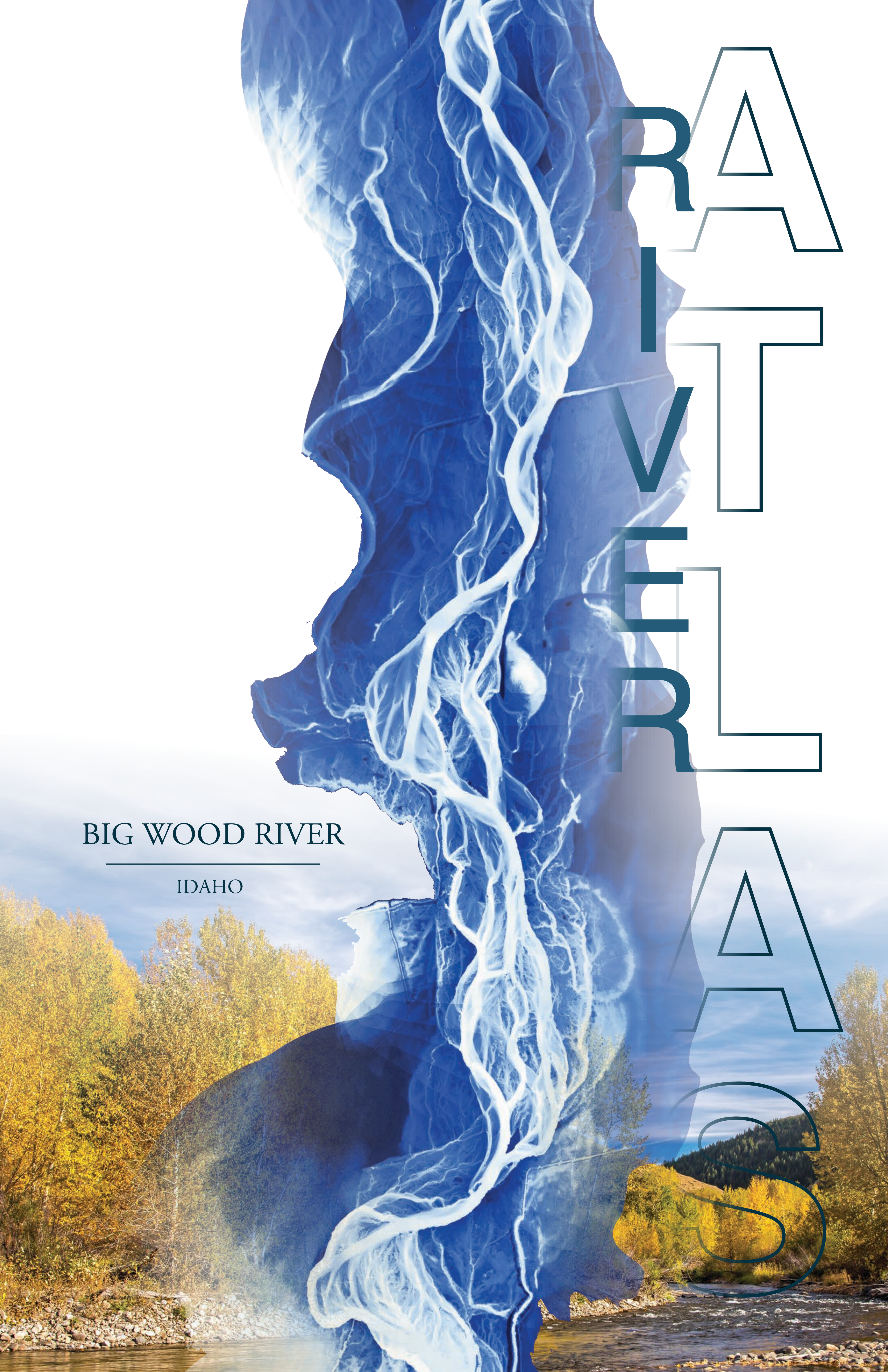


RIVER ATLAS

BIG WOOD RIVER

IDAHO

BIG WOOD RIVER ATLAS

Blaine County
Land Use & Building Services
219 1st Ave South, Suite 208
Hailey, Idaho 83333

Project Manager: Kristine Hilt
Certified Floodplain Manager
Code Compliance Specialist
Phone: (208) 788-5570

Preferred Citation:

Cardno and Ecosystem Sciences, 2020. Big Wood River Atlas. Prepared for Blaine County, Idaho.

Technical Analyses and Engineering:
Cardno // www.cardno.com
Project Manager: Jonathan Ambrose
Principal River Scientist
(206) 799-3687

Design, graphics and content layout:
Ecosystem Sciences, LLC
www.ecosystemsciences.com
Zach Hill, Principal Environmental Design
(208) 383-0226

All photographs are by Blaine County, Cardno and Ecosystem Sciences, LLC unless specifically noted.

A Dynamic and Complex History

The image on the front cover and to the left depicts a Lidar relative elevation model (REM), showing current and previous channels carved out by the Big Wood River. In typical satellite and aerial imagery only the active, vegetation free river channels are clearly visible. The Lidar imagery uses a striking technique to reveal the history of how the river channels have changed through time. The elevation heights have been represented by a range of colors from white in the lower elevations to dark blue in the higher elevations. The complex and braided channels reveal a dynamic river landscape.

Photo: Bob Pool/Shutterstock

Acknowledgements

Blaine County, Idaho

Blaine County's topography, geographic location and seasonal variation in climate create a unique and varied natural environment, ranging from the scenic, high alpine country in the north to the desolate lava plains and high-desert mountains in the south. Natural environmental attributes, including scenic vistas, public open space, healthy forests, clean water and air, and abundant fish and wildlife are the heart and soul of the community. As a recreational area, Blaine County is known throughout the world for the quality and beauty of its natural environment and recreational opportunities.

Blaine County is a world-class rural resort county home to roughly 23,000 full time residents. Recreation may be the centerpiece of the local and visitor life experience; however, the agricultural land uses are an important historic and community heritage that provide an economic resource for the community. The Big Wood River, which runs through the heart of Blaine County, is central to the quality of life, providing a valuable source of irrigation water, recreation opportunities, fish and wildlife habitat, and aesthetic beauty valued by residents and visitors alike.

Contributors

This Big Wood River Atlas was developed using a stakeholder-led, collaborative process to develop information and recommendations that will best serve the community to manage river resources in the near and long-term. The stakeholder process is discussed in detail on page 4. Technical contributions to this Atlas were led by a team from Cardno, Ecosystem Sciences and Blaine County, including:

Cardno

- Jonathan Ambrose, MSc. Principal River Scientist and Project Manager
- Steven Rodriguez, PE. Hydraulic Engineer
- Jacob Zinsli, EIT. Geospatial Analyst
- Lucas Evans, EIT. Staff Scientist

Ecosystem Sciences

- Zach Hill, Principal of Environmental Design and Planning

Blaine County

- Kristine Hilt, CFM. County Floodplain Manager
- Jeff Loomis, PE. County Engineer

From its source in the Sawtooth mountains near Galena Summit, the Big Wood River flows south for 137 miles, amongst the Boulder Mountains to the north, Pioneer Mountains to the east, and the Smoky Mountains to the west. The river flows through Sun Valley and Ketchum, where it receives the tributary streams of Warm Springs Creek and Trail Creek. Below Ketchum, it is joined by the East Fork Wood River at Gimlet before passing by the cities of Hailey and Bellevue. Continuing south, the river enters the Wood River Valley and the northern part of Magic Valley, after which it flows into Magic Reservoir.

■ *Big Wood River*

Table of Contents

Photo: AdobeStock

Map of the Upper Big Wood River Watershed

1 Introduction to the Atlas

Vision, Goals, Objectives, Purpose

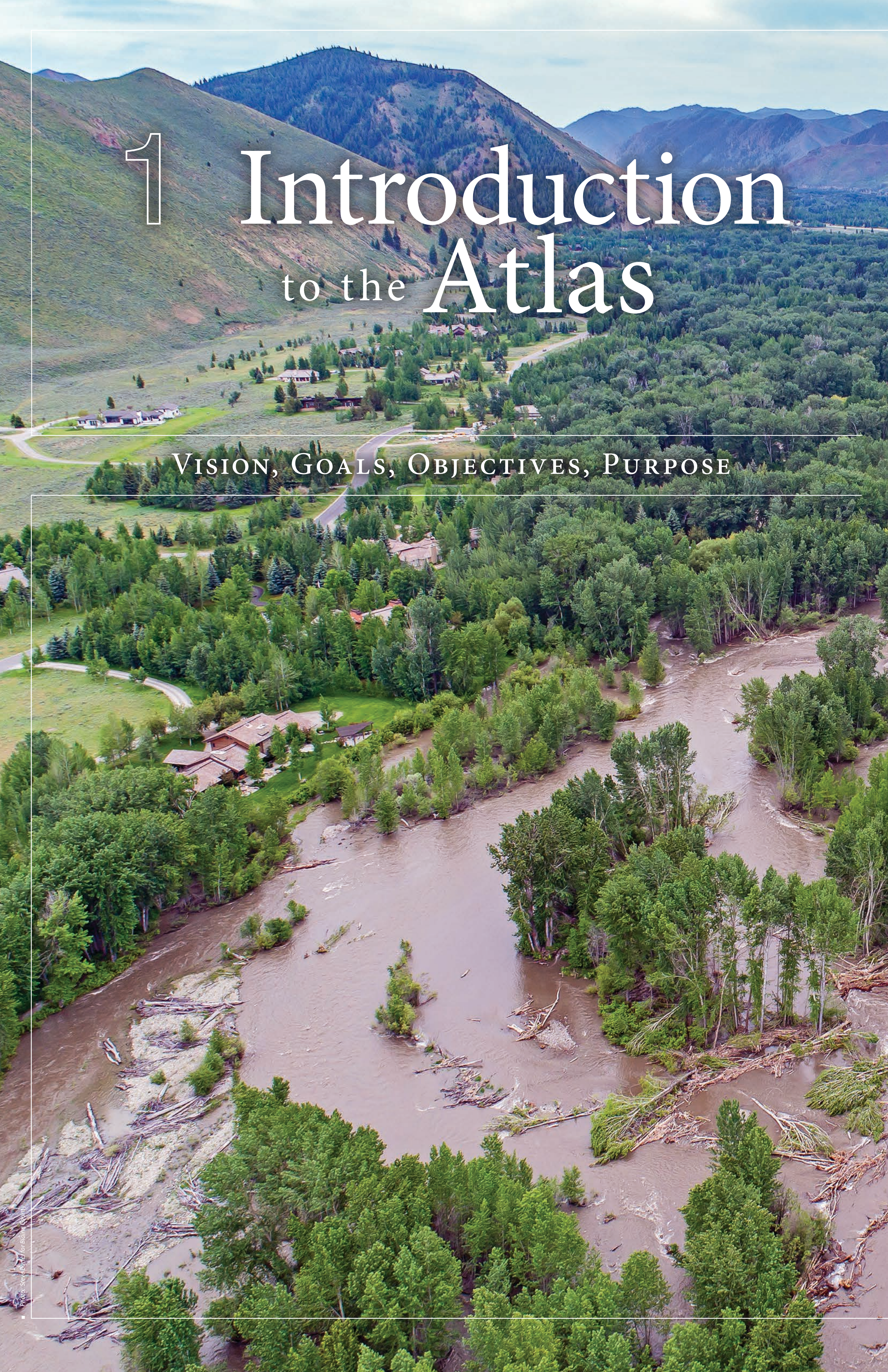


Photo: Steve Butler for Blaine County

Big Wood River at flood stage, 2017

Vision, Goals and Objectives

Our communities shared Vision is a Big Wood River that continues to serve as the centerpiece of the Wood River Valley, contributing to the aesthetic, ecological and economic abundance for all residents.

We hope through proper understanding of river behavior we can manage river resources in a sustainable manner and provide continued opportunities for recreation, education, commerce, and irrigated agriculture while maintaining functional ecosystems and a healthy fishery.

In the wake of significant and prolonged flooding in the Big Wood River valley in 2017, the community recognized the need to better understand river behavior and to develop river management policies and priorities shaped by a shared Vision for the river. It is understood that floodplain development has altered historic channel behavior and led to unintended consequences, affecting both human and wildlife communities.

Goals // Objectives

Build Community Trust and Collaboration over River Management Issues

- Create a stakeholder group to lead development of the Big Wood River Assessment
- Maintain stakeholder involvement to guide future river management and restoration activities
- Educate stakeholders on watershed processes and river behavior, particularly channel response to management decisions
- Increase citizen awareness of river management issues, conservation, and restoration actions.
- Encourage and foster continued community input

Understand Historic and Current River Processes

- Identify the historical channel migration zone
- Identify areas at risk of flooding
- Identify areas at risk of erosion

Develop a flood risk management framework that supports the connectivity of floodplains

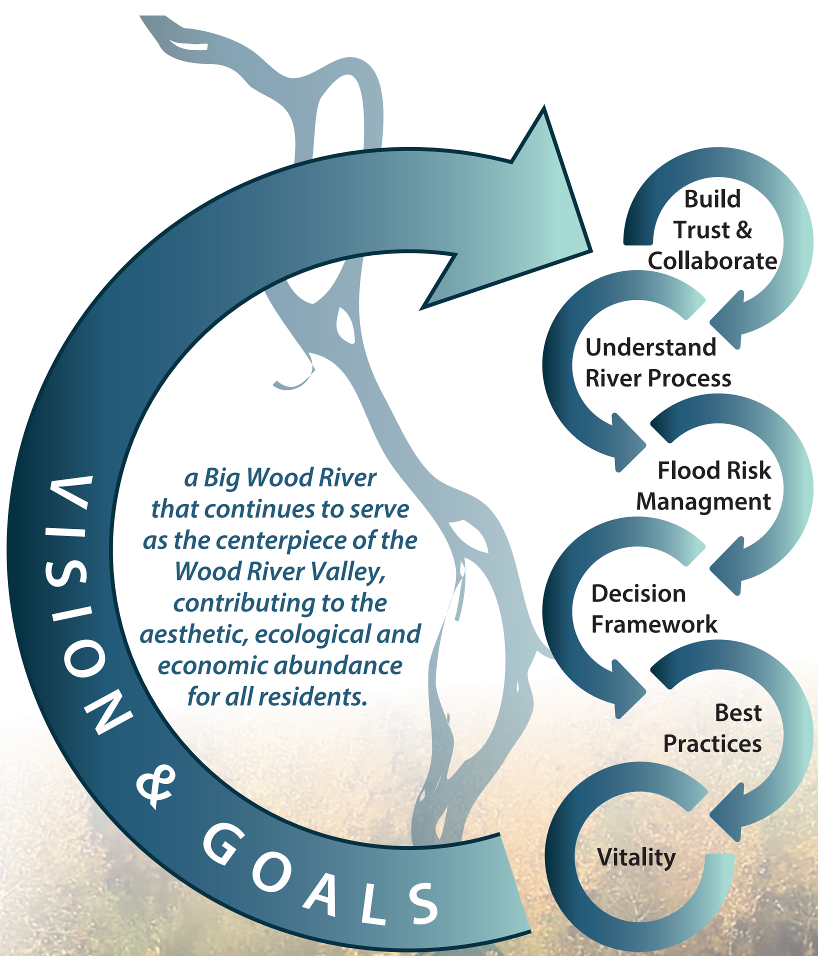
- Utilize this framework to guide future floodplain management decisions which impact flood risk.
- Collaborate with stakeholders to develop and implement framework.

Develop a decision-making framework to identify and evaluate projects that work to restore natural river processes, and encourages aquatic habitat formation

- Describe areas of lost or degraded aquatic and floodplain habitat
- Describe the habitat and geomorphic impacts resulting from channel confinement and bank hardening
- Conceptualize project types for floodplain and ecosystem restoration that will:
  - Decrease high water impacts to communities within the study area,
  - Decrease erosion along the Big Wood River, and
  - Enhance ecosystem health along the Big Wood River and its tributaries, with special emphasis on reconnecting the floodplain and restoring natural river function.
- Define a methodology for project identification, prioritization, and evaluation consistent with the River Vision and the tenets of process based restoration.

Assist river managers with identifying specific best management practices for development within the river that supports the River Vision and minimizes negative consequences to downstream reaches, communities, and habitat.

- Develop concept-level best management practices (BMPs) for flood risk reduction and ecosystem restoration projects that can be used in:
  - Prioritizing project goals,
  - Managing emergency response, and
  - Improving County floodplain and riparian area land use codes and their enforcement.
- Provide resources to stakeholders related to best available science and engineering practices related to stream and river restoration assessment and techniques.
- Work to balance protection of private property with offsite impacts to river behavior and aquatic habitat



River Assessment Strategy

The strategy is to reach this Vision for the Big Wood River through a progressive approach, and to do so with effective collaboration between stakeholders and members of the community.

The first phase of the strategy is to develop this Assessment of the Big Wood River that clearly communicates: 1) major processes governing river function; 2) changes in historical river behavior resulting from floodplain development; 3) a framework to develop and evaluate projects to restore ecosystem function, and reduce flooding and erosion risks.

The intent is to use the information presented in this Assessment as a tool to develop a common understanding of the Big Wood River's flood and channel migration hazards, the types of opportunities available to reduce the hazards posed to floodplain development, priority project types for implementation of those opportunities, and proper techniques to implement those projects utilizing best available science and engineering standards.

River Assessment Strategy

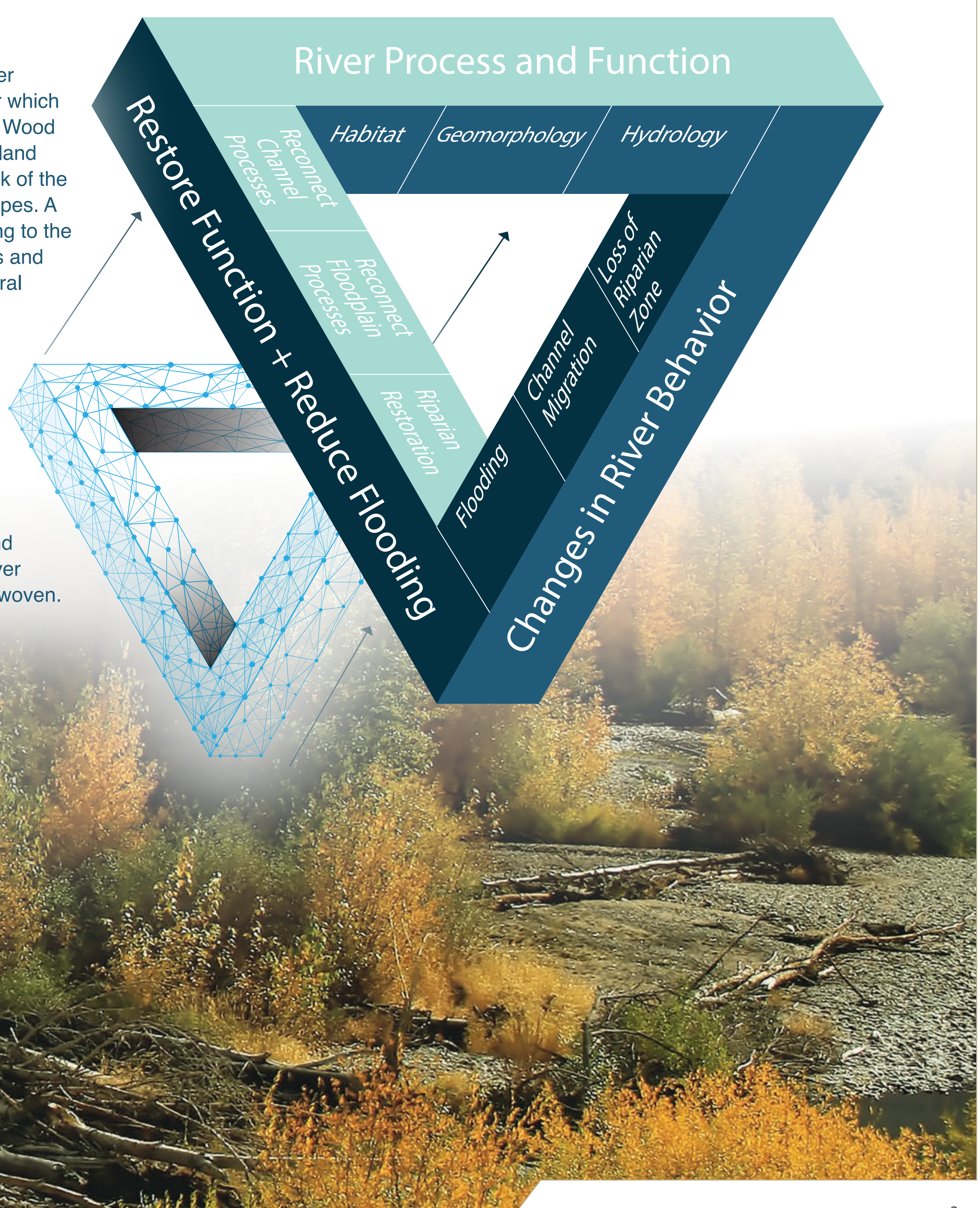
Understand River Process and Function

Identify Changes in River Behavior

Develop Opportunities to Restore Function and Reduce Risks

Complexity

All land is part of a watershed or river basin and all is shaped by the water which flows over it and through it. The Big Wood River is such an integral part of the land that it would be as appropriate to talk of the riverscape as it would be of landscapes. A river is much more than water flowing to the sea. Its ever–shifting bed and banks and the groundwater below, are all integral parts of the river system. Even the meadows, forests, marshes and backwaters of its floodplain can be seen as part of a river – and the river as part of them. A river carries downhill not just water, but just as importantly sediments, wood, dissolved minerals, and the nutrient–rich detritus of plants and animals. Both the natural system and methods employed to assess the river are detailed, multi-layered and interwoven.



Executive Summary

The Big Wood River Atlas represents a collaborative, multi-year process undertaken by Blaine County as a response to major river flooding and channel erosion that occurred during summer 2017. The 2017 flood was extreme in both magnitude and duration, and the channel response exacerbated by high sediment load contributions from major fires in 2007 and 2013. However, climatic and hydrologic trends indicate that the 2017 flood can be considered a bellwether event, with flooding and channel movement similar to that which managers should anticipate in future river corridor planning.

Blaine County retained Cardno and Ecosystem Sciences to complete the technical analyses and Atlas development. The Atlas is intended to provide a scientific foundation for future river management decisions in a manner most conducive to widespread understanding by the scientific community, policy makers, and the broader Wood River Valley community.

The Atlas evaluated geomorphic and flood characteristics for 42 miles extending from the Sawtooth National Recreation Area (SNRA) headquarters downstream to the Stanton Crossing Bridge on Highway 20. The primary focus areas of the Atlas, developed in coordination with project stakeholders include:

- Identifying areas and resources at risk of flooding and severe erosion;
- Identifying and describing areas of lost or degraded riverine habitat;
- Prioritizing areas and project types for flood risk management and ecosystem restoration;
- Discussing alternatives for balancing flood and erosion risk mitigation with ecosystem enhancement and restoration goals and objectives; and,
- Developing concept-level best management practices (BMPs) for flood risk reduction and ecosystem restoration projects.

The Atlas is organized into the following Chapters:

Chapter 1- Introduction. Presents the Vision, Goals, and Objectives framework for the Atlas. This section establishes the cornerstone for the shared community vision for the Big Wood River and the process through which the vision can be implemented, including development of this Atlas.

Chapter 2- Watershed Setting. This chapter introduces the reader to some of the underlying physical and biological processes that govern river behavior and create quality aquatic habitat in the Big Wood River.

Chapter 3- Hazards Analysis. Graphically depicts the steps completed in the creation of flood and erosion hazard areas that are presented in the reach maps of Chapter 4.

Chapter 4- Project Framework and River Reach Maps. The bulk of the Atlas is used in the mapping of 22 reaches that encompass the 42 mile study area. Prior to the reach maps, a process based framework is provided to identify project opportunities that will yield the greatest outcomes and suggestions for a regulatory framework that ensures those processes are pursued.

Each reach is then depicted both in an aerial photo on the left side of the fold, and using LiDAR mapping depicting colored elevation bands on the right side of the fold. Flood and erosion hazard zones are overlain on each reach, along with the location and extents of bank armoring, levees, irrigation diversions, and polygons showing zones of recent bank erosion. A general reach description is provided, along with representative photos, physical metrics, and a coarse evaluation of project opportunities in the reach.

Chapter 5- Guidance for Project Planning and Design. This chapter offers a suite of design guidance and conceptual designs intended to meet a variety of project types for implementation in multiple river settings. The intent of this chapter is to provide resources to landowners, designers, and application reviewers seeking to implement projects in the river environment. Design examples are provided from both resource agency publications and Cardno projects.

Partners and Stakeholders

The Big Wood River Atlas was developed using a collaborative, stakeholder-led process. Stakeholders represent a broad cross section of organizations with interest and responsibility for management of the Big Wood River including federal, state, county and local government, flood control managers, irrigators, non-profit groups, and members of the local engineering community.

Stakeholder meetings were held throughout the duration of the Atlas project to seek input at key milestones, such as Work Plan Development, Review of Preliminary Findings, Presentation of Hazards Analysis approach, and review of the Draft Atlas. Meetings were led by Kristine Hilt of Blaine County, Jon Ambrose of Cardno and Zach Hill of Ecosystem Sciences. Meetings were held open to the public, with agenda and minutes posted to the County web site.

The following excerpt from the Stakeholder Engagement document describes the overall intent of the stakeholder participation:

> *Stakeholder Group Participation*
>
> *The County and Cardno wish to engage a stakeholder group over the course of completing the watershed assessment to:*
>
> *1. Gain a broader perspective on the most pressing challenges faced by vested groups in management of river resources and adjacent infrastructure in the Big Wood valley.*
>
> *2. Access groups and individuals with institutional memory and available data sources that may improve the quality of the assessment.*
>
> *3. Share and receive input on provisional data and analysis at key project milestones*
>
> *4. Work with other groups that share responsibility over river and resource management in the Big Wood valley to develop a product that creates value for the broader community."*

Photo: Steve Butler fpr Blaine County

The Stakeholder group provided important sources of information and feedback that was critical in completion of the Atlas, and we thank them for their participation. The Stakeholder group consisted of representatives from the following organizations:

- Unites States Forest Service
- Bureau of Land Management
- Idaho Dept. of Fish & Game
- Idaho Dept. of Water Resources
- Cities of Bellevue, Hailey and Ketchum
- Trout Unlimited
- The Nature Conservancy
- Wood River Land Trust
- Idaho Conservation League
- Flood Control District #9
- Hiawatha Canal Company
- Galena Engineering
- Various members of the public

Blaine County was represented by the following individuals:

- Former County Commissioners Larry Schoen, Len Harlig and Alan Reynolds
- Commissioner Jacob Greenberg
- Commissioner Angenie McCleary
- Commissioner Dick Fosbury
- County Engineer Jeff Loomis
- County Floodplain Manager Kristine Hilt
- Former County Engineer Jim Koonce

Technical Data, Sources and Availability

Many data sources and reference documents were used in preparation of the Big Wood River Atlas. Data such as aerial imagery and geospatial data were provided through various sources such as Blaine County and the USDA' National Agriculture Imagery Program (NAIP). Where applicable, reference is given to those primary data sources in the relevant sections of the Atlas. Similarly, key reference documents used in the development of the Big Wood Atlas are provided in relevant sections and also in a comprehensive reference list at the end of the document.

Primary data sources such as georectified aerial photos and geospatial data developed by Cardno and Ecosystem Science (i.e., channel traces, hazard boundaries) will be made available through Blaine County's Planning Department. Those data sources will have appropriate metadata associated with data files describing the sources of information, dates of data collection, and analytical procedures used in data manipulation/analyses. Recognizing the value to the public, Blaine County may develop a web-based application in the future to present many of the data layers developed for and used in the Atlas.

Recommendations for Future Study

The background data investigation and process of developing the Atlas revealed some key areas of recommendation for continued work, and other areas representing significant data gaps that could provide greater understanding of the Big Wood River ecosystem.

LiDAR- The value of Light Detection and Ranging (LiDAR) survey of the river corridor cannot be overstated. We recommend that LiDAR surveys are completed on a regular basis (consider every 5 years) to track channel and floodplain evolution.

Aerial imagery- Aerial imagery is provided through the NAIP every two years. When floods occur in off years, it could be advantageous to collect aerial imagery both during flood events and also later in the same year following major floods.

Bathymetric Surveys- Bathymetric surveys provide topographic data of the river bed and banks and can be collected using various methods. Periodic bathymetric surveys can be useful to document bed elevation changes over time in river reaches subject to incision or aggradation.

Sediment Transport Studies-Limited work has been completed in the Big Wood River with respect to sediment transport. The only empirical study of sediment transport in the Big Wood River was completed by the USFS in 2004, and at a single cross section upstream of Ketchum. Given the large role played by sediment production and delivery in the channel evolution of the Big Wood River, and the highly variable nature of sediment delivery throughout the watershed, detailed studies of sediment supply and transport would provide valuable baseline data with many applications to river managers and project proponents. Currently, many restoration projects implemented in the Big Wood River rely on extremely coarse sediment data to make recommendations for channel design; better data resolution is needed in design of projects seeking to address sediment transport.

Habitat Mapping and Biological Sampling- Little investigation of the correlation between habitat units and biological productivity has been completed in the Big Wood River. Studies competed by Thurow in the late 1980's remain perhaps the most comprehensive evaluation of habitat availability and trout populations. A more current understanding of the distribution, quantity, and quality of aquatic habitat on a reach by reach basis would greatly aid in prioritizing restoration opportunities and guiding restoration design.

Effectiveness Monitoring of Restoration Projects- More rigorous monitoring and analysis of specific geomorphic, hydraulic, and habitat variables associated with completed restoration projects is recommended. This point is elaborated upon in Chapter 4 - Project Framework. It is essential to monitor outcomes of river projects over time to determine if goals are met, if design assumptions are confirmed, and to improve the quality of project design and review in the future.

Reach and Project Prioritization- This Atlas presents the framework for an approach to process based restoration in the Big Wood River. This Atlas also provides much of the data needed to pursue future efforts of a more rigorous and data driven prioritization of restoration opportunities. Though specific types of restoration opportunities were identified for each reach, those recommendations represent the product of a coarse analysis, with no specific locations or design concepts provided. Basin stakeholders and project sponsors will likely better achieve their overall program objectives through a strategic prioritization of project types within particular reaches that may yield the greatest geomorphic, flooding, and habitat benefits.

- *Big Wood River at flood stage transporting wood and sediment, June 2017.*

History of the Big Wood River Valley

- As recounted by Jim Koonce. Jim was born and raised in Hailey, and served as the Blaine County Engineer for upwards of 41 years.

“The Big Wood River is an extremely powerful and laterally mobile water course that will surprise and humble those who do not recognize and respect that power. Studying failures advances science and the Big Wood River always gets the last say. ”

The Wood River Valley of central Idaho is surrounded by the Boulder, Pioneer, and Smoky mountains. The bedrock geology of this area is complex and comprised primarily of plates of Paleozoic marine rocks such as limestone. These plates are intruded by the Cretaceous Idaho batholith and Eocene dikes and stocks, and overlain by sedimentary and volcanic rocks of the Eocene Challis Volcanics. Although no historically active faults are known in the area, Blaine County is located within the Idaho Seismic Belt, which is among the most seismically active areas in Idaho. The present valley is a topographic reflection of the Wood River graben, which is filled by Cenozoic deposits comprised of sand, gravel, cobble and sediment, sometimes reaching several hundred feet in depth.

The more recent geology of the area is a product of Pleistocene glaciation in the high mountains, which produced outwash deposits and terraces in the Wood River and tributary valleys. Cyclical episodes of Pleistocene glaciation between about 2.5 million to 10,000 years ago produced glaciers in most of the high mountain ranges surrounding the Wood River Valley. The glaciers themselves usually did not reach as far down into the valley as the Big Wood River. All high valleys in the Big Wood drainage experienced glacial activity during the Pleistocene. Most of the glacial till in terminal and lateral moraines were washed down into the stream basins as sediment that diminishes in size the further downstream you go. Very few moraines are still preserved south of Galena Summit, but can be seen in Prairie Creek and throughout the Sawtooth Valley to the north. Challis Volcanics and more recent basaltic flows filled these erosion channels and were subsequently eroded, transported downstream and deposited in stream valleys. Post-glacial deposits are mainly the result of active slope processes, including landslides, that tend to thicken the valley fill, and active river-channel processes that redistribute gravel and sand.

Fur trappers roamed the Rocky Mountains in the early 1800s. Alexander Ross led a team of trappers to the Wood River Valley in 1824. According to Ross’s accounts from 1825, “In the vicinity of [the Trail Creek confluence with the Big Wood River] were the finest appearances of beaver we had yet seen. In one place we counted 148 poplar trees cut down by that animal in less than one hundred yards square.” (from Rapp 2006, as quoted from Spaulding, 1956). Along with contributing to human settlement of the Wood River valley, beaver trapping resulted in removal of a key participant in the riverine ecosystem, which undoubtedly substantially influenced aquatic and riparian habitats (Rapp, 2006)

One hour catch in the Big Wood River Hailey, ID.
Courtesy of Blaine County Historical Museum

Old trestle bridge near Colorado Gulch with log cribbing for abutments.
Photo by Martyn Mallory (1880-1936). Courtesy of Blaine County Library

■ *In 1936, Union Pacific started building Sun Valley.* Courtesy of Blaine County Library

The area contains a variety of metallic ore deposits which proved critical to the settlement and early economic development of the Wood River valley. Mining of these deposits left a legacy of impacts to local streams and rivers. The first mining claim was filed in the Gold Belt west of Hailey in the summer of 1865. Mines in the Wood River Valley area date back to the 1860s and are partly responsible for the establishment of the Idaho Territory. The mining districts include the Mineral Hill, Bullion, Warm Springs, Camas and the Hailey Gold Belt. These mines produced silver, gold, lead, and zinc, some as recently as the 1970s.

"Settlers and miners came in earnest in 1879 and later to mine the rich silver deposits of Broadford, Bullion, Galena, East Fork and elsewhere. There was no stream protection or environmental problems related to any stream before this time. Sadly, they are everywhere now. Although no longer active, the effects of mining still play a major role as significant cultural and historical resources as well as ongoing sources of environmental concerns" - Jim Koonce

Although not as prominent as the mining industry, a parallel economic force in the early settlement of the Wood River valley, starting in 1880, was sheep. From 1910-1920 more than one million sheep annually were raised or trailed through the Wood River Valley, making it one of the largest sheep shipping centers in the world, second only to Sydney, Australia. The impact of sheep grazing on riparian communities and channel geomorphology in the Wood River valley is not well documented, nor investigated as part of this study. The area's sheep industry has substantially diminished in recent years, but several sheep ranching outfits continue to operate in the valley and historic river crossings are still used to this day.

■ *Boxcar Bend, Big Wood River.*
Courtesy of Wood River Land Trust.

The Union Pacific railroad skirted the banks of the Big Wood River much of the way through the Wood River Valley from north to south. It was originally built in the early 1880s to serve the booming mining industry sweeping across the Western states at the time. While this industry largely collapsed before the turn of the 20th century, the railroad found other sources of traffic for several decades following. During the 1930s, the Union Pacific railroad company developed the popular Sun Valley Resort, sparking a resurgence of railroad traffic until the 1960s. As the years passed and traffic dried up, Union Pacific found little remaining use for the branch, downgrading its status until it was finally abandoned during the mid-1980s. Today, the abandoned railroad serves as a maintained trail along the length of the entire valley, adjacent to the river in many locations.

"Evidence visible 50 years ago below the alluvial terrace west of W. Channel Ln. (East Fork Rd) and east of Highway 75 seems to prove that the Oregon Shortline Railroad attempted to construct the railroad alignment north next to the Big Wood River in 1884. This railroad embankment extended northerly past the Triumph Mine tipples (a ramp that ore trucks back up to dump into railroad cars). There was abundant lava rock evidence that they riprapped the embankment extensively to protect from erosion. At sometime later that year, railroad contractors backed up south of East Fork Road, climbed northwest up onto the high Terrace and continued to Ketchum with the tracks.

All dump ramps were well south of this embankment downstream of the river meander and this railroad bed was never used. The next major left hand meander upstream is called Boxcar Bend and Union Pacific and maybe Oregon Short Line Railroad have fought continuously to protect the tracks, which were finally undermined by the river in about 1983 even though six or more railroad box cars were placed in the river for protection.

These box cars were used as early as 1950s and mostly have gravitated out of sight by turbulent erosive forces. Farmers and settlers treasured their land (and still do) and used old car bodies in many places instead of riprap. This was evident on East Fork and one old car body still rests on the West Bank of the Big Wood between the Hulen Meadows bridge and Lake Creek confluence. Since there was a short span wooden sheep bridge just downstream of this wreck, which washed out in 1974 it may have been placed there to protect this bridge from being circumvented or washed out. Sheep used this bridge in my youth in the 1950s.

Continued; History of the Big Wood River Valley

In 1936, Union Pacific started building Sun Valley. Wealthy new residents wanted homesites as close as possible to the streams and rivers and these homes were protected by riprap shortly there after. I saw this near Hideaway Motel area of west Ketchum and below Guyer Hot Springs on Warm Springs Creek in my youth by the mid-1950s. There was riprap used around the black railroad bridges near St. Luke's and below East Fork.

The old Deer Creek Bridge was riprapped and so was the "old red bridge" on Bullion Street in Hailey at least by 1954. I lived just east of the Deer Creek Bridge and had relatives next to the Bullion Street bridge. Hailey kids swam in the deep pool at the base of Carbonate just upstream, so I saw this. To illustrate the power of river turbulence on objects in the Big Wood River, it was common practice to ford the river just upstream of the Bullion Street bridge because the steel truss structure was unable to carry the load of a D7 cat. In the 1940s my grandfather held me and my brothers hands while a D7 cat tried to ford the river. It was instantly undermined, stalled and stuck in the river sediment. The cat Skinner was rescued by rope as I recall and the cat apparently towed out later. The Board Sawmill owners cut off a major meander to the east and downstream of the Bullion Street bridge and turned the deep thalweg into their log pond. This occurred perhaps as early as the 1930s. It was in use in the 1940s when Hailey urchins played along the river. The river was straightened and controlled by all sorts of car bodies and steel waste. This material is still evident visible today as you walk the east bank above the Bow Bridge. No one thought anything of this at the time. Bill Janss bought Sun Valley from the Union Pacific in 1964 and this set off rapid development on the tributaries and Big Wood River from North Fork at least to Hailey.

Streamside owners, the cities, Blaine County Flood Control District and Army Corps have been performing SAP projects of questionable longevity and efficacy ever since. Other than where the river touches mountains, the only place I am aware of that the Big Wood flows with safe bedrock on both banks is adjacent to portions of Audubon place below the East Fork confluence. All other stretches of the Big Wood River are highly susceptible to erosion and meander growth at flows of 3000 cfs or higher (Hailey Gage).

Some banks with dense root vegetation are remarkably stable. The greatest intensity of riprapping was probably done by the Army Corps of Engineers at the request of local authorities starting in 1965. The Corps seemed to have plenty of funds during that period and found projects for the next 20 years or more. There was no objection that I remember until perhaps 1986 after Geomax introduced the concept of drop structures. Bio stabilization techniques were alien to this valley until perhaps the early 1980s. Very few of those drop structures are still in place or without serious damage. There was very little maintenance on them I believe. Soon after in the 1980s, river experts introduced many different bio stabilization techniques that have worked with varying degrees of effectiveness. River science has advanced a great deal by failures and in my 55 years of watching scores of different techniques I can't think of one that has not failed to at least a small degree. I am aware of two that are still installed because the river moved.

I saw the Big Wood River eroding the bank very close to a Zinc Spur Subdivision house in 1983 at the rate of 1 ft./min. Aerial photographs prove the same river eroded laterally 350 feet during the 1983 flood in Flying Heart Ranch Subdivision. The Big Wood River is truly a very mobile stream. I believe the disparity in high and low flows from 1915 to 1955 versus 1956 to present are indicative of climate change. Army Corps hydrologists also suspect a compressed runoff window. Coincidental with this is the appearance of many volunteer Douglas firs south of Ketchum where they have never grown before. We are probably both right and it seems interesting and meaningful.

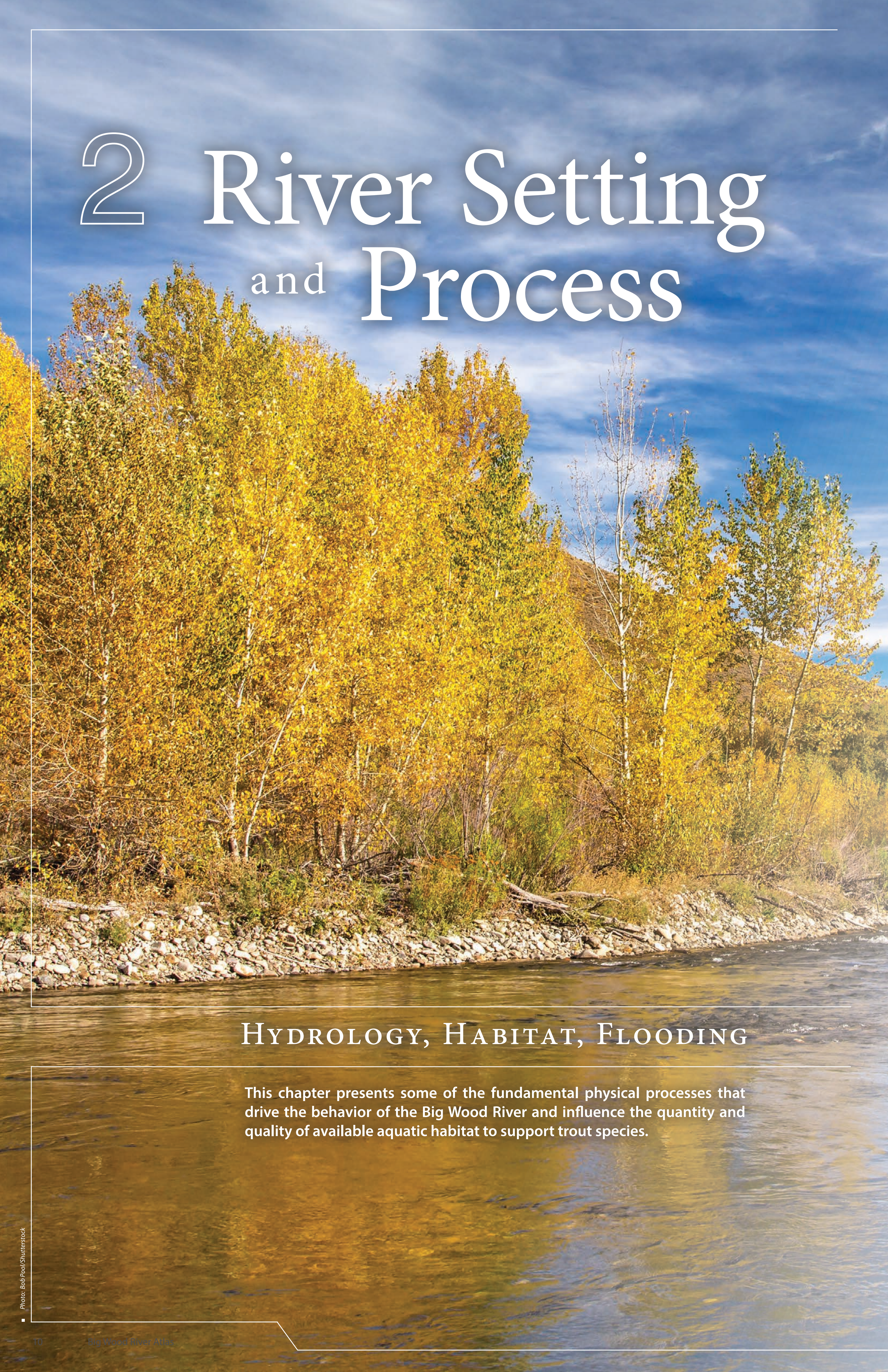
The nasty wet snow to rain storm of late January to the first days of February, 1963 had not been seen before as far as I can tell. Several inches of moisture fell on frozen ground and lead to flash floods out of Indian Creek, Quigley, Slaughterhouse and Siemens canyons, Bellevue. Since then we have observed similar events several times in the months of March. These last events were characterized by warm, wet weather events where low elevation draws and even flat fields north of Bellevue in Slaughterhouse Gulch as well as School Boy Gulch, Outcry Creek and Ohio Gulch almost instantly liquefied and flooded roads in residential areas.

This probably is a new normal perhaps related to climate change. Further evidence of faulting from severe folding and Mountain building events (orogeny), is what appears to be receded fault scarps from Broadford to Baldy. Normal faults dropped land masses that then led to the creation of canyons and valleys which were further defined by glaciation and stream erosion. The south side of East Fork has this characteristic as well.

It would not be hyperbole to say that most meander apogees and fragile banks from above Ketchum to below Bellevue have been riprapped to prevent loss of land, bridges, roads or other improvements." - Jim Koonce

■ Photos on this page: Big Wood River, oblique aerial images from 1965. Bulldozing and grading of the river channel and streambanks.

■ Big Wood River, oblique aerial images from 1965. Above: Hospital Bridge. Below: Warm Springs Bridge

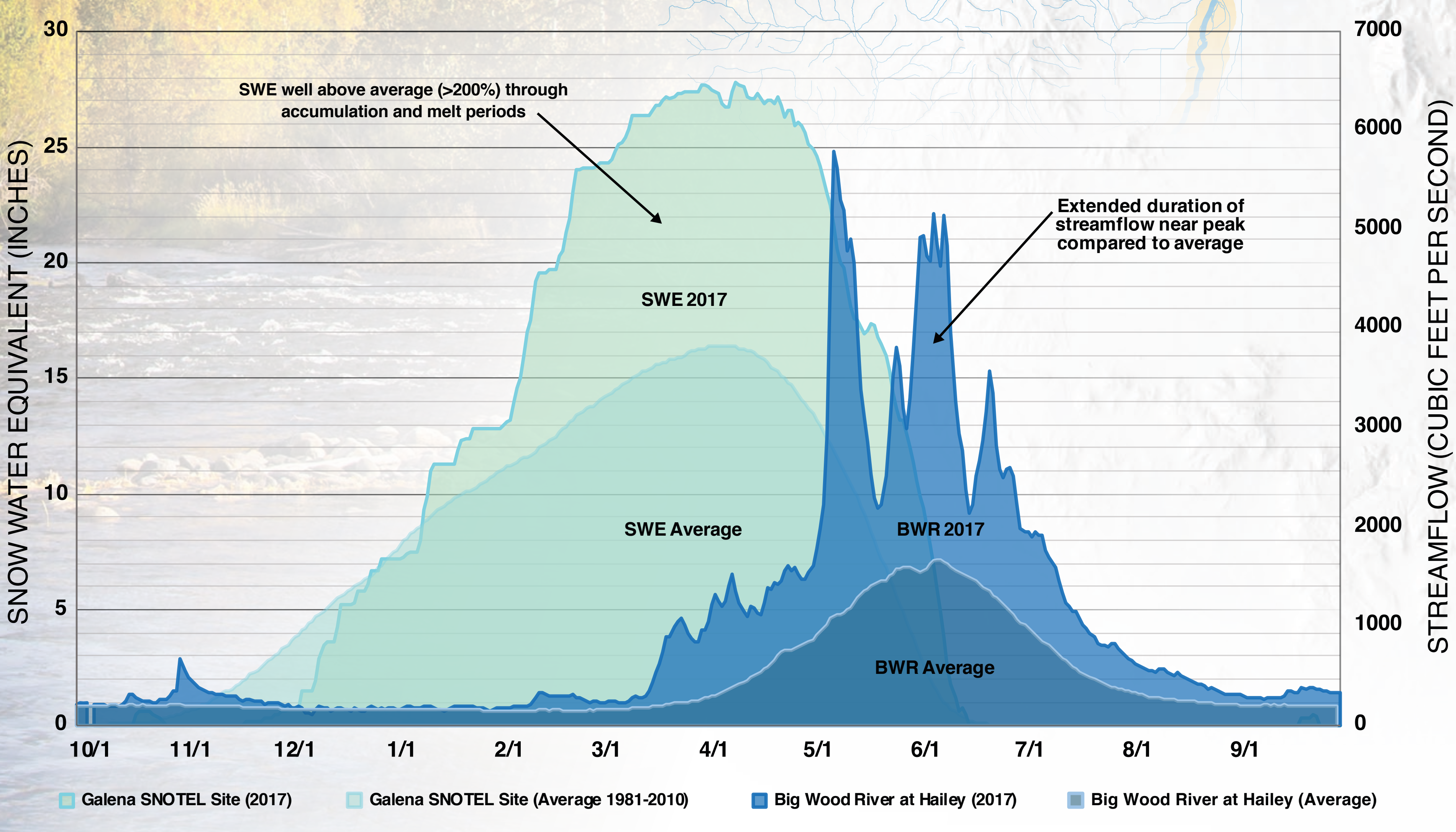


2 River Setting and Process

Hydrology, Habitat, Flooding

This chapter presents some of the fundamental physical processes that drive the behavior of the Big Wood River and influence the quantity and quality of available aquatic habitat to support trout species.

Photo: Bob Pool/Shutterstock



Big Wood River Watershed - Snow Water Equivalent versus Streamflow (2017 Water Year and Long Term Average)

2017 saw a significant climatological event in the Big Wood River watershed, leading to an unprecedented hydrological event that caused a major geomorphic response along the entirety of the river corridor. The graph above presents Snow Water Equivalent and Streamflow for Calendar Year 2017 compared to long term averages. For much of the 2017 winter season, snow water equivalent (the amount of water contained in the snowpack) exceeded 200% of the 30 year (1981-2010) average. The hydrologic response led to an early occurrence, high magnitude, and extreme duration of flood flows. 2017 experienced the second highest flood peak in recorded history at Hailey (USGS Station 13139510) but the longest duration of flood flows in excess of the bankfull flow (>50 days), resulting in significant flooding and channel response.

Fisheries and Habitat

The Big Wood River watershed is valued both locally and regionally as a high quality, freestone fishery supporting abundant trout species. Beyond the intrinsic ecological value of functional aquatic habitat, the tourism generated from trout fishing is a significant contributor to the economic health of the Big Wood community, with bigger and more plentiful fish leading to increased tourism.

This assessment does not include additional data collection or analysis related to fish populations in the Big Wood River or correlations of habitat types to fish densities/presence. Habitat studies of the Big Wood River completed by Idaho Department of Fish and Game (Thurow, 1987 and 1990) remain the most comprehensive investigations of fisheries populations relative to river morphology and habitat availability ever completed. Their findings support process based habitat restoration to maintain and restore high quality fisheries to the Big Wood River.

Among the key findings of these prior studies are:

- The most critical factor limiting the trout population in the Big Wood River is the amount and quality of fish habitat.
- Game fish populations in altered reaches of the Big Wood River were 1/10 of those in unaltered, or "natural" reaches.
- **Trout densities were eight to ten times larger in unaltered reaches where cover components were present than in reaches with no cover, or in reaches with rock revetments.**
- Large woody debris were the most preferred cover component for wild rainbow trout
- The presence of riprap decreased trout densities to the same level as river reaches with no cover habitat

The implications for future restoration priorities are clear: efforts should be undertaken to restore lost and degraded habitats through reconnection of stream channel processes and floodplain processes. Removal of riprap and reconnection of the historic channel migration zone will lead to development of a greater diversity and quantity of habitat. Where reconnection of channel and floodplain areas is not feasible, efforts should be made to maintain a functional riparian corridor to provide shade and cover to edge habitats. Bank hardening and riprap should be considered only in cases where threats to infrastructure are imminent; and to the extent feasible, revetment design should include planting benches or other design elements to maintain edge cover. Large woody debris should be incorporated where appropriate into restoration designs within the context of proper engineering and channel response analysis.

Rainbow trout utilizing instream cover from large wood. *A critical factor limiting the trout population in the Big Wood River is the amount and quality of fish habitat.*

Table - Density of wild rainbow trout observed in snorkeling transects in association with cover, no cover, and riprap; Big Wood River, 1986. IDFG snorkel data indicates the importance of maintaining cover and reducing riprap for maintenance of a healthy fishery (from Thurow 1987).

		Cover Component	No Cover Component	Riprap
Reach (trout/100m)	1	12	0.9	N/A
	2	51.8	9.1	8.8
	3	126.4	9.7	N/A
	4	43.8	4.1	9.1
	6	43.9	4	6.4
Mean Trout/ 100m		57.4	5.7	8.2
Mean trout/100m^2		17.4	1.2	2.1
Variance		0.81	0.001	0.001
Standard Deviation		0.284	0.025	0.028
Sample Size		90	85	9

Primary resources for fisheries and habitat related studies for the Big Wood River include:

Thurow 1987. Wood River Fisheries Investigations, Fish Distribution, Abundance, and Movements. Idaho Department of Fish and Game

Thurow, 1990. Effects of Stream Alterations on Rainbow Trout in the Big Wood River, Idaho. Idaho Department of Fish and Game.

Wood River Land Trust, 2005. The Big Wood River Fishery Assessment: Healthy Waters, Healthy Future.

USGS 2014. Aquatic Biological Communities and Associated Habitats at Selected Sites in the Big Wood River Watershed, South-Central Idaho.

Photo: Adobe Stock

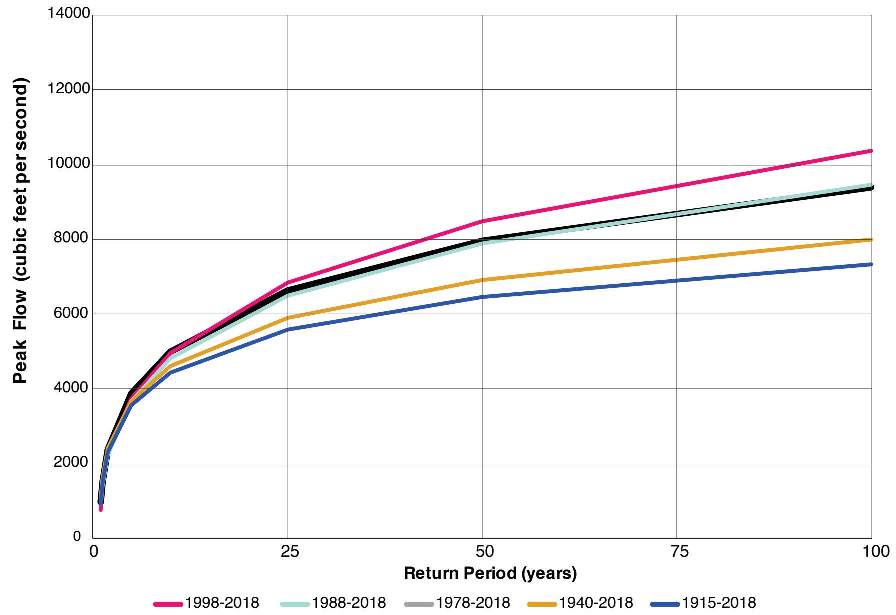
Hydrology and Flooding

The Big Wood River is subject to both a changing flow regime and river behavior that has led to increased flood damage in recent years. Peak flows are anticipated to increase in magnitude, while base flows are expected to increase in duration. Patterns of aggradation (sediment deposition) in certain river reaches create overbank flooding at lower streamflow than was experienced historically. Though relatively extreme in nature, the 2017 flood represents the type of event that river managers should anticipate and plan for.

The Big Wood River valley within the study area is located between approximately 5,000 and 6,200 feet in elevation, draining a watershed that extends to a maximum elevation of over 12,000 feet. The annual hydrograph is dominated by snowmelt-derived high flows extending from April to July, with peak flows typically occurring in May or June. During peak flows, especially when flows exceed bankfull discharge*, overbank flooding is a natural phenomenon for rivers situated in alluvial valleys, and is common in the Big Wood River valley. According to Blaine County's 2010 Flood Insurance Study (FIS), the Big Wood River in Hailey has a nominal bankfull capacity of 3,000 cfs. In the past 50 years, the Big Wood River has exceeded that flow at the Hailey Gage 19 of those years, or an average of a 2.6 year span between each recurrence. Challenges occur when natural overbank flooding creates hazards and nuisances for the surrounding communities and properties.

Hydrologic analyses for this study was completed to update prior estimate of peak flow return intervals and utilized data obtained from USGS Gage 13139510 located on the Bullion Bridge in Hailey, which has continuous flow records dating back to 1915. Using statistical methods and available flow data, flood return intervals were determined and compared with previous estimates by FEMA used in developing regulatory floodplain maps in 1998. Since 1988, the flood of record for the Big Wood River occurred in 2006, and was followed in 2017 by a flood of near comparable magnitude. Both of these events exceeded any year's peak that was considered in the effective flood studies used by FEMA to establish the current regulatory flood boundaries. Current analyses, incorporating the full data set from 1915-2019 predicts an increase in annual exceedance flows than utilized to establish the regulatory flood boundaries.

*Bankfull discharge is the discharge that fills a stable alluvial channel up to the elevation of the active floodplain (USDA 2001).



Comparison of peak flow estimates for Big Wood River Using the full period of record and sequentially more recent time periods, data indicates upward trends in peak flow estimates. With shifting climate, more recent hydrologic trends could be better predictors of future flows.

Table - Comparison of FEMA determined peak flow estimates (1915-1988) and statistically determined peak flow estimates from Hailey Gage data (1915-2018, USGS Gage 1319510).

Return Period (years)	Annual Exceedance Probability (%)	Flow Estimate (cfs)*	FEMA Flood Insurance Study Flow Estimate (cfs)
500	0.2	9,410	8,290
200	0.5	8,210	
100	1	7,320	6,680
50	2	6,450	6,000
25	4	5,590	
10	10	4,450	4,280
5	20	3,570	
2	50	2,300	
1.25	80	1,450	
1.05	95	913	

*Peak flows estimated based on Log Pearson Type III Analysis

Primary resources for Hydrology and Flooding related studies for the Big Wood River include:

FEMA, 2010. Flood Insurance Study: Blain County, Idaho and Incorporated Areas.

FEMA, 1998. Flood Insurance Study: City of Bellevue, Idaho, Blaine County.

Rapp, 2006. Geomorphic Assessment of the Big Wood River.

U.S. Army Corps of Engineers, Walla Walla District, 2019. Flood Insurance Study Hydrology Report for The Big Wood River, Warm Springs Creek, Deer Creek, East Fork Big Wood River, Trail Creek, Clear Creek, Eagle Creek, Lake Creek, Quigley Creek, Seamans Creek, Blaine County, ID.

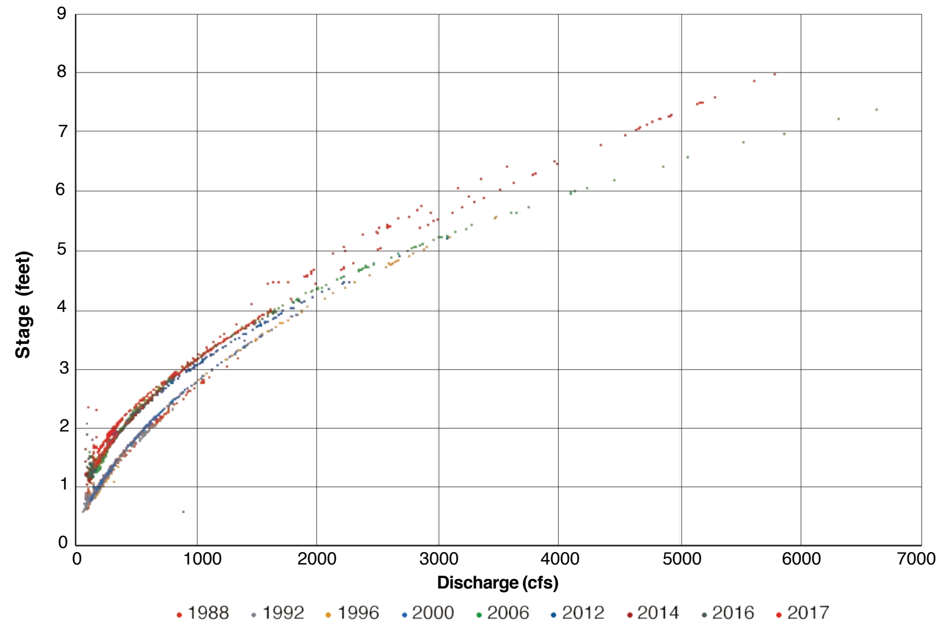
USDA NRCS, 2001. Stream Corridor Restoration: Principles, Processes, and Practices.

USGS National Water Information System: Web Interface. USGS 13139510 Big Wood River at Hailey ID Total Flow. https://nwis.waterdata.usgs.gov/nwis/uv/?site_no=13139510&agency_cd=USGS

The FEMA determined regulatory floodplain is of the official predictive tool to evaluate flood hazards along the Big Wood River for the County's residents. Flood mapping is a very useful hazard evaluation tool for the community; but, given the outdated peak flow estimates and also the coarse topography used in the FEMA modeling, the FEMA floodplain extents likely underestimate actual flood hazards. In addition to potential underestimates in flood levels, a number of other factors can further aggravate local flooding along the Big Wood, with two worth discussing in more detail: shallow channel geometry and debris accumulations. Shallow channels in combination with erodible banks can lead to rapid channel shifts, subsequently changing flood patterns. To compound this, certain portions of the river have shown signs of aggradation, further reducing channel capacity, and increasing the frequency of overbank flooding. Evidence of channel aggradation is evident both from a comparison of 2016 and 2017 LiDAR data (shown in the reach maps) and in an analysis of stage-discharge relationships from various years for the Hailey Gage (see graph). Over time, as the channel aggrades, bankfull capacity decreases, meaning smaller, and more frequent, magnitude floods will result in overbank flooding.

Debris accumulation, typically in the form of woody debris, at channel obstructions is a common occurrence along the Big Wood River during major flood events (Photo Right). Whether upstream of a bridge pier, diversion gate, or mid-channel gravel bar, these debris jams create local effects by inducing bed or bank scour and can also exacerbate local flooding by raising water surface elevations upstream of obstructions. As restoration efforts employ the use of woody debris, this flood impact potential needs to be evaluated by designers.

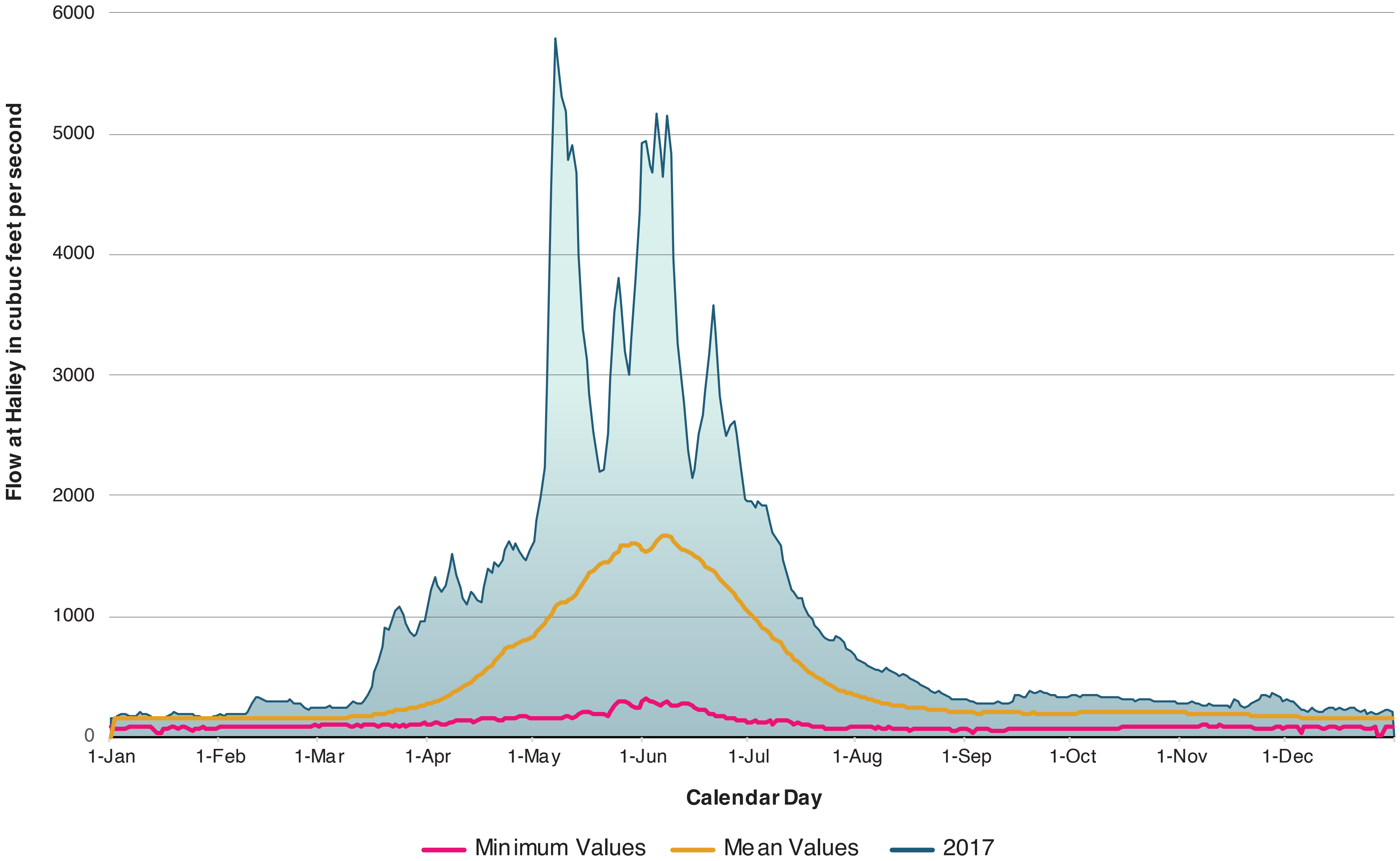
A large portion of the residential development in the Wood River valley is located both adjacent to the river and within historical floodplain areas. Current and accurate peak flow predictions and flood limits are critical for planning, and existing information is over 20 years old. As of the writing of this Atlas, FEMA is in the process of updating both the peak flow estimates and modeling work to delineate regulatory flood boundaries. This Atlas also offers an updated approach to considering flood hazard boundaries in Chapter 3.



Historical Stage - Discharge at Hailey Gage

The analysis revealed an increase in water surface elevations over time for floods of similar magnitude, possibly a result of streambed aggradation.

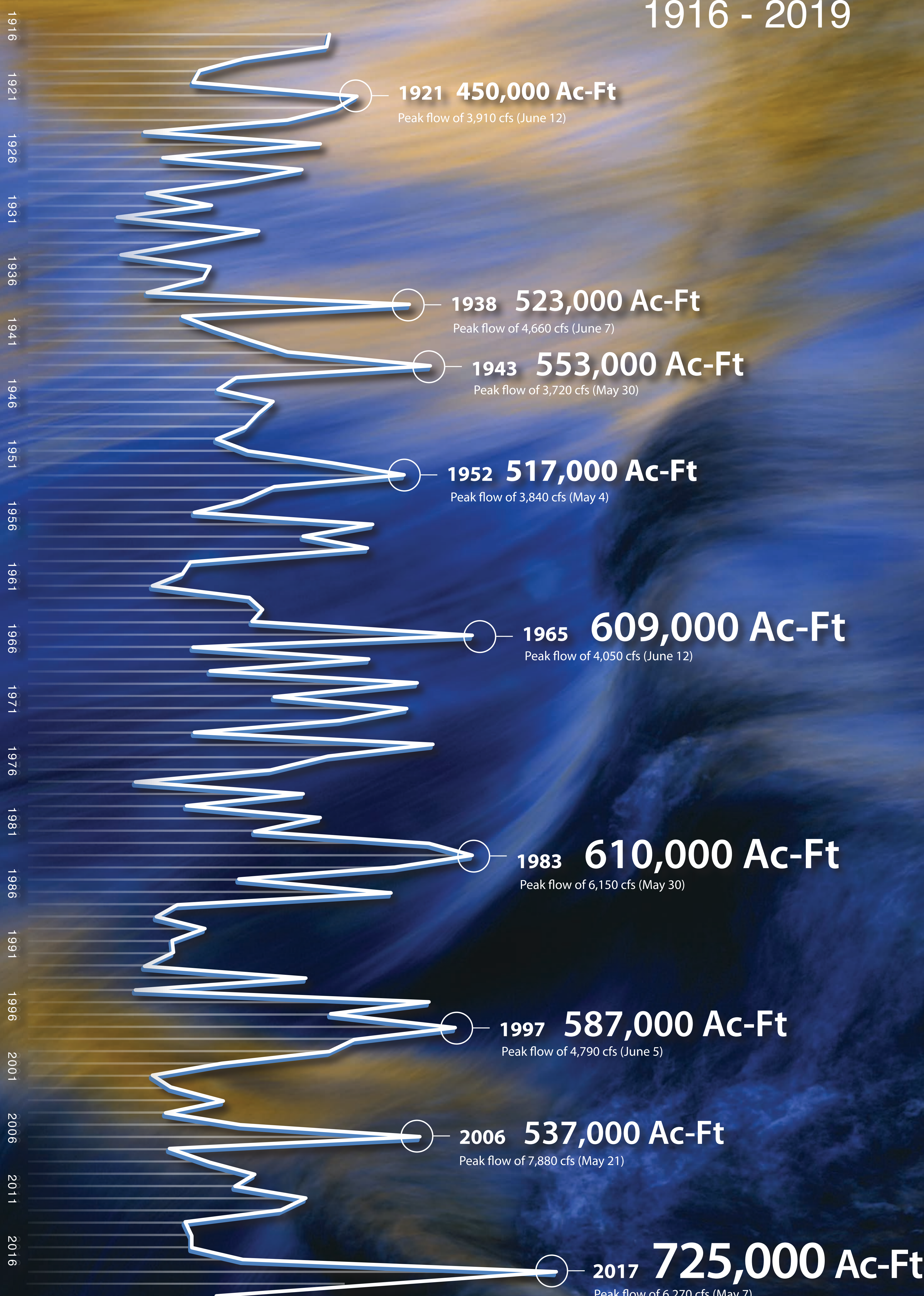
Woody Debris accumulation at Highway 75 bridge pier.



Comparison of Annual Flow Statistics to the 2017 Calendar Year.

Flood History of the Big Wood River

1916 - 2019



- *High water flows and flooding in the Big Wood River are a normal and recurring event. This hygrograph / time line illustrates the total annual yield of river flow passing Hailey (in acre/feet) along with major peak flow events (in cubic feet per second). High flow and flood events have increased in magnitude over this time period.*

Fires and Floods

Up until the last 15 years, wildfire had not been a major factor in the Big Wood River watershed or in the river's channel behavior or flood response in recent times. However, two large wildfires in the Big Wood River watershed, bracketed by two major flood events may have contributed significantly to the extensive channel changes and flooding experienced in 2017.

The flood of record occurred in the Big Wood River (7,880 cfs at Hailey) in May 2006. A period of relatively low flows followed until the flood of 2017 (6,270 cfs at Hailey). During this 11-year period, the Big Wood River experienced very few flows in excess of a 2 year-event (approx. 2,100 cfs), with no single day's median flow exceeding a 5-year flood level (approx. 3,300 cfs). This period of low streamflow coincided with 2 of the largest wildfires in the watershed in recent memory: the Castle Creek Fire in 2007 and the Beaver Creek Fire in 2013.

The Castle Creek fire burned 48,520 acres and suppression costs topped $30 million. Affected land was dominated by moderate (16,888 acres) and high (10,946 acres) burn severity. Following a post-fire storm event on September 5, the Big Wood River ran turbid for several days and deposited fine sediment along shallow depositional areas. The affected areas included Greenhorn Creek, Warm Springs Creek, Adams Gulch, Fox Creek, Barr Gulch and the East Fork Baker Creek.

The Beaver Creek fire burned 111,497 acres and had severe impacts on sediment loads in tributaries to the Big Wood River. A majority of the burned area was classified as "moderate severity" by the USFS and occurred primarily on Forest Service land. The primary impacted tributaries included Greenhorn Creek, Deer Creek, Croy Creek, Baker Creek and Warm Springs Creek. On September 2nd, a day after the fire was contained, a large thunderstorm produced ~0.75" of rainfall over the burned zone within 1-1.5 hours. Numerous debris/mud flows and flooding occurred in drainages. Subsequent storms occurred on September 3rd and 5th resulting in more debris flows and overland flooding. Large sediment deposits were observed along Baker Creek, Warm Springs Creek, and the Big Wood River following the events.

The increased sediment yield generated from two large fires in the watershed, along with the lack of channel forming flow events between 2007 and 2016, likely led to an abundance of stored sediment in the watershed, particularly in areas affected by fire. The 2017 flood was unprecedented in its duration, with over 50 days of streamflow in excess of the 2-year flood and 20 days in excess of a 10-year flood. The USFS studied sediment transport in the Big Wood River (King 2014) and found that flows in excess of the 1.5-year flood are capable of moving the larger sediment sizes observed in the Big Wood River. The duration of flows in excess of the 1.5 year flood in 2017 provided the river the means to transport significant quantities of stored sediment in addition to recruit more sediment as a result of bank erosion and channel avulsions, and to experience rapid channel adjustments not typically observed in a single flood.

Though "significant" and "uncharacteristic", the 2017 flood event is indicative of the type of channel response that could be expected as fire incidence in the watershed becomes more common and more severe, and as long periods of low flows are interrupted by large peak flow events.

"Projected climatic trends, increased frequency of wildfires, and changing hydrology are likely to increase sediment yields [in Idaho Rivers]… These elevated sediment yields will likely impact downstream [streams, rivers and] reservoirs, which were designed under conditions of historically lower sediment yield"

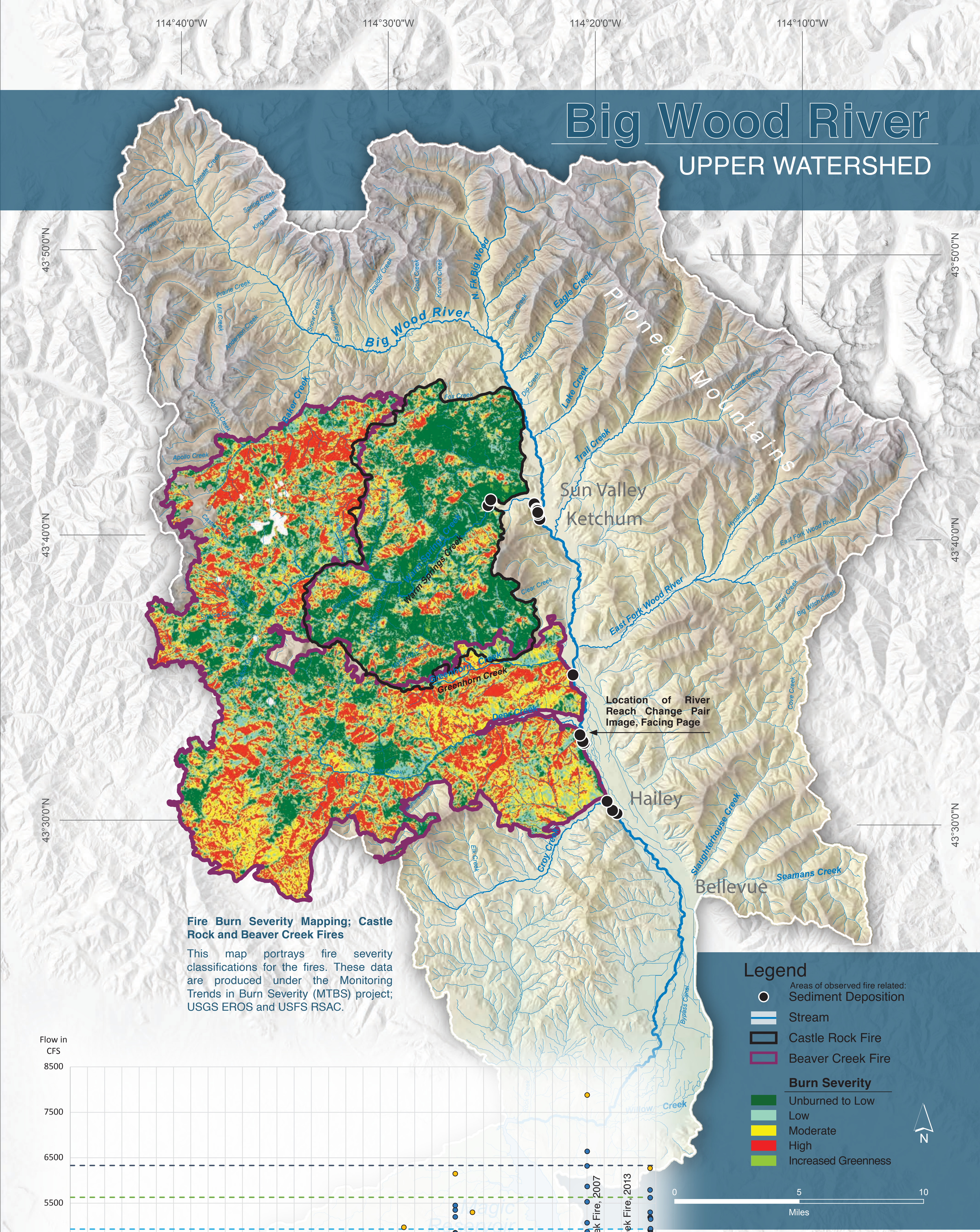
Sediment Delivery in a Changing Climate, USDA Rocky Mountain Research Station, Boise Idaho, 2014

Channel Change and Sediment Deposits, 2015-2017. River reach downstream of Deer Creek.

These images demonstrate the degree of channel change that occurred in a single reach as a result of the flood and fire processes.

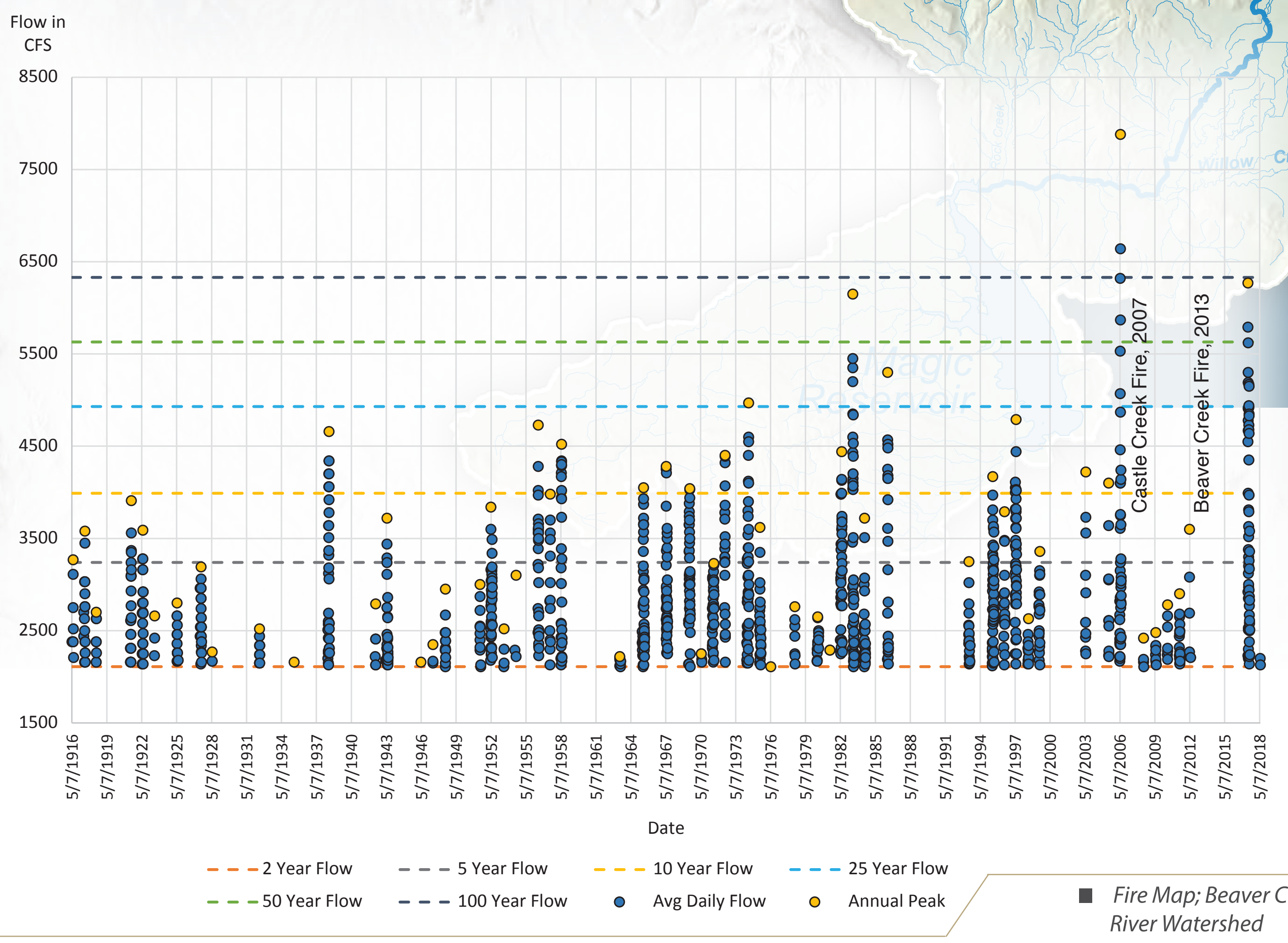
Photo: Adobe Stock

Big Wood River
UPPER WATERSHED



Fire Burn Severity Mapping; Castle Rock and Beaver Creek Fires

This map portrays fire severity classifications for the fires. These data are produced under the Monitoring Trends in Burn Severity (MTBS) project; USGS EROS and USFS RSAC.



Frequency of Flows > 2-, 5-, 10-, 25-, 50-, and 100- year Peak Flows Big Wood River at Hailey; From 1915-2018

The graph to the left depicts a blue point for each day in which the daily average flow exceeded each specified return interval and a yellow point for the peak flow (USGS Station 13139510 at Hailey). The lowest threshold shown in the graph is a 2-year flow, which is the minimum flow associated with channel forming events. Data shows a lack of channel forming events between 2007 and 2016, the same period that the watershed was affected by major fires. 2017 shows the highest duration of channel forming flows ever recorded, which led to a significant redistribution of sediments, channel change, and flooding

The Role of Wood

The role of wood, and in particular large woody debris (LWD) and associated stable log jams, is linked to geomorphic processes that benefit aquatic habitat. Woody debris plays an role in controlling channel morphology, the storage and routing of sediment and organic matter, and the creation of fish habitat.

The role of wood, and in particular large woody debris (LWD) and associated stable log jams, are linked to geomorphic processes that benefit aquatic habitat (Fox and Bolton 2003). Woody debris plays an important role in controlling channel morphology, the storage and routing of sediment and organic matter, and the creation of fish habitat (Bisson et al, 1987). The role of wood in creating local-scale habitat features through pool formation and hydraulic heterogeneity has been well known for decades (Spence et al. 1996) along with the function that wood plays as cover for juvenile salmonids vulnerable to predation (Larsson 1985) and as a source of food and nutrients (Naiman and Sedell 1979; Spence et al. 1996).

More recently, recognition has been given to the landscape and watershed scale effects of large wood present in the riverine environment. Deposition associated with stable jams has the ability to maintain vertical channel position and aggrade channels (Montgomery et al. 2003), particularly in confined reaches. In steep, glacially influenced channels with poorly consolidated substrate, removal of the hydraulic roughness created by wood and log jams can lead to sudden and catastrophic incision, particularly where peak flows are increasing due to urbanization (Booth 1990 and 1991) or climate change.

Wood removal from rivers and floodplains occurred during early European settlement of river valleys. The settlers trapped and removed beavers from the ecosystem, cleaned rivers of log jams to raft wood downstream during commercial harvest operations, scoured channels and banks during splash damming in tributaries and harvested floodplain forests that ultimately were converted to urban development.

It is likely that large stable log jams played a major role in development and maintenance of the historical anastomosing channel system described by Rapp (2006). This historical channel planform occupied a much greater portion of the valley than the modern channel, with a network of smaller and interconnected channels stabilized by mature riparian forests. Such a channel network is more resilient to disturbances such as flood, fire, and large sediment events than the modern channel, in addition to creating a more complex mosaic of habitat types throughout the floodplain that supported native fishes through various life stages.

Today's river lacks the large, mature riparian and upland forest stands and stable log jams that created and sustained this historical ecosystem; but examples are still evident of the value of log jam formation to both habitat formation and planform stabilization. Downstream of Deer Creek, channel migration and avulsion during the 2017 flood recruited substantial volumes of small and medium wood, some of which assembled into several large, semi-stable log jams. These jams have since created the deepest observed pools in the river and are stabilizing mid-channel islands (photos). The reintroduction of stable log jams throughout the study area is a key recommendation for restoring functional habitats, stabilizing eroding banks, maintaining channel planform in dynamic reaches and storing sediment. More on this topic is discussed in Chapter 4 and Appendix A.

Multiple approaches can be used to reintroduce large wood to the Big Wood River. Techniques such as flood fencing (driving wood pile arrays at select locations) can be very effective to trap smaller wood that is currently being transported downstream during typical flood events. Depending on the availability of large wood pieces, placement of key pieces throughout the watershed to act as a "foundation" to initiate wood accumulation at selected locations can also be an effective measure, often implemented via aerial transport (helicopter drop) due to transport limitations of such large pieces. Engineered log jams are specially designed and sited accumulations of wood using ballast and/or anchoring methods and are a common and effective restoration technique. All efforts to place wood in rivers should only be completed following a risk based assessment and proper geomorphic and engineering analysis, as discussed in Appendix A.

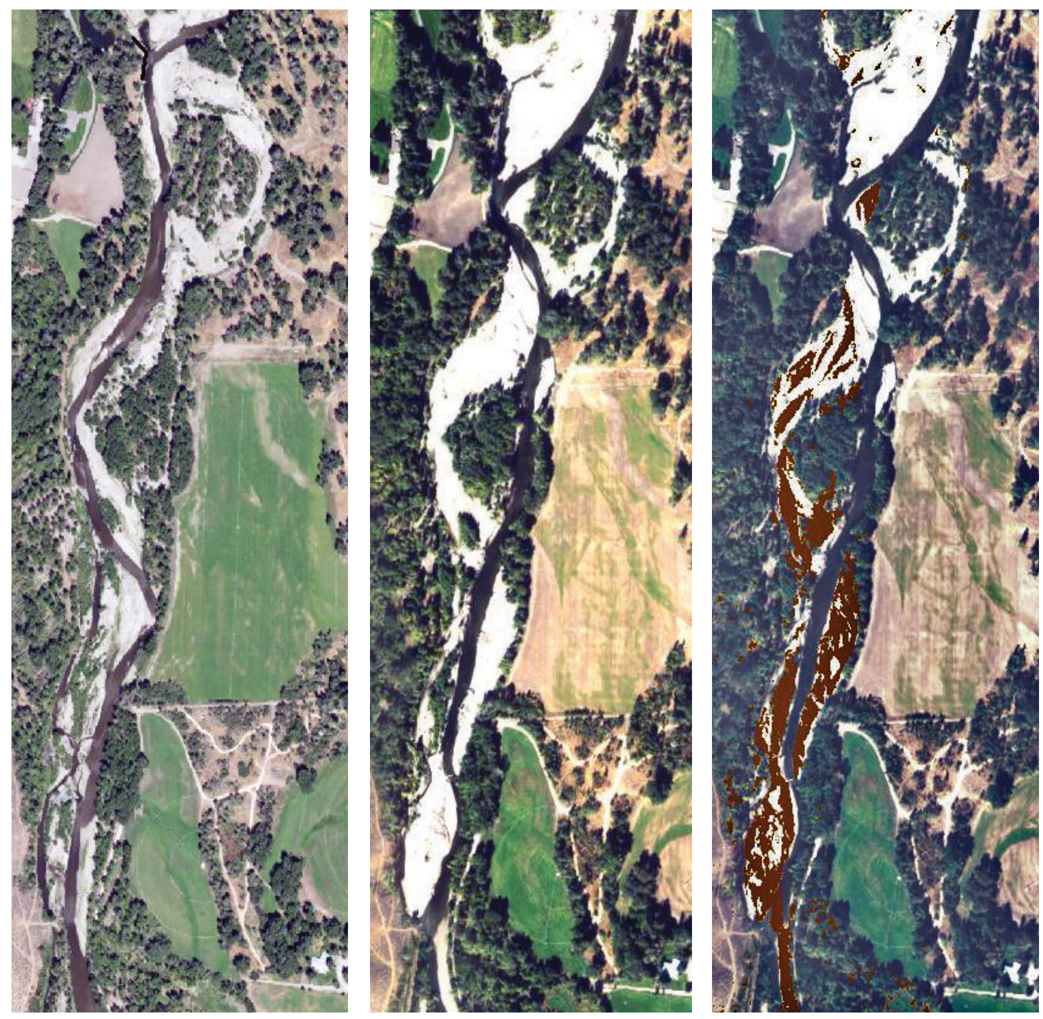
The Role of Sediment

The source, size, and quantity of sediment load in a river system is a fundamental element in how rivers form, evolve over time, and respond to watershed scale changes driven by climate, hydrology, and human disturbance.

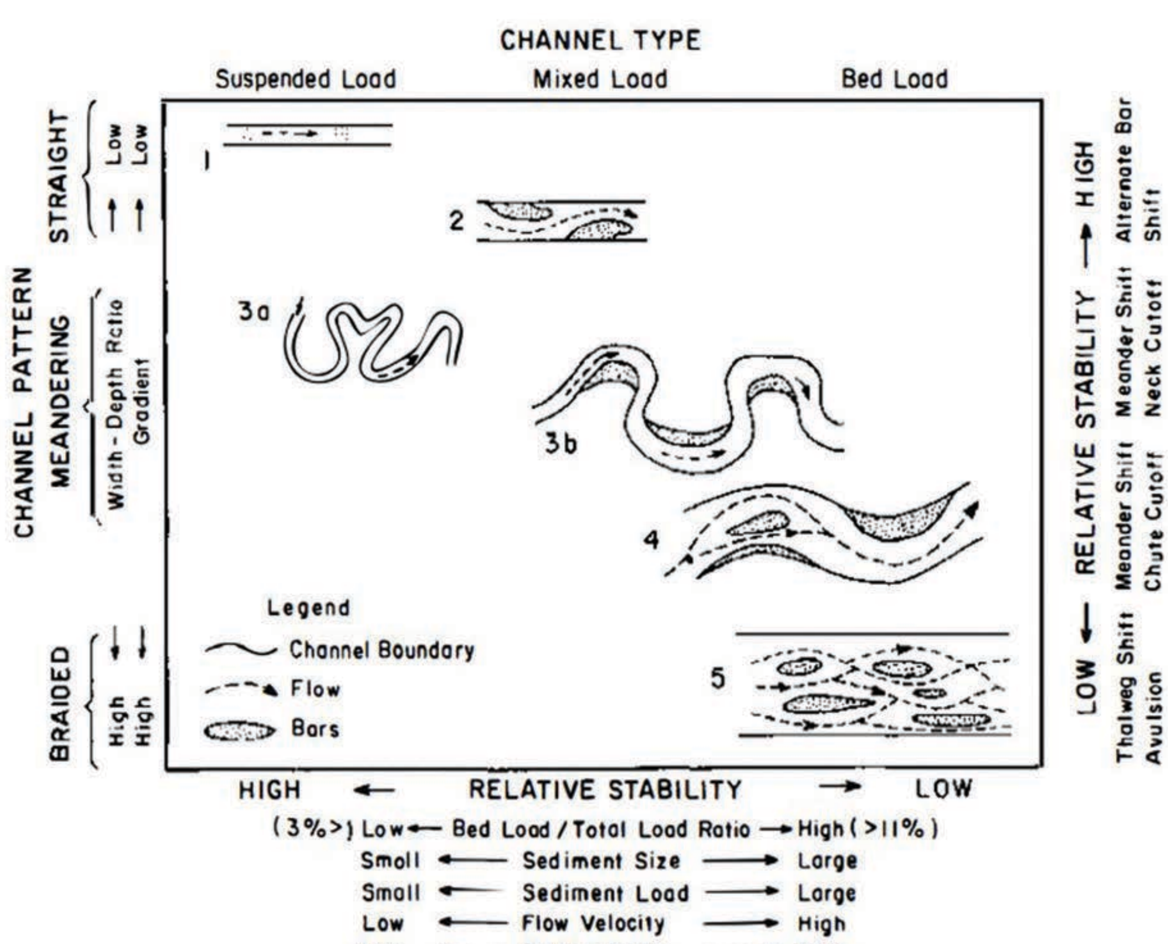
The modern day Big Wood River has been influenced by the geological history of the valley, which is underlain by thick, unconsolidated Quaternary glacial and alluvial deposits (Rapp, 2006; Lutrell and Brockway, 1984; Smith, 1959). The bed and banks of alluvial channels are composed of sediment transported by the stream. This quality makes the channels susceptible to major pattern change and to significant shifts in channel position as the alluvium is eroded, transported, and deposited. The dynamic nature of alluvial rivers makes them sensitive to changes in sediment load and water discharge over time. (Schumm, 1985).

Rapp (2006) points out the conversion of historical channel planform in the Big Wood River from a pre-settlement river dominated by anastomosing and meandering channel pattern to a post-settlement channel pattern dominated by braided and straight/sinuous reaches. Rapp describes the effects of this channel conversion as follows: “Widespread braiding, channel widening, and channel instability [in braided reaches] appear to be the result of climatic factors, potential fluxes in sediment supply, and land use activities in upstream reaches that isolate the channel from its floodplain, eliminate or restrict in-channel sediment storage functions, and increase stream power. Braided sections of the Big Wood River respond to increases in upstream stream power and sediment transport by serving as a sediment sink, partially compensating for the loss of in-channel sediment storage functions historically present in upstream reaches”.

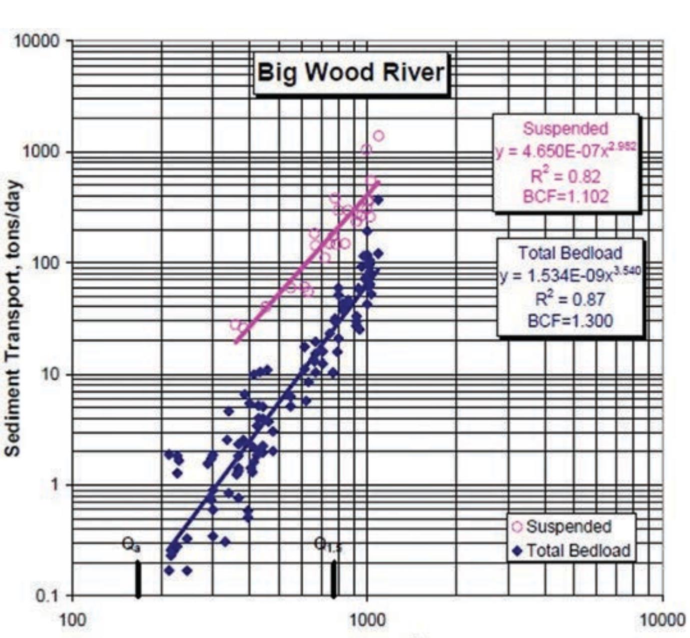
Knighton (1984) discusses the conditions necessary for the development of braided channels as: (i) an abundant bed load, (ii) erodible banks, (iii) highly variable discharge, and (iv) steep slopes. None of these conditions appears to be sufficient on its own to produce braiding, although an abundant bed load, erodible banks, and relatively high stream power are probably necessary. Where these factors occur in association, as in proglacial areas [Wood River valley], braiding tends to be most prevalent (Knighton, 1984).



■ *Areas of sediment deposition; 2015 image on left; 2017 image in center; and, sediment deposition from 2017 flood shown in brown over the 2017 aerial photo, image on right.*



■ *Above: Schumm’s classic figure: Channel classification based on pattern and type of sediment load, showing types of channels, their relative stability, and associated variables (After Schumm 1981). The Big Wood River sediment load has a high percentage of bed load (>11%) versus total load, as measured by the USFS (see accompanying image to the left), indicating relatively low inherent channel stability.*



■ *Left: Suspended and bedload measurements collected by the USFS upstream of Ketchum in 1999 and 2000 (King, 2004). Data shows that at bankfull discharges and above, that bedload comprises roughly 10-15% of the total sediment load.*

(Continued) The Role of Sediment

■ *Photos on this page: Big Wood River, oblique aerial images from 1965. Bulldozing and grading of the river channel and streambanks.*

Though the physical conditions for braid formation are clearly present in portions of the Big Wood River, the historical conversion to this form from the more stable anastomosing pattern noted by Rapp suggests the influence of watershed scale changes.

Most notably, geomorphic changes induced by channel confinement, peak flow increases, riparian forest removal, bank erosion, and increased sediment yields. Collectively, these impacts can have substantial influence on channel form and behavior.

The effects of sediment deposition during the 2017 floods on channel dynamics are evident through a comparison of aerial photos and LiDAR collected before and after the flood event. The series of photos below shows the Big Wood River just south of Bellevue before (2015) and after the 2017 flood (September 2017). The third photo in the series shows the output of a geospatial analysis that was conducted to compare topographic surfaces collected through LiDAR in 2016 and 2017. Results of the analysis depict approximate changes in gravel bar elevations attributed to the 2017 flood event. Channel movement across the braided channel has resulted from sediment deposition within the active channel and floodplain, the locations of which are clearly visible in the LiDAR differencing maps in brown. This LiDAR differencing is shown on all reach maps (Chapter 4) where data was available.

Conversion of braided reaches back to a more stable anastomosing form will provide greater resiliency to floods, fires, buffer the effects of high sediment loads and limit channel migration, while restoring ecosystem scale biological processes.

Restoration of braided reaches in the Big Wood River requires stabilizing in channel sediment deposits and riparian islands. The application of certain process based approaches to channel restoration in these areas, such as flood fencing and log jam installations, is discussed later in the document.

Gravel Removal

The high sediment loads in the Big Wood River were apparently considered a nuisance to residents in the early 1960's, as these photos of gravel removal from 1965 demonstrate. Photos indicate dozer tracks where gravel was dredged from the channel and pushes up onto banks. This was done both in the lower portions of the valley (first photo) and upper reaches (second photo), presumably to address flooding or channel migration concerns. 1965 also correlates with the initiation of levee building in the valley by the US Army Corps of Engineers (Koonce, 2020), so perhaps the two activities are associated.

Gravel removal from the river is considered to be a means of addressing symptoms, rather than causes, of river modification, geomorphic change, and flood responses. Process based approaches that deal with reversing the root causes of river modification are preferred over symptomatic approaches, and tend to provide multiple benefits and be sustainable over time. The benefits and sustainability of gravel removal are difficult to quantify, are extremely site specific, and require detailed analysis and modeling to quantify and should be pursued only following efforts at process based restoration.

The Role of Riparian Vegetation

Riparian zones adjacent to the Big Wood River contain a complex mosaic of habitats that bridge the gap between the aquatic system and its upland watershed… A healthy and diverse riparian corridor is vital to sustain a resilient river system that can provide high-quality habitat, clean water, erosion control and vibrant recreational opportunities.

Riparian zones adjacent to the Big Wood River contain a complex mosaic of habitats that bridge the gap between the aquatic system and its upland watershed. Functionally, these zones are the area of direct interaction between the river channel and the bordering landscape. This transitional corridor includes streamside vegetation, forested wetlands, and other frequently flooded habitats (Figure on bottom of page 22). Frequent disturbance in riparian zones from flooding creates complex landforms which commonly have a more rich and abundant biological community compared to upland areas (Gregory et al. 1991). A healthy and diverse riparian corridor is vital to sustain a resilient river system that can provide high-quality habitat, clean water, erosion control and vibrant recreational opportunities.

The productivity of riverine species are closely linked to the quality and biological complexity within riparian zones. These zones provide rivers a majority of their organic matter inputs, which contribute the necessary energy to sustain aquatic food webs. Riparian plant communities offer an abundant array of food resources for aquatic invertebrates which make up the base food for fish (Gregory et al. 1991; Tabacchi et al. 1998). Juvenile and adult trout populations have been shown to double in river and stream reaches which have an unconstrained riparian corridor compared to a degraded one (Gregory et al. 1991). Furthermore, mature riparian forests are the primary source of woody branches and trees in river systems that sustain habitat-forming processes. This addition of large woody debris creates the preferred habitat cover component for rainbow trout in the Big Wood River (Thurow, 1987 and 1990).

The presence of riparian vegetation is an important factor in a river systems morphology because vegetation can influence channel form, migration and erosion rates, and the formation of stable channels and islands. Streamside vegetation can decrease the number of active channels in braided rivers by increasing bank stability and reducing lateral migration rates. The resulting channels are generally deeper, narrower, and with a greater distribution of depths (Gran and Paola 2001; Tal and Paola 2007). Important lateral habitats including backwaters, eddies, and side channels are created by the interaction of flow with vegetation and woody debris (Gregory et al. 1991). The removal of riparian vegetation can destabilize riverbanks, which facilitates erosion, and ultimately increases sediment delivery into the Big Wood River (Poole and Berman 2001). Vegetation aids in bank stabilization by increasing soil cohesion through the spatial distribution of roots that physically bind the soil together (Simon and Collison 2002). Trees have been found to have the greatest capacity to increase bank stability under a wide range of conditions compared to grass species (Simon and Collison 2002).

Riparian buffers have been widely accepted as a best management practice for water quality protection because of their ability to reduce sediment inputs, filter surface runoff, and reduce pollutant concentrations (Dosskey et al. 2010; Osborne and Kovacic 1993). The buffers are also effective at reducing in-stream temperatures by shading the river and trapping cool air near the water surface (Tabacchi et al. 1998; Poole and Berman 2001). These functions are particularly important for much of the Big Wood River and its tributaries, whose water quality has been federally listed as impaired for sediments, total phosphorus, bacteria, and temperature in some locations (DEQ 2017). The Big Wood River has been impacted by urban development in the central valley, which has encroached upon or eliminated riverside vegetation in many locations. Re-introducing a multi-species forested riparian corridor may be a promising solution to the water quality impairments, as these corridors have been shown to remove greater than 90% of sediment and 80% of phosphorus from overland flow in some conditions. Forested buffers have been shown to be more effective at pollutant reduction than herbaceous or grass zones (Daniels and Gilliam 1996).

The importance of maintaining a forested riparian zone along the Big Wood River cannot be understated. Given the high migration and erosion rates which are characteristic of the river, private properties that have removed vegetation are likely at a higher risk of flooding, erosion, and bank failure. Revegetation of riparian zones should be considered as a cost effective alternative to bankside stabilization, which has the added benefit of improving aquatic habitat and reducing water quality impairments. Riparian habitat is an important feature of any healthy river and should be prioritized to maintain the holistic, ecological, and economic abundance of the Big Wood River.

Established riparian vegetation supporting edge habitat in Ketchum

Intact riparian corridor along the Big Wood River upstream of Ketchum

Riprap bank and cleared riparian vegetation, downstream of Ketchum

River at Glendale Road, Riparian vegetation cannot be sustained downstream of the Glendale diversion, leading to lack of bed and bank stability, thermal impacts and habitat degradation

Ecological and Geomorphic Effects of Riprap

The time line and pace of channel modification, though not covered in detail in this Atlas, generally follows the rate of community development in the Wood River valley over the last century. The result has been significant channelization of the Big Wood River for the purposes of protecting the expansion of agricultural and municipal areas into historical floodplain.

The historical transformation of the Big Wood River from an anastomosing channel network to a braided and meandering dominated channel network is discussed by Rapp (2006). The timeline and pace of channel modification, though not covered in detail in this Atlas, generally follows the rate of community development in the Wood River valley over the last century. The result has been significant channelization of the Big Wood River for the purposes of protecting the expansion of agricultural and municipal areas into historical floodplain. The main tool used to exert control over river behavior has been rock, in one form another, commonly referred to as riprap. Riprap now lines a significant portion of the banks along the Big Wood River, upwards of 40% of the total river length through the study area.

Though riprap can be quite effective in achieving its objectives of limiting channel migration and reducing flooding on a reach scale, it also alters stream morphology and aquatic habitat in manners that lead to degradation of fish populations and exacerbate flooding and erosion in untreated reaches.

Habitat Quality and Quantity

The negative impacts of riprap placement on trout populations were well documented in Thurow's seminal work in the Big Wood River (Thurow 1987 and 1990). Thurow observed trout according to various cover types and habitat units, and found that riprap areas contain the lowest percentage of trout of all observed unit types. Given the overall low utilization of riprap banks by trout in the Big Wood River, expansion of rock armoring is likely to reduce river-wide trout populations, and restoration of natural bank conditions likely to increase river-wide trout populations.

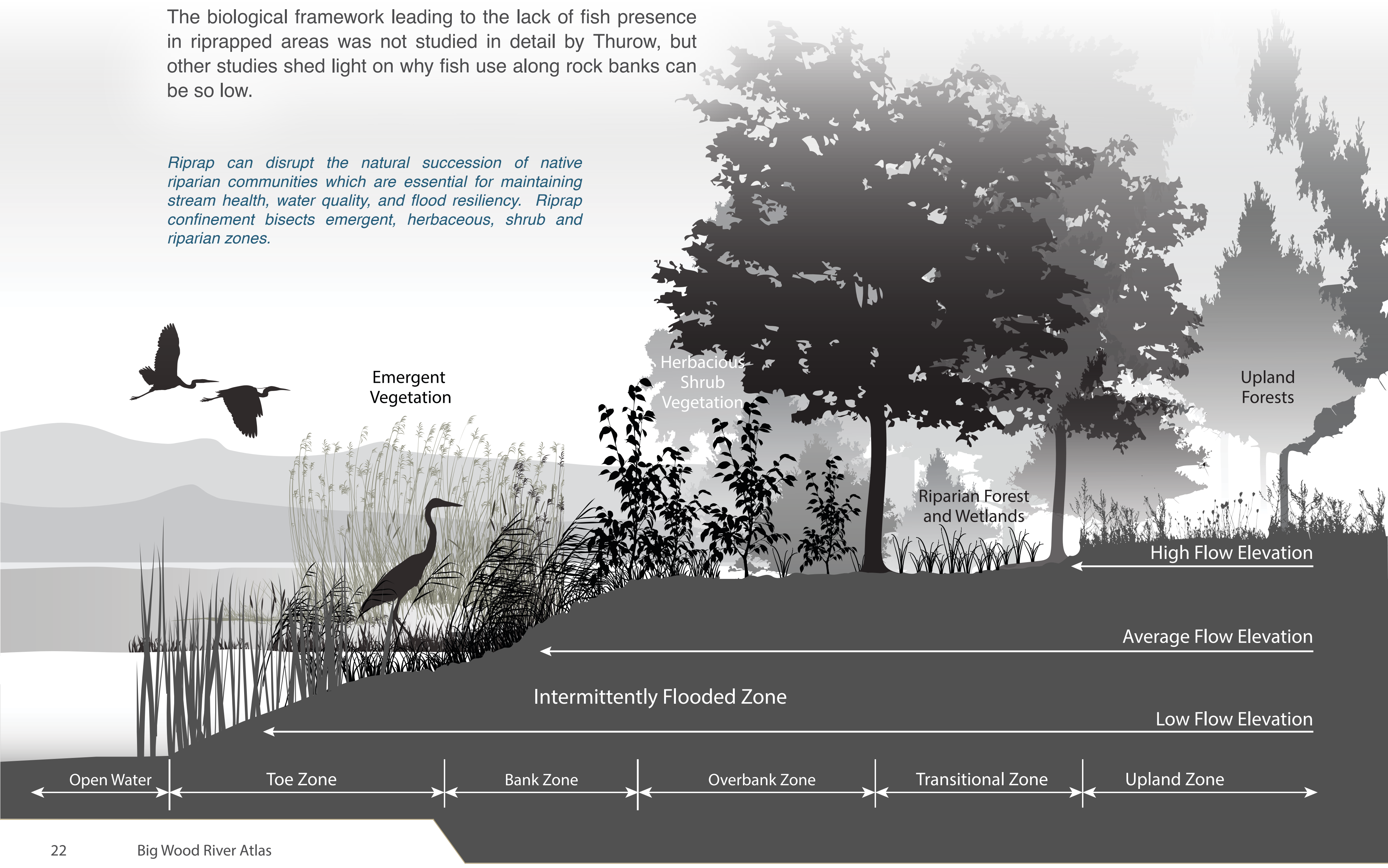
The biological framework leading to the lack of fish presence in riprapped areas was not studied in detail by Thurow, but other studies shed light on why fish use along rock banks can be so low.

Riprap banks and cleared riparian zone, Big Wood River.

Table - Number and percent of wild rainbow trout observed; snorkeling transects in association with cover, no cover, mid-channel and riprap areas, 1987. Trout Observations by Cover Type, Big Wood River. From Thurow, 1990.

	Trout by Reach							
	2		3		4		Total	
Category	No.	%	No.	%	No.	%	No.	%
Cover Component	599	79%	367	69%	613	65%	1579	71%
No Cover Component	102	14%	38	8%	83	9%	223	10%
Mid-channel	50	7%	124	23%	169	18%	343	15%
Riprap	3	1%	-	-	76	8%	79	4%
Total	754		529		941		2224	

Riprap can disrupt the natural succession of native riparian communities which are essential for maintaining stream health, water quality, and flood resiliency. Riprap confinement bisects emergent, herbaceous, shrub and riparian zones.



Hardening of eroding banks with rock eliminates undercut banks and reduces available resting areas for fish species (Schmetterling et al. 2001). Studies have reported that overhead bank cover declines following riprap placement up to 80% (Wesche et al. 1987), dramatically reducing the amount of channel shading along adjacent river reaches. Hyporheic exchange of shallow groundwater and surface water in the river provides cool oxygen rich water heavily utilized by salmonids during spawning and rearing. These cool zones of upwelling water can be disrupted and disconnected as a result of channel incision (Swanson 1999), leading to local reductions in habitat quality. Wood input from streambank erosion plays important roles in both stream habitat and channel morphology (Reid et al. 2015). By locally restricting bank erosion, riprap dramatically reduces the volume of wood input to channels (Schmetterling et al. 2001; Quigley and Harper, 2004). Wood is a major contributor of organics to riverine ecological systems, serving a key role in primary food production. Wood creates pools, provides cover from predation, and thermoregulation that improves aquatic habitat.

Riparian Succession

Hardening of banks with rock interrupts the natural patterns of sediment deposition and the spread of organics throughout floodplain areas as well as limiting natural riverward expansion of vegetated areas. Riparian zones are the intersection of riverine and upland ecosystems, and play an integral role for aquatic and terrestrial species.

Channel Response/Morphologic Evolution

The primary purpose of riprap banks are to artificially confine a channel to prevent lateral migration or erosion, and to cut off the river from side channels and overbank flood pathways. These actions alter the natural channel evolution on both a reach-scale and watershed-scale, with implications that may take decades to fully develop. In the Big Wood River, channel confinement in steep, high energy reaches has been observed to lead to channel incision. In laterally unstable, gravel-bed channels, sediment is eroded from outer banks and deposited on the next downstream point bar. As local sediment supply is diminished due to riprap placement, and where stream energy is sufficient, channels may respond by transporting bed material, leading to down-cutting (Reid and Church 2015).

Down-cutting of the river bed can in turn destabilize riprap banks or bridge infrastructure, isolate floodplain areas, lower groundwater levels to the detriment of riparian areas, and degrade habitat conditions as streambeds become armored with coarse material.

By replacing natural banks with rock lined banks, flow vectors (direction of flow) are also manipulated. Where stream energy traditionally could dissipate through overbank flow or channel erosion, rock walls can both increase velocities along their face, thereby altering natural flow patterns, gravel bar formation, and channel response. As a result, riprap placement often results in unintended downstream impacts that may be difficult to predict.

In lower gradient, response reaches, riprap banks and levees are observed to limit the movement of water and sediment into historic side channel networks or overflow pathways, leading in many cases to excess in-channel deposition. As sediment content becomes too great, the stream energy cannot transport it during typical bankfull events, and the channel responds by migrating and avulsing into new, more hydraulically efficient pathways. This process can be seen in reaches of the river downstream of Hailey and has been made worse by the lack of large wood in the system (also partly a result of bank armoring) to store sediment in geomorphically appropriate locations.

Mitigation Alternatives

The evidence is clear that riprap banks contribute to impaired aquatic habitat and modified patterns of sedimentation and flooding. **Future efforts should focus on removal of riprap where deemed not critical, modification of existing riprap to incorporate greater hydraulic complexity and wood, and limiting construction of new riprap.** More detail is provided in Appendix A on alternatives to traditional riprap design and construction.

Primary resources for the ecological and geomorphic effects of riprap:

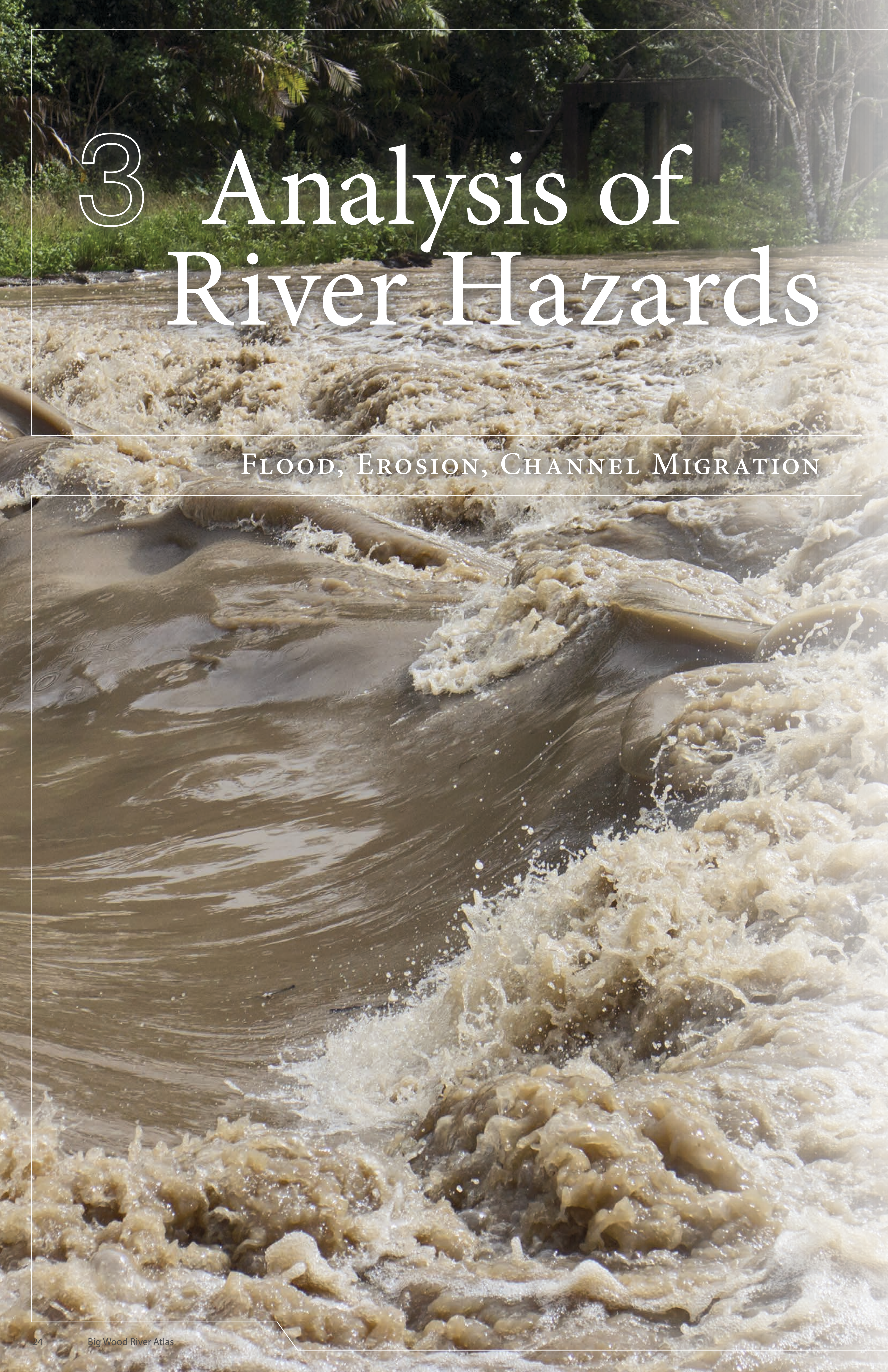
Fischenich. 2003. Effects of Riprap on Riverine and Riparian Ecosystems. U.S. Army Corps of Engineers Research and Development Center. Vicksburg, MS.

Reid and Church. 2015. Geomorphic and Ecological Consequences of Riprap Placement in River Systems. Journal of the American Water Resources Association.

Schmetterling et al. 2001. Effects of Riprap Bank Reinforcement on Stream Salmonids in the Western United States. Fisheries Habitat.

Riprap streambank; Hardening of streambanks with rock eliminates undercut banks and reduces available resting and cover areas for fish.

Aerial Image of Riprap placement (in yellow) along successive opposing downstream banks, Big Wood River. *Riprap placement can often lead to a cascading effect as downstream erosion worsens as a result of upstream projects.*



3 Analysis of River Hazards

Flood, Erosion, Channel Migration

There are a wide range of flood risk management methods available that can reduce flood risks. Proper estimation of risk is challenging and requires careful consideration of a number of factors. The following sequence of map overlays describe the data and analytical methods used to create the composite Flood Hazards Maps and Erosion Hazard Zones for the Big Wood River presented in Chapter 4.

Flood Hazard Analysis

The flood hazard analysis completed for the Big Wood River Assessment consisted of a review of multiple data sources and additional analyses to develop two flood zones. These flood zones are presented on the reach maps, but the underlying data used to develop those zones is not. The intent of this section is to describe and graphically display the process used to develop the zones depicted on the reach maps through an example mapping sequence.

Flood Zones I and II were developed through a multi-step process, using best available flood data and floodplain topography recently collected throughout the Big Wood River valley. No hydraulic modeling was completed as part of this Assessment to define flood hazards; rather the process relies on both modeled flood limits completed by FEMA, the observed limits of flooding from the 2006 and 2017 floods, and detailed topographic data.

Step 1- Overlay the FEMA 100-year flood boundary. The current, regulatory Special Flood Hazard Area (SFHA) based on modeling of the Base Flood Elevation (BFE) was acquired from FEMA. Though the analysis and mapping completed to produce these boundaries by FEMA is outdated, this area is the sole regulatory mandated zone requiring federal flood insurance and typically represents the only means for a property owner to evaluate a property's risk of flooding. The FEMA boundary is based on hydraulic modeling and flood mapping utilizing bathymetric and topographic data collected in 1970/71, 1993, and 2007, and statistically determined peak flow estimates last updated in 1998. FEMA's countywide flood analysis currently is in the process of updates. FEMA's estimate of the SFHA boundary is based on hydraulic modeling predictions of flood extents during a 6.680 cfs event, which was their estimate of a 100-year flood (1% annual exceedance) at Hailey, at the time of analysis*

*In addition to topographic updates, FEMA is performing updates to its hydrologic analyses for the Big Wood River. Initial analyses indicate previously Flood Insurance Studies underestimated peak discharge values for the Big Wood River, consistent with findings from this study.

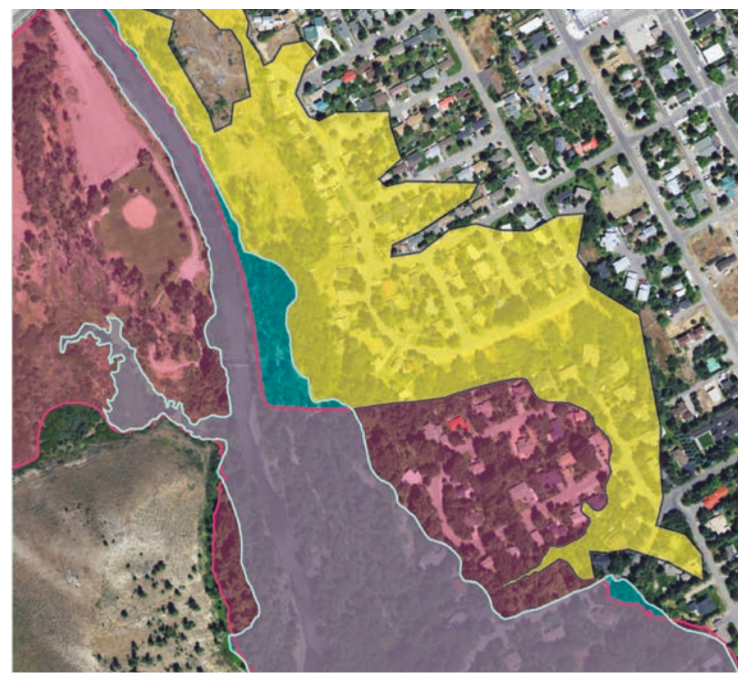
Step 2- Overlay the 2006 and 2017 Flood Limits. Significant flooding events occurred in 2006 and 2017. During those flood events, Blaine County and US Army Corps of Engineers collected aerial photos throughout the project area to assess flood damage and map flood extents. The visible limits of flooding were digitized and mapped. Though the 2006 and 2017 floods peaked at different flows (approx. 7,800** and 6,270 cfs, respectively), the aerial flights both occurred following the maximum peak during each flood, and at a roughly similar flow of 5,500 cfs. These mapped flood extents offer a unique opportunity to observe the true extents of flooding rather than data generated via hydraulic modeling; and to observe changes in flood patterns occurring at a similar flow level but 11 years apart.

**All flow values represent discharge recorded at the USGS Gage in Hailey (Station 13139510). For comparison purposes, FEMA's statistically determined 1% annual exceedance peak flow value for their model cross section nearest the Hailey Gage is 6,680 cfs.

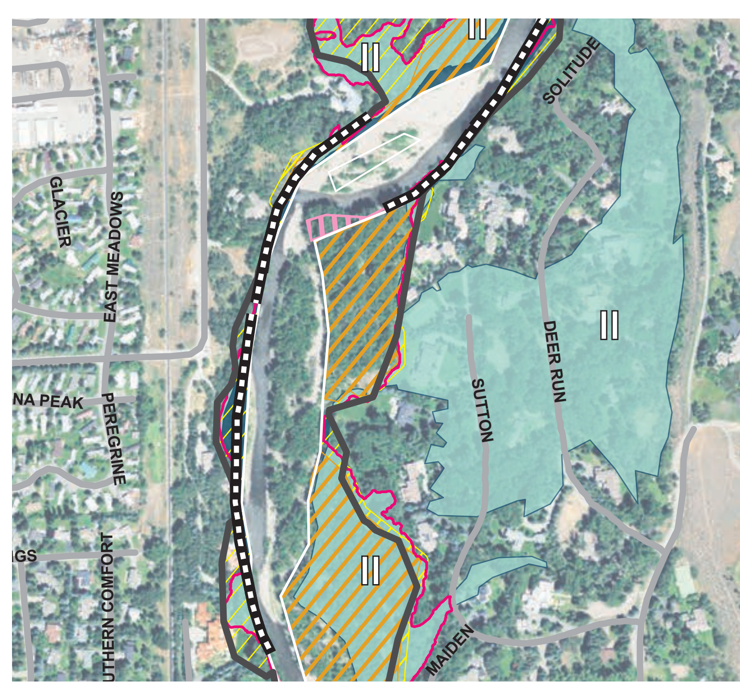
Steps 3 and 4- Develop a Relative Elevation Map to Identify Areas Lower than the BFE. Using the FEMA water surface elevation contours for the BFE, we developed a flood surface. Using this elevation surface overlain atop the 2017 LiDAR topography, areas below the BFE were identified. These low lying areas were often not captured or included in the FEMA Zone SFHA since the resolution of their floodplain survey was very coarse and failed to pick up areas in between survey transects. These zones then represent areas of potential flooding, especially those areas contiguous to known or modeled flood zones.

Analysis of River Hazards - Mapping Sequence

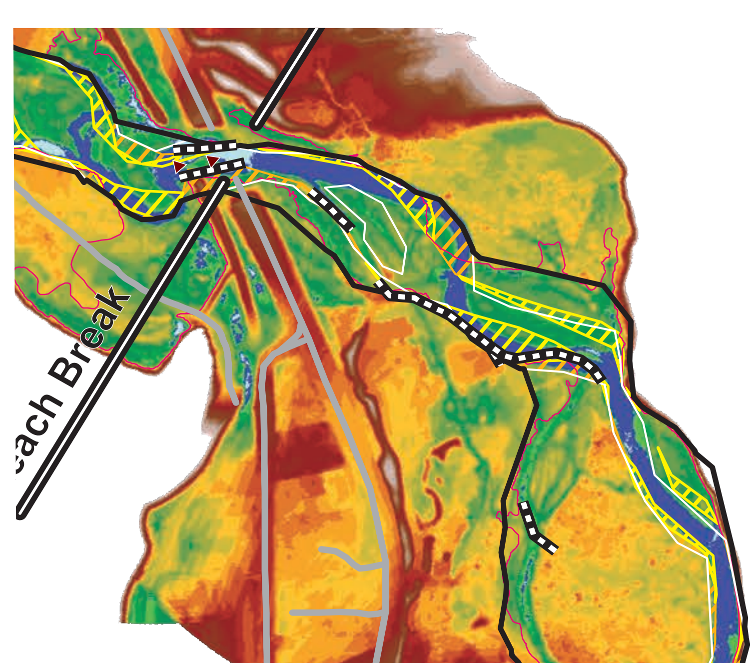
This Chapter of the Atlas includes detailed descriptions, mapping, technical overlays and delineations that are brought together to illustrate the process and outcomes for flood hazards, erosion hazards and channel migration.



Flood Hazard Sequence



Erosion Hazard Sequence

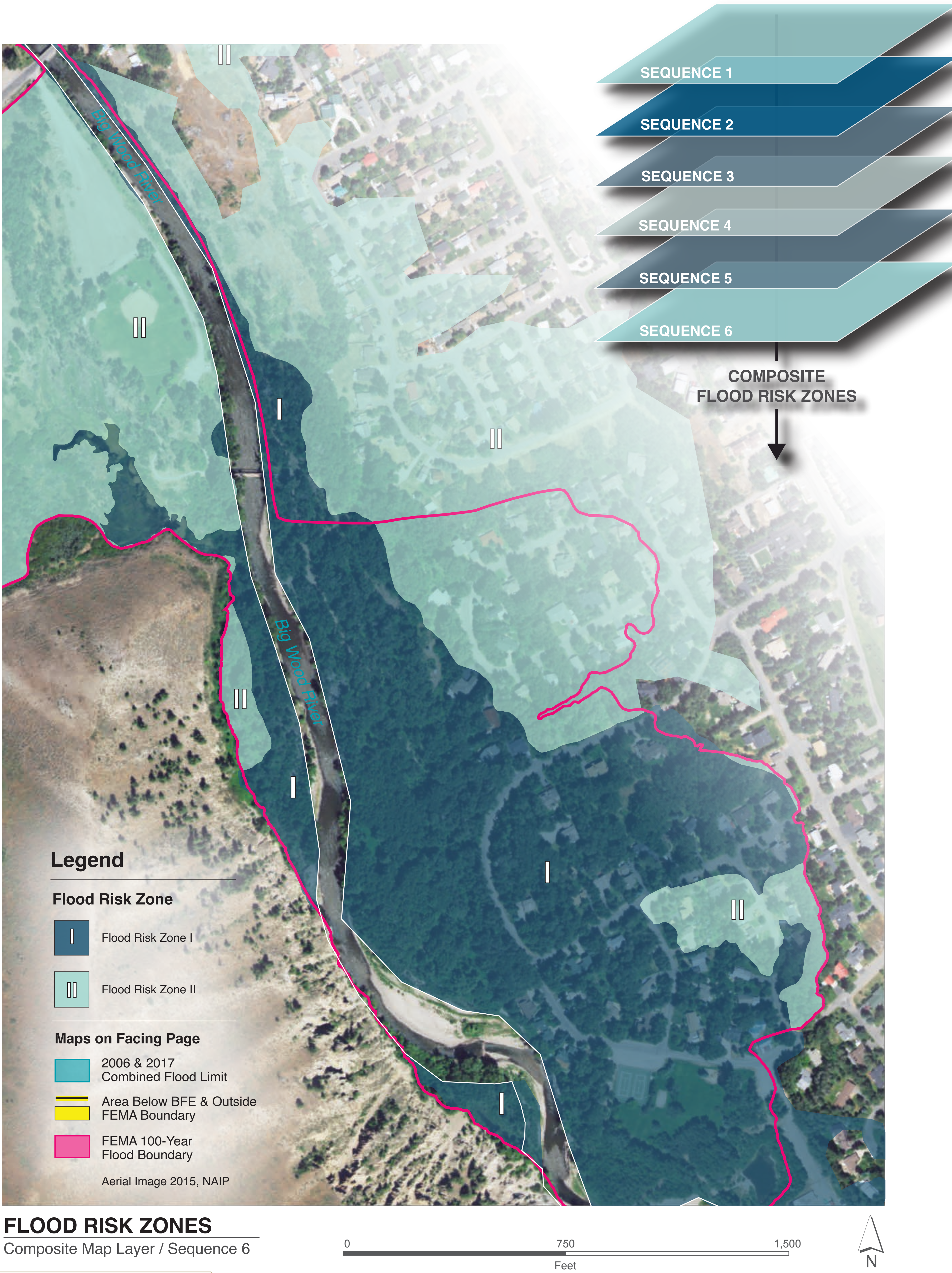


Channel Migration Sequence

Flood Hazard Sequence

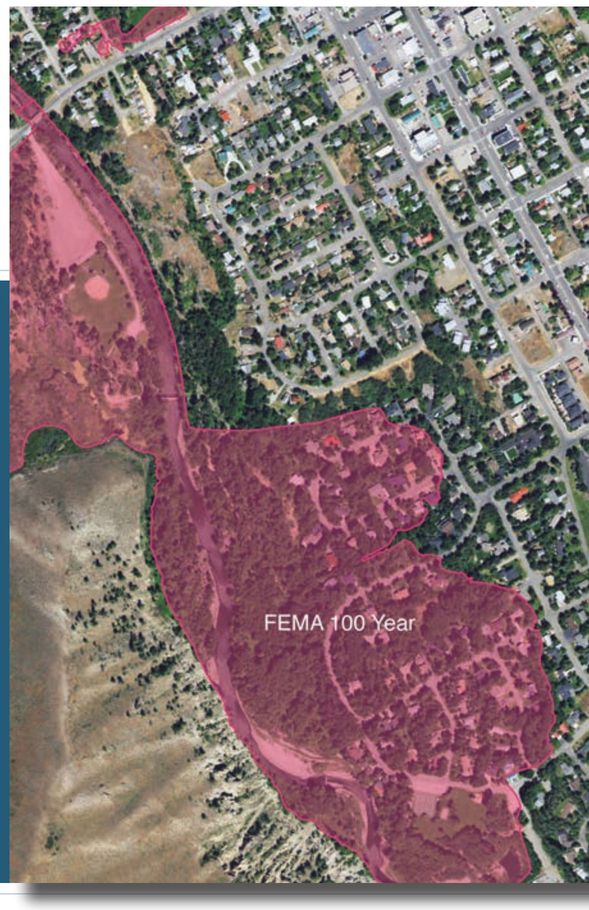
Step 5 - Develop Preliminary Flood Zones. Four initial flood zones were created based on the overlay of the zones developed through steps 1-4. Those 4 zones are: (1) Within the FEMA Zone SFHA and within the known flood limits; (2) Within the FEMA Zone SFHA and beyond the known flood limits; (3) Outside the FEMA Zone SFHA and within the known flood limits; and (4) Outside the FEMA boundary but below the BFE flood surface.

Step 6 - Develop Two Flood Risk Zones. Using the overlay of the various sources of flood analysis, two flood risk zones were developed, shown on the opposite page, and presented in the reach maps. Flood Risk Zone 1 represents areas that have experienced flooding in either 2006 or 2017, and fall within the FEMA Zone SFHA. Flood Risk Zone 2 represents areas that fall within the FEMA Zone SFHA, but may have not flooded during 2006 or 2017, and adjacent areas below the BFE elevation.



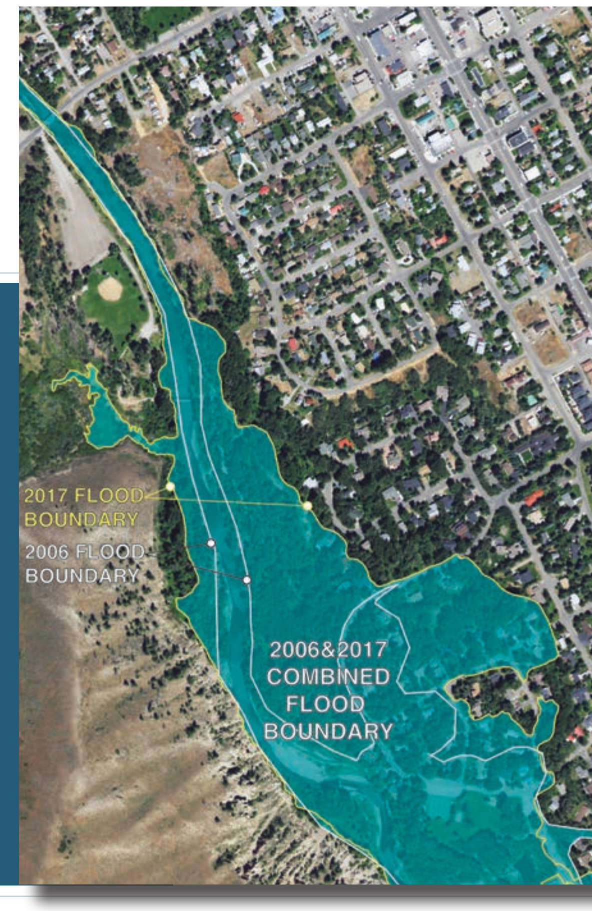
FLOOD RISK ZONES
Composite Map Layer / Sequence 6

Map Sequence 1



Sequence 1: FEMA 100-Year Flood Boundary

Map Sequence 2

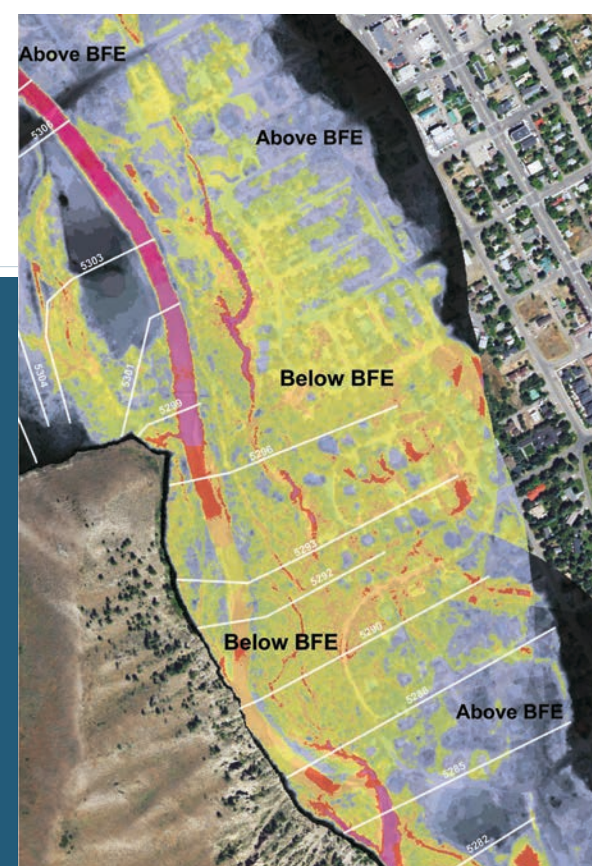


Sequence 2: Observed Flood Limits from 2006 & 2017

Map Sequence 3

Sequence 3: FEMA 100-Year Flood Boundary and Base Flood Elevation (BFE)

Map Sequence 4a

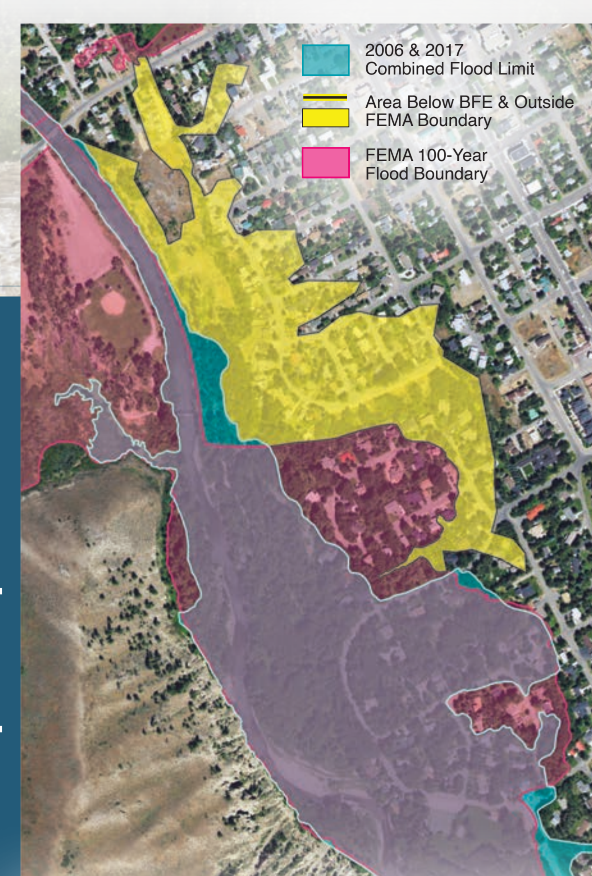


Sequence 4a: Relative Elevation Model (REM) and BFE

Map Sequence 4b

Sequence 4b: BFE / REM comparison with FEMA 100-Year Flood Boundary

Map Sequence 5



Sequence 5: Output of Layered Analyses

Channel Migration/Erosion Hazard Sequence

The purpose of this channel migration study is to inform the community of the dynamic nature of the river, and identify areas susceptible to channel migration and riverbank erosion. Mapping of the Historical Channel Migration Zone (HCMZ) and identification of the Zones of Potential Erosion relied upon a procedure modified from two methodologies outlined in the following documents: (1) A Framework for Delineating Channel Migration Zones (Rapp and Abbe, 2003) and, (2) A Methodology for Delineating Planning-Level Channel Migration Zones (Olson et al, 2014). Historical channel migration rates were not determined in this study, nor projected into the future to estimate future channel positions. The intent of this study was not to develop regulated CMZ boundaries.

The following steps were completed to identify the Historical Channel Migration Zone and to develop the Zones of Potential Erosion, both of which are presented on a reach-by-reach basis in Chapter 4 of this Atlas:

Step 1- Georectification of historical aerial photos.
The Aerial photos of the project area were accessed from multiple sources, including Blaine County and the National Aerial Imagery Program (NAIP). These aerial images were then georectified and projected to the NAD 1983 Central Idaho State Plane coordinate system. Time periods selected for aerial photo analysis are intended to span significant flood events and other meaningful watershed events such as fires and land development. The following years were georectified and used in the analysis- 1943, 1966, 1986, 2004, 2015, and 2017.

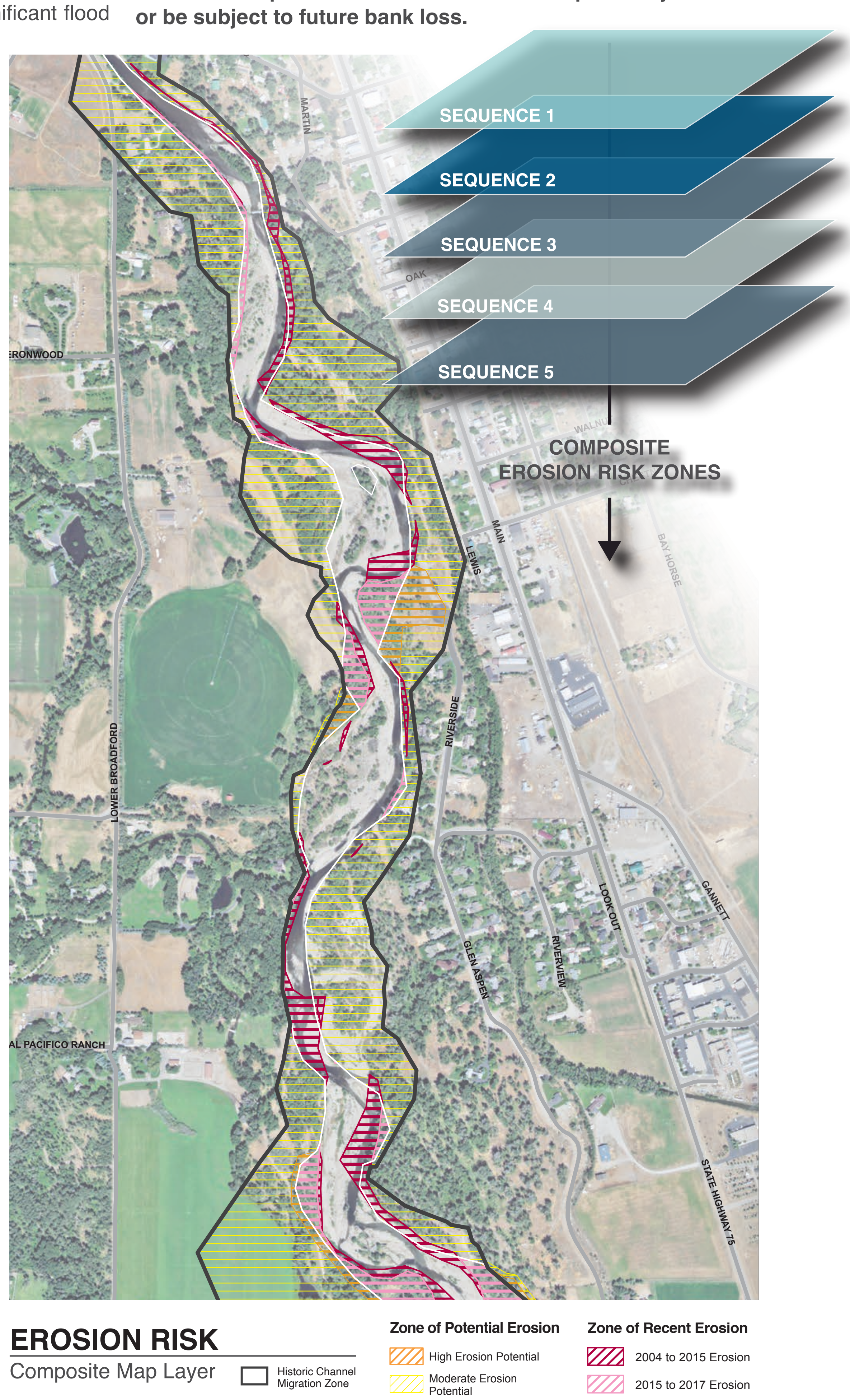
Step 2 - Delineation of the active channel margins for each photoperiod.
The margins of the active, or bankfull channel, were delineated for each georectified photoperiod and digitized using Geographic Information System (GIS) ArcMap software. The extents of the active channel were identified using geomorphic and vegetative indicators. To maintain consistency in interpretive bias, a single analyst completed all channel boundary delineations, with review conducted by a senior geomorphologist.

Step 3 - Overlay all historical channel traces and set the landward limits of the combined channel occupation area as the HCMZ.
The total area occupied by the channel within the known historical record delineates the Historical Channel Migration Zone.

Step 4 - Compare HCMZ to modern (2017) channel boundary and delineate Zones of Moderate Erosion Potential.
This step considers the potential of the river to re-occupy areas between the current channel location and areas of prior channel occupation. River channels tend to migrate within their former HCMZ unless cut off or confined from doing so. The area in between the 2017 channel and the edge of the HCMZ is considered to have Moderate Erosion Potential unless a High Potential Area is identified.

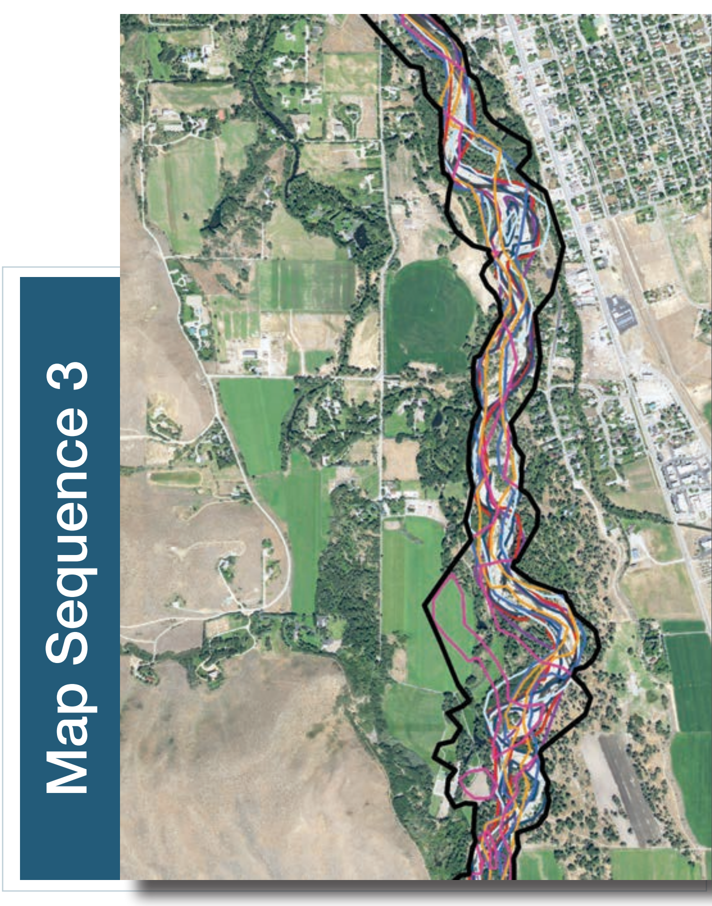
Step 5 - Identify Zones of High Erosion Potential.
Some areas along the channel margins are observed to be eroding at a more rapid pace, putting adjacent riparian and upland zones at a higher risk of erosion. Channel migration during the 2017 floods was delineated by comparing the 2015 channel trace and the 2017 channel trace (in blue on Map Sequence 5). The areas between the traces represent the current directional trends of channel erosion. These zones were compared to underlying topographic information using the HAWS mapping. Where erosion trends intersected with topographically favorable (i.e. low lying) conditions, areas of high erosion potential were identified and delineated. Where these zones are identified within the HCMZ, the remaining area to the edge of the HCMZ is delineated as moderate; where these zones extend beyond the HCMZ, a narrow buffer of moderate erosion potential is applied beyond the HCMZ.

A Note on Riprap and Channel Migration/Erosion Potential.
In some cases, armored banks, levees, roads, and other infrastructure can act as a barrier to channel migration. Nearly 40% of the entire Big Wood River is lined with some sort of bank armoring, and much of it acts as a temporary barrier to migration, while some may act as a more permanent barrier (levees or roads that are maintained by government of flood control district entities). As part of the assessment, areas identified by others (Rapp 2016, Biota 2016, or Blaine County 2018) as armored by riprap or levees were included in the geospatial analysis and presented in the reach maps (Chapter 4), but a detailed evaluation of the condition of those areas was not conducted. The mapping efforts identified reaches where riprap banks failed or where migration upstream of riprap banks risks flanking and failure from the landward side. Efforts were not made in this assessment to determine which armored banks are more prone to failure than others. Therefore, it is assumed that, without maintenance, all banks are prone to failure over the long term. **The presence of rock-lined banks does not eliminate the potential of an area to be re-captured by the river or be subject to future bank loss.**



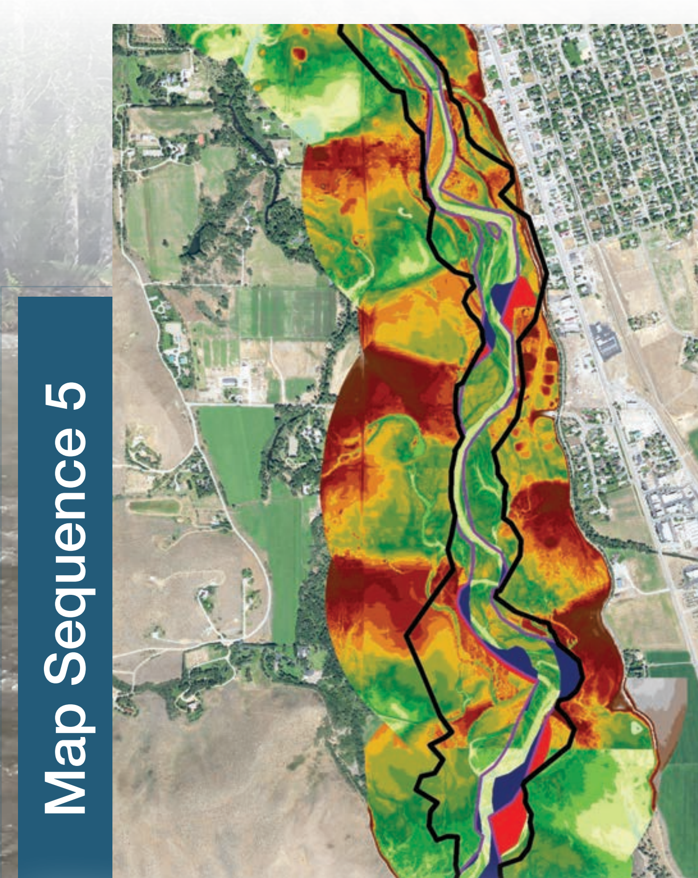
Sequence 1: 1943 Aerial Photo with 1943 active channel trace in pink (near Bellevue)

Sequence 2: 1986 Aerial Photo with 1943 channel boundary (pink) and 1986 channel boundary (blue)



Sequence 3: Delineation of the Historical Channel Migration Zone (in black), established using the outer limits of all channel boundaries.

Sequence 4: 2015 Aerial Photo with the 2017 channel boundary in purple and the HCMZ in black. The areas in between are considered Zones of Moderate Erosion Potential.



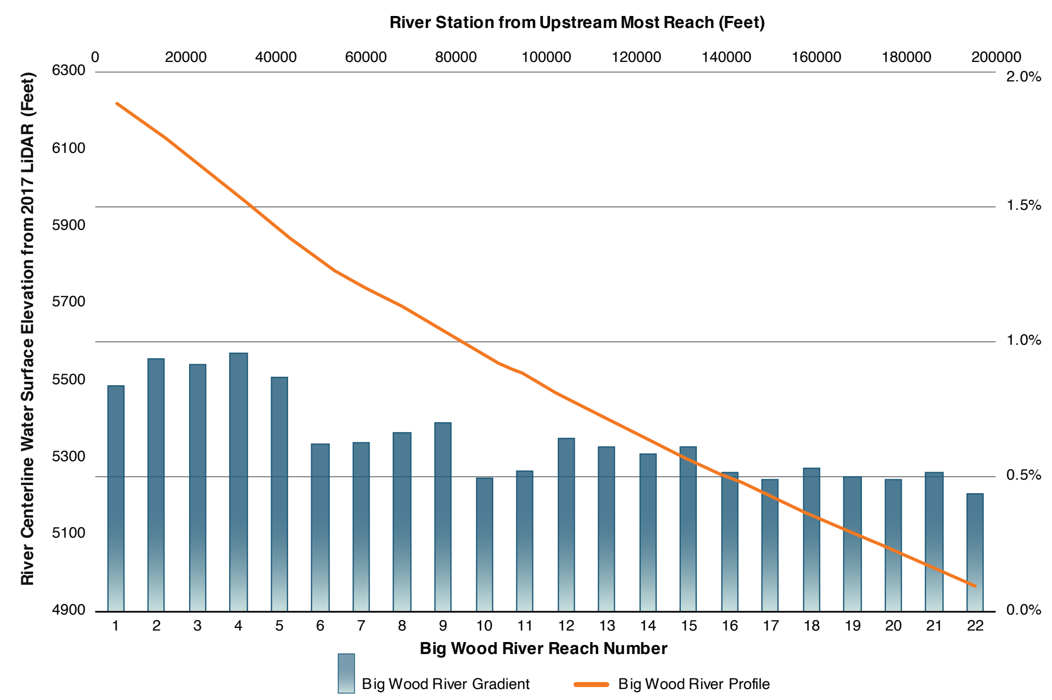
Sequence 5: HAWS (developed using 2017 LiDAR data) mapping with areas of recent channel migration in blue and high erosion potential areas in red

4 River Reaches Maps & Data

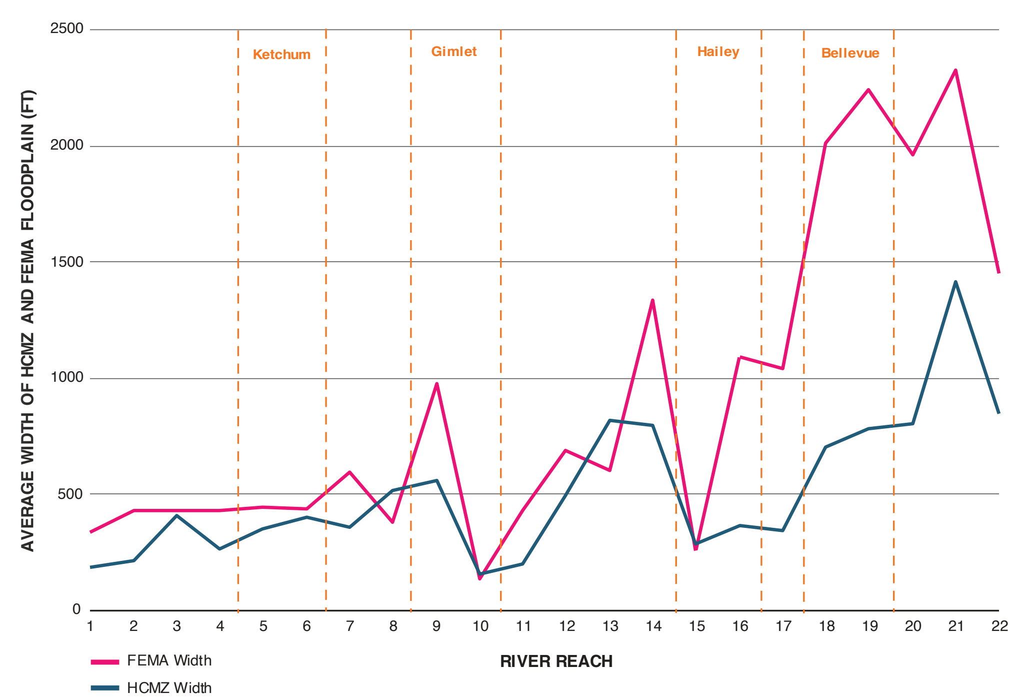
This chapter presents maps of the 42-mile study area delineated into 22 reaches. The reaches are numbered from upstream to downstream, with Reach 1 starting at the SNRA boundary and Reach 22 ending at Stanton Crossing. A legend to the river maps is provided on the adjacent page (pp. 25). Reaches boundaries were delineated in a manner to best distinguish unique river characteristics and capture meaningful geomorphic metrics. Given the dense drainage network of the Wood River valley, and the significant contribution to mainstem river processes from tributary streams, many reach breaks are upstream of tributary confluences. Other reach breaks are determined by well-known infrastructure, such as bridges or roads. The magnitude of the study area required delineation of reaches perhaps longer than would be selected to assist in project specific analysis, though the trends identified through the reach analysis offer valuable insight and direction for any project specific analysis. Should project sponsors wish to further sub-delineate reaches for specific purposes, all GIS data used in this Atlas can be made available through Blaine County upon request.

General trends can be seen by plotting various metrics for each reach. The upper graph displays a continuous stream profile for the entire study area and channel gradients on a reach by reach basis. The river upstream of Warm Springs Creek (at the upstream end of Reach 6) is significantly steeper than downstream of Warm Springs. Warm Springs is the largest tributary by flow volume and a major sediment source, especially in recent years as a result of wildfire. Another major slope break is seen at Reach 16, as the Big Wood flows into Hailey at Bullion Bridge. Stage analysis at the USGS gage at Bullion and prior work by Rapp (2006) suggests the river transitions to a depositional channel near Bullion, which may partially be responsible for slope reductions.

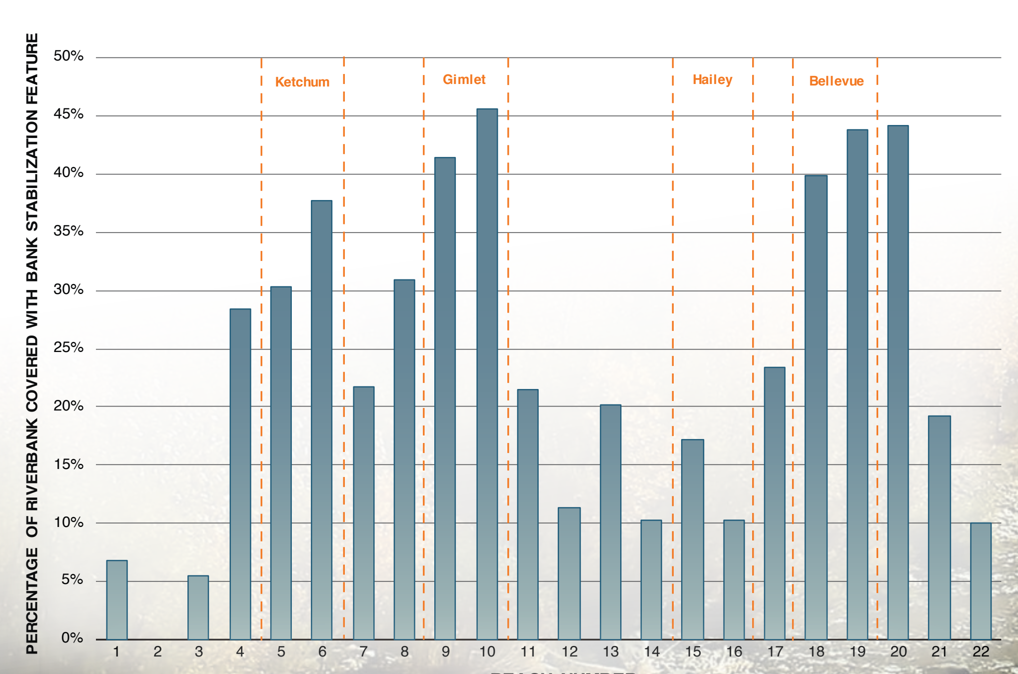
The middle graph displays the average widths of both the floodplain and channel migration zone. The floodplain data is from the FEMA Special Flood Hazard Area and the migration zone width is calculated from the Historical Channel Migration Zone (HCMZ) determined by Cardno. Trends show gradually increasing floodplain and HCMZ widths from the upper basin through Hailey, then major increases in both metrics around Bellevue and downstream. The lower graph shows the total % of riverbank that is confined by riprap or levees for each reach. Close to 40% of the total river length is protected by some sort of armoring, with reaches close to population centers generally showing the highest occurrence of bank stabilization.



Big Wood River Gradient and Profile



Big Wood River FEMA Floodplain (Zone SFHA) and HCMZ Widths by Reach



Total Length of Bank Stabilization (as a %) Per River Reach

Big Wood River
UPPER WATERSHED

Locator map of River Reaches; Upper Big Wood River Watershed

Process Based Restoration Strategy and Project Framework

Consistent with the Vision, Goals, and Objectives defined in Chapter 1, this section describes an approach to identify, evaluate and prioritize restoration actions necessary to meet the stated objectives. The process based approach described here identifies watershed-wide recommendations for restoration activities in the Big Wood River; reach scale priorities are presented on the reach maps which follow.

Habitat and flooding impairments to the Big Wood River reflect systemic, watershed-scale problems that cannot be corrected solely with local solutions; furthermore, the recent behavior of the channel following the 2017 floods may not persist over time. Therefore, systemic restoration and preservation solutions are needed that follow a process based hierarchical framework, such as those described by Roni et al. (2002), Roni et al. (2005), Beechie et al. (2008), Beechie et al. (2010), and followed by the Bureau of Reclamation on reach assessments throughout the Upper Columbia/Snake/Salmon watersheds. The river does not function in isolation, rather as a continuum, and ecosystem recovery requires an understanding of these linkages and an approach that seeks to identify opportunities according to a methodical strategy rather than by happenstance. Project partners should work together to pool resources in efforts to acquire lands and implement projects that can affect the greatest benefits.

The framework used in this assessment considers preservation and conservation of functional areas and process based restoration projects as the highest priorities. Localized habitat enhancement projects are secondary priorities, followed by stabilization measures, the lowest priority for process based or ecosystem based restoration. Project potential is defined by five main categories for the purpose of the assessment and for evaluating potential on a reach-by-reach basis. **Project Potential in order of priority:**

1. Protect and Maintain - Slowing or eliminating further development within the floodplain or HCMZ is considered among the greatest priorities for the Big Wood River. Protection of the remaining intact functional floodplain areas should be pursued through acquisition, easements, or legislation.

2. Reconnect Stream Channel Processes - Much of the area previously occupied by historical channels has been cut off, disconnected, and the modern channel artificially confined by riprap and levees. Stream channel reconnection projects should be pursued in areas where evidence shows prior channel occupation (within the HCMZ) and opportunity exists to remove or setback confining measures. These projects create opportunities for process based restoration on a reach-scale, influencing sediment transport dynamics, buffering flood response, and creating complex, functional floodplains and reclaiming habitat that was once part of the river.

3. Reconnect Floodplain Processes - Floodplain reconnection projects have the ability to improve both the physical and biochemical functions of floodplains through expansion into previously flooded areas. On a watershed scale, reduction of the historic floodway and floodplain has led to altered geomorphic processes, flood patterns, and in turn habitat formation and maintenance. Increases in peak flow magnitude and duration will exacerbate this response. Floodplain reconnection should be pursued in locations where development encroaches into floodplains, where levees or embankments can be set back or removed to allow greater flood expansions, and by removing floodplain infrastructure where feasible.

4. Riparian Restoration - Riparian restoration should be pursued in areas where native riparian communities have been removed or modified to the point of compromised function. Much of the developed areas along the Big Wood River have modified or altogether cleared the native riparian forests. These riparian zones provide critical function in stabilizing streambanks from erosion, providing shade, cover and food sources for aquatic species, and in natural recruitment of woody debris to the river. Incentives and regulation should be considered to maintain healthy riparian buffers along the entire river corridor.

5. In-stream Habitat Enhancement Actions - In-stream habitat enhancement measures are proposed for areas where dynamic channel planform could be stabilized through the use of flood fence or apex LWD jams. The 2017 floods entrained a great deal of stored sediment that is working through the system; capture of that sediment using wood could meter the downstream advance of sediment in a way that reduces flooding, channel erosion, while also improving habitat conditions and stabilizing riparian areas.

Program Goals for the Big Wood River

- Develop a decision-making framework to identify and evaluate projects that work to restore natural river processes, and encourages aquatic habitat formation
- Describe areas of lost or degraded aquatic and floodplain habitat
- Describe the habitat and geomorphic impacts resulting from channel confinement and bank hardening
- Conceptualize project types for floodplain and ecosystem restoration that will:
  - Decrease high water impacts to communities within the study area,
  - Decrease erosion along the Big Wood River, and
  - Enhance ecosystem health along the Big Wood River and its tributaries, with special emphasis on reconnecting the floodplain and restoring natural river function.
- Define a methodology for project identification, prioritization, and evaluation consistent with the River Vision

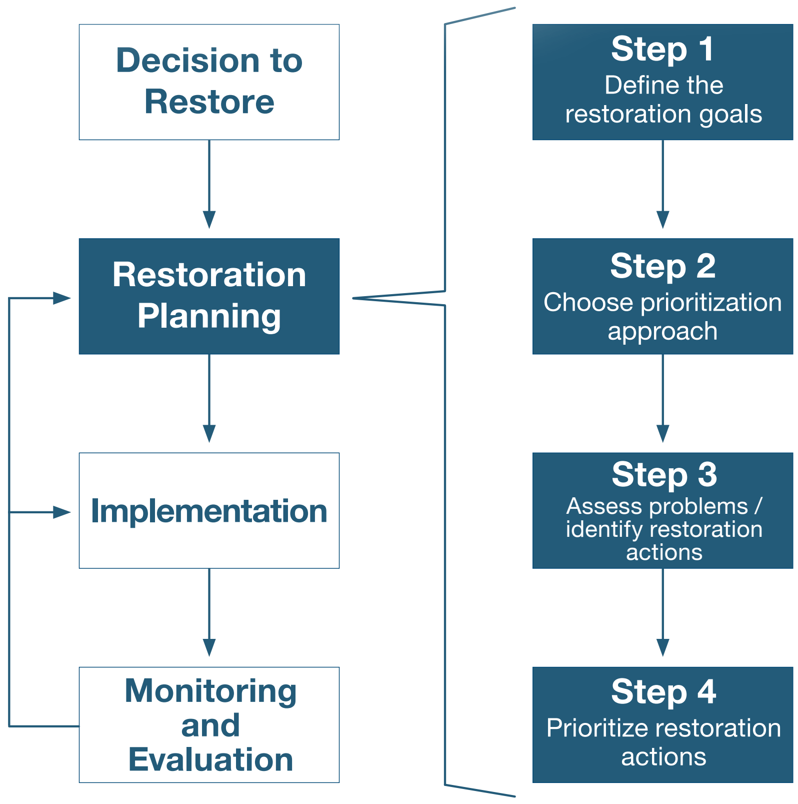


***Diagram of the river restoration process;** four steps for identifying and prioritizing river restoration actions that are nested within this [hierarchical strategy] broader process. Beechie et al (2008).*

Project Prioritization and Reach Potential Ranking

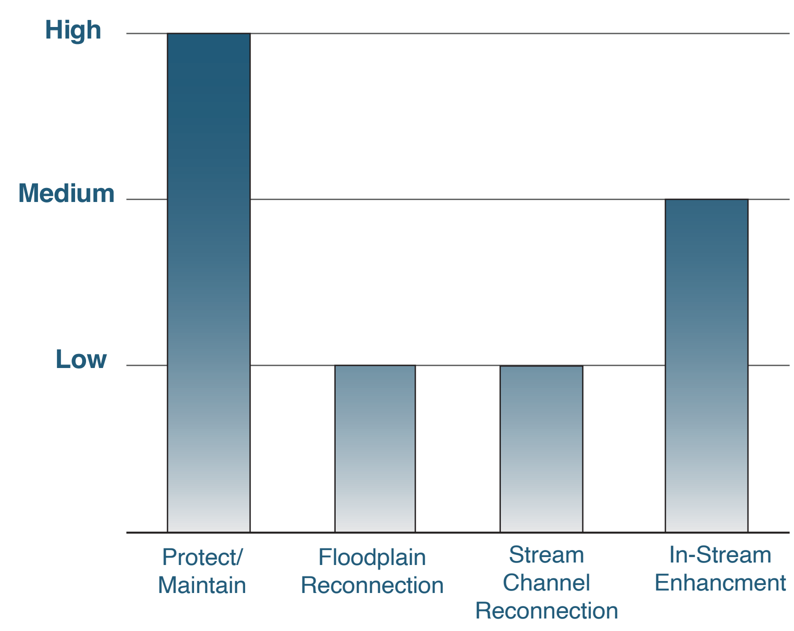
The project potential of each reach was coarsely evaluated in this assessment as a means to begin a conversation about opportunities within each reach. Rather than identifying specific sites, each reach was evaluated for its overall opportunity types using the hierarchy presented above and understanding of the overall river vision and goals to improve ecological processes, sediment management, flood reduction, habitat enhancement and conservation. The assessment was qualitative in nature and is meant to provide stakeholders with broad, guiding principles for each reach.

Project potential for each reach was split into the four primary categories that generally defined different process based restoration/conservation strategies. These categories included the potential to: (1) protect and maintain habitat, (2) improve floodplain processes, (3) improve stream processes, and (4) improve in-stream channel habitat. The categories were ranked as “High Potential”, “Medium Potential”, or “Low Potential” for each reach using a subjective and qualitative method, relying heavily on best professional judgment. **A more rigorous quantitative analysis is recommended as a next step before specific projects can be appropriately identified, prioritized and implemented**

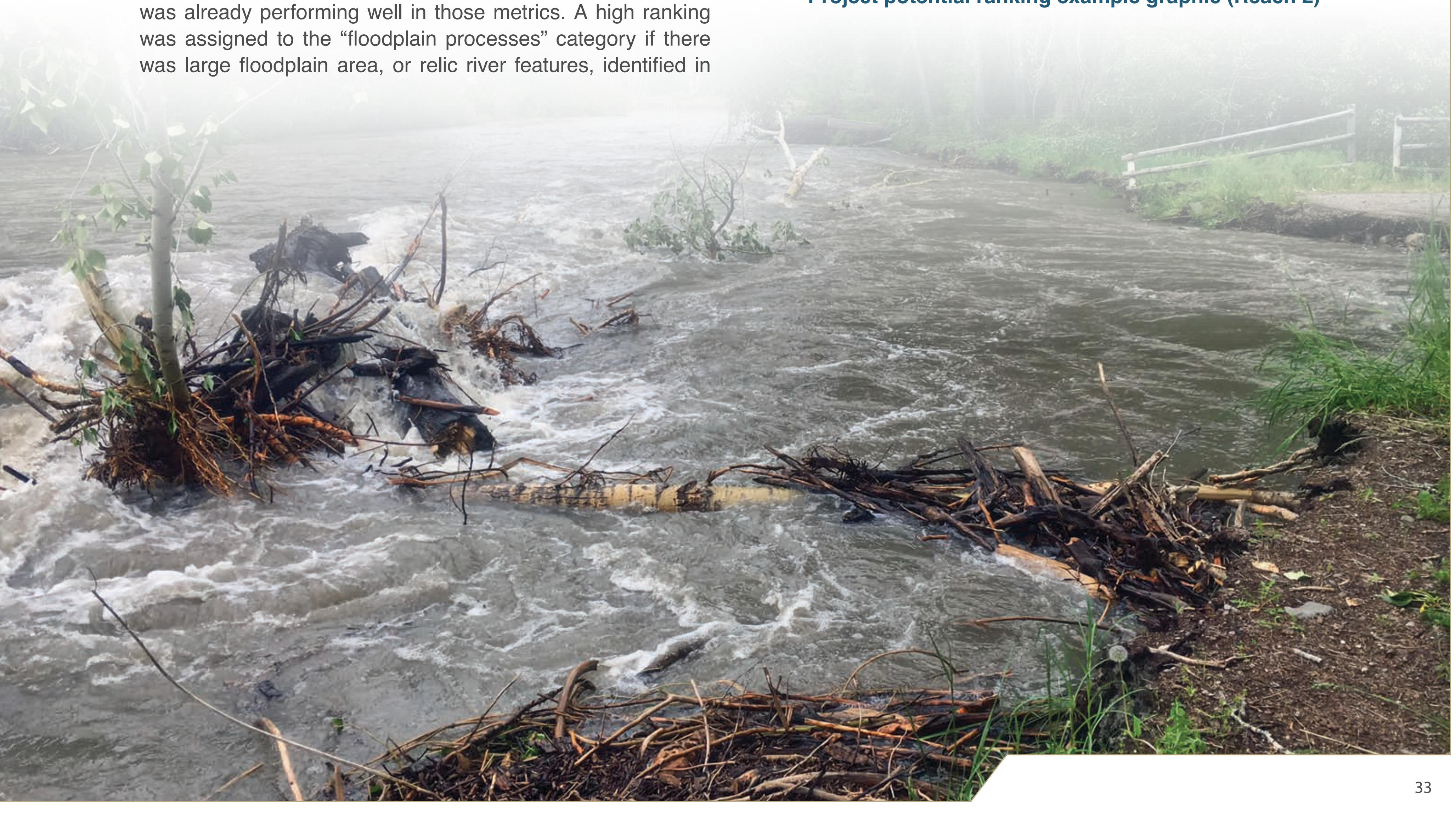
Project potential was evaluated by considering the existing land cover conditions within the adjacent HCMZ and river floodplain (i.e. forested, developed), and the dominant geomorphic processes that shaped existing and historical habitat conditions within each reach. We utilized the historical imagery record to contrast existing and historical river conditions, assess existing riparian habitat, and identify general areas for conservation. A height above water surface (HAWS) map developed for each reach was utilized to determine the presence of remnant river features and the possibility for floodplain reconnection projects. Further geomorphic data collected from geospatial analyses were utilized to determine the level of existing channel degradation, deposition, and confinement from bank stabilization. A reach was ranked as having high potential for the “Protect and Maintain” category if there were large relative areas of high quality, undeveloped, riparian or floodplain habitat within the HCMZ.

A reach identified as high potential in this category generally had lower rankings in the other categories because the reach was already performing well in those metrics. A high ranking was assigned to the “floodplain processes” category if there was large floodplain area, or relic river features, identified in the HAWS map that could be reconnected to the river corridor. The “stream processes” category was ranked as high if the reach had room to migrate or form more complex channel planforms but was confined by existing bank stabilization or other hindrances. A high rank for the “instream habitat category” indicated that the reach had relatively poor instream habitat and would benefit from installation of large woody debris and other in-stream structures.

As a case study, reach 2 was ranked as “high” for protect and maintain, “low” for floodplain processes, “low” for stream processes, and “medium” for instream channel habitat (See Figure 1). The reach had a high protect and maintain ranking because its west bank contains relatively large areas of high-quality forested land within the HCMZ. These should be a high-priority for conservation. The floodplain and stream process categories were subsequently ranked as “low” because the river is constrained on the east bank by development and already has a high level of performance in those metrics on the west bank. Instream channel habitat was ranked as “medium” because aerial imagery revealed that there was an absence of large woody debris within the channel, which is vital to sustain habitat-forming processes.



Project potential ranking example graphic (Reach 2)



Project Development and Review

In addition to identifying project locations, prioritizing project opportunities and defining project objectives based on a hierarchical strategy and adhering to process based principles, project designs must meet and demonstrate minimum design standards to offer the highest likelihood of success. Standards of care should be established by regulatory bodies, communicated clearly, and applied uniformly to establish the expectations for all project proponents and all project types completed in the river and floodplain.

The current Blaine County Stream Alteration Permit (SAP) approval process contains the following language that pertains to evaluation criteria that the County may consider in the approval or denial of a permit;

Excerpt from Blaine County, ID Stream Alteration Permit Application Evaluation Criteria Language:

2. The proposed stream alteration shall have no adverse impact on the property of another person or entity, including the areas upstream, downstream and across the steam. No adverse impact means that the proposed use or activity will not have any deleterious impacts in terms of increased flood peaks, flood stage, flood velocity, erosion and sedimentation, or water quality or those impacts that have been identified and mitigated to the maximum extent feasible.

3. The stream alteration desired will not involve placing an encroachment, structure, fill, deposit, obstruction, storage of materials or equipment in the floodway, all of which are prohibited by subsection 9 17 583 of this Chapter, unless certification by a registered engineer is provided and accepted by the County Engineer, demonstrating that encroachments shall not result in any increase in flood levels during the occurrence of the 100-year flood discharge and other standards of this Section are met.

4. The stream alteration desired shall not have any adverse impacts or go against the stated purposes of the Floodplain Management District (Section 9-17-2) and the Stream Alteration Permit program (subsection 9-17-11A of this Chapter).

5. The proposed application (:use) does not conflict with the local public interest, i.e., the affairs of the people in the area directly affected by the proposed use. This includes, but is not limited to, property values, fish and wildlife habitat, aquatic life, recreation, aesthetic beauty, water quality or an impact upon a locally important factor. The burden of proof always rests with the applicant.

These criteria provide the County with some key guiding principles upon which to evaluate project proposals, but lack mention of particular scientific methodologies or engineering standards project proponents must meet in order to demonstrate adherence to these criteria. Lack of more specific guidance may result in sub-standard engineering practices, confusion among project sponsors and engineers regarding design expectations, inequitable interpretation of the evaluation criteria by decision makers, and under performing projects.

Standards of Care for Hydraulic Engineering and River Restoration Design

At a minimum it is recommended that more specific guidance and/or reference to the current standards of care in the field of hydraulic engineering and river restoration design be provided in the following areas:

1. Hydraulic Modeling/Analysis

A key evaluation criteria in the SAP process is to demonstrate no adverse impacts with respect to flood elevations and velocities. Proper analyses and application of hydraulic models can be essential to both characterizing existing conditions and simulating proposed conditions. Minimum standards of care should be met when utilizing hydraulic models, according to guidance provided by FEMA, the USACE, or the Northwest Regional Floodplain Management Association (NORFMA), or other relevant organization.

2. Channel Response Assessment

Determination of issues related to erosion, sediment, transport, and migration potential of a proposed project should be made by a qualified Geomorphologist, with appropriate state licensure in Geology or Engineering. An evaluation of reach-scale processes, and expected future channel behavior under both a no-action and with project scenario should be presented to the County for consideration.

3. Aquatic Habitat Conditions/Impacts Assessment

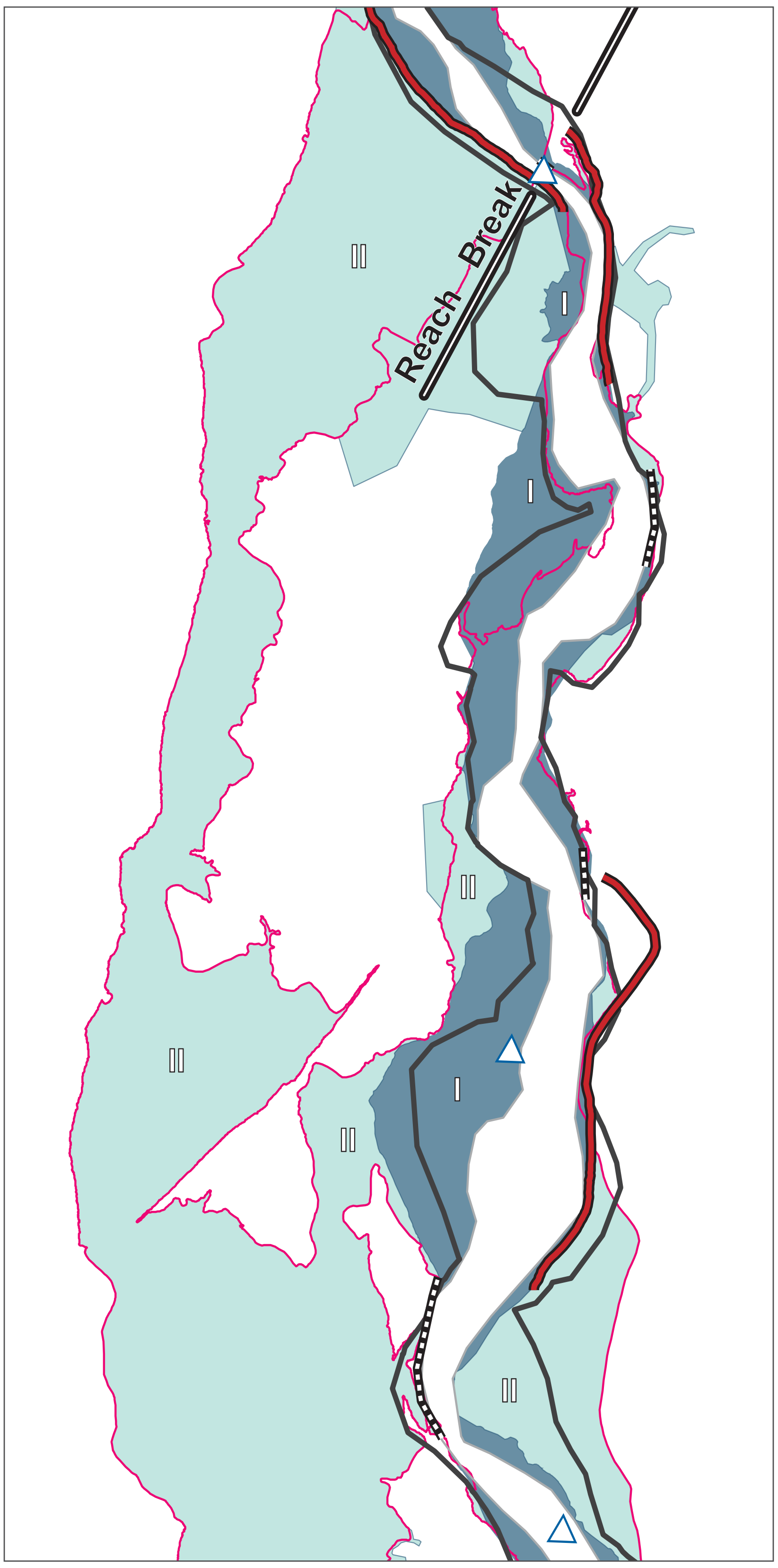
An assessment should be made by a qualified fisheries biologist to characterize both the existing habitat quantity and quality within a project area, the proposed changes in aquatic habitat resulting from the project, and potential short-term (construction-related) or long term (as a result of project outcomes) impacts on habitat. Mitigation measures are recommended for projects that result in net loss of habitat quantity or quality to maintain no further loss of valuable aquatic resources.

4. Large Woody Materials (LWM) Risk Assessment, Design and Stability Analysis

Design of large wood structures is an integral component to restore lost geomorphic function and create improved aquatic habitat. Installation of LWM creates inherent risks to the public and infrastructure that should be evaluated according to guidelines described in the Large Woody Material-Risk Based Design Guidelines (Knutson and Fealko, 2014) and design criteria established according to a risk-based evaluation. Design and stability analysis of LWM structures should follow current standards of care as described in Knutson and Fealko (2014), the National Large Wood Manual (Reclamation and USACE, 2015), and Computational Tools for Evaluating the Stability of Large Wood Structures (USDA, 2016).

Key to Reach Maps and Data

The following layers of data and information are used in each of the River reach maps.



Flood Risk Zones

Flood risk zones are presented on the left side of the fold for each river reach, overlain atop a high resolution 2015 aerial photo. Flood Risk Zones 1 and 2 were developed specifically for this Atlas using a combination of data sources and the process to develop those 2 zones is fully described in Chapter 3. The boundary of the FEMA Special Flood Hazard Area, which depicts the regulatory boundary for the 1% annual exceedance probability flood (100-year flood), is displayed in a pink boundary on each reach map. The 2017 channel boundary is also displayed on the 2015 aerial image to show the location of the modern channel. The 2017 aerial image quality was not of sufficient quality to use for presentation purposes in the Atlas.

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I — Flood Risk Zone I
- II — Flood Risk Zone II

Erosion Zones

Erosion risk Zones are labeled as High or Moderate Erosion Potential. The process to determine these risk zones is fully described in Chapter 3. The Zones are presented atop the 2015 aerial photo on the left side of the fold for each reach. The Historic Channel Migration zone (HCMZ) is displayed on both the aerial photo and HAWS map. A Zone of Recent Erosion is displayed atop the aerial photo to indicate areas subject to recent trends in rapid erosion, mostly associated with the 2017 flood.

Rock armoring and levee layers are shown on both sides of the fold, with data for these layers supplied by Blaine County.

Legend

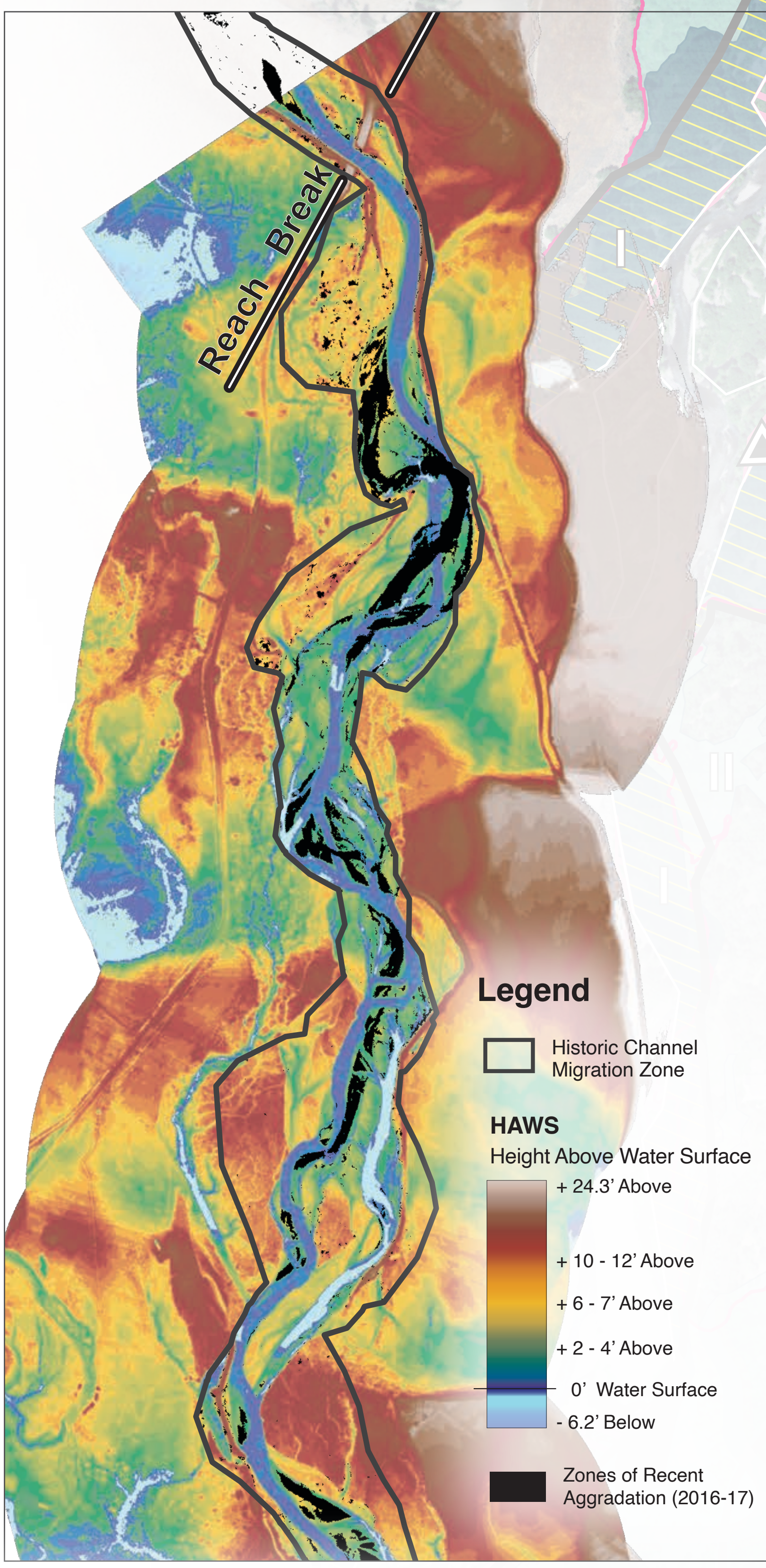
- Historic Channel Migration Zone

Zone of Recent Erosion

- 2004 to 2015 Erosion
- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential



Height Above Water Surface

The Height Above Water Surface Map, or HAWS, was developed by Cardno using 2017 LiDAR collected and provided by Blaine County. Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Zones of Recent Aggradation is the product of a LiDAR differencing process completed by Cardno. Black hatch displays the output of a geospatial analysis that was conducted to compare topographic surfaces collected through LiDAR in 2016 and 2017. Results of the analysis depict approximate changes in gravel bar elevations attributed to the 2017 flood event. A filtering technique was used to best reduce potential errors associated with this process due to data resolution and false signals created by vegetation.

Aerial Imagery

High resolution aerial imagery from 2015 was selected to use for the background of the reach mapping. 2017 aerial imagery was of insufficient quality and resolution for presentation purposes. Aerial imagery from multiple years was used to determine the HCMZ and evaluate historical trends in the Bog Wood River. Photoperiods that were used in the analysis include 1943, 1966, 1986, 2004, 2006, 1974, 2015, and 2017. Primary data sources for aerial imagery are Blaine County and the US Department of Agriculture's National Agriculture Imagery Program (NAIP), both available for use by the public.

SNRA to Eagle Creek

River Reach Locator Map

REACH 1

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

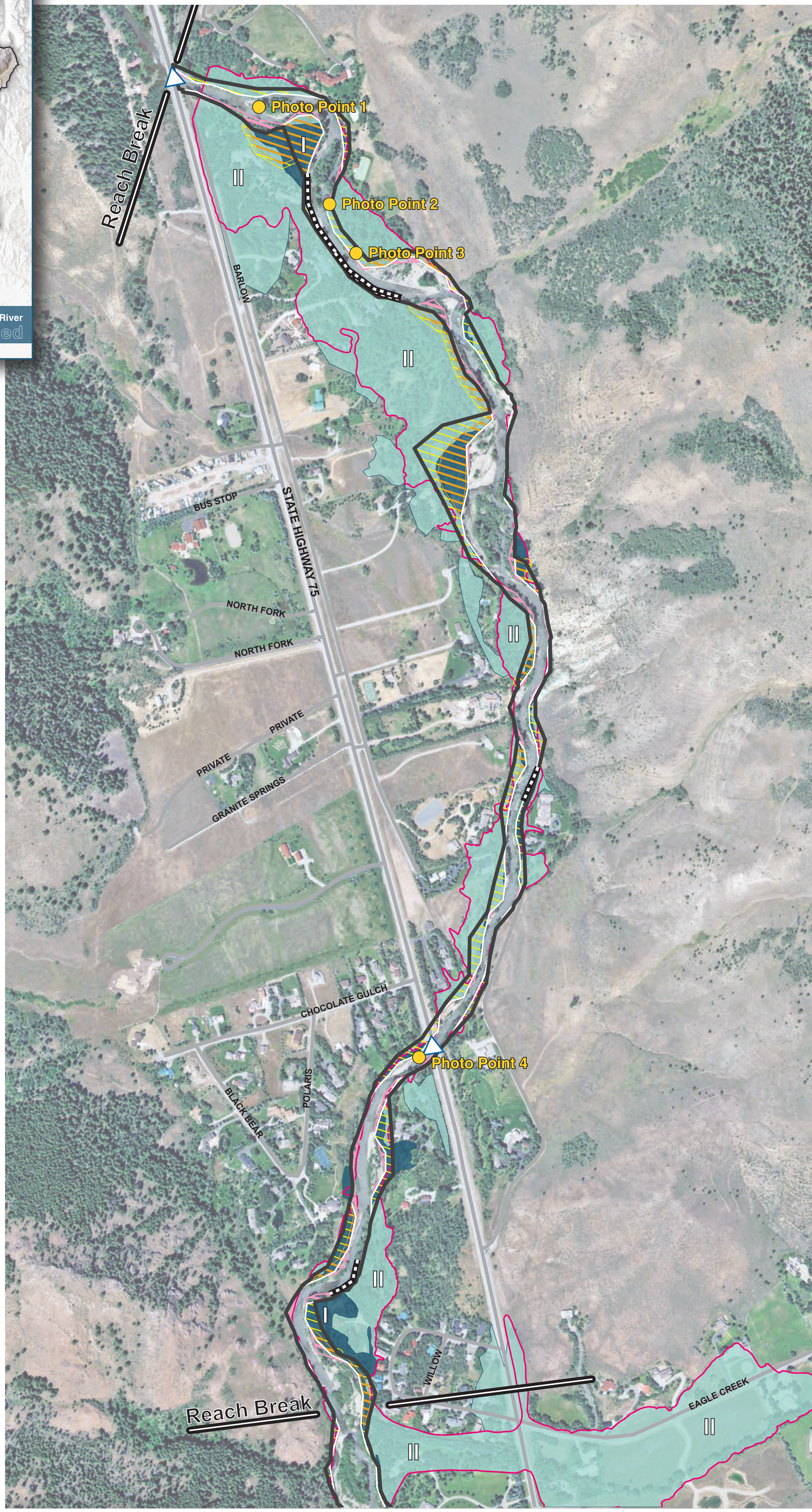
- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point

Reach Description

The SNRA reach extends 2 miles downstream from the confluence of the North Fork Big Wood River to the confluence of Eagle Creek. This reach is dominated in the upper section by a steep valley wall along the east and low-density residential development along the west side, and then by low-density development along both sides of the river downstream of the Highway 75 crossing. The reach is a steep, transport-dominated section of the Big Wood River with indications of vertical degradation (downcutting) that isolates the river from its floodplain. Flood hazard areas expand westward into both undeveloped and developed areas.



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

N

0 1,000 2,000

Feet

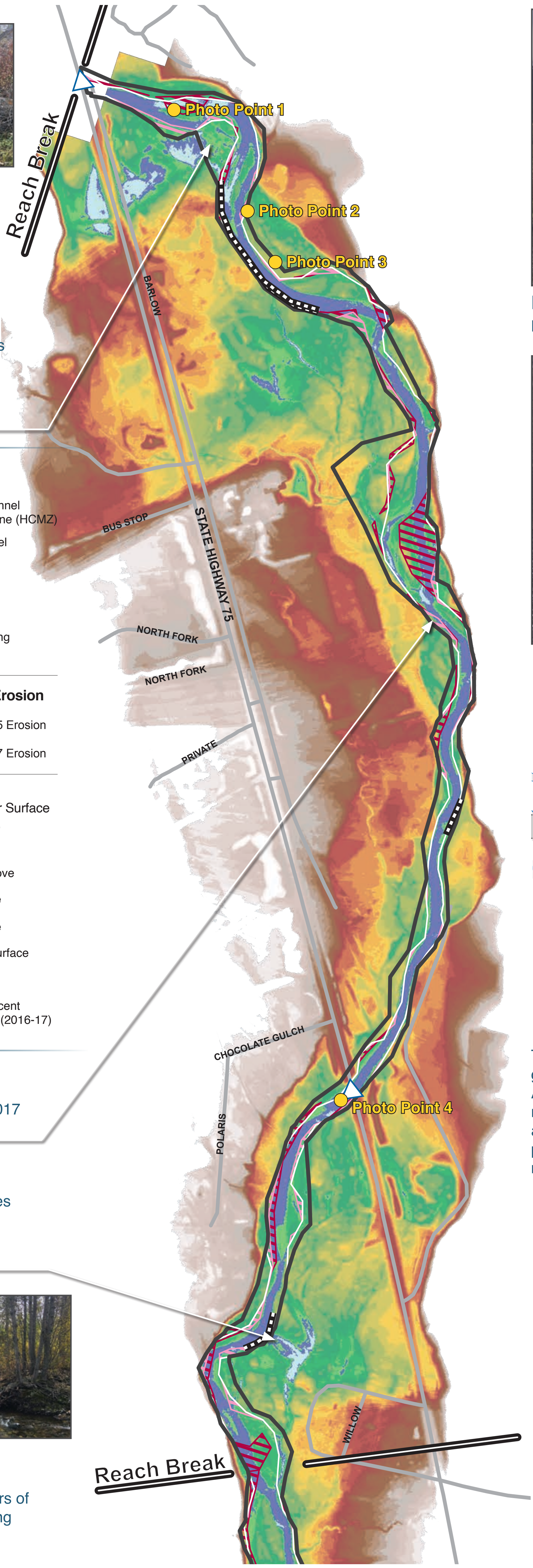
Average FEMA Floodplain Width: 338 feet

2017 Average Bankfull Channel Width: 108 feet

REACH 1

Photo Point 2
Beaver activity on large cottonwood

Forested meanders and side channels within HCMZ provide complex floodplain habitat



Westward channel migration during 2017 flood

Low elevation zones landward of HCMZ provide floodplain connectivity.

Photo Point 3
Geomorphic and vegetative indicators of channel downcutting

REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

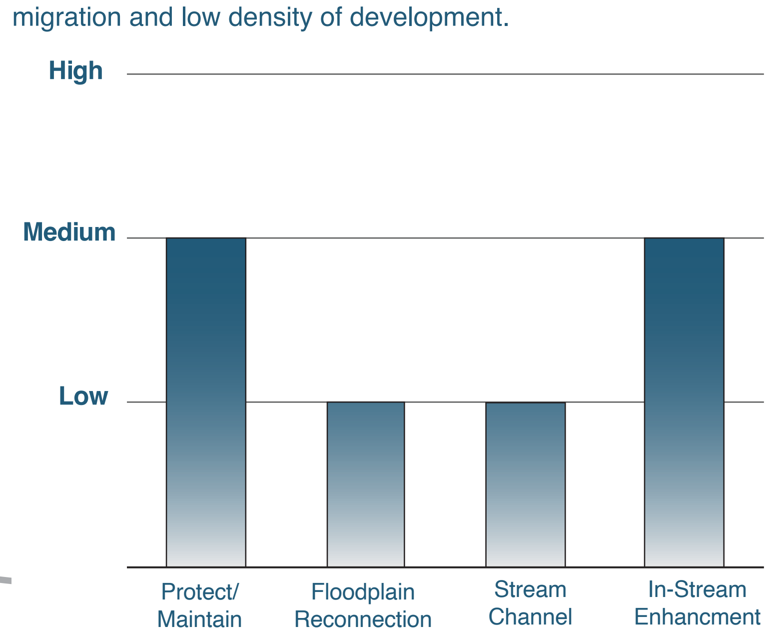
Reach Characteristics

Reach 1 - Photo Point 1
Looking upstream towards Highway 75

Reach 1 - Photo Point 4 - Looking downstream

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.13	1.15
Gradient (ft/ft)	0.0084	0.0064
HCMZ Width (ft)	185	513
Bankloss 2015-2017 (acre/river mile)	1.5	4.9
Bankloss 2004-2015 (acre/river mile)	2.7	6.8
Bank Stabilization (%)	7%	24%

The SNRA reach displays characteristics resulting from its steep gradient, small watershed area, and the confined valley setting. As such, the reach has the second smallest HCMZ width of all reaches, a FEMA floodplain that is 2.7x smaller than average, and the fifth steepest gradient. Reach 1 has the third smallest percentage of bank stabilization due to the limited channel migration and low density of development.



Reach Project Potential

The SNRA reach contains undeveloped areas located beyond the HCMZ but within flood hazard areas. These areas, particularly forested zones, represent good opportunities for conservation or protection given their value to promote healthy floodplain function.

Eagle Creek to Fox Creek

River Reach Locator Map

REACH 2

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

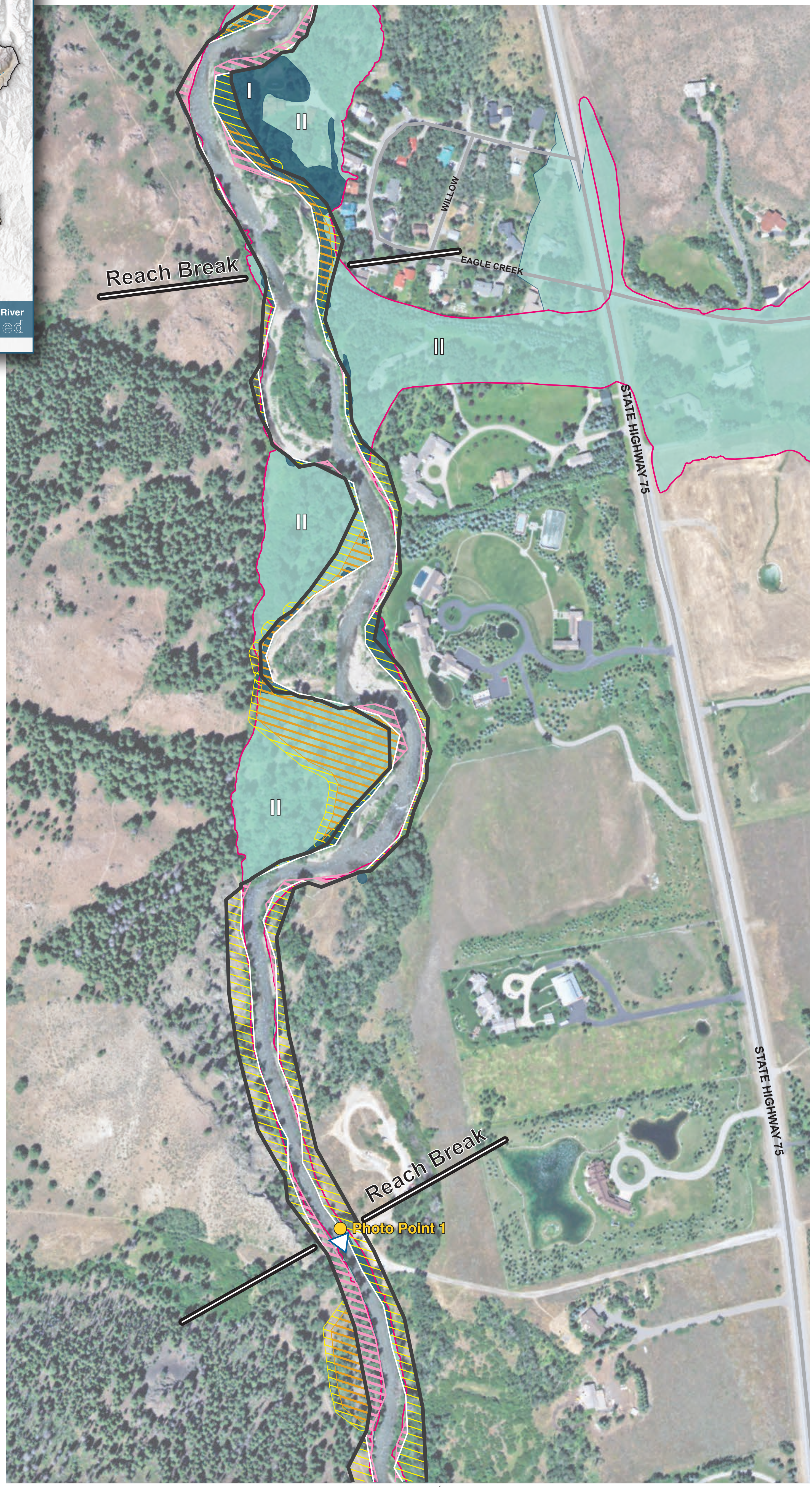
Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point

Reach Description

The Eagle Creek reach extends less than 1 mile downstream to the Fox Creek Bridge and is dominated by three meander bends that have been intact through the available photo record.

This short, high gradient reach has low-density residential development along the eastern floodplain, mostly centered along Eagle Creek. Low lying, undeveloped areas along the western floodplain, beyond the HCMZ but riverward of the valley wall, may be inundated during extreme flows.



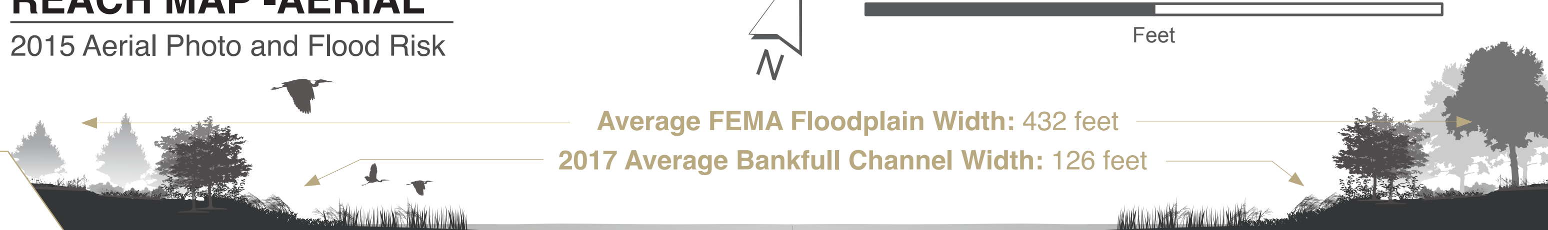
REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

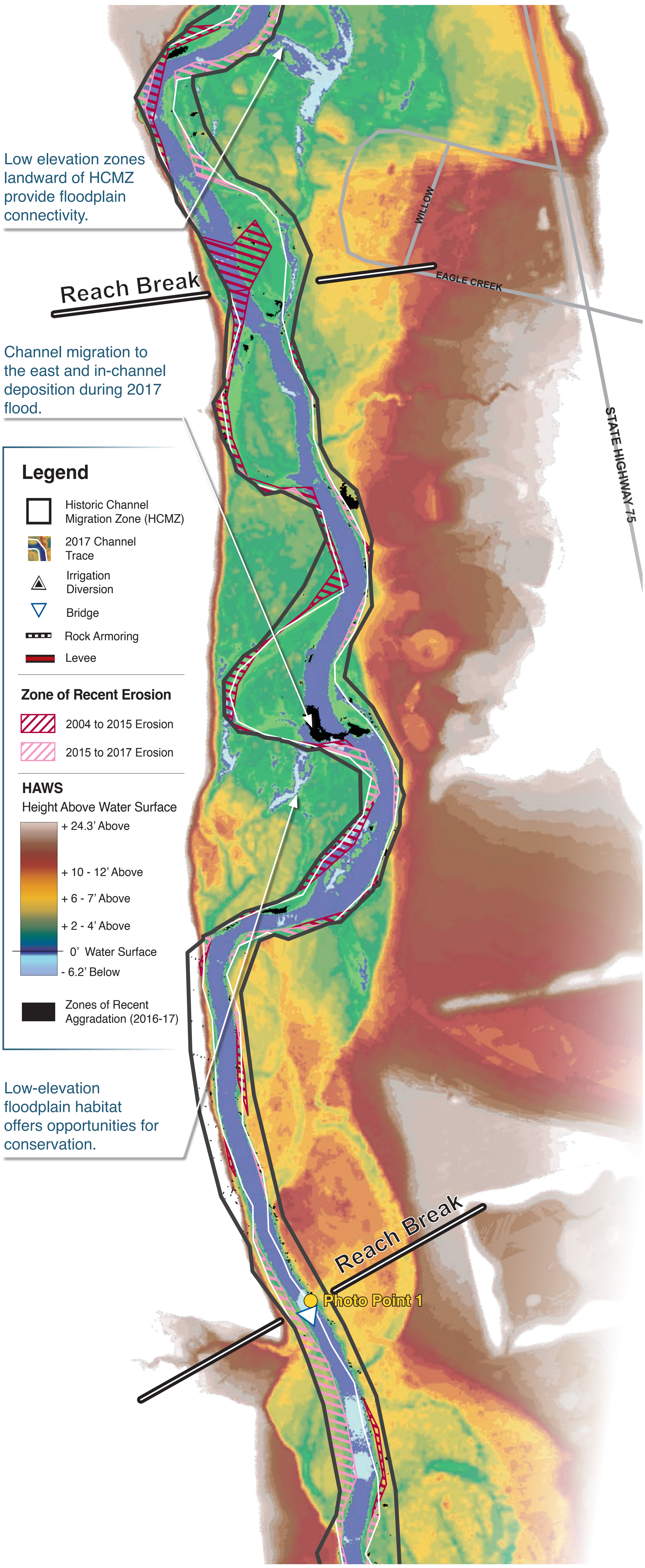
N

0 500 1,000

Feet



REACH 2



REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

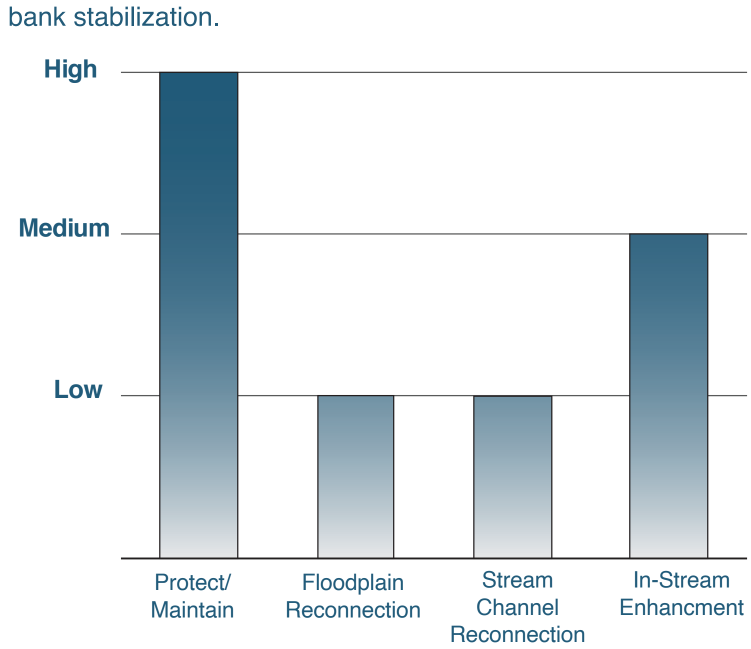
Reach Characteristics

Reach 2 - Photo Point 1

Looking upstream from Fox Creek bridge

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.18	1.15
Gradient (ft/ft)	0.0094	0.0064
HCMZ Width (ft)	216	513
Bankloss 2015-2017 (acre/river mile)	1.1	4.9
Bankloss 2004-2015 (acre/river mile)	2.4	6.8
Bank Stabilization (%)	0%	24%

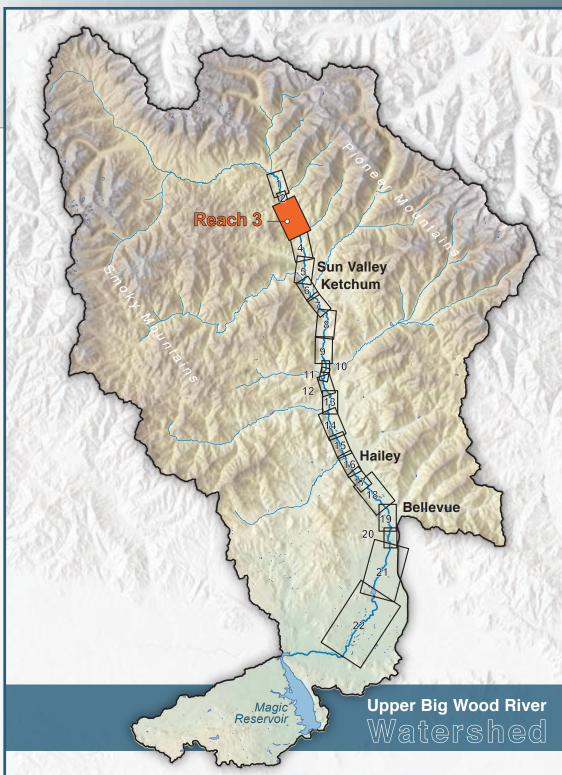
The Eagle Creek reach has a relatively stable river channel. The reach had 4.5x less channel migration and bank loss between 2015-2017 and the third least bank loss between 2004-2015 compared to other reaches. The HCMZ is 2.4x narrower than the river wide average, which indicates that this stability has been long-term. The high river gradient (2nd steepest of all reaches) functions to limit channel migration, which likely is among the reasons that this is the only reach along the study area with no bank stabilization.



Reach Project Potential

There is potential to protect and maintain the undeveloped riparian and floodplain habitat adjacent to the valley wall on river right. Note: areas identified as high priority for protect and maintain projects may have low rankings for other project types because the reach is already performing well.

Fox Creek to Lake Creek



River Reach Locator Map

REACH 3

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

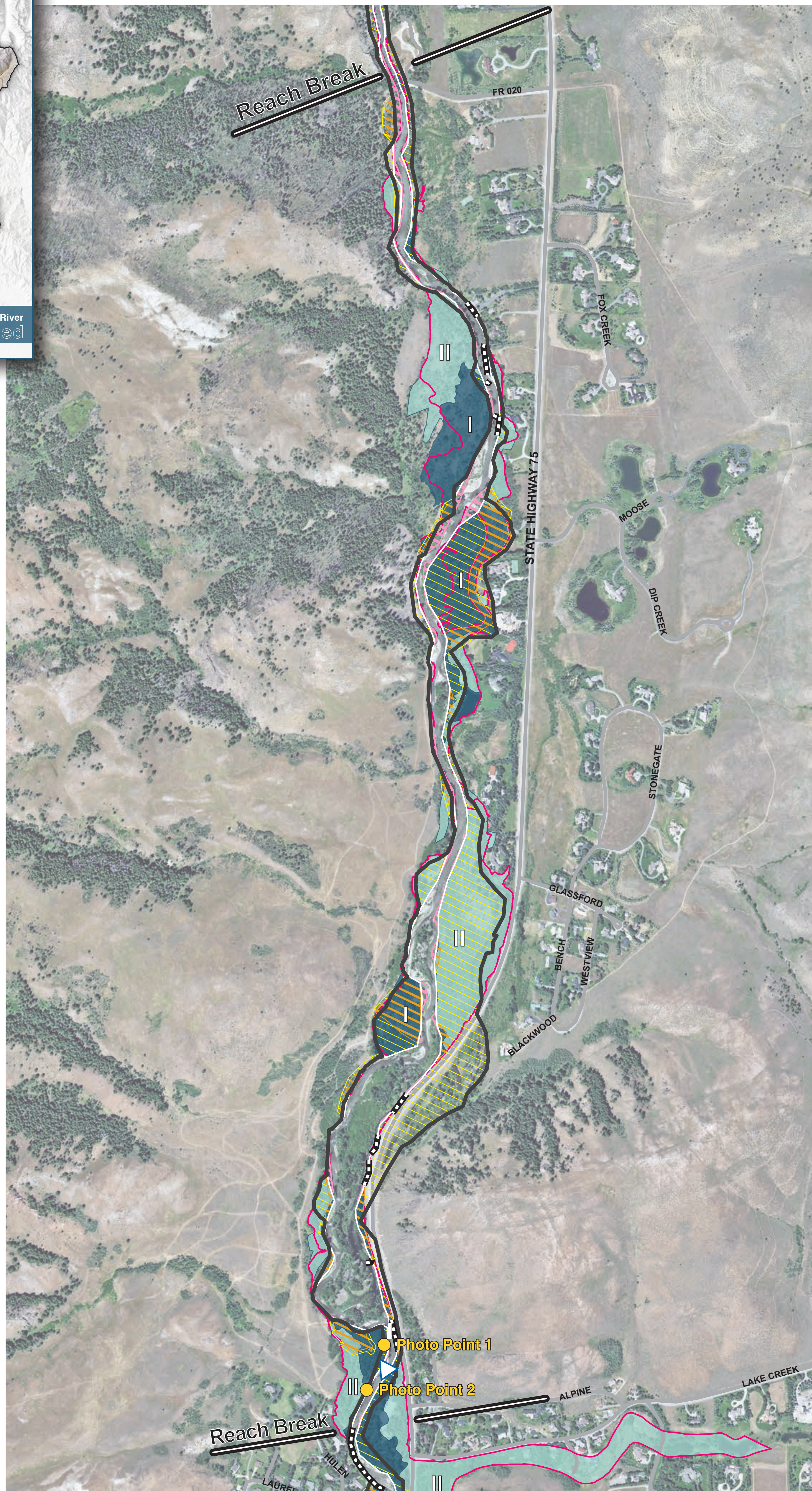
Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential

- Photo Point

Reach Description

The 2.7-mile reach from Fox Creek to Lake Creek is adjacent to USFS land along most of its western boundary and residential development along the eastern boundary. This reach fluctuates between sections of steep, confined transport dominated zones with zones of significant channel response that create complex channel and floodplain conditions. Highway 75 bisects the river's HCMZ in the lower third of the reach. This reach likely supported an anastomosing channel planform, partially evident in the 1943 photo record. A major shift in channel position between 2004 and 2015 (likely during the 2006 flood) led to major channel adjustments in this reach leaving behind the current low floodplain meadows, high flow conveyance areas, and zones of high migration potential.



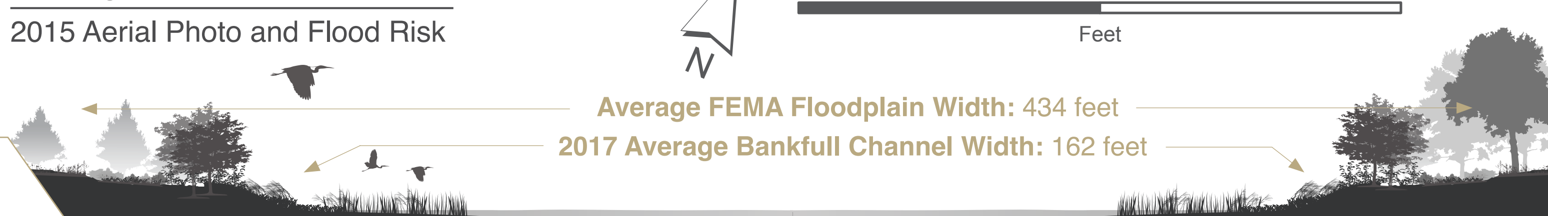
REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

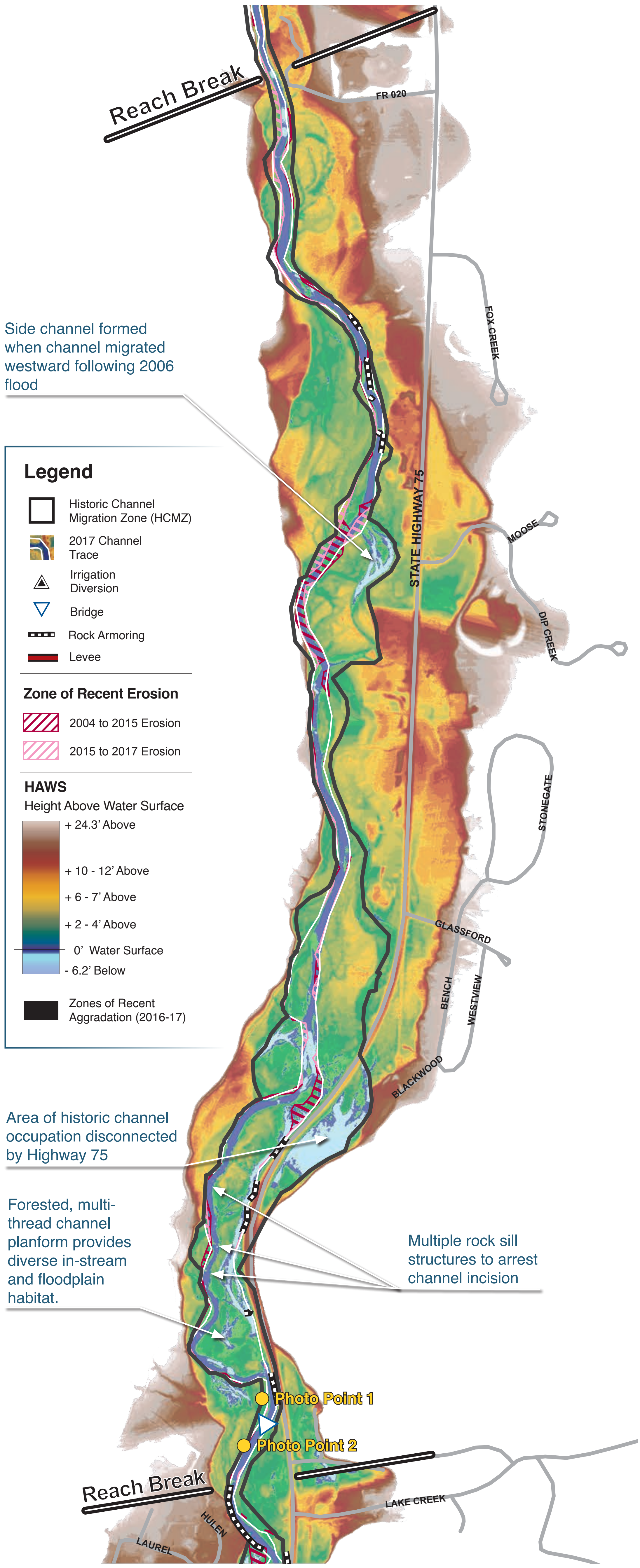
N

0 1,500 3,000

Feet



REACH 3



REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

Reach 3 - Photo Point 1

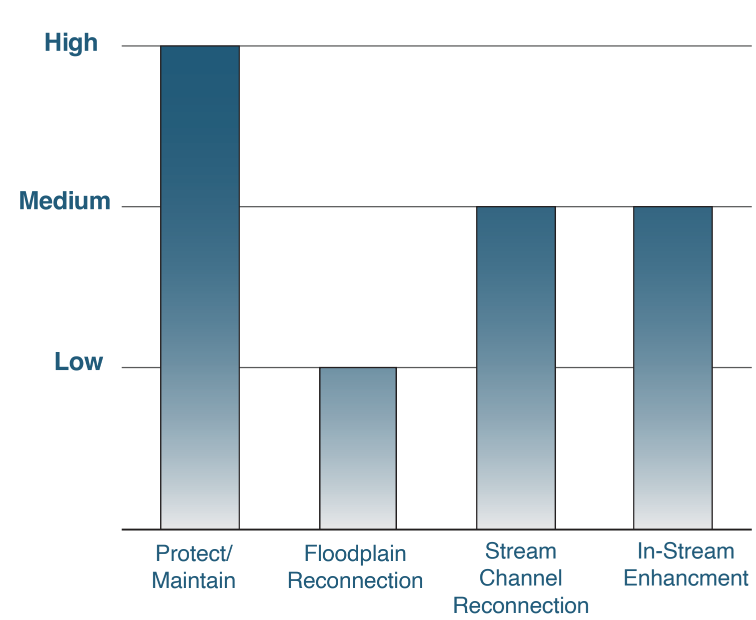
Looking upstream in Reach 3

Reach 3 - Photo Point 2

Pedestrian bridge crossing over Big Wood River

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.13	1.15
Gradient (ft/ft)	0.0091	0.0064
HCMZ Width (ft)	408	513
Bankloss 2015-2017 (acre/river mile)	2.4	4.9
Bankloss 2004-2015 (acre/river mile)	2.7	6.8
Bank Stabilization (%)	5%	24%

On average, this reach has similar characteristics to reach 1 and 2. It has the third steepest gradient and the second least presence of bank stabilization. The river here displays less area of recent channel movement than average and a narrow FEMA floodway and HCMZ. However, these averages mask multiple zones of significantly wide flood potential and channel movement, as seen in the images.



Reach Project Potential

Limiting further development within the HCMZ in Reach 3 is a priority to maintain floodplain function, channel migration potential, and in development of complex habitat features. Existing federal ownership of lands along the west floodplain will hopefully provide long term protection and conservation of these parcels.

River Reach Locator Map

REACH 4

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- Flood Risk Zone I
- Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

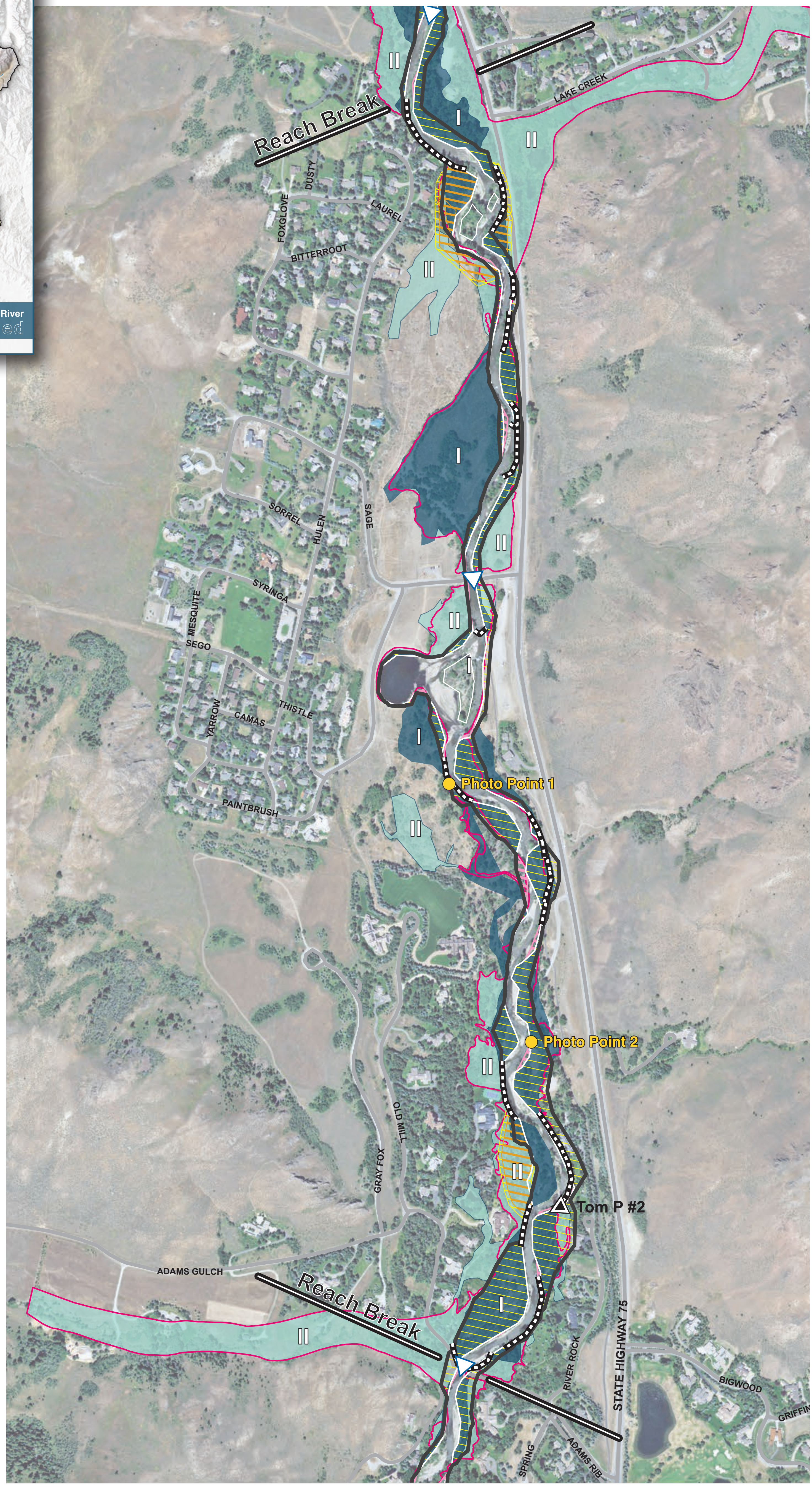
Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point

Reach Description

The 2-mile reach from Lake Creek to Adams Gulch represents the upstream transition into higher density development, as the river enters the City of Ketchum. Armoring of the banks becomes more widespread in Reach 4 to protect both residential development along the west bank, and Highway 75 along the east bank, from river expansion.

Likely related to these confining measures, Reach 4 also contains historical river management features such as gravel traps and grade control measures (rock sills).



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

N

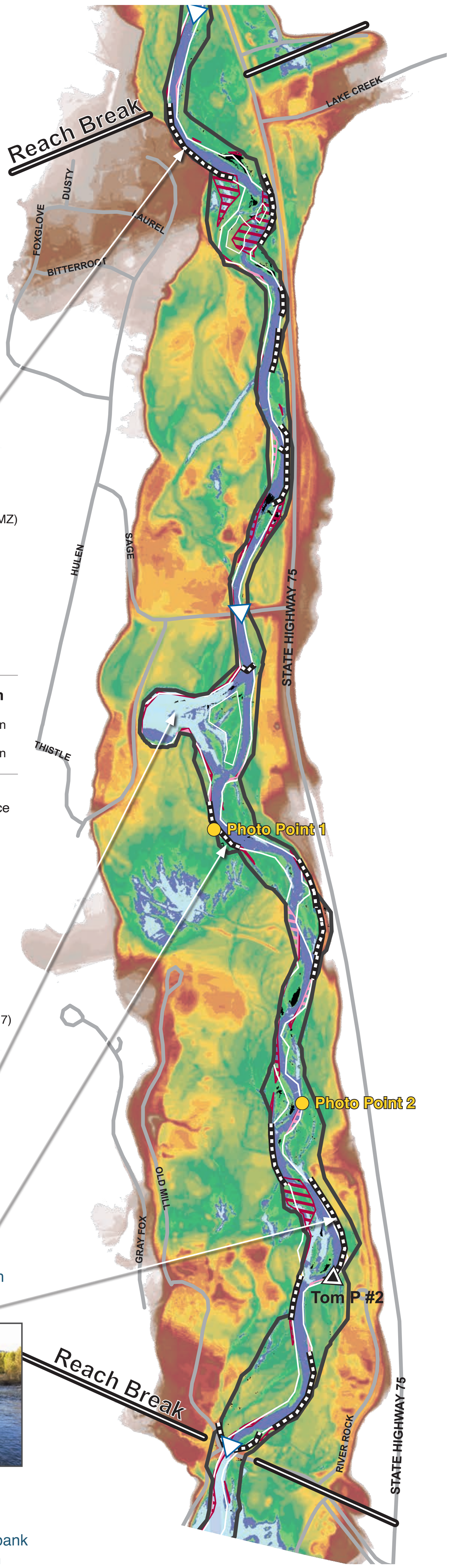
0 1,000 2,000
Feet

Average FEMA Floodplain Width: 432 feet

2017 Average Bankfull Channel Width: 101 feet

REACH 4

This reach displays commonly observed impacts from riprap placement, including flow deflection, channel confinement, and floodplain disconnection. A restoration concept here could include redirecting flows into the western floodplain through placement of engineered log jams, thereby reducing the need and impacts from riprap along the eastern bank and increasing habitat availability.



Legend

- Historic Channel Migration Zone (HCMZ)
- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- Rock Armoring
- Levee

Zone of Recent Erosion

- 2004 to 2015 Erosion
- 2015 to 2017 Erosion

HAWS

Height Above Water Surface

- + 24.3' Above
- + 10 - 12' Above
- + 6 - 7' Above
- + 2 - 4' Above
- 0' Water Surface
- - 6.2' Below
- Zones of Recent Aggradation (2016-17)

Hulen Meadows Pond; constructed to manage excess sediment

Bank armoring preventing lateral and downvalley channel migration into undeveloped low lying floodplain

Rock grade controls installed throughout Reach 4 to control downcutting

Photo Point 2

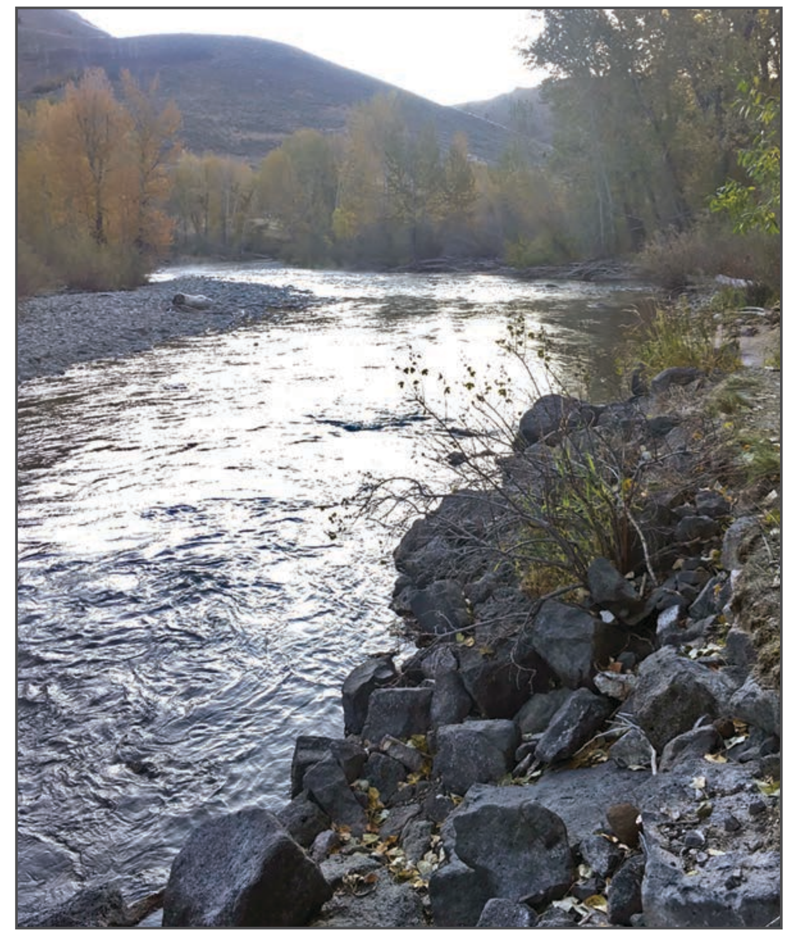
Opportunity for increased floodplain interaction to reduce pressure on right bank infrastructure downstream

REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

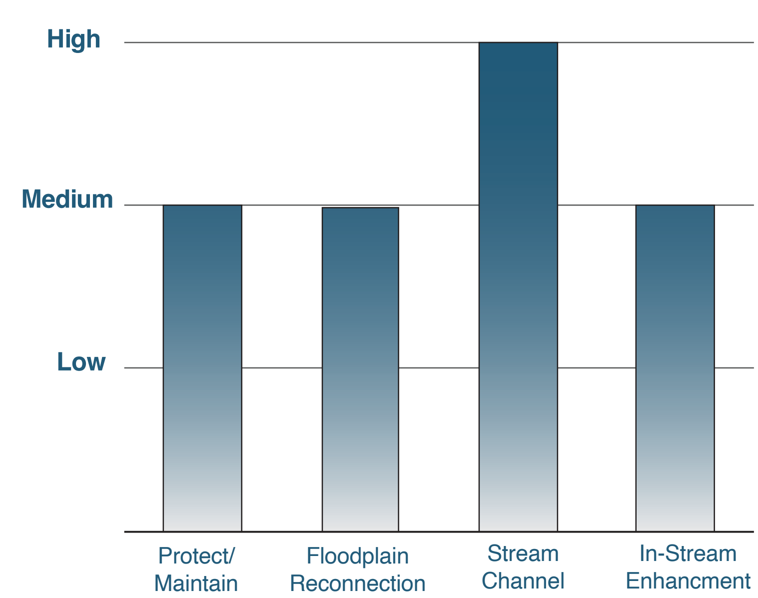


Reach 4 - Photo Point 1

Riprap wall preventing natural channel migration and floodplain connectivity

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.16	1.15
Gradient (ft/ft)	0.0096	0.0064
HCMZ Width (ft)	267	513
Bankloss 2015-2017 (acre/river mile)	0.92	4.9
Bankloss 2004-2015 (acre/river mile)	2.8	6.8
Bank Stabilization (%)	28%	24%

The Lake Creek to Adams Gulch reach had the least amount of bank loss of all reaches between 2015-2017 (>5x less bank loss area than average). This reach has the steepest gradient (0.96%) of all reaches in the study area along with the third narrowest bankfull width. The reach, however, is artificially confined by riprap along 30% of the reach length, subject to the effects of gravel trapping and grade control measures, thereby eliminating much of the rivers natural potential to expand laterally in key locations.



Reach Project Potential

Reach 4 presents potential opportunities for reach-scale channel and floodplain restoration. Open space along the western floodplain offers area to push the river away from the roadway and reduce the need for riprap to limit eastern channel migration. The Sun Peaks project currently in planning represents one such opportunity.

Adams Gulch to Warm Springs Crk

River Reach Locator Map

REACH 5

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

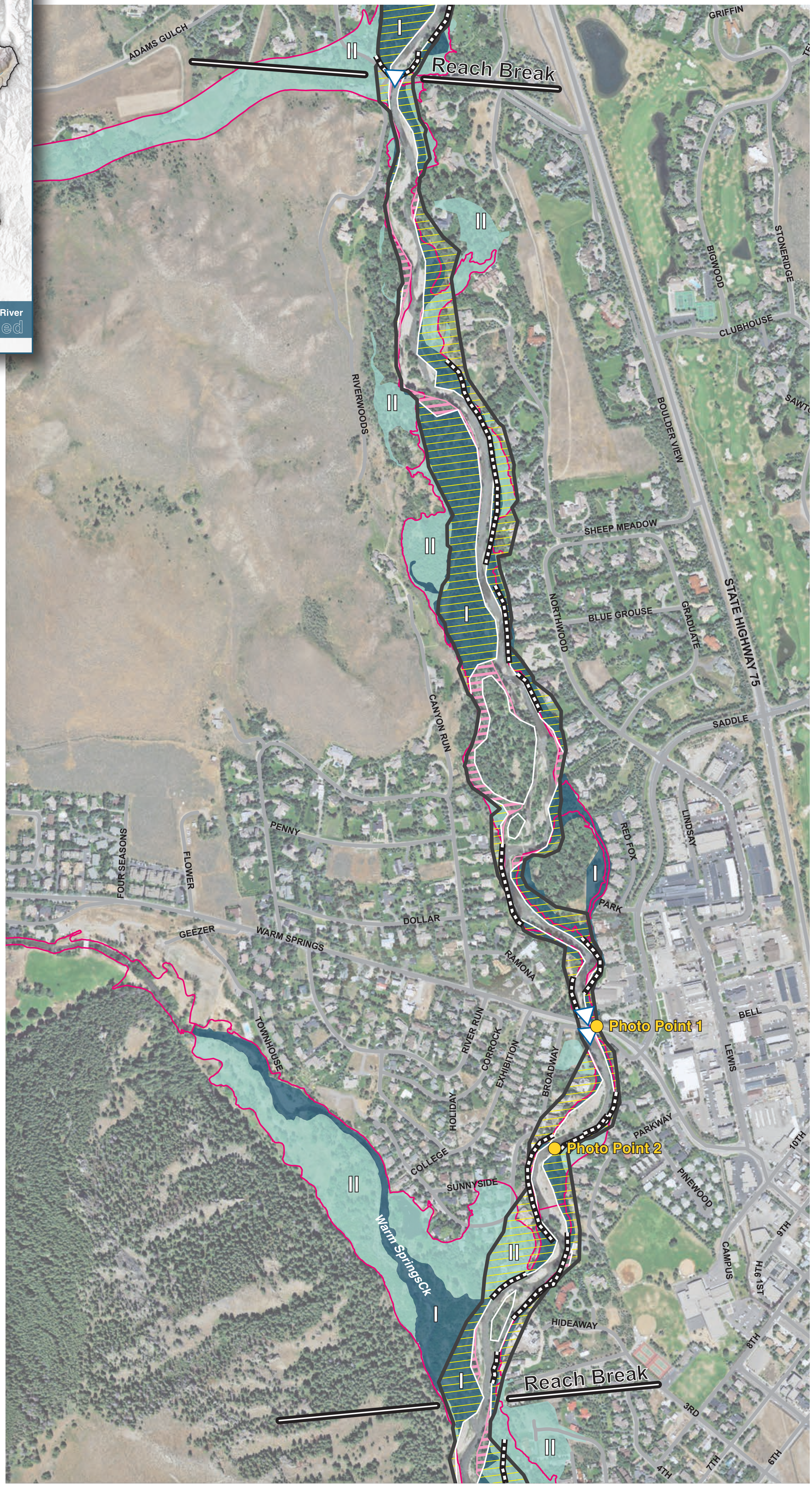
- Flood Risk Zone I
- Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

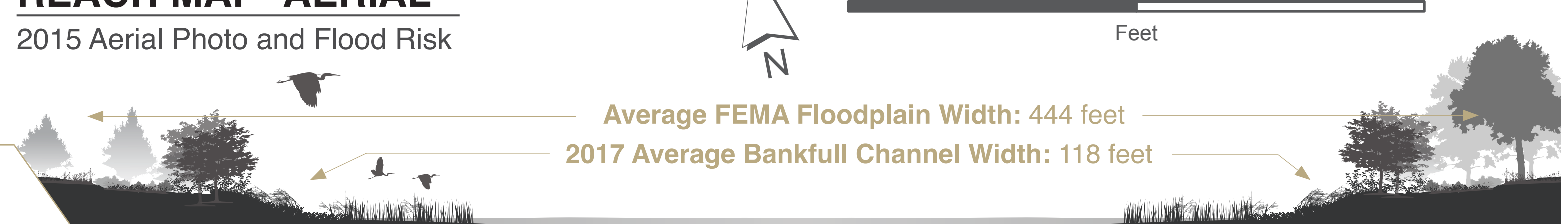
N

0 1,000 2,000

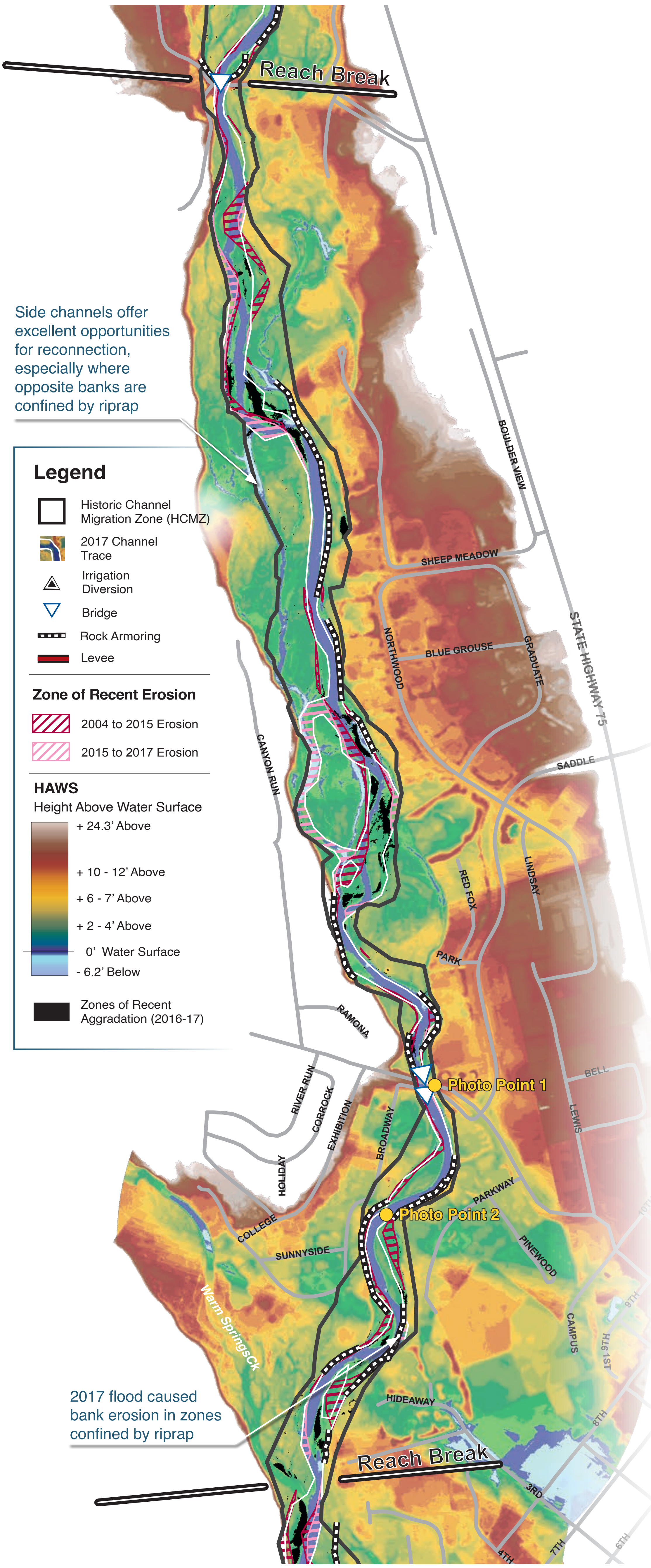
Feet

Reach Description

The 1.8-mile reach from Adams Gulch to Warm Springs Creek runs through the heart of the City of Ketchum. The channel has maintained uniform channel position within this reach since photo records are available (1943-present), with the notable exception of the river corridor through the Hemingway/Northwood Natural Area. Significant bank armoring is located along the eastern bank upstream of Warm Springs Bridge and along both banks downstream to protect homes from river erosion.



REACH 5



REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

Reach 5 - Photo Point 1

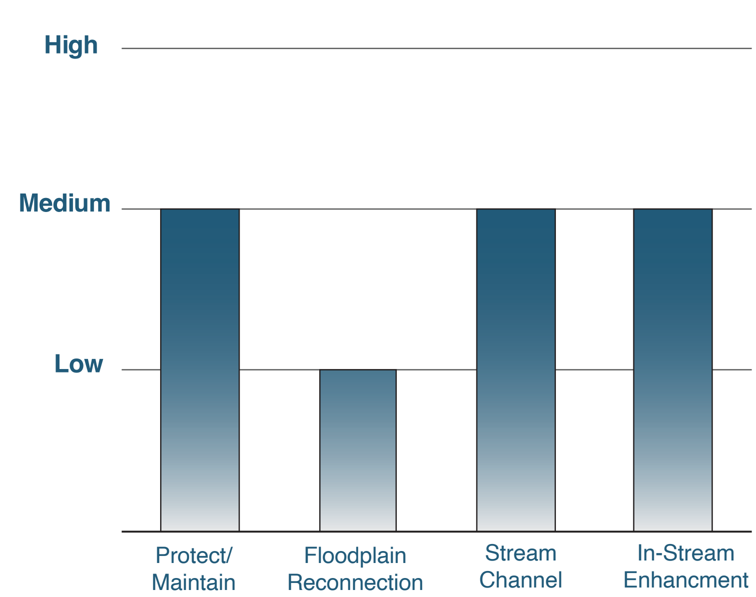
Looking downstream from Warm Springs Rd bridge

Reach 5 - Photo Point 2

Looking downstream, riprap wall in background

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.13	1.15
Gradient (ft/ft)	0.0087	0.0064
HCMZ Width (ft)	350	513
Bankloss 2015-2017 (acre/river mile)	2.5	4.9
Bankloss 2004-2015 (acre/river mile)	3.7	6.8
Bank Stabilization (%)	30%	24%

This reach presents a relatively narrow HCMZ and FEMA floodplain potentially caused by its close proximity to Ketchum. The reach also experienced about 2x less bankloss between 2015-2017 than average, has the fourth steepest river gradient, and was the first reach to experience noticeable areas of aggradation between 2016-2017.



Reach Project Potential

The western floodplain throughout the upper sections of this reach are currently undeveloped and subject to some protection in the Northwood Natural Area. These areas serve a high value in floodplain function upstream of a highly developed zone. Efforts should be made to maintain and expand protected status, as well as restore channel processes in areas of prior channel occupation.

Warm Springs Crk to Trail Creek

River Reach Locator Map

REACH 6

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

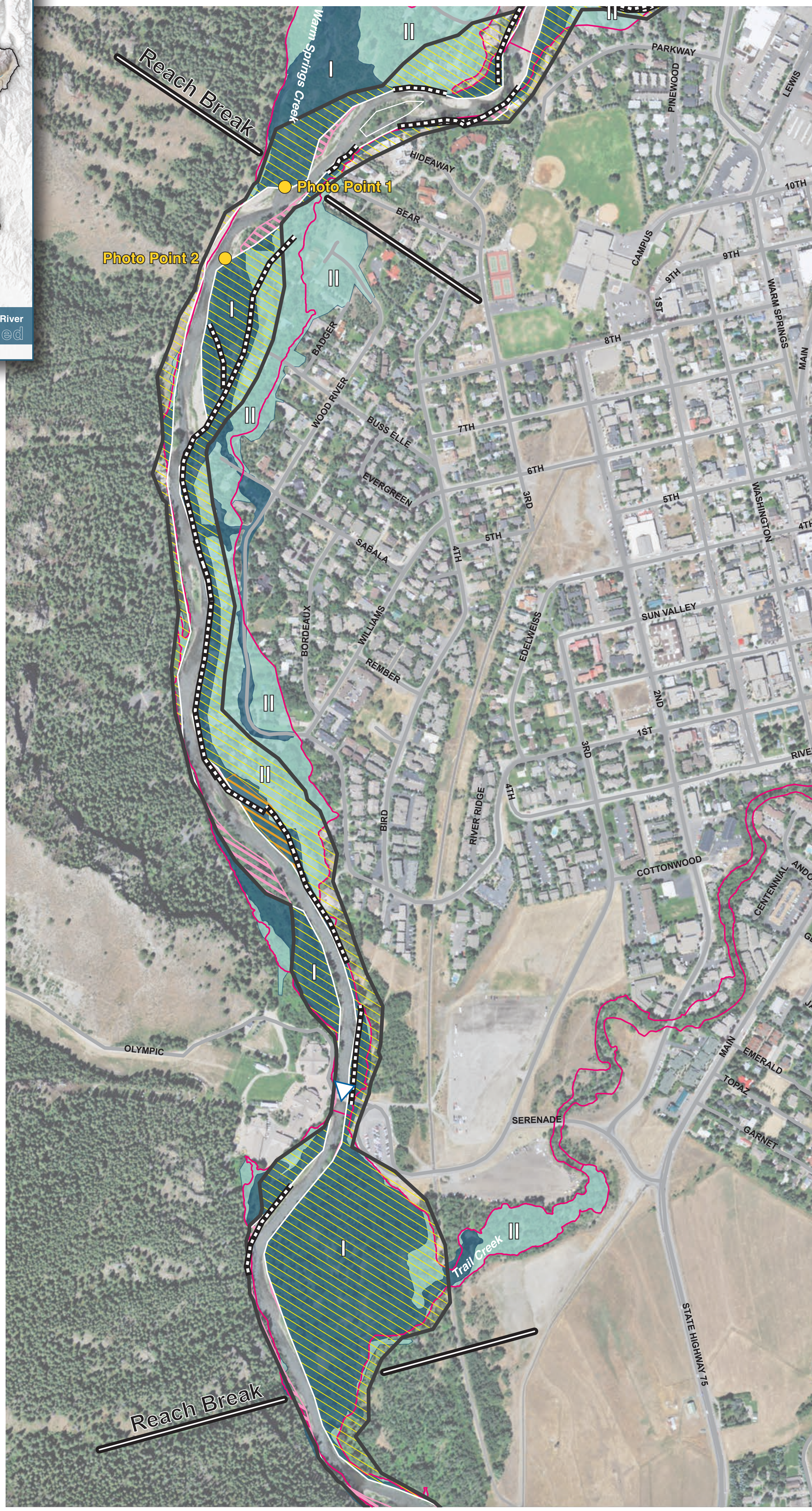
- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

0 1,000 2,000
Feet

Average FEMA Floodplain Width: 436 feet

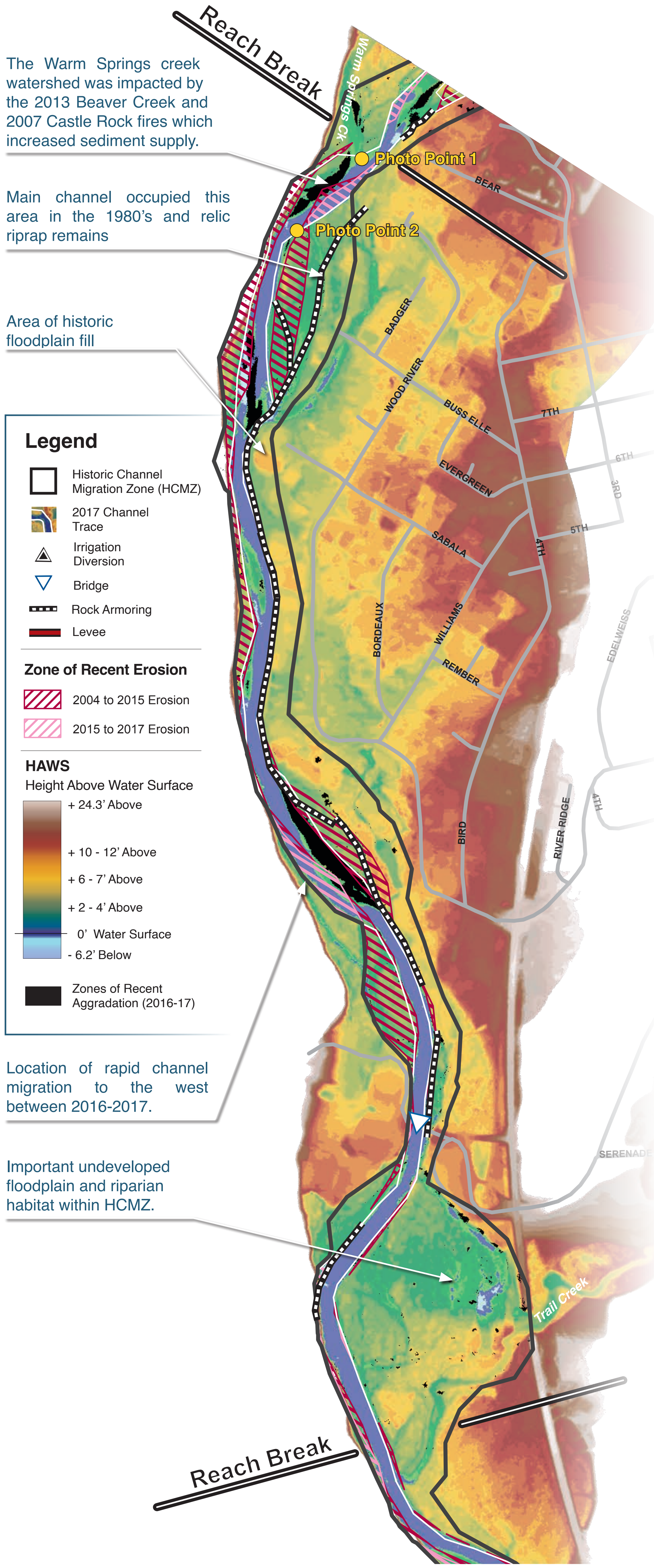
2017 Average Bankfull Channel Width: 104 feet

Reach Description

Reach 6 runs 1.6 miles from the confluence of Warm Springs Creek to Trail Creek. This reach is adjacent to highly developed lands along the eastern floodplain and confined by riprap along this bank almost its entire length through Ketchum.

A major westward shift in channel alignment occurred near Buss Elle Rd between 1986 and 2004. The 2017 flooding resulted in large zones of in-channel deposition and heightened flood risk. Sediment inputs from Warm Springs Creek play a major role in channel evolution, flood risk, and migration risk in Reach 6.

REACH 6



REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

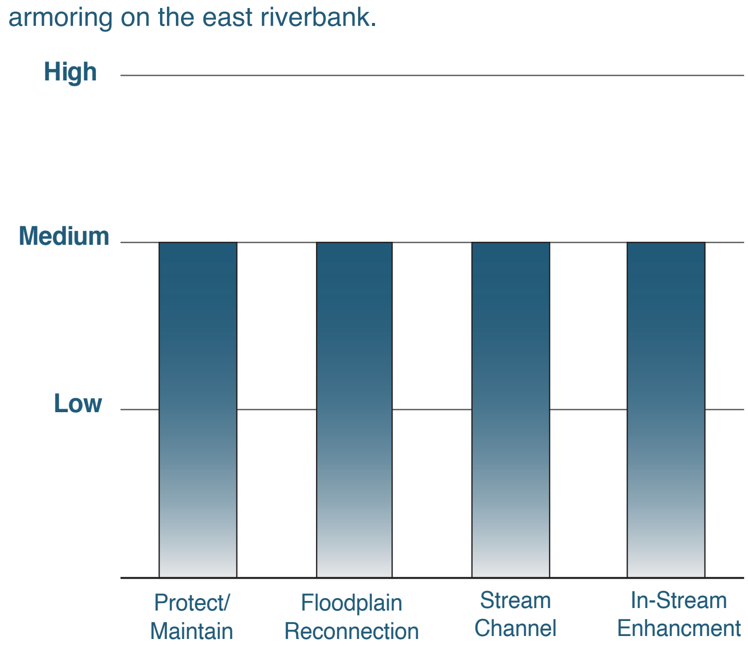
Reach Characteristics

Reach 6 - Photo Point 1
Warm Springs Creek confluence

Reach 6 - Photo Point 2 - Looking downstream

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.04	1.15
Gradient (ft/ft)	0.0062	0.0064
HCMZ Width (ft)	403	513
Bankloss 2015-2017 (acre/river mile)	1.4	4.9
Bankloss 2004-2015 (acre/river mile)	8.5	6.8
Bank Stabilization (%)	38%	24%

The Warm Springs Creek reach is the first reach that transitions to a lower energy system (less steep river gradient). Lower energy rivers tend to have more channel migration and a higher sinuosity, but this reach had the third least sinuous channel with very little channel migration between 2015-2017 (3.5x less than average). This observation may be explained by the near continuous bank armoring on the east riverbank.



Reach Project Potential

Opportunities in Reach 6 include efforts to promote removal or modification of rock arming where feasible. In-stream sediment management through placement of flood fencing or engineered log jams could assist in sediment retention. The area around the Trail Creek confluence may offer opportunities for stream channel or floodplain process reconnection.

Trail Creek to HWY 75

River Reach Locator Map

REACH 7

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

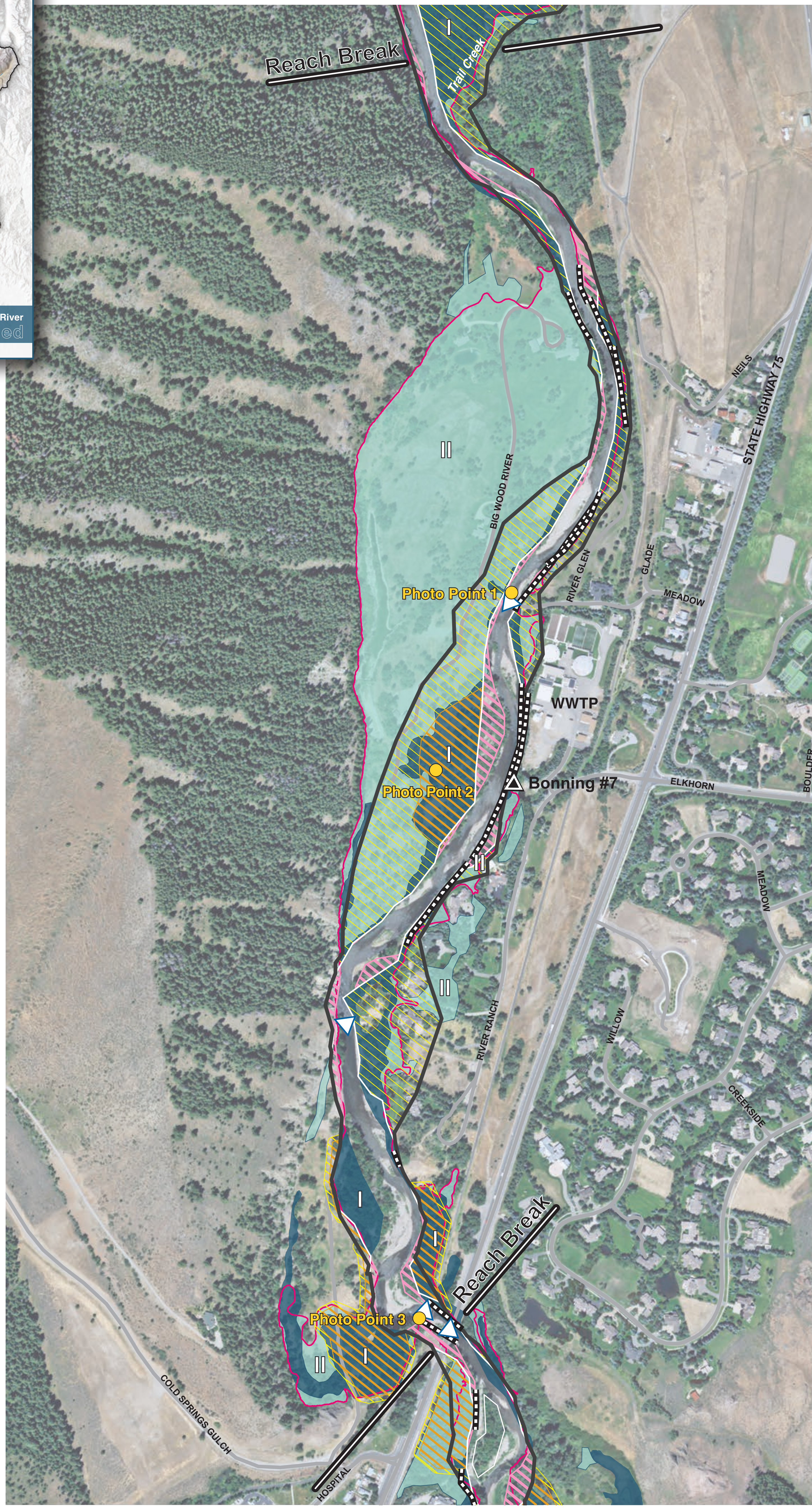
- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

N

0 1,000 2,000

Feet

Reach Description

Reach 7 extends 1.5 miles from the Trail Creek confluence downstream to the Hospital bridge. The upstream section of the reach is dominated by the Wastewater Treatment Plant (WWTP) on the eastern floodplain and low lying, private property to the west. The west floodplain here appears to have valley wall channel features that pre-date the 1943 aerial photo, and today are flood prone and susceptible to channel migration. The lower section of the reach contains the upstream limits of a very dynamic zone surrounding the Hospital bridge. The presence of the bridge, and the channel training structures placed to maintain channel position under the bridge, have resulted in significant channel response on both sides of the bridge.

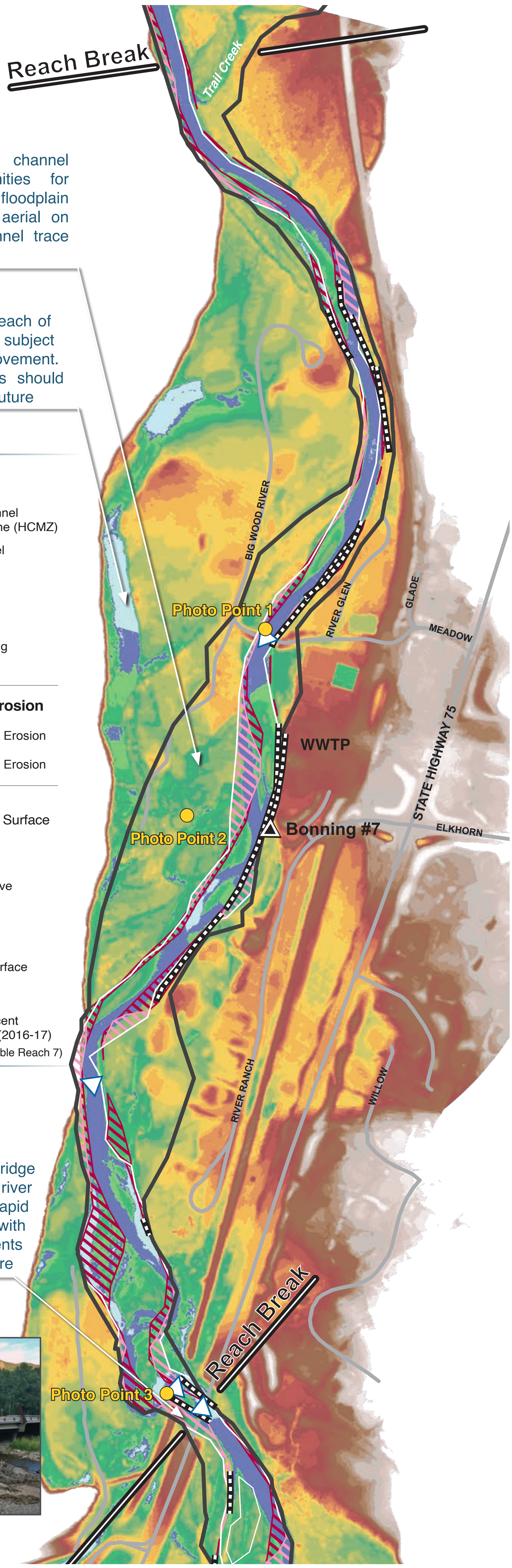
Average FEMA Floodplain Width: 593 feet

2017 Average Bankfull Channel Width: 127 feet

REACH 7

Historic 1943 channel presents opportunities for channel and floodplain reconnection (see aerial on right of 1943 channel trace over 2015 aerial).

This is a dynamic reach of the Big Wood River subject to rapid channel movement. Further adjustments should be expected in the future



The Hospital Bridge reach is a dynamic river reach subject to rapid channel movement with further adjustments expected in the future

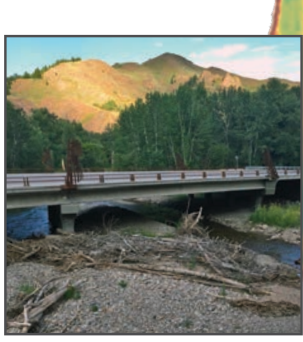


Photo Point 3

REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

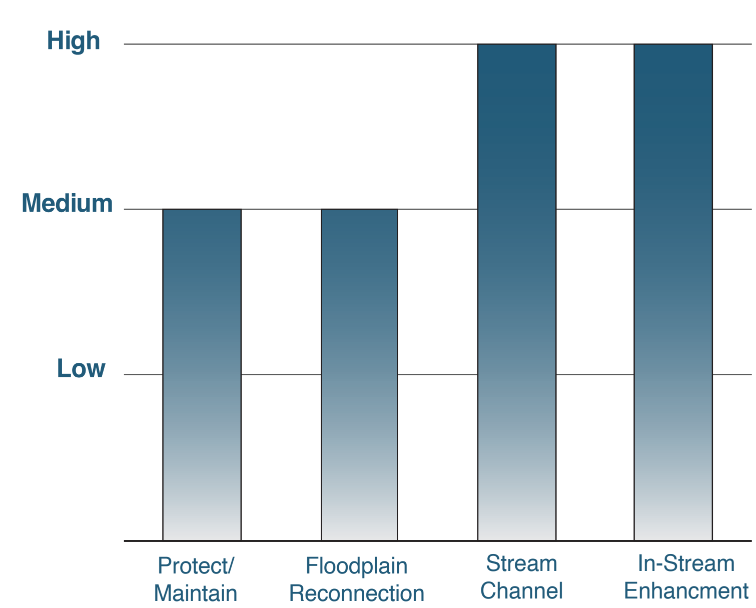
Reach 7 - Photo Point 1 - looking downstream

Reach 7 - Photo Point 2

An excellent opportunity exists across from the WWTP to reconnect the channel to its historic 1943 location (in red). Consideration must be given to the maintenance of WWTP intake or discharge locations

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.18	1.15
Gradient (ft/ft)	0.0063	0.0064
HCMZ Width (ft)	362	513
Bankloss 2015-2017 (acre/river mile)	3.6	4.9
Bankloss 2004-2015 (acre/river mile)	5.3	6.8
Bank Stabilization (%)	22%	24%

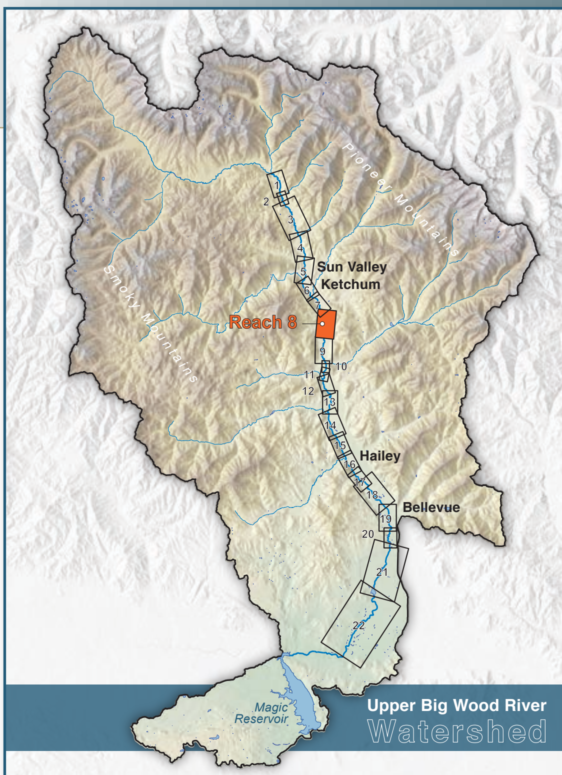
The Trail Creek to Hwy 75 reach had characteristics that were generally close to the Big Wood River average due to its location near the middle of the study area. The HCMZ, 2017 bankfull channel, and FEMA floodplain were narrower than average but gradient, sinuosity and bank stabilization had typical values. The lower reaches around Hwy 75 are more dynamic than the upstream section.



Reach Project Potential

An excellent opportunity exists across from the WWTP to reconnect the channel to its historic 1943 location (see aerial image above). Given the impacts of high sediment deposition on channel dynamics farther downstream near the hospital bridge, opportunities to restore natural channel processes upstream of the bridge are recommended.

Hwy 75 / Hospital to Gimlet



River Reach Locator Map

REACH 8

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential

- Photo Point

REACH MAP -AERIAL

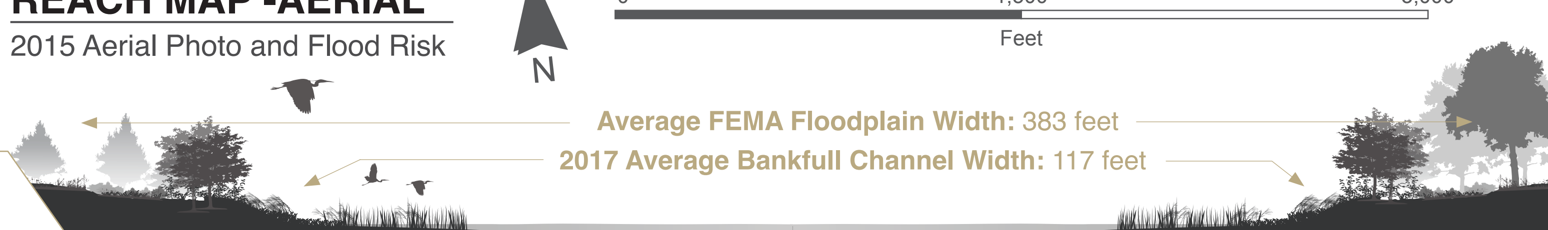
2015 Aerial Photo and Flood Risk

N

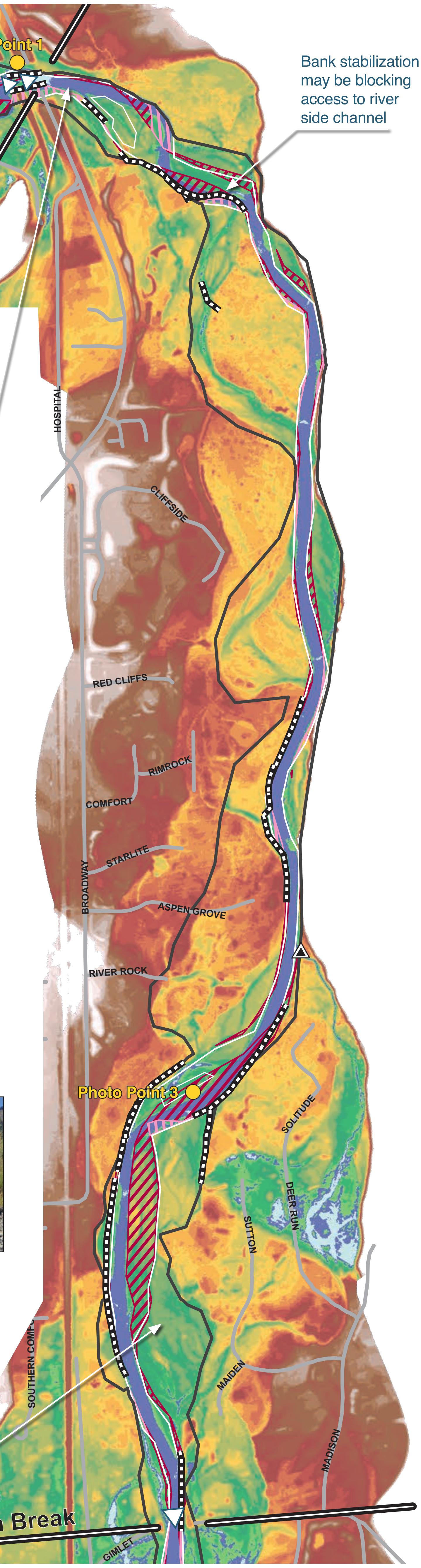
0 1,500 3,000
Feet

Reach Description

The 2.1-mile reach from Hospital Bridge to Gimlet Rd is a highly dynamic reach bound primarily on the east by steep valley walls, and zones of historic channel migration across the western floodplain. The current channel position along the eastern valley wall masks the very active channel dynamics seen along the western valley in prior times, leaving behind relic channel features susceptible to flooding and channel reoccupation. Upstream of Gimlet Rd, a very active channel pattern developed following the 2017 floods, leading to high hazards for erosion into developed areas. Channel adjustments upstream of the Hospital Bridge will likely transport large volumes of sediment into Reach 8 in the future, leading to further dynamic response.



REACH 8



Reach 8 - Photo Point 3

REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

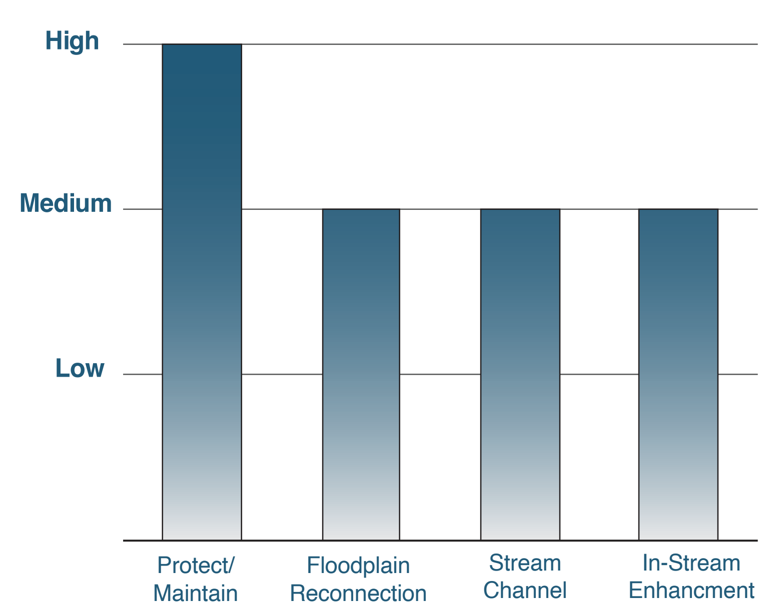
Reach Characteristics

Reach 8 - Photo Point 1

Reach 8 - Photo Point 2

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.10	1.15
Gradient (ft/ft)	0.0066	0.0064
HCMZ Width (ft)	514	513
Bankloss 2015-2017 (acre/river mile)	1.6	4.9
Bankloss 2004-2015 (acre/river mile)	6.5	6.8
Bank Stabilization (%)	22%	24%

There was little rapid channel migration and bankloss between 2015-2017 in the Hospital Bridge to Gimlet bridge reach (>3x less than average). This could have been caused by the higher than average percentage of bank stabilization, and lower than average FEMA floodplain width. There were no other unique characteristics in this reach.



Reach Project Potential

Reach 8 offers opportunities for collaborative, reach-scale channel and floodplain restoration. The challenges within the reach are the continued migration of the river into former channel locations and expansion beyond the HCMZ into residential areas. However, areas of former channel occupation along the western floodplain could be reconnected, providing expanded zones for flooding and sediment conveyance/deposition. Armored banks could be modified to incorporate bioengineering techniques.

Gimlet to East Fk Bridge

River Reach Locator Map

REACH 9

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point

REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

N

0 1,000 2,000
Feet

Reach Description

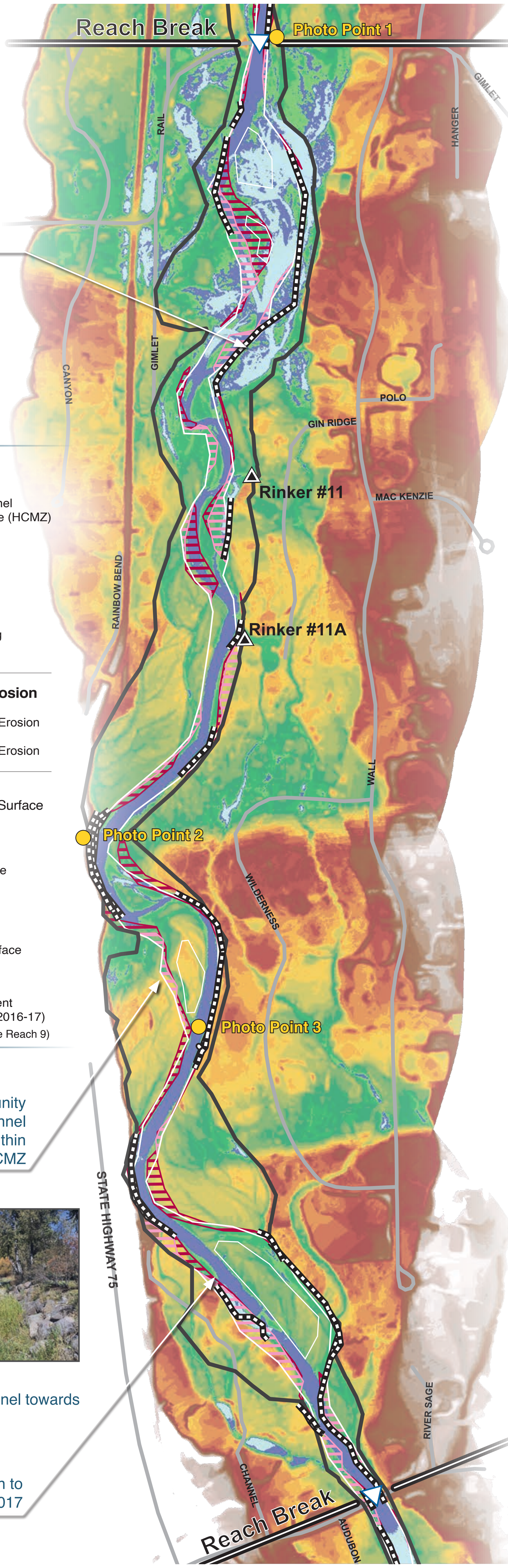
Downstream of Gimlet Bridge, the Big Wood River has been in an active migration pattern since before 2004. The 2-mile reach from Gimlet Rd to East Fork Rd. Bridge is characterized by residential development along both sides of the river up to the limits of, and in some cases within, the HCMZ. Channel expansion within the reach is shown in the image for two periods of time (2004-2015 and 2015-2017), clearly delineating channel responses to confining measures during large flood events. High erosion hazards exist adjacent to and downstream of these zones of recent channel expansion, as trends indicated continued lateral movement is likely.

Average FEMA Floodplain Width: 973 feet

2017 Average Bankfull Channel Width: 178 feet

REACH 9

Riprap set well within HCMZ, riverward of residences, and in a high erosion hazard zone may offer opportunities for floodplain and channel restoration.



Excellent opportunity for stream channel reconnection within the HCMZ

Photo Point 3

Looking across channel towards new channel outlet

Channel migration to west during 2017

REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

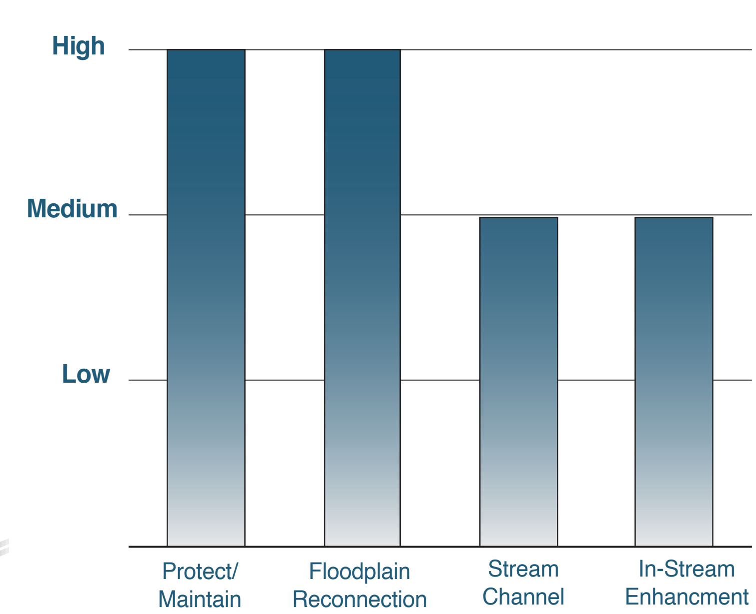
Reach 9 - Photo Point 1

Looking downstream from Gimlet Rd bridge towards split flow channel.

Reach 9 - Photo Point 2

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.19	1.15
Gradient (ft/ft)	0.0070	0.0064
HCMZ Width (ft)	561	513
Bankloss 2015-2017 (acre/river mile)	4.7	4.9
Bankloss 2004-2015 (acre/river mile)	5.1	6.8
Bank Stabilization (%)	41%	24%

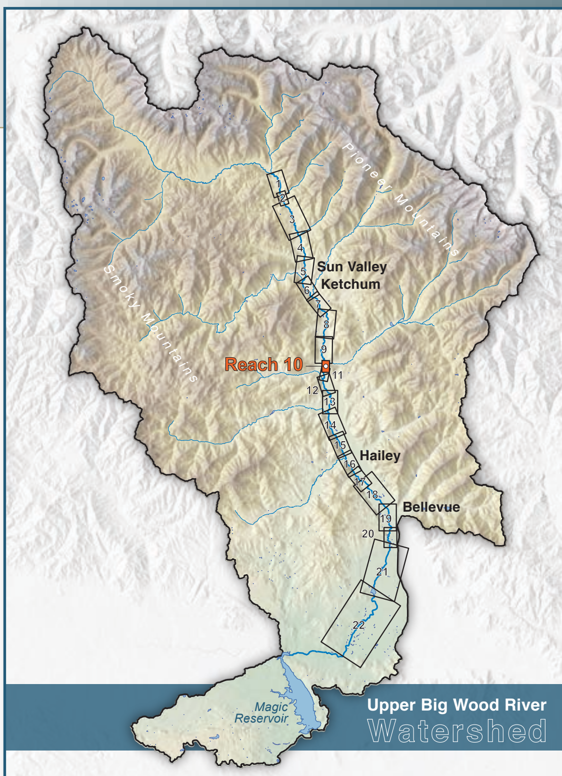
This reach is more prone to flooding than indicated by the FEMA floodplain boundary, with residential areas along both banks at risk from large flood events. This reach is also highly confined by riprap banks, with over 40% of the total bank length hardened by rock.



Reach Project Potential

The downstream extents of Reach 9 have large, undeveloped areas within the HCMZ where channel migration could be encouraged through application of log jams or grading to route the channel away from armored banks and residences. Opportunities to remove or setback riprap should be pursued to limit channel confinement. In-channel structures can assist in maintaining riparian forests, manage sediment and provide habitat.

East Fk Bridge to HWY 75



River Reach Locator Map

REACH 10

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

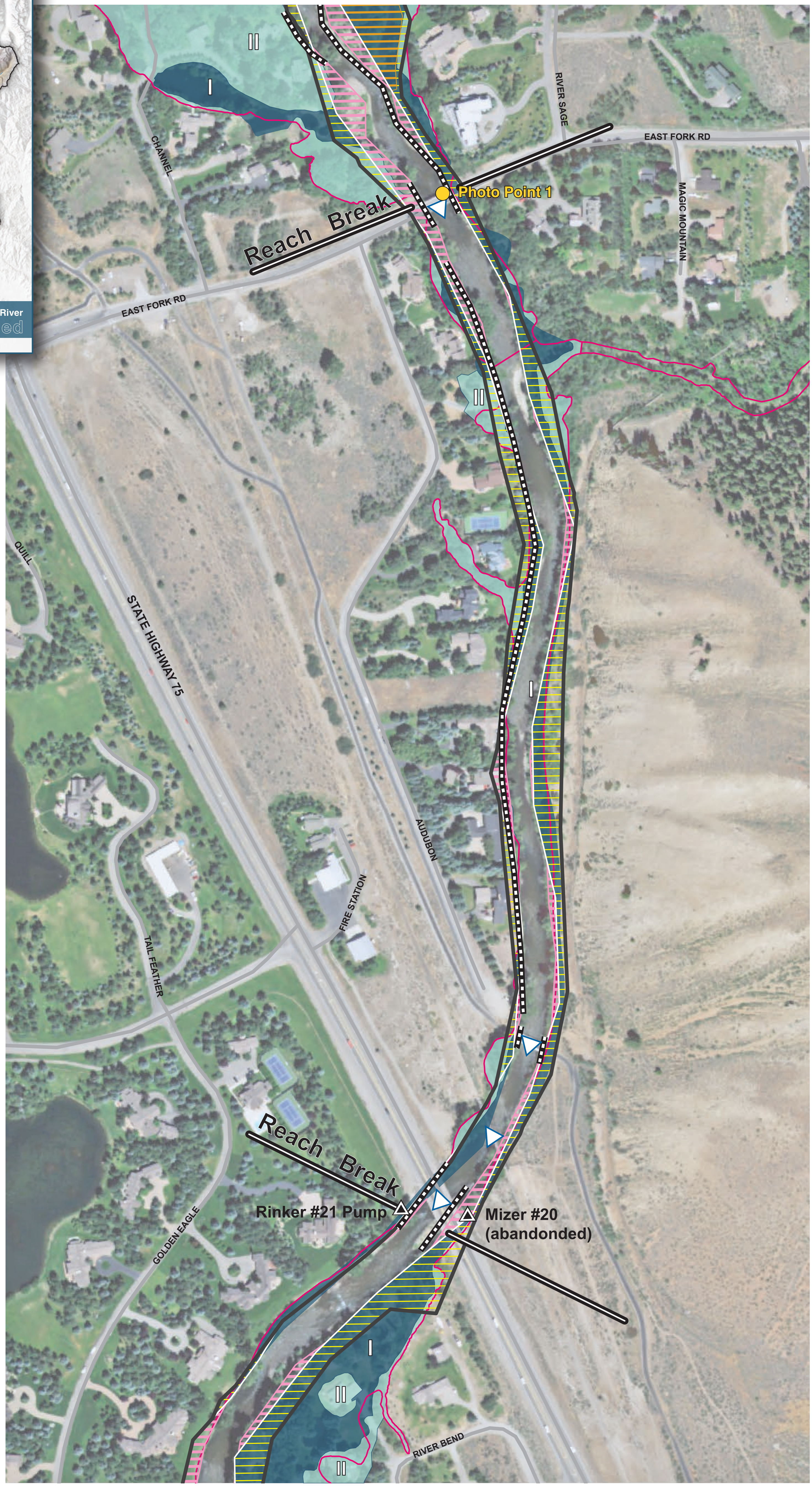
- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point

Reach Description

This short, 0.6-mile reach, appears to be geologically controlled as it has demonstrated consistent channel position since 1943. Though the reach is currently riprapped along its entire west bank to protect homes, the channel showed no indications of westward channel migration even prior to rock placement. The East Fork is a significant tributary (2nd largest flow estimates of any tributary, per FEMA) of the Big Wood River that enters near the upstream limits.



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

N

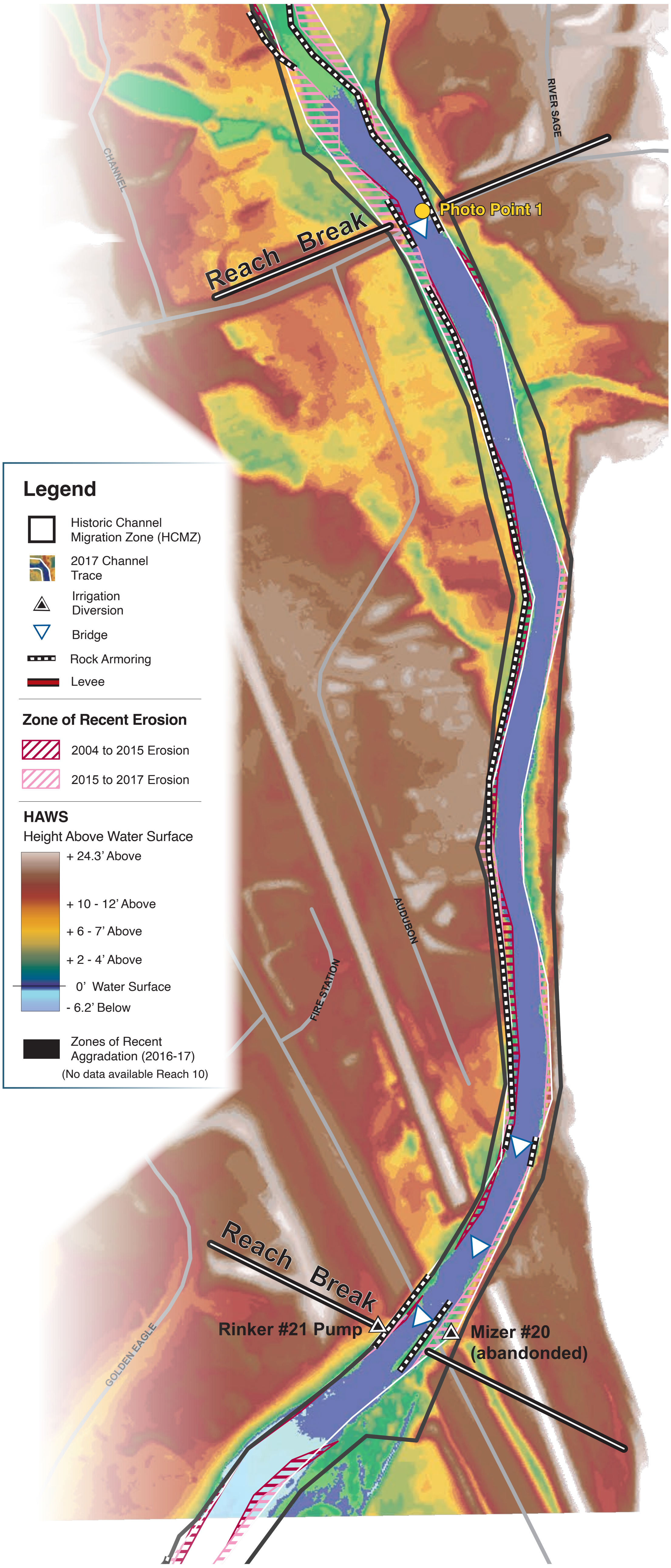
0 500 1,000

Feet

Average FEMA Floodplain Width: 137 feet

2017 Average Bankfull Channel Width: 93 feet

REACH 10



REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

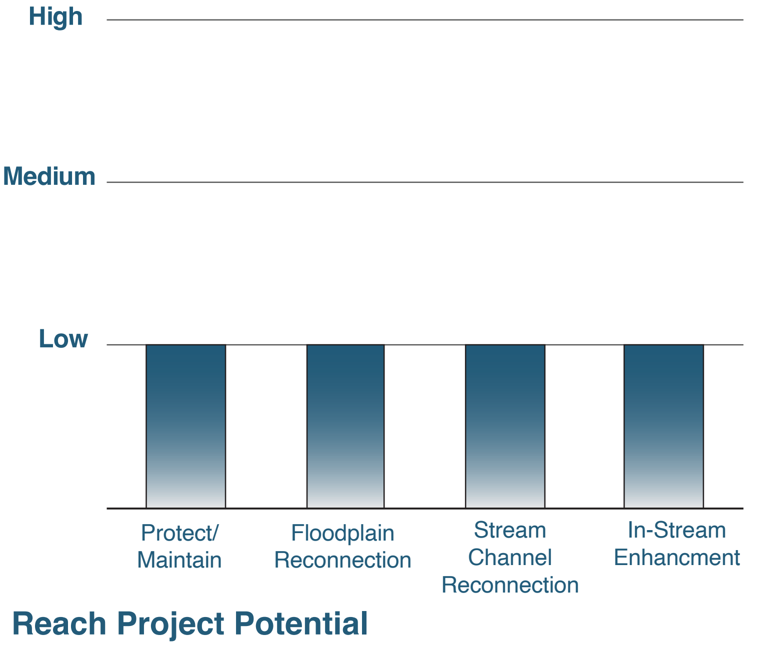
Reach Characteristics

Reach 10 - Photo Point 1

Looking downstream from East Fork Road Bridge

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.029	1.15
Gradient (ft/ft)	0.0050	0.0064
HCMZ Width (ft)	157	513
Bankloss 2015-2017 (acre/river mile)	1.9	4.9
Bankloss 2004-2015 (acre/river mile)	1.5	6.8
Bank Stabilization (%)	46%	24%

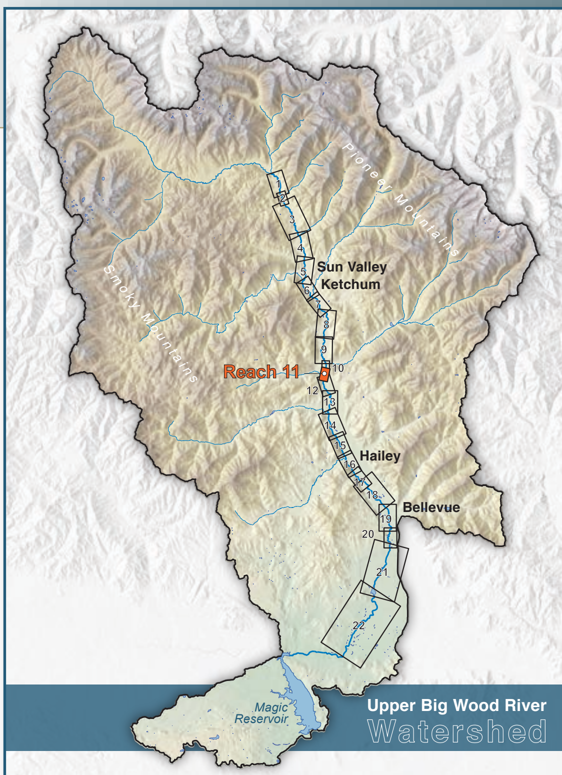
The East Fork reach has multiple characteristics that deviated greatly from the river-wide average because the reach is short, confined on both sides, and heavily armored (approx. 50%). Reach 10 is 6.6x narrower than average FEMA floodplain width, has the smallest HCMZ width, and the least amount of bank loss between 2004-2015 of all reaches. The reach also has the second lowest sinuosity.



Reach Project Potential

Given the confined nature of the reach, with continuous residential development and rock armoring along the west bank- the greatest project potential in reach 10 is restoration of the native riparian buffer.

HWY 75 to End of Golden Eagle Ranch



River Reach Locator Map

REACH 11

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

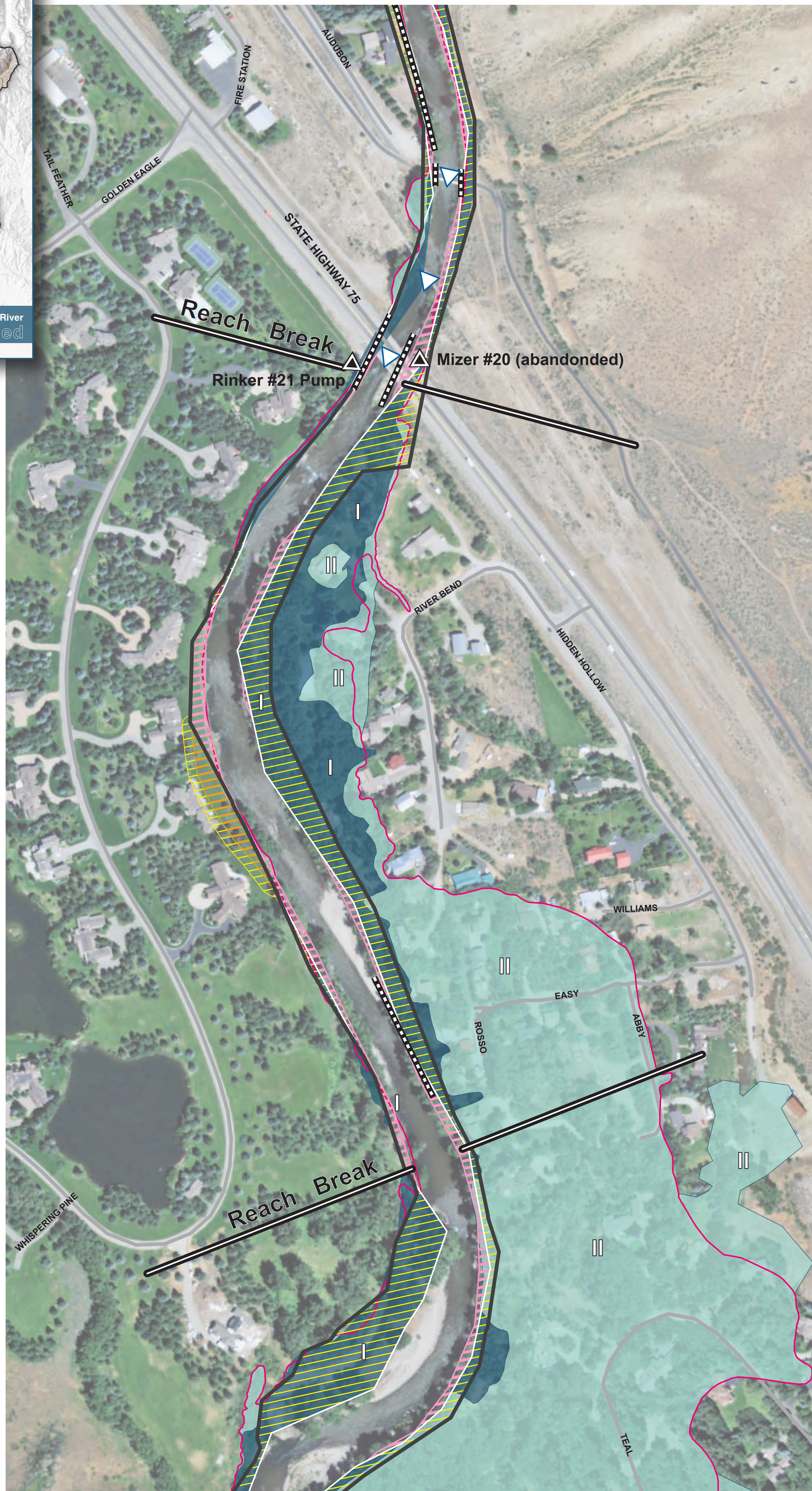
- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point

Reach Description

This short reach, similar to the reach upstream, has displayed consistent channel position throughout the available photographic record (1943-present), suggesting geologic controls. Unlike Reach 10, however, only 20% of the reach is currently stabilized by rock armoring (per prior studies and County data). The properties along the west side of the river have cleared riparian zones, which offers very little habitat value.



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

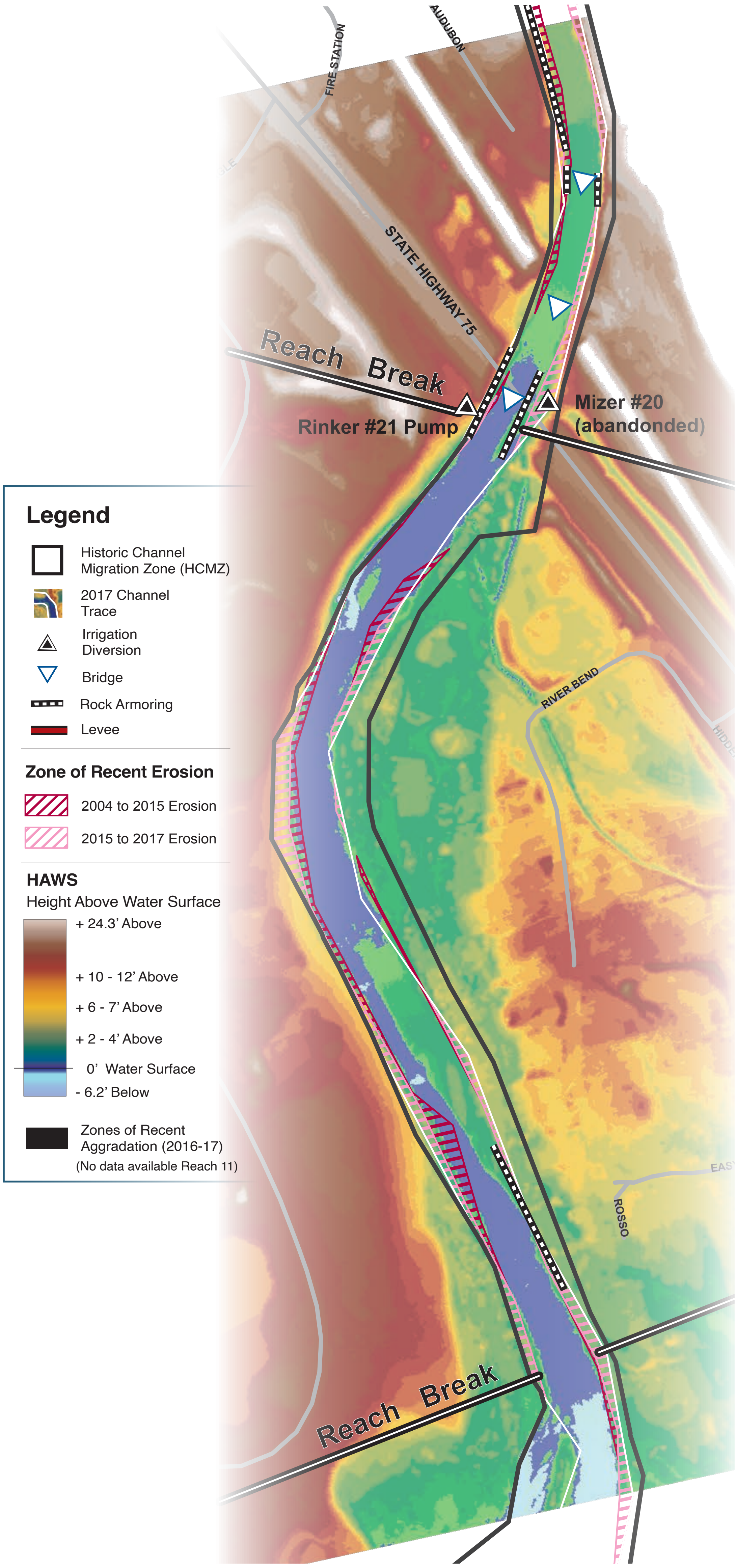
N

0 500 1000
Feet

Average FEMA Floodplain Width: 428 feet

2017 Average Bankfull Channel Width: 131 feet

REACH 11



REACH MAP - HAWS

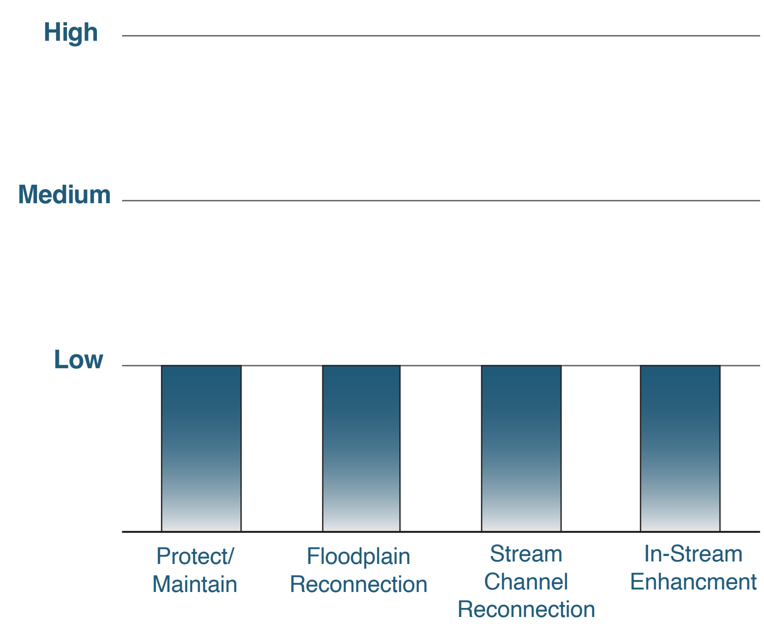
Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.028	1.15
Gradient (ft/ft)	0.0052	0.0064
HCMZ Width (ft)	200	513
Bankloss 2015-2017 (acre/river mile)	2.6	4.9
Bankloss 2004-2015 (acre/river mile)	1.9	6.8
Bank Stabilization (%)	21%	24%

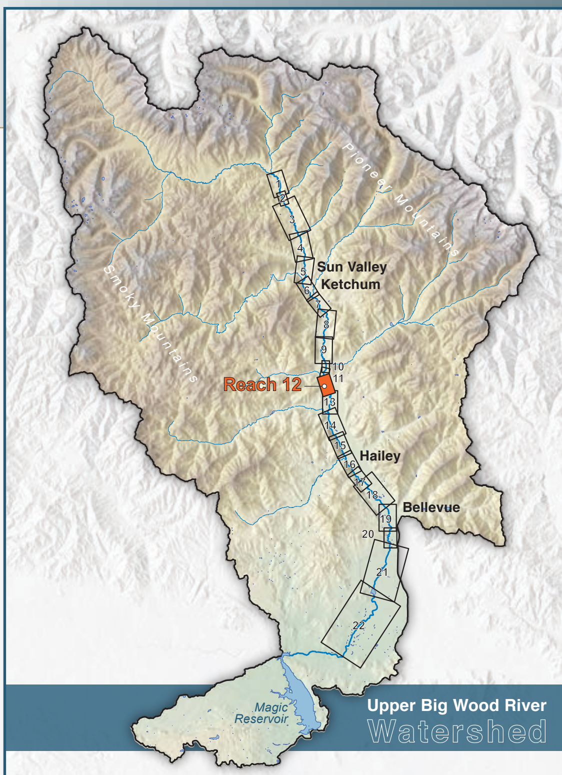
HWY 75 to Golden Eagle Ranch was the shortest identified reach (<0.5 miles) and has similar characteristics to the East Fork reach just upstream. This reach had second smallest area of bankloss between 2004-2015, was the least sinuous of all reaches, and it has an HCMZ width that is 2.6x smaller than average. The reach is confined to the east by Hwy 75 and the west by developments.



Reach Project Potential

Cover and shade are essential for development and survival of local trout populations. Riverbanks that are converted to lawn or open space with no riparian buffer degrade habitat conditions and re-establishment of a riparian buffer is recommended.

End Golden Eagle Ranch to Zinc Spur



River Reach Locator Map

REACH 12

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

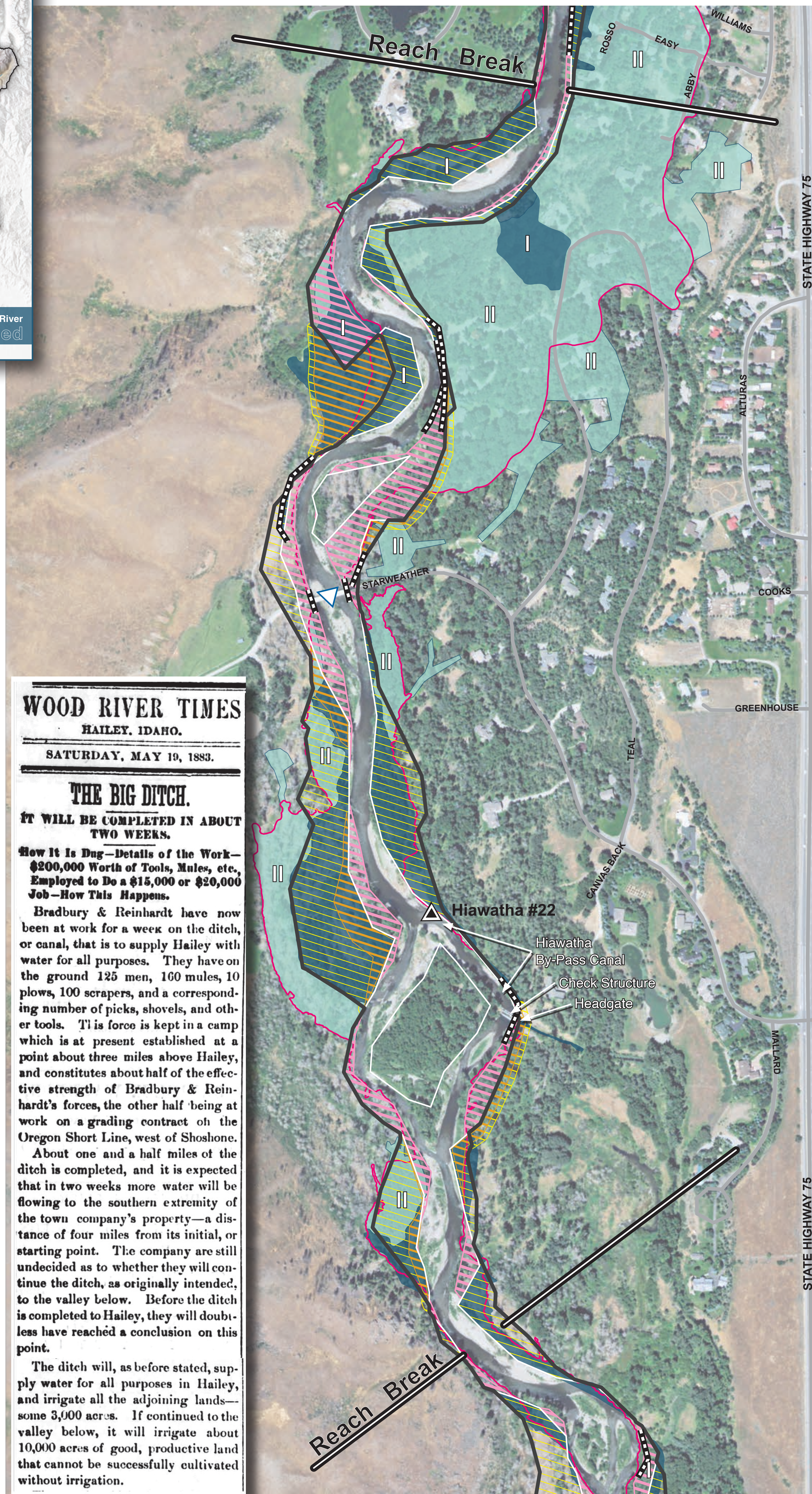
- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point

Reach Description

Reach 12 represents a major transition in channel behavior from the reaches immediately upstream. Reach 12 and 13 are the most sinuous of all reaches in the study area, and contain the least amount of riprap in the developed reaches of the valley. The channel has freely migrated across this portion of the valley, developing a network of side channels and split flow channels that are hydraulically connected at varying flow levels, creating complex habitat for a range of trout life histories. The HAWS map (right side of fold) shows the topographic complexity that can be created by freely meandering rivers. Sediment generated and delivered to this reach as a result of the Beaver Creek fire of 2013 may have played a major role in channel response of the 2017 flood. The Hiawatha Canal, constructed in 1883, is located in Reach 12 (see inset news article from 1883).



WOOD RIVER TIMES

HAILEY, IDAHO.

SATURDAY, MAY 19, 1883.

THE BIG DITCH.

IT WILL BE COMPLETED IN ABOUT TWO WEEKS.

How It Is Dug—Details of the Work—$200,000 Worth of Tools, Mules, etc., Employed to Do a $15,000 or $20,000 Job—How This Happens.

Bradbury & Reinhardt have now been at work for a week on the ditch, or canal, that is to supply Hailey with water for all purposes. They have on the ground 125 men, 160 mules, 10 plows, 100 scrapers, and a corresponding number of picks, shovels, and other tools. This force is kept in a camp which is at present established at a point about three miles above Hailey, and constitutes about half of the effective strength of Bradbury & Reinhardt's forces, the other half being at work on a grading contract on the Oregon Short Line, west of Shoshone.

About one and a half miles of the ditch is completed, and it is expected that in two weeks more water will be flowing to the southern extremity of the town company's property—a distance of four miles from its initial, or starting point. The company are still undecided as to whether they will continue the ditch, as originally intended, to the valley below. Before the ditch is completed to Hailey, they will doubtless have reached a conclusion on this point.

The ditch will, as before stated, supply water for all purposes in Hailey, and irrigate all the adjoining lands—some 3,000 acres. If continued to the valley below, it will irrigate about 10,000 acres of good, productive land that cannot be successfully cultivated without irrigation.

REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

N

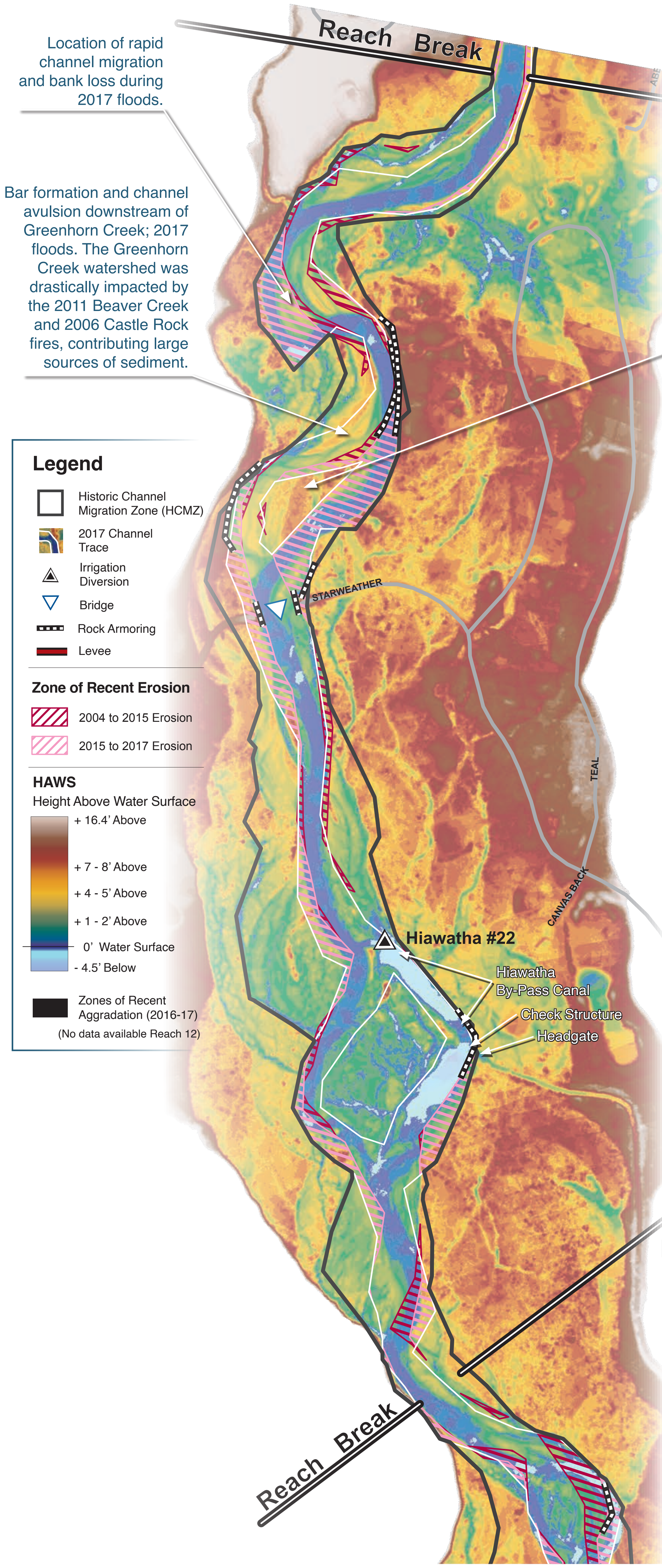
0 500

Feet

Average FEMA Floodplain Width: 687 feet

2017 Average Bankfull Channel Width: 206 feet

REACH 12



REACH MAP - HAWS

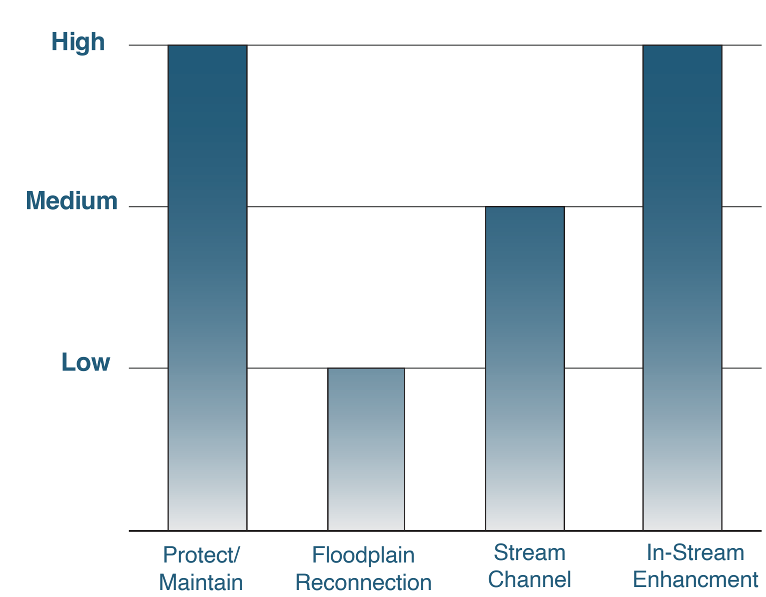
Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.31	1.15
Gradient (ft/ft)	0.0064	0.0064
HCMZ Width (ft)	493	513
Bankloss 2015-2017 (acre/river mile)	9.6	4.9
Bankloss 2004-2015 (acre/river mile)	3.2	6.8
Bank Stabilization (%)	11%	24%

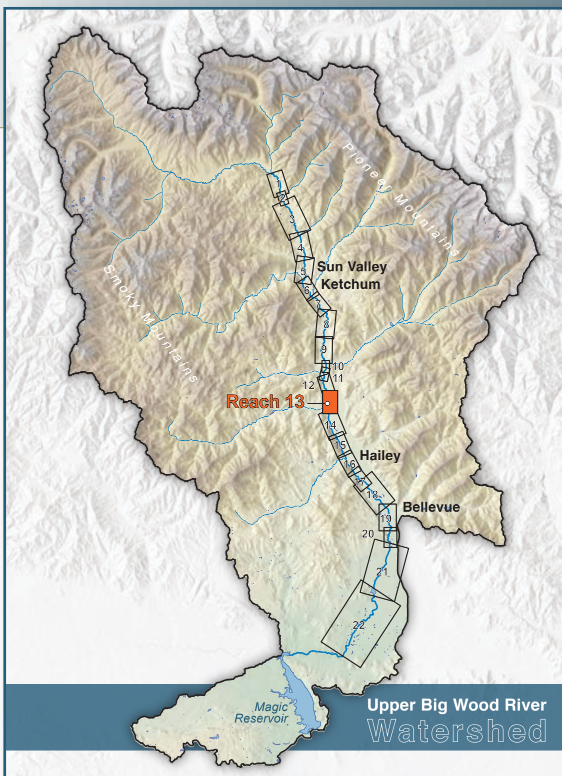
In contrast to the preceding reaches, Reach 10 has the highest sinuosity (1.3) of all reaches (based on 2017 channel centerline). This reach had significant areas of rapid channel migration and bank loss during the 2017 flood 2x larger than the Big Wood River average. This reach and its direct tributaries were heavily affected by the Beaver Creek fire in 2013.



Reach Project Potential

Given the sediment deposition evident further downstream near Hailey, and the flooding implications of that sediment, it may be advantageous to seek opportunities for sediment storage in Reach 12. Proper design and construction of in-stream structures can play a key role in trapping sediment, maintaining island braided planform, and improving local habitat conditions.

Zinc Spur to Deer Creek Rd



River Reach Locator Map

REACH 13

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

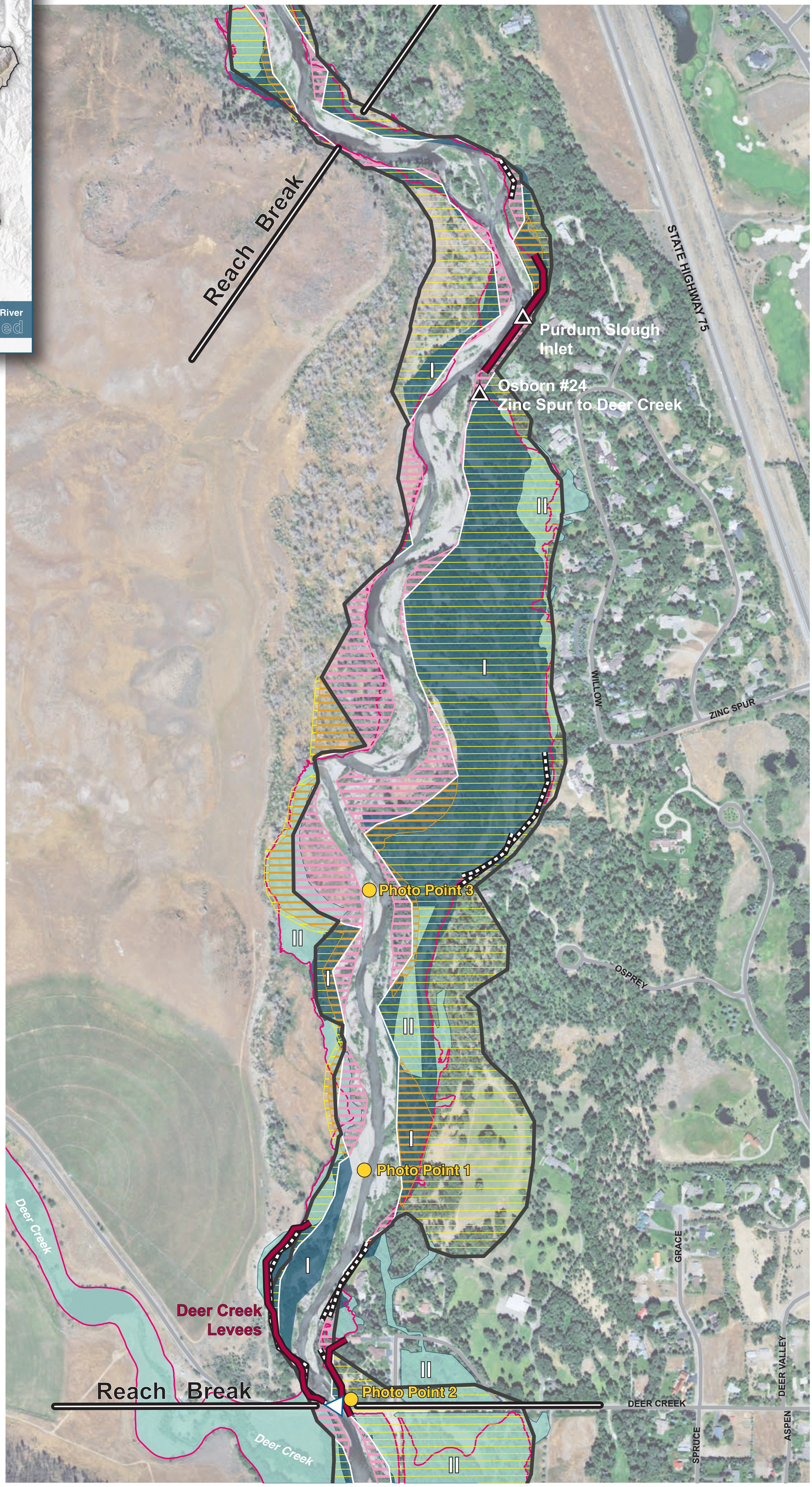
- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

0 1,000 2,000

Feet

N

Average FEMA Floodplain Width: 606 feet

2017 Average Bankfull Channel Width: 247 feet

Reach Description

The Big Wood River through this reach demonstrates many physical characteristics of a naturally functioning stream channel capable of supporting healthy aquatic ecosystems. The river has shifted gradually, and occasionally dramatically westward over the last 80 years, leaving a complex mosaic of high flow channels, riparian islands, and an array of habitat types. Lack of stable log jams may be a contributing factor to the transition from anastomosing to braided planform in this reach and others. Sediment generated and delivered to this reach as a result of the Beaver Creek fire of 2013 may have played a major role in channel response of the 2017 flood.

REACH 13

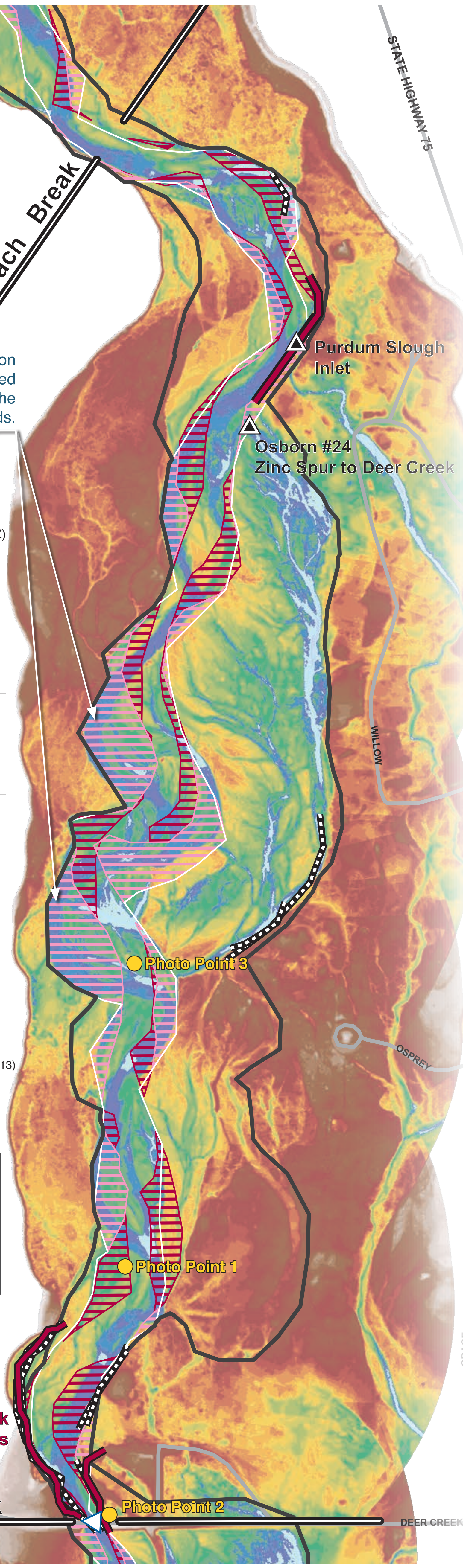


Photo Point 3
Looking upstream

REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

Reach 13 - Photo Point 1

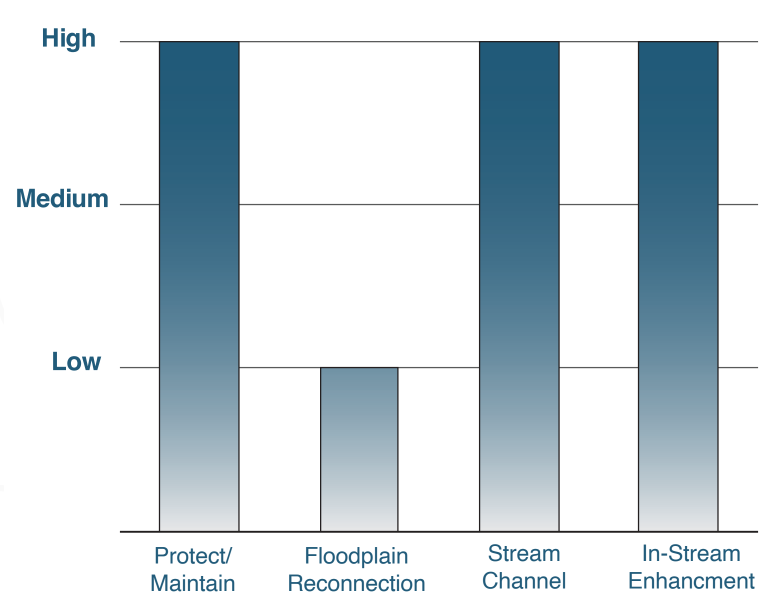
2017 floods led to major channel changes; use of log jams or flood fencing could help store sediment and reduce impacts on channel migration and bank loss downstream.

Reach 13 - Photo Point 2

Looking upstream from Deer Creek Bridge.

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.30	1.15
Gradient (ft/ft)	0.0061	0.0064
HCMZ Width (ft)	819	513
Bankloss 2015-2017 (acre/river mile)	13.4	4.9
Bankloss 2004-2015 (acre/river mile)	11.8	6.8
Bank Stabilization (%)	20%	24%

The Zinc Spur reach experienced the greatest amount of channel movement during the 2017 floods, indicated in the image by bank loss between 2015-2017. The reach has the second highest channel sinuosity and 3rd widest HCMZ in the study area. The metrics indicate that this reach has experienced this kind of dynamic channel movement for decades. This reach and its direct tributaries were heavily affected by the Beaver Creek fire in 2013.



Reach Project Potential

The potential for rapid channel change in this reach could result in migration beyond the HCMZ and recruitment of large volumes of sediment to downstream reaches. Efforts could be made to stabilize riparian islands with flood fencing or apex log jams, which would maintain existing riparian stands to provide shade and cover.

Deer Creek Rd to Aspen Lakes Dr

River Reach Locator Map

REACH 14

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

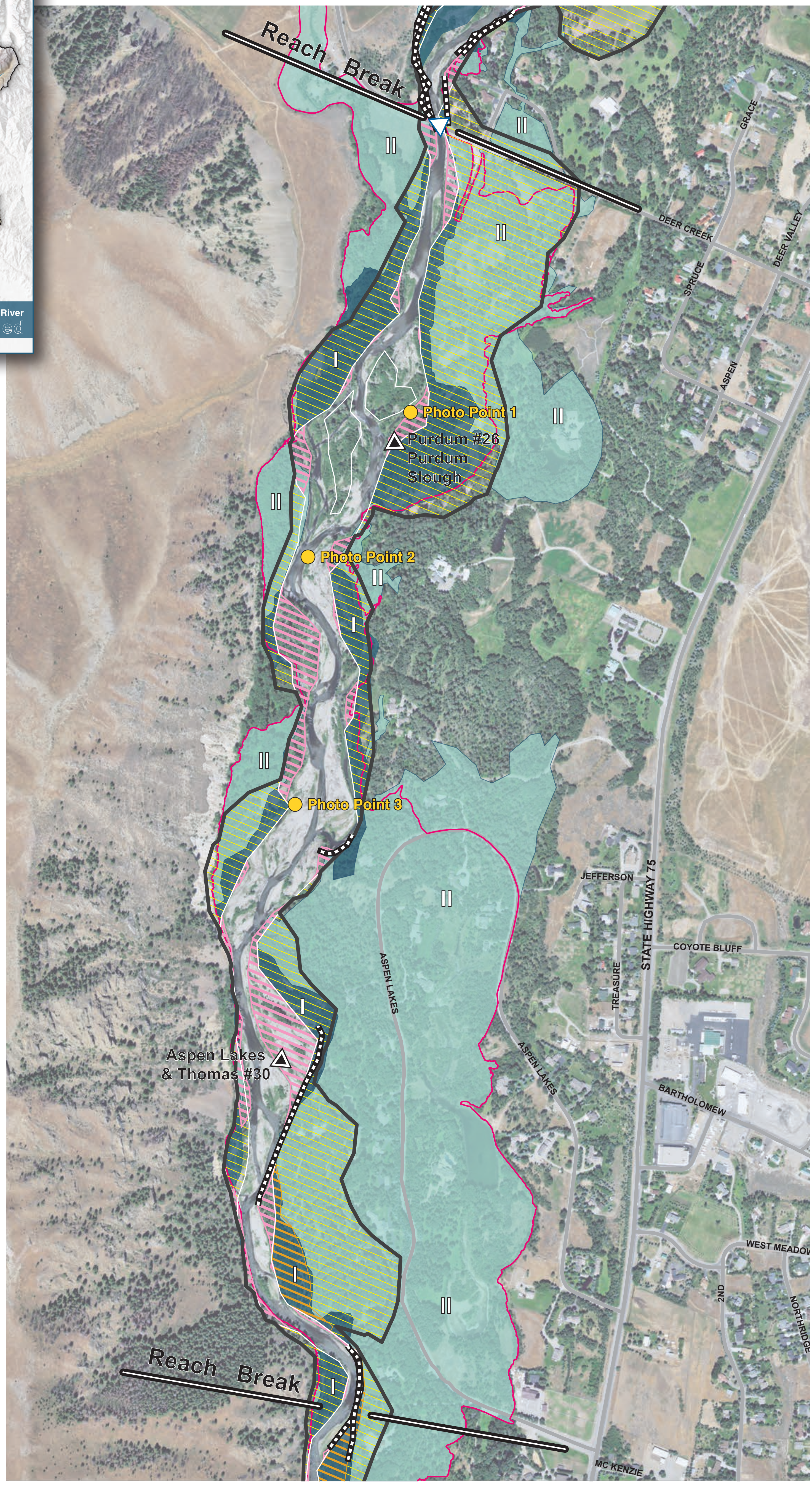
- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

N

0 1,000 2,000
Feet

Reach Description

Reach 14 extends 2 miles from the Deer Creek Rd. Bridge to Aspen Lakes Drive, running west along Flying Heart Ranch. The Beaver Creek fire affected Deer Creek, along with adjacent tributaries, in 2013, generating sediment sources that may have been delivered and redistributed during the 2017 flood, exacerbating channel response. Significant channel changes occurred in this reach during the 2017 flood, leading to over 16 acres of total channel migration in a single flood event. As a result, this reach now contains many large, stable logjams creating deep scour pools and influencing channel development.

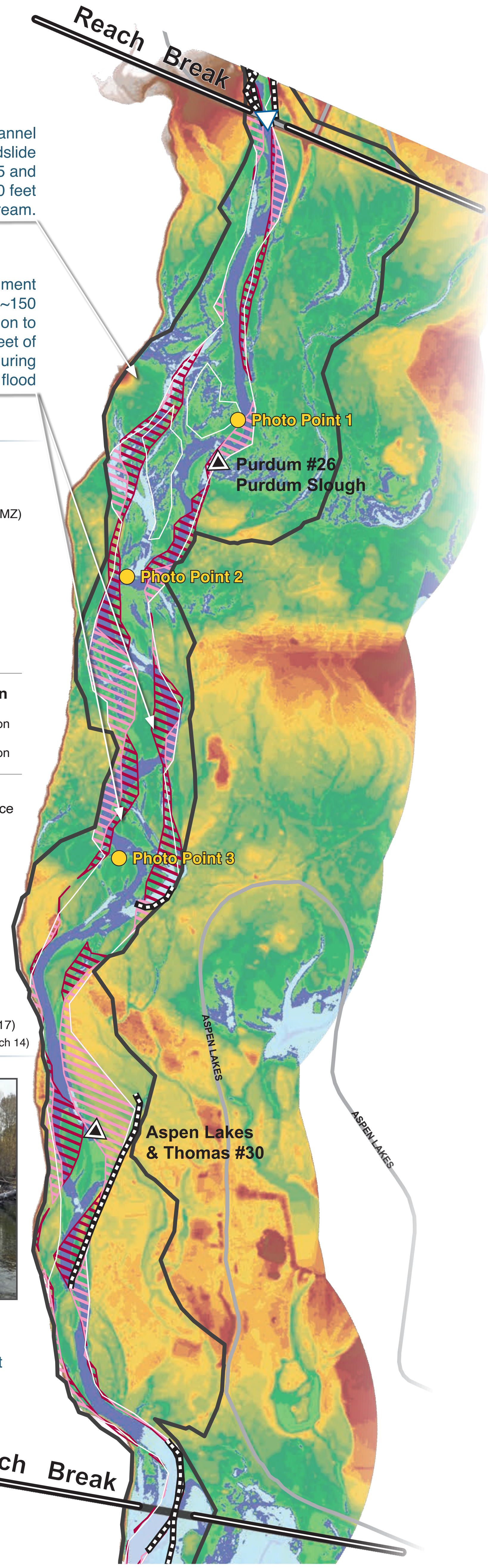
Average FEMA Floodplain Width: 1,333 feet

2017 Average Bankfull Channel Width: 264 feet

REACH 14

Former Deer Creek channel blocked by a landslide between 2004 - 2015 and re-routed into river 500 feet upstream.

Bar formation from sediment deposition caused ~150 feet of channel migration to the east and ~200 feet of migration to the west during 2017 flood



Legend

- Historic Channel Migration Zone (HCMZ)
- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- Rock Armoring
- Levee

Zone of Recent Erosion

- 2004 to 2015 Erosion
- 2015 to 2017 Erosion

HAWS
Height Above Water Surface

- + 24.3' Above
- + 10 - 12' Above
- + 6 - 7' Above
- + 2 - 4' Above
- 0' Water Surface
- - 6.2' Below

- Zones of Recent Aggradation (2016-17) (No data available Reach 14)

Photo Point 3
Deep scour pools along wood jams offer excellent habitat

REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

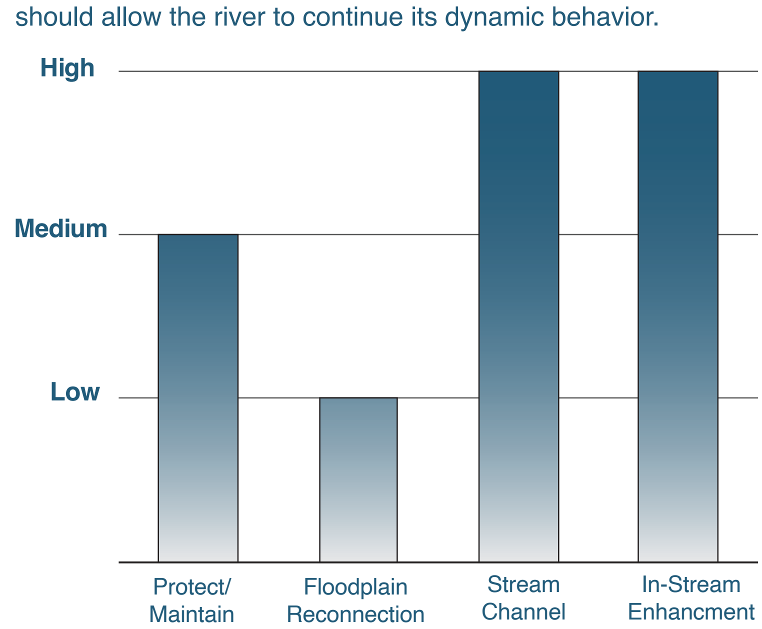
Reach Characteristics

Reach 14 - Photo Point 1
Wood recruitment into Reach 14 during 2017 flood.

Reach 14 - Photo Point 2
Rapid channel change during 2017 flood leaves complex and varied channel conditions.

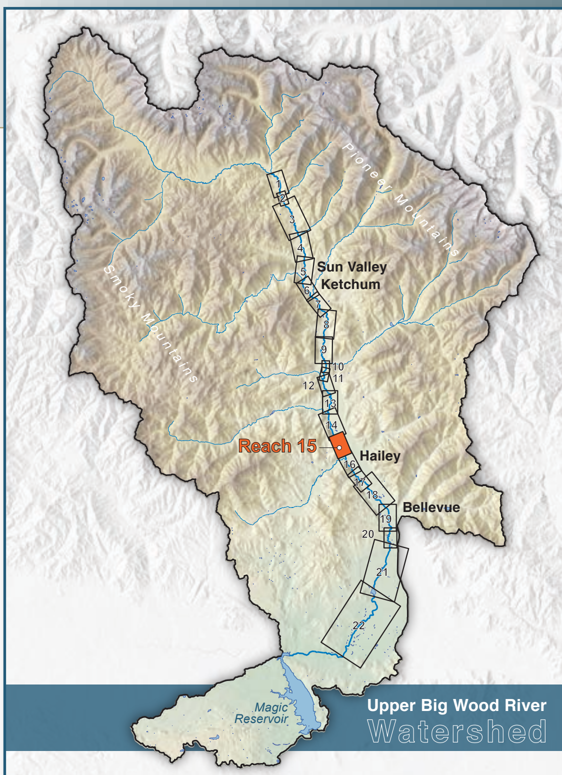
Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.22	1.15
Gradient (ft/ft)	0.0059	0.0064
HCMZ Width (ft)	801	513
Bankloss 2015-2017 (acre/river mile)	9.8	4.9
Bankloss 2004-2015 (acre/river mile)	9.7	6.8
Bank Stabilization (%)	10%	24%

The Deer Creek to Aspen Lakes reach has the second largest bankfull width and the 4th largest HCMZ width of any reach. Similar to Reaches 12 and 13, these metrics indicate historical channel movement and dynamic river behavior. The reach currently has the second smallest length of bank stabilization (10%) of any river segment downstream of reaches 1-3, this should allow the river to continue its dynamic behavior.



Reach Project Potential

Similar to reach just upstream, this reach has been extremely dynamic between 2015-2017 and has a large area of exposed bars and scoured banks that could be stabilized to form vegetated islands and LWD habitat features. Sediment retention in the reach can stabilize planform and reduce downstream delivery.



River Reach Locator Map

REACH 15

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

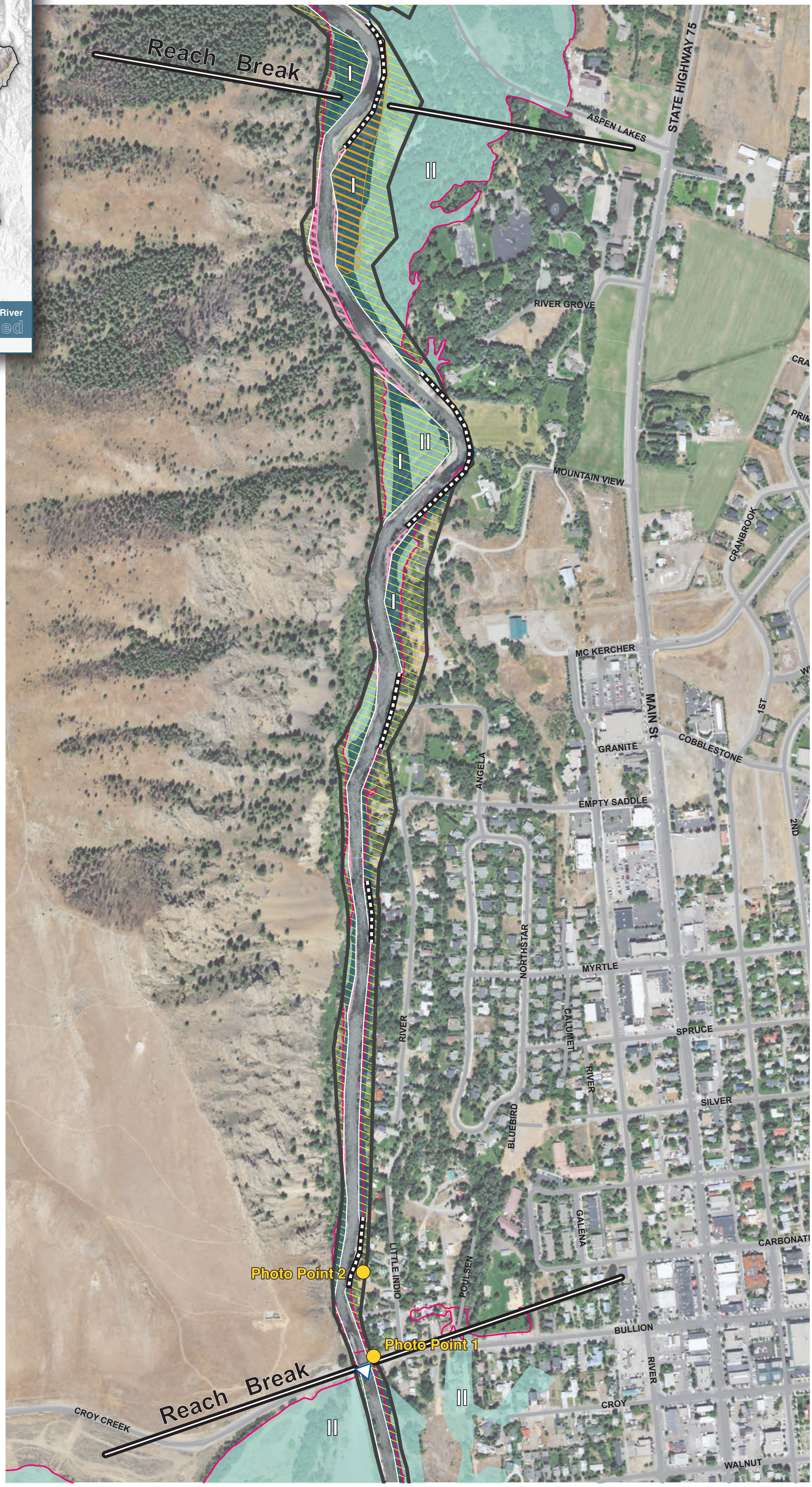
- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point



Reach Description

Reach 15 runs 1.4 miles from Aspen Lakes Dr. to Croy Creek/Bullion St bridge. The channel position has been remarkably stable over the available photographic record (1966-present), locked between the west valley wall and high-density development in the City of Hailey. There are indications that high flow channels had previously migrated along the eastern floodplain in the 1966 aerial photos, but direct evidence of channel occupation are faint. The reach is transport dominated, with a narrow floodplain and flood prone area.

REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

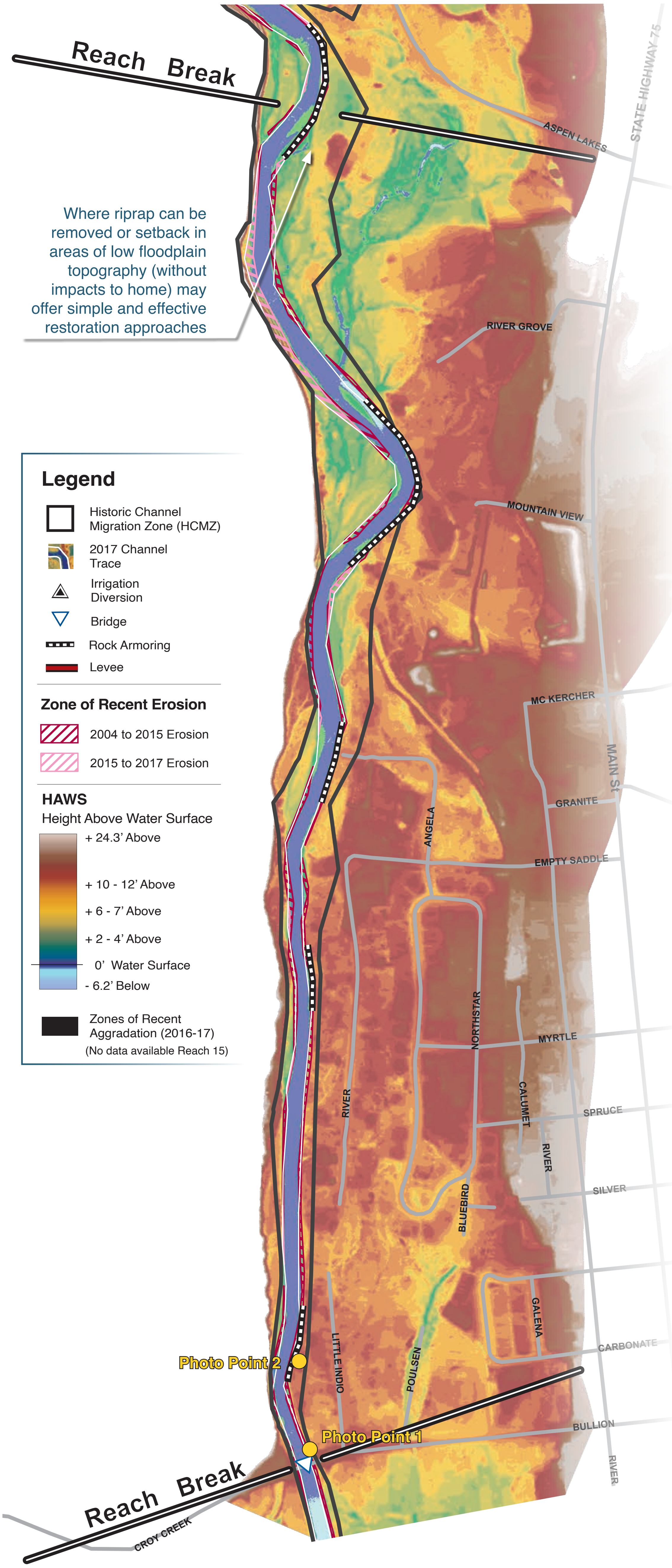
N

0 1,000 2,000
Feet

Average FEMA Floodplain Width: 261 feet

2017 Average Bankfull Channel Width: 99 feet

REACH 15



REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

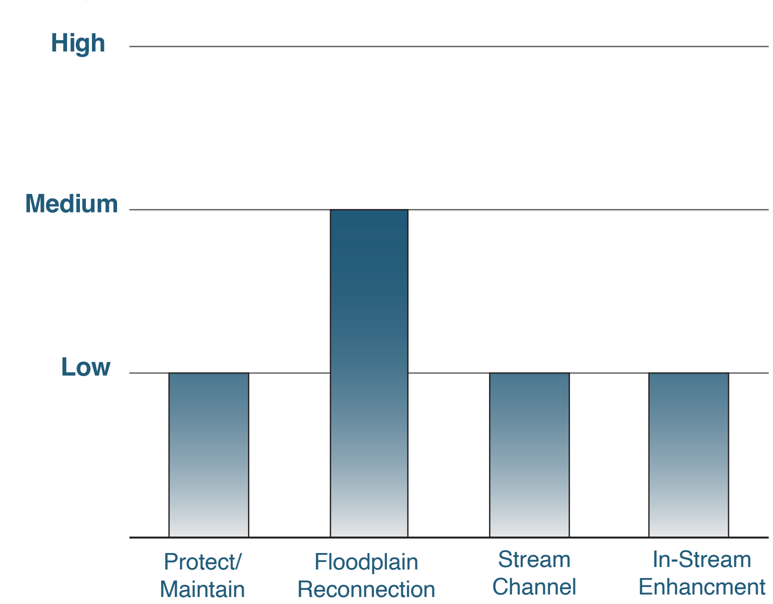
Reach Characteristics

Reach 15 - Photo Point 1
Looking upstream from Croy Creek bridge.

Reach 15 - Photo Point 2
Looking upstream in Reach 15

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.08	1.15
Gradient (ft/ft)	0.0061	0.0064
HCMZ Width (ft)	288	513
Bankloss 2015-2017 (acre/river mile)	1.2	4.9
Bankloss 2004-2015 (acre/river mile)	2.8	6.8
Bank Stabilization (%)	17%	24%

The Aspen Lakes to Bullion Bridge reach has the narrowest HCMZ in the lower valley. It has the 2nd smallest FEMA floodplain width and bankfull width of any reach in the study area. The confined valley geometry and stable channel position explains why this reach had the fourth smallest area of channel bank loss or migration from 2015-2017, yet only 17% of banks are armored with rock.



Reach Project Potential

Limited opportunity for process-based restoration exists in the reach. Even in such a highly developed reach, riparian buffers remain improved over other reaches where lawns dominate. There may be opportunity to set back riprap banks where they are placed well riverward of infrastructure.

Bullion to Colorado Gulch

River Reach Locator Map

REACH 16

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

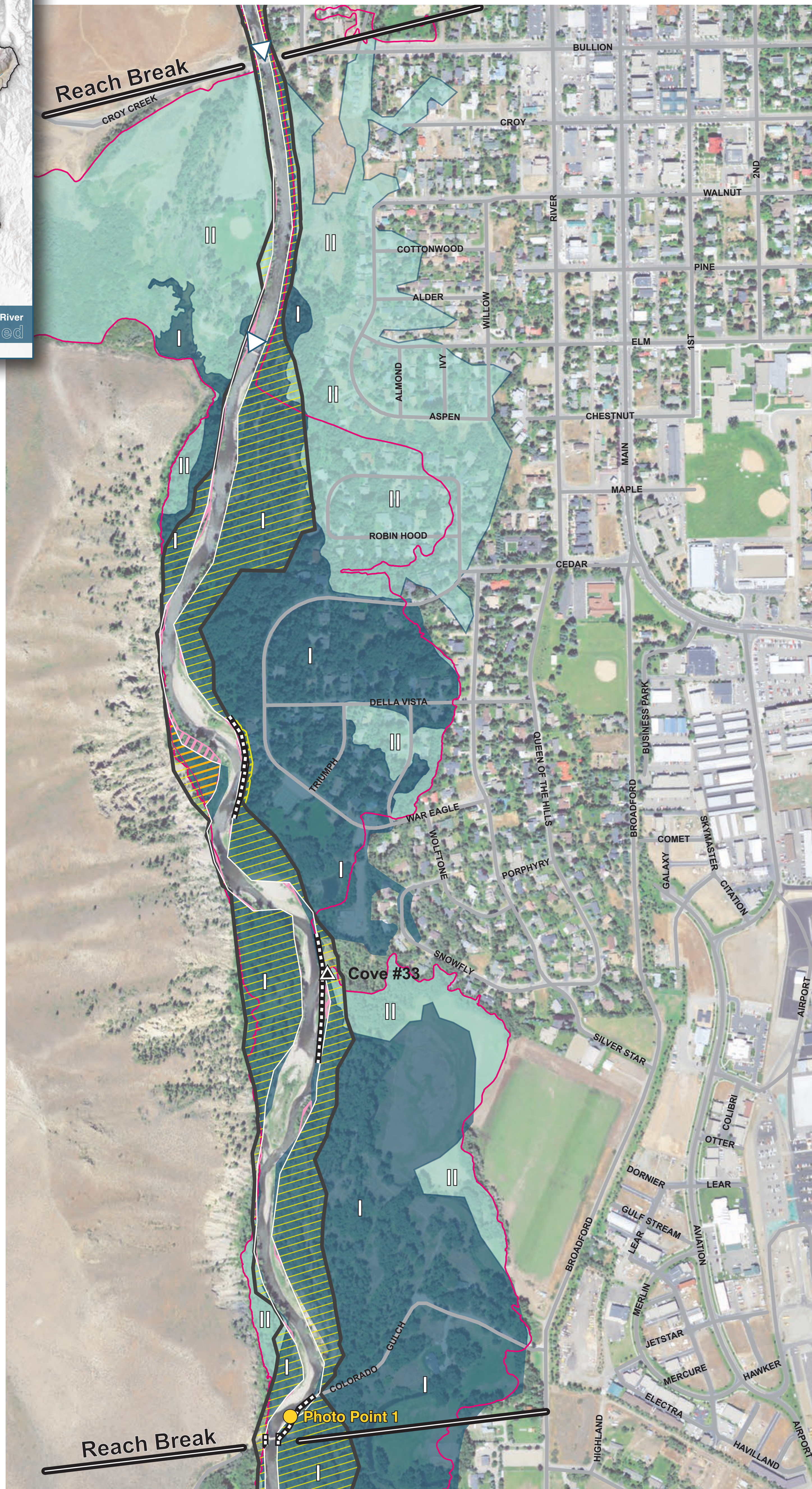
- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point

Reach Description

The Croy Creek reach extends from the Croy Creek Bridge to the old Colorado Gulch bridge crossing. Damage to the Colorado Gulch bridge abutments occurred during the 2017 flood and it was removed. This reach experienced significant flooding along its eastern floodplain during the 2017 floods, as indicated in the figure. LiDAR differencing and filtering indicates potential areas of significant sediment deposition adjacent to flooded areas (War Eagle Dr. loop), shown in the HAWS map to the right.



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

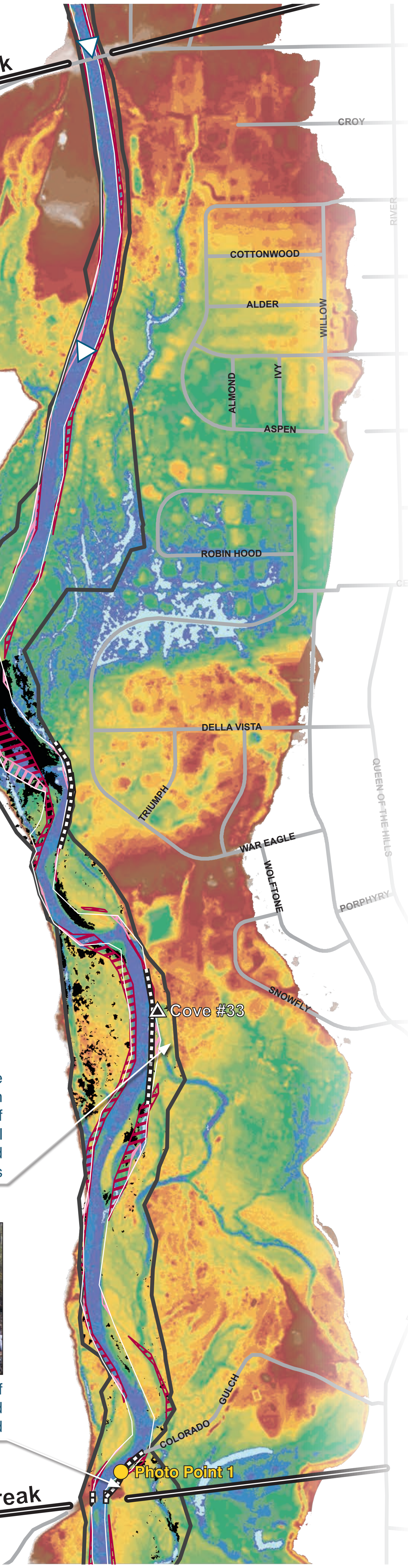
0 1,000 2,000
Feet

N

Average FEMA Floodplain Width: 1,090 feet

2017 Average Bankfull Channel Width: 114 feet

REACH 16



Historic channel features east of Colorado Gulch Road prism could be reconnected and restored

REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

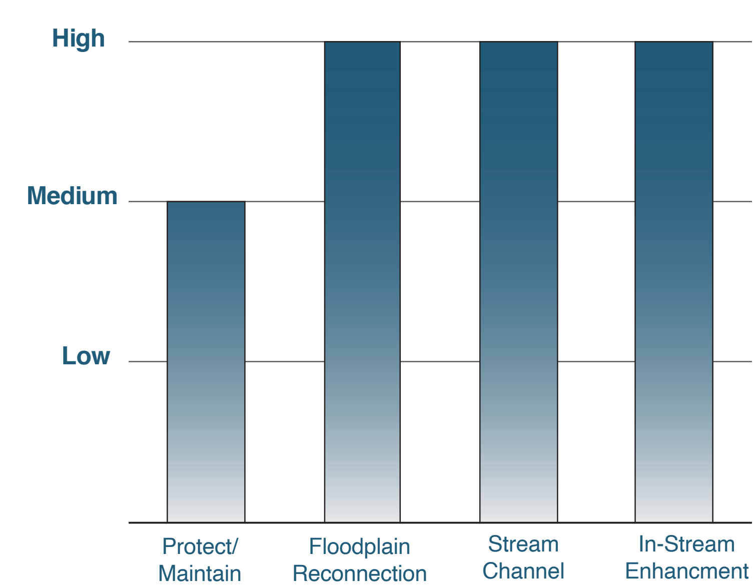
Reach 16 - Site Photo 1, Upstream

Reach 16 - Site Photo 1, Downstream

In channel wood and sediment deposition that could disperse throughout the floodplain with removal of riprap and road fill in Colorado Gulch reach

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.11	1.15
Gradient (ft/ft)	0.0052	0.0064
HCMZ Width (ft)	364	513
Bankloss 2015-2017 (acre/river mile)	0.95	4.9
Bankloss 2004-2015 (acre/river mile)	3.9	6.8
Bank Stabilization (%)	10%	24%

This reach had the second least area of bank loss between 2015-2017, narrow HCMZ and 2017 channel width, coupled with the least amount of bank stabilization (only 10%). Though having a narrow HCMZ, the ratio of HCMZ to flood prone area is among the lowest in the study area (0.33), indicating significant expansion of the flood zone beyond the HCMZ.



Reach Project Potential

The proposed Colorado Gulch floodplain reconnection project presents an excellent opportunity to remove riprap, old road grades, and restore channel processes to a reach that has been impacted by artificial confinement. Relic channel features are easily identified on the HAWS map. We recommend a process based design approach in this reach to optimize the unique opportunity. Channel and floodplain connectivity could potentially yield upstream flood mitigation benefits.

Colorado Gulch to Star Bridge

River Reach Locator Map

REACH 17

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

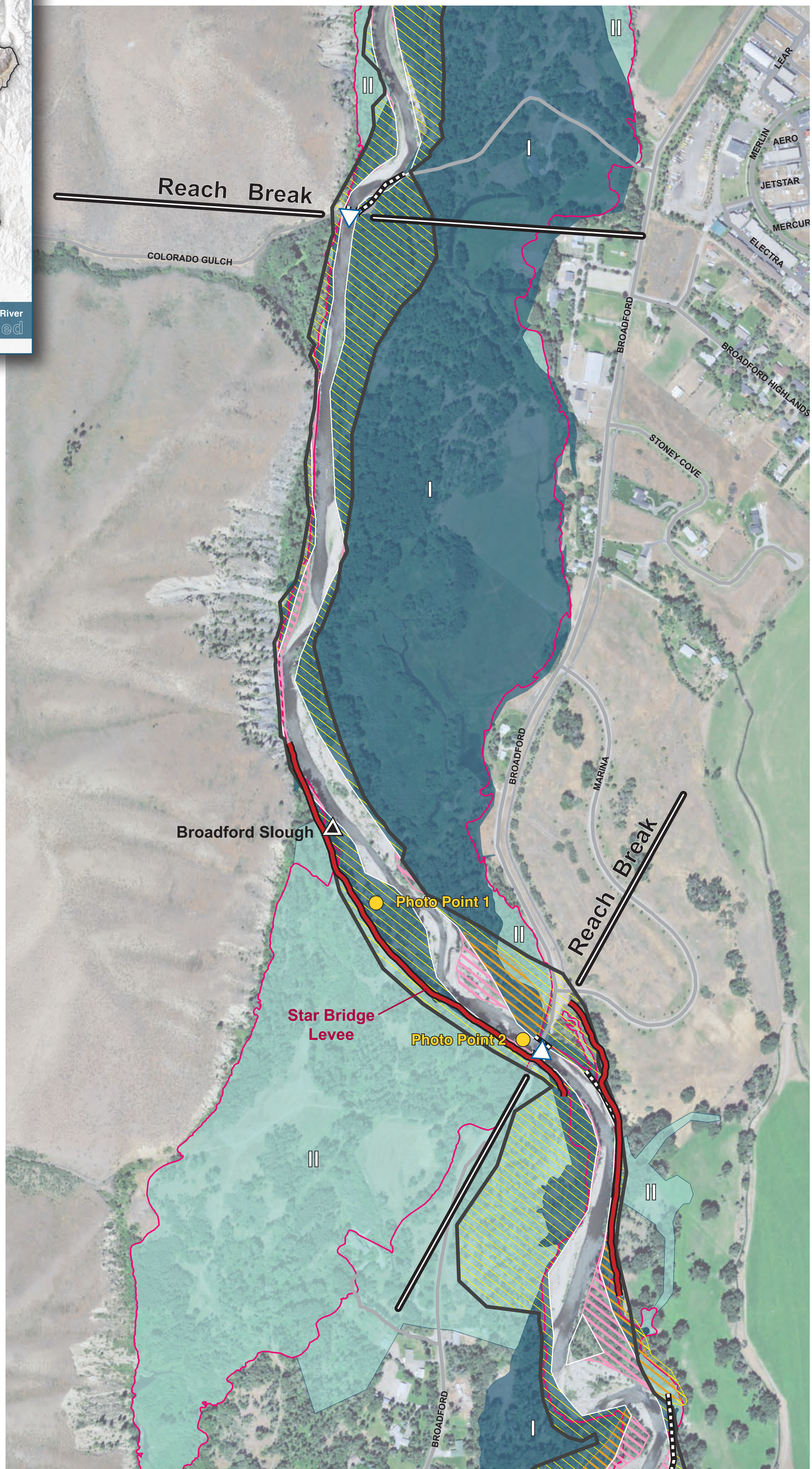
- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

N

0 1,000 2,000

Feet

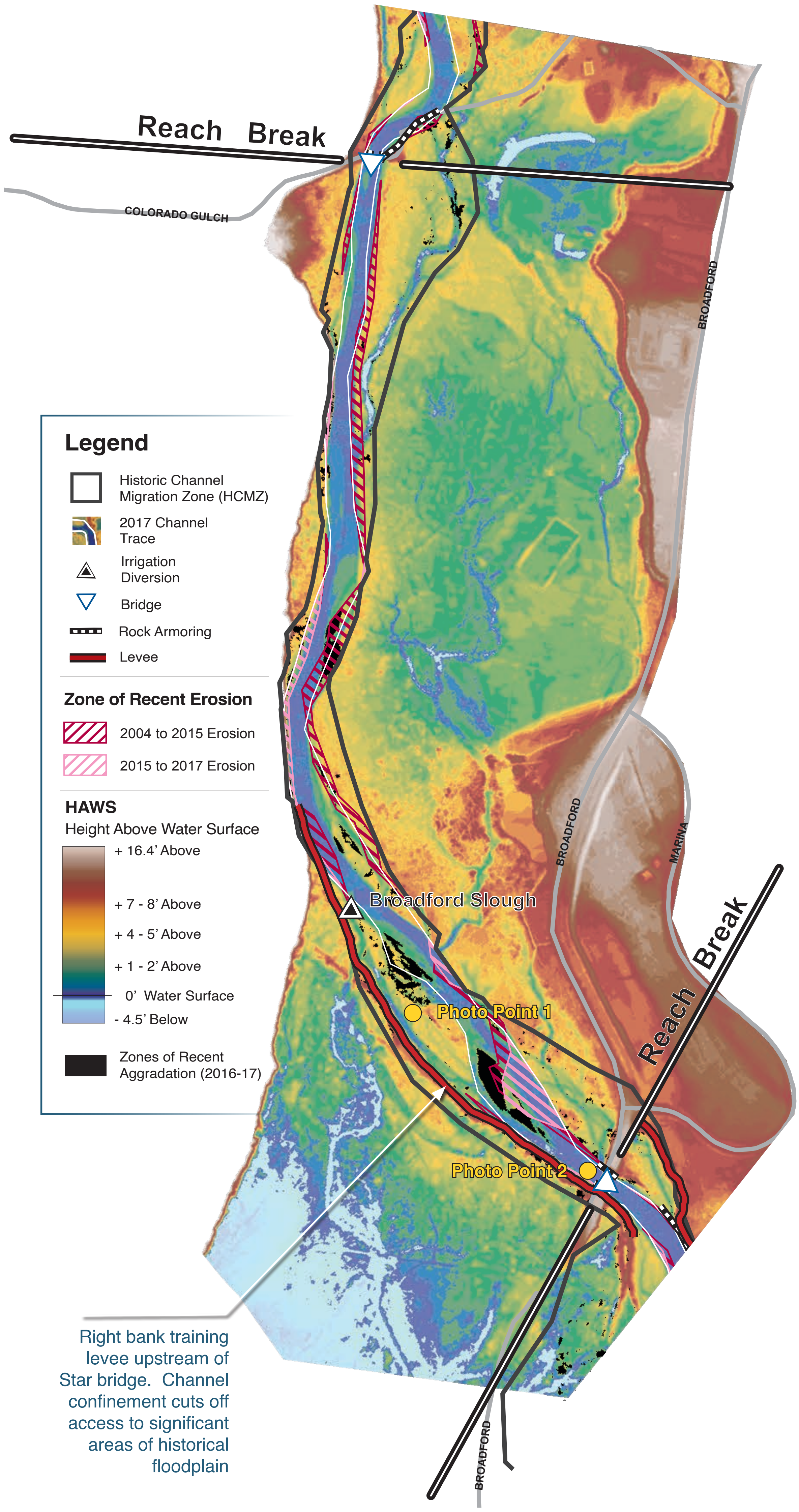
Reach Description

The 1.6-mile reach from Colorado Gulch to Star Bridge represents another major transition in channel pattern and behavior in the valley. The gradient flattens to less than 0.5% as the river transitions to a much more uniformly depositional, or "response", character. This reach represents another significant transition, in that there is no development within or adjacent to the HCMZ or FEMA floodplain and agriculture dominates the floodplain in this portion of the valley. Near the downstream end of the reach on river right, a levee was constructed to limit flooding and possible channel occupation of what appears to be a relic channel of the Big Wood River.

Average FEMA Floodplain Width: 1,041 feet

2017 Average Bankfull Channel Width: 130 feet

REACH 17



REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

Reach 17 - Photo Point 1

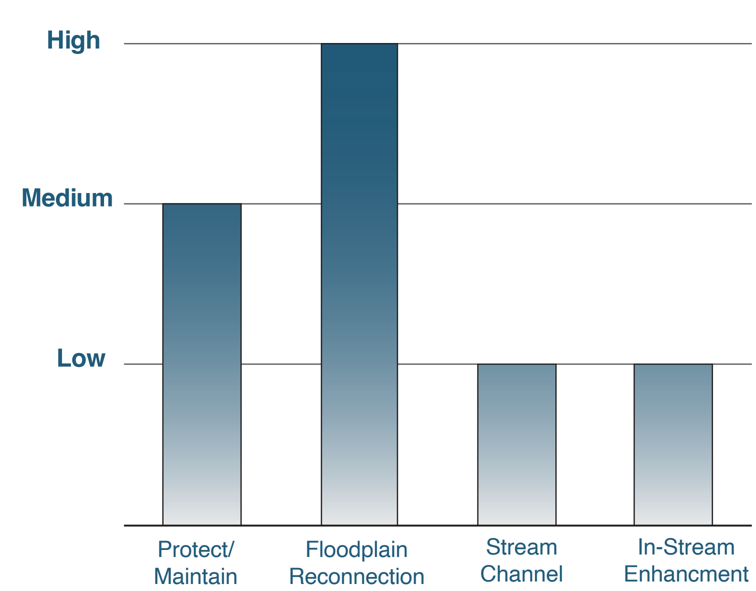
Right bank levee and Broadford Road disconnect the river from historic channels and floodplain.

Reach 17 - Photo Point 2

Looking upstream from Star Bridge crossing the river.

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.05	1.15
Gradient (ft/ft)	0.0049	0.0064
HCMZ Width (ft)	347	513
Bankloss 2015-2017 (acre/river mile)	2.4	4.9
Bankloss 2004-2015 (acre/river mile)	4.7	6.8
Bank Stabilization (%)	23%	24%

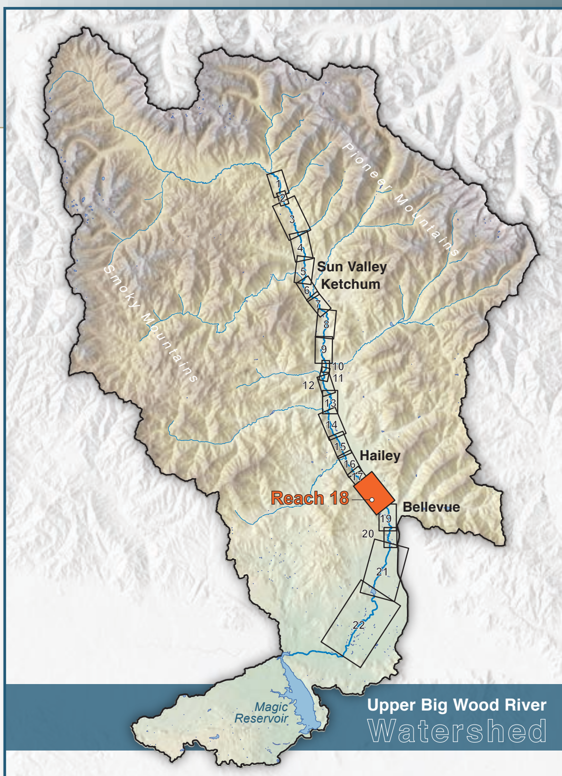
The Colorado Gulch to Star Bridge reach is the first river corridor with a gradient <0.005. It is a relatively straight reach (4th lowest sinuosity), with a narrow HCMZ and it has the first identified levee present upstream of Star bridge, which contributes to the 13% increase in bank stabilization relative to the preceding upstream reach (Bullion Bridge to Colorado Gulch).



Reach Project Potential

The down valley extents of the potential project at Colorado Gulch cross into Reach 17 where historical side channels within the HCMZ can be reconnected to the main channel. Much of the eastern floodplain offers high value to flood conveyance and ecosystem function and protection and conservation of these areas are a high priority.

Star Bridge to Broadford Bridge



River Reach Locator Map

REACH 18

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

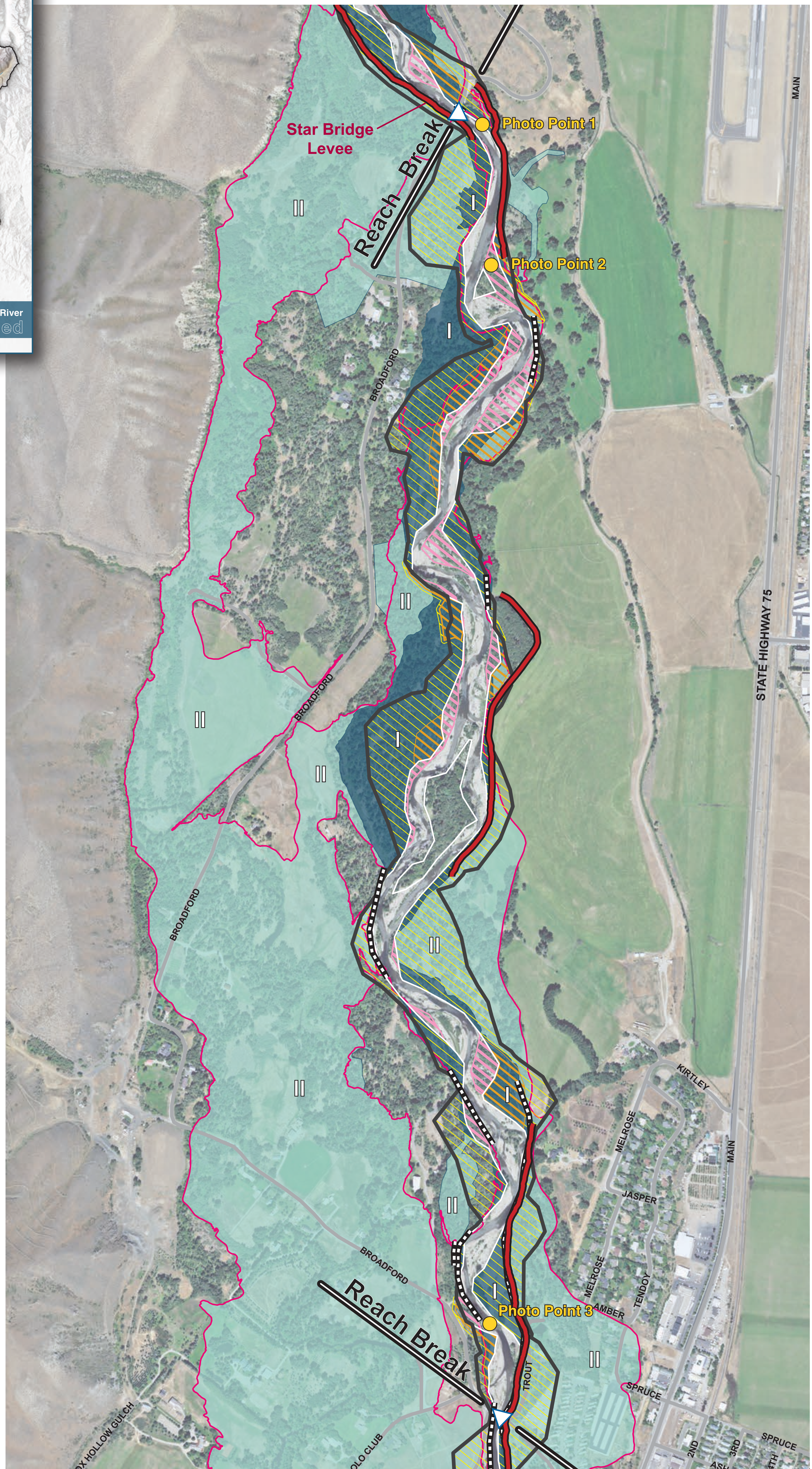
- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point

Reach Description

The reach extends 2.7 miles through one of the most dynamic stretches of river. This reach experienced significant bank loss, sediment deposition and resultant channel migration during the 2017 flood. The reach is heavily leveed on both sides of the river, presumably to protect agricultural areas from flooding and channel reoccupation of historic positions landward of the levees. Areas of high erosion potential are numerous in this reach, many adjacent to or opposite of channel confining levees. Upstream of Broadford Bridge, channel erosion threatens the road at Fisherman's Access; a project is in planning to address that hazard.



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

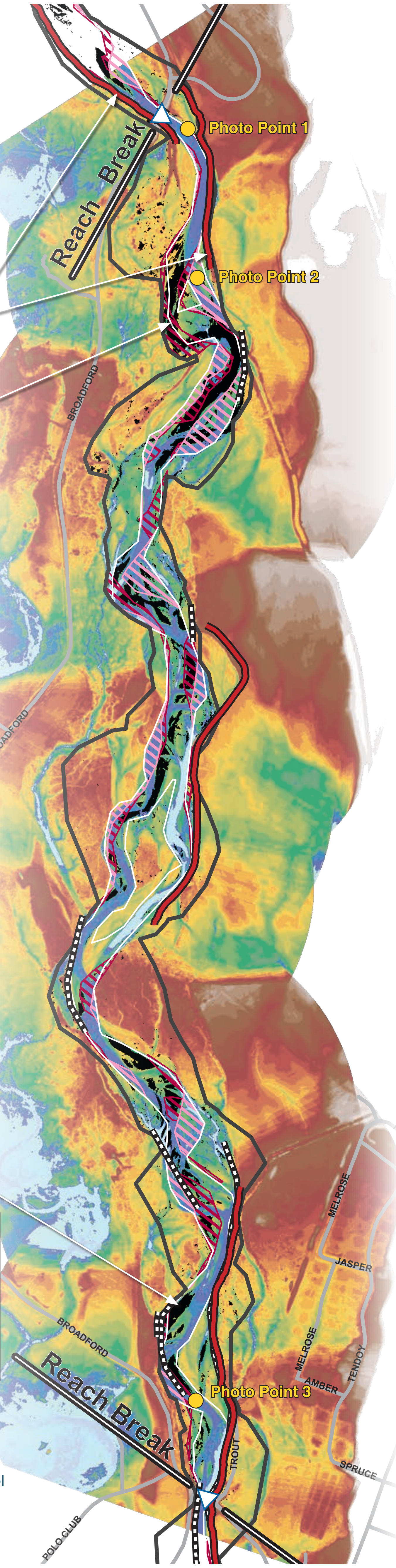
0 1,500 3,000

Feet

Average FEMA Floodplain Width: 2,011 feet

2017 Average Bankfull Channel Width: 216 feet

REACH 18



Reach 18 - Photo Point 3

Significant erosion along west bank along Broadford Road. The reach upstream is highly altered by levees and riprap, resulting in major channel adjustments within and downstream of the reach.

REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

Reach 18 - Photo Point 1

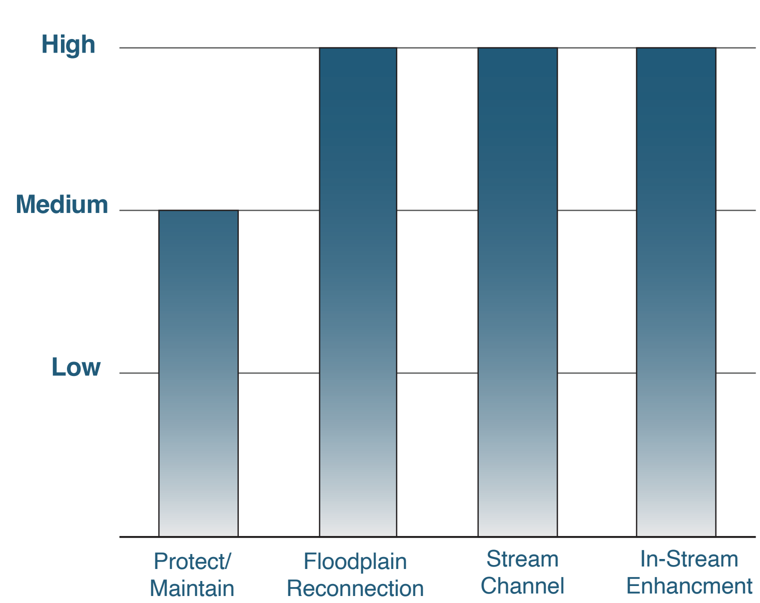
Broadford levee is an imposing barrier to natural channel movement into the east floodplain of the river

Reach 18 - Photo Point 2

Channel expansion as a response to confinement upstream led to erosion and migration during the 2017 floods

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.22	1.15
Gradient (ft/ft)	0.0053	0.0064
HCMZ Width (ft)	707	513
Bankloss 2015-2017 (acre/river mile)	6.8	4.9
Bankloss 2004-2015 (acre/river mile)	7.2	6.8
Bank Stabilization (%)	40%	24%

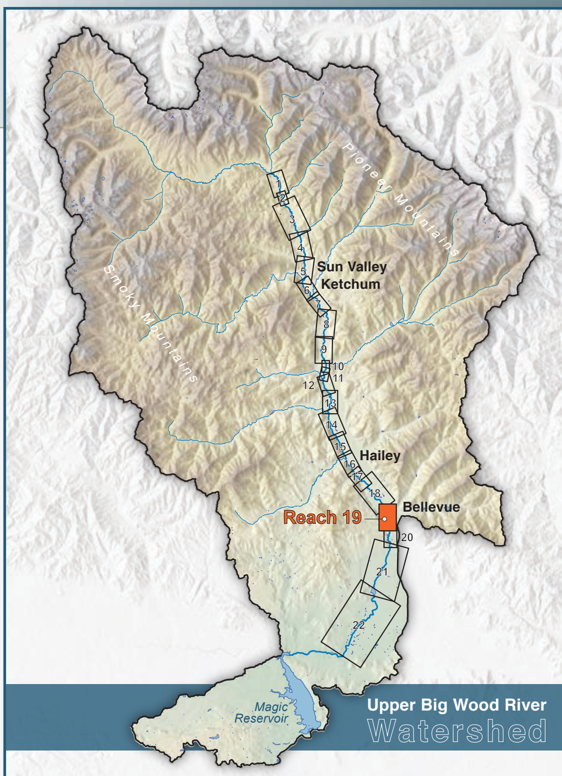
The Star Bridge to Broadford bridge is one of only three reaches with a flood control levee which contributes to its high percentage of bank stabilization (>40%). This reach has the 3rd largest FEMA floodplain width and high amounts of areas in erosion hazard zones.



Reach Project Potential

Opportunities should be explored to lower heights, strategically breach, or setback levees in this reach. Allowing the river to access a wider portion of its natural meander belt will improve sediment transport, flooding, and habitat conditions. Installation of flood fencing and/or apex jams could serve to stabilize planform, retain sediment, and improve aquatic habitat through pool formation and shade/cover.

Broadford Bridge to Townsend Gulch



River Reach Locator Map

REACH 19

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

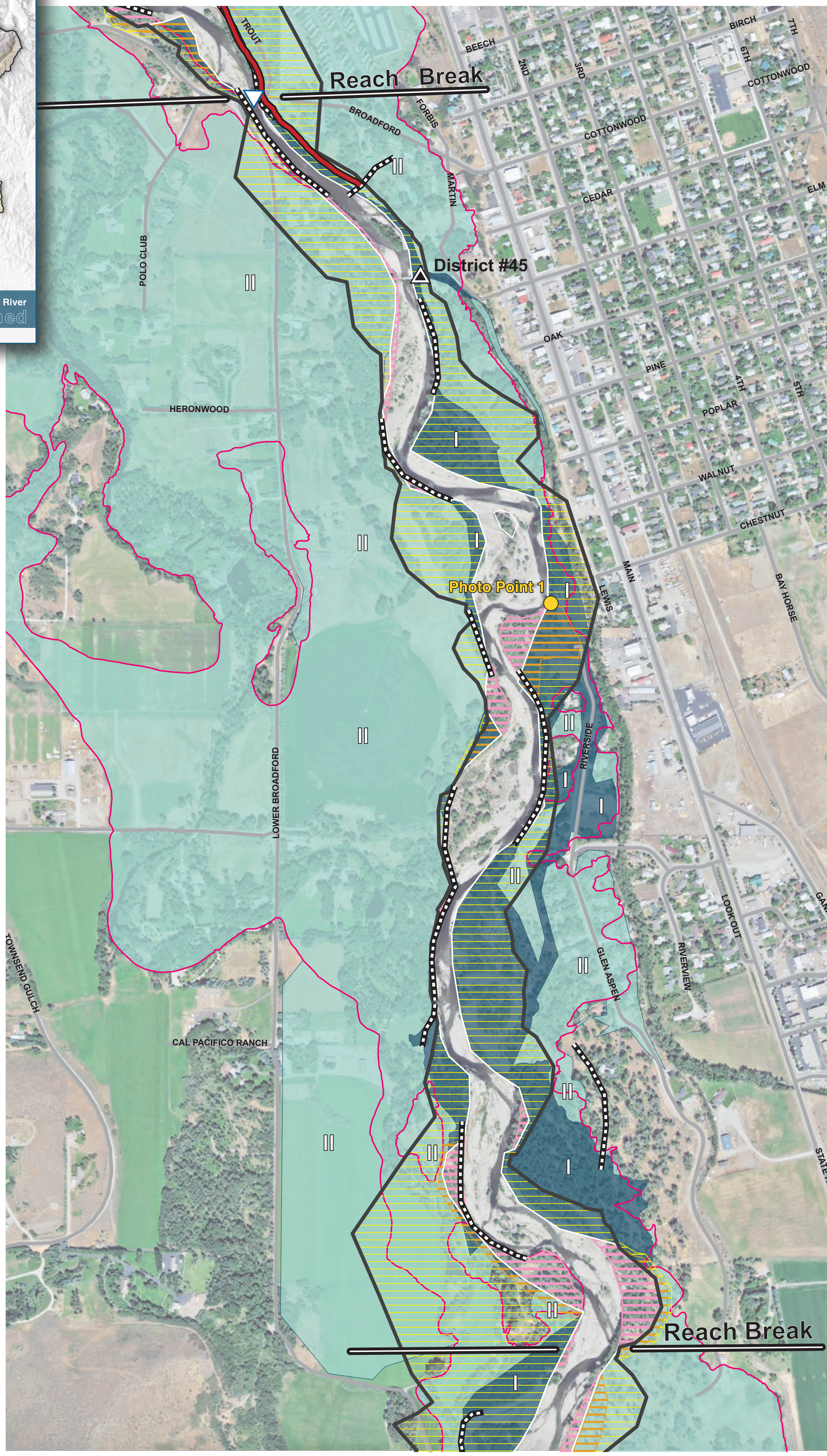
- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point



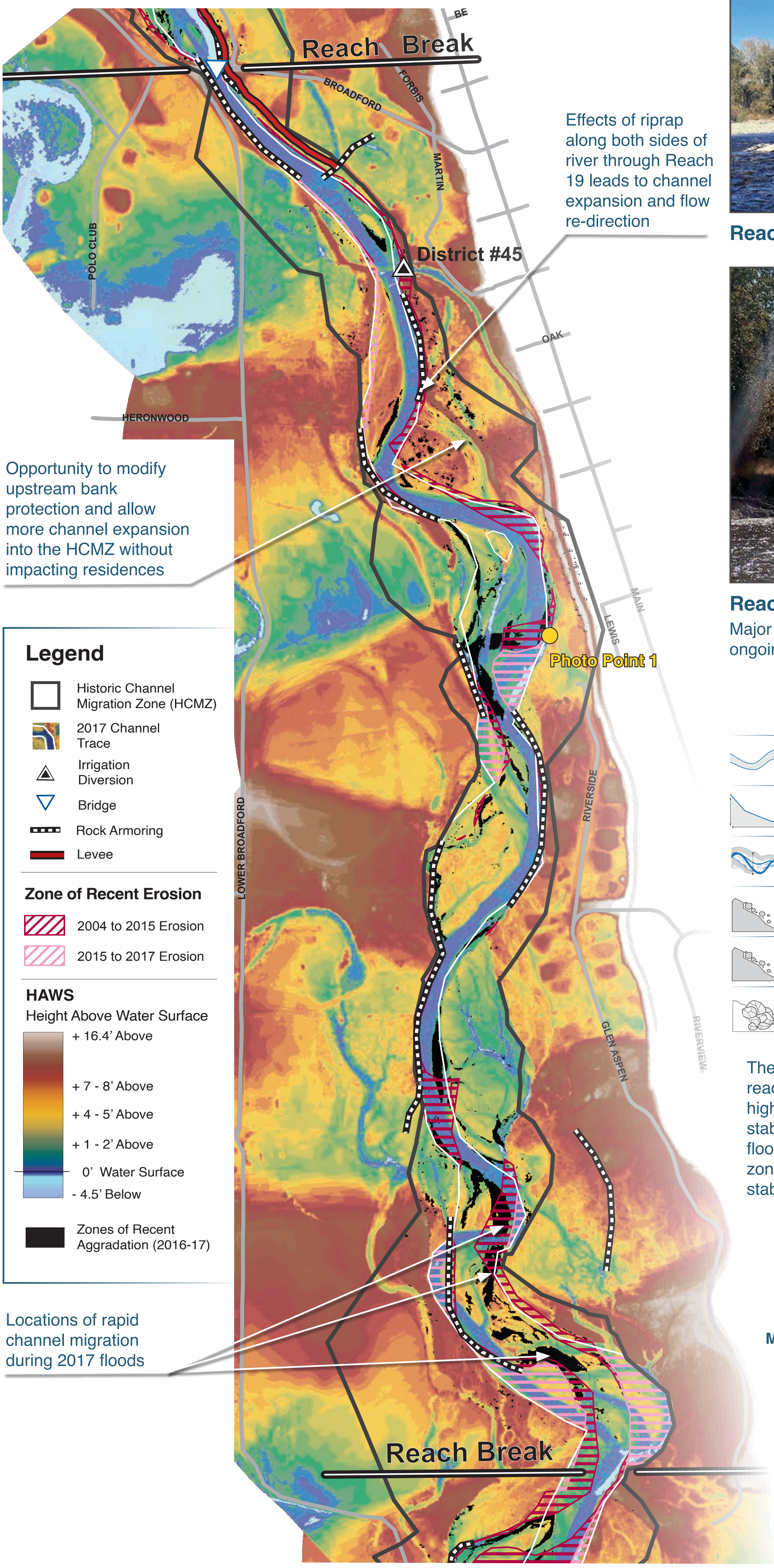
REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

Reach Description

The Broadford Bridge reach extends 2 miles to Townsend Gulch, running adjacent to farmland on the west bank and the City of Bellevue to the east. A major irrigation diversion diverts water from the river just downstream of Broadford Bridge. Levees and riprap line much of the banks (44%), mostly along the outside of meander bends to protect agricultural fields. The river channel has shifted dynamically across the HCMZ in this reach, preventing the evolution of stable riparian islands with mature stands of trees. Efforts to confine the river have also disconnected access to side channels and overflow flood pathways. Sediment deposition was significant during the 2017 flood, as seen in the HAWS mapping.

REACH 19



REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

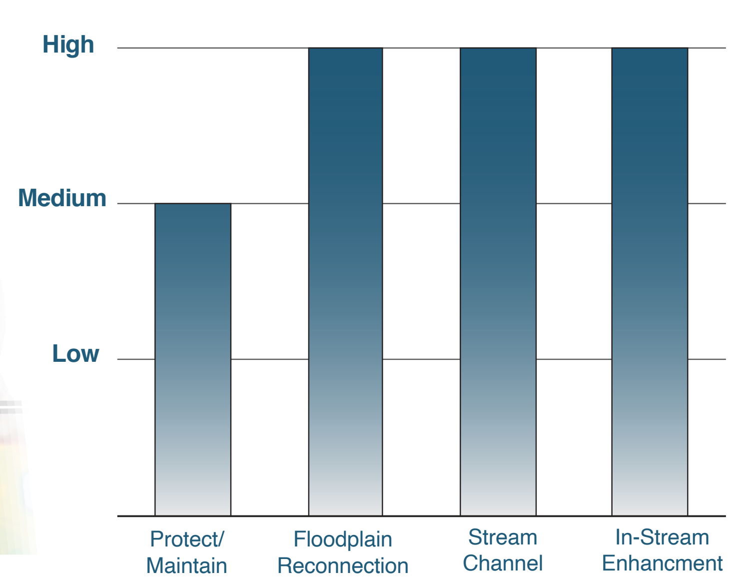
Reach 19 - Photo Point 1

Reach 19 - Photo Point 1

Major channel adjustments in 2017 led to bank erosion and ongoing high risk along Riverside Drive

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.24	1.15
Gradient (ft/ft)	0.0062	0.0064
HCMZ Width (ft)	783	513
Bankloss 2015-2017 (acre/river mile)	6.5	4.9
Bankloss 2004-2015 (acre/river mile)	7.3	6.8
Bank Stabilization (%)	44%	24%

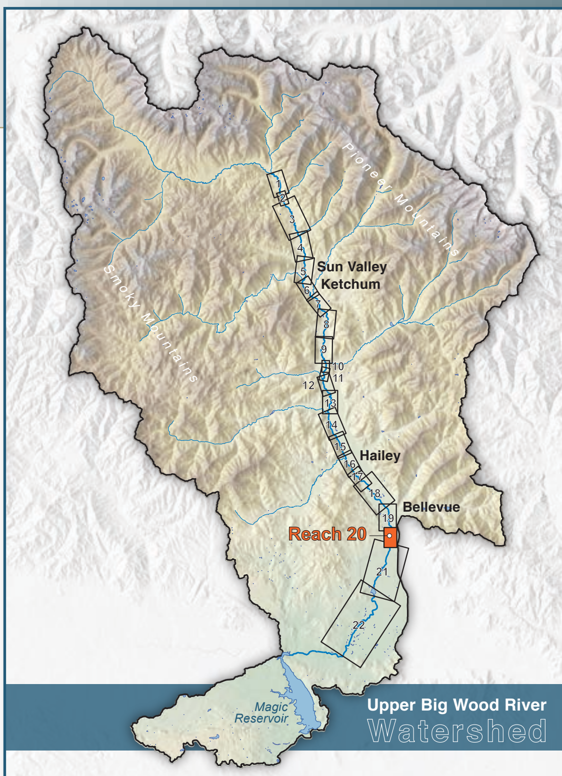
The Broadford Bridge to Townsend Gulch reach is the last reach which partially contains a levee and it has the third highest percentage of riverbank confined by some sort of stabilization measure. This reach has the second largest FEMA floodplain width of all reaches, which would seem to indicate a zone prone to flooding and channel movement; but heavy bank stabilization has limited natural channel migration.



Reach Project Potential

There may be advantageous locations in this reach to remove rock riprap in key locations that would not impact infrastructure. HAWS mapping indicates the presence of many near channel and off channel features that are topographically desirable for reconnection. This reach contains similar flood fencing and LWD jam potential as the upstream reach.

Townsend Gulch to Glendale Rd



River Reach Locator Map

REACH 20

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

Zone of Recent Erosion

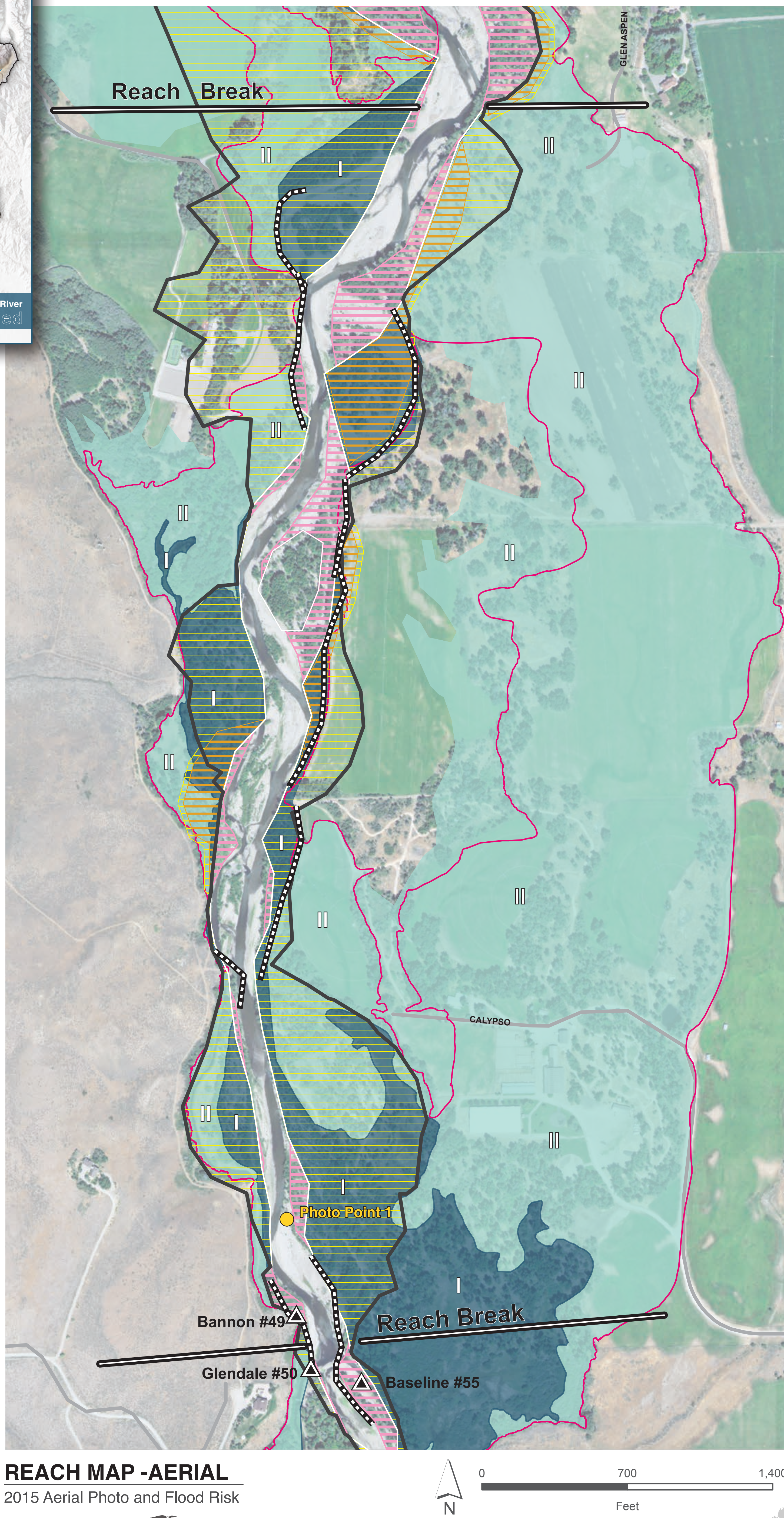
- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point

Reach Description

In the 1943 aerial photo, well-developed multi-thread channels are visible in this reach with mature riparian canopy. Conversion of that anastomosing channel network to a braided system, and the impacts on channel geomorphology are well documented (Rapp 2006). This reach is almost continuously armored along the entire length of the east bank. LiDAR differencing indicates very high levels of sediment deposition in this reach, an indicator of both its valley position as a "response reach", but also the degree of channel modification it has been subject to and the inability to deposit material in its broader floodplain.



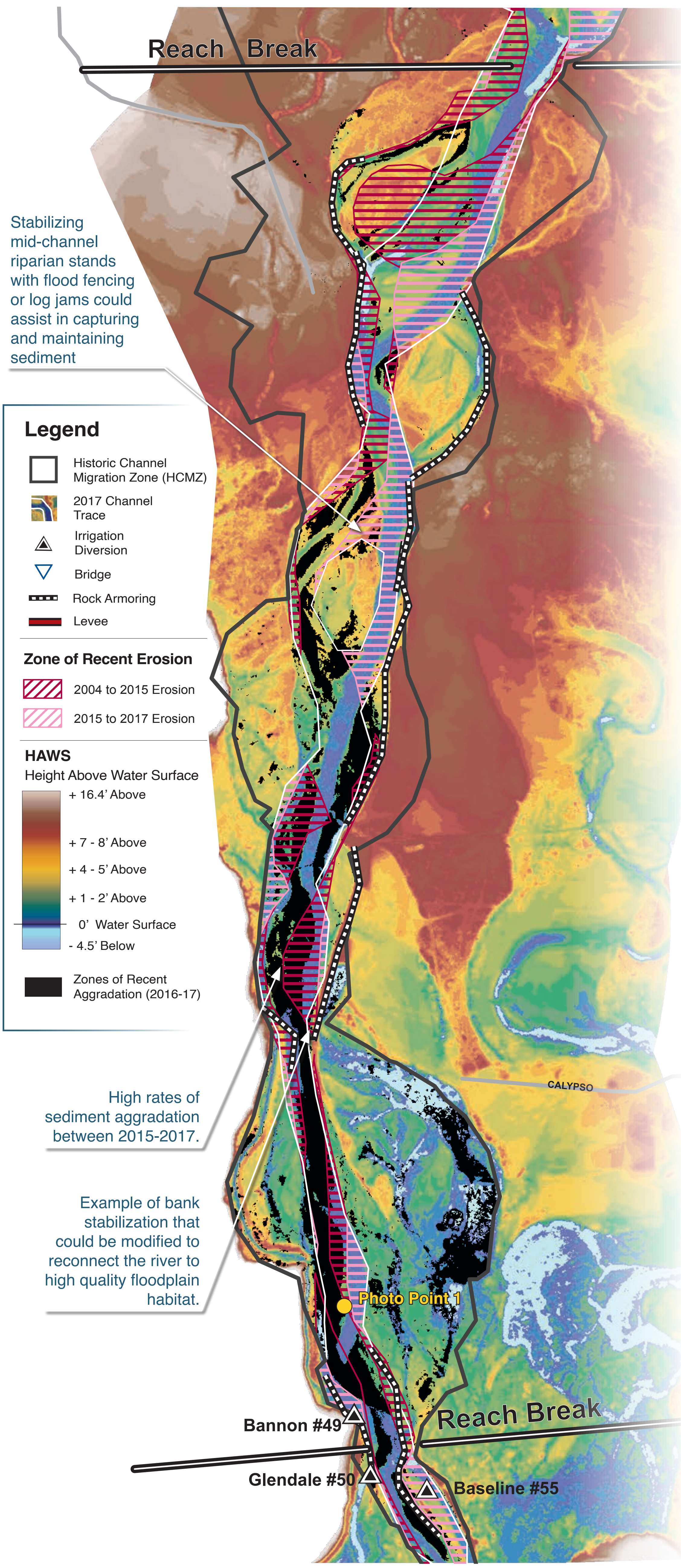
REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

Average FEMA Floodplain Width: 1,964 feet

2017 Average Bankfull Channel Width: 232 feet

REACH 20



REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

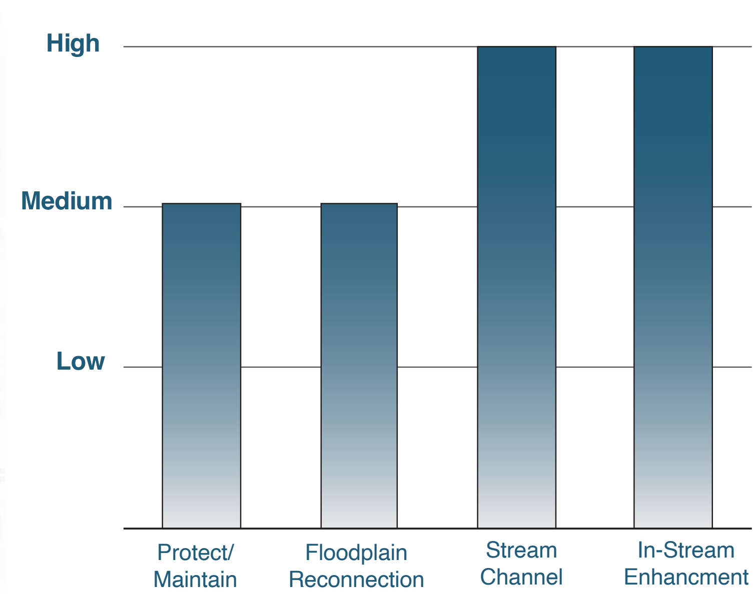
Reach Characteristics

Reach 20 - Photo Point 1

Reach 20 - Photo Point 1

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.11	1.15
Gradient (ft/ft)	0.0049	0.0064
HCMZ Width (ft)	807	513
Bankloss 2015-2017 (acre/river mile)	8.6	4.9
Bankloss 2004-2015 (acre/river mile)	13.2	6.8
Bank Stabilization (%)	44%	24%

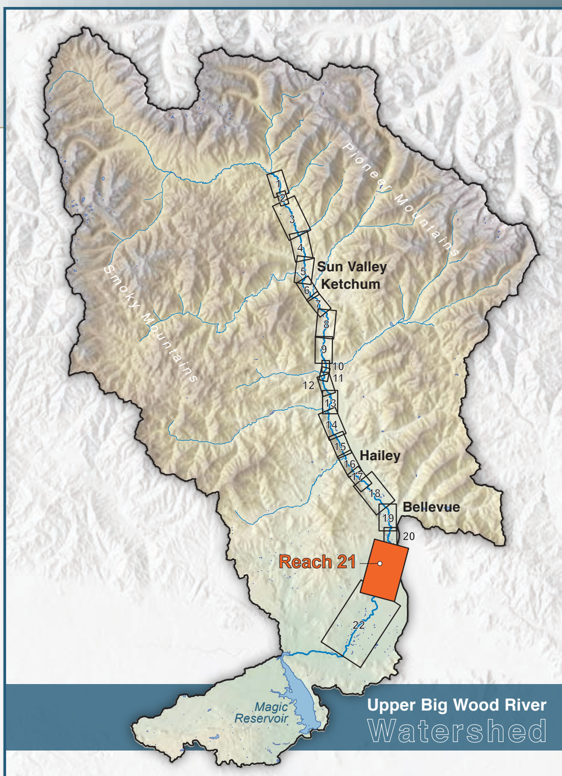
The Townsend Gulch to Glendale reach has the second lowest river gradient and a very wide FEMA floodplain which have amplified bank loss and rapid channel migration. This reach had the third most bank loss between 2004-2015 and ~2x more bank loss between 2015-2017. This channel movement coincided with extreme aggradation between 2016-2017. The reach has the second highest percentage of bank stabilization, implemented in attempts to channelize the river.



Reach Project Potential

Opportunities should be explored to remove bank armoring where willing landowners are interested. Allowing the river to access a wider portion of its natural meander belt will improve sediment transport, flooding, and habitat conditions. Installation of flood fencing and/or apex jams could serve to stabilize planform, retain sediment, and improve aquatic habitat through pool formation and shade/cover.

Glendale Rd to Mule Shoe Ln



River Reach Locator Map

REACH 21

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

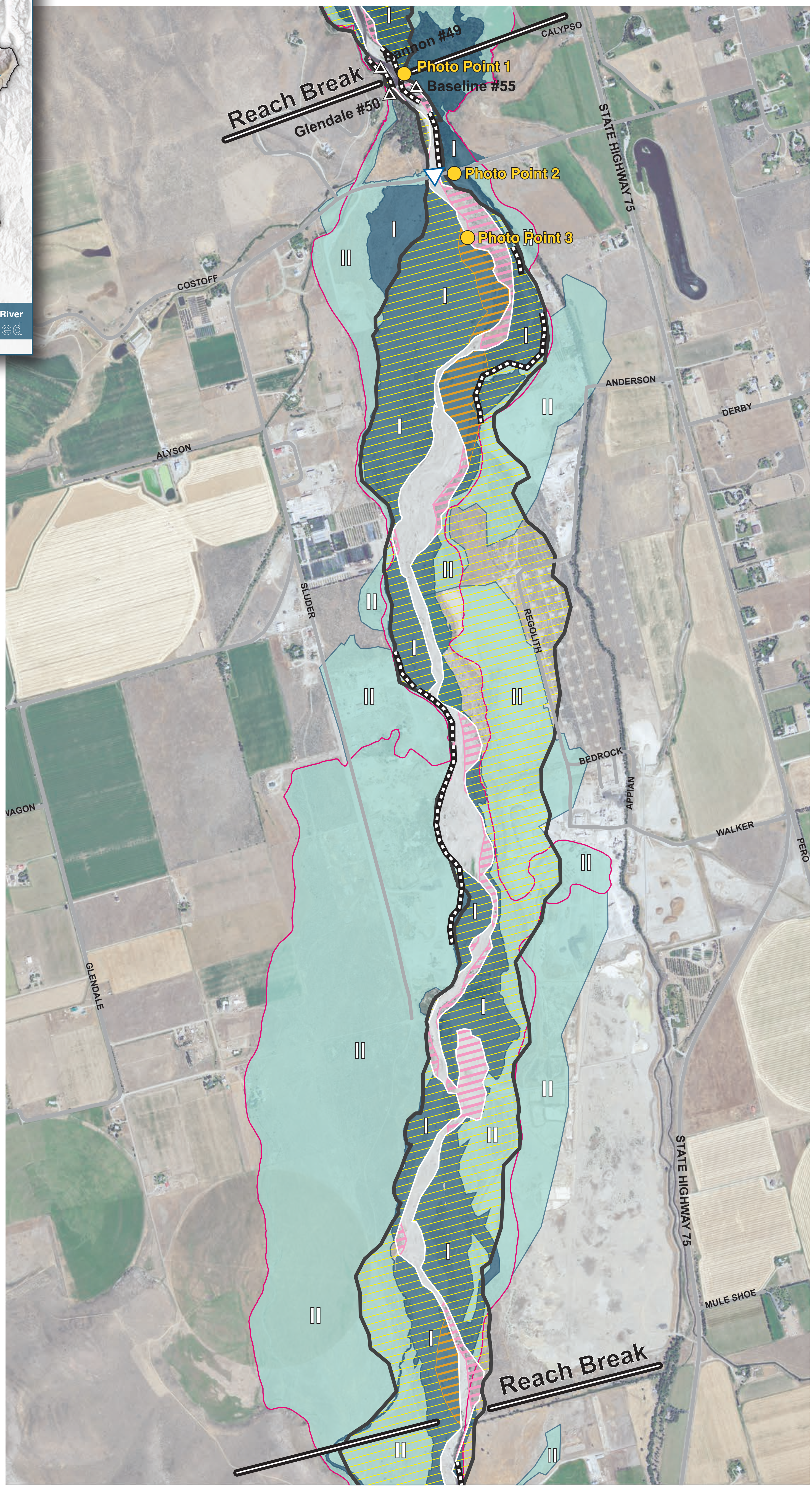
- Flood Risk Zone I
- Flood Risk Zone II

Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential
- Photo Point



REACH MAP -AERIAL

2015 Aerial Photo and Flood Risk

N

0 2,000 4,000

Feet

Average FEMA Floodplain Width: 2,326 feet

2017 Average Bankfull Channel Width: 219 feet

Reach Description

The large valley expansion at the beginning of the Glendale Rd. reach signifies a major transition in geographic setting; the river progresses from a high velocity channel confined by the valley wall to a sinuous lower gradient river with an expansive floodplain. This is reflected in the large channel migration zone and dynamic channel movement within the reach. The unconfined valley bottom is dominated by agricultural practices, which were made possible by a gradual accumulation of fine sediment deposited by the Big Wood River. Diversion of water for agriculture, and alterations to the river from in-channel gravel mining have reduced habitat quality and vegetative cover in this reach. This section of the Big Wood River is much more arid in climate and likely did not support similar flow regime or riparian communities as present upstream. The significant impacts resulting from flow diversion make it difficult to isolate the climate versus human induced ecosystem impacts.

REACH 21

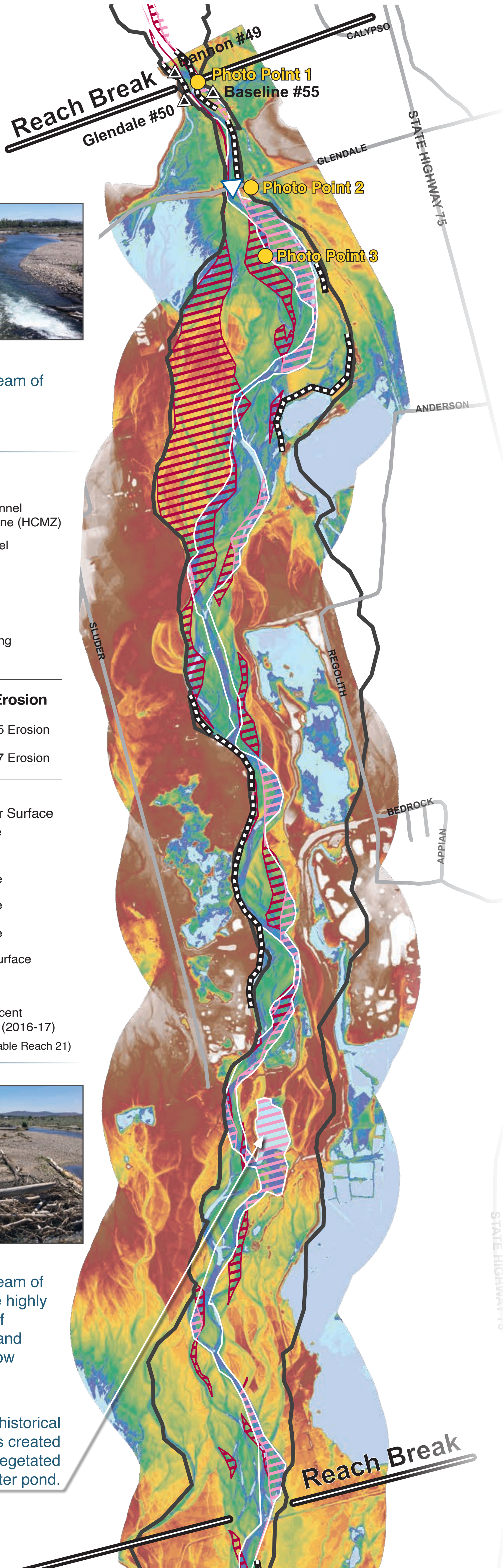


Photo Point 2
Conditions downstream of Glendale Bridge

Legend

- Historic Channel Migration Zone (HCMZ)
- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- Rock Armoring
- Levee

Zone of Recent Erosion

- 2004 to 2015 Erosion
- 2015 to 2017 Erosion

HAWS
Height Above Water Surface
- + 16.4' Above
- + 7 - 8' Above
- + 4 - 5' Above
- + 1 - 2' Above
- 0' Water Surface
- - 4.5' Below

Zones of Recent Aggradation (2016-17)
(No data available Reach 21)

Photo Point 2
Conditions downstream of Glendale Bridge are highly influenced by lack of riparian vegetation and late summer baseflow

Location of historical mining has created an unvegetated backwater pond.

REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

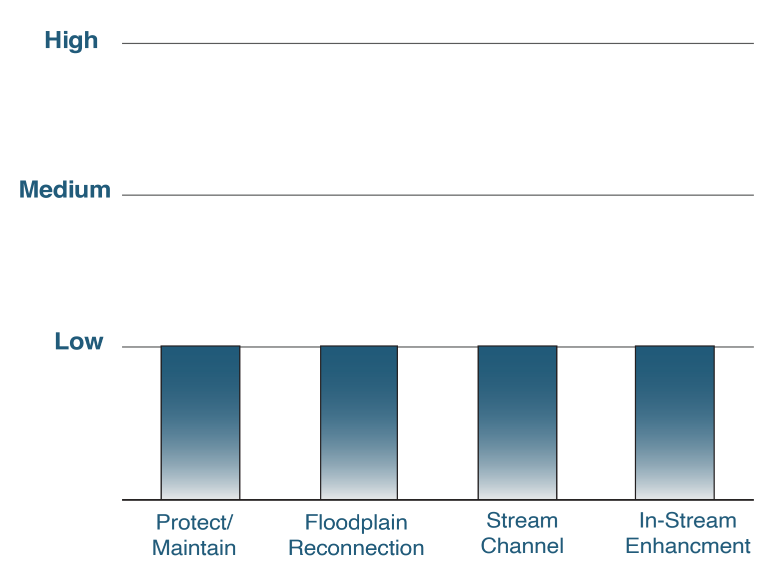
Reach Characteristics

Reach 21 - Photo Point 1
Looking upstream of Glendale Diversion

Reach 21 - Photo Point 3
Looking upstream towards Glendale Road

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.17	1.15
Gradient (ft/ft)	0.0052	0.0064
HCMZ Width (ft)	1,415	513
Bankloss 2015-2017 (acre/river mile)	12.1	4.9
Bankloss 2004-2015 (acre/river mile)	25.8	6.8
Bank Stabilization (%)	19%	24%

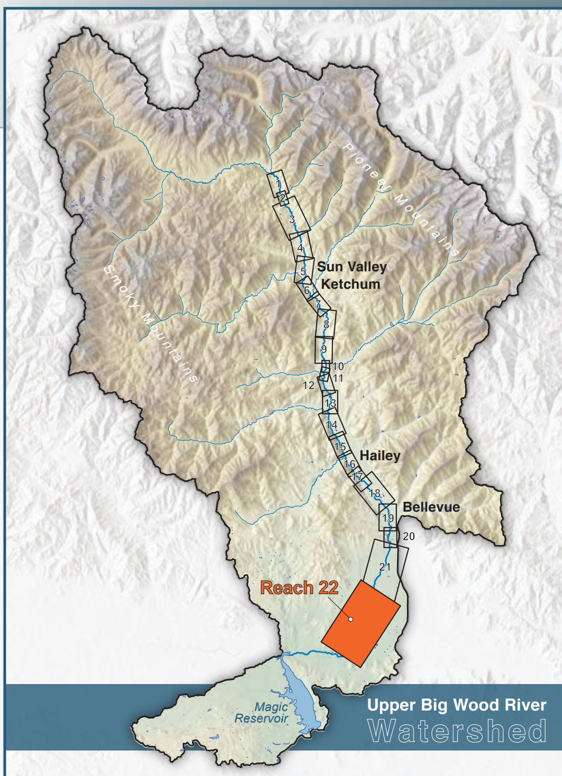
The transition to an unconfined, sinuous and low gradient river is reflected in the reach's FEMA floodplain and HCMZ widths, which are 2.6x and 2.8x greater than average respectively. This is arguably the most dynamic reach with the second most bank loss between 2015-2017 and the most bank loss between 2004-2015 (3.8x greater than average).



Reach Project Potential

It is hard to envision restoration of a functional river ecosystem below Glendale Diversion until such time that a more natural flow regime is restored, meaning major modifications to the management of the Glendale Irrigation system. In-stream sand and gravel mining or other heavy industrial uses within the HCMZ also limit any potential for ecosystem recovery. If there is community desire to modify thee uses and improve riverine function downstream of Glendale, opportunities could be pursued to retain sediment through the use of flood fencing, which would reduce frequent shifts in channel position and perhaps help better establish native riparian communities

Mule Shoe Ln to Stanton Crossing



River Reach Locator Map

REACH 22

Legend

- 2017 Channel Trace
- Irrigation Diversion
- Bridge
- FEMA 100 Year
- Levee
- Rock Armoring
- Historic Channel Migration Zone

Flood Risk Zone

- I Flood Risk Zone I
- II Flood Risk Zone II

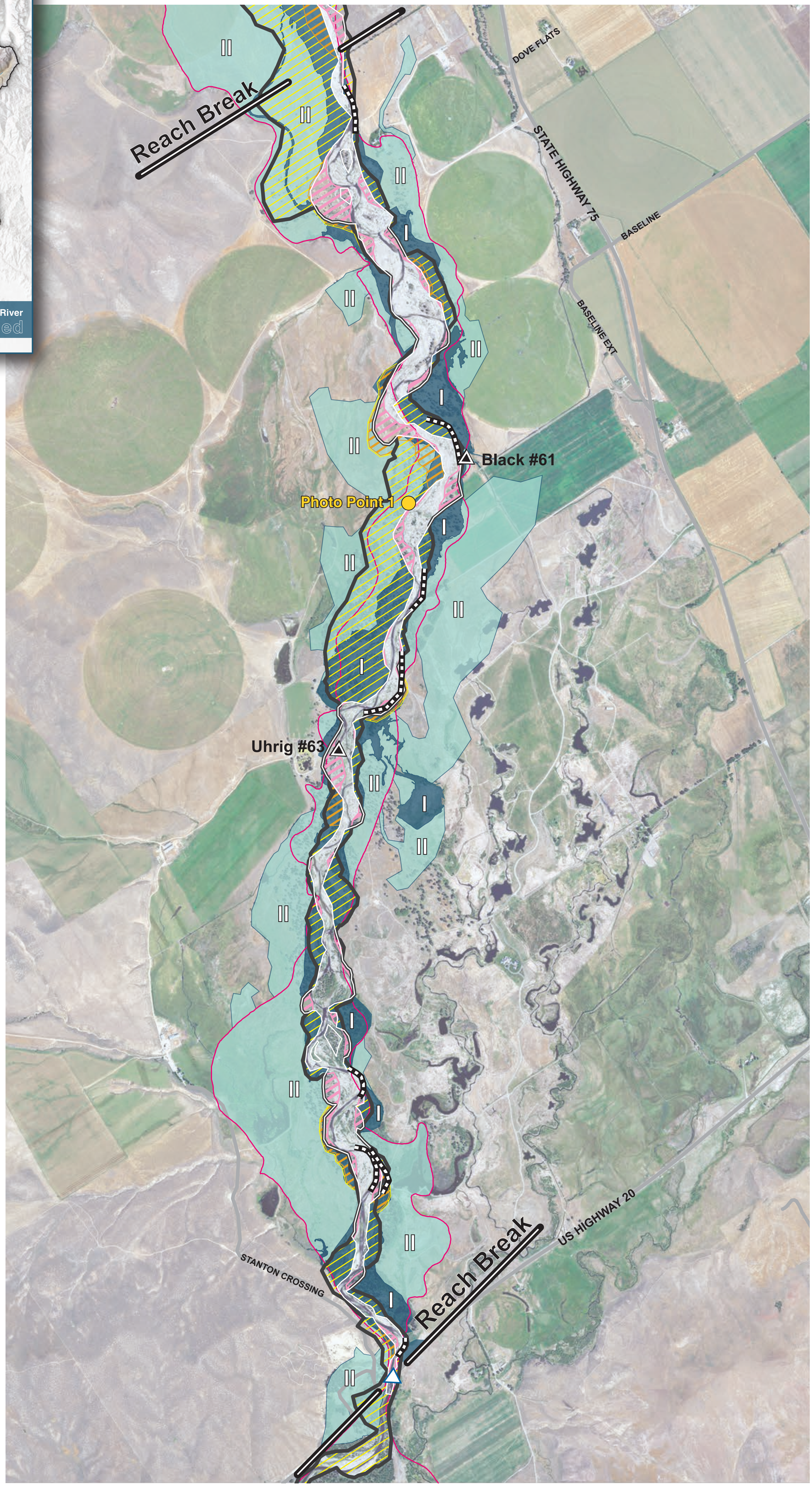
Zone of Recent Erosion

- 2015 to 2017 Erosion

Zone of Potential Erosion

- High Erosion Potential
- Moderate Erosion Potential

- Photo Point

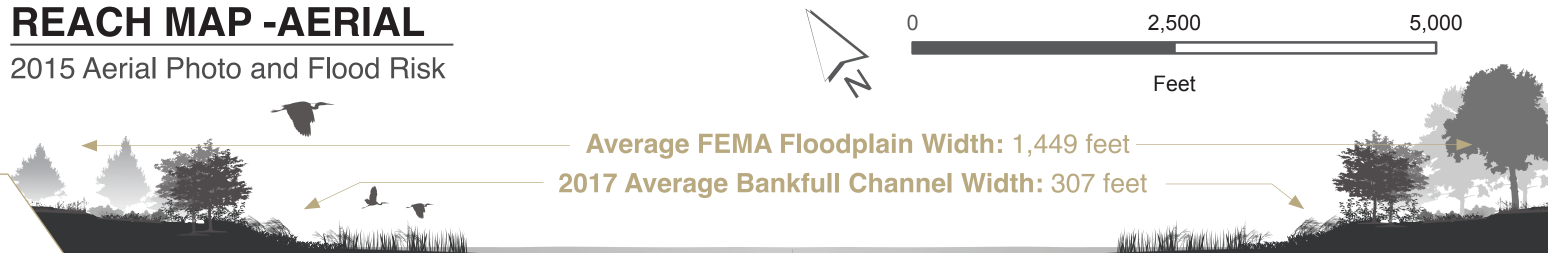


REACH MAP -AERIAL
2015 Aerial Photo and Flood Risk

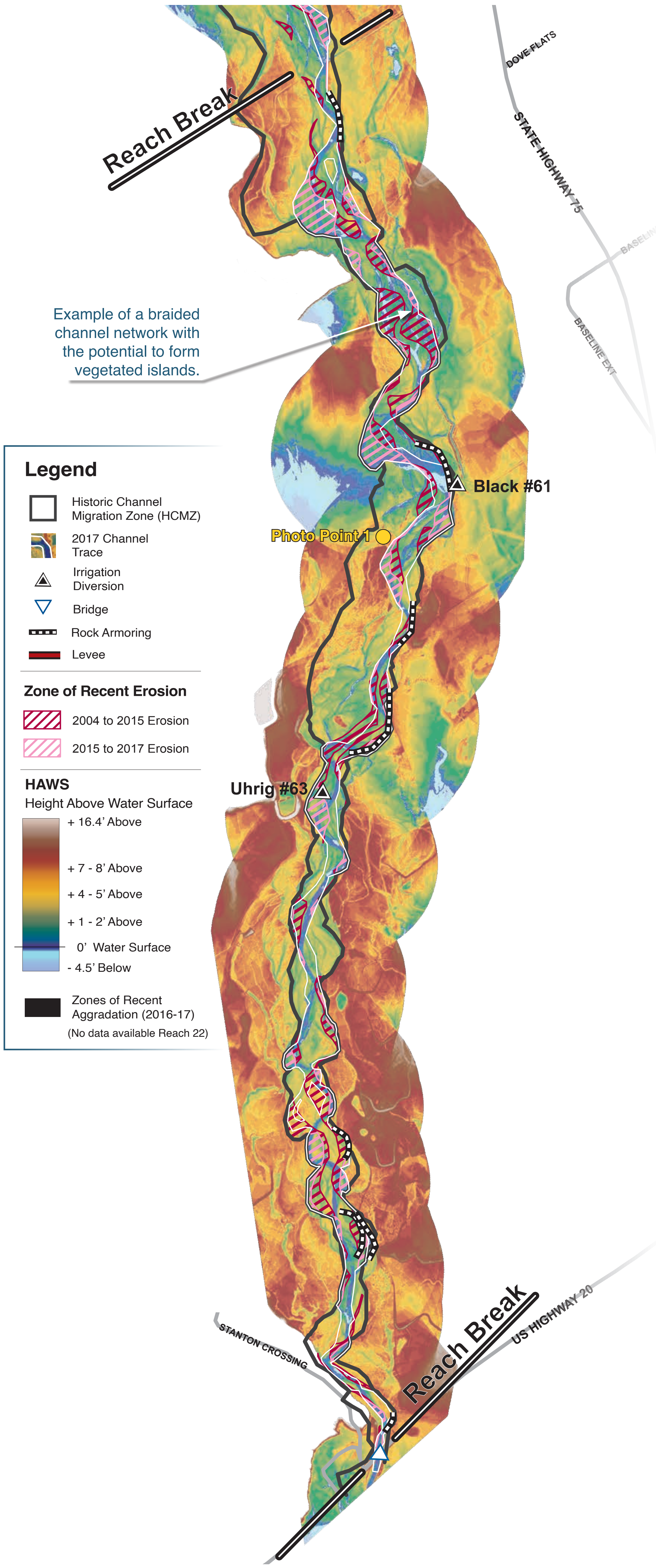
0 2,500 5,000
Feet

Reach Description

As the farthest downstream reach, Stanton Crossing has a low gradient slope and wide valley bottom, which have allowed it to form large meander bends that migrate frequently. This reach is situated within a primarily agricultural area, which has reduced or eliminated in-stream flows during much of the irrigation season. Groundwater extraction and upstream river diversions have limited water availability within the reach, while the absence of large woody debris has created a dynamic channel that is unable to support healthy vegetation. In the future, water management practitioners will need to balance the need for irrigation while maintaining instream flows for habitat and recreational opportunities.



REACH 22



REACH MAP - HAWS

Height Above Water Surface (HAWS), Erosion Hazards, HCMZ

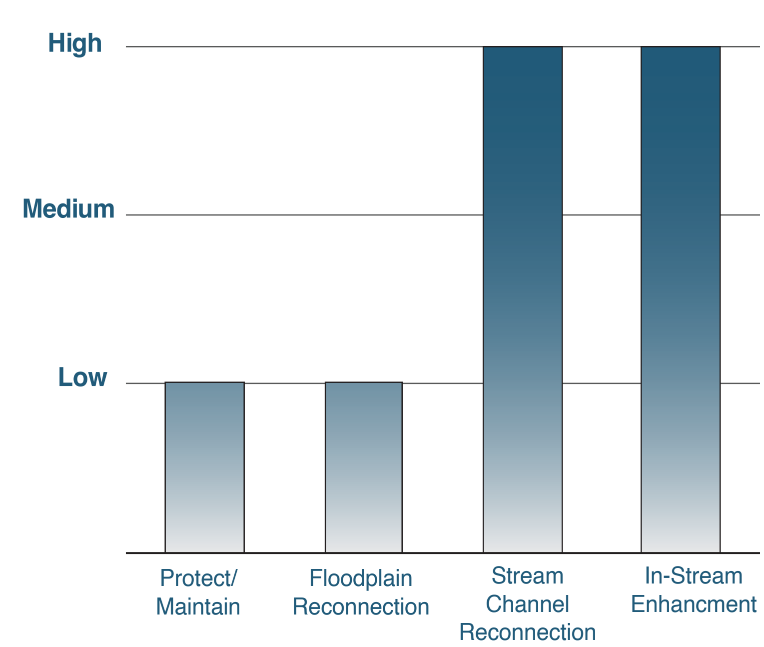
Height Above Water Surface mapping of the Big Wood River uses a technique to show elevation difference of the floodplain topography relative to the river water surface. The map shows relic features in the floodplain created by the river, such as abandoned channels, meander bends, and oxbows. This illustrates how the river has actively meandered across the width of the geomorphic floodplain.

Reach Characteristics

Reach 22 - Photo Point 1
Looking downstream towards HWY 20

Reach Characteristics	Reach Average	Big Wood River Average
Sinuosity	1.3057	1.15
Gradient (ft/ft)	0.0044	0.0064
HCMZ Width (ft)	848	513
Bankloss 2015-2017 (acre/river mile)	11.9	4.9
Bankloss 2004-2015 (acre/river mile)	16.9	6.8
Bank Stabilization (%)	10%	24%

The Mule Shoe Ln to Stanton Crossing reach exhibits dynamic channel migration similar to the upstream Glendale Rd reach. It had the third most channel bank loss between 2015-2017 and second most between 2004-2015. The river corridor has the second widest HCMZ width and the greatest 2017 channel width of all study reaches.



Reach Project Potential

There is great potential to restore riparian and floodplain habitat within this reach by utilizing in-stream large woody debris structures to manage sediment dynamics. The river corridor has sparse riparian vegetation and few stable vegetated islands or meander bends because of its dynamic channel migration. Large woody debris structures or flood fencing could be installed to locally stabilize riverbanks or islands, which would then be colonized by vegetation.

5 River Treatments

Best Management Practices and Guidance for Project Planning and Design

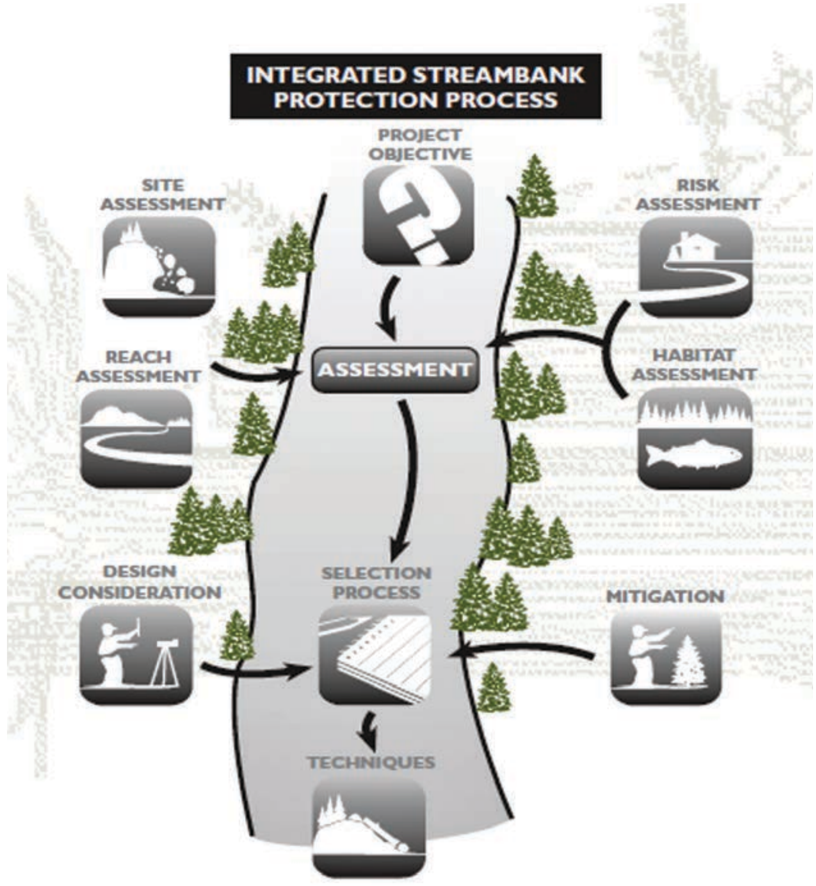
This section presents guidance for project proponents or project reviewers to consider during planning and design of projects in the river environment.

Chapter 1 discusses an overall approach, hierarchical strategy, and priorities for process based habitat restoration in the Big Wood River.

This appendix offers examples of some typical treatments, or Best Management Practices (BMP's) that may be applied in the river environment and rough guidance on the steps recommended to identify the project need and develop designs. This section also provides a library of reference documents which offer much more detailed information on design processes and the current standard of care for river restoration and river bank stabilization.

Design Process

For the purposes of this Atlas, and based on expressed needs in the Big Wood watershed, a focus of the BMP's presented here are for the primary purposes of addressing bank erosion and bank stabilization projects/treatments to treat such failures. However, the approach and processes presented below is recommended for larger, process-based or restoration focused projects as well. To ensure that projects address site-scale, reach-scale, and watershed-scale processes, a minimum level of assessment, analysis, engineering and design is recommended.



Integrated streambank-protection process; *from the Washington State Aquatic Habitat Guidelines Program Integrated Streambank Protection Guidelines (ISPG) (2003).*

A sample graphic representation of such a process is shown to the right. The graphic presents the basic steps expected for the assessment, analysis and design necessary for not just a bank stabilization project, but also for riverine projects of any scale. Much of the information outlined in the project design process is referenced from the Washington State Aquatic Habitat Guidelines Program's Integrated Streambank Protection Guidelines (ISPG) (WSAHGP, 2003).

Project Objectives and Design Criteria

Every project should have a purpose defined by a set of goals and objectives. Goals can be general and projects can have multiple goals. Projects in the Big Wood watershed often address bank erosion, so example project goals can include "stabilize streambank to reduce loss of property" or "improve floodplain riparian vegetation". Once project goals are developed, project objectives can be developed to evaluate whether a project meets those stated goals. Objectives should be specific and measurable. Example project objectives might include "stabilize XX linear feet of streambank with roughened rock toe" or "achieve 70% vegetation cover over pre-project conditions for a floodplain revegetation project." Measurable objectives allow a designer/reviewer/stakeholder to evaluate design alternatives or evaluate project success following implementation.

Project designers follow design criteria in designing, evaluating and constructing projects that aim to achieve a project's stated goals and objectives. An example of a common design criterion is design flow (i.e. "the proposed project shall be able to withstand the estimated hydraulic forces of a 100-year flood event"). In some circumstances or locales, specific design criteria is established which must be followed for all riverine projects (i.e. all bank stability projects shall be designed to withstand the 100-year flood event").

In others, there is flexibility in design criteria based on other factors. An example would be design criteria dependent on level of risk; design criteria could vary based on the project's potential risk determined through risk analysis. Projects deemed to present "low" potential risk to public safety, property or infrastructure could have lower design requirements (such as design flow [10-, 50-, 100-year flow]) than projects deemed to pose "high" potential risk. Design criteria varies by location and is typically determined by the local regulatory agencies.

Site and Reach Assessment

For any project a site and reach assessment should be performed. A minimum understanding of the site-scale and reach-scale geomorphic, hydraulic, and habitat conditions should be determined as part of the site assessment. In the case of bank stabilization projects, the assessment should aim to understand the extent, mechanism (toe erosion, scour,, etc.) and root cause (site-based or reach-based) of bank failure. This assessment is critical in the selection of treatment types as some techniques may be inappropriate for the site conditions.

When considering the reach-level stream characteristics of a site, one should look to answer:

1. What are the basic physical conditions of the stream channel?
2. What are the natural and human-induced processes that are occurring?
3. Do these processes indicate a stable channel?
4. Do these processes indicate an unstable channel? If so, what is causing the instability?
5. How can the streambank be protected in order to achieve long-term ecological success?

Habitat Considerations and Mitigation

Since the mission of the community is to optimize land use and natural processes of the river, and since the habitat value of the river is critical to the community's identity; the status, potential loss and any potential mitigation of the river's habitat should be assessed and considered for every project.

Risk Assessment

"Throughout the design process, it is important to understand and evaluate the many types and levels of risk associated with a streambank-protection project (WSAHGP, 2003)." During the planning of a river or streambank project, the project team must consider the risks associated with continued failure or streambank erosion and also the new risks created as a result of the proposed project. Questions to be posed during the course of project assessment and design may include:

• Will the proposed project pose a risk to private property (site of project and surrounding properties) with potential increased flooding or bank erosion?

• Will the proposed project pose a risk to public safety by increasing risk to recreation users or to nearby infrastructure?

• Will the proposed project pose an ecological risk by potentially degrading habitat?

Levels of risk determined in a risk assessment influence the design criteria a project must follow (i.e, as the risks associated with a proposed project increase, so should the degree of analysis and engineering).

Selection Process

Information gained from the steps above lead to a selection process for an appropriate treatment/technique, which there are numerous of varying levels of appropriateness for a particular project. One potential course of action and the consequences thereof which should always be considered is the no action alternative.

Treatment Techniques

Treatment techniques can be grouped into a number of sub-categories, each with multiple treatment options capable of meeting project objectives. The following primary groups are grouped according to the degree of direct influence on the channel (i.e. "No Action" requires no work in the river, while "Structural Techniques" require installing physical structures in the channel that influence channel form and function).

Though not intentionally grouped this way, the order can also be described relative to typical design and implementation cost and permitting difficulty (low-to-high).

No Action

Allow bank erosion and river processes to continue without any intervention.

Riparian Buffer Restoration/Biotechnical Techniques

Land management practices

Remove infrastructure at risk

Native riparian planting

Floodplain roughness

In-Channel Structural Techniques

Rock or Large Wood

Bank Roughness

Engineered Log Jams (ELJs)

Riprap

Sample site assessment checklist; *from ISPG (2003).*

Site Characterization Checklist

❑ channel geometry: cross section, streambank height, gradient, pool riffle system.

❑ planform: meander bend (how tight?), straight reach, physical features.

❑ over-bank topography.

❑ soils in terrace and bank.

❑ bed materials (bed substrate) and armoring (surficial material).

❑ woody debris abundance and location.

❑ geologic features.

❑ vegetation: species, abundance, location on streambank (lower vegetative limit).

❑ indication of the height of flood waters, or the peak erosive energy of such high flows; for example, lichen and moss limits on rocks indicating annual high water mark, debris collected in bushes indicating the height of a flood, and the size of cobbles on bars reflecting the maximum flow over the surface.

❑ location and depth of scour holes.

❑ flow patterns for existing conditions: flow direction, thalweg, angle of attack on streambank, impacts of physical features.

❑ approximate flow and stage at time of observation (e.g., during a flood, base flow, at bank-full flow).

❑ visualize flow patterns at higher or lower flows (something that may be difficult for the untrained or inexperienced observer).

❑ sediment transport indicators: bed-load caliber, bar formation, deposited material in eddies and backwaters, patterns in deposited sizes on bars.

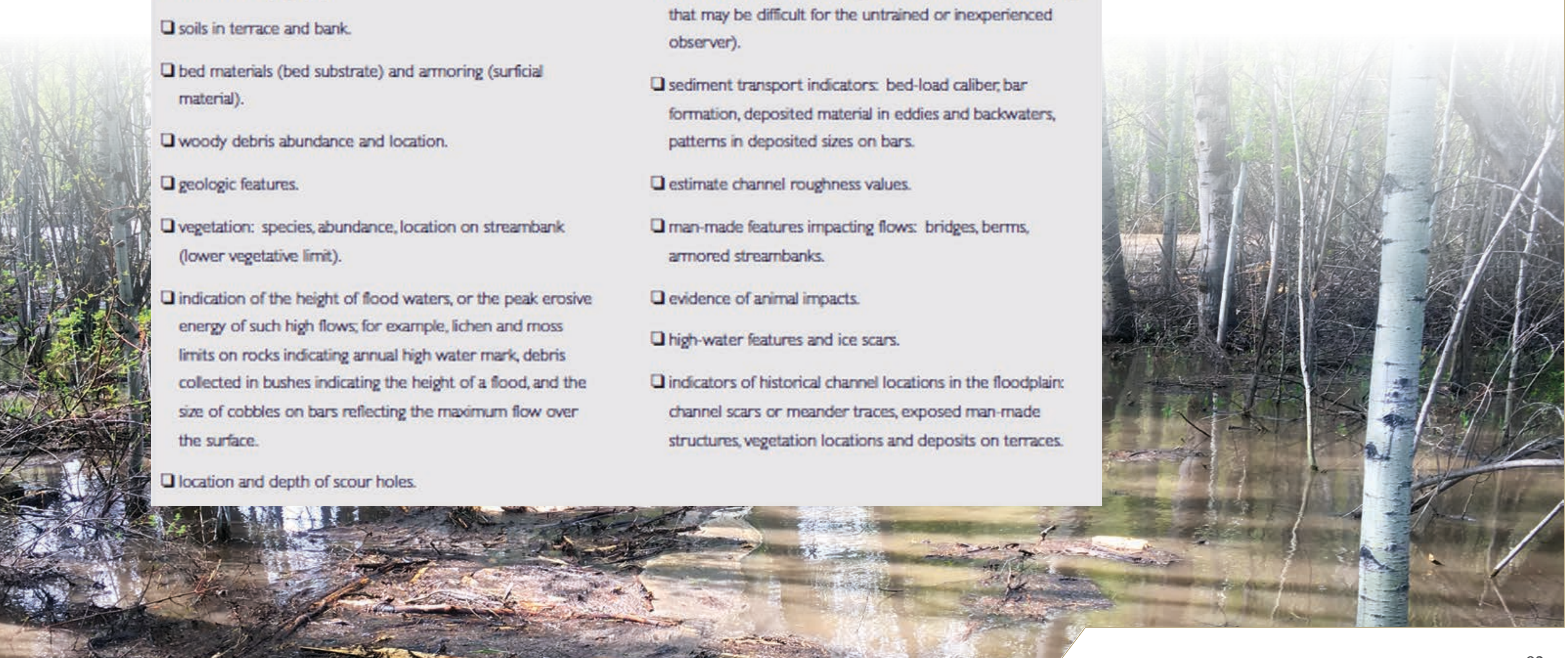
❑ estimate channel roughness values.

❑ man-made features impacting flows: bridges, berms, armored streambanks.

❑ evidence of animal impacts.

❑ high-water features and ice scars.

❑ indicators of historical channel locations in the floodplain: channel scars or meander traces, exposed man-made structures, vegetation locations and deposits on terraces.

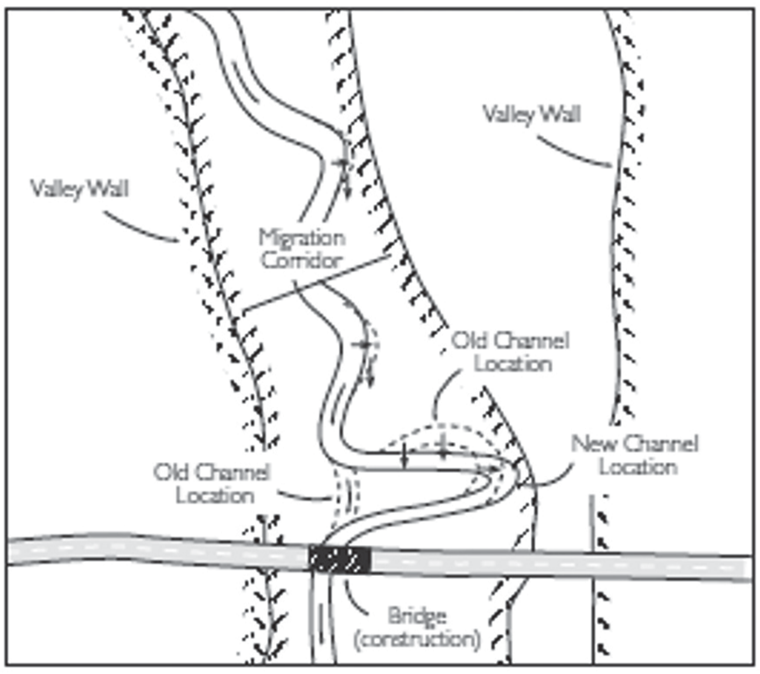


Treatment Techniques

No Action

The “No action” approach aims to allow the river’s natural processes to dictate the response. Within a narrow, developed corridor, this may not be realistic as risks to property, infrastructure and public safety must be considered. Where property is at risk of erosion, but infrastructure is set back from eroding streambanks, the no-action alternative should be closely evaluated before limiting natural channel migration. In locations where there are minimal or isolated structures at risk, and potential for larger scale restoration, consideration should be given to potentially moving at risk infrastructure, land acquisition, and pursuing site restoration. The information collected during the site assessment process is critical for the consideration of this alternative. Knowledge of such information as the channel’s migration history and expected migration rates, flood frequency, stability or instability of the site in question, risk of continued failure and potential consequences, and risk of proposed actions can inform this decision.

Every project should consider a range of alternatives that always includes a no-action scenario. *(Reclamation and USACE, 2016.)*



Schematic of a channel within a channel migration corridor taken from ISPG (2003). *Assuming there were no bridge or other risks, no action may be an appropriate approach on a bank erosion site for a channel completely within its migration corridor that does not threaten public safety or infrastructure.*

Riparian Restoration/ Biotechnical Techniques

This section considers approaches to provide protection to property and infrastructure that do not require alterations to the stream channel, focusing treatment on the riparian corridor adjacent to the stream. The overall objective of these approaches is restoring the natural riparian buffer between the channel and property/infrastructure that can provide improvements for flooding and erosion as well as allow room for the river’s natural processes.

In natural conditions, streamside forests protected most of the rivers and streams of our nation, but deforestation associated with agricultural and urban expansion has drastically reduced the extent of stream bank protected by forest. *(Welsch, 1991)*

Benefits Riparian Restoration/Biotechnical Techniques:

- Flood Resiliency
- Water Quality
- Erosion Control/Property Protection
- Ecological/Habitat Benefits
- Aesthetics
- No direct impact on channel
- Low Design and Implementation Costs

Infrastructure Relocation

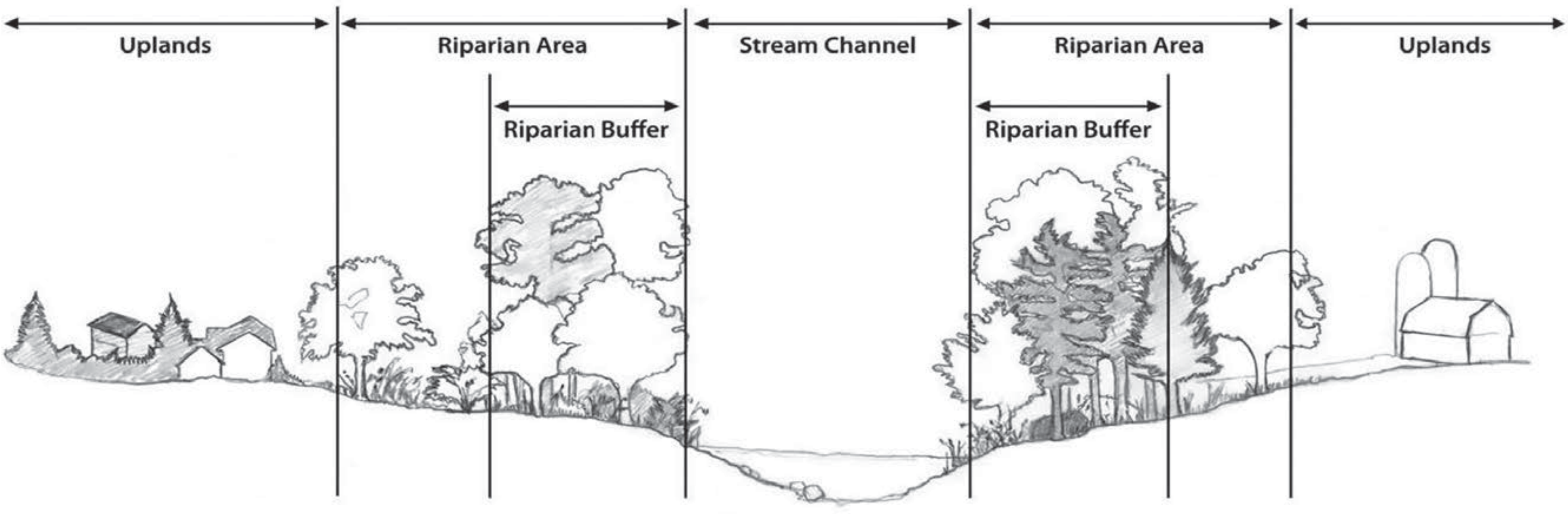
Degradation of riparian areas is often a result of land practices and urban development encroaching into riparian corridors. Prior to considering attempts at in-channel techniques, or at a minimum in conjunction with in-channel techniques, potential for restoring the health and function of the adjacent riparian area should be considered, allowing the river the buffer for natural processes and self-healing.

Considerations:

- Land Acquisition
- Relocation of infrastructure at risk
- Changes in land uses
- Native Riparian Revegetation (See Below)
- Floodplain Roughening (See Below)

Native Riparian Plantings

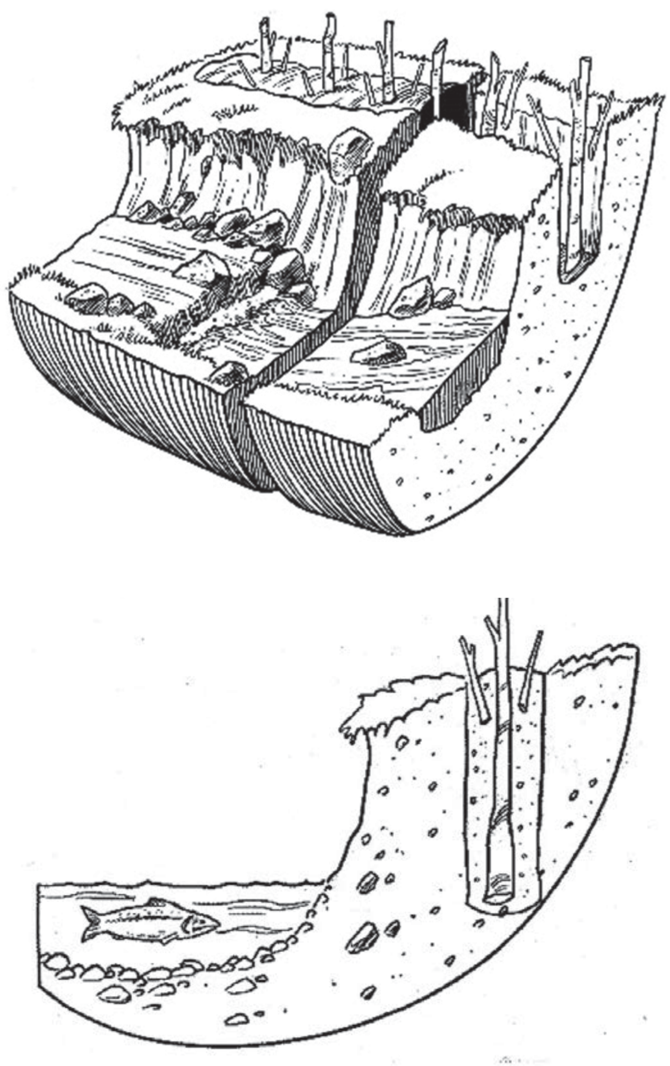
- Re-establish native riparian vegetation and root structure in soil
- Re-establish both understory and canopy species.
- Low cost and low risk
- Can be done as stand-alone treatment or in conjunction with structural techniques (LWD, RipRap, etc.)



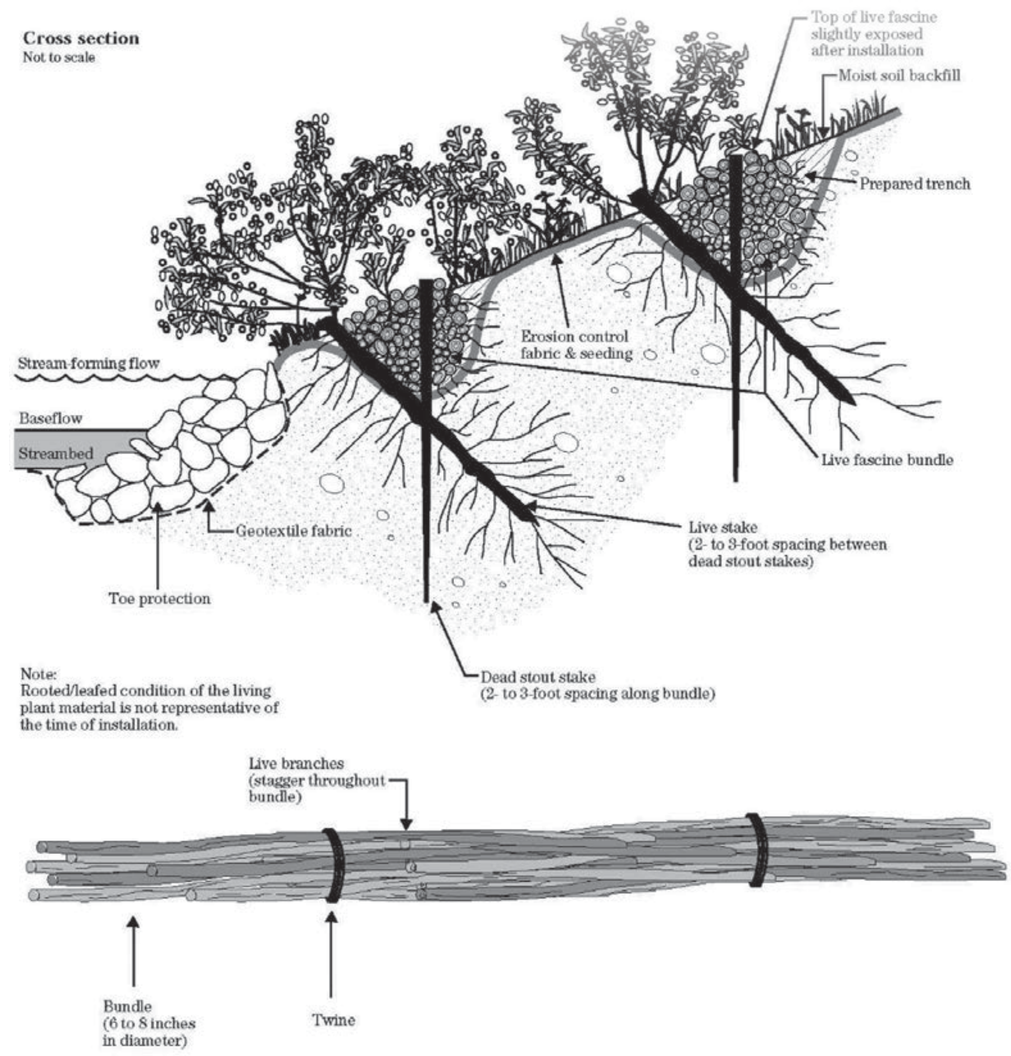
Relationship between uplands, riparian areas, riparian buffers, and the stream channel (EPA, 2010).

Riparian Restoration/Biotechnical Techniques

Woody Planting Techniques

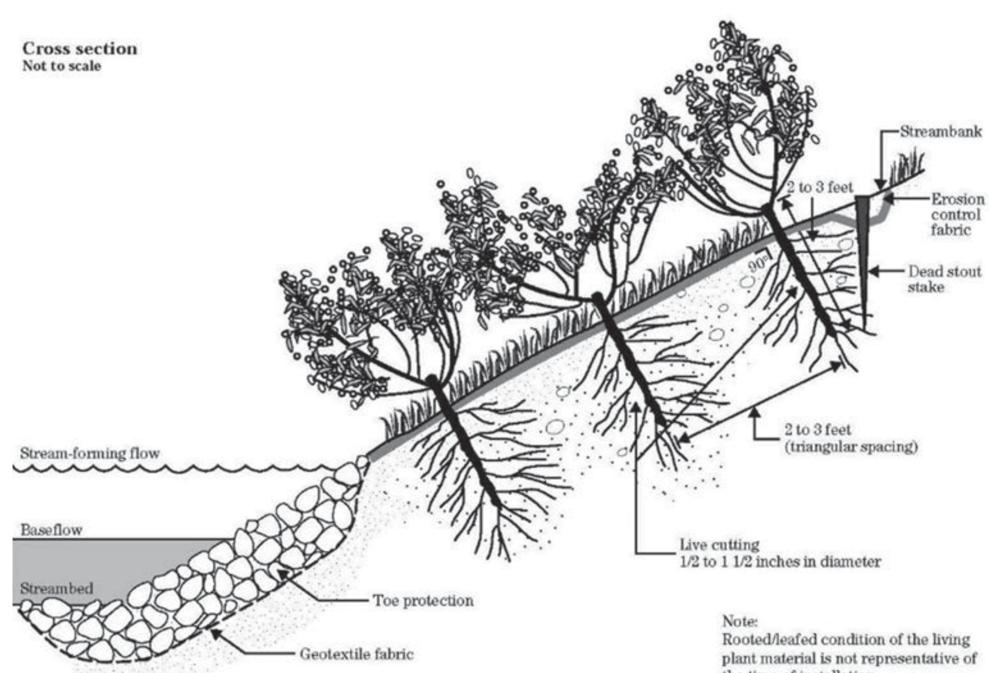


Live Palisades; Courtesy Polster Environmental Services Ltd. (2003)



Live Fascines; Courtesy NRCS (2006).

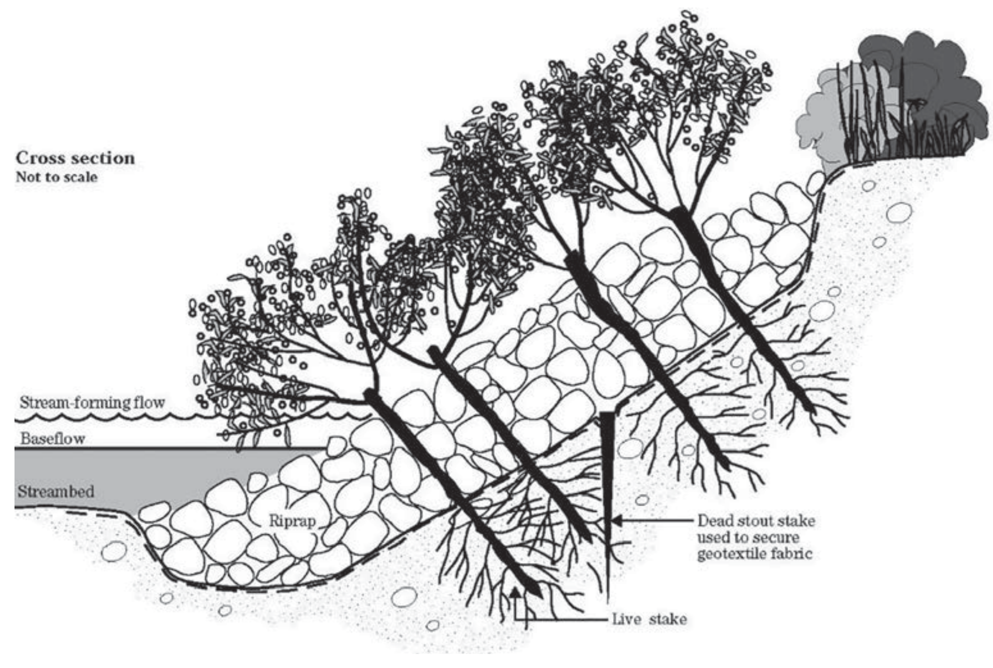
Example of floodplain with established riparian trees, but with understory removed and replaced with landscaped grass that provides minimal hydraulic roughness and soil stability



Live Stakes; Courtesy NRCS (2006).

Resources: Publicly Available Resources for suggested techniques, native species selection and density/spacing for Woody Planting and Riparian Corridor Restoration:

Author	Title	Date
Johnson, Craig W., and Buffler, Sunsan. US Department of Agriculture, Forest Service. Rocky Mountain Research Station.	Riparian Buffer Design Guidelines for Water Quality and Habitat Functions on Agricultural Landscapes in the Intermountain West	2008
US Department of Agriculture, Natural Resources Conservation Service, Boise, Idaho	TN Plant Materials No. 23, How to Plant Willows and Cottonwoods for Riparian Restoration	2007
US Department of Agriculture, Natural Resources Conservation Service	National Engineering Handbook, Part 654, Stream Restoration Design	2006
US Department of Agriculture, Natural Resources Conservation Service, Plant Materials Center and National Design, Construction, and Soil Mechanics Center	Streambank Soil Bioengineering Field Guide for Low Precipitation Areas	2002
US Department of Agriculture, Natural Resources Conservation Service, Plant Materials Center	The Practical Streambank Bioengineering Guide	1998

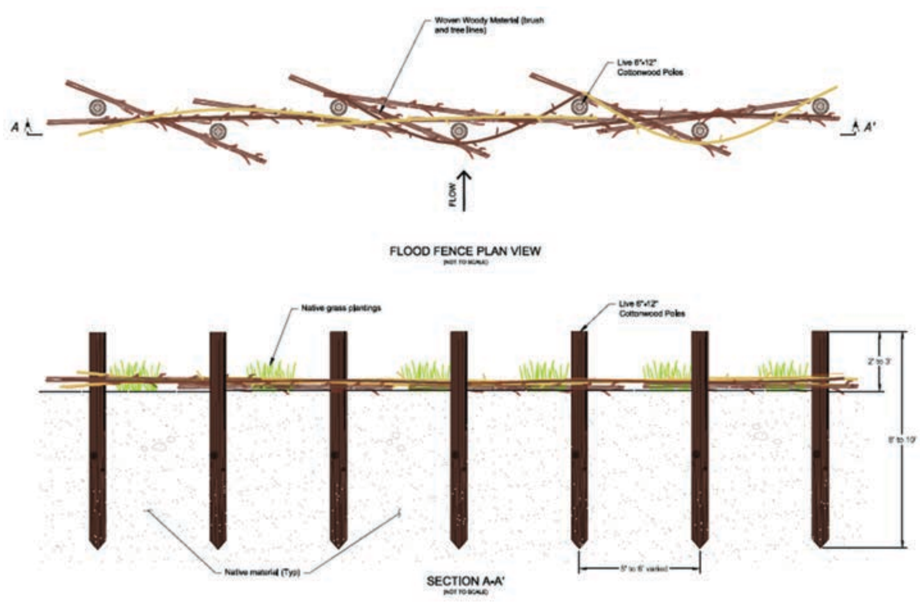


Joint Planting; Courtesy NRCS (2006).

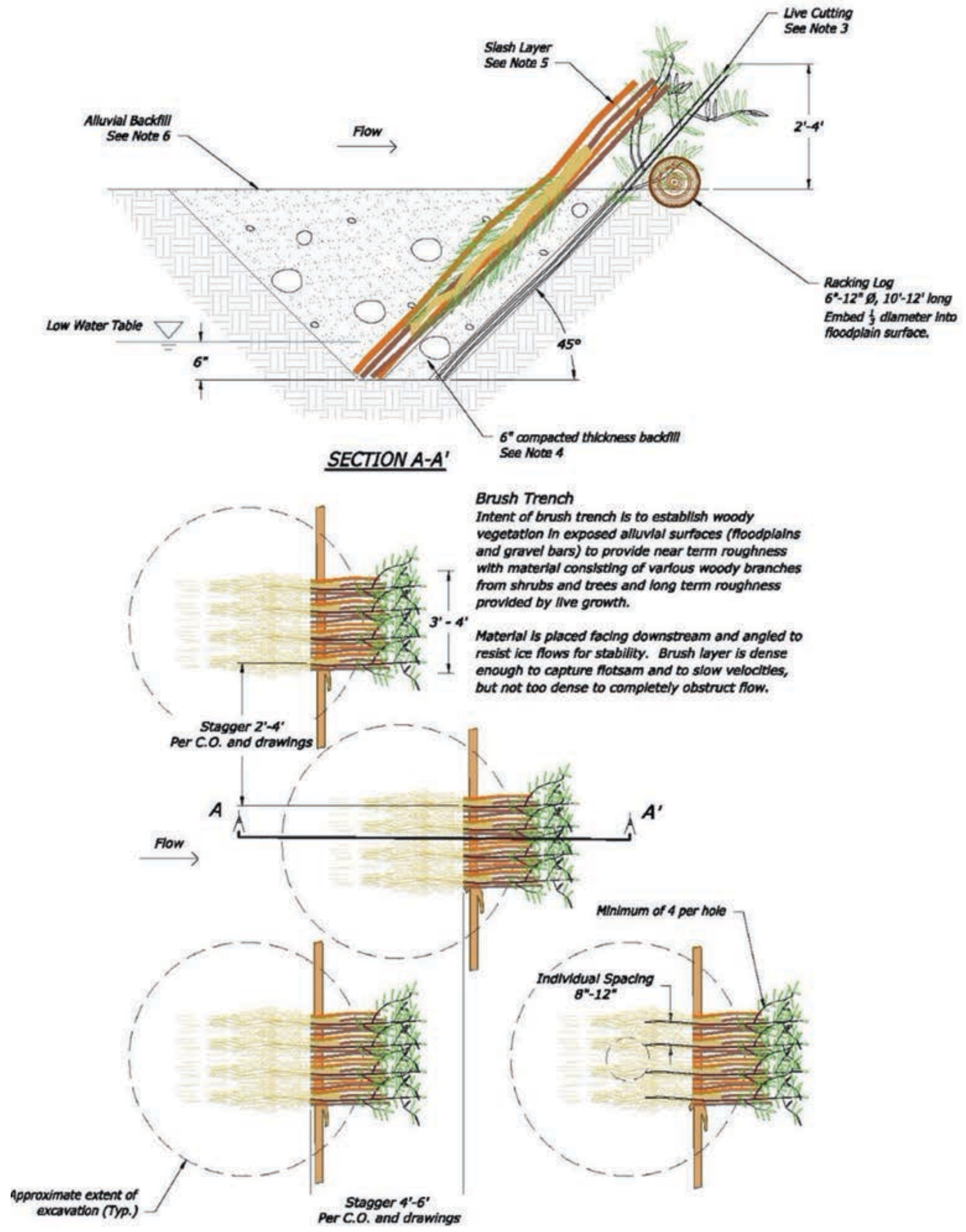
Riparian Restoration/Biotechnical Techniques

Floodplain Roughening

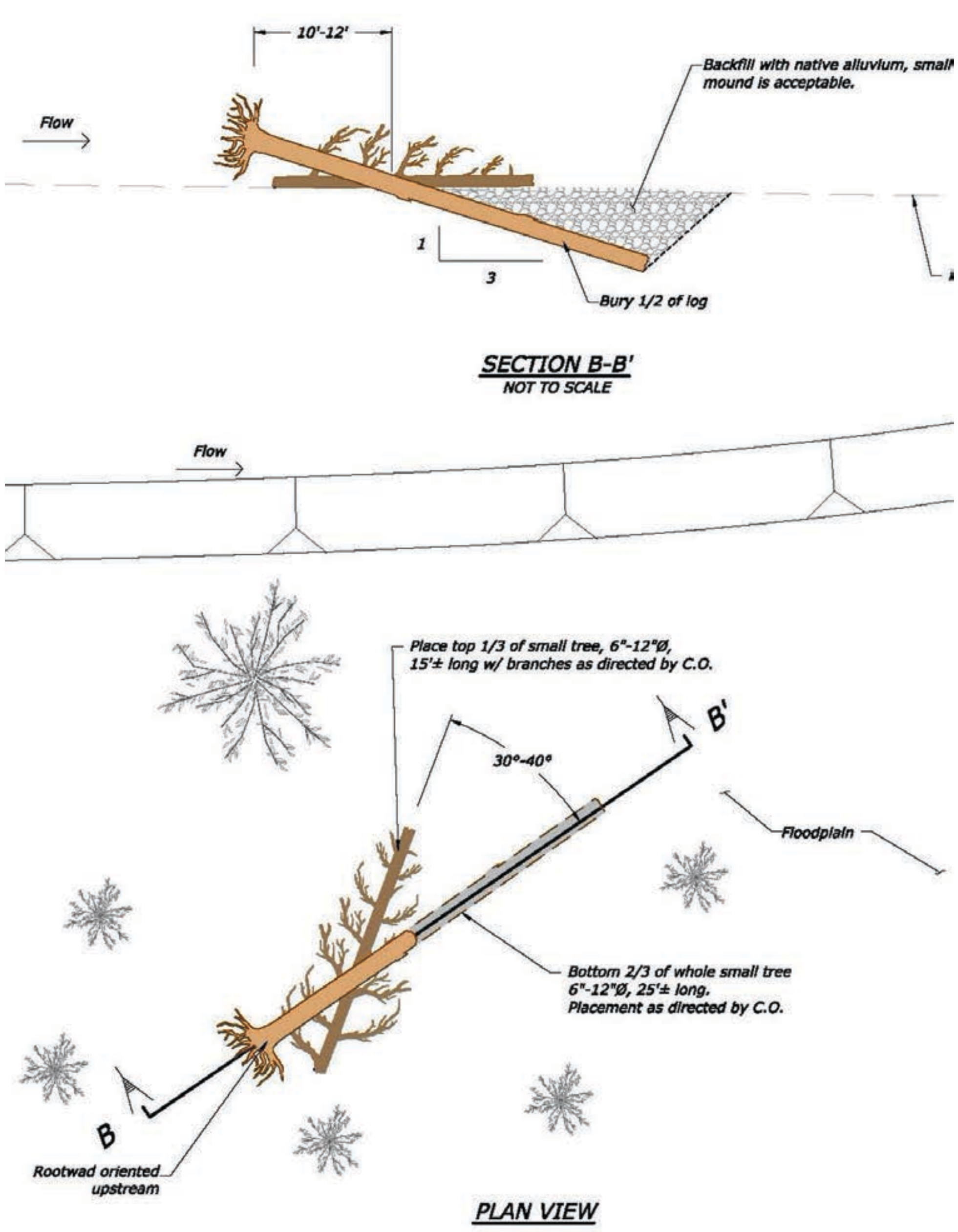
- Increase hydraulic roughness on floodplains
- Stabilize bars
- Increase floodplain soil stability/reduce erosion
- Promote natural vegetation/seed recruitment through sediment deposition (long term approach to revegetation)



Flood Fence; Courtesy of Cardno.



Brush Trench; Courtesy of Cardno.



Floodplain Wood; Courtesy of Cardno.

Structural treatment techniques, or any treatments that aim to influence channel hydraulics, should not be attempted without proper evaluation of the potential risks they may pose to public safety, adjacent property, and surrounding infrastructure and habitat. If proper care is not taken to fully understand potential impacts, unintended consequences to safety, property and ecology can be severe.

The techniques and publicly available resources provided in the following pages offer examples of bank and bar stabilization techniques utilized in bank stabilization and habitat restoration projects; they are not intended to serve as “design standards”. The application of in-channel structural techniques requires proper evaluation and analysis by experienced practitioners to ensure a technique’s appropriateness, proper design and probable success of meeting a project’s stated goals and objectives.

The design and placement of large wood structures and riparian reforestation has been recognized as a beneficial element of stream and river restoration strategies (Roni et al. 2014a). *(Reclamation and USACE, 2016. P. 7-1)*

Inappropriate placements and poorly designed structures can introduce unacceptable risks. *(Reclamation and USACE, 2016. P. 7-1)*

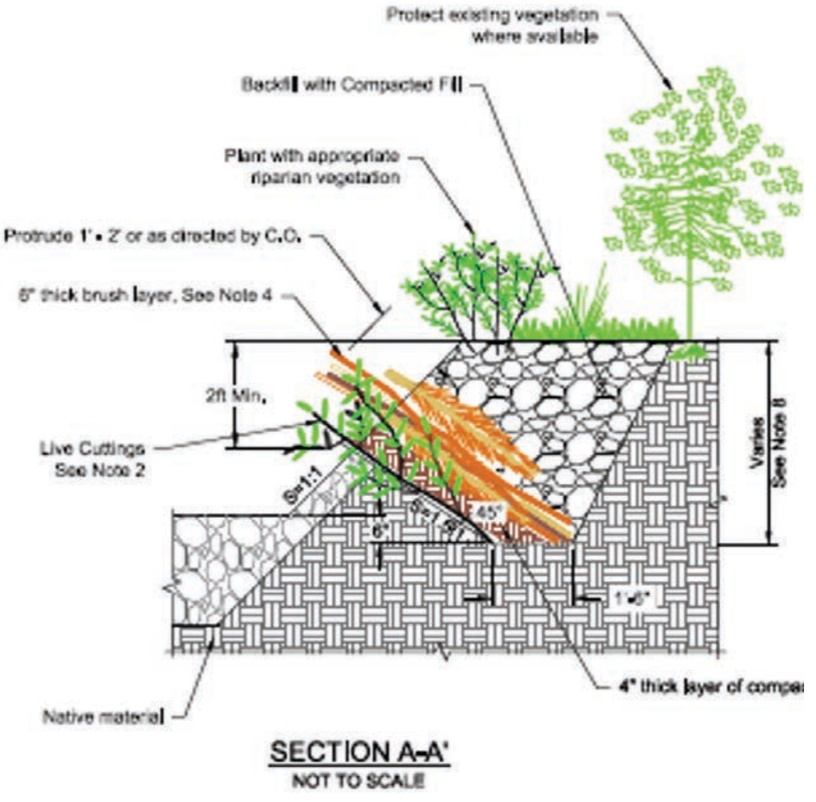
Resources: Publicly Available Resources for design considerations and analysis of Large Woody Material structural techniques.

Author	Title	Date
US Department of the Interior Bureau of Reclamation and US Army Corps of Engineers	National Large Wood Manual. Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure	2016
Knutson, M. and Fealko, J. US Department of the Interior Bureau of Reclamation, Pacific Northwest Region Resource & Technical Services	Large Woody Material - Risk Based Design Guidelines	2014
US Department of Agriculture, Natural Resources Conservation Service	National Engineering Handbook, Part 654, Stream Restoration Design	2006
Washington State Aquatic Habitat Guidelines Program.	Integrated Streambank Protection Guidelines.	2003

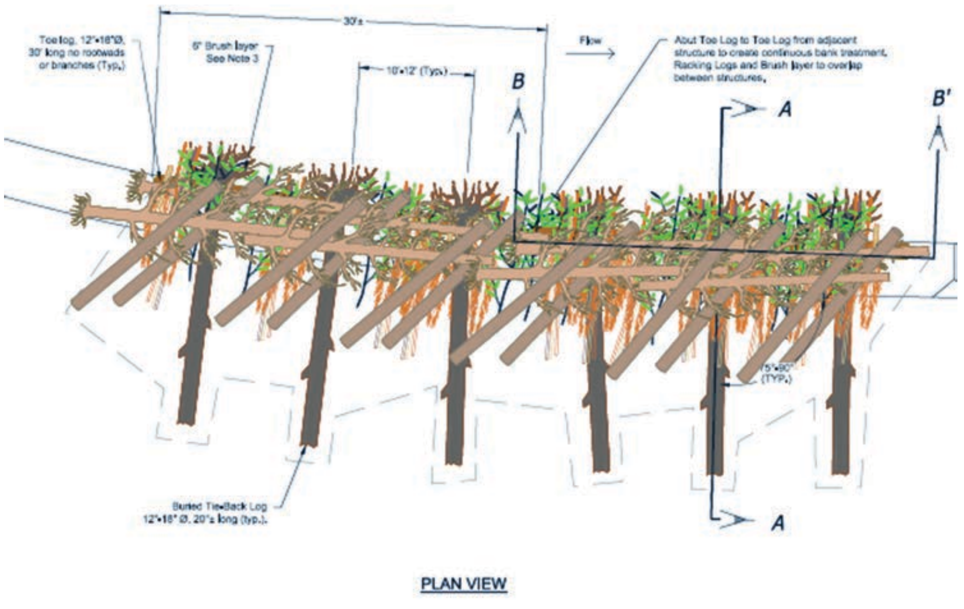
Roughness Trees/Small Woody Debris

- Roughness provided by woody material provides short term bank stability through slowing of flow velocities
- Incorporation of live vegetation re-establishes long term bank strength through root structure

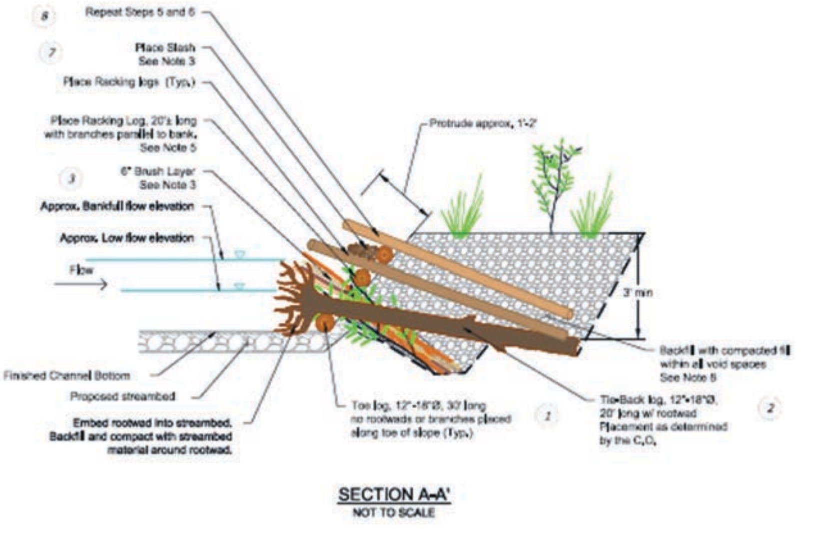
Installed Brush Bank Treatment; *Courtesy of Cardno.*



Brush Bank Treatment; *Courtesy of Cardno.*



Roughened Edge; *Courtesy of Cardno.*



Roughened Edge; *Courtesy of Cardno.*

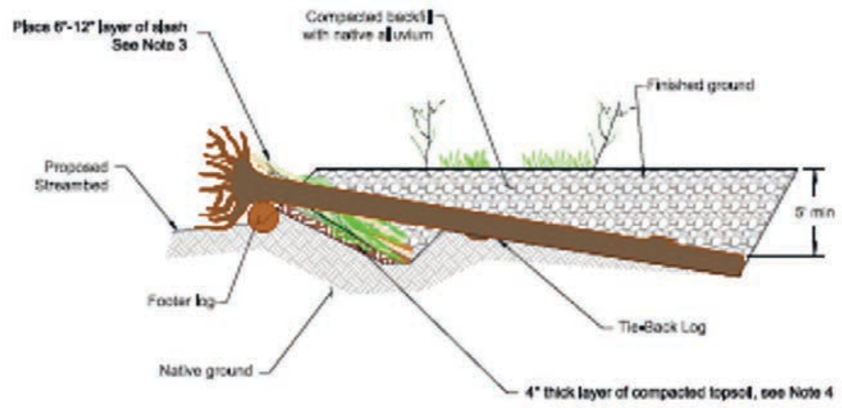
In-Channel Structural Techniques

Bank/Outside Bend

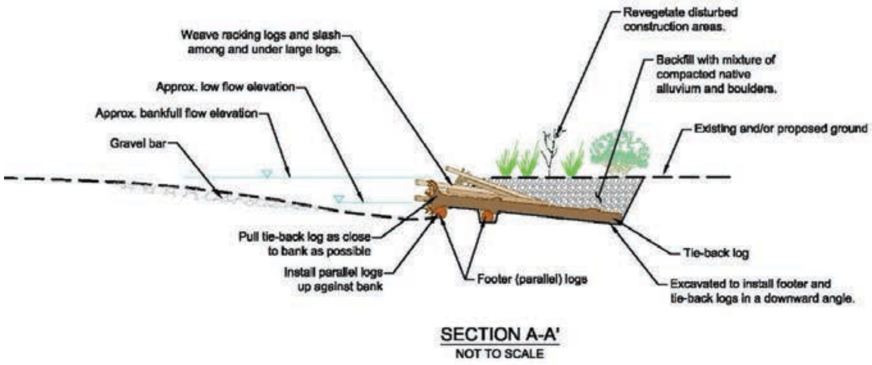
- Provide scour/erosion protection
- Increase hydraulic roughness and reduce velocities and shear stresses along channel margins
- Incorporation of live vegetation re-establishes long term bank strength through root structure

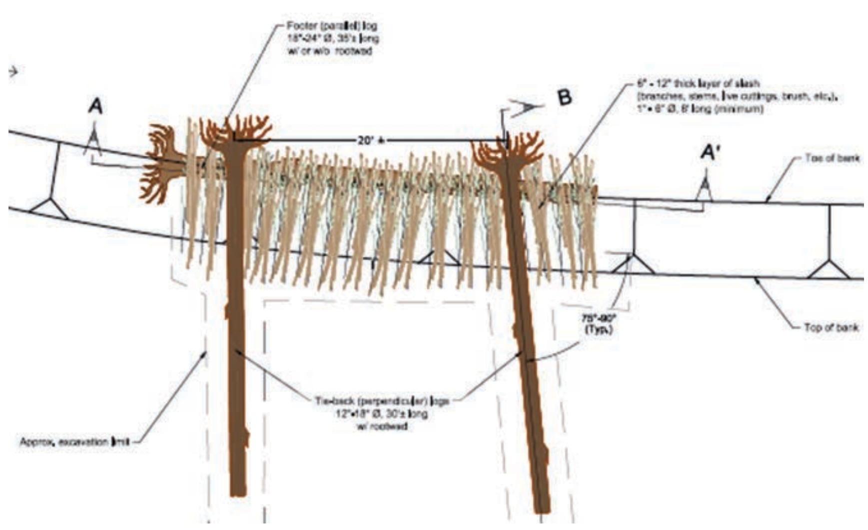
Channel Margin Jams; *Courtesy of Cardno.*

Meander Bend Jams; *Courtesy of Cardno.*

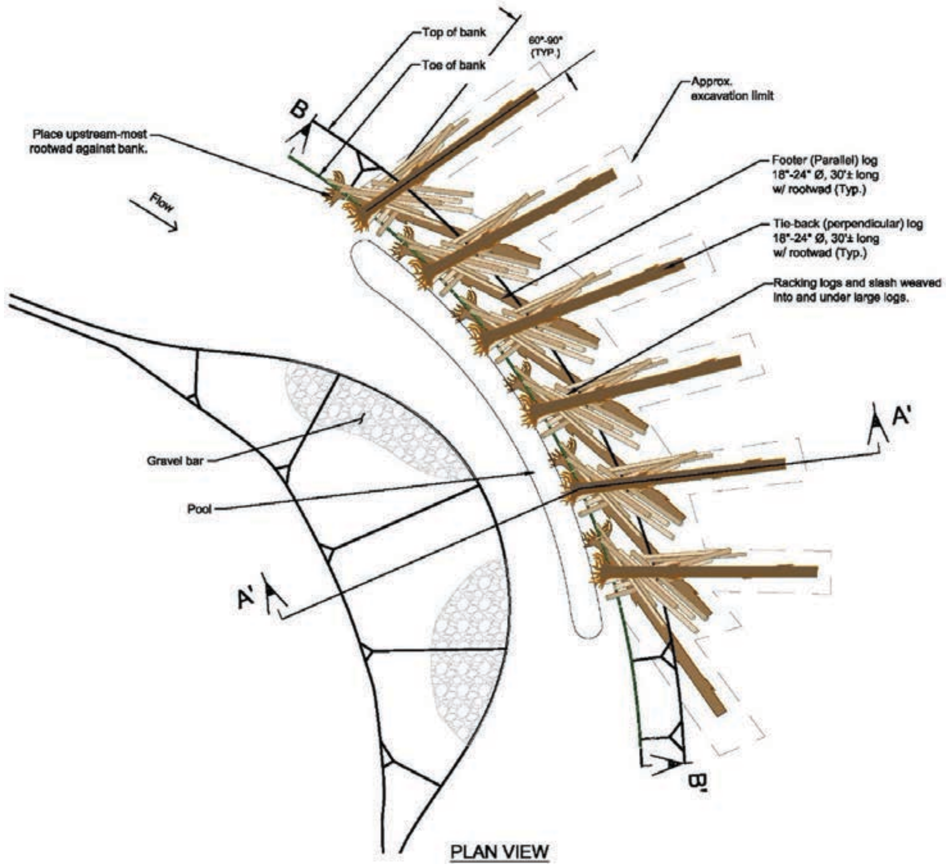


Channel Margin Jams; *Courtesy of Cardno.*





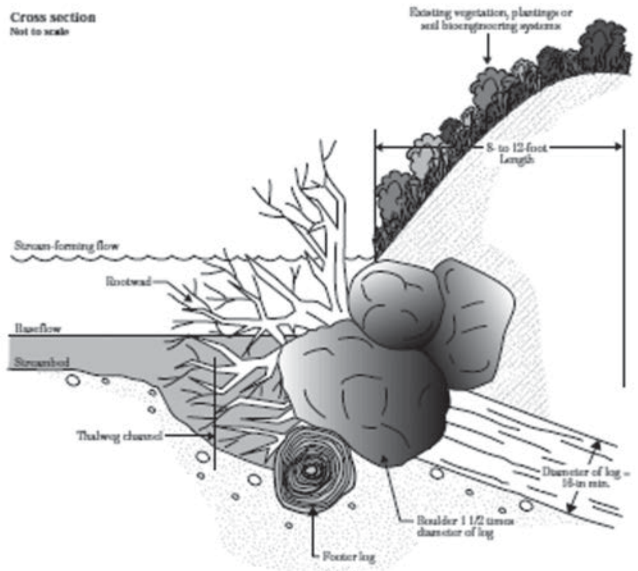
Channel Margin Jams; *Courtesy of Cardno.*



Meander Bend Jams; *Courtesy of Cardno.*

Roughened Rock Toe

- Combination of Large woody debris and rock bank protection (riprap)
- Technique used throughout Wood River Valley



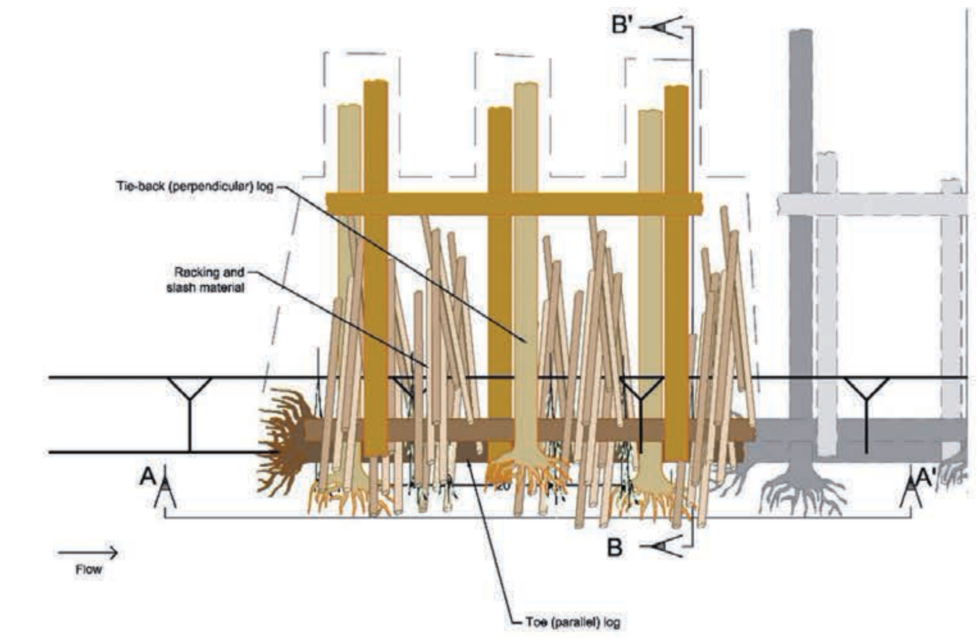
Log rootwad and boulder revetment; *Courtesy of Cardno.*

Log rootwad and boulder revetment in Big Wood River; *Courtesy of Cardno.*

In-Channel Structural Techniques

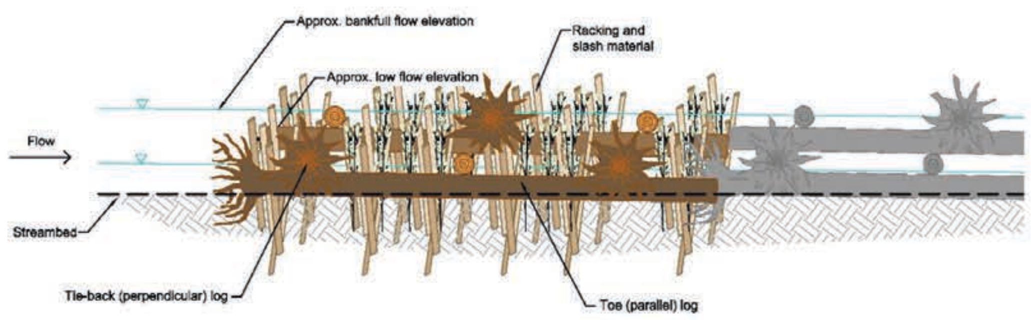
LWD Revetment/Crib Walls/Log Toes

- Provides bank stability by increasing hydraulic roughness along outside of bends and reducing channel velocities and shears
- Directs concentrated flows away from the bank
- Good application in areas with limited desire for bank deformability

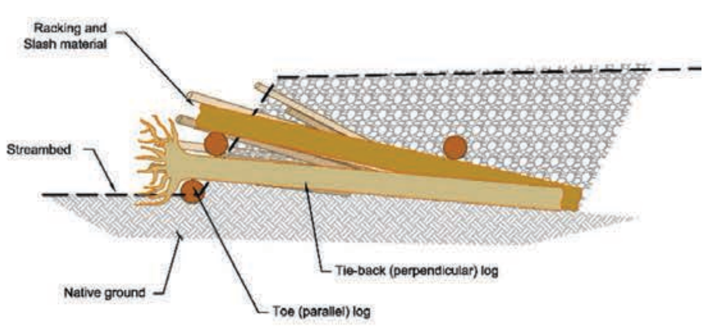


PLAN VIEW

EXAMPLE: INSTALLED LOG TOE
Note: Log Toe installed along outside of bend in newly constructed bank (devoid of vegetation) providing bank stabilization. Looking downstream.
(Photo courtesy of S. Rodriguez)



SECTION A-A'
NOT TO SCALE



SECTION B-B'
NOT TO SCALE

ELJ in Clackamas County. Bank adjacent to bridge piles was experiencing erosion. ELJ installed upstream of bridge to prevent further erosion and re-direct flows away from piles (notice concentrated flows away from piles).; *Courtesy of Cardno.*

Log Revetment protecting eroding bank and downstream bridge pier ; *Courtesy of Cardno.*

Flow Redirection

Flow-Redirection Techniques involve placing materials, such as wood or rock, in the channel to influence flow patterns and hydraulics in order to reduce erosive forces acting on a bank or bed. These techniques directly and/or indirectly affect channel cross-sectional shape, erosion and deposition patterns, channel roughness, and hydraulic slope and capacity (WSAHGP, 2003).

Groins /ELJs in series

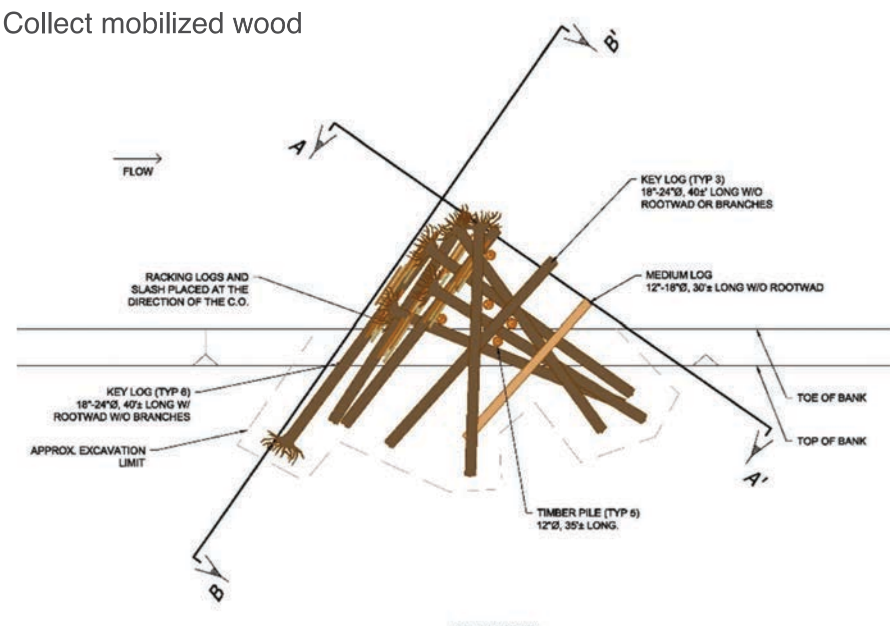
- Recommend wood rather than rock
- As high as channel forming flows but not higher than bank height to avoid flanking.
- ~15% bankfull width
- Spaced 2-5 times the length of the groin apart
- Keyed into the bank

Groins /ELJs in series

Bury at limits of allowable migration corridor to allow more room for the river's natural processes, minimizing attempts to confine the river and risks of project failure associated with such attempts while still providing protection to critical infrastructure (See Figure 6-4 of ISPG).

Barbs - Deflectors/ELJs

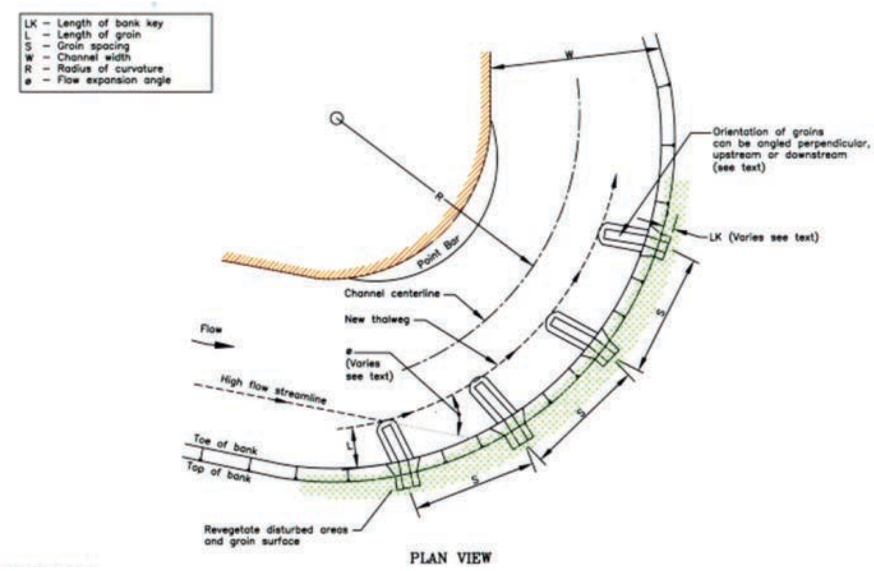
- Along streambanks to redirect flow, reduce near bank velocities and shear stresses
- Recommend use of LWD rather than rock
- Often in conjunction with other bank treatments
- Directs flow away from bank
- Often does not fix the root problem
- Collect mobilized wood



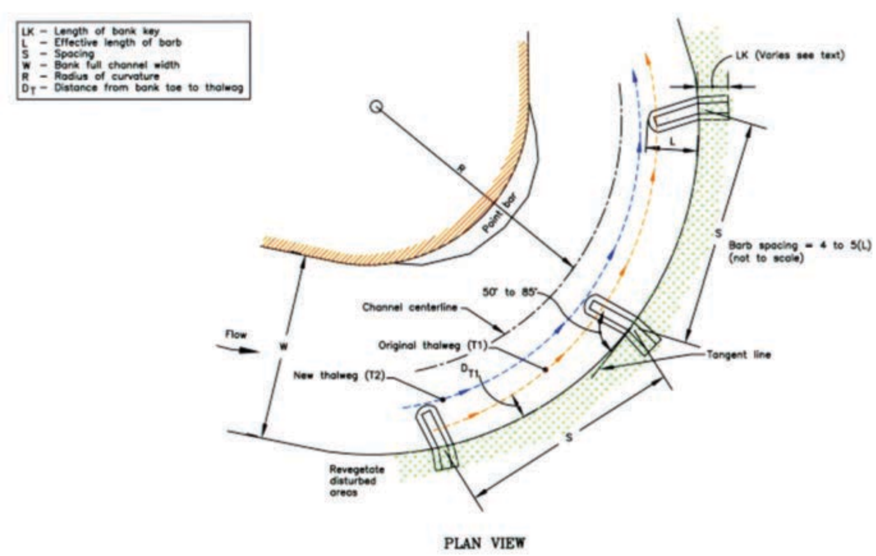
Mid-Channel Structures

- Protect/stabilize downstream riparian islands and gravel bars
- Recruit LWD debris upstream of vulnerable reach/infrastructure (i.e. bridges)
- Redirect flows into off-channel areas

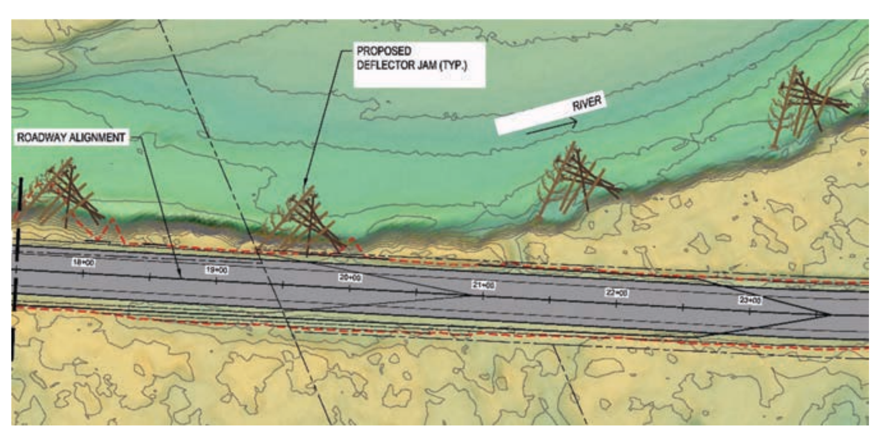
Detail of mid-channel bar-apex jam. Photo of installed mid-channel bar apex after high flows with recruited mobilized debris in Yankee Fork River, Custer County, Idaho; Courtesy of Cardno.



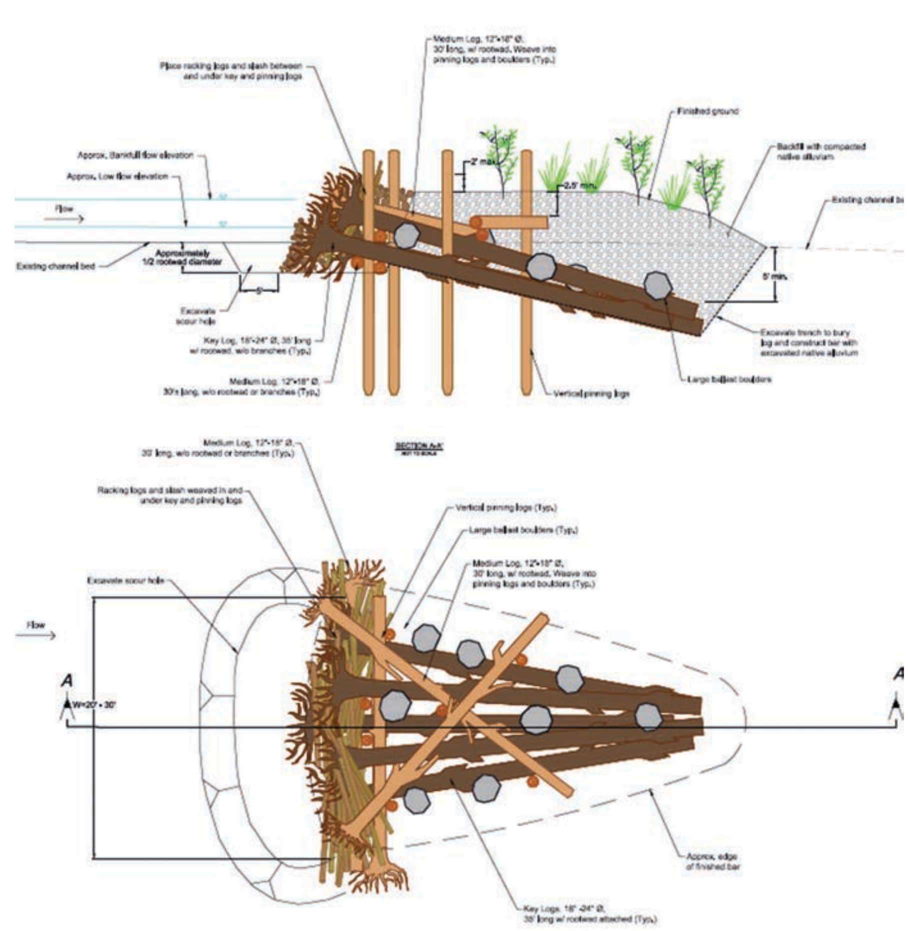
Conceptual layout of groin field taken from ISPG (2003). In place of riprap groins, a more ecologically friendly option is to utilize ELJs (large wood groins) in place of riprap; Courtesy of Cardno.



Conceptual layout of barbs taken from ISPG (2003). In place of riprap barbs, a more ecologically friendly option is to utilize large wood pieces, partially buried in banks. Wood barbs often utilized together with softer bank treatments between barbs; Courtesy of Cardno.



Layout of ELJs along road bank functioning as barbs; Courtesy of Cardno.

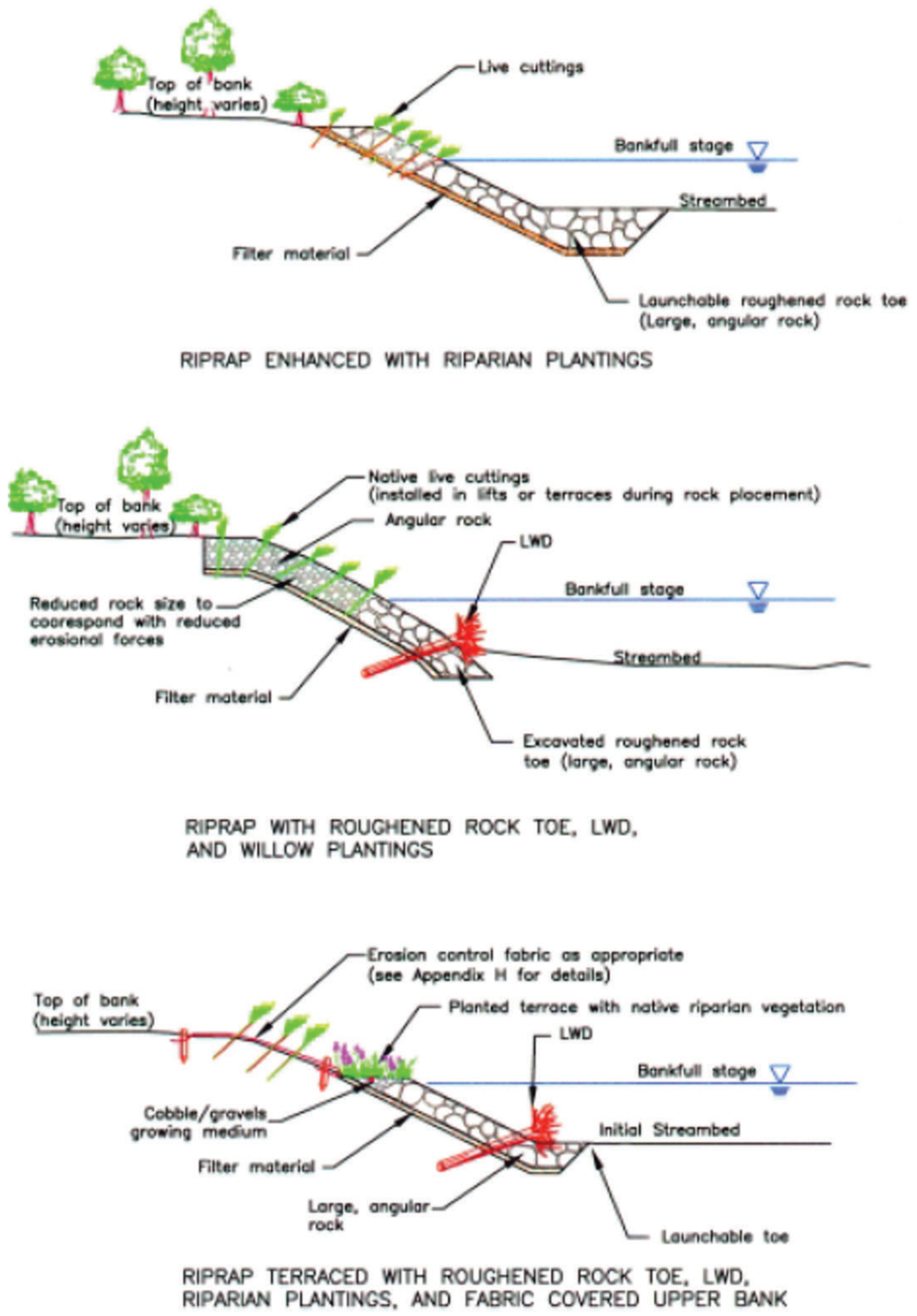


Riprap

Riprap has been shown to severely limit the habitat potential for wild trout in the Big Wood River (Thurow 1987 and 1990); however, conditions may necessitate the use of riprap; such as in the case of emergency bank repairs or when insufficient land between the top of bank and adjacent infrastructure exists to allow preferable bank treatments.

If properly designed, installed and maintained, riprap can adjust to most scour conditions and withstand very high shear forces. It can be useful in circumstances of toe erosion and mass failure. When utilizing riprap, like any other treatments, the designer must assess the site and reach, reasons for failure, and likely response to treatment. There are options to utilize riprap in conjunction with softer, more habitat-friendly, approaches, such as vegetated riprap, rock and LWD treatments, and rock-toes with LWD/vegetation above (Figure).

Riprap is effective in emergency situations when deep, fast water precludes installation of preferable treatments. Modifications can be made to riprap placement when flows recede to low levels, and riprap can be removed from the bank down to approximately channel forming flow elevations and more ecologically friendly composite bank treatments can be applied.



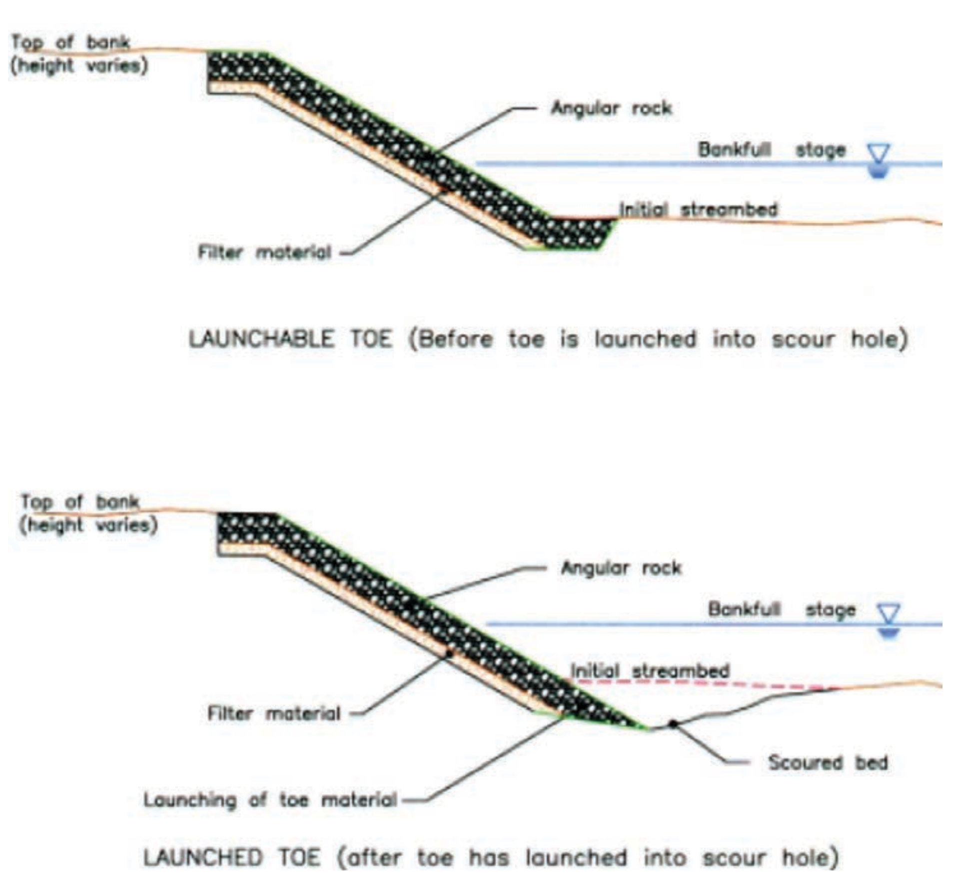
Riprap configurations in conjunction with bioengineering methods *(WSAHGP, 2003).*

RipRap Design Considerations

- Proper rock sizing and thickness capable of withstanding peak shear forces. Many resources and methods are available for sizing riprap (Table).
- Riprap should account for future scour, so the design should include a launchable toe or installation down to probable scour depths (Figure).
- Table 0 6. List of some of the readily available resources for riprap design considerations.
- Riprap is a non-deformable bank stabilization measure and should not be utilized within the allowable channel migration corridor.
- The channel's hydraulic and geomorphic response should be analyzed when considering the use of riprap as it can have negative and unintended site- and reach-scale impacts.

Resources: Publicly Available Resources for riprap design considerations.

Author	Title	Date
USACE	Hydraulic Design of Flood Control Channels Engineer Manual 1110-2-1601	1994
Vanoni, V.A.	Large Woody Material - Risk Based Design Guidelines	2014
(American Society of Civil Engineers)	Sedimentation Engineering	2006
American Society of Civil Engineers (ASCE)	Integrated Streambank Protection Guidelines.	2003
Manuals and Reports on Engineering Practice – No. 54	1977	2003
US Geological Survey	Rock Riprap Protection for Protection of Stream Channels Near Highway Structures	2003
US Department of Agriculture, Natural Resources Conservation Service	National Engineering Handbook, Part 654, Stream Restoration Design, Technical Supplement 14-C: Stone Sizing Criteria.	2006



Conventional configurations of riprap revetment *(WSAHGP, 2003).*

Primary resources for treatment techniques:

Washington State Aquatic Habitat Guidelines Program. 2003. Integrated Streambank Protection Guidelines.

USDA Natural Resources Conservation Service (NRCS). December 1996. Engineering Field Handbook, Chapter 16 Streambank and Shoreline Protection.

US Bureau of Reclamation (Reclamation) Pacific Northwest Region Resource & Technical Services. September 2014. Large Woody Material – Risk Based Design Guidelines.

Reclamation and US Army Corps of Engineers (USACE). January 2016. National Large Wood Manual.

United States Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds. 2010. Guidance for Federal Land Management in the Chesapeake Bay Watershed.

Welsch, D.J. 1991. Riparian forest buffers: function and design for protection and enhancement of water resources. USDA Forest Service, NA-PR-07-91.

6 References

Biota Research and Consulting. 2016. Final Geomorphic Assessment Report, Big Wood River, Blaine County, Idaho. Prepared for Trout Unlimited.

California Department of Public Works. 1970. Bank and Shore Protection in California Highway Practice.

Cook and Becker. 2016. Preliminary Estimates of the Economic Effects of Stream Restoration on the Big Wood River Valley, Idaho. University of Idaho College of Natural Resources, Issue Brief No. 18.

Daniels, R. B., and J. W. Gilliam. 1996. “Sediment and Chemical Load Reduction by Grass and Riparian Filters.” Soil Science Society of America Journal 60 (1): 246–51. https://doi.org/10.2136/sssaj1996.03615995006000010037x.

DEQ. 2017. “The Big Wood River Watershed Management Plan TMDL Five-Year Review.” Twin Falls Regional Office 650 Addison Avenue West, Suite 110 Twin Falls, Idaho 83301: State of Idahoe Department of Environmental Quality.

Dosskey, Michael G., Philippe Vidon, Noel P. Gurwick, Craig J. Allan, Tim P. Duval, and Richard Lowrance. 2010. “The Role of Riparian Vegetation in Protecting and Improving Chemical Water Quality in Streams1.” Journal of the American Water Resources Association 46 (2): 261–77. https://doi.org/10.1111/j.1752-1688.2010.00419.x.

Gran, Karen, and Chris Paola. 2001. “Riparian Vegetation Controls on Braided Stream Dynamics.” Water Resources Research 37 (12): 3275–83. https://doi.org/10.1029/2000WR000203.

Gregory, Stanley V., Frederick J. Swanson, W. Arthur McKee, and Kenneth W. Cummins. 1991. “An Ecosystem Perspective of Riparian Zones.” BioScience 41 (8): 540–51. https://doi.org/10.2307/1311607.

Federal Highway Administration. 1989. Design of Riprap Revetments. Hydraulic Engineering Circular No. 11.

FEMA (Federal Emergency Management Agency). 2010. Flood Insurance Study: Blaine County, Idaho and Incorporated Areas.

———. 1998. Flood Insurance Study: City of Bellevue, Idaho, Blaine County.

Idaho Department of Environmental Quality. 2001. The Big Wood River Watershed Management Plan [TMDL Assessment]. Approved by USEPA, May 2002.

Johnson, C.W., and S. Buffler. 2008. Riparian Buffer Design Guidelines for Water Quality and Habitat Functions on Agricultural Landscapes in the Intermountain West. General Technical Report RMRS-GTR-203. US Department of Agriculture, Forest Service. Rocky Mountain Research Station, Fort Collins, Colorado.

King, J.G., W.W. Emmett, P.J. Whiting, R.P. Kenworthy, and JJ. Barry. 2004. Sediment Transport Data and Related Information for Selected Coarse Bed Streams and Rivers in Idaho. General Technical Report RMRS-GTR-131. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.

Knighton, David. Fluvial Forms and Processes. Halstead Press.

Knutson, M. and J. Fealko. 2014. Large Woody Material-Risk Based Design Guidelines. U.S Department of the Interior, Bureau of Reclamation Pacific Northwest Region. Boise, Idaho.

Oppenheimer, J. 2018. Fire in Idaho: Lessons for Human Safety and Forest Health. A Review of Idaho’s 2007 Fire Season. Idaho Conservation League.

Osborne, Ll, and Da Kovacic. 1993. “Riparian Vegetated Buffer Strips in Water-Quality Restoration and Stream Management.” Freshwater Biology 29 (2): 243–58. https://doi.org/10.1111/j.1365-2427.1993.tb00761.x.

Poole, Geoffrey C., and Cara H. Berman. 2001. “An Ecological Perspective on In-Stream Temperature: Natural Heat Dynamics and Mechanisms of Human-CausedThermal Degradation.” Environmental Management; New York 27 (6): 787–802. http://dx.doi.org.ezproxy.proxy.library.oregonstate.edu/10.1007/s002670010188.

Rafferty, M. 2016. Computational Design Tool for Evaluating the Stability of Large Wood Structures. Technical Note TN-103.2. US Department of Agriculture, Forest Service, National Stream & Aquatic Ecology Center. Fort Collins, Colorado.

Rapp, C. 2006. Geomorphic Assessment of the Big Wood River, Glendale Diversion to Warm Springs Creek. Prepared for Wood River Land Trust.

Simon, A., and A. J. C. Collison. 2002. “Quantifying the Mechanical and Hydrologic Effects of Riparian Vegetation on Streambank Stability.” Earth Surface Processes and Landforms 27 (5): 527–46. https://doi.org/10.1002/esp.325.

Schumm, S.A. 1981. Evolution and response of the fluvial system, sedimentologic implications. Soc. Econ. Paleontol. Mineral. Spec. Publ. 31: 19-29.

Schumm, S.A. 1985. Patterns of alluvial rivers. Annual Review of Earth Planetary Sciences. 13: 5-27.

Tabacchi, Eric, David L. Correll, Richard Hauer, Gilles Pinay, Anne-Marie Planty-Tabacchi, and Robert C. Wissmar. 1998. “Development, Maintenance and Role of Riparian Vegetation in the River Landscape.” Freshwater Biology 40 (3): 497–516. https://doi.org/10.1046/j.1365-2427.1998.00381.x.

Tal, Michal, and Chris Paola. 2007. “Dynamic Single-Thread Channels Maintained by the Interaction of Flow and Vegetation.” Geology 35 (4): 347–50. https://doi.org/10.1130/G23260A.1.

Thurow, R. 1987. Wood River Fisheries Investigations, Fish Distribution, Abundance, and Movements. Idaho Department of Fish and Game.

———. 1990. Effects of Stream Alterations on Rainbow Trout in the Big Wood River, Idaho. Idaho Department of Fish and Game.

USACE (US Army Corps of Engineers). 2019. Flood Insurance Study Hydrology Report for the Big Wood River, Warm Springs Creek, Deer Creek, East Fork Big Wood River, Trail Creek, Clear Creek, Eagle Creek, Lake Creek, Quigley Creek, Seamans Creek. Blaine County, Idaho. Prepared for FEMA. Project #S140493Y.

———. 1994. Hydraulic Design of Flood Control Channels. Engineer Manual 1110-2-1601.

US Bureau of Reclamation and USACE. 2015. National Large Wood Manual: Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Systems: Restoring Process, Function, and Structure.

USDA NRCS (US Department of Agriculture, Natural Resources Conservation Service). 2007. How to Plant Willows and Cottonwoods for Riparian Restoration. TN Plant Materials No. 23, USDA NRCS Plant Materials Center, Boise, Idaho.

———. 2006a. Stream Restoration Design. National Engineering Handbook, Part 654. Natural Resource Conservation Service.

———. 2006b. Stream Restoration Design, Technical Supplement 14-C: Stone Sizing Criteria. National Engineering Handbook, Part 654. Natural Resource Conservation Service.

———. 2002. Streambank Soil Bioengineering Field Guide for Low Precipitation Areas. Plant Materials Center and National Design, Construction, and Soil Mechanics Center.

———. 2001. Stream Corridor Restoration: Principles, Processes, and Practices.

———.1998. The Practical Streambank Bioengineering Guide. Plant Materials Center.

———.1996. Streambank and Shoreline Protection. Engineering Field Handbook, Chapter 16. December.

USEPA (US Environmental Protection Agency). 2010. Guidance for Federal Land Management in the Chesapeake Bay Watershed. Office of Wetlands, Oceans and Watersheds, EPA.

USFS (US Forest Service). 2013. Burned Area Report-Beaver Creek Fire, Sawtooth National Forest, Ketchum and Fairfield Ranger Districts. Blaine and Camas Counties, Idaho.

USGS (US Geological Survey). 2014. Aquatic Biological Communities and Associated Habitats at Selected Sites in the Big Wood River Watershed, South-Central Idaho.

———. 2020. National Water Information System: Web Interface. USGS 13139510 Big Wood River at Hailey, ID Total Flow. Available at: https://nwis.waterdata.usgs.gov/nwis/uv/?site_no=13139510&agency_cd=USGS.

———. 1986. Rock Riprap Protection for Protection of Stream Channels Near Highway Structures. Water Resource Investigations Report 86-4128.

Vanoni, V.A. 2013. Sedimentation Engineering. American Society of Civil Engineers, Manuals and Reports on Engineering Practice.

Washington State Aquatic Habitat Guidelines Program. 2003. Integrated Streambank Protection Guidelines.

Welsch, D.J. 1991. Riparian Forest Buffers: Function and Design for Protection and Enhancement of Water Resources. USDA Forest Service, NA-PR-07-91.

Wood, M.S., R.L. Fosness, K.D. Skinner, and A.G. Veilleux. 2016. Estimating Peak Flow Frequency Statistics for Selected Gaged and Ungagged Sites in Naturally Flowing Streams and Rivers in Idaho. US Geological Survey Scientific Investigations Report 2016-5083.

Wood River Land Trust. 2005. The Big Wood River Fishery Assessment: Healthy Waters, Healthy Future.

River Atlas

Big Wood River

Blaine County, Idaho