FINAL
GEOMORPHIC ASSESSMENT REPORT
BIG WOOD RIVER
BLAINE COUNTY, IDAHO

Prepared For

Trout Unlimited

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Biota

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1.0 INTRODUCTION

Biota Research and Consulting, Inc. (Biota) was retained by Trout Unlimited (Attn: Chad Chorney, 300 North Main Street, Hailey, Idaho) to complete a geomorphic assessment of the Big Wood River from the confluence with the North Fork Big Wood River downstream to Magic Reservoir in Blaine County, Idaho. Project proponents include the Bureau of Land Management and the Wood River Land Trust. The assessment effort was an attempt to quantitatively describe fluvial system conditions and to develop restoration guidelines and management objectives within the watershed.

The Geomorphic Assessment Report includes discussion of morphologic assessments completed within the project area; hydrologic investigations; hydraulic analyses; sediment transport analyses; and discussion of restoration guidelines. These materials are intended to inform resource management; collaboration with landowners and project proponents; public outreach; regulatory agencies; future project implementation; and the long-term assessment of riverine conditions.

2.0 PROJECT AREA AND APPROACH

The objective of the Geomorphic Assessment Project was to quantitatively describe fluvial conditions in the main stem of the Big Wood River and to develop objective recommendations for resource management and restoration efforts. The study area extends from the confluence with the North Fork Big Wood River downstream to Magic Reservoir and is comprised of three sub-reaches, or sections; Section 1 extends from the North Fork downstream to Warm Springs Creek, Section 2 extends from Warm Springs Creek downstream to the East Fork, Section 3 extends from the East Fork downstream to Magic Reservoir.

Phase 1 of the effort included a general watershed assessment to characterize watershed landscape setting and inform the selection of main stem sub-reaches for field investigation and comprehensive analysis. Phase 2 included detailed field evaluation of study and reference conditions. Phase 3 involved identification of stream stability consequences. Phase 4 focused on interpretation of findings, identification of natural channel design restoration guidelines and approaches, and recommendation of specific channel treatments to meet objectives.

3.0 PHASE 1: WATERSHED ASSESSMENT

The intent of field investigations of sub-reaches within each of the three study segments was to describe functional and impaired channel conditions within the watershed, and to quantify departure of impaired reaches from the functional state. Watershed assessment methodologies that prioritize restoration needs across tributaries in the basin were therefore not informative to the effort. Instead, watershed assessment tools were applied to qualify the relative influence of tributary systems on the main stem, and to correspondingly inform the selection of main stem sub-reaches that reflected the most impaired, least impaired, and typical conditions found in the system.

3.1 STUDY AREA SUB-CATCHMENTS

The Big Wood River study basin is 556,800 acres and is comprised of 60% (337,200 acres) lands administered by the U.S. Forest Service, 20% (107,900 acres) lands administered by the Bureau of Land Management, and 20% (110,900 acres) lands under private ownership (Attached Exhibit 1). The watershed is composed of 29 Hydrologic Units (HUC 12's) that range in size from 10,648 to 37,539 acres (Attached Exhibit 2). In order to enable assessment of the relative influence of existing tributaries on the main stem Big Wood River, the HUC 12's were combined to delineate sub-basins (referred to as *tributary catchments*) applicable to the assessment. Delineated tributary catchments associated with substantive tributaries include the Upper big Wood River, North Fork Big Wood River, Trail Creek, East Fork Wood River, Warm Springs Creek, Greenhorn Creek, Deer Creek, Quigley Creek, Croy Creek, Seamans Creek, Rock Creek, and Dry Creek. Delineated sub-basins that encompass reaches of the main stem and smaller tributary systems include Eagle Creek, Lake Creek, Elkhorn Gulch (both upstream and downstream) Indian Creek, Slaughterhouse Creek, and Poverty Flat (Attached Exhibit 3).

3.2 GEOLOGY

The Surficial Geologic Map of the Wood River Valley Area, Blaine County, Idaho (Breckenridge and Othberg, 2006, www.idahogeology.org; map version 1-10-2006) was incorporated into the project Geographic Information System (GIS). Mapped geologic features do not encompass the entire watershed study area, but do cover a roughly 9-13 mile wide area bounding the main stem Big Wood River from the North Fork Big Wood River confluence to an area five miles south of Bellevue. Map units were combined to obtain six geologic classes including colluvium, alluvial deposits, glacial deposits, talus, alluvial fans, and debris-flows and landslides (Attached Exhibit 4). Mapped geologic features were used to identify and locate colluvial landscapes, alluvial fans, and unstable areas associated with debris flows, landslides, and talus in order to inform selection of main stem sample reaches and identification of tributary influences on the Big Wood River.

3.2 ROADS

Digital road data were obtained from the Blaine County GIS Department and were incorporated into the project GIS (Attached Exhibit 5). Spatial analyses were completed to quantify the length of roads located within 50, 100, and 200 ft of watercourses identified in the National Hydrography Dataset (mapped at 1:24,000 scale in the National Hydrography Dataset, NHD; Attached Exhibit 6). Road crossings of watercourses were also identified and tallied (Attached Exhibit 7). Each tributary catchment was then assigned a score based upon potential impact on the main stem Big Wood River resulting from road network attributes using the algorithm presented below. Rankings were used to develop a chloropleth map to summarize relative influence of tributary catchments on the main stem Big Wood River (Attached Exhibit 8).

<u>Algorithm to Determine Relative Influence of Tributary Catchment Road Network Attributes on the Main Stem Big Wood River</u>

*(Road Length w/in 50ft of Watercourses [ft] / Total Length of Watercourses [ft]) * 3 pts*
Plus
*(Road Length w/in 100ft of Watercourses [ft] / Total Length of Watercourses [ft]) * 2 pts*
Plus
*(Road Length w/in 200ft of Watercourses [ft] / Total Length of Watercourses [ft]) * 1 pt*
Plus
(Road Crossing Number [n]/ Total Length of Watercourse [miles]) x 3 pts
Equals
Point Value for Relative Ranking

3.3 LAND SLOPE

National Elevation Dataset (NED; 10m resolution) topographic information spanning the study area watershed was obtained and incorporated into the project GIS. Slope data were used to identify areas within the watershed with slope less than 30%, between 30 and 40%, and greater than 40% (Attached Exhibit 9). Each tributary catchment was then assigned a score based upon potential impact on the main stem Big Wood River resulting from land slope attributes using the algorithm presented below. Rankings were used to develop a chloropleth map to summarize relative influence of tributary catchments on the main stem Big Wood River (Attached Exhibit 10).

<u>Algorithm to Determine Relative Influence of Tributary Catchment Land Slopes on the Main Stem Big Wood River</u>

*(Percentage of Tributary Catchment w/ Slope > 40%) * 3 pts*
Plus
*(Percentage of Tributary Catchment w/ Slope 30-40%) * 2 pts*
Plus
*(Percentage of Tributary Catchment w/ Slope < 30%) * 1 pt*
Equals
Point Value for Relative Ranking

3.4 SOILS

The Blaine County Soil Survey Report, which contains mapped soil attributes updated from the NRCS National Soil Information System (SSURGO), was obtained and incorporated into the project GIS. Soil types were combined to generate three categories based upon the soil erosion hazards of 'very sever', 'severe', or 'moderate' (Attached Exhibit 11). Soils data do not cover the entire study area watershed so soil erosion hazard could not be applied to assess the relative influence of tributary catchments on the main stem river. Soils data do generally characterize BLM and private lands located along the main stem river along most of the three sections of the main stem study area. Data were used to assess the relative influence of soil erosion hazard on the main stem Big Wood River using the algorithm presented below, and results were used to rank the three study sub-reaches based upon relative soil erosion hazard conditions (Attached Exhibit 12).

<u>Algorithm to Determine Relative Influence of Tributary Catchment Soil Erosion Attributes on Sub-Reaches of the Main Stem Big Wood River</u>

*(Percentage of Area w/ 'Very Severe' Soil Erosion Hazard within 0.5 mi of the Big Wood River) * 3 pts*
Plus
*(Percentage of Area w/ 'Severe' Soil Erosion Hazard within 0.5 mi of the Big Wood River) * 2 pts*
Plus
*(Percentage of Area w/ 'Moderate' Soil Erosion Hazard within 0.5 mi of the Big Wood River) * 1 pts*
Equals
Point Value for Relative Ranking

3.5 LAND COVER

Land cover data were obtained from the Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) and were incorporated into the project GIS. Macrogroup land cover categories were combined according to the following Table 1 to generate nine classes of land cover described as Forest, Shrubland, Grassland, Cliff and Scree, Barren, Agricultural, Disturbed, Developed, or Riparian Vegetation. The nine classes were used to map land cover attributes throughout the study area watershed (Attached Exhibit 13). Each tributary catchment was then assigned a score based upon potential adverse impact on the main stem Big Wood River resulting from land cover types of ‘Barren’, ‘Disturbed’, and ‘Developed’ using the algorithm presented below. Rankings were used to develop a chloropleth map to summarize relative adverse influence of tributary catchments on the main stem Big Wood River (Attached Exhibit 14). Each tributary catchment was also assigned a score based upon potential benefit to the main stem Big Wood River resulting from the abundance of ‘Riparian Vegetation’ land cover. Rankings were used to develop a chloropleth map to summarize relative benefit to the main stem Big Wood River (Attached Exhibit 15).

Table 1. Land cover classes and macrogroup covertypes.

Assessment Class	Macrogroup Land Cover Type
Forest Polygon	Northern Rocky Mountain Lower Montane and Foothill Forest Rocky Mountain Subalpine & High Montane Conifer Forest Intermountain Singleleaf Pinyon-Western Juniper Woodland
Shrubland Polygon	Northern Rocky Mountain Vancouverian Montane & Foothill Grassland & Shrubland Southern Rocky Mountain Montane Grassland and Shrubland Great Basin Saltbrush Scrub Great Basin & Intermountain Tall Sagebrush Shrubland & Steppe Great Basin & Intermountain Dry Shrubland & Grassland
Grassland Polygon	Rocky Mountain Alpine Scrub, Forb Meadow & Grassland
Cliff & Scree Polygon	Rocky Mountain Cliff, Scree & Rock Vegetation Intermountain Basin Cliff, Scree & Rock Vegetation Rocky Mountain Alpine Cliff, Scree & Rock Vegetation
Barren Polygon	Barren
Agricultural Polygon	Herbaceous Agricultural Vegetation Introduced & Semi Natural Vegetation
Disturbed Area Polygon	Recently Disturbed or Modified Quarries, Mines, Gravel Pits, and Oil Wells
Developed Area Polygon	Developed & Urban
Riparian Vegetation Polygon	Rocky Mountain-Vancouverian Subalpine & High Montane Mesic Grass & Forb Meadow Western North American Montane Wet Meadow & Low Shrubland Warm Desert Freshwater Shrubland, Meadow & Marsh Rocky Mountain Subalpine and Montane Fen Rocky Mountain and Great Basin Flooded & Swamp Forest

Algorithm to Determine Relative Adverse Influence of Tributary Catchment Land Cover on the Main Stem Big Wood River

(Percentage of Tributary Catchment Area w/ ‘Barren’ Land Cover)
Plus
(Percentage of Tributary Catchment Area w/ ‘Disturbed’ Land Cover)
Plus
(Percentage of Tributary Catchment Area w/ ‘Developed’ Land Cover)
** 3 pts*
Equals
Point Value for Relative Ranking

Algorithm to Determine Relative Beneficial Influence of Tributary Catchment Land Cover on the Main Stem Big Wood River

*(Percentage of Tributary Catchment Area w/ 'Riparian Vegetation') * 3 pts*
Equals
Point Value for Relative Ranking

3.6 TRIBUTARY CATCHMENT ANALYSIS

The influences of tributary catchments on the main stem Big Wood River resulting from landscape attributes (soil erosion hazard, road network attributes, land slope, and land cover) were combined to summarize landscape conditions. Tributary catchments were assigned a point value based upon gradation clast from the chloropleth analysis completed for each landscape attribute; catchments with the most influence were allocated the most points (five) and catchments with the least influence were allocated the fewest points (one). Points assigned based upon each landscape attribute were summed and the final values were used to define 3 categories (most, moderate, least) of relative influence on the Big Wood River, as depicted in the summary chloropleth map (Attached Exhibit 16).

3.7 FIRE

The impacts of fire regime in the Big Wood River basin were considered independently of other analyzed landscape attributes due to the severe and dramatic influence of fire on fluvial conditions. Spatial data depicting historic fire extents and locations obtained from the US Forest Service were incorporated into the project GIS (Attached Exhibit 17). Polygon features included in the data set depict the spatial extent of historic fires with area greater than 10 acres and point data depict the location of historic fires with area less than 10 acres in size. The following algorithms were used to assign a score to each tributary catchment based upon potential adverse impact on the main stem Big Wood River resulting from (1) the percentage of sub-basin area burned, and (2) the density of historic fires. Results were used to generate two chloropleth maps depicting relative adverse influence of tributary catchments resulting from percentage of sub-basin burned (Attached Exhibit 18) and sub-basin fire density (Attached Exhibit 19).

Algorithm to Determine Relative Adverse Influence of Tributary Catchment Historic Fire Size on the Main Stem Big Wood River

*(Percentage of Tributary Catchment Burned within 5 Years) * 10 pts*
Plus
*(Percentage of Tributary Catchment Burned within 5-15 Years) * 1 pts*
Plus
*(Percentage of Tributary Catchment Burned more than 15 Years ago) * 0.1 pts*
Equals
Point Value for Relative Ranking

Algorithm to Determine Relative Adverse Influence of Tributary Catchment Historic Fire Quantity on the Main Stem Big Wood River

*(Density of Historic Fires in Tributary Catchment Area within 5 Years [#/ac]) * 10 pts*
Plus
*(Density of Historic Fires in Tributary Catchment Area from 5 to 15 Years Ago [#/ac]) * 1 pts*
Plus
*(Density of Historic Fires in Tributary Catchment Area from more than 15 Years Ago [#/ac]) * 0.1 pts*
Equals
Point Value for Relative Ranking

3.8 ANTHROPOGENIC CHANNEL MODIFICATIONS

The Big Wood River mainstem has been directly altered by diverse anthropogenic activities including residential, commercial, and public infrastructure development encroachment; installation of grade control and instream structures; establishment and maintenance of transportation crossings; and construction and operation of diversion structures. Existing direct channel manipulations within the project area reach were mapped in the Geographic Information System (GIS) at a screen scale of 1 inch to 400 feet. Manipulations were categorized as one of the following: (1) grade control structures; (2) bank hardening or similar structures; (3) bridges; or (4) diversions. Grade control structures, bridges, and diversions were conservatively estimated to have direct influence on channel form for a stream length of approximately 2 channel widths extending both upstream and downstream from the feature. Bank hardening and instream treatments were conservatively estimated to have direct influence on channel form for the length of the treatment. Results of these mapping efforts indicate that anthropogenic channel modifications directly influence approximately 126,111 ft of the 240,296 ft project area, or 52% of the river reach located between the North Fork Big Wood River confluence and Magic Reservoir.

The encroachment of development on the Big Wood River was also investigated in the project GIS. Development defined as residential structures, landscape manipulation (inclusive of manicured or graded yards), public infrastructure, and riparian corridor alterations were mapped in the GIS at a screen scale of 1 inch to 400 feet. The channel alignment (approximate centerline) was used to estimate the floodprone width of the river (the width of the channel at twice the maximum bankfull depth of riffles). To calculate floodprone widths, measured riffle widths from surveyed river reaches were multiplied by the entrenchment ratio (the relation of floodprone width to bankfull channel width) observed in reference conditions. Applied entrenchment ratios were determined based upon potential function channel form, so an entrenchment ratio of 3.9 was applied in river segments where current development and valley settings would accommodate a slightly entrenched and meandering (C-type) channel, and an entrenchment ratio of 1.9 was applied in river segments where established development or valley conditions (colluvial side slopes and narrow valley widths) would accommodate a moderately entrenched and moderately sinuous (Bc-type) channel. Spatial analyses were then completed to identify areas where mapped development extended into the Big Wood River floodprone width. These analyses conservatively identified development encroachment because reduced floodprone widths were applied to river reaches adjacent to development because the potential river form was identified as a Bc-type channel. Analysis indicated that development encroachment has occurred within approximately 12.3 acres of the Big Wood River floodprone area, and that encroachment has occurred along a majority of the project reach. Graphical results of development encroachment and anthropogenic channel alteration analyses are depicted in attached Exhibits 20-82.

4.0 PHASE 2: GEOMORPHIC SURVEYS

The relative influences of tributary catchments on the main stem Big Wood River stemming from both summarized landscape attributes and from fire history were considered and used to select locations for morphologic field surveys. The objective was to identify main stem locations with the following: (1) minimal adverse impacts; (2) most severe impacts; and (3) moderate or average conditions. Based upon initial watershed assessment findings, geomorphic channel surveys were completed at 13 sites on the main stem Big Wood River and two active US Geological Survey stream gauges. Geomorphic survey data were used to inform assessment of channel instabilities, floodplain connectivity and function, peak flow hydraulic conditions and shear stress, and sediment transport. Field data were also used to identify stream classification, quantify channel form, and analyze departure from stable functional conditions. Geomorphic surveys were conducted at the following locations (Attached Exhibit 83):

- Big Wood River Upstream Reference Site
- US Forest Service Wood River Campground Site
- US Geological Survey Stream Gauge (near Ketchum, #13135500)
- Fox Creek Reference Site
- Training Channel Area Site
- Hulen Meadows Site
- Ski Hill Site
- Highway 75 Reach Site
- Downstream of East Fork Site
- Downstream of Deer Creek Site
- Bullion Street Bridge Site (and US Geological Survey Stream Gauge in Hailey, #13139510)
- Colorado Gulch Site
- Broadford Street Bridge Site
- Glendale Site

4.1 CHANNEL MORPHOLOGY

Geomorphic channel surveys included measurement of bankfull indicators, water surface elevation, thalweg, bed features (riffle-run-pool-glide sequences), floodplain and terrace features, top of bank elevations, channel geometry, local slope, and planform. Survey reaches generally encompassed multiple channel meanders and approximately 20 bankfull channel widths. Collected data were used to generate longitudinal profiles; cross sections of representative bed features; and planform depictions of the stream channels. These data were used to identify stream classification, analyze departure from stable (reference) conditions, investigate floodplain connectivity, identify channel instability, and quantify peak flow hydraulic conditions and sediment transport regime.

The Bank Assessment for Non-point source Consequences of Sediment (BANCS) model was used to predict the erosive potential of stream banks within the surveyed river reaches, and to estimate annual sediment contributions to the watershed resulting from bank erosion. The Bank Erosion Hazard Index (BEHI) model was used to qualify bank stability based upon seven variables including bank height, root depth, root density, bank angle, surface protection, bank material, and stratification of bank material. The model was used to rank bank stability within 6 categories ranging from ‘very low’ to ‘extreme’. The Near-Bank Stress (NBS) was simultaneously rated adjacent to all stream banks using up to 7 criteria including channel pattern, radius of curvature, pool slope compared to average slope, pool slope compared to riffle slope, near-bank depth, or velocity isovels. BEHI and NBS ratings were then used to estimate bank erosion rates and sediment inputs using an empirical relationship developed from field data collected in the region. Model output was used to quantify total sediment input from the surveyed river reaches, and to identify the rate of sediment input per unit bank length (tons/year/foot) for use during generalized assessment of larger river segments.

4.2 HYDROLOGIC REGIME

Hydrologic investigations completed within each surveyed river reach included identification of bankfull discharge, which is the design discharge used for site assessment and analysis. Bankfull discharge is the flow rate, and bankfull stage is the corresponding water surface elevation, at which instream water escapes the active channel and inundates the floodplain (when incipient flooding occurs). There is natural variability in the recurrence interval of bankfull discharge between sites that ranges from 1 to 2.5 years according to published literature. However, professional experience in the region suggests that a reasonable estimation of bankfull discharge recurrence interval is 1.1-1.5 years. Bankfull discharge was selected as the primary hydrologic parameter for assessment purposes because it can be identified and corroborated through field investigations, as opposed to potential alternate parameters of dominant discharge (e.g., the flow rate responsible for the stable morphology) or effective discharge (e.g., the flow rate that transports the greatest fraction of the annual sediment load) that are primarily derived through analytical processes, without empirical corroboration.

Estimation of bankfull discharge was performed using hydraulic modeling of open channel flow conditions based upon field-measured morphologic and sediment data (floodplain elevation, bankfull indicators, channel dimension and profile, sediment size class distribution, hydraulic roughness). Hydraulic analysis techniques included:

1. Determination of channel roughness based on hydraulic radius and substrate size class distribution (known as relative roughness), and incorporation of cross sectional area and slope to derive bankfull discharge.

2. Determination of channel roughness based on an empirical correlation between relative roughness, friction factor, and roughness coefficient, then incorporation of cross sectional area and slope to derive bankfull discharge.

These 2 approaches were used to analyze typical riffle bed features in each surveyed river segment. The calculated bankfull discharges obtained using the 2 hydraulic analysis methodologies were generally similar, so the average of the results from the 2 methods was used to identify the bankfull discharge in each surveyed river reach.

Peak flow and flow duration characteristics within the basin were quantified in order to inform analysis of channel function and sediment transport. The US Geological Survey (USGS) maintains stream gauges in the Big Wood River at the North Fork Campground (near Ketchum #13135500) and at Bullion Bridge in Hailey (#13139510). Geomorphic channel surveys were conducted through both stream gauge reaches, and included measurement of local gauge datum, riffle cross sectional geometry, bankfull indicators, and channel profile (slope). Active stage-discharge rating curves for both gauges were obtained from the USGS and were used to determine the discharge corresponding to local bankfull indicators.

Analysis indicates that bankfull discharge at the gauge near Ketchum is 686 cfs and the bankfull discharge at the gauge in Hailey is 1,300 cfs. Peak flow and mean daily discharge from the period of record at the Ketchum gauge (28 years) and at the Hailey gauge (100 years) were obtained and used to identify peak flow return intervals (Figures 1 and 2, respectively).

Mean daily discharge rates from the period of record at both gauges were obtained and used to develop flow duration curves. Flow duration curve analysis indicates that the bankfull discharge of 686 cfs at the Ketchum gauge occurs for about 4% of the time, or about 15 days per year. The bankfull discharge of 1,300 cfs at the Hailey gauge occurs for about 8% of the time, or about 30 days per year. Dimensionless flow duration curves were developed from both gauge data sets (Figure 3) and were used to analyze hydraulic and sediment transport conditions at surveyed river reaches within the Big Wood River basin.

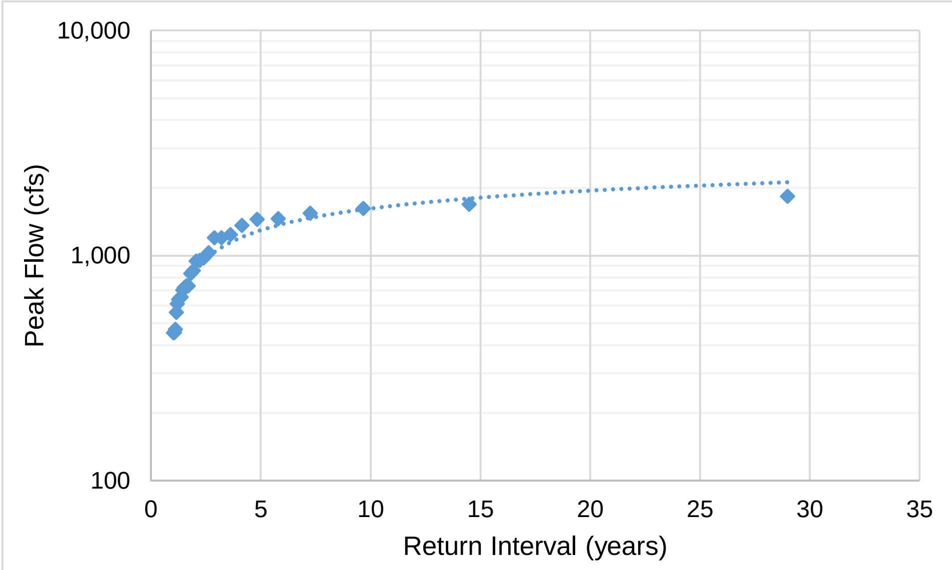

Figure 1. Peak flow recurrence interval at the USGS Big Wood River gauge near Ketchum (#13135500).

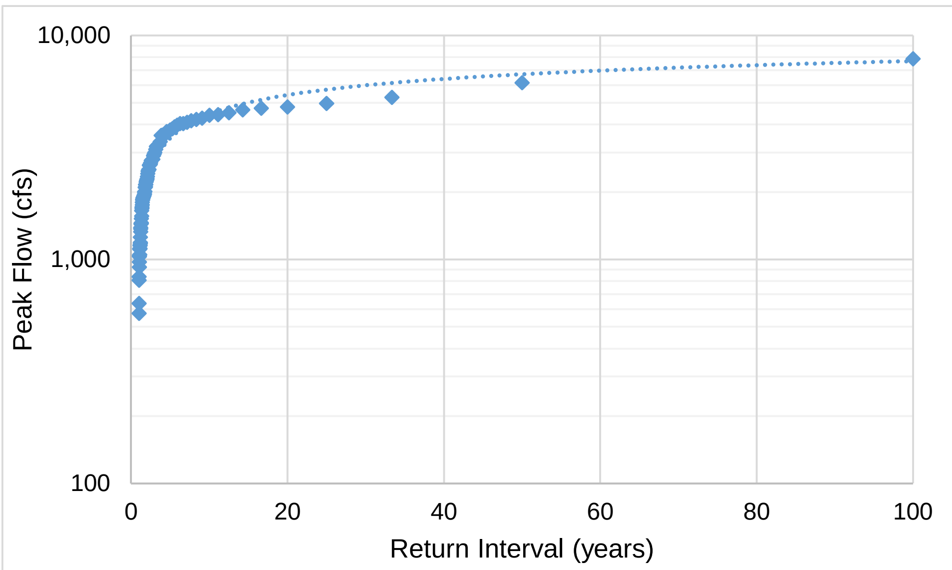

Figure 2. Peak flow recurrence interval at the USGS Big Wood River gauge at Hailey (#13139510).

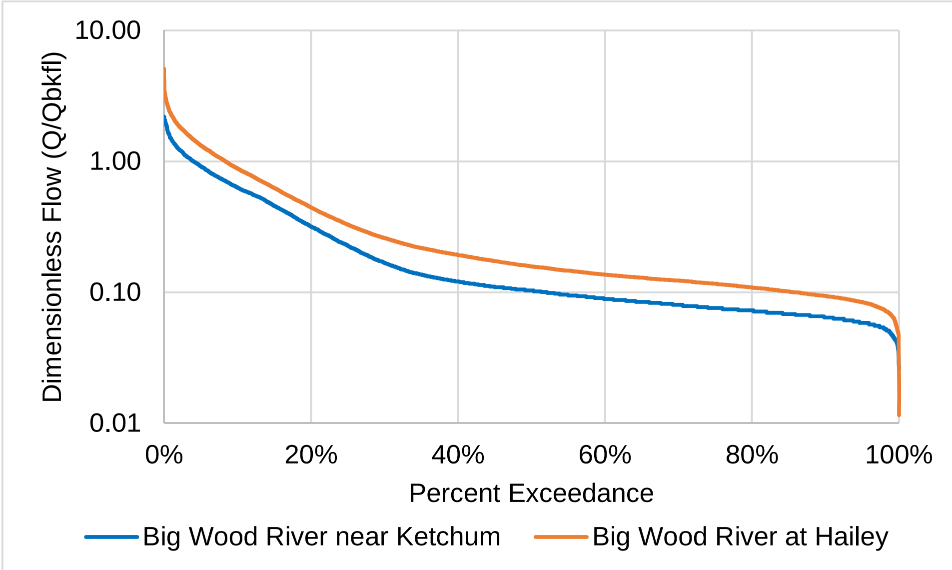

Figure 3. Dimensionless flow duration curves developed from USGS Big Wood River gauges near Ketchum (#13135500) and at Hailey (#13139510).

4.3 SEDIMENT ATTRIBUTES

Sediment data collected within surveyed river reaches were used to quantify sediment transport competence (i.e., the ability of the river to move sediment based upon particle size) and sediment transport capacity (i.e., the total volume of sediment moved by the river per unit time). Sediment transport quantification is a critical component of a fluvial assessment because sediment movement drives channel changes; excess sediment transport can result in channel incision, bank failure, and xerification of the riparian area. Conversely, insufficient sediment transport can result in channel aggradation, reduced slope, lateral migration, increased avulsion potential, and loss of riparian lands.

Collected sediment data included surface and sub-surface grain sampling within surveyed river segments. Surface grain sediment samples on the active bed were collected in accordance with the Wolman pebble count protocol, and were comprised of the measured B-axis of each particle. Sub-surface sample materials were collected in accordance with the Rosgen bar sample protocol, which identified the sample location in the downstream 1/3 of the feature at an elevation midway between the thalweg and bankfull. Pavement and sub-pavement materials were collected from riffle bed features within surveyed river segments where depositional features were absent. Bar, pavement, and sub-pavement sample materials were retained, dried, and sieved using a standard sieve set, and the relative weights of each size class were used during analyses.

4.4 SEDIMENT TRANSPORT COMPETENCE

Sediment transport competence, or the size particle entrained during bankfull discharge, at each surveyed river reach was quantified using morphologic and sediment data including riffle bed feature surface grain particle size class distribution, depositional bar or sub-pavement sample data, surveyed riffle geometry, and bankfull channel slope. Critical dimensionless shear stress or actual dimensional shear stress were calculated for each surveyed stream reach depending upon the suitability of data to particle entrainment equations. Calculated shear stress values were used to identify the size particle entrained at bankfull discharge based upon a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen, 2010. *Watershed Assessment of River Stability and Sediment Supply*). Transport competence results were compared to available bedload (depositional bar material) size class distribution and active bed surface grain size class distribution to assess potential for channel aggradation or degradation.

4.5 SEDIMENT TRANSPORT CAPACITY

Sediment transport rates are highly variable in space and time, and published literature acknowledges that both analytical calculations and field measurements of sediment transport typically demonstrate variability of an order of magnitude or more. The temporal constraints on the Big Wood River Geomorphic Assessment Project precluded field measurement of sediment transport rates because assessment work occurred from spring to fall of 2015, during which time local peak flow rates did not reach bankfull discharge. Therefore, alternate methods of estimating bankfull sediment transport rates in the project area were explored.

The US Forest Service Rocky Mountain Research Station collected sediment transport data across a range of flow rates in the Big Wood River at the North Fork Campground from 1999 to 2000. Data were obtained and used to generate bedload and suspended sediment transport rating curves specific to the location (Figures 4 and 5). Geomorphic survey data collected at the site in 2015 were used to analyze bankfull indicators, channel geometry, and profile. Results indicated that the bankfull discharge at the site is 686 cubic feet per second (cfs). The site-specific sediment transport rating curves were used to determine that the bedload transport rate is 0.39 lbs/sec and the suspended sediment transport rate is 72.1 mg/L at the bankfull discharge of 686 cfs. These results are specific to the North Fork Campground site and cannot be extrapolated across the Big Wood River basin to other surveyed river reaches. Therefore, these empirical results were used to assess whether or not an available regional sediment transport rating curve accurately represents conditions at the North Fork Campground, and could therefore be assumed to reflect conditions across the Big Wood River basin.

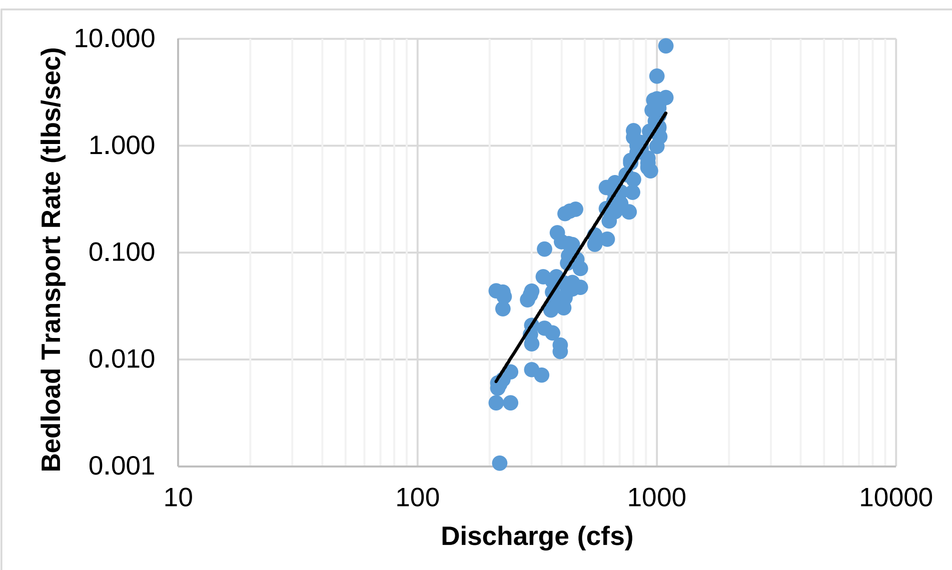

Figure 4. Bedload sediment transport rating curve, North Fork Campground on the Big Wood River.

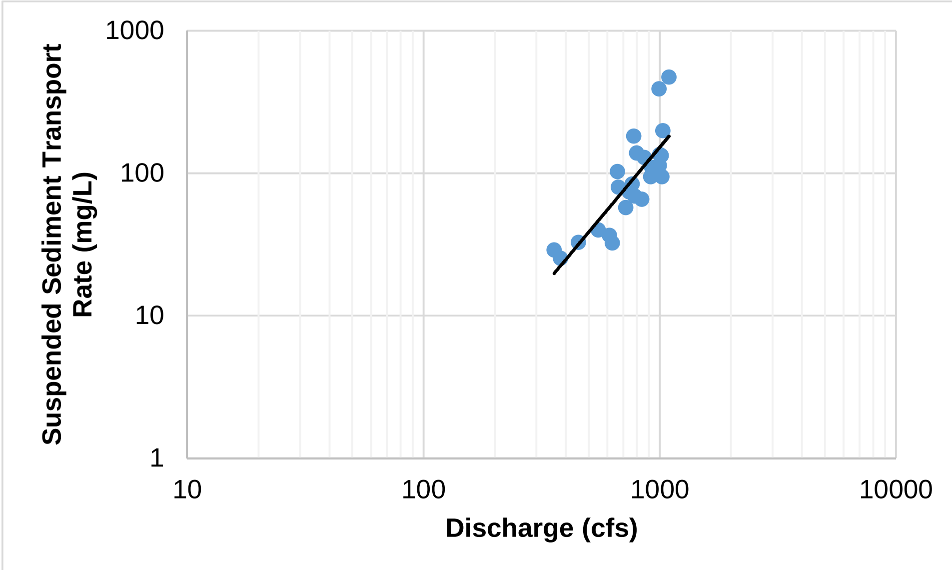

Figure 5. Suspended sediment transport rating curve, North Fork Campground on the Big Wood River.

Biota maintains regional bedload and suspended sediment transport rating curves comprised of empirical data collected in the region (Figures 6 and 7). The regional curves were used to estimate bankfull sediment transport rates in the Big Wood River at the North Fork Campground, and results were compared to measured transport rates collected by the USFS at the North Fork Campground. The regional curves identify a bankfull bedload transport rate of 0.37 lbs/sec (standard error 41.0%, range of 0.22 to 0.52 lbs/sec) and a bankfull suspended sediment transport rate of 43.3 mg/L (standard error of 68.9%, range of 13.5 to 73.1 mg/L). Application of the regional sediment transport rating curves to the North Fork Campground site yields sediment transport rates that are commensurate with empirical data collected at the site, so the regional sediment transport rating curves were considered suitable for estimating sediment transport rates at surveyed river reaches located across the Big Wood River basin.

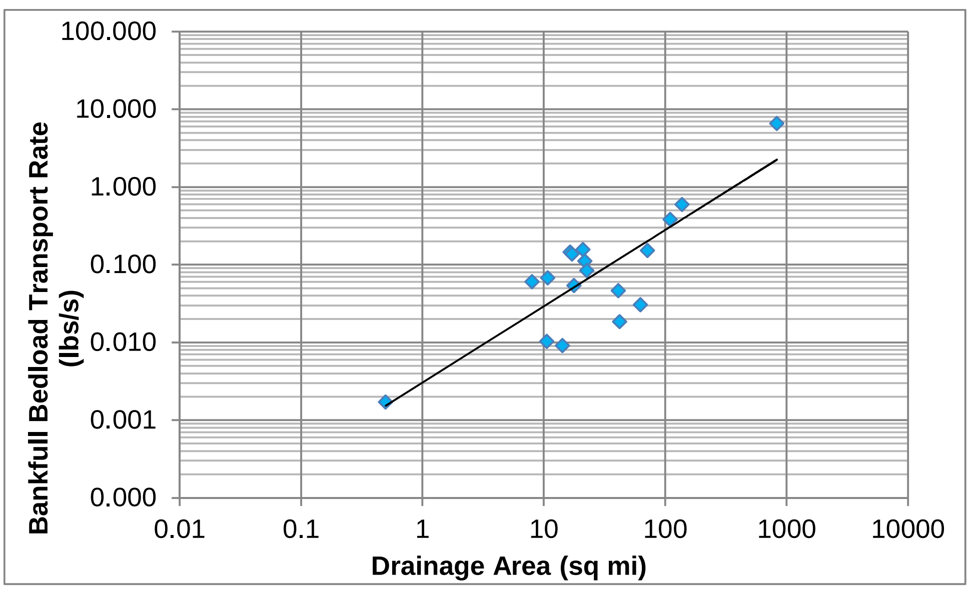

Figure 6. Bedload sediment transport rate regional curve.

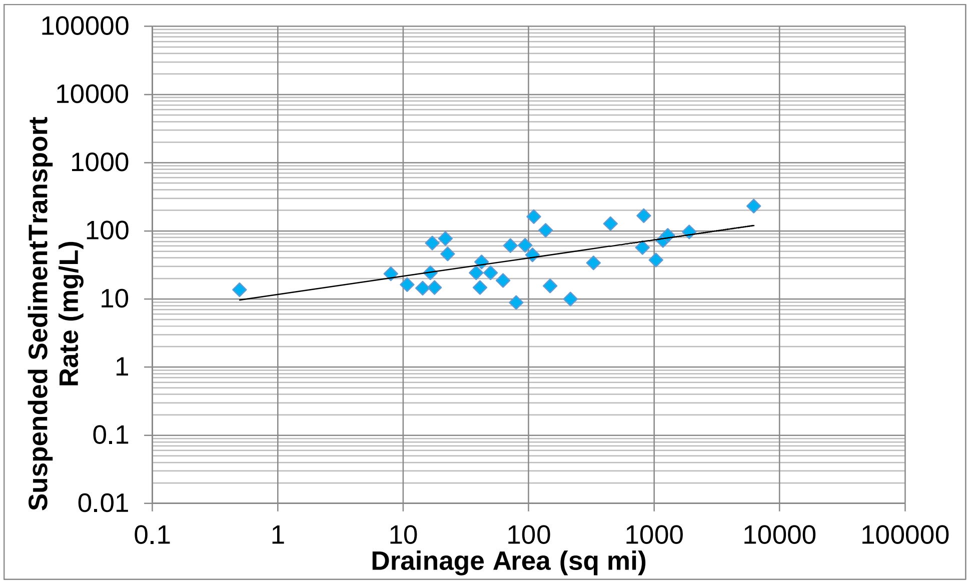

Figure 7. Suspended sediment transport rate regional curve.

Estimated bankfull sediment (bedload and suspended) transport rates were used to scale dimensionless sediment transport rating curves to each surveyed river reach in the Big Wood River study area. Annual sediment load (supply) at each surveyed river reach was calculated by applying the local sediment transport-rating curve to the site-specific mean daily flow duration curve. Annual bedload and suspended sediment transport capacities of each surveyed river reach were then calculated by applying the FLOWSED/POWERSED model (which calculates stream power based on hydraulic geometry, develops sediment transport rating curves as a function of stream power, and applies the flow duration curve to quantify total annual transport capacity). Results were used to quantify the discrepancy between sediment supply and capacity at surveyed river reaches, and to develop predictions related to vertical channel stability.

5.0 PHASE 3: ASSESSMENT RESULTS AND STREAM STABILITY

River reaches surveyed in the Big Wood River project area extended from the headwaters downstream through BLM lands where previous channel modifications have been implemented; through dispersed residential developments; through densely populated urban areas in Ketchum, Hailey, and Bellevue; and through reaches heavily influenced by surface water diversions. Geomorphic conditions of surveyed river reaches are presented in the following sections.

5.1 UPSTREAM REFERENCE REACH

The Upstream Reference Reach is located on US Forest Service lands in a slightly confined alluvial valley with bounding features composed of alluvial deposits and well-developed floodplains (attached Exhibit 85). The stream channel is slightly entrenched, has moderate width/depth ratio, and has moderate sinuosity. The reach has bankfull channel width of 47.3 ft, mean depth of 1.57 ft, width/depth ratio of 30, and bankfull discharge of 244 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is greater than 6 ft/ft, and the channel is classified as a C-type stream. Typical conditions are depicted in Figures 8, 9 and 10, and morphologic channel attributes are summarized in Table 2.

Figure 8. Photograph of spill over log and typical robust riparian vegetation resulting in low BEHI ratings and moderately stable channel conditions in Upstream Reference Reach.

Figure 9. Typical moderate width/depth ratio and moderately stable channel conditions in Upstream Reference Reach.

Figure 10. Typical moderate sinuosity and slightly confined valley in the Upstream Reference Reach.

Table 2. Summary of morphologic channel conditions in the Upstream Reference reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	47.3
Mean Bankfull Depth (ft)	1.57
Maximum Bankfull Depth (ft)	2.61
Width/Depth Ratio (ft/ft)	30
Entrenchment Ratio (ft/ft)	>6
Meander Width Ratio (ft/ft)	2.8
Bankfull Mean Velocity (ft/sec)	3.3
Bankfull Discharge (ft^3/sec)	244
Particle Size Index D_{50} (mm)	85
Sinuosity (ft/ft)	1.12
Annual Streambank Erosion Rate (tons/yr/ft)	0.0699
Slope (ft/ft)	0.011
Existing Stream Type	C3
Potential Stream Type	C3

The bank erosion rate at the Upstream Reference Reach is 0.0.0699 tons/year/foot, and the 600-ft long surveyed stream segment contributes an estimated 42 tons of sediment to the watershed in an average year through bank erosion.

The Upstream Reference Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 11) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 1.1%, and a typical riffle cross section depicting moderate entrenchment and hydraulically connected floodplain is presented in Figure 12.

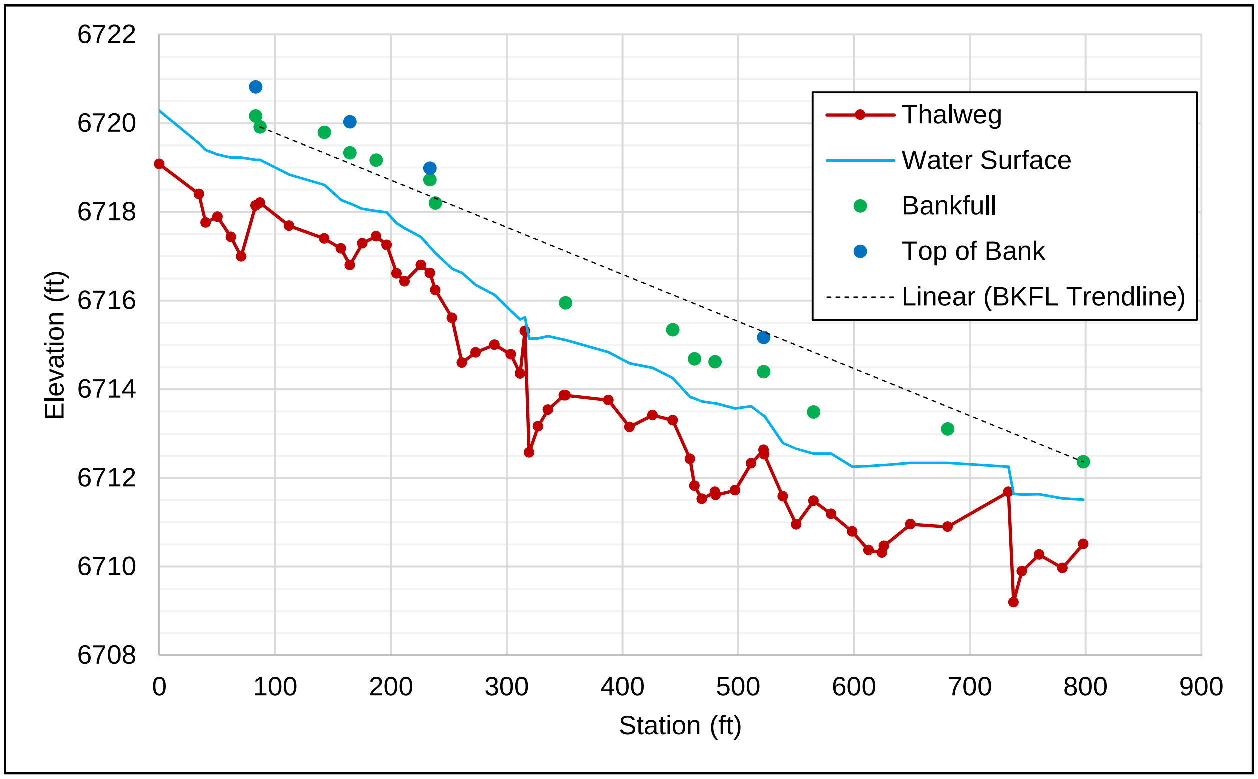

Figure 11. Longitudinal profile through Upstream Reference Reach.

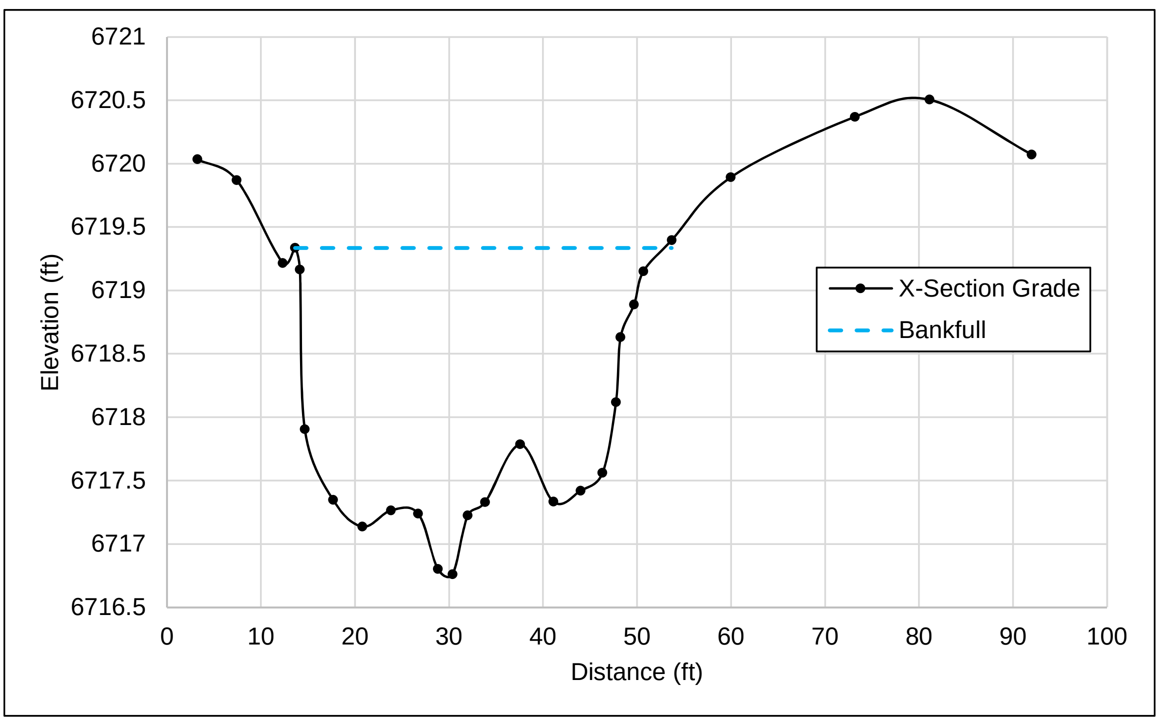

Figure 12. Typical C-type riffle cross section in Upstream Reference Reach.

The dimensionless bankfull shear stress in the Upstream Reference Reach is 0.022 and the dimensional shear stress is 1.038 lbs/ft^2. Bankfull hydraulic conditions result in the mobilization of a 156 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is capable of transporting the largest particles in the available bedload, and is capable of mobilizing the approximate 75th percentile particle (D75) of the surface grains based upon material size class distribution (Figure 13). These analyses indicate that the reach is competent to mobilize the available bedload and that the existing surface grain size class distribution promotes vertical channel stability.

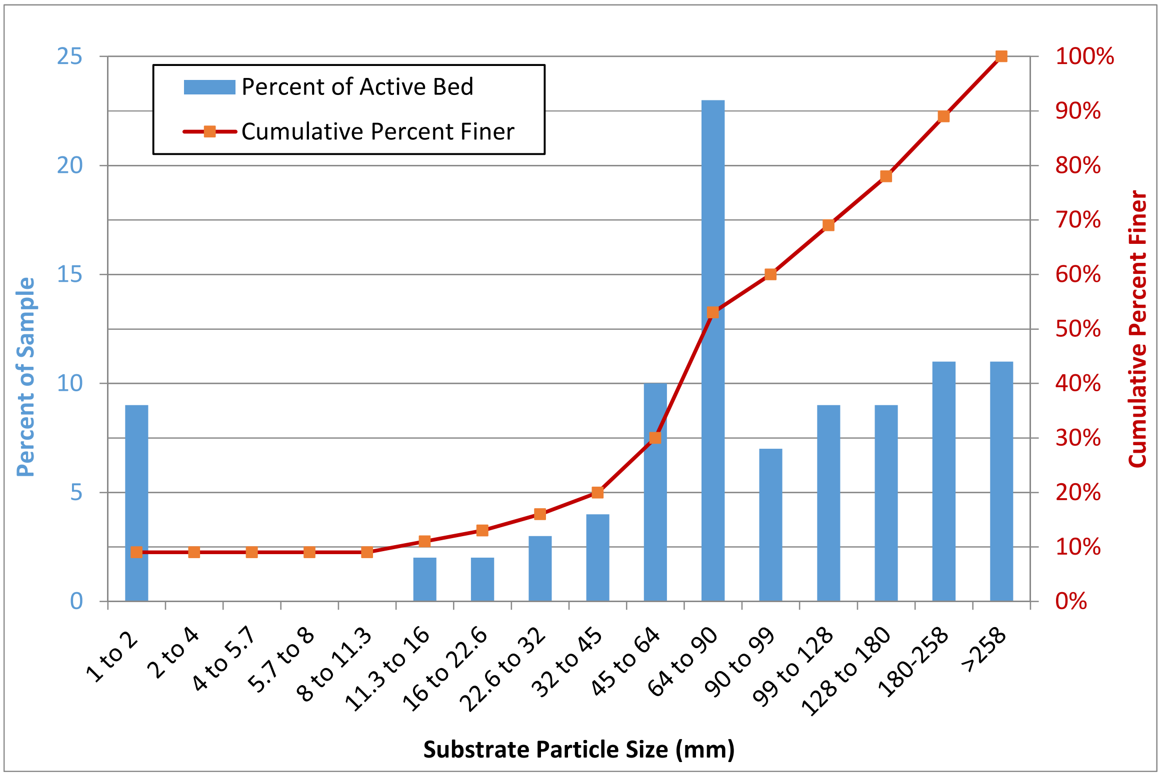

Figure 13. Surface particle size class distribution in the Upstream Reference reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at the Upstream Reference Reach is comprised of 221 tons/year of suspended sediment and 190 tons/year of bedload. Sediment transport modeling indicates that the Upstream Reference Reach has capacity to transport the available suspended and bedload supply. These sediment transport conditions result in stable channel conditions because the reach has competence and capacity to convey the supplied sediment load but lacks the ability to mobilize the largest surface grains (armor layer).

Stream stability analyses indicate that the reach has sufficient sediment transport capacity, is moderately unstable laterally, has no deposition or evidence of aggradation, is not incised, has slight channel enlargement potential, and is a moderate supply of sediment. Stream stability findings are summarized in Table 3.

Table 3. Summary of stream channel stability indices of Upstream Reference Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Sufficient Capacity
Lateral Stability	Moderately Unstable
Vertical Stability (Aggradation)	No Deposition
Vertical Stability (Degradation)	Not Incised
Channel Enlargement Potential	Slight Increase
Sediment Supply (Channel Source)	Moderate

5.2 WOOD RIVER CAMPGROUND REACH

The Wood River Campground Reach is located on US Forest Service lands in a confined alluvial valley with bounding features composed of alluvial deposits (attached Exhibit 86). The stream channel is entrenched, has moderate to high width/depth ratio, and has moderate sinuosity. The reach has bankfull channel width of 64.2 ft, mean depth of 2.11 ft, width/depth ratio of 30.5, and bankfull discharge of 646 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is 1.14 ft/ft, and the channel is classified as an F-type stream. Typical conditions are depicted in Figures 14, 15 and 16, and morphologic channel attributes are summarized in Table 4.

Figure 14. Photograph looking upstream at typical moderate to high width/depth ratio, low entrenchment ratio, and heavily vegetated riparian zone in the Wood River Campground Reach.

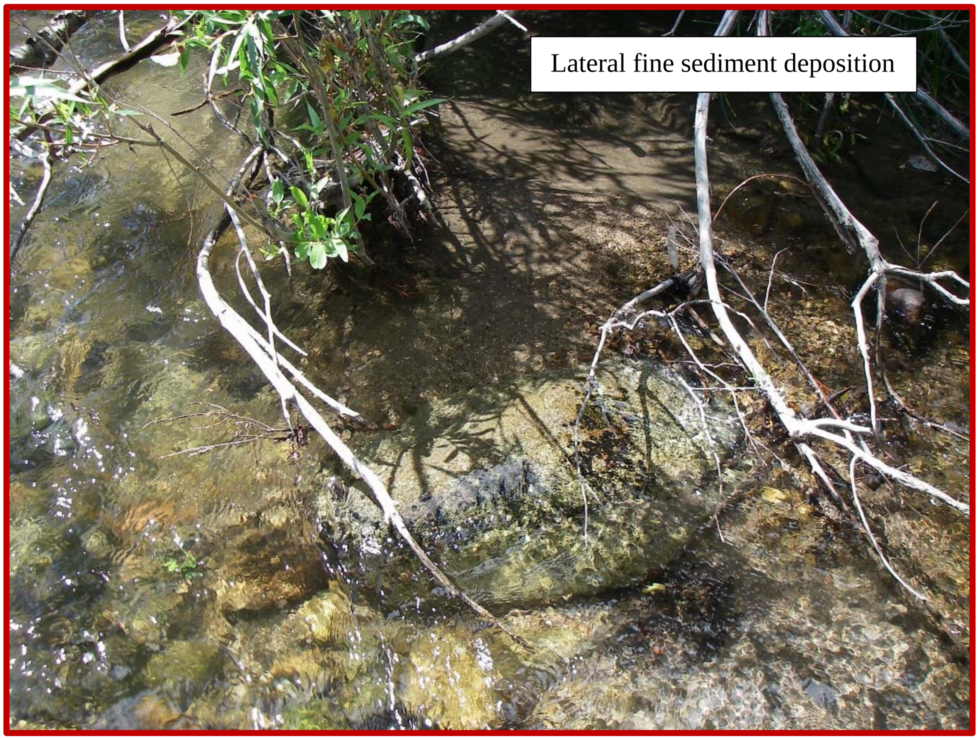

Figure 15. Photograph of coarse substrate with fine sediment accumulations in the Wood River Campground Reach.

Figure 16. Photograph of typical channel confinement and robust riparian vegetation in Wood River Campground Reach.

Table 4. Summary of morphologic channel conditions in the Wood River Campground Reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	64.2
Mean Bankfull Depth (ft)	2.11
Maximum Bankfull Depth (ft)	2.78
Width/Depth Ratio (ft/ft)	30.5
Entrenchment Ratio (ft/ft)	1.14
Meander Width Ratio (ft/ft)	5.4
Bankfull Mean Velocity (ft/sec)	4.8
Bankfull Discharge (ft^3/sec)	646
Particle Size Index D_{50} (mm)	66
Sinuosity (ft/ft)	1.15
Annual Streambank Erosion Rate (tons/yr/ft)	0.1242
Slope (ft/ft)	0.0087
Existing Stream Type	F3
Potential Stream Type	B3c

The bank erosion rate at the Wood River Campground Reach is 0.1242 tons/year/foot, and the 832-ft long surveyed stream segment contributes an estimated 103 tons of sediment to the watershed in an average year through bank erosion.

The Wood River Campground Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 17) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 0.87%, and a typical riffle cross section depicting an entrenched channel with moderate to high width/depth ratio is presented in Figure 18.

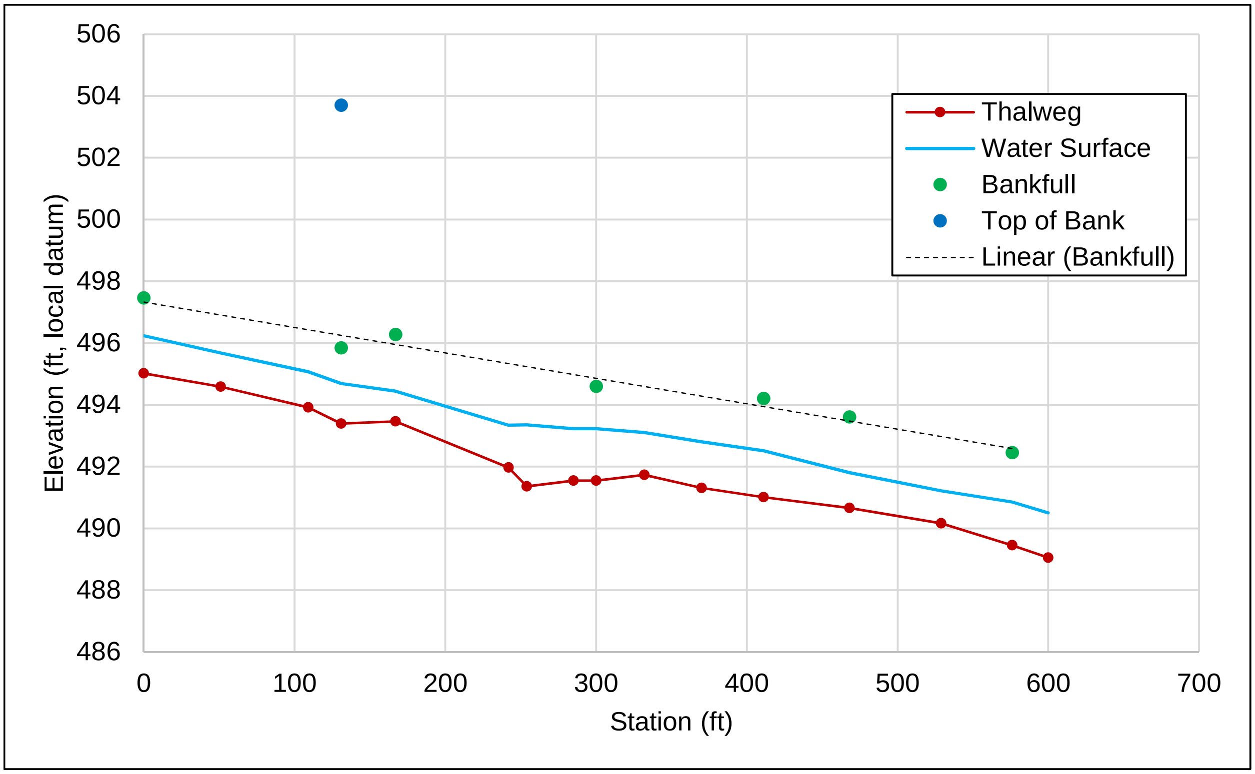

Figure 17. Longitudinal profile through Wood River Campground Reach.

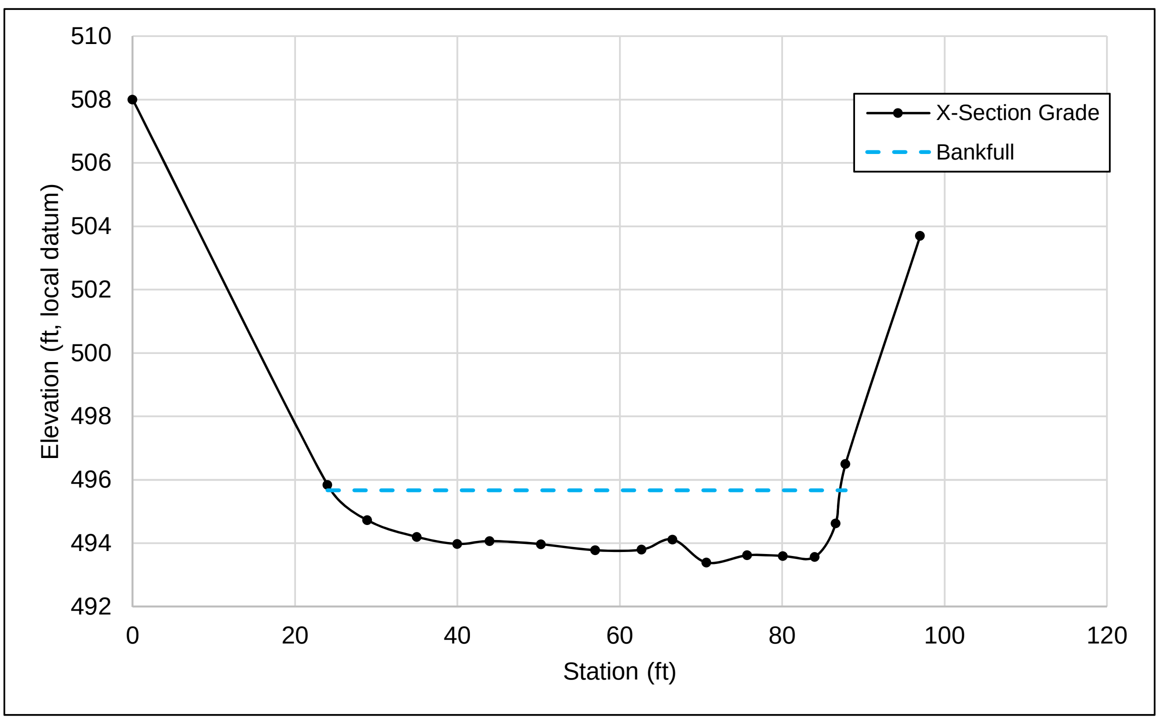

Figure 18. Typical riffle cross section in Wood River Campground Reach.

The dimensionless bankfull shear stress in the Wood River Campground Reach is 0.0215 and the dimensional shear stress is 1.308 lbs/ft^2. Bankfull hydraulic conditions result the mobilization of a 185 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is competent to mobilize the largest particles in the available bedload, and is competent to mobilize up to the D90 of the surface grains based upon material size class distribution (Figure 19). These analyses indicate that the reach is competent to transport the available bedload, but that excess shear stress could achieve mobilization of larger surface grains and result in channel degradation.

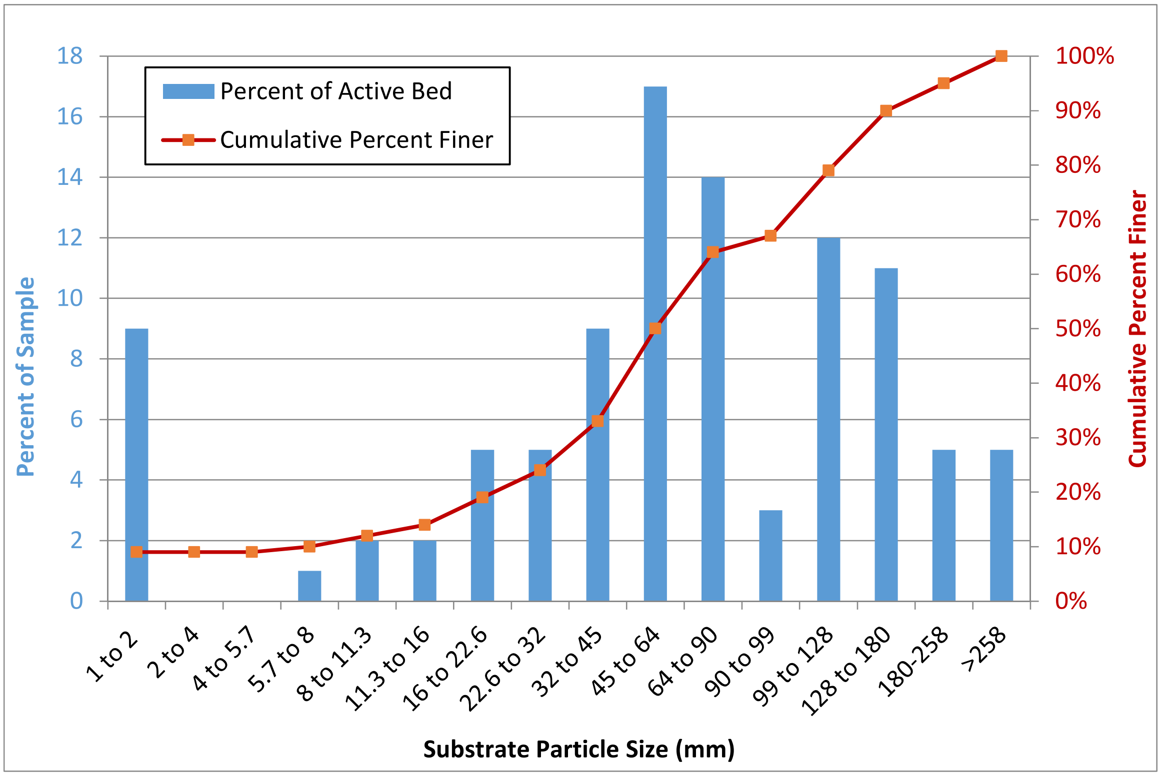

Figure 19. Surface particle size class distribution in the Wood River Campground Reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at Wood River Campground Reach is comprised of 719 tons/year of suspended sediment and 679 tons/year of bedload. Survey data from Wood River Campground Reach indicate that the reach has capacity to transport 818 tons/year of suspended sediment and 516 tons/year of bedload. The reach therefore has excess capacity to transport the supplied suspended sediment (net capacity of 14%) and the reach has insufficient capacity to transport the supplied bedload (net capacity of -24%). These sediment transport conditions result in moderate sediment deposition.

Stream stability analyses indicate that the reach has insufficient sediment transport capacity, is laterally unstable, has moderate deposition and evidence of aggradation, is slightly incised, has moderate channel enlargement potential, and is a high supply of sediment. Stream stability findings are summarized in Table 5.

Table 5. Summary of stream channel stability indices of Wood River Campground Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Insufficient Capacity
Lateral Stability	Unstable
Vertical Stability (Aggradation)	Moderate Deposition
Vertical Stability (Degradation)	Slightly Incised
Channel Enlargement Potential	Moderate Increase
Sediment Supply (Channel Source)	High

5.3 USGS STREAM GAUGE NEAR KETCHUM (#13135500)

The USGS Stream Gauge Reach (near Ketchum) is located on US Forest Service lands in an alluvial valley with bounding features composed of alluvial deposits. The stream channel is moderately entrenched, has moderate width/depth ratio, and has moderate sinuosity. The reach has bankfull channel width of 61.1 ft, mean depth of 2.46 ft, and width/depth ratio of 24.8. The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is greater than 2.2 ft/ft, and the channel is classified as a C-type stream. The site was surveyed to enable determination of bankfull discharge based upon local bankfull indicators and the USGS stage-discharge correlation; a complete geomorphic assessment was not completed at the site. Typical conditions are depicted in Figure 20 and morphologic channel attributes are summarized in Table 6.

Figure 20. Photograph of slightly entrenched channel conditions during near bankfull discharge at the USGS Stream Gauge near Ketchum.

Table 6. Summary of morphologic channel conditions in the Wood River Campground Reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	61.1
Mean Bankfull Depth (ft)	2.46
Maximum Bankfull Depth (ft)	3.78
Width/Depth Ratio (ft/ft)	24.8
Entrenchment Ratio (ft/ft)	>2.2
Bankfull Discharge (ft^3/sec)	686
Slope (ft/ft)	0.0095
Existing Stream Type	C
Potential Stream Type	C

The Big Wood River channel profile at the USGS Stream Gauge near Ketchum was analyzed through derivation of a longitudinal profile of the survey reach (Figure 21) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, and bankfull slope is depicted in dashed black line. The reach-wide bankfull channel slope is approximately 0.95%., and a typical riffle cross section depicting moderate width/depth ratio is presented in Figure 22.

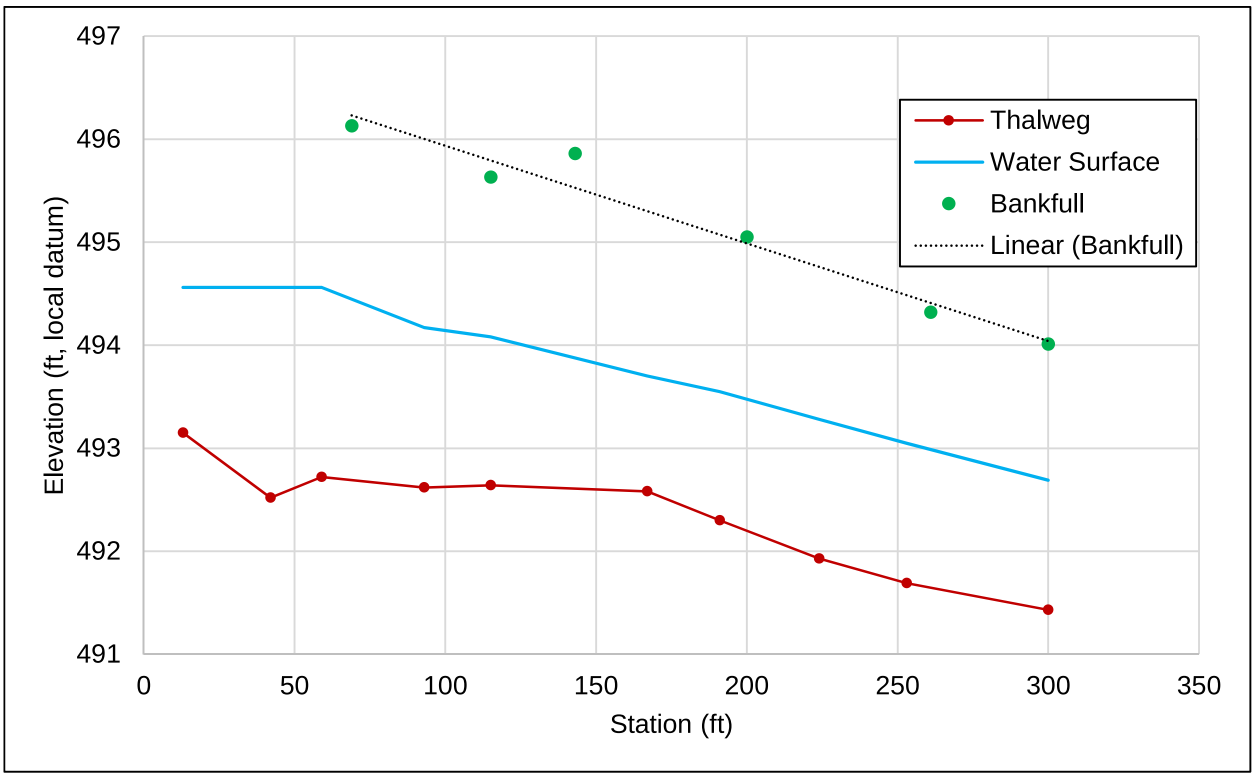

Figure 21. Longitudinal profile through the USGS Stream Gauge Reach.

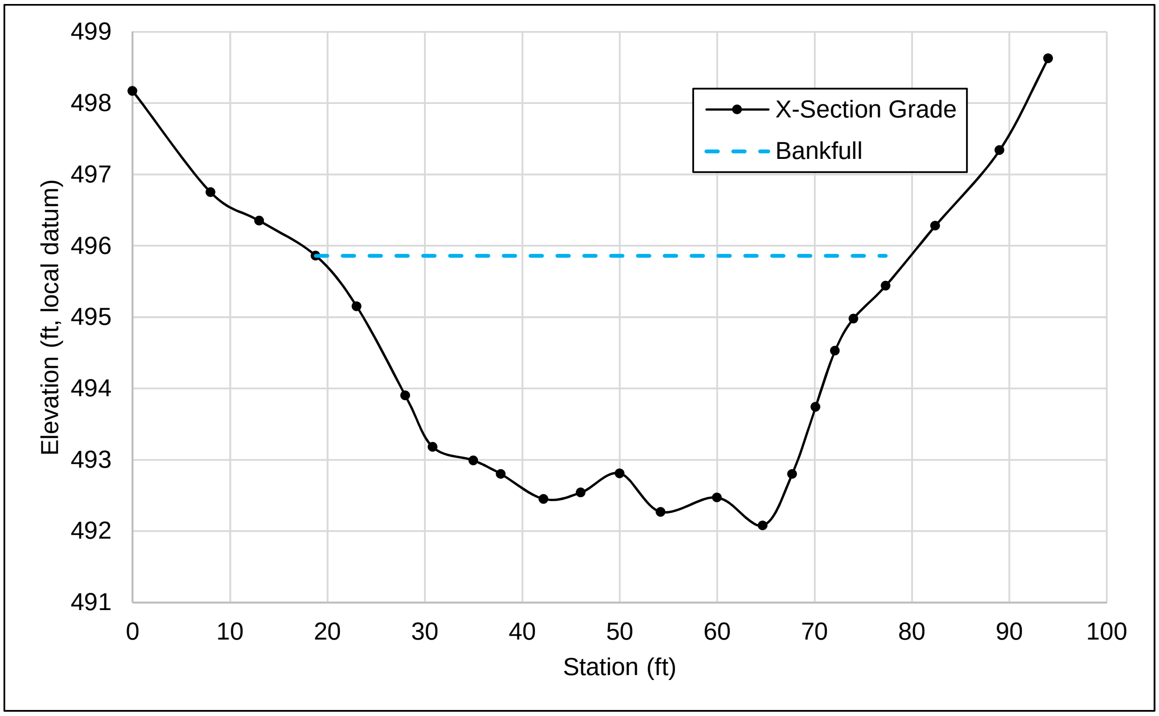

Figure 22. Typical riffle cross section in the USGS Stream Gauge Reach

5.4 FOX CREEK REFERENCE REACH

The Fox Creek Reference Reach is located on US Forest Service lands in an alluvial valley with bounding features composed of alluvial deposits and well-developed floodplains (attached Exhibit 87). The stream channel is moderately entrenched, has moderate width/depth ratio, and has moderate sinuosity. The reach has bankfull channel width of 61 ft, mean depth of 3.05 ft, width/depth ratio of 20, and bankfull discharge of 758 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is 1.9 ft/ft, and the channel is classified as a Bc-type stream. Typical conditions are depicted in Figures 23, 24 and 25, and morphologic channel attributes are summarized in Table 7.

Figure 23. Photograph looking downstream at typical robust riparian vegetation in Fox Creek Reference Reach.

Figure 24. Photograph looking upstream from bridge at typical moderate channel incision in the Fox Creek Reference Reach.

Figure 25. Photograph of typical low bank height, bank erosion conditions, and coarse substrate in Fox Creek reference reach.

Table 7. Summary of morphologic channel conditions in the Fox Creek Reference reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	61
Mean Bankfull Depth (ft)	3.05
Maximum Bankfull Depth (ft)	3.84
Width/Depth Ratio (ft/ft)	20
Entrenchment Ratio (ft/ft)	1.9
Meander Width Ratio (ft/ft)	5.7
Bankfull Mean Velocity (ft/sec)	4.1
Bankfull Discharge (ft^3/sec)	758
Particle Size Index D_{50} (mm)	0.0058
Sinuosity (ft/ft)	1.21
Annual Streambank Erosion Rate (tons/yr/ft)	0.0349
Slope (ft/ft)	0.0058
Existing Stream Type	B3c
Potential Stream Type	B3c

The bank erosion rate at the Fox Creek Reference Reach is 0.0349 tons/year/foot, and the 2,847-ft long surveyed stream segment contributes an estimated 99 tons of sediment to the watershed in an average year through bank erosion.

The Fox Creek Reference Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 26) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 0.58%, and a typical riffle cross section depicting moderate width/depth ratio and hydraulically connected floodplain is presented in Figure 27.

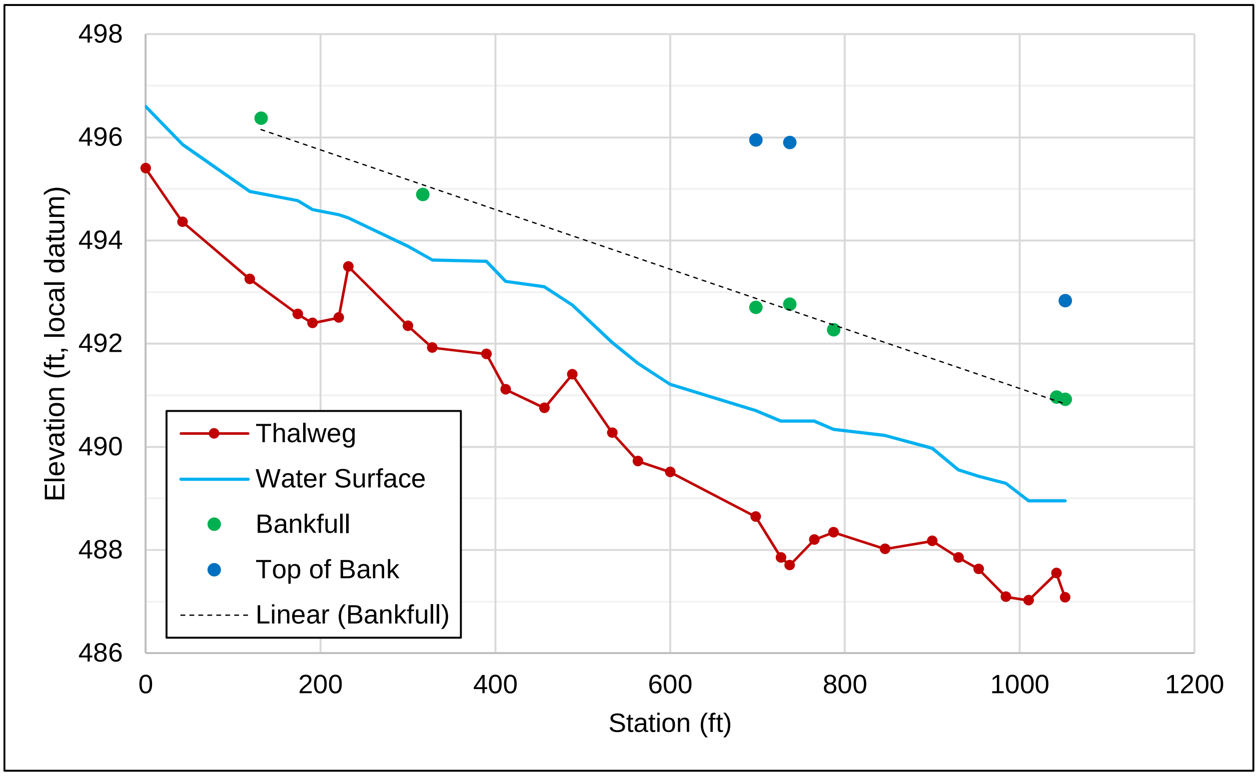

Figure 26. Longitudinal profile through Fox Creek Reference Reach.

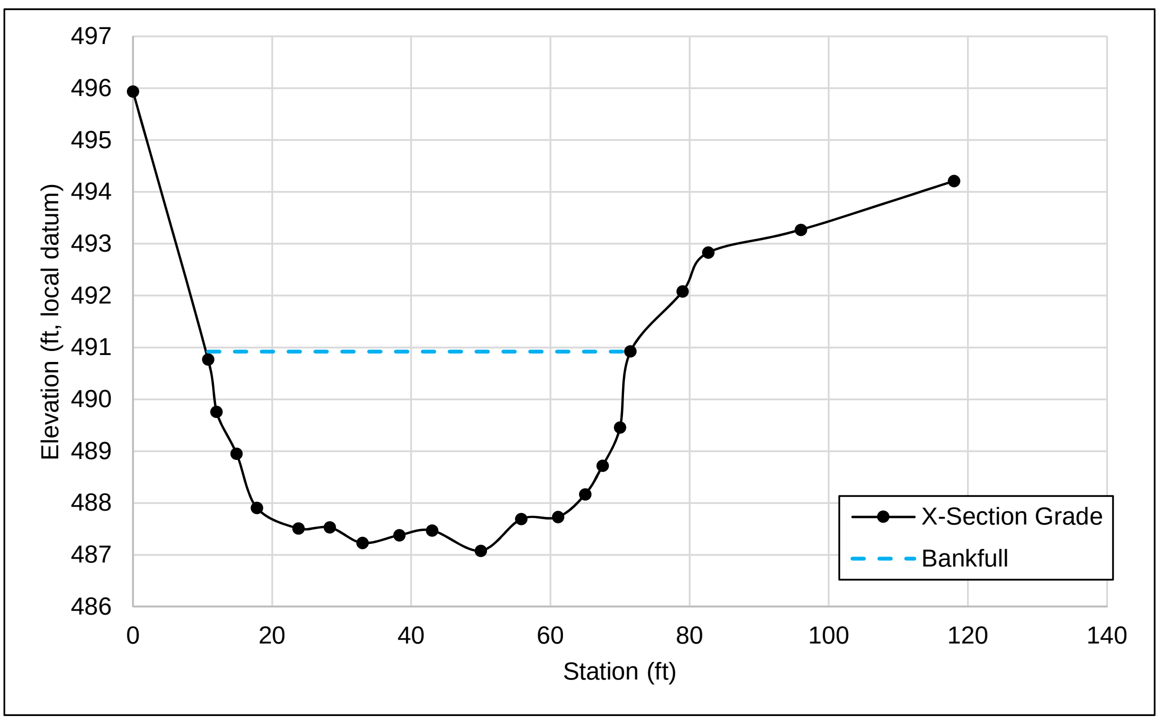

Figure 27. Typical riffle cross section at Fox Creek Reference Reach.

The dimensionless bankfull shear stress in the Fox Creek Reference Reach is 0.0298 and the dimensional shear stress is 1.104 lbs/ft^2. Bankfull hydraulic conditions result the mobilization of a 163 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is competent to transport the largest particles in the available bedload, and is competent to mobilize up to the D65 of the surface grains based upon material size class distribution (Figure 28). These analyses indicate that the reach is competent to transport the available bedload and that the existing surface grain size class distribution promotes vertical channel stability.

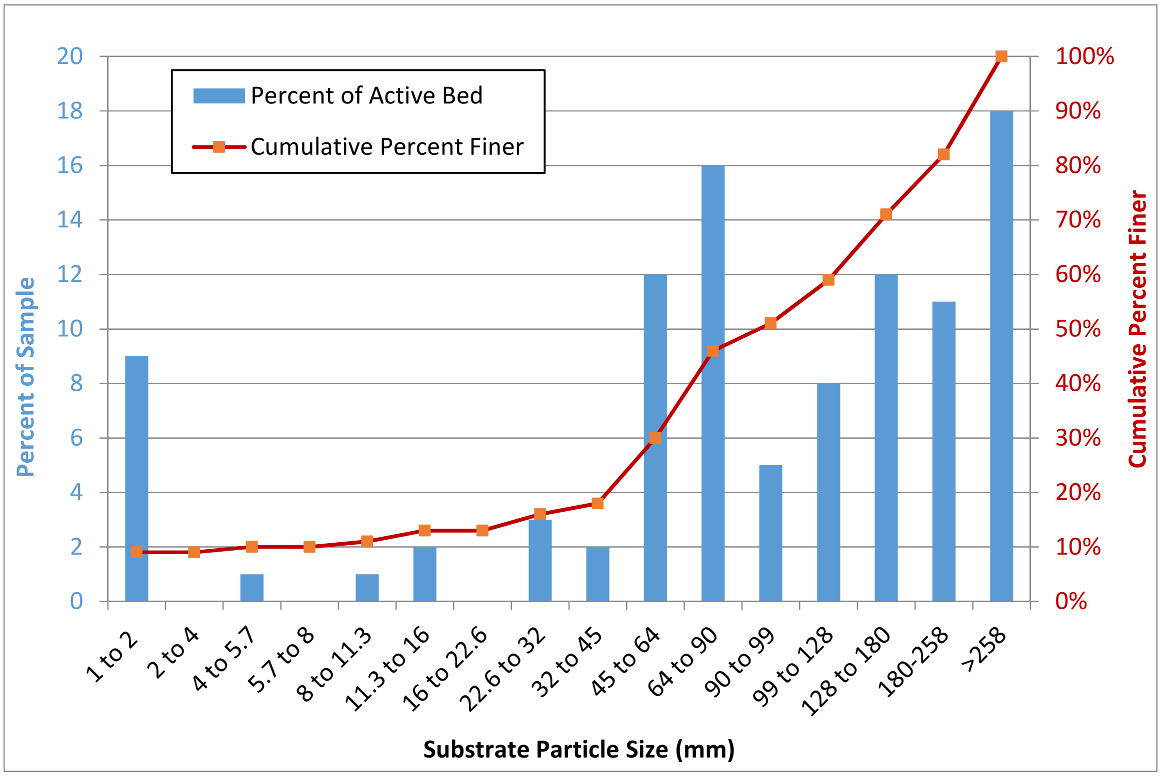

Figure 28. Surface particle size class distribution in the Fox Creek Reference Reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at the Fox Creek Reference Reach is comprised of 1157 tons/year of suspended sediment and 462 tons/year of bedload. Survey data from Fox Creek Reference Reach indicate that the reach has capacity to transport 1319 tons/year of suspended sediment and 564 tons/year of bedload. The reach therefore has sufficient capacity to transport the supplied suspended sediment (net capacity of 14%) and the reach has sufficient capacity to transport the supplied bedload (net capacity of 22%). These sediment transport conditions result in stable channel conditions because the reach has competence and capacity to convey the supplied sediment load but lacks the ability to mobilize the largest surface grains (armor layer).

Stream stability analyses indicate that the reach has sufficient sediment transport capacity, is moderately unstable laterally, has no deposition, slight evidence of degradation, is moderately incised, has a slight increase in channel enlargement potential, and has a moderate supply of sediment. Stream stability findings are summarized in Table 8.

Table 8. Summary of stream channel stability indices of Fox Creek Reference Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Sufficient Capacity
Lateral Stability	Moderately Unstable
Vertical Stability (Aggradation)	No Deposition
Vertical Stability (Degradation)	Slightly Incised
Channel Enlargement Potential	Slight Increase
Sediment Supply (Channel Source)	Moderate

5.5 TRAINING CHANNEL REACH

The Training Channel Reach is located on Bureau of Land Management lands in an alluvial valley with bounding features composed of alluvial deposits and well-developed floodplains (attached Exhibit 88). The stream channel has varied entrenchment, moderate to high width/depth ratio, and moderate sinuosity. A suite of rock sills were installed during a past river stabilization project, and those constructed features maintain an artificial channel morphology in comparison to free-flowing riffles located intermittently along the reach. Sills maintain a bankfull channel width of 63 ft, mean depth of 1.32 ft, width/depth ratio of 57, and entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) of 1.4 ft/ft. Free flowing riffles in the reach demonstrate a bankfull channel width of 69 ft, mean depth of 2.11 ft, width/depth ratio of 33 ft/ft, and entrenchment ratio of greater than 2.2 ft/ft. The channel morphology maintained by the rock sills is used in hydraulic analysis of the surveyed river segment because these persistent structures dominate channel form and process through the reach. Typical conditions are depicted in Figures 29, 30 and 31, and morphologic channel attributes are summarized in Table 9.

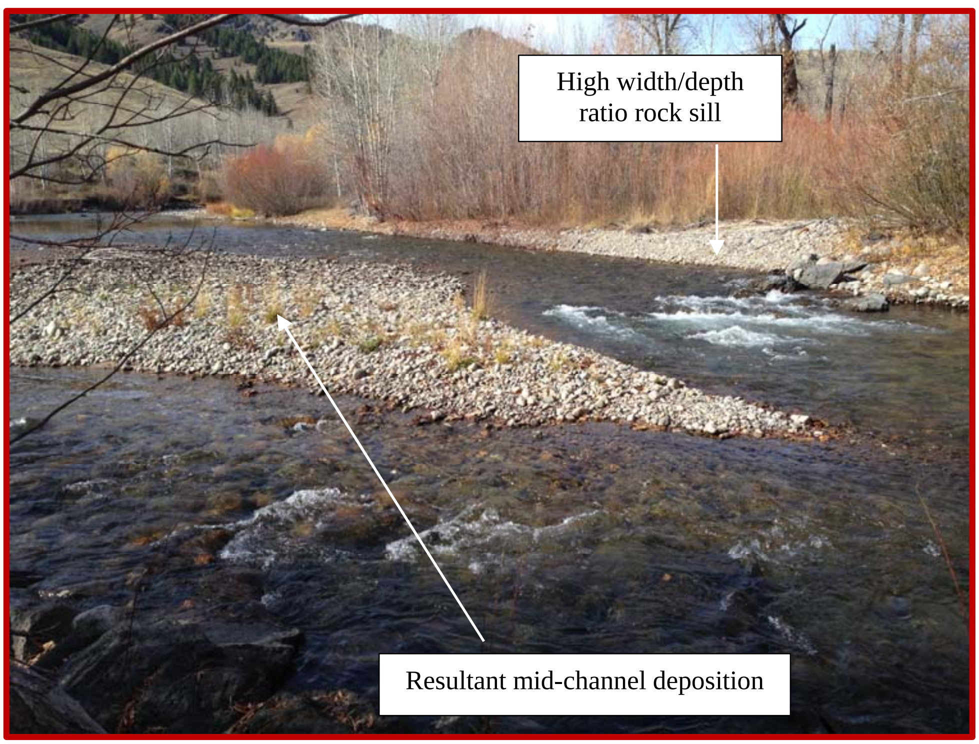

Figure 29. Photograph depicting an installed rock sill and resultant sedimentation in the Training Channel Reach.

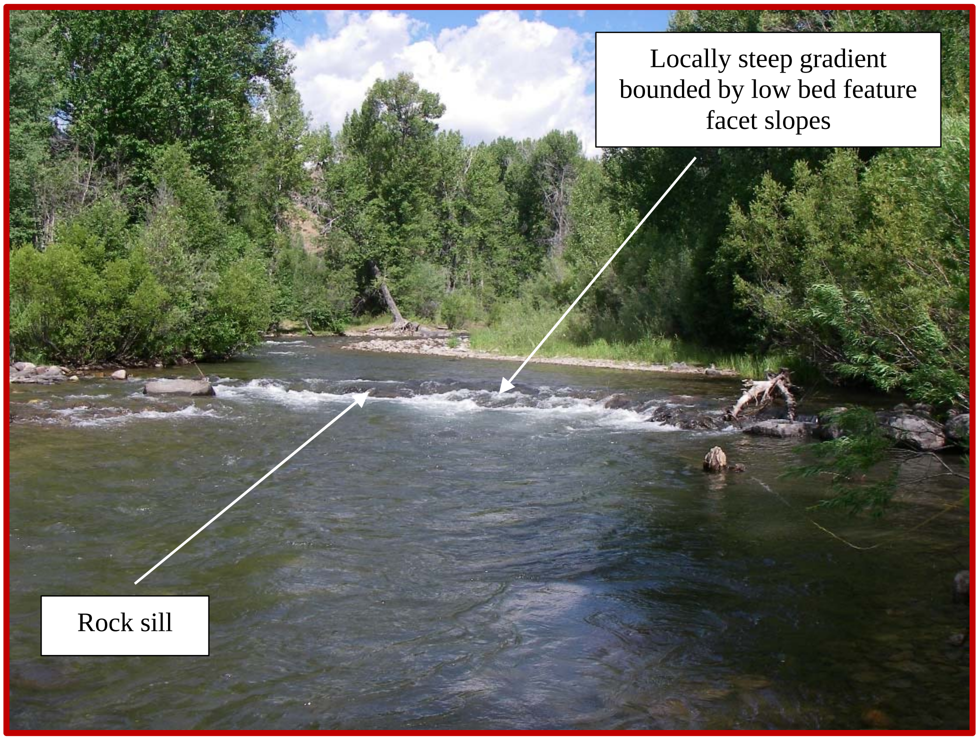

Figure 30. Photograph depicting an installed rock sill and localized confinement of available gradient in the Training Channel Reach.

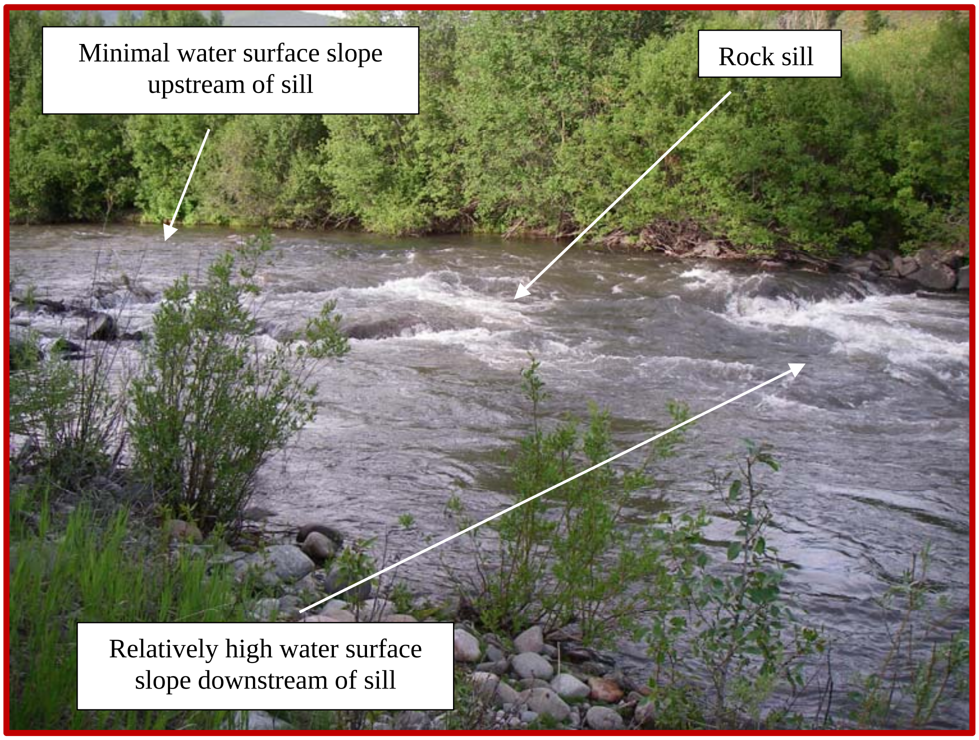

Figure 31. Photograph depicting an installed rock sill at near bankfull conditions in the Training Channel Reach.

Table 9. Summary of morphologic channel conditions in the Training Channel Reach.

Channel Parameter	Value	
	Rock Sills	**Free Flowing Riffles**
Bankfull Channel Width (ft)	63	69
Mean Bankfull Depth (ft)	1.3	2.11
Maximum Bankfull Depth (ft)	2.1	3.4
Width/Depth Ratio (ft/ft)	57	33
Entrenchment Ratio (ft/ft)	1.4	>2.2
Meander Width Ratio (ft/ft)	--	3.2
Bankfull Mean Velocity (ft/sec)	--	5.1
Bankfull Discharge (ft^3/sec)	--	736
Particle Size Index D_{50} (mm)	--	45
Sinuosity (ft/ft)	--	1.23
Annual Streambank Erosion Rate (tons/yr/ft)	--	0.0849
Slope (ft/ft)	--	0.0069
Existing Stream Type	B4c	C4
Potential Stream Type	C4	C4

The bank erosion rate in the Training Channel Reach is 0.1683 tons/year/foot, and the 2089-ft long surveyed stream segment contributes an estimated 351 tons of sediment to the watershed in an average year through bank erosion.

The Training Channel Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 32) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The longitudinal profile depicts the locally flat water surface elevations maintained upstream of rock sills (at stations 224 and 519 ft) and the locally steep slopes achieved immediately downstream of the structures. These slope distributions are contrary to natural functional watercourse conditions, in which the facet slopes of riffles are generally twice the bankfull slope and the facet slopes of pools are generally flat. The configuration of rock sills in the reach reverses typical bed feature facet slopes by promoting flat upstream riffles and steep downstream pool bed features. These anomalies in channel profile are the result of inappropriately configured rock sills in the reach. Typical cross sections of a constructed rock sill and a free flowing riffle are presented in Figures 33 and 34, respectively.

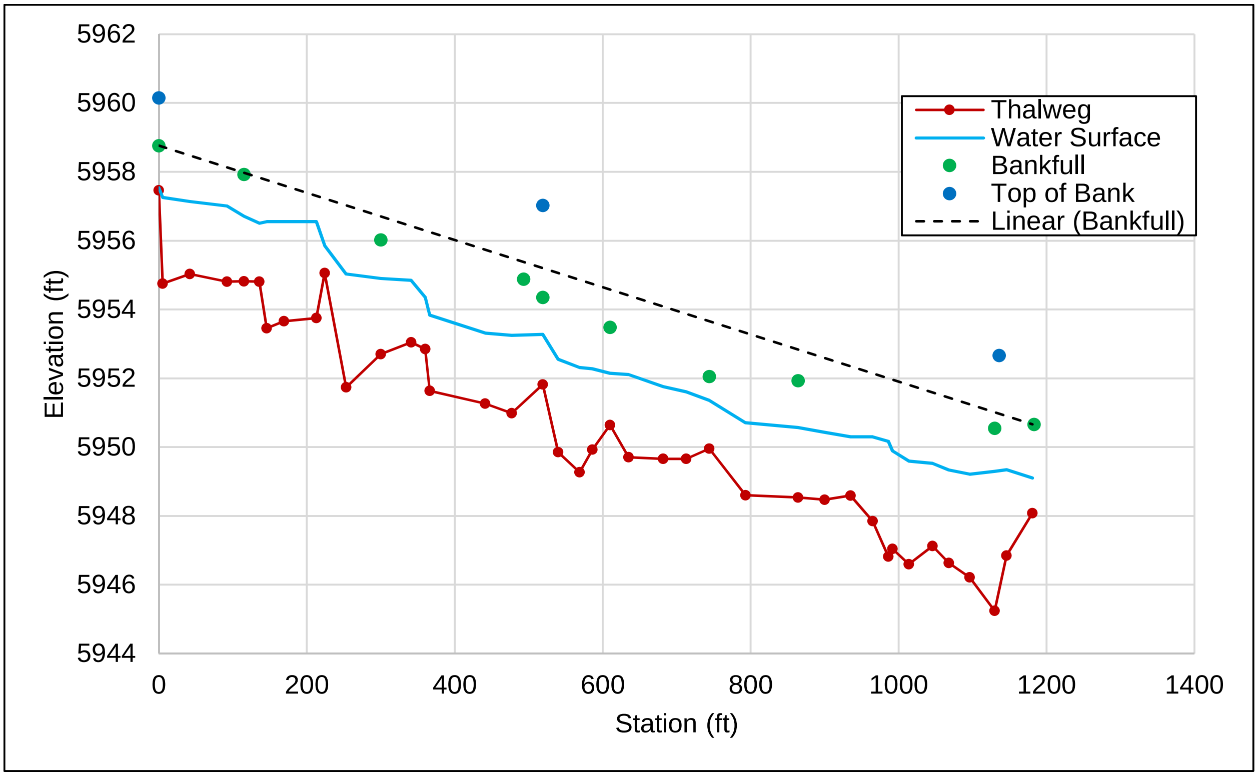

Figure 32. Longitudinal profile through Training Channel Reach.

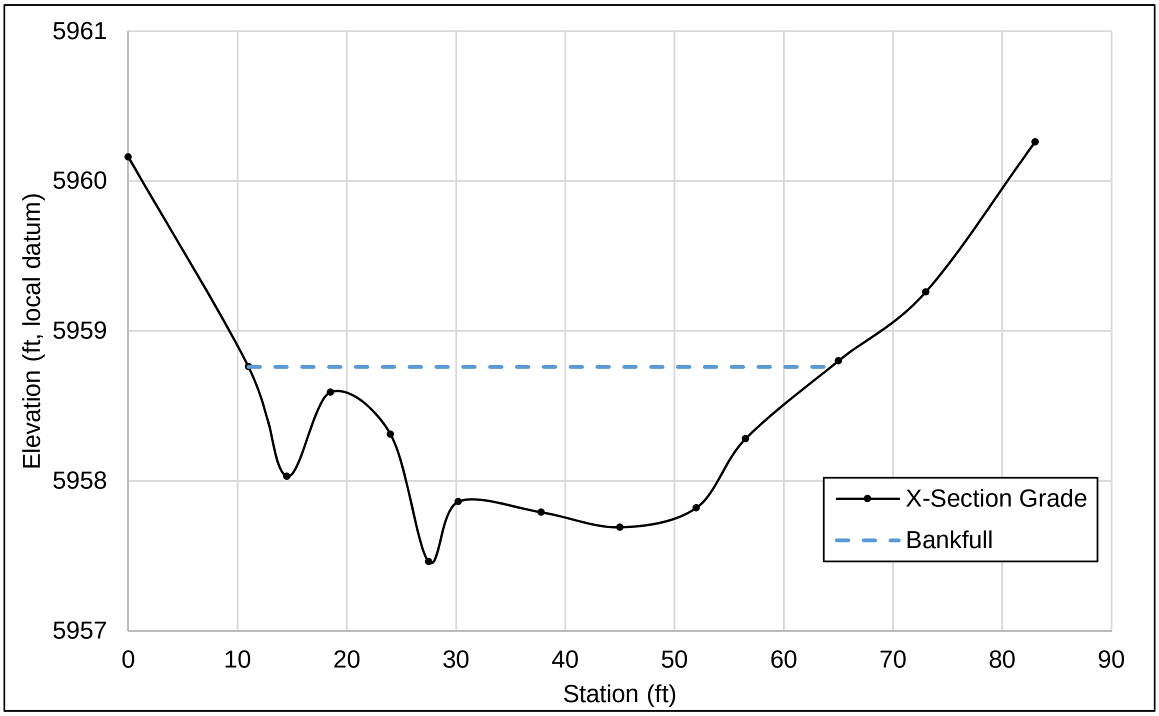

Figure 33. Typical constructed sill cross section in the Training Channel Reach.

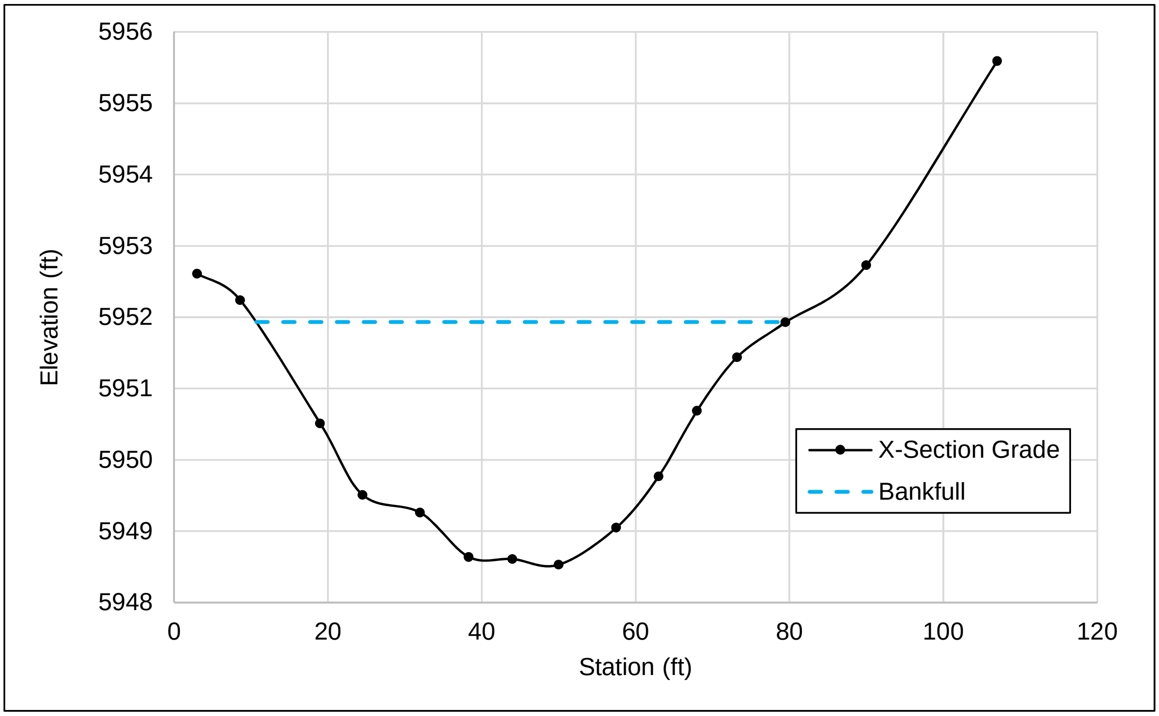

Figure 34. Typical riffle cross section in Training Channel Reach.

The dimensionless bankfull shear stress in the Training Channel Reach is 0.015 and the dimensional shear stress is 0.908 lbs/ft^2. Bankfull hydraulic conditions result the mobilization of a 142 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is competent to transport the largest particles in the available bedload, and is capable of mobilizing up to the D90 of the surface grains based upon material size class distribution (Figure 35). These analyses indicate that the reach is competent to mobilize the available bedload, but that excess shear stress could achieve mobilization of the largest surface grains and result in channel degradation. However, the installed rock sills appear to have maintained grade control and precluded channel degradation.

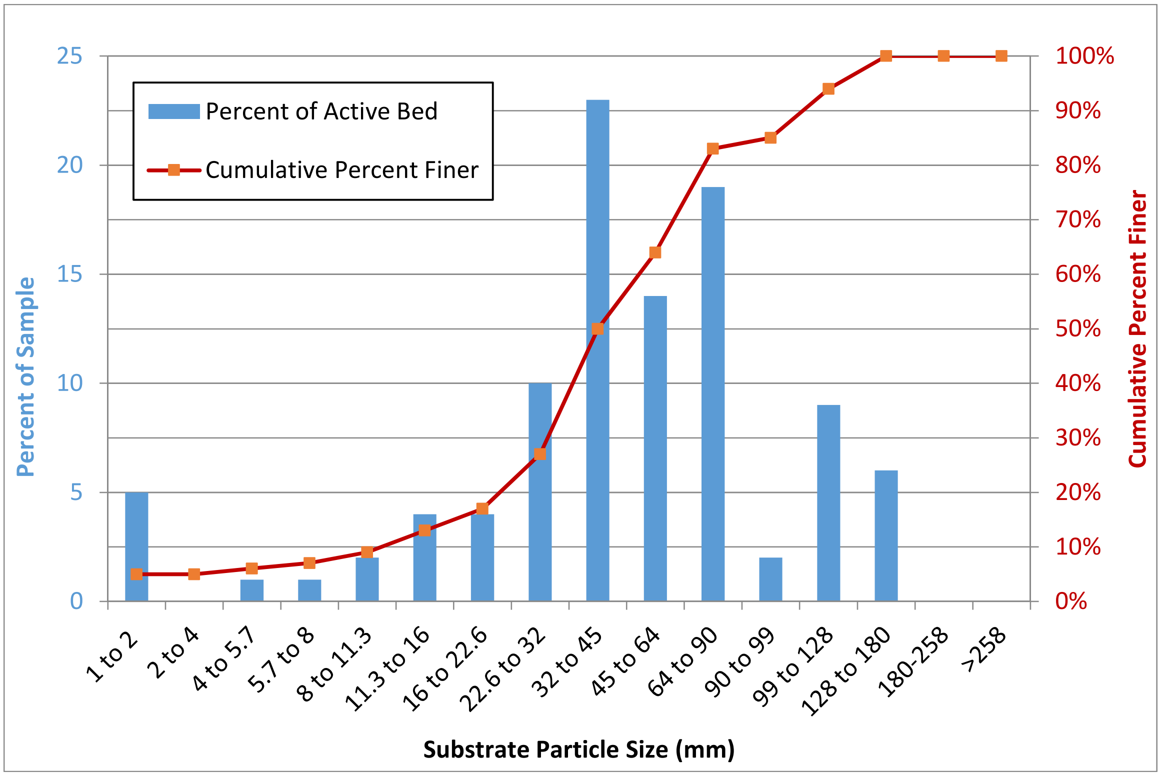

Figure 35. Surface particle size class distribution in the Training Channel reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at Training Channel Reach is comprised of 1150 tons/year of suspended sediment and 493 tons/year of bedload. Survey data from Training Channel Reach indicate that the reach has capacity to transport 1050 tons/year of suspended sediment and 126 tons/year of bedload. The reach therefore lacks the capacity to transport the supplied suspended sediment (net capacity of -9%) and the reach also lacks the capacity to transport the supplied bedload (net capacity of -74%). These sediment transport conditions result in excess sediment deposition. Sediment transport disequilibrium at the reach-scale is further impaired by rock sills that maintain locally flat upstream slopes because decreased local gradient further reduces sediment transport capacity.

Stream stability analyses indicate that the reach has insufficient sediment transport capacity, is laterally unstable, has excess deposition and evidence of aggradation, is slightly incised, has moderate channel enlargement potential, and is a high supply of sediment. Stream stability findings are summarized in Table 10.

Table 10. Summary of stream channel stability indices of the Training Channel Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Insufficient Capacity
Lateral Stability	Unstable
Vertical Stability (Aggradation)	Excess Deposition
Vertical Stability (Degradation)	Slightly Incised
Channel Enlargement Potential	Moderate Increase
Sediment Supply (Channel Source)	High

5.6 HULEN MEADOWS REACH

The Hulen Meadows Reach is located on US Bureau of Land Management lands in an alluvial valley with bounding features composed of alluvial deposits and well-developed floodplains (attached Exhibit 89). The stream channel is slightly entrenched, has a very high width/depth ratio, and has low sinuosity. The reach has bankfull channel width of 110.4 ft, mean depth of 2.02 ft, width/depth ratio of 57.9, and bankfull discharge of 925.4 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is greater than 2.2 ft/ft, and the channel is classified as a D-type stream due to the presence of multiple channels. Typical conditions are depicted in Figures 36, 37, 38, 39 and 40, and morphologic channel attributes are summarized in Table 11.

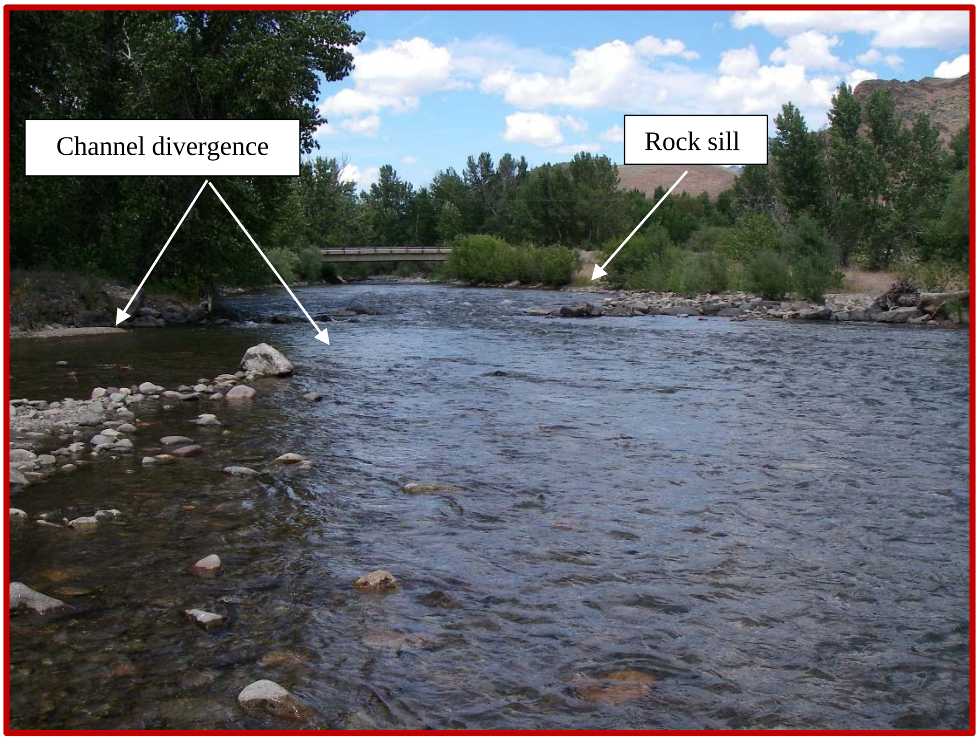

Figure 36. Photograph looking upstream from the top of the site at a rock sill directly upstream of the channel split in the Hulen Meadows Reach.

Figure 37. Photograph looking downstream along a side channel at a sediment collection pond in the Hulen Meadows Reach.

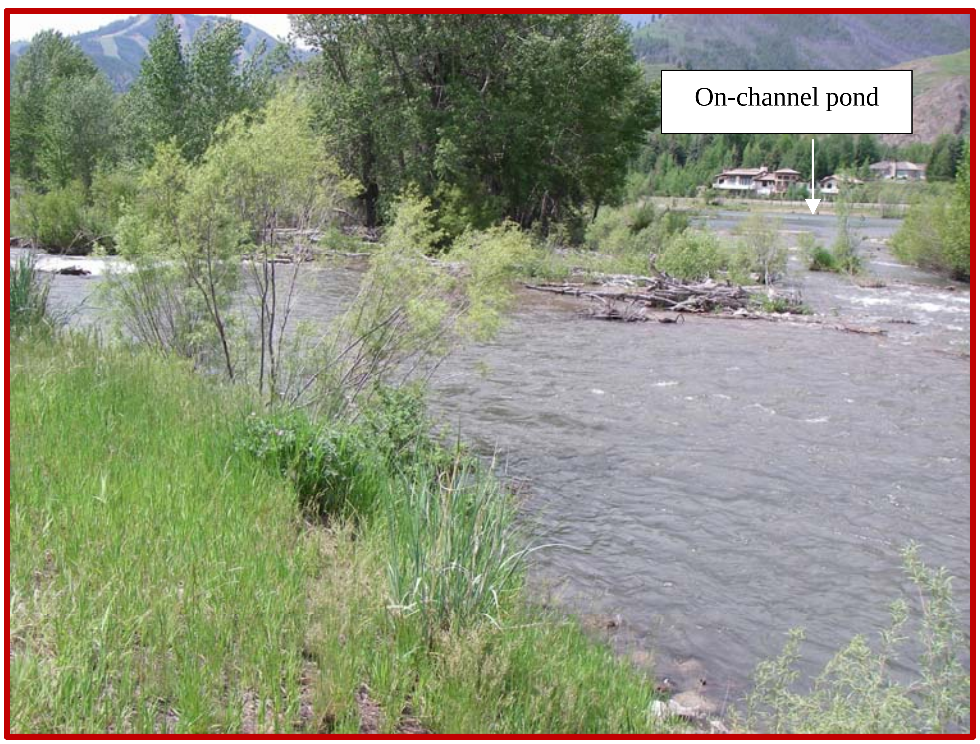

Figure 38. Photograph looking downstream at the channel split during spring runoff with the pond in the background on the right side of the photo, Hulen Meadows Reach.

Figure 39. Photograph looking upstream at the on-channel pond outlet with breached beaver dam and significant fine sediment accumulation in the Hulen Meadows Reach.

Figure 40. Photograph looking upstream at constructed rock sill, depositional side bars, and confluence of split channel configuration in Hulen Meadows Reach.

Table 11. Summary of morphologic channel conditions in the Hulen Meadows Reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	110.4
Mean Bankfull Depth (ft)	2.02
Maximum Bankfull Depth (ft)	3.39
Width/Depth Ratio (ft/ft)	57.9
Entrenchment Ratio (ft/ft)	>2.2
Meander Width Ratio (ft/ft)	3
Bankfull Mean Velocity (ft/sec)	4.3
Bankfull Discharge (ft^3/sec)	925.4
Particle Size Index D_{50} (mm)	120
Sinuosity (ft/ft)	1.13
Annual Streambank Erosion Rate (tons/yr/ft)	0.1447
Slope (ft/ft)	0.0101
Existing Stream Type	D3
Potential Stream Type	C3

The bank erosion rate at the Hulen Meadows Reach is 0.1447 tons/year/foot, and the 3,470-ft long surveyed stream segment contributes an estimated 502 tons of sediment to the watershed in an average year through bank erosion.

The Hulen Meadows Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 41) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 1%, and a typical riffle cross section depicting moderate width/depth ratio and hydraulically connected floodplain is presented in Figure 42.

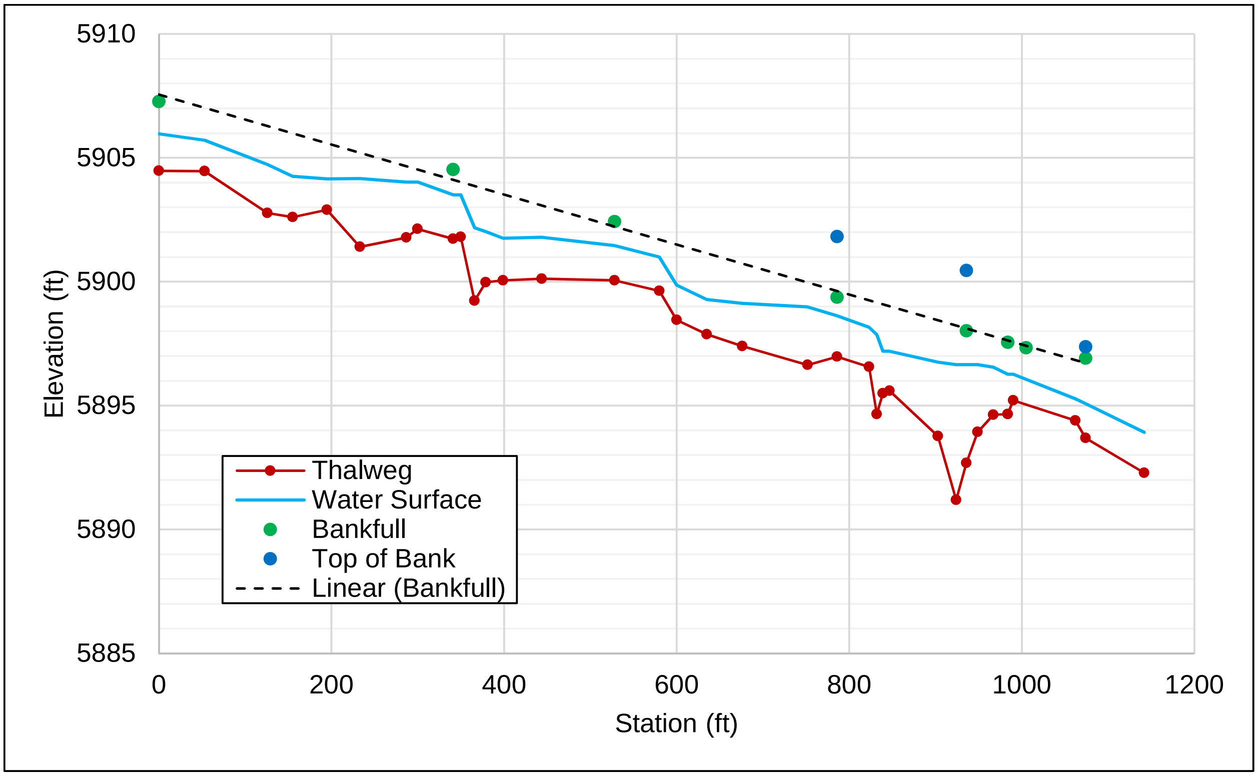

Figure 41. Longitudinal profile of the Hulen Meadows Reach.

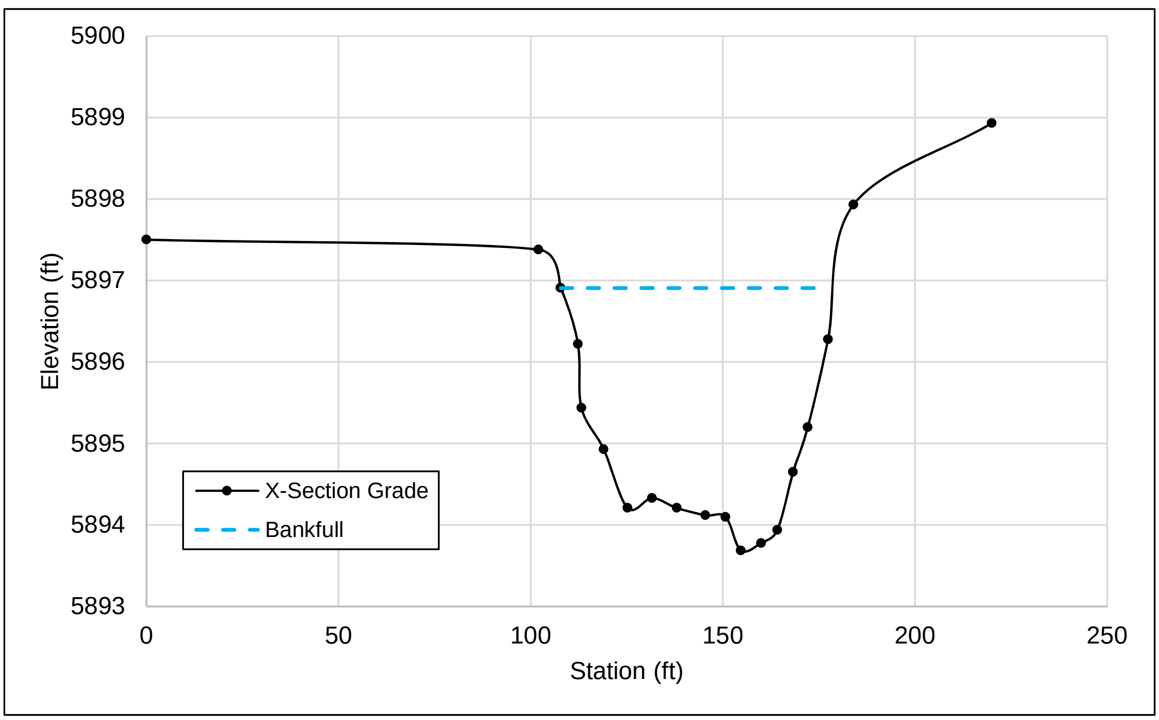

Figure 42. Typical riffle cross section in the Hulen Meadows Reach

The dimensionless bankfull shear stress in the Hulen Meadows Reach is 0.032 and the dimensional shear stress is 1.273 lbs/ft^2. Bankfull hydraulic conditions result the mobilization of a 182 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is competent to transport the largest particles in the available bedload, and is capable of mobilizing up to the D75 of the surface grains based upon material size class distribution (Figure 43). These analyses indicate that the reach is competent to mobilize the available bedload and that the existing surface grain size class distribution promotes vertical channel stability.

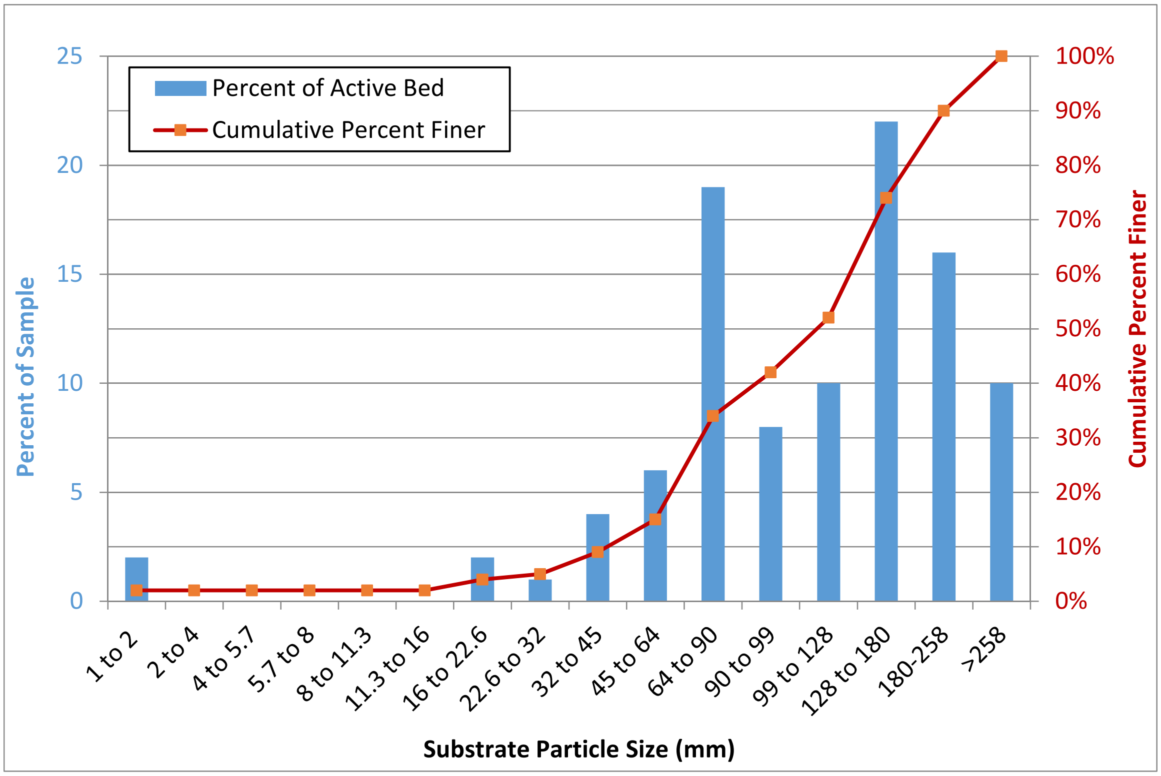

Figure 43. Surface particle size class distribution in the Hulen Meadows Reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at the Hulen Meadows Reach is comprised of 1468 tons/year of suspended sediment and 527 tons/year of bedload. Survey data from the Hulen Meadows Reach indicate that the reach has capacity to transport 790 tons/year of suspended sediment and 90 tons/year of bedload. The reach therefore lacks the capacity to transport the supplied suspended sediment (net capacity of -46%) and the reach also lacks the capacity to transport the supplied bedload (net capacity of -83%). These sediment transport conditions result in widespread sediment deposition and channel aggradation. The existing on-channel pond retains some of the sediment load that exceeds the transport capacity of the reach, but sedimentation of aggradation are evident throughout the Hulen Meadows Reach.

Stream stability analyses indicate that the reach has insufficient sediment transport capacity, is highly unstable laterally, has moderate deposition and evidence of aggradation, is not incised, has extensive channel enlargement potential, and is a very high supply of sediment. Stream stability findings are summarized in Table 12.

Table 12. Summary of stream channel stability indices of the Hulen Meadows Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Insufficient Capacity
Lateral Stability	Highly Unstable
Vertical Stability (Aggradation)	Aggradation
Vertical Stability (Degradation)	Not Incised
Channel Enlargement Potential	Extensive
Sediment Supply (Channel Source)	Very High

5.7 SKI HILL REACH

The Ski Hill Reach is located on private lands in an alluvial valley with bounding features composed of alluvial deposits and bedrock (attached Exhibit 90). The stream channel is moderately entrenched, has moderate width/depth ratio, and has moderate sinuosity. The reach has bankfull channel width of 95 ft, mean depth of 2.66 ft, width/depth ratio of 35.7, and bankfull discharge of 1370 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is 1.9 ft/ft, and the channel is classified as a Bc-type stream. Typical conditions are depicted in Figures 44, 45, 46, 47, 48, and 49, and morphologic channel attributes are summarized in Table 13.

Figure 44. Photograph depicting near bankfull discharge and moderate entrenchment in Ski Hill Reach.

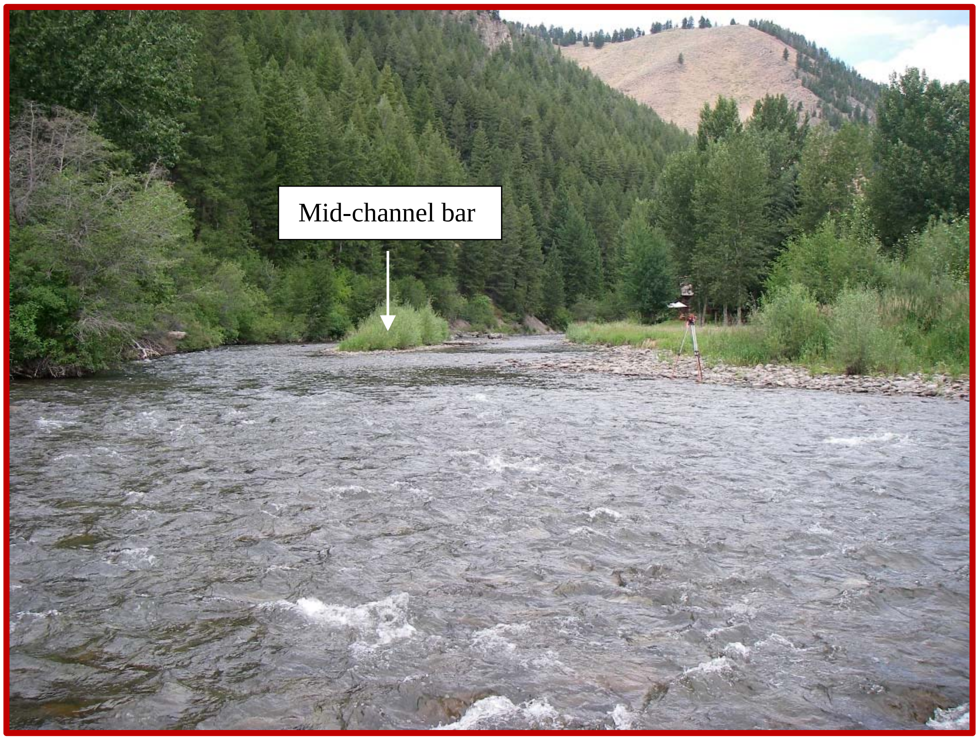

Figure 45. Photograph looking upstream at depositional features in the Ski Hill Reach.

Figure 46. Photograph depicting steep eroding hillside on river right in the Ski Hill Reach.

Figure 47. Photograph depicting mid-channel bar and residential development encroachment in the Ski Hill Reach.

Figure 48. Photograph depicting bank stabilization and development encroachment in Ski Hill Reach.

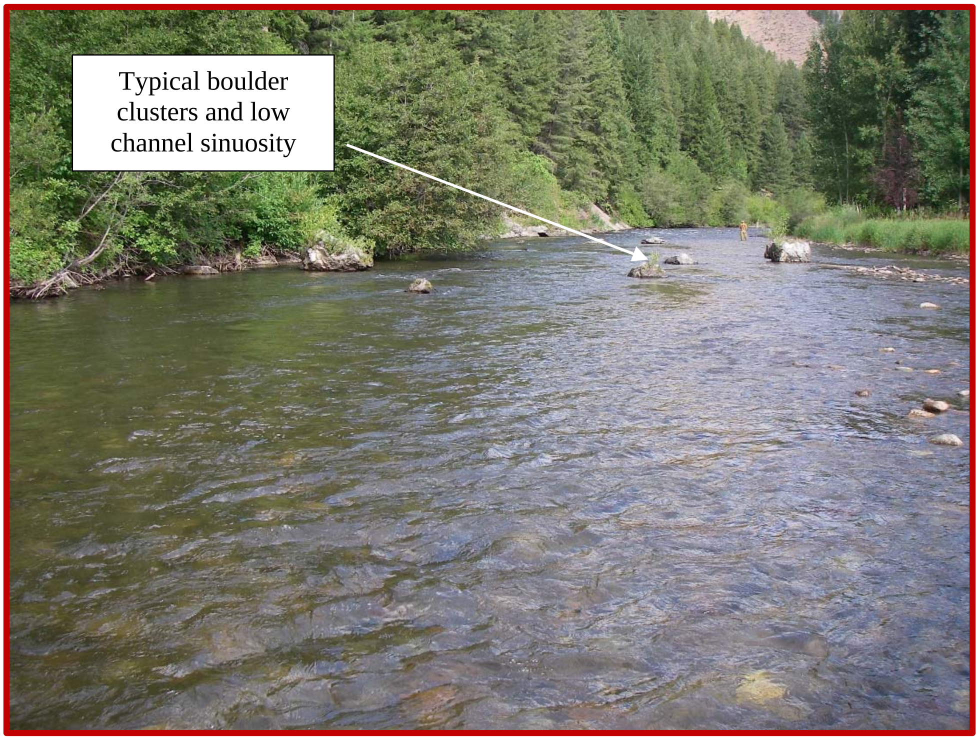

Figure 49. Photograph depicting typical channel conditions in the Ski Hill Reach.

Table 13. Summary of morphologic channel conditions in the Ski Hill reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	95
Mean Bankfull Depth (ft)	2.66
Maximum Bankfull Depth (ft)	3.89
Width/Depth Ratio (ft/ft)	35.7
Entrenchment Ratio (ft/ft)	1.9
Meander Width Ratio (ft/ft)	6.8
Bankfull Mean Velocity (ft/sec)	5.4
Bankfull Discharge (ft^3/sec)	1370
Particle Size Index D_{50} (mm)	75
Sinuosity (ft/ft)	1.15
Annual Streambank Erosion Rate (tons/yr/ft)	0.1854
Slope (ft/ft)	0.0061
Existing Stream Type	B3c
Potential Stream Type	B3c

The bank erosion rate at the Ski Hill Reach is 0.1854 tons/year/foot, and the 2266-ft long surveyed stream segment contributes an estimated 420 tons of sediment to the watershed in an average year through bank erosion.

The Ski Hill Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 50) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 0.61%, and a typical riffle cross section depicting moderate width/depth ratio and narrow confined floodplain is presented in Figure 51.

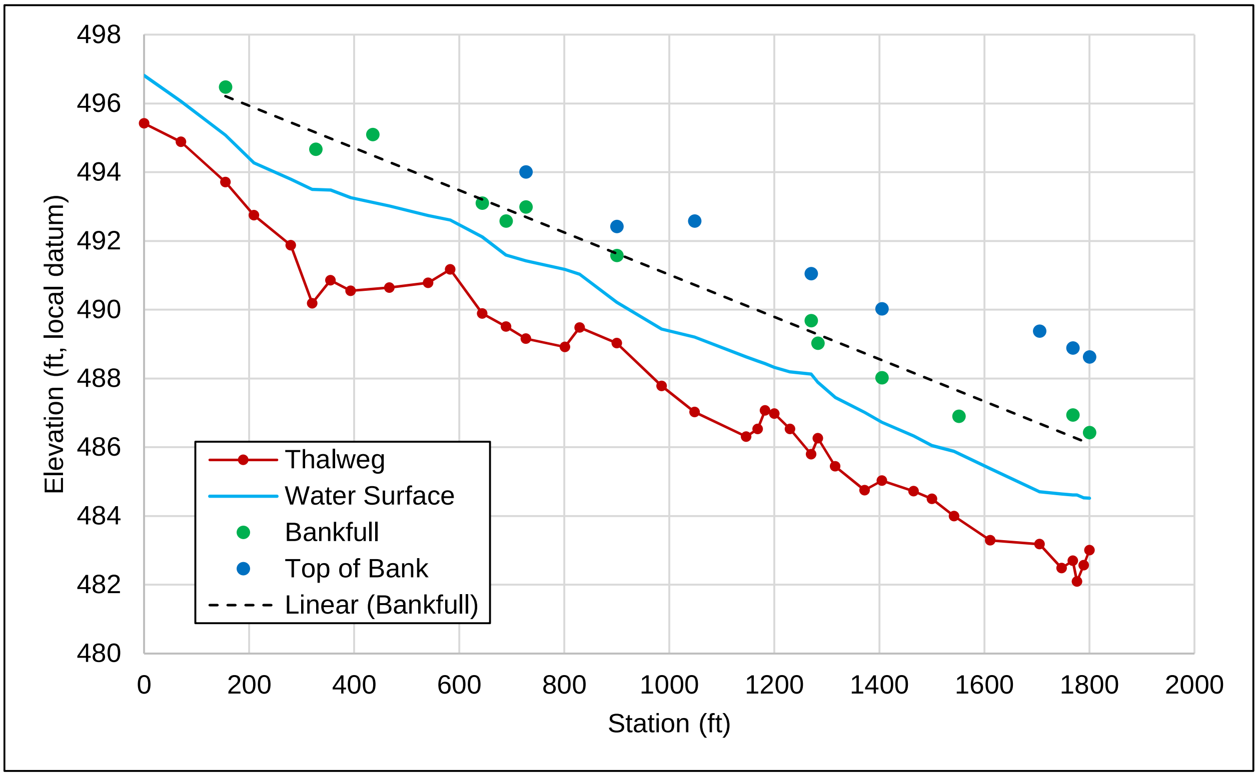

Figure 50. Longitudinal profile through the Ski Hill Reach.

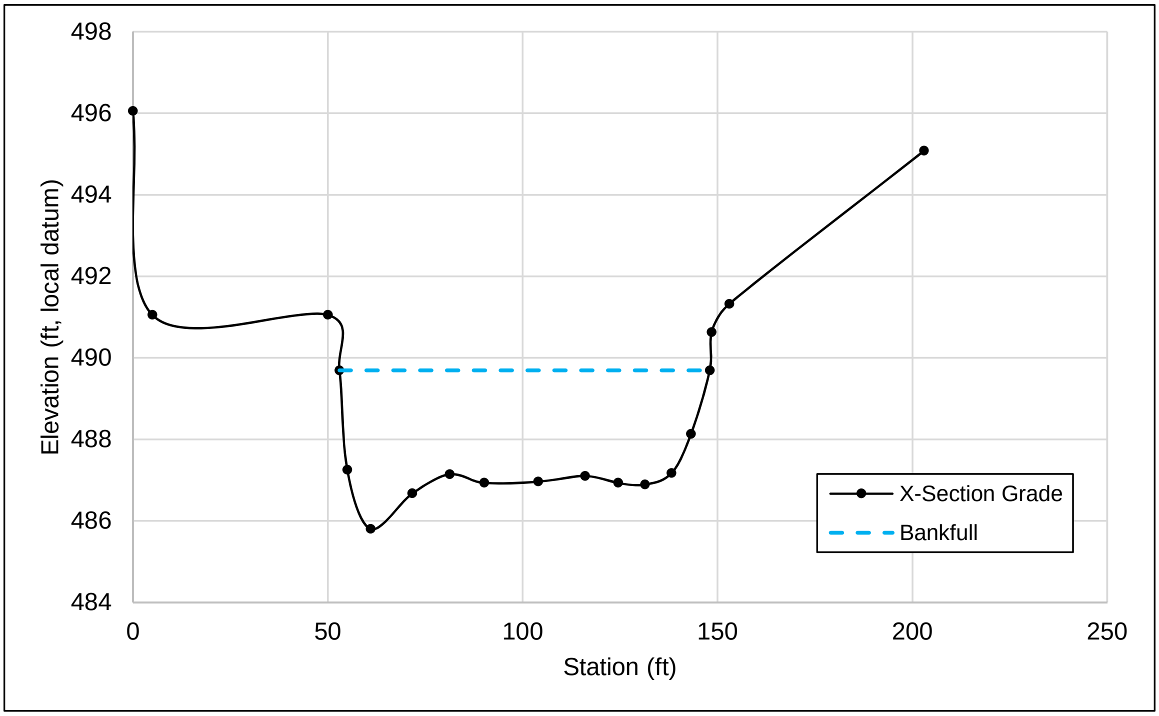

Figure 51. Typical riffle cross section in the Ski Hill Reach.

The dimensionless bankfull shear stress in the Ski Hill Reach is 0.0275 and the dimensional shear stress is 1.013 lbs/ft^2. Bankfull hydraulic conditions result the mobilization of a 153 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is capable of transporting the largest particles in the available bedload, and is capable of mobilizing up to the D90 of the surface grains based upon material size class distribution (Figure 52). These analyses indicate that the reach is competent to mobilize the available bedload, but that excess shear stress could achieve mobilization of the largest surface grains and result in channel degradation.

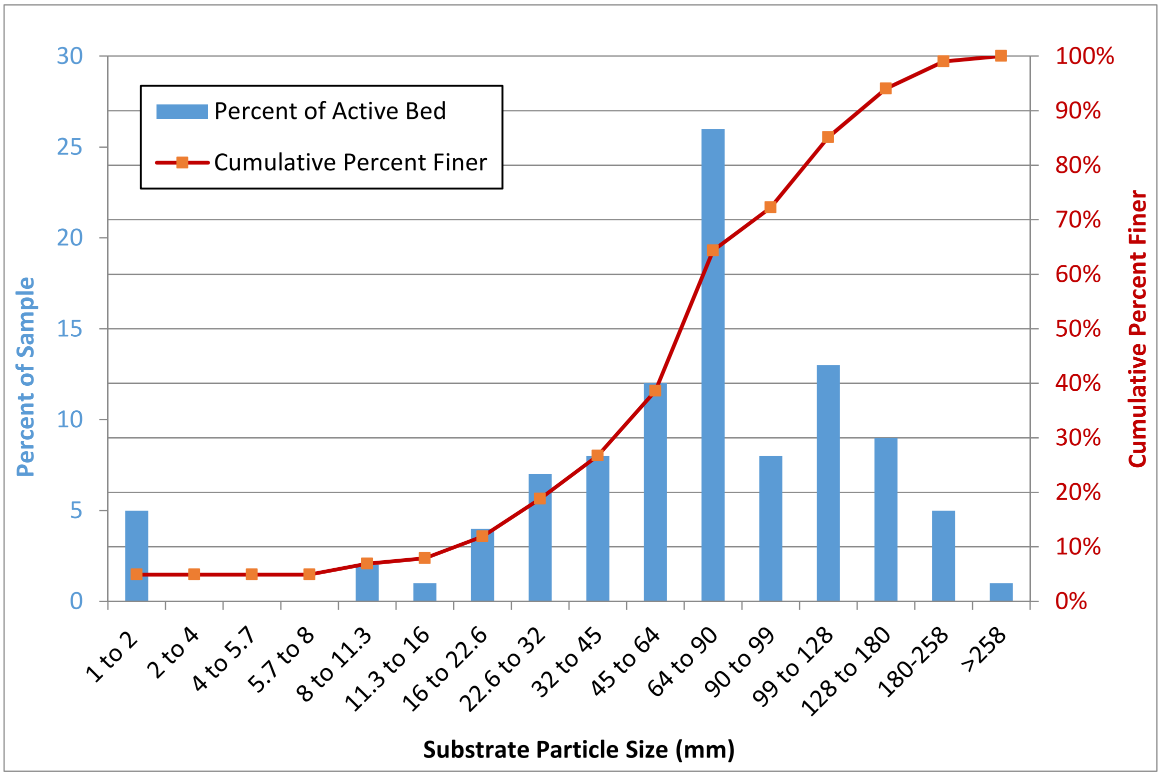

Figure 52. Surface particle size class distribution in the Ski Hill Reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at Ski Hill Reach is comprised of 1,962 tons/year of suspended sediment and 1,672 tons/year of bedload. Survey data from Ski Hill Reach indicate that the reach has capacity to transport 2,205 tons/year of suspended sediment and 1,158 tons/year of bedload. The reach therefore has excess capacity to transport the supplied suspended sediment (net capacity of 12%) and the reach has insufficient capacity to transport the supplied bedload (net capacity of -31%). These sediment transport conditions result in widespread sediment deposition and channel aggradation.

Stream stability analyses indicate that the reach has insufficient sediment transport capacity, is highly unstable laterally, has moderate deposition and evidence of aggradation, is slightly incised, has moderate channel enlargement potential, and is a very high supply of sediment. Stream stability findings are summarized in Table 14.

Table 14. Summary of stream channel stability indices of Ski Hill Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Insufficient Capacity
Lateral Stability	Highly Unstable
Vertical Stability (Aggradation)	Aggradation
Vertical Stability (Degradation)	Slightly Incised
Channel Enlargement Potential	Moderate Increase
Sediment Supply (Channel Source)	Very High

5.8 HIGHWAY 75 REACH

The Highway 75 Reach is located on private lands in an alluvial valley with bounding features composed of alluvial deposits (attached Exhibit 91). The stream channel is slightly entrenched, has high width/depth ratio, and has moderate sinuosity. The reach has bankfull channel width of 130.1 ft, mean depth of 2.37 ft, width/depth ratio of 51, and bankfull discharge of 896 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is greater than 2.2 ft/ft, and the channel is classified as a D-type stream. Typical conditions are depicted in Figures 53-64 and morphologic channel attributes are summarized in Table 15.

Figure 53. Photograph depicting mid-channel bar and sedimentation in the Highway 75 Reach.

Figure 54. Photograph depicting split channel configuration and sedimentation in the Highway 75 Reach.

Figure 55. Photograph depicting point bar enlargement (river right) and unstable eroding cut bank (river left) in the Highway 75 Reach.

Figure 56. Photograph depicting steep riffle bed feature and tall eroding bank with extreme BEHI in the Highway 75 Reach.

Figure 57. Photograph depicting point bar enlargement and tall eroding bank with extreme BEHI upstream of the highway bridge in the Highway 75 Reach.

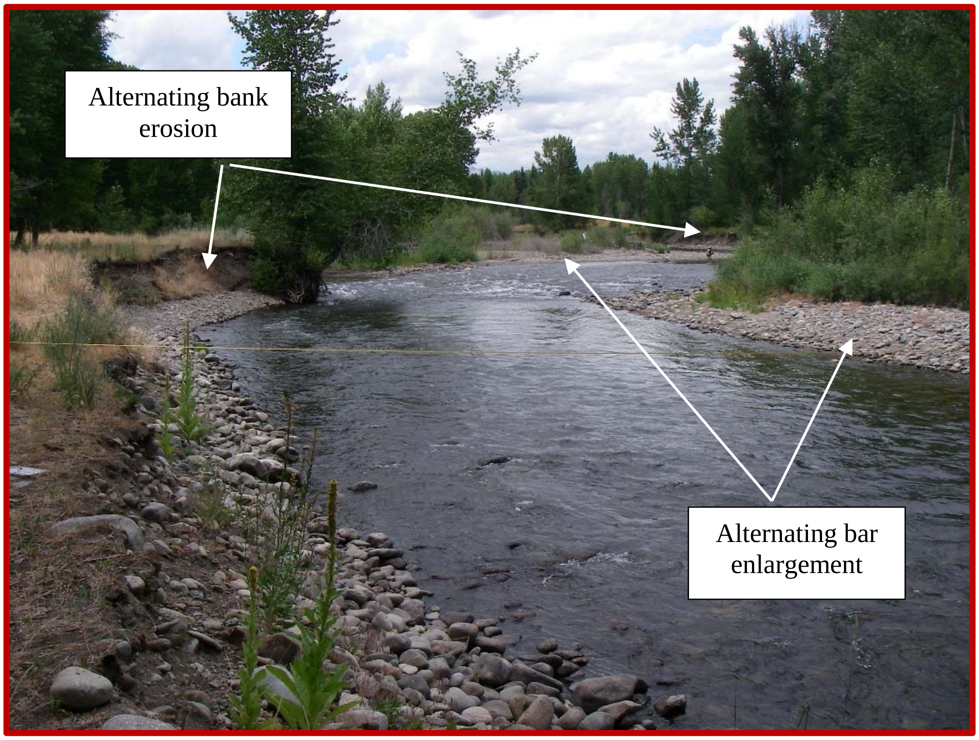

Figure 58. Photograph looking upstream at typical conditions in the Highway 75 Reach.

Figure 59. Photograph looking downstream at point bar enlargement, installed rock sill, and bridges in the Highway 75 Reach.

Figure 60. Photograph depicting sedimentation and point bar enlargement under highway bridge in the Highway 75 Reach.

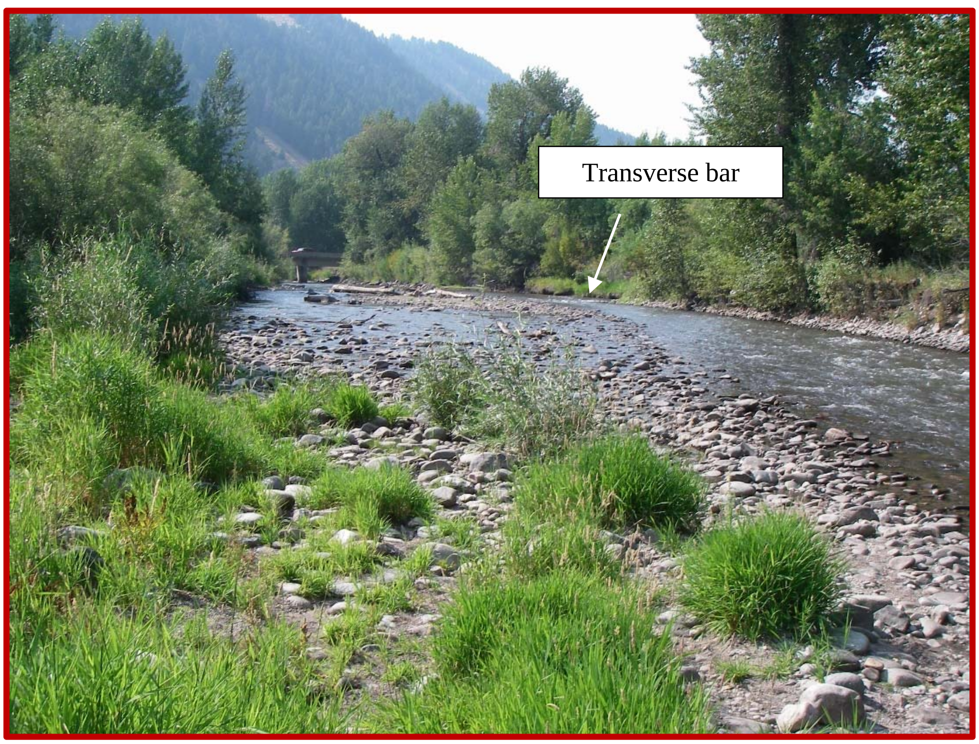

Figure 61. Photograph looking upstream at sedimentation and transverse bar in the Highway 75 Reach.

Figure 62. Photograph depicting bar enlargement (river right) and bank erosion (river left) in the Highway 75 Reach.

Figure 63. Photograph of river right diversion structure in the Highway 75 Reach.

Figure 64. Photograph depicting failed rock sill and development encroachment in the Highway 75 Reach.

Table 15. Summary of morphologic channel conditions in the Highway 75 Reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	130.1
Mean Bankfull Depth (ft)	2.37
Maximum Bankfull Depth (ft)	3.14
Width/Depth Ratio (ft/ft)	51
Entrenchment Ratio (ft/ft)	>2.2
Meander Width Ratio (ft/ft)	5.3
Bankfull Mean Velocity (ft/sec)	4.2
Bankfull Discharge (ft^3/sec)	896
Particle Size Index D_{50} (mm)	113
Sinuosity (ft/ft)	1.28
Annual Streambank Erosion Rate (tons/yr/ft)	0.3254
Slope (ft/ft)	0.0058
Existing Stream Type	D3
Potential Stream Type	C3

The bank erosion rate at the Highway 75 Reach is 0.3254 tons/year/foot, and the 2,442-ft long surveyed stream segment contributes an estimated 794 tons of sediment to the watershed in an average year through bank erosion.

The Highway 75 Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 65) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 0.58%, and a typical riffle cross section depicting high width/depth ratio is presented in Figure 66.

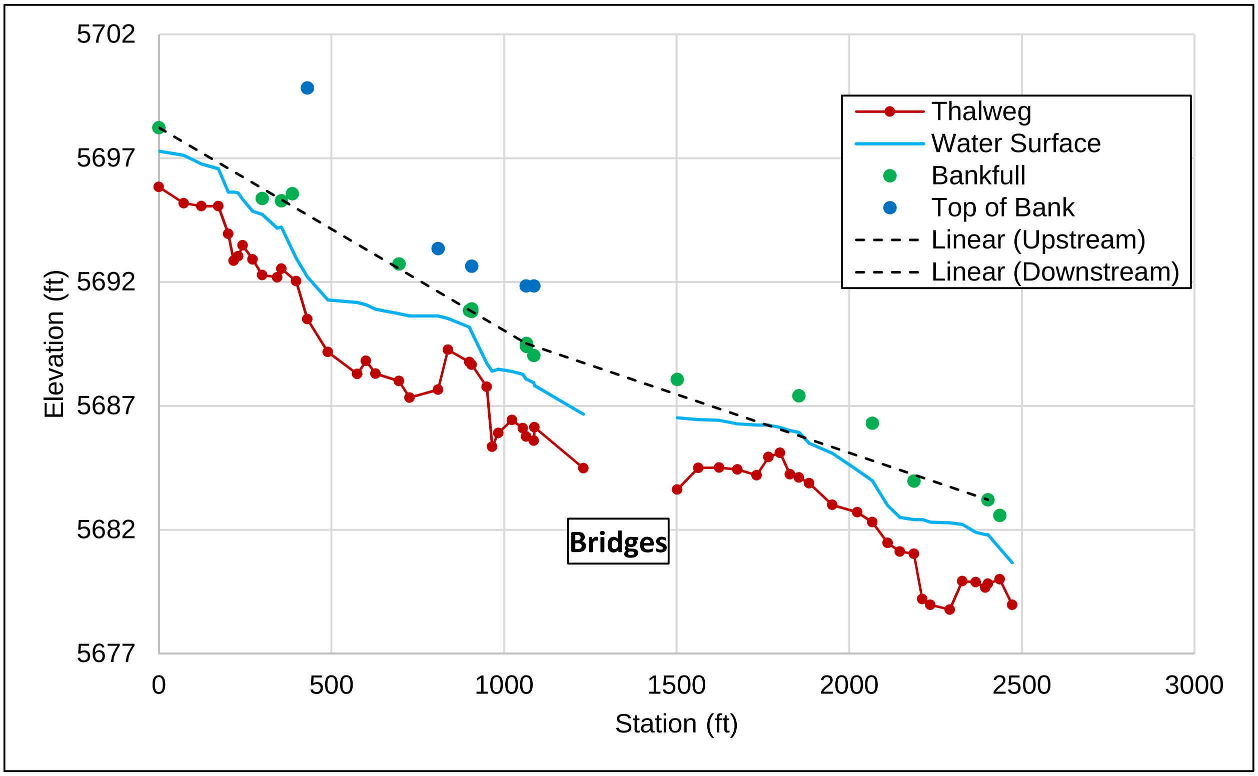

Figure 65. Longitudinal profile through the Highway 75 Reach

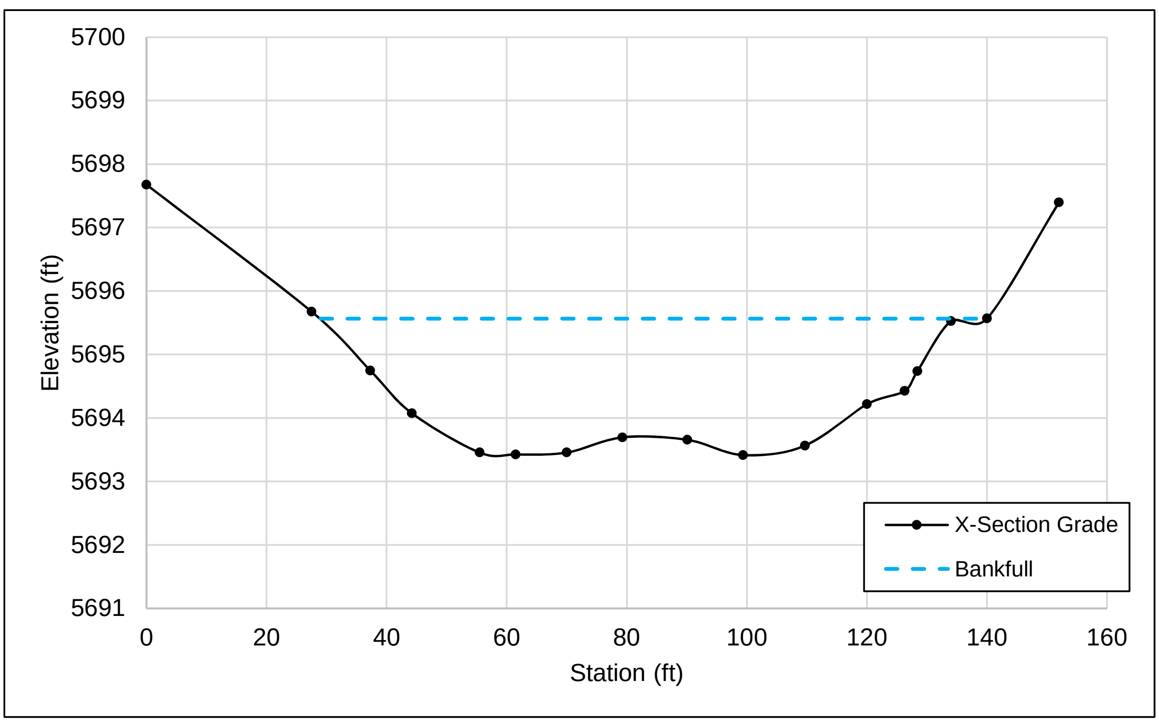

Figure 66. Typical riffle cross section in the Highway 75 Reach.

The dimensionless bankfull shear stress in the Highway 75 Reach is 0.0192 and the dimensional shear stress is 0.691 lbs/ft^2. Bankfull hydraulic conditions result in the mobilization of a 116 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is capable of transporting the largest particles in the available bedload, but is capable of mobilizing only up to the D50 of the surface grains based upon material size class distribution (Figure 67). These analyses indicate that the reach is competent to transport the available bedload and that the existing surface grain size class distribution promotes vertical channel stability.

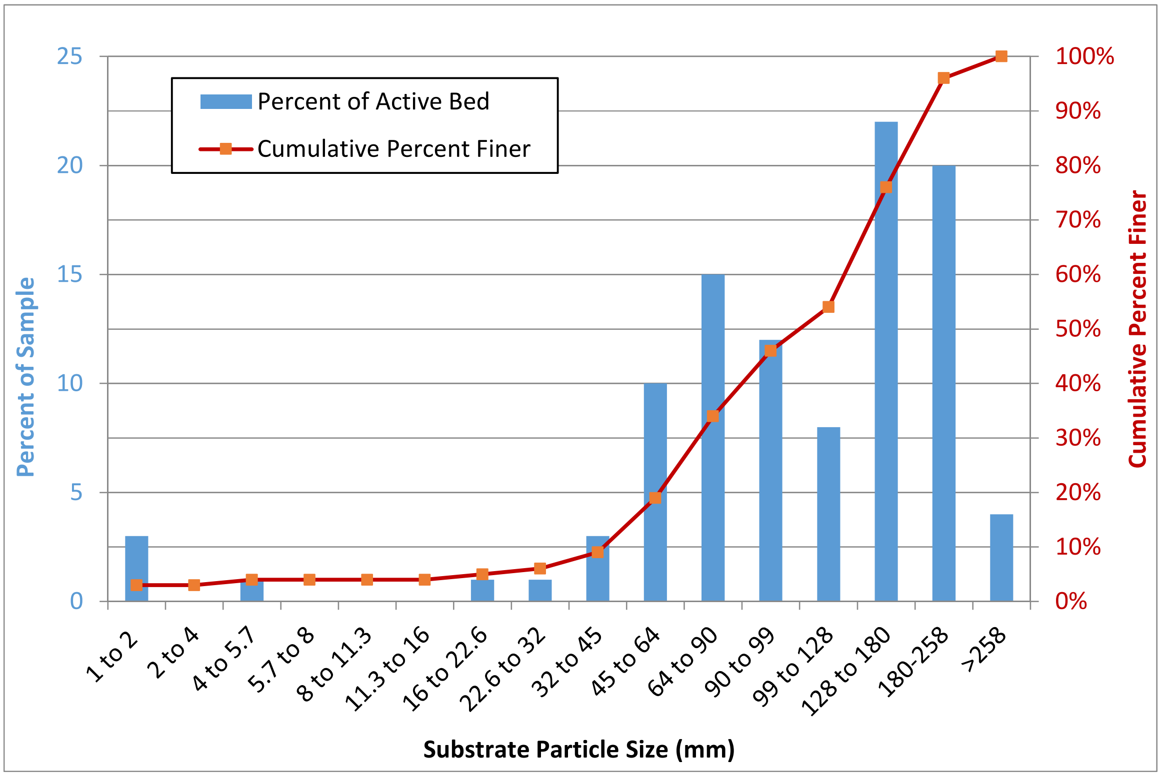

Figure 67. Surface particle size class distribution in the Highway 75 Reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at Highway 75 Reach is comprised of 1,334 tons/year of suspended sediment and 1,998 tons/year of bedload. Survey data from Highway 75 Reach indicate that the reach has capacity to transport 1,537 tons/year of suspended sediment and 1,815 tons/year of bedload. The reach therefore has excess capacity to transport the supplied suspended sediment (net capacity of 14%) and the reach has insufficient capacity to transport the supplied bedload (net capacity of -9%). These sediment transport conditions result in excess sediment deposition.

Stream stability analyses indicate that the reach has insufficient sediment transport capacity, is highly unstable laterally, has excessive deposition and evidence of aggradation, is slightly incised, has moderate channel enlargement potential, and is a very high supply of sediment. Stream stability findings are summarized in Table 16.

Table 16. Summary of stream channel stability indices of the Highway 75 Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Insufficient Capacity
Lateral Stability	Highly Unstable
Vertical Stability (Aggradation)	Excess Deposition
Vertical Stability (Degradation)	Slightly Incised
Channel Enlargement Potential	Moderate Increase
Sediment Supply (Channel Source)	Very High

5.9 DOWNSTREAM OF EAST FORK WOOD RIVER REACH

The Downstream of East Fork Reach is located on a combination of private and US Bureau of Land Management lands in a confined alluvial valley with bounding features composed of bedrock and colluvial formations (attached Exhibit 92). The stream channel is entrenched, has moderate to high width/depth ratio, and has low sinuosity. The reach has bankfull channel width of 88.6 ft, mean depth of 2.62 ft, width/depth ratio of 33.8, and bankfull discharge of 850 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is 1.1 ft/ft, and the channel is classified as an F-type stream. Typical conditions are depicted in Figures 68, 69, and 70, and morphologic channel attributes are summarized in Table 17.

Figure 68. Photograph depicting typical channel entrenchment in Downstream of East Fork Reach.

Figure 69. Photograph depicting steep bedrock banks in the Downstream of East Fork Reach.

Figure 70. Photograph depicting development encroachment and fine sediment deposition in the Downstream of East Fork Reach.

Table 17. Summary of morphologic channel conditions in the Downstream of East Fork Reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	88.6
Mean Bankfull Depth (ft)	2.62
Maximum Bankfull Depth (ft)	3.23
Width/Depth Ratio (ft/ft)	33.8
Entrenchment Ratio (ft/ft)	1.1
Meander Width Ratio (ft/ft)	5.1
Bankfull Mean Velocity (ft/sec)	3.7
Bankfull Discharge (ft^3/sec)	850
Particle Size Index D_{50} (mm)	90.5
Sinuosity (ft/ft)	1.08
Annual Streambank Erosion Rate (tons/yr/ft)	0.0539
Slope (ft/ft)	0.0041
Existing Stream Type	F3
Potential Stream Type	B3c

The bank erosion rate at the Downstream of East Fork Reach is 0.0539 tons/year/foot, and the 1321-ft long surveyed stream segment contributes an estimated 71 tons of sediment to the watershed in an average year through bank erosion.

The Downstream of East Fork Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 71) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 0.41%. Scour pools of moderate depth are sparse along the reach, which is dominated by shallow bed features. A typical riffle cross section depicting high width/depth ratio and channel entrenchment is shown in Figure 72.

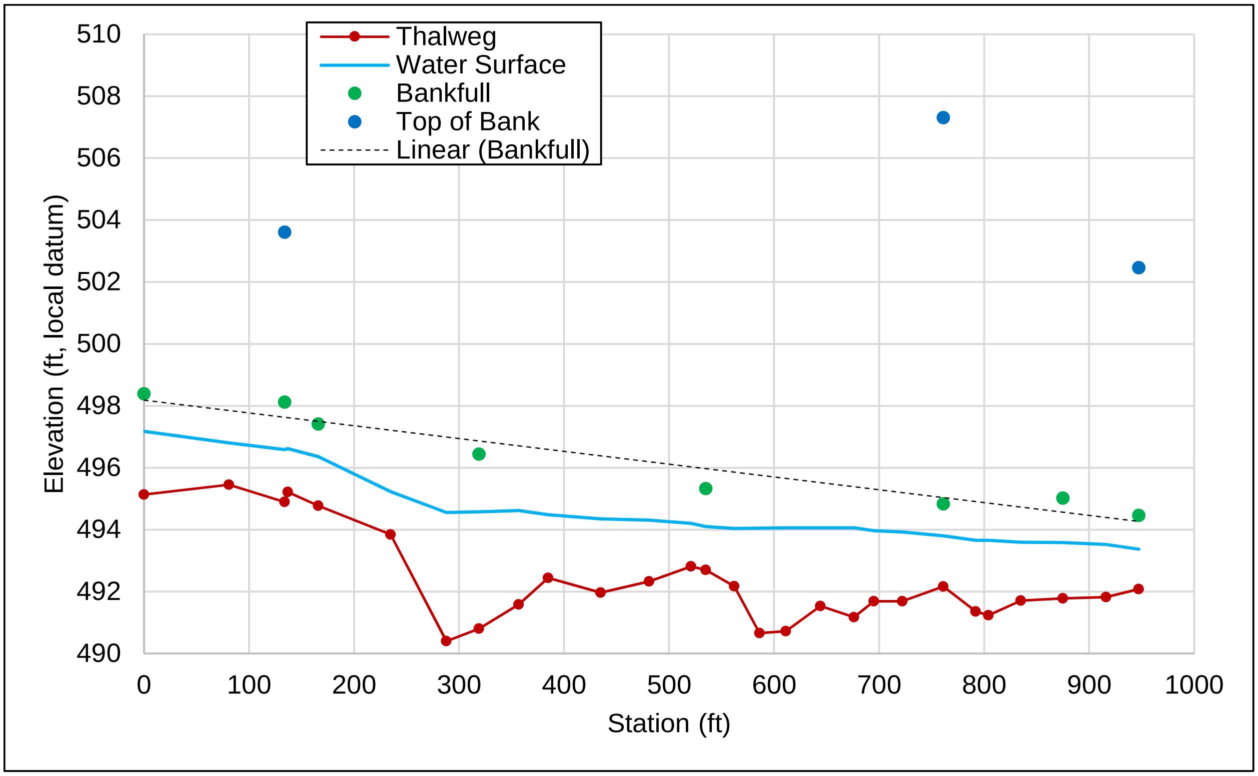

Figure 71. Longitudinal profile through the Downstream of East Fork Reach.

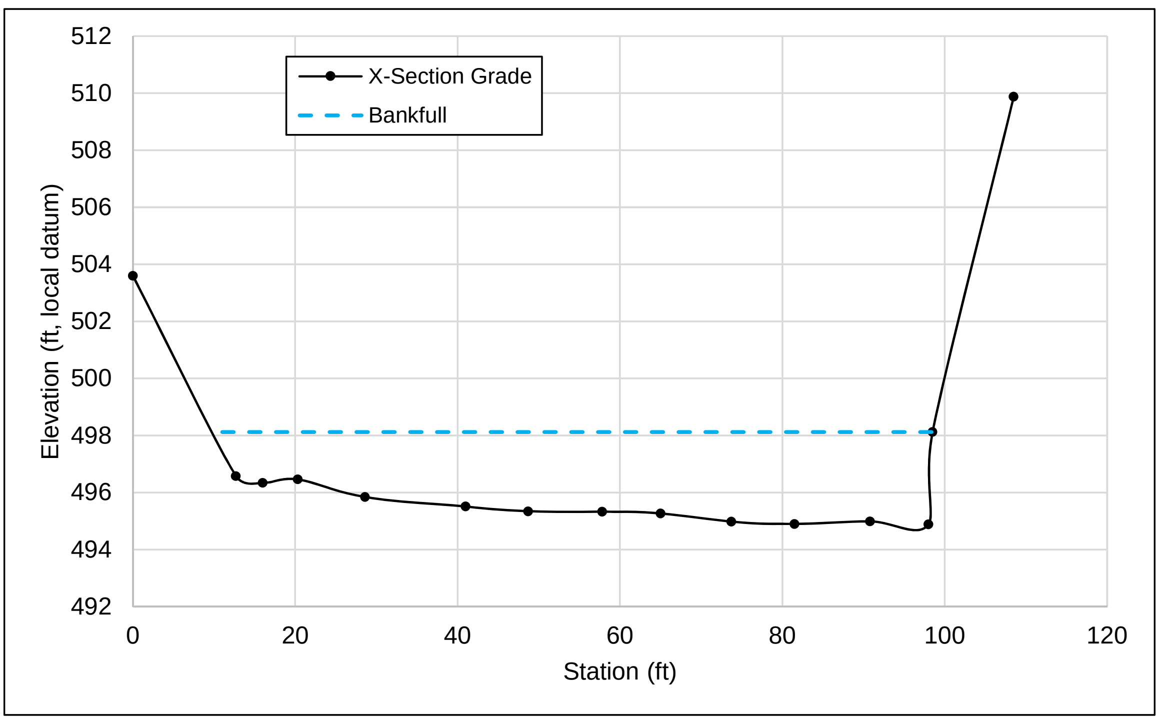

Figure 72. Typical riffle cross section in the Downstream of East Fork Reach.

The dimensionless bankfull shear stress in the Downstream of East Fork Reach is 0.0233 and the dimensional shear stress is 0.67 lbs/ft^2. Bankfull hydraulic conditions result the mobilization of a 113 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is capable of transporting the largest particles in the available bedload, but is capable of mobilizing only up to the D55 of the surface grains based upon material size class distribution (Figure 73). These analyses indicate that the reach is competent to transport the available bedload and that the existing surface grain size class distribution promotes vertical channel stability.

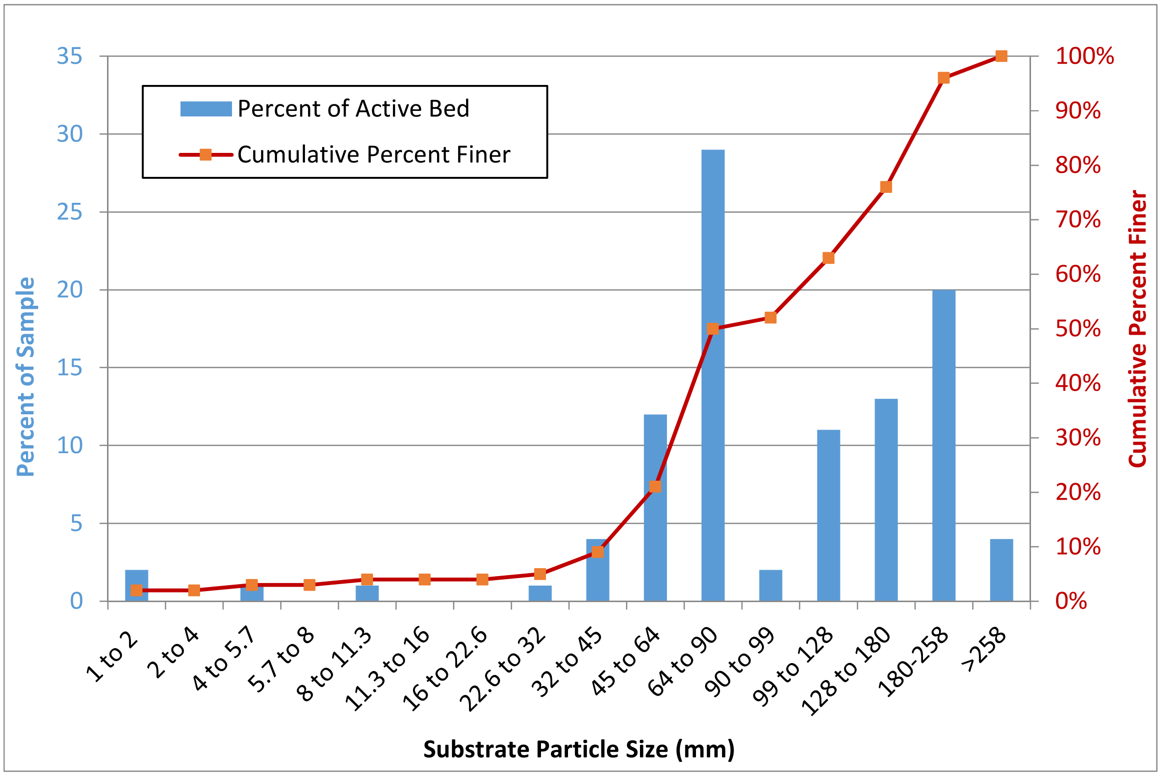

Figure 73. Surface particle size class distribution in the Downstream of East Fork

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at Downstream of East Fork Reach is comprised of 1,013 tons/year of suspended sediment and 1,228 tons/year of bedload. Survey data from Downstream of East Fork Reach indicate that the reach has capacity to transport 1,035 tons/year of suspended sediment and 594 tons/year of bedload. The reach therefore has sufficient capacity to transport the supplied suspended sediment (net capacity of 2%) and the reach has insufficient capacity to transport the supplied bedload (net capacity of -52%). These sediment transport conditions result in excess sediment deposition.

Stream stability analyses indicate that the reach has insufficient sediment transport capacity, is moderately unstable laterally, has excess deposition and evidence of aggradation, is slightly incised, has moderate channel enlargement potential, and is a high supply of sediment. Stream stability findings are summarized in Table 18.

Table 18. Summary of stream channel stability indices of Downstream of East Fork Wood River Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Insufficient Capacity
Lateral Stability	Moderately Unstable
Vertical Stability (Aggradation)	Excess Deposition
Vertical Stability (Degradation)	Slightly Incised
Channel Enlargement Potential	Moderate Increase
Sediment Supply (Channel Source)	High

5.10 DOWNSTREAM OF DEER CREEK REACH

The Downstream of Deer Creek Reach is located on a combination of private and US Bureau of Land Management lands in an alluvial valley with bounding features composed of alluvial deposits (attached Exhibit 93). The stream channel is slightly entrenched, has high width/depth ratio, and has low sinuosity. The reach has bankfull channel width of 249.4 ft, mean depth of 1.5 ft, width/depth ratio of 166.3, and bankfull discharge of 1122 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is greater than 2.2 ft/ft, and the channel is classified as a D-type stream due to multiple channels. Typical conditions are depicted in Figures 74, 75, 76, 77, and 78, and morphologic channel attributes are summarized in Table 19.

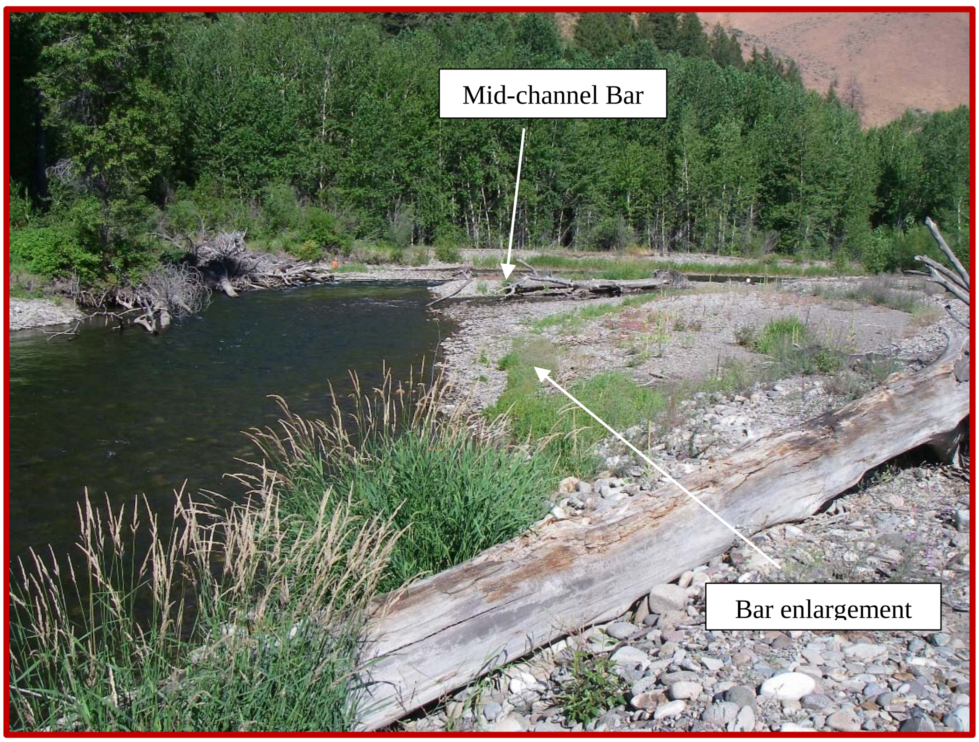

Figure 74. Photograph depicting bar enlargement, mid-channel bar, and split channel configuration of the Downstream of Deer Creek Reach.

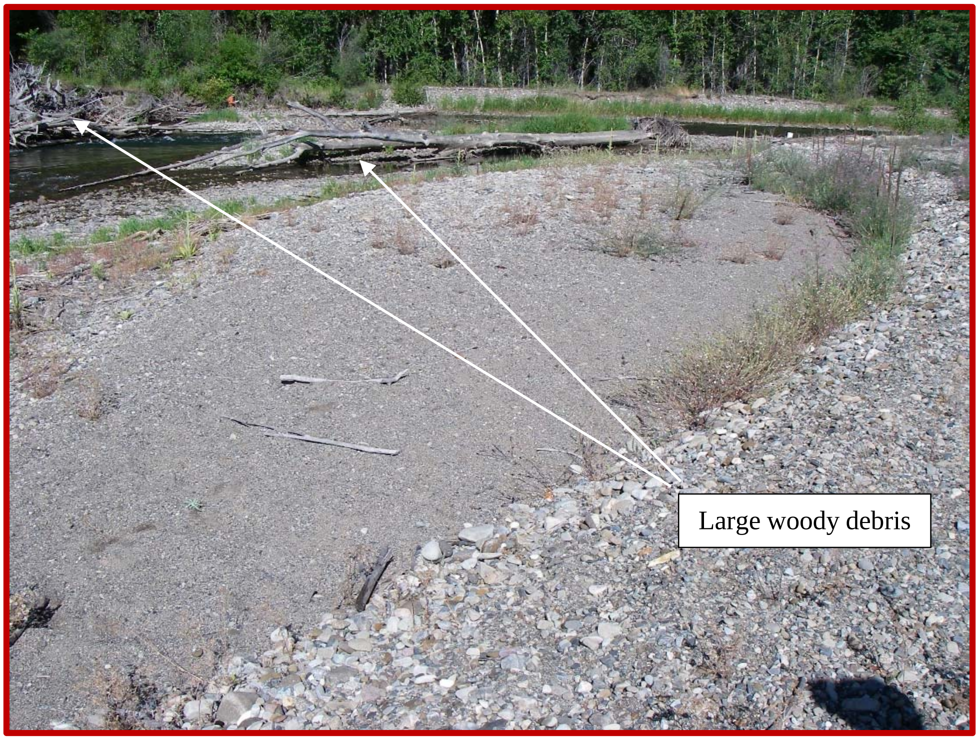

Figure 75. Photograph depicting sedimentation and woody debris accumulations in the Downstream of Deer Creek Reach.

Figure 76. Photograph depicting multiple mid-channel bars and split channel configuration in the Downstream of Deer Creek Reach.

Figure 77. Photograph depicting undercutting vegetated bank with moderate BEHI rating in the Downstream of Deer Creek Reach.

Figure 78. Photograph depicting high width/depth ratio slightly entrenched channel in the Downstream of Deer Creek Reach.

Table 19. Summary of morphologic channel conditions in the Downstream of Deer Creek Reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	249.4
Mean Bankfull Depth (ft)	1.5
Maximum Bankfull Depth (ft)	3.25
Width/Depth Ratio (ft/ft)	166.3
Entrenchment Ratio (ft/ft)	>2.2
Meander Width Ratio (ft/ft)	1.37
Bankfull Mean Velocity (ft/sec)	3
Bankfull Discharge (ft^3/sec)	1122
Particle Size Index D_{50} (mm)	79
Sinuosity (ft/ft)	1.2
Annual Streambank Erosion Rate (tons/yr/ft)	0.2472
Slope (ft/ft)	0.0059
Existing Stream Type	D3
Potential Stream Type	C3

The bank erosion rate at the Downstream of Deer Creek Reach is 0.2742 tons/year/foot, and the 1976-ft long surveyed stream segment contributes an estimated 542 tons of sediment to the watershed in an average year through bank erosion.

The Downstream of Deer Creek Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 79) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 0.59%. The reach is characterized by short, steep, braided riffles separated by long pool bed features. A typical riffle cross section depicting high width/depth ratio and multiple channels is presented in Figure 80.

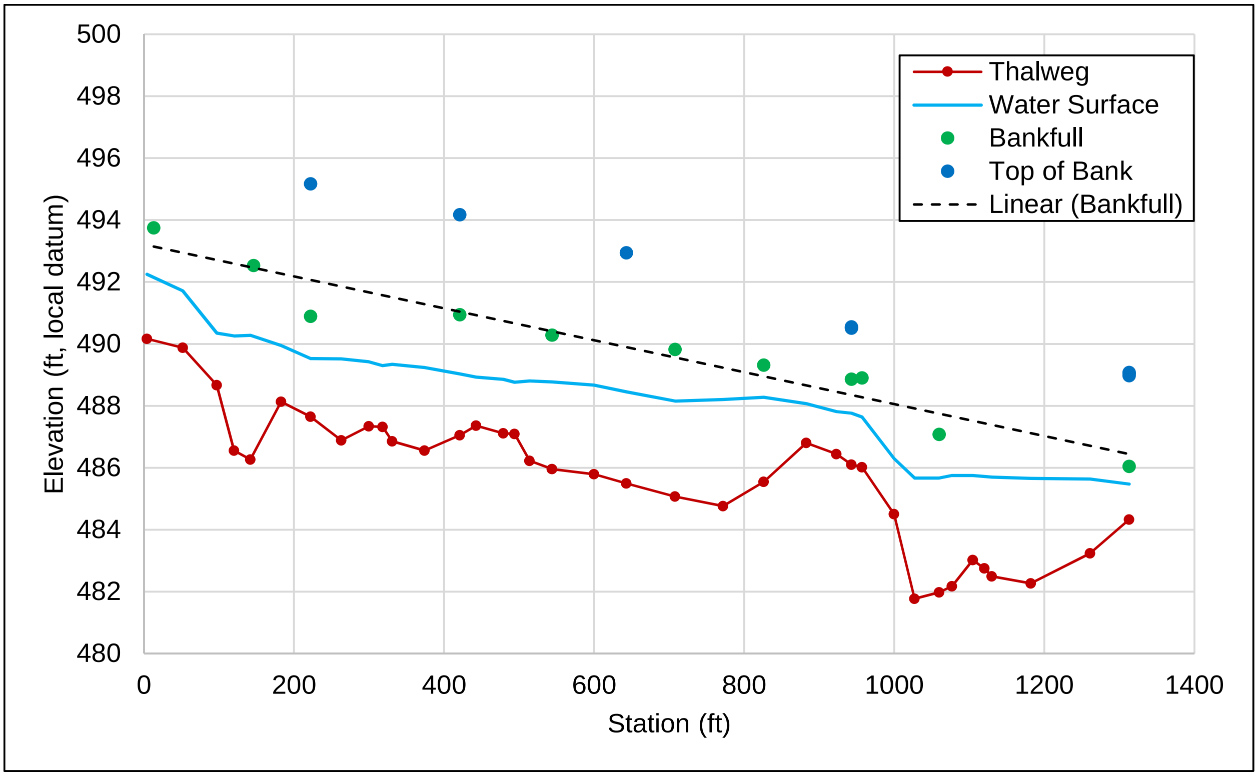

Figure 79. Longitudinal profile through Downstream of Deer Creek Reach.

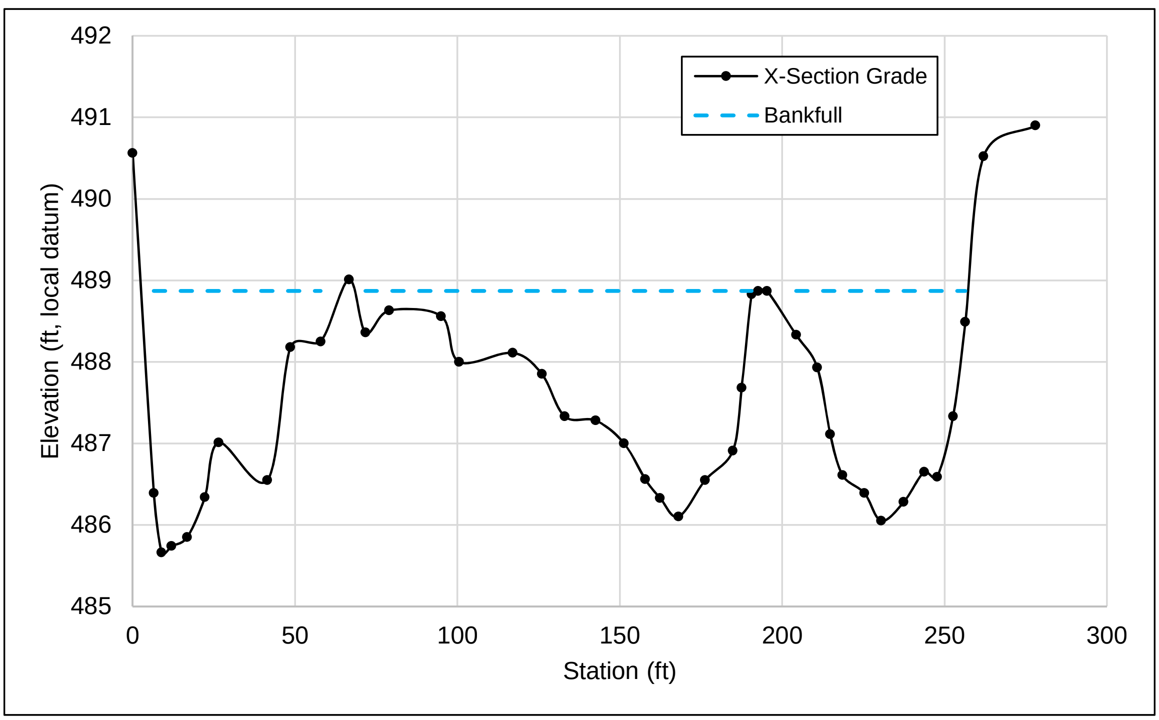

Figure 80. Typical riffle cross section across multiple channels in Downstream of Deer Creek Reach.

The dimensionless bankfull shear stress in the Downstream of Deer Creek Reach is 0.016 and the dimensional shear stress is 0.552 lbs/ft^2. Bankfull hydraulic conditions result the mobilization of a 98 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is capable of transporting the largest particles in the available bedload, but is capable of mobilizing only up to the D60 of the surface grains based upon material size class distribution (Figure 81). These analyses indicate that the reach is competent to transport the available bedload and that the existing surface grain size class distribution promotes vertical channel stability.

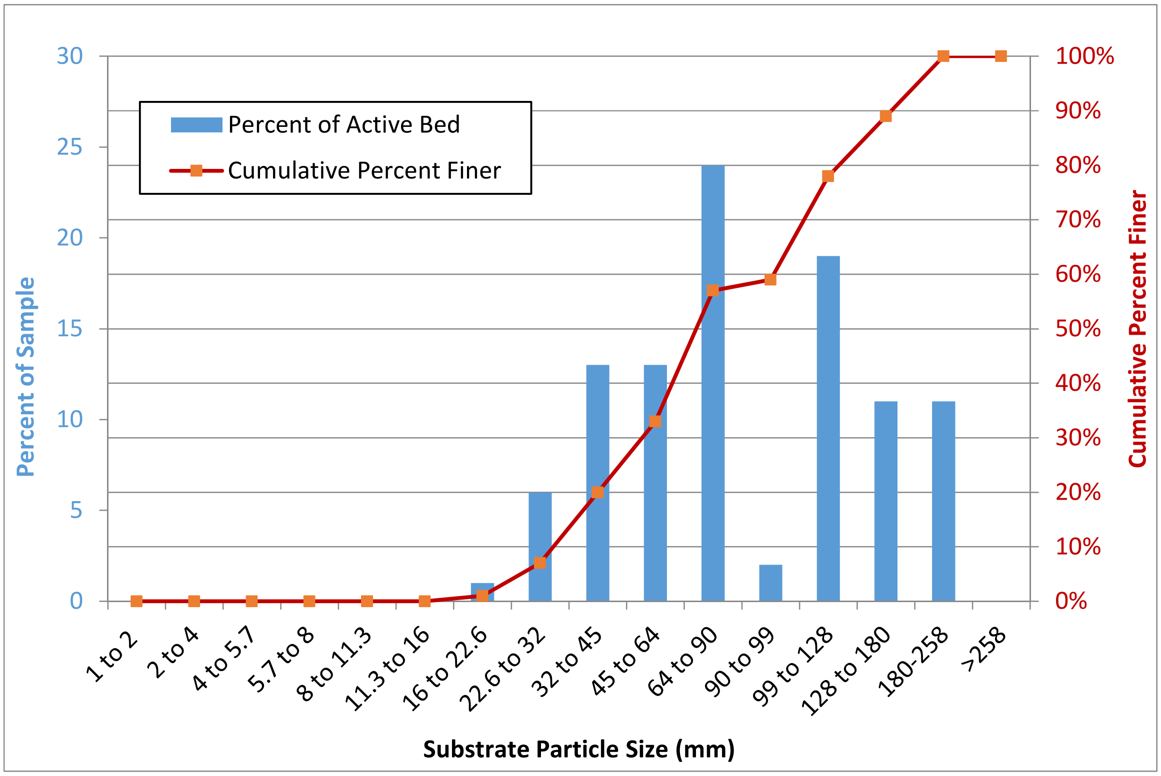

Figure 81. Surface particle size class distribution in the Downstream of Deer Creek Reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at Downstream of Deer Creek Reach is comprised of 1,355 tons/year of suspended sediment and 3,033 tons/year of bedload. Survey data from Downstream of Deer Creek Reach indicate that the reach has capacity to transport 1,339 tons/year of suspended sediment and 1,766 tons/year of bedload. The reach therefore has sufficient capacity to transport the supplied suspended sediment (net capacity of approximately zero) and the reach has insufficient capacity to transport the supplied bedload (net capacity of -42%). These sediment transport conditions result in excess sediment deposition and channel aggradation.

Stream stability analyses indicate that the reach has insufficient sediment transport capacity, is highly unstable laterally, has moderate deposition and evidence of aggradation, is slightly incised, has extensive channel enlargement potential, and is a very high supply of sediment. Stream stability findings are summarized in Table 20.

Table 20. Summary of stream channel stability indices of Downstream of Deer Creek Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Insufficient Capacity
Lateral Stability	Highly Unstable
Vertical Stability (Aggradation)	Aggradation
Vertical Stability (Degradation)	Slightly Incised
Channel Enlargement Potential	Extensive
Sediment Supply (Channel Source)	Very High

5.11 BULLION BRIDGE REACH

The Bullion Bridge Reach is located on a combination of private and city lands in an alluvial valley with bounding features composed of alluvial deposits and well-developed floodplains (attached Exhibit 94). The stream channel is entrenched, has high width/depth ratio, and has low sinuosity. The reach has bankfull channel width of 84.4 ft, mean depth of 2.98 ft, width/depth ratio of 28, and bankfull discharge of 1,175 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is 1.18 ft/ft, and the channel is classified as an F-type stream. Typical conditions are depicted in Figures 82, 83, and 84, and morphologic channel attributes are summarized in Table 21.

Figure 82. Photograph depicting typical channel confinement and failing rock sill structure in the Bullion Bridge Reach.

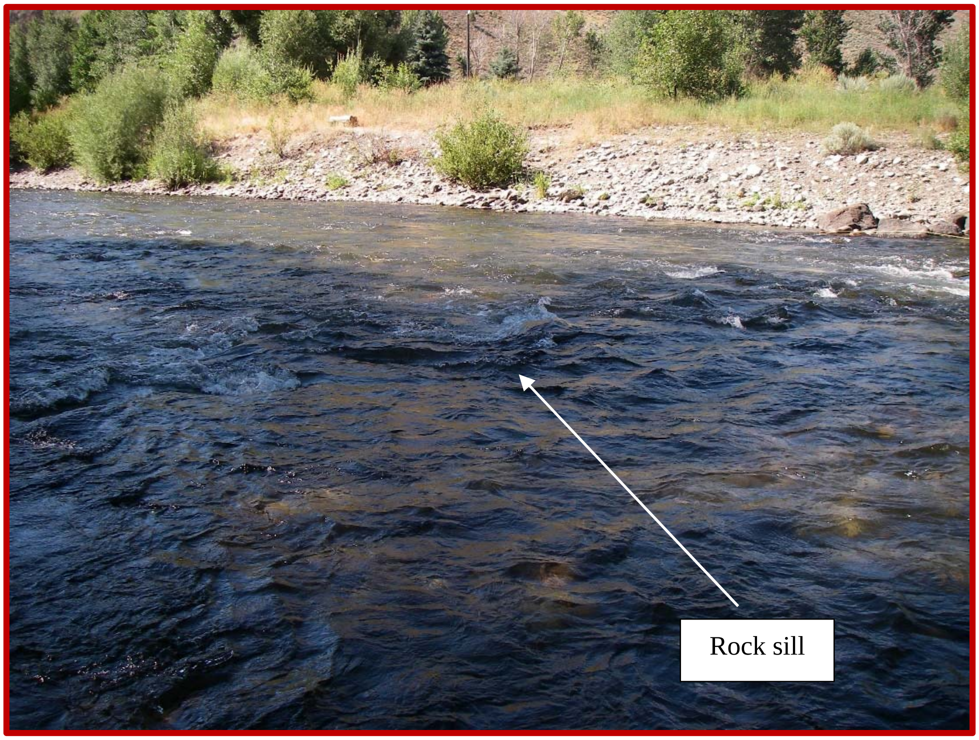

Figure 83. Photograph depicting typical channel entrenchment and constructed rock sill in the Bullion Bridge Reach.

Figure 84. Photograph depicting typical high width/depth ratio channel in the Bullion Bridge Reach.

Table 21. Summary of morphologic channel conditions in Bullion Bridge Reach

Channel Parameter	Value
Bankfull Channel Width (ft)	84.4
Mean Bankfull Depth (ft)	2.98
Maximum Bankfull Depth (ft)	3.74
Width/Depth Ratio (ft/ft)	28
Entrenchment Ratio (ft/ft)	1.18
Meander Width Ratio (ft/ft)	2.6
Bankfull Mean Velocity (ft/sec)	4.7
Bankfull Discharge (ft^3/sec)	1175
Particle Size Index D_{50} (mm)	84
Sinuosity (ft/ft)	1.03
Annual Streambank Erosion Rate (tons/yr/ft)	0.3690
Slope (ft/ft)	0.0041
Existing Stream Type	F3
Potential Stream Type	B3c

The bank erosion rate at the Bullion Bridge Reach is 0.369 tons/year/foot, and the 1595-ft long surveyed stream segment contributes an estimated 588 tons of fine sediment to the watershed in an average year through bank erosion.

The Bullion Bridge Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 85) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 0.41%. The reach has few scour pools and is dominated by long shallow riffle bed features. A typical riffle cross section depicting high width/depth ratio and channel entrenchment is presented in Figure 86.

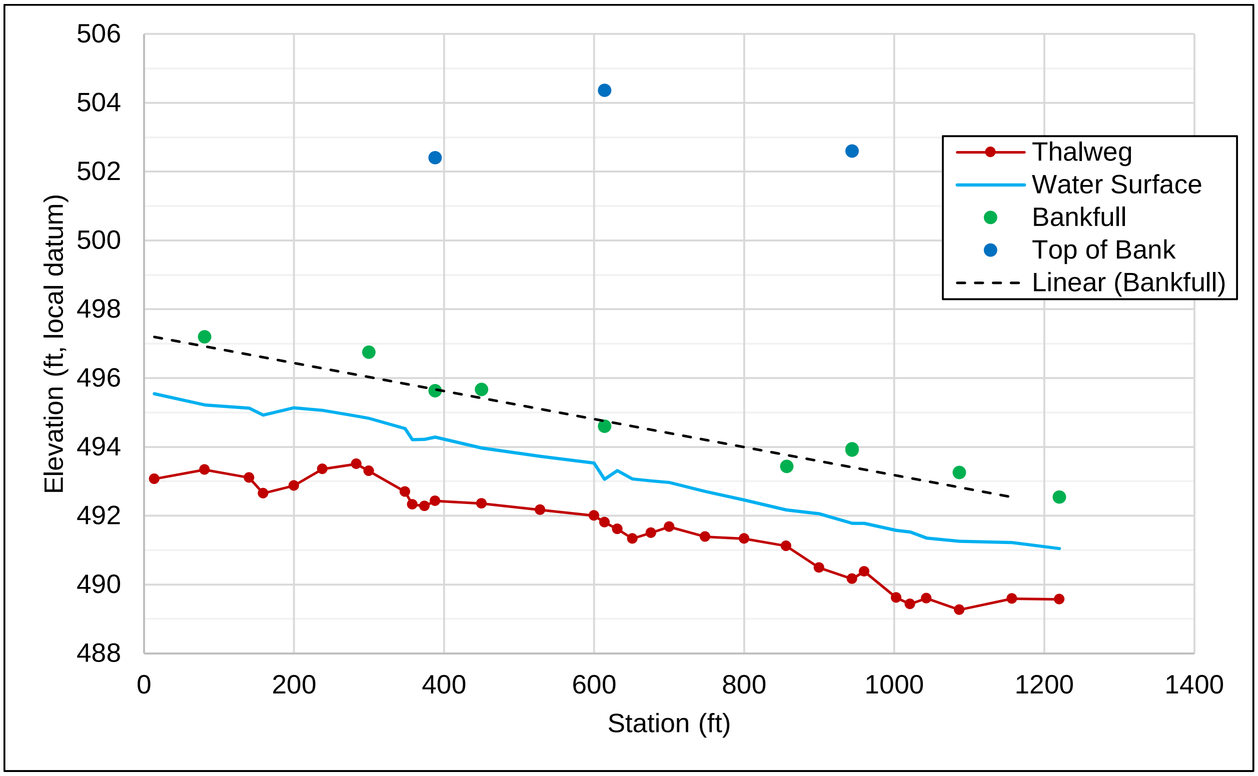

Figure 85. Longitudinal profile through the Bullion Bridge Reach.

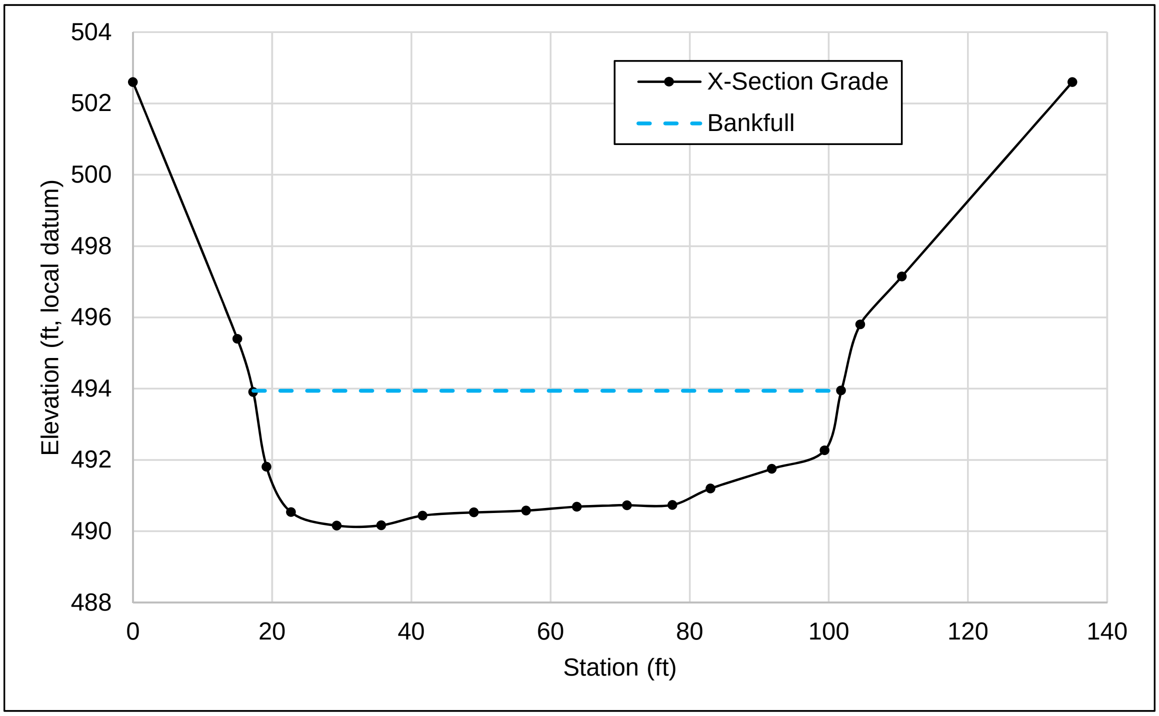

Figure 86. Typical riffle cross section in the Bullion Bridge Reach.

The dimensionless bankfull shear stress in the Bullion Bridge Reach is 0.0153 and the dimensional shear stress is 0.762 lbs/ft^2. Bankfull hydraulic conditions result the mobilization of a 125 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is capable of transporting the largest particles in the available bedload, and is capable of mobilizing up to the D75 of the surface grains based upon material size class distribution (Figure 87). These analyses indicate that the reach is competent to mobilize the available bedload and that the existing surface grain size class distribution promotes vertical channel stability.

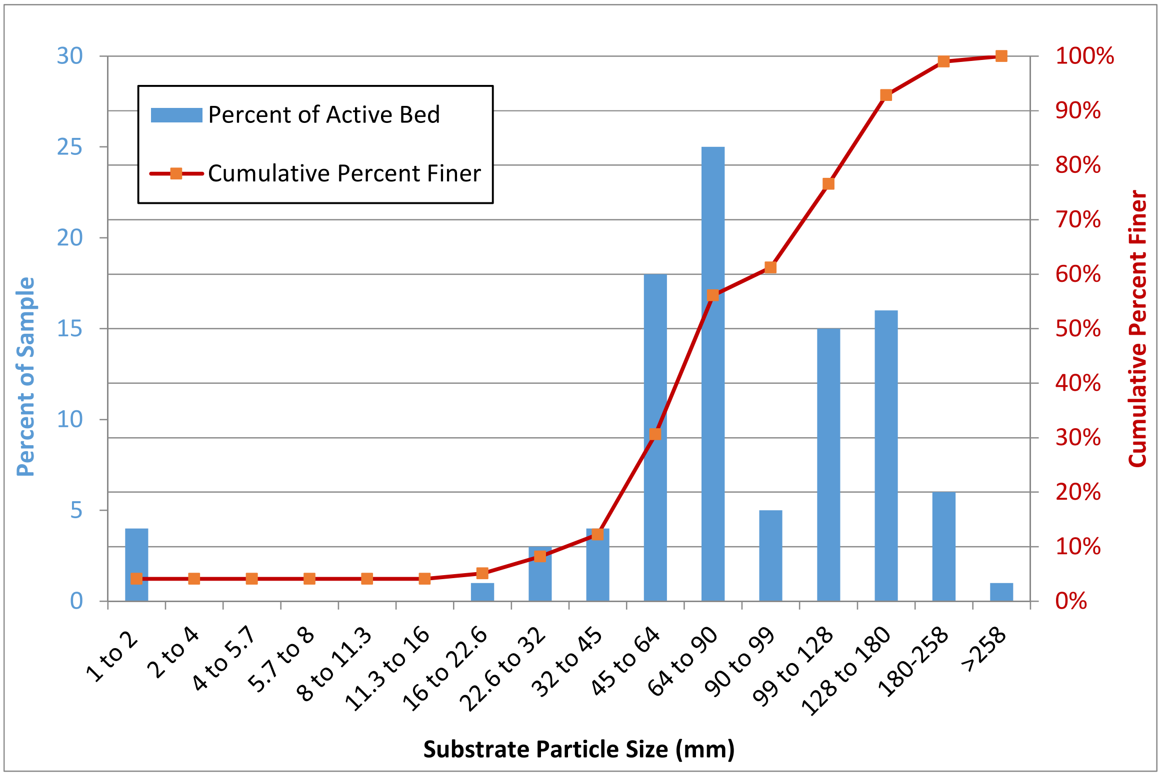

Figure 87. Surface particle size class distribution in the Bullion Bridge Reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at Bullion Bridge Reach is comprised of 1,436 tons/year of suspended sediment and 3,087 tons/year of bedload. Survey data from Bullion Bridge Reach indicate that the reach has capacity to transport 1,505 tons/year of suspended sediment and 2,548 tons/year of bedload. The reach therefore has sufficient capacity to transport the supplied suspended sediment (net capacity of 5%) and the reach has insufficient capacity to transport the supplied bedload (net capacity of -17%). These sediment transport conditions result in excess sediment deposition.

Stream stability analyses indicate that the reach has insufficient sediment transport capacity, is unstable laterally, has excess deposition and evidence of aggradation, is slightly incised, has moderate channel enlargement potential, and is a high supply of sediment. Stream stability findings are summarized in Table 22.

Table 22. Summary of stream channel stability indices of Bullion Bridge Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Insufficient Capacity
Lateral Stability	Unstable
Vertical Stability (Aggradation)	Excess Deposition
Vertical Stability (Degradation)	Slightly Incised
Channel Enlargement Potential	Moderate Increase
Sediment Supply (Channel Source)	High

5.12 COLORADO GULCH REACH

The Colorado Gulch Reach is located on private lands in an alluvial valley with bounding features composed of alluvial deposits (attached Exhibit 95). The stream channel is entrenched, has high width/depth ratio, and has moderate sinuosity. The reach has bankfull channel width of 98.3 ft, mean depth of 2.16 ft, width/depth ratio of 45.5, and bankfull discharge of 878 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is greater than 2.2 ft/ft, and the channel is classified as a D-type stream. Typical conditions are depicted in Figures 88, 89, 90, and 91, and morphologic channel attributes are summarized in Table 23.

Figure 88. Photograph depicting typical high width/depth ratio and sedimentation in the Colorado Gulch Reach.

Figure 89. Photograph depicting mid-channel bar, braided channel configuration, and large woody debris accumulations in the Colorado Gulch Reach.

Figure 90. Photograph depicting woody debris jam and scour pool in the Colorado Gulch Reach.

Figure 91. Photograph depicting bar enlargement and eroding cut bank in the Colorado Gulch Reach.

Table 23. Summary of morphologic channel conditions in the Colorado Gulch Reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	98.3
Mean Bankfull Depth (ft)	2.16
Maximum Bankfull Depth (ft)	3.24
Width/Depth Ratio (ft/ft)	45.5
Entrenchment Ratio (ft/ft)	>2.2
Meander Width Ratio (ft/ft)	2.25
Bankfull Mean Velocity (ft/sec)	4.1
Bankfull Discharge (ft^3/sec)	878
Particle Size Index D_{50} (mm)	80
Sinuosity (ft/ft)	1.2
Annual Streambank Erosion Rate (tons/yr/ft)	0.2904
Slope (ft/ft)	0.0058
Existing Stream Type	D3
Potential Stream Type	C3

The bank erosion rate at the Colorado Gulch Reach is 0.2904 tons/year/foot, and the 2217-ft long surveyed stream segment contributes an estimated 643 tons of fine sediment to the watershed in an average year through bank erosion.

The Colorado Gulch Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 92) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 0.58%. The reach is characterized by short steep riffle bed features and deep lateral scour pools associated with large woody debris jams. A typical riffle cross section is presented in Figure 93.

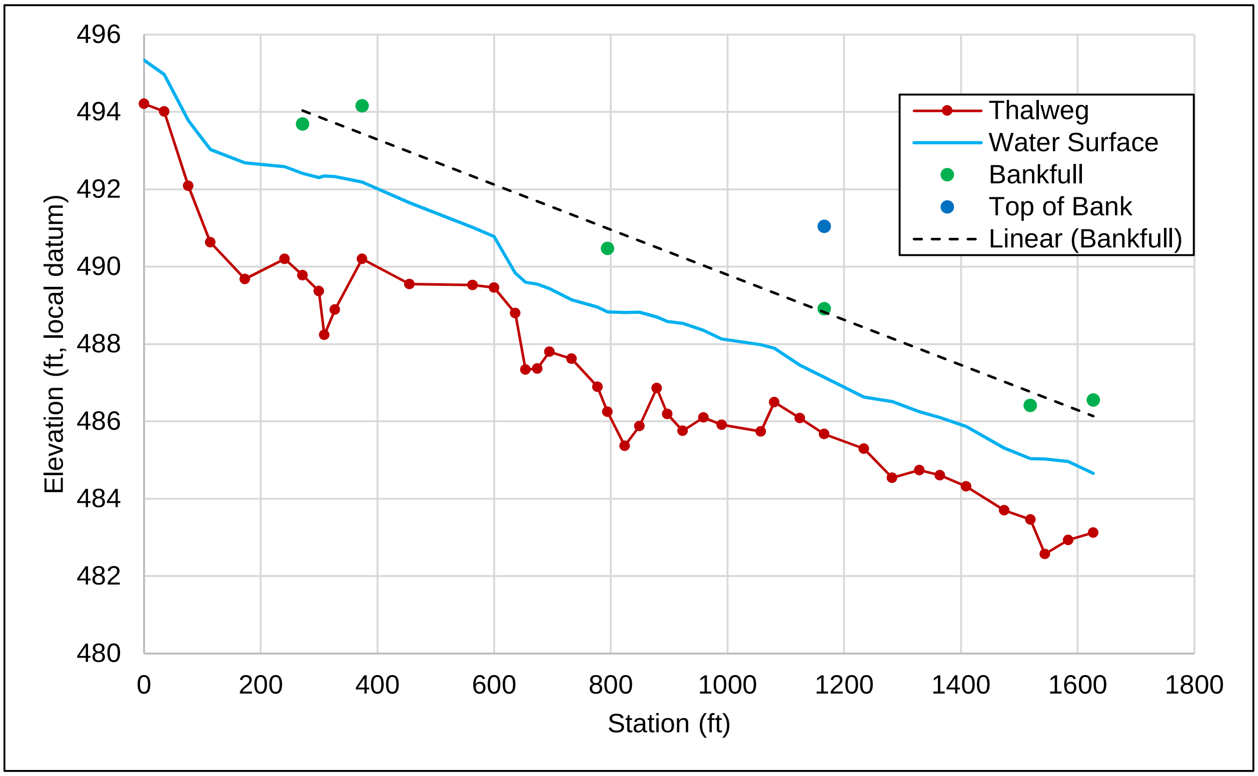

Figure 92. Longitudinal profile through the Colorado Gulch Reach.

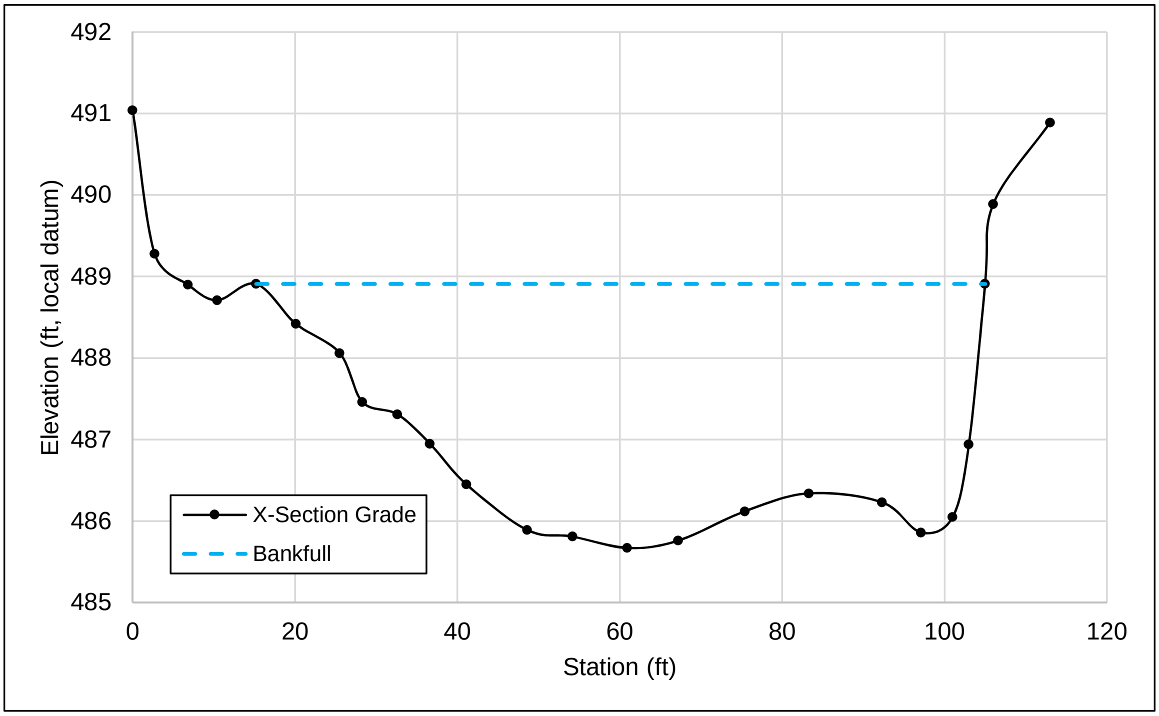

Figure 93. Typical riffle cross section of the main channel in the Colorado Gulch Reach.

The dimensionless bankfull shear stress in the Colorado Gulch Reach is 0.0171 and the dimensional shear stress is 0.762 lbs/ft^2. Bankfull hydraulic conditions result the mobilization of a 125 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is capable of transporting the largest particles in the available bedload, and is capable of mobilizing up to the D65 of the surface grains based upon material size class distribution (Figure 94). These analyses indicate that the reach is competent to transport the available bedload and that the existing surface grain size class distribution promotes vertical channel stability.

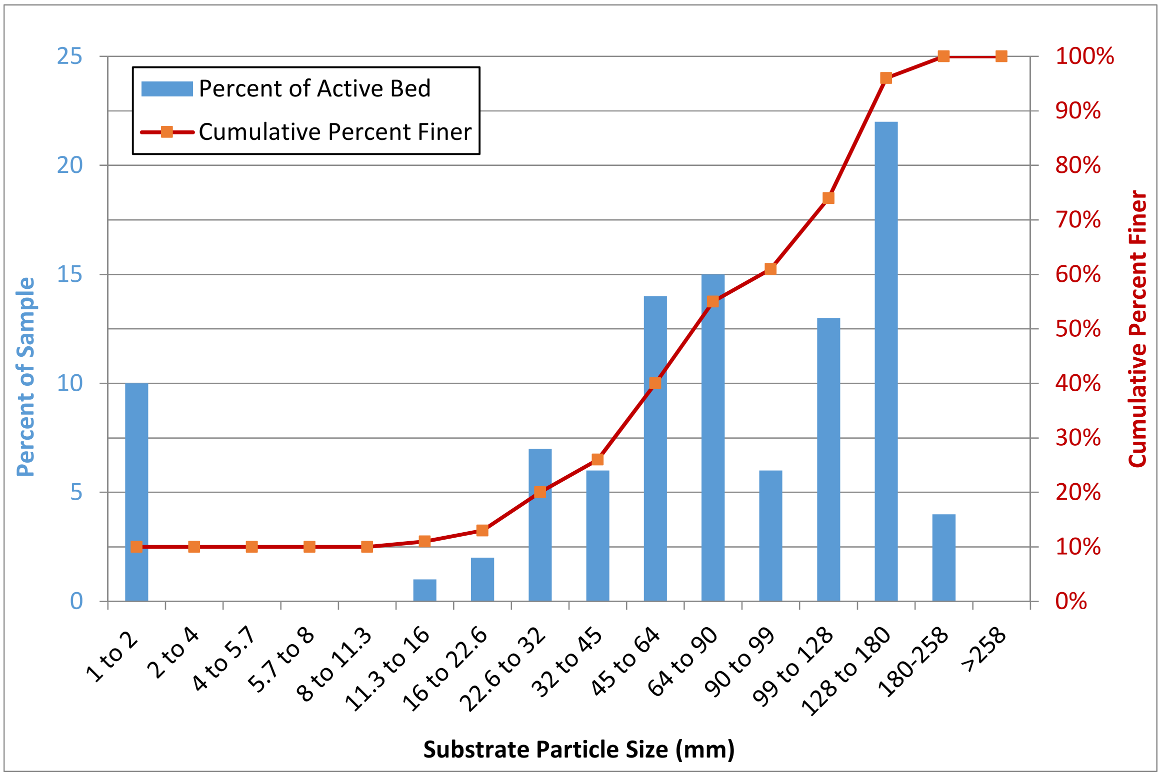

Figure 94. Surface particle size class distribution in the Colorado Gulch Reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at Colorado Gulch Reach is comprised of 1,109 tons/year of suspended sediment and 3,333 tons/year of bedload. Survey data from Colorado Gulch Reach indicate that the reach has capacity to transport 1,137 tons/year of suspended sediment and 2,548 tons/year of bedload. The reach therefore has sufficient capacity to transport the supplied suspended sediment (net capacity of 3%) and the reach has insufficient capacity to transport the supplied bedload (net capacity of -24%). These sediment transport conditions result in excess sediment deposition.

Stream stability analyses indicate that the reach has insufficient sediment transport capacity, is highly unstable laterally, has excess deposition, is slightly incised, has extensive channel enlargement potential, and is a very high supply of sediment. Stream stability findings are summarized in Table 24.

Table 24. Summary of stream channel stability indices of the Colorado Gulch Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Insufficient Capacity
Lateral Stability	Highly Unstable
Vertical Stability (Aggradation)	Excess Deposition
Vertical Stability (Degradation)	Slightly Incised
Channel Enlargement Potential	Extensive
Sediment Supply (Channel Source)	Very High

5.13 BROADFORD STREET BRIDGE REACH

The Broadford Street Bridge Reach is located on private lands in an alluvial valley with bounding features composed of alluvial deposits (attached Exhibit 96). The stream channel is slightly entrenched, has high width/depth ratio, and has moderate sinuosity. The reach has bankfull channel width of 113.2 ft, mean depth of 1.62 ft, width/depth ratio of 69.9, and bankfull discharge of 557.4 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is 1.1 ft/ft. The channel is classified as an F-type stream, although D-type stream conditions are evident within portions of the reach. Typical conditions are depicted in Figures 95, 96, 97, 98, and 99, and morphologic channel attributes are summarized in Table 25.

Figure 95. Photograph depicting transverse bar in the Broadford Street Bridge Reach.

Figure 96. Photograph of installed bank stabilization treatment in the Broadford Street Bridge Reach.

Figure 97. Photograph depicting typical high width/depth ratio, slight entrenchment, and eroding banks in the Broadford Street Bridge Reach.

Figure 98. Photograph depicting typical sedimentation (mid-channel bars) in the Broadford Street Bridge Reach.

Figure 99. Photograph depicting sedimentation in the Broadford Street Bridge Reach.

Table 25. Summary of morphologic channel conditions in the Broadford Reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	113.2
Mean Bankfull Depth (ft)	1.62
Maximum Bankfull Depth (ft)	2.93
Width/Depth Ratio (ft/ft)	69.9
Entrenchment Ratio (ft/ft)	1.1
Meander Width Ratio (ft/ft)	7.8
Bankfull Mean Velocity (ft/sec)	3
Bankfull Discharge (ft^3/sec)	557.4
Particle Size Index D_{50} (mm)	79
Sinuosity (ft/ft)	1.23
Annual Streambank Erosion Rate (tons/yr/ft)	0.252
Slope (ft/ft)	0.0055
Existing Stream Type	F3
Potential Stream Type	C3

The bank erosion rate at the Broadford Street Bridge Reach is 0.252 tons/year/foot, and the 1545-ft long surveyed stream segment contributes an estimated 389 tons of fine sediment to the watershed in an average year through bank erosion.

The Broadford Street Bridge Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 100) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 0.55%. High bank heights within the reach result in an F-stream type classification, although the presence of D-type stream conditions in portions of the reach indicates that the reach might be in transition. A typical riffle cross section depicting high width/depth ratio and entrenched channel conditions is presented in Figure 101.

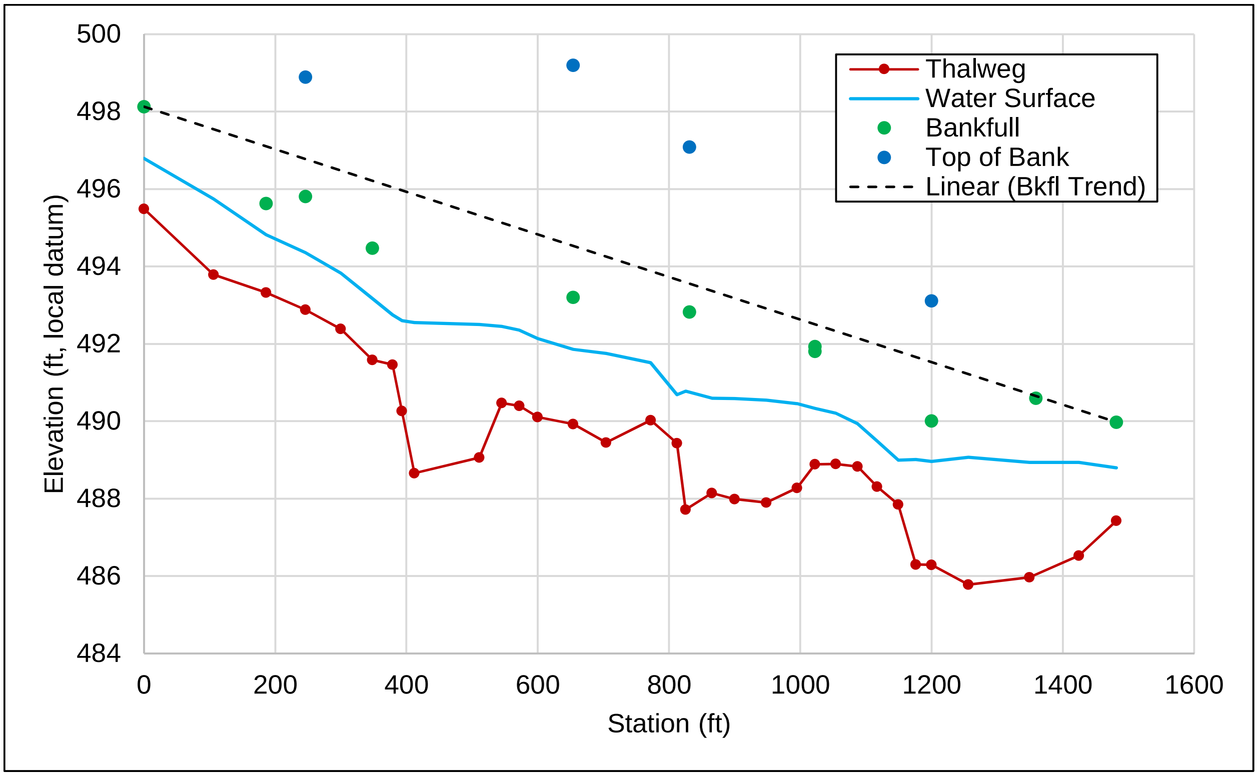

Figure 100. Longitudinal profile through Broadford Reach

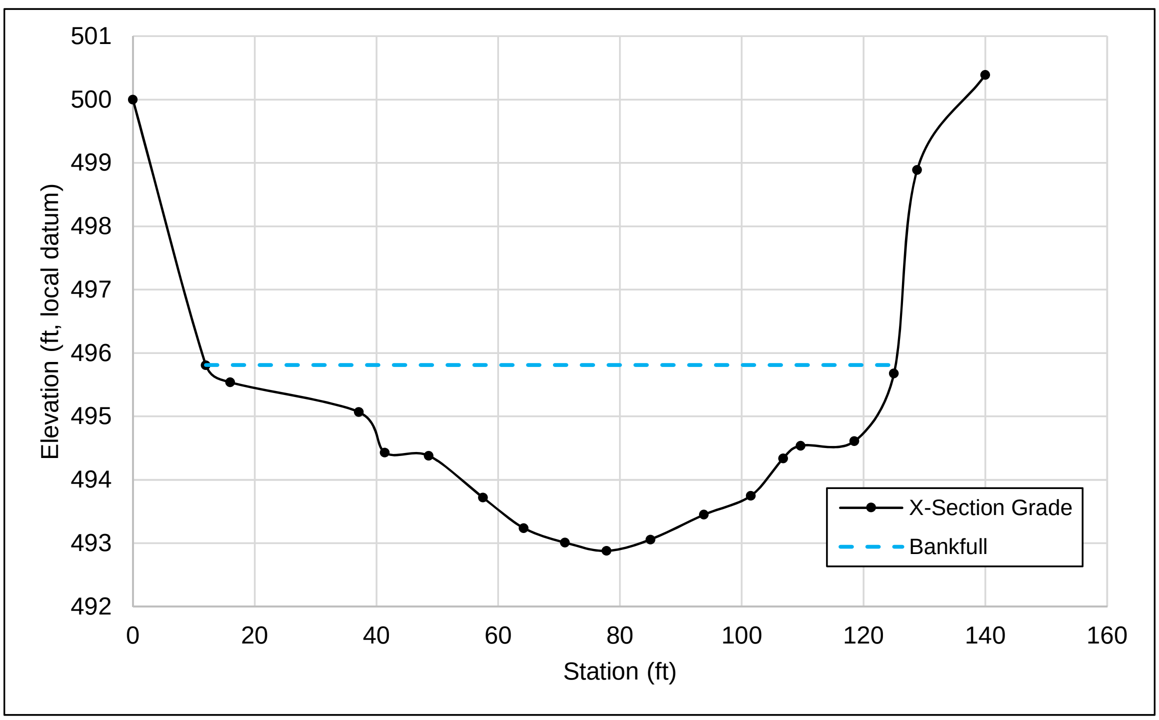

Figure 101. Typical riffle cross section of main channel in Broadford Reach.

The dimensionless bankfull shear stress in the Broadford Reach is 0.0174 and the dimensional shear stress is 0.556 lbs/ft^2. Bankfull hydraulic conditions result the mobilization of a 99 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is capable of transporting the largest particles in the available bedload, and is capable of mobilizing up to the D65 of the surface grains based upon material size class distribution (Figure 102). These analyses indicate that the reach is competent to transport the available bedload and that the existing surface grain size class distribution promotes vertical channel stability.

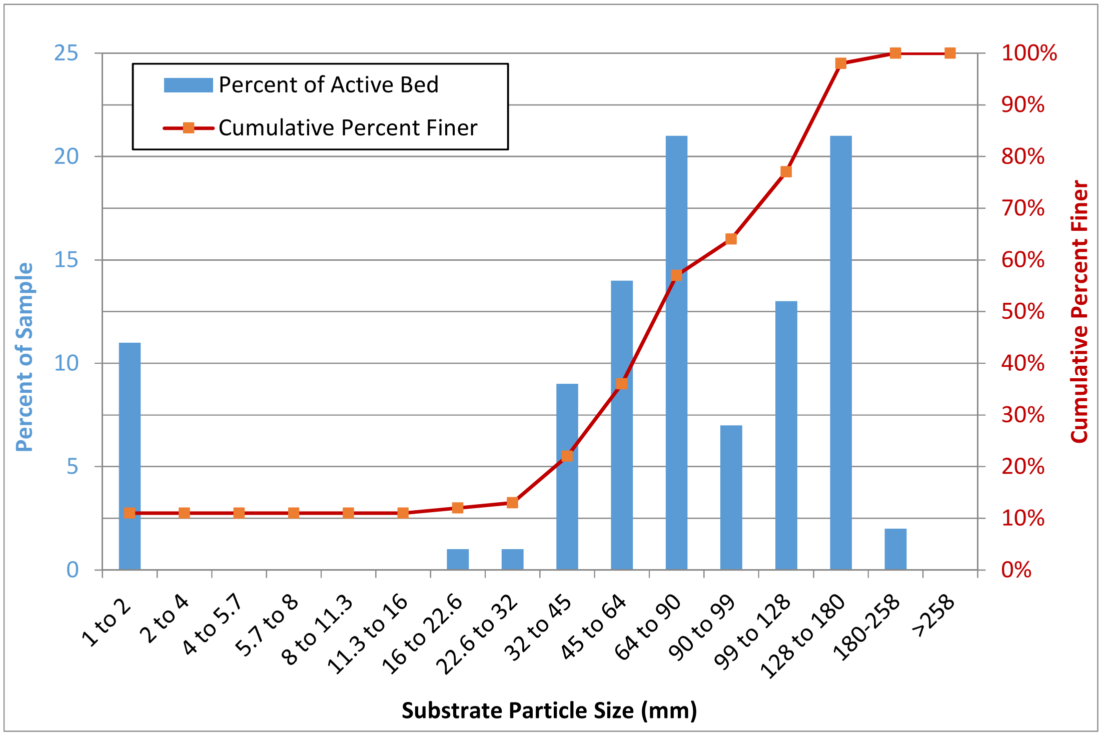

Figure 102. Surface particle size class distribution in the Broadford Reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at Broadford Reach is comprised of 705 tons/year of suspended sediment and 3,485 tons/year of bedload. Survey data from Broadford Reach indicate that the reach has capacity to transport 702 tons/year of suspended sediment and 2,551 tons/year of bedload. The reach therefore has sufficient capacity to transport the supplied suspended sediment (net capacity of approximately zero) and the reach has insufficient capacity to transport the supplied bedload (net capacity of -27%). These sediment transport conditions result in excess sediment deposition and channel aggradation.

Stream stability analyses indicate that the reach has insufficient sediment transport capacity, is highly unstable laterally, demonstrates aggradation, is slightly incised, has extensive channel enlargement potential, and is a very high supply of sediment. Stream stability findings are summarized in Table 26.

Table 26. Summary of stream channel stability indices of Broadford Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Insufficient Capacity
Lateral Stability	Highly Unstable
Vertical Stability (Aggradation)	Aggradation
Vertical Stability (Degradation)	Slightly Incised
Channel Enlargement Potential	Extensive
Sediment Supply (Channel Source)	Very High

5.14 GLENDALE REACH

The Glendale Reach is located on a combination of private and US Bureau of Land Management lands in an alluvial valley with bounding features composed of alluvial deposits (attached Exhibit 97). The stream channel is slightly entrenched, has high width/depth ratio, and has moderate sinuosity. The reach has bankfull channel width of 130.1 ft, mean depth of 1.34 ft, width/depth ratio of 97.1, and bankfull discharge of 517 cubic feet per second (cfs). The entrenchment ratio (the relation of the width at twice the riffle maximum depth [floodprone width] to that of the bankfull channel) is greater than 2.2 ft/ft, and the channel is classified as a D-type stream due to the dominant braided channel form. Large scale diversion of water for irrigation purposes upstream of this reach result in dewatering of the channel for a significant portion of the year. Typical conditions are depicted in Figures 103, 104, 105, and 106, and morphologic channel attributes are summarized in Table 27.

Figure 103. Photograph depicting typical high width/depth ratio channel and dewatered conditions in the Glendale Reach.

Figure 104. Photograph depicting typical denuded riparian vegetation in the Glendale reach.

Figure 105. Photograph depicting typical channel conditions in the Glendale Reach.

Figure 106. Photograph depicting mid-channel bars and dominant braided channel form in the Glendale Reach.

Table 27. Summary of morphologic channel conditions in the Glendale Reach.

Channel Parameter	Value
Bankfull Channel Width (ft)	130.1
Mean Bankfull Depth (ft)	1.34
Maximum Bankfull Depth (ft)	2.37
Width/Depth Ratio (ft/ft)	97.1
Entrenchment Ratio (ft/ft)	>2.2
Meander Width Ratio (ft/ft)	5.3
Bankfull Mean Velocity (ft/sec)	2.9
Bankfull Discharge (ft^3/sec)	517
Particle Size Index D_{50} (mm)	63
Sinuosity (ft/ft)	1.42
Annual Streambank Erosion Rate (tons/yr/ft)	0.2142
Slope (ft/ft)	0.0057
Existing Stream Type	D3
Potential Stream Type	C3

The bank erosion rate at the Glendale Reach is 0.2142 tons/year/foot, and the 2188-ft long surveyed stream segment contributes an estimated 468 tons of fine sediment to the watershed in an average year through bank erosion.

The Glendale Reach channel profile was analyzed through derivation of a longitudinal profile of the surveyed river reach (Figure 107) in which channel thalweg is depicted in red, water surface is depicted in blue, bankfull indicators are depicted in green, bankfull slope is depicted in dashed black line, and top of bank elevations are depicted in blue. The reach-wide bankfull channel slope is approximately 0.57%. The reach is characterized as a braided depositional area with minimal riparian vegetation and irregular bed feature sequences. A typical riffle cross section depicting high width/depth ratio braided channel conditions is presented in Figure 108.

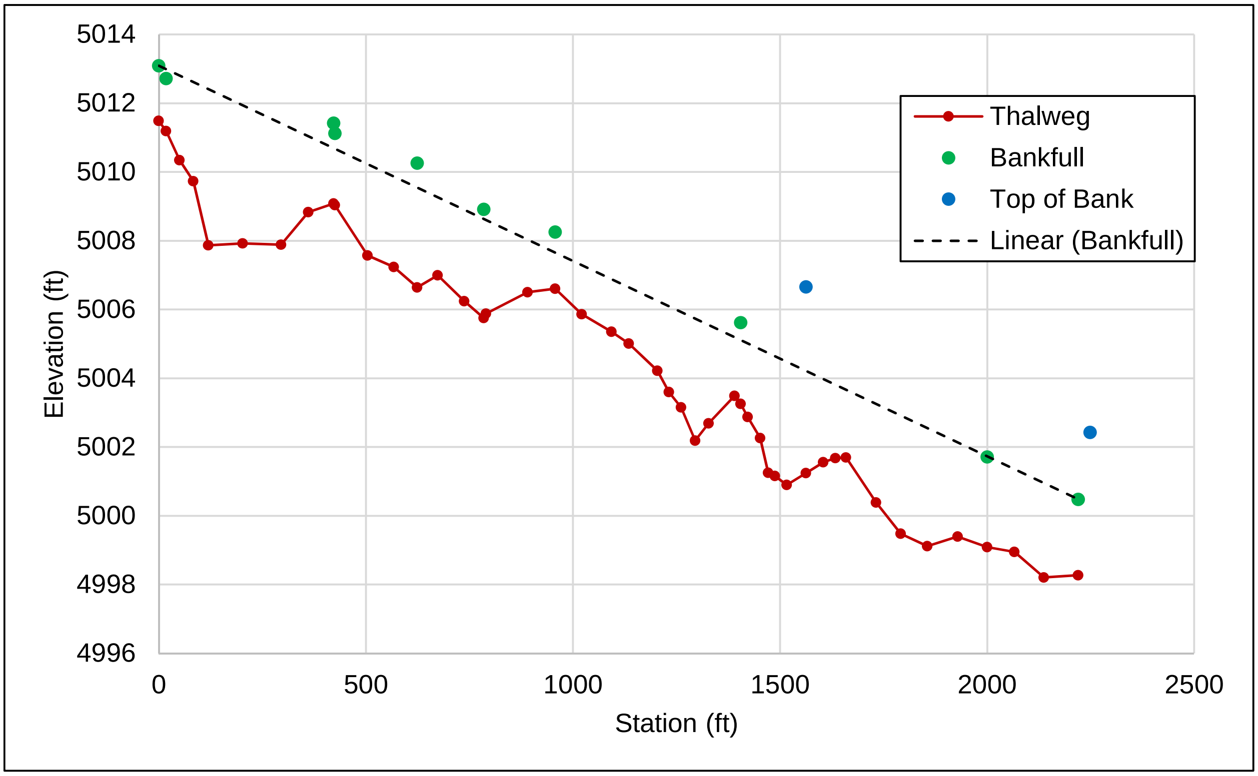

Figure 107. Longitudinal profile through the Glendale Reach.

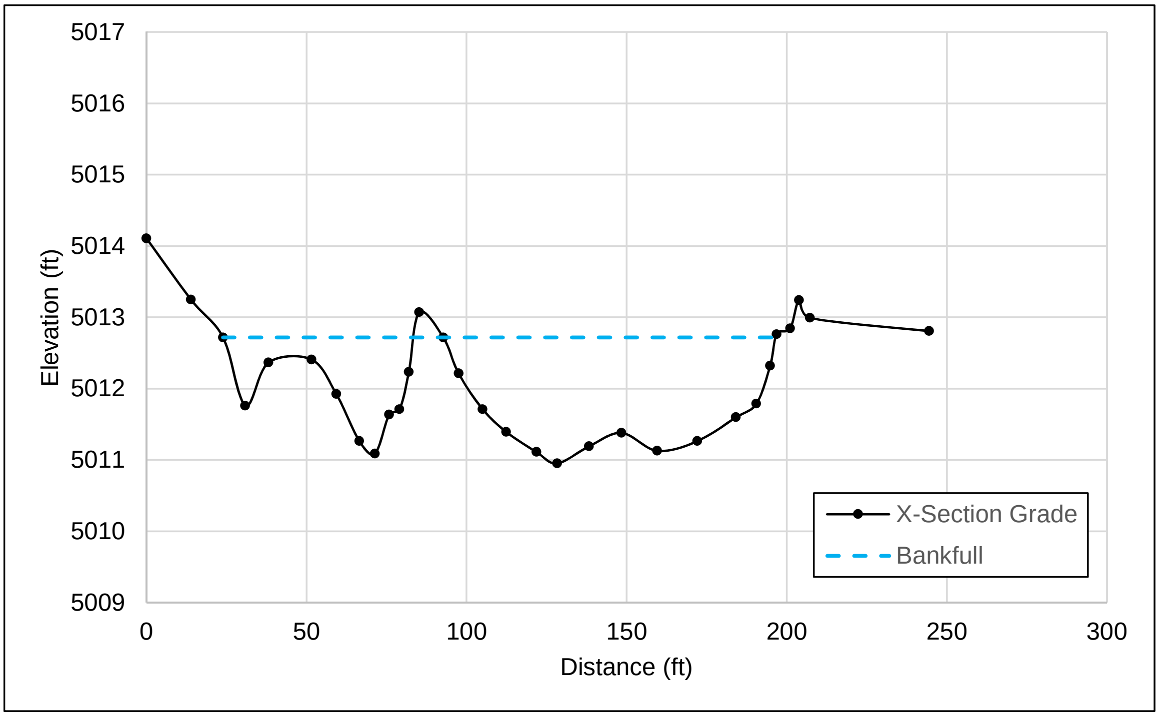

Figure 108. Typical riffle cross section in the Glendale Reach.

The dimensionless bankfull shear stress in the Glendale Reach is 0.0211 and the dimensional shear stress is 0.477 lbs/ft^2. Bankfull hydraulic conditions result the mobilization of an 88 mm particle according to a modified Shields curve depicting the incipient motion of sediment particles based on shear stress (Rosgen 2010). Survey data indicate that the reach is capable of transporting the largest particles in the available bedload, and is capable of mobilizing up to the D70 of the surface grains based upon material size class distribution (Figure 109). These analyses indicate that the reach is competent to transport the available bedload and that the existing surface grain size class distribution promotes vertical channel stability.

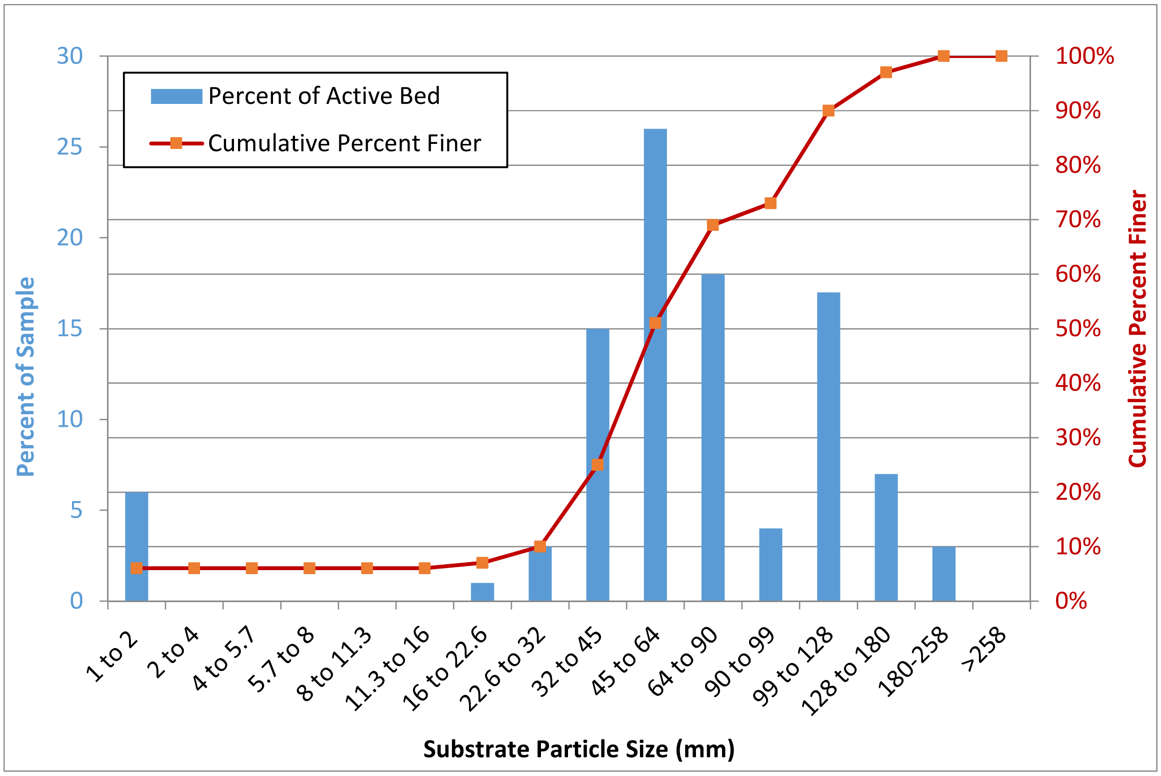

Figure 109. Surface particle size class distribution in the Glendale Reach.

Sediment transport analyses completed using the regional curve for bankfull sediment transport rates and the FLOWSED/POWERSED model indicate that the sediment supply at Glendale Reach is comprised of 663 tons/year of suspended sediment and 3,606 tons/year of bedload. Survey data from Glendale Reach indicate that the reach has capacity to transport 663 tons/year of suspended sediment and 2,265 tons/year of bedload. The reach therefore has sufficient capacity to transport the supplied suspended sediment (net capacity of approximately zero) and the reach has insufficient capacity to transport the supplied bedload (net capacity of -37%). These sediment transport conditions result in excess sediment deposition and channel aggradation.

Stream stability analyses indicate that the reach has insufficient sediment transport capacity, is highly unstable laterally, has deposition and evidence of aggradation, is not incised, has extensive channel enlargement potential, and is a very high supply of sediment. Stream stability findings are summarized in Table 28. The primary cause of impaired fluvial function in the Glendale Reach is seasonal de-watering resulting from the routing of irrigation supply water. Xeric conditions in the river channel result in the loss of riparian vegetation and the corresponding de-stabilization of river banks, increased channel width, decreased hydraulic radius, reduced sediment transport capacity, and channel aggradation. Opportunities to enhance fluvial conditions in the reach must initially address altered hydrologic regime (e.g. by modifying the irrigation water delivery system to reduce water requirements, or by reducing seepage loss in the river to enable downstream diversion of irrigation water).

Table 28. Summary of stream channel stability indices of Glendale Reach.

Channel Parameter	Rating
Sediment Transport Capacity	Insufficient Capacity
Lateral Stability	Highly Unstable
Vertical Stability (Aggradation)	Aggradation
Vertical Stability (Degradation)	Not Incised
Channel Enlargement Potential	Extensive
Sediment Supply (Channel Source)	Very High

5.15 ASSESSMENT SUMMARY

The dominant riverine setting in the Big Wood River project area is characterized as a terraced alluvial valley with well-developed floodplains (Rosgen valley type VIII). Valley widths vary from narrow (<4 bankfull channel widths, or valley type VIIIa) to wide (>10 bankfull channel widths, or valley type VIIIc). The stream types appropriate within these settings under equilibrium conditions include C-type and Bc-type channels, and C-type channel conditions are the dominant unaltered channel form in the Big Wood River study area. C-type channels have slight entrenchment (ratio >2.2 ft/ft), moderate to high width/depth ratio (>12), moderate to high sinuosity (>1.2), and gentle slope (<2%).

Bc-type channel conditions typically occur in narrow valleys bounded by steep side slopes. These conditions exist naturally in the Big Wood River basin at locations where colluvial features restrict valley width. These natural conditions are also mimicked in the Big Wood River basin by anthropogenic development associated with residential, public, and municipal infrastructure. Existing development encroaches on the width of riverine and riparian areas, but it is unreasonable to consider that existing infrastructure could be removed to restore more natural valley conditions. Therefore, the functional channel form appropriate within sub-reaches of the Big Wood River directly influenced by development is generally considered to be that of a more entrenched and confined channel, or a Bc-type channel with moderate entrenchment (ratio of 1.4-2.2 ft/ft), moderate width/depth ratio (>12 ft/ft), moderate sinuosity (>1.2), and gentle slope (<2 %).

Impaired fluvial conditions observed in the Big Wood River project area include channel degradation and incision, rapid lateral channel migration, and sedimentation. These altered channel processes are associated with impaired channel form that results in channel type classifications of F-type (severely entrenched) or D-type (braided) channels. A predominant cause of system impairment in the basin is the reduced floodplain conveyance of flood waters that has resulted from development encroachment. The confinement of flood waters has increased hydraulic forces and erosion (vertical and lateral) in the active channel. Historic treatments installed in the river channel include rock sills and bank armoring that have not promoted the natural evolution and recovery of the channel form. Morphologic attributes and channel types are presented in Table 29, in which reaches with the highest unit bank erosion rate (greater than 0.2 tons/yr/ft) are highlighted with bold text.

Table 29. Summary of geomorphic conditions in the Big Wood River basin.

Study Site	Cross Section Area (sq ft)	Bankfull Flow (cfs)	Bankfull Slope (ft/ft)	Drainage Area (sq mi)	Bankfull Bedload Transport Rate (lbs/s)	Bankfull Suspended Sediment Transport Rate (mg/L)	Bank Erosion Rate (tons/yr /ft)	Sediment Contribution from Bank Erosion (tons/yr)	Stream Type
Upstream Reference Reach	68	244	0.0106	63	0.176	35.3	0.070	42	C
Wood River Campground	136	646	0.0087	135	0.37	43.3	0.124	103	F
Fox Creek Reference	186	758	0.0058	198	0.54	47.9	0.035	99	Bc
Training Channel	145	736	0.0035	212	0.58	48.8	0.168	351	Bc
Hulen Meadows	213	925	0.0101	226	0.62	49.6	0.145	502	D
Ski Hill	253	1370	0.0061	338	0.92	55.2	0.185	420	Bc
Hwy 75 Reach	**213**	**896**	**0.0082**	**406**	**1.1**	**58**	**0.325**	**794**	**D**
East Fork Downstream	232	850	0.0041	517	1.39	61.8	0.054	71	F
Deer Creek Downstream	**374**	**1122**	**0.0059**	**605**	**1.62**	**64.5**	**0.274**	**542**	**D**
Bullion Bridge	**252**	**1175**	**0.0041**	**615**	**1.64**	**64.8**	**0.369**	**588**	**F**
Colorado Gulch	**213**	**878**	**0.0058**	**665**	**1.78**	**66.1**	**0.290**	**643**	**D**
Broadford Street Bridge	**183**	**557**	**0.0055**	**696**	**1.86**	**66.9**	**0.252**	**389**	**F**
Glendale	**175**	**517**	**0.0057**	**720**	**1.92**	**67.6**	**0.214**	**468**	**D**

The altered channel form in the Big Wood River study area disrupts sediment transport regime along the watercourse. Surveyed river reaches generally have sufficient capacity to transport the supplied suspended sediment load. The notable exceptions are the Training Channel and Hulen Meadows sites, which lack suspended sediment transport capacity by 9% and 46%, respectively. Nearly all impaired surveyed river reaches lack capacity to transport the bedload supply. The most severe discontinuity in bedload transport is observed in the Training Channel and Hulen Meadows reaches, which lack capacity to transport the bedload supply by 74% and 83%, respectively. Numerous sites lack bedload transport capacity by more than 30%, including the Ski Hill, East Fork Downstream, Deer Creek Downstream, and Glendale sites. Sediment transport regimes of surveyed river reaches are summarized in Table 30, in which sites with the greatest disequilibrium in bedload transport capacity (>70%) are highlighted in red and sites with the greatest disequilibrium in total sediment transport capacity (~30% or more) are highlighted in bold.

Table 30. Summary of sediment transport conditions in the Big Wood River basin.

Study Site	Suspended Sediment Annual Supply (tons/yr)	Suspended Sediment Capacity (tons/yr)	Net Suspended Sediment Transport (percent)	Bedload Annual Supply (tons/yr)	Bedload Capacity (tons/yr)	Net Bedload Transport (tons/yr)	Net Bedload Transport (percent)	Percent Deviation in Total Sediment Supply vs. Capacity
Upstream Reference Reach	221	221	0%	190	190	0%	0%	0%
Campground Sediment Study Site	719	818	14%	679	516	-163	-24%	-5%
Fox Creek Reference	1,157	1,319	14%	462	564	102	22%	16%
Training Channel	**1,150**	**1,050**	**-9%**	**493**	**126**	**-367**	**-74%**	**-28%**
Hulen Meadows	**1,468**	**790**	**-46%**	**527**	**90**	**-437**	**-83%**	**-56%**
Ski Hill	1,962	2,205	12%	1,672	1,158	-514	-31%	-7%
Hwy 75 Reach	1,344	1,537	14%	1,998	1,815	-183	-9%	0%
East Fork Downstream	**1,013**	**1,035**	**2%**	**1,228**	**594**	**-634**	**-52%**	**-27%**
Deer Creek Downstream	**1,355**	**1,339**	**-1%**	**3,033**	**1,766**	**-1267**	**-42%**	**-29%**
Bullion Bridge	1,436	1,505	5%	3,087	2,548	-539	-17%	-10%
Colorado Gulch	1,109	1,137	3%	3,333	2,548	-785	-24%	-17%
Broadford Street Bridge	705	702	0%	3,485	2,551	-934	-27%	-22%
Glendale	**663**	**663**	**0%**	**3,606**	**2,265**	**-1,341**	**-37%**	**-31%**

6.0 PHASE 4: INTERPRETATION AND RESTORATION GUIDELINES

Analysis indicates that sub-reaches of the Big Wood River project area display varying degrees of morphologic alteration that result in impaired fluvial processes associated with sediment movement, lateral channel stability, and aquatic ecosystem values. Fluvial enhancement guidelines have been generated to inform active and passive efforts to improve channel form and function.

6.1 GOALS AND OBJECTIVES

Fluvial system enhancement objectives were developed based upon analysis of channel stability, fluvial conditions, and hydrologic regime within the Big Wood River project area. Project objectives were used to inform the development of the following restoration guidelines:

1. Implement treatments that correct the unstable evolution from a slightly entrenched meandering river to a moderately or severely entrenched, high width/depth ratio, confined (or severely braided) channel form;
2. Restore sufficient capacity to river reaches that cannot transport the sediment load (change stability rating from ‘insufficient capacity’ to ‘sufficient capacity’);
3. Increase lateral channel stability (change lateral stability ratings from ‘highly unstable’ and ‘unstable’ to ‘moderately unstable’);
4. Increase vertical channel aggradation stability (change stability rating from ‘aggradation’ and ‘excess deposition’ to ‘moderate deposition’ or ‘no deposition’);
5. Reduce channel enlargement potential (change enlargement potential ratings from ‘extensive’ to ‘slight increase’);
6. Reduce the channel source sediment supply (change stability rating from ‘very high’ and ‘high’ to ‘moderate’);
7. Identify the stable functional channel form appropriate under the current (anthropogenically altered) hydrologic regime;
8. Ensure sediment transport continuity and balanced streambed erosion and deposition;
9. Reduce sediment input to the watershed through stabilization of severely eroding river banks;
10. Restore channel morphology where dysfunctional instream rock structures impair fluvial function;
11. Enhance spawning, rearing, holding, and winter habitat for all age classes of target species including rainbow trout, cutthroat trout, and brown trout;
12. Implement fluvial enhancement treatments that reduce, or leave unaltered, the flood hazard proximate to development;
13. Implement self-maintaining treatments that maximize the ecological and recreational values of the Big Wood River.

6.2 MORPHOLOGIC RESTORATION AND ENHANCEMENT

Efforts to restore fluvial function in the Big Wood River should address the channel instabilities, severe bank erosion rates, and discontinuity in sediment transport regime quantified during the geomorphic assessment. Individual and large-scale efforts to enhance fluvial conditions and aquatic habitat in the Big Wood River should adhere to holistic management guidelines, founded upon a common core of objectives.

The following pages present guidelines than can be applied across the basin during development and implementation of improvements in the main stem Big Wood River.

A morphologically stable channel form was identified based upon existing hydrologic regime, sediment inputs, and valley conditions using analogy, empirical, and analytical design techniques. Analogy techniques include replicating examples of existing stable channel morphology (reference reach data). Empirical techniques include replication of hydraulic geometry and morphologic parameters typical of regional stable watercourses. Analytical techniques include verification that the morphologic design achieves desired bankfull and peak flow hydraulic conditions, sediment transport competence, sediment transport capacity, and suitable bank stability.

Restoration treatments and guidelines presented below were designed to be implemented in concert. For example, bank stabilization should not involve hardening of an existing bank alignment without consideration of resultant channel width, floodplain extent, and meander pattern. Instead, bank stabilization should be constructed in a configuration that achieves functional channel geometry (width and depth) and alignment (meander pattern). The following sub-sections present sequential guidelines to inform the enhancement of channel form and function within sub-reaches of the Big Wood River.

6.3 DESIGN PROCESS

Enhancement efforts within the Big Wood River should establish a self-maintaining channel form that conveys peak flows and the supplied sediment load. Dimensionless ratios obtained from reference conditions relate channel morphology to bankfull channel width, and can be used to determine channel pattern (alignment), profile, and suitable bed feature layout. An iterative design process (depicted graphically in Figure 110) should generally begin with the identification of design channel slope. The process should then involve specification of the design channel cross section from hydraulically scaled reference condition channel geometry. Dimensionless ratios should then be applied to determine channel pattern and profile. Analytical techniques should then be used to determine the vertical and lateral stability of design conditions, and suitable channel stabilization treatments can be incorporated as warranted.

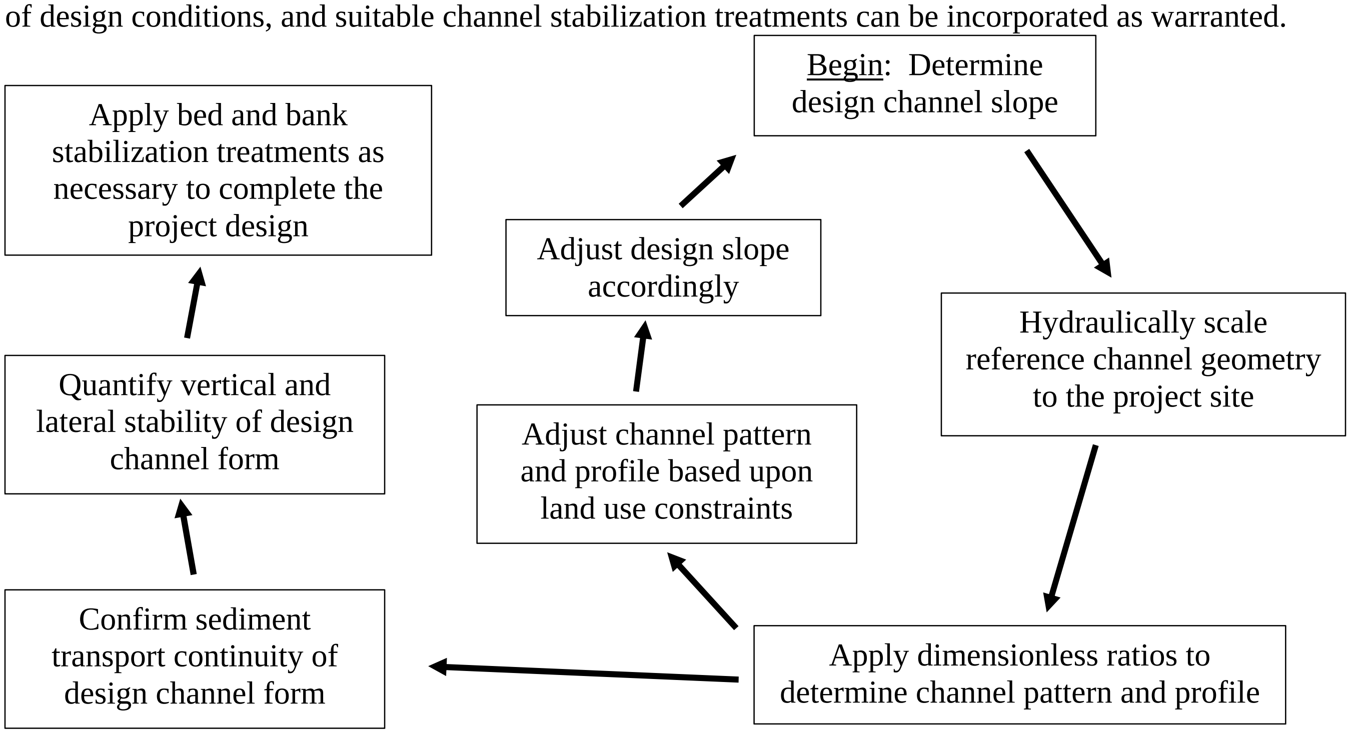

Figure 110. Generalized design process diagram.

6.4 DESIGN CHANNEL GEOMETRY

Enhancement efforts within sub-reaches of the Big Wood River should include specification of the desired functional channel geometry. The functional channel geometry, or cross section, can be used to determine other attributes of the functional channel form, including channel pattern, profile, and stability. The design channel type (e.g. C-type or Bc-type) can be preliminarily identified based upon geomorphic assessment results (attached Exhibits 26-83), and should then be confirmed through field assessment of local site conditions and land use constraints. Design geometries, or cross sections, for C-type and Bc-type channel forms were derived based upon reference reach conditions, and were made dimensionless by dividing measured values by existing bankfull channel maximum depth and width (Figures 111 and 112, respectively). The design channel cross sections can be scaled based upon hydraulic geometry to achieve the bankfull cross sectional area necessary to convey the bankfull discharge of any sub-reach of the Big Wood River main stem. Development of design cross sections from hydraulically scaled reference reach conditions preserves critical attributes of channel geometry including an inset channel to consolidate low flows; achievement of the proper ratio of maximum depth to mean depth (1.6 in the C-type channel and 1.3 in the Bc-type channel); and establishment of proper relationship between local stage, stream power, and sediment transport.

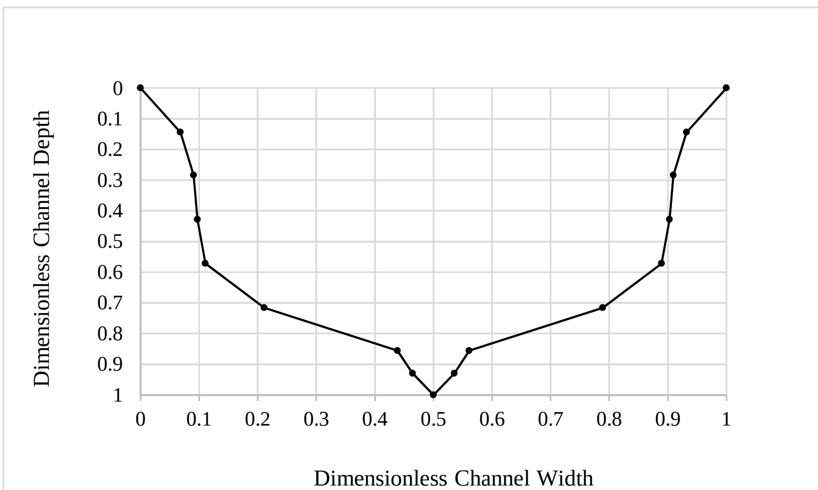

Figure 111. Dimensionless design C-type channel geometry, Big Wood River project area.

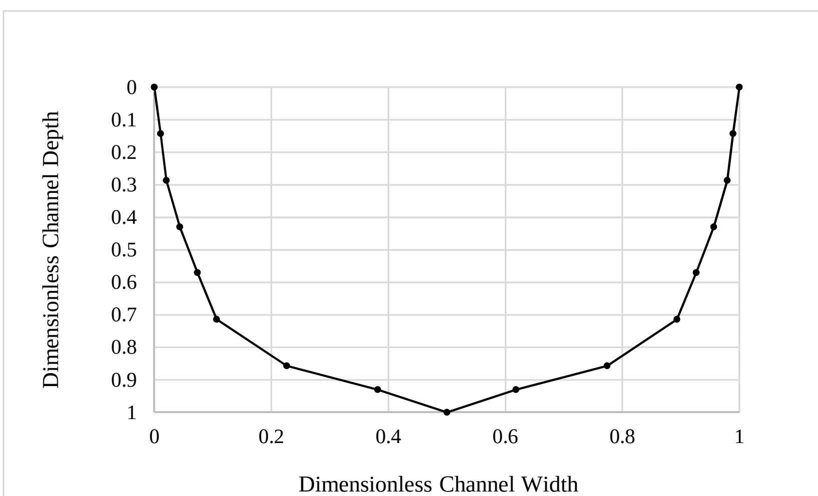

Figure 112. Dimensionless design Bc-type channel geometry, Big Wood River project area.

The design channel geometry derived from hydraulically scaled reference conditions can be compared to existing conditions to identify appropriate system enhancement treatments. For example, Figure 113 presents the existing braided channel form in the Big Wood River downstream of Deer Creek (solid black line). The dashed blue line identifies local bankfull elevation. The dashed black line depicts design channel geometry hydraulically scaled from reference C-type channel conditions. Comparison of the existing and design channel geometries reveals areas where channel fill and cut should be completed to achieve the functional channel geometry.

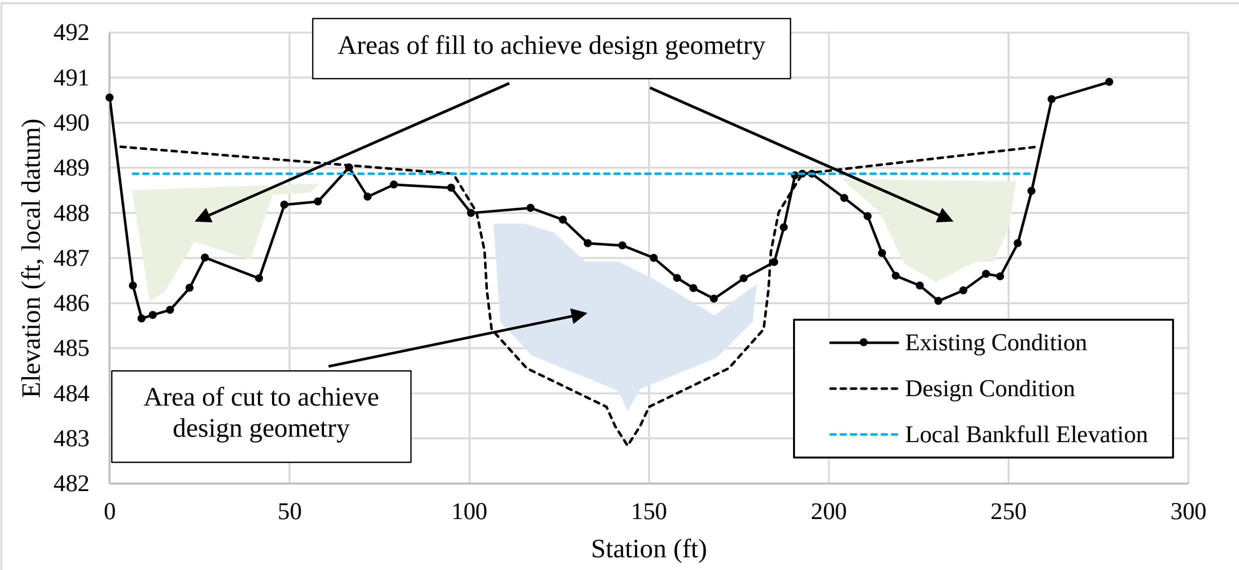

Figure 113. Example existing and design channel geometry from Big Wood River downstream of Deer Creek Site.

Hydraulic analyses (e.g. FLOWSED/POWERSED model) can be used to confirm that the design channel geometry achieves sediment transport capacity sufficient to transport the supplied load. The supplied sediment loads presented herein were calculated for typical functional conditions and do not account for augmented point source sediment contributions, such as the effects of fire in the basin. An independent ongoing investigation of tributary fluvial conditions will quantify sediment supply related to burn areas within tributary catchments. Preliminary findings of that effort indicate that the effects of tributary fires on downstream main stem reaches are primarily associated with fine (suspended) sediment; tributary streams appear to store excess bedload within sub-basins during the natural recovery process, which reduces adverse downstream impacts associated with increased coarse bedload supply. Appropriate measures to address increased suspended sediment supply in the main stem Big Wood River include incorporation of fine sediment depositional areas within the design channel geometry. Appropriate fine sediment storage opportunities in the main stem Big Wood River include micro-topographic features on the floodplain, under-sized constructed point bars, and back bays located on the inside bank downstream of meanders because these features can be implemented simultaneous to establishment of the functional channel geometry.

The sediment transport competence of design morphologic conditions can be calculated individually for sub-reach treatment areas based upon site specific design channel slope and hydraulic radius. Results can be interpreted in the context of existing river bed surface grain particle size class distribution to ensure the design promotes vertical channel stability. If surface grains are not of sufficient size to achieve vertical channel stability, installation of grade control measures may be necessary (as discussed below).

6.5 REFERENCE DATA DIMENSIONLESS RATIOS

The design channel (riffle) geometry can be used to specify morphologic attributes of channel pattern and profile based upon dimensionless ratios obtained from reference reach conditions, regional empirical data, and professional experience. The dimensionless ratios derived for the Big Wood River project area (Table 31) reflect empirical data collected in the Big Wood River basin and proximate watersheds. Dimensionless ratios are stratified by stream type to provide a set of restoration guidelines for both C-type and Bc-type channel forms.

Channel dimension, pattern, and profile are designed using dimensionless ratios (below), which describe functional channel form based upon bankfull channel width and depth. For example, multiplication of the dimensionless ratio of riffle length to riffle width by the design bankfull channel width yields a value for suitable design riffle length. The dimensionless ratios presented below include the average value, and the range of observed values, for several important morphologic parameters. Inclusion of a range of values (and not just the average condition) within a restoration design prevents the pursuit of a homogeneous channel, and ensures that the restored riverine system demonstrates a range of hydraulic and fluvial conditions reflective of natural functional systems.

Table 31. Summary of dimensionless variables in C-type and Bc-type reference conditions, Big Wood River basin.

Parameter	C-type Channel Reference Dimensionless Ratios		Bc-type Channel Reference Dimensionless Ratios	
	Mean Value	Range of Values	Mean Value	Range of Values
Entrenchment Ratio	3.9	--	1.9	--
Width/Depth Ratio	32	--	20	--
Meander Width Ratio	4.8	2.8-10	2.7	2.1-4.0
Riffle Length/Riffle Width	3.2	2.5-4.9	2.6	1.9-3.4
Riffle Dmax/Dmean	1.6	1.4-1.7	1.3	1.2-1.5
Inner Berm Width/Riffle Width	0.46	0.39-0.53	0.5	0.4-0.55
Riffle Slope/Reach Slope	2.2	1.5-3.2	1.72	1.6-2.1
Pool Length/Riffle Width	2.5	2.0-3.2	1.5	1-1.8
Pool Width/Riffle Width	0.78	0.7-1.1	1.1	0.9-1.2
Pool Dmax/Riffle Dmean	2.4	1.9-3.5	1.5	1.4-1.8
Pool Slope/Reach Slope	0.03	0.02-0.05	0.51	0.1-0.6
Pool-Pool Spacing/Riffle Width	8.2	5.3-14.5	4.3	4.0-5.0
Linear Wavelength/Riffle Width	14.2	10-18	21.2	11.2-33.3
Stream Meander Length Ratio	19.1	15.8-29	25.6	11.1-40.0
Radius of Curvature/Riffle Width	4.2	3.1-6.2	5.5	4.2-7.0

Dimensionless ratios can be used to inform both local and large-scale restoration efforts in the main stem Big Wood River. For example, bank stabilization implemented in the Big Wood River downstream of Deer Creek (as in Figure 112) should be implemented to achieve a design bankfull channel width of 90 feet. Correspondingly, bank stabilization implemented in the reach should not constrict the meander width ratio to less than 2.8 (or a dimensional value of 252 ft, based upon the design bankfull channel width of 90 ft). Bank stabilization in the reach should generally strive to enable a meander width ratio of 4.8 (the mean dimensional ratio for that parameter, which coincides with a value of 432 ft, based upon the design bankfull channel width of 90 ft). Similarly, bank stabilization implemented on meander bends in the reach should achieve a radius of curvature of 279 to 837 ft with an average of about 378 ft (which coincides with the dimensionless ratio range of 3.1 to 6.2 and average of 4.2).

The application of these tools can similarly provide utility during the assessment of large-scale projects that incorporate changes in channel pattern or profile. For example, assessment of the Training Channel Site reveals that previously installed rock sill structures maintain riffle facet slopes of 0.1% to 0.03%. The reach-wide bankfull channel slope is 0.69%, and application of C-type dimensionless ratios indicates that riffle facet slopes should exceed the reach slope by about 2.2 times to achieve a value of 1.5%. The discrepancy between existing and suitable riffle facet slope is more than an order of magnitude and reveals a primary cause of the widespread sedimentation that inflicts the reach.

The identification of suitable design channel geometry and the subsequent application of dimensionless ratios enables identification of a functional channel form. Comparison of the functional channel form to existing channel conditions can be used to identify locations where channel shaping, excavation, discharge, and armoring are required.

The establishment of suitable channel width, depth, and profile is critical to the prevention of sedimentation, maintenance of channel stability, and maximization of fish habitat. This component of river restoration is depicted visually in Figure 114 from a recent project during which an over-widened, channelized, and degraded creek in eastern Idaho was re-constructed based upon design bankfull channel width and dimensionless ratios obtained from upstream functional conditions.

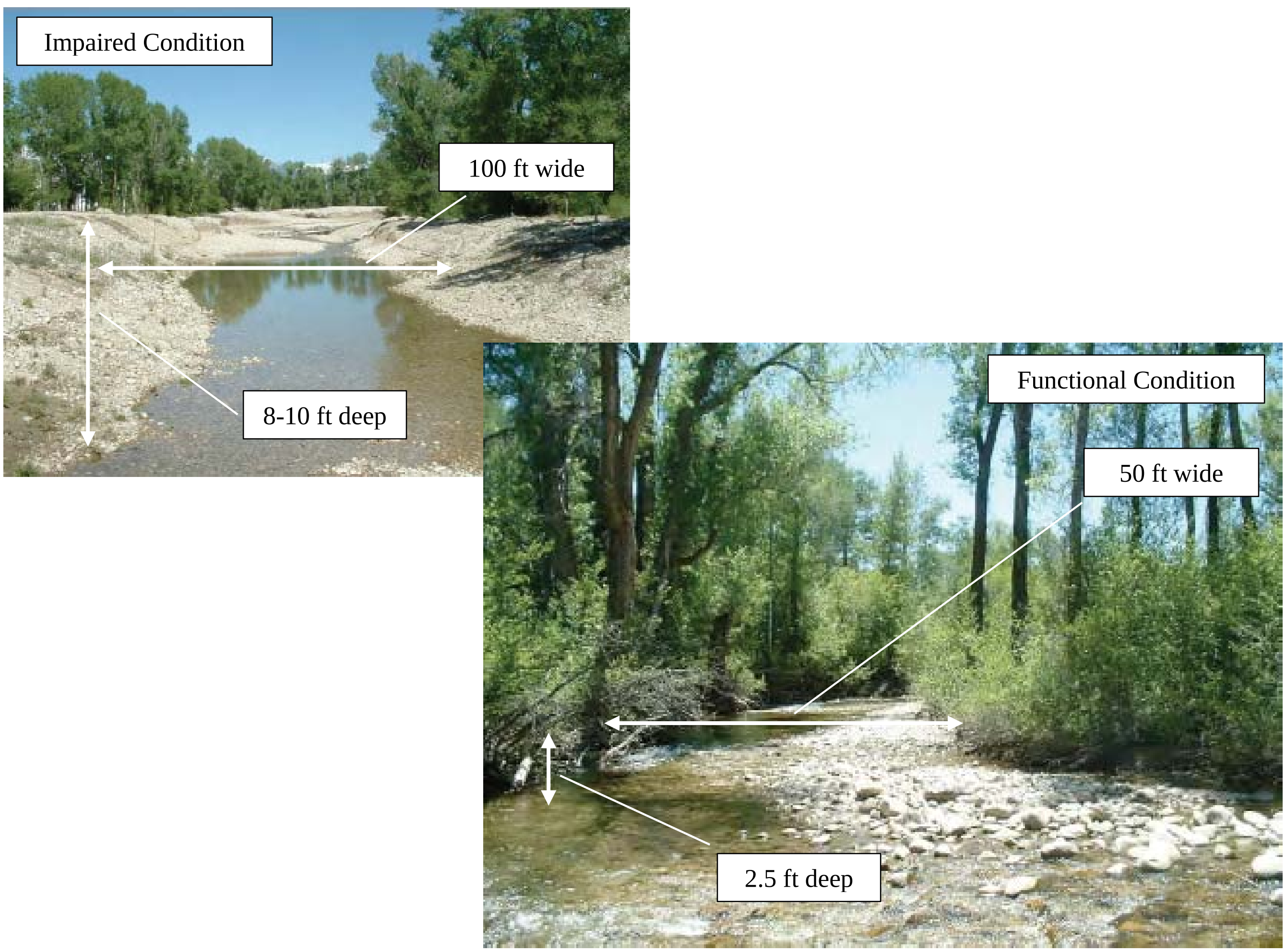

Figure 114. The over-widened and degraded river channel (top) was narrowed and shaped to mimic stable functional conditions (bottom). The functional channel with proper width, depth, profile, and alignment (bottom) provides river functions and fish habitat superior to those of the impaired channel condition (top).

Channel realignment is a restoration tool that can be applied to establish a functional channel pattern (alignment) as specified through application of dimensionless ratios. This component of river restoration is depicted visually in Figure 115 from a recent project that involved construction of a functional channel alignment where the existing channel meander pattern impaired sediment movement, compromised bank stability, and reduced fish habitat values.

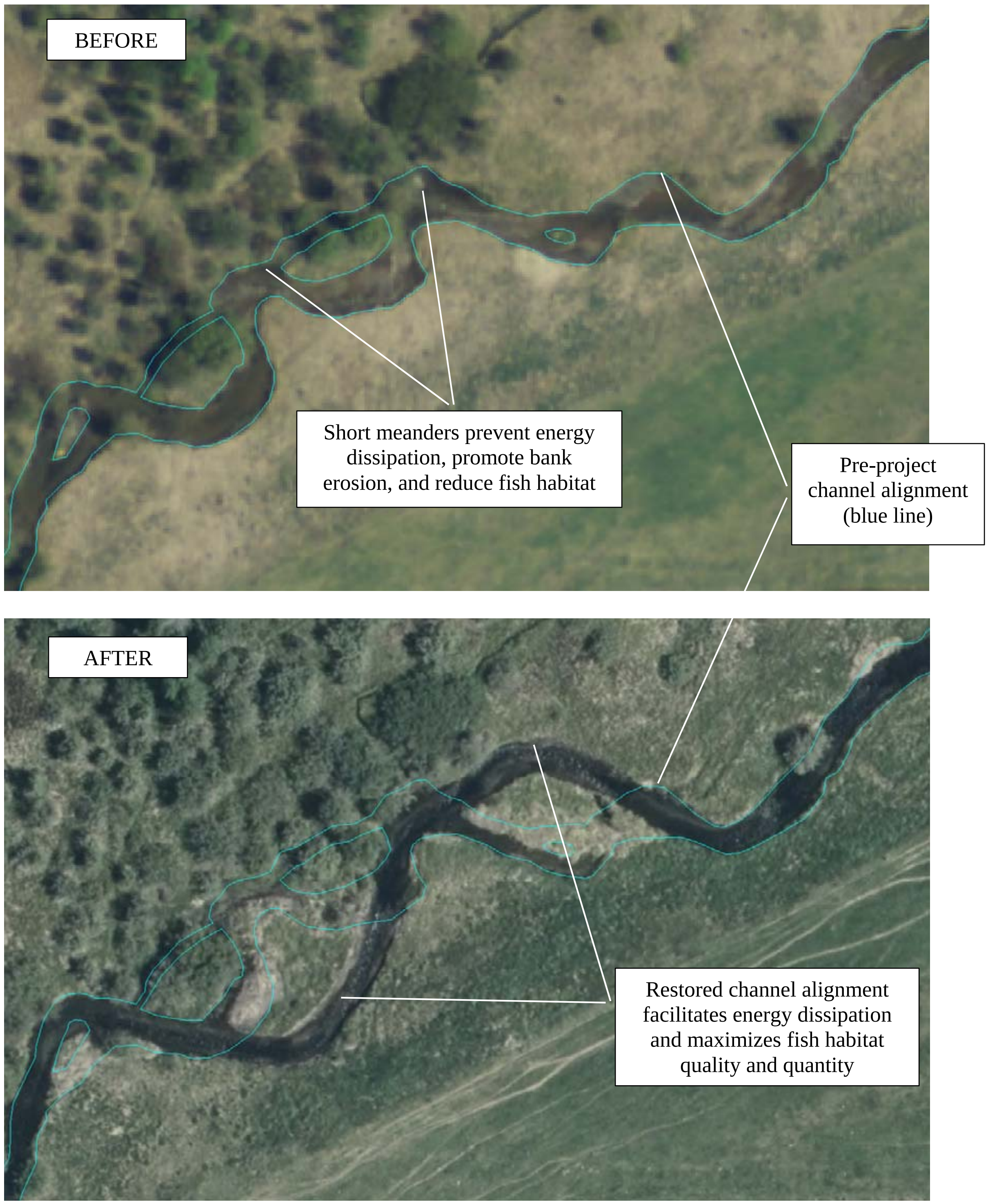

Figure 115. An unstable channel alignment (top) was corrected through construction of suitable meander pattern (bottom). The constructed meander pattern maintains aquatic habitat complexity associated with riffles and lateral scour pool bed features to maximize fish habitat.

6.6 WOOD REVETMENT BANK STABILIZATION

The wood revetment bank stabilization treatment utilizes large woody members (root wads, conifer or cottonwood logs, woody shrubs, broken-ended logs) to stabilize the bank toe, transplanted woody clump vegetation to increase near-bank hydraulic roughness, and transplanted sod mats (or similar herbaceous vegetative treatment) to achieve a vegetated bench at the local bankfull elevation. The incorporation of woody members to accomplish bank stabilization is preferable to a traditional rock riprap treatment because the protrusion of wood into the bankfull channel increases hydraulic roughness at the channel margin and reduces near-bank flow velocities and shear stress. These effects, in combination with hardening of the bank toe material, constitute a multi-faceted approach to bank stabilization that reduces near bank erosion potential while simultaneously increasing the erosion resistance of the bank.

The treatment design does not incorporate unnatural materials such as cable, rebar, or concrete. All live plant materials associated with the bank stabilization treatment are installed in precise configurations using techniques described in the *Streambank Soil Bioengineering Field Guide* (Hoag 2002). Figures 116 and 117 depict the bank stabilization treatment in profile and plan view.

The wood revetment bank stabilization treatment is implemented as follows:

1. A trench is excavated in the channel bed parallel to the bank at the desired treatment location.
2. Footer logs are placed in the trench below local scour depth, are oriented at about 15 degrees from parallel to the bank, are shingled in the downstream direction, and overlap each other by about 5-6 ft.
3. Transplanted woody vegetation clumps are placed in the trench on the bank side of the footer log location, are backfilled with native alluvium slurry, and are bucket compacted to ensure good soil-to-stem contact.
4. Perpendicular woody members are placed between transplanted clump vegetation such that pieces rest on the footer log(s), extend a minimum of 20 ft into the stream bank, are sloped down at about 10% into the stream bank, cross one another as possible to form a matrix of intertwined pieces, and protrude about 2 feet beyond the footer log into the active channel.
5. Native alluvium and rock ballast, as needed, are placed as backfill on the perpendicular woody members and are bucket compacted in lifts until an elevation of approximately 1 ft below bankfull is achieved. Simultaneously, the canopy of each transplanted woody vegetation clump is split such that half protrudes into the river channel and half protrudes vertically above the bankfull elevation on the floodplain.
6. Transplanted sod mats (or similar herbaceous vegetative treatments) are placed on the alluvium fill to form a bench at the bankfull elevation with continuous bank edge and evenly vegetated surface with intermittent protruding willow canopies.

Woody members utilized in the bank stabilization treatment are comprised of root wads, broken-ended (not sawed) logs, or hard woody shrubs/trees, depending upon material availability. However, woody material should under no circumstances protrude above the bankfull elevation, and bank stabilization materials should be placed to achieve the local design channel width.

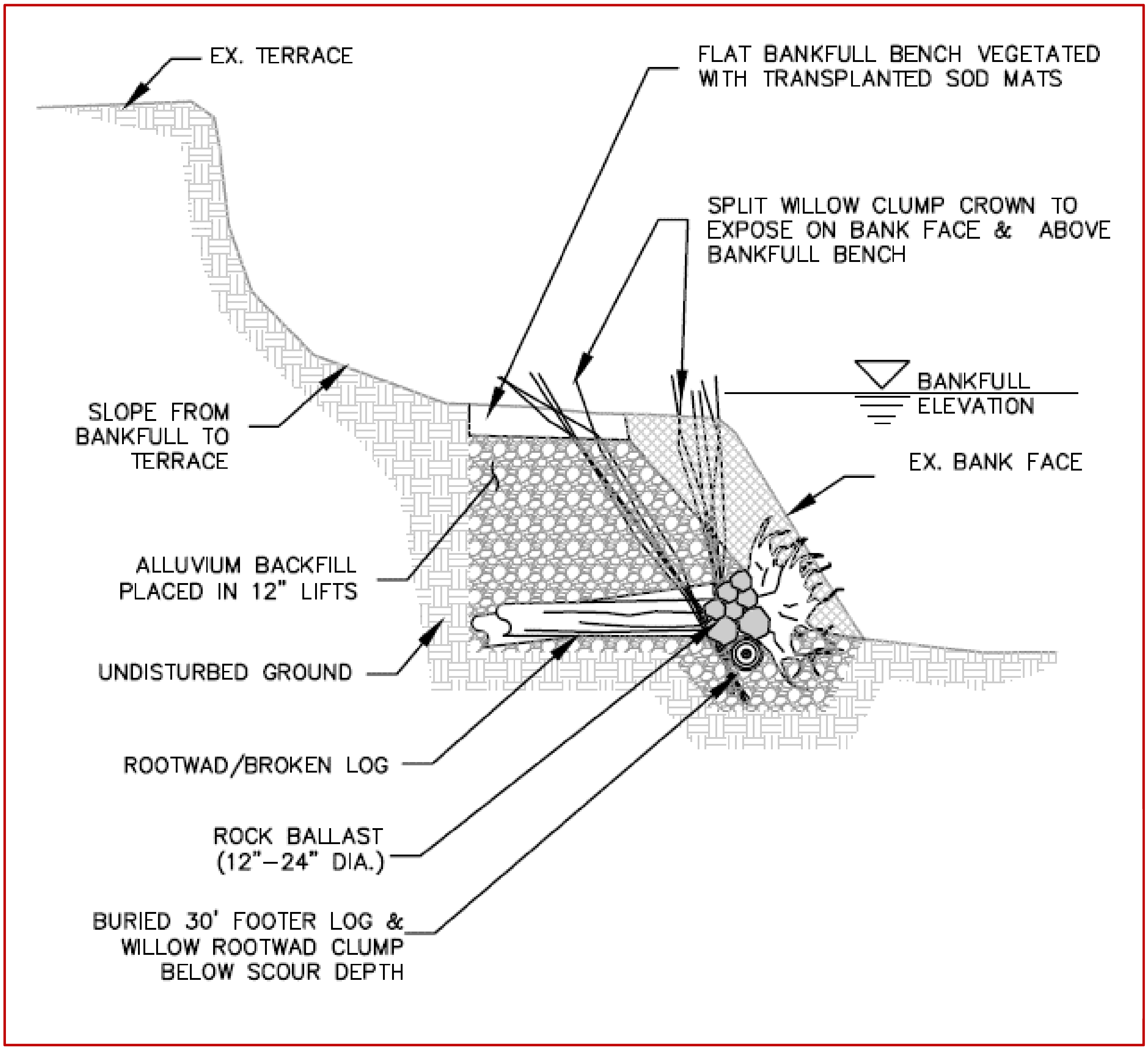

Figure 116. Profile view of typical wood revetment bank stabilization treatment.

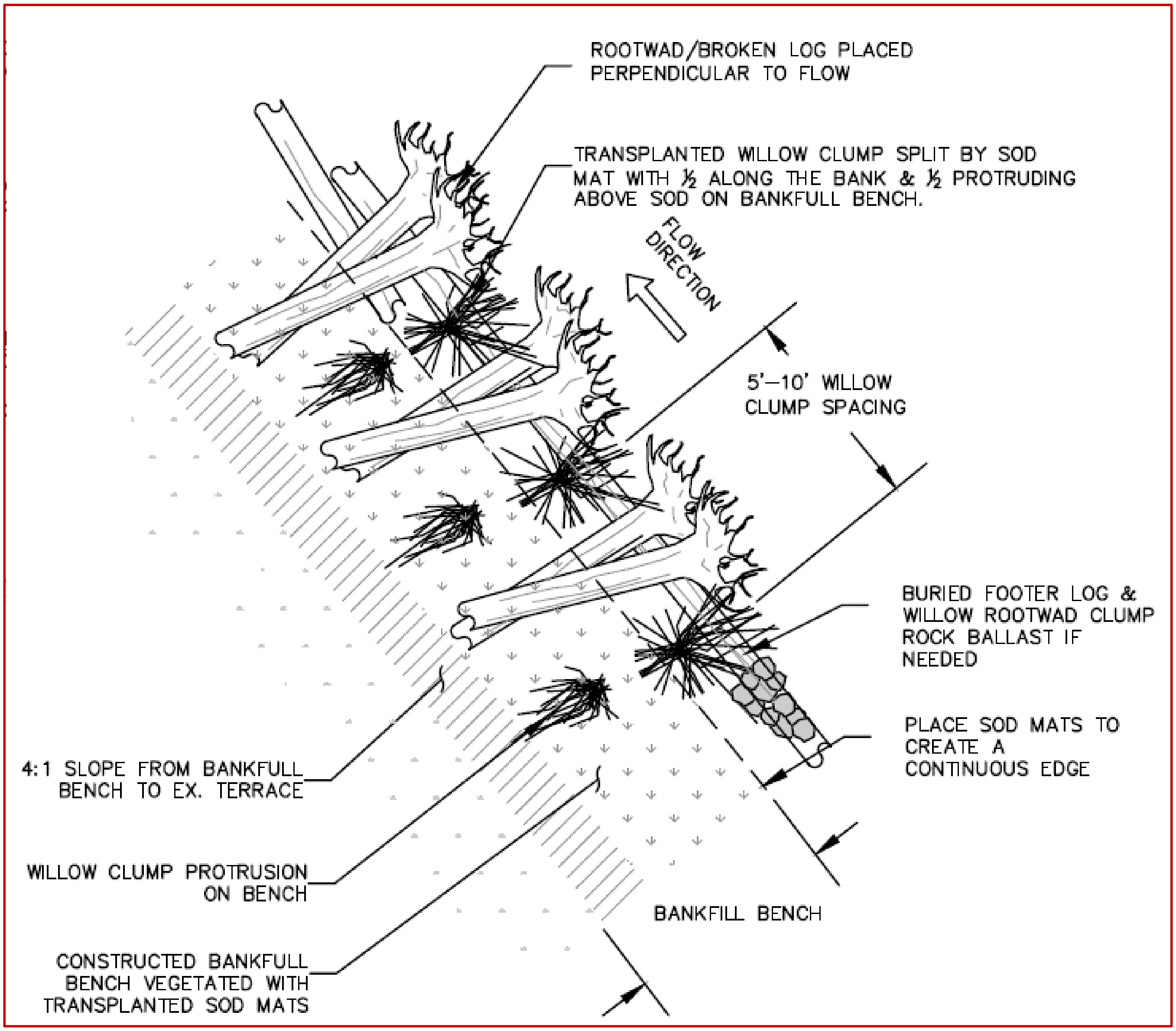

Figure 117. Plan view of typical wood revetment bank stabilization treatment.

The wood revetment bank treatment is depicted visually in Figures 118 and 119 from projects recently completed in the region. Installed large wood (root wads and logs) harden the lower half of the river bank. Ballast and herbaceous vegetation were installed to establish a floodplain bench at the bankfull elevation. The installed large wood protrudes into the channel several feet (below the water surface), which reduces flow velocities, increases bank stability, and provides complex cover for fisheries benefit.

Figure 118. Wood revetment installed along river bank to prevent bank erosion, establish suitable channel width, and improve fish habitat (cover and refuge).

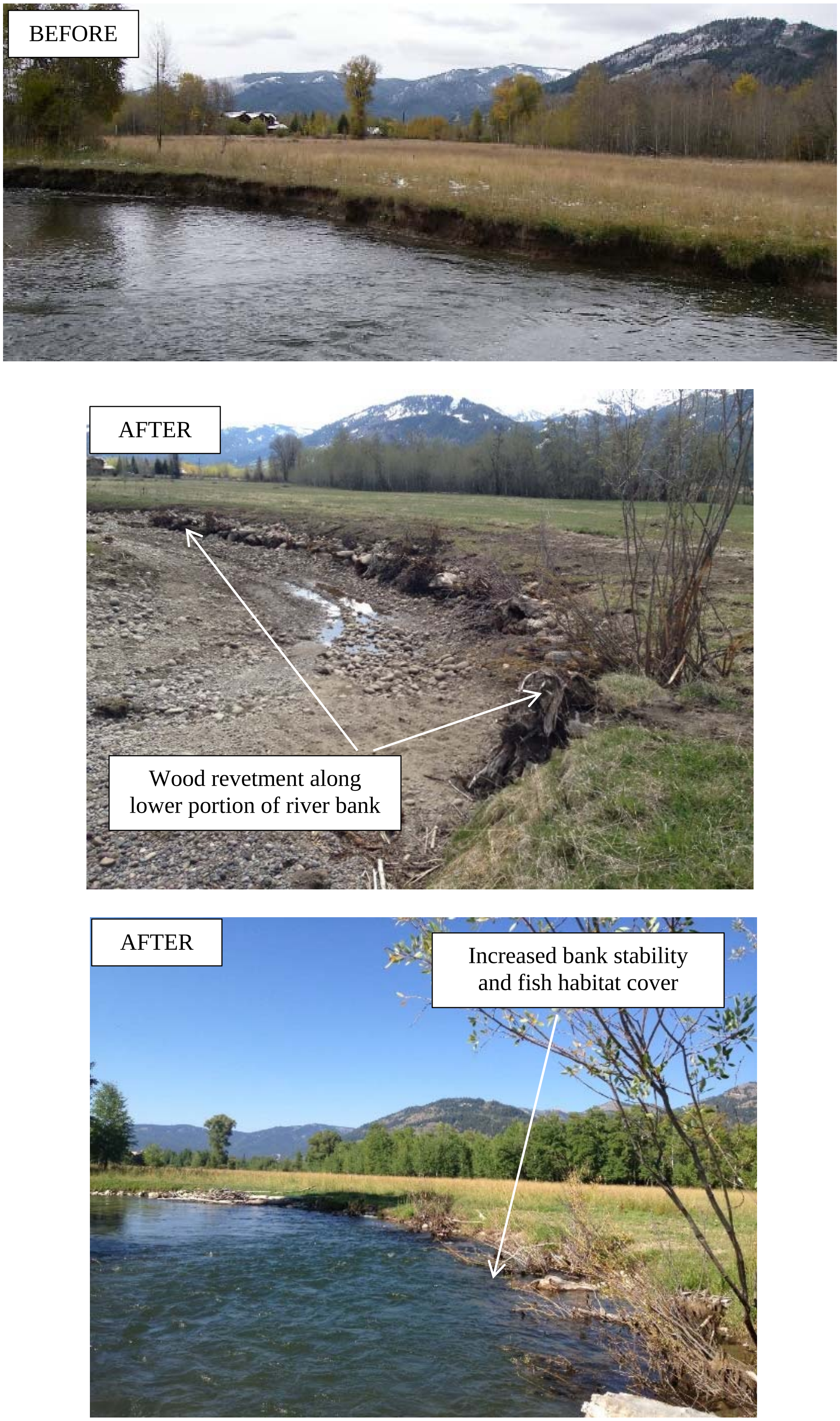

Figure 119. A severely eroding river bank (top) was stabilized with the wood revetment treatment (middle). The treatment effectively reduces potential for bank erosion, reduces near-bank flow velocities and erosive energy, and dramatically increases fish habitat through establishment of cover (structural, wood, and overhead).

6.7 ROCK REVETMENT BANK STABILIZATION WITH WILLOWS

Rock revetment bank stabilization is a less preferable treatment than the wood revetment treatment because the rock treatment typically does not incorporate features that increase hydraulic roughness or reduce flow velocities in the near bank zone. However, rock revetments can be better suited to bank stabilization at locations where existing infrastructure or landforms inhibit the installation of woody members that are sufficiently keyed into the bank.

The rock revetment treatment involves placement of rock from a key trench located adjacent to the bank toe up to the local bankfull elevation. Installed rock should not protrude above the local bankfull elevation and should not encumber flood water access to the floodplain; the dispersal of peak flows across the floodplain enables energy dissipation and helps prevent excessive shear stress (and related erosion) in the near bank zone. During installation of the rock revetment, bundles of dormant woody vegetation cuttings are installed in the river bank at sufficient depth to access the lowest seasonal groundwater elevation. Bundles are installed vertically and at 45 degree angles from horizontal. The rock revetment treatment is designed to accomplish bank stabilization with minimal excavation into the river bank itself. The incorporated vegetative bundles provide long-term benefit associated with increased deep root mass, increased near bank hydraulic roughness, canopy cover at the channel margins, and increased riparian vegetative complexity.

Fundamental to the rock revetment bank stabilization treatment (depicted in Figure 120) is the incorporation of live dormant woody vegetation in accordance with the following guidelines:

1. Both vertical and 45 degree angle bundles are installed within the rock revetment.
2. The bottom of installed bundles is 1 ft (or more) below the low water table elevation.
3. Installed bundles protrude 1-2 ft above the rock revetment.
4. Bundles have diameter of 3-6 inches, incorporate 3-8 cuttings, and are tied with twine every 2-3 ft.
5. Bundles are installed every 8-10 ft along the river bank.
6. Bundle installation occurs simultaneous to rock installation.
    a. Rock is placed in the key trench and up the bank until reaching the bundle installation location.
    b. The excavator bucket is placed above the rock and inserted into the river bank to reach the low water table elevation.
    c. The bucket is lifted up slightly (6 inches) and bundles are installed in the created space.
    d. The bucket is lowered and removed and the location is compacted with the bucket, after which rock installation is continued up the river bank.

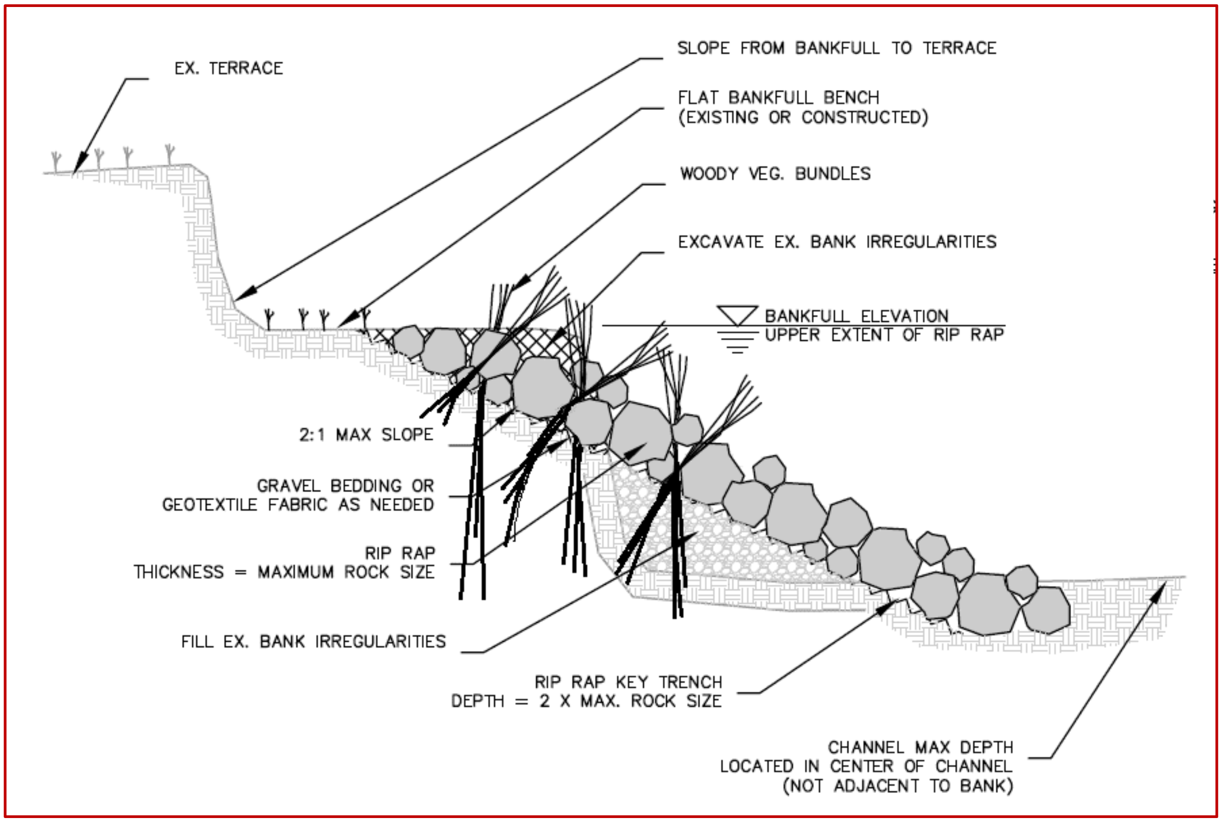

Figure 120. Profile view of typical bank rock protection treatment.

The incorporation of woody vegetation within the rock revetment increases the functional and ecological benefits of the treatment through improved riparian vigor and structure, increased channel shading (and cooling), and increased roughness and overhead cover for fish habitat. The rock revetment treatment is depicted visually in Figure 121 from a project recently completed in the region.

Figure 121. The rock revetment with bioengineering treatment incorporates vegetative material installed throughout the placed rock (top left). Installed vegetation establishes in the first year after construction (top right) and continues to expand in the second year after construction (bottom). The vegetation eventually establishes a complex root system to reinforce bank stability, and develops a robust canopy to provide over-head cover and fish habitat in addition to shade and riparian structure.

6.8 FLOODPLAIN CONSTRUCTION

Floodplain construction includes the placement of fill to create an inset floodplain in excessively wide channel conditions or the excavation of high terrace banks to create a floodplain bench at the local bankfull elevation. Establishment of a hydraulically connected floodplain with suitable width is paramount to the enhancement of the Big Wood River system. Floodplain width determines channel entrenchment ratio, which dictates channel form and processes associated with sediment transport, stable peak flow hydraulic conditions, and aquatic habitat. Reestablishment of suitable floodplain width also provides for seasonal inundation of riparian lands, which facilitates sediment deposition and recruitment of woody vegetation adjacent to the river channel.

Floodplain creation is designed to provide distinct bank zones (Figure 122) to establish suitable conditions for the recruitment and growth of specific riparian vegetation. The overbank zone is comprised of active floodplain located at the bankfull elevation. This zone is inundated by the approximate 1.5-year return interval flow. Micro-topographic variability in the overbank zone provides for frequent scouring, fine sediment deposition, and recruitment of robust willow and riparian shrub communities.

The transitional bank zone is located beyond the overbank zone and transitions between the bankfull and floodprone elevations. The transitional bank zone is inundated by large peak flow events and provides suitable conditions for the recruitment and establishment of overstory vegetation inclusive of robust cottonwood galleries. The overbank and transitional bank zones along the Big Wood River have been directly impacted by development encroachment and channel incision, and re-establishment of specific bank morphology will provide substantive benefit to in-stream and riparian conditions.

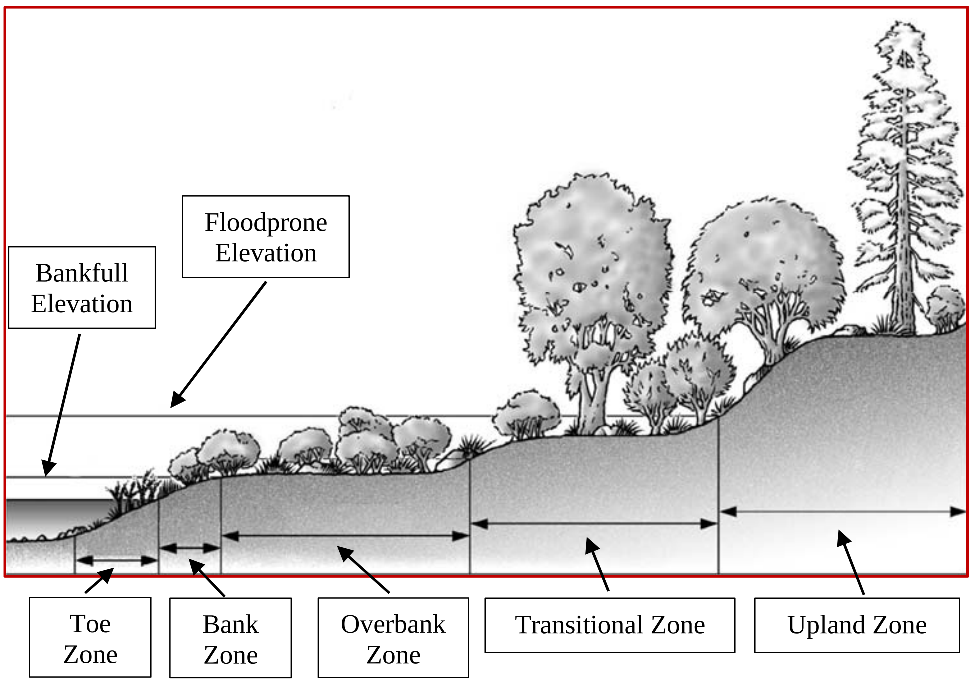

Figure 122. Profile view of typical bank zones.

Floodplain creation through fill involves the placement of consecutive lifts of native alluvium below the ordinary high water mark, compaction of lifts with excavator bucket or similar force, and installation of transplanted woody and herbaceous vegetation mats atop placed fill to achieve the design elevation. The most coarse available materials (or imported rock of specified gradation) are placed on the river side of the fill to achieve increased critical shear of the constructed feature; fine sediments and unclassified fill materials are generally placed on the landward side of the fill area. All implemented channel narrowing treatments are oriented and situated to achieve the functional bankfull channel width.

The channel constriction design utilizes the following treatment configurations to construct the edge of the floodplain fill, or the new stream bank, dependent upon local bank erosion potential:

A. At locations where bank erosion potential is high due to near bank shear stress, local slope, or channel alignment, new stream bank construction incorporates a log or rock revetment bank stabilization treatment;

B. At locations where bank erosion potential is low (e.g. inside of meanders, stream banks with low near bank shear stress), the density of woody members is reduced and the quantity of transplanted woody clump vegetation remains consistent; and

C. At locations where flood flows have potential to bypass channel meanders, the treatment should incorporate large rock (2-4 ft diameter) placed as ballast on woody members to reduce potential for post-construction meander cutoff during elevated flow events.

Floodplain creation through excavation involves removal of materials from high terrace features in order to construct a vegetated floodplain bench at the bankfull elevation. Floodplain excavation is completed using equipment and techniques (e.g. tracked excavator operating from the terrace elevation) that enable sorting of materials during excavation so that salvaged topsoil and vegetation can be placed on floodplain surfaces to achieve finish grade. Typical treatment installation includes collection and stockpiling of existing vegetation and top soil with an excavator bucket (e.g. scooping motions instead of dragging or pushing motions), mass excavation of unclassified fill material from the treatment area, and replacement of topsoil and salvaged vegetation on the sub-graded floodplain feature. The landward side of the treatment area is gently sloped (e.g. 5H:1V) up to the existing terrace grade, and intermediate benches should be constructed on the slope face to increase revegetation success and slope stability, as site conditions allow.

At all locations where floodplain creation (through fill or excavation) is implemented, the post-construction floodplain benches (river right and left) and the river channel should have a combined width that achieves the identified dimensionless entrenchment ratio (minimum of 3.9 in C-type channels and minimum of 1.9 in Bc-type channels). The relatively flat features that comprise the total width requirement are located below the floodprone elevation. A typical section depicting existing and design floodplain geometry is depicted in Figure 123, in which the floodplain created through excavation is depicted in green fill and the floodplain created through discharge is depicted in blue fill.

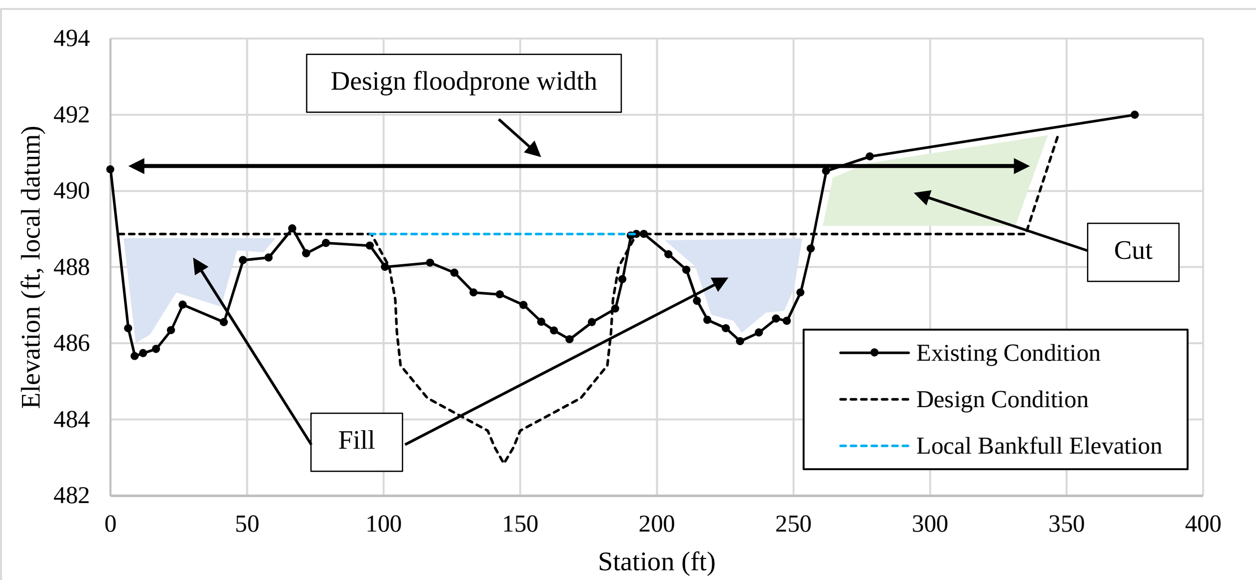

Figure 123. Typical existing and design floodplain geometry.

Floodplain reconnection and re-establishment is an important component of river system restoration because it enables flood waters to escape the channel and disperse, which reduces erosive energy. Floodplain inundation promotes diverse wildlife habitat through increased vigor of riparian vegetation and increases groundwater recharge to benefit the riparian and river systems. Floodplain restoration is depicted visually in Figures 124 to 126 from projects recently completed in the region.

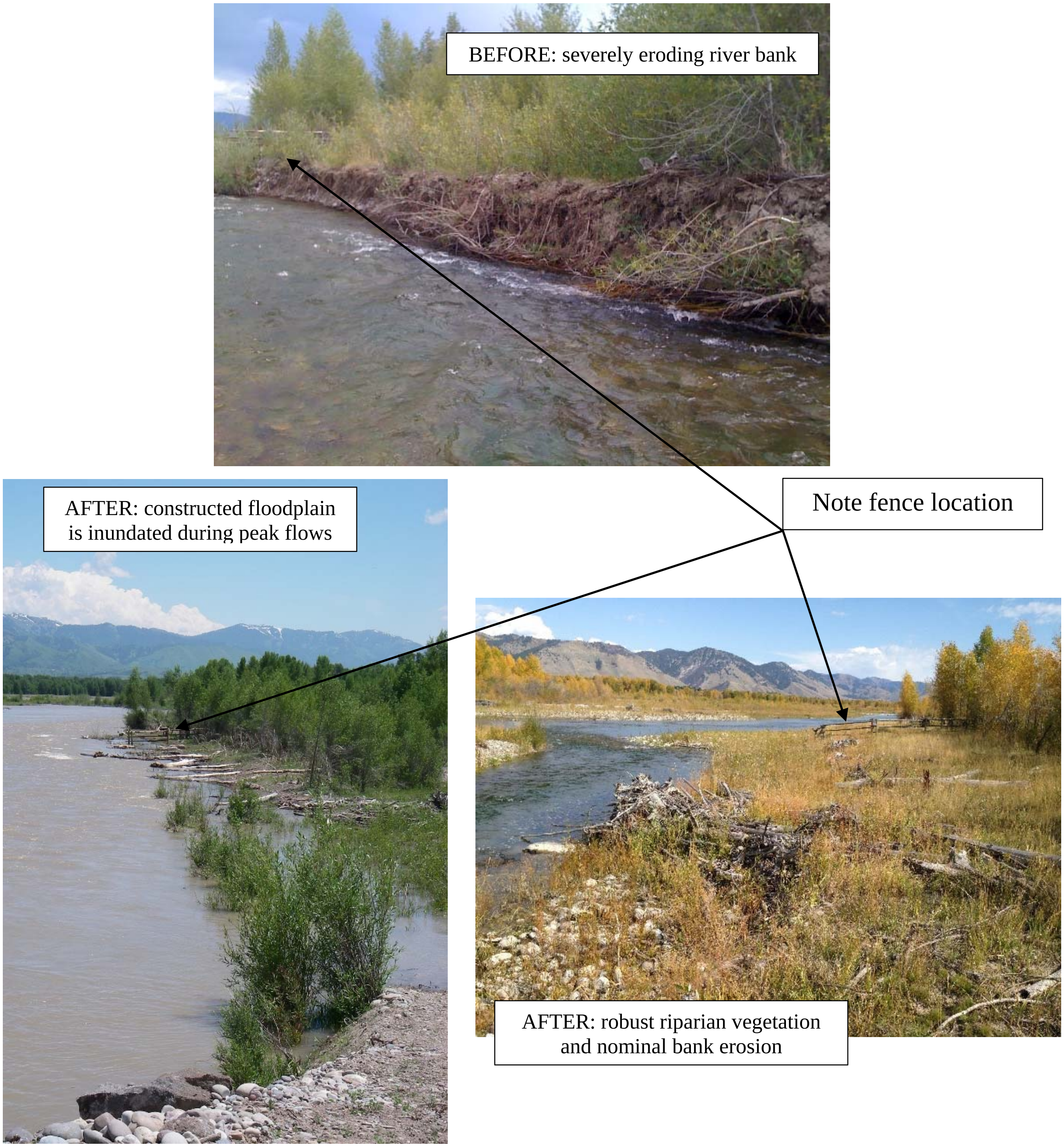

Figure 124. A floodplain bench was created within an over-widened reach of river to eliminate severe bank erosion (top), promote over-land flooding (bottom left), and aquatic conditions and riparian vegetation (bottom right).

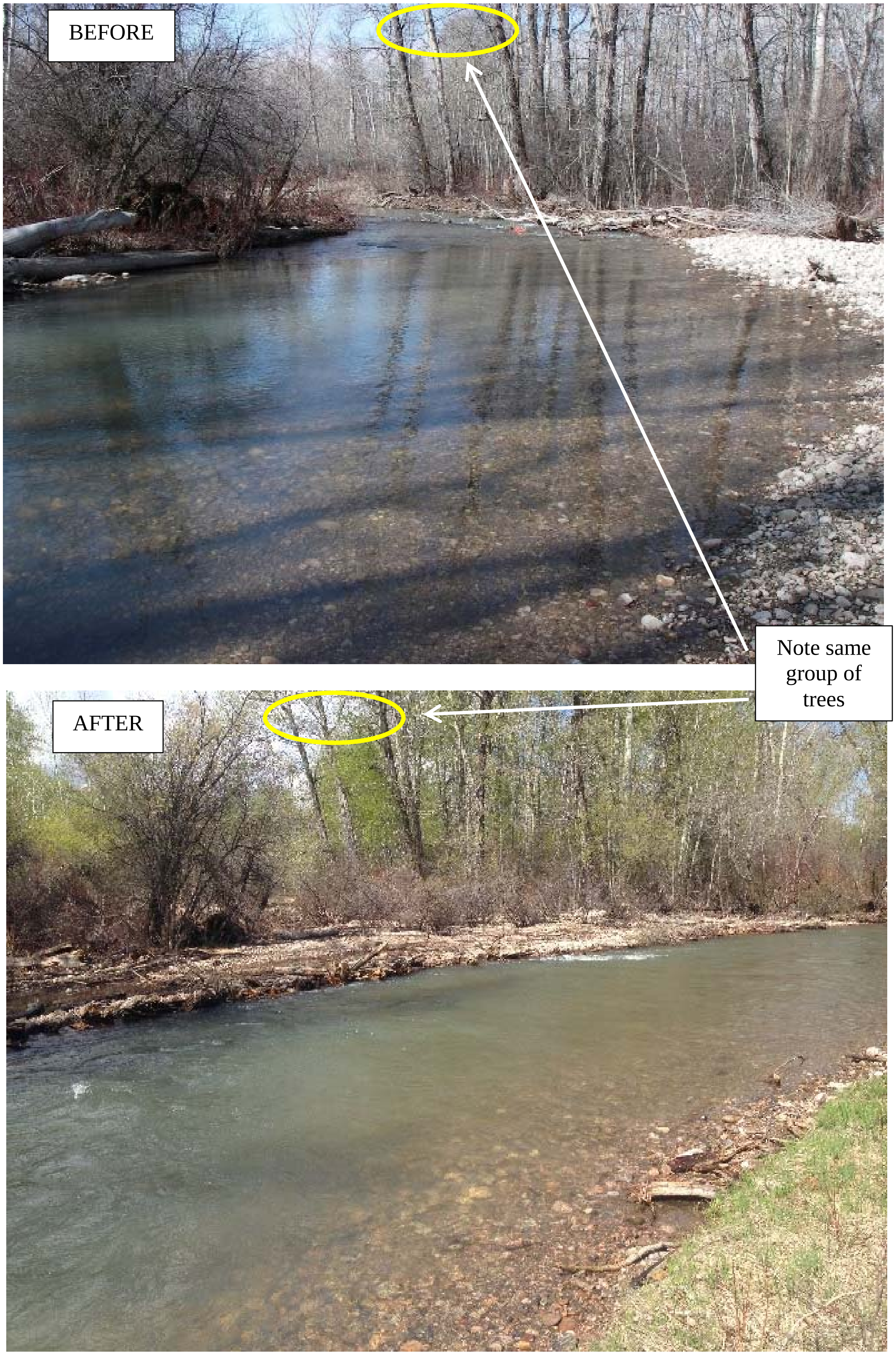

Figure 125. Floodplain creation was used to fill a braided channel network and restore functional channel width within a re-activated historic channel alignment. The treatment achieved flood water dissipation across the floodplain, increased riparian vegetation complexity and abundance, and improved fish habitat associated with increased depth, turbulence, and structural cover.

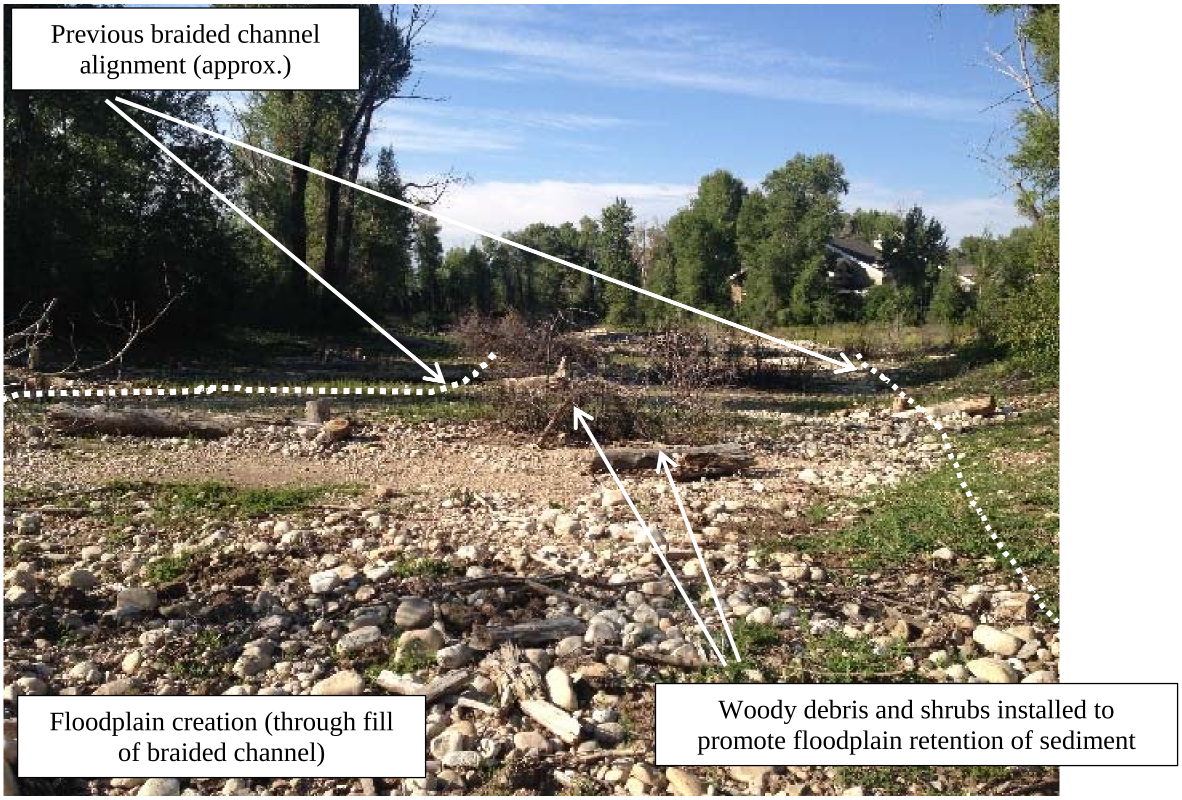

Figure 126. Photograph depicting created floodplain in a braided river system. An over-widened, dispersed, and braided river channel was filled to create floodplain and enable floodwater dispersal through the riparian area. Eroded areas were filled to create additional floodplain and re-establish a stable river channel to achieve sediment transport restoration and fish habitat enhancement objectives. The treatment enabled flood water dispersal, inundation, and groundwater recharge.

6.9 GRADE CONTROL

Grade control is necessary in the Big Wood River when the gradation of native alluvium is deficient of particles large enough to resist channel degradation. Reference channel conditions in the Big Wood River basin result in shear stress competent to mobilize up to only the D65 to D75 of the surface grain size class distribution at the bankfull discharge. Existing impaired reaches, or future project designs, that result in hydraulic conditions capable of mobilizing particles larger than the D65 to D75 of the available surface grain size class distribution warrant application of suitable grade control treatments. Hardened riffles, or distinct riffle bed features constructed of particles that are immobile under design hydraulic conditions, are an appropriate treatment to implement within the Big Wood River basin. Hardened riffles are preferable to typical rock vane structures, or hybrid rock-log vane structures, because hardened riffles distribute available gradient, are less prone to failure than vane structures, maintain fish passage at lower installed densities than vane structures, are more economical to install than structures comprised of large rock, and are less aesthetically obtrusive than large rock structures that span the bankfull channel. Hardened riffles are the preferred grade control structure within the Big Wood River main stem.

Typical installation of hardened riffle structures includes excavation of unsuitable foundation material from the treatment footprint, followed by placement of rock (with specified gradation) in a layer that is twice as thick as the maximum particle size (Figure 127). Bank keys are constructed at the corners of the treatment area, and consist of 6 ft wide extensions of the rock layer that protrude into the stream bank a minimum of 12 ft at 30-40 degrees from bank perpendicular (Figure 128). Bank keys are vegetated with dormant woody vegetation cuttings installed around the perimeter of placed rocks with buried ends extending to the low water groundwater elevation. Bank key footprints are capped with topsoil and revegetated with transplanted herbaceous and woody vegetation, and broadcast seeding is completed across remaining areas of open soil. Placement of the rock mix layer achieves the design finish channel geometry with maximum depth, mean depth, bank slopes, and inner berm attributes (Figure 129). Treatments maintain constructed gradient distribution and are aesthetically unobtrusive within the riverine environment.

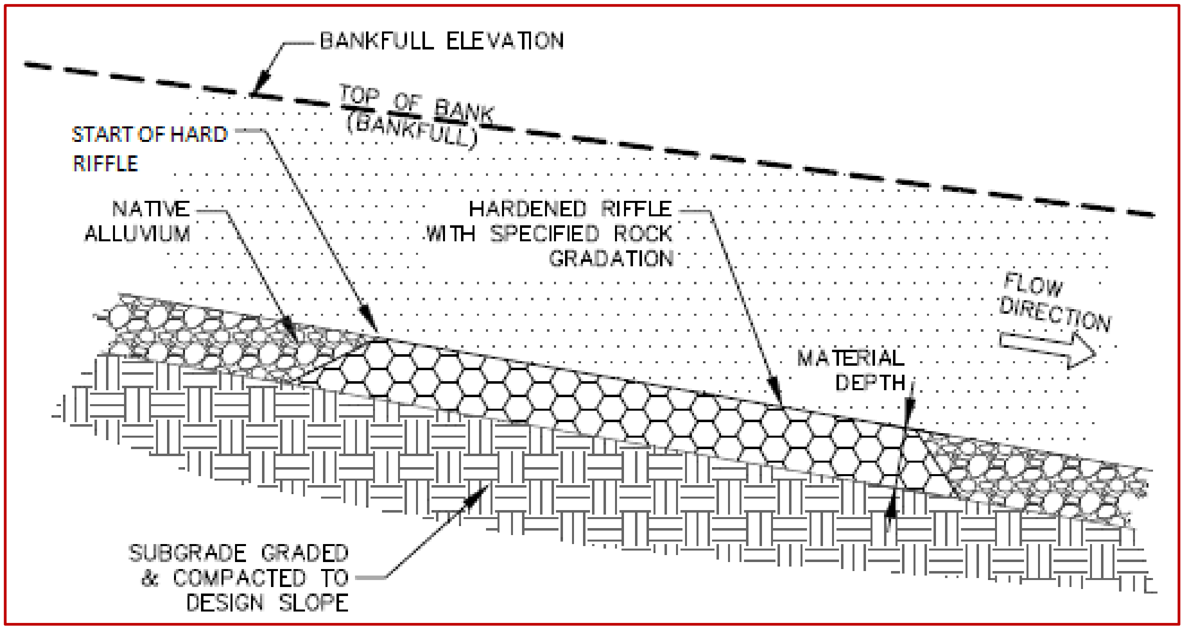

Figure 127. Profile view of typical hardened riffle treatment design.

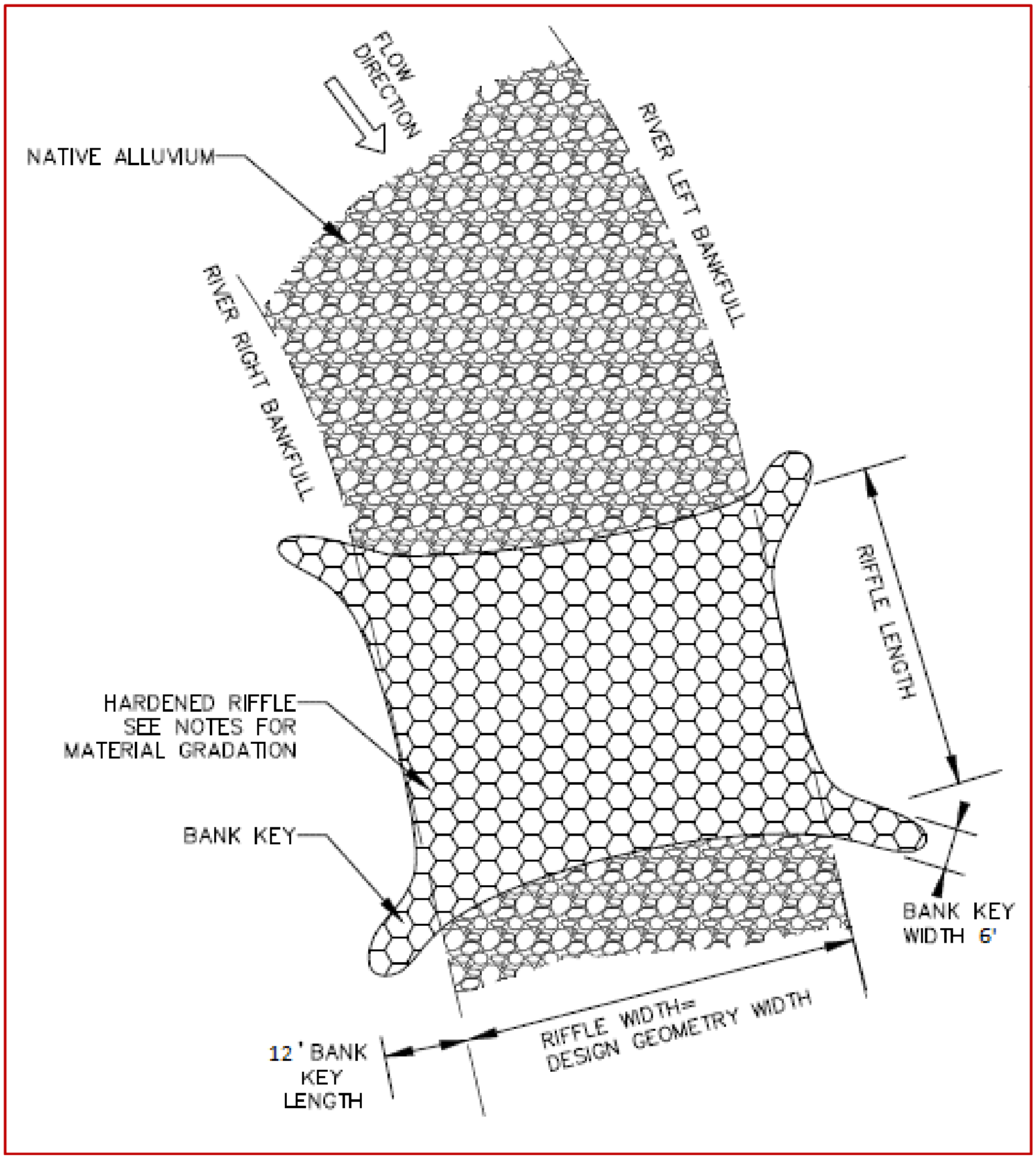

Figure 128. Plan view of typical hardened riffle treatment design.

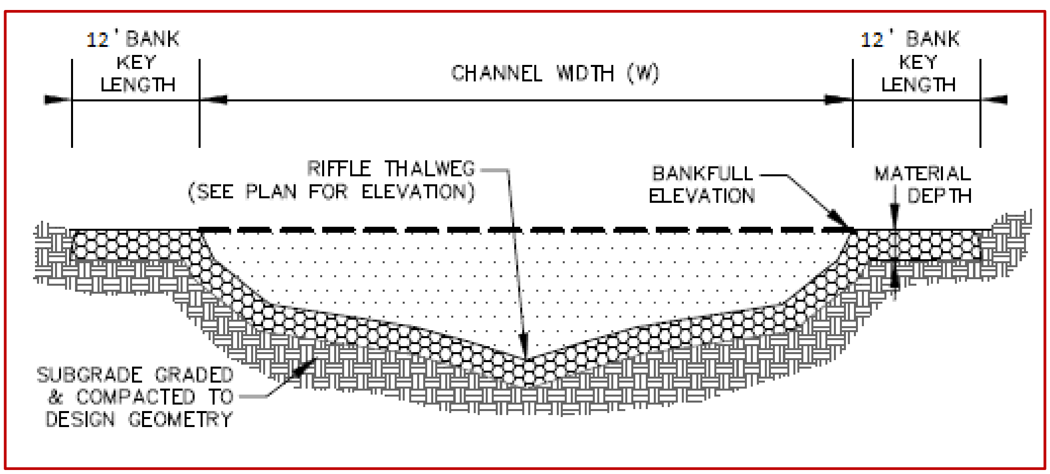

Figure 129. Section view of typical hardened riffle treatment design.

The hardened riffle treatment does not incorporate large boulders, but utilizes moderately sized rock to achieve vertical channel stability. The treatment maintains long riffle bed features, downstream scour pools for energy dissipation, and depth and turbulence cover for fish habitat. The hardened riffle treatment is depicted visually in Figure 130 from a project recently completed in the region.

Figure 130. Hardened riffles maintain vertical channel stability and establish design channel width while maintaining downstream scour pools (top left and right). The hardened riffle treatment enables conveyance of native alluvium (sediment transport) while maintaining channel stability using moderately sized rock (bottom).

The rock cross vane treatment can also be used to accomplish grade control, but this treatment alternative is less desirable than the hardened riffle in the Big Wood River because cross vanes are susceptible to failure (if individual boulders are undermined or mobilized) and vanes promote artificially short drops with plunge pools instead of more natural lengthy riffles with scour pools. However, rock cross vanes are preferable to traditional rock sills that extend straight across the river channel because vanes consolidate flows in the center of the channel in order to maximize sediment transport and downstream scour. The treatment is depicted visually in Figure 131 from projects recently completed in the region.

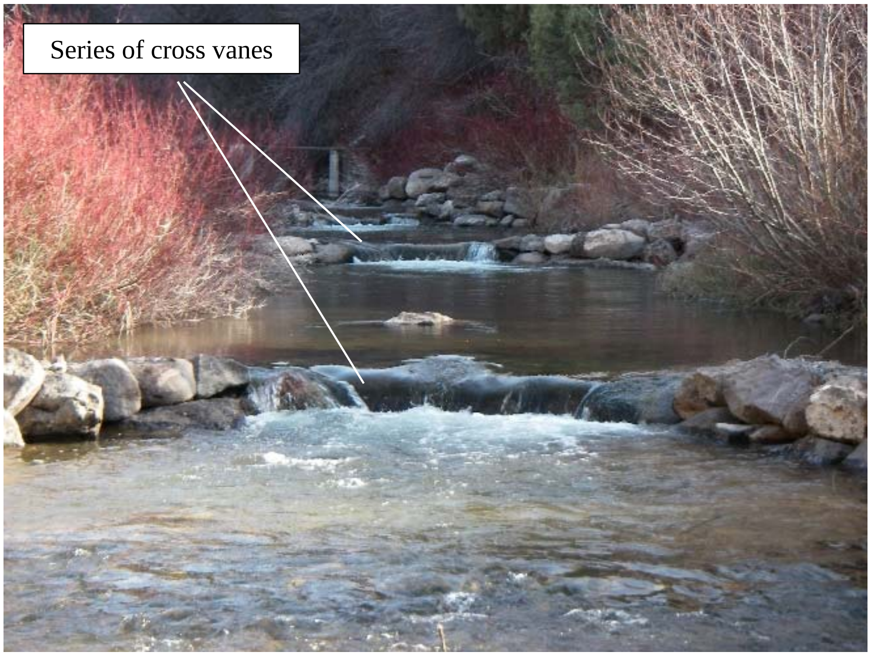

Figure 131. A series of rock cross vanes (top) distributes excessive local gradient while enabling sediment transport and maintaining downstream pools and mid-channel turbulence cover for fish habitat. A single large rock cross vane (bottom) maintains grade control and channel width while consolidating low flows in the center of the channel for hydraulic and fisheries benefits.

6.10 DESIGN CONSIDERATIONS

Application of the presented design approach can inform the assessment of large-scale projects (past or future). Specifically, the design guidelines can be applied to investigate the suitability of the channel form (dimension, pattern, profile) achieved by project treatments. For example, assessment of the Training Channel Site reveals that existing rock sill structures maintain riffle facet slopes of 0.1% to 0.03%. The reach-wide bankfull channel slope is 0.69%, and application of C-type dimensionless variables indicates that riffle facet slopes should exceed the reach slope by about 2.2 times, which would result in riffle slopes of about 1.5%. The discrepancy between existing and suitable riffle facet slopes (0.1% and 1.5%, respectively) is more than an order of magnitude. The flat riffles maintained by existing rock sills lack capacity to transport the supplied sediment load, and the inappropriate channel profile maintained by the rock sills is a primary cause of the widespread sedimentation inflicting the reach. This example is depicted graphically in Figure 132, in which the existing channel invert (with rock sills) is depicted by a red line, and a dashed black line depicts a suitable channel profile with appropriate riffle slopes lengths. Sub-reaches of the Big Wood River currently altered by installed rock sill structures (e.g. the Training Channel reach, Hulen Meadows reach, Bullion Bridge reach, Highway 75 downstream reach) are appropriate priorities for restoration efforts designed to achieve stable and functional channel form. These principles also apply to the potential establishment of water parks or recreational wave features within the watershed; efforts to establish recreational wave patterns should ensure appropriate channel profile (slopes) to achieve sediment transport continuity, and may consider hardened lateral encroachment structures instead of elevated river bed conditions to achieve desired hydraulics.

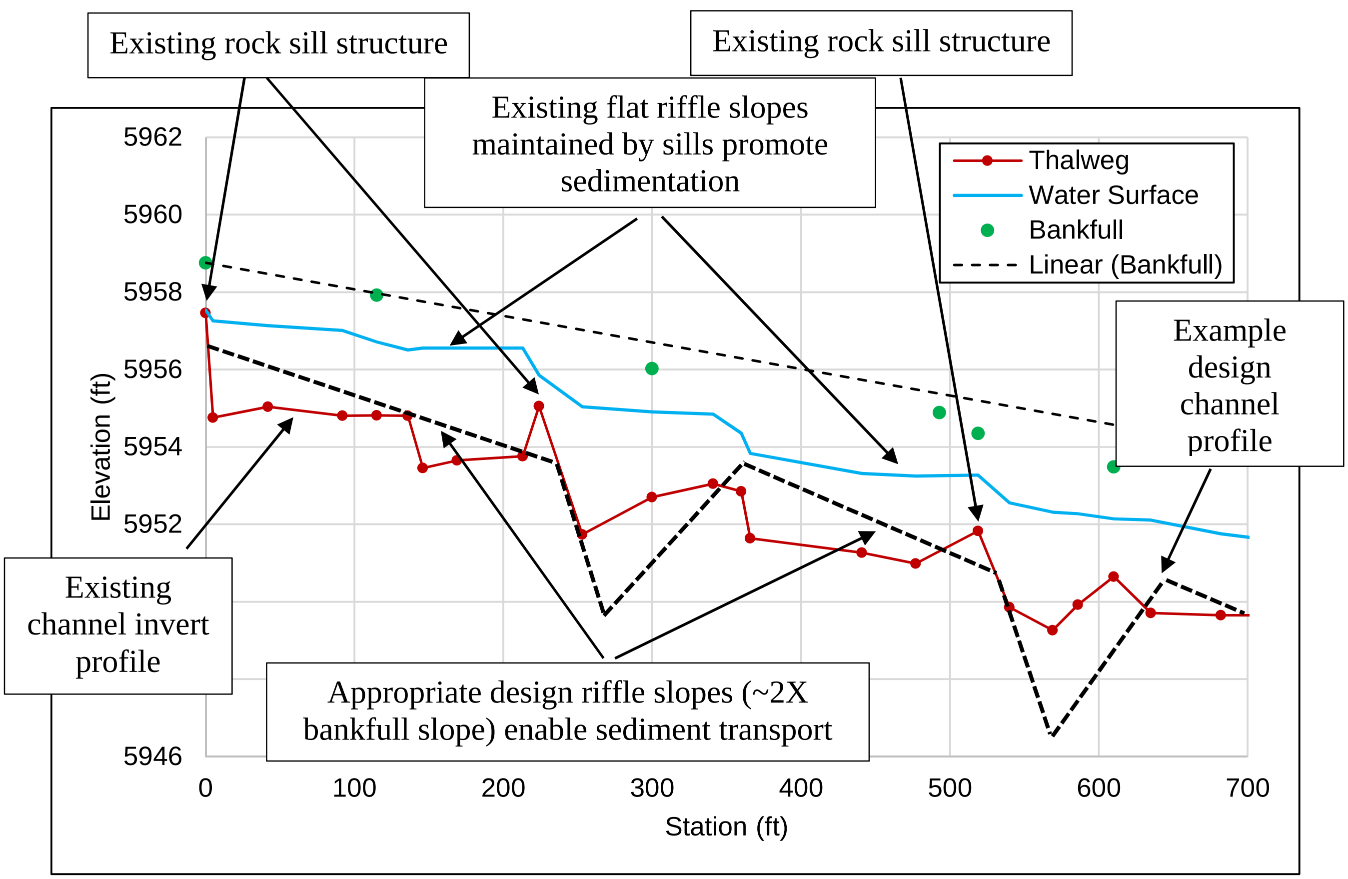

Figure 132. Existing and example design channel profile proximate to sills in the Training Channel reach.

The incorporation of on-channel sediment collection basins, such as the Hulen Meadows pond, is not recommended within the Big Wood River system. On-channel sediment collection basins present costly and perpetual maintenance requirements. Maintenance is typically not possible during periods of elevated flow due to access limitations and safety concerns. Therefore, the ability of an on-channel sediment basin to capture and store sediment may or may not last throughout any individual runoff period, dependent upon the severity and duration of the flow event. The unpredictable functionality and significant maintenance needs of on-channel sediment basins limit the potential benefits of such features.

In addition, sediment basins that divert a significant proportion of river flows result in unpredictable main stem conditions. When the sediment basin is empty, the main stem receives reduced hydrologic inputs because flows are diverted through the basin. Diversion of peak flows from the main stem can alter vertical channel stability through bed surface fining (Parker et al., 2003: *Effect of Floodwater Extraction on Mountain Stream Morphology*) and can result in decreased channel width and conveyance capacity (Ryan, 1994: *Effects of Trans-basin Diversion on Flow Regime, Bedload Transport, and Channel Morphology*; and Bohn and King, 2000: *Stream Channel Responses to Stream Flow Diversion*). When the sediment basin is full, the main stem receives the full magnitude of flow and sediment inputs. Any realized reduction in channel capacity can then result in flooding, erosion, flushing of fine particle accumulations, and channel degradation. The capacity of the sediment basin can fluctuate rapidly during a significant runoff event when large amounts of sediment are delivered to the reach. Widespread channel manipulations (grade control, bank armoring, and flood hazard reduction treatments) are typically required to maintain stability when main stem flow and sediment conditions fluctuate so dramatically. Flood water attenuation, river functions, aquatic habitat, and ecological values are generally compromised by those channel manipulations and artificial conditions. Therefore, the recommended approach to addressing sedimentation issues in the Big Wood River basin is to restore sediment transport continuity while reducing sediment inputs from bank erosion. These conditions require nominal maintenance and typically result in a net reduction in sediment input to the watershed and an increase in ecological values and aquatic habitat conditions.

Restoration projects designed to restore sediment transport continuity within sub-reaches of the main stem Big Wood River can be implemented to benefit watershed conditions without adversely impacting adjacent river reaches. For example, the 8,200 foot reach of river between Bullion Bridge and Colorado Gulch near Hailey currently lacks bedload transport capacity by 600-700 tons/year. However, deposition of this excess load results in channel filling and promotes lateral channel migration and erosion. Resultant bank erosion in the 8,200-ft reach is estimated to contribute an additional 2,700 tons/year of sediment to the watershed, and ultimately to downstream river reaches. The restoration of sediment transport capacity and channel stability within the river reach between Bullion Bridge and Colorado Gulch would result in the conveyance of an additional 600-700 tons of sediment per year, but would reduce sediment inputs from bank erosion by about 2,700 tons/year. This approach to fluvial restoration would reduce the total sediment supplied to the watershed, and would provide direct benefit to downstream river reaches.

Implementation of restoration activities should be completed cognoscente of adjacent existing channel conditions. The dominant impaired channel forms in the watershed are D-type (braided, laterally migrating) and F-type (incised, high width/depth ratio) channels. Restoration of sub-reaches of river should incorporate transitional channel conditions at the upstream and downstream treatment extents. D-type channels are generally prone to aggradation and lateral channel migration. Restoration located downstream of D-type channel conditions should, therefore, incorporate suitable lateral channel stabilization to maintain channel alignment at the upstream end of the project area. Restoration located downstream of F-type channel conditions should incorporate treatments to maintain grade through a transitional area located between the upstream high width/depth ratio conditions and the project reach.

Restoration activities implemented proximate to established diversion structures should consider the direct and indirect influences of diversion operations on channel function. Direct alteration of mean daily flow duration resulting from diversion operations should be considered in the context of peak flow rates and sediment transport capacity. In addition, diversions that incorporate channel spanning sills or grade control structures are likely to promote upstream degradation and downstream channel incision. Restoration efforts located downstream of diversion sills should incorporate suitable grade control in anticipation of sediment-starved conditions at the upstream project area boundary. Restoration efforts implemented downstream of diversions that incorporate bank armoring and maintenance of maximum channel depth adjacent to the river bank should incorporate treatments to transition from high near-bank flow velocities and shear stress into the design channel geometry.

6.11 DEVELOPMENT SET-BACKS

The constriction of meander width, floodprone width, and channel migration resulting from existing development encroachment along the Big Wood River main stem is a fundamental cause of current impaired riverine function and ecological value. Existing development encroachments are not likely to dissipate, but reasonable regulation of future encroachment into the fluvial environment would provide benefit to the riverine system. Sub-reaches of the main stem Big Wood River have potential to dramatically and rapidly migrate laterally through channel avulsion or rapid bank erosion rates, and such shifts in river alignment are not always deleterious to riverine function. However, homogeneous development setbacks from the mean high water mark, or river edge, are not universally appropriate. In addition, the reduction of Blaine County development river setbacks from 200 ft to 75 ft triggered by the establishment of a local riparian management plan does not accommodate fluvial function at the watershed scale.

Reasonable development setbacks should consider river form, which reflects stability and function. Geomorphic assessment completed along the main stem Big Wood River quantified channel form and stability, and identified sub-reaches within which functional C-type or Bc-type channel conditions could reasonably be achieved. The entrenchment ratio (or ratio of floodprone width to bankfull channel width) of typical reference C-type channels is 3.9 and is 1.9 within Bc-type channels. These dimensionless ratios could be applied to identify areas within which development should not occur. The floodprone area is subject to semi-regular inundation by flood waters, so prohibiting development within the area would eliminate the potential for infrastructure damage during large magnitude runoff events. In addition, the maintenance or enhancement of intact robust riparian vegetation within the floodprone region would benefit the fluvial system at the watershed scale.

Regulation of development within the floodprone area would inherently be based upon current channel alignment. However, future anticipated channel migration should be incorporated into the establishment of meaningful development buffers, especially within sub-reaches of the main stem Big Wood River that are currently impaired. Geomorphic assessment completed along the main stem Big Wood River identified sub-reaches within which either C-type or Bc-type functional channel forms could be achieved, and specified typical meander width ratios characteristic of both stream types. Functional (reference) conditions demonstrate a mean meander width ratio of 4.8 (range of 2.8 to 10) in C-type channels and a mean ratio of 2.7 (range of 2.1 to 4) in Bc-type channels. These ratios could be applied, in concert with identified sub-reach functional channel width, to identify areas within which functional channel pattern could be achieved, and within which development could be correspondingly discouraged. Development setbacks established based upon meander width ratio would likely be less than the existing 200 ft county setback in sub-reaches with Bc-type potential restored form, but the associated setback width is reasonable given the relative lateral stability of the Bc-type channel conditions. Conversely, development setbacks derived in this manner would likely be more than the existing 200-ft county setback in sub-reaches with

C-type potential restored form, and this result is appropriate given the relative lateral instability of these river reaches.

Establishment of buffers to *prohibit* development within floodprone areas and to *restrict* development within the quantified channel meander width would provide appropriate protection of both fluvial processes and development infrastructure.

6.12 RIVER SYSTEM BENEFIT

In addition to development encroachment, primary resource concerns along the Big Wood River main stem are related to unstable channel braiding, widening or enlargement, and severe lateral instability (bank erosion). These conditions threaten public and private infrastructure and reduce the ecological (and fisheries) value of the river system. Previous morphologic investigations (Rapp, 2006. *Geomorphic Assessment of the Big Wood River*) acknowledged that, historic riparian vegetation and channel conditions provided flood flow attenuation (reduced flood severity), suitable sediment storage, appropriate channel stability, reduced severe bank erosion, and high quality fish habitat. The existing impaired channel form does not provide these important ecological services.

Previous fisheries investigations completed within the Big Wood River (Thurow, R.F. 1987. *Effects of Stream Alterations on Rainbow Trout in the Big Wood River, Idaho*) found that trout densities increased with scour pools and cover provided by large wood and over-head vegetation. Trout densities were found to be 8-10 times higher at locations with cover than at locations without cover, and trout densities proximate to rock riprap were similar to densities where there was no cover. These findings reflect why the current impaired Big Wood River provides reduced fisheries value; the over-widened channel provides minimal pool habitat, the channel has limited cover, and riprap is prevalent.

Fisheries enhancement, flood hazard reduction, reduced sedimentation, and reduced severe bank erosion could all be achieved through implementation of local or large-scale restoration efforts that utilize the presented suite of river restoration treatments, including:

1. Establishment of functional channel width, depth, profile, and alignment;
2. Hardened riffles or rock cross vanes to achieve grade control;
3. Wood revetment or rock revetment with bioengineering to achieve bank stabilization; and
4. Floodplain reconnection and re-establishment through excavation or fill.

These channel restoration treatments coincide with the optimal approach to fish habitat improvement recommended by Thurow (1987), which is to, “Pin down [sustainable] bedload movement, allow riparian revegetation to restore instream woody debris, and maintain natural sheet flooding.”

6.13 CONSERVATION OPPORTUNITIES

Potential conservation priority areas along the Big Wood River main stem were identified based upon potential channel form of sub-reaches (either C-type or Bc-type), reference reach dimensionless entrenchment ratios, and the characteristics of existing development proximate to the watercourse. Spatial analyses completed to quantify development encroachment into the Big Wood River floodprone area (as discussed in the *Anthropogenic Channel Modifications* sub-section) were used to identify river reaches of significant length with minimal existing development encroachment. Identified river reaches do not demonstrate stable or functional channel form, but are instead identified as locations where conservation could be prioritized. Implementation of conservation measures designed to curtail further development encroachment would enable future efforts to passively or actively restore fluvial conditions in the identified river reaches. Implementation of conservation measures, and potentially restoration activities, across prioritized river reaches of meaningful length is an avenue through which watershed-level benefits could be achieved. Prioritized conservation opportunities within the Big Wood River project area include the following:

1. Approximately 3,500 ft of river channel proximate to the Fox Creek Reference Reach Site (attached Exhibit 98);
2. Approximately 6,000 ft of river channel proximate to the Training Channel Site (attached Exhibit 99);
3. Approximately 8,000 ft of river channel proximate to the Highway 75 Reach Site (attached Exhibit 100);
4. Approximately 7,000 ft of river channel upstream of the East Fork Big Wood River confluence (attached Exhibit 101);
5. Approximately 27,000 ft of river channel upstream and adjacent to the Deer Creek confluence (attached Exhibit 102);
6. Approximately 4,000 ft of river channel downstream of the Bullion Street Bridge in Hailey (attached Exhibit 103); and
7. Approximately 22,000 ft of river channel located between Colorado Gulch and the Broadford Street Bridge in near Bellevue (attached Exhibits 104 and 105).

7.0 SUMMARY

The Big Wood River Geomorphic Assessment project involved qualitative and quantitative description of channel form and function from the confluence with the North Fork Big Wood River downstream to Magic Reservoir. Initial project investigations identified relative impacts of tributary systems on the main stem river associated with geology, road networks, land slope, soils, land cover, fire regime, and anthropogenic system modifications. Tributary catchments with the most significant adverse impacts on the river system were identified, and main stem river reaches were correspondingly selected for detailed field evaluation.

A total of 14 river reaches and 2 USGS gauge sites were selected for field investigation, which included geomorphic surveys to quantify channel form, function, hydrologic attributes, bankfull hydraulic conditions, sediment transport regime, bank erosion rates, and stream stability indices. Assessment results obtained within surveyed river reaches can reasonably be extrapolated to adjacent reaches of the Big Wood River. Based upon quantification of channel departure from functional (reference) conditions, a suite of riverine management objectives and tools were compiled.

River restoration and enhancement treatments appropriate to the Big Wood River main stem include application of design channel geometry from hydraulically scaled reference conditions and determination of design channel pattern and profile from empirical reference condition dimensionless ratios. In order to accomplish design (functional) channel form, a suite of treatments are specified that includes wood revetment bank stabilization, rock revetment bank stabilization with willows, floodplain construction, and grade control. Emphasis is placed on the importance of applying specified treatments in concert to address underlying causes of fluvial system instability, as opposed to applying individual treatments to address symptoms of system degradation (the typical Band-Aid approach).

Appropriate application of the presented restoration treatments can achieve objectives of reduced flood hazard and improved flood attenuation, improved continuity of sediment movement, increased channel stability, and reduced severe bank erosion. Installation of presented treatments can also help regain the historic vibrant fisheries values of the Big Wood River. Fisheries investigations completed in the system in the 1980's (Thurow, 1987) found 71% of trout at locations with sufficient cover, 15% of trout in mid-channel areas, only 10% of trout at locations with no cover, and only 4% of trout at locations with rock riprap. Restoration of proper channel width and depth through floodplain creation and channel shaping will enable the river to maintain pools with complex cover components to benefit the fishery. Installation of large wood for bank stabilization, and establishment of woody riparian vegetation along the river banks (especially where riprap is located), will increase structural and overhead cover critical to the quality of the fishery. These approaches to morphologic river restoration will improve fluvial processes *and* re-establish river conditions that have been documented to support the highest densities of trout in the Big Wood River.

Specific recommendations are presented for passive restoration efforts including modified development set-backs and identified conservation priority areas within the study area. Application of passive and active restoration measures, implemented in conjunction with presented objectives, will enable resource managers and property owners to achieve meaningful watershed level benefit within the fluvial system.

LIST OF ATTACHED EXHIBITS