RIVERDALE CITY COUNCIL AGENDA-AMENDED
CIVIC CENTER - 4600 S. WEBER RIVER DR.
TUESDAY – MARCH 6, 2012

5:00 p.m. – Council River Restoration Site Visit
(Meet at Civic Center for 5 p.m. departure)

RiverRestoration.org Flood Assessment Map for Riverdale City 2011

1. Weber River Parkway Collapse

2. Riverdale Kayak Park, Grade Control and Riprap Failure

3. Failed Bank Stabilization along the Weber River Trail

4. Creekside Trailhead Path Erosion and Weber River Trail Bank Erosion Upstream of River Glen Subdivision

Riverdale City 2011 Flood Damage Assessment prepared by RiverRestoration.org

Adjournment

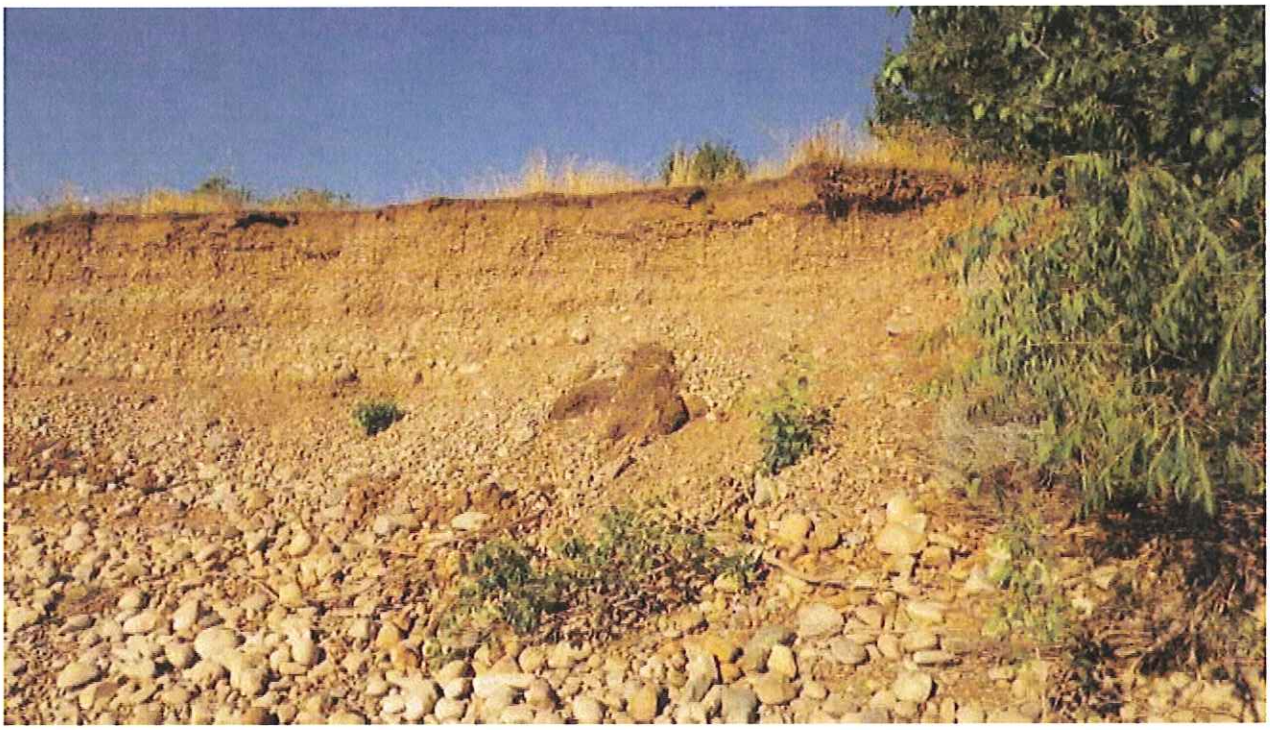
- The public is invited to attend all Council meetings.
- In compliance with the Americans with Disabilities Act, persons in need of special accommodation should contact the City Recorder at 394-5541 x 1232.
- This agenda has been properly posted and a copy provided to local news media.

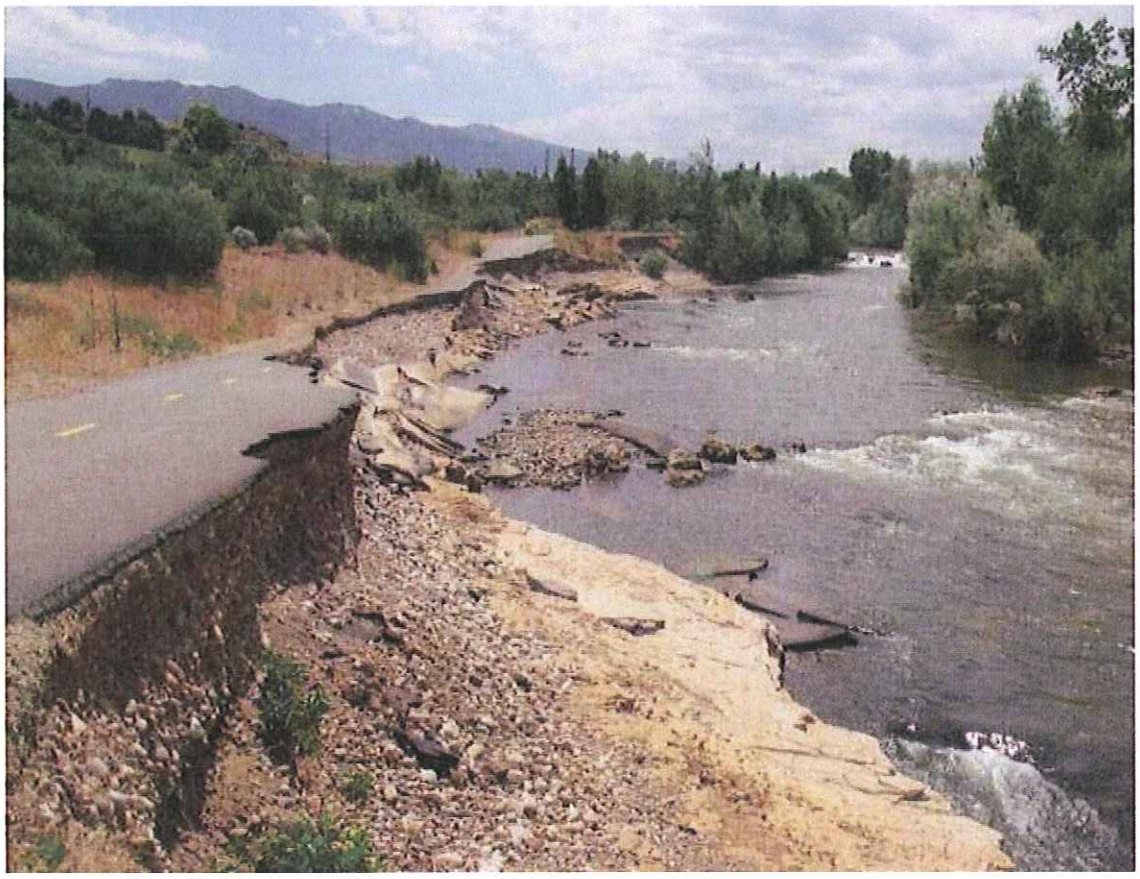
Figure 9-Flood Damage Sites

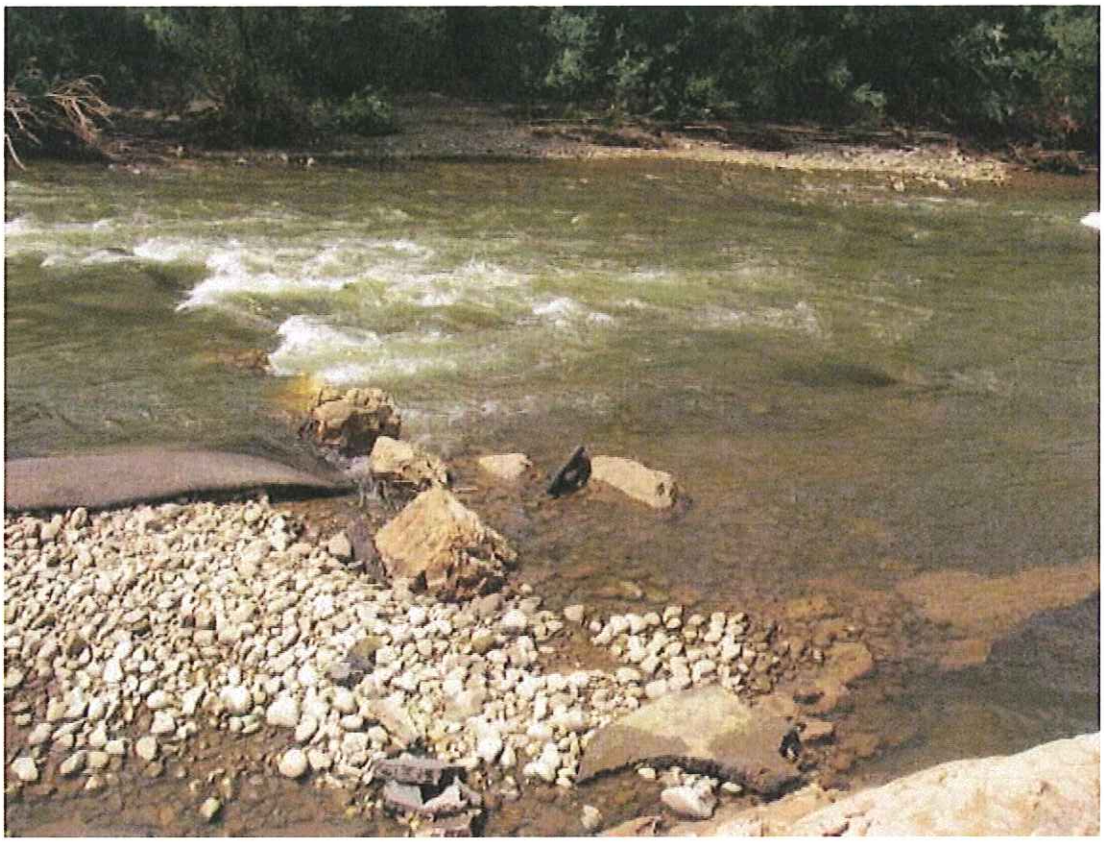
APPENDIX A-Flood Damage Assessments

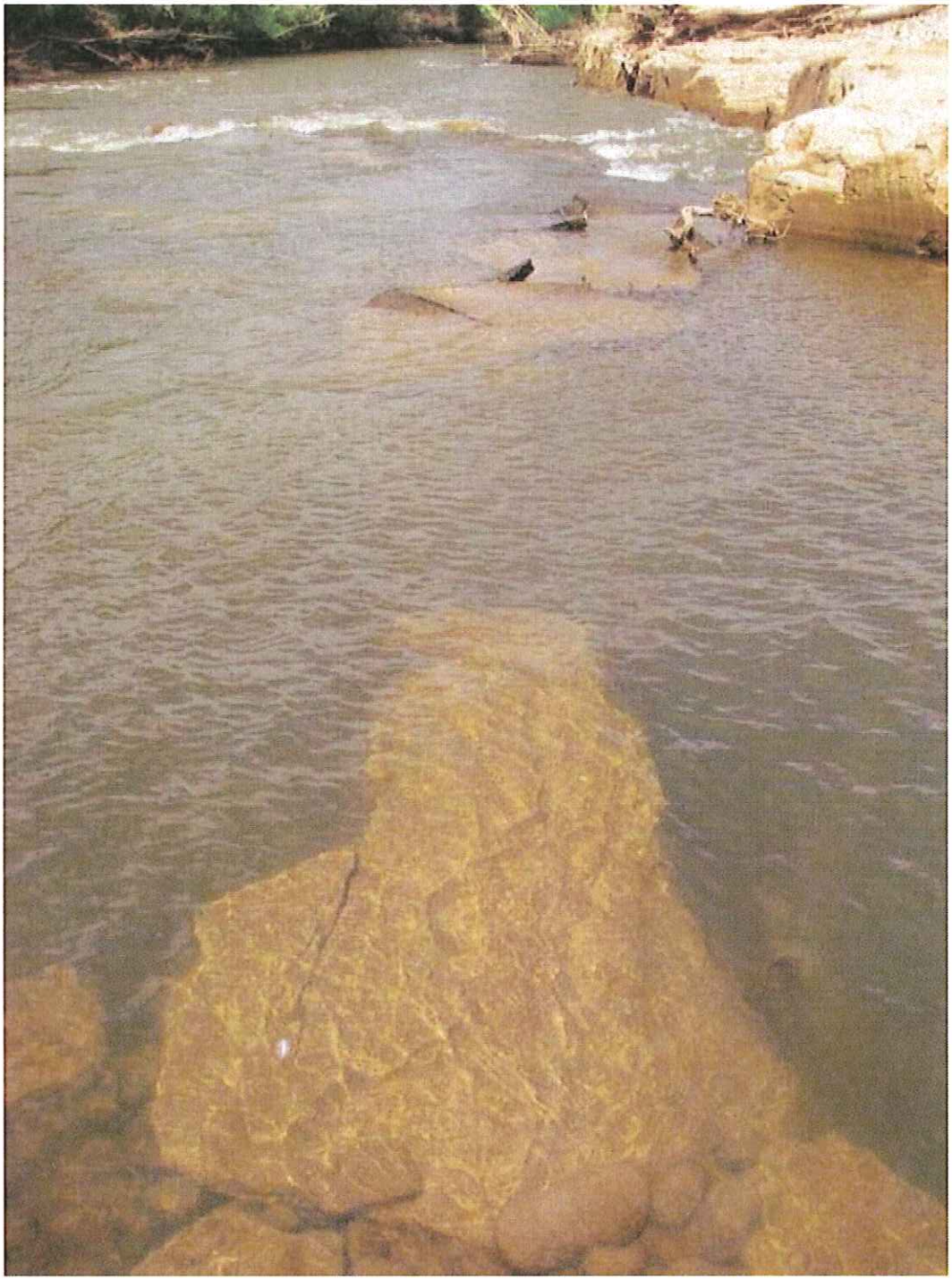
Flood Assessment Point:	**#1-Weber River Parkway Collapse**
GPS Coordinates:	Waypoints RC-10 to 29
Direction to Assessment Point:	Approximately 5260ft upstream from Weber River Dr. on bike path.
Project Priority:	High X Moderate Low
Description of Issue:	Sever erosion of nearly 550 ft of bank resulting in collapse of 300' of asphalt pathway.
Structures:	Bike Path
Geomorphic Description:	Aerial photographs from 1953, 1954, 1971, 1973, 1979, 1980, 1997, 2003, 2006, and 2009 were reviewed to understand the geomorphic evolution of this reach. This portion of the Weber River was channelized in the early 1970's for the construction of I-84. Prior to channelization this reach had meanders with a similar planform to the upstream DNR reach as it exists today. Aerial photography from 1953 shows that the reach length has been reduced by over 20% (7500 feet to 5800 ft). In addition to decreasing the length and a subsequent decrease in slope the construction of the highway also narrowed the effective floodplain of the river. Historic channel patterns are also evident in the 1953 photo. These patterns indicate that the Weber River may have had a meander belt width in excess of 1500ft. Aerial Photographs from 1999 and 2009 show that virtually all of the meanders have been eliminated through channelization and the riparian corridor is less than 150 ft wide. In addition to the channelization a water main crossing was placed just upstream of the failed bike path (RC-9) creating a large drop structure. The river has responded to these changes by cutting into the right bank as it attempts to adjust its flow path length. The river was cutting at this bank prior to the construction of the path in 2009. Between 1997 and 2006 the bank eroded a horizontal distance of approximately 55-60 ft. Some of this bank loss was reclaimed with the construction of the path in 2009. The 1971 photo shows a mid-channel bar formed immediately across the river from the area of the failed bike path. Portions of this bar were left unaltered during the construction of the highway. It is likely that during high flows this mid channel bar become inundated and provided extra conveyance. During the extended drought period that ended in 2008 riparian vegetation was established on this bar thus closing off any significant conveyance. The lack of overbank flooding and the establishment of mature riparian vegetation has effectively eliminated any overbank

	conveyance through this reach. Additionally there is evidence of bank toe erosion throughout this reach, indicating that the river is down cutting. Evidence of overbank flooding at downstream end of bank failure. Large amounts of driftwood caught in overgrown understory may have decreased overbank conveyance.
Habitat Considerations:	Throughout this reach there is a lack of habitat diversity. Channelization has created uniform flow patterns and in portions the riparian vegetation is sparse. There is little evidence of deposition through this reach. Eroded bank material is likely transported through the reach and deposited downstream of Riverdale City.
Flood Damage Repair	• $250,000-$350,000
Measures:	• Option 1 (Flood Damage Improved Project): o Reconstruct Bike path further northeast. o Biostabilize Bank o $50,000-$100,000 + Lands • Option 2 (Flood Damage Improved Project): o Reconstruct bike path in new alignment o Stabilize Toe o Lay river bank back at 3:1 and biostabilize o Thin out overgrown riparian vegetation on river left to open up flood conveyance channels. o $200,000 to $300,000 + Lands
Photographs:	





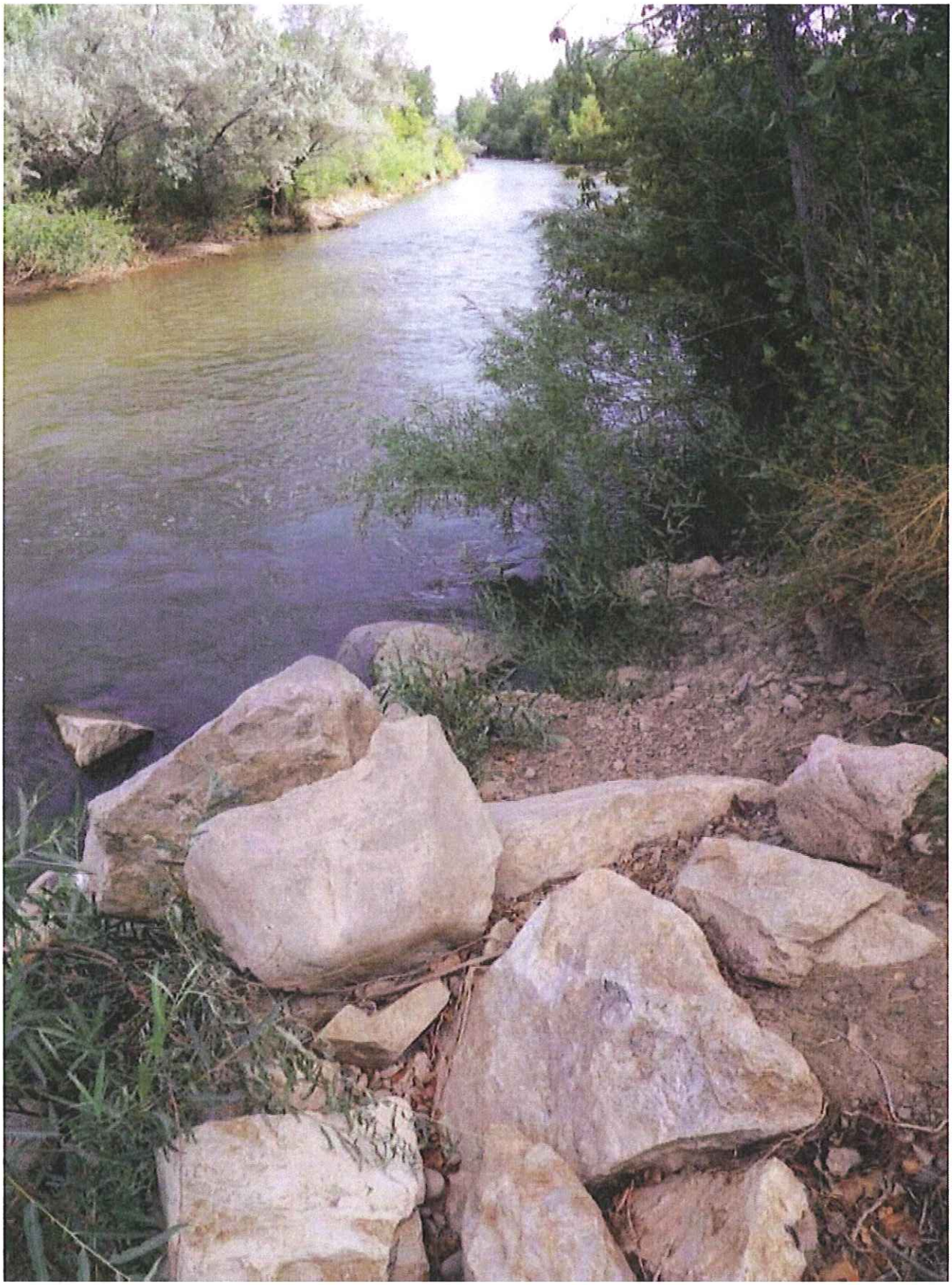


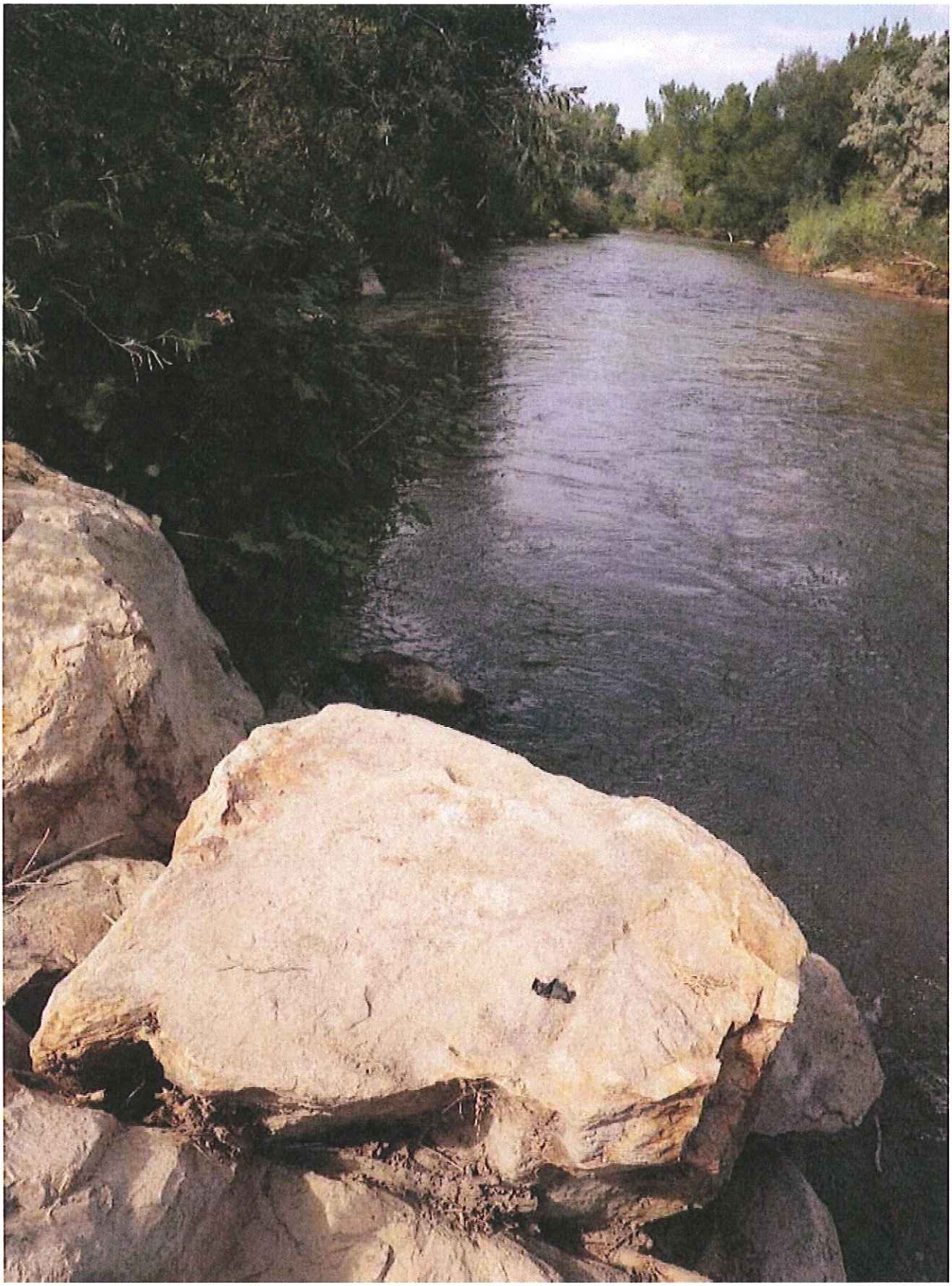


Flood Assessment Point:	**#4-Riverdale Play Park, Grade control and Riprap Failure**
GPS Coordinates:	8-16-11: Pts 9 & 10
Direction to Assessment Point:	Approximately 600 ft downstream on the bike path from the South Weber River Dr. trailhead.
Project Priority:	High X Moderate Low
Description of Issue:	Grouted Riprap appears to be failing and as a result the whitewater wave no longer functions. Probing indicates 8'deep hole upstream of the grouted grade control and an 8' deep hole downstream of the structure. Design drawings indicate that the cutoff wall above the lower drop is only 5' deep; it is likely that the grouted riprap has been undercut. Additionally the grouted grade control on the left bank between the two structures has also failed and there is significant erosion in the viewing area on the left bank at the lower drop. This erosion extend downstream over 350 ft. This is a High Priority project for a number of reasons: 1) the Riverdale Whitewater Park is a world class whitewater feature that brings tourism $ into Riverdale, 2) **Potential significant entrapment hazard to boaters/swimmers (There is a popular rope swing just upstream of the lower structure)**
Structures:	Sewer Line, Kayak Wave, Bike Path
Geomorphic Description:	This grouted grouted grade control structure was constructed in 2005. The primary goal of this structure is to protect the sewer line crossing. The structure was also designed to create a whitewater wave. Based on design drawings there is a 5' concrete cutoff wall upstream of the lower drop structure. Like much of the Weber River through Riverdale City, this reach has been channelized during the urbanization of Riverdale in the 1970s. Historically, this reach of the river was more similar to the upstream reaches that pass through the DNR property; it was a dynamic, aggrading system. The modified channel has a greater sediment transport capacity and is capable of transporting most of the alluvium supplied by the upstream reaches. As a result of this excess transport capacity the Weber river is degrading through much of Riverdale City. This is evidenced by bank toe erosion and little evidence of sediment deposition throughout the Riverdale reach. While it is difficult to assess the condition of the structure due to high flows, the presence of 8' deep holes upstream and downstream of the structure indicate that the 2011 flood flows were sufficiently large, and of a sufficient duration that they may have undercut the 5 foot cutoff wall and eroded under the grouted grade control. It is

	not uncommon for grouted grouted grade control structures to be undercut. Additionally, the downstream hydraulics have caused significant bank erosion on the right bank of the river. General channel degradation is likely downstream of the grade control structure. Due to the excessive channel scour the structure no longer functions as designed.
Habitat Considerations:	This structure provides better fish passage than the upstream drop structures.
Flood Damage Repair:	• $250,000-$350,000
Measures:	• Option 1 (Flood Damage Lower Structure Improved Project) o Re-Grout riprap o Fill voids under structure with Flowable Fill o Replace Cutoff Wall (sheet pile) o Biostablize Left Bank o Repair downstream grade control o $200,000-$300,000 • Option 2- (Replace Lower Structure, Alternate Project) o Remove grouted rip-rip o Construct new structure out of large boulders embedded below scour depth o Install pre-cast "Wave Blocks" to create play wave o Install Sheet pile cutoff. o Protect viewing area with boulder and flagstone o $350,000-$650,000
Photographs:	• IMGP0159 • IMGP0160 • IMGP0161 • IMGP 2796

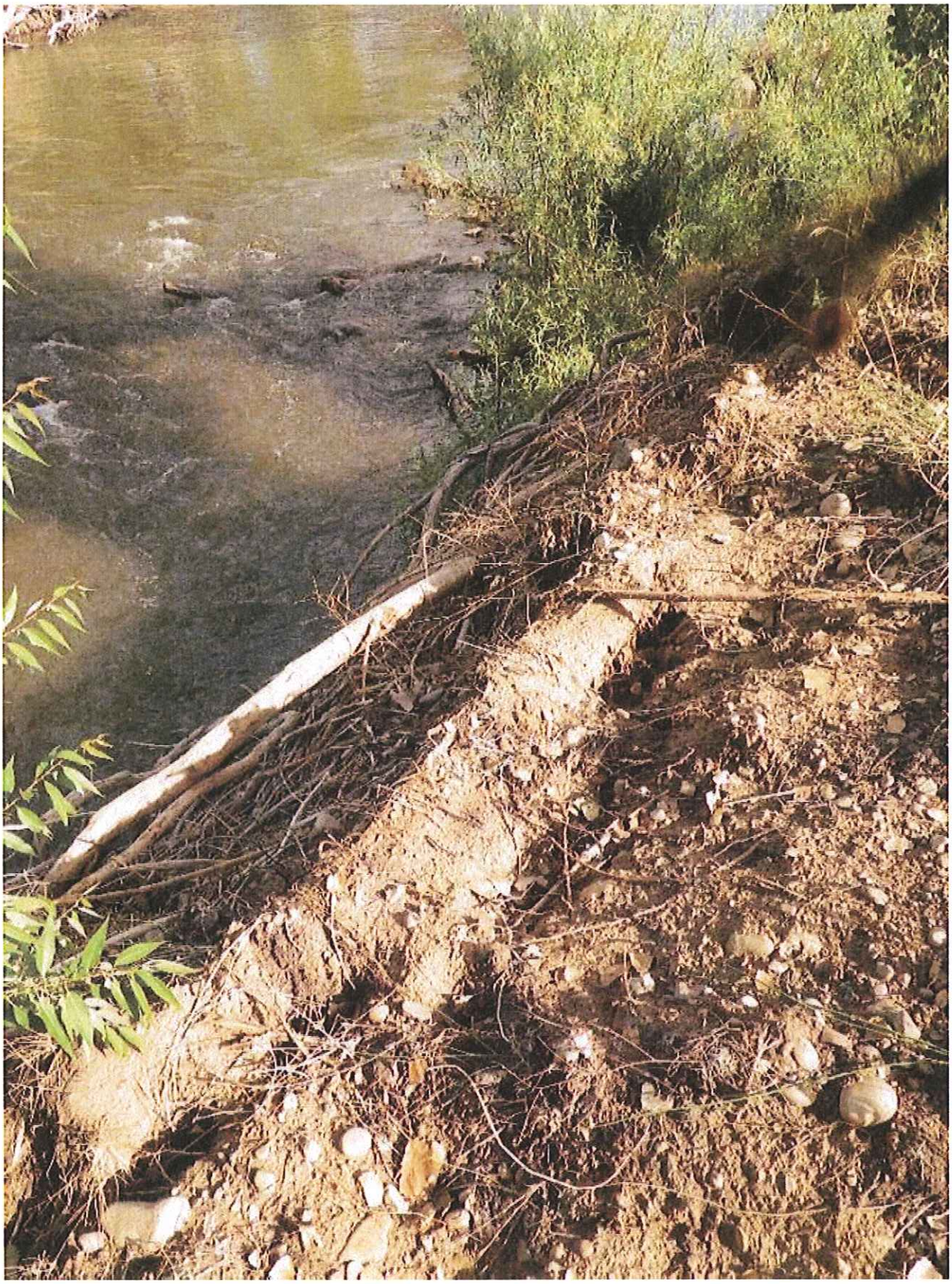
Flood Assessment Point:	**#10-Failed Bank Stabilization**
GPS Coordinates:	8-16-11 Points 46
Direction to Assessment Point:	This specific location is at the Junction of the Hunter Creek Trail and the Weber Parkway See also Failed J-Hooks Point 50 (8-16-11)
Project Priority:	High X Moderate Low
Description of Damage:	Non systemically planned constructed J-hooks and localized erosion
Structures:	J-hooks, Path
Geomorphic Description:	Similar to other location along the Weber River, these structure were placed to prevent bank erosion and the subsequent migration of the river channel. Installed in the 1980s or early 1990, these structures may have been intended to reduce shear stress on the bank by forcing the flow towards the centerline of the channel. Many of these structures were designed without consideration of systemic response. Other stabilization methods may be more appropriate for this location
Habitat Considerations:	j-hooks cause erosion which contributes to non-point source sediment pollution.
Flood Damage Repair:	• $20,000-$40,000
Measures:	• Option 1 (Flood Damage Replacement Project) o Remove J-hook structures o Use boulders for toe protection/Stabilization o Biostabilize bank o Toe Stability o $35,000 - $64,000
Photographs:	• IMGP0203 • IMGP0205 • IMGP0206





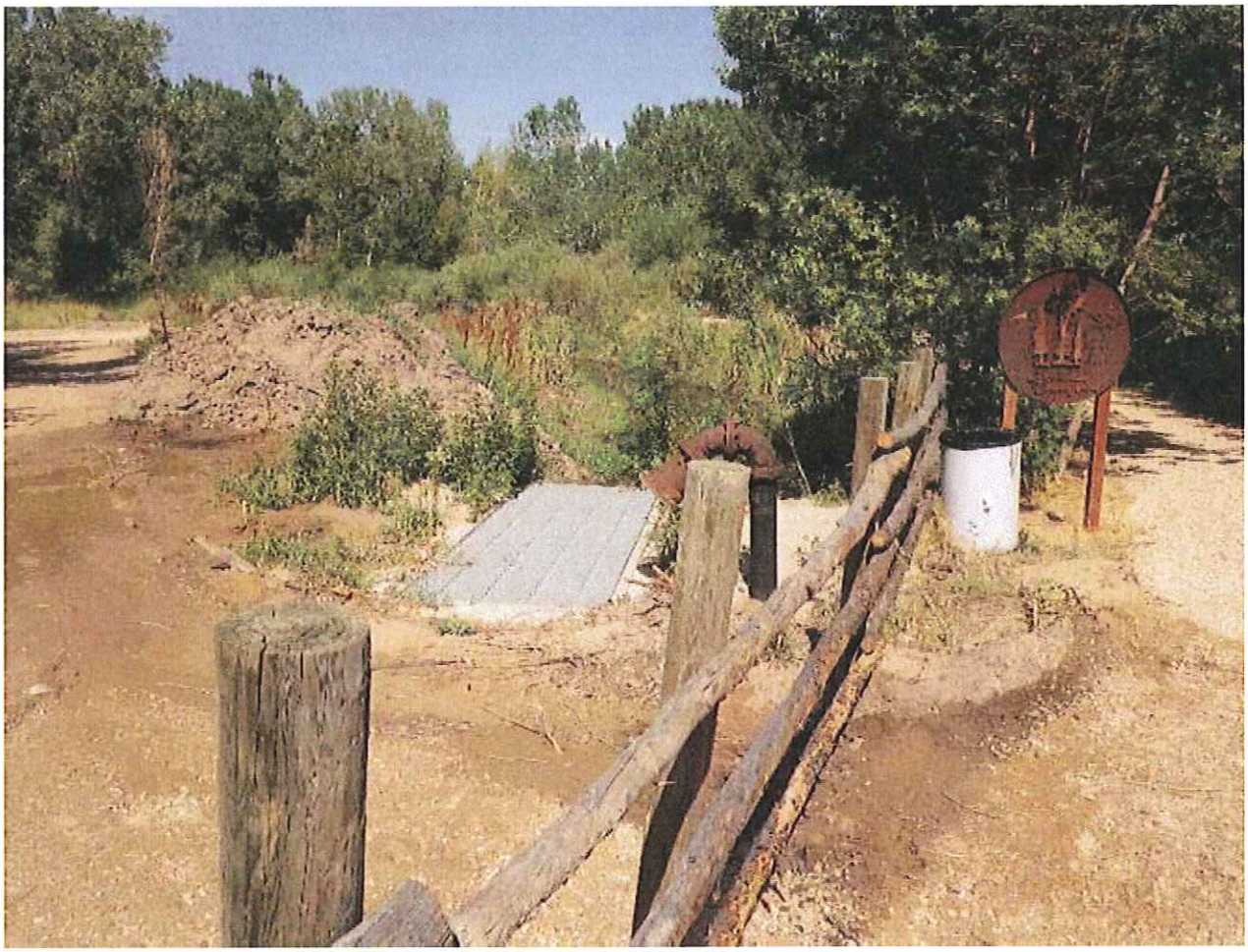
Flood Assessment Point:	**#11-Failed Bank Stabilization**
GPS Coordinates:	8-16-11 Points 50, 51
Direction to Assessment Point:	Upstream end is approximately 330ft downstream of the Riverdale Kayak Park on the Pathway
Project Priority:	High X Moderate Low
Description of Damage:	Numerous failed J-hook structures, failed rip-rap and eroded banks and resulted bank failure is approximately 700' long and 10' high.
Structures:	Path, Homes, Land
Geomorphic Description:	These structures (rip-rap and J-hooks) were installed in response to the rivers channelized flow path to protect land and the Parkway. The residential areas to the west of this location were constructed in the late 1970s and early 1980s. Aerial photography from the 1950s shows that the location of the River Valley Subdivision was a historic flow path for the Weber River. Prior to the subdivision development the Weber Rivers geomorphically active floodplain was more than 1000ft wide. The historic photos also show a large oxbow flood channel located in the exact location of 4300 S (A.K.A. Oxbow Dr.) and River Valley Dr. Presently the River is constrained to a corridor that is 100 to 150 ft wide.
Habitat Considerations:	Source of non-point source sediment pollution.
Flood Damage Repair	• $100,000-$200,000
Measures:	• Option 1-(Flood Damage Replacement) o 700 ft of bank stabilization o Remove J-Hooks and use boulders for toe protection o Import material to protect bank. o $200,000-$350,000 • Option 2-(Flood Improvement, Improved Project) o Remove upper bank boulders and riprap and place 150' D.S. to connect left bank levee (100' Long) o Improving D.S. flood overflow channel. o $64,000 • Options 3-(Flood Mitigation Project) o Remove upper bank boulders and riprap and place 150' D.S. to connect left bank levee (100' Long) o Improving D.S. flood overflow channel. o Realign Bike Path away from River. o Biostabilize Left Bank o $85,000-$120,000
Photographs:	• IMGP0211

	• IMGP0212 • IMGP0213 • IMGP0214 • IMGP0215



Flood Assessment Point:	**#9 & #13-Creekside Tr ailhead Path Erosion @ River Glen Subdivision**
GPS Coordinates:	8-16-11 Point 39, 40, 41, 42
Direction to Assessment Point:	At the junction of the Creekside trail and the Weber River Pathway. Approximately 1000ft on the bike path upstream from north trail head.
Project Priority:	High X Moderate Low
Description of Damage:	The path that leads from the River Bend Subdivision was completely eroded by overbank flooding. This path was reconstructed immediately after the 2011 flood event. 275 ft of split rail fence destroyed, 275 ft path destroyed. There are also issues with the stormwater conveyance at this location. There is a drainage channel that discharges at the west end of the Creekside trail. During high flow events this structure backs up, causing flooding in the River Bend subdivision.
Structures:	Path, Fence, stormwater return channel, homes.
Geomorphic Description:	This portion of the Weber River Floodplain has historically been very active. Historic aerial photos from prior to 1971 show that the active channel of the Weber River flowed through this area. The historic channel passed directly across the junction of the two paths, continued northwest directly through what is now Wildcat Storage and the trailhead facility. The construction of I-15 and Parker Drive has encroached on the active channel at this point, forcing the river east, into its current, channelized location. The river overbanks approximately 500 ft south of the trail junction on the Pathway. FEMA mapping indicates that the trail junction is in ZONE AE and the majority of the Creekside Trail is in the 500 year floodplain. During 2011 runoff this area was inundated by a 10-year flood, indicating that the FEMA information May need updating. *It's important to note that the DFIRM identifies most of this area as 100-year and 500-year floodplain. This was a ten year event; this area should be remapped.* Also we may want to separate this into two damage sites.
Habitat Considerations:	None
Flood Damage Repair:	• $5,000-$15,000

Measures:	• Option 1(Flood Damage Replacement) o Repair path o Repair fence o Biostabilize left bank at location of overbank. o $30,000-$64,000 • Option 2 (Flood Mitigation Project) o Rebuild path to handle overbank flows o Remove fence to facilitate overbank flows o Create overbank flow path between Weber Parkway and Riverbend Subdivision o Reconstruct Weber Pathway to have boardwalk to allow overbank flows o Biostabilze overbank area o Construct return flow channel upstream of North trailhead and downstream of trail junction. o Build offset levee along property lines o Install pump station at trailhead to pump stormwater against floodflow head, discharge downstream in Weber River. o $250,000-$500,000
Photographs:	• IMGP0192 Trailhead • IMGP0193 Looking upstream flood channel • IMGP0195 Bank failure at overbank area • IMGP0196 Looking downstream at overbank area, flood flow path.



Riverdale City 2011 Flood Damage Assessment

October 13, 2011

Prepared By:

RIVER RESTORATION.ORG

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Riverdale City 2011 Flood Assessment

October 13, 2011

Table of Contents

Table of Figures

Introduction

Water year 2011 was marked by a significant snowpack in Northern Utah and a wet spring that detained runoff well past the typical peak flow periods of mid May. As a result a significant flood event occurred on the Weber River within Riverdale City, UT in April, May and June of 2011. Stream flows of 4,640 cfs, on April 18th, and 4,610 cfs, on June 10, were measured at the USGS gage station located at Gateway, UT (USGS 10136500). Average daily flows were sustained above the 10-year recurrence interval for a total of 27 days. This year's stream flows on the Weber River almost reached the 50-year recurrence interval event of 5,300 cfs (100-year event is 7,000 cfs, FIS, FEMA, 2005). Flows were on the order of a 25 year event which has a 4% chance of occurrence in any given year. USGS gage records indicate that this flow has been exceeded 15 times since 1890.

While communities throughout Utah experienced significant flooding Riverdale City was hit particularly hard. Riverdale City's emergency response efforts combined with citizen volunteers minimized the flood extent. However, significant damage was sustained by property and public infrastructure. Furthermore, the duration and magnitude of flows this season caused channel instabilities in several areas that may continue to threaten infrastructure, result in loss of land, flood property, destabilize banks, devalue recreational resources, and reduce the stability of the channel with future flood events. The extent of 2011 flood damage has caused Riverdale City to declare a State of Emergency on June 20th, 2011. Flooding was severe enough that President Obama declared a Major Disaster for the State of Utah making federal disaster aid available to communities impacted by the disaster.

The Weber River in Riverdale City is located in a dynamic alluvial system that once migrated across a broad floodplain as it made its way to the Great Salt Lake. The Weber River has a highly mobile riverbed whose configuration can change dramatically from one high flow event to the next. Development along the river corridor has confined the channel in many locations, constraining the river's pre-development tendency to shift its channel over a broad floodplain. The Weber River conveys heavy bedload, has steep bank slopes and is comprised of poorly consolidated soils. In many areas there is insufficient vegetation to support the banks while in other areas the riparian vegetation is extremely dense, encroaches on the river, and limits the ability of the over bank areas to convey flood flows. The combination of development, flooding and channel instabilities has adversely impacted infrastructure, degraded habitat, limited flood attenuation and altered flood flow conveyance.

This report presents the results of a flood damage assessment performed during August, 2011. RiverRestoration performed a reconnaissance survey of a 3.15 mile reach of the Weber River within Riverdale City. The River was assessed for damage to public infrastructure resulting from the 2011 flooding. Recommendations for damage repair were developed for each of the identified locations. The flood damage information was used to develop recommendations for possible flood mitigation approaches intended to reduce the impact of future events. Additionally, opportunities to improve riverine and riparian ecosystem functions were identified as well as a number of opportunities for recreational enhancements.

Flood events are a rare occurrence. The river is dynamic system with multiple functions. RiverRestoration took a systemic approach to make recommendations for flood control, bank stabilization, and riparian ecological health balanced with development and recreation within the river corridor.

Weber River Geomorphology and Ecology

Gilbert White, the preeminent American geographer, once said, "Floods are acts of God, but flood losses are largely acts of man." This quote points to the fact that it is important to have a thorough understanding of the Weber River's human history as well as geologic and ecologic history in order to identify the underlying causes of the flood damage incurred during the 2011 runoff season.

Upstream of Riverdale City the Weber River drains an area of approximately 1640 square miles. The Weber River rises in the Uinta Mountains at the foot of Reids Mountain in the Unita-Wasatch-Cache National Forest, approximately 65 miles to the southeast of Riverdale City. The River flows approximately 125 miles north and west cutting through the Wasatch Mountains just to the east of Riverdale City and eventually discharging into the Great Salt Lake. During the Pleistocene epoch much of the area between the Wasatch Front and what is now the Great Salt Lake was covered by Lake Bonneville. As the Weber River discharged into Lake Bonneville it formed a large delta. Evidence indicates that Lake Bonneville may have advanced and receded a number of times over the past three million years. Approximately 14,500 year ago a large portion of Lake Bonneville drained through the Red Rocks Pass in Idaho in what is referred to as the Bonneville Flood. Subsequently the lake level has continued to rise and fall a number of times to reach its present level. The shore lines of some of these historic lake levels are evident along the Wasatch Front. At each level the Weber River formed a new delta where it entered the lake. Riverdale City is located in a valley that the Weber River has formed by cutting through these old delta and lakeshore deposits.

The Weber River Valley where Riverdale City lies ranges from less than 3000 ft wide to over 6000 ft wide. Prior to human development the river was free to move across this entire valley in a dynamic process of aggradation and degradation. As the river deposits alluvium in one location, the bed aggrades, and the river is forced to flow in another direction. This result of this process is an ever changing meandering plan form and multiple channels. This action is most evident upstream of Riverdale City where large alluvial deposits and active bank erosion are particularly evident (Figure 1 and Figure 2). The reach upstream of Riverdale City is owned by the Utah Department of Natural Resources and has seen little urbanization when compared to Riverdale City. The river upstream has many cobble bars and changes its channel course every year.

Figure 1-Example of large alluvial deposits upstream of Riverdale City.

Figure 2-Active channel upstream of Riverdale City

As the valley was urbanized over the last 100 years the river's ability to meander through Riverdale City has been significantly reduced by urbanization. Aerial photographs from 1953, 1954, 1971, 1973, 1979, 1980, 1997, 2003, 2006, and 2009 were reviewed to understand the geomorphic evolution of the reach through Riverdale City. In the photos from the 1953 and 1954 it is apparent that Riverdale City

was largely an agricultural community with farmlands dominating the landscape (Figure 1). While the river was somewhat constrained by the railroad and Highway it was free to migrate across much of the valley. Historic flow paths are evident throughout the 1953 photo. Historic channel alignments appear as dark oxbow shaped areas, which are older alignments that have become vegetated, or light oxbow shaped areas, which are more recent (see Figure 3). These historic channels indicate that the Weber River may have had a meander belt width in excess of 1500ft. Analysis of Figure 3 indicates that the Weber River had a meander belt width over 1000 ft wide in 1953. In this active system as the main channel aggrades and a new main channel is formed the old channel is still available to convey water at high flows. These overflow channels relieve pressure within the main channel. Shear stress in the main channel is thus reduced resulting in less bank erosion than if all flood flow remained in the main channel. Loss of these overflow side channels results in increased pressure in the main channel causing excessive bank erosion and down cutting (degradation) of the channel bed.

Although riparian areas represent less than one percent of the land within Utah, they are among the most diverse and densely used wildlife habitat in this region. Animals including migratory songbirds, deer, elk and amphibians rely on these riparian corridors for food, cover, breeding habitat and movement corridors. Riparian areas also provide many important functions to humans, from recreation to providing clean and abundant water, to reducing flooding. Disturbance of a riparian area also has a cause and effect that changes the characteristic of these environments. The aggradation of historic flow paths and the resultant migration of the river to new flow paths create a mosaic of diverse habitat. Some remnant channels remain open, filling with water and becoming oxbow lakes or wetlands. Newly exposed point bars provide new habitat for riparian plants. Diversity is one of the most important measures of habitat quality.

Riparian forest species such as Fremont Cottonwoods (*Populus fremontii*) have evolved with channel migration as a critical component of their life cycle. High flows during spring runoff mobilize sediments at the edge of active channels and create point bars. Additionally overbank flows may scour areas of vegetative cover and mulch. These exposed areas are essential for cottonwood establishment. The cottonwood seeds are deposited in these areas which remain wet as the river recedes. The seeds germinate at this time and grow a tap root that follows the water table as the hydrograph declines, creating new riparian forests. These forests in turn capture sediment and retain floods. Many other plant and animal species are similarly adapted to this dynamic environment.

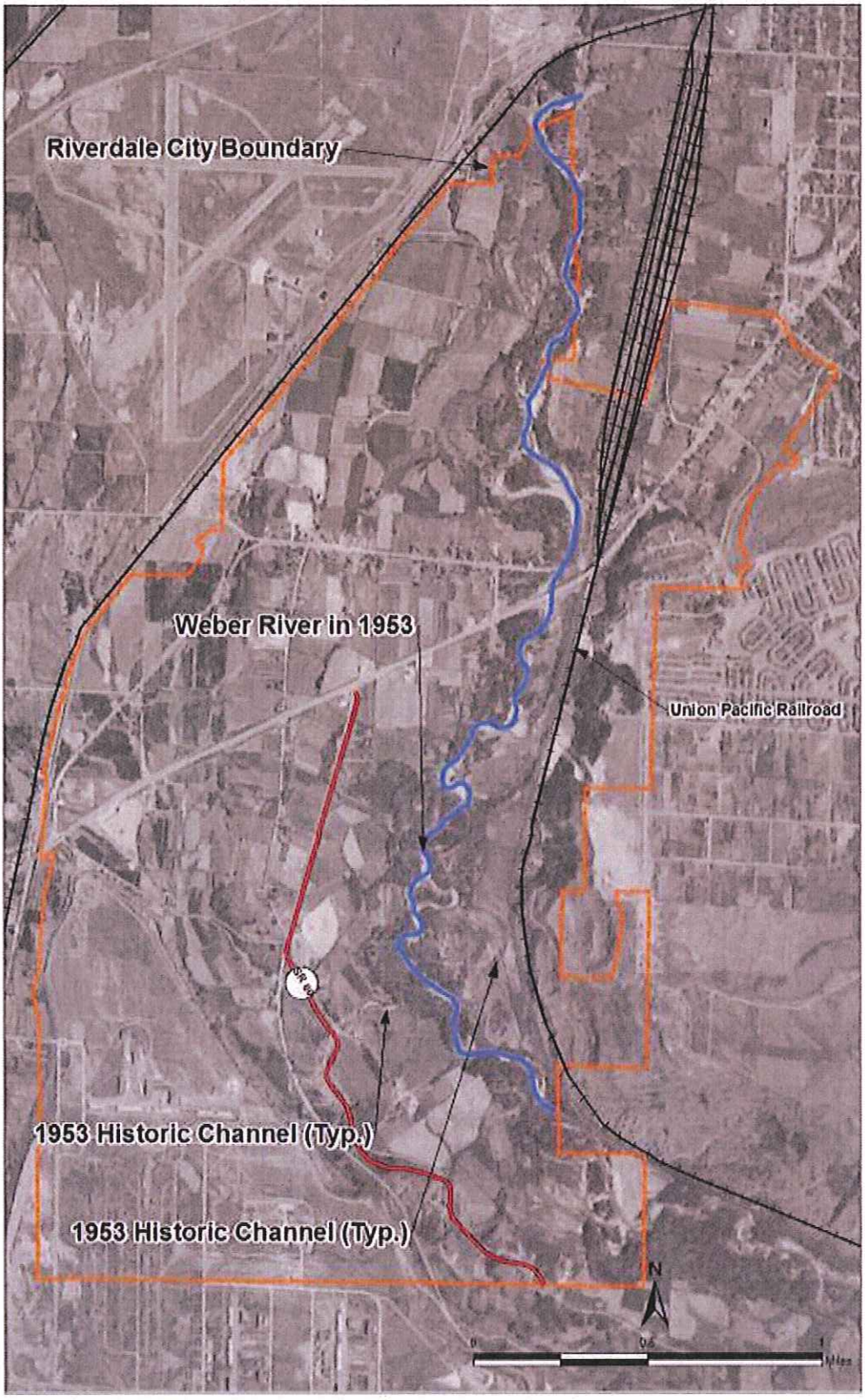


Figure 3-1953 Aerial photo shows channel meander pattern of Weber River through Riverdale City.

Over the last 58 years Riverdale City has become significantly urbanized. Figure 4 shows the 2009 aerial photo and the current meander pattern of the Weber River. The 1953 meander pattern is also shown for reference. As the community has developed the river has been straightened and encroached. The length of the Riverdale City reach has been reduced by approximately 20%. Historically the river had a meander belt width in excess of 1500 ft. In places this width has been reduced to less than 150 ft. The sinuosity of the reach has been reduced from more than 1.38 to less than 1.14. This also means that the river has been steepened by 20%. This has increased channel degradation. This encroachment has significantly altered the form and function of the Weber River through Riverdale City.

The encroachment of the river has significantly reduced the quantity and quality of riparian habitat. The main channel of the Weber River has been significantly narrowed and deepened and the channel slope has increased. There is a decreased connection between the main channel and the floodplain. Side channels that were once available to convey flood flows have either been completely destroyed or they have become isolated from the main channel. These hydromodifications have increased the shear stress on the bottom and banks of the streams. This process has pushed the stream across a threshold; the stream no longer functions like the upstream and downstream reaches; aggrading the channel, eroding banks and forming new channels, floodplains, and point bars. Now this reach of the river has a much greater sediment transport capacity than the upstream reach. There is very little evidence of mid channel and point bar deposits throughout the Riverdale City reach. As the river responds to these changes, significant portions of the river bank have been hardened with concrete refuse such as old sidewalks, curb and gutter, etc. River impoundments upstream have also altered the natural hydrograph of the river, which makes the river function differently.

Environmental factors have added to the human alteration of the Weber River. Specifically, the severe drought of the early 2000s limited overbank disturbance (Figure 5). While the most severe drought period was early 2001 through mid 2005 the extended drought period for Utah lasted until 2010. The lack of flood flows and disconnect between the main channel and overbank areas has allowed vegetation to encroach the channel (Figure 6). What few flood flow channels that were connected to the river have become overgrown. In portions of the riparian corridor the forest understory has become so overgrown that it is difficult to walk through (from humans and wildlife). This thick growth has limited the flood conveyance capacity of these flood relief channels as well as exacerbated wildfire risk. The decreased velocities in the connected over bank areas has also increased the deposition of fine sediment. This is evidenced by Figure 7, which shows an old barb wire fence and t-post. This fence was likely used by ranchers or farmers prior to the urbanization of Riverdale. This side channel appears to have aggraded by over three feet since the post was set.

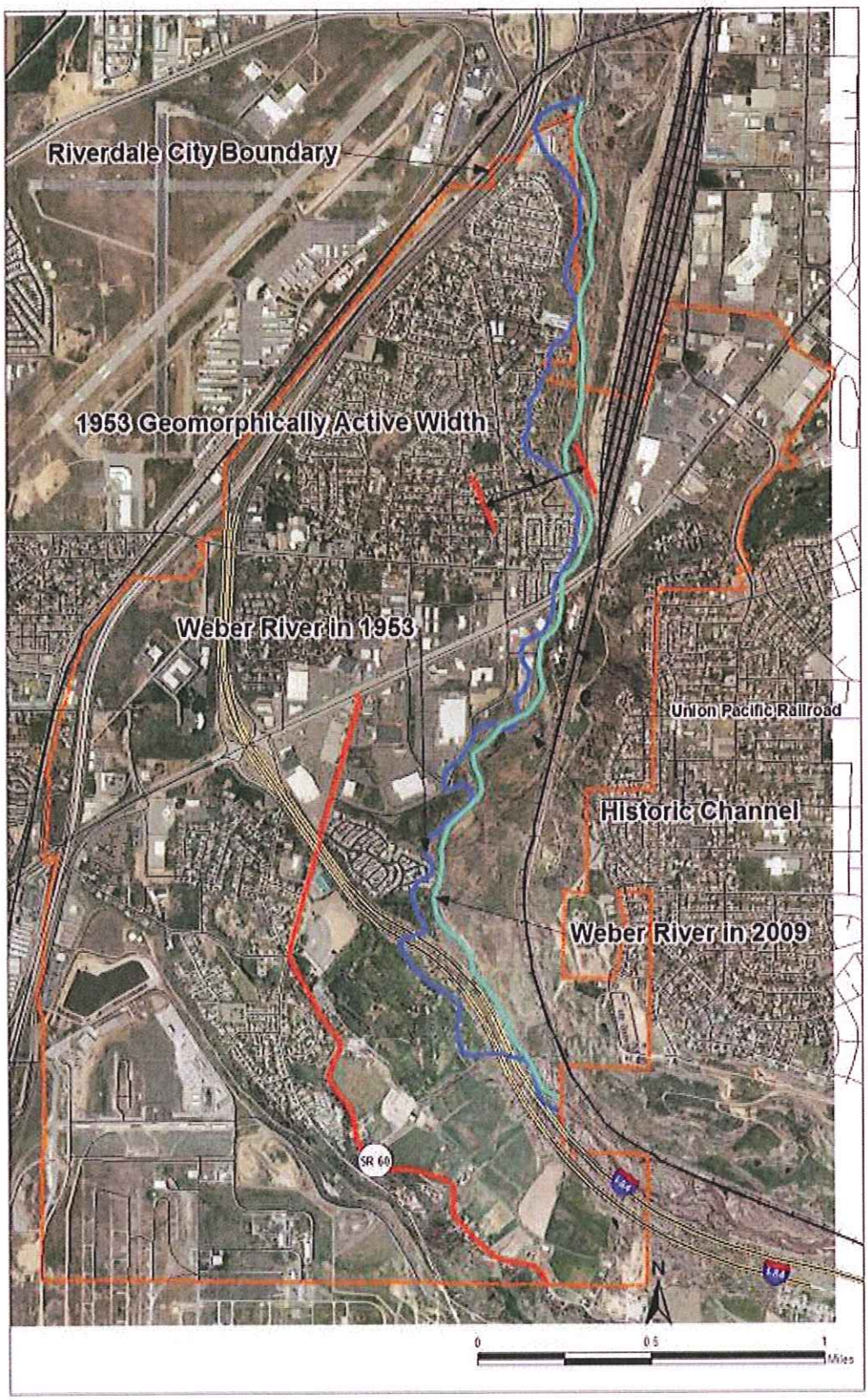


Figure 4-2009 Aerial photo shows current meander pattern of Weber River through Riverdale City.

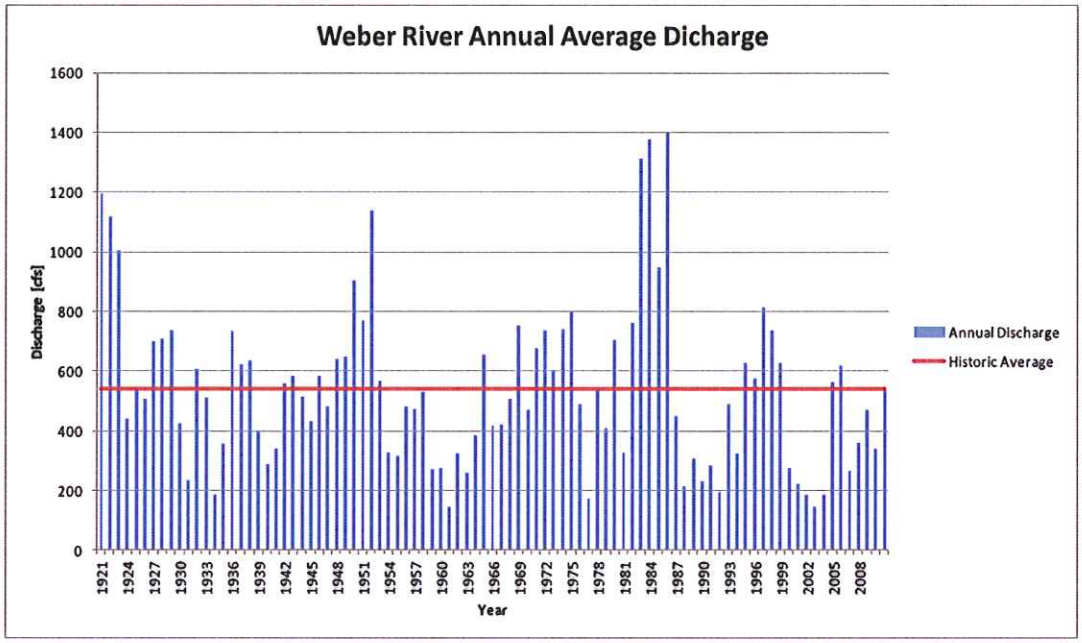


Figure 5-Weber River Annual Average Discharge

Figure 6-Overgrown Riparian Vegetation.

Figure 7-Fine sediment deposition resulting from decreased overbank velocities.

Weber River Flood Damage Assessment

The human and environmental factors outlined above combined with a record setting snowpack to cause the severe flooding experienced during the 2011 runoff. Fortunately, the cool, wet weather of last spring reduced the intensity of runoff and prevented even more severe flooding in Riverdale City. Riverdale City residents are not unfamiliar with these types of flooding events; the historic record indicates that there have been 15 years where peak discharges have been larger than 2011 (Figure 8) and certainly many residents remember the devastating flood caused by the breach of the Weber-Davis Canal in 1999. The Weber River Project (USBR) including Rockport and Echo reservoirs has provided an accumulated $12M in flood control benefits from 1950-1999.

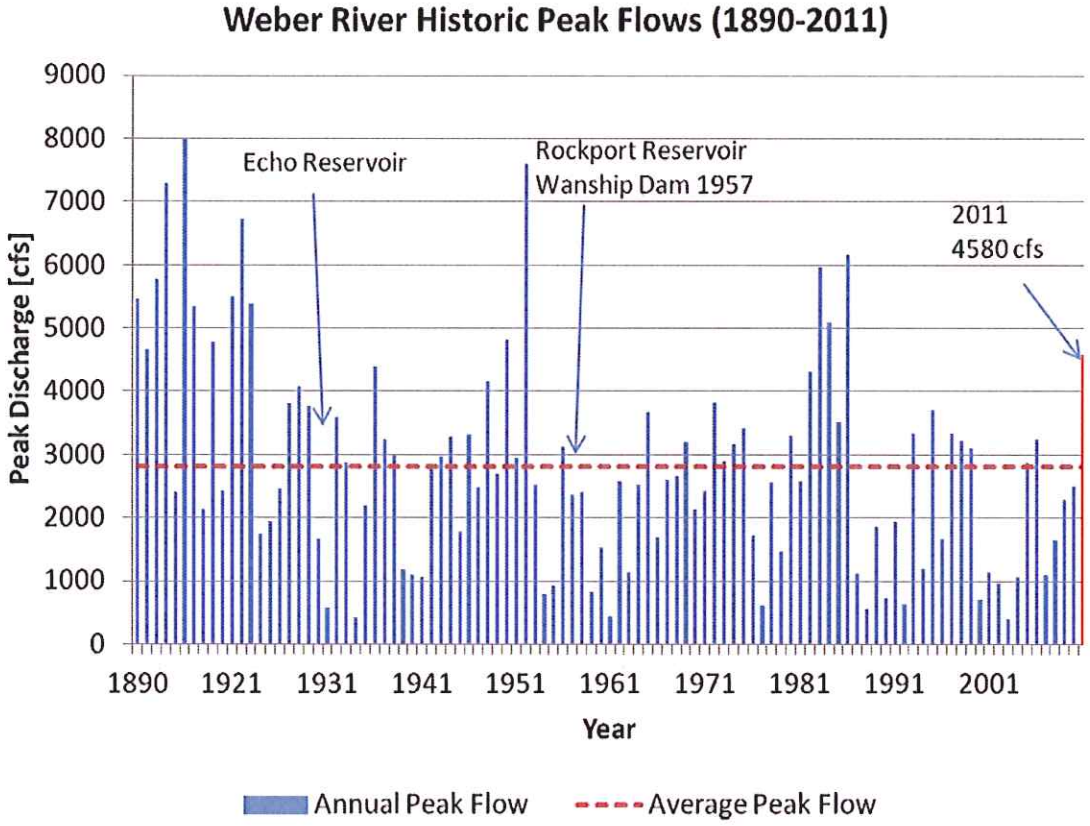


Figure 8-Historic Peak Discharge [cfs]

During our assessment, RiverRestoration identified 14 locations where public infrastructure was damaged during the 2011 flood event. Table 1 presents the damaged sites and the locations of the damaged areas are indicated in Figure 9. Individual site assessments are presented in Appendix A. These assessments described the damage incurred and identify any contributing factors as outlined in the previous section. The site assessments also identify the actions necessary to repair the damaged sites to their pre-flood conditions. Where alternative approaches to individual site reparations are feasible those alternatives are identified. Order of magnitude costs are included in the site assessments.

Table 1-Flood Damage Assessment Sites

Site #	Site Name
1	Weber River Parkway Collapse
2	Across From Riverdale Mobile Estates
3	Frisbee Golf Course Riprap Failure
4	Riverdale Play Park and Riprap Failure
5	54" RCP outfall @ W4400S & S Weber River Dr.
6	Two 36" RCP outfalls Downstream of Riverdale Road
7	Concrete Revetment at Les Schwab Tire
8	Riprap at 4600S and Weber River Dr. Bridge
9	Creekside Trailhead Path Erosion @ River Glen Subdivision
10	Failed J-Hooks
11	Failed J-Hooks and Riprap
12	Failed J-Hooks
13	Weber Rivertrail Bank Erosion Upstream of River Glen Subdivision
14	Failed Riprap at Riverdale Rd. Bridge

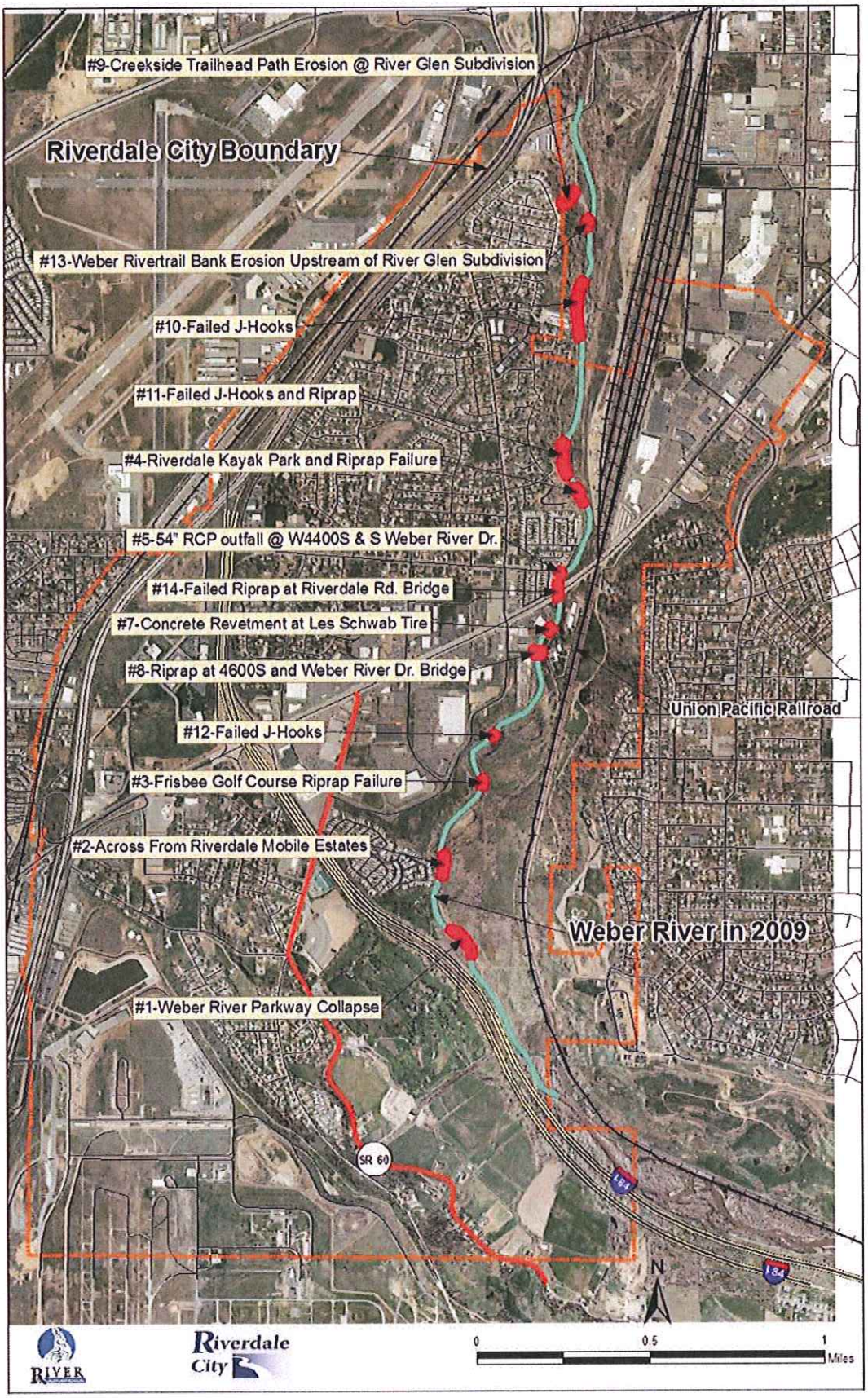


Figure 9-Flood Damage Sites

As indicated in the previous section and outlined in the individual assessments, repairing these damaged sites to their pre-flood conditions may result in similar future flooding and associated damages. While the Individual Site Assessment Sheets contain recommendations for reparations and associated opinions of the magnitude of cost for these reparations, RiverRestoration urges the community to consider addressing these issues on a more systemic basis. The following section, Flood Mitigation Opportunities, identifies alternative approaches to addressing these issues that may lessen the impact of future flooding, while benefiting the Weber River as a whole.

Flood Mitigation Opportunities

While the flood of 2011 was the direct cause of these damages, there are systemic problems with this reach of the Weber River. RiverRestoration believes that addressing these issues on a system wide basis has a number of benefits. Some of the damaged areas, like the rip-rap around a sewer outfall, are easily repaired back to their pre-flood conditions and the systemic implications are insignificant. In contrast, repairing some of the damaged sites to their pre-flood conditions may inevitably lead to future damages, maintenance, human risk and expense for the community. Particular examples of this are the numerous j-hooks that were placed in the river to reduce bank erosion. As indicated in the individual site assessments, many of these J-hooks were installed without a systemic approach and may have caused bank instabilities elsewhere. Additionally, their application in the Weber River is questionable.

Approaching the flooding issues on the Weber River with a system wide approach may have added benefits to the community and the river ecosystem. It is RiverRestoration's experience that this approach has the added benefit of bringing a wide range of collaborating partners to the table, creating greater opportunities for project funding and success. Entities that may be supportive of this approach include, but are not limited to, the Utah DNR, USFWS, USFS, NRCS, FEMA, USACE, Weber County Parks and Recreation, Utah State Parks, Central Weber County Sewer Improvement District, DEQ, EPA, Irrigation Ditch Companies, USGS, Weber Basin Water and Conservation District, Trout Unlimited, and private donors. RiverRestoration has identified a number of synergistic approaches to addressing the critical issues on the Weber River within Riverdale City and beyond. The following paragraphs describe these general approaches. Figure 10 presents one possible system wide concept plan for addressing these complex issues.

Let the river have room to do what it needs to do. Where the bike path has been damaged do not reconstruct it in the same alignment. While land acquisition and easements may seem burdensome, the benefit of providing adequate room for the river to function may result in long term cost benefit advantages due to decrease closures, maintenance and repairs.

Provide overflow channels where possible. Backwater areas may help attenuate the peak flows of flashy floods like those caused by a thunderstorm, but they do not help with a flood that has a peak duration like the one Riverdale City experienced this past spring. These back water areas may inundate early in the sustained flood event and once they are inundated the main channel of the river is left to convey the remainder of the flood event. Sustained floods are addressed by providing conveyance. As previously indicated the Weber River has lost much of its overbank conveyance. Urban development has encroached on the river eliminating many of the overbank conveyance areas that would naturally be available to relieve pressure on the main channel. Where these overbank conveyance areas have not been eliminated they have become overgrown and silted in, reducing their capacity to provide sufficient conveyance. Recreating these channels were possible may improve the overall conveyance of the river and reduce associated flood impacts. Where these channels exist they should be cleared of overgrowth to increase conveyance during the high flow events. This may also provide needed wildfire mitigation. This could be done any number of way including mechanical removal, hand removal, or prescribed burns.

Provide offset levees. There are currently a number of levees throughout Riverdale City that provide intermittent protection. Many of them are discontinuous, providing opportunity for flood flows to either flow or backwater around and providing little protection for Riverdale City residents. Additionally,

many of these levees are located too close to the river, eliminating the connection of the floodplain to the river. A preferable approach would be to remove these levees, allowing the river to reconnect to the floodplain. In their place offset levees should be constructed at the limits of the floodplain, along adjacent property lines, to provide protection for the adjacent residential and commercial properties. This approach may provide needed overbank conveyance, improve riparian habitat, and eliminate the nearly annual practice of placing sandbags to protect the community.

Where feasible lay back banks. This may improve conveyance of the main channel while reducing bank shear stress. This should be done with caution. As previously indicated the Riverdale City reach of the Weber River has been so constrained that it no longer functions as it did in its natural state. The river has crossed a transport threshold creating a situation much like placing a collar on tiger. The reach upstream of Riverdale City displays the dynamic behavior of aggradation, point and mid channel bar formation and the subsequent formation of a new channel. It appears that all of the alluvial material supplied by the upstream reach is conveyed through Riverdale City. There is evidence of aggradation downstream (Fort Buenaventura Park, Parked Rd. Photo) but almost no evidence of aggradation within Riverdale City. In a sense the Weber River has become a contained beast within Riverdale City and care should be taken that this beast is not unleashed. Significant aggradation within Riverdale City could have detrimental impacts (i.e. Fort BV). The sediment transport of this system, from canyon mouth downstream to Ogden, needs to be maintained.

We recommend that the City revisit the 2005 FIS to ensure that it is still applicable. The FEMA mapping indicates that the open area between the River Bend Subdivision and the Weber River (Creekside Trailhead) is located in Zone AE (the 100-year flood). As previously indicated, the flood event of 2011 was on the order of a 15 to 25 year event yet this area was inundated. The FEMA profile shows that the elevation of the 100-year flood is approximately 2.5 ft higher than the 10 year event. The Creekside Trailhead and adjacent homes experienced flooding during this event. This flooding may be the result of an overwhelmed stormwater system and an unusually high groundwater table combining with the Weber River Flooding. A 1.5 to 2.5 ft increase in water surface elevation could significantly impact these residential areas. High groundwater and an overwhelmed stormwater system would worsen the impact of a 100-Year event. This issue may be address by constructing a stormwater pump system that increases the conveyance of the existing stormwater infrastructure. However a pump system may not be effective if it is not incorporated into an associated offset levee to prevent the recirculation of the pumped stormwater.

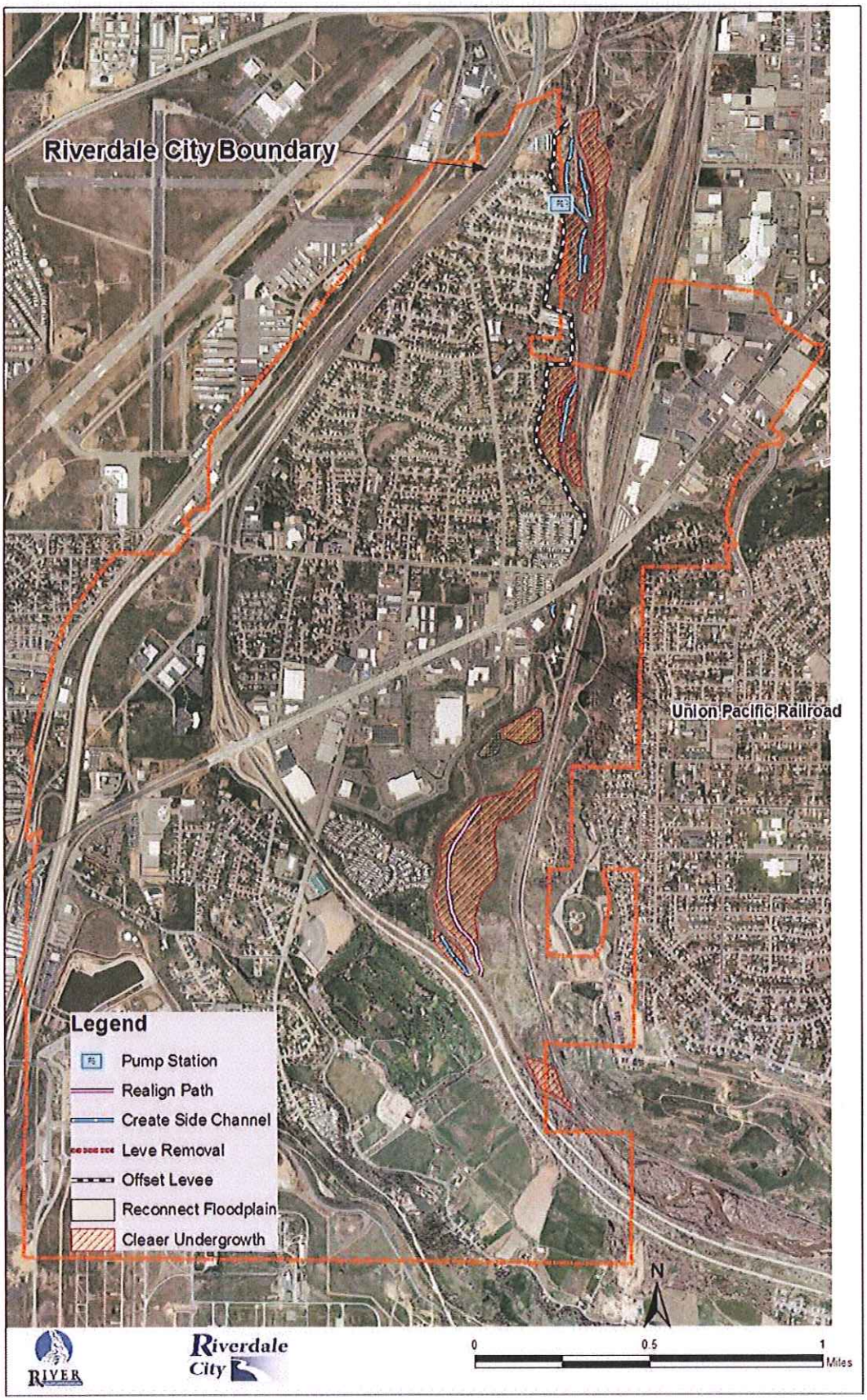


Figure 10-Flood Mitigation Concept Plan

Ecosystem Enhancement Opportunities

Many of the recommendations presented in the previous section may have direct positive impacts on the Weber River's riparian and in-channel habitats. It is RiverRestoration underling philosophy that a healthy river provides a multitude of services. A healthy river provides a verity of in channel habitat to support a diverse assembly of aquatic species. It interacts with the floodplain to maintain robust and resilient riparian habitat for the wide range of species that depend on this critical ecosystem. It conveys flood flows and sediment while protecting and preserving the adjacent human uses. It provides adequate water quality and quantity for human uses (irrigation, domestic water supply, etc.). And lastly a healthy river supports the economy of the adjacent communities by providing recreational opportunities for locals and visitors alike (fishing, boating, passive recreation, etc.).

Providing the river sufficient room to function naturally has many ancillary benefits. Providing an adequate buffer along the river allows riparian ecosystems to function naturally. The land preserved for the river may be used as open space, providing opportunities for recreational activities as well as providing conveyance and attenuation of floods. Reconnecting the river to the floodplain, where feasible, may also help restore the riparian ecosystem while providing the added benefit of flood mitigation. Opening up side channels may not only provide flood relief but also provide habitat diversity. Creating a dynamic and diverse riverine ecosystem may recreate the natural disturbance this system would experience in its undeveloped state, creating a mosaic of habitat. This may have the additional benefit of reducing wildfire risk by eliminating the contiguous stands of overgrown forest that currently have the potential for large scale catastrophic fires. Increasing in channel diversity by providing substrate diversity, mimicking natural pool and riffle sequencing, retaining some cobble material, and creating fishing holes can substantially improve the in channel habitat.

In addition to the recommendations presented in the Flood Mitigation section there are additional ecosystem enhancement opportunities available throughout Riverdale City. There are a number of locations were the ecosystems are not fully functional. These areas can be placed into five general categories. The first four are wetlands, riparian forests, drop structures and in-stream habitat. The last category is stormwater returns. While stormwater returns are not natural ecosystems they have the potential to become excellent habitat as well as improve overall water quality. The following paragraphs address the general opportunities for each one of these categories. These specific locations of identified enhancement opportunities are presented Figure 11.

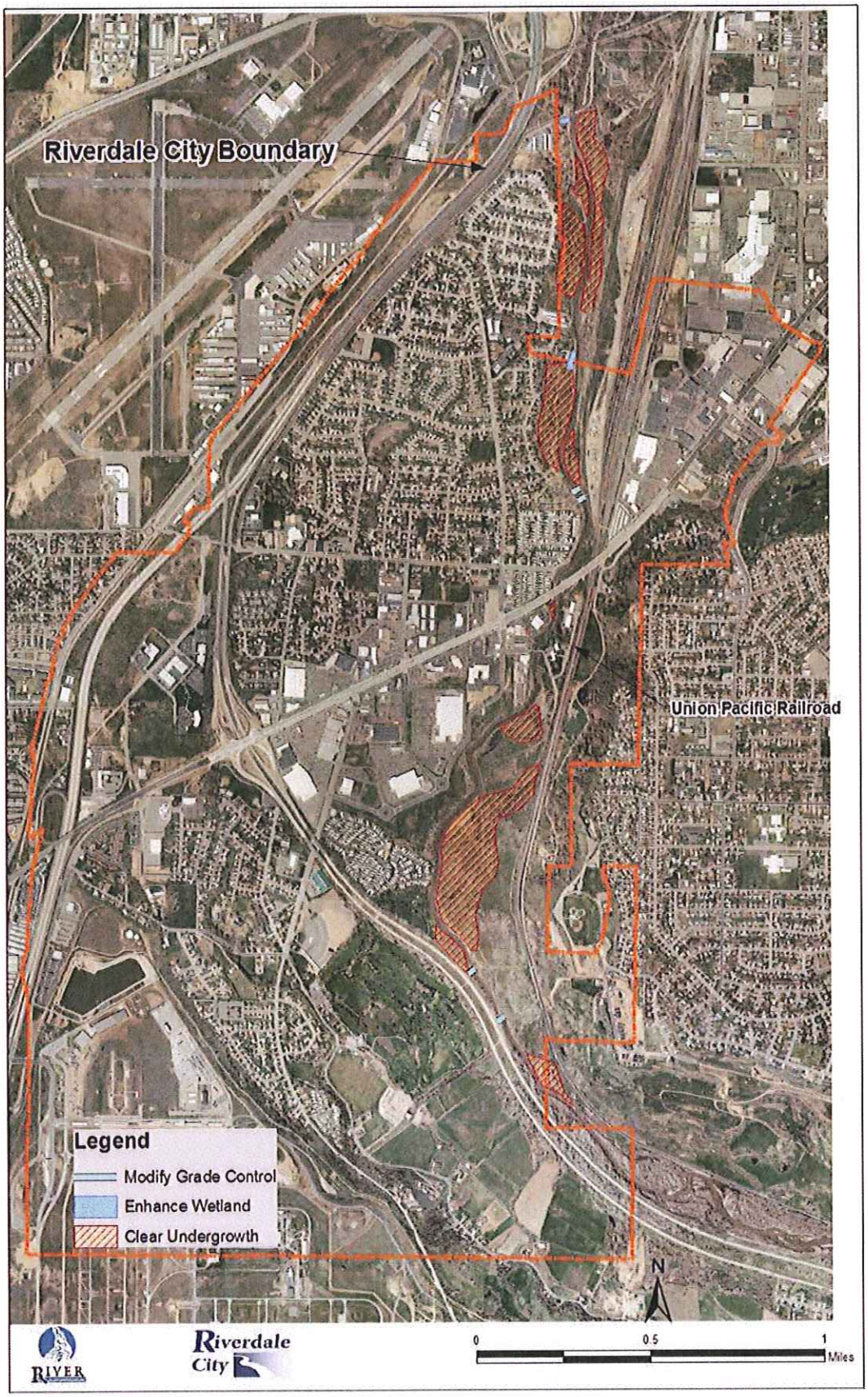


Figure 11-Ecosystem Enhancement Opportunities

Wetlands

Adjacent to the Weber River, RiverRestoration identified three emergent wetlands. One wetland appears to be healthy and is located approximately 825 feet upstream of the Creekside Trail on the Parkway. This wetland has a robust diversity of species and appears to have adequate flow and oxygenation. The other two emergent wetlands have the potential to provide invaluable habitat and improve water quality but are in need of enhancement.

The smallest and most downstream wetland is located adjacent to the North Trail Head. This wetland appears to be the associated with stormwater runoff from the adjacent area. This wetland drains under the Weber River Pathway just upstream of the Parker Rd. underpass. There is an abundance of algae and trash present in the wetland (Figure 12). This wetland may have insufficient flow to provide adequate oxygenation. The garbage should be removed and the mechanical drainage system should be inspected to ensure there is adequate flow through the wetland.

Figure 12-North Trailhead Wetland

The second emergent wetland is located approximately 550 ft upstream on the Parkway from the Great Salt Lake Brine Shrimp warehouse. This wetland appears to be a historic meander (or oxbow) that has been isolated from the river due to the trail construction (Figure 13). This wetland is completely covered with algae which reduces the amount of available oxygen. It is likely that this wetland is anoxic (lacking oxygen) below the surface. Additionally there is a substantial amount of concrete rubble dumped on the sides of the wetland. This concrete may have been placed there to protect the bank from erosion when this was an active channel. RiverRestoraion recommends reconnecting this wetland to the river with small culverts under the Parkway to improve its hydraulics as well as allow it to provide some level of backwater storage during flashy flood events. This wetland is unique within Riverdale City and has the potential to provide critical ecosystem functions as well as excellent educational (interpretive) opportunities. Removal of the concrete would also provide aesthetic benefits to the community.

Figure 13-Oxbow wetland

There is an additional non-emergent wetland adjacent to the Great Salt Lake Brine Shrimp warehouse. This wetland may be the result of backwater due to a tributary channel. There is a substantial amount of concrete rubble (Figure 14). The concrete may have been placed to protect the warehouse from flooding due to backwater. The concrete should be removed and potential flooding risk should be addressed with an offset levee as described in the previous section.

Figure 14-Brine Shrimp Wetland concrete fill

Riparian Areas

In general riparian areas are overgrown due to lack of disturbance. There are areas were the forest is dominated by exotic species, particularly Russian Olive (*Elaeagnus angustifolia L.*). The understory is extremely overgrown. This overgrowth limits the habitat value of the riparian forest and creates a significant wildfire risk. As previously indicated, this thick growth has also limited the flood conveyance capacity of these flood relief channels as well as exacerbated wildfire risk. The decreased velocities in the connected over bank areas has also increased the deposition of fine sediment. There are numerous areas were the understory should be thinned and places where Class 4 pruning would benifict the forest canopy and reduce fire risk. This could be done any number of way including mechanical removal, hand removal, or prescribed burns.

In-stream Habitat

Due to the encroachment and channelization, the in-stream habitat lacks sufficient diversity in current and channel substrate throughout the City. The channel should be modified to mimic the natural pool riffle sequence. This could be done with strategic placement of habitat boulder clusters and vanes. Care should be taken to ensure that the sediment transport capacity of the stream is maintained to prevent aggradation and subsequent flooding issues.

Drop Structures

The two drop structures upstream of the Parkway collapse pose a significant impediment to fish passage. This is particularly important for the Bluehead Sucker (*Catostomusdiscobolus*), a Species of Special Concern for the State of Utah. The Utah DNR is interesting in having these two structures modified to allow appropriate passage for the Bluehead. This presents an excellent opportunity for the

City to form a partnership with the DNR to address this issue. The upper structure is a Central Weber Sewer line, the lower structure is a Riverdale City waterline. The Weber River has down cut throughout Riverdale City upwards of eight feet. Unfortunately, we were unable to assess these facilities for damage due to the high flows this past spring and summer. It is likely that these structures have significant scour and are compromised. As soon as flows drop to a safe level we recommend inspecting these structures to ensure that the utilities are not compromised.

Stormwater Returns

Numerous stormwater returns discharge directly into the Weber River. Many of these outfalls pose an opportunity to construct wetland treatment basins. These constructed wetlands have the potential to not only increase stormwater quality but also provide essential habitat. Where land ownership and configuration allow stormwater treatment wetlands should be constructed.

Recreational Enhancement Opportunities

Riverdale City is excellently positioned to enhance the recreational opportunities available along the Weber River. The City has a history of successful river recreation development. Specifically, the Riverdale Play Park, constructed in 2005, has become well known and heavily used on a local, regional and national scale. Internationally renowned kayakers such as Devon Barker (2 Time National Freestyle Champion from McCall, Idaho), Ruth Gordon (2007 Freestyle Kayaking World Champion from Reno, NV), and Tanya Faux (2006 ICF Freestyle World Cup Champion from Reno, NV) go out of their way to travel to Riverdale to surf at the play park. These types of features have direct economic impacts on the communities they serve: Erin Bastian, manager of Canyon Sports (4598 South, 700 West, Riverdale, UT) indicated that the Riverdale Play Park has a significant impact on the number of kayak rentals and sales and subsequent revenue. While this is a sample of one commercial operation realizing the economic benefits of river recreation there are likely other business in Riverdale City that are positively impacted (lodging, restaurants, gas stations, etc.). Unfortunately the Riverdale Play park was damaged during the floods of 2011 (Site #4, Appendix A). While it is somewhat different than the Play Park, the Riverdale Frisbee Golf Course is another example of successful recreation along the river. The Golf Course is a popular amenity for not only Riverdale residents, but Weber County residents as well.

There are numerous opportunities for different recreational enhancements throughout Riverdale, City. Additional kayak play waves could be constructed at a number of drop structure locations within the City. Options for whitewater recreation are continually increasing. In addition to kayaking and rafting activities such as stand up paddle boarding, river surfing, river boarding, and squirt boating are becoming increasing popular. Squirt boating involves boats that are design to be extremely low in volume while still allowing the paddler to float. These boats can utilize surface and subsurface currents to effect navigation and perform tricks. Unlike freestyle kayaking which requires sufficient hydraulic drop to create a powerful wave, squirt boating requires smaller hydraulic drops and eddy lines. There is opportunity to augment the river to enhance these activities by modifying drop structures and modifying currents. In addition, whitewater structures can be designed to improve fishing habitat and fishing recreation.

Providing river access is essential to increasing in stream river recreation opportunities. The construction of a boat ramp for put-in and take-out has the potential to significantly increase the recreational use of the Weber. There are a number of locations were a boat ramp could be constructed; the Riverdale Play Park, the North Weber River Parkway Trail Head, and the South Weber River Parkway Trail Head. The reach of the river between the mouth of Weber Canyon and Riverdale City is a beautiful stretch of river that is underutilized by whitewater and float fishing enthusiasts. This stretch of the river is stocked by the Utah DNR Division of Wildlife and numerous fishing access points are provided for wade fishing. Combining a boat ramp in Riverdale City with an upstream put in would significantly increase recreational use of this reach, resulting in significant vitality and economic benefits for the City. The DNR is contemplating a public boat ramp near the junction of Cottonwood Dr. and Adams Ave. Parkway. This presents a synergistic opportunity for both Riverdale City and the DNR.

Another important aspect of access is navigation. Currently the two drop structures located at the upstream boundary of Riverdale City present significant impediments to boat passage as well as fish

passage. These structures could be reconstructed to not only be more environmentally appropriate but to also provide passage for kayaks, whitewater rafts, and drift boats. When these improvements are combined with the construction of the aforementioned boat ramps there is the potential to significantly increase the recreation uses of the Weber River throughout the City by both private users as well as commercial operations. Again, it is important to note the economic impact that these improvements could have for the City. In addition to the increased tax revenue generated by sales taxes, there may be opportunities to collect user fees from the commercial operations (whitewater rafting companies, fishing outfitters, etc). There are numerous examples of these types of river improvements generating sufficient user fees from commercial operations to cover the cost of maintaining the facilities.

Passive recreation opportunities are frequently overshadowed by projects such as play parks and boat ramps. But passive recreation opportunities present perhaps the greatest benefit to the greatest number of citizens. The Weber River Parkway is an excellent amenity that could be further enhanced. Constructing river viewing areas, picnic areas, and interpretive facilities (some of which already exist) would improve the recreational experience for a wide range of constituents. The construction of the Riverdale Play Park was intended as a recreational opportunity for whitewater users. Augmenting this facility with an observation area capable of accommodating a large number of people would turn the park into a potential venue for freestyle kayak and surfing competitions, creating yet another new revenue stream for the community.

The Unity Enterprises property, located in the vicinity of the Parkway collapse, presents an excellent opportunity for passive and active recreation. As indicated in the flood damage assessment for the Parkway collapse, the City should consider purchasing this property or gaining an easement to re-route the Parkway away from the river at this location. This parcels location adjacent to the South Trail Parking Lot, BMX course and Frisbee Golf Course makes it a logical addition to the community's open space program. There are numerous potential uses for this property. It should be noted that according to the FEMA FIS (49057CV000A) the Unity property is located in Zone X shaded. The flood of 2011 was on the order of a 15-25 year event. Unfortunately FIS the does not indicate the elevation of the 10, 50 or 500 year water surface elevations at this location. Photographs of the flood event show that water surface was just a few feet below the elevation of the Unity Property at the location of the Parkway collapse. Based on our analysis elsewhere, there is the potential that the river has changed since the 2005 FIS and the actual flood elevations may be higher than reported by FEMA. As indicated in the Flood Mitigation Section, we recommend revisiting the 2005 FIS to ensure that it accurately depicts the flood hazard potential throughout Riverdale City. Depending on the outcome of this analysis the Unity Property may be more subject to flooding hazard than the Zone X Shaded classification would indicate.

A conceptual recreational enhancement plan is presented in Figure 15.

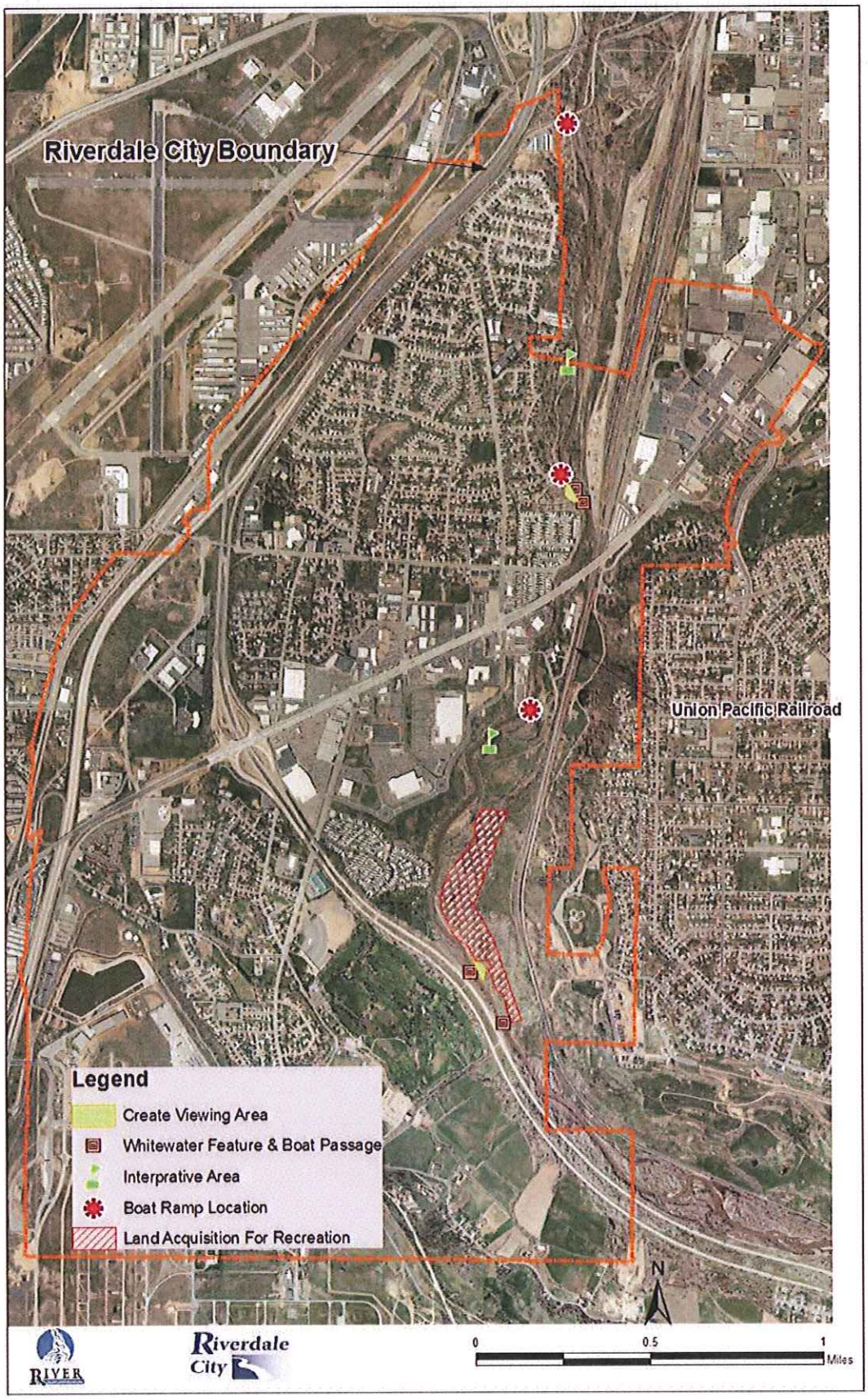


Figure 15-Recreational Enhancements

Summary

The recommendations presented in this report are intended to support and guide future planning efforts on the Weber River through Riverdale City. The recommendations and cost opinions are conceptual in nature and are not based on detailed survey or engineering design.

Urban development has encroached and changed the natural function of the Weber River. This has not only impacted critical ecosystems but also exacerbated flooding conditions throughout Riverdale City. Continued urban development is essential to the economic vitality of the City, but wiser future planning can limit further encroachment of this valuable resource. In particular the community should consider reviewing community development standards (river/riparian setbacks, floodplain administration). The community should also revisit FEMA 2005 study to ensure that the flood risk to Riverdale Residents is accurately characterized.

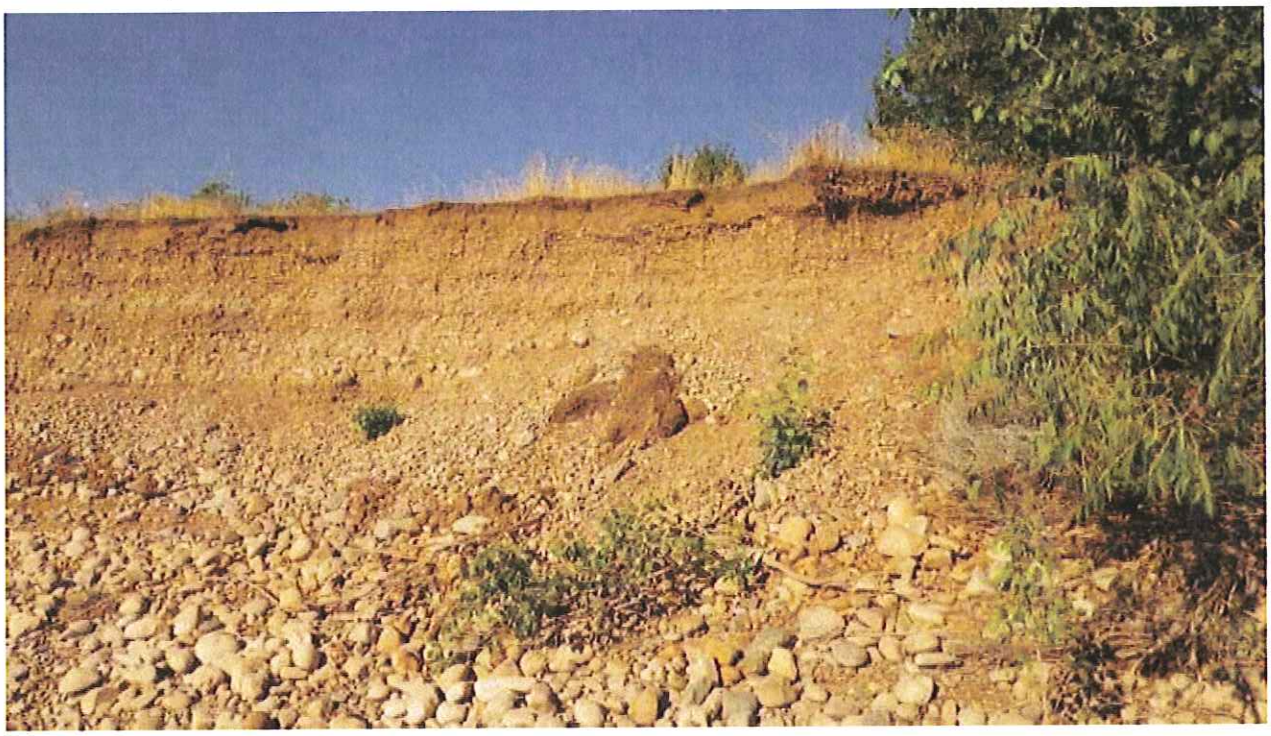
The best way to resolve the flooding issues through Riverdale City is to take a systemic approach; approaching these issues on a reactionary basis may result in future flood damage and ongoing maintenance. Using this document as a basis for developing a Weber River Restoration and Flood Mitigation Master Plan will increase the partnering opportunities; improve funding options and ensure for a successfully constructed project.

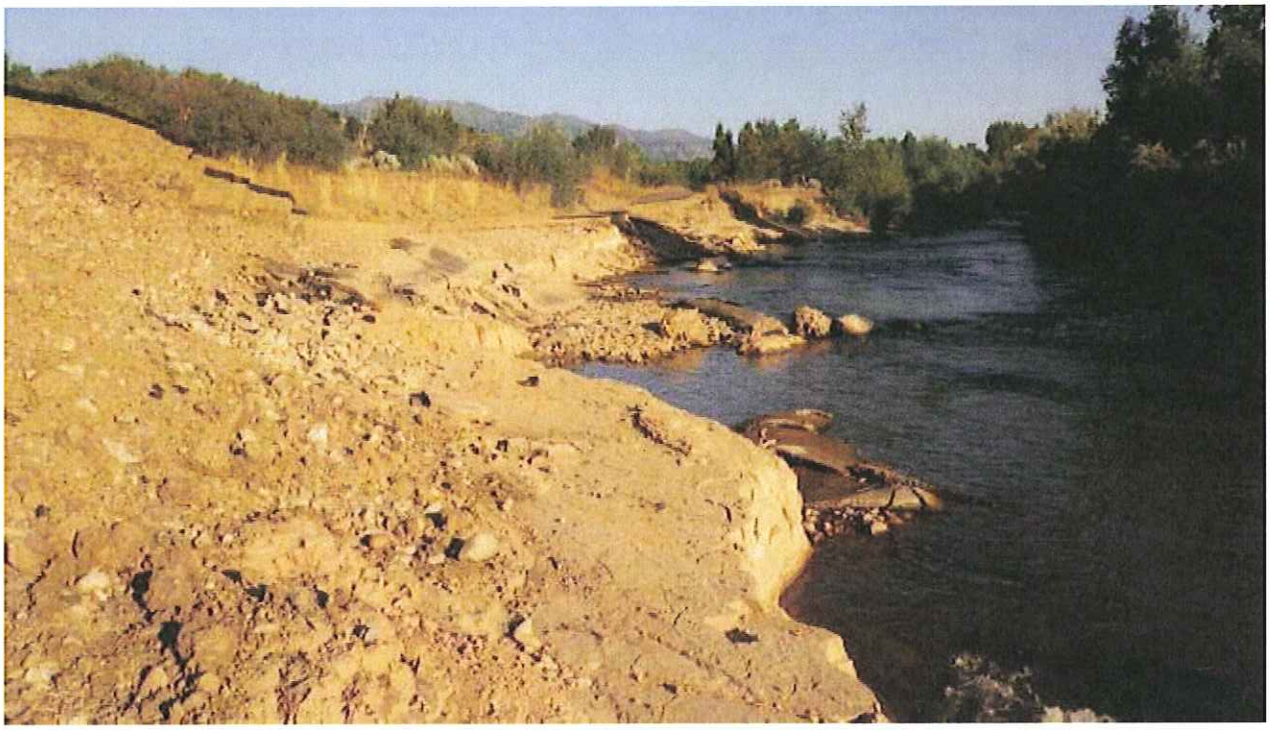
In addition to the restoration and flood mitigation options presented in this report a number of recreational and habitat improvement opportunities are identified. The types of projects the potential to create a new revenue stream for the community but also develop a new generation of river stewards.

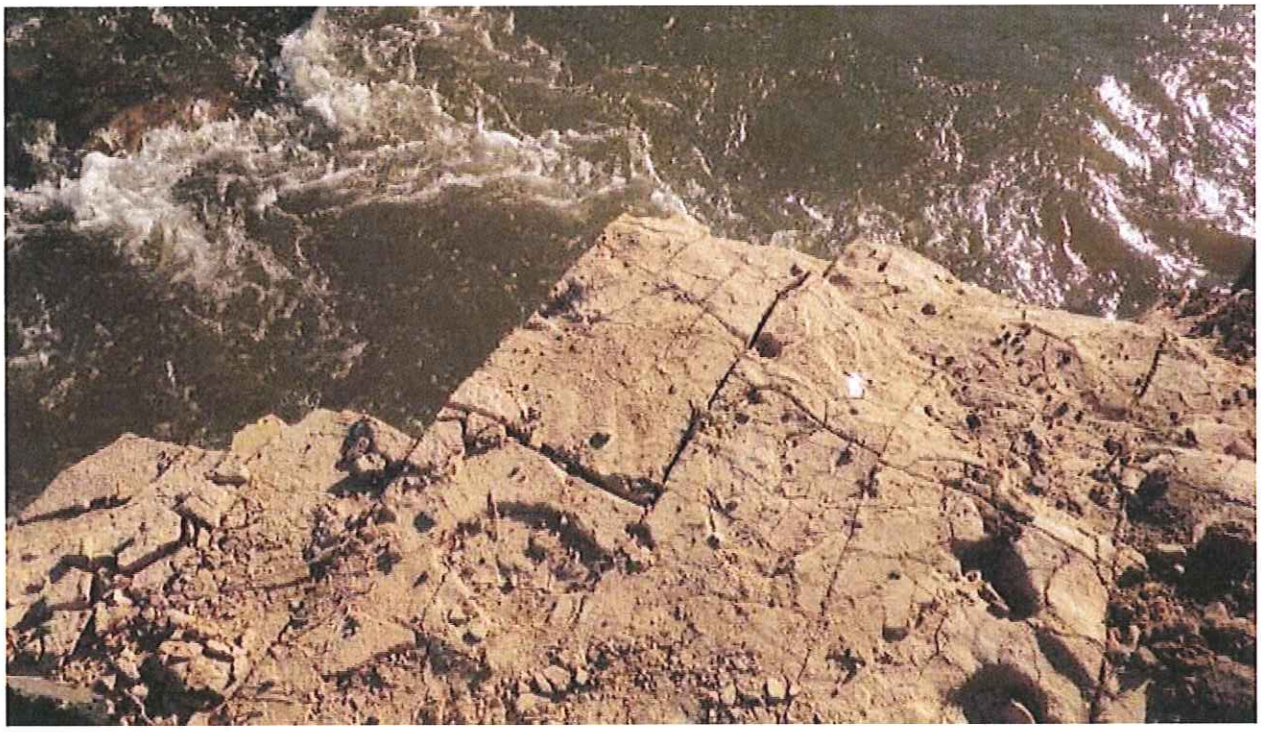
APPENDIX A-Flood Damage Assessments

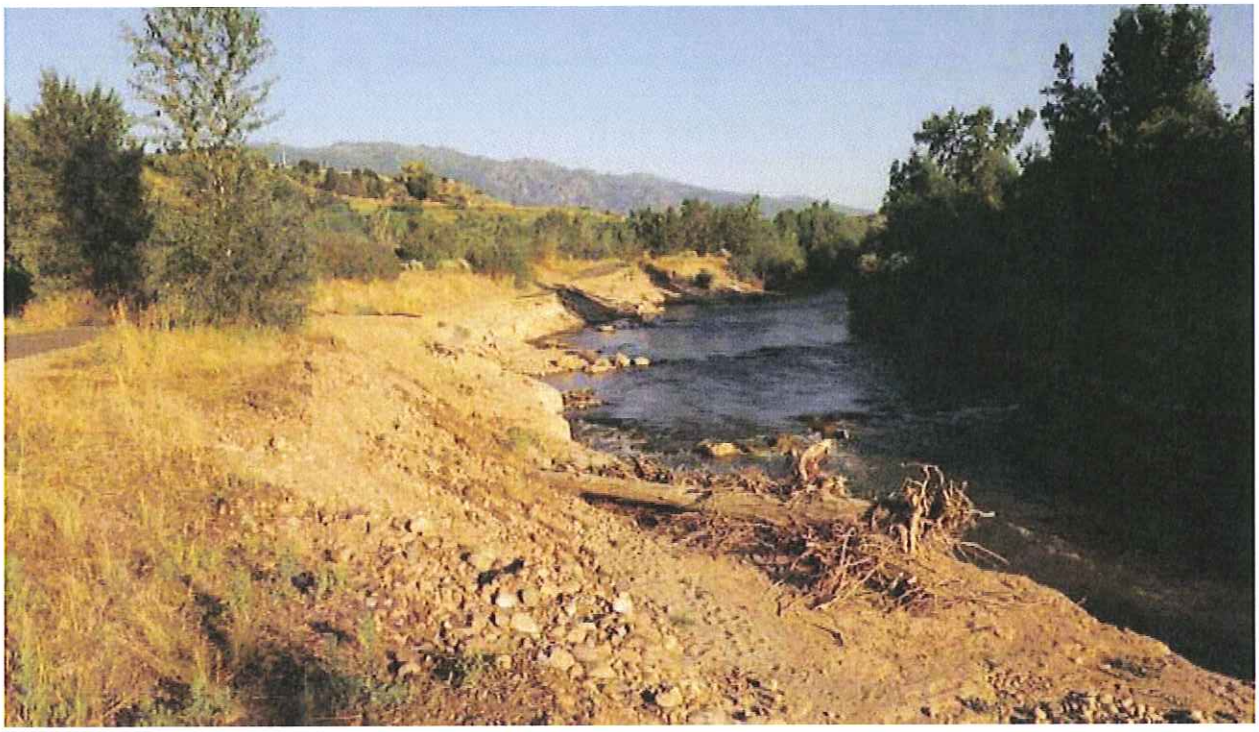
Flood Assessment Point:	**#1-Weber River Parkway Collapse**
GPS Coordinates:	Waypoints RC-10 to 29
Direction to Assessment Point:	Approximately 5260ft upstream from Weber River Dr. on bike path.
Project Priority:	High X Moderate Low
Description of Issue:	Sever erosion of nearly 550 ft of bank resulting in collapse of 300' of asphalt pathway.
Structures:	Bike Path
Geomorphic Description:	Aerial photographs from 1953, 1954, 1971, 1973, 1979, 1980, 1997, 2003, 2006, and 2009 were reviewed to understand the geomorphic evolution of this reach. This portion of the Weber River was channelized in the early 1970's for the construction of I-84. Prior to channelization this reach had meanders with a similar planform to the upstream DNR reach as it exists today. Aerial photography from 1953 shows that the reach length has been reduced by over 20% (7500 feet to 5800 ft). In addition to decreasing the length and a subsequent decrease in slope the construction of the highway also narrowed the effective floodplain of the river. Historic channel patterns are also evident in the 1953 photo. These patterns indicate that the Weber River may have had a meander belt width in excess of 1500ft. Aerial Photographs from 1999 and 2009 show that virtually all of the meanders have been eliminated through channelization and the riparian corridor is less than 150 ft wide. In addition to the channelization a water main crossing was placed just upstream of the failed bike path (RC-9) creating a large drop structure. The river has responded to these changes by cutting into the right bank as it attempts to adjust its flow path length. The river was cutting at this bank prior to the construction of the path in 2009. Between 1997 and 2006 the bank eroded a horizontal distance of approximately 55-60 ft. Some of this bank loss was reclaimed with the construction of the path in 2009. The 1971 photo shows a mid-channel bar formed immediately across the river from the area of the failed bike path. Portions of this bar were left unaltered during the construction of the highway. It is likely that during high flows this mid channel bar become inundated and provided extra conveyance. During the extended drought period that ended in 2008 riparian vegetation was established on this bar thus closing off any significant conveyance. The lack of overbank flooding and the establishment of mature riparian vegetation has effectively eliminated any overbank

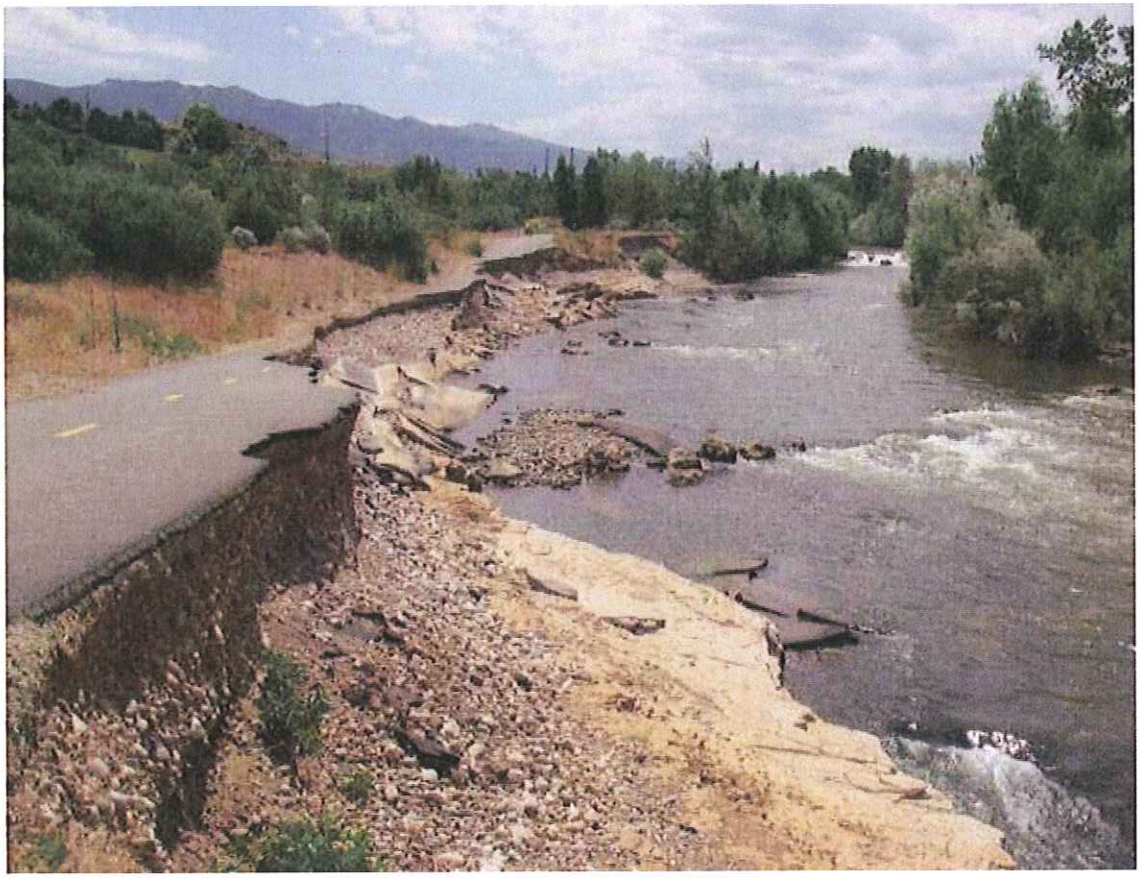
	conveyance through this reach. Additionally there is evidence of bank toe erosion throughout this reach, indicating that the river is down cutting. Evidence of overbank flooding at downstream end of bank failure. Large amounts of driftwood caught in overgrown understory may have decreased overbank conveyance.
Habitat Considerations:	Throughout this reach there is a lack of habitat diversity. Channelization has created uniform flow patterns and in portions the riparian vegetation is sparse. There is little evidence of deposition through this reach. Eroded bank material is likely transported through the reach and deposited downstream of Riverdale City.
Flood Damage Repair	• $250,000-$350,000
Measures:	• Option 1 (Flood Damage Improved Project): o Reconstruct Bike path further northeast. o Biostabilize Bank o $50,000-$100,000 + Lands • Option 2 (Flood Damage Improved Project): o Reconstruct bike path in new alignment o Stabilize Toe o Lay river bank back at 3:1 and biostabilize o Thin out overgrown riparian vegetation on river left to open up flood conveyance channels. o $200,000 to $300,000 + Lands
Photographs:	

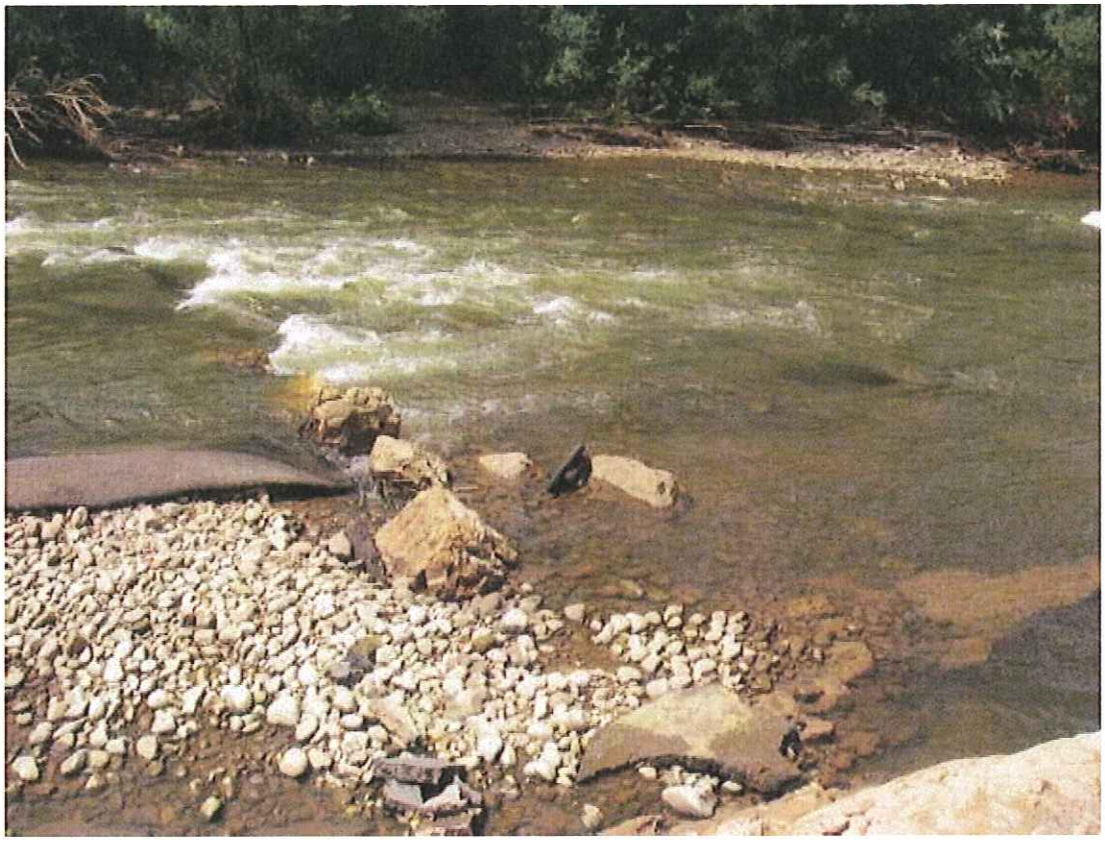


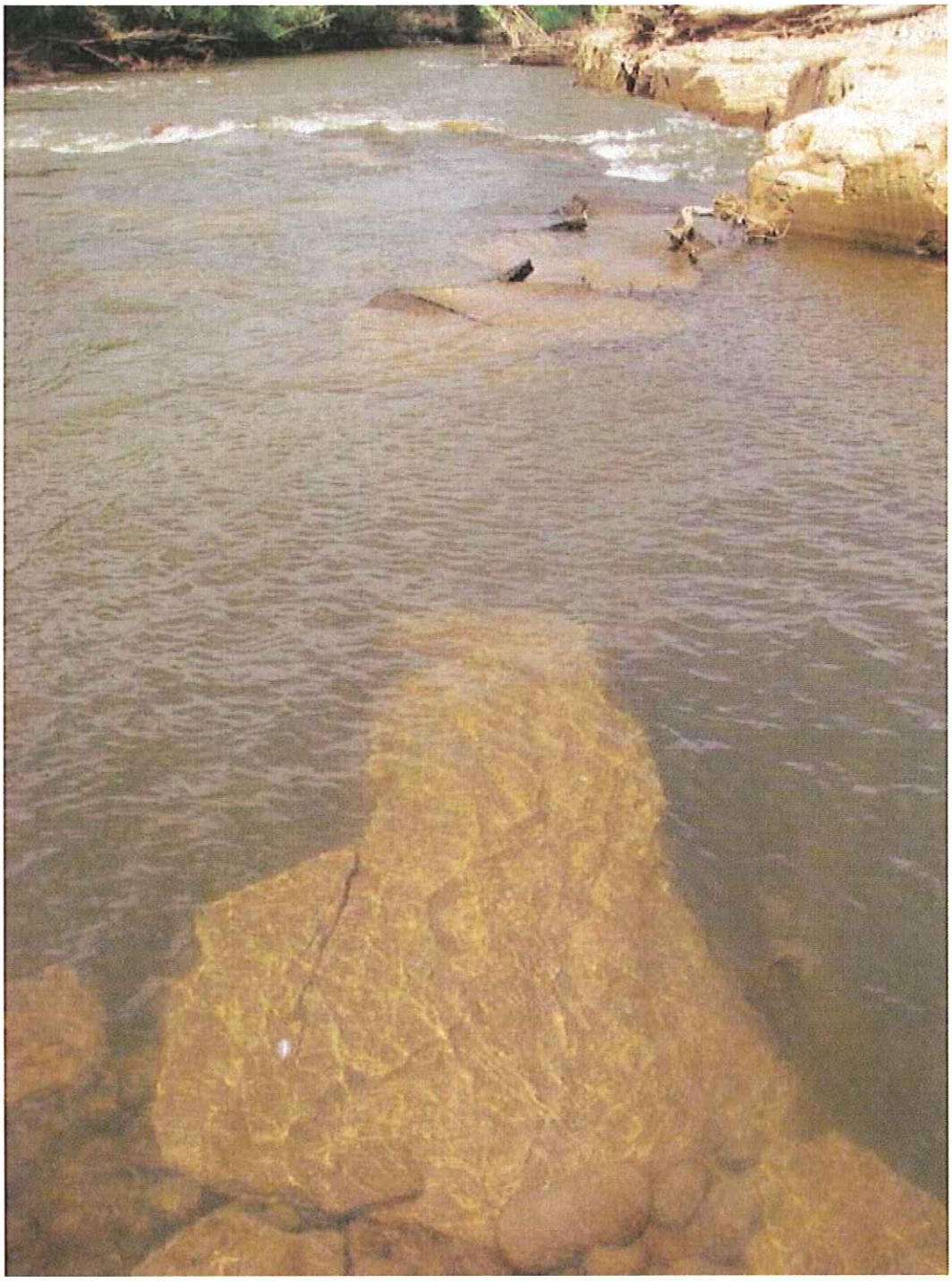






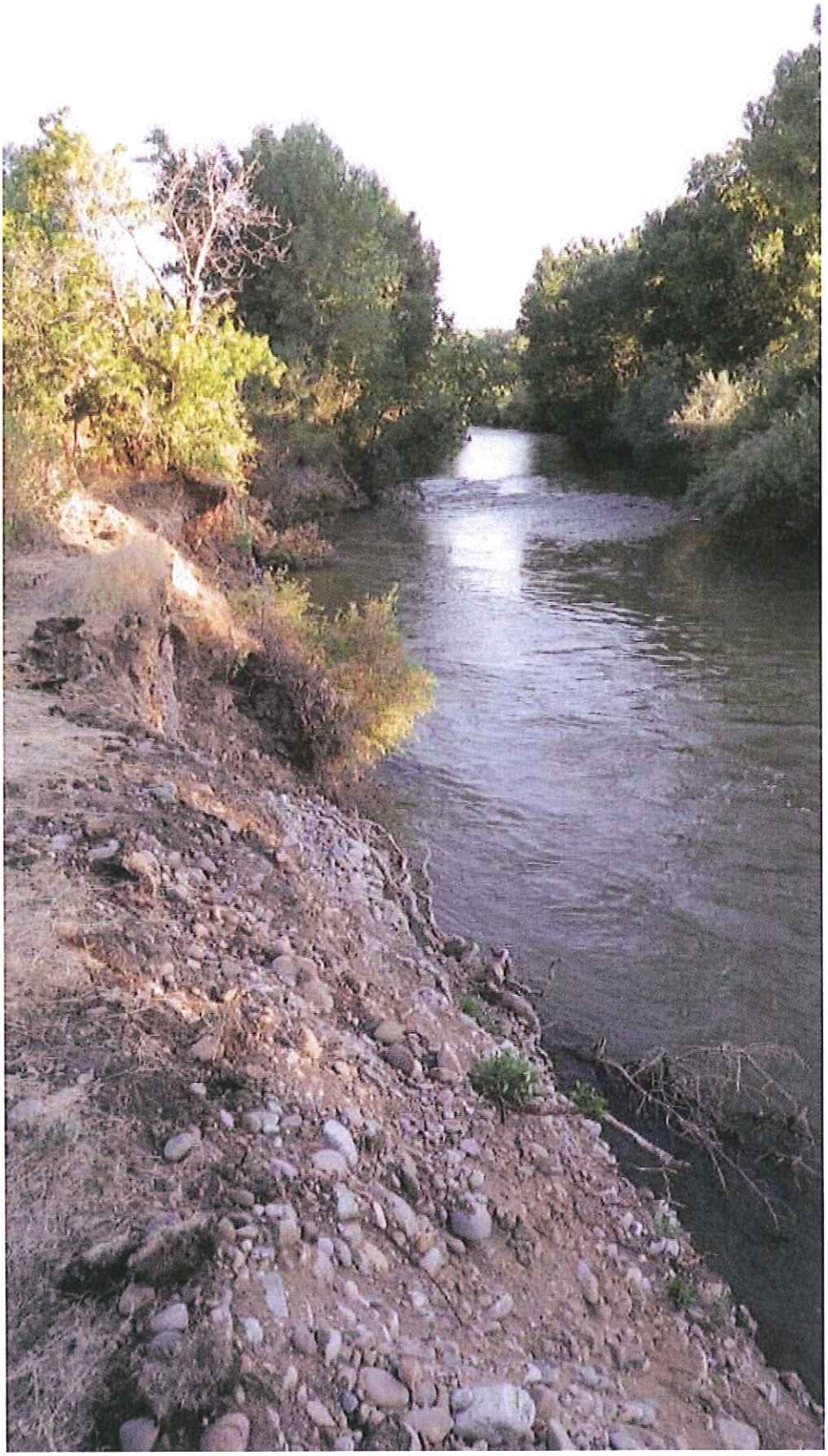






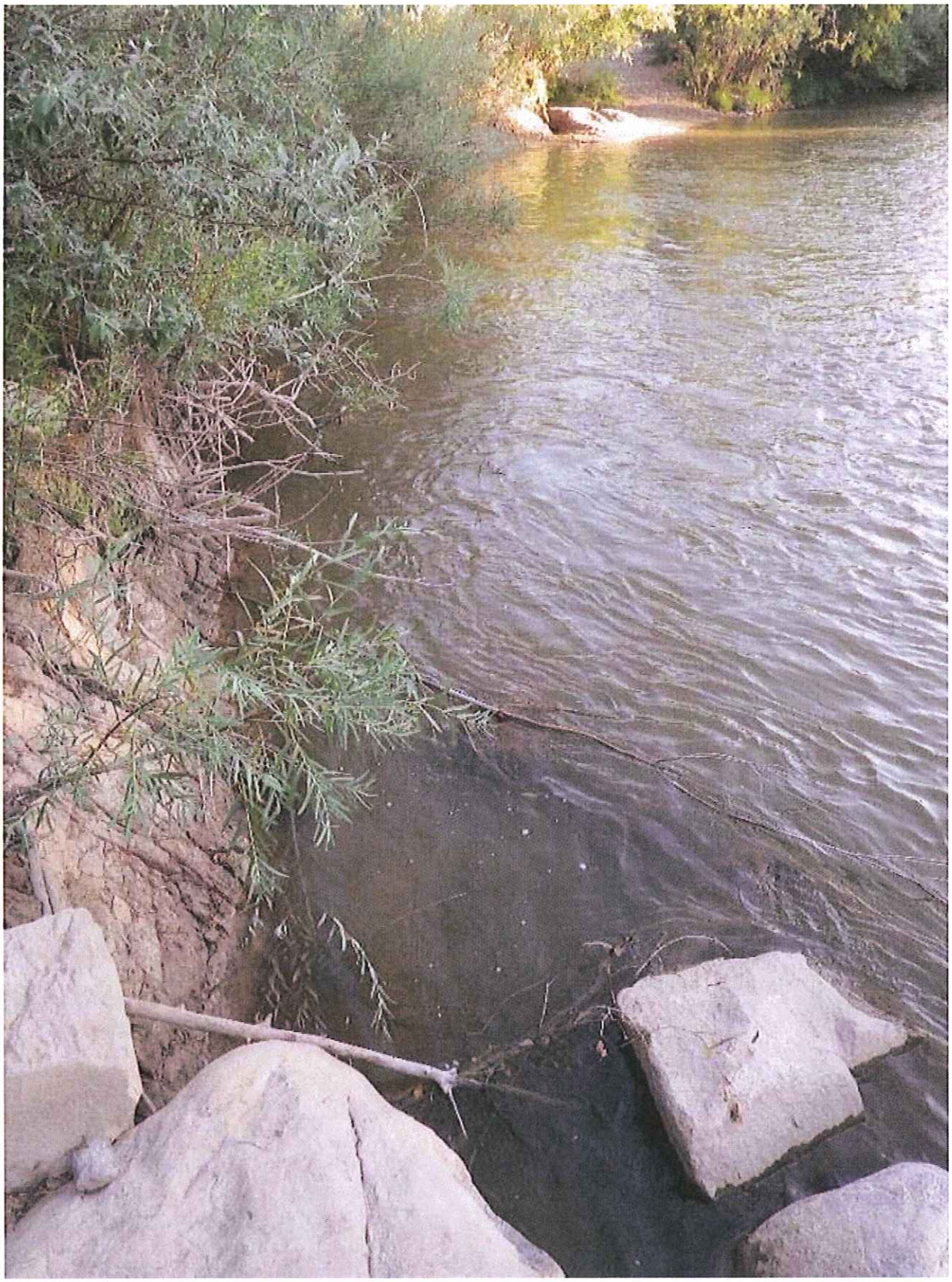
Flood Assessment Point:	**#2-Bank Collapse Across From Riverdale Mobile Estates**
GPS Coordinates:	Waypoints RC-30 to 32
Direction to Assessment Point:	Approximately 4100ft upstream from Weber River Dr. on bike path across from Riverdale Mobile Estates
Project Priority:	High Moderate Low X
Description of Issue:	Sever erosion of approximately 325 ft of bank up to 30' deep threatening bike path.
Structures:	Bike Path
Geomorphic Description:	Aerial photographs from 1953, 1954, 1971, 1973, 1979, 1980, 1997, 2003, 2006, and 2009 were reviewed to understand the geomorphic evolution of this reach. This portion of eroded bank is approximately 840 ft downstream of the failing bike path and is within the same reach. This portion of the Weber River was channelized in the late 1964 for the construction the mobile home park. The reach immediately upstream of this was encroached by the construction of I-84 in the 1970's. Aerial photography from 1953 and 54 shows that at this location the Weber River had a meander belt width of 800 ft and historically the main channel of the river has shifted across over 1500 ft of active floodplain. Comparison of aerial photographs shows that the mobile home park was constructed in the same location as the main active channel in 1953. This encroachment shortened the stream length through this reach by over 20%. Additionally the width of the active floodplain was reduced from over 1500 ft to less than 900 ft. The resulting channel is completely straight and the active channel width was reduced from over 150 ft to less than 90 ft. The steeper, narrower channel has a greater transport capacity than the unaltered channel. In response to the encroachment of the mobil home park the river started to move to the river right. Aerial photos from the 1971 show a completely straight Weber River located immidatly behind mobile homes on L Street. Aerial photos from the last decade show a slightly more sinuous river. Analysis of the photographic records indicates that the river has moved nearly 80 ft to the east resulting in increased forces on the river right bank. The sustained high flows during the 2011 runoff put significant strain on the right bank across and downstream of the mobile home park.
Habitat Considerations:	Throughout this reach there is a lack of habitat diversity. Channelization has created uniform flow patterns and in portions the riparian vegetation is sparse. There is little

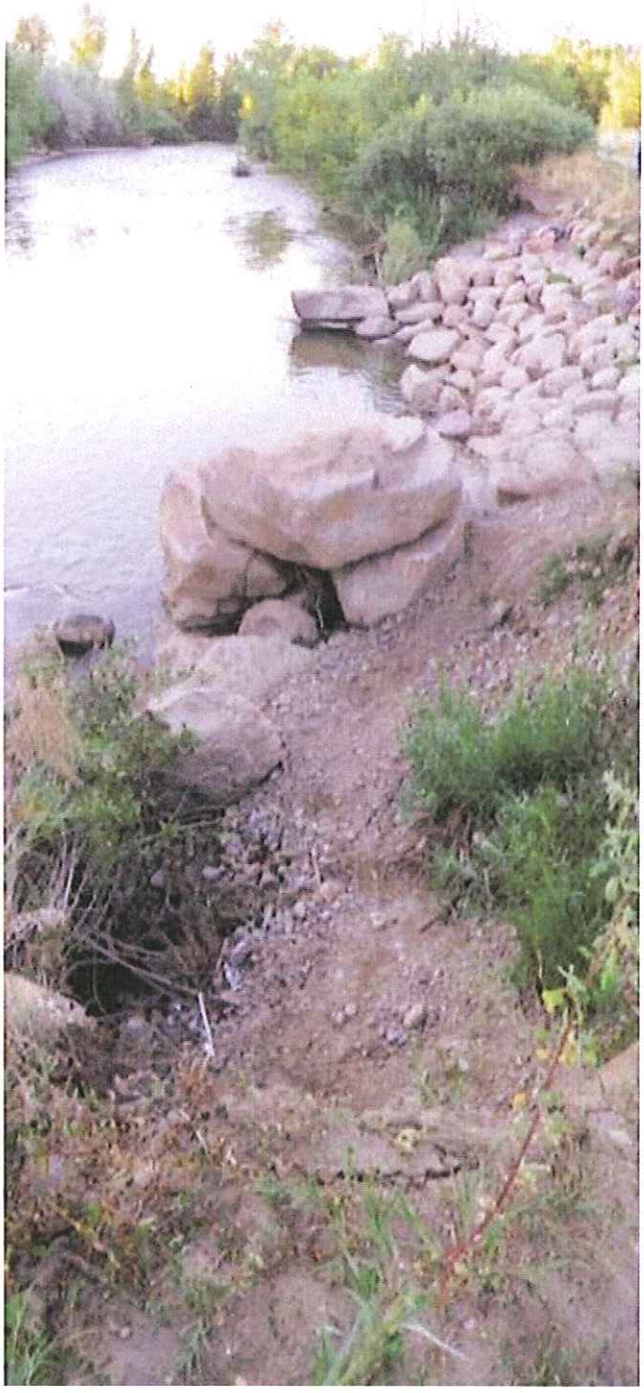
	evidence of deposition through this reach. Eroded bank material is likely transported through the reach and deposited downstream of Riverdale City.
Flood Damage Repair	• $30,000-$64,000
Measures:	• Option 1 (Flood Damage Improved Project) o Lay back right bank o Offset Bike path and allow some bank erosion o $50,000-$100,000
Photographs:	• IMGP0096 • IMGP0098



Flood Assessment Point:	**#3-Frisbee Golf Course Riprap Failure**
GPS Coordinates:	Waypoints RC-33 to 34
Direction to Assessment Point:	Approximately 2400ft up path from Weber River Dr.
Project Priority:	High Moderate Low X
Description of Issue:	Sever localized erosion, poorly installed rip-rap and J-hooks. Rip-rap and J-hooks failing. Bank erosion
Structures:	Bike Path, Rip Rap
Geomorphic Description:	Aerial photographs from 1953, 1954, 1971, 1973, 1979, 1980, 1997, 2003, 2006, and 2009 were reviewed to understand the geomorphic evolution of this reach. This is at the downstream end of the reach that was channelized in the 1960ss and 1970s with the construction of I-84 and the mobile home park. Additionally downstream of this location the river was channelized during the commercial development along Riverdale Rd. in the early 1970s. This reach is downstream of the mobile home park and upstream of the Crabtree Investments Property (adjacent to the Bridge over the Weber River on 4600 S/Weber River Dr.). It appears from the historic aerial photos that this reach between these two channelized reaches remained in a relatively natural state until after 1980. As the lands between the Weber River and Riverdale Rd. were developed during the 1980s and the Riverdale City park lands were being developed the river was further constrained. During this time the sinuosity of this portion of the river has decreased from 1.26 to 1.06. One of the causes of this decrease in sinuosity is a meander cutoff that happened between 1980 and 1992 just downstream of the failed rip-rap area. This cutoff is part of a natural process that may have been impacted by human encroachment. Prior to this cutoff the area were the rip-rap was placed was on the outside of a bend. Just upstream of this location there is a resistant clay deposit on the right bank which has prevented the river from significantly cutting into the bank.(Photo 221, 222). At the downstream end of this clay deposit the stream expands and encounters more erodible material. Since the meander cutoff happened, a high tension power line and the bike path have been installed on the right bank. A number of J-hooks were installed on the right bank through this reach, likely to protect the path and power line alignments. Many of these J-Hooks appear to be placed to high on the bank to function properly. Their improper placement can cause adverse hydraulics on the banks resulting localized erosion.

	Aerial photographs show evidence of historic flow paths in the floodplains on either side of the current alignment. The open field just to the east of this rip-rap failure appears to contain one of these old river alignments. These alignments are visible because they have differing vegetation and stand out. The difference in vegetation is due to the different soils that the river deposits as it alters its alignment. Often these old channel alignments contain deposits of gravel and small cobbles that are easily mobilized during flood events. Just downstream of this rip-rap failure a mid channel bar has become vegetated, the J-hooks have caused aggradation around this bar decreasing capacity on the right of the vegetated bar. At low flows this mid channel bar becomes connected to the right bank and functions as a large vegetated point bar. A riffle has formed at the head of this point bar, just downstream of the failed riprap. These morphologic changes have altered the local hydraulics and put greater stress on the right bank. Lastly there is less riparian vegetation along this portion of the river. The increased bank stress combined with the adverse hydraulics created by the non systemically planned J-hooks, the lack of bank stabilizing vegetation and the easily erodible channel deposit resulted in the bank failing between 2006 and 2010. The riprap was placed between two of the J-hooks to prevent further damage of the bank. It's likely that while the rip-rap failed it succeeded in preventing further damage to the path. However, the rip-rap installation was not extensive enough to truly address this situation. An engineered riprap design for this location could extend over 300 ft.
Habitat Considerations:	Throughout this reach there is a lack of habitat diversity. Channelization has created uniform flow patterns. There is some evidence of deposition in this reach. Eroded bank material is likely transported through the reach and deposited downstream of Riverdale City.
Flood Damage Repair:	• $25,000-$50,000
Measures:	• Option 1(Flood Damage Replacement Project) o Move Path to East (City Owned Land) o Lay back right bank o Bio stabilize right bank. o Remove J-hooks. Use as Toe Boulders o Place Excess J-hook boulders in River as habitat/squirt boat features. o Construct overbank relief channel o $50,000-$100,000
Photographs:	• IMGP0099 • IMGP0221 • IMGP0222





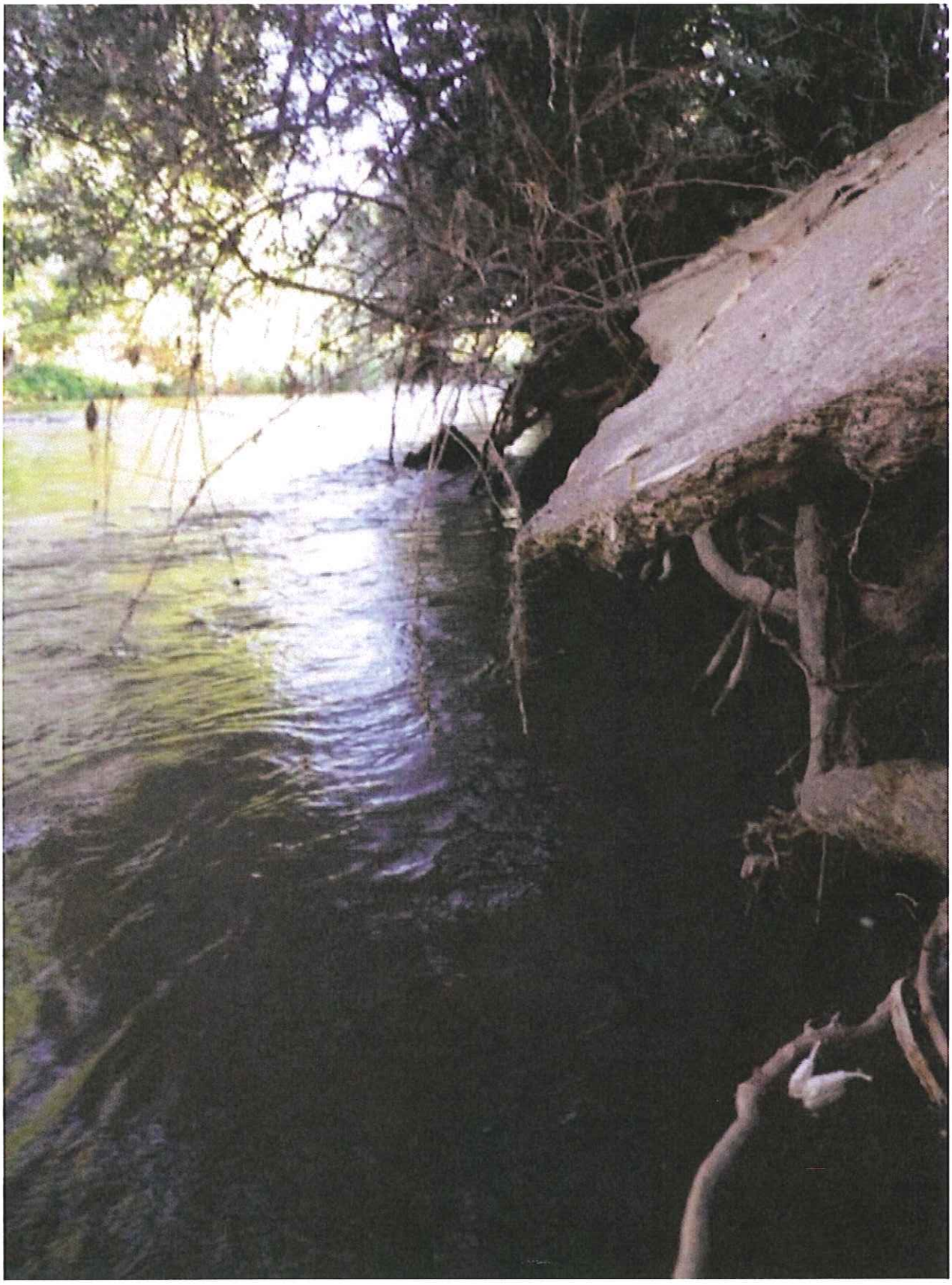
Flood Assessment Point:	**#4-Riverdale Play Park, Grade control and Riprap Failure**
GPS Coordinates:	8-16-11: Pts 9 & 10
Direction to Assessment Point:	Approximately 600 ft downstream on the bike path from the South Weber River Dr. trailhead.
Project Priority:	High X Moderate Low
Description of Issue:	Grouted Riprap appears to be failing and as a result the whitewater wave no longer functions. Probing indicates 8'deep hole upstream of the grouted grade control and an 8' deep hole downstream of the structure. Design drawings indicate that the cutoff wall above the lower drop is only 5' deep; it is likely that the grouted riprap has been undercut. Additionally the grouted grade control on the left bank between the two structures has also failed and there is significant erosion in the viewing area on the left bank at the lower drop. This erosion extend downstream over 350 ft. This is a High Priority project for a number of reasons: 1) the Riverdale Whitewater Park is a world class whitewater feature that brings tourism $ into Riverdale, 2) **Potential significant entrapment hazard to boaters/swimmers (There is a popular rope swing just upstream of the lower structure)**
Structures:	Sewer Line, Kayak Wave, Bike Path
Geomorphic Description:	This grouted grouted grade control structure was constructed in 2005. The primary goal of this structure is to protect the sewer line crossing. The structure was also designed to create a whitewater wave. Based on design drawings there is a 5' concrete cutoff wall upstream of the lower drop structure. Like much of the Weber River through Riverdale City, this reach has been channelized during the urbanization of Riverdale in the 1970s. Historically, this reach of the river was more similar to the upstream reaches that pass through the DNR property; it was a dynamic, aggrading system. The modified channel has a greater sediment transport capacity and is capable of transporting most of the alluvium supplied by the upstream reaches. As a result of this excess transport capacity the Weber river is degrading through much of Riverdale City. This is evidenced by bank toe erosion and little evidence of sediment deposition throughout the Riverdale reach. While it is difficult to assess the condition of the structure due to high flows, the presence of 8' deep holes upstream and downstream of the structure indicate that the 2011 flood flows were sufficiently large, and of a sufficient duration that they may have undercut the 5 foot cutoff wall and eroded under the grouted grade control. It is

	not uncommon for grouted grouted grade control structures to be undercut. Additionally, the downstream hydraulics have caused significant bank erosion on the right bank of the river. General channel degradation is likely downstream of the grade control structure. Due to the excessive channel scour the structure no longer functions as designed.
Habitat Considerations:	This structure provides better fish passage than the upstream drop structures.
Flood Damage Repair:	• $250,000-$350,000
Measures:	• Option 1 (Flood Damage Lower Structure Improved Project) o Re-Grout riprap o Fill voids under structure with Flowable Fill o Replace Cutoff Wall (sheet pile) o Biostablize Left Bank o Repair downstream grade control o $200,000-$300,000 • Option 2- (Replace Lower Structure, Alternate Project) o Remove grouted rip-rip o Construct new structure out of large boulders embedded below scour depth o Install pre-cast "Wave Blocks" to create play wave o Install Sheet pile cutoff. o Protect viewing area with boulder and flagstone o $350,000-$650,000
Photographs:	• IMGP0159 • IMGP0160 • IMGP0161 • IMGP 2796

Flood Assessment Point:	**#5-54" RCP outfall @ W4400S & S Weber River Dr.**
GPS Coordinates:	8-16-11 Point 20
Direction to Assessment Point:	On left bank at east end of W4400S @ S Weber River Dr. left turn
Project Priority:	High Moderate Low X
Description of Issue:	Rip-Rap around outfall is failing. Evidence of piping around headwall.
Structures:	Stormwater Outfall.
Geomorphic Description:	The riprap has been compromised by the high flows of 2011. The rip-rap has insufficient depth, toe stability and does not appear to have any filter material.
Habitat Considerations:	Sediment source.
Damage Assessment	• $15,000-$35,000
Measures:	• Option 1 (Flood Damage Replacement Project) o Repair rip-rap with sufficient blanket depth and filter material o Opportunity to create stormwater treatment wetland? o Stabilize toe o $30,000-$64,000
Photographs:	• IMGP0165 • IMGP0166

Flood Assessment Point:	**#6 #14-Two 36" RCP outfalls and Rip-rap @ Riverdale Rd. Bridge**
GPS Coordinates:	8-16-11 Point 22 & 23
Direction to Assessment Point:	On left bank just downstream of Riverdale Rd. Bridge
Project Priority:	High Moderate Low X
Description of Issue:	Rip-Rap around outfall is failing. Evidence of piping around headwall. Filter Fabric exposed. Riprap under bridge failing. No fabric evident under bridge. This is intended to be a continuous blanket of rip-rap. There is insufficient toe stability.
Structures:	Riverdale Rd. Bridge Abutment and Stormwater Outfall
Geomorphic Description:	The riprap has been compromised by the high flows of 2011. The rip-rap has insufficient depth and does not appear to have any filter material. There is also evidence of bank erosion up and downstream of this location. Some of the erosion may be cause by the rip-rap blanket; if the rip-rap does not extend up and downstream a sufficient distance, and is not keyed in properly it can cause adverse hydraulics. There is also a failed J-hook structure that may have further exacerbated the adverse hydraulics.
Habitat Considerations:	Sediment source.
Damage Assessment	• $20,000-$40,000
Measures:	• Option 1 (Flood Mitigation Replacement Project) o Repair rip-rap with sufficient blanket depth and filter material. o Bio stabilize up and downstream., o Remove J-hook and use boulders for Toe protection or habitat enhancement. o Opportunity to create stormwater treatment wetland at stormwater outfalls? o Stabilize Toe o $35,000-$64,000
Photographs:	• IMGP0171 • IMGP0172 • IMGP0173

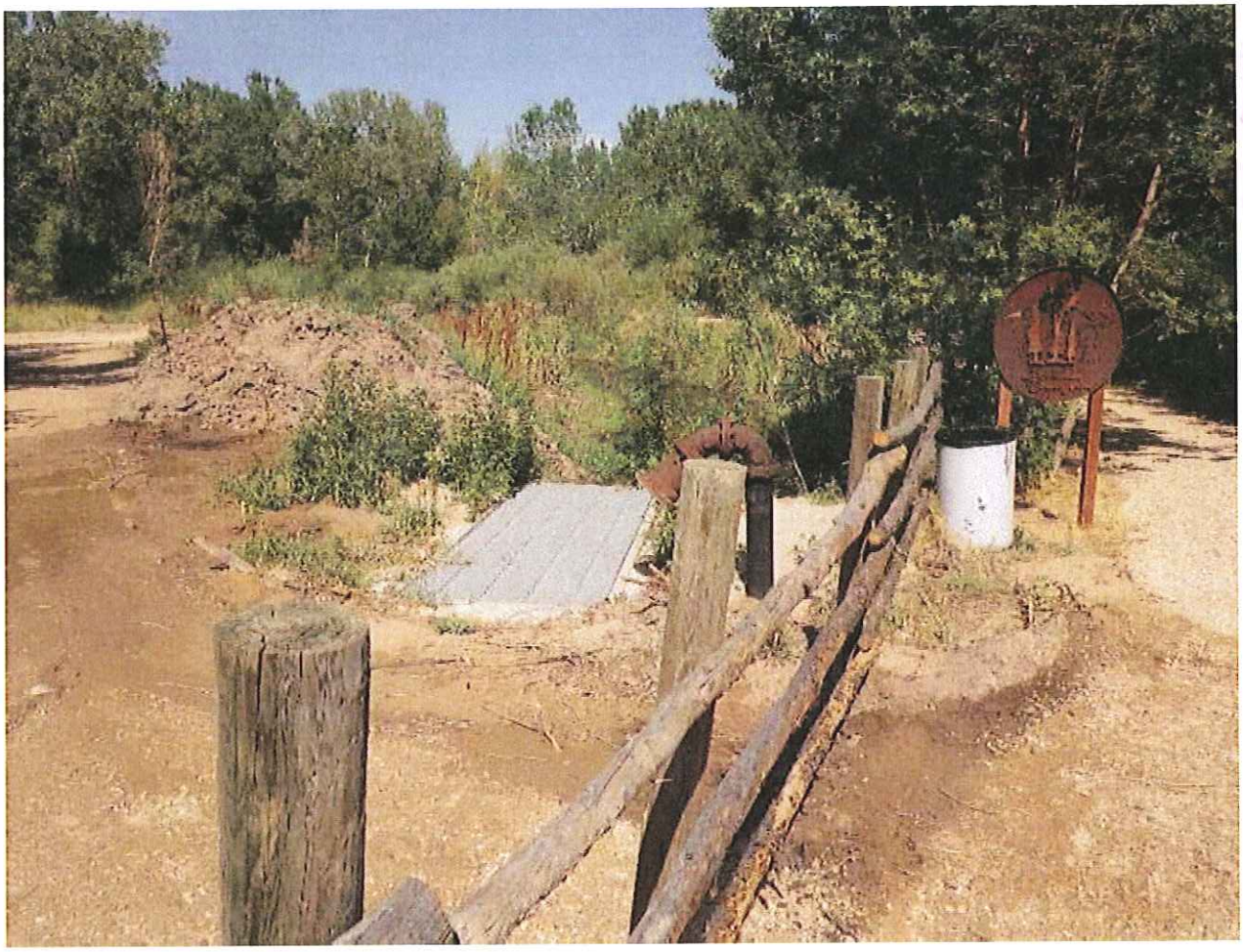
Flood Assessment Point:	**#7-Concrete Revetment at Les Schwab Tire**
GPS Coordinates:	8-16-11 Point 26
Direction to Assessment Point:	On left bank approximately 450 ft upstream of the Riverdale Rd. Bridge on the bike path.
Project Priority:	High Moderate Low X
Description of Issue:	There is 15'x50' concrete slab poured on the bank, ostensibly done for bank protection. The concrete slab is undercut and failing. The exposed slab may be causing adverse hydraulics exacerbating bank erosion and may create a safety hazard. There is insufficient toe stability.
Structures:	Bank protection, sculpture
Geomorphic Description:	This concrete slab is not constructed properly for bank protection. Generally, flexible rip-rap is preferable to a concrete slab due to its ability to conform to the changing river bank.
Habitat Considerations:	Degraded Riparian habitat, source of sediment
Flood Damage Repair Measures:	• $5,000-$10,000 • Option 1 (Flood Damage Replacement Project) o Remove concrete o Stabilize Toe o Biostabilize bank o $35,000-$64,000
Photographs:	• IMGP0175 • IMGP0176 • IMGP0177



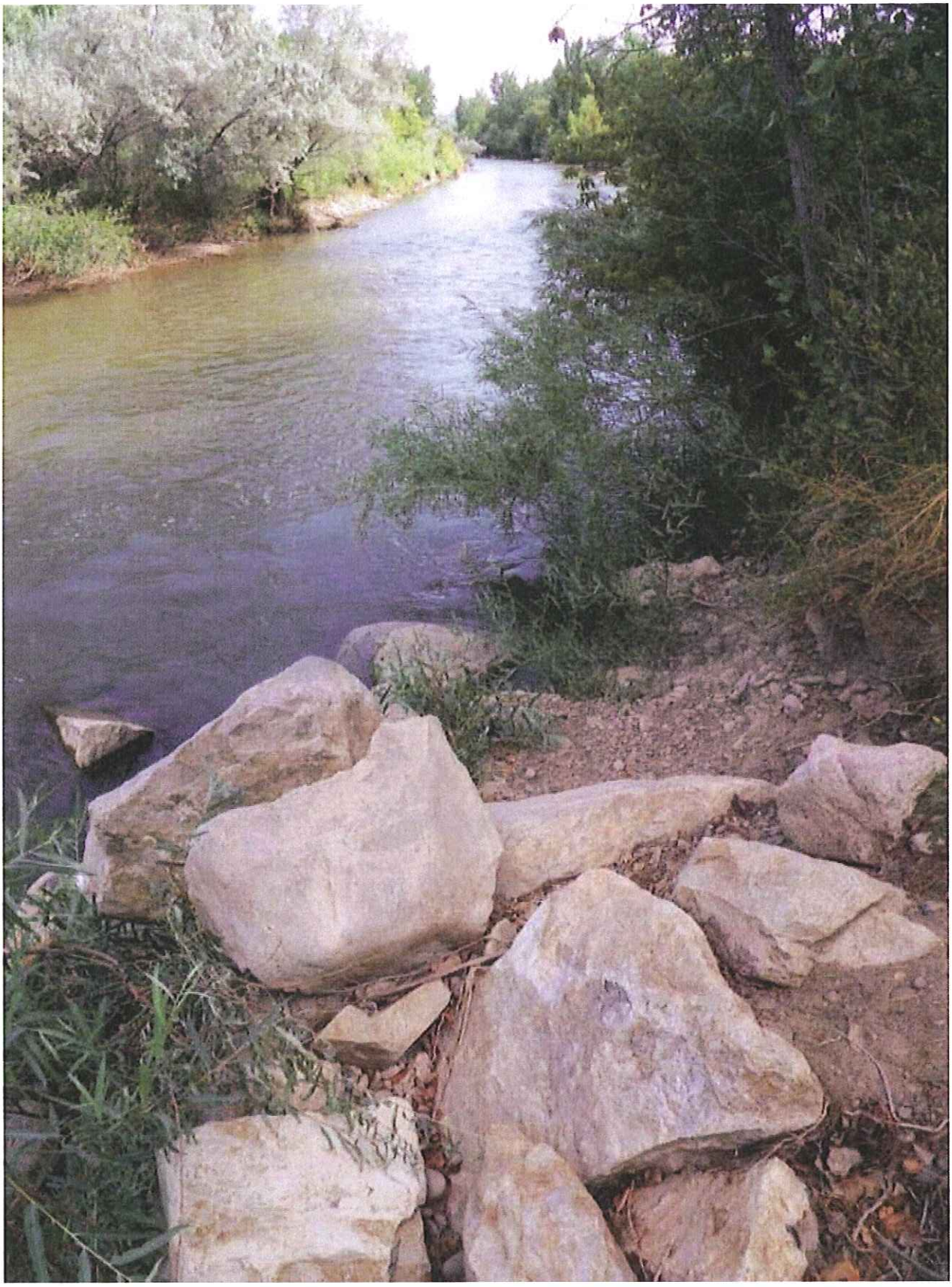
Flood Assessment Point:	**#8-Riprap at 4600S and Weber River Dr. Bridge**
GPS Coordinates:	8-16-11 Points 28 30
Direction to Assessment Point:	Under Bridge at 4600S and Weber River Dr.
Project Priority:	High: Moderate: X Low:
Description of Damage:	The rip-rap failing and unstable.
Structures:	Bridge
Geomorphic Description:	The riprap blanket is not thick enough, does not extend far enough, does not appear to have fabric, and is not keyed in. Additionally, the riprap may be inadequately sized and may not be angular enough. There is insufficient toe stability.
Habitat Considerations:	Source of sediment
Flood Damage Repair:	• $25,000-$50,000
Measures:	• Option 1 (Flood Damage Replacement Project) o Install properly engineered revetment, extending up and downstream sufficient distance, and keyed in o Biostabilize up and downstream of revetment o Stabilize Toe o $30,000-$64,000
Photographs:	• IMGP0178

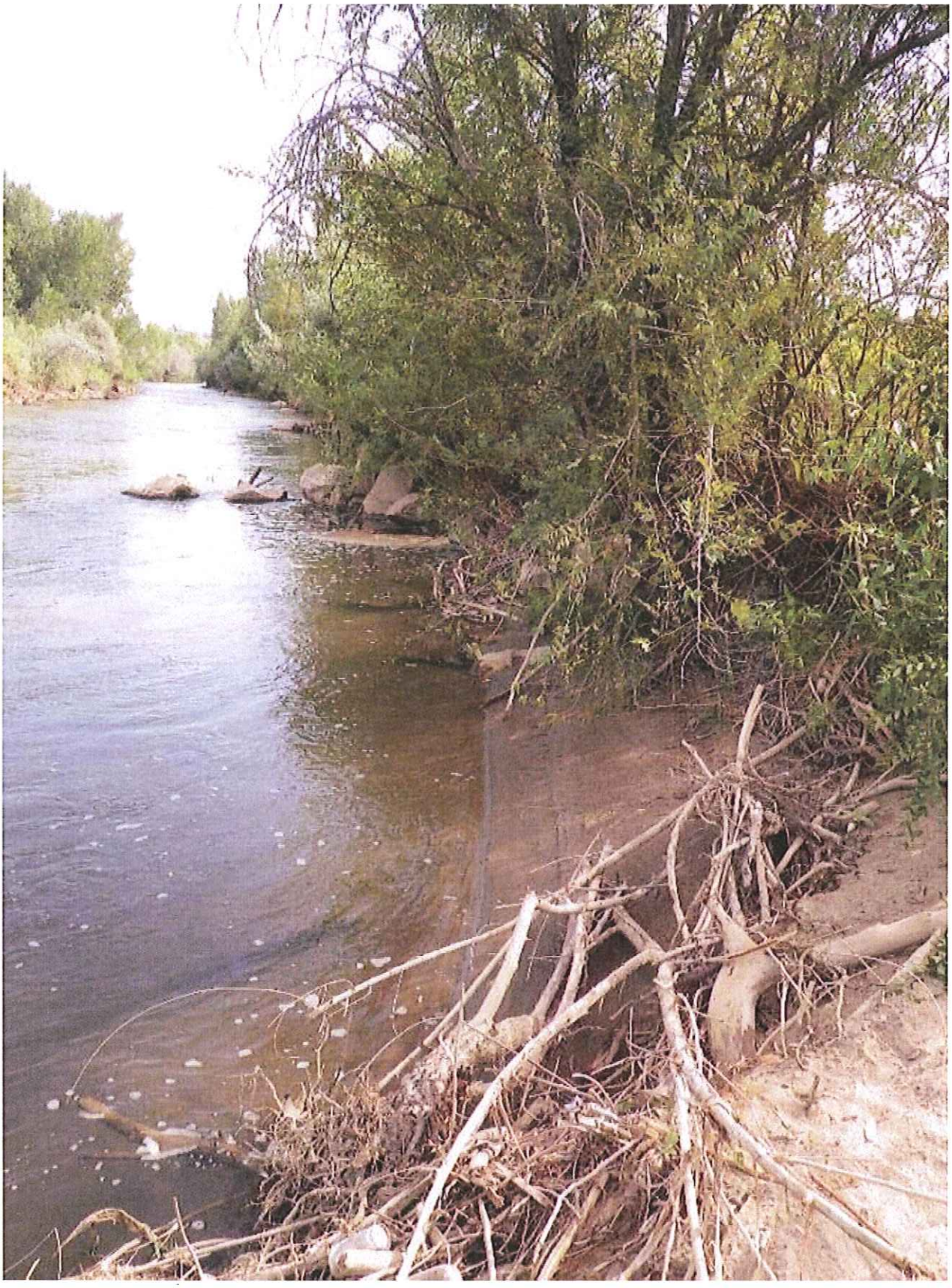
Flood Assessment Point:	**#9 & #13-Creekside Tr ailhead Path Erosion @ River Glen Subdivision**
GPS Coordinates:	8-16-11 Point 39, 40, 41, 42
Direction to Assessment Point:	At the junction of the Creekside trail and the Weber River Pathway. Approximately 1000ft on the bike path upstream from north trail head.
Project Priority:	High X Moderate Low
Description of Damage:	The path that leads from the River Bend Subdivision was completely eroded by overbank flooding. This path was reconstructed immediately after the 2011 flood event. 275 ft of split rail fence destroyed, 275 ft path destroyed. There are also issues with the stormwater conveyance at this location. There is a drainage channel that discharges at the west end of the Creekside trail. During high flow events this structure backs up, causing flooding in the River Bend subdivision.
Structures:	Path, Fence, stormwater return channel, homes.
Geomorphic Description:	This portion of the Weber River Floodplain has historically been very active. Historic aerial photos from prior to 1971 show that the active channel of the Weber River flowed through this area. The historic channel passed directly across the junction of the two paths, continued northwest directly through what is now Wildcat Storage and the trailhead facility. The construction of I-15 and Parker Drive has encroached on the active channel at this point, forcing the river east, into its current, channelized location. The river overbanks approximately 500 ft south of the trail junction on the Pathway. FEMA mapping indicates that the trail junction is in ZONE AE and the majority of the Creekside Trail is in the 500 year floodplain. During 2011 runoff this area was inundated by a 10-year flood, indicating that the FEMA information May need updating. *It's important to note that the DFIRM identifies most of this area as 100-year and 500-year floodplain. This was a ten year event; this area should be remapped.* Also we may want to separate this into two damage sites.
Habitat Considerations:	None
Flood Damage Repair:	• $5,000-$15,000

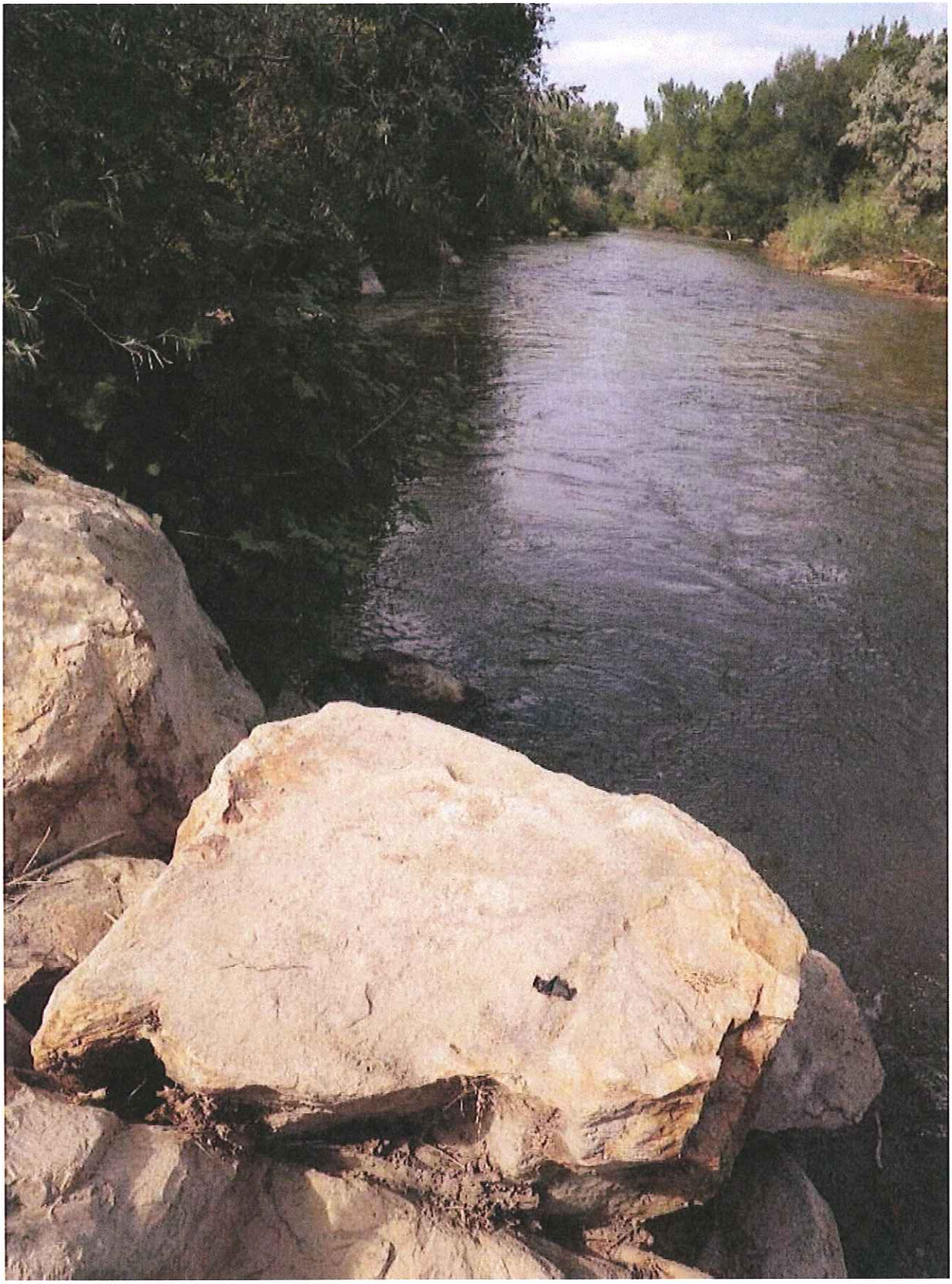
Measures:	• Option 1(Flood Damage Replacement) o Repair path o Repair fence o Biostabilize left bank at location of overbank. o $30,000-$64,000 • Option 2 (Flood Mitigation Project) o Rebuild path to handle overbank flows o Remove fence to facilitate overbank flows o Create overbank flow path between Weber Parkway and Riverbend Subdivision o Reconstruct Weber Pathway to have boardwalk to allow overbank flows o Biostabilze overbank area o Construct return flow channel upstream of North trailhead and downstream of trail junction. o Build offset levee along property lines o Install pump station at trailhead to pump stormwater against floodflow head, discharge downstream in Weber River. o $250,000-$500,000
Photographs:	• IMGP0192 Trailhead • IMGP0193 Looking upstream flood channel • IMGP0195 Bank failure at overbank area • IMGP0196 Looking downstream at overbank area, flood flow path.



Flood Assessment Point:	**#10-Failed Bank Stabilization**
GPS Coordinates:	8-16-11 Points 46
Direction to Assessment Point:	This specific location is at the Junction of the Hunter Creek Trail and the Weber Parkway See also Failed J-Hooks Point 50 (8-16-11)
Project Priority:	High X Moderate Low
Description of Damage:	Non systemically planned constructed J-hooks and localized erosion
Structures:	J-hooks, Path
Geomorphic Description:	Similar to other location along the Weber River, these structure were placed to prevent bank erosion and the subsequent migration of the river channel. Installed in the 1980s or early 1990, these structures may have been intended to reduce shear stress on the bank by forcing the flow towards the centerline of the channel. Many of these structures were designed without consideration of systemic response. Other stabilization methods may be more appropriate for this location
Habitat Considerations:	j-hooks cause erosion which contributes to non-point source sediment pollution.
Flood Damage Repair:	• $20,000-$40,000
Measures:	• Option 1 (Flood Damage Replacement Project) o Remove J-hook structures o Use boulders for toe protection/Stabilization o Biostabilize bank o Toe Stability o $35,000 - $64,000
Photographs:	• IMGP0203 • IMGP0205 • IMGP0206

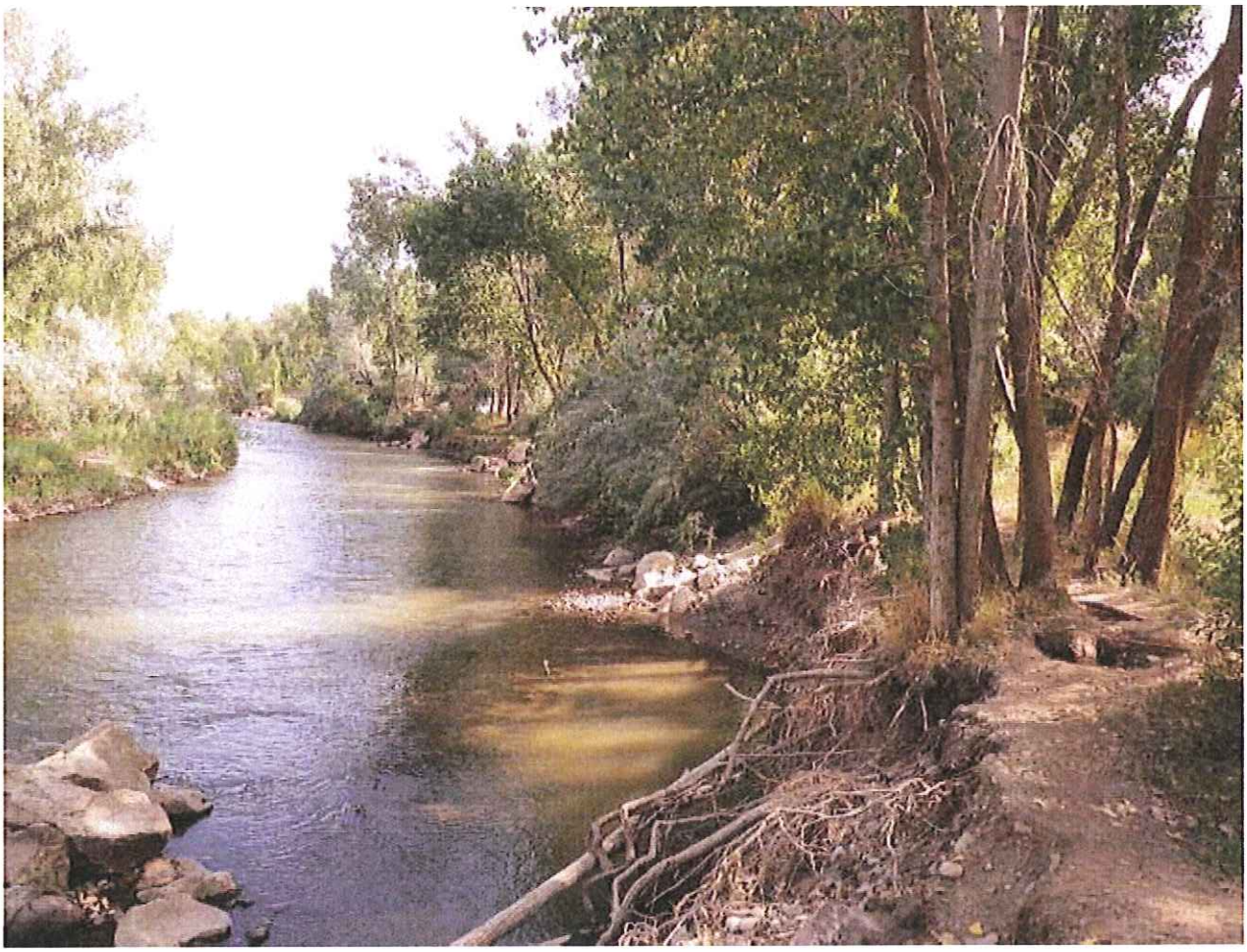


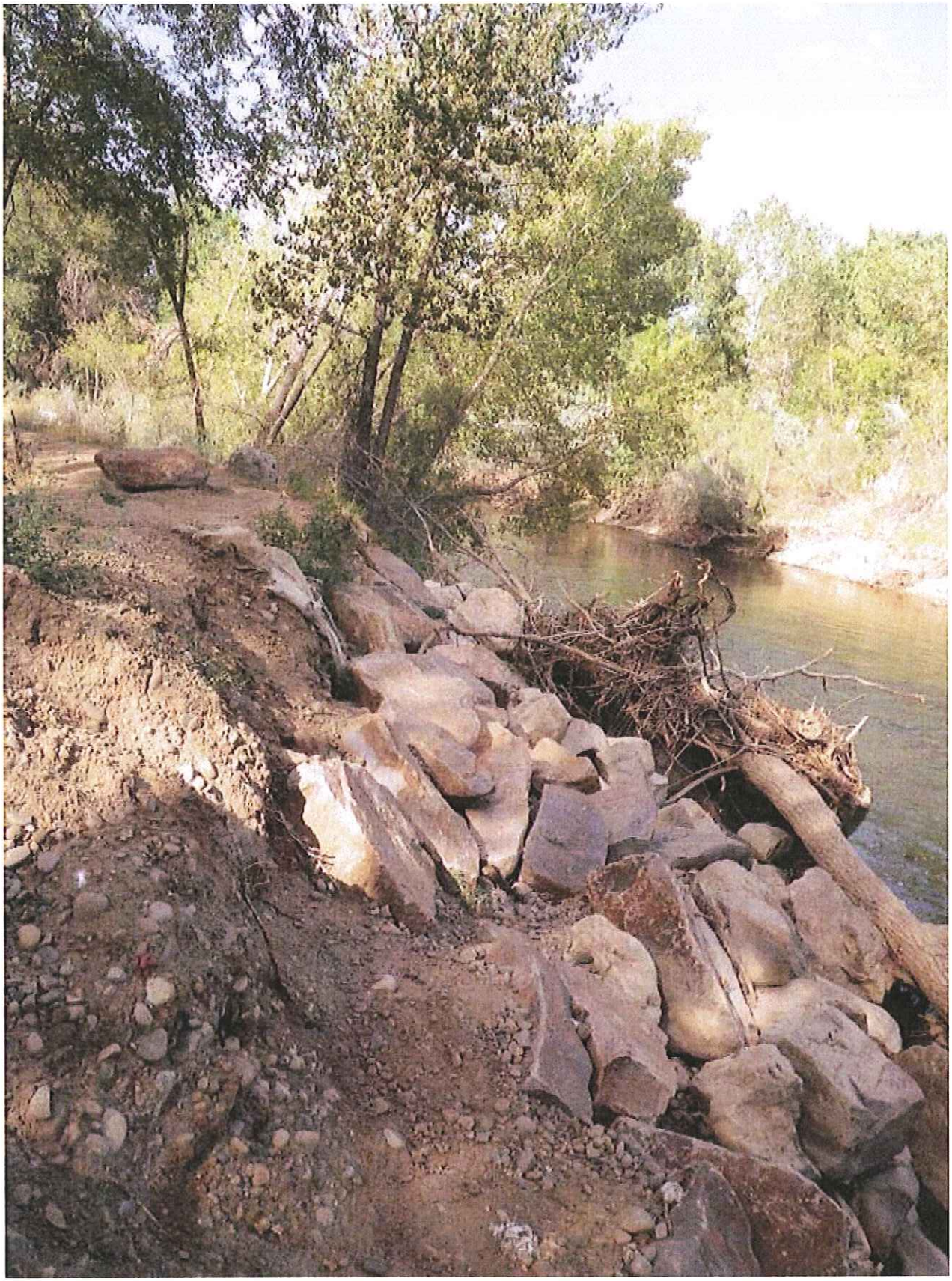




Flood Assessment Point:	**#11-Failed Bank Stabilization**
GPS Coordinates:	8-16-11 Points 50, 51
Direction to Assessment Point:	Upstream end is approximately 330ft downstream of the Riverdale Kayak Park on the Pathway
Project Priority:	High: X Moderate: Low:
Description of Damage:	Numerous failed J-hook structures, failed rip-rap and eroded banks and resulted bank failure is approximately 700' long and 10' high.
Structures:	Path, Homes, Land
Geomorphic Description:	These structures (rip-rap and J-hooks) were installed in response to the rivers channelized flow path to protect land and the Parkway. The residential areas to the west of this location were constructed in the late 1970s and early 1980s. Aerial photography from the 1950s shows that the location of the River Valley Subdivision was a historic flow path for the Weber River. Prior to the subdivision development the Weber Rivers geomorphically active floodplain was more than 1000ft wide. The historic photos also show a large oxbow flood channel located in the exact location of 4300 S (A.K.A. Oxbow Dr.) and River Valley Dr. Presently the River is constrained to a corridor that is 100 to 150 ft wide.
Habitat Considerations:	Source of non-point source sediment pollution.
Flood Damage Repair	• $100,000-$200,000
Measures:	• Option 1-(Flood Damage Replacement) o 700 ft of bank stabilization o Remove J-Hooks and use boulders for toe protection o Import material to protect bank. o $200,000-$350,000 • Option 2-(Flood Improvement, Improved Project) o Remove upper bank boulders and riprap and place 150' D.S. to connect left bank levee (100' Long) o Improving D.S. flood overflow channel. o $64,000 • Options 3-(Flood Mitigation Project) o Remove upper bank boulders and riprap and place 150' D.S. to connect left bank levee (100' Long) o Improving D.S. flood overflow channel. o Realign Bike Path away from River. o Biostabilize Left Bank o $85,000-$120,000
Photographs:	• IMGP0211

	• IMGP0212 • IMGP0213 • IMGP0214 • IMGP0215





Flood Assessment Point:	**#12-Failed Bank Stabilization**
GPS Coordinates:	8-19-11 Point 54
Direction to Assessment Point:	River right approximately 1600 ft upstream on the bike path of the 4600 S/Weber River Dr. Bridge
Project Priority:	High Moderate Low X
Description of Damage:	Failed J-hook has and localized bank failure
Structures:	Path, J-Bank stabilization
Geomorphic Description:	Similar to other location along the Weber River, these structure may have been placed to prevent bank erosion and the subsequent migration of the river channel. Installed in the 1980s or early 1990, these structures are usually intended to reduce shear stress on the bank by forcing the flow towards the centerline of the channel. Many of these structures were installed without consideration of the systemic response.
Habitat Considerations:	Source of non-point source sediment pollution.
Flood Damage Repair Measures:	• $15,000-$35,000 • Option 1 (Flood Damage Replacement Project) o Remove J-hook and use boulders for toe protection or habitat structures o Biostabilize bank o $35,000-$64,000
Photographs:	• IMGP0216