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Clear Creek – Tech Memo Channel Migration Mapping

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Contents

1 Introduction

In 2010, Channel Migration Zone mapping was developed for the Ruby River from the Ruby Dam to its confluence with the Beaverhead River in Twin Bridges (AGI/DTM, 2010). This mapping focused on the main stem of the Ruby River and did not include Clear Creek, other than to acknowledge it as a potential avulsion risk.

This memo details recent work to add the Clear Creek channel to the Ruby River CMZ mapping, and to update the Ruby CMZ mapping to include detailed bank protection mapping developed by the Natural Resource Conservation Service (NRCS) in 2012. This work is part of a larger effort to map approximately 440 miles of river in the Upper Missouri River headwaters. Other rivers in the study include the Beaverhead, Jefferson, Madison, Gallatin, East Gallatin, and Big Hole Rivers. In total, approximately 493 miles of river in the Missouri River headwaters will have CMZ mapping. Other rivers in Montana that have CMZ significant areas of mapping include the Yellowstone River, sections of the Flathead, Clark Fork, and Bitterroot Rivers, Deep Creek (Broadwater County), and Prickly Pear and Tenmile Creeks (Lewis and Clark County).

The work is funded through a 2013 Montana Department of Natural Resources and Conservation (DNRC) Reclamation and Development Grants Program (RDGP) titled *Upper Missouri Headwaters River/Flood Hazard Map Development*. The project is administered by the Ruby Valley Conservation District, but includes input and review from stakeholders associated with each of the mapped rivers.

1.1 The Project Team

This project work was performed by Tony Thatcher of DTM Consulting and Karin Boyd of Applied Geomorphology, with support from Chris Boyer of Kestrel Aerial Services (Kestrel). Over the past decade, we have been collaborating to develop CMZ maps for numerous rivers in Montana, to provide rational and scientifically-sound tools for river management. It is our goal to facilitate the understanding of rivers regarding the risks they pose to infrastructure, so that those risks can be managed and hopefully avoided. Furthermore, we believe the mapping supports the premise that managing rivers as dynamic, deformable systems contributes to ecological and geomorphic resilience while supporting sustainable, cost-effective development.

1.2 What is Channel Migration Zone Mapping?

The goal of Channel Migration Zone (CMZ) mapping is to provide a cost-effective and scientifically-based tool to assist land managers, property owners, and other stakeholders in making sound land use decisions along river corridors. Typically, projects constructed in stream environments such as bank stabilization, homes and outbuildings, access roads, pivots, and diversion structures are built without a full consideration of site conditions related to river process and associated risk. As a result, projects commonly require unanticipated and costly maintenance or modification to accommodate river dynamics. CMZ mapping is therefore intended to identify those areas of risk, to reduce the risk of project failure while minimizing the impacts of development on natural river process and associated ecological function. The mapping is also intended to provide an educational tool to show historic stream channel locations and rates of movement in any given area.

CMZ mapping is based on the understanding that rivers are dynamic and move laterally across their floodplains through time. As such, over a given timeframe, rivers occupy a corridor area whose width is dependent on rates of channel shift. The processes associated with channel movement include lateral channel migration and more rapid channel avulsion (Figure 1).

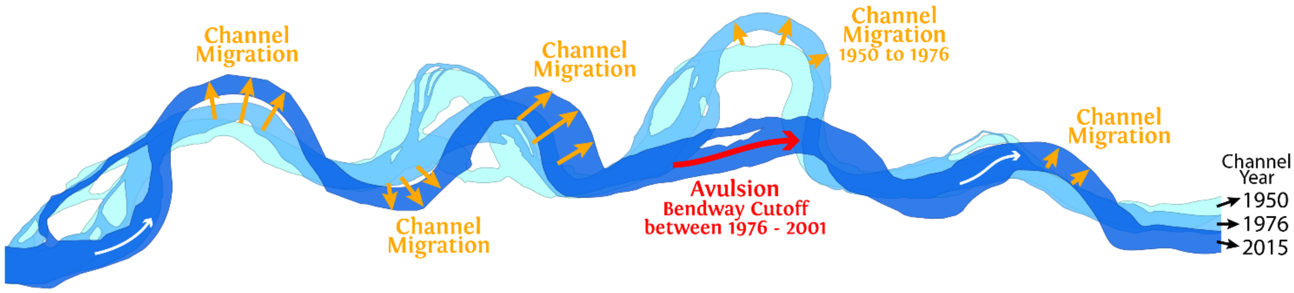

Figure 1. Typical patterns of channel migration and avulsion evaluated in CMZ development.

The fundamental approach to CMZ mapping is to identify the corridor area that a stream channel or series of stream channels can be expected to occupy over a given timeframe – typically 100 years. This is defined by first mapping historic channel locations to define the Historic Migration Zone, or HMZ (Figure 1). Using those mapped banklines, migration distances are measured between suites of air photos, which allows the calculation of migration rate (feet per year) at any site. Average annual migration rates are calculated on a reach scale and extended to the life of the CMZ, which in this case is 100 years. This 100-year mean migration distance defines the Erosion Buffer, which is added to the modern bankline to define the Erosion Hazard Area, or EHA.

For a detailed discussion of the Channel Migration Zone mapping process, please refer to the detailed documentation for each of the project's rivers.

1.3 CMZ Mapping on Clear Creek

Clear Creek runs parallel to the Ruby River for about 4.6 valley miles from its upstream diversion point above Judy Lane near Alder (Figure 2) to its confluence with the Ruby River due west of Bivens Creek Road. The Channel Migration Zone (CMZ) developed for Clear Creek covers this entire extent, which includes about 11 miles of stream channel.

Although the basic concept for Channel Migration Zone mapping efforts is largely the same throughout the country, different approaches to defining CMZ boundaries are used depending on specific needs and situations. These differences in assessment techniques can be driven by the channel type, different project scales, the type and quality of supporting information, the intended use of the mapping, etc. For this study, the CMZ is defined as a composite area made up of the existing channel, the collective footprint of mapped historic channel locations shown in the 1955, 1979, and 2015 imagery (Historic Migration Zone, or HMZ), and an Erosion Hazard Area (EHA) that is based on reach-scale average migration rates. Areas beyond the Erosion Buffer that pose risks of channel avulsion are identified as Avulsion Hazard Areas or AHZ. This approach generally falls into the minimum standards of practice for Reach Scale, Moderate to High Level of Effort mapping studies as defined by the Washington State Department of Ecology (www.ecy.wa.gov). This approach does not, however include a geotechnical setback on hillslopes; these areas would require a more site-specific analysis than that presented here.

Figure 2. View west across Ruby River showing head of Clear Creek near road crossing at Judy Lane. (Kestrel)

1.4 Potential Applications of the CMZ Maps

The CMZ mapping developed for Clear Creek is intended to support a myriad of applications and was not developed with the explicit intent of either providing regulatory boundaries or overriding site-specific assessments. Any use of the maps as a regulatory tool should include a careful review of the mapping criteria to ensure that the approach used is appropriate for that application.

Potential applications for the CMZ maps include the following:

- Identify specific problem areas where migration rates are notably high and/or infrastructure is threatened;
- Strategically place new infrastructure to avoid costly maintenance or loss of capital;
- Strategically place new infrastructure to minimize impacts on channel process and associated ecological function;
- Assist in the development of river corridor best management practices;
- Improve stakeholder understanding of the risks and benefits of channel movement;
- Identify areas where channel migration easements may be appropriate;
- Facilitate productive discussion between regulatory, planning, and development interests active within the river corridor;
- Help communities and developers integrate dynamic river corridors into land use planning; and,

- Assist long-term residents in conveying their experiences of river process and associated risk to newcomers.

1.5 Disclaimer and Limitations

The boundaries developed on the Channel Migration Zone mapping are intended to provide a basic screening tool to help guide and support management decisions within the mapped stream corridor and were not developed with the explicit intent of providing regulatory boundaries or overriding site-specific assessments. The criteria for developing the boundaries are based on reach scale conditions and average historic rates of change. The boundaries can support river management efforts, but in any application, it is critical that users thoroughly understand the process of the CMZ development and its associated limitations.

Primary limitations of this reach-scale mapping approach include a potential underestimation of migration rates in discrete areas that are eroding especially rapidly, which could result in migration beyond the mapped CMZ boundary. Additionally, site-specific variability in alluvial deposits may affect rates of channel movement. Mapping errors introduced by the horizontal accuracy of the imagery, digitizing accuracy, and air photo interpretation may also introduce small errors in the migration rate calculations. Future shifts in system hydrology, climate, sediment transport, riparian corridor health, land use, or channel stability would also affect the accuracy of results, as these boundaries reflect the extrapolation of historic channel behavior into the future. As such, we recommend that these maps be supplemented by site-specific assessment where near-term migration rates and/or site geology create anomalies in the reach-averaging approach, and that the mapping be revisited in the event that controlling influences change dramatically. A site-specific assessment would include a thorough analysis of site geomorphology, including a more detailed assessment of bank material erodibility, both within the bank and in adjacent floodplain areas, consideration of the site location with respect to channel planform and hillslope conditions, evaluation of influences such as vegetation and land use on channel migration, and an analysis of the site-specific potential for channel blockage or perching that may drive an avulsion.

1.6 Image Licensing and Use Restrictions

Many of the oblique color photographs taken by plane presented in this document and included on the associated project DVD were taken by Kestrel Aerial Services (Kestrel) and are subject to use restrictions. Kestrel grants that these photos can be used as follows:

> ***For use as river and floodplain documentary imagery in efforts related to this study by project partners.***

For uses outside these stated rights, contact Kestrel Aerial Services, Inc. (406) 580-1946.

2 Physical Setting

The following section contains a general description of the geographic, hydrologic, and geologic influences on the Ruby River and Clear Creek, to characterize the general setting and highlight how that setting may affect river process. For a detailed discussion, please refer to *Ruby River - Channel Migration Zone Mapping* (AGI/DTM, 2010).

2.1 Geography

The Ruby watershed is located in Madison County, Montana, and encompasses approximately 623,000 acres. At its headwaters, the Ruby flows northward through a valley defined by the Gravelly Range to the east and the Snowcrest Range to the west (Figure 3). At Ruby Reservoir, the river enters a narrow bedrock canyon carved through the eastern edge of the Ruby Range; this canyon section comprises the uppermost portion of the 2010 Ruby River CMZ mapping project reach. Below the canyon, the river flows onto a largely unconfined floodplain where the channel is relatively flat and sinuous. Multiple channel threads and meander scrolls are common, recording historic channel changes, and creating a patchy riparian zone on a topographically subtle floodplain. Riparian clearing has been extensive since the 1950s along the Ruby River, especially in downstream reaches approaching the Beaverhead River floodplain.

Floodplain irrigation in the Ruby Valley is supported by flow diversions out of the Ruby River, Clear Creek, and several tributaries. The tributaries commonly flow parallel to the Ruby River, and many have been converted to ditches. Clear Creek is somewhat unique as it is a major side channel that has been present since at least 1870, when it was identified on GLO maps. The upper and lower ends of the side channel remain very close to those shown in the GLO maps (Figure 4 and Figure 5). Flows into Clear Creek are currently controlled by a diversion structure on the Ruby River just above Judy Lane.

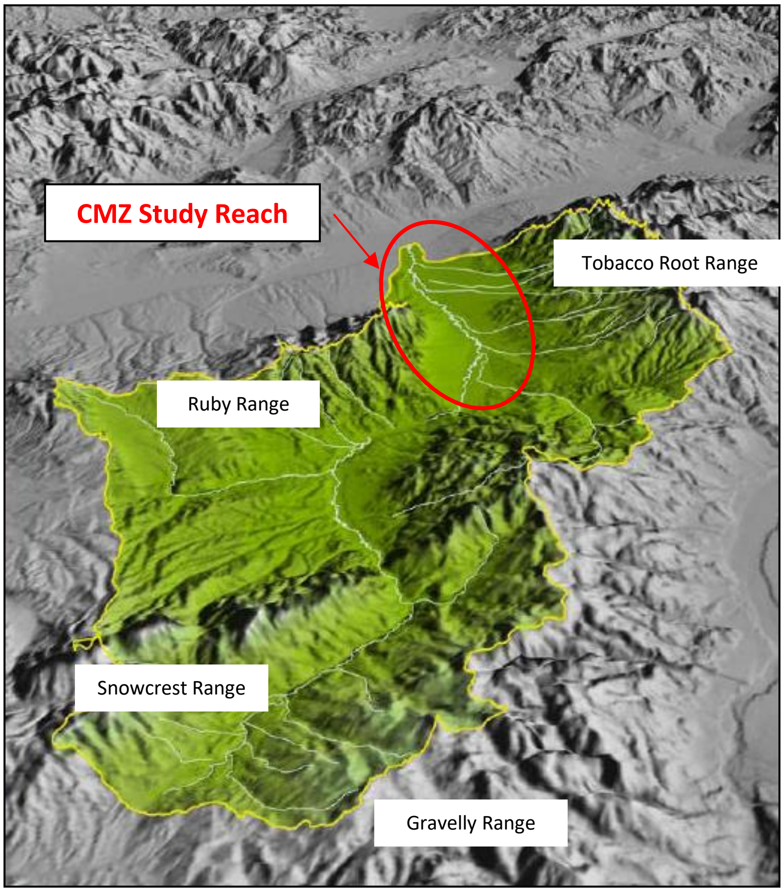

Figure 3. Ruby River Watershed (MTDEQ, 2006)

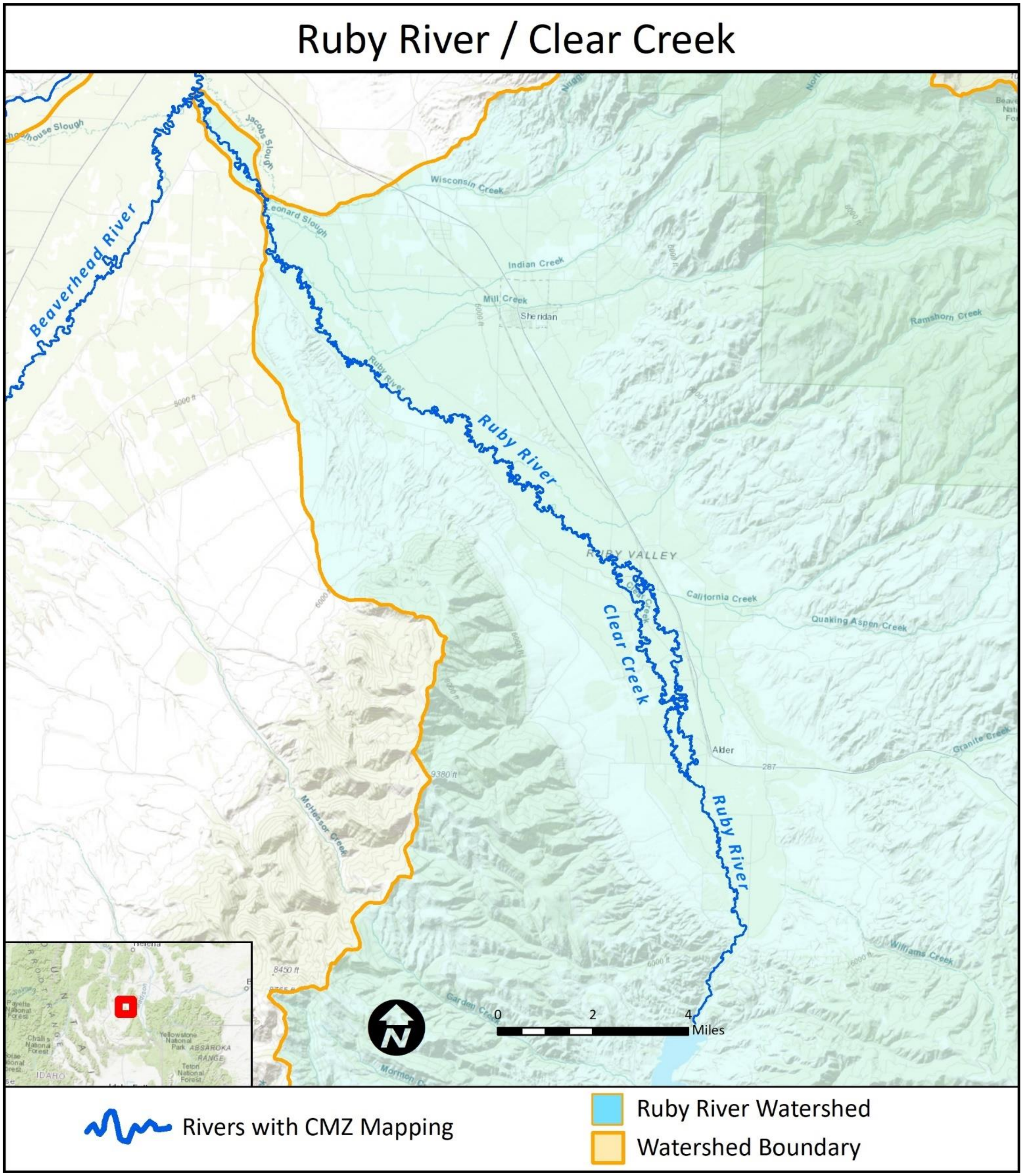

Figure 4. CMZ mapping on the Ruby River and Clear Creek.

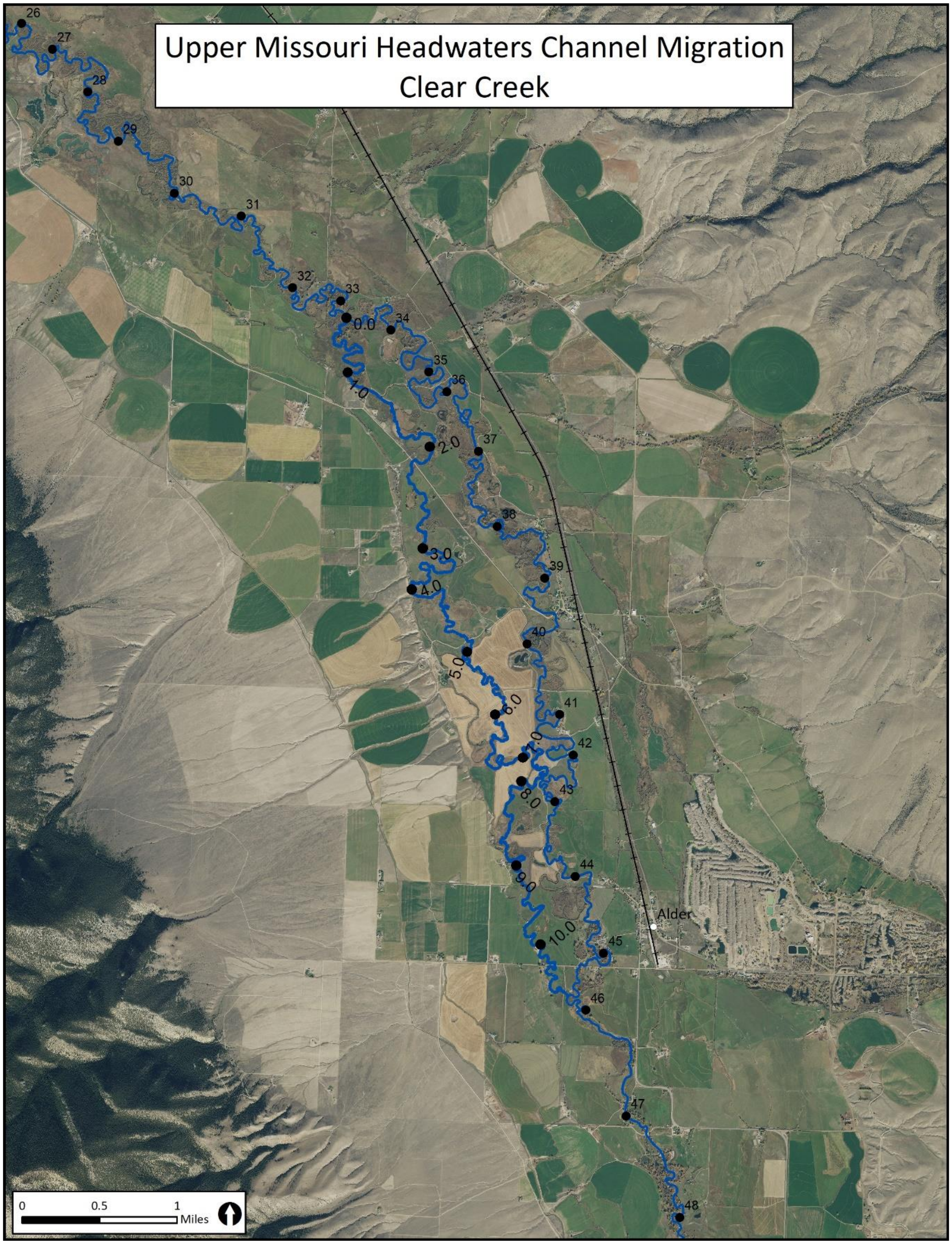

Figure 5. Ruby River and Clear Creek split flow; Clear Creek flows on left side of Ruby River mainstem.

2.2 Hydrology and Flow Management

The hydrology of the project reach largely reflects the managed flow releases through the Ruby Dam, a 111 ft high structure that was completed in 1939 (State of Montana Natural Hazards Mitigation Plan, 2001). Ruby Dam is a state-owned water project that impounds Ruby Reservoir, a 38,000 acre-foot impoundment managed primarily for irrigation water storage and flood control. The following is a brief summary of project reach flood history.

USGS stream gage data for the Ruby River exists at the reservoir outlet (USGS 06020600), near Alder (06021000), and near Twin Bridges (USGS 06023000) (Figure 6). These discontinuous flow records collectively depict the general flood history of the area. The gage at the reservoir has the most complete peak flow record, extending from 1963 to 2016. At this location, the 10-year discharge is 1,740 cfs and the 5-year flood is 1,450 cfs (www.mt.water.usgs.gov). Since 1962, the 100-year event has been exceeded once, on May 16, 1984, when the discharge measured at the gage was 3,010 cfs. This event, which is the flood of record on the Ruby River, exceeded the 200-year discharge of 2,900 cfs (www.mt.water.usgs.gov). This event has been associated with extensive flooding in the Missouri River basin due to intermittent heavy rainstorms that occurred during the months of May and June (NOAA, 2010).

The 10-year flood discharge (1,740 cfs) was exceeded only two times since 1962; the 1984 flood and in 1995, when the river peaked at 1820 cfs. The peak flow record on the Ruby generally shows that there have been few major floods below the reservoir since the mid-20th century.

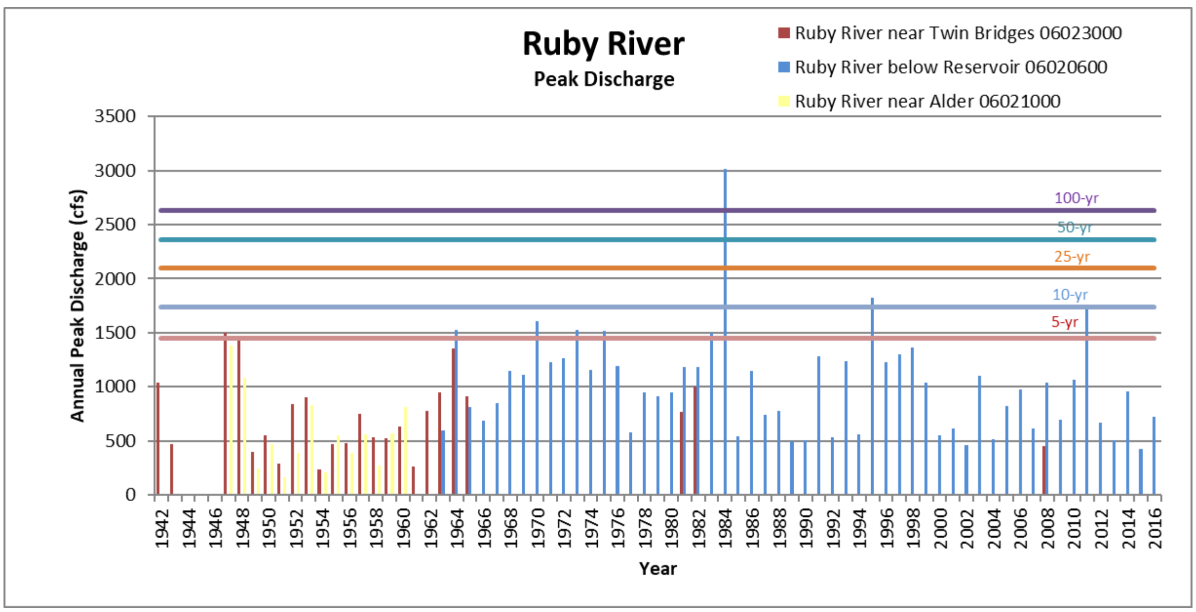

Figure 6. Annual peak discharges, Ruby River; flood frequency values are for the USGS 06020600 gage.

3 Methods

The development of the Clear Creek Channel Migration Zone (CMZ) mapping is based on established methods used by the Washington State Department of Ecology (Rapp and Abbe, 2003), and closely follows methodologies used on other rivers in Montana.

3.1 GIS Project Development

All project data was compiled using ESRI's ArcMap Geographic Information System (GIS) utilizing a common coordinate system - Montana State Plane NAD83 Feet (HARN). This matches the coordinate system used in the original 2010 Ruby River CMZ study (AGI/DTM, 2010).

3.2 Aerial Photography

CMZ development from historic imagery is dependent on the availability of appropriate imagery that covers the required time frame (50+ years), the spatial coverage of that imagery, and the quality of the photos. It is important to use imagery with the best possible quality, scale, extent, and dates so that historic and modern features can be mapped in sufficient detail.

Table 1 lists imagery used for this project from the USDA and archives of current GIS data sets. Except for adding the 2015 NAIP imagery, the imagery used for the Clear Creek mapping are the same as what was used for the original Ruby River CMZ study. Examples of the imagery used in the analysis are shown in Figure 7 through Figure 10.

Table 1. Aerial photography used for the Clear Creek update to the Ruby River CMZ study.

Date	Source	Scale	Notes
1955	USDA APFO	1:20,000	High-resolution Scans (black-and-white)
1995	DOQ	~5 meter resolution	Digital Download
2009 NAIP	NRIS	~ 1 meter resolution	Digital Download, Compressed County Mosaics (color)
2015 NAIP	NRIS	~ 1 meter resolution	Digital Download, Compressed County Mosaics (color)

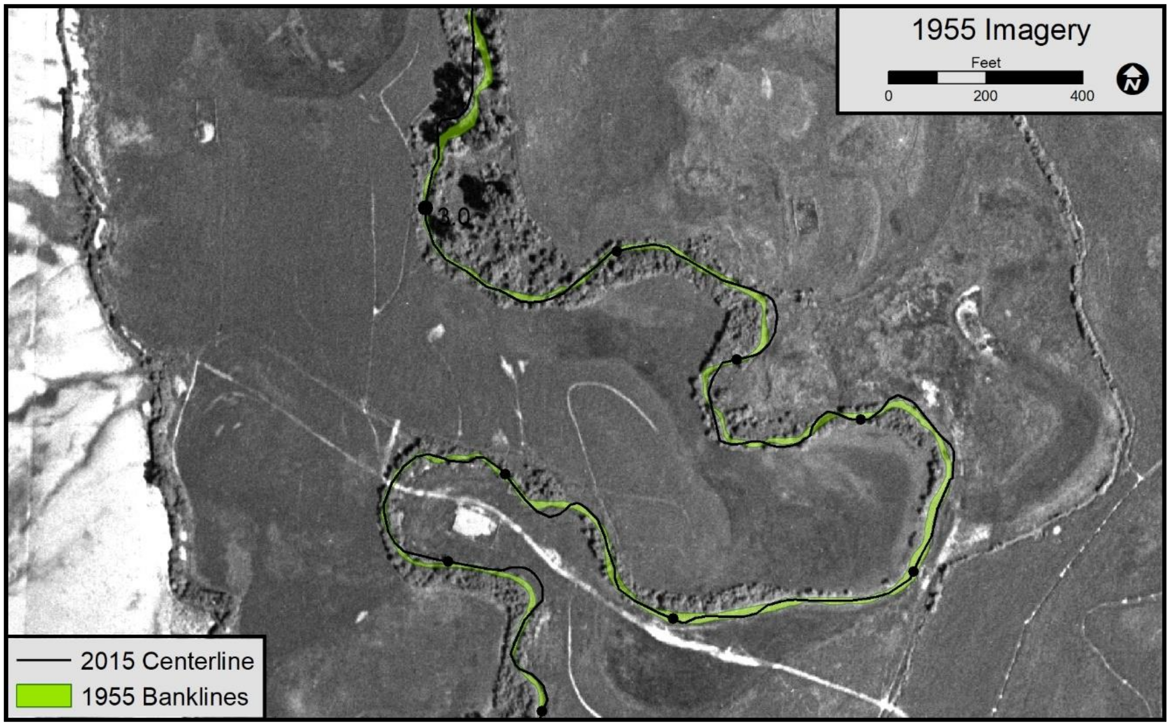

Figure 7. Example 1955 imagery used for Clear Creek CMZ development.

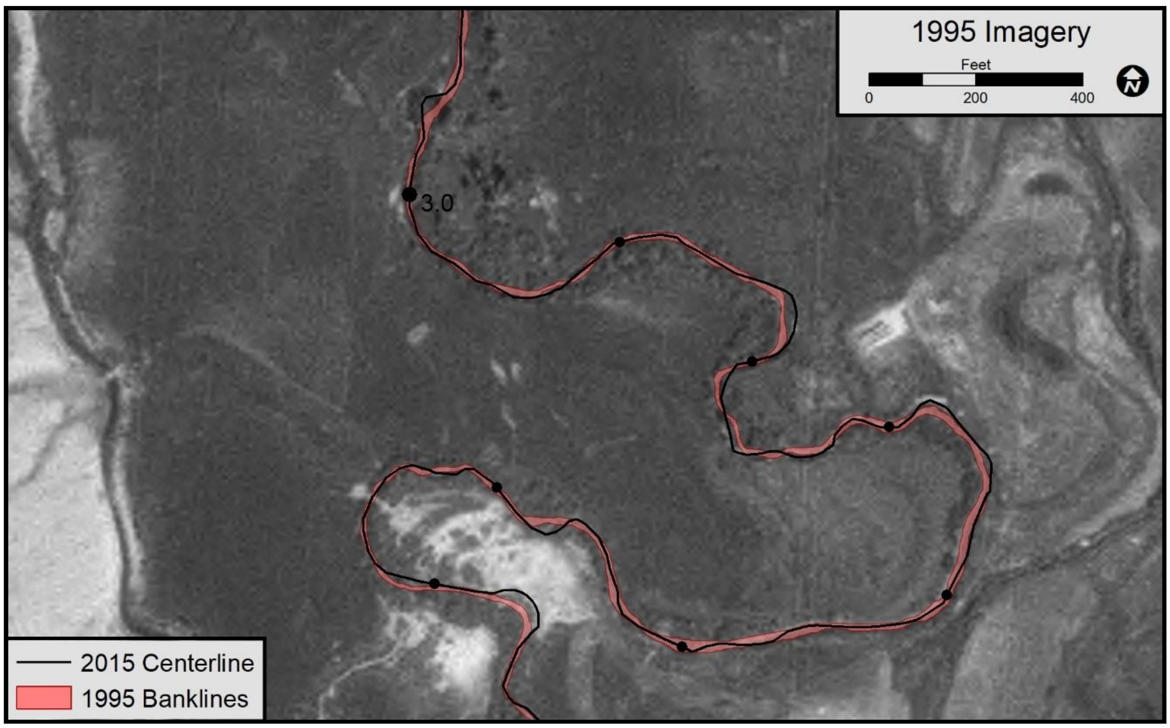

Figure 8. Example 1995 imagery used for Clear Creek CMZ development.

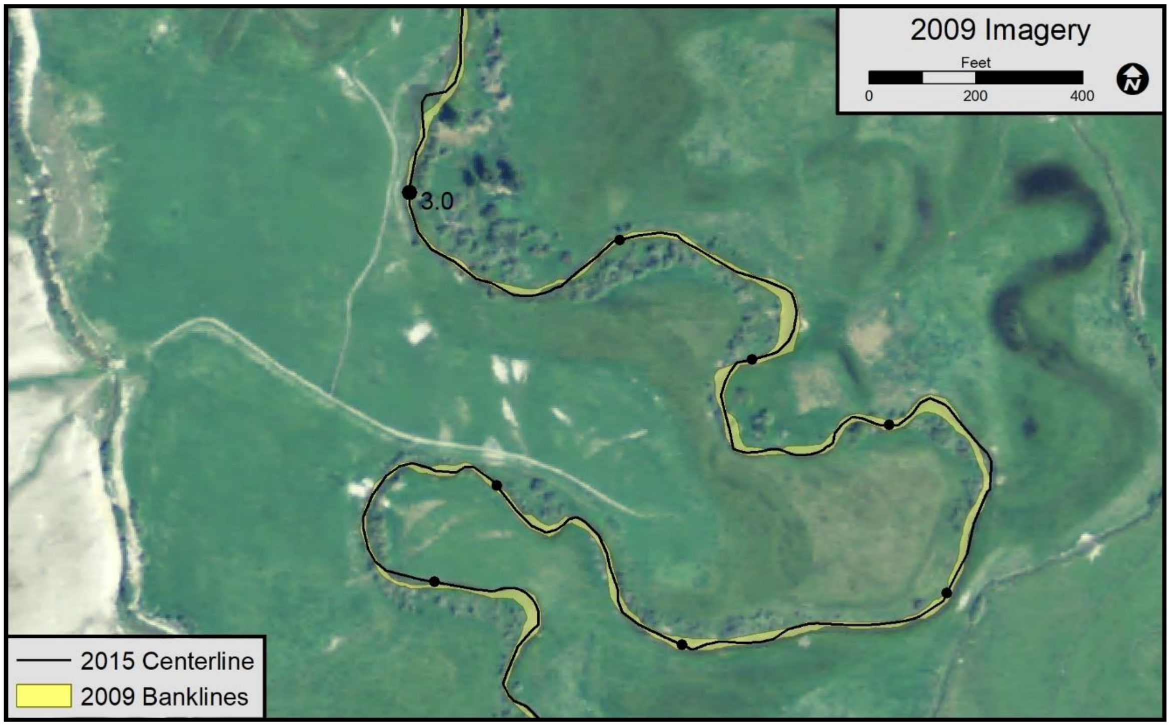

Figure 9. Example 2009 NAIP imagery used for Clear Creek CMZ development.

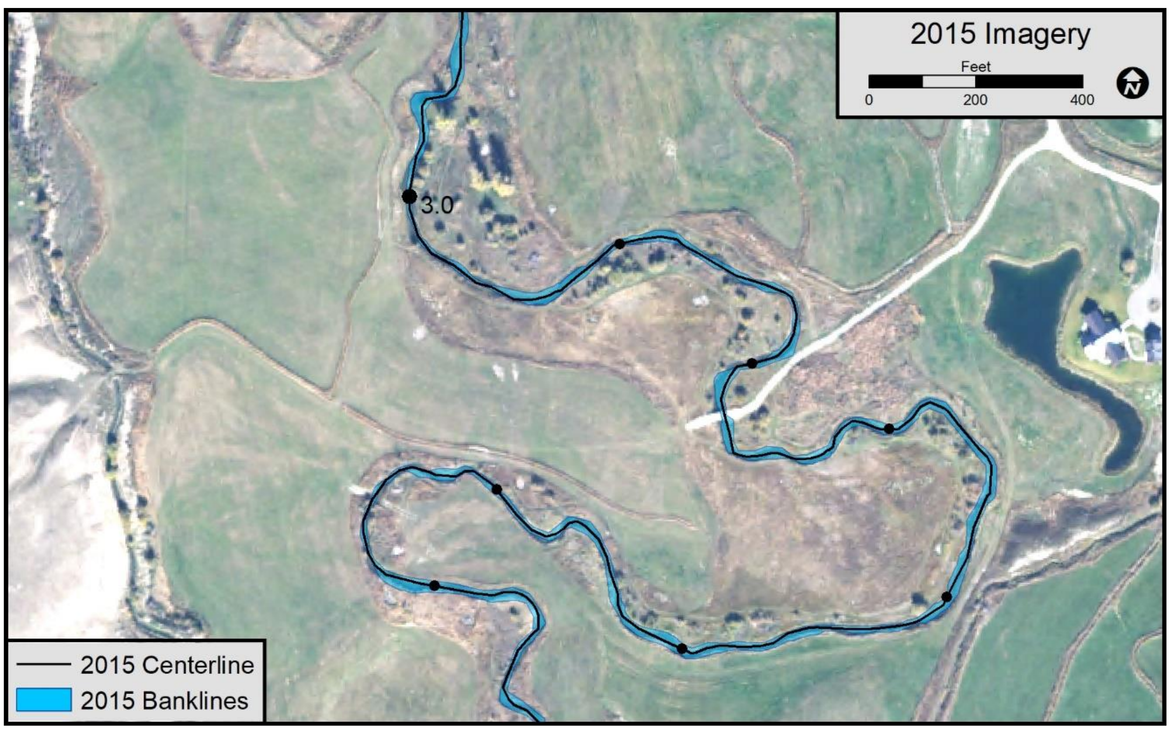

Figure 10. Example 2015 NAIP imagery used for Clear Creek CMZ development.

3.3 Bankline Mapping

Banklines representing bankfull margins were digitized for each year of imagery at a scale of 1:1,500 (Figure 7 through Figure 10). A tablet computer running ArcGIS and using a pen stylus was used to trace the banklines using stream mode digitizing. This methodology allowed us to capture a much more detailed bankline than using a mouse. Bankfull is defined as the stage above which flow starts to spread onto the floodplain. Although that boundary can be identified using field indicators or modeling results (Riley, 1972), digitizing banklines for CMZ development requires the interpretation of historic imagery. Therefore, we typically rely on the extent of the lower limit of perennial, woody vegetation to define channel banks (Mount & Louis, 2005). This is based on the generally accepted concept that bankfull channels are inhospitable to woody vegetation establishment. Fortunately, shrubs, trees, terraces, and bedrock generally show distinct signatures on both older black-and-white as well as newer color photography. These signatures, coupled with an understanding of riparian processes, allow for consistent bankline mapping through time and across different types of imagery.

3.4 Migration Rate Measurements and Buffer

Once the banklines were digitized, they were evaluated in terms of discernable channel migration since 1955. Where migration was clear, vectors (arrows with orientation and length) were drawn in the GIS to record that change. At each site of bankline migration, measurements were collected approximately every 25 feet (Figure 11). A total of 463 migration vectors were generated for Clear Creek at a scale of 1:1,500. As there were no logical reach breaks for the 11-mile length of Clear Creek, the channel was treated as a single reach. The average migration distance for the 60 years of record was 29 feet. This results in an annual migration rate of 0.48 feet/year, or a 100-year migration buffer of 48 feet, significantly lower than any of the buffers for the Ruby River reaches (Figure 12). This migration buffer was applied to the outside of the 2015 banklines to generate the Erosion Hazard Area (EHA)(Figure 13).

Each location of channel migration (bendway or section of bankline) was assigned a Migration Site ID based on the river mile location of the site. Each site may have anywhere from 1 to 13 migration vectors, depending on the length of the site. A total of 137 migration sites were identified throughout the study area. An accounting of the reach and site based statistics can be found in Appendix A.

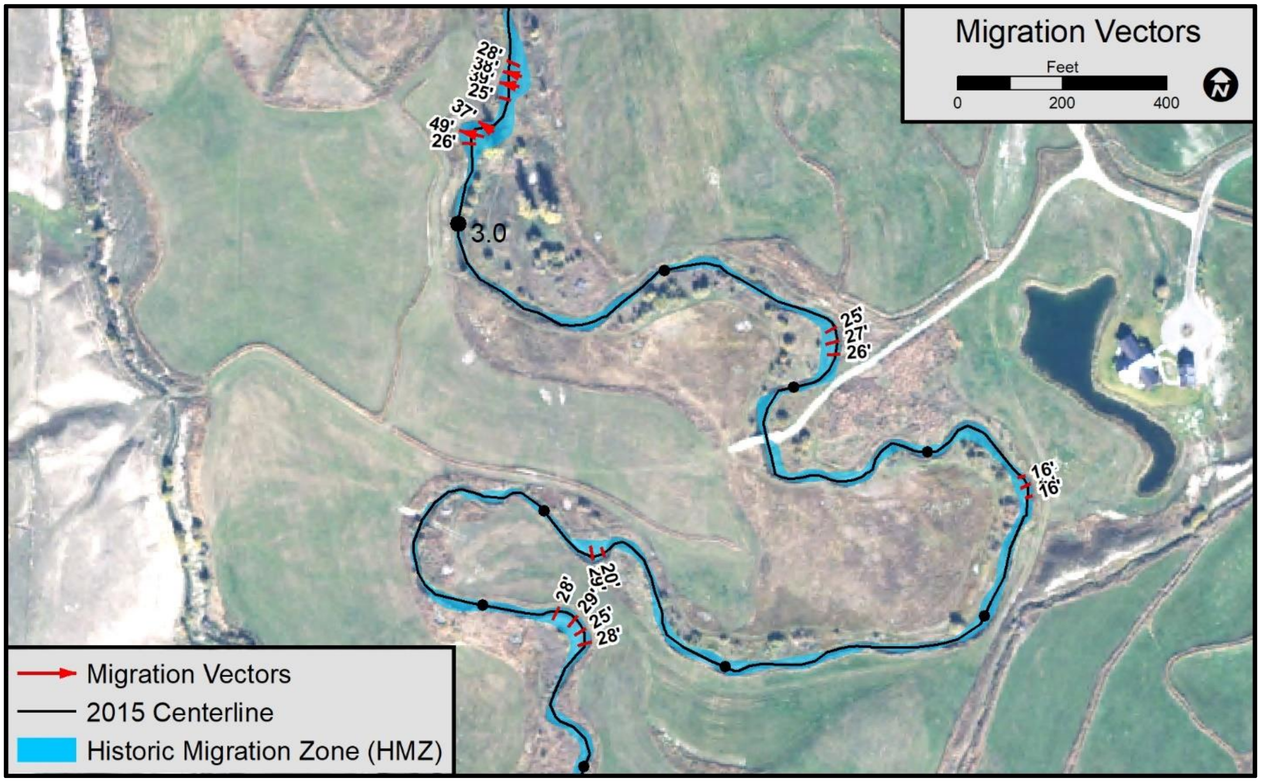

Figure 11. Example of migration measurements between 1965 and 2015 (migration distance in feet).

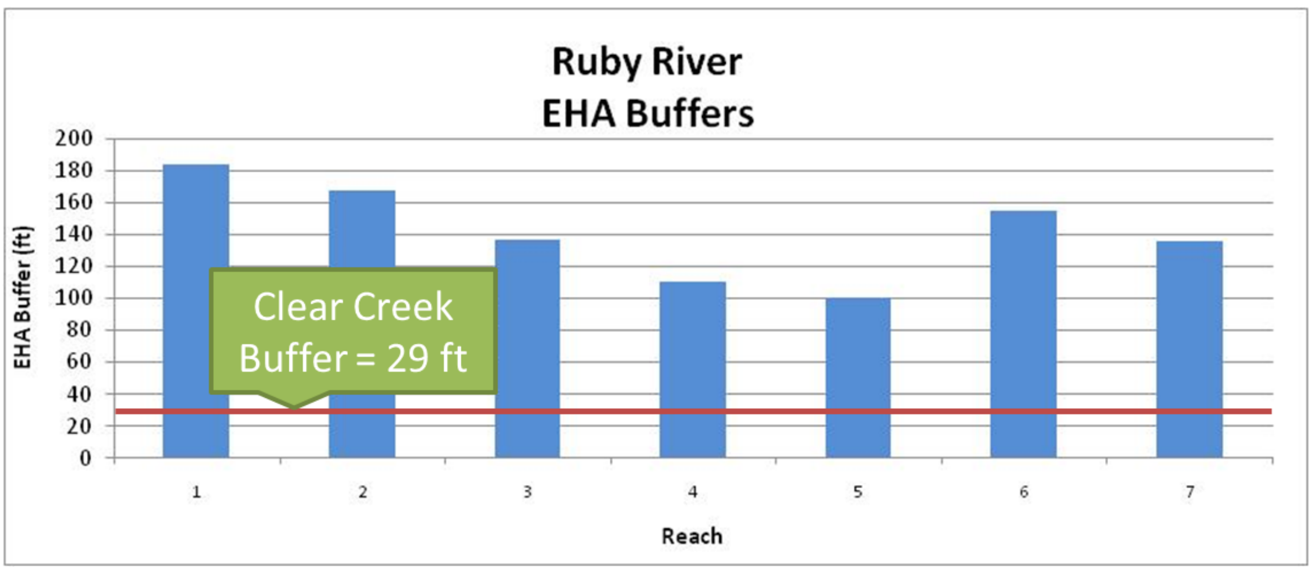

Figure 12. Clear Creek erosion buffer compared to Ruby River buffers.

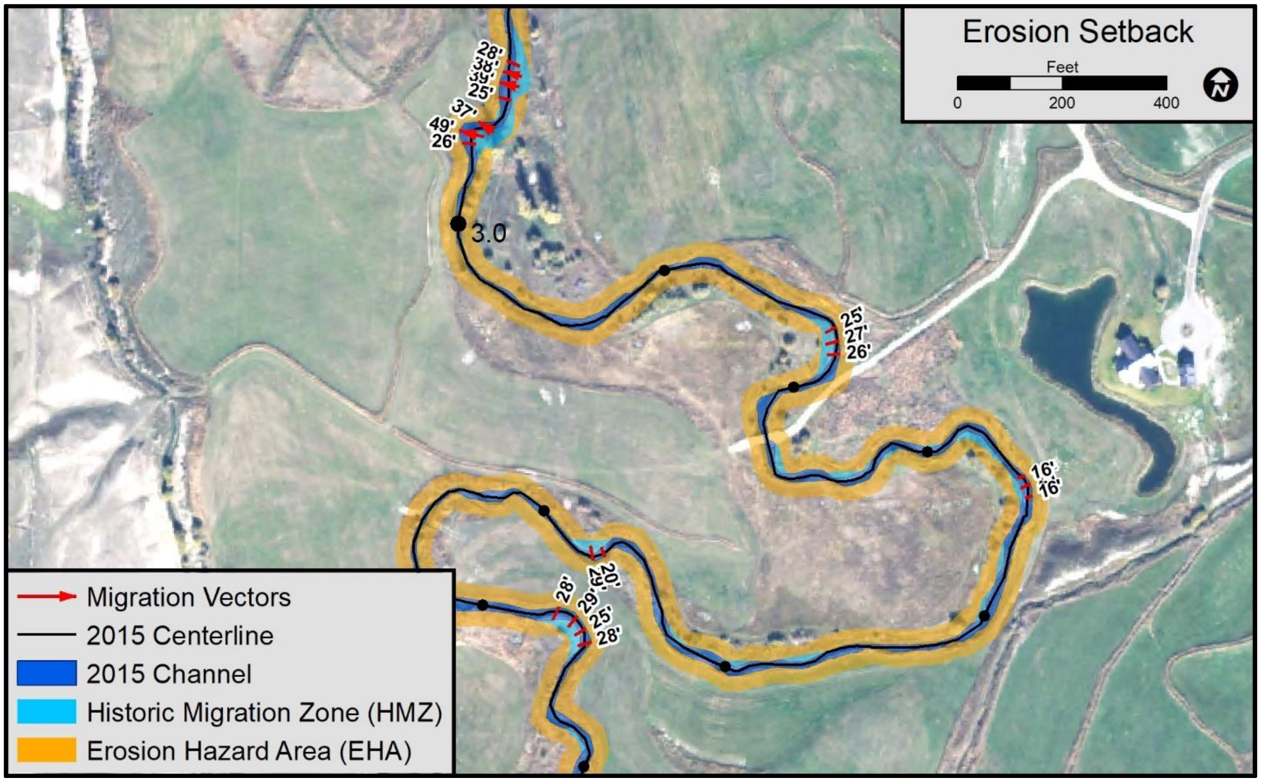

Figure 13. Clear Creek Erosion Hazard Area buffer.

3.5 Bank Armor

In 2012, the Natural Resource Conservation Service (NRCS) performed a detailed inventory of bank armor, channel features, and bank features for the Ruby River from the Ruby Dam, downstream to just above the Silver Spring Road Bridge. This inventory included Clear Creek (Figure 14). This data formed the basis for developing a bank armor data set for the Ruby River and Clear Creek. The NRCS inventory was supplemented below Silver Spring Bridge, and updated throughout the corridor, by reviewing more recent imagery in both GIS and Google Earth. The combined data was used to identify areas that may experience reduced channel migration due to their being behind bank armor. These areas are defined as Restricted Migration Areas (RMA) in the CMZ mapping (Figure 15).

The 2010 Ruby River CMZ mapping did not have a bank armor inventory. Thus, Restricted Migration Areas (RMA) were not defined in that study. As part of the Clear Creek mapping, the Ruby River CMZ mapping was updated to include Restricted Migration Areas (Figure 16).

Figure 14. Intermittent bank armor on Clear Creek associated with roads, bridges, and fields. (Kestrel)

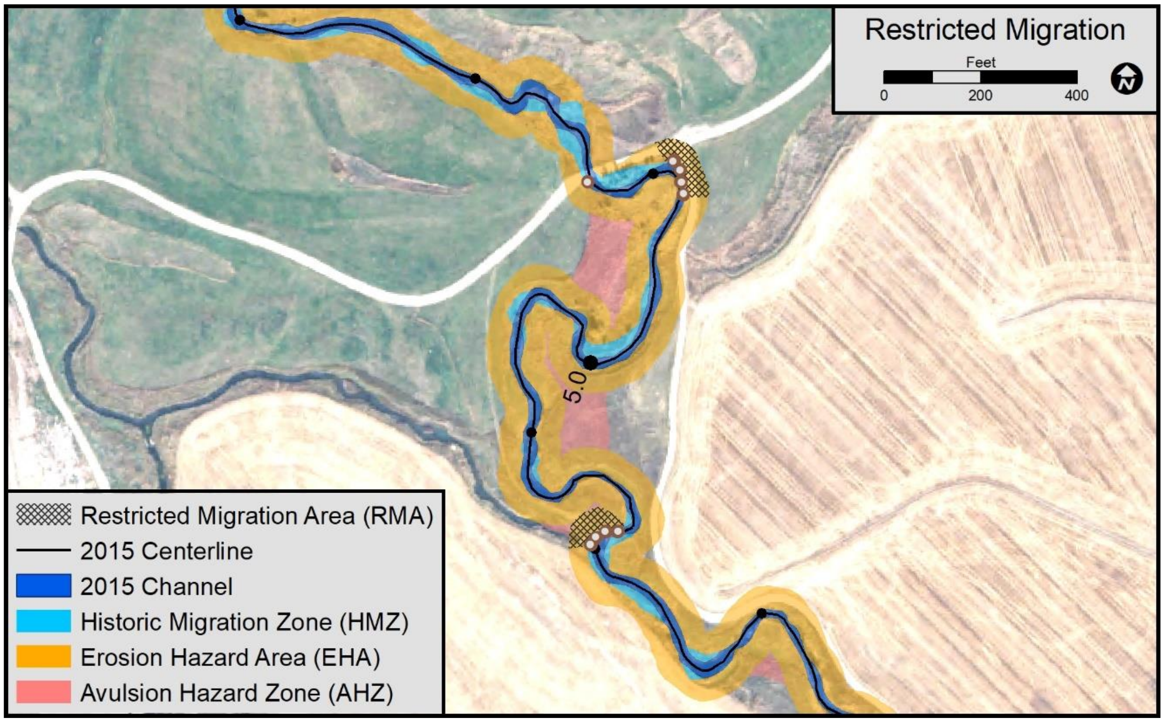

Figure 15. Restricted Migration Areas on Clear Creek.

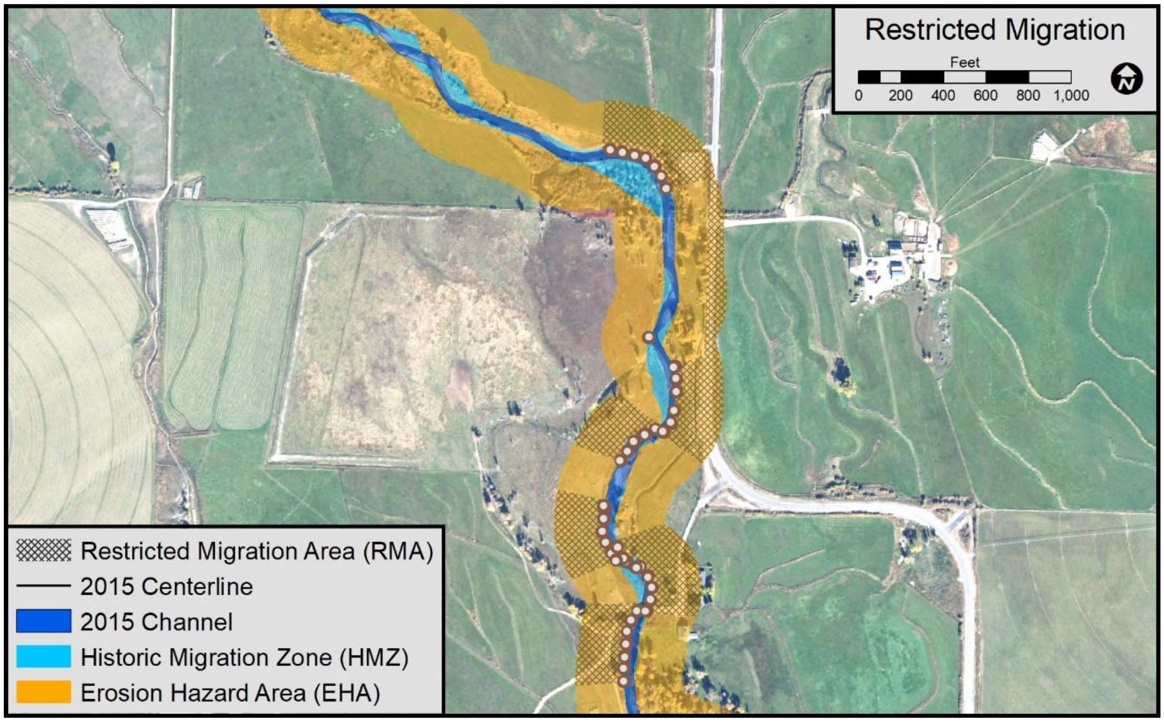

Figure 16. Restricted Migration Areas on the Ruby River.

3.6 Avulsion Hazard Mapping

Avulsion hazards can be difficult to identify on broad floodplains, because an avulsion could occur virtually anywhere on the entire floodplain if the right conditions were to occur. As such, avulsion pathways were identified and mapped using criteria that identify a relatively high propensity for such an event. These criteria usually include the identification of high slope ratios between the floodplain and channel, perched channel segments, and the presence of relic channels that concentrate flow during floods. These features were identified for the Clear Creek / Ruby River project reach using aerial photos and inundation modeling results.

Features that can help determine avulsion hazard areas include (WSDE, 2010):

- Low, frequently flooded floodplain areas with relic channels
- Compressed meander-bends
- Main channel aggradation, particularly medial bar formation or growth, in the upstream limb of a bend
- Lower elevation of relict channel than active channel bed
- Present and former distributary channels on alluvial fans, deltas, and estuaries
- Channels that diverge from the main channel in a downstream direction
- Creeks that run somewhat parallel to main channel.

Clear Creek and the Ruby River collectively form a wide, sinuous stream corridor that has experienced numerous avulsions since 1965. Most of those avulsions were in areas where sinuous channel segments cut off one or several bendways, straightening the channel onto a steeper flow path. Using that pattern of recorded avulsions, additional potential avulsion pathways were identified and incorporated into the CMZ. Additional information used in mapping avulsion paths included oblique photos from Kestrel Aerial Services. Avulsion risks on the Ruby/Clear Creek system are located both within each individual stream corridor, and in some cases, extend between the two systems (Figure 17).

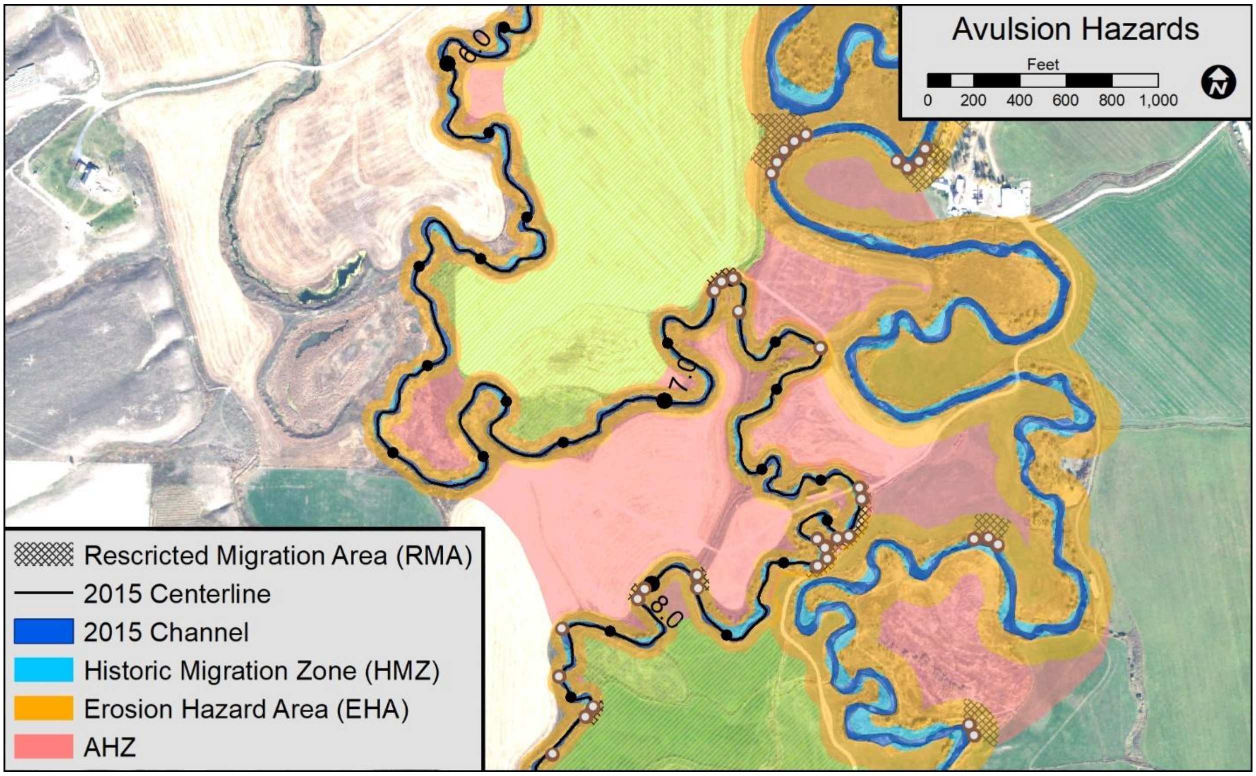

Figure 17. Complex avulsion pathways on Clear Creek and Ruby River.

4 Clear Creek Update to Ruby River CMZ Mapping

The Channel Migration Zone (CMZ) developed for Clear Creek is defined as a composite area made up of the existing channel, the historic channel since 1955 (Historic Migration Zone, or HMZ), and an Erosion Hazard Area (EHA) that encompasses areas prone to channel erosion over the next 100 years. Areas beyond the EHA that pose risks of channel avulsion comprise the Avulsion Hazard Zone (AHZ). Lastly, those areas where migration has been restricted are highlighted as Restricted Migration Area (RMA). The results of this mapping have been combined with the earlier Ruby River mapping to provide a composite CMZ map for the entire corridor.

Because of its low rates of erosion, the composite footprint of the HMZ and EHA on Clear Creek are relatively narrow. Segments of Clear Creek were channelized prior to 1955, and these straightened segments appear to be slowly widening but gaining little additional length. The riparian corridor on Clear Creek was also cleared, reducing the erosion resistance of the streambanks and adjacent floodplain. With both channelization and riparian clearing, Clear Creek could be prone to major future changes in planform due to both bank erosion and avulsion. That said, Clear Creek shows little in the way of responding to those human impacts. This is probably due to the flow split between Clear Creek and the Ruby River, which maintains a multi-thread condition that effectively dissipates flood energy and reduces rates of geomorphic change.

Although the Clear Creek CMZ corridor tends to closely follow the channel, wider avulsion prone areas occur where the stream forms large composite meanders on a low floodplain that are prone to shortening, creating an hourglassing effect in the CMZ that is controlled by planform (Figure 17). In addition, where Clear Creek flows close to the Ruby River, the core CMZ boundaries intersect, and thus define areas prone to complex interactions between the two stream systems.

Because the Ruby River and Clear Creek flow within a composite, topographically continuous floodplain, the floodplain area in between the two channels has been identified as having a moderate risk of avulsion. This designation is intended to highlight the potential for cross-floodplain interaction of the two channels, although no high-risk indicators of an imminent avulsion have been identified.

It should be noted that the 2010 Ruby River CMZ maps (AGI/DTM) remain valid. The mapping was reviewed to determine if the river migrated beyond the CMZ boundaries during the 2011 flood, which caused extensive bank erosion and numerous avulsions on the Ruby. During that event a total of 14 meander cutoffs shortened the river by almost two miles between the reservoir and the mouth, however the CMZ boundary was not breached (Figure 18 and Figure 19).

The mapped pattern of 2011 avulsions on the Ruby River supports the interpretation that the split flow condition created by Clear Creek helps dissipate flood energy and associated geomorphic response of each channel. Although fourteen avulsions occurred during that flood, none of them occurred in the approximately 17-mile-long split flow reach (Figure 20). The general "rule of thumb" in terms of the existing flow split at the head of Clear Creek is that one third of the Ruby River flows are diverted down Clear Creek. This conveyance has clearly dampened the geomorphic response potential of the Ruby River in this area.

It is important to note that there has been only one major flood on the Ruby River since the 1940s (Figure 6). The 2011 event peaked at 1,720 cfs, which is just under a 10-year event. The occurrence of 14 avulsions during that flood indicates that, in the event of a major flood on the Ruby River, substantial geomorphic change through both avulsion and bank migration should be expected.

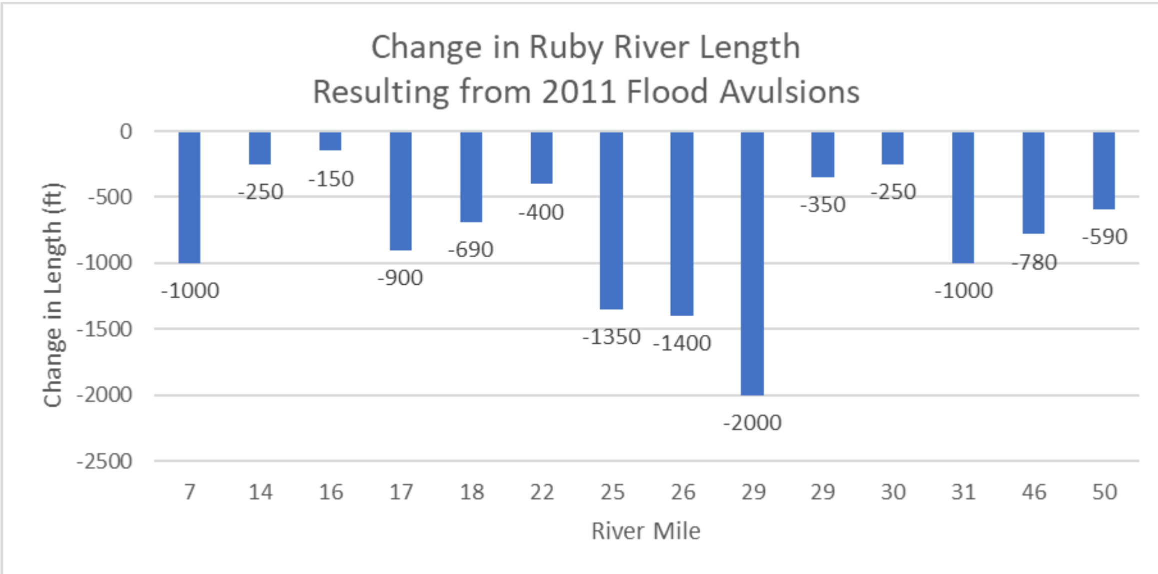

Figure 18. Sites of major changes in channel length on the Ruby River during the 2011 flood.

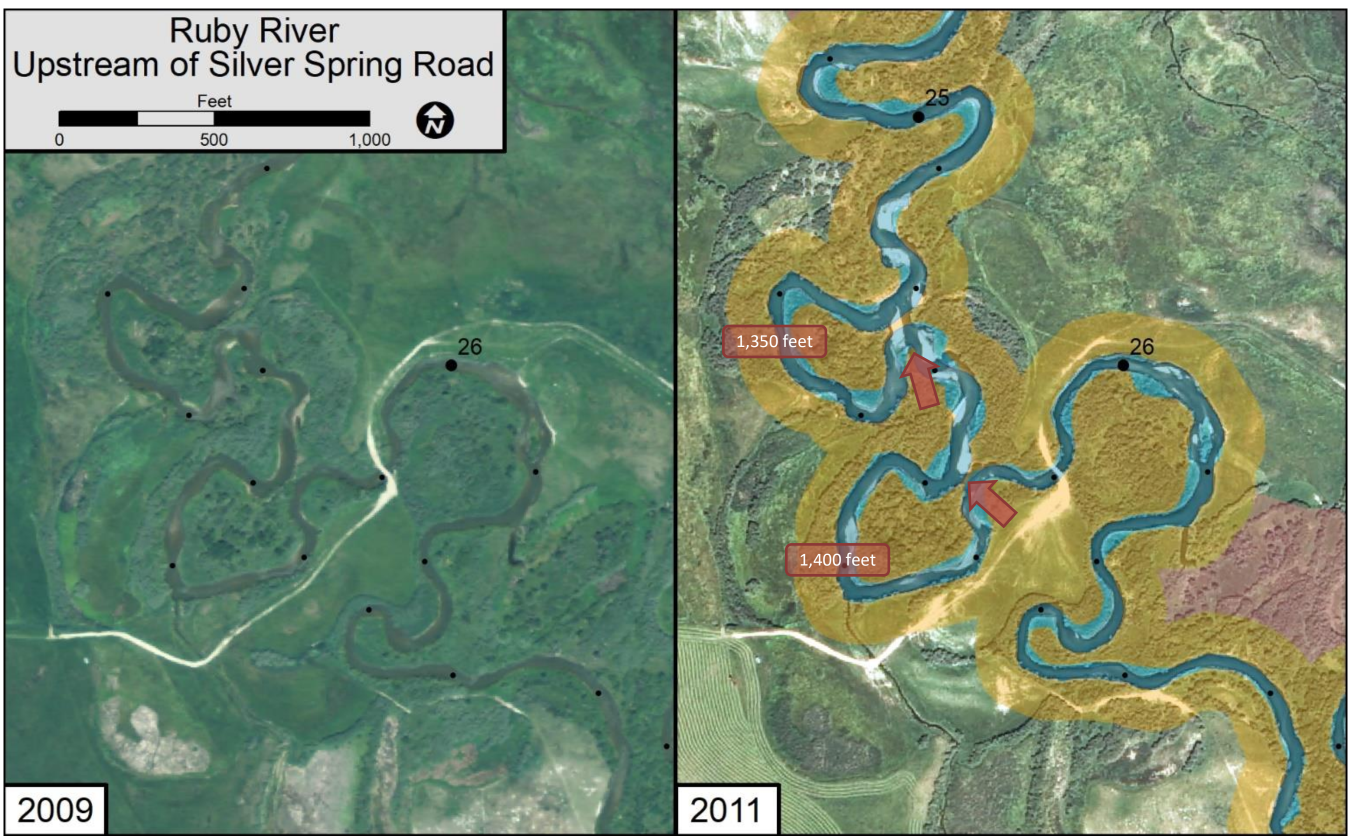

Figure 19. Comparison of 2009 (left) and 2011 (right) showing two cutoffs that shortened river by 2,750 feet above Silver Spring Road.

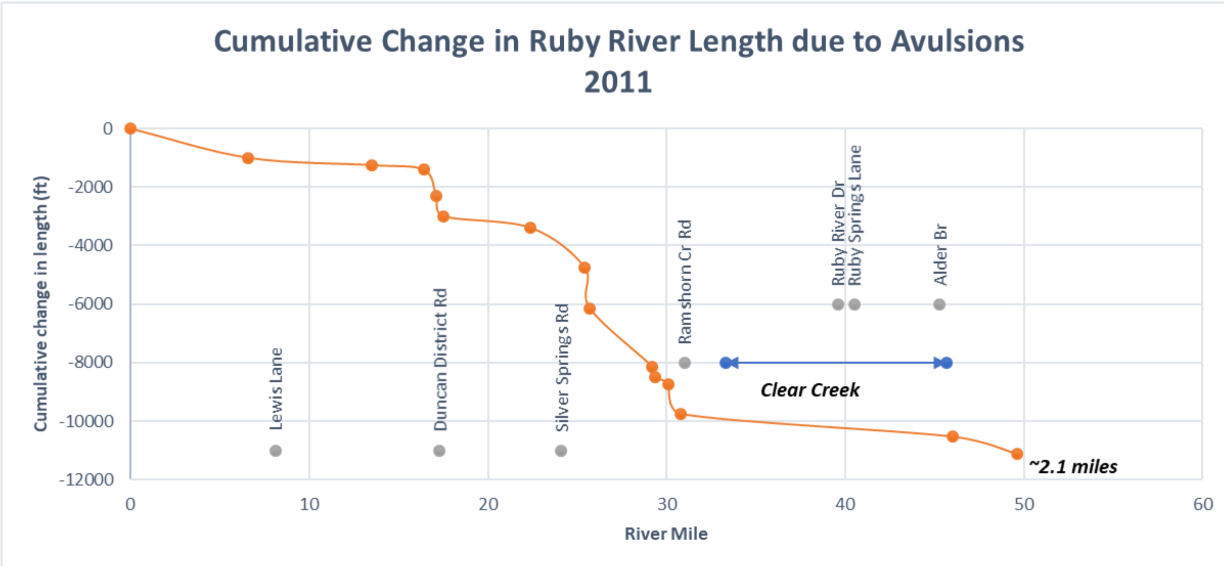

Figure 20. Downstream- to upstream cumulative change in channel length from 2011 avulsions showing lack of change in Clear Creek Reach (blue arrow).

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Appendix A: Reach and Site Migration Statistics

The Channel Migration Zone Mapping for Clear Creek resulted in 463 individual measurements of channel movement between 1955 and 2015. These measurements were taken at approximately 25 foot intervals where notable movement has occurred. Each grouping of migration measurements, such as a bendway, was assigned a Migration Site ID (MSID) that includes the river mile as part of the ID. The statistics for each site are presented in the table below.

Site ID	Count	Avg (ft)	Min (ft)	Max (ft)
Clear Creek				
MSID-CC-8.74	2	16	15	16
MSID-CC-8.68	2	16	13	19
MSID-CC-8.64	4	16	11	18
MSID-CC-8.63	2	16	16	16
MSID-CC-8.6	3	26	21	31
MSID-CC-8.58	2	18	18	18
MSID-CC-8.57	2	18	17	18
MSID-CC-8.56	3	20	15	26
MSID-CC-8.53	2	16	14	18
MSID-CC-8.48	6	14	9	19
MSID-CC-8.42	3	24	21	29
MSID-CC-8.38	4	22	18	25
MSID-CC-8.35	4	37	25	52
MSID-CC-8.15	6	28	24	35
MSID-CC-8.07	4	25	16	33
MSID-CC-8.05	2	14	12	16
MSID-CC-7.97	3	18	14	20
MSID-CC-7.94	1	18	18	18
MSID-CC-7.88	13	36	19	58
MSID-CC-7.82	2	15	12	18
MSID-CC-7.71	3	31	20	45
MSID-CC-7.67	2	20	18	22
MSID-CC-7.6	3	22	21	23
MSID-CC-7.57	3	19	14	22
MSID-CC-7.54	3	26	22	29
MSID-CC-7.53	2	23	18	27
MSID-CC-7.5	4	15	12	20
MSID-CC-7.48	2	14	11	16
MSID-CC-7.45	3	17	15	20
MSID-CC-7.41	2	21	19	23
MSID-CC-7.33	2	17	17	17
MSID-CC-7.31	2	14	12	16
MSID-CC-7.25	4	22	14	30
MSID-CC-7.17	4	22	18	26
MSID-CC-6.96	4	18	12	22
MSID-CC-6.83	5	16	10	22
MSID-CC-6.79	6	23	16	36
MSID-CC-6.68	6	21	16	25
MSID-CC-6.55	4	28	25	32
MSID-CC-6.47	2	24	23	25
MSID-CC-6.35	7	24	12	30
MSID-CC-6.32	2	26	23	29
MSID-CC-6.27	2	17	16	17
MSID-CC-6.23	5	25	19	32

Site ID	Count	Avg (ft)	Min (ft)	Max (ft)
MSID-CC-6.12	7	29	20	38
MSID-CC-6.09	3	28	24	32
MSID-CC-6.06	5	14	8	19
MSID-CC-6.03	5	27	15	37
MSID-CC-6.01	3	15	12	18
MSID-CC-5.99	2	16	14	18
MSID-CC-5.97	3	18	16	21
MSID-CC-5.92	5	26	18	35
MSID-CC-5.9	3	27	24	31
MSID-CC-5.87	4	25	19	29
MSID-CC-5.84	2	21	17	25
MSID-CC-5.71	3	24	23	26
MSID-CC-5.68	2	16	15	17
MSID-CC-5.66	2	18	17	19
MSID-CC-5.65	1	27	27	27
MSID-CC-5.63	3	24	21	27
MSID-CC-5.53	4	20	16	27
MSID-CC-5.27	4	27	20	36
MSID-CC-5.18	2	18	16	20
MSID-CC-5.12	3	21	19	26
MSID-CC-5.06	3	17	12	19
MSID-CC-5.04	3	22	17	25
MSID-CC-5	6	23	15	29
MSID-CC-4.84	1	42	42	42
MSID-CC-4.83	3	37	27	47
MSID-CC-4.8	2	17	15	19
MSID-CC-4.74	3	25	21	28
MSID-CC-4.64	2	17	15	18
MSID-CC-4.61	3	28	25	31
MSID-CC-4.35	3	21	19	23
MSID-CC-4.01	5	18	11	23
MSID-CC-3.74	4	28	25	29
MSID-CC-3.57	2	25	20	29
MSID-CC-3.35	3	18	16	21
MSID-CC-3.17	3	26	25	27
MSID-CC-2.97	3	37	26	49
MSID-CC-2.94	4	33	25	39
MSID-CC-2.85	3	25	23	26
MSID-CC-2.79	2	20	19	21
MSID-CC-2.76	3	35	29	39
MSID-CC-2.71	5	54	40	69
MSID-CC-2.67	3	25	22	29
MSID-CC-2.61	2	29	23	34
MSID-CC-2.48	2	20	15	24
MSID-CC-2.44	3	32	30	36

Site ID	Count	Avg (ft)	Min (ft)	Max (ft)
MSID-CC-2.29	3	19	18	20
MSID-CC-2.2	3	27	24	29
MSID-CC-2.08	4	30	21	39
MSID-CC-2.05	2	22	15	29
MSID-CC-1.93	2	20	18	21
MSID-CC-1.82	2	23	21	25
MSID-CC-1.74	3	20	18	22
MSID-CC-1.59	4	41	29	52
MSID-CC-1.53	4	35	30	41
MSID-CC-1.48	9	25	17	31
MSID-CC-1.44	3	31	23	38
MSID-CC-1.42	3	36	32	40
MSID-CC-1.39	4	32	23	37
MSID-CC-1.29	3	28	22	35
MSID-CC-1.18	5	27	20	35
MSID-CC-1.1	2	26	25	26
MSID-CC-0.61	5	23	14	37
MSID-CC-0.48	2	20	19	20
MSID-CC-0.29	2	33	32	33
MSID-CC-0.27	4	25	21	26
MSID-CC-0.24	2	25	23	26
MSID-CC-0.2	2	20	19	20
MSID-CC-0.17	2	19	18	20
MSID-CC-10.68	5	19	14	23

Site ID	Count	Avg (ft)	Min (ft)	Max (ft)
MSID-CC-10.65	3	19	14	26
MSID-CC-10.62	6	24	10	38
MSID-CC-10.54	7	16	12	22
MSID-CC-10.49	3	20	17	23
MSID-CC-10.44	4	24	18	30
MSID-CC-10.42	3	12	11	13
MSID-CC-10.41	2	23	22	24
MSID-CC-10.38	3	13	12	16
MSID-CC-10.35	2	18	16	19
MSID-CC-10.29	5	40	32	48
MSID-CC-10.17	3	19	18	20
MSID-CC-10.05	4	38	23	54
MSID-CC-10.02	3	16	10	20
MSID-CC-9.77	2	16	15	17
MSID-CC-9.66	3	17	15	18
MSID-CC-9.46	5	18	15	20
MSID-CC-9.18	4	27	19	33
MSID-CC-9.12	7	34	17	55
MSID-CC-9.09	3	14	11	20
MSID-CC-9.04	6	39	24	47
MSID-CC-8.93	3	11	9	14
MSID-CC-8.84	3	29	25	34
MSID-CC-8.82	3	11	11	12
MSID-CC-8.79	2	9	9	9

Appendix B: Clear Creek and Ruby River Photos

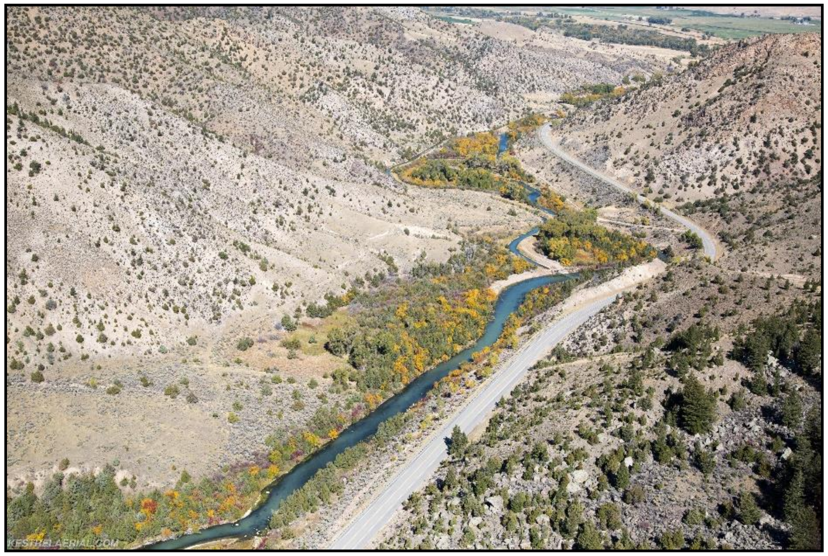

Figure 21. West Bench Canal Diversion on September 29, 2017. (Kestrel)

Figure 22. West Bench Canal Diversion on September 29, 2017. (Kestrel)

Figure 23. Diversion at RM 51.2 on September 29, 2017. (Kestrel)

Figure 24. Diversion at RM 50.9 on September 29, 2017. (Kestrel)

Figure 25. Private bridge at RM 50.5 on September 29, 2017. (Kestrel)

Figure 26. Judy Lane bridge on September 29, 2017. (Kestrel)

Figure 27. Miller Ranch channel reconstruction on September 29, 2017. (Kestrel)

Figure 28. Bridge at RM 46.9 September 29, 2017. (Kestrel)

Figure 29. Clear Creek Diversion on September 29, 2017. (Kestrel)

Figure 30. Judy Land bridges near Alder looking upstream on September 29, 2017. (Kestrel)

Figure 31. Ruby Springs Lodge (right) on September 29, 2017. (Kestrel)

Figure 32. Ruby Springs Lane on September 29, 2017. (Kestrel)

Figure 33. Ruby Springs Lane crossing Clear Creek on September 29, 2017. (Kestrel)

Figure 34. Ruby River Drive bridge on September 29, 2017. (Kestrel)

Figure 35. Farm bridge on Clear Creek RM 1.2 on September 29, 2017. (Kestrel)

Figure 36. Silver Spring Road bridge on September 29, 2017. (Kestrel)

Figure 37. Duncan District bridge on September 29, 2017. (Kestrel)

Figure 38. Diversion above Lewis Lane on September 29, 2017. (Kestrel)

Figure 39. Lewis Lane bridge on September 29, 2017. (Kestrel)

Figure 40. Seyler Lane bridge on September 29, 2017. (Kestrel)