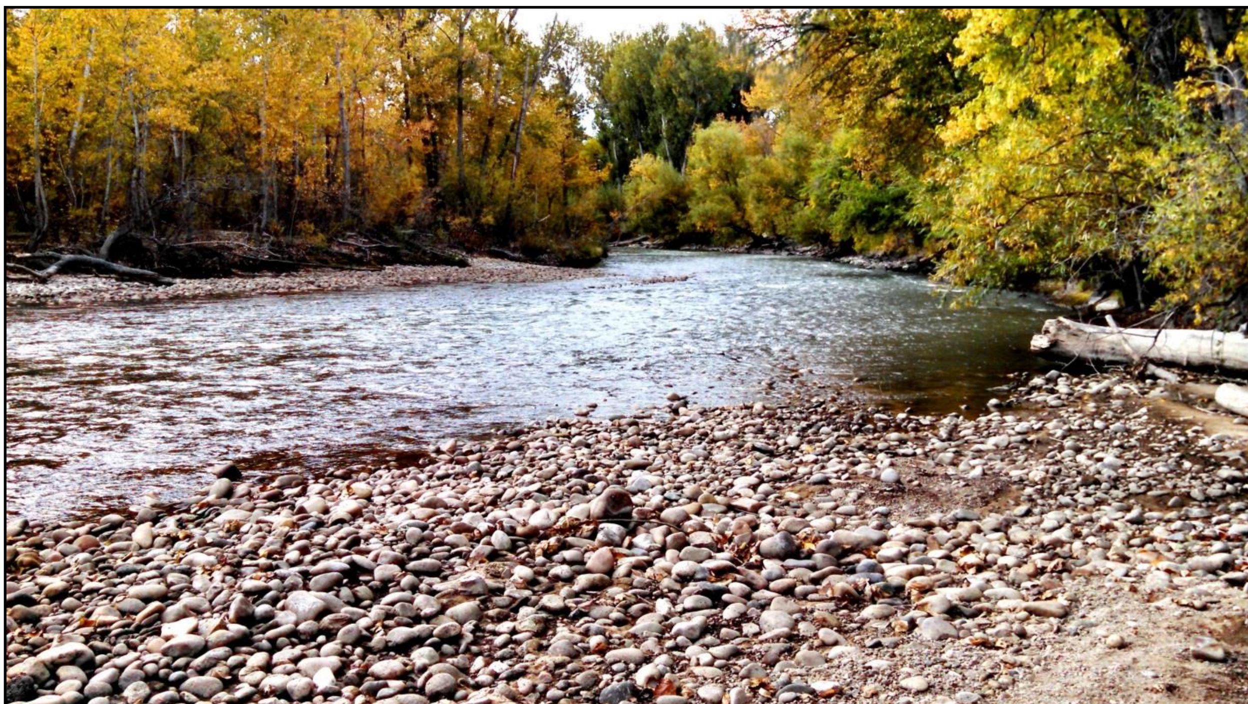
Geomorphic Assessment of the Lower Boise River, Idaho

Prepared by: Rob Richardson, P.G. and James Guilinger

February, 2015



BOISE RIVER ENHANCEMENT NETWORK

- We are a network of people that live, work and play in the Boise River watershed dedicated to promoting the ecological enhancement of the river

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Prepared for:

Boise River Enhancement Network

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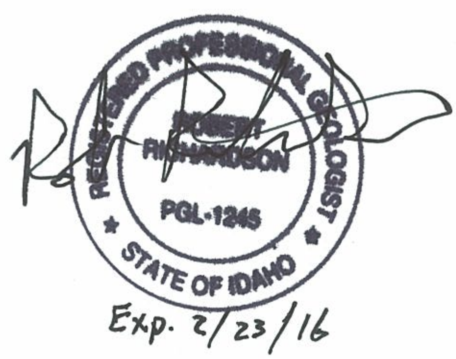

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1. Rob Richardson is a geomorphologist with over 15 years of experience performing geomorphic assessments and developing river restoration actions throughout the northwestern United States. Mr. Richardson volunteered personal time apart from his current position as a geomorphologist with the U.S. Bureau of Reclamation in order to develop this assessment.

2. James Guilinger is a recent graduate from the geosciences program at Boise State University. Mr. Guilinger has volunteered his personal time as a Student Conservation Association (SCA) student intern working through the U.S Bureau of Reclamation.

The findings and recommendations provided within this assessment are solely those of Mr. Richardson and Mr. Guilinger, and do not necessarily reflect the views and opinions of the U.S. Bureau of Reclamation.

Acknowledgements

Special thanks to the U.S. Bureau of Reclamation for providing computers, software and a work space enabling us to work on and complete this project. Thanks to Ellen Berggren and staff at the Army Corps of Engineers for providing the HEC-RAS model we used during our analysis. Thanks to all of the partners who helped fund, acquire, and process the LiDAR used for much of our analyses including: US Bureau of Reclamation, Idaho Dept. of Water Resources, US Geological Survey, Army Corps of Engineers, Trout Unlimited (Ted Trueblood Chapter), Harris Ranch, Idaho Conservation League, Flood Control Districts 10 and 11, City of Boise, City of Eagle. Thanks to SCA for providing a modest weekly stipend for Mr. Guilinger's efforts. Thanks to the Boise River Enhancement Network (BREN) for providing feedback and incorporating this assessment into the larger body of work underway by BREN. Thanks to Derek Risso and the rest of the staff at Ecosystems Sciences for your support, feedback, and guidance. Thanks to Liz Paul at Idaho Rivers United for your continual support and stellar communication throughout the development of BREN and this assessment. And thanks to my wife Betsie who allowed me several days' time to complete this assessment during the holiday season with a newborn baby in the house.

Contents

Introduction

This report addresses the geomorphology of the lower Boise River from the Boise Diversion Dam upstream of Boise, ID to its confluence with the Snake River near Parma, ID (Figure 1). Geomorphology is a subset of the geosciences concerned with the creation, evolution, and configuration of surface landscapes through physical and chemical processes. Geomorphology as applied to rivers addresses forms (the river's shape) and physical processes (actions that create and maintain these forms). A geomorphic assessment evaluates how river forms and processes change over time and provides insight into the potential future conditions of a river.

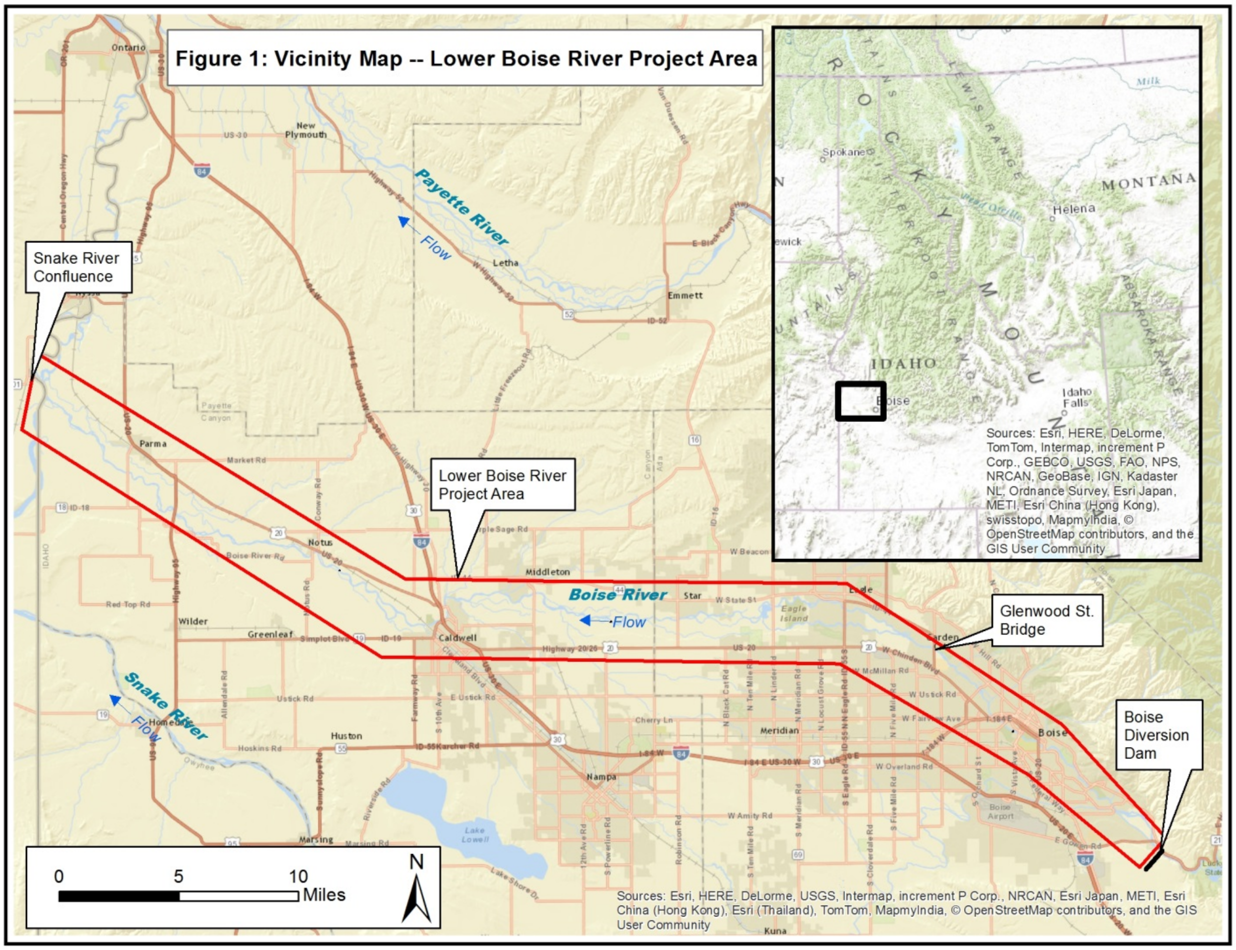

Figure 1: Vicinity Map

The purpose of this report is to provide a high-level assessment of the geomorphic character of the lower Boise River by evaluating and comparing historic, existing, and target future conditions that define the river. An evaluation of the Historic Conditions offers a picture of the natural geomorphic setting of the river prior to broad-scale Euro-American settlement. Existing Conditions detail the modern forms and processes of the river and how they have changed over time. Finally, Target Conditions identify favorable geomorphic forms and processes allowing for the greatest future physical enhancement of the river given known modern constraints.

This report is intended for the use of interdisciplinary scientists, engineers, and planners focusing on enhancement of the lower Boise River. Conclusions from this assessment are intended to guide future enhancement efforts as one tool among many others in a collaborative effort to enhance river form and function. The assessment provides pertinent background information regarding reach-scale geomorphic conditions, physically appropriate target conditions and proposed actions to achieve those conditions. As a follow-up to this report, appropriate enhancement actions should also be assessed and prioritized based on perceived risk vs. benefit and stakeholder feedback. This reach-scale assessment should not be used exclusively as the basis for site-specific enhancement efforts. Detailed, site-specific analyses should be conducted to identify the most appropriate suite of actions, refine conceptual plans, and develop detailed plans for implementation.

Background

The Boise River drainage area covers approximately 4100 square miles in southwestern Idaho, extending east from the confluence of the Boise River with the Snake River near Parma, ID upstream to its western drainage divide in the Sawtooth Mountains. There are three large dams which impound the river for irrigation storage, flood control and hydropower. Altogether these dams have a reservoir capacity of approximately 1.05 million acre-feet (US Bureau of Reclamation, 2015). The two most upstream dams, Anderson Ranch and Arrowrock, are owned and operated by the U.S. Bureau of Reclamation. The most downstream of these three dams, Lucky Peak, is owned and operated by the U.S. Army Corps of Engineers and was built with the primary purpose of flood control of the lower Boise River. A fourth, much smaller dam, Boise River Diversion Dam, was built by the U.S. Bureau of Reclamation in 1912 approximately 2.25 miles below the current site of Lucky peak Dam. The river and floodplain downstream of the Boise River Diversion Dam is the primary focus of this geomorphic assessment.

Methods

Over a period of approximately three months, data for this report was collected through the use of available data and on-site observations. Data acquisition included existing reports, LiDAR (Light Detection and Ranging) topography and bathymetry, existing hydraulic models, GIS relative surface models, and on-site observations.

A list of reports referenced in this document can be found in the reference section.

LiDAR uses an airborne laser to create an accurate and detailed topographic surface of the project area. Green-light lasers were used in the Boise River mission due to high transmissivity of green wavelengths through water, allowing for the addition of bathymetric measurements of the river channel. The LiDAR data for the lower Boise River was collected in spring 2007. Data was collected as bare earth and vegetation point clouds and interpolated as a rasterized digital elevation model (DEM) with sub-meter accuracy. A bare earth DEM was used as the basis for evaluation within this project.

The existing hydraulic model was developed using HEC-RAS (Hydraulic Engineering Center – River Analysis System) by the Army Corps of Engineers and partners in 2012. The model encompasses the project area from the Boise Diversion Dam to Glenwood Bridge (Figure 1 and Figure 2). This is a one-dimensional model based off cross-sections obtained from the 2007 LiDAR DEMs. A 1D model is suitable for estimating water surface elevation and depth-averaged water velocity and shear stress on a per-cross-section basis. HEC-RAS is the industry standard for flood evaluations in the United States. An interactive demonstration of output from the Lower Boise River HEC-RAS model has been made available by the National Weather Service:

http://water.weather.gov/ahps2/inundation/inundation_google.php?gage=bigi1

Relative surface models (RSMs) were constructed for this project to provide a rough estimate of high- versus low-elevation ground relative to the level of water in the River. Each model was built in ArcGIS using cross-sections from the 2007 LiDAR. At each of these cross-sections, a mean bed depth was determined and applied to each cross section from which a topographic surface (DEM) was constructed. The elevation of the constructed surface representing the mean bed depth was subtracted from the LiDAR bare earth surface representing the ground, yielding a relative elevation above or below the bed of the river. Using a rating curve comparing observed water stage heights and measured discharges at Glenwood Bridge, the relative surface was adjusted to approximate water heights for low (~300cfs) and approximate bankfull (~7000cfs) flows extrapolated across the entire study area (Figure 2).

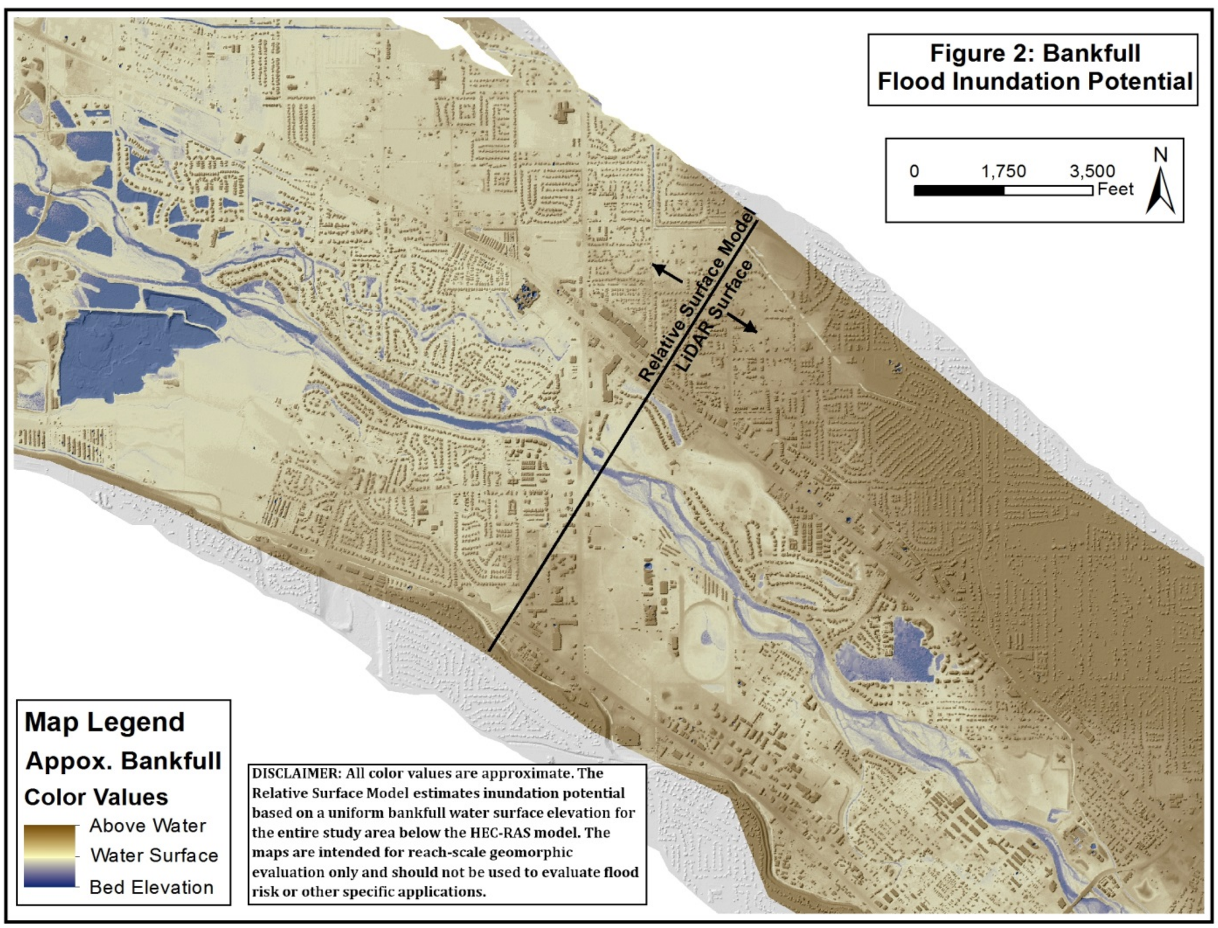

Figure 2: Bankfull Flood Inundation Potential Map

Using these models and available aerial imagery, sites of interest were identified and prioritized for field reconnaissance, which occurred during low flows (~500cfs) in October 2014. During field reconnaissance site-specific geomorphic characteristics were documented including grain size estimates, channel type and character, evidence of active processes, and other defining characteristics.

Geologic History

The lower Boise River is located in a structural basin known as the Western Snake River Plain (WSRP). During an approximate time period ranging from 9 to 2 million years ago, the WSRP accommodated a large lake during wetter climactic cycles. The last lake-filling sequence of this environment formed a lake that is popularly known as “Lake Idaho.” During this period, lake sediment and near-shore sand deposition filled what is now the lower Boise River valley. Drainage of Lake Idaho occurred during a wet period approximately 2-4 million years ago when the water level within the lake had risen to a point where it overtopped and scoured a passage to the north forming modern day Hell’s Canyon (Haller and Wood, 2004). From this point forward, the WSRP no longer accommodated lake-style sedimentation and the lower Boise River Valley was formed as the Boise River slowly carved a broad valley through these lake sediments through periods of episodic channel incision and valley fill.

Each period of incision is geomorphically represented through abandoned floodplains known as terraces. A series of eight terraces of the lower Boise River has been identified (Othberg et al., 1997). The minimum age of these terraces coincides with the outlet of the Snake River through Hell’s Canyon and the most recent glacial cycles (Othberg et al., 1997). The downcutting phase began as a response to the decreasing base level of the Snake River to its modern elevation at the confluence of the Columbia River. Episodes of incision coincided with wetter glacial periods during which stream discharge and the erosive capacity of the river was greater. At each successively lower base level, the river cut down forming terraces above the river and a new floodplain between the terraces. By the end of the last ice age the lower Boise River valley was formed, and the river began establishing its modern character.

Historic Conditions

Prior to Euro-American settlement, the Boise River functioned under a completely different flow regime than the highly regulated river of today (Figure 3). Frequent small-scale floods and occasional large floods associated with this historic hydrologic regime shaped the landscape creating a diverse and ever-evolving river corridor. Historic accounts and maps from the 1800s suggest the Boise River was primarily single-threaded with several islands in the area near the cities of Boise and Eagle. The channel in this area was described in 1834 by John Kirk Townsend as “a beautiful stream, about one hundred yards in width, clear as crystal, and, in some parts, probably twenty feet deep.” Early drawings from farther downstream suggest the lower 30-40 miles of the channel became primarily multi-threaded with “many islands” as depicted on David Thompson’s 1818 Map of the River. Recent detailed LiDAR topographic surveys of the lower Boise River floodplain reveal many channel scars and relic riverine landforms reaching in some cases thousands of feet from the current river, all of which support these early accounts of a generally sinuous, commonly multi-threaded river with a broad and active floodplain (Figure 4).

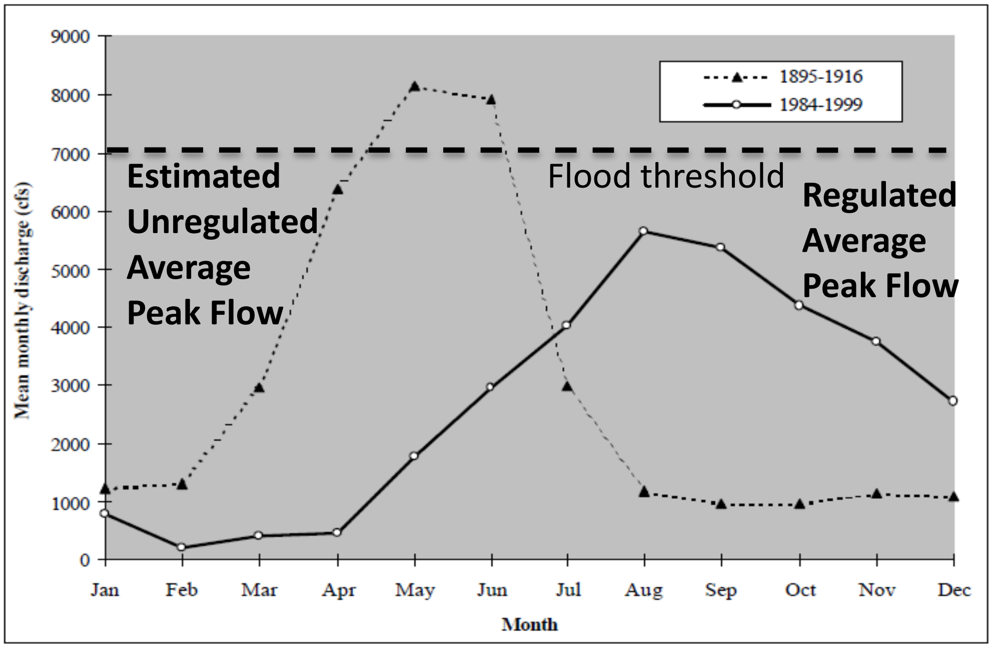

Figure 3: Boise River historic versus existing hydrograph. The average historic hydrograph included higher magnitude floods typically occurring during the late spring compared with lower magnitude floods and peaks occurring later in the season. Existing base flows are also generally lower than historic averages (figure adapted from ID DEQ, 2001).

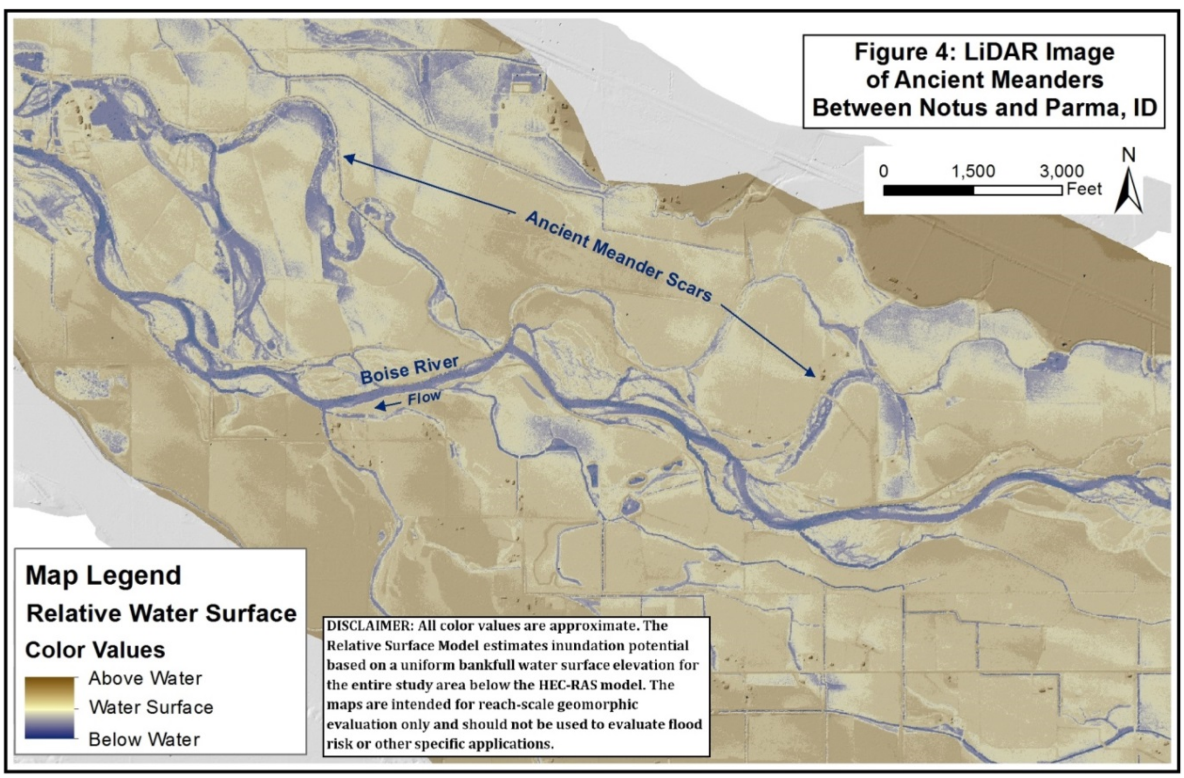

Figure 4: Relative surface model generated from LiDAR topography illustrating historic channel scars in the floodplain of the Boise River between Notus and Parma, ID.

Based on exposed river sediment in terraces and the modern floodplain, it can be concluded that the bed and banks of the historic lower Boise River channel were primarily composed of coarse cobble and gravel sediment – primarily cobble in the upper reaches and gravel in the lower reaches. As evident by the large volume of river sediment visible in floodplain exposures (e.g. gravel pits) throughout the lower Boise River valley, the historic lower Boise River clearly flowed over sediment of its own deposition, meaning it was an alluvial channel. Alluvial channels are generally dynamic and complex, commonly referred to as functioning under a dynamic equilibrium. This means the channel may have frequently scoured its bed and banks, deposited sediment on growing point bars, and migrated significantly across its floodplain. With minimal influence from bedrock, alluvial channels tend to scour deep pools where increased shear and velocity occur as a result of flow convergence often associated with in-stream obstructions such as large woody material (LWM), converging flows where side channels rejoin the main-stem channel, and along the outside of bends where momentum forces more flow to one side of the channel. Based on this understanding of alluvial channels and the evidence provided from historical accounts, it is likely that the bed of the historic Boise River was comprised of frequently mobilized sediment and characterized by pools and riffles in regular intervals.

The banks of the Boise River are typically composed of sand and silt overlying coarser gravels and cobbles. The sand and silt represents historic floodplain deposition. The coarser material underlying the flood deposits represents the deposited bedload of the historic channel. Bank erosion and the resultant channel migration of the historic river were aided by the poor cohesion of these alluvial bank materials. Bank stability was principally provided by riparian vegetation and large woody material (LWM). LWM was recruited to the cannel from upland and/or up-river debris flows and bank erosion undermining trees in the riparian area.

Recruited LWM is typically deposited on gravel bars, was pinned against the bank, or was retained by stable in-stream obstructions. The historic Boise River had the potential to accumulate substantial volumes of LWM as discussed below. The largest most substantial pieces (key members) had the potential to rack additional LWM transported through the system forming log jams. These logjams created hard points that obstructed flow, which forced flow convergence and scoured pools. Additionally, logjams and other in-stream obstructions often produce velocity shadows in their lee, promoting deposition and the formation of a bar and potentially a vegetated island with split flow around it (Figure 5).

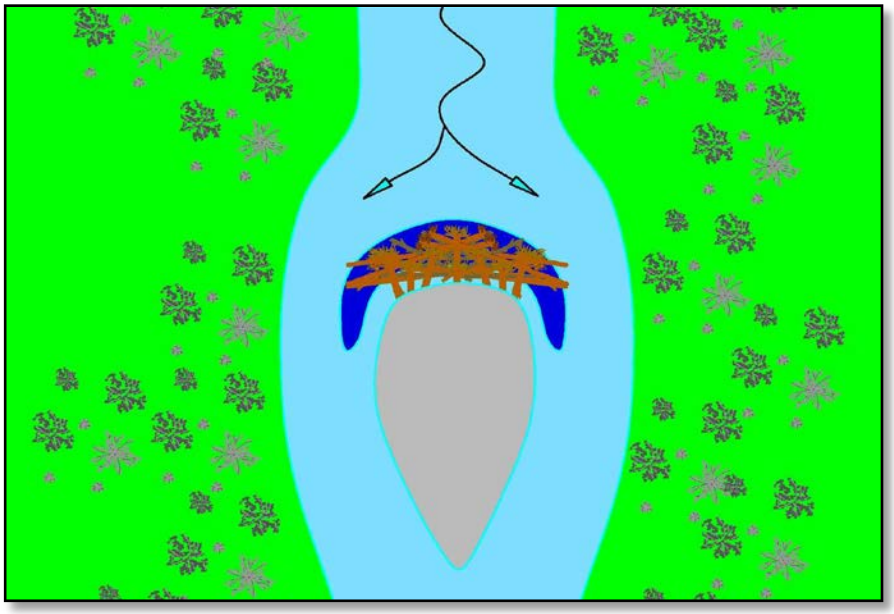

Figure 5: Hypothetical apex log jam shown forcing a split channel that concentrates flow immediately upstream and adjacent the log jam which scours pools in those areas (dark blue). A low-velocity zone is created downstream of the log jam (gray) promoting deposition and potential for formation of a mid-channel island.

Evidence of a historical river shaped by LWM and log jams is rooted within the name “Boise”. Early in its settlement history, upon seeing the broad riparian forest of the lower Boise River floodplain, English explorers coined it the “Woody River.” The current name is derived from French fur trappers favoring the popularized French name “Bois”, which translates to “wood” (Townsend, 1834.). Records also show that the riparian vegetation was dominated by cottonwoods and willows (McCoy and Blew, 2005). These trees require frequent floodplain disturbance in order to expand their area. Studies have shown that cottonwood seed dispersal typically occurs during declining river flows following floodplain inundation events that expose barren and moist microsites in which transported seeds may germinate (Braatne *et al.* 1996).

Based on the large expanse of cottonwoods present in the historic floodplain, it was likely that the floodplain experienced frequent disturbance. Historic accounts, maps, and photos further suggest the lower Boise River floodplain was broad and frequently inundated. Historically, there were many more floodplain features connected to the main channel such as side channels, split flows, sloughs, and alcoves (Thompson, 1818). Evidence of this can be seen in the existing topography as relic channel scars (see Figure 4) visible across large portions of the floodplain. Side channels are small, low-velocity channels connected to the main stem. An example of a common side channel type in the lower reaches of the Boise River is a *back-bar channel*, which forms between the bank and elevated sediment deposited on a point bar. Split flows are channels formed around an island or mid-channel bar where both channels possess similar characteristics. Alcoves typically represent the most downstream portion of a seasonal side channel with a perennial surface-water connection to the main-stem channel at its downstream end and an upstream connection fed from groundwater at low flow and surface water during floods. Sloughs are typically represented by low-energy oxbow channels connected to the active channel with limited or no through flow. The number of side channels, split flows, alcoves and sloughs likely increased in the lower reaches of the Boise River where low gradients favored processes such as sediment deposition, channel migration, and LWM recruitment historically responsible for such off-channel features.

Existing Conditions

Over the past 150 years following large-scale Euro-American settlement the overall geomorphic condition of the Boise River has changed. The first impacts were primarily from logging and the clearing of riparian forest as the demand for building lumber increased after the incorporation of the city of Boise in 1863. A relic of historic logging activities can be seen from one of the first dams built on the Boise River, the Goodwin Dam, designed and built in 1882 to divert log drives along a slough located along Warm Springs Avenue to the Goodwin Lumber Mill (City of Boise, 2015). A much larger dam, Barber Dam, was installed for log runs at the town of Barber 6 miles upstream of present downtown Boise. Eventually, the majority of the riparian woodland was cleared, giving rise to rangeland and farmland along with urban development within much of the floodplain in the upper reaches.

Floodplain encroachment along the Boise River continued throughout the 20th century. An 1890 “Birds-Eye View” of Boise shows the original establishment of Boise City proper well off of the banks of the river (Figure 6). Large floods in the early 1900s impacted expanding urban development and agricultural operations in the area necessitating improved flood protection and irrigation. A series of dams, levees and revetments were installed over several decades to control the river and meet the needs of the new populous. The resulting channel was primarily single-threaded, and channelized with limited floodplain accessibility.

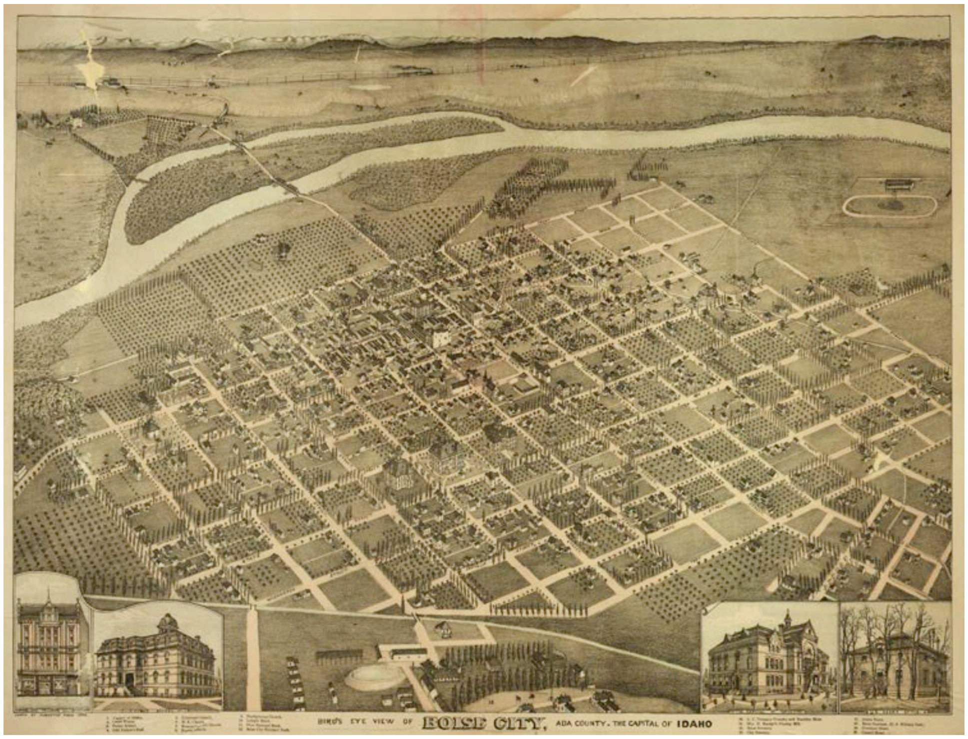

Figure 6. "Birds-Eye View of Boise, 1890." Original development of the city is shown to have occurred away the immediate floodplain. This figure also shows a major split-flow around what is now Ann Morrison Park (Boise State Library, 2015).

Increased irrigation needs and floodplain encroachment warranted the use of dams to manage flood risk by moderating flows. Four major dams were constructed between 1910 and 1960 impounding water and sediment delivered from the upper drainage area. This has starved the system of coarser bedload material that drove many of the historic geomorphic processes. Flow regulation also reduces annual peak flows to a maximum target of 7,000 cfs compared with historical floods that commonly exceeded 10,000 cfs (see Figure 3). Large annual peak flows likely represented times during the year in which the river underwent many of its geomorphic adjustments as greater flows generally correspond to increased erosion, sediment transport, deposition and channel dynamics. The combination of regulated peak flows, sediment starvation, and channelization on the other hand has resulted in a relatively homogenous and geomorphically static river.

Reach Descriptions

For the purpose of this report, the lower Boise River has been divided into 6 geomorphically distinct reaches (Figure 7). The existing geomorphic conditions are described below for each reach. Data included in this section were derived from LiDAR surface models, aerial photos and field observations taken during low flow conditions in October, 2014. Two of the data points include the floodplain width and meander beltwidth. Floodplain width was measured in GIS using an estimated 2yr water surface elevation at a representative cross section. Where levees were observed in the LiDAR topography, the floodplain width measurement was carried out to the lateral extent of the levee, in many cases reducing the overall width. Unlike the floodplain width, the meander beltwidth is a theoretical value based on the maximum amplitude of one meander bend independent of levees or other infrastructure. The amplitude of meander bends typically grows until it reaches a maximum at which time the meander is cut off leaving behind an oxbow channel scar. The maximum measured meander amplitude from each reach was used to define the minimum meander beltwidth (Figure 8).

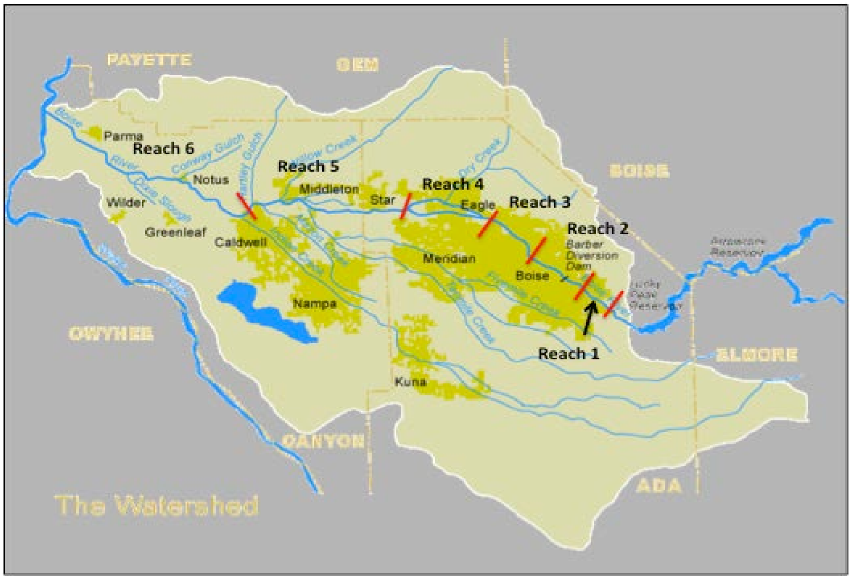

Figure 7. Study area showing the locations of the six reaches of this assessment. Reach number increases in the downstream direction, with Reach 1 being the most upstream reach and Reach 6 being the most downstream reach (Figure adapted from Lower Boise River Watershed Council).

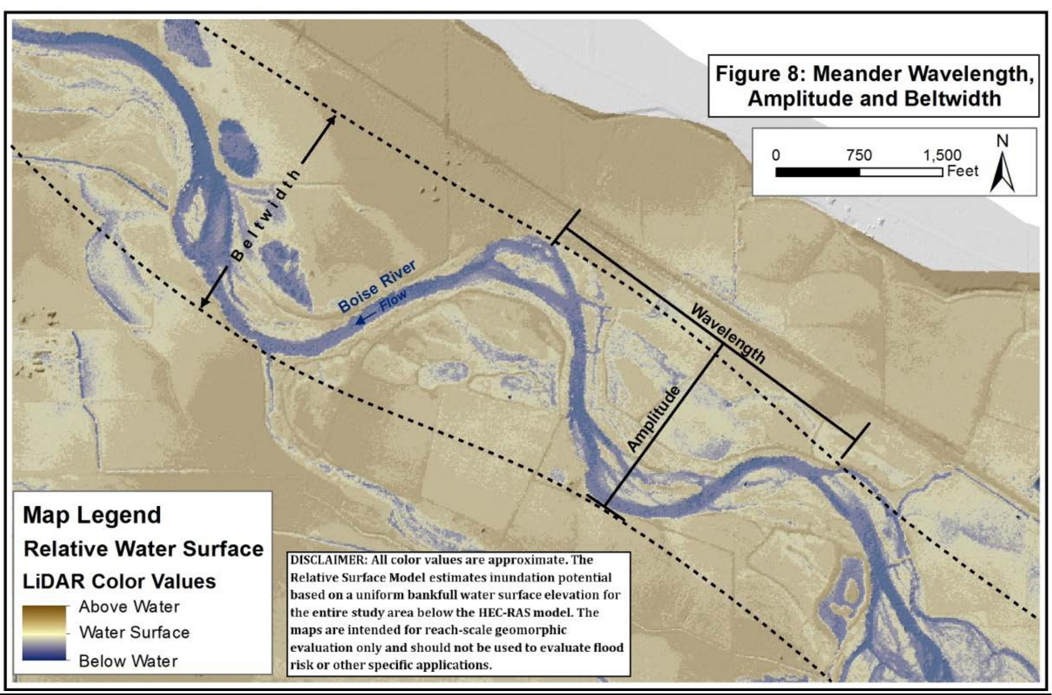

Figure 8. LiDAR map showing representative meander pattern including meander wavelength, amplitude and beltwidth (near Notus, ID).

Reach 1: Diversion Dam to Barber Dam

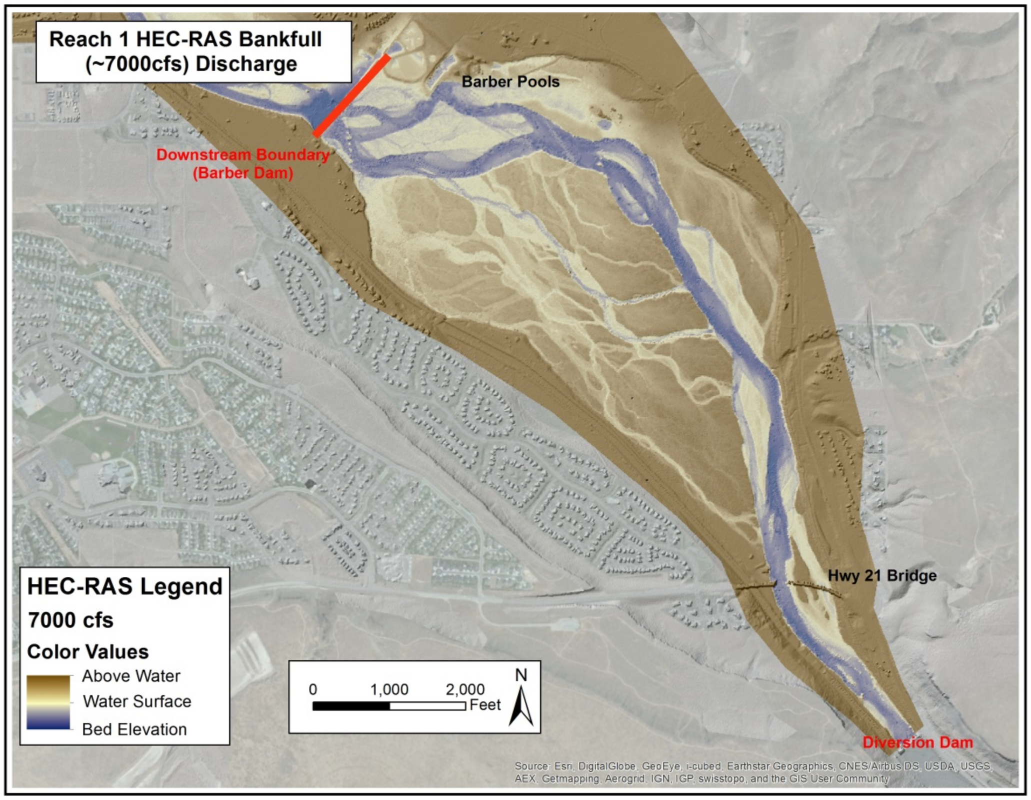

Figure 9: HEC-RAS model showing approximate bankfull discharge (~7000cfs). Color values of blue correspond to areas below the water surface while brown colors convey areas above the water surface. The model dos not consider levees, and therefore represents a maximum potential inundation area.

Figures 10 and 11: Photos of the channel in Reach 1 above Barber Pools showing an overwidened channel. The photo on the right shows a wide backwater zone formed by Barber Dam. The photo on the left illustrates how shallow the channel is, barely reaching above this wader's knees (Richardson, 2014).

REACH 1 – Boise Diversion Dam to Barber Dam	
Channel Metric	**Existing Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.2
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Plane-Bed
Rosgen Classification Classification system specific to channel forms and bed composition (Rosgen, 1998)	F3 Entrenchment ratio <1.4
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	45
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	Upstream of Barber Pool: 2.5, 5, 12 Within Barber Pool: Predominantly Sand
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	Low
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	Moderate immediately below Boise Diversion Dam; Low above Barber Dam
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0005
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Low
Bank Composition Average grain size of bank material	Gravel and sand become primarily sand upstream of Barber Dam
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Grass-Shrub dominated; continuous
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	Less than 50ft
Meander Belt Width (ft) Equivalent to a single active meander amplitude; may be truncated by levees/riprap	325
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	High-flow side channels and perennial wetlands
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	Not Measured
Primary Landuse	Undeveloped

Form

- Channel Planform: Primarily single-threaded with a high width-to-depth ratio
- Bed: Bed composition changes in a downstream longitudinal direction, from a cobble-gravel dominated bed in the upstream section to a sandy bed in the lower section. Very few pools. Primarily homogenous bed-form.
- Structure: Lacking structure.
- Banks: Primarily gravel-sand; evidence of slump failures
- Floodplain: Seasonal side channels scoured into first terrace surface (evidenced by active sand deposition within channels), backwater inundated downstream sections of side channels. Side channels augmented by beaver activity.

Process

- Sediment recruitment and bank erosion: Local bed material recruited from bank erosion resulting from channel widening. The backwater from Barber Dam has raised the water surface in this reach resulting in some bank slumping as water is lapped up against banks.
- Deposition: Recent deposition within backwater zone of the reach from upland runoff and local bank erosion.

Function

- A lack of coarse sediment below the upriver dams and the backwater conditions formed by Barber Dam have combined to create an environment dominated by sand where upwards of 6-feet of sand deposition have resulted in a wide, low gradient channel lacking physical complexity.
- High water table due to dam has allowed for continuous and thriving riparian environment in low-lying areas.

Reach 2: Barber Dam to Americana Boulevard

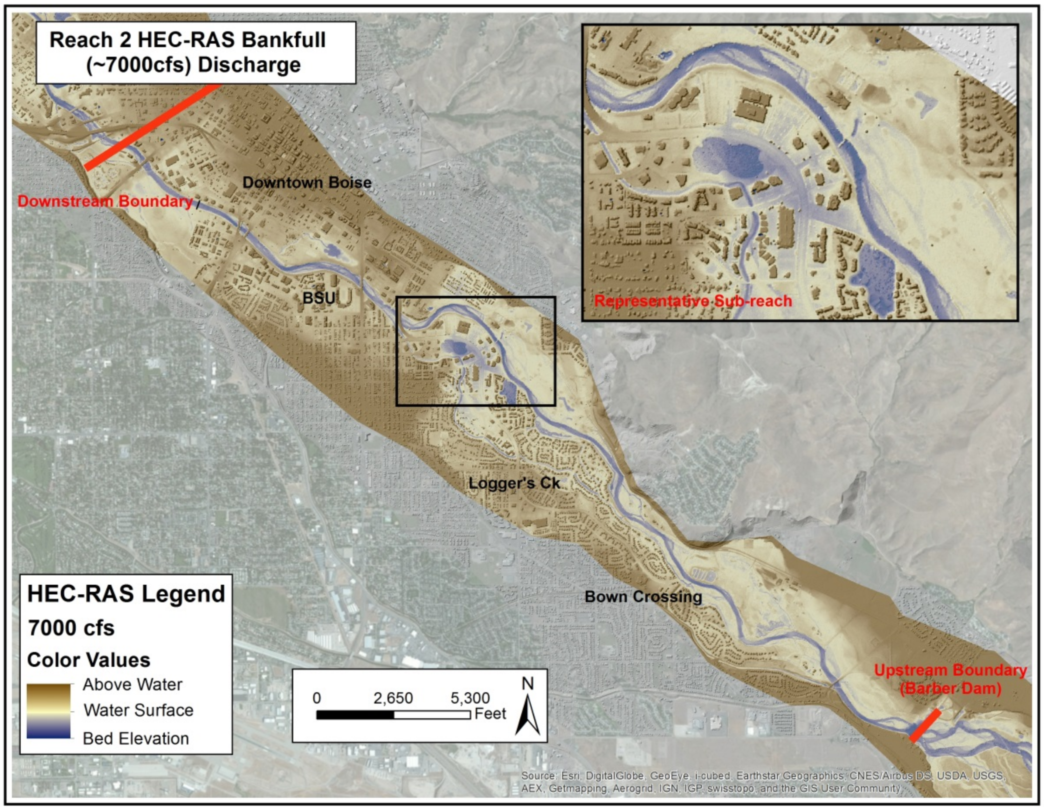

Figure 12: HEC-RAS model showing approximate bankfull discharge (~7000cfs). Color values of blue correspond to areas below the water surface while brown colors convey areas above the water surface. The model dos not consider levees, and therefore represents a maximum potential inundation area.

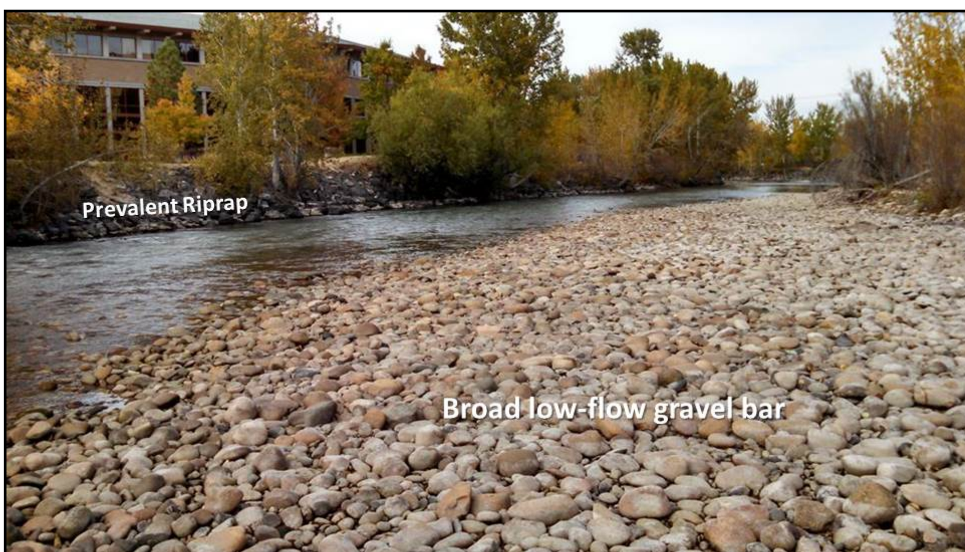

Figure 13: The low-flow channel is commonly drawn away from one or both banks due to the wide bankfull channel through much of the urban corridor (Richardson, 2014).

REACH 2 – Barber Dam to Americana Blvd.	
Channel Metric	**Existing Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.1
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Pool-Riffle (Plane-bed in many sub-reaches)
Rosgen Classification Classification system specific to channel forms and bed composition (Rosgen, 1998)	F3 Entrenchment Ratio < 1.4
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	25
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	2.5, 5, 12
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	Moderate
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	High
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0024
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Low; primarily man-made (bridge piers)
Bank Composition Average grain size of bank material	Cobble-Gravel; rip-rap common
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Tree-shrub dominated; continuous; narrow
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	90
Meander Belt Width (ft) Equivalent to a single active meander amplitude; may be truncated by levees/riprap	150
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	Occasional side-channels, alcoves, and minor wetlands
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	224
Primary Landuse	Urban

Form

- Channel Planform: Primarily single-threaded and low sinuosity with long, straight sub-reaches
- Bed: Primarily cobble-gravel dominated; few pools primarily along the outside of armored (rip-rap) bends
- Structures/Obstructions: Primarily lacking; bridge piers represent some of the only structure in the reach; little to no LWM.
- Floodplain: Logger's Creek is the most significant perennial side channel with excellent cover and connectivity (regulated inlet structure). Some back bar channels and minor side channels, most only active during high flows.

Process

- Scour: Infrequent; some localized scour associated with flow convergence and pools due to man-made structure (rip-rap and bridge piers).
- Deposition: Localized reworking of in-stream sediment, some minor sand deposition derived from upland runoff.
- Bank erosion: Primarily lacking; no measurable channel migration.

Function

- Channel confinement by levees and riprap, and a lack of sufficient flow and sediment to drive channel change have resulted in a highly stable, single-thread channel lacking both the presence of and the ability to create new significant in-stream structure, cover, floodplain connection, and side channels.

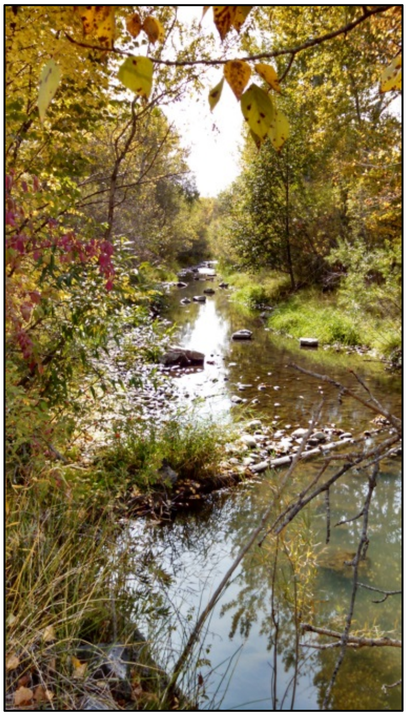

Figure 14: View of Logger's Creek, an old logging diversion and major perennial side channel in Reach 2. Note the extensive canopy cover and in-channel structure.

Reach 3: Americana Boulevard to the head of Eagle Island

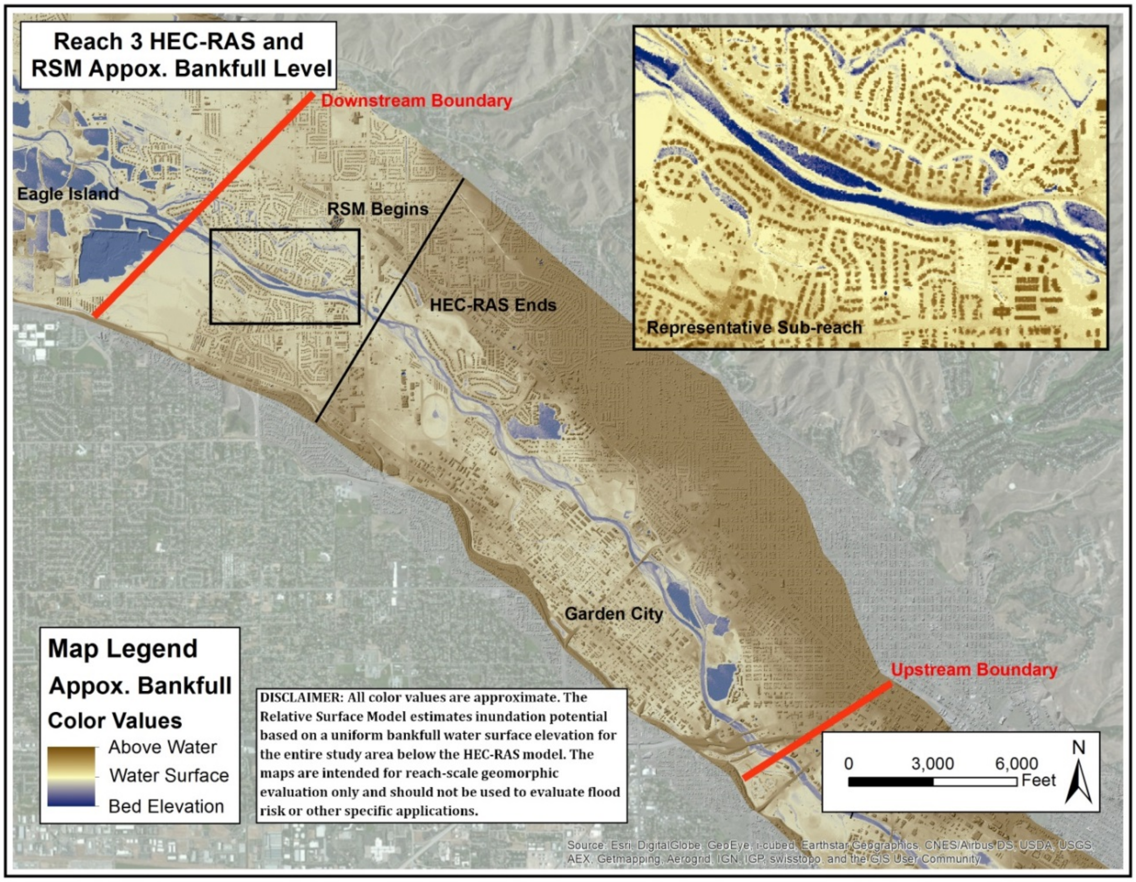

Figure 15: RSM and HEC-RAS models showing approximate bankfull discharge (~7000cfs) for Reach 3. Color values of blue correspond to areas below the water surface while brown colors convey areas above the water surface. The RSM and HEC-RAS models do not consider levees, and therefore represents a maximum potential inundation area.

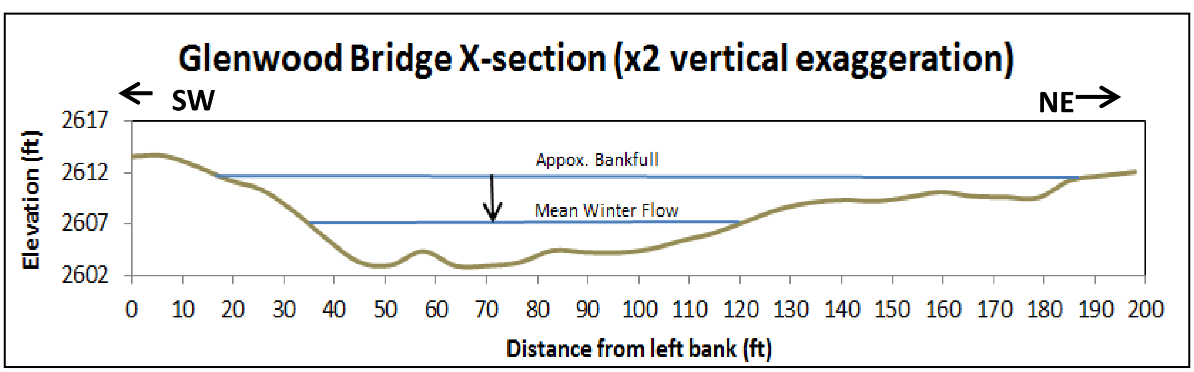

Figure 16: Cross-section showing the approximate bankfull stage versus mean winter flow stage near Glenwood Bridge in Reach 3. Note the differences in relative active channel widths, a common condition in both Reach 2 and 3.

REACH 3 – Americana Blvd. to Eagle Island	
Channel Metric	**Existing Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.1
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Pool-Riffle
Rosgen Classification Classification system specific to channel forms and bed composition (Rosgen, 1998)	F3 Entrenchment Ratio < 1.4
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	23
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	2, 4.5, 10
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	Moderate
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	High
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0026
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Moderate; Primarily man-made (e.g.: bridge piers)
Bank Composition Average grain size of bank material	Cobble-gravel; rip-rap
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Tree-shrub dominated; continuous; narrow
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	140
Meander Belt Width (ft) Equivalent to a single active meander amplitude; may be truncated by levees/riprap	160
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	Occasional side-channels, alcoves, and minor wetlands
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	202
Primary Landuse	Urban

Form

- Channel Planform: Primarily single-threaded; low sinuosity with many straight subreaches
- Bed: Primarily cobble-gravel dominated; few pools primarily in areas of flow convergence such as along the outside of armored (rip-rap) bends and where split flows converge.
- Structures/Obstructions: More common than in Reach 2, man-made: diversion weirs, bridge piers, and rip-rap. Little to no LWM.
- Floodplain: Occasional perennial side channels with hard points provided by mature willow root-mat partially defining the side channel banks. Some seasonal back-bar channels also present.
  - Best example: Right bank adjacent the West Boise Waste Water Treatment Plant.

Process

- Scour: Localized scour associated with flow contraction associated with meander bends and occasional in-stream structures.
- Deposition: Reworking of local gravels deposited on the inside of bends (point bars) and in areas of flow divergence around structure.
- Bank erosion: primarily lacking; no measurable channel migration

Function

- Regulated peak flows and limited sediment transport (erosion and deposition) have greatly diminished most channel processes resulting in a primarily single-threaded reach lacking channel dynamics. Limited in-stream variability is driven largely by the presence of obstructions forcing flow contraction (scour pools) and expansion (deposition) often associated with existing meander bends.
- Channel confinement by levees and riprap significantly reduce floodplain connection and formation of off-channel features.

Figure 17: View of a perennial side channel adjacent Willow Lane in Reach 3. Note the Willow root-mats acting as structural hard-points stabilizing the banks throughout much of the side channel (Richardson, 2014).

Reach 4: North and South Channels of Eagle Island

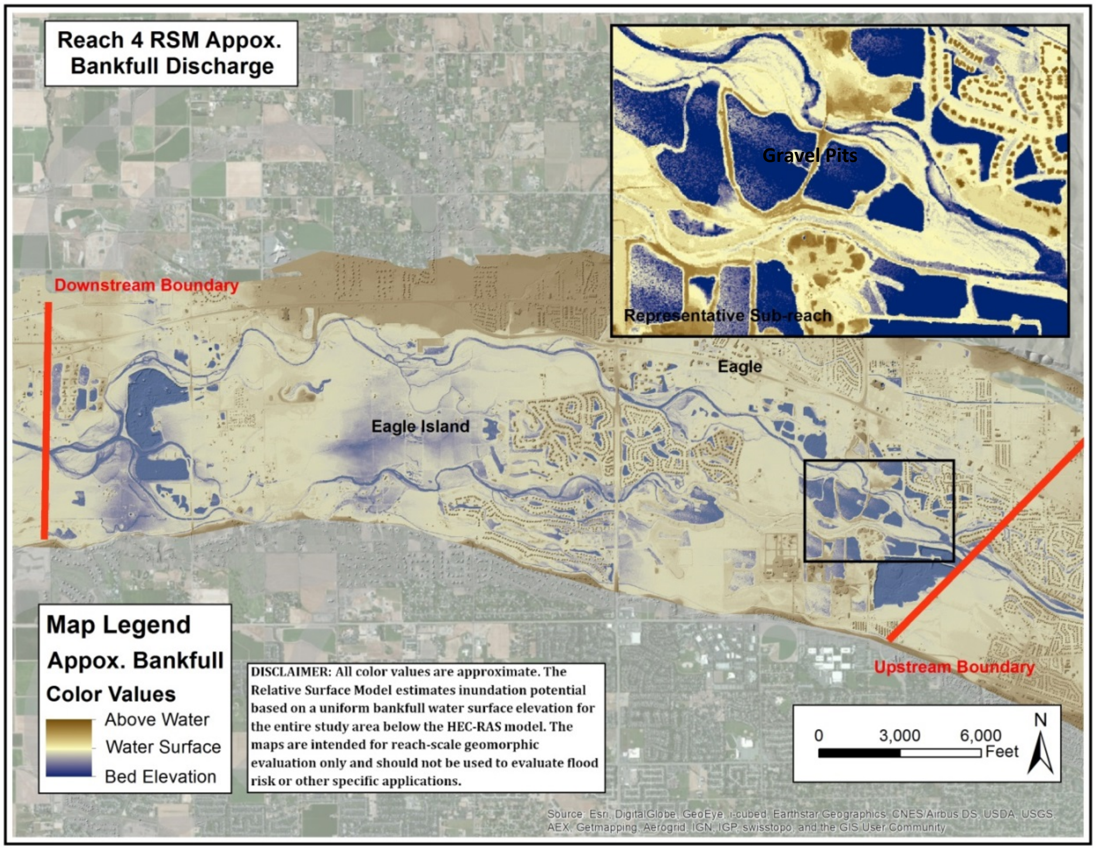

Figure 18: RSM showing an approximate bankfull discharge (~7000cfs) for Reach 4. Color values of blue correspond to areas below the water surface while brown colors convey areas above the water surface. The RSM does not consider levees, and therefore represents a maximum potential inundation area.

Figure 19: Gravel pit south of Eagle Island, approximately 1 mile wide (Richardson 2014).

REACH 4 – North and South Channels of Eagle Island	
Channel Metric	**Existing Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.2
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Pool-Riffle
Rosgen Classification Classification system specific to channel forms and bed composition (Rosgen, 1998)	F3 Entrenchment Ratio < 1.4
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	20
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	1.5, 5, 7
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	Moderate to Low
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	High
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0019
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Low to moderate; man-made (e.g.: bridge piers), some LWM
Bank Composition Average grain size of bank material	Gravel-cobble, some sand
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Tree-shrub dominated; continuous and narrow
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	North Channel: 170 South Channel: 170
Meander Belt Width (ft) Equivalent to a single active meander amplitude; may be truncated by levees/riprap	110 for each channel
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	Split flow; few side channels; many gravel quarry pits and small ponds
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	187
Primary Landuse	Suburban

Form

- Channel Planform: Two single threads, both with low sinuosity especially in the upper half of the reach.
- Bed: Cobble-gravel dominated; increasing frequency of pools compared with upstream reaches; pools primarily associated with in-stream structure and flow convergence (outside of bends).
- Structures/Obstructions: primarily man-made including flow diversion weirs and some rip-rap material. Occasional LWM interacting with low flow. Most significant flow obstruction is the concrete structure maintaining the flow split on upstream end of Eagle Island.
- Floodplain: Few minor side channels; increasing frequency of small back-bar channels and alcoves associated with meander bends in the downstream half of the reach. Large, expansive floodplain areas are blocked by levees. Many ponds have been excavated in the floodplain, but ponds lack continuity for floodwater conveyance.

Process

- Scour: Scour pools associated with a sinuous, relatively well-defined thalweg; pools located primarily on the outside of bends
- Deposition: Local deposition on slowly prograding gravel point bars; progradation appears to be advancing both laterally and downstream in the few locations where it was measurable based on historic aerial photos and depositional features on gravel bars.
- Bank erosion: Minor bank erosion observed on the outside of a handful of bends; observed in conjunction with prograding point bars.
- Migration: Few areas identified where very slow, localized migration may be taking place where bank erosion is occurring on the outside of prograding gravel bars.

Function

- Relic split-flow conditions are partially maintained by a concrete diversion structure and occasional in-stream excavation splitting flow into two similar channels with a narrow but continuous riparian corridor including overhanging vegetation along much of the bank area. As a result of regulated peak discharges and limited sediment transport, both channels are generally stable, lacking significant dynamic change. Levees restrict floodplain function.

Reach 5: Below Eagle Island to Caldwell (W. Plymouth St. Bridge)

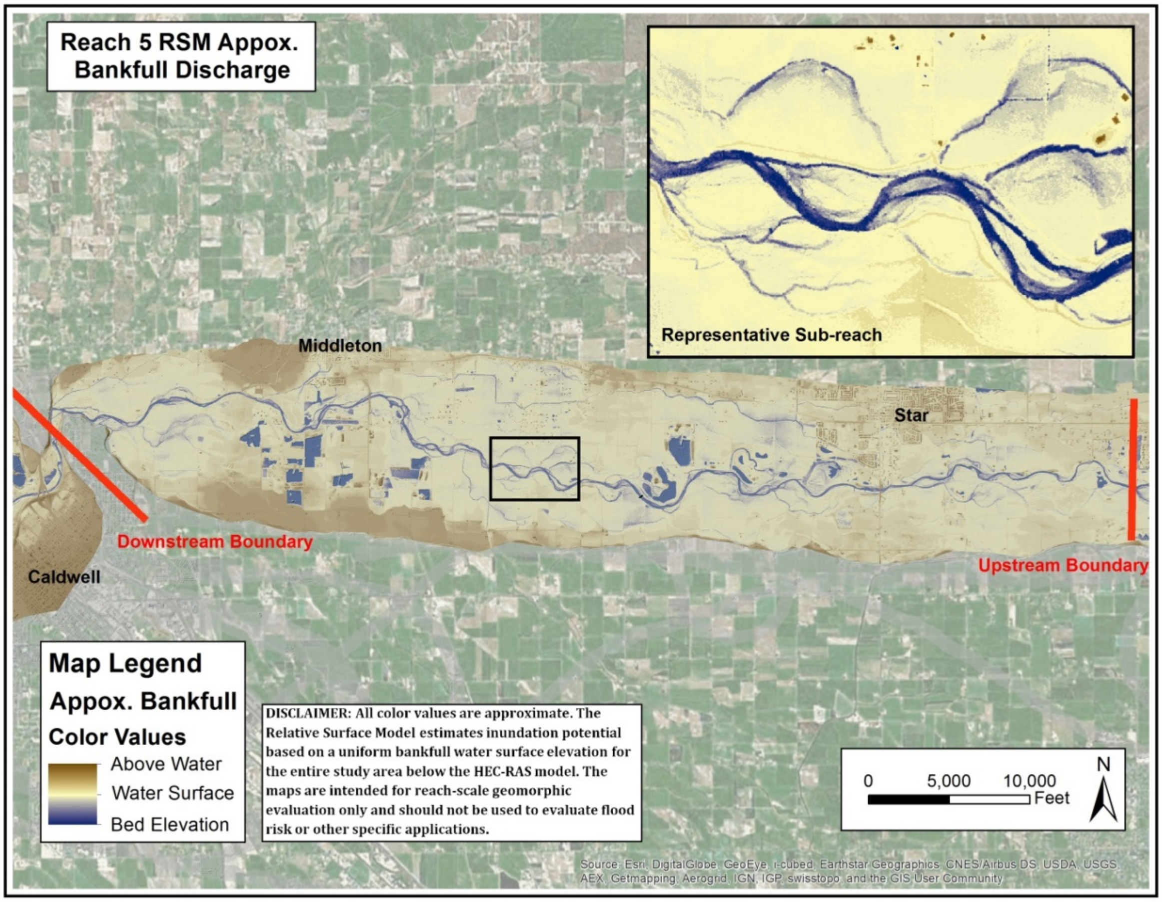

Figure 20: RSM showing an approximate bankfull discharge (~7000cfs) for Reach 5. Color values of blue correspond to areas below the water surface while brown colors convey areas above the water surface. The RSM does not consider levees, and therefore represents a maximum potential inundation area.

Figure 21: Looking upstream at the Star Diversion, one of the many irrigation diversions in Reach 5. Note the basalt rip-rap in the lower right, common in many parts of Reaches 5 and 6 (Richardson 2014).

REACH 5 – Eagle Island to Caldwell	
Channel Metric	**Existing Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.2
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Primarily Plane-Bed
Rosgen Classification Classification system specific to channel forms (with levees) and bed composition (Rosgen, 1998)	F4 Entrenchment Ratio < 1.4
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	27
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	1.5, 4.5, 6
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	High
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	High
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0017
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Low; man-made (e.g.: bridge piers and diversions)
Bank Composition Average grain size of bank material	Gravel-cobble, some sand; rip-rap common
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Tree-shrub dominated; discontinuous and narrow
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	300
Meander Belt Width (ft) Equivalent to a single active meander amplitude; may be truncated by levees/riprap	185
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	Many short, active back bar channels
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	147
Primary Landuse	Agricultural

Form

- Channel Planform: primarily single-threaded and low to moderate sinuosity; occasional split flow around mid-channel bars/islands.
- Bed: gravel-cobble dominated; few pools associated with structure and/or flow convergence along the outside of bends.
- Structure/Obstructions: diversion weirs, occasional bridge piers; very few observed LWM
- Banks: Primarily composed of gravel and cobble overlain by floodplain silt and sand with significant areas of rip-rap and many levees
- Floodplain: Few active side channels, primarily in the form of back-bar channels. Floodplain connection severely restricted by levees.

Process

- Scour: localized scour forming pools associated with man-made structures (e.g.: bridge piers) and flow convergence along the outside of bends.
- Deposition: Recent deposition observed in the lee of in-stream structures (e.g.: bridge piers); minor amounts of deposition from reworked local sediment observed on point bars.
- Bank Erosion: Limited bank erosion resulting from prolific bank stabilization (rip-rap) and armored levees.
- Migration: The lack of bar-building sediment deposition and associated bank erosion has severely reduced the rates of channel migration, which are unmeasurable in most places, with a maximum measurable rate of only 3ft/yr in the most (relatively) active areas.

Function

- Sinuosity, floodplain connection, and side channels increase compared with upstream reaches, but channel processes remain limited primarily by levees and riprapped banks. Few areas of hydraulic complexity are associated with in-stream structures resulting in pools, steep velocity gradients (eddies), split flow, and LWM.

Reach 6: Caldwell Basalt Flow to Snake River Confluence

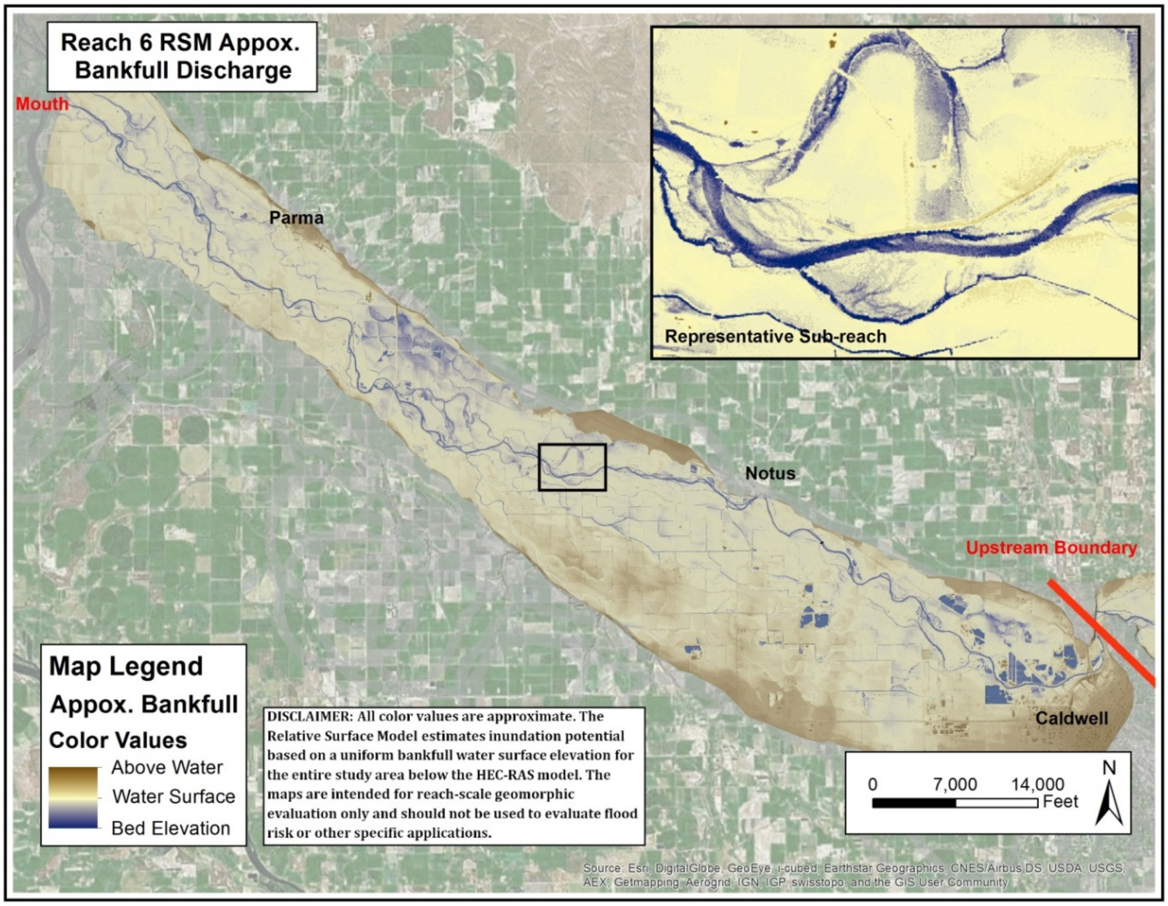

Figure 22: RSM showing an approximate bankfull discharge (~7000cfs) for Reach 5. Color values of blue correspond to areas below the water surface while brown colors convey areas above the water surface. The RSM does not consider levees, and therefore represents a maximum potential inundation area.

Figure 23: View of the wide and physically homogeneous channel with poorly-defined thalweg common in Reach 6. Side channel inlet is maintained by periodic excavation (Richardson, 2014).

REACH 6 – Caldwell to Snake River	
Channel Metric	**Existing Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.2
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Primarily Plane-Bed
Rosgen Classification Classification system specific to channel forms (with levees) and bed composition (Rosgen, 1998)	F4 Entrenchment Ratio < 1.4
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	33
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	1, 3, 5
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	High
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	Moderate to High
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0013
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Low; man-made (e.g: bridge piers and diversions)
Bank Composition Average grain size of bank material	Sand-silt over gravel
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Grass-shrub dominated, poor condition; narrow and discontinuous
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	780
Meander Belt Width (ft) Equivalent to a single active meander amplitude; may be truncated by levees/riprap	170
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	Many small side channels and back-bar channels
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	184
Primary Landuse	Agricultural

Form

- Channel Planform: Primarily single-threaded and sinuous
- Bed: gravel-cobble, subaqueous vegetation growth trapping silt in shallower stretches; very few pools
- Structure/obstructions: The reach is severely lacking in-stream structure; little to no LWM; most in-stream obstructions are associated with man-made structures (e.g.: diversion weirs, bridge piers)
- Banks: Composed of silt and sand over gravel with minimal vegetative root mat stabilization; rip-rap least common in this reach compared to the rest of the study area.
- Floodplain: Minor back-bar side channels, some appear to be augmented by irrigation diversions; sparse, narrow and discontinuous buffer of riparian vegetation.

Process

- Scour: Very few scour pools, each associated with forced flow convergence around in-stream obstructions. The few pieces of in-stream LWM have each resulted in sizeable scour pools.
- Deposition: Minor sediment deposition on pre-existing bars; sediment likely locally derived
- Bank Erosion: Evidence of bank erosion most prevalent in this reach compared to other reaches, likely occurring during high flows through the reach and is associated with poor riparian bank conditions and erosive bank material.

Function

- Poor riparian vegetation, erosive bank materials and flood flow concentrated between a vast network of discontinuous levees and riprap have resulted in bank erosion and over-widening of the largely single-threaded channel. The channel character is largely homogenous due to a lack of in-stream structure. The few scour pools observed in the reach were nearly all associated with structure.

Target Conditions

Target Conditions represent those geomorphic forms and processes that allow for the greatest physical enhancement of the river given known modern constraints. It is unrealistic to restore the lower Boise River to historic conditions without addressing changes to the hydrograph (dams) and alterations to the floodplain (agriculture and urbanization). Target conditions identified in this section assume the existing hydrograph and floodplain alterations will persist into the future. Significant future changes to either hydrograph or floodplain may warrant reconsideration of some or all of the target conditions proposed.

Hydraulic Complexity

Hydraulic complexity is an important aspect of the overall physical function of an alluvial river system like the Boise River. Hydraulic complexity is most simply defined as variability in the velocity, flow direction and/or depth of water in a river. A hydraulically complex channel has abrupt water velocity gradients forming eddies, strong flow contraction (convergence) forming scour pools, flow expansion causing deposition that forms riffles and bars, and variable depth associated with different bed forms and floodplain interactions. Flow obstructions are largely responsible for driving hydraulic complexity by forcing the river to diverge horizontally and vertically from a straight line. The most common natural flow obstructions include in-stream structure (large woody material, boulder clusters, riffles, etc.) and meander bends, both of which force localized zones of flow contraction and expansion resulting in steep velocity gradients, scour, deposition, and the potential for improved floodplain connection (Figure 24). The partitioning of flow through split-flows and side channels can also enhance hydraulic complexity by effectively doubling the bank area where in-stream obstructions are most common. Improving the geomorphic character of the Boise River is largely centered around enhancing the river's hydraulic complexity while recognizing and accounting for modern constraints.

Target conditions identify appropriate forms and processes supporting increased hydraulic complexity and enhanced geomorphic function given existing constraints. Enhancement actions therefore should work with existing geomorphic trends of the river over the short- and long-term, and implementing the actions should result in the least amount of disturbance possible. Listed below are prioritized steps toward achieving these two objectives – maximum use of natural processes and minimal disturbance.

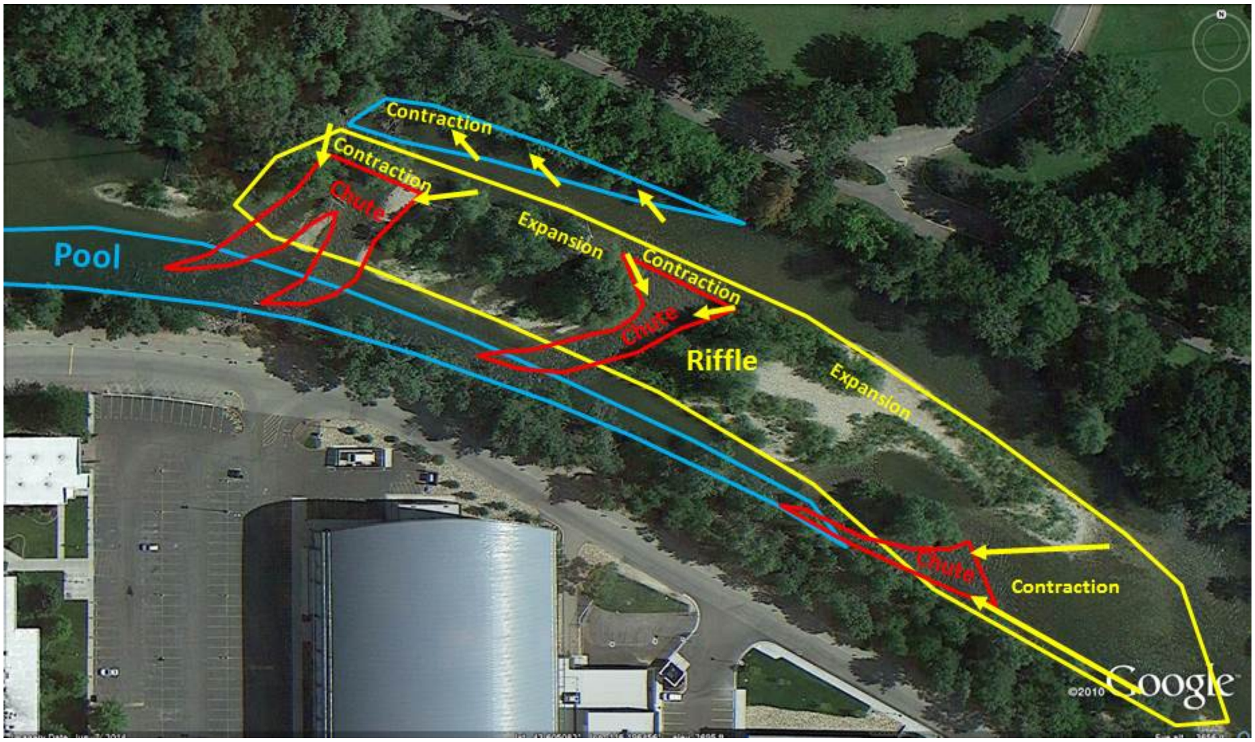

Figure 24: Example of channel complexity near Boise State University. Multiple zones of flow expansion and contraction resulting in riffle and pool formation. Areas of expansion increase width, decrease depth, and result in high-roughness and deposition forming riffles. Water flowing over the top of the riffle is contracted vertically (to account for the vertical relief created by the riffle) and horizontally (where forced between log jams and riparian forest). Areas of contraction create chutes of decreasing width and increasing depth of flow creating high-velocity zones that scour pools. Steep velocity gradients, where high and low velocity flows meet, form eddies on either side of the chutes.

General Geomorphic Enhancement Priorities:

1. <u>Protect</u> existing areas favoring target geomorphic conditions.

   Efforts should be made to protect land, water and in-stream structure supporting favorable geomorphic conditions. Notable areas to protect include accessible floodplain, riparian zones, islands, and other undeveloped areas within the target meander belt width. Additionally, protection should include existing side channels, wetlands, and in-stream structures as well as minimum in-stream flows and water quality. Protecting the land surrounding an existing side channel with a conservation easement is a good example of this type of enhancement approach.

2. <u>Improve natural river processes</u> enabling the river to restore natural forms on its own.

   Flow, sediment and LWM recruitment are the three dominant processes shaping natural river form. Improving rates and volumes of flow, sediment input and LWM recruitment to the river will enhance natural processes allowing the river to restore itself. Additionally, reconnecting isolated historical forms such as oxbows, wetlands, side channels, alcoves, and low floodplain areas allows for the reestablishment of natural river processes by removing the isolating feature (commonly a levee or riprap). These projects are highly cost effective as the river naturally restores and maintains the previously disconnected forms typically without the need for complex engineering or intrusive construction. Allowing the river, for example, to erode its banks and migrate in strategic locations is a good example of this type of enhancement approach as it will simultaneously recruit sediment, form pools and point bars, increase sinuosity, and improve floodplain connection.

3. Force river processes enabling the river to create improved forms.

   Areas that have been identified as geomorphically homogenous and/or overly stable typically lack process that force dynamic change. Geomorphic forcing is a natural process whereby in-stream structure forces flow expansion and contraction to create hydraulic complexity. Most processes shaping alluvial rivers represent a combination of driver (flow and sediment) and a forcing mechanism (in-stream structure). Forcing, in this case, would require building a structure such as a barb, log jam or engineered riffle that would complement an existing process driver creating advantageous forms that could not otherwise exist without the enhancement. The design of any forcing mechanism requires detailed engineering analysis to ensure the result is geomorphically appropriate and therefore sustainable over the long-term. Building an engineered log jam at the head of a point bar to force a percentage of flow across the back of the bar creating a back-bar side channel is a good example of this type of enhancement approach.

4. Construct forms that the river can maintain.

   If all other options have been exhausted or it is deemed necessary, the target form may have to be constructed rather than allowing or forcing the river to crate it. This approach is appropriate if utilizing existing river processes and/or building forcing mechanism to create desirable forms is too risky or will take too long to meet stakeholder needs. Projects falling under this category should be designed in such a way as to ensure the existing river processes will be able to maintain the structure once it has been built. Excavating a side channel through a portion of the floodplain is a good example of this type of enhancement approach.

Study Area General Recommended Actions

The following general recommended actions apply to all reaches where appropriate. As has been noted previously in this report, any proposed action should also be assessed at the project scale to ensure feasibility and to maximize potential project success. This report and the recommendations identified herein have been developed at a reach-scale to establish possible opportunities and to prioritize efforts in order to facilitate future project-scale efforts. The recommendations outlined in this report should not be used exclusively as the basis for site-specific enhancement. Detailed, site-specific analyses should be conducted to identify the most appropriate suite of actions, refine conceptual plans, and develop detailed plans for implementation.

Protect

- Any area within the active floodplain and/or meander beltwidth that has not been developed.

- Existing natural in-stream structure (LWM); especially those structures creating hydraulic complexity by forming/maintaining split flows, side channels, and large pools.
- Existing in-stream flows

Improve Natural Process

- Enhance flows – particularly peak flows that promote channel dynamics and low flows that provide minimal habitat.
- Remove or improve existing irrigation diversion dams enabling more natural flow and sediment transport. Diversion dams act to restrict conveyance of flow and sediment, creating physically homogeneous backwater zones upstream of the diversion. Consolidating several points of diversion into one, or replacing in-stream diversions with pumps enables the removal of in-stream diversion dams while continuing to meet irrigation needs. Alternatively, rather than removing diversion dams, consider replacing traditional structures with those that allow for natural flow and sediment passage during the irrigation off-season. Lay-flat stanchion dams (Figure 25) and adjustable dams such as the dam installed at the Boise White Water Park (Figure 26) are good examples of diversion structures that can be lowered enabling natural flow and sediment passage. Additionally, improvements can be made to the irrigation delivery system such that smaller volumes of water are required thereby facilitating diversion consolidation, improvement, and or removal. Enabling more natural passage of flow and sediment will enhance geomorphic process and improve hydraulic complexity.

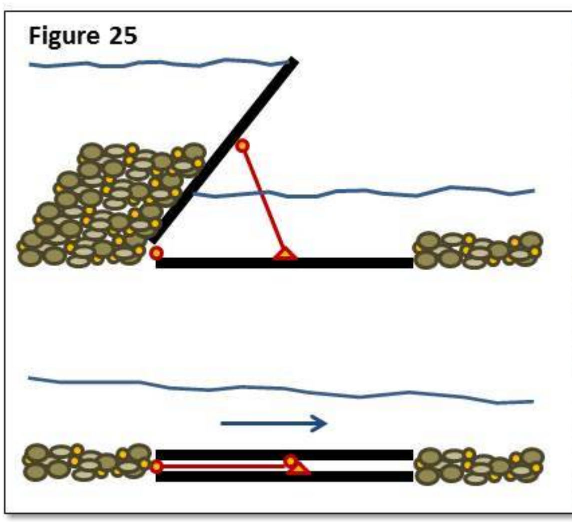

Figure 25: Simplified diagram of example lay-flat stanchion dam (wicket dam). When in use each stanchion is raised to impound water and sediment (top). When not in use, each stanchion is lowered reestablishing "normal" flow and sediment transport (bottom).

Figure 26: Boise River Whitewater Park wave. Sections of the dam can be raised or lowered incrementally to shape waves, impound water for irrigation purposes, or increase flow and sediment passage.

- Remove or set-back levees where feasible enabling greater floodplain interaction. Allowing the river access to larger areas of floodplain improves natural geomorphic process while improving flood storage and conveyance, which may reduce flooding in developed areas. Frequent flooding on bars and the near-river floodplain also enables the establishment of a robust cottonwood riparian community which is dependent on elevated floodwaters and floodplain deposition in order to become established and flourish.
- Promote bank erosion and channel migration where feasible. Allow bank erosion by removing unnecessary rip-rap and other bank protection devices. Bank erosion will simultaneously recruit sediment, form pools and point bars, increase sinuosity, and improve floodplain connection.
- Establish an appropriate meander beltwidth where feasible. The meander beltwidth is the lateral distance utilized by a stream in order to meander. The minimum geomorphically appropriate beltwidth generally equates to the amplitude of one mature meander bend. Establishing an appropriate beltwidth will allow the river to function more naturally within a specified corridor while allowing a separate area for development and agriculture outside the beltwidth. In this way, infrastructure and development can be established in areas that will not require continual maintenance resulting from flood damage and the river can be allowed to function more naturally.
- Reduce embeddedness by filtering silt and sand from stormwater by routing stormwater flow through existing or constructed wetlands.

Force Process

- Where appropriate, build engineered log jams or boulder obstructions at the head of strategic point bars to force a percentage of flow across the back of the bar creating a back-bar side channel that is active across a wide range of flows. Boulder clusters become less appropriate in most portions of Reaches 5 and 6 where the distance to bedrock (the source of boulders) is greatest.
- Build engineered log jams to force channel migration into areas of accessible floodplain and away from developments or other vital infrastructure. Promoting channel migration will recruit gravel, promote bar building, improve riffle-pool formation, and generally enhance hydraulic complexity.
- Build engineered riffles with V-shaped cross-sections focusing flow into high-velocity chutes scouring pools downstream of the riffle (Newberry, 2008, 2010). This type of application can create vertical in-stream complexity where lateral dynamism (channel migration and bar building) is unrealistic due to constraints or unachievable due to channel confinement (Figure 27). This treatment is especially applicable in Reaches 2 and 3.
- Reduce overall in-stream width-to-depth ratio by adding bank structure, creating islands (split flow) and improving riparian conditions. Lower width-to-depth ratios improves thalweg development and improves shade and bank cover. This treatment is especially applicable in Reaches 1-3.

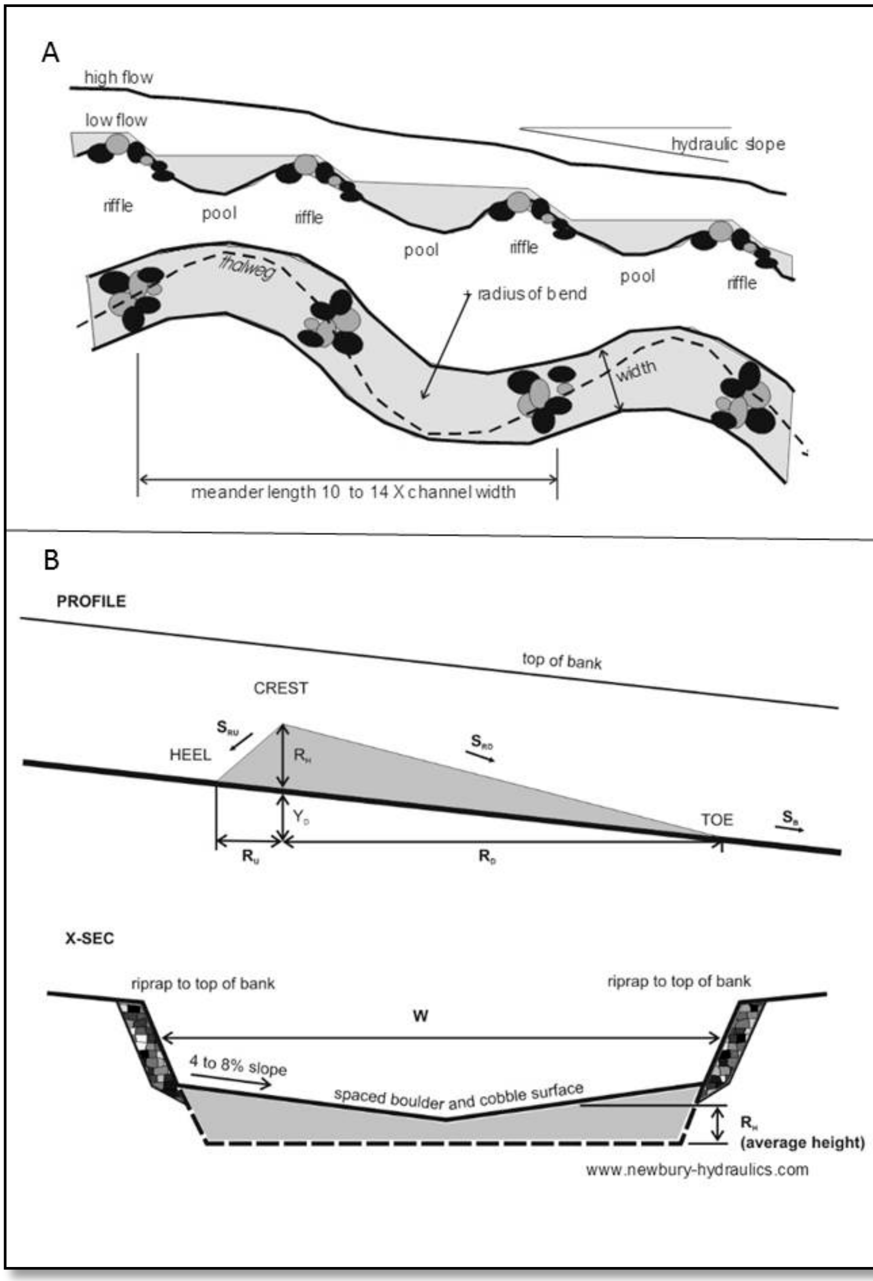

Figure 27: Schematic of riffle design as described by Robert Newbury (Newbury, 2008, 2010). Riffles can be used to constrict flow vertically forcing a transition from subcritical to supercritical and back to subcritical flow resulting in a riffle-chute-pool morphology respectively. Diagram "A" illustrates a typical profile and plan-view of a riffle sequence. Diagram "B" illustrates typical single riffle profile and cross section schematics where: S_{RU} = Slope of upstream riffle face; S_{RD} = Slope of downstream riffle face; S_a = Channel slope; R_H = Riffle height; Y_D = Height of bed at crest above toe; R_U = Distance of heal to crest; R_D = Distance of crest to toe; W = Average width of flow.

Construct Appropriate Forms

- Excavate side channels (e.g.: Alta Harris Ranch Creek) or excavate improved inlets/outlets to topographic low areas effectively creating side channels taking advantage of existing topography (e.g.: Loggers Creek). Side channels can simultaneously enhance geomorphic function, improve hydraulic complexity and reduce flood risk.
- Improve in-stream hydraulic complexity by adding obstructions including LWM and boulder clusters. In-stream structures force flow contraction and expansion forming localized pools and riffles aiding the development of a well-defined thalweg.
- Place whole trees and pieces of LWM into off-channel features including side-channels, sloughs and alcoves to promote scour pool development during high flows, stabilize banks, and provide shade/cover.

Target Conditions and Recommended Actions per Reach

Following are proposed target geomorphic conditions and recommended actions that can be utilized to achieve those conditions:

Reach 1 – Boise Diversion Dam to Barber Dam

REACH 1		
Channel Metric	**Existing Conditions**	**Target Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.2	1.3
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Plane-Bed	Pool riffle with multiple split-flows
Rosgen Classification Classification system specific to channel forms and bed composition (Rosgen, 1998)	F3 Entrenchment ratio < 1.4	C3 (entrenchment ratio >2.2)
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	45	25
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	2.5, 5, 12 below Boise Diversion Dam, becoming predominantly sand above Barber Dam	2.5, 5, 12
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	Low	Low
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	Moderate immediately below Boise Diversion Dam; Low above Barber Dam	Moderate (allowing annual bed mobility)
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0005	0.0015-0.0020
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Low	High (to support split flow)
Bank Composition Average grain size of bank material	Gravel and sand become primarily sand upstream of Barber Dam	Gravel-sand
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Grass-shrub dominated, continuous	Tree-shrub dominated, continuous, broad
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	Less than 50ft	650
Meander Belt Width (ft) Equivalent to a single meander amplitude; required for "natural" channel migration	325	1000 feet or greater
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	High flow side channels and perennial wetlands	Split flows, perennial side channels, and wetlands
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	Not Measured	Not Measured
Primary Landuse	Undeveloped	Undeveloped

Target Form

- Island-braided reach with multiple channels and in-stream flow obstructions
- Lower width-to-depth ratio
- Higher gradient
- Bed grain size diversity
- Active floodplain inset between terraces

Recommended Actions

Protect

- Extensive wetlands located along existing high-flow side channels south of the main channel should be protected from development and their connection to the main stem channel should be maintained or improved.

Improve Natural Process

- Remove or allow for the temporary lowering of Barber Dam during high flow to reestablish a more natural flow regime and gradient thereby enhancing in-stream velocity and sediment transport competency. In so doing, the river would rapidly incise through the existing sand substrate, reestablishing a cobble-gravel bed. Natural channel evolution models suggest that following incision the channel would widen and create an inset floodplain (Figure 28) (Schumm, 1985; Simon and Rinaldi, 2006; Cluer and Thorne, 2014). Due diligence assessment of the entrainment and subsequent downstream transport of the sediment created by this action will need to be completed to assess the risk and ultimate feasibility of this potential action. Rough estimates suggest nearly 400,000 cubic yards of deposited sand and gravel are trapped behind Barber Dam, which would be made incrementally available to the lower river system given removal of the dam. It should also be noted that removal of Barber Dam would lower the water table in the reach, possibly having negative effects on the wetlands in the area.

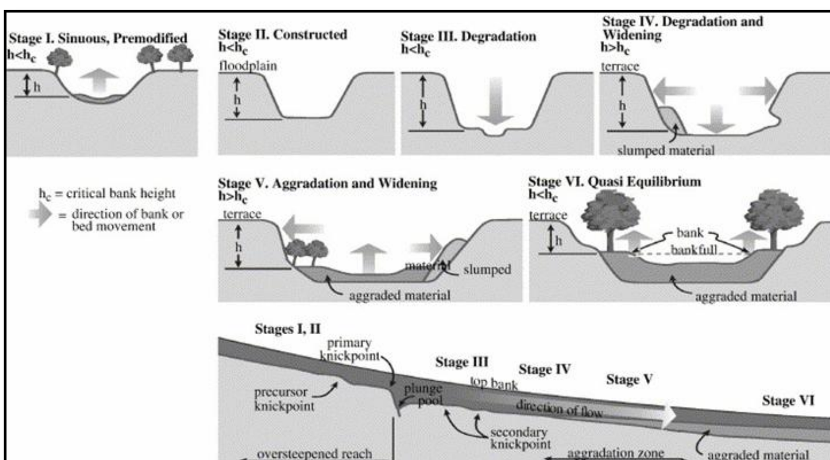

Figure 28: Channel Evolution Model (Simon and Rinaldi, 2006).

Force Process

- Build mid-channel obstructions (e.g.: engineered log jams) to force flow expansion and channel widening accelerating natural channel evolution and the formation of an inset floodplain between the existing terraces. This action could occur with or without the removal of Barber Dam depending on stakeholder goals and objectives. Formation of an inset floodplain will enable the long-term establishment of a forested riparian area capable of naturally stabilizing the banks thereby facilitating a lower width-to-depth ratio, increased LWM recruitment, and improved hydraulic complexity.

Construct Appropriate Forms

- Allowing natural and forced processes to develop enhanced geomorphic conditions may take several years or decades. Excavating an inset floodplain and/or improved side channels emulating the likely product of natural channel evolution provides immediate enhancement to the reach while maintaining geomorphic continuity.

Summary

Establishing mid-channel bars, islands and a well-vegetated inset floodplain between the existing terraces is the most geomorphically important enhancement action for Reach 1. These conditions will facilitate the natural establishment of a more appropriate (lower) width-to-depth ratio, recruitment and retention of LWM, development of pools and improved overall hydraulic complexity over the long-term.

Reach 2 – Barber Dam to Americana Blvd.

REACH 2		
Channel Metric	**Existing Conditions**	**Target Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.1	1.2
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Pool-Riffle with plane-bed sub-reaches	Pool-Riffle with multiple split-flows
Rosgen Classification Classification system specific to channel forms and bed composition (Rosgen, 1998)	F3 Entrenchment Ratio < 1.4	C3 (entrenchment ratio >2.2)
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	25	20
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	2.5, 5, 12	2.5, 5, 12
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	Moderate	Low
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	High	Moderate; occasional bed mobility
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0024	0.0024
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Low; primarily man-made (bridge piers)	Moderate; low-profile bank structures and boulders safe for recreational users
Bank Composition Average grain size of bank material	Cobble-gravel; rip-rap common	Cobble-gravel; less rip-rap
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Tree-shrub dominated; continuous; narrow	Tree-shrub dominated, continuous and wide
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	90	1000
Meander Belt Width (ft) Equivalent to a single meander amplitude; required for "natural" channel migration	150	800 feet or greater
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	Occasional side-channels, alcoves, and minor wetlands	More connected perennial side channels and alcoves; protected wetlands and riparian buffer
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	224	224
Primary Landuse	Urban	

Target Form

- Hydraulic complexity derived from in-stream flow obstructions including low-profile bank barbs
- Localized pools and riffles
- Well-defined, sinuous thalweg
- Greater connection to the floodplain including frequent side channels and back-bar channels active over a broad range of flows

Recommended Actions

Protect

- Functioning side channels: Logger's Creek and Alta Harris Ranch Creek
- Riparian buffer: especially Bethine Church Birding trail area and riparian area north of channel along Warm Springs Road
- Any area within the active floodplain that has not been developed.

Improve Natural Process

- Remove or improve existing irrigation diversion structures as discussed in the "General Recommendations" section.
- Remove or set-back levees as discussed in the "General Recommendations" section.
- Promote bank erosion and channel migration where feasible as discussed in the "General Recommendations" section.

Force Process

- Build a series of low-profile, in-stream bank barb structures along otherwise straight, homogenous sub-reaches to strategically force flow convergence toward alternating banks establishing a well-defined and sinuous thalweg (Figure 29). These structures should be built such that the top can host riparian vegetation which would provide year-round cover and increase long-term structure stability. Through the urban corridor, it may not be feasible to allow significant channel migration and the formation of a more sinuous channel, but it may be possible to emulate the pool-riffle morphology associated with a more sinuous channel by forcing the establishment a sinuous thalweg. A well-defined, sinuous thalweg also serves to reduce the width-to-depth ratio of the channel particularly during periods of low-flow when bank structure may otherwise be scarce.
- Build engineered log jams or boulder obstructions to enhance side channels as discussed in the "General Recommendations" section.
- Build V-shaped engineered riffles to force flow convergence forming a series of pools and riffles as discussed in the "General Recommendations" section.

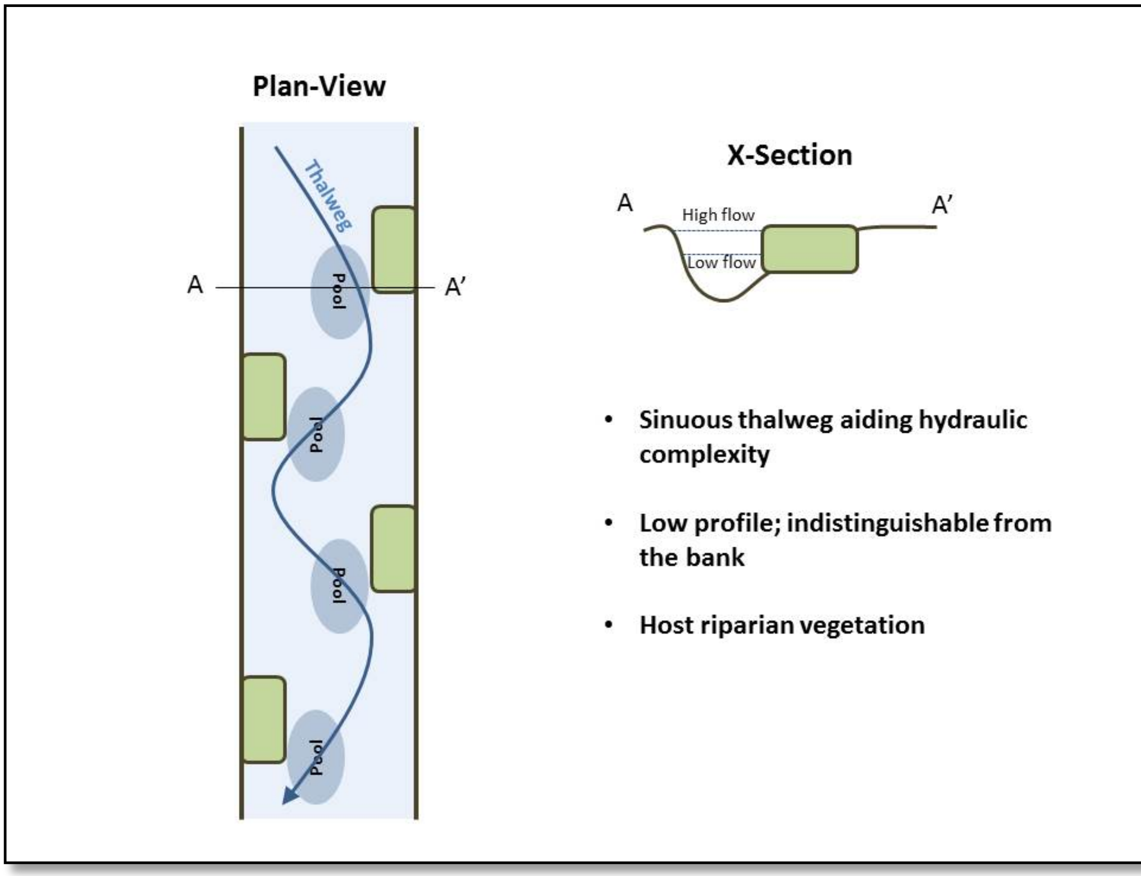

Figure 29: Low-profile barbs constructed to force flow convergence resulting in a sinuous thalweg and riffle-pool formation.

Construct Appropriate Forms

- Excavate side channels as discussed in the "General Recommendations" Section.
- Excavate pools adjacent existing and newly constructed in-stream obstructions. With regulated flows, it is rare that high flows produce enough volume, velocity and in-stream shear to scour many pools in the heavily armored cobble bed of the river. Mechanically excavating pools is appropriate if located such that an existing or new in-stream obstruction can prevent the pool from filling with available sediment (primarily sand) over time.

Summary

Establishing a well-defined and sinuous thalweg with more frequent side-channels and associated in-stream obstructions will emulate a more natural geomorphic morphology without disregarding the existing and real constraints associated with an urban river corridor. Where feasible, levees can be removed or set-back improving local floodplain connection as well as providing greater floodwater storage and conveyance potentially reducing flood risks to adjacent areas.

Reach 3 – Americana Blvd. to Eagle Island

REACH 3		
Channel Metric	**Existing Conditions**	**Target Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.1	1.2
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Pool-Riffle	Pool-Riffle
Rosgen Classification Classification system specific to channel forms and bed composition (Rosgen, 1998)	F3 Entrenchment Ratio < 1.4	C3 (entrenchment ratio >2.2)
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	23	20
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	2, 4.5, 10	2, 4.5, 10
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	Moderate	Moderate
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	High	Moderate; allowing occasional bed mobility
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0026	0.0026
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Moderate; Primarily man-made (e.g.: bridge piers)	High; low-profile bank structures, boulders, and LWM where feasible
Bank Composition Average grain size of bank material	Cobble-gravel; rip-rap	Cobble-gravel
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Tree-shrub dominated; continuous; narrow	Tree-shrub dominated, continuous and broad
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	140	1300
Meander Belt Width (ft) Equivalent to a single meander amplitude; required for "natural" channel migration	160	600 feet or greater
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	Occasional side-channels, alcoves, and minor wetlands	More connected perennial side channels and alcoves; protected riparian buffer
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	202	202
Primary Landuse	Urban	

Target Form

- Hydraulic complexity derived from in-stream flow obstructions including low-profile bank barbs
- Localized pools and riffles
- Well-defined, sinuous thalweg
- Greater connection to the floodplain including frequent side channels and back-bar channels active over a broad range of flows

Recommended Actions

Protect

- Existing side channels including immediately downstream of Willow Lane park (best example of a side channel within study area).
- Existing established riparian areas including adjacent Veteran's Memorial Bridge, the wetland area immediately downstream of Willow Lane Park, and the area upstream and adjacent to Glenwood Bridge.
- Any area within the active floodplain that has not been developed.

Improve Natural Process

- Remove or improve existing irrigation diversion structures as discussed in the "General Recommendations" section.
- Remove or set-back levees as discussed in the "General Recommendations" section. For example, strategically remove, breach or lower levees to allow flooding into gravel pits, ponds and undeveloped areas to expand floodplain connection and improve floodwater storage and flood conveyance. This strategy has been shown to provide valuable flood storage and long-term habitat in the Yakima River Basin, among others (Nelson, et al. 2015). A good candidate for this treatment includes the pond series in Ester Simplot Park (Quinn's Pond, Ester Simplot Pond I and II, and Veteran's Pond). Hydraulic modeling of a 10,000 cfs flood suggests that strategically lowering portions of the levee along these ponds can lower the overall floodwater elevation by as much as 1.5ft and reduce the floodwater elevation for several thousand feet upstream. Additionally, the levee system bordering and immediately downstream of Willow Lane Park could be set back allowing an improved meander corridor, greater opportunity for side channel development, and/or expanded floodplain connection – all of which would improve floodwater storage, flood conveyance, and overall geomorphic function.
- Build V-shaped engineered riffles to force flow convergence forming a series of pools and riffles as discussed in the "General Recommendations" section.
- Promote bank erosion and channel migration where feasible as discussed in the "General Recommendations" section.

Force Process

- As with Reach 2, build a series of low-profile, in-stream bank barb structures along otherwise straight, homogenous sub-reaches to strategically force flow convergence toward alternating banks establishing a well-defined and sinuous thalweg. These structures should be built such that the top can host riparian vegetation which would provide year-round cover and increase long-term structure stability. Through the urban corridor, it may not be feasible to allow significant channel migration and the formation of a more sinuous channel, but it may be possible to emulate the pool-riffle morphology associated with a more sinuous channel by establishing a sinuous thalweg. A well-defined, sinuous thalweg also serves to reduce the width-to-depth ratio of the channel particularly during periods of low-flow when bank structure may otherwise be scarce.
- Build engineered log jams or boulder obstructions to enhance side channels as discussed in the "General Recommendations" section.

Construct Appropriate Forms

- Place LWM into off-channel features as discussed in the "General Recommendations" section.
- Excavate side channels or build improved inlets/outlets as discussed in the "General Recommendations" (e.g.: side channel adjacent the West Boise Waste Water Treatment Plant).
- Excavate pools adjacent existing and newly constructed in-stream obstructions. With regulated flows, it is rare that high flows produce enough volume, velocity and in-stream shear to scour many pools in the heavily armored cobble bed of the river. Mechanically excavating pools is appropriate if located such that an existing or new in-stream obstruction can prevent the pool from filling with available sediment (primarily sand) over time.

Summary

Establishing a well-defined and sinuous thalweg with more frequent side-channels and associated in-stream obstructions will emulate a more natural geomorphic morphology without disregarding the existing and real constraints associated with an urban river corridor. Where feasible, levees can be removed or set-back improving local floodplain connection as well as providing greater floodwater storage and conveyance potentially reducing flood risks to adjacent areas.

Reach 4 – North and South Channels at Eagle Island

REACH 4		
Channel Metric	**Existing Conditions**	**Target Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.2	1.3
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Pool-Riffle	Pool-Riffle
Rosgen Classification Classification system specific to channel forms and bed composition (Rosgen, 1998)	F3 (entrenchment ratio <1.4)	C3 (entrenchment ratio >2.2)
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	20	20
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	1.5, 5, 7	1.5, 5, 7
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	Moderate to Low	Low
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	High	Moderate; allowing occasional bed mobility
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0019	0.0019
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Low to moderate; man-made (e.g.: bridge piers), some LWM	High; Installed boulders and LWM. Additional LWM through recruitment
Bank Composition Average grain size of bank material	Gravel-cobble, some sand	Gravel-cobble, some sand
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Tree-shrub dominated, continuous and narrow	Tree-shrub dominated, continuous and broad
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	North Channel: 170 South Channel: 170	2200 total width
Meander Belt Width (ft) Equivalent to a single meander amplitude; required for "natural" channel migration	North Channel: 110 South Chanel: 110	600 feet or greater
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	Split flow; few side channels; many gravel quarry pits and small ponds	Split flow; more side channels and alcoves; floodplain connection to gravel pits
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	187	
Primary Landuse	Suburban	

Target Form

- Split flow
- Many localized pools and riffles
- Hydraulic complexity derived from in-stream flow obstructions including LWM recruitment and meander bends
- Well-defined, sinuous thalweg
- Increased flood conveyance and greater connection to the floodplain including gravel pits
- Improved channel migration where feasible
- Densely vegetated and broad riparian area

Recommended Actions

Protect

- Existing established riparian areas including the riparian buffer around Eagle Road Bridge on North Channel)
- Existing natural in-stream structure (LWM)
- Any area within the active floodplain that has not been developed.

Improve Natural Process

- Remove or improve existing irrigation diversion structures as discussed in the "General Recommendations" section.
- Remove or set-back levees as discussed in the "General Recommendations" section. Similar to Reach 3, strategically removing, breaching or lowering levees to allow flooding into gravel pits, ponds and undeveloped areas can significantly lower the overall floodwater elevation locally and for several thousand feet upstream. In the long-term, these gravel pits could be filled to an appropriate floodplain elevation and reopened as vegetated terrestrial floodplain and/or meander corridors for the north and south channels with an offset levee if necessary.
- Connect existing floodplain ponds by creating strategically located low swales or culverts to improve floodwater conveyance through neighborhoods. Where feasible, creating floodways using existing interconnected ponds and streets will increase flood conveyance and focus flood flows away from buildings and other above-ground infrastructure potentially reducing overall flood risk in the areas adjacent this reach. Increased through-flow of floodwater to off-channel features such as ponds and wetlands will also enhance the geomorphic processes maintaining these features and/or improve sediment and nutrient cycling.
- Promote bank erosion and channel migration where feasible as discussed in the "General Recommendations" section.

Force Process

- Historically, the primary mechanism of hydraulic diversity in the lower reaches was in-channel LWM forcing flow contraction and expansion. In the short-term, this process could be partially emulated through the construction of LWM flow obstructions with the goal of creating localized pools and hydraulic diversity. Over time, improving riparian condition would produce denser stands of trees, and channel migration would recruit woody debris as a source of long-term hydraulic diversity.
- As with Reaches 2 and 3, build a series of low-profile, in-stream bank barb structures along otherwise straight, homogenous sub-reaches to strategically force flow convergence toward alternating banks establishing a well-defined and sinuous thalweg. These structures should be built such that the top can host riparian vegetation which would provide year-round cover and increase long-term structure stability. Through the suburban corridor, it may not be feasible to allow significant channel migration and the formation of a more sinuous channel, but it may be possible to emulate the pool-riffle morphology associated with a more sinuous channel by forcing the establishment a sinuous thalweg.
- Build engineered log jams or boulder obstructions to enhance side channels as discussed in the "General Recommendations" section.
- Build engineered log jams to force channel migration as discussed in the "General Recommendations" section.

Construct Appropriate Forms

- Place LWM into off-channel features as discussed in the "General Recommendations" section.
- Excavate side channels or build improved inlets/outlets as discussed in the "General Recommendations".

Summary

Maintain split flow conditions while strategically improving in-stream hydraulic complexity with LWM, and improve channel migration and floodplain activation by removing or setting-back levees allowing flood access to undeveloped areas and gravel pits where feasible. Establish a broad riparian corridor where trees can mature, and future channel migration can recruit LWM to the river providing long-term structure and diversity.

Reach 5 – Eagle Island to Caldwell AND Reach 6 – Caldwell to Snake River

REACH 5		
Channel Metric	**Existing Conditions**	**Target Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.2	1.3
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Primarily Plane-Bed	Pool-Riffle
Rosgen Classification Classification system specific to channel forms (with levees) and bed composition (Rosgen, 1998)	F4 (entrenchment ratio < 1.4)	C4 (entrenchment ratio >2.2)
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	27	20
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	1.5, 4.5, 6	1.5, 4.5, 6
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	High	Moderate to Low
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	High	Moderate; allowing occasional bed mobility
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0017	0.0017
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Low; man-made (e.g.: bridge piers and diversions)	High; Additional LWM through recruitment
Bank Composition Average grain size of bank material	Gravel-cobble, some sand; rip-rap common	Gravel-cobble, some sand; less rip-rap
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Tree-shrub dominated, discontinuous and narrow	Tree-shrub dominated; continuous and broad
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	300	2900
Meander Belt Width (ft) Equivalent to a single meander amplitude; required for "natural" channel migration	185	900 feet or greater
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	Many short, active back-bar channels	Additional and longer side channels; split flows
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	147	147
Primary Landuse	Agricultural	

REACH 6		
Channel Metric	**Existing Conditions**	**Target Conditions**
Sinuosity (ft/ft) Channel length along the thalweg divided by valley length	1.2	1.2
Montgomery-Buffington Channel Morphology Classification system specific to the processes and forms of mountainous streams (Montgomery and Buffington, 1997)	Primarily Plane-Bed	Plane-bed with localized pools and riffles
Rosgen Classification Classification system specific to channel forms (with levees) and bed composition (Rosgen, 1998)	F4 (entrenchment ratio < 1.4)	C4 (entrenchment ratio >2.2)
W:D Ratio (ft/ft) Representative bankfull channel width divided by average channel depth	33	25-27
Bed Composition: D50, D85, D100 (in) D50 = median grain size of bed, D85 = 85% of material is finer, D100 = upper threshold of material transported in stream (based on ocular estimates)	1.5, 3, 5	1.5, 3, 5
Embeddedness Qualitative measurement of sand/silt filling interstitial space of bed material on a relative scale from Low to High	High	Moderate to Low
Bed Armoring Qualitative measurement of the amount of coarse material covering finer material on the bed on a relative scale from Low to High	Moderate to High	Armoring with some grain turnover
Channel gradient (ft/ft) Average slope of channel defined as thalweg length divided by elevation difference	0.0013	0.0013
In-channel Structure In-channel structures obstruct flow (e.g.: boulders and woody material) Low (Primarily lacking) to High (Prevalent)	Low; man-made (e.g.: bridge piers and diversions)	Many additional flow obstructions
Bank Composition Average grain size of bank material	Sand-silt over gravel	Sand-silt over gravel
Riparian Condition Riparian vegetation type and continuity of riparian buffer	Grass-shrub dominated, poor condition; narrow and discontinuous	Tree and shrub dominated; continuous broad riparian buffer
Average Floodplain Width (ft) Width of active floodplain on both sides of the channel (excluding the channel width)	780	6,600
Meander Belt Width (ft) Equivalent to a single meander amplitude; required for "natural" channel migration	170	1000 feet or greater
Floodplain Features Off-channel features within the active floodplain (e.g.: side channels, alcoves, sloughs and wetlands)	Many small side channels and back-bar channels	Additional longer side channels
Drainage Density Area of main channel and tributaries divided by total drainage area. A high drainage density may correspond with a more flashy hydrograph	184	184
Primary Landuse	Agricultural	

Target Form

- Many split flows around islands; many, diverse side-channels activated across a broad range of flows
- Hydraulic complexity derived from in-stream flow obstructions including LWM recruitment and meander bends
- Many localized pools and riffles
- Well-defined thalweg
- Improved channel migration where feasible
- Well-connected, densely vegetated, continuous, and broad riparian buffer

Recommended Actions

Protect

- Existing established riparian areas including broad riparian buffers (greater than 100ft) Some notable examples include the Fort Boise WMA near the confluence with the Snake River and Curtis Park upstream of Caldwell in Reach 5.
- Existing natural in-stream structure (LWM); especially those forming/maintaining split flows, side channels, and large pools.
- Any area within the active floodplain that has not been developed.

Improve Natural Process

- Remove or set-back levees as discussed in the "General Recommendations" section. Reaches 5 and 6 possess the greatest area of potential active floodplain if not for levees and other barriers. Levee removal or setback only refers to allowing passage of floodwater and does not imply promoting bank erosion and channel migration which can affect property boundaries. Frequent flooding across agricultural fields has the potential to reestablish nutrient and sediment cycles that can improve soil conditions and off-channel processes. Additionally, improved floodplain connection can elevate water tables and improve sub-irrigation capabilities reducing the need for surface-water diversions.
- Promote bank erosion and channel migration where feasible as discussed in the "General Recommendations" section.
- Remove or improve existing irrigation diversion structures as discussed in the "General Recommendations" section.

Force Process

- Historically, the primary forcing mechanism creating hydraulic diversity in the lower reaches was in-channel LWM forcing flow contraction and expansion. In the short-term, this process can be emulated through the construction of engineered log jams to create localized pools and enhance hydraulic diversity. Over time, improving riparian conditions will produce denser stands of trees, and channel migration will recruit woody debris providing a source of long-term hydraulic diversity.

- Build engineered log jams to force split flows and the formation of islands. Log jams are common hard-points providing structure and form to streams and floodplains of low-gradient alluvial rivers. Specifically, apex log jams (located at the apex of bars and islands) work to split and maintain flow around islands facilitating target conditions over the long-term.
- Build engineered log jams or boulder obstructions to enhance side channels as discussed in the "General Recommendations" section.
- Build engineered log jams to force channel migration as discussed in the "General Recommendations" section.

Construct Appropriate Forms

- Place LWM into off-channel features as discussed in the "General Recommendations" section.
- Excavate side channels or build improved inlets/outlets as discussed in the "General Recommendations".

Summary

Promote split flows and island formation with a broad, densely vegetated riparian area and active floodplain. Remove or set-back levees where feasible to accommodate target conditions. Utilize constructed log jams over the short-term and naturally recruited LWM over the long-term to promote and maintain split flows, side channels, and a high degree of hydraulic complexity.

Conclusions

The Boise River is one of the principal gems defining in the Treasure Valley. In order to maintain this treasure one must also maintain the gems from which it is comprised. The geomorphic condition of the lower Boise River has undergone many significant and arguably deleterious changes over the past 150 years. Most notably the hydrologic and sediment regimes have been severely altered by a series of large dams upstream of the study area as well as urban and agricultural development encroaching upon the floodplain within the study area. It is impractical and unrealistic to consider restoring the lower Boise River to a condition equivalent to that of the pre-dam, pre-urban and agricultural development conditions, but working within these existing constraints, there remain many potential actions that can be taken to enhance the geomorphic character of the Boise River. The authors hope that this assessment can be added to the body of knowledge surrounding the lower Boise River to help inform knowledgeable and progressive decisions regarding the future enhancement and development of this valuable and unique gem.

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