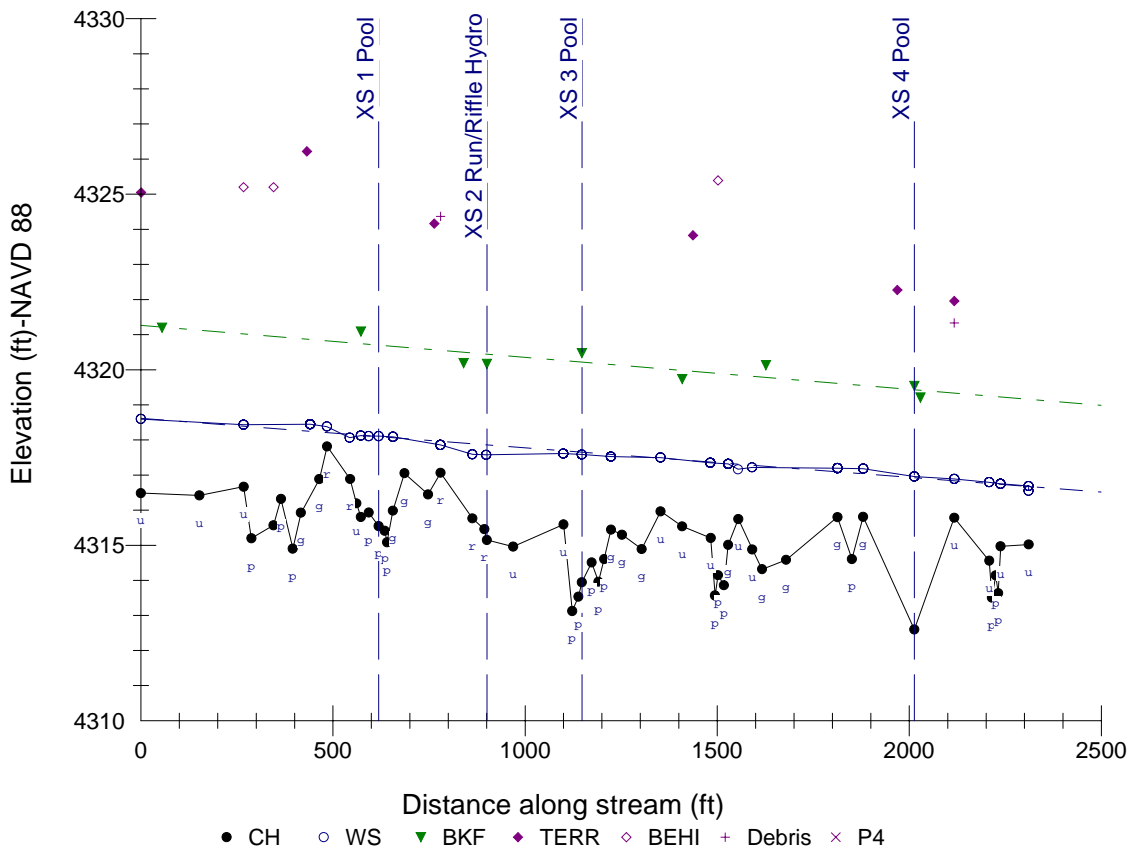


Figure B-14. The Reach 2 longitudinal channel profile graph with GPS-survey cross-section locations.

Longitudinal channel profile data results are summarized in Table B-21.

Table B-21. Summary of Reach 2 longitudinal channel profile data (ft).

Reach	Average Bankfull Slope	Average Water Surface Slope	Riffle Bankfull Slope	Riffle Water Surface Slope	Pool Bankfull Slope	Pool Water Surface Slope
Reach 2	0.0009	0.0009	0.0032	0.0035	0.0009	0.0006

Bank Integrity

The bank integrity analysis included an evaluation of three bank sites that were representative of the bank stability conditions in Reach 2 (Table B-22). The three sites were given bank erosion potential scores of Very High to Extreme. The R2 Cat 1a and R2 Cat 1b designations were based on the second site having two soil layers in the bank profile. Sites were monumented with a rebar and bank profiles were completed. Validation of the BEHI Score and BEHI Rating, as well as volume of sediment delivery to the Sycan River will require resurveying the BEHI cross-sections.

Table B-22. Bank Erosion Hazard Index (BEHI) scores for Reach 2.

Parameter	R2 Cat 1a	R2 Cat 1b*	R2 Cat 2
Bankfull Stage (ft)	3.2	3.7	3.3
Bank Height (ft)	9.0	9.5	7.2
Root Depth (ft)	3.0	1.5	3.0
Root Density (%)	15	2.5	5.0
Bank Angle (degrees)	85	85	85
Surface Protection (%)	20	5.0	5.0
Total Bank Length (ft)	1,726	N/A	720
Total BEHI Reach Length (ft)	4,299	4,299	4,299
Percent of BEHI Reach (%)	40	40	17
Bank Material Adjustment	Sand +7	Sand +7	Sand +7
Bank Stratification Adjustment	None	Yes +5	Yes +5
BEHI Score	45.7	55.3	51.7
BEHI Rating	V. High	Extreme	Extreme

*: A separate bank length for R2 Cat 1b was not defined.

In general, bank height ratios (bank height/bankfull height) approached 3.0, indicating a moderate to substantial degree of vertical entrenchment of the bankfull channel relative to the adjacent landform. Typical bank erosion was characterized by bank cleaving and vegetated chunks at the bank toe (Figure B-15).



Figure B-15. Example bank conditions in Reach 2.

Bed Resistance and Channel Hydraulic Analysis

Riffle cross-section data were analyzed using WinXSPRO Version 3.0 (Hardy et al. 2005). The channel bed material in Reach 2 was predominantly fine gravel to very coarse gravel. Hydraulic modeling and incipient motion results for a typical cross-section in Reach 1 are presented in Table B-11 and Table B-12.

Table B-23. Hydraulic analysis results for the measured baseflow and estimated bankfull discharge.

Discharge	Channel Area (ft ²)	Velocity (ft/sec)	Discharge (cfs)	Water Surface Slope (ft/ft)	Hydraulic Radius (ft)	Manning's N Value
Baseflow	36.9	1.20	44.4	0.0009	1.6	0.051
Bankfull	238	3.17	753	0.0009	2.27	0.025

*: High Manning's n-values suggests velocities outside of Price AA meter range.

Table B-24. Hydraulic and incipient motion modeling results for bankfull discharge.

Velocity (f/s)	Manning's n-value	Total shear stress (lbs/ft ²)	Grain Diameter (mm)	Size Class (% finer than)
3.17	0.025	0.12	20-30 ¹ 6-10 ²	D ₆₀₋₇₈ D ₄₂₋₄₃

¹ Modified Shields curve (D. Rosgen, Wildland Hydrology, unpublished data)

² Shields curve

Pebble count data collected at two cross-sections in Reach 2 are presented in Table B-16. A gradation curve for the glide and riffle pebble counts is included in Figure B-9. The shear stress generated at the glide hydraulic cross-section station would be expected to mobilize the D50 particle size.

Table B-25. Bed sediment descriptive statistics for Reach 2 (mm).

Cross-section	Feature	D16	D35	D50	D84	D95	D100
R2 XS2	Glide	0.1	0.5	12	56	155	362
LID R2XS2	Riffle	0.1	0.8	5	19	47	90

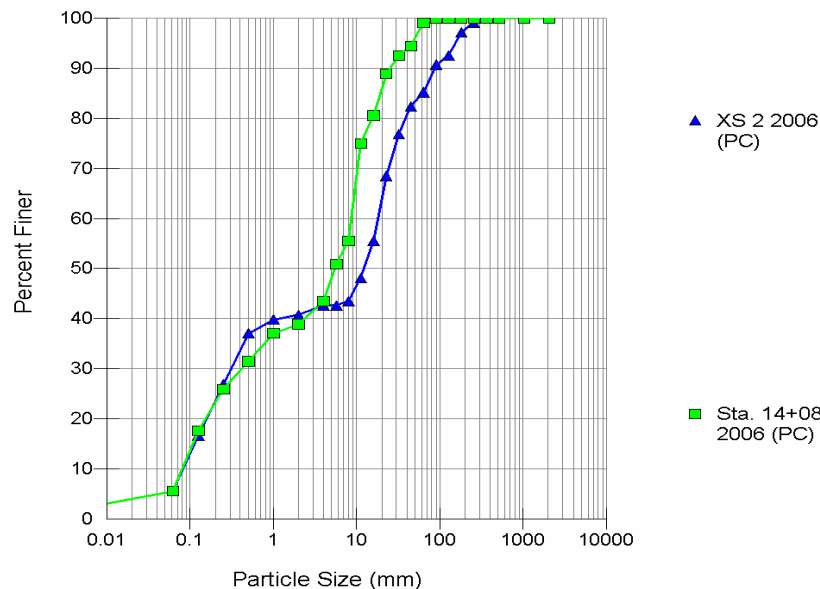


Figure B-16. Pebble count particle size gradation curve for R2 XS2-Glide and LID R2 XS2-Riffle.

B.3.7 Reach 3 – Upper Confined Reach Existing Conditions

The following sections discuss the existing reach conditions of Reach 3 – Upper Confined Reach.

Overview

Reach 3 is characterized by the transition from a meandering to a confined channel morphology. In the upstream portion of Reach 3, the Sycan River accesses adjacent floodplains that are dissected by flood channels. Prominent disconnected meanders suggest past channel locations and continue to hold water after runoff. The valley narrows through the Shields' property as the Sycan River is confined by the eastern hillslope and the western terraces at the foot of the Knott Tablelands. The river has a straight planform through lower Reach 3. Spring-fed ponds on the western terraces discharge to the river, emanating along the right river bank. The river's location through this reach has varied since the 1941 air photo. The channel in the upstream extent of the reach has straightened and apparently degraded since 1941. The middle and lower portions of the reach remain in the same location as the 1941 alignment. It is unknown if the channel elevation has changed in a similar manner to the upstream portion of the reach since 1941. Livestock tend to congregate in the upstream portion of Reach 3 in the summer when they access water remaining in the abandoned meanders. Vegetation also remains lush near these relict channels.

Valley Form

The Reach 3 valley is characterized as a Valley Type X (Rosgen 1996) typified by broad and gentle slopes formed by riverine and lacustrine depositional processes. Although not recognized by the Rosgen classification system for this valley type, wind-delivered sediment is also critical in the Sycan watershed. The Sycan River is characterized as a Rosgen C/F stream type (Rosgen 1996) through the reach. The Sycan River is entrenched through portions of the reach and is therefore classified as an F stream type. The channel morphology is referred to as a riffle-pool channel using the Montgomery and Buffington classification system (Montgomery and Buffington 1997).

Channel Planform

The Reach 3 planform morphology was assessed using field and remote sensing data including the 1941 and 1998 aerial photo series. The dominant channel classified as a single thread channel. Floodplains adjacent to the river support wetlands, riparian vegetation, and store sediment and debris. Reach 3 planform dimensions are included in Table B-26.

Table B-26. The existing planform channel dimensions in Reach 3. Mean values (1 SD).

Channel Type	Sinuosity	Bankfull Width (ft)	Width/Depth	Meander Belt Width (ft)	Meander Length (ft)	Radius of Curvature (ft)
C4/F4	1.10	70.7 (5.8)	19.4 (4.6)	179 (73.6)	845 (570)	406 (286)

Channel planform dimensions from the 1941 and 1998 air photos are compared in Table B-27. The Sycan River through the majority of the reach has a low sinuosity. A floodplain area near the upstream extent of Reach 3 accounts for most of the planform diversity in the reach. Changes in the planform geometry (meander length and radius of curvature) between 1941 and 1998 are due to the abandonment of a channel meander in the floodplain inclusion (Figure B-17).

Table B-27. Reach 3 meander geometry summary statistics for the 1941 and 1998 air photos. Presented data include the mean and 1 standard deviation values.

Reach	1941				1998			
	Meander Length (ft)	Meander Belt Width (ft)	Radius of Curvature (ft)	Sinuosity	Meander Length (ft)	Meander Belt Width (ft)	Radius of Curvature (ft)	Sinuosity
Reach 3	364 (176)	167 (54.8)	142 (144)	1.19	845 (570)	179 (73.6)	406 (286)	1.10



Figure B-17. A channel meander (circled) that was active in the 1941 air photo (left) was abandoned by the 1998 air photo (right). The abandoned channel segment remains apparent on the landscape although it is located above the current alignment's elevation, suggesting the channel has degraded in the reach since 1941.

Channel Cross-Sections

Three cross-sections were surveyed in Reach 3. Surveyed sections were located in pool and run habitat features (Table B-28). Table B-29 includes channel cross-section dimensions for riffle cross-sections sampled from the LIDAR data.

Table B-28. Descriptive statistics for GPS-surveyed channel habitat features in Reach 3.

Feature	Channel Station	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
Pool XS1	09+99	305	67.5	4.5	6.2	14.9
Pool XS2	14+24	340	88.8	3.8	7.8	23.2
Run/Riffle XS3	18+85	398	69.7	5.7	8.2	12.2
Average Pool Stats (1 SD)		323 (24.8)	78.2 (15.1)	4.2 (0.5)	7.0 (1.1)	19.1 (5.9)

Table B-29. Descriptive statistics for LIDAR-surveyed riffle features in Reach 3.

Feature	Channel Station	Area (ft ²)	Width (ft)	Mean Depth (ft)	Max Depth (ft)	Width/Depth
LID R3XS1 Riffle	2+97	260	79.5	3.3	4.6	24.3
LID R3XS2 Riffle	4+65	237	76.0	3.1	4.8	24.4
LID R3XS3 Riffle	18+25	225	66.3	3.4	4.1	19.5
LID R3XS4 Riffle	20+20	230	65.7	3.5	4.1	18.8
LID R3XS5 Riffle	21+10	256	66.8	3.8	4.6	17.4
Average Riffle XS Stats (1 SD)		242 (15.6)	70.9 (6.40)	3.4 (0.3)	4.4 (0.30)	20.9 (3.30)

Figures B-18 and B-19 include the channel cross-section diagrams and site photographs.

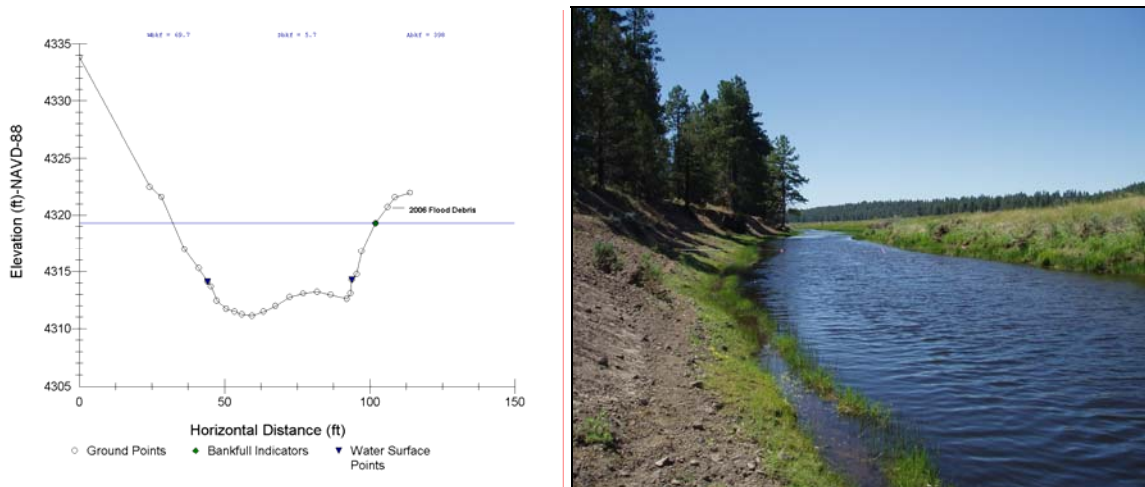


Figure B-18. The channel cross-section (left) and site photo (right) for XS3-Riffle/Run in Reach 3.

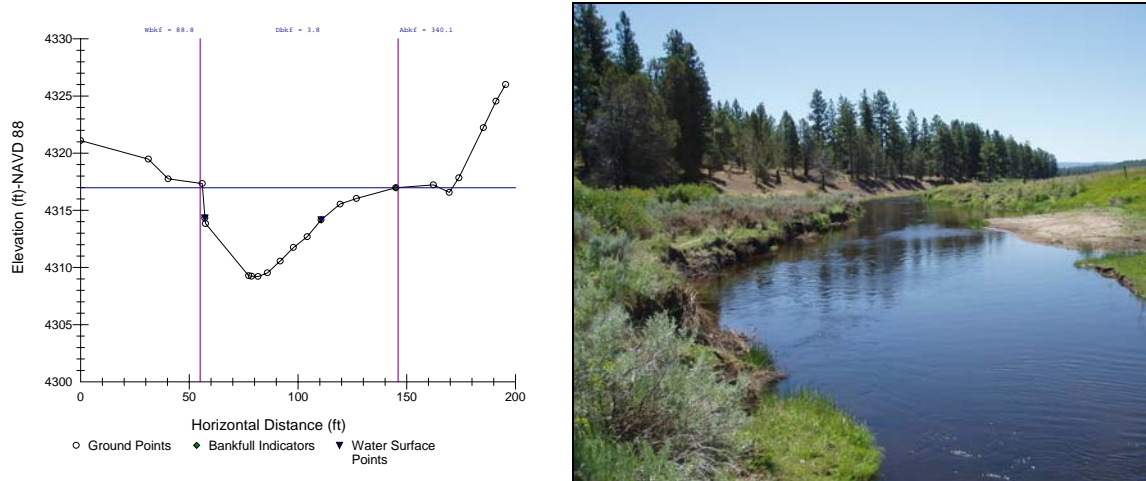


Figure B-19. The channel cross-section (left) and site photo (right) for XS2-Pool in Reach 3.

Channel Profile

A 2,300 ft longitudinal profile was surveyed to characterize Reach 3. Figure B-20 presents two photos of existing site conditions in the reach. Figure B-21 illustrates the longitudinal profile graph depicting the dominant channel thalweg, water surface, bankfull feature, and other geomorphic features. Debris deposited during the 2006 runoff was also surveyed. Best-fit trend lines were applied to the water surface and bankfull data. Field survey cross-section locations are also noted.

The Reach 3 channel profile exhibits a bed morphology similar to Reach 2 although the channel slope is flatter than in the upstream reach. Two deep pools are located in the reach. Sediment is stored in point bars. Point bar vegetation was typically sedge/rush with silver sagebrush. The floodplain to the west of the channel alignment exhibits remnant channel segments that hold water through spring and early summer. Willows populate the floodplain surface. Large wood on the floodplain suggests periodic overbank flows and debris storage.



Figure B-20. Reach 3 site conditions include the Sycan River upstream from the eroding bank at Station 97+00 (left) and in the vicinity of Station 122+00 (right). The channel is entrenched through the lower half of the reach. The Sycan River is confined by the western terrace and the eastern hillslope.

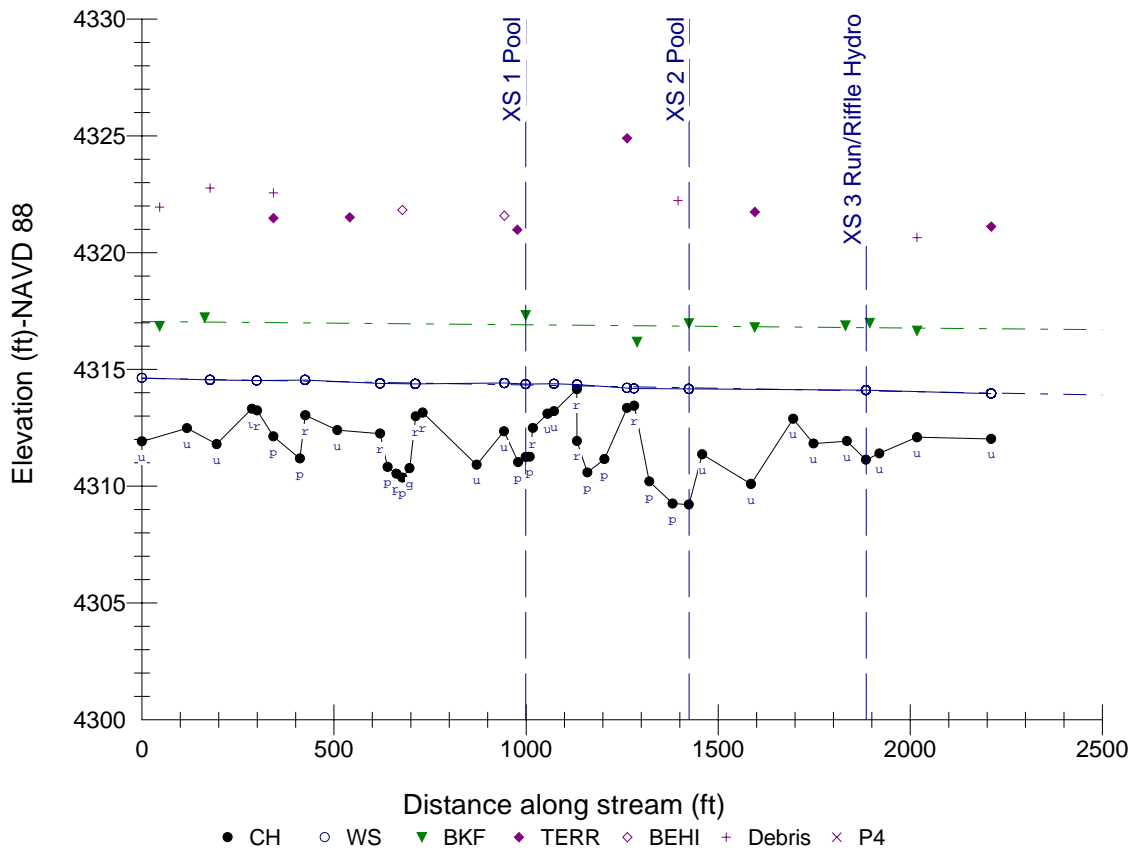


Figure B-21. The Reach 3 longitudinal channel profile graph with GPS-survey cross-section locations.

Longitudinal channel profile data results are summarized in Table B-30.

Table B-30. Summary of Reach 3 longitudinal channel profile data (ft).

Reach	Average Bankfull Slope	Average Water Surface Slope	Riffle Bankfull Slope	Riffle Water Surface Slope	Pool Bankfull Slope	Pool Water Surface Slope
Reach 3	0.0001	0.0003	0.0003	0.0004	0.0001	0.0002

Bank Integrity

The bank integrity analysis included an evaluation of three bank sites that were representative of the bank stability conditions in Reach 3 (Table B-31). The three sites were given bank erosion potential scores of Very High to Extreme. The reach was defined by the three BEHI classifications. Differences in the BEHI scores included variation in the bank heights, root density, bank angle, and surface protection.

Table B-31. Bank Erosion Hazard Index (BEHI) scores for Reach 3.

Parameter	R3 Cat 1	R3 Cat 2	R3 Cat 3
Bankfull Stage (ft)	4.2	3.4	2.4
Bank Height (ft)	9.0	16	7.2
Root Depth (ft)	1.0	3.0	1.5
Root Density (%)	22	10	42
Bank Angle (degrees)	85	35	60
Surface Protection (%)	5.0	20	42
Total Bank Length (ft)	570	762	1,128
Total BEHI Reach Length (ft)	3,887	3,887	3,887
Percent of BEHI Reach (%)	15	20	29
Bank Material Adjustment	Sand +7	Sand +5	Sand +7
Bank Stratification Adjustment	Yes +5	None	Yes +5
BEHI Score	55.2	42.3	46.5
BEHI Rating	Extreme	V. High	Extreme

In general, bank height ratios (bank height/bankfull height) were greater than 2.0, indicating a moderate to substantial degree of vertical entrenchment of the bankfull channel relative to the adjacent landform. Severe bank erosion is occurring from Station 97+00 to 99+00 (Figure B-22).



Figure B-22. Example bank conditions in Reach 3. Severe bank erosion from Station 97+00 to 99+00 (left) suggests continued down valley meander migration.

Bed Resistance and Channel Hydraulic Analysis

Riffle cross-section data were analyzed using WinXSPRO Version 3.0. The channel bed material in Reach 3 was predominantly fine gravel to medium gravel. Hydraulic modeling and incipient motion results for a typical cross-section in Reach 3 are presented in Table B-32 and Table B-33.

Table B-32. Hydraulic analysis results for the measured baseflow and estimated bankfull discharge.

Discharge	Channel Area (ft ²)	Velocity (ft/sec)	Discharge (cfs)	Water Surface Slope (ft/ft)	Hydraulic Radius (ft)	Manning's N Value
Baseflow	78.7	0.53	41.7	0.0003	1.6	0.066
Bankfull	500.9	1.49	748	0.0001	6.4	0.033

Table B-33. Hydraulic and incipient motion modeling results for bankfull discharge.

Velocity (f/s)	Manning's n-value	Total shear stress (lbs/ft ²)	Grain Diameter (mm)	Size Class (% finer than)
1.49	0.033	0.04	7-9 ¹	D ₄₃₋₄₉
			2-4 ²	D ₁₅₋₂₀

¹ Modified Shields curve (D. Rosgen, Wildland Hydrology, unpublished data)

² Shields curve

Pebble count data collected at two cross-sections in Reach 3 are presented in Table B-34. A gradation curve for the riffle/run and riffle pebble counts is included in Figure B-23. The shear stress generated at the glide hydraulic cross-section station would be expected to mobilize the approximately the D50 particle size.

Table B-34. Bed sediment descriptive statistics for Reach 3 (mm).

Cross-section	Feature	D16	D35	D50	D84	D95	D100
Sta. 4+25	Riffle	0.2	0.5	1	10	16	45
R3 XS3	Riffle/Run	2	7	9	22	43	Bedrock/ Hard Pan

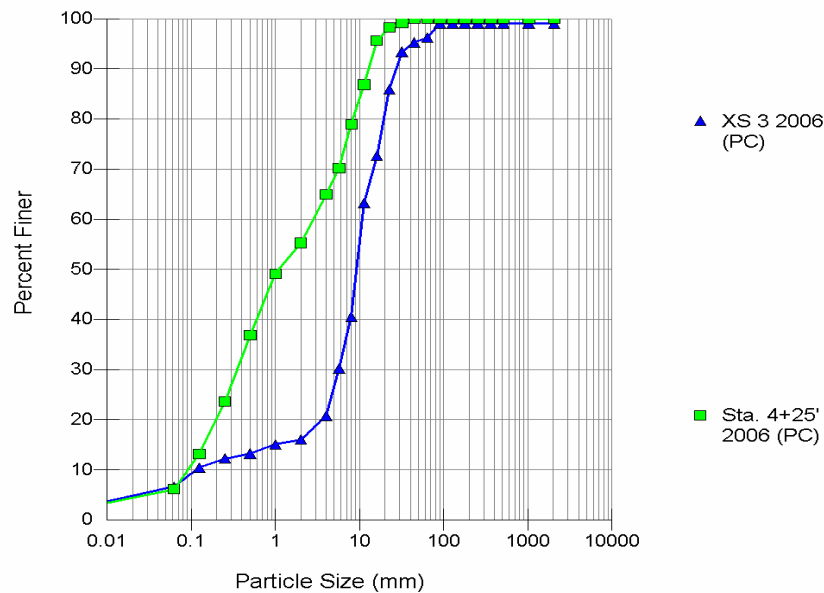
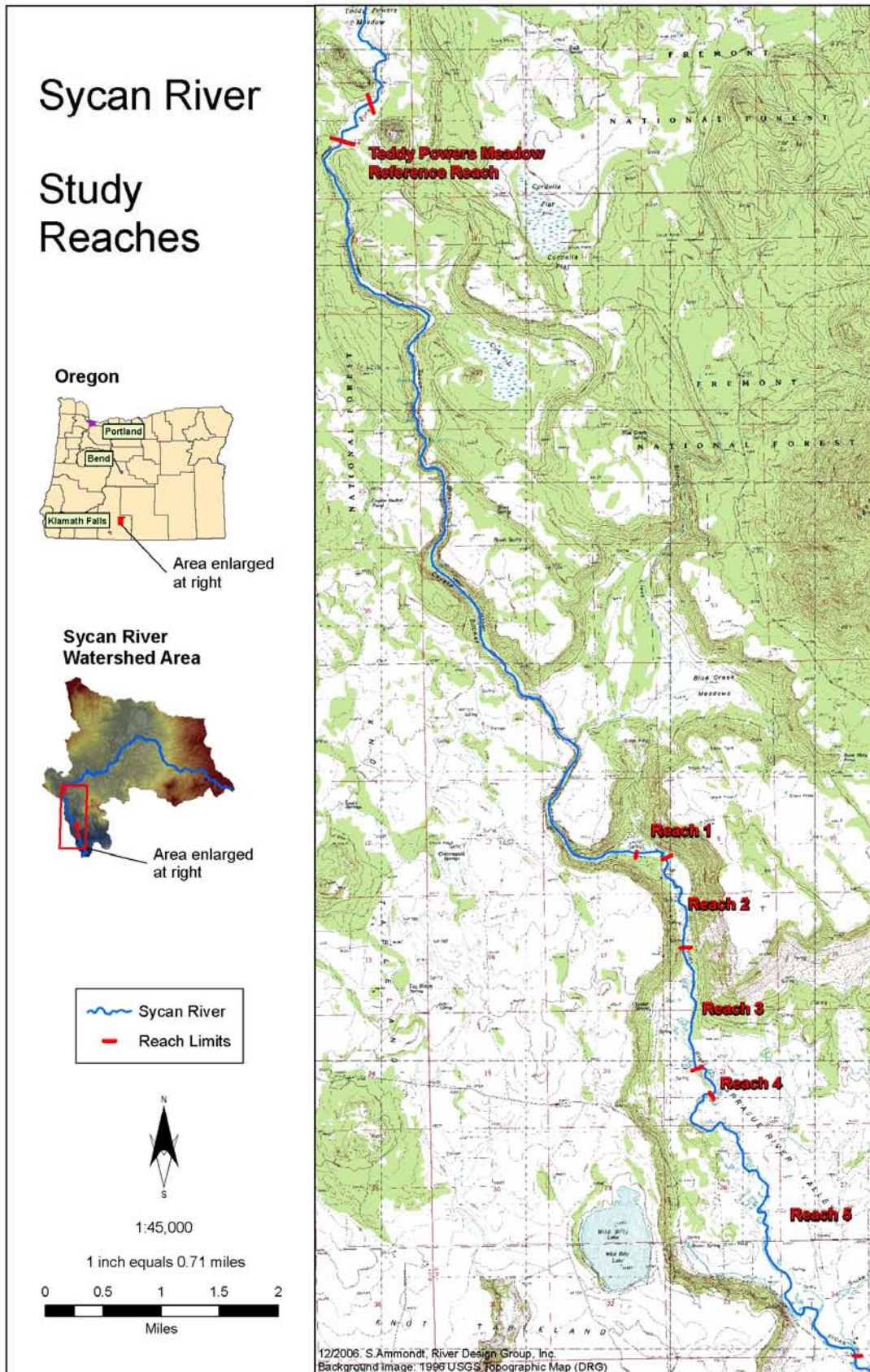
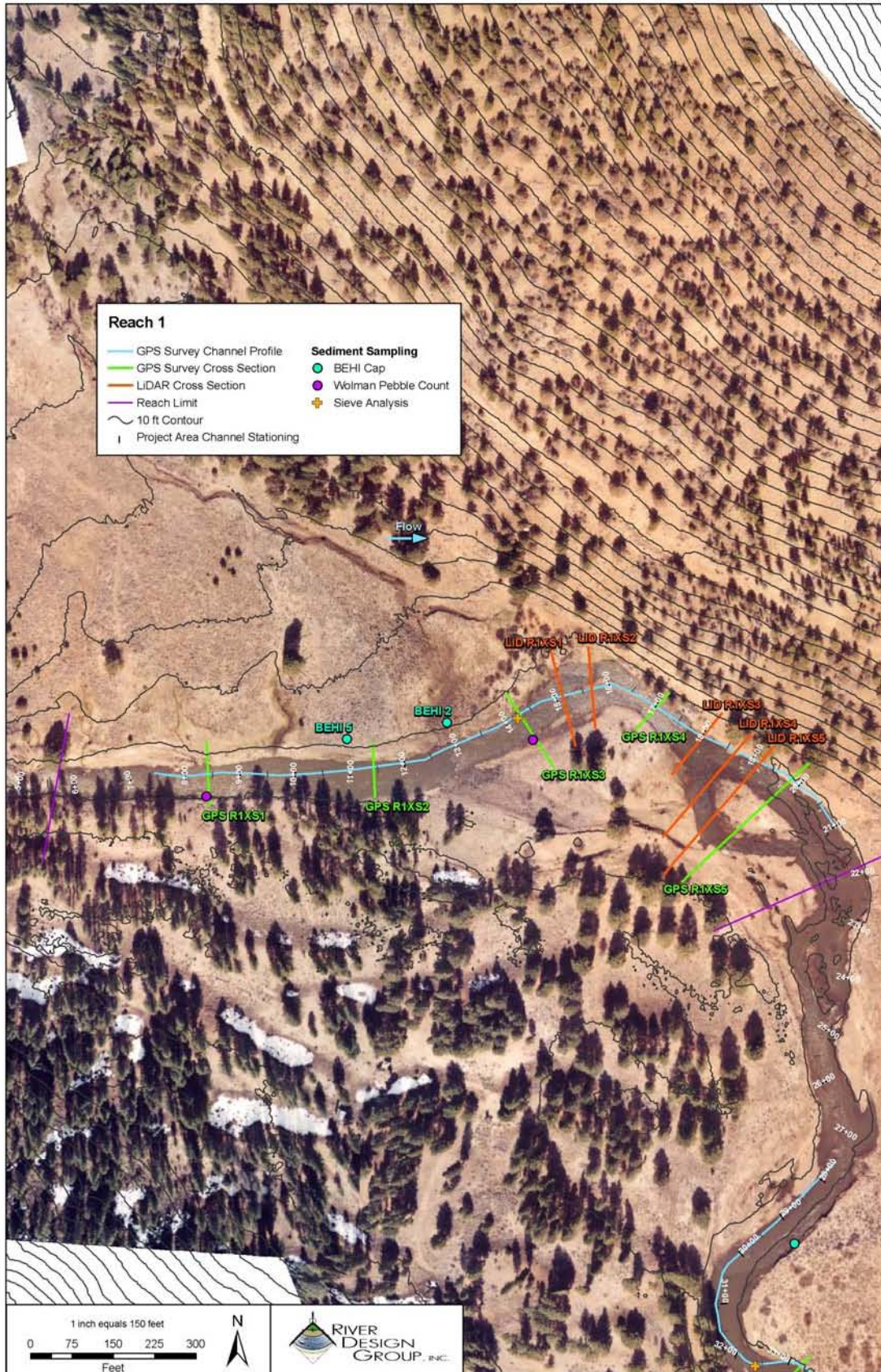
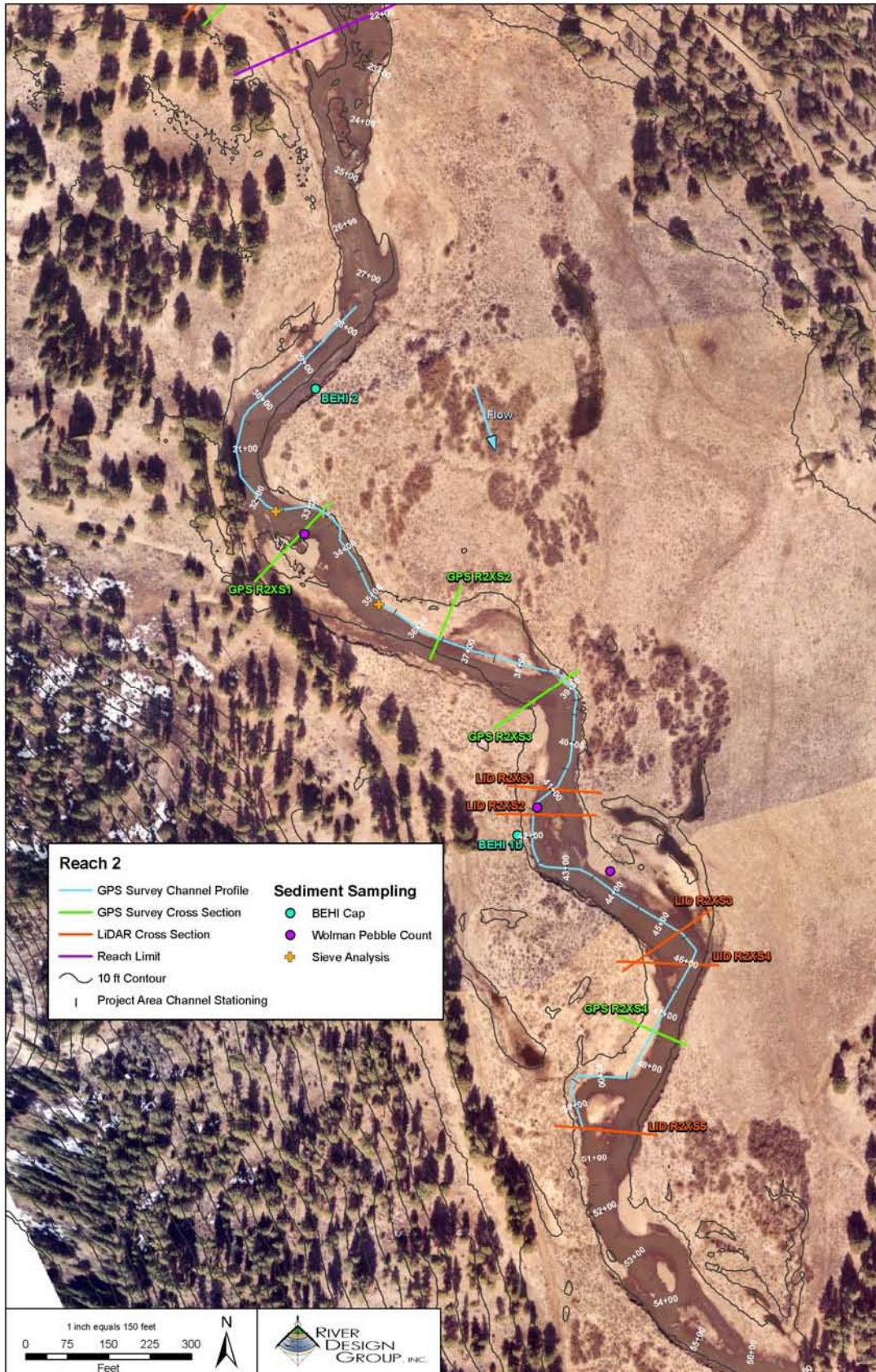
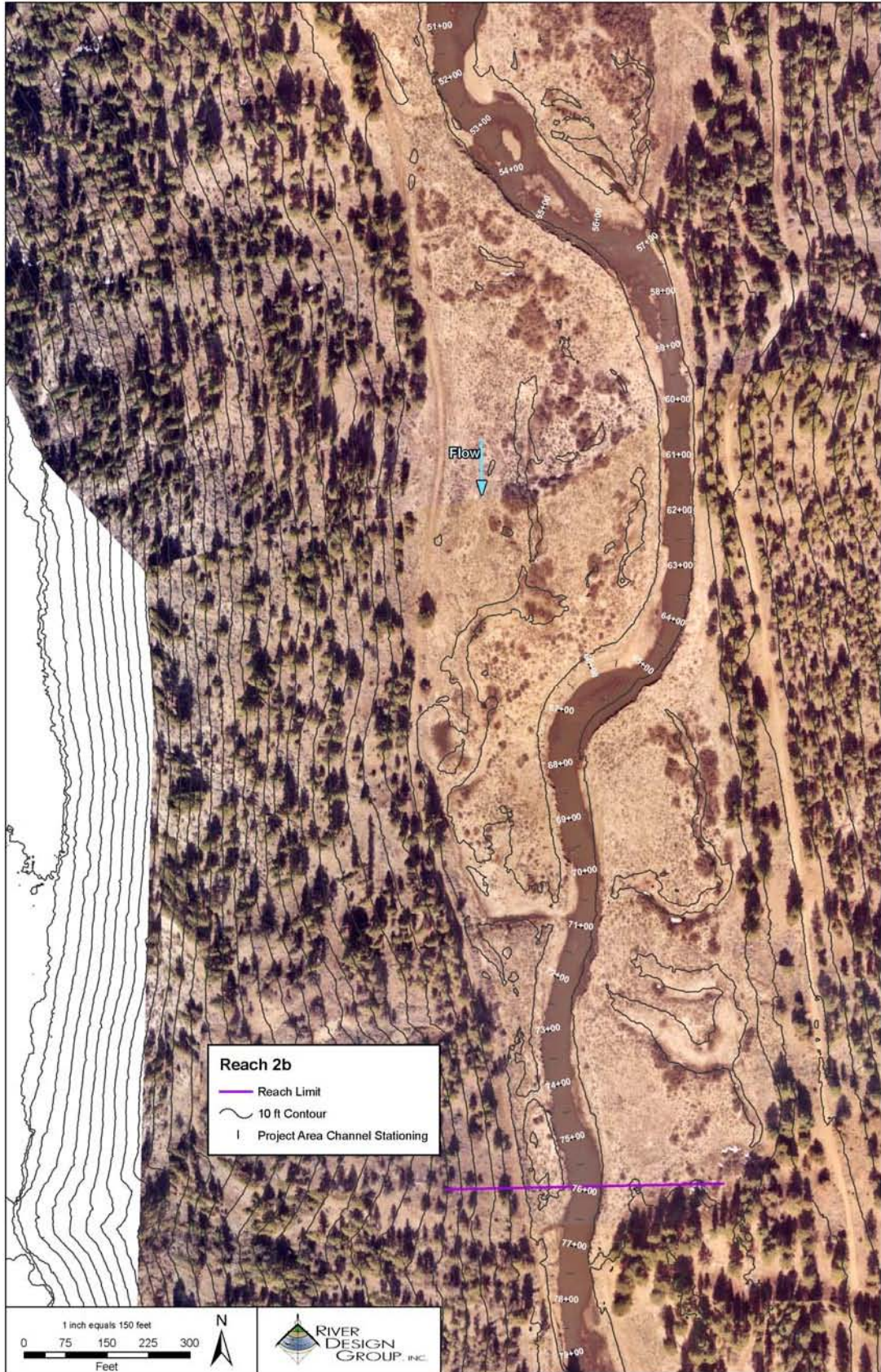


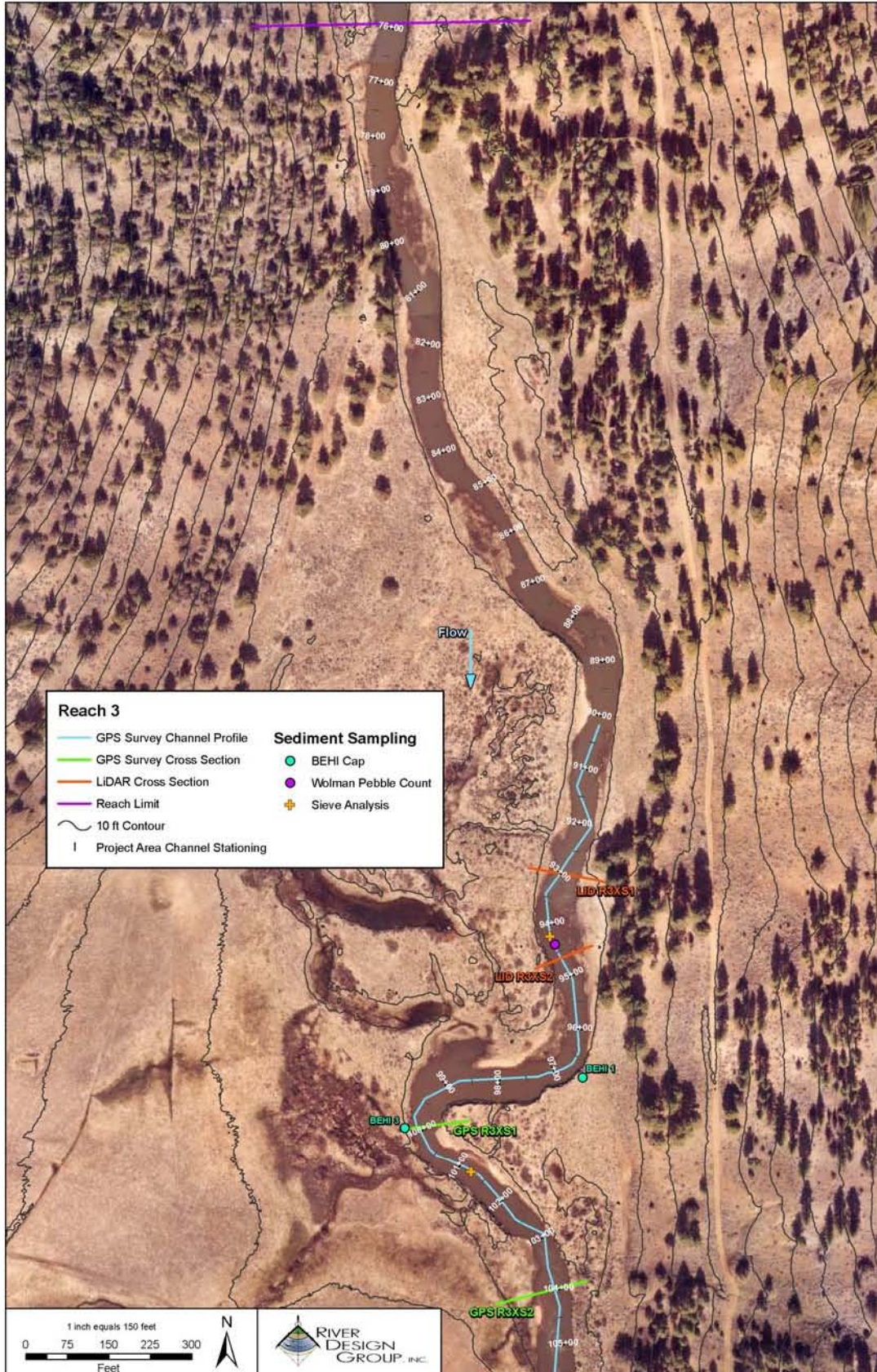
Figure B-23. Pebble count particle size gradation curve for R3 XS3-Riffle/Run and a riffle at Station 4+25.









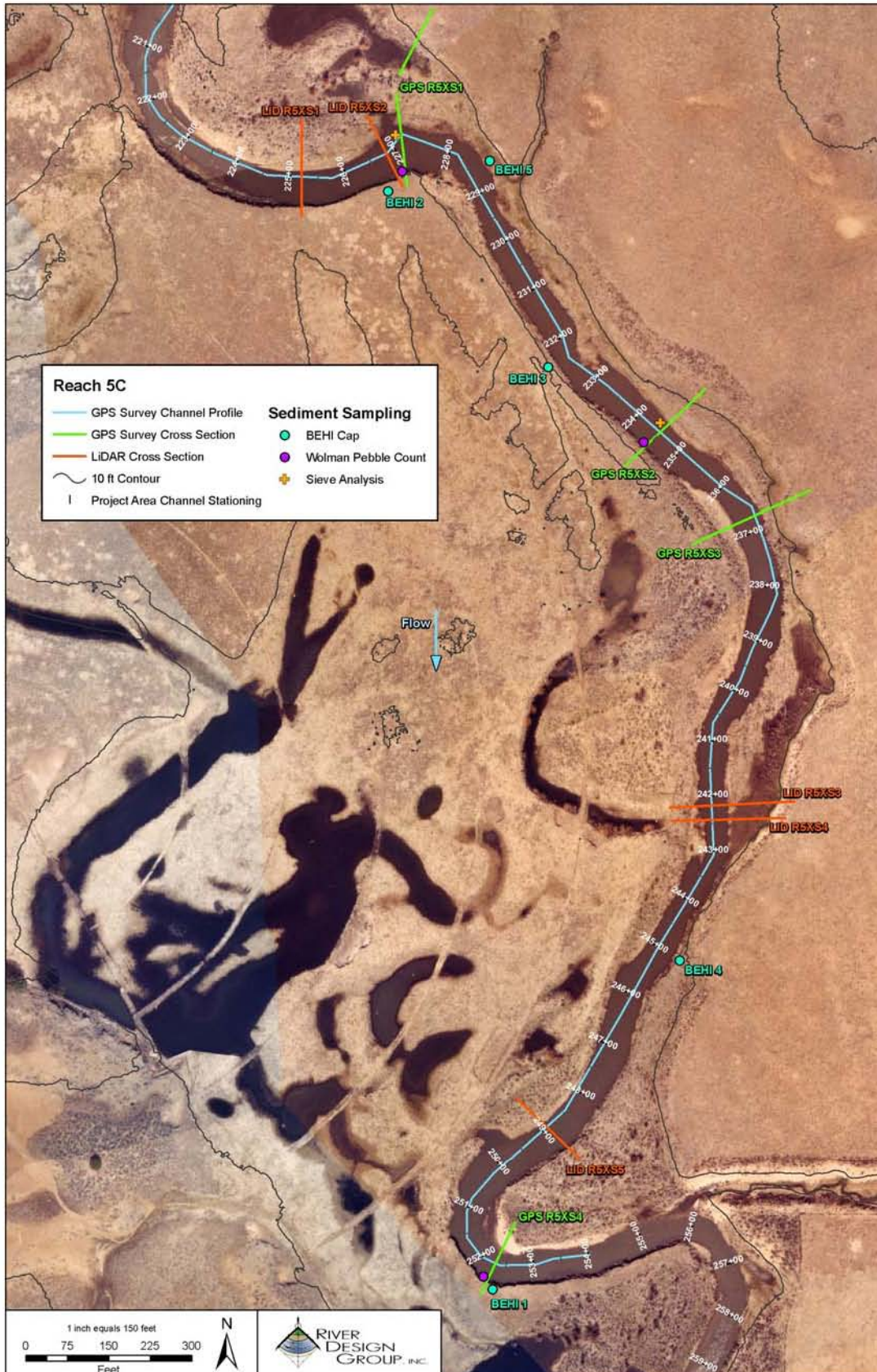










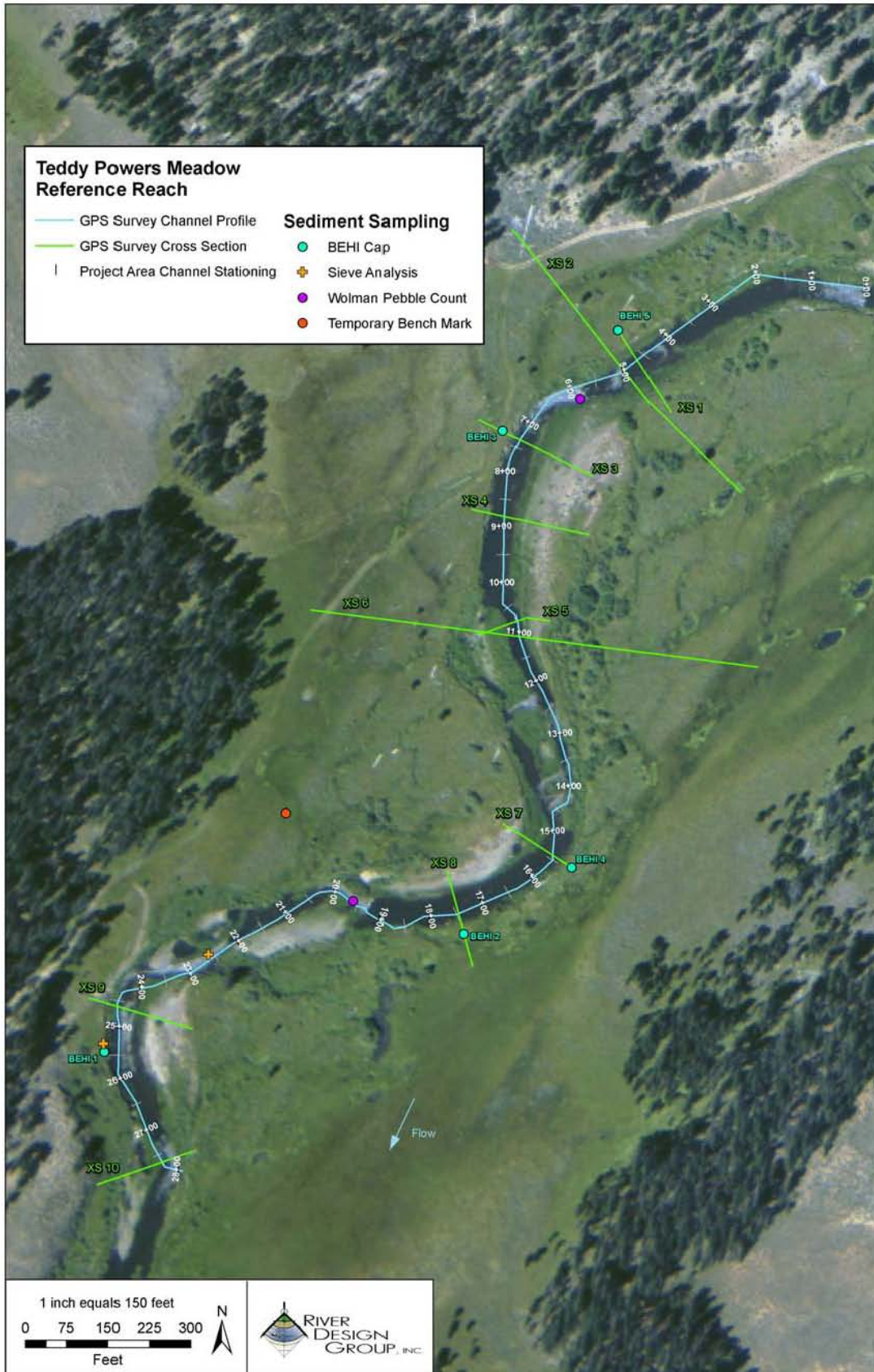












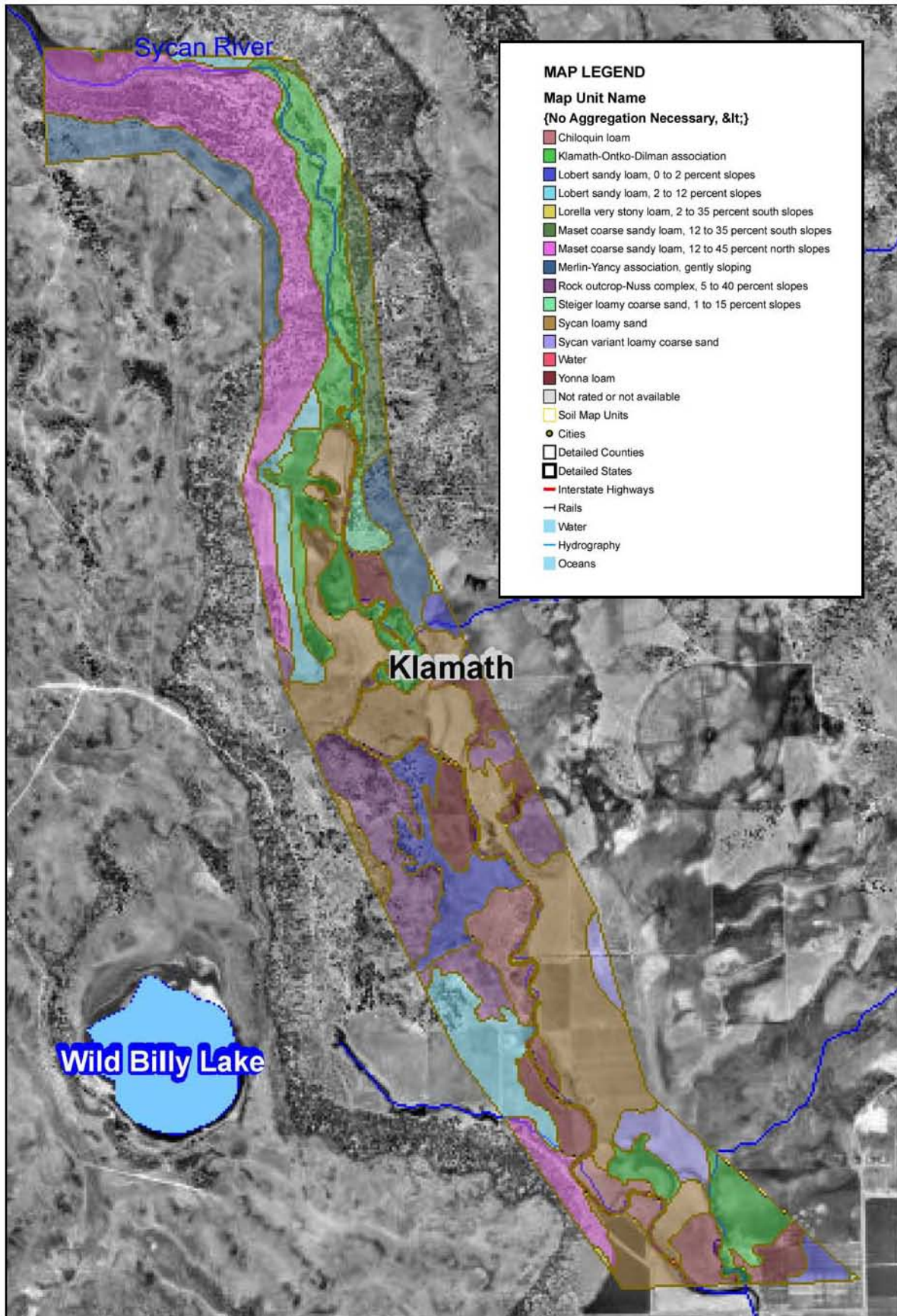


Figure D-1. Sycan River corridor soil types (SCS 1985).

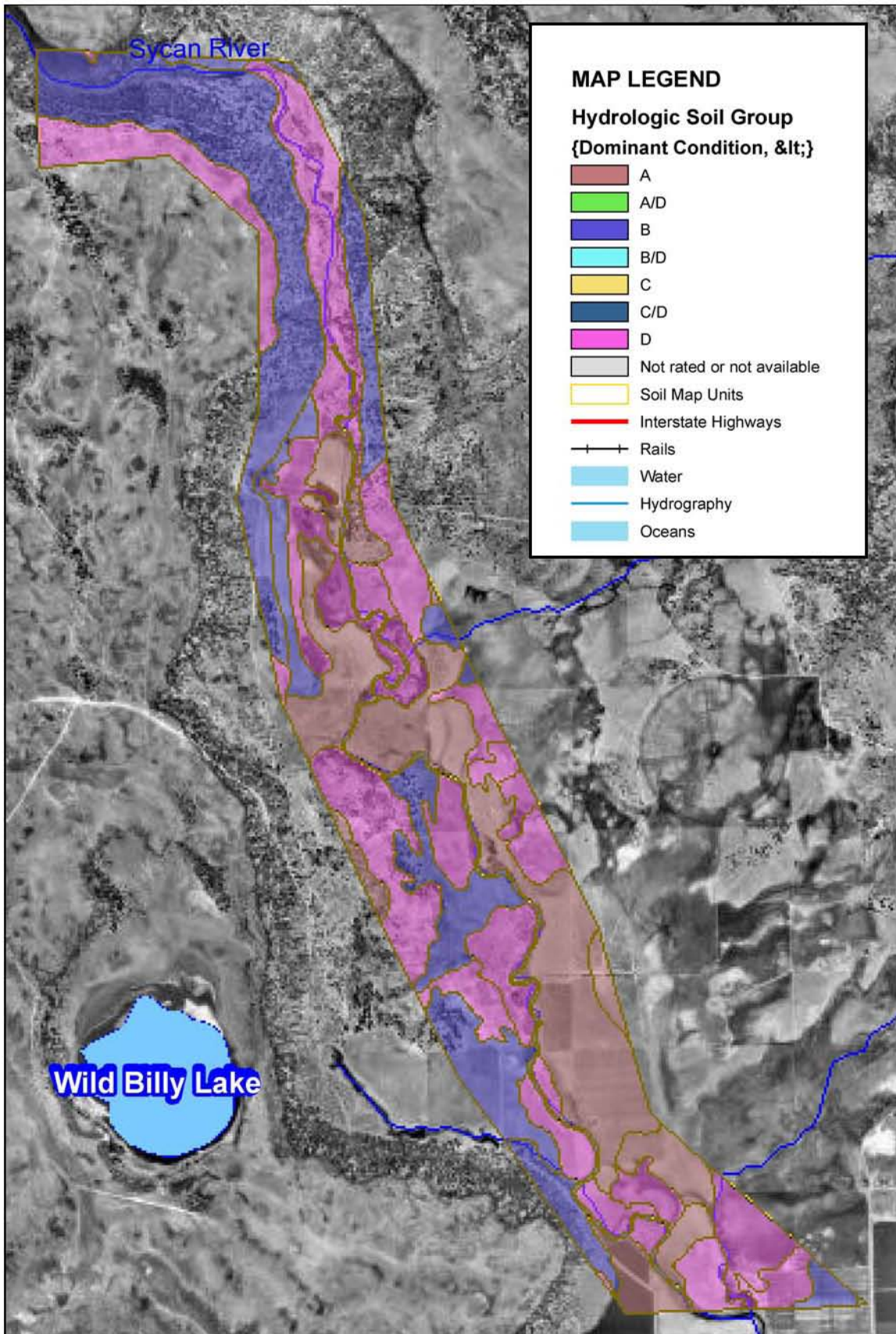


Figure D-2. Sycan River corridor hydrologic (infiltration rates) soil groups (SCS 1985).

Tables - Hydrologic Soil Group

Summary by Map Unit - Klamath County, Oregon, Southern Part

Soil Survey Area Map Unit Symbol	Map Unit Name	Rating	Total Acres in AOI	Percent of AOI
10	Chiloquin loam	D	60.8	3.5
34	Klamath-Ontko-Dilman association	D	252.5	14.5
47A	Lobert sandy loam, 0 to 2 percent slopes	B	92.0	5.3
47B	Lobert sandy loam, 2 to 12 percent slopes	B	109.8	6.3
50E	Lorella very stony loam, 2 to 35 percent south slopes	D	0.9	0.1
55E	Maset coarse sandy loam, 12 to 45 percent north slopes	B	301.2	17.2
56E	Maset coarse sandy loam, 12 to 35 percent south slopes	B	50.1	2.9
57B	Merlin-Yancy association, gently sloping	D	115.9	6.6
67E	Rock outcrop-Nuss complex, 5 to 40 percent slopes	D	140.5	8.0
73B	Steiger loamy coarse sand, 1 to 15 percent slopes	A	15.7	0.9
75	Sycan loamy sand	A	394.6	22.6
76	Sycan variant loamy coarse sand	A	44.7	2.6
89	Yonna loam	D	137.4	7.9
W	Water	Null	31.2	1.8

Description - Hydrologic Soil Group

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

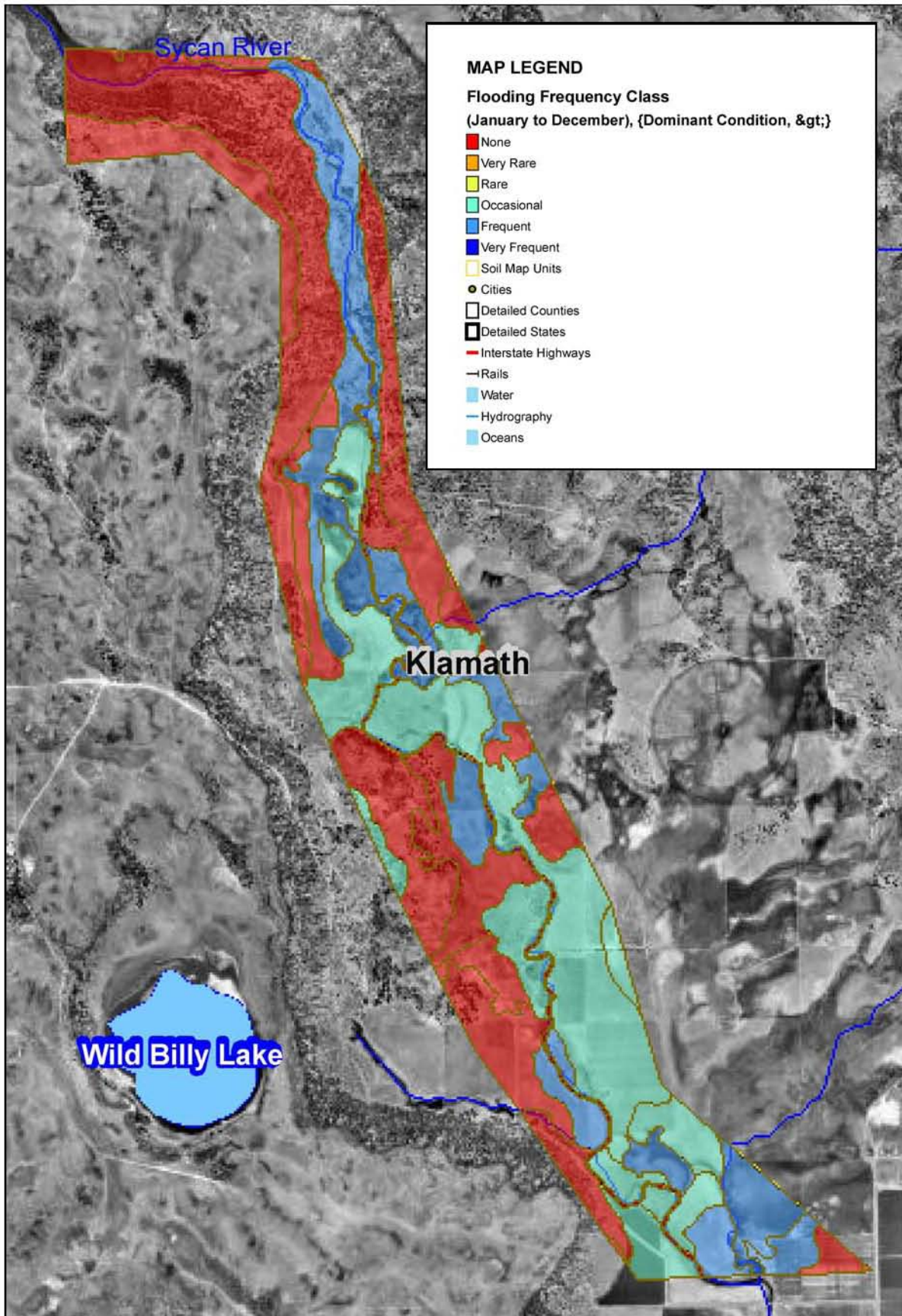


Figure D-3. Sycan River flooding frequency class map (SCS 1985).

Tables - Flooding Frequency Class

Summary by Map Unit - Klamath County, Oregon, Southern Part

Soil Survey Area Map Unit Symbol	Map Unit Name	Rating	Total Acres in AOI	Percent of AOI
10	Chiloquin loam	Occasional	60.8	3.5
34	Klamath-Ontko-Dilman association	Frequent	252.5	14.5
47A	Lobert sandy loam, 0 to 2 percent slopes	None	92.0	5.3
47B	Lobert sandy loam, 2 to 12 percent slopes	None	109.8	6.3
50E	Lorella very stony loam, 2 to 35 percent south slopes	None	0.9	0.1
55E	Maset coarse sandy loam, 12 to 45 percent north slopes	None	301.2	17.2
56E	Maset coarse sandy loam, 12 to 35 percent south slopes	None	50.1	2.9
57B	Merlin-Yancy association, gently sloping	None	115.9	6.6
67E	Rock outcrop-Nuss complex, 5 to 40 percent slopes	None	140.5	8.0
73B	Steiger loamy coarse sand, 1 to 15 percent slopes	None	15.7	0.9
75	Sycan loamy sand	Occasional	394.6	22.6
76	Sycan variant loamy coarse sand	Occasional	44.7	2.6
89	Yonna loam	Frequent	137.4	7.9
W	Water	Null	31.2	1.8

Description - Flooding Frequency Class

Flooding is the temporary inundation of an area caused by overflowing streams, by runoff from adjacent slopes, or by tides. Water standing for short periods after rainfall or snowmelt is not considered flooding, and water standing in swamps and marshes is considered ponding rather than flooding.

Frequency is expressed as none, very rare, rare, occasional, frequent, and very frequent.

"None" means that flooding is not probable. The chance of flooding is nearly 0 percent in any year. Flooding occurs less than once in 500 years.

"Very rare" means that flooding is very unlikely but possible under extremely unusual weather conditions. The chance of flooding is less than 1 percent in any year.

"Rare" means that flooding is unlikely but possible under unusual weather conditions. The chance of flooding is 1 to 5 percent in any year.

"Occasional" means that flooding occurs infrequently under normal weather conditions. The chance of flooding is 5 to 50 percent in any year.

"Frequent" means that flooding is likely to occur often under normal weather conditions. The chance of flooding is more than 50 percent in any year but is less than 50 percent in all months in any year.

"Very frequent" means that flooding is likely to occur very often under normal weather conditions. The chance of flooding is more than 50 percent in all months of any year.

APPENDIX E CHANNEL HYDRAULICS SUMMARY

E.1 INTRODUCTION

The U.S. Fish & Wildlife Service retained River Design Group, Inc. (RDG) to conduct a detailed existing conditions assessment of the Syscan River from the end of the Coyote Bucket Canyon to Drews Road. The primary goal of the project was to characterize existing river corridor conditions and evaluate the feasibility of restoration treatments. One task of the assessment included a hydraulic analysis of the Syscan River. This report presents and summarizes the methods and results of the hydraulic analysis.

RDG developed the following objectives for the hydraulic analysis.

1. To model existing channel hydraulics to evaluate discharge, water surface elevation, and water velocities over a range of flows.
2. To compare modeled water surface elevations to landforms in the Syscan River corridor.
3. To evaluate the potential for increasing the frequency of river access to the adjacent floodplain.

This report is organized in five main sections. Section 1 provides a general project background and presents hydraulic modeling purposes. Section 2 details the hydraulic modeling methods. Section 3 presents the modeling results. Section 4 reviews the hydraulic conditions in the context of potential restoration opportunities in the project area.

E.2 HYDRAULIC MODELING PURPOSE

Modeling was completed to evaluate channel hydraulics in the project area. The modeling exercise was broken out into two tasks. The first task included developing the model for the purpose of evaluating water surface elevations by recurrence interval. The hydraulic model output included flood maps (see *Appendix F – Flood Inundation Maps*) for the 1.7-year, 2-year, 5-year, 10-year, and 20-year flood events. Events greater than the 20-year runoff were not modeled as the entire project area valley bottom is flooded at the 20-year event.

The second task included evaluating water surface elevations associated with the 1.7-year, 2-year discharge, and the 5-year discharge, in relation to the landform surfaces in the project area. The purpose of this exercise was to evaluate the degree of channel entrenchment. The modeled cross-sections were located in both low, moderate and highly confined reaches. Modeling output is included Section D.4 Modeling Results.

E.3 MODELING METHODS

The LIDAR/bathymetry data set was used for modeling the existing channel conditions. Forty channel cross-sections (Figure E-1) were extracted from the data set using HEC-GeoRAS Version 4.1.1 (USACE 2006). In addition to the cross-sections, other input GIS layers included the main channel center line, flow direction path lines for the main channel and for the floodplain, stream

bank lines, and ineffective flow area polygons. After the necessary input layers were created, the HEC-GeoRAS extension tools were used to attribute the input layers and to extract the GIS data to a RAS geometry import file. The resulting RAS import file was imported into HEC-RAS for hydraulic modeling.

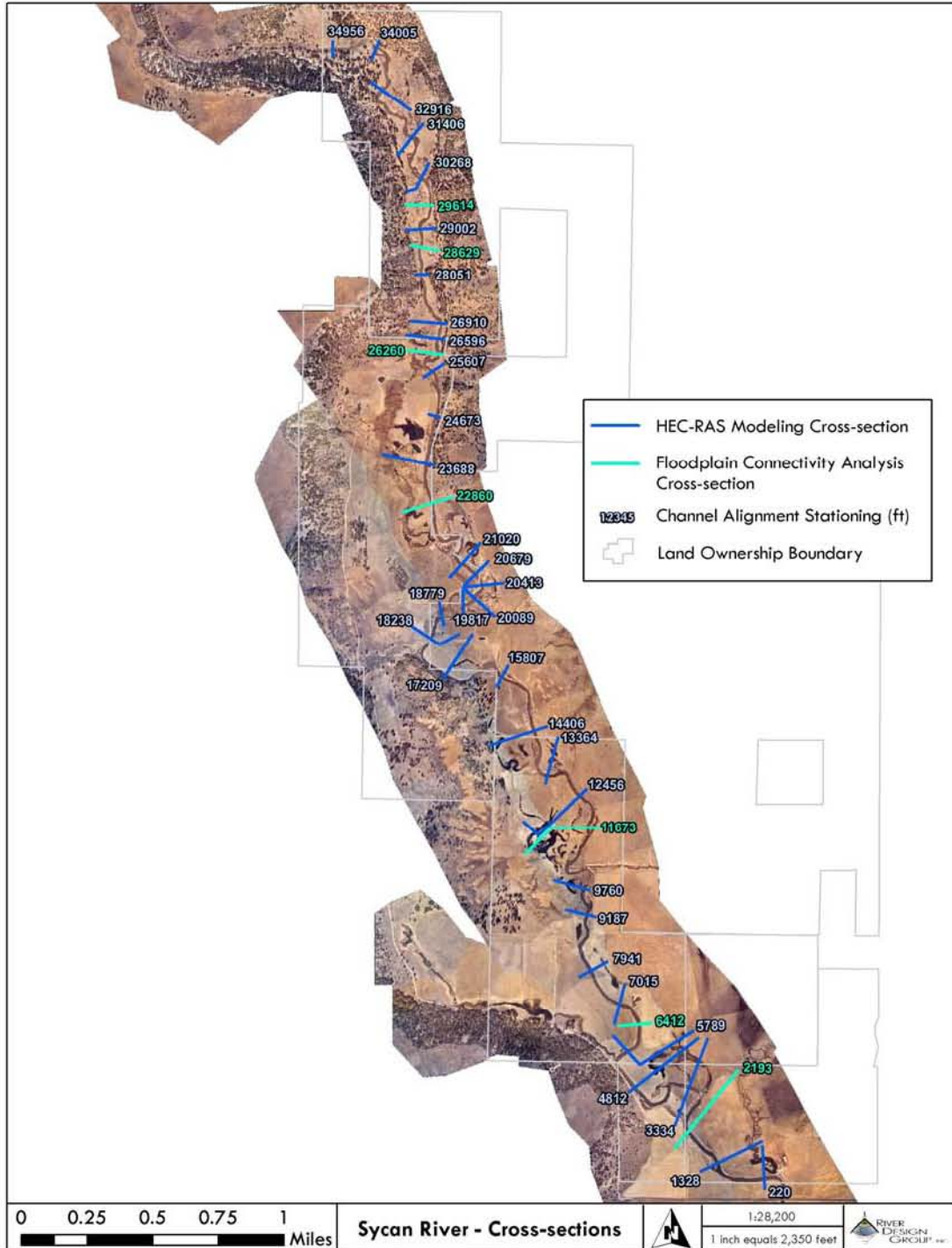


Figure E-1. The cross-section locations for the Sycan River project area HEC-RAS hydraulic model.

E.3.1 Modeling Considerations

Channel Cross-sections

River corridor morphology was delineated into three features: active channel, floodplain, and terraces. The active channel conveys flows from baseflow up to approximately the 2-year discharge. The floodplain is a flat or undulating landform adjacent to the active channel that is undated when the active channel’s capacity is exceeded. Terraces are the highest elevation landforms in the river corridor. Terraces are generally not inundated until the 5-year or greater discharge. Figure E-2 illustrates a river corridor cross-section from Reach 2 and a ground photo from Reach 3 to illustrate the varying landform positions in the Sycan River project area.

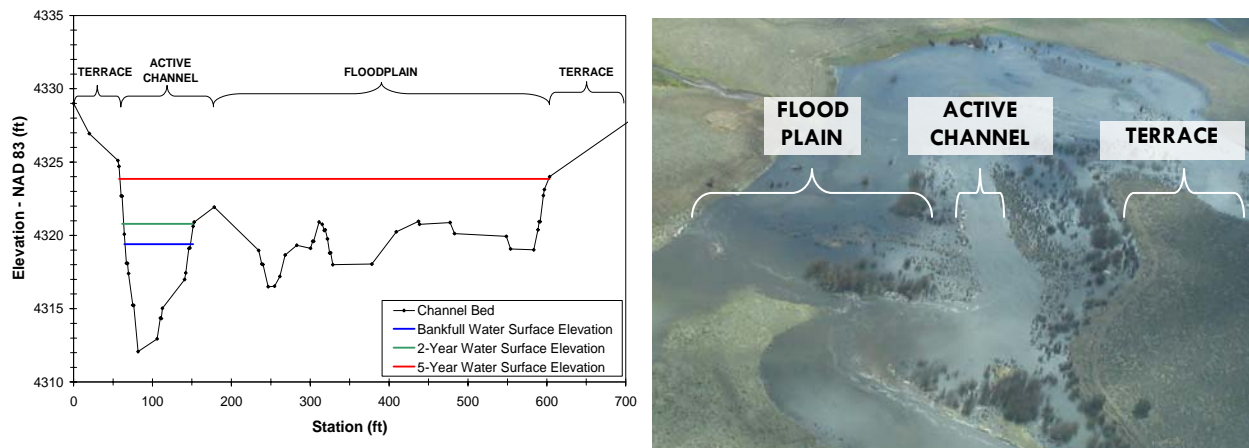


Figure E-2. A typical cross-section (left) and photograph (right) of the river corridor and determination of geomorphic features. The photograph was taken during an approximately 2.4-year flood event.

Flood Frequency Values

Modeled discharge values were taken from the Sycan River flood frequency (see Appendix A-Hydrology). The flood frequency is based on 12 years of peak flow data, a relatively short period of record for completing a flood frequency analysis. OWRD regional equations were also used to compile the flood frequency. The flood frequency table is included in Table E-1. The Log Pearson Type III results were used in the hydraulic modeling (Table E-2). Previous modeling at the Sycan River gaging station at Drews Road suggests the 1.7-year discharge approximates the Sycan River’s bankfull discharge.

Table E-1. The log Pearson Type III flood frequency for the Sycan River developed from the 12 years of peak flow data. Results from the OWRD regional equations are also presented.

Method	Recurrence Interval (yrs)								
	1.5	1.7	2	5	10	20	50	100	500
Log Pearson Type III	720	750	1,180	2,770	3,970	5,130	6,590	7,620	9,714
OWRD Regional Equations			1,120	2,160	3,070	4,100	4,460	7,040	10,900

Table E-2. Recurrence interval events that were used for the Sycan River hydraulic analysis.

Method	Recurrence Interval (yrs)				
	1.7	2	5	10	20
Log Pearson Type III	750	1,180	2,770	3,970	5,130

The 2006 peak flow of 1,930 cfs occurred on April 14 (Graham Matthews and Associates, unpublished data). The peak was approximately a 3.5-year return interval event. The peak flow occurred two days after air photos were taken of the project area (Faye Weekly, USFWS, unpublished data). The flow at the time of the air photos was approximately 1,400 cfs, approximately a 2.4-year event. Air photos were used to validate modeling results for the 2-year model.

Estimation of Channel Roughness

Manning's-n value is used as a surrogate indicator of channel roughness for hydraulic calculations. An explanation of the Manning's-n value is included below.

The following information is taken from Limerinos (1970).

...the "Manning formula," has been used extensively as an indirect method for computing flows in natural channels. Although this equation was theorized and developed for uniform-flow conditions, adjustments for assumed energy losses attributable to an expanding or contracting river reach permit its use in channels with gradually varied flow. These assumptions have led to relatively reliable results when used within the range of verified channel-roughness data. Confident selection of values of the Manning roughness coefficient, n , usually requires considerable experience. Tables of computed n values for various channel conditions, and illustrations and stereoscopic color slides of channels for which n has been verified, are available to help the practicing engineer select an appropriate n value...However, the lack of complete similarity in channel conditions and geometry from stream to stream makes it difficult to estimate channel roughness from illustrations and stereoscopic slides.

In streams with relatively stable boundaries, the total resistance to flow or retardation of velocity results from the interaction of many elements. Among them are particle size of streambed material, bank irregularity, vegetation, channel alignment, bed configuration, channel obstructions, converging or diverging stream lines, sediment load, and surface waves. With our present knowledge the quantitative effect of most of these factors is not determinable and must be estimated subjectively.

Because the Sycan River is a low gradient system, channel roughness strongly influences hydraulics. Preliminary modeling runs suggested that moderate changes in channel roughness (Manning's-n value) corresponded with considerable changes in water surface elevations and velocities. For example, by increasing the Manning's-n value from 0.025 to 0.035, water surface elevations in the project area increased by 1 ft.

Discharge measurements completed on the Sycan River from Coyote Bucket downstream to Drews Road by RDG, and from Drews Road downstream through the lower Sycan River by Graham Matthews and Associates, support using a range of Manning's-n values for evaluating channel

hydraulics. Low stage discharge measurements in the project area yielded Manning's-n values from 0.066 to 0.030. Flood stage values ranged from 0.057 at the mouth of Coyote Bucket Canyon where the bed is characterized by large boulders and the flow is turbulent, to 0.027 on the Shields' property in Reach 5 where the channel is relatively smooth and flow is more laminar. Hydraulic modeling of field surveyed cross-sections that had low stage discharge measurements suggested a range of bankfull discharge Manning's-n values from 0.022 to 0.030.

For the HEC-RAS model, modeling runs were completed with Manning's-n values of increasing roughness; 0.020, 0.025, 0.030, and 0.035. The values bracket the range of high stage channel roughness values determined from field sampling and at-a-station hydraulic modeling.

Average Channel Slope

An average channel slope of 0.0002 was used for the hydraulic model. Channel slopes in the project area based on field data collection are included in Table E-3.

Table E-3. Summary channel slope information for the project area.

Reach	Average Bankfull Slope	Average Water Surface Slope	Riffle Bankfull Slope	Riffle Water Surface Slope	Pool Bankfull Slope	Pool Water Surface Slope
Reach 1	0.0049	0.0058	0.0146	0.0112	0.0022	0.0019
Reach 2	0.0009	0.0009	0.0032	0.0035	0.0009	0.0006
Reach 3	0.0001	0.0003	0.0003	0.0004	0.0001	0.0002
Reach 4*	N/A	N/A	N/A	N/A	N/A	N/A
Reach 5	0.00007	0.00004	0.00007	0.00011	0.00007	0.00002

*: A channel profile was not completed in Reach 4.

Ineffective Flow Areas

Ineffective flow areas were delineated at each cross-section. Ineffective flow areas included off-channel wetlands and other depressions that had lower elevations than the surrounding land surface. By designating ineffective flow areas, the hydraulic model does not include these areas in the active channel conveyance until the ineffective flow elevation is exceeded. Once the ineffective flow elevation is exceeded, the ineffective flow area is included in the channel conveyance calculation.

E.4 MODELING RESULTS

E.4.1 Flood Extent Model

Flood inundation maps (see *Appendix F – Flood Inundation Maps*) were produced from the HEC-RAS model. The maps were completed with an average slope of 0.0002 and a Manning's-n value of 0.030. Variation in water surface elevations associated with increasing Manning's-n values is discussed in the next section. Anomalies that occur in the flood maps such as truncation of flood boundaries is due to model irregularities associated with the LIDAR data and HEC-RAS cross-section properties.

The 1.7-year flood interval map shows the discharge is generally confined within the channel. Several off-channel features especially in Reach 4 are also inundated. These inundated off-channel habitats are likely related to groundwater and low areas that are connected with the channel. The 2-year interval flood map indicates more frequent flooding of off-channel habitats especially in Reach 2, Reach 4, and the middle of Reach 5. Reach 3 and the lower section of Reach 5 contain the flow within the channel. Floodplain interaction is most widespread on the Cornelson property in the middle of Reach 4, and in the Kronenberger wetland area of Reach 5.

The 5-year interval flood inundates the lower elevation floodplain features throughout the river corridor. High terraces in Reach 3 and Reach 5 continue to confine the flows although surface channels are also inundated. The 10-year event inundates the entire valley bottom in Reach 2. Confining hillslopes and terraces limited lateral flooding through Reach 3. High terraces through Reach 5 have limited flooding along the terrace edges. The 20-year interval model suggests the greatest change in inundation area between the 10-year and 20-year events is upstream of the Snake Creek confluence in lower Reach 5.

E.4.2 Floodplain Connectivity Model

Discharge Profiles

Two processes were completed to evaluate floodplain connectivity. The first process included modeling the 40 HEC-RAS cross-sections at the 1.7-year, 2-year, and 5-year return interval flood events. The Manning's-n value was adjusted from 0.020 to 0.035 to provide a range of water surface elevations and water velocities as a function of channel roughness. Reach models were also completed with reach-specific slopes based on field data collection. The results are graphed to illustrate differences in water surface (Figure E-3) and velocity (Figure E-4) by event and Manning's-n value.

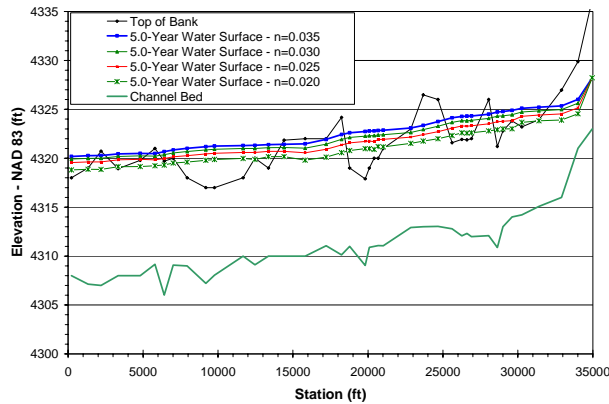
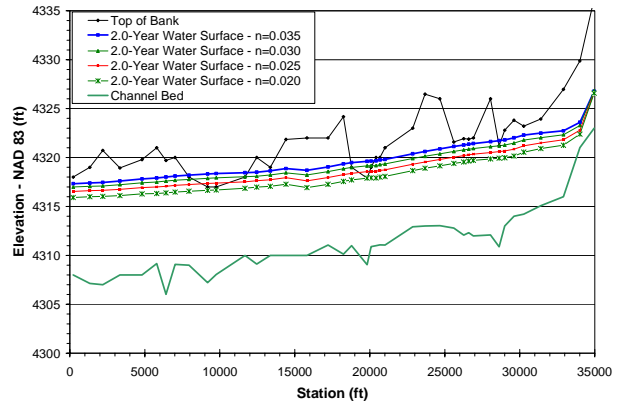
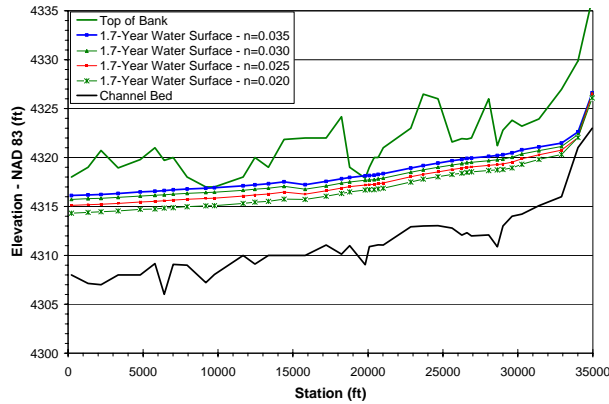


Figure E-3. Modeled water surface elevations in the Sycan River project area. Graphs illustrate the 1.7-year (upper left), 2-year (upper right), and 5-year (lower left) return interval flood events. Graphed curves illustrate the influence of the Manning’s-n value on the water surface elevation. Increasing Manning’s-n values corresponded with increasing water surface elevations for a given discharge.

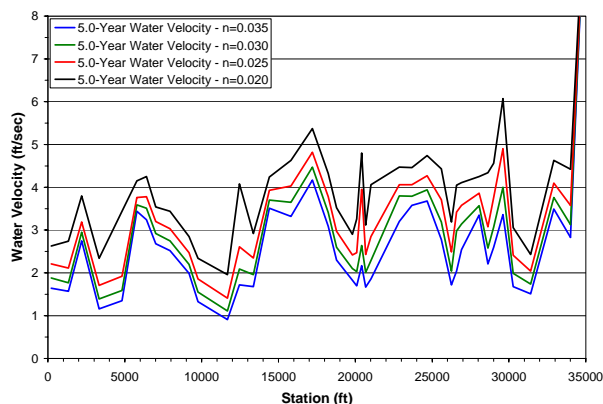
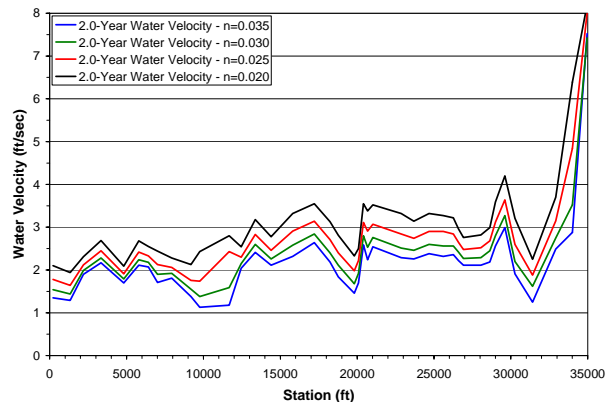
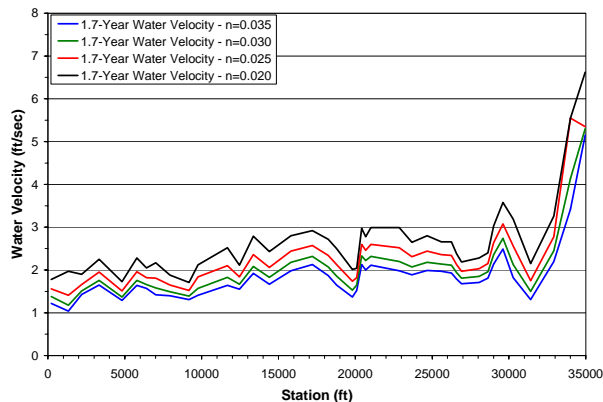


Figure E-4. Modeled water velocities in the Sycan River project area. Graphs illustrate the average water velocities associated with the 1.7-year (upper left), 2-year (upper right), and 5-year (lower left) return interval flood events. Graphed curves illustrate the influence of the Manning’s-n value on the water velocity. Increasing Manning’s-n values corresponded with decreasing water velocities (and increased water surface elevation) for a given discharge.

Figure E-5 illustrates water surface elevations for the 1.7-year, 2-year, and 5-year return interval events using a Manning's-n value of 0.030. The applied Manning's-n value is on the high end of the range of channel roughness but illustrates the degree of connectivity between the channel and floodplain. The channel thalweg and top of bank elevations are presented for reference. The reach breaks were delineated based on valley and channel morphologies and were determined based on field assessment and remote sensing. The degree of channel confinement in each reach is also noted. Sections qualified as 'Highly Confined' if the 5-year discharge was confined within the channel. 'Moderately Confined' sections confined the 2-year event but did not confine the 5-year event. 'Low Confinement' sections were exemplified by land surfaces that were accessed by the 1.7-year to 2-year event.

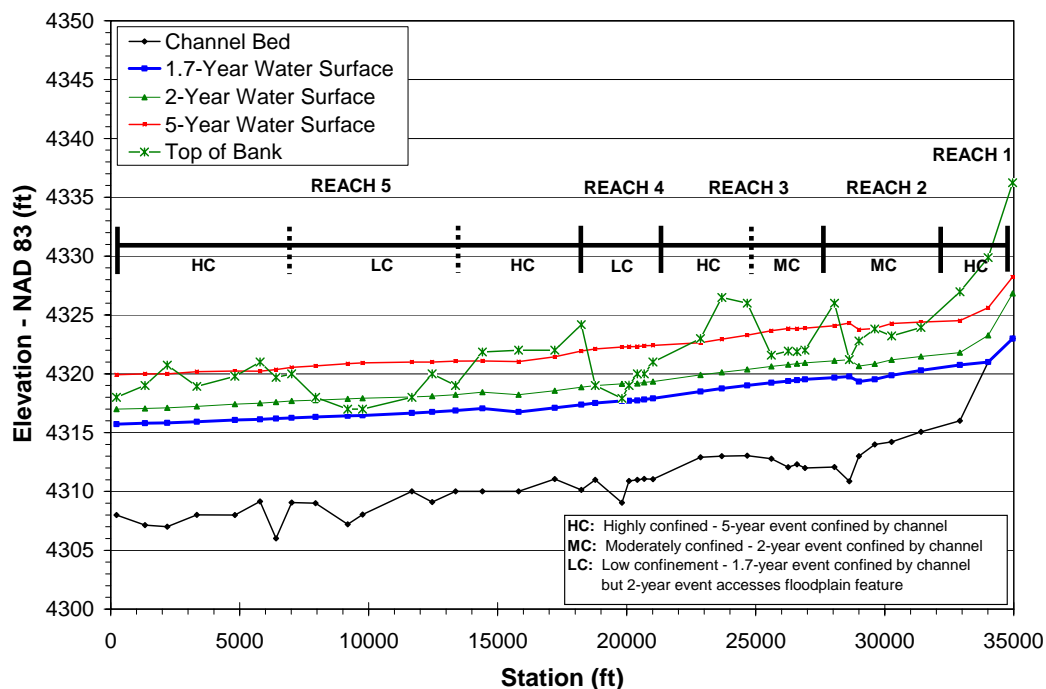


Figure E-5. Water surface elevations associated with the modeled return interval events with a Manning's-n value of 0.030. Reach breaks and degree of channel confinement are also noted.

The 1.7-year event was confined within the channel in the entire project area. The 2-year event accessed adjacent floodplain surfaces in Reach 2 and Reach 4. The 5-year event accessed floodplain surfaces through most of the project area although the 5-year discharge remained within the channel in portions of Reach 2, Reach 3, and Reach 5. Confining landforms in these reaches included high terraces and hill slopes.

Water velocities were also plotted to evaluate the influence of channel confinement (Figure E-6). In general, the highest water velocities were associated with the 5-year event in highly confined sections of the project area. In reaches with moderate to low channel confinement, the 5-year event average water velocities were similar to or less than the 1.7 year and 2-year water velocities. This pattern suggests the stream energy reduction benefits of a channel connected to an adjacent floodplain. 2-year event water velocities were generally higher than 1.7-year velocities except where the 2-year discharge accessed floodplains.

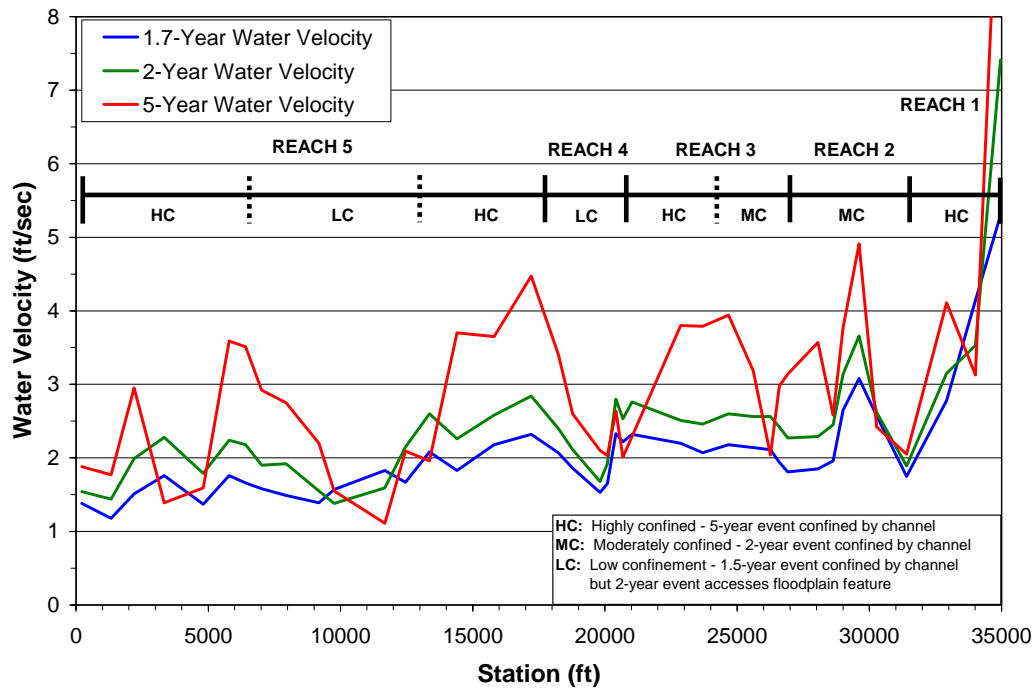


Figure E-6. Average water velocities associated with the modeled return interval events with a Manning's-n value of 0.030. Reach breaks and degree of channel confinement are also noted.

Figure E-5 and Figure E-6 illustrate the influence of channel roughness on water surface elevation and water velocities for a given discharge. In short, an increase in Manning's n-value corresponds with higher water stage and lower water velocity. Further increasing water stage for a given discharge would increase floodplain storage of floodwater for release later in the season. Lower water velocities correspond with lower bank erosion potential and longer retention of nutrients.

Discharge Cross-sections

The second process included modeling seven cross-sections to evaluate water surface elevations relative to adjacent landforms. The seven cross-sections were located in Reach 2 (two cross-sections), Reach 3 (two cross-sections), and Reach 5 (three cross-sections). Cross-sections were located in low confinement, moderately confined, and highly confined sections of Reach 2, Reach 3, and Reach 5.

Modeling results suggest most of the Sycan River does not access adjacent floodplain surfaces until discharge exceeds the 2-year interval flood. Modeled cross-sections that included floodplain surfaces generally had floodplain channels with invert elevations lower than the modeled bankfull discharge water surface elevation. Air photo and ground photo documentation of floodplain inundation in 2006 suggests that floodplain channels are inundated by groundwater and surface water when accessed by the river. Although modeled cross-sections suggest floodplain channels are not inundated by the river until after the 2-year discharge, flooding does occur due to bank irregularity, surface water inputs from upstream portions of floodplain channels, and groundwater upwelling.

In Reach 3 and Reach 5 where the Sycan River is confined by lateral terraces and hillslopes, flood flows up to the 5-year event are confined within the channel. Soil properties and vegetation conditions in these reaches also suggest infrequent flooding of high terraces.

Figures D-7 through D-13 provide brief descriptions of the modeled cross-sections.

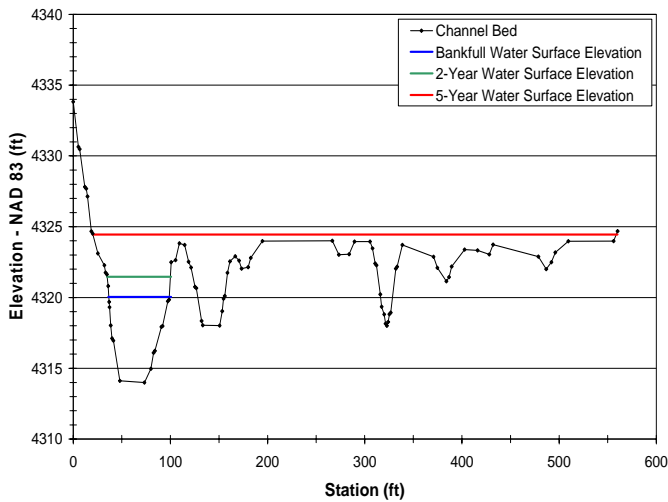


Figure E-7. The hydraulic channel cross-section at Station 29613 (left) and an air photo of the reach at a 2.4-year event on April 12, 2006 (right). The modeled cross-section suggests that over a 2-year discharge is contained within the channel.

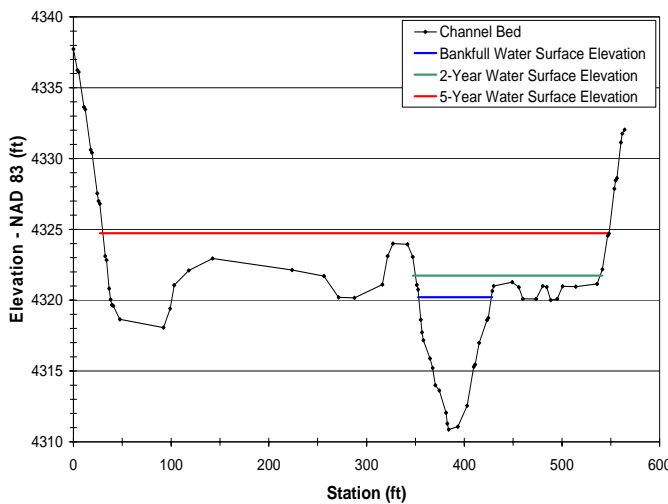


Figure E-8. The hydraulic channel cross-section at Station 28628 (left) and a ground photo taken in June 2006 after recession of peak flows (right). The modeled cross-section suggests that the 2-year event accesses floodplain channels. The valley bottom is inundated during a 5-year event. Floodplain channels hold water through spring and early summer.

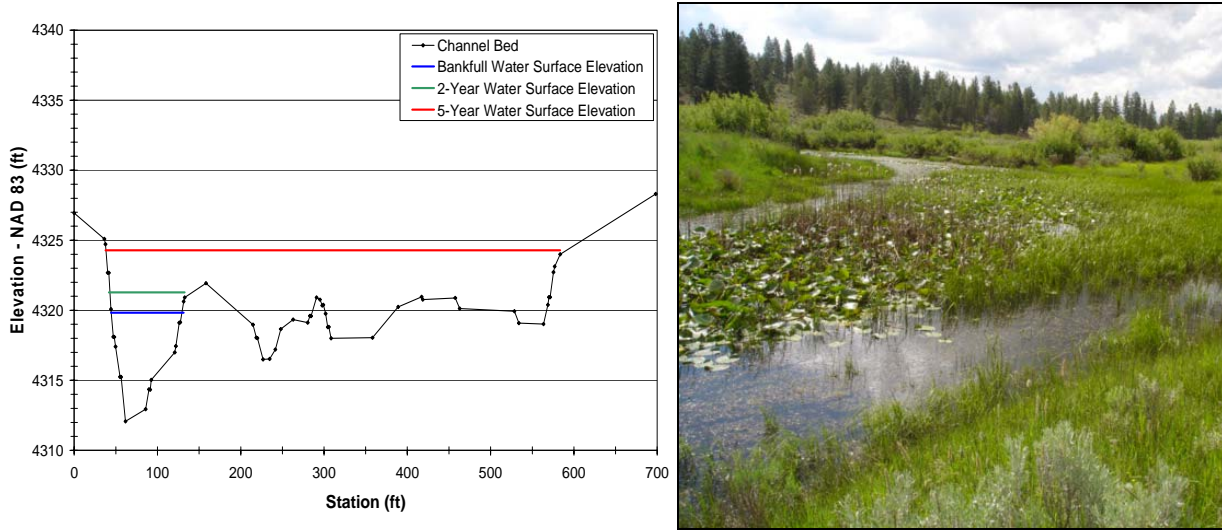


Figure E-9. The hydraulic channel cross-section at Station 26260 (left) and a ground photo taken in June 2006 after recession of peak flows (right). Floodplain channels are lower than the primary channel’s bankfull water surface elevation. Although groundwater inundates the sidechannels, the river does not overtop its banks until approximately the 2-year event at the cross-section location.

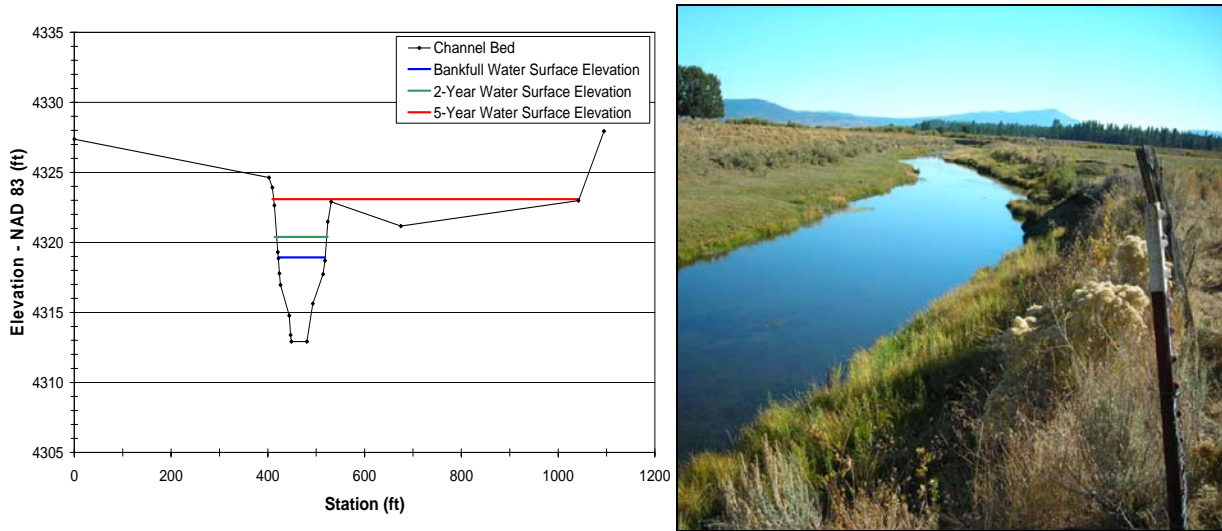


Figure E-10. The hydraulic channel cross-section at Station 22860 (left) and a ground photo taken in September 2006 (right). Located in lower Reach 3, the Sycan River on the Shields’ property is confined between the eastern hillslope and the western terrace. Flows are confined in the channel until at least the 20-year event through most of lower Reach 3. The hydraulic channel cross-section was located in a portion of the reach with an off-channel wetland.

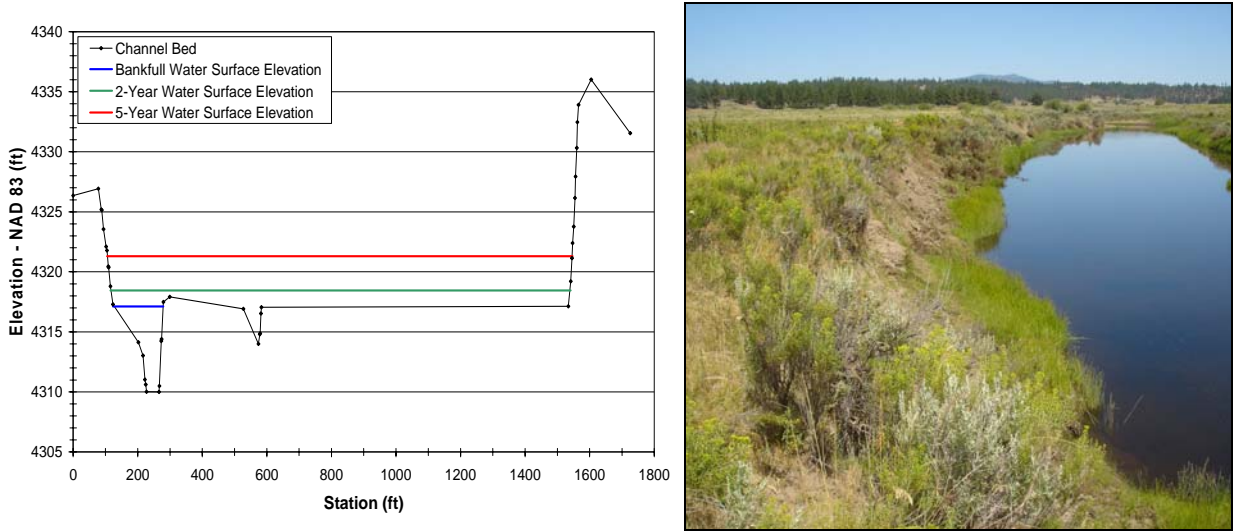


Figure E-11. The hydraulic channel cross-section at Station 11672 (left) and a ground photo (looking upstream) taken in July 2006 (right). Located in Reach 5 on the Kronenberger property, the flat land surface between station 2+50 and 14+75 corresponds to the sagebrush surface in the left portion of the photo. The high peak in the cross-section chart is the western hill slope leading to the Knott Tablelands. The 2-year event accesses the flat to the west of the river.

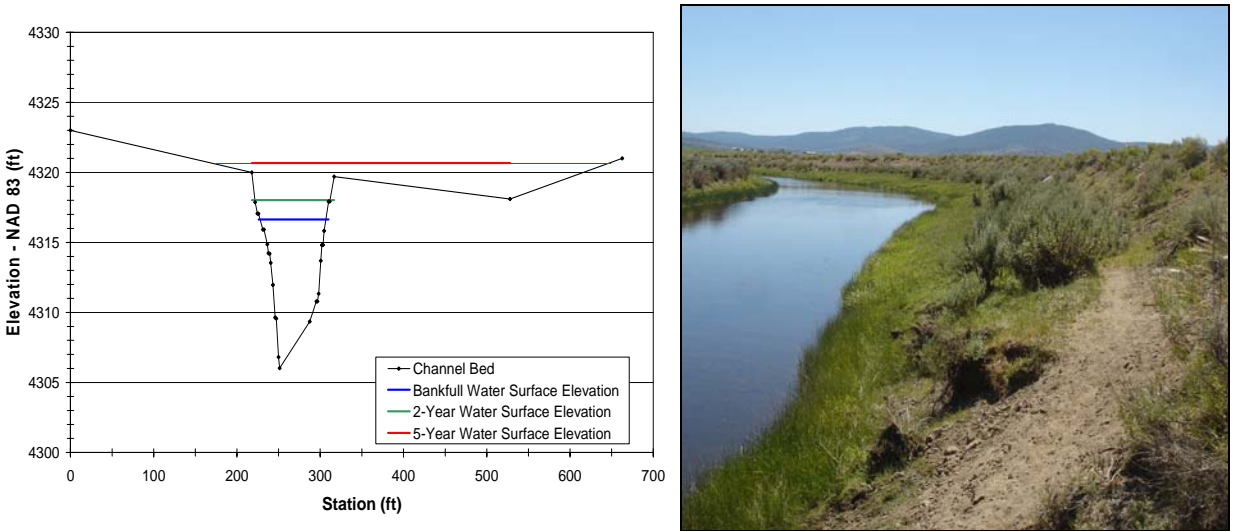


Figure E-12. The hydraulic channel cross-section at Station 6411 (left) and a ground photo taken upstream of the cross-section location illustrating typical river corridor conditions in lower Reach 5. The channel is confined between high terraces. Up to the 5-year event is contained in the channel. This area is also influenced by the backwater that is created when the Sprague River floods.

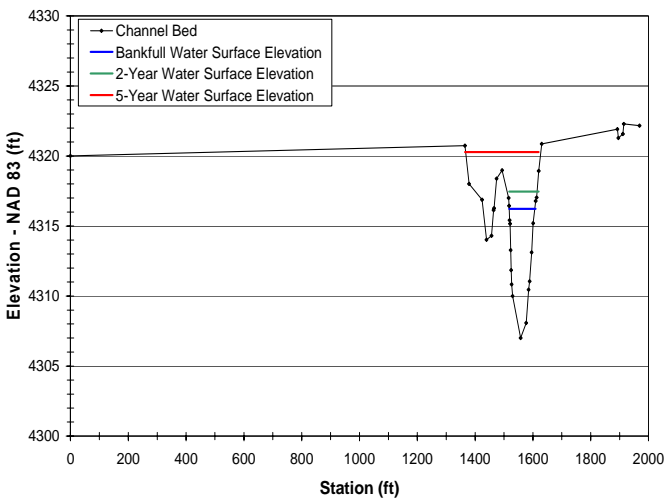


Figure E-13. The hydraulic channel cross-section at Station 2192 (left). The channel is confined between high terraces. A wetland adjacent to the channel provides off-channel habitat. The photo on the right shows the Sycan River during high water in May 2005. This area is also influenced by the backwater that is created when the Sprague River floods.

E.5 DISCUSSION

Hydraulic modeling was completed to investigate flood inundation and floodplain connectivity in the Sycan River project area. A HEC-RAS model was developed using cross-sections extracted from the LIDAR dataset. Due to the Sycan River's flat channel slope, channel roughness has a substantial influence on channel hydraulics. Manning's- n values ranging from 0.020 to 0.035 and flood return intervals ranging from the 1.7-year to the 20-year event were modeled. Water surface elevations increased with increasing channel roughness. Water velocities decreased with increasing channel roughness. Water velocities also responded to degree of channel confinement.

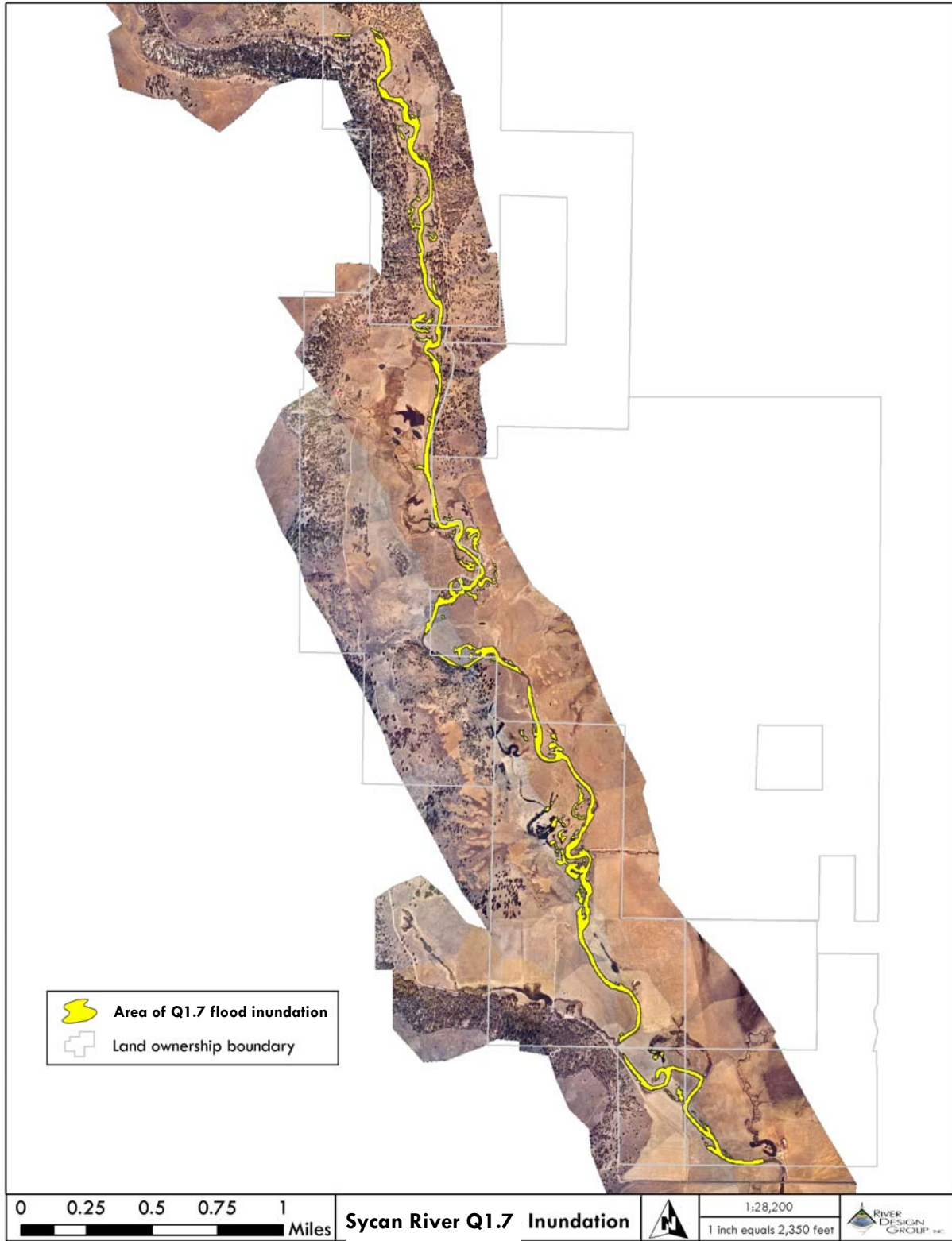
The Sycan River interacts with floodplain surfaces in Reach 2 and Reach 4. When the discharge exceeds the 2-year event, the river accesses floodplains in portions of Reach 3 and Reach 5. Where high terraces or hillslopes narrow the valley bottom or limit lateral channel migration, the Sycan River does not flood these landforms until at least the 5-year flood event.

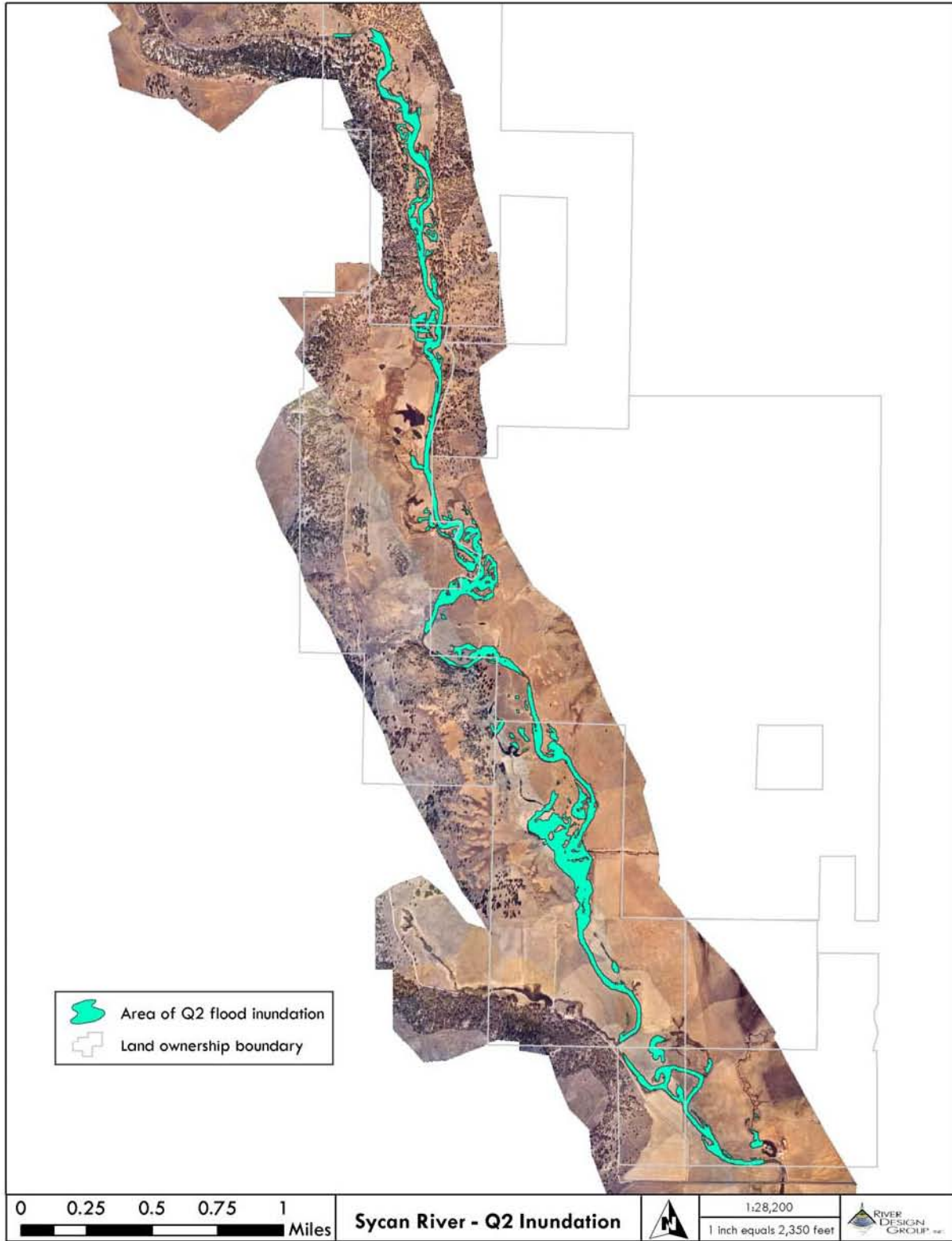
Although the recurrence interval of bankfull has been variously reported as ranging from about 1 to 25 years (Williams 1978), the majority of reported recurrence intervals range from 1 to 2 years with common values spanning from 1.5 to 1.7 years (Emmett and Wolman 2001). Results from the Sycan River hydraulic analysis suggest that the channel's capacity is not exceeded until at least a 2-year event is reached. Aerial photographs completed at approximately a 2.4-year event show much of the lower elevation floodplain surfaces receive water at this recurrence interval. Lower sections of the Sycan River that are bracketed by hillslopes and high terraces confine discharge events up to the 5-year discharge.

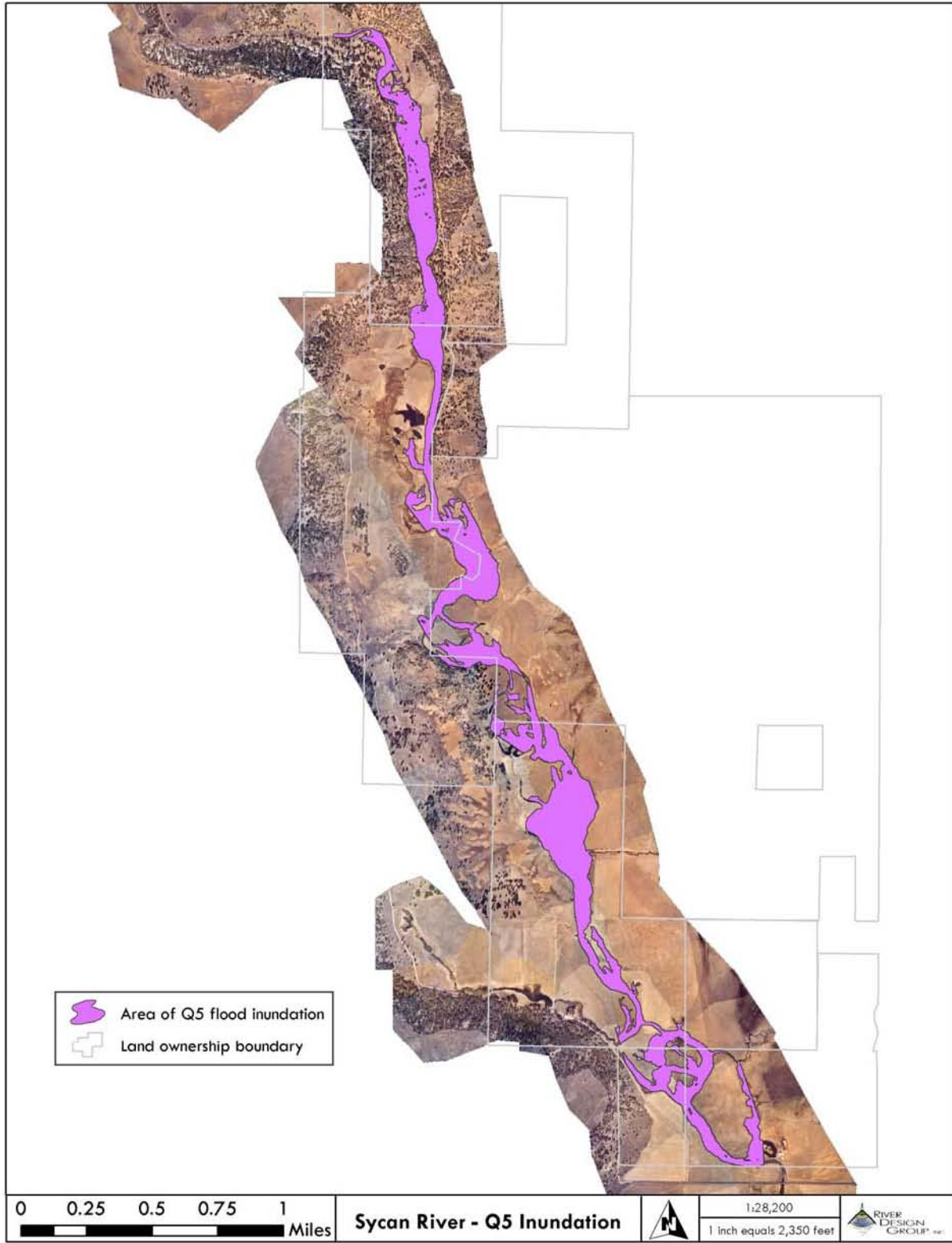
It is unclear if the Sycan River has degraded relative to an historical condition. However, based on modeling results and the abandonment of former baseflow channel features since 1941, minor incision appears to have occurred in the project area. If the Sycan River historically accessed adjacent floodplains at a recurrence interval of 1.7-years, current channel conditions suggest the

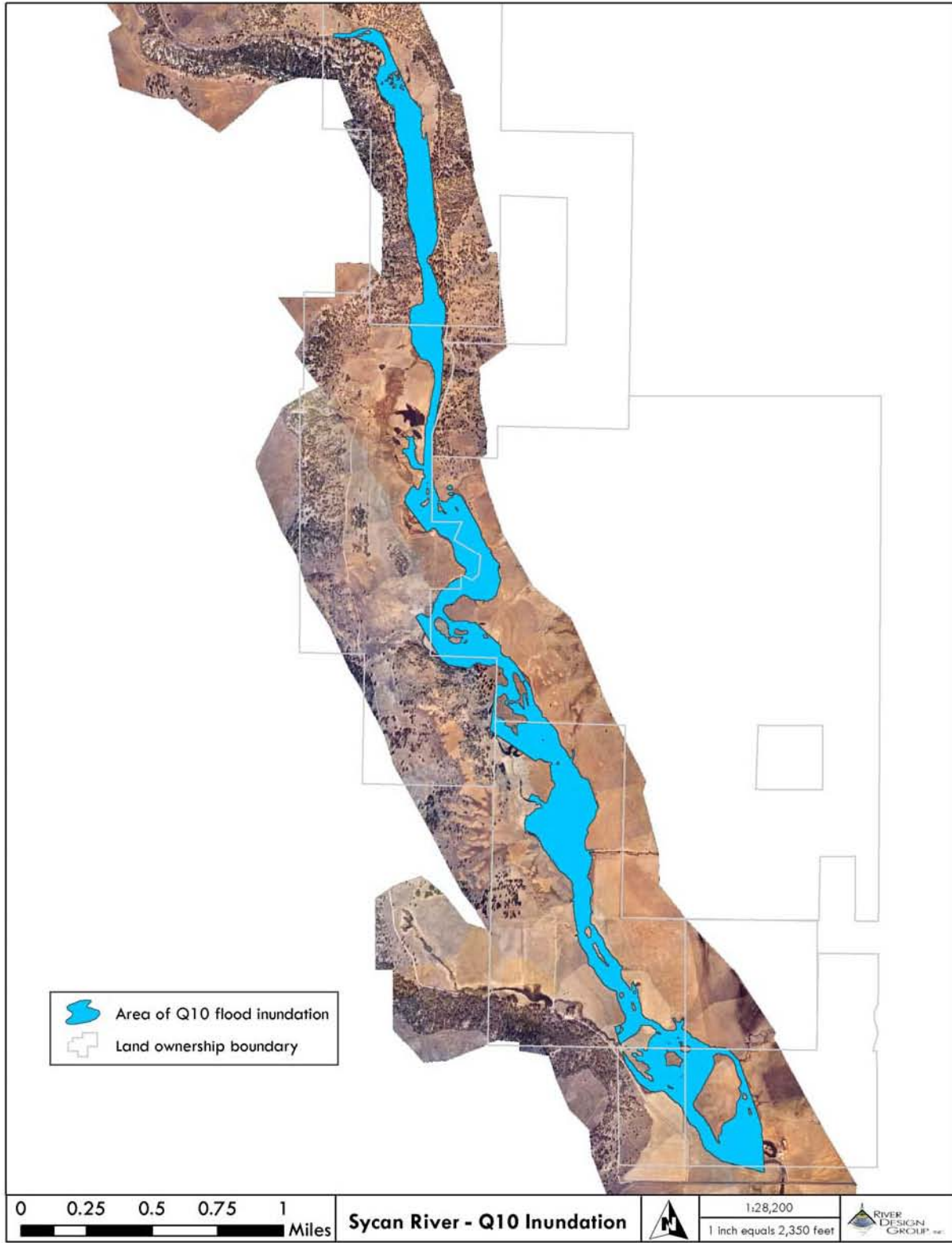
river has degraded approximately 3 ft. Processes that may have resulted in channel incision include increased peak flows related to altered hydrology in the Sycan Marsh, vegetation removal by grazing, and periodic flood events that affected streambank stability.

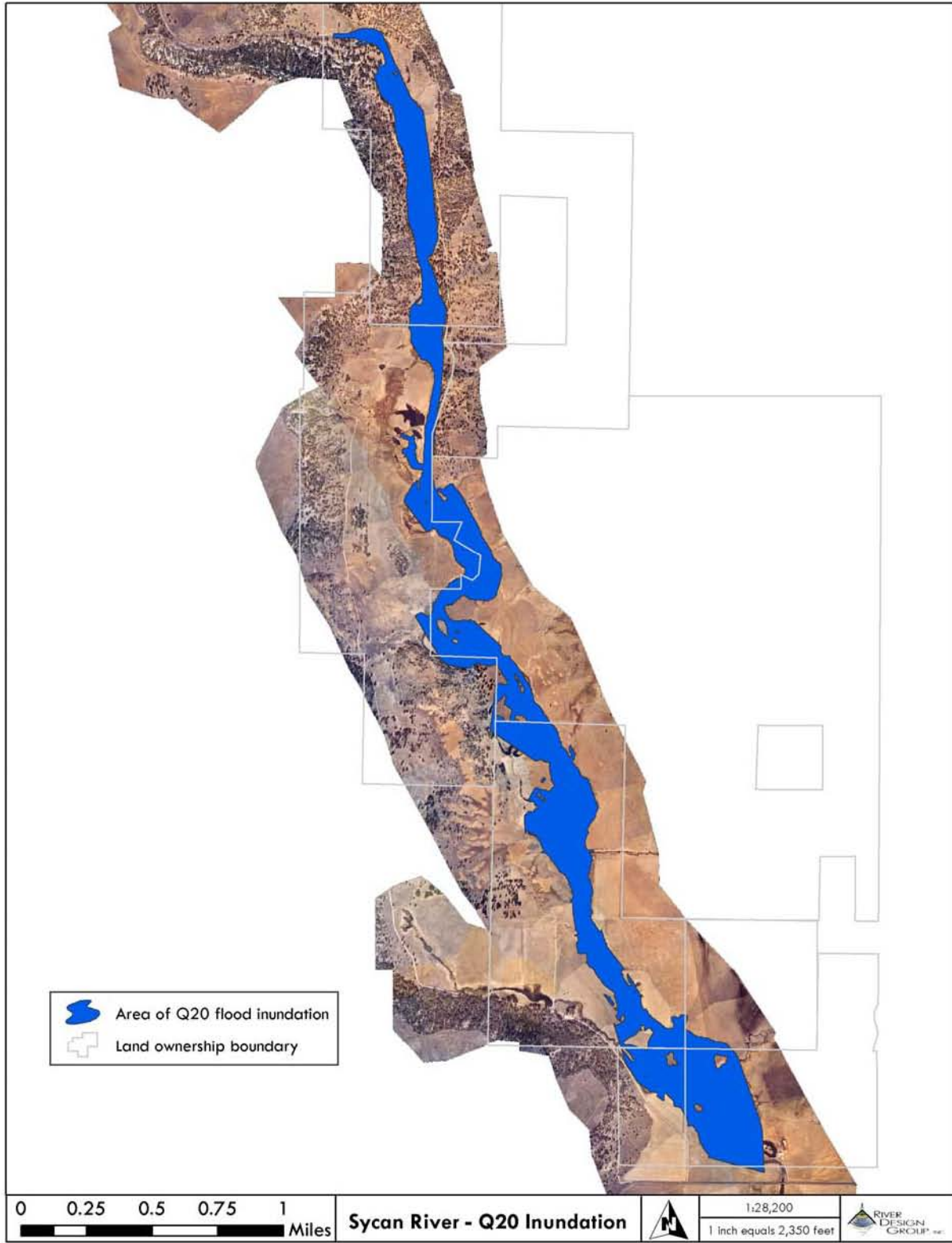
Increasing channel roughness is one means of increasing water stage and reducing instream velocities. On-going efforts in the Sycan Marsh to restore the historical hydrology are expected dampen peak flood events. Excluding livestock from the active channel and floodplains would improve vegetation conditions, resulting in denser riparian corridor. Sediment storage and vegetation colonization of sediment deposits would increase channel roughness and increase the frequency of channel-floodplain interaction. Increasing the beaver population would also be expected to increase water and sediment storage in the basin. Marsh restoration, livestock exclusion, and beaver are three possible elements for addressing current hydraulic conditions in the Sycan River project area.











APPENDIX G VEGETATION AND WETLANDS ANALYSIS

G.1 INTRODUCTION

This section describes the historical, existing and desired future conditions of the riparian, wetland, and associated upland plant communities in the Syscan River project area. Many factors influence existing vegetation patterns including geomorphic setting, water source, hydrodynamics, soils, and disturbance. In addition, land use patterns and human-caused disturbance have affected significant shifts in vegetation communities, composition, and distribution.

G.2 VEGETATION

The following sections review the historical, current, and desired future conditions for vegetation communities in the Syscan River project area. Channel stationing relates to reach maps air photos in *Appendix C – Index Maps*.

G.2.1 HISTORICAL VEGETATION CONDITIONS

Because little information is available about vegetation prior to recent settlement of the Syscan River drainage, historical conditions are discussed based on observing riparian plant communities in the Teddy Powers Meadows reference reach, combined with our knowledge of general disturbances affecting vegetation. The existing plant communities in the project area likely resemble the historical plant communities. However, several changes to the historical plant communities including the introduction of noxious weeds, grazing effects, and reduction in the beaver population mark several changes to project area plant communities.

Introduced weed species are prominent in the project area. Bull thistle (*Cirsium vulgare*) and Canada thistle (*Cirsium arvense*) are found throughout the project area. Bull thistle grows singularly or in low density patches. Canada thistle can form dense patches. Both species are capable of displacing native vegetation and degrade forage value. These species tend to colonize drier sites and favor disturbed areas.

Livestock grazing is the primary land use in the Syscan River project area. Sheep were the earliest livestock brought to the Upper Klamath Basin. Cattle displaced sheep in the early 1900s. Reports of several hundred thousand head of livestock grazed open range in the Upper Klamath Basin in the late 1800s and early 1900s. Cattle continue to graze either open range or with limited management in the project area.

Livestock effects on the river corridor includes vegetation removal, land surface compaction, and streambank trampling. Vegetation removal is most prominent on land surfaces paralleling the low flow channel. Although these areas are submerged during high flows, sedges, rushes, and willows colonize these sites. These species provide high quality forage proximate to a water source. Grazing of this vegetation is believed to have modified the Syscan River's resistance to bank erosion and contributed to channel instability. Near-bank vegetation that would increase sediment retention and promote streambank building has been lost from much of the upper project area. Grazing on floodplain and terraces has lead to soil compaction. Compacted

surfaces decrease surface permeability and promote surface water routing. Disturbed surfaces are also more susceptible to noxious weed invasion. Cattle trampling of streambanks increases bank instability and erosion (Figure G-1). Repeated trampling related to travel routes breakdown banks and decrease vegetation diversity.



Figure G-1. Examples of grazing impacts on the Sycan River floodplain in the project area. Repeated trampling of floodplain areas (left) and grazing vegetation within the active channel corridor have led to channel instability.

Widespread beaver trapping occurred in the mid to late 1800s. Historically, beaver were likely more abundant and may have played an important role affecting the Sycan River corridor. Similar to other areas in the Sprague River valley, beaver influenced channel morphology by harvesting vegetation, building dens, and perhaps damming the main channel and side channels. The undulating surface of floodplains and terraces parallel to the Sycan River suggest historical beaver activity. Relict beaver dams and modified channel morphology is apparent in the Teddy Powers Meadows reach of the Sycan River. Currently, there are limited signs of recent beaver activity in the project area although at least beaver home has been identified in the project area. Continued trapping over the past decades has perpetuated beaver suppression. Allowing beavers to return to the project area would be expected to result in greater riparian vegetation diversity, a wider range of aquatic habitats, and a higher local water table.

In summary, the land use practices, introduced weed species, and beaver removal have influenced the Sycan River's vegetation community. Livestock grazing and removal of beaver have increased the channel's erosion potential by creating a smoother channel network. The historical riparian vegetation community was likely more dense and more functional than the existing vegetation conditions.

G.2.2 Existing Vegetation Conditions

Existing vegetation patterns are influenced by hydrology, soils, human land uses, and natural river disturbance processes. Vegetation communities may be characterized according to their position in the river corridor. A sedge/rush community is located from the edge of the baseflow channel to approximately the bankfull elevation, a willow and silver sagebrush community that brackets the bankfull elevation (plus or minus one foot), and an upland community dominated by big sagebrush. Sedge/rush and willow communities also occupy floodplain and terrace depressions.

The sedge/rush community may be an early successional community that reflects riparian area recovery from over-widening or entrenchment. Sedges and rushes colonize sediment deposited within steep banks, often forming a stable bench between the baseflow channel and the toe of floodplain and terrace slopes. Over time, if left undisturbed, these herbaceous communities will trap sediment, thereby rebuilding streambanks. Once the sedge/rush communities are established, and have built banks to an elevation that corresponds to a hydroperiod that will support willows, the sedge/rush communities may begin to shift toward a willow community. In addition to this process, willow communities can also be early successional communities and will colonize some of the depositional features as well.

Silver sage (*Artemisia cana*) was observed in several locations growing within the active floodplain of the Sycan River, often right down to the water's edge. Silver sage is considered a riparian shrub in dry regions such as the Columbia Basin, Great Basin, eastern Montana, Wyoming, and the western Dakotas. It is common on transitional wet to dryland sites where soils are dry by midsummer. Silver sage inhabits moister, colder soils and has superior flooding tolerance as compared to other woody species of *Artemisia*. A listing of riparian and wetland plant communities in Oregon includes various silver sage associations (Kovalchik 1987; Crowe 2004).

In some locations, silver sage is recognized as an early seral species that is later replaced by cottonwood, willow, and other riparian vegetation. It has also been noted as an increaser under grazing pressure. The presence of silver sage as the dominant species in riverbank and floodplain locations along the Sycan River suggests that the riparian vegetation here is in a state of disclimax potentially due to grazing. With heavy grazing various graminoids and forbs such as Nebraska sedge, Baltic rush, Kentucky bluegrass, yarrow, cinquefoil and pussytoes increase in cover in this riparian association and with continued overgrazing, Kentucky bluegrass becomes the dominant graminoid in the plant community (NRCS 1985; Crowe 2004). This vegetation change sequence appears to have occurred within some of the Sycan floodplain areas. A change in hydroperiod resulting from vertical channel incision and lack of diverse riparian plant communities is likely another factor that favors silver sage dominance; this species may be more tolerant to these conditions than other riparian shrub communities.

Along the Sycan River, we observed silver sage functioning much like other woody riparian vegetation: creating near-bank channel roughness, trapping sediment, building floodplain, and providing cover for willow seedlings to establish (Figure G-2). If livestock grazing is eliminated, stands of silver sage along the riverbanks should continue to perform these functions and will likely transition to more diverse stands of woody riparian trees and shrubs.

Channel morphology influences vegetation conditions in the project area. Lateral and vertical channel instability has occurred to varying degrees in the project area. As a result of channel incision, the distance between the floodplain surface and the baseflow channel increases. Floodplain plants may be less resilient over time with a lower water table. Similarly, with an increase in channel capacity related to channel incision and widening, overbank flood events are less frequent. Nutrient and sediment delivery to floodplain surfaces is less common.

In summary, the establishment of good riparian vegetation to resist the erosive flows is necessary to trap sediments and build new streambanks and a new floodplain at the lower elevation. This process is occurring in the Teddy Powers Meadows reference reach and also locally in other

assessment reaches along the Sycan River but many areas of actively eroding streambanks are also present.



Figure G-2. Two examples of the influence of riparian vegetation on sediment trapping on the Sycan River illustrate the role of floodplain vegetation in storing fine sediment. Silver sagebrush on the floodplain creates turbulence and sediment deposition. If left undisturbed over time, these sites would be colonized by vegetation and bank building would take place.

G.2.3 Desired Future Condition

The Teddy Powers Meadows reference reach offers an example of the desired future condition for the project area (Figure G-3). The reference reach is characterized by a riparian vegetation community recovering from past season-long grazing. The Teddy Powers Meadows reach exhibits a vegetation pattern that probably reflects a true early- to mid-seral reference condition for the majority of the Sycan River project area, with the exception of most of Reach 1 – Canyon Reach. The reference reach appears to be fifteen to twenty years into a period of recovery from season-long grazing, a land use pattern that is still occurring in much of the project area. Vegetation in the Teddy Powers Meadows reach consists of a narrow fringe of perennially inundated rush/sedge communities along the channel margin transitioning to seasonally inundated sedge/rush and willow communities. Above the sedge/rush and willow communities is a floodplain terrace dominated by big sagebrush.

Changing the grazing regime in the project area will be the most effective way to achieve the desired future condition. By removing the grazing pressure from the active channel and near-channel areas, the vegetation community will improve. The sedge/rush community adjacent to the low flow channel will become more dense and trap sediment. Willows that are currently grazed will rebound and also provide more channel roughness, trap sediment, and provide cover. Affecting these changes will require fencing the river corridor and changing the current grazing management.



Figure G-3. Recovery riparian vegetation conditions in the Teddy Powers Meadows reference reach illustrate how vegetation responds to grazing exclusion. The vertical cutbank in the left photo is the old streambank prior to cattle exclusion. Complex riparian vegetation transitions from sedges/rushes at the water edge to willow thickets at slightly higher floodplain elevations. Vegetated fringes provide habitat for juvenile fish and amphibians.

G.3 WETLANDS AND OFF-CHANNEL HABITATS

The following sections present historical, existing, and desired future condition information for wetlands and off-channel habitats in the Sycan River project area.

G.3.1 Historical Wetlands and Off-channel Habitats

Many factors influence wetland patterns—geomorphic setting, water source, hydrodynamics, soils, vegetation, land use practices, and disturbance, for example. Specific data are not available to determine the historical extent of wetland and off-channel habitats in the project area. However, review of existing conditions and the 1941 air photos provide a means to evaluate historical wetlands and off-channel habitats. In general, historical wetlands and off-channel habitats were likely similar to current wetlands and off-channel habitats (description included below). However, from the air photo analysis and observations in the field, the historical channel in Reach 2 and Reach 3 appears to have been at a higher elevation in 1941 relative to present day. A higher baseflow channel elevation would have corresponded with higher water surface elevations and greater connection between the channel and off-channel habitats. Beaver activity would have also influenced off-channel habitats and wetlands. Beaver modification of floodplain swales and backwater channels would have likely increased floodplain storage of water, enhancing soil moisture. Historical vegetation communities would have also influenced wetland and off-channel attributes. A more dense and diverse vegetation community would have lead to more complex wetland areas.

G.3.2 Existing Wetlands and Off-channel Habitats

Existing wetlands are described using the Cowardin System, Identification of Wetlands and Deepwater Habitats, used by the U.S. Fish & Wildlife Service (USFWS) (Cowardin et al. 1979). The information in this section is based on field observations from 2005 through 2006.

Reach 1 – Transitional Reach

Very little wetland habitat exists in Reach 1 due to the confined nature of the channel leaving the Coyote Bucket Canyon. Downstream of the canyon mouth, the channel belt width expands as the valley widens (Figure G-4). There is little opportunity for wetland development in the canyon due to the confined valley bottom. Through Reach 1, the valley widens and the channel transitions from a steep confined channel, to a lower gradient meandering channel. The floodplain expands with the retreating valley walls and emergent palustrine wetlands are located to the west of the channel (Station 18+00 to 19+00). The wetland area conveys water during elevated flows and supports emergent vegetation and willows during the growing season. Inundated areas provide temporary shallow rearing habitats for fish and aquatic insects. At the mouth of the canyon, vegetation adjacent to the channel includes sedges/rushes and alder. Ponderosa pine and understory shrubs including snowberry occupy the transition to adjacent uplands. Riparian vegetation is more common and the upland plants recede through the transition to the broader floodplain.



Figure G-4. The Coyote Bucket Canyon (left) and the transition to a wider valley and meandering channel (right). The canyon confines the Sycan River and there is no off-channel wetland development.

Reach 2 – Upper Meandering Reach

Reach 2 extends from Station 22+00 to Station 76+00. The Sycan River in Reach 2 is characterized by increasing channel sinuosity, alternating pool-riffle morphology, and frequent point bars and lateral bars where sediment is stored (Figure G-5 and Figure G-6). Palustrine wetlands are located on lateral terraces and floodplains. Wetlands are seasonally inundated during spring runoff when the river accesses the adjacent floodplain. Additionally, the rising water table and springs inundate off-channel wetlands. Vegetation in the wetlands includes sedges/rushes in depressional features with willows and golden current at mid-elevations, and big sagebrush and bunch grasses at higher elevations. Discontinuous swales suggest possible historical beaver activity. Some relict channel patterns may be related to past primary channel locations or high stage overflow channels. These terrace features appear to have preferential ground water flow that increases vegetation persistence through the year. Large wood accumulations on floodplains also increase riparian habitat diversity, store sediment, and provide protective areas for vegetation.

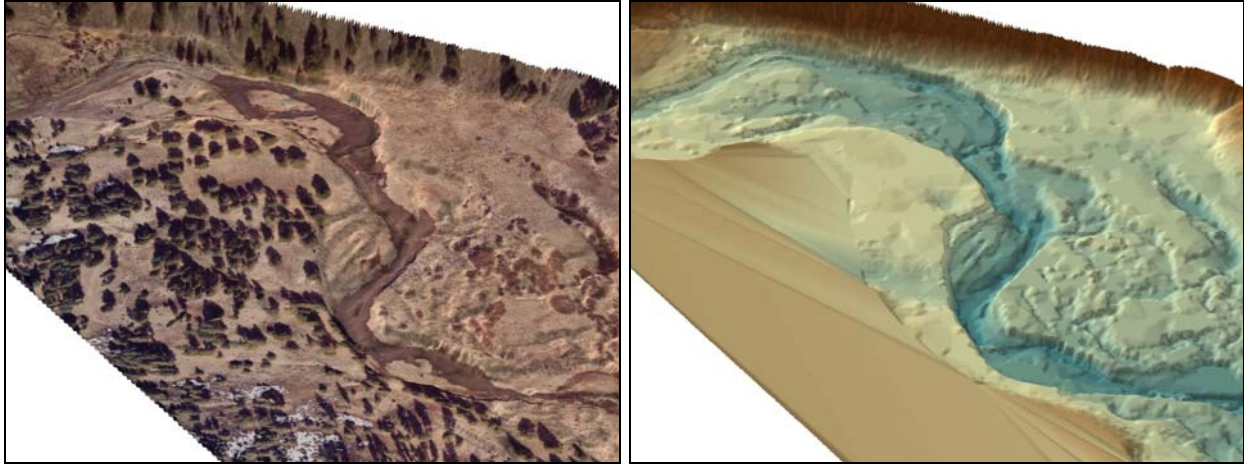


Figure G-5. An air photo draped over the LiDAR generated surface (left) and the bare earth LiDAR surface (right) illustrating floodplain swales that convey water during the spring and early summer in the upstream portion of Reach 2.



Figure G-6. Large wood is deposited on the Reach 2 floodplain (left). Swales on the terrace hold water through the spring and early summer (right).

Reach 3 – Upper Confined Reach

Reach 3 extends from Station 76+00 to Station 137+00. The Sycan River valley bottom narrows as the eastern hillslope and the western terrace encroach on the channel. Wetland development in this section is limited to Station 90+00 through Station 102+00 (Figure G-7). West of the active channel is an historical channel meander that was last active in the 1941 air photos. The channel remains defined and contains water in the spring and early summer. The feature functions similarly to the wetlands in Reach 2. Large wood accumulations and riparian vegetation patterns are similar to the Reach 2 palustrine wetland.

Downstream of the wetland inclusion, the channel follows the valley fall line. The narrowed valley bottom limits lateral channel migration and off-channel wetland formation. Seeps emanate from the western terrace. Ponds have been excavated into the top of the western terrace, accessing groundwater flowing from the Knott Tablelands towards the Sycan River. Prior to the ponds, the area was a wet meadow.



Figure G-7. A floodplain wetland in Reach 3 (left) occupies an historical channel location. Bank erosion in Reach 3 suggests the river is continuing to adjust to channel changes that have occurred over the past 60 years (right). Willow thickets in the background of the right photo show the location of relict channels.

Reach 4 – Lower Meandering Reach

Reach 4 extends from Station 137+00 to Station 172+00. Palustrine wetlands in Reach 4 are located primarily to the east of the channel. Springs discharging at the toe of the western hillslope, form shallow wetlands and ponds that ultimately discharge to the Sycan River. These off-channel wetlands provide fish and wildlife habitat and serve as coldwater refugia. Beaver dams located at the outlets of two of the wetland control flow to the river and may limit fish access to the wetlands. Floodplain vegetation is characterized by sedges/rushes and willow thickets. Higher elevation land forms are colonized by sage brush, occasional Ponderosa pines, and juniper.

Reach 5 – Lower Confined Reach

Reach 5 extends from Station 172+00 to Station 363+00 at the Drews Road Bridge. Palustrine wetlands are associated with floodplain areas, the western terrace on the Kronenberger property, and at spring creek tributary confluence areas (Figure G-8). The floodplain areas are inundated during periodic flood events when the river leaves its low bank and access the valley bottom. The Kronenberger's palustrine wetlands located to the west of the Sycan River are inundated by groundwater during high flow periods, have springs that discharge into them, and are also augmented by groundwater wells.



Figure G-8. A palustrine wetland on a terrace west of the Sycan River (left). An off-channel wetland adjacent to the Sycan River currently disconnected by floodplain fill (right).

G.3.3 Desired Future Conditions

Similar to the desired future channel conditions, changing the grazing regime is expected to be the most beneficial means for improving wetlands and off-channel habitats in the Sycan River project area. Wetland areas currently provide nutritious forage and water sources for livestock. Livestock overuse of wetlands is apparent where livestock trails and loafing areas have compacted soil, displaced vegetation, and lead to weed invasions of disturbed areas. Excluding livestock from wetland areas is expected to improve vegetation conditions, reduce weed infestations, and increase soil porosity. Lateral palustrines in the project area that are currently disconnected from the river by floodplain fills, would be improved by removing the fills.

G.4 PROPOSED RESTORATION STRATEGIES AND TECHNIQUES

The following revegetation treatments are conceptual in nature and provide the foundation for developing final designs. More detailed information for certain reaches is presented in *Appendix I – Restoration Strategies*. For revegetation to be successful, acknowledging the role that fluvial processes play in determining plant community structure on streambanks, floodplains, wetlands and associated uplands is necessary. This document describes different components of the revegetation process that fit into the following categories.

- Influence site potential, as determined by topography, substrate, hydrology, and interactions with other biological components, by creating conditions that will support a natural, sustainable, and dynamic distribution of plant communities.
- Anticipate and manage for invasive species that are not in balance with the natural system.
- Identify appropriate plant materials that are adapted to the local area and to the different geomorphic features in the fluvial environment.
- Anticipate the need to maintain revegetated areas during their establishment period and allow some areas to naturally revegetate.

Final designs for project area reaches will include specific implementation strategies tailored to each site. Final designs are beyond the scope of this document. Final designs would include the following items.

- An implementation plan with construction phasing, detailed materials lists, and sources and quantities for plant materials.
- A detailed site grading plan that includes microtopography enhancement and creation; rock, log and brush pile placement on the floodplain; locations of off-channel wetlands, channels and drainage areas; and substrate and topsoil requirements.
- A detailed planting plan including plant mixes and specifications for planting.
- An erosion control plan for surface water and streambank erosion control.
- A monitoring and maintenance plan that includes a weed control and management plan.

The following revegetation concepts were developed to meet the following multiple objectives.

- Re-establish a self-sustaining native plant community in balance with fluvial processes.
- Mitigate surface erosion and associated off-site impacts.
- Restore near-bank channel roughness by excluding livestock and allowing for vegetation recolonization.
- Inhibit the establishment of undesirable plant species including noxious weeds.

No revegetation plan is capable of precisely replicating the historical native plant communities in a short time frame. The most effective restoration strategy for the project area will be to exclude livestock from the river corridor and re-establishing natural processes responsible for maintaining native vegetation communities. The revegetation plan is designed to “jump-start” the recovery of the complex ecologic interactions.

G.4.1 Riparian and Wetland Restoration Strategies and Techniques

This section provides additional information on existing conditions within each reach and general restoration recommendations for restoring processes necessary to establish and maintain diverse riparian and wetland vegetation communities along the Sycan River. Additional restoration treatment descriptions are included in *Appendix I – Restoration Strategies*.

Reach 1 – Transitional Reach

Reach 1 is substantially steeper, and the valley narrower, than the reference reach and downstream project area reaches. Because this reach has a significantly higher gradient than downstream reaches, beavers and large wood recruitment were probably the most important ecological processes that supported riparian vegetation recruitment and determined floodplain hydroperiod (by slowing flows, beaver dams would lengthen hydroperiods at some locations along the reach). Abundant beaver signs were observed in relict channels within the floodplain. It is likely that within this higher gradient reach, roughness both in and near the channel would promote sediment deposition differentially across the floodplain surface, which would in turn support recruitment of diverse plant life forms. Floodplain roughness would also provide the refugia necessary for patches of seedlings to survive large flood events occurring within the first

few growing seasons after germination. To create roughness and encourage natural processes within Reach 1, the following revegetation/restoration strategies are recommended.

- Install fencing to exclude livestock from the river and adjacent wetlands. Provide upland water sources for livestock.
- Construct engineered log jams to trap organic matter, divert flows onto adjacent floodplains, provide water holding/storage capacity and influence zones of sediment deposition to re-establish channel plan form and create new floodplain surfaces/streambanks.
- Create finger bars on inside meanders and enhance with woody debris to encourage plan form development and beaver activity;
- Reconnect wetlands with low flow channels connected to the Sycaan River.
- Eliminate beaver trapping and reintroduce beavers if possible.

Reach 2 – Upper Meandering Reach and Reach 4 – Lower Meandering Reach

The Sycaan River through Reach 2 and Reach 4 is generally deeper and narrower compared with Reach 1 and has a more stable plan form and consistent pool frequency. The channel and floodplain are still mostly connected throughout this reach and the floodplain is more extensive. Within the upstream end of Reach 2, some narrow point bars are developing, but bar materials appear to be re-distributed too frequently for woody vegetation to become established. Most vegetation on bars appeared to be annual forbs although the vegetation community is also impacted by livestock grazing.

Because the channel and floodplain appear to be connected and sediment deposition is occurring in the proper areas necessary to build and maintain streambanks, recommendations for this reach focus on establishing woody vegetation along the channel margins. The following revegetation strategies are recommended for Reach 2.

- Install fencing to exclude livestock from the river and adjacent wetlands. Eliminating grazing disturbance adjacent to the channel will result in improved vegetation recruitment. Provide upland water sources for livestock.
- Create a stable near-channel zone to allow natural recruitment of riparian and wetland plant communities similar to the reference reach. This can be accomplished by constructing a bankfull bench with stable toe (using woody debris, coir bioengineering materials or large cobble) and a substrate surface suitable to support desired vegetation.
- Construct buried vegetated sills using dormant willow fascines in developing point bars to establish woody vegetation along the channel, and provide roughness to trap organic matter, sediments and seed.
- Construct engineered log jams to trap organic matter, divert flows onto adjacent floodplains, provide water holding/storage capacity and influence zones of sediment deposition to re-establish channel plan form and create new floodplain surfaces/streambanks.

Reach 3 – Upper Confined Reach and Reach 5 – Lower Confined Reach

These reaches function fairly similarly though Reach 5 has more frequent floodplain wetlands. Similar to all reaches in the project area, Reach 3 and Reach 5 continue to be affected by full-

season livestock grazing. Due to grazing, the near-bank vegetation communities have been largely degraded. The original wet→dry vegetation gradient probably followed this pattern: (1) a sedge zone at the water's edge (from the baseflow channel's wetted edge to 1-2 feet below bankfull); (2) a willow/sedge zone at the approximate bankfull elevation plus or minus a half foot; (3) a silver sagebrush/tufted hairgrass zone occurring between the willow zone and approximately two feet above bankfull; and (4) a silver sagebrush/bluegrass zone above this elevation, blending into upland landforms. This vegetation plant community transition is similar to the one observed to be establishing within the formerly entrenched/eroded channel in the reference reach above. This pattern of wet→dry riparian plant communities has been documented in the literature across a broad range of landforms and elevations in this region (Kovalchik 1987; Crowe 2004) so it is reasonable to conclude that the Teddy Powers Meadows reference reach is an appropriate model for the project area.

The most important natural process needed to support the restoration of diverse riparian and wetland plant communities within Reach 3 and Reach 5 is deposition and trapping of sediment. Sediment deposition will result in new floodplain surfaces along the channel and support woody vegetation along eroding streambanks or streambanks with minimal existing vegetation. To support sediment recruitment and promote native vegetation establishment, the following revegetation/restoration recommendations for Reach 3 and Reach 5 are presented.

- Install fencing to exclude livestock from the river and adjacent wetlands. Eliminating grazing disturbance adjacent to the channel will result in improved vegetation recruitment. Provide upland water sources for livestock.
- In Reach 5, remove floodplain fills that restrict river access to floodplain wetlands.
- Use streambank bioengineering in conjunction with woody debris jams and bank re-contouring on outer banks (at select locations) to stabilize channel plan form and establish woody vegetation, particularly if the banks are significant sediment sources.
- In areas that lack vegetation and have low shear energy, consider adding near-bank in-channel roughness (e.g. buried willow fascines) to promote sediment deposition and plant recruitment.
- In areas where a small vegetated bench is present along the channel and the streambank is not vertical, use dormant willow treatments such as staking or buried fascines to establish woody vegetation and create roughness to trap sediment and seeds to promote bank building. If willows are lacking from the vegetated bench, consider placing a buried coir log to promote moisture retention, and pack willow cuttings around the coir log.
- In areas where point bars are forming, stagger buried willow fascines in the newly deposited material to establish woody vegetation, create roughness, and ultimately provide a seed source.
- Plant containerized shrubs in 'islands' within the floodplain in areas where native seed sources are distant.
- Restore floodplain roughness and create microsites by adding woody debris to the floodplain.
- Control localized heavy weed infestations using herbicide.

In summary, existing wetland and off-channel habitats are believed to be functioning below their historical level due to grazing impacts. Proposed wetland and off-channel habitat improvements focus on excluding livestock, allowing natural vegetation recruitment, installing engineered log jams and woody debris for habitat and sediment trapping, and improving wetland connectivity with the Sycan River.

APPENDIX H FISH COMMUNITY

H.1 INTRODUCTION

Fish population and fish community data are fairly limited for the Sycan River assessment area. Unique characteristics including emergent springs, variable substrates, and aquatic habitat conditions likely influence the fish community. The fish community includes both native and introduced fish species. Species of significance include Lost River and shortnose suckers, both listed as federally endangered by the U.S. Fish & Wildlife Service. Other species of special concern include Klamath large scale suckers and Klamath redband trout. Limited empirical data have been collected to establish the distribution, habitat use, and seasonal patterns of the Sycan River fish community. The following sections provide an overview of the fish species with summary data provided by the U.S. Fish & Wildlife Service. Additional data collected by Oregon Department of Fish and Wildlife, U.S. Geological Survey, and the Klamath Tribes are discussed but not presented.

H.2 SYCAN RIVER FISH COMMUNITY

The Sycan River hosts a fish community comprised of both native and introduced fish species. Two endangered species, the Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris*), have been afforded special designation due to dwindling populations throughout the Upper Klamath Basin. Klamath large scale sucker (*Catostomus snyderi*) and redband trout (*Oncorhynchus mykiss newberri*) are two species of special concern recognized by the State of Oregon. Introduced species inhabiting the Sycan River include fathead minnow (*Pimephales promelas*), large mouth bass (*Micropterus salmoides*), and yellow perch (*Perca flavascens*). Table H-1 presents a fish species list for fish sampled in the Sycan River from 2003 through 2006 by the U.S. Fish & Wildlife Service.

Table H-1. Fish species common name, scientific name, and origin for fish sampled in the Sycan River between 2003 and 2006 by the U.S. Fish & Wildlife Service.

Common Name	Scientific Name	Native/Introduced
Lost River sucker	<i>Deltistes luxatus</i>	Native/Endemic; Federally Endangered
Shortnose sucker	<i>Chasmistes brevirostris</i>	Native/Endemic; Federally Endangered
Klamath large scale sucker	<i>Catostomus snyderi</i>	Native/Endemic; Species of Special Concern
Tui chub	<i>Gila bicolor</i>	Native
Blue chub	<i>Gila coerulea</i>	Native/Endemic
Fathead minnow	<i>Pimephales promelas</i>	Introduced
Speckled dace	<i>Rhinichthys osculus klamathensis</i>	Native; Klamath speckled dace
Marbled sculpin	<i>Cottus klamathensis</i>	Native
Yellow perch	<i>Perca flavascens</i>	Introduced
Redband trout	<i>Oncorhynchus mykiss</i> spp.	Native; Species of Special Concern
Brown trout	<i>Salmo trutta</i>	Introduced
Brown bullhead	<i>Ameiurus nebulosus</i>	Introduced
Large mouth bass	<i>Micropterus salmoides</i>	Introduced
Lamprey	Multiple	Native/Endemic

Based on data collected by USFWS, blue chub and speckled dace were the most numerous species at four sites sampled in September 2006. Juvenile suckers and redband trout were also common in the upper portion of the assessment reach downstream from Coyote Bucket Canyon and on the northern end of the Shields' property. Fathead minnows and other introduced species were far less common than the native species at the four USFWS sampling stations. .

H.3 FISH LIFE HISTORIES

Data collected by USFWS, USGS, ODFW, and the Klamath Tribes suggest the Sycan River provides spawning, rearing, and adult habitat for native and introduced fish species. Telemetry studies completed by USGS found one Klamath largescale sucker and one Lost River sucker entered the Sycan River in 2005 and 2006 (see fish monitoring summary below). Electrofishing and netting completed by USFWS has sampled juvenile suckers as well as many other species. The results suggest the importance of the Sycan River for both adult spawning and juvenile rearing.

Recreational anglers target the sizeable adult brown trout and redband trout in the Sycan River in the Coyote Bucket area. Although we have rarely seen adult fish in the Sycan River during our summer surveys, deeper holes, runs, and undercut banks provide moderate-quality fish habitat. Grazed riparian zones and minimal instream large wood limit habitat complexity. An improved riparian condition and more complex instream structure could increase the Sycan River's carrying capacity for adult fish.

Fish that do not remain in the Sycan River, migrate to the Sprague River and perhaps as far as Upper Klamath Lake or other portions of the basin. Variable stream flows in the Sycan River likely influence fish movement in the system. Ranging from over 600 cfs for an average runoff, to a low of 10 cfs during the summer time in a drought year, fish residing in the Sycan River rely on cold water discharging from groundwater springs. Large accumulations of juvenile fish in lower Brown Spring Creek suggest the importance of cold water spring discharge especially during the warmer summer months.

H.4 FISH SAMPLING SUMMARY

The following Sycan River fish monitoring summary was provided by Ms. Faye Weekley (USFWS). The section summarizes USFWS sampling efforts on Brown Spring Creek and the Sycan River.

Draft Report - Results of Fish Monitoring in the lower Sycan River and the Brown Spring Creek Tributary in Klamath County, Oregon, from 2003 through 2006. Faye Weekley, Fish & Wildlife Biologist, U.S. Fish & Wildlife Service, August, 2007.

A fish sampling effort was initiated by USFWS in spring, 2003, in the Sprague and Sycan rivers and their tributaries in Klamath County, Oregon, to obtain baseline information to be used in planning habitat restoration projects geared to enhance native fish populations. Sampling focused on collecting fish information on species assemblage, habitat use at various life stages, and seasonal variation in habitat use for all species, although the primary native fish of interest were the two federally endangered suckers endemic to the Klamath Basin, the Lost River sucker (*Deltistes luxatus*) and the shortnose sucker (*Chasmistes brevirostris*).

The following paper summarizes information collected on the Sycan River and its tributary, Brown Spring Creek. Data was collected before and after the Brown Spring Creek fish passage project was completed in 2005 which restored fish passage from the Sycan River to the headwater springs after 60 years of fish passage exclusion.

Methods

Sampling methods included snorkeling, electro-fishing, and netting. Sampling sites were located in reaches of the Sycan River below Coyote Bucket to the confluence of Brown Spring Creek, in Brown Spring Creek, and in backwaters and associated wetlands and springs. In addition to fish species identification and age class, data were collected on substrate characteristics, water temperature and percent in-stream vegetation cover. Up to 10 larval and juvenile suckers were collected at each site, preserved in 95% denatured alcohol, and sent to the Oregon State University's Department of Fisheries and Wildlife for identification to species by vertebral x-rays, otoliths, and lip morphology. Incidental observations of fish in Brown Spring Creek and the Sycan River were also recorded.

Snorkeling was only used when electro-fishing or netting were not feasible, such as in off-stream wetland "ponds" along Brown Spring Creek and in some deep reaches of the Sycan River. Although this method enabled the observation of large native trout in deep water areas or lamprey ammocoetes startled from the debris along the streambank, little information was gathered on species assemblage or age classes due to the inability to trap the fish. Electro-fishing was effective in all of the shallow reaches (up to 3 feet deep). A backpack shocker and nets were used to capture fish for identification. Catch per unit effort (CPUE) was determined in 2005 and 2006. However, large schools of juvenile redband trout were commonly viewed racing upstream of the electrofishing crew. Netting alone was effective for larval fish in all shallow habitats. It is important to note that sample periods were in different months (June-September) in different years (2003-2006), usually only 1-2 times per year, and under different water year conditions.

Table 1 through Table 3 present fish monitoring data collected in Brown Spring Creek from June 2003 through October 2006. Comparisons are typically from downstream and upstream of the first fish passage barrier in the project area.

Table 1. Fish sampling results for Brown Spring Creek from 2003 to 2006. Presented data include results from downstream and upstream of the fish passage barrier for three periods. The barrier was in place in 2003 and 2004. The barrier was removed in September 2005.

Species	Before Barrier Removal				After Barrier Removal
	June 2003		July 2004		October 2006
	Below Barrier	Above Barrier	Below Barrier	Above Barrier	Above Former Barrier
Lost River sucker	4	-	4		-
Shortnose sucker	1	-	3		-
Klamath largescale sucker	-	-			-
Tui chub	1	-			-
Blue chub	7	-	7		100
Fathead minnow	1	2	2		-
Speckled dace	3	-	1	2	-
Marbled sculpin	2	-	5		-
Yellow perch	-	-			-
Largemouth bass	1	-	-	-	-
Redband trout	21	-	10	-	200 juveniles (Nov 2005)
Lamprey (spp.)	-	-	1	8	-

Table 2. A comparison of the fish community downstream of the fish passage barrier prior to barrier removal, and the fish community upstream of the former barrier following barrier removal.

Species	August 25, 2005	September 19, 2005
	Below Barrier Prior to Barrier Removal	Above Former Barrier After Barrier Removal
Sucker spp.	27	-
Tui chub	2	7
Blue chub	132	1,000
Fathead minnow	17	2
Speckled dace	251	10
Marbled sculpin	109	7
Yellow perch	2	-
Redband trout	31	-
Lamprey (spp.)	6	2

Table 3. A comparison of the fish community downstream and upstream from the former fish passage barrier 1 Year after barrier removal.

Species	July 28, 2006	
	Below Former Barrier Approximately 1 Year After Removal	Above Former Barrier Approximately 1 Year After Barrier Removal
Sucker spp.	1,811	-
Tui chub	-	-
Blue chub	2,396	7
Fathead minnow	344	-
Speckled dace	994	6
Marbled sculpin	2,697	10
Yellow perch	-	-
Redband trout	1,021	16
Lamprey (spp.)	545	-

Table 4 and Table 5 present fish monitoring data collected in the Sycan River at four locations. Observations from other sampling efforts are also included.

Sycan River – Kronenberger Property July 2004

Instream Springs with vegetation adjacent to 5 ft deep pool

Ten 12 inch juvenile suckers observed within the vegetation bed.

Sycan River – Above Sycan Crossing July 2005, June 2006

Schools of 50 -100 juvenile suckers (2-3 inches) were observed in in-stream pools.

Sycan River – USGS radioed suckers, Klamath largescale sucker (2005) and Lost River sucker (2006) located in the Sycan River sampling area.

Table 4. Fish monitoring results for three sites on the Sycan River. Sampling was completed in August 2005. Water temperature ranged from 11 – 14 °C at the time of sampling.

Species	Above Brown Spring Creek Confluence with Sycan River	Below Rock Ford	Emergent Spring Outlet
Sucker (spp.)		4	
Tui chub		3	
Blue chub		29	4
Fathead minnow	2	38	12
Speckled dace		2	
Marbled sculpin	11	32	13
Lamprey (spp.)		4	
Bed Sediment	(silt/pebble/sand)	(silt/pebble/sand)	(gravel/sand/detritus)

Table 5. Fish monitoring results for five sites on the Sycan River. Sampling was completed on September 25, 2006. Water temperature was 12 °C at the time of sampling.

Species	Mouth of Coyote Bucket Canyon	Northern Shields' Property	Southern Shields' Property	Downstream of Ford	Upstream of Brown Spring Creek Confluence
Total Sucker (spp.)	22	Schools of 100	25	3	
Lost River sucker	5				
Klamath largescale sucker	17				
Tui chub		2	1		
Blue chub	6	13	32	313	
Fathead minnow			16	5	1
Speckled dace	120	23	53	8	2
Marbled sculpin	24	19	46	29	44
Redband trout	130				
Brown trout	2				
Lamprey (spp.)		23		4	
Brown bullhead					2
Bed Sediment	(cobble/boulder)	(gravel/silt)	(gravel)	(sand/silt)	(watersponge/sand)

Results and Discussion

Data collected in summer months in Brown Spring Creek and the lower Sycan River suggest that the fish assemblage is predominately native fishes (10 species). Non-native fishes (5 species) comprised less than 1 percent of the total observed fish. Native fish were distributed throughout the entire sample area.

From 2003 through 2004, larval redband trout and larval suckers were collected in the pool below the lowest fish barrier on Brown Spring Creek. This spawning site was at the highest point in the system for fish to move. The substrate was snail shells and some gravels. Aquatic vegetation was present in and around the edge of the pool. This area of Brown Spring Creek had the largest aggregation of larval fish in lower Brown Spring Creek. Schools of juvenile redband trout were commonly observed when walking the creek or moving ahead of the electrofishing crew. (A trapnet would probably be more efficient in sampling redband trout). The larval suckers that were collected over the four years were identified to all three species of suckers by the OSU Department of Fisheries. In 2006, the number of fish in lower Brown Spring Creek was much greater than in previous years (see Table 3). However, in 2006 the Sprague and Sycan rivers had higher fish numbers in all sampling areas.

Brown Spring Creek was sampled above and below the lowest fish barrier before the barrier was removed in September 2005. The presence of only lamprey, speckled dace and fathead minnows above the barrier in 2003 and 2004 compared to an assemblage of redband trout, suckers, chubs, sculpins, lamprey, and others below the barrier suggests that the barrier effectively excluded fish from upper Brown Spring Creek. Dace and fatheads located upstream from the barrier may have been used as bait in fishing above the barrier. Shortly after fish passage was reinstated in lower Brown Spring Creek, large schools of blue chubs were observed at the upper end of the channel near the headwater springs. In early winter of 2005, after the project completion, Oregon Department of Fish and Wildlife observed approximately 200 juvenile redband trout above the step pool (Bill Tinniswood, ODFW, personal communication). A

spawned-out adult redband trout was also found in Brown Spring Creek upstream from the step pool in March 2006. A depression in the channel upstream from the carcass suggested the fish may have spawned in Brown Spring Creek. In 2006, numerous species were observed in the channel above the former lowest barrier, including adult redband trout and large numbers of juvenile redband trout.

The Sycan River has varying substrates, gradients and vegetation conditions from the canyon reach to the confluence of Brown Spring Creek. Below the canyon where boulders and higher water velocities are present, trout and suckers of all age classes were observed. Electro-fishing produced a greater number of fish in areas characterized by gravel bed sediment and aquatic vegetation, especially when associated with deeper pools, outside riverbends, and instream springs. In 2004, in a reach approximately 1 mile above the confluence of Brown Spring Creek, ten 12 inch suckers were observed in a mat of instream vegetation in an instream spring area adjacent to a 5 foot pool. Other suckers of this size have been observed in the river corridor adjacent to spring inflows or seeps. An area with consistently few fish was between the Kronenberger ford and the confluence with Brown Spring Creek. This area is low gradient, sandy, shallow and has little instream or riparian vegetation.

A telemetry study by the U.S. Geological Survey in 2005 and 2006 recorded a radio-tagged Klamath largescale sucker and a Lost River sucker in the Sycan River during the spring spawning migration. Anecdotally, local residents describe yearly spawning by suckers in the Sycan River below Snake Creek, a tributary located 1 mile downstream from the Brown Spring Creek confluence.

Summary

The results of the baseline fish sampling effort in Brown Spring Creek and the Sycan River indicate that a healthy native fishery is present, spawning is occurring and signs of production are apparent on a yearly basis. Non-native fish comprise less than 1 percent of the fish community based on the number of sampled individuals. Areas of the Sycan River with greatest fish use appear to be areas of gravel, cobble or boulder substrate associated with aquatic or riparian vegetation or boulder cover, and areas associated with spring waters (creeks, seeps or instream springs). The removal of the barriers on Brown Spring Creek resulted in fish passage to the headwater springs.

APPENDIX I RESTORATION STRATEGIES

I.1 INTRODUCTION

In addition to completing the Sycan River assessment, River Design Group, Inc. (RDG) was also instructed to evaluate the feasibility of restoring the privately owned section of the Sycan River from the mouth of the Coyote Bucket Canyon downstream to Drews Road. The following sections present the desired future conditions for the project area, restoration alternatives that were considered, and techniques to enhancing the river corridor.

This report is organized in four main sections. Section 1 provides an overview of the desired future conditions. Section 2 summarizes the restoration alternatives. Section 3 presents restoration techniques. Section 4 presents conceptual restoration treatments by reach.

I.2 THE DESIRED FUTURE CONDITION

The Sycan River in the project area exhibits varied channel morphology, streambank stability, riparian vegetation, and aquatic habitats. Through Reach 2, the upstream portion of Reach 3, and Reach 4, the Sycan River appears to be laterally unstable based on widespread bank erosion. Bank erosion is believed to be related to both the natural site conditions and human influences. Site conditions that contribute to the bank erosion include climatic conditions (low precipitation), hydrology (water surface elevation differences between peak flows and base flows), ash and pumice-based soils, and vegetation communities. Human-related effects include livestock grazing, historical beaver removal, and watershed modifications including the alteration of the Sycan Marsh.

The desired future condition focuses on a more stable river corridor by enhancing the riparian vegetation community. A more stable river corridor is expected to result in reduced bank erosion and sediment delivery to the Sycan River, improved riparian vegetation coverage, and enhanced aquatic habitat. Stability does not imply stopping natural processes such as bank erosion and deposition, but rather, slowing the rate of channel change through natural processes. Addressing current land management and promoting vegetation recovery is believed to be the most prudent action for achieving reach-level ecosystem recovery.

The Teddy Powers Meadows section of the Sycan River was selected as a reference reach based on the riparian vegetation community, recovery of eroding stream banks, and the diverse channel morphology. The Teddy Powers Meadows section (reference reach) provides an example of the desired future condition for the project area (Figure I-1). The reference reach is characterized by a riparian vegetation community recovering from past season-long grazing. The reach exhibits a vegetation pattern that probably reflects a true early- to mid-seral reference condition for the majority of the Sycan River project area. The reference reach appears to be fifteen to twenty years into a period of recovery from season-long grazing, a land use pattern that is still occurring in much of the project area. Vegetation in the reference reach consists of a narrow fringe of perennially inundated rush/sedge communities along the channel margin transitioning to seasonally inundated sedge/rush and willow communities. Above the sedge/rush and willow communities is a floodplain terrace dominated by big sagebrush.

Beaver remain active in the reference reach although their activity level appears to be less than in the past. Signs of old dams on the main channel and diverse floodplain areas suggest a more active beaver community inhabited the area in the past.



Figure I-1. Riparian vegetation in the Teddy Powers Meadows reference reach is characterized by sedges/rushes at the channel edge grading to willows at the edge of the active flood channel. Sage brush and other drier upland species occupy the low terrace.

The vertical height from the channel bed to the low terrace is less in the reference reach than in the project area. This characteristic is largely related to the geology and the depth to bedrock or a hardpan layer that resists erosion. The depth to the confining layer also influences groundwater/surface water interactions and vegetation conditions. The denser riparian community in the reference reach may be responding to both the cessation of grazing as well as better access to the water table.

Aquatic habitat conditions are more diverse in the reference reach compared to the project area. Channel edge vegetation provides protective habitat for rearing juvenile fish. Off-channel habitats including floodplain channels and ponds also contribute to habitat diversity (Figure I-2). These features are generally connected to the base flow channel.



Figure I-2. River corridor habitats including a floodplain pond (left) and side channels contribute to aquatic habitat diversity in the reference reach. Several features appear to have been influenced by beavers.

I.3 RESTORATION ALTERNATIVES

The following section presents the four restoration alternatives that were evaluated for the Syscan River project area. Restoration goals include the following items.

- Address river corridor stability by reducing bank erosion and sediment delivery, improving riparian vegetation conditions, and enhancing habitat.
- Raise water surface elevations to increase the interaction of the river with adjacent floodplains. Enhanced river-floodplain interaction would increase floodplain storage of sediment, debris, and water. Water released from floodplain storage has the potential for increasing the magnitude of summer base flows, lowering summer water temperature, and increasing soil moisture conditions for the benefit of riparian vegetation.
- Restoration projects are to be implemented in the context of the watershed conditions. Projects should focus on re-establishing natural processes like vegetation and woody debris recruitment to the river, and habitat formation and maintenance.

I.3.1 Alternative 1 – Grazing Management and Bioengineering

Alternative 1 – Grazing Management and Bioengineering focuses on excluding livestock from the river corridor and implementing bioengineering projects to accelerate revegetation of disturbed areas. Alternative 1 is the preferred alternative. The foundation of this alternative is that livestock must be excluded from the river bottom in order to improve vegetation conditions. Bioengineering projects are also proposed to help accelerate vegetation colonization, stabilize eroding banks, and improve aquatic habitat.

A geographic information system (GIS) analysis was completed to estimate the exclusion acreage under the two proposed grazing exclusion alternatives. The GIS maps were produced from the hydraulic model that estimated the water surface elevations associated with the 2-year, 5-year, and 10-year flood events. The flood extents for each flood interval were mapped. The fence locations are presented in reference to the flood extents. Figure I-3 through Figure I-5 provide the fence locations for the two alternatives. Landownership boundaries area also presented.

Two grazing exclusion alternatives were developed. Under both alternatives, off-channel watering sites would be established. Landowner compensation and/or easements are recommended to compensate the landowners for lost livestock production. Alt. 1 would set fence lines outside of the approximate 2-year flood extent. Although livestock would be excluded from the base flow channel, livestock would have access to the majority of floodplain and terraces areas. The benefits of Alt. 1 would be that livestock would continue to have access to high quality forage. Costs associated with Alt. 1 include the cost of the longer fence, fence maintenance due to the close proximity to the channel, and maintenance of off-channel watering sites. Alt. 2 would set the fences outside of most of the 5-year/10-year flood inundation area. The benefits of Alt. 2 would include more protection of the river corridor and lower fence installation and maintenance costs. Costs associated with Alt. 2 include less grazing income for landowners as the accessible forage is lower quality forage.

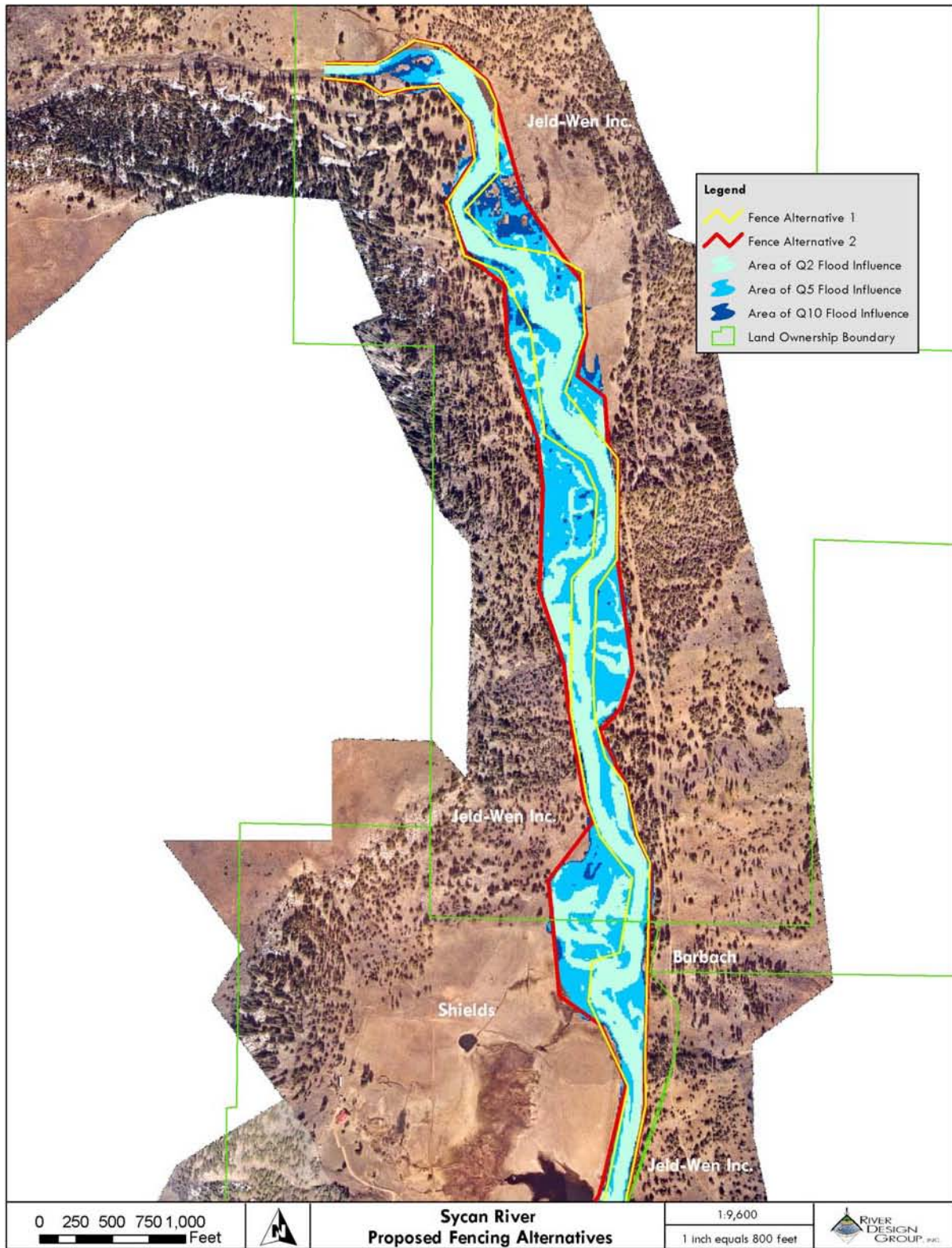


Figure I-3. The proposed fencing alternatives map for Reach 1 through the middle of Reach 3. The flood extents, Alt. 1 and Alt. 2 fence locations, and landownership boundaries are presented.

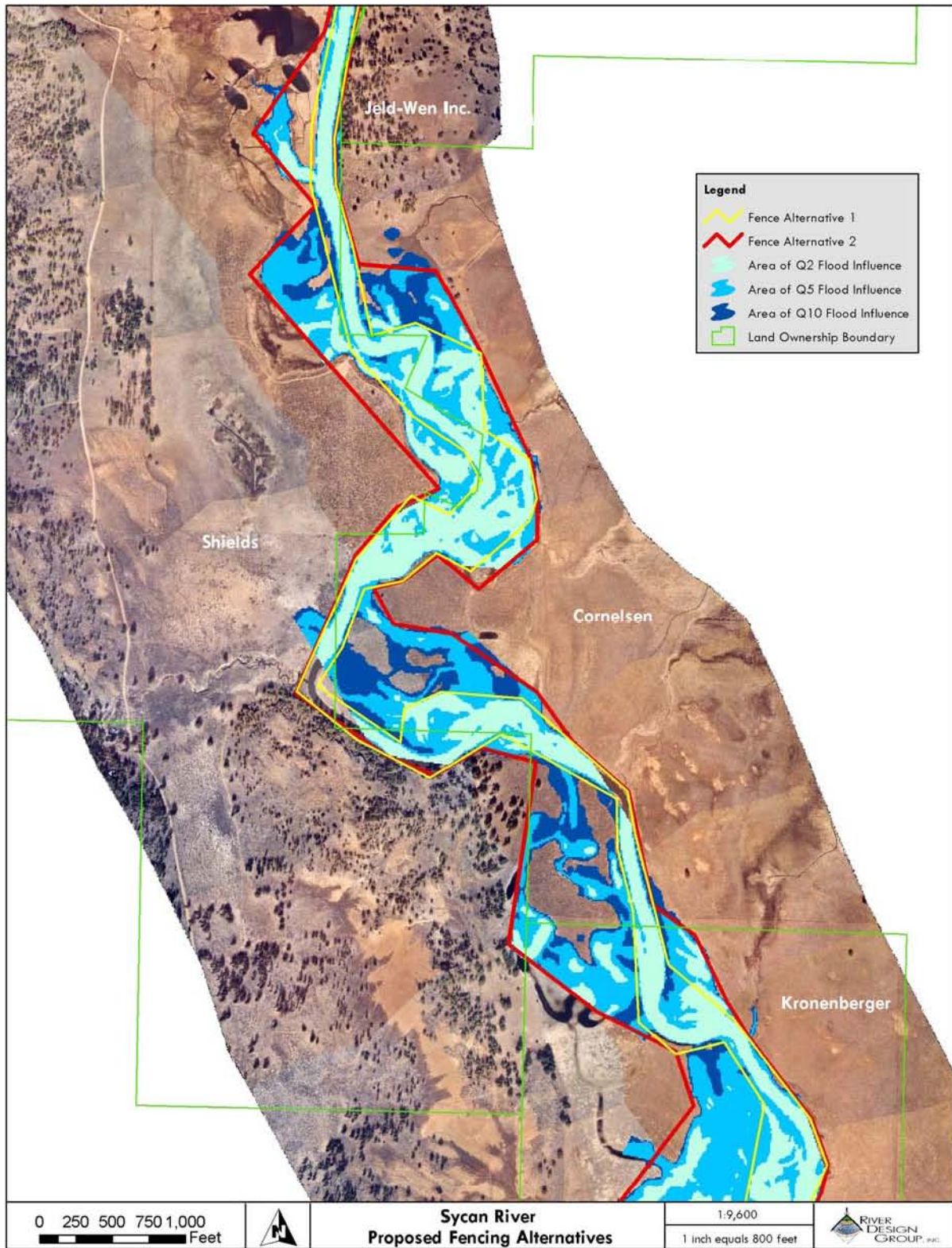


Figure I-4. The proposed fencing alternatives map for the middle of Reach 3 through upper Reach 5. The flood extents, Alt. 1 and Alt. 2 fence locations, and landownership boundaries are presented.

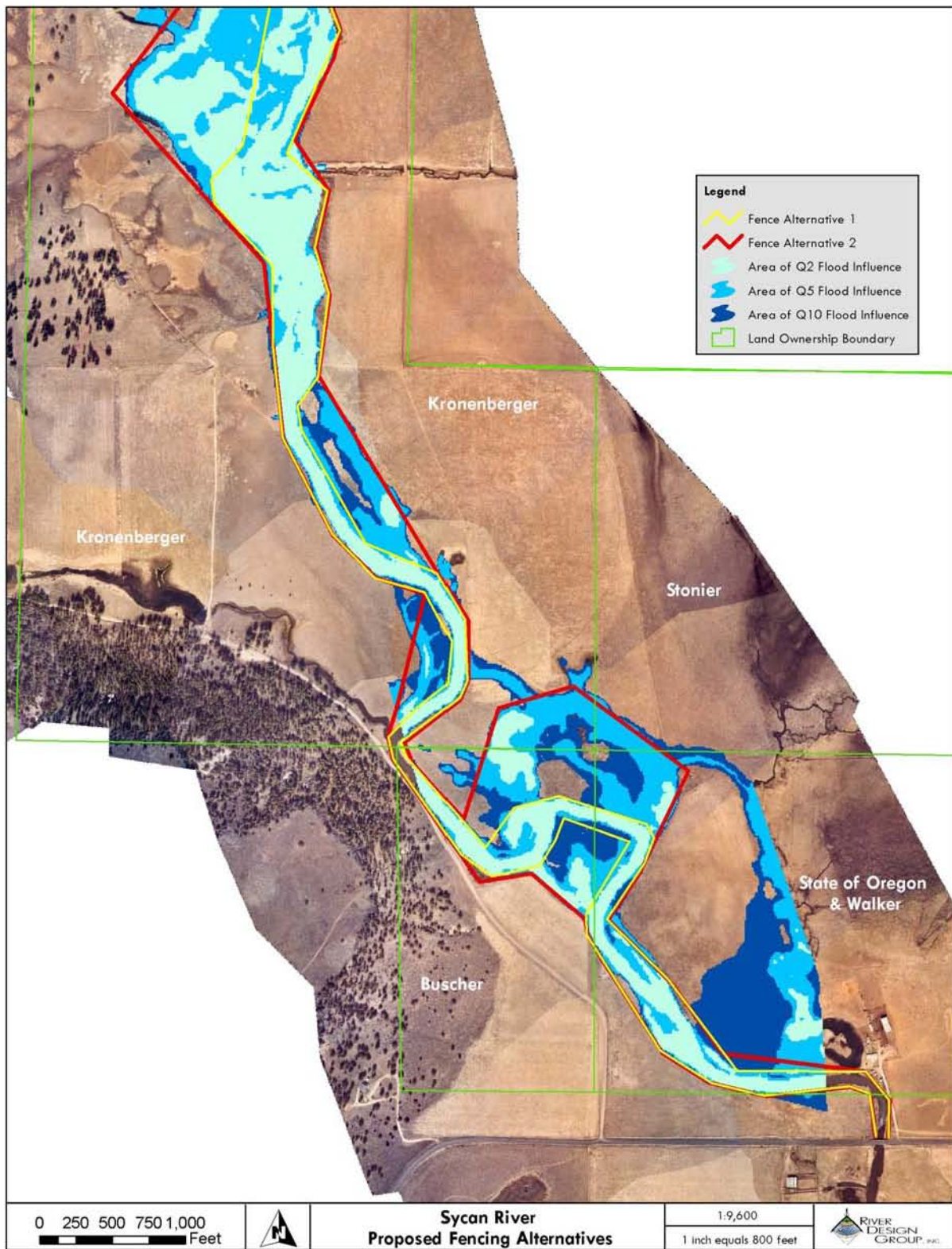


Figure I-5. The proposed fencing alternatives map from the middle of Reach 3 to upstream of Snake Creek. The flood extents, Alt. 1 and Alt. 2 fence locations, and landownership boundaries are presented.

The area of lost livestock production by landownership was calculated by measuring the land area within the two enclosure alternatives and subtracting the area of the base flow channel (Table I-1).

Table I-1. Acres of livestock enclosure under Alt. 1 and Alt. 2 by landownership.

Landowner	Acres of River	Alt. 1 Enclosure Acreage	Alt. 1 Acres of Lost Livestock Production	Alt. 2 Enclosure Acreage	Alt. 2 Acres of lost livestock production
Jeld-Wen, Inc.	10.0	36.2	26.2	67.6	57.6
Shields	8.4	29.3	21.0	56.9	48.5
Cornelsen	6.3	32.8	26.4	74.1	67.7
Kronenberger	11.8	48.1	36.3	108.0	96.2
Stonier	0.0	--	--	1.7	1.7
Buscher	2.9	8.1	5.2	20.6	17.7
State of Oregon & Walker	5.3	14.7	9.4	23.0	17.7
Total	44.7	169.2	124.5	351.9	307.1

Forage values were estimated after discussions with one of the landowners in the project area. We estimated the lost livestock production by breaking forage values into three categories. Channel margin vegetation was given the highest forage value of \$130 (\$120-\$140) per acre per summer. Approximately 1 acre of channel margin vegetation supports one cow/calf pair per summer. Floodplain and terrace vegetation was given an intermediate forage value of \$70 (\$60-\$70) per acre per summer. Approximately 2 acres of terrace vegetation are necessary to support one cow/calf pair per summer. Upland vegetation (e.g. sage brush/Ponderosa pine community) typically requires considerable acreage to support livestock and was not included in the lost forage value calculations.

To estimate the area of channel margin vegetation in a reach, we multiplied the baseflow channel area by 1.5. This provides a channel margin vegetation area 50% greater than the baseflow channel area and is believed to accurately represent the channel margin vegetation area. Field verification would be necessary to improve this estimate. To estimate the terrace area, we subtracted the baseflow channel area and the channel margin fringe area from the total fenced area. The channel fringe area was multiplied by \$130 to determine the value of the excluded channel margin forage. The terrace area was multiplied by \$70 to determine the value of the excluded terrace forage. These values were added together to calculate a total lost forage value. Other costs including the fence materials and installation, maintenance, and off-channel livestock watering were not determined. These more detailed costs will be determined during final project designs. Table I-2 estimates the cost of the lost production for Alt. 1 and Table I-3 estimates the cost of the lost production for Alt. 2. Costs for fencing and off-channel watering were not calculated. Lost forage costs could be used as one means to secure landowner compensation.

Table I-2. Estimated cost of lost livestock production based on the Alt. 1 livestock exclusion.

Landowner	Area Captured by Fence Alt. 1 (acres)	Baseflow Channel Area (acres)	Area of Lost Livestock Production (acres)	Estimated Cost of Lost Livestock Production		
				River Fringe Estimate (\$130/ac)	Riparian Terrace Estimate (\$70/ac)	Total Estimate
Jeld-Wen, Inc.	36.2	10.0	26.2	\$1,946	\$789	\$2,735
Shields	29.3	8.4	21.0	\$1,634	\$587	\$2,221
Cornelsen	32.8	6.3	26.4	\$1,234	\$1,185	\$2,420
Kronenberger	48.1	11.8	36.3	\$2,307	\$1,297	\$3,604
Stonier	--	--	--	--	--	--
Buscher	8.1	2.9	5.2	\$566	\$60	\$625
State of Oregon & Walker	14.7	5.3	9.4	\$1,032	\$101	\$1,133
Total	169.2	44.7	124.5	\$8,718	\$4,019	\$12,738

Table I-3. Estimated cost of lost livestock production based on the Alt. 2 livestock exclusion.

Landowner	Area Captured by Fence Alt. 2 (acres)	Baseflow Channel Area (acres)	Area of Lost Livestock Production (acres)	Estimated Cost of Lost Livestock Production		
				River Fringe Estimate (\$130/ac)	Riparian Terrace Estimate (\$70/ac)	Total Estimate
Jeld-Wen, Inc.	67.6	10.0	57.6	\$1,946	\$2,982	\$4,928
Shields	56.9	8.4	48.5	\$1,634	\$2,516	\$4,150
Cornelsen	74.1	6.3	67.7	\$1,234	\$4,076	\$5,310
Kronenberger	108.0	11.8	96.2	\$2,307	\$5,491	\$7,798
Stonier	1.7	0.0	1.7	\$0	\$121	\$121
Buscher	20.6	2.9	17.7	\$566	\$934	\$1,499
State of Oregon & Walker	23.0	5.3	17.7	\$1,032	\$686	\$1,717
Total	351.9	44.7	307.1	\$8,718	\$16,805	\$25,524

Fencing costs were estimated for each of the landowners adjacent to the Sycan River in the project area (Table I-4). Estimated fencing costs are provided in Table I-4. Fencing costs are based on a \$2.25/ft cost. The fencing cost is based on a base cost of \$1.85/ft provided by the Natural Resources Conservation Service from recent fencing projects completed in the Upper Klamath Basin. The base cost was revised to account for the remoteness of the project area. The fence construction cost for Alt. 2 is less than for Alt. 1 due to the shorter fencing length.

Table I-4. Estimated fencing costs for the Alt. 1 and Alt. 2 fencing options. Costs are based on price of \$2.25 per linear foot of fence.

Landowner	Alt. 1 Fence Length (ft)	Alt. 1 Fence Cost	Alt. 2 Fence Length (ft)	Alt. 2 Fence Cost
Jeld-Wen, Inc.	17,021	\$38,297	28,637	\$64,433
Shields	11,846	\$26,653	12,947	\$29,130
Cornelsen	10,959	\$24,658	8,750	\$19,687
Kronenberger	16,089	\$36,201	16,569	\$37,281
Stonier	--	--	567	\$1,275
Buscher	4,100	\$9,226	3,160	\$7,110
State of Oregon & Walker	6,476	\$14,572	5,946	\$13,379
Total	49,471	\$111,310	47,938	\$107,861

Potential bioengineering treatments would be directed towards enhancing habitat, promoting sediment deposition, and accelerating revegetation. Example projects would include stable large wood placement in the active channel and off-channel wetlands. Planting willow cuttings would be an additional treatment to potential speed willow colonization in areas where they have been displaced by grazing. Figure I-6 illustrates engineered log jams and bioengineering projects completed on the Sprague River.



Figure I-6. Example bioengineering (left) and engineered log jams (right) on the Sprague River. Bioengineering and log jams provide bank stability and diverse aquatic habitat. Over time, the willows planted in the soil lift will form a dense willow thicket.

Bioengineering and ELJ projects would be implemented at select locations based on site conditions and access. Potential priority sites for bioengineering would include bare eroding banks where willow colonization would meet the restoration objectives. Potential ELJ sites would include off-channel wetlands where the trees would provide habitat for juvenile rearing. Other sites in the active channel would provide overhead cover and habitat diversity for all life history stages of fish inhabiting the Sycan River. ELJs could also be placed to deflect streamflow from unstable banks. Increasing the vegetation density and frequency of large wood in the system would increase channel roughness.

Alternative 1 Summary

Alternative 1 addresses the restoration goals. Excluding livestock from the river would improve vegetation conditions and ultimately reduce sediment loading to the river. The increased channel roughness related to the improved vegetation condition and installation of ELJs would potentially increase water surface elevations. Higher water surface elevations would increase channel-floodplain connectivity. The bioengineering and ELJs are also in the context of the watershed conditions. The bioengineering sites would accelerate willow colonization in the river corridor. ELJs would collect debris transported from the upper watershed and through the Coyote Bucket Canyon. Over time, riparian vegetation would be expected to colonize the surfaces adjacent to the baseflow channel and within the margins of the 2-year flood channel. Vegetation will improve habitat complexity, contribute wood to the stream, and slow flood water.

I.3.2 Alternative 2 – Grazing Exclusion/No Habitat Enhancement

Alternative 2 would include fencing the Syscan River according to the fencing options presented in Alternative 1. Bioengineering outlined in Alternative 1 would not be completed under Alternative 2. Excluding livestock from the active channel would provide the greatest long-term benefits for the system. Habitat improvements would be slower under Alternative 2 than under Alternative 1, but Alternative 3 would also be less costly and lower risk.

Alternative 2 Summary

Alternative 2 addresses the restoration goals. Excluding livestock from the river would improve vegetation conditions and ultimately reduce sediment loading to the river. The increased channel roughness related to the improved vegetation condition potentially increase water surface elevations over time. Higher water surface elevations would increase channel-floodplain connectivity. The fencing would allow vegetation to recolonize naturally. The shorter-term bank stabilization, habitat, and improved vegetation condition benefits related to bioengineering and ELJ installation would not be realized under Alternative 2. Over time, riparian vegetation would be expected to colonize the surfaces adjacent to the baseflow channel and within the margins of the 2-year flood channel. Vegetation will improve habitat complexity, contribute wood to the stream, and slow flood water. Alternative 2 would be less expensive than Alternative 1 since no habitat enhancement work would be completed.

I.3.3 Alternative 3 – Habitat Enhancement/No Grazing Exclusion

Alternative 3 would address aquatic and riparian habitat in the river corridor through bioengineering and large wood placement; however, the river corridor would not be fenced. Alternative 3 would improve habitat complexity but would not provide the greater watershed benefits that would be expected from the grazing exclusion. Habitat improvements would likely be short-term in nature and would be undermined by the continued grazing pressure.

Alternative 3 Summary

Alternative 3 does not entirely address the restoration goals. Excluding livestock from the river is necessary to improve vegetation conditions and ultimately reduce sediment loading to the river. Installation of ELJs would potentially increase water surface elevations, but continued grazing would reduce the potential for increasing channel roughness at the reach scale. Although the

bioengineering and ELJs are also in the context of the watershed conditions, the effectiveness of these treatments would be minimal relative to the negative effects of continued grazing.

I.3.4 Alternative 4 - Channel Reconstruction

Under Alternative 4, portions of the Sycan River would be reconstructed to increase channel sinuosity and increase channel-floodplain connectivity. The reconstructed channel would follow the alignments of floodplain channels adjacent to the active river channel. Portions of the existing channel that were to be left in place would be modified to raise the channel invert elevation. Bioengineering, ELJs, and grade control would be used to provide channel stability and habitat.

This approach would address the original idea presented by Water Consulting, Inc. (2002) that the Sycan River was entrenched relative to the floodplain elevation and that only periodic floods accessed adjacent floodplains. The hydraulic modeling exercise suggests that the Sycan River is confined to approximately the 2-year discharge event in most of the reach upstream from the Shields' property. The lower Sycan River that is bracketed by high terraces, confines stream flows up to an exceeding the 5-year event.

This alternative was not pursued further due to the relative risk and costs associated with channel reconstruction. Channel reconstruction in the Sycan River system would have moderate risk due to periodic flood events, ice floes, fine soils, and vegetation conditions. Relocating the channel would require substantial earth moving and stabilization. Rock and gravel would be required to ensure channel stability. Because these materials are limited in the project area, materials would need to be imported into the project area.

Reducing the project risk would be exceedingly expensive due to the need for vertical and lateral channel stabilization. The remoteness of the project area would require long haul routes to import project materials if they were not available on-site.

Furthermore, the channel through most of the reach is only slightly entrenched and adjacent floodplains are inundated with moderate frequency. Higher terraces in the lower project area are infrequently inundated. High terrace soil properties suggest these landforms have not been active floodplains in the recent past.

In summary, implementing channel reconstruction through the project area is considered to be a high risk, low reward project alternative. Channel reconstruction would be expensive with questionable benefits and a moderate to considerable level of risk. For these reasons, Alternative 4 was not developed further.

Alternative 4 Summary

Alternative 4 addresses the restoration goals, however, considerable cost and risk are associated with this alternative. Channel reconstruction would include increasing the channel sinuosity, improving channel-floodplain connectivity, and stabilizing eroding banks. These efforts would be expensive due to the materials costs, remote project area, and extent of stabilization structures that would have to be installed to reduce the potential for project failure. Livestock would need to be excluded from the river corridor. Alternative 4 would be the most expensive project alternative.

I.3.5 Alternative 5 – Maintain Existing Land Management Practices and Existing Conditions

Alternative 5 would maintain the existing land management practices. Continuing with the current land management regime will likely result in the continuation of the existing degraded river corridor conditions. Livestock will graze the riparian zone and bank erosion will continue. The Sycan River will continue to have stability issues, and channel roughness and channel-floodplain connectivity are not expected to improve.

No additional monetary costs would be incurred with this option. Over time if the river continues to widen, the landowners may lose property due to erosion. Environmental costs would include continued sediment delivery to the Sprague River and ultimately Upper Klamath Lake, aquatic habitat degradation, and further invasive weed colonization. The primary landowner benefit of Alternative 5 is that the existing land management regime would continue. This would not require any change in the current management costs.

Alternative 5 Summary

Alternative 5 would not achieve the restoration goals.

I.4 EXAMPLE HABITAT ENHANCEMENT TREATMENTS

The following sections outline example habitat enhancement treatments for the Sycan River project area.

I.4.1 Engineered Log Jams

Large woody debris stabilizes stream banks (Buffington and Montgomery 1999; Bilby 1984) and provides aquatic habitat (Bryant and Sedell 1995; Bilby and Ward 1989). Engineered log jams (ELJs) are constructed to mimic naturally occurring woody debris accumulations that typically form in the lower third of outside meander arcs. Natural jams accumulate over time as high water events overtop the lower portion of the meander, depositing wood on the floodplain. Large wood traps smaller materials, increasing the jam volume, vertically influencing the stream from the channel bed to the floodplain and creating diverse aquatic and overhead habitat for fish (Shields and Knight 2003), riparian habitat for mammals and birds (Dykaar and Wigington 2000), bank protection, fine sediment deposition areas (Shields et al. 2001; Piegay and Gurnell 1997), and protected growing sites (Abbe and Montgomery 1996; Malanson and Butler 1990). In restoration projects, ELJs are constructed out of several large trees, various-sized rootwads, small diameter woody material, and large anchor rocks (NRCS 2001). The large trees are trenched into the bank and anchored with large rocks. Other woody material is interlaced among the large key trees to create a diverse array of woody material. Several rootwads and logs are extended out into the channel to diversify the local aquatic environment. Over time the jams are expected to grow in size as the jam captures other woody debris transported during high water (NRCS 2001).

Local trees would be used to construct ELJs in the Sycan River project area. Trees should be at least 30 ft in length and should retain branches and rootwads when possible. If a substantial number of trees are available, stacking the trees would provide enough ballast that large rock

would not be needed. Large rock could be incorporated if additional stability is necessary to reduce the risk of structure failure.

ELJs could be used to achieve multiple goals including streambank protection, aquatic habitat enhancement, and site revegetation. ELJ location, orientation, size, and composition would vary depending on the project objectives. Example ELJs are presented in Figure I-7.



Figure I-7. Example ELJs constructed on a moderate gradient alluvial stream in Idaho (left) and on the Sprague River near Beatty, Oregon (right).

I.4.2 Vegetated Soil Lifts

Vegetated soil lifts are a revegetation and bank construction technique that combines layers of dormant willow cuttings with fabric-wrapped soil to revegetate and stabilize stream banks and slopes. Soil is wrapped within two layers of biodegradable coconut fiber (coir) fabric, to hold the soil in place while vegetation becomes established in the relatively high stress land/water interface. Soil lifts, combined with a bankfull bench, will result in near bank areas where native woody vegetation can become established. To increase success, the face of soil lifts should be reinforced with either a coir log or coir wattle to help maintain the lift shape, keep fine soil particles from filtering out through the lift face, and maintain surface tension. In addition to these functions, coir wattles also retain moisture. If a combination of the two is desired, coir logs should be used in areas where greater strength and moisture capacity are needed. Note that coir wattles are a lower density version of coir log fascines, described below. The uppermost soil lift should be filled with salvaged sod or seeded with the seed mix developed for the site. Example soil lifts are included in Figure I-8.

If soil lifts must be constructed during the summer, and willow cuttings cannot be collected while dormant and kept in cold storage, containerized plants should be used in the lifts. If the timing of soil lift installation is appropriate for using dormant, live cuttings, cuttings should be installed at a spacing of five per linear foot between lifts. If containerized plants are used, plants should be installed between lift layers at a spacing of one per linear foot. Denser spacing is acceptable, but is probably not necessary if it is possible to irrigate the soil lifts during the first two growing seasons.



Figure I-8. Examples of soil lifts on the Sprague River (left) and Belmont Creek (right). The Sprague River photo was taken in the spring following installation. The Belmont Creek photo was taken 2 years after installation.

I.4.3 Coir Log Fascines

Coir logs, combined with dormant willow cuttings, are proposed for compacted and/or eroding streambank areas where objective is to accelerate willow recovery. Coir log fascines (also referred to as coir logs) have either a synthetic (polyethylene) mesh or natural fiber netting that contains high-density coir (coconut fiber) bales. Coir is used for bioengineering because it stores water for long periods, and its durable fibers trap sediment and mimic soil matrices formed by living roots. Coir biodegrades over approximately five to seven years, and provides a stable growing medium while native riparian plants become established. New banks are created behind the coir fascines by filling the area with cobble and soil. These areas can then be planted with woody vegetation.

I.4.4 Revegetation Treatments

Planting native species in specific sections of the project area is recommended to accelerate riparian recovery. The following sections highlight revegetation considerations for the Sycan River project area. Planting recommendations focus on planting native species including willows, golden currant, and silver sage. Selecting plants grown from local stock are preferable. Planting willow cuttings is an inexpensive means of jump-starting plant community recovery. Containerized plants are typically more expensive than cuttings. Mixing containers in with cuttings is a cost-effective approach to re-establishing a diverse riparian community. The following revegetation treatments could be applied throughout the Sycan River project area.

Containerized Plantings

Planting containerized riparian tree and shrub species is recommended for outside meander bends and other areas on the channel and floodplain. Container plantings will supplement other treatments such as live willow staking, to provide species diversity and accelerate the rate of vegetation establishment. Container plants should be grown in one gallon containers and planted at an average of 6 ft spacing. Plants should be installed in a clumping pattern. This concentrated layout will not only promote woody species development in the most vulnerable areas but also

allow for more efficient planting and maintenance. Planting holes can be dug by hand or using an auger.

In order to reduce grass competition and increase moisture holding capacity, either wood mulch or 3-foot by 3-foot brush blankets should be placed at the base of each container plant. If using brush blankets, container plants are installed first and the brush blanket is subsequently placed around the base of the stem. A browse protector may be installed after the brush blanket if there is potential for significant browse by deer or other ungulates. If using wood mulch, it should be applied after the container plant and optional browse protector are installed.

Willow Cuttings

The installation of willow cuttings in depositional areas, adjacent to the channel, and around off-channel wetlands is a relatively quick and easy way to establish vegetation if collected and installed correctly. Cuttings should be collected and installed while dormant if possible. Willow cuttings used for direct planting can be collected and installed in the fall after they have gone dormant or in the spring before bud break. Cuttings should be healthy, vigorously growing, stout enough to drive into soil, $\frac{3}{4}$ " to $1\frac{1}{2}$ " in diameter, and 2 ft to 3 ft long. Willow cuttings should be buried up to $\frac{3}{4}$ of their length so that more nodes are below ground than above ground. Cuttings should be able to access the baseflow water table for best survival. Suggested species for use include *Salix exigua* (sandbar willow), *Salix lasiolepis* (arroyo willow), *Salix lucida* spp. *lasiandra* (shining willow), and *Salix boothii* (Booth's willow).

Herbivory Control

Protection is needed for newly installed vegetation and seeded areas in locations where ungulate grazing could be a problem. A few herbivore protection options exist including area exclusion and individual plant protection. *Area exclusion* makes a discrete sensitive area less accessible to herbivores. *Individual plant protection* protects a single plant from browse, but does not protect the ground from compaction, trampling, or erosion.

One option for area exclusion is to temporarily fence the affected area with electric fencing or a similar product. The size of the area to be fenced and feasibility of frequent maintenance must be considered if choosing this option.

Individual plant protection commonly consists of 4-foot tall, 8-inch diameter browse protectors secured with a 2-inch by 2-inch wooden stake. Other methods such as spraying planted plants with products such as Plantskydd® Deer Repellent, has proven effective in some areas, but requires frequent application to be effective in areas with heavy browse pressure. Plantskydd Deer Repellent works by emitting an odor that animals associate with predator activity which, in theory, repels the animal before it browses the plant.

I.4.5 Noxious Weed and Invasive Plant Species Management (Integrated Pest Management)

Noxious and invasive plant species management is essential to achieving restoration goals along the Syscan River. Numerous weed species have spread across the valley in the recent past. Non-native pasture grasses and legumes (clovers) are widespread due to the use of non-native pasture mixes and other disturbances, the spread of seed by livestock, and natural colonization. These non-native pasture grasses and legumes are of particular use to livestock grazing but have caused declines in native shrubs, grasses and forbs. Noxious weeds, a legal classification, are of much greater concern, due to their invasiveness, their ability to outcompete native vegetation, and the fact that they are largely unpalatable to wild and domestic grazers. Dominant noxious

weeds that are now common in the Sycan River project area include Canada thistle (*Cirsium arvense*) and bull thistle (*Cirsium vulgare*). These weeds are actively spread by human activities such as livestock grazing and off-road-vehicle use. An “Integrated Pest Management” (IPM) approach is necessary for long-term weed control. Example methods include:

- a. *Herbicide application*, via hand or mechanical means;
- b. *Mechanical controls*, including;
 - Hand weeding in special circumstances, such as new introductions of invasive weeds or around planted seedlings;
 - Mowing to reduce competition or limit flowering;
 - Disking to reduce competition; and
 - Cutting weed tree species, coupled with poison application to stems;
- c. *Biocontrols*, generally limited to introduction of weed-species-specific herbivorous insects;
- d. *Irrigation*, applied to favor desirable species and/or disadvantage more xeric weed species;
- e. *Tilling*, implemented after irrigation has forced germination of undesirable species.
- f. *Weed barriers or mulches*, either synthetic or organic. This can include application of sufficient wood fiber mulch or composts to bury and kill weed populations (however, this will generally be limited to active restoration measures);
- g. *Soil nutrient modification*, such as mulching to suppress excess nitrogen levels, or adding soil amendments to improve soil fertility (also generally limited to active measures).

I.4.6 Maintenance and Monitoring

Maintain planted vegetation

It is necessary to maintain planted material during the first two years after initial project implementation, to ensure adequate survival and establishment. Maintenance activities include: supplemental irrigation, invasive species control, repair of structures, and re-planting.

Supplemental Irrigation

Planted material should be deep watered two to three times per month during the growing season, depending upon precipitation and the hydrologic regime of the planting site. Deep watering will encourage the formation of deep root systems.

Invasive Species Control

Controlling weedy species that may invade areas of disturbed soil will help newly establishing plants to survive by limiting competition. Brush blankets, mulch applications, and seeding with fast-growing native species may prevent weedy species from colonizing disturbed areas. Other weed control measures such as herbicide application or solarization treatments may be necessary for weedy areas that are already established. Solarization is the installation of woven polyethylene fabric over areas of undesirable vegetation. Solarization eliminates light and heats the soil, causing thin-coated grass seed to die and potentially stimulating germination of hard-coated native seed. This treatment can be used as either a pre-planting treatment or as long-term weed barrier treatment where plants are installed through the material.

Re-planting

Many factors that are difficult to either control or predict may affect plant survival, and some re-planting may be necessary during the first year or two after initial planting. Further, browse

protection on surviving plants may need maintenance to ensure their stability or allow for plant growth.

Monitoring vegetation establishment and revegetation success

Monitoring should be completed annually during the first two or three growing seasons after initial project implementation. At a minimum, monitoring should include estimates of survival by treatment type, survival by species, and observations of the integrity and function of bioengineering structures (vegetated soil lifts). Monitoring should be tailored toward determining the degree of success of various revegetation treatments and the need for any additional revegetation actions necessary to meet project goals. In addition, monitoring nearby completed riparian revegetation projects will provide guidance to support implementation of this plan.

I.4.7 Summary

Engineered log jams are used to achieve multiple project objectives. Depending on the placement location, orientation, size, and composition, ELJs may be used to protect streambanks, enhance habitat, and protect revegetated areas. ELJ installation must account for site conditions that may influence ELJ stability and effect on the river corridor. Materials found within the Sycan River project area could be used to construct ELJs.

Bioengineering techniques incorporate plant materials, soil, and coir products to stabilize streambanks and accelerate site revegetation. Plant materials include cuttings and containers derived from local stock. Coir products provide a protective envelop containing the soil medium. Bioengineering offers a cost-effective, low risk tools for improving stream corridor conditions.

I.5 RESTORATION STRATEGIES SUMMARY

Proposed restoration strategies outlined in this section may be applied throughout the Sycan River project area. The preferred approach to improving the conditions of the Sycan River corridor is to exclude livestock from the river corridor for at least 5-10 years. This period of time is believed to be necessary to improve the riparian vegetation community that has been subjected to over 100 years of grazing. Using the Teddy Powers Meadow Reference Reach as an example, the riparian community is expected to rapidly respond to the livestock exclusion. An improved riparian condition will increase the channel roughness leading to more frequent flooding of adjacent floodplains.

Bioengineering techniques for accelerating riparian recovery and enhancing aquatic habitat were also presented. Techniques including engineered log jams, vegetated soil lifts, willow cuttings, and containerized plants achieve multiple project objectives. While fencing the river corridor will exclude livestock from the river margins, implementing bioengineering techniques will address near-term conditions until the river corridor naturally recovers.

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