

Final Technical Report

Clark Canyon Creek Sediment Reduction Project

Beaverhead County, Montana

January 15, 2013



Prepared by:

Allied Engineering Services, Inc.

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Appendix 2. Photos
Appendix 3. Excerpts from BOR (sediment distribution and map of samples)
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Attachments

Attachment 1. CD containing the following:
a. Technical Report in PDF format
b. Digital Photos
c. All other reports and relevant data
d. Hydrologic Analysis
e. ESRI Shapefiles
f. Montana Natural Resource Grant Programs

1.0 EXECUTIVE SUMMARY

High sediment loading from Clark Canyon Creek typically associated with rain on snow events or intense localized thunderstorms has had a negative effect on the Beaverhead River fishery. The problem is most pronounced when these events coincide with relatively low flow releases from the Clark Canyon Reservoir. The offending sediment has been shown to significantly reduce the trout population for years after an event. Because of the environmental and economic importance of the Beaverhead River, sediment mitigation has been identified as a high priority management goal. This document presents several alternatives to reduce or manage sediment loading from Clark Canyon Creek into the Beaverhead River and develops a description and conceptual evaluation for each considered alternative. Conceptual design and cost estimates are developed for alternatives identified for further consideration.

An evaluation of existing conditions was conducted including review of previous reports/studies, a site visit, an analysis to characterize the hydrology of Clark Canyon Creek and the Beaverhead River, and characterization of the problem sediment. The following list highlights the information gathered from the review of existing conditions:

- Sediment production in Clark Canyon watershed is primarily from the East Fork Clark Canyon Creek and is most likely the result of natural conditions with an estimated minimal input from anthropogenic influences.
- A flushing flow of 350 cfs in the Beaverhead River was estimated by the Bureau of Reclamation to effectively mobilize and move fine sediment downstream.
- Estimated average sediment contributions from hillslopes in the Clark Canyon Creek watershed total 146 tons per year.
- Three USGS gages are located in the project vicinity: on the Beaverhead River just downstream of the Clark Canyon Reservoir and 1.5 miles upstream of Clark Canyon Creek; on Clark Canyon Creek near the mouth of Clark Canyon; and on the Beaverhead River approximately 9 miles downstream of Clark Canyon Creek. Evaluation of the mean daily flow data for the downstream Beaverhead River gage indicates post-dam flows are lower during spring and higher during summer months. Peak flows developed from the Clark Canyon Creek gage data indicate annual peak discharges of 44 cfs up to 438 cfs for the 50% exceedance probability (2-year) and 1% exceedance probability (100-year) events, respectively.
- Analysis of the East Fork basin using the SCS Curve Number Method indicates a runoff volume of roughly 20 acre-feet up to 50 acre-feet for the 20% exceedance probability (5-year) and 4% exceedance probability (25-year) events, respectively.
- Four bed material shovel samples were taken along the edge of the Beaverhead River in January 2010 for the Bureau of Reclamations flushing flow study. At Clark Canyon Creek and 6 miles downstream, roughly 4% of the material was determined to be silt. Clays made up a negligible portion of the sediment at these locations.
- Based on evaluation of the available data and logical inference, the offending sediment is characterized as silt with a particle size greater than 0.01 mm.

The following five alternatives to mitigate sediment delivery to the Beaverhead River were identified for evaluation:

1. Alternative 1 – Storage/Settling Pond. Water storage can be accomplished with a single pond located on the East Fork near the confluence with the main stem and/or a series of terrace ponds located on the East Fork or one of several ephemeral drainages located

north of Clark Canyon Creek.

2. Alternative 2 – Water Spreading. This alternative would utilize flatter areas in the watershed to distribute water as sheet flow. Sediment would drop out in these low sloping areas as the sheet flow travels over the landscape. The estimated runoff volumes indicate that fields available for water spreading are too small to handle the large events occurring in the basin. This alternative was not considered further.
3. Alternative 3 – Flushing Flows on the Beaverhead River. High flows in the Beaverhead River that coincide with high sediment runoff from Clark Canyon Creek have the potential to reduce sediment issues in a cost efficient manner. Implementing flushing flows, while an attractive solution from many environmental and cost perspectives, may not be feasible given timing considerations and agricultural water needs. Because of these issues, Alternative 3 was not discussed further.
4. Alternative 4 – Modify Existing Irrigation Practices. This alternative would retrofit existing diversion sites located on Clark Canyon Creek to allow diversion of sediment laden stream flows to irrigated fields where it would be spread and stored with low berms. Because of the required maintenance and possible damage to diversion structures, Alternative 4 was discarded as a possible solution to mitigate the problematic sediment.
5. Alternative 5 – Check Dams. This alternative would place small obstructions across a drainage channel to lower the speed of flows and to capture sediment runoff. The check dams would not provide a viable option for storing or settling fine grained sediment due to the steepness of the sub-basins. However, they may be useful to stabilize eroding gullies. More extensive site reconnaissance is necessary to determine if gully erosion is a significant source of sediment.

Alternative 1 – Storage/Settling Pond was the only alternative selected for further consideration in this document. An on-stream pond in the field located just upstream from the confluence of the East Fork and the main stem was selected for conceptual evaluation. While terrace ponds located on the East Fork and/or on ephemeral drainages located north of Clark Canyon Creek are also potential options, their efficiency relative to cost vs. storage volume is significantly less than a single pond located in the flatter area near the confluence of the East Fork with the main stem.

A trial pond was conceptually designed to evaluate performance characteristics and cost. The trial pond includes the following major elements: normal impoundment volume of 50 acre-feet or less; in-stream location; rock lined spillway located on natural ground; and provisions to drain the pond for maintenance. A trial pond with a storage volume of roughly 20 acre-feet appears effective at removing silt particles greater than 0.01 mm in diameter. The estimated cost to construct a single on-stream storage/settling pond is roughly \$150,000 to \$300,000.

Based on the analysis conducted for the Clark Canyon Creek Sediment Reduction Project, the following recommendations are made:

1. Collect field samples of the problematic sediment deposits in the Beaverhead River and perform analysis on the samples to characterize the composition of the problem sediment;
2. Further evaluate Alternative 1 – Storage/Settling Pond. A minimum storage volume of 19-acre feet is recommended and would store the runoff from the estimated 20% exceedance probability annual peak flow. A maximum storage volume of about 49 acre-feet is recommended and would store the runoff from the estimated 4% exceedance probability annual peak flow.
3. A single sediment pond should be constructed and monitored before Alternative 1 is fully

implemented. This will provide better understanding of the scale and type of problem sediment;

4. Conduct a thorough site reconnaissance to evaluate Alternative 5 – Check Dams and to evaluate the degree of gully erosion as a potential significant sediment source; and
5. Seek funding for detailed analysis and design.

2.0 INTRODUCTION

Clark Canyon Creek is the first major tributary of the Beaverhead River downstream of the Clark Canyon Reservoir. Within this area, the Beaverhead River provides Montana with one of its premier trout fisheries. It is estimated that 2,000 to 3,000 trout per mile are typically supported in the reach immediately following the dam. The Beaverhead's importance to trout populations has resulted in its hydraulic functioning being designated a high priority. Periodic high sediment loading from Clark Canyon Creek has had a negative effect on the fishery.

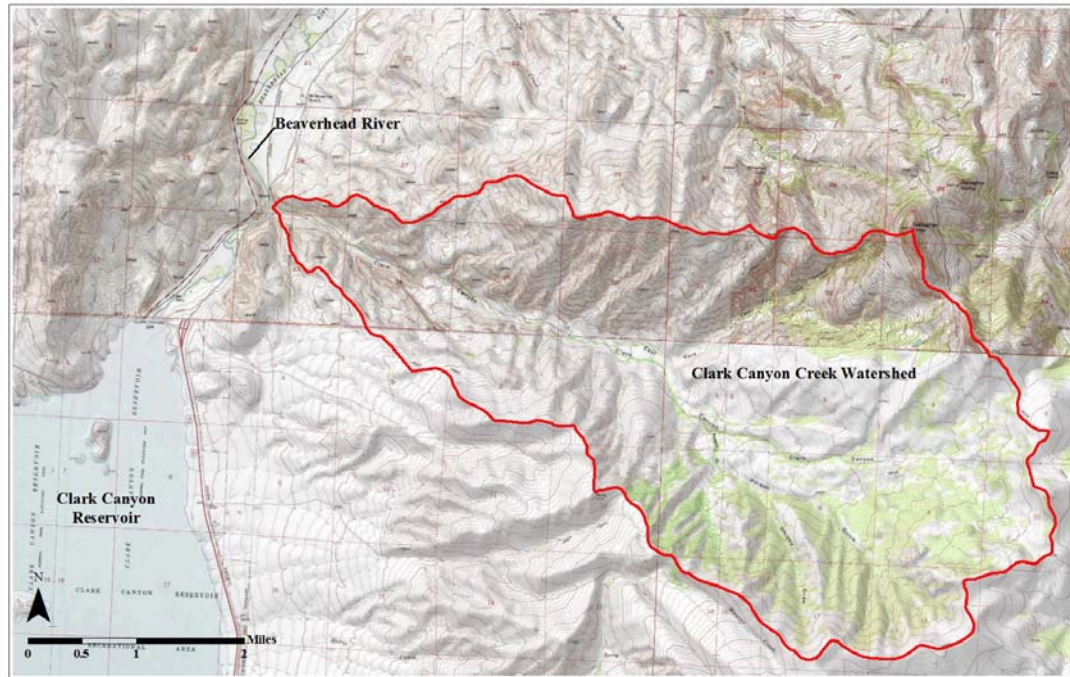
2.1 PROBLEM

Clark Canyon Creek has demonstrated a tendency to produce high sediment loading during large, non-typical runoff events. These events take the form of rain on snow events or intense, localized thunderstorms. Sediment loading can be particularly damaging when dumping from Clark Canyon Creek coincides with low flows in the Beaverhead River. In absence of flushing flows in the Beaverhead, the fine grain sediment entering from Clark Canyon Creek builds up along the river's gravel and chokes out spawning and invertebrate habitat, reducing the trout population by up to 50% for several years after an event (Beaverhead Watershed Committee, 2012). The economic and environmental importance of the Beaverhead fishery means sediment mitigation is of high importance, and the Beaverhead Watershed Committee (BWC) has commissioned Allied Engineering Services, Inc. to review geomorphic alternatives to address the issue.

2.2 PROJECT LOCATION

Clark Canyon Creek joins the Beaverhead River approximately 1.5 miles downstream of the Clark Canyon Reservoir in Beaverhead County in southwest Montana (Figure 1). The latitude 44.997328 and longitude -112.760239 describe where the East Fork Clark Canyon Creek enters Clark Canyon Creek, a main site of interest for possible sediment mitigation efforts.

Figure 1. Overview of the project area.



2.3 OBJECTIVE

This report presents several alternatives to reduce or manage sediment loading from Clark Canyon Creek into the Beaverhead River and develops a description and conceptual-level evaluation for each. Conceptual design and cost estimates are developed for alternatives identified for further consideration.

2.4 SCOPE OF THIS PROJECT

The scope of this report consists of four general tasks, which were developed at the onset of the project. These tasks include the following, as briefly described and as taken from the scope of work.

- 1) Identification and analysis of highly erosive areas.
- 2) Provide alternatives for sediment reduction practices including a study of previous work, field observations and measurements, engineering judgment, conceptual-level analysis, and conceptual design and costing.
- 3) Prepare and submit a Technical Report including conceptual-level design, feasibility assessments, cost estimates for each alternative, and estimated annual O&M.
- 4) Meet twice with the BWC Technical Advisory Panel – once to visit the site and discuss and refine a scope of work and once for an interim update and to discuss the Draft Technical Report.

3.0 EXISTING CONDITIONS

3.1 INTRODUCTION

The Clark Canyon Dam was constructed between 1961 and 1964 and has affected flows in the Beaverhead River. Notably, it has dampened flows during runoff events and limited the flushing of sediment (Figure 2). Sediment deposition issues have occurred during 3 of the last 6 years because of larger-than-average spring precipitation. Following a recent sediment discharge event, the confluence with the Beaverhead River was choked to a degree that application was made to excavate the sediment from the confluence.

Figure 2. Sediment entering the Beaverhead River from Clark Canyon Creek.



Photo provided by the Beaverhead Watershed Committee.

Sediment production in Clark Canyon watershed is primarily from the East Fork Clark Canyon Creek and is most likely the result of natural conditions and less likely caused by anthropogenic influences, e.g., grazing (Boyd, 2011). Rock type includes massive conglomerate derived from volcanic mud flows that is relatively erodible in several areas of the watershed. Since the problem sediment does settle out in the Beaverhead River but also has some plasticity, it is mostly likely elastic silt with some fine sand and greater than 0.01mm in size.

Currently, one culvert approximately 7.5 feet in diameter conveys flow at the outlet of Clark Canyon Creek under a railroad while another culvert just downstream of the railroad conveys water under a frontage road to the Beaverhead River. The road has not been known to overtop during large events, but debris has blocked the culverts.

3.2 EXISTING STUDIES/REPORTS

Several investigations have been completed regarding this particular area of the Beaverhead River and apply directly to this report.

Karin Boyd from Applied Geomorphology, Inc. was commissioned by the Beaverhead Watershed

Committee to complete a site visit for an assessment of erosion sources (2011). Her findings showed that ash-laden Tertiary volcanics with sparse vegetation cover are producing much of the problematic sediment and are largely contained in the East Fork Clark Canyon Creek. Additionally, several conceptual mitigation approaches were suggested. They include trapping sediment through check dams and gully plugs, riparian buffers, settling basins, induced floodplain aggradation, and flushing flows on the Beaverhead River.

In September of 2010, the Bureau of Reclamation modeled the Beaverhead River to determine the flows needed to mobilize sediment. They documented their methods and findings in the “Beaverhead River Flushing Flow Study”. The hydraulic model used to determine effective flushing flows was created in HEC-RAS with cross-sections derived from a 10 meter DEM and limited survey data. Flows between 200 and 800 cfs were simulated in the model, and the hydraulic outputs were used as inputs for two sediment models. The Shields Method predicted an effective flushing flow of 350 cfs in the upper reach of the river near the dam. For the lower reach from Pipe Organ to Barretts Dam, the study predicted an effective flushing flow of 200 cfs. These results should be considered preliminary because of the poor elevation data provided by the DEM and the wide spacing of the cross-sections used to build the model. Additionally, the study would benefit from a larger range of flows being tested since it is possible that the Meyer-Peter and Müller method could show a smaller effective flow than those tested.

Confluence, Inc. modeled sediment contributions to the Beaverhead River from the surrounding hills and documented the results in the report titled “Beaverhead TMDL Planning Area Sediment Contribution from Hillslope Erosion” (2011). Their findings stress that problematic sediment in the Beaverhead River mostly originates naturally in upland areas and would be unaffected by BMPs. Estimated contributions from hillslopes in Clark Canyon Creek Watershed total 146 tons per year.

The Beaverhead area’s roads were assessed for their contribution to sediment in the report “Road Assessment & Modeling” (Atkins, 2011). Unpaved roads produce an estimated total of 66 tons of sediment annually for the Beaverhead River while only 0.3 tons of this comes from Clark Canyon Creek. Compared to hillslope contributions, sediment loading from roads is relatively small. Best Management Practices have the capability of reducing road sediment in the Clark Canyon Creek watershed to 0.1 tons.

3.3 SITE RECONNAISSANCE

A site visit on September 19, 2012 was attended by Paul Sanford, Doug Chandler, and Jennifer Johnson from Allied Engineering, Katie Tackett from the Beaverhead Watershed Committee, Tom Miller, Frank Snellman representing the Clark Canyon Ranch, and Matt Jaeger from Montana Fish, Wildlife & Parks. Road crossings and irrigation diversion structures previously damaged by large runoff events were visited. The mouth of the East Fork Clark Canyon Creek was also visited. Allied Engineering staff discussed basin characteristics and history with the other attendees, obtained ground photographs and logged notes regarding the site visit.

3.4 HYDROLOGY

3.4.1 Beaverhead River

Two USGS gages are located on the Beaverhead River near Clark Canyon Creek (Figures 3). The Beaverhead River near Grant gage (USGS 06015400) is located just downstream of Clark Canyon Reservoir and is approximately 1.5 miles upstream of Clark Canyon Creek. The Grant gage has daily, peak stream flow, and various flow statistics available for data starting at 1962 and running through 1983. Because the gage was not installed until 1962 and no records exist before the construction of Clark Canyon Reservoir, the gage cannot characterize the river’s

natural hydrology since water is released from the reservoir on a controlled basis. However, the gage is useful in characterizing typical reservoir releases. The Beaverhead River at Barretts is located approximately 9.0 miles downstream of Clark Canyon Creek. The Barretts gage has daily, peak stream flow, and various flow statistics based on data from 1907 through the present. Figures 4 and 5 summarize mean daily flows for the Beaverhead near Grant and at Barretts. The gage near Barretts was split into two categories: pre-dam construction (1907-1961) and post-dam construction (1965-2012). Data during the dam's construction was not included.

Figure 3. Gage locations near the project location for the Beaverhead River and Clark Canyon Creek.

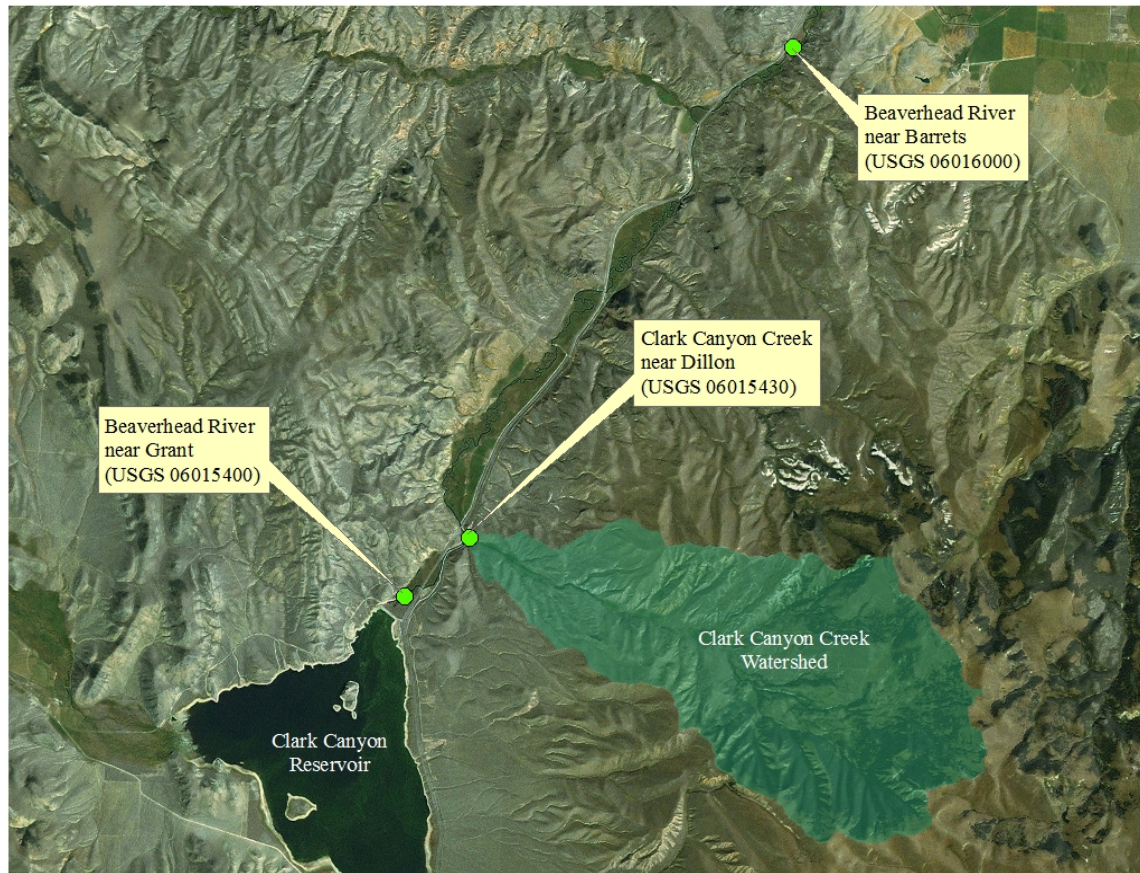


Figure 4. The mean, the 20th percentile of mean, and the 80th percentile of mean daily flows for the Beaverhead River near Grant for the years 1962 through 1984.

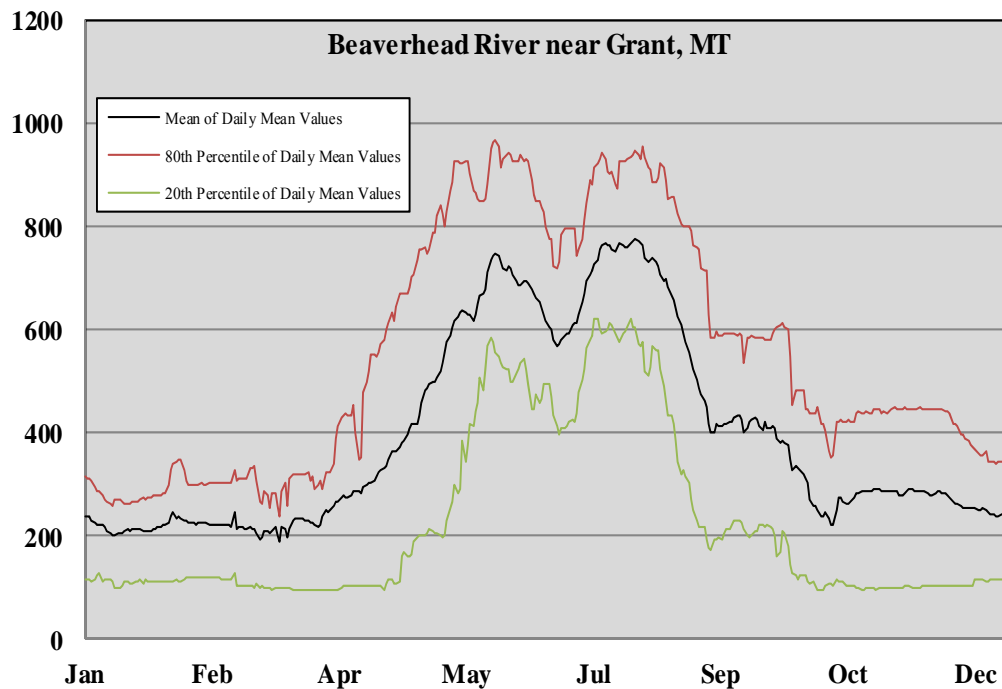
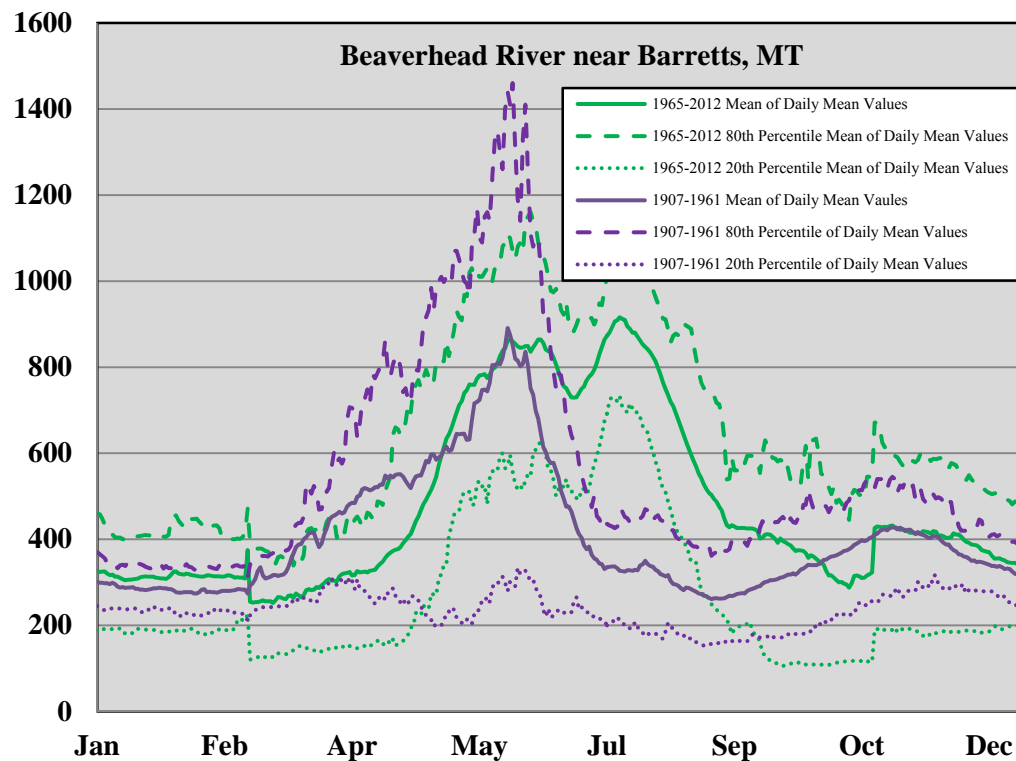


Figure 5. The mean, the 20th percentile of mean, and the 80 percentile of mean daily flows for the Beaverhead River near Barretts for the years 1907 through 1961 and 1965 through 2012.



As expected, flow data from pre-dam construction in Figure 5 shows more variability between the mean, 20th percentile, and 80th percentile mean daily flows because of the natural hydrology. Additionally, post-dam flows are lower during spring, indicating an increase in reservoir storage, and much higher during summer months when there is a demand for irrigation water.

3.4.2 Clark Canyon Creek

Clark Canyon Creek drains an area of 18.0 square miles (see Figure 1). The watershed is mostly undeveloped and consists of a large percentage of soil belonging to the “C” hydrologic soil group. A “C” designation indicates lower infiltration capabilities. Observations noting a flashy hydrologic response agree well with the soil classification.

Existing gage data was used to characterize annual peak flows and estimate return intervals for Clark Canyon Creek Watershed. USGS stage gage 06015430, Clark Canyon near Dillon, located at the creek’s outlet has been in place since 1969 and has recorded 39 annual peak stream flows. The number of recorded peak stream flows allowed for implementation of a Pearson Type III frequency distribution using USGS’s PeakFQ Program version 5.2 (Flynn, Kirby, & Hummel, 2006) to estimate annual chance flood events. The results are summarized in Table 1.

Table 1. Peak discharges for various return intervals for Clark Canyon Creek.

Return Interval (% Exceedance Probability)	2-YR (50%)	10-YR (10%)	50-YR (2 %)	100-YR (1%)	500-YR (0.2%)
Annual Peak Discharge (cfs)	44	144	323	438	829

Since the runoff volume from Clark Canyon Creek Watershed was a necessary parameter to determine the feasibility of two of the alternatives discussed, runoff hydrographs were modeled for a variety of 24-hour precipitation events. The National Oceanic and Atmospheric Administration’s Atlas 2 (1973) for Montana provided the necessary precipitation depths. A Soil Conservation Service (SCS) Type I Storm was determined in the Army Corps of Engineer’s Hydrologic Modeling Software (HEC-HMS). Total precipitation depths are summarized in Table 2.

Table 2. Precipitation depths for the return interval storms modeled.

Storm (RI) (Exceedance Probability)	2-Year (50%)	5-Year (20%)	10-Year (10%)	25-Year (4%)	50-Year (2%)	100-Year (1%)
Total Precip (in)	1.36	1.8	2	2.4	2.8	2.94

Runoff was modeled using HEC-HMS after the watershed was delineated in ArcGIS version 9.3 (ESRI, 2008). Separate models were run in HEC-HMS for the entire Clark Canyon Creek Watershed and for the East Fork Clark Canyon Creek portion of the watershed. Parameters such as slope, area, and curve number were adjusted to coincide with the appropriate contributing area (Table 3).

Table 3. Parameter inputs for the HEC-HMS model.

Watershed	Area mi ²	Hydraulic Length ft	Curve Number	Slope %	T _{lag} min.
Entire Clark Canyon Creek Watershed	18.0	45,598	64.6	29.1	115
East Fork Clark Canyon Creek	2.5	16,247	68.5	28.6	46

Within HEC-HMS, the SCS Curve Number Method (NRCS, 1997) estimated excess precipitation (runoff volume) for the watersheds (Table 4). The Curve Number (CN) Method requires only land cover and soil properties to estimate CN, the method's only parameter. GIS layers published on the Montana State Library Natural Resource Information System (NRIS) give these necessary watershed characteristics. The soil map (1:24,000 scale) was developed by the National Cooperative Soil Survey through the U.S. Department of Agriculture and the NRCS. The land cover data set was published by the Wildlife Spatial Analysis Lab of the University of Montana in 1998 and shows land cover at a resolution of 90 meter grid cells.

A synthetic unit hydrograph translated excess precipitation to an outflow hydrograph to determine peak flow rates (Table 4). Specifically, the SCS Unit Hydrograph was used.

Table 4. Runoff results obtained in HEC-HMS for a variety of return interval storms.

Storm (RI) (Exceedance Probability)	2-Year (50%)	5-Year (20%)	10-Year (10%)	25-Year (4%)	50-Year (2%)	100-Year (1%)
Entire Excess Precipitation (acre-ft)	11.8	77.2	123.1	240.8	388.1	445.8
Entire Peak Flow Rate (cfs)	20	82	120	235	411	490
East Fork Clark Canyon Creek Excess Precipitation (acre-ft)	5.2	19.1	27.7	48.6	73.6	83.2
East Fork Clark Canyon Creek Peak Flow Rate (cfs)	6	19	29	69	135	163

The SCS Curve Number method calculated similar peak flow rates compared to the peak flow rates calculated from the USGS gage data. For example, the 10% exceedance probability annual peak flow calculated from the SCS method was 120 cfs (Table 4) compared to 144 (Table 1) for the USGS gage data method.

3.5 PROBLEM SEDIMENT

The sediment impacting fish habitat and reducing river functioning is fine grained. The Bureau of Reclamation's study on flushing flows included the classification of bed material for several areas on the Beaverhead, including near Clark Canyon Creek. Bed material shovel samples were taken at 4 locations along the edge of the Beaverhead River in January 2010. Though precise sample locations were not provided, the following describes the general sampling locations: 1. near Clark Canyon Dam; 2. near the mouth of Clark Canyon Creek; 3. near Pipe Organ; and 4. Near Barretts Diversion Dam. Particle size distributions were developed from the samples. Excerpts from the Bureau report describing the bed material sample data are included in Appendix 3. Roughly 4% was determined to be silt at Clark Canyon Creek and at Pipe Organ (roughly 6 miles downstream of Clark Canyon Creek). Clays make up a negligible portion of sediment distributions at both of these locations. The average sediment size increases downstream and only 1% of sediment is classified as silt when the Beaverhead River reaches Barretts Diversion Dam located 14 miles from Clark Canyon Creek.

Since the problem sediment does settle out in the lower flows of the Beaverhead River, the size of the silt must be greater than 0.01 mm (sediment smaller than 0.01 mm cannot be removed by conventional gravity settling) (Tchobanoglous and Schroeder, 1987). The observation matches found sizes for silt present at sampling locations in the Bureau's bed material analysis.

The estimated upland erosion sediment load from Clark Canyon Creek is 146 tons/year (Confluence, 2011). Assuming the silt is deposited in the Beaverhead River and laid at a density of 79 lb/ft³ (this assumes about 75% of max density which is about 105 lb/ft³ for silt) this sediment load would result in volume of about 0.09 acre-feet or 137 cubic yards deposited per year. Another way to visualize this sediment load is a 0.1 foot thick layer of sediment with a width of 1.2 feet laid over a 6 mile length of the Beaverhead River (note: this is not the actual geometric configuration of the sediment but simply a way to visualize the estimated amount of sediment deposited each year). It is noted that the 146 ton/year estimated by Confluence determined is an estimated average annual number, and the watershed may produce more sediment during problematic events.

It should also be mentioned that larger bed material (gravel and sand) is beneficial to the riverine system and should not be categorized as problematic. In fact, efforts should be made to continue Clark Canyon Creek's delivery of coarser sized sediment.

4.0 DESCRIPTION OF IDENTIFIED ALTERNATIVES

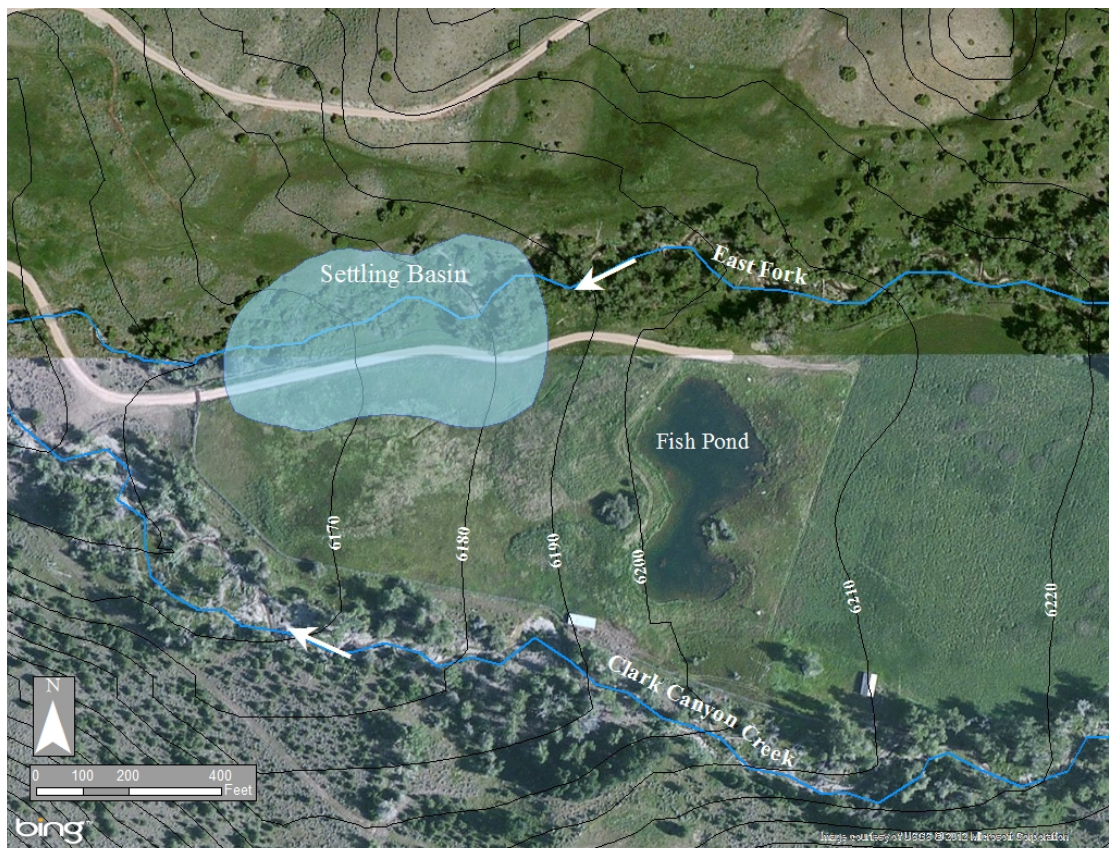
The following alternatives are presented as possible methods to mitigate the excessive sediment coming from Clark Canyon Creek Watershed. This section provides general descriptions of the alternatives considered, and the following chapter provides a more complete discussion regarding feasibility and cost.

4.1 ALTERNATIVE 1 – STORAGE/SETTLING POND

Water storage to induce settlement is one potential mitigation method. Water storage can be accomplished through a single, large settling basin or a series of smaller settling basins. The alternative would require an appropriately sized basin to store runoff from larger events (e.g. 10-

Year Return interval) or to allow particle settling to occur as water travels from the inlet of the settling basin to the outlet of the basin. Figure 6 displays a conceptual configuration of a settling basin located in the field just upstream from the confluence of the South Fork and East Fork Clark Canyon Creek. In this configuration, the settling basin is located on-stream. While an off-stream settling basin with an in-stream diversion structure would allow for the passage of coarse sediment and base flows, the maintenance required to keep the diversion unobstructed is not seen as feasible since the East Fork experiences high debris flow during problematic events. An in-stream basin will be simpler and more effective at removing sediment despite requiring some regular maintenance to remove coarse sediment. At this time, the field just upstream of the East Fork's confluence with the main stem is recommended for the basin's placement. The conceptual figure shows basin placement downstream of the fish pond since there is some concern regarding the pond's placement upstream of the fish pond. Failure of the basin could result in costly damage to the fish pond. However, the flatter slopes upstream of the fish pond are more desirable, and construction further upstream depends upon owner approval.

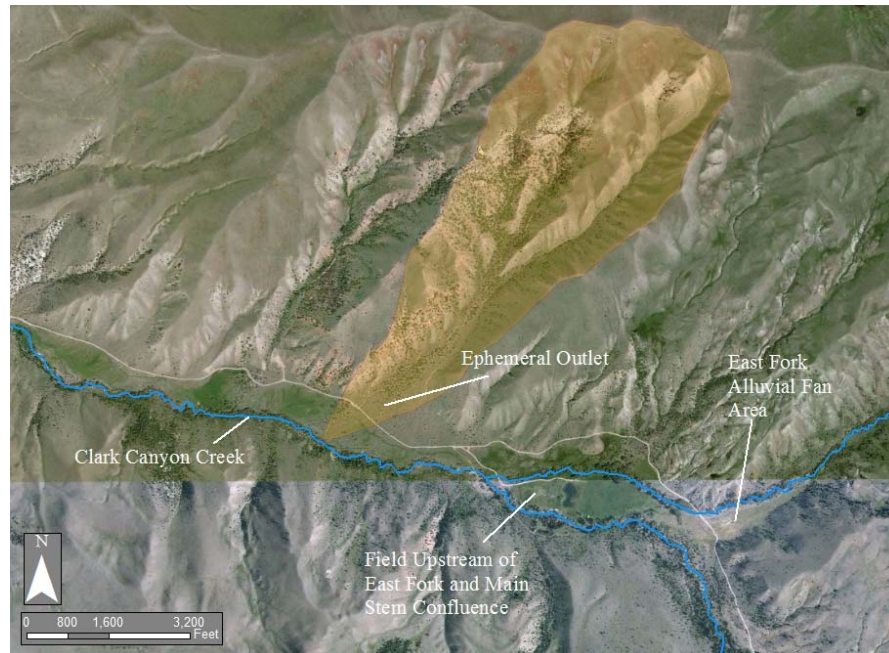
Figure 6. Conceptual layout of a settling pond near the outlet of the East Fork Clark Canyon Creek.



The alluvial fan area located northeast of where the East Fork Clark Canyon Creek crosses Clark Canyon Road was also considered for a sediment pond. It is not recommended for a single, large sediment pond because of the steep slope of the land in this area, and mass balances and dam heights become unmanageable on increasingly sloped landscapes. However, a series of terrace ponds may provide some storage and be used in conjunction with a larger settling pond. It is estimated that three, -ft high spreader dikes could provide approximately 5.5 acre-feet of storage.

The ephemeral streams along the north side of Clark Canyon Creek Watershed provide another opportunity for sediment storage. It is noted that the outlets of these streams are much steeper than the other recommended locations, and terrace ponds would be required. A single ephemeral drainage was examined to generalize the feasibility of the setup (Figure 7).

Figure 7. The ephemeral drainage examined for the construction of terrace ponds.

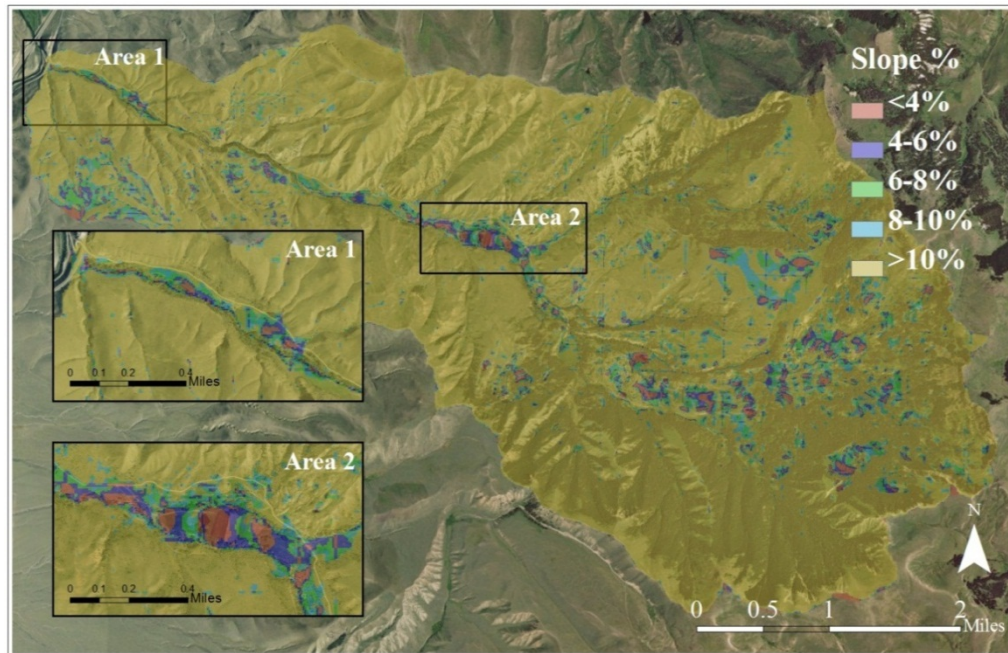


The ephemeral watershed shown in Figure 7 is approximately 0.5 square miles or about 20% the size of the East Fork drainage. Together, the northern ephemeral watersheds may be producing comparable runoff volumes to the East Fork. However, sediment ponds located near the outlet of the ephemeral streams may not be treating the main offending sediment since runoff from these watersheds moves through riparian areas that help treat the excess rain. Also, the ephemeral stream's runoff is less concentrated than that of the East Fork. Despite these considerations, the ephemeral streams will still be considered as possible mitigation sites until further investigations can be completed.

4.2 ALTERNATIVE 2 – WATER SPREADING

Water spreading is another alternative examined. This solution would utilize flatter areas in the watershed to distribute water as sheet flow. Sediment would drop out in these low sloping areas as the sheet flow travels over the landscape. Water would be conveyed to open fields using a series of ditches or spreader dykes. The ditches also have potential for some water storage. The 10 meter Digital Elevation Model (DEM) available from the National Elevation Dataset (NED) by USGS was processed to highlight relatively flat areas and determine where water spreading may be effective (Figure 7). Usable flat areas are mostly adjacent to Clark Canyon Creek, and two areas with potential are shown below.

Figure 8. Low slope areas in Clark Canyon Creek Watershed.



The estimated runoff volumes indicate that fields available for water spreading are too small to handle large events occurring in the basin. Assuming only 0.5 inches of water could be infiltrated by soil already saturated from a precipitation event, the fields will not have infiltration rates capable of absorbing flood flows, and most sediment laden water will return to the system. Additionally, the relatively steep slopes could create velocities too high to allow settling. Several specific areas are further evaluated below.

The alluvial fan area northeast of where the East Fork Clark Canyon Creek crosses Clark Canyon Road supplies an area of approximately 7 acres. With the assumption of 0.5 inches of water infiltrated, only roughly 0.3 acre-feet of water would be infiltrated on the field. Compare this to the estimated 5.2 acre-feet of runoff from a 2-year, 24-hour storm and it is obvious the field is too small to provide much infiltration. The large field just upstream of the East Fork Clark Canyon Creek's confluence with Clark Canyon Creek has more area available for spreading (~20 acres), but the acreage is still inadequate to manage sediment. Areas near the outlet of Clark Canyon Creek have about 16 acres available for water spreading but would have significantly more runoff to handle. The limited area available for water spreading results in discouragement for its employment as a mitigation method, and it will not be discussed further in this Alternatives Analysis.

4.3 ALTERNATIVE 3 – FLUSHING FLOWS ON THE BEAVERHEAD RIVER

Releasing flushing flows from Clark Canyon Reservoir is another alternative considered. The construction of Clark Canyon Reservoir has dampened peak flows during spring runoff, and sediment now stagnates in the area of Clark Canyon Creek's confluence with the Beaverhead. High flows in the Beaverhead that coincide with high sediment runoff in Clark Canyon Creek have the potential to reduce sediment issues in a cost efficient manner. This alternative is also desirable since it mimics the river's natural functioning. Initiating flushing flows could be beneficial to several riverine processes and to help remove fine sediment accumulation.

As previously discussed in the Existing Studies/Reports section of this document (Chapter 3), the Bureau of Reclamation has completed a study determining the flow rate necessary to move

sediment through the system. However, before implementing a flushing flows solution, more detailed hydraulic and sediment models may be beneficial since the Bureau of Reclamation had limited channel and floodplain elevation data.

It is interesting to note that the effective flushing flow found by the study, 350 cfs, is a common flow (Figure 4). In fact, the mean of mean daily flow data at the USGS gage Near Grant shows a flow higher than 350 cfs typically occurs from early May through early October, and the USGS Gage near Barrets shows the mean of mean daily flows higher than 350 cfs from late March through early September. Assumptions made by the BOR may not have accounted for the fact that the problem sediment has a tendency to set up on the edges of the active channel and may not mobilize with larger bed material. If flushing flows are implemented, a much higher flow for a shorter duration may be more effective to quickly and efficiently remove fine grain sediment.

If another hydraulic model is created to further explore this alternative, detailed cross-sections should be analyzed for shallow inundation areas. Large increases in wetted perimeter compared to relatively smaller increases in discharge can result in settling, and discharges resulting in shallow flow should be avoided (Boyd, 2011). Additional study should also focus on the problem sediment that has a tendency to “set-up” on the edges of the Beaverhead River active channel.

Implementing flushing flows, while an attractive solution from many environmental and cost perspectives, may not be feasible given timing considerations and agricultural water needs. High sediment producing events tend to be the result of sudden precipitation, and a lack of warning may create difficulties in appropriately timing flow from the reservoir. Additionally, landowners holding water rights downstream of the dam could object to higher reservoir releases, especially during drought years. Because of these issues, Alternative 3 will not be discussed further.

4.4 ALTERNATIVE 4 – MODIFY EXISTING IRRIGATION PRACTICES

Alternative 4 would retrofit existing diversion sites to allow diversion of sediment laden stream flows to irrigated fields where it would be spread and stored with low berms (spreader dikes). The diversion structures would be retrofitted to allow passage of coarse sediment and some portion of flow but would divert the majority of sediment laden flood flow to the irrigated fields. The alternative is conceptually similar to Alternative 1

At least three irrigation diversions are located on Clark Canyon Creek. Several of these diversions have been re-built in recent years. The re-built diversions consist of rectangular jack-leg wood weirs with concrete splash pads and roughly 18-inch headgates controlling flow to an irrigation ditch. Figure 8 shows one of these rebuilt diversions located just downstream of where East Fork Clark Canyon Creek crosses Clark Canyon Road.

The alternative would require leaving the diversion headgates open during large precipitation events. Currently, Clark Canyon Ranch representatives open the diversion weirs and close the headgates prior to anticipated sediment transport events to limit the sediment deposition at the diversions and in the irrigation ditches. Despite this adopted management practice, some sediment is known to build up around diversions as can be seen in Figure 8 (sand deposited in front of the headgate). Leaving the headgates open would result in sediment buildup, and Alternative 4 would require maintenance after a sediment event to clean out the diversions and irrigation ditches. Because of the required maintenance and possible damage to diversion structures, Alternative 4 was discarded as a possible solution to mitigate the problematic sediment. It will not be discussed further in this report.

Figure 9. An existing irrigation diversion structure located just downstream of where East Fork Clark Canyon Creek crosses Clark Canyon Road. Note the sand deposited in front of the headgate.



4.5 ALTERNATIVE 5 – CHECK DAMS

Check dams, often referred to as gully plugs, are another possible mitigation method. Check dams are small obstructions placed across a drainage channel to lower the speed of flows and capture sediment runoff. The structure's life span ranges from temporary to more permanent and usually requires some level of maintenance to remove sediment build-up.

Ephemeral channels on the north side of Clark Canyon Creek appear to be partial culprits of the offending sediment and are candidates for check dam applications. However, there are concerns regarding their effectiveness for these channels. The steepness of the sub-basins may create difficulties for check dams to slow and spread water to such a degree that fine grained sediments settle. Additionally, the installation of check dams risks trapping only courser-sized sediment – an undesirable outcome since sand and gravel are beneficial to the stream system. Check dams are recommended at a spacing of 33 feet for a ditch grade of 6% and 50 feet for a ditch grade of 4% (Metropolitan Council, 2012). The number of gully plugs required for a watershed with such steep grades may be unreasonable and costly. Finally, the significance of the ephemeral channels' contribution to runoff is unknown, and it is possible that much of the problem sediment will not be addressed.

While conventional gully plugs are probably not a viable option for storing or settling fine grained sediment, they may be useful to stabilize eroding gullies. More extensive site reconnaissance is necessary to determine if gully erosion is a significant source of sediment. If gully erosion is thought to be a major contributor of the offending sediment, check dams/grade control structures placed in the gullies could stabilize the bed of the gullies and reduce sediment contribution from eroding gullies. Check dams may also provide grade control and prevent in-stream erosion for the main stem of Clark Canyon Creek.

5.0 ALTERNATIVES ANALYSIS

This section provides a discussion of the analysis of Alternative 1 – Storage/Settling Pond, the only alternative selected for further consideration in this report. In this Chapter of the report, the proposed modifications are summarized, the alternative is discussed and a conceptual cost estimate is provided. Potential funding sources are also discussed at the end of this chapter.

Alternatives not discussed were rejected either for lack of feasibility or for need of additional study to make a reasonable judgment of feasibility. Gully plugs to reduce gully erosion and higher flushing flows (simulated spring flows) fell into the latter category and are alternatives that are believed to be worthy of additional study. Water spreading on the alluvial fan or other existing land forms in the basin is not likely a feasible mitigation method during the offending events. It may be feasible or worthwhile to spread or irrigate with water stored in the sediment pond described in that alternative. Modification of existing irrigation practices was also discarded as a feasible alternative due to required maintenance and potential damage to the irrigation infrastructure.

5.1 ALTERNATIVE 1 – STORAGE/SETTLING POND

5.1.1 Proposed Conditions

Alternative 1 Storage/Settling Pond: Construct an on-stream pond in the field located just upstream from the confluence of East Fork Clark Canyon Creek and Clark Canyon Creek. Specific elements of the pond include:

- Normal impoundment volume less than 50-acre feet. Volumes above 50-acre feet would result in a high-hazard dam classification;
- In-stream pond constructed with an earthen dam in East Fork Clark Canyon Creek;
- Rock lined spillway located on natural ground to convey the East Fork from the pond back to the stream channel; and
- Provisions to drain the pond for maintenance (low-level outlet, bypass system, or some other means to divert flow around the pond).

As discussed in Chapter 4, other areas may be feasible for storing water using terrace ponds (Figure 7). The other areas have steeper slopes and more earth moving would be required to obtain a storage volume comparative to the storage/settling pond at the location described above which is located on a flatter slope.

5.1.2 Discussion of Alternative

Runoff volume was an important consideration when determining the feasibility of Alternative 1. The runoff volumes reported in Chapter 3 indicate that designing for the entire watershed is unreasonable. It is more practical to focus on the East Fork Clark Canyon Creek problem area and design a settling basin near its outlet. A 10-year return interval storm applied to the East Fork Clark Canyon Creek Watershed gives a runoff volume of almost 28 acre-feet. This is a sizable volume to store, and the only practical location to place a storage pond is in the large field just upstream of the East Fork Clark Canyon Creek's confluence with the main stem of Clark Canyon Creek.

An example pond was graded in the computer program AutoCAD Civil 3D to evaluate pond volume and rough grading required relative to the landscape and to calculate settling times. A first trial with a pond approximately 260 x 360 feet with a sloping bottom and a dam height of about 11 feet at the downstream end holds about 19.5 acre feet, a significant portion of runoff for

the 5 and 10-Year events. Additional iterations of pond grading may determine a pond configuration with more storage. However, a detailed topographic survey would be necessary to justify further evaluation of pond grading. The point is that it appears feasible to grade a pond into the landscape that could store a significant runoff event.

Settling velocities were calculated for the trial pond and indicate that adequate size and depth is provided for sediment to fall out, although it makes sense that sediment would fall out in a large pond since it falls out in the Beaverhead. The analysis was completed by estimating the velocity of a particle moving through a settling basin in both the horizontal and vertical directions. Velocity in the horizontal direction is derived from the inlet discharge and pond volume, and velocity in the vertical direction is a function of the particle's size and density. The 10-Year, 24-Hr peak discharge of 29 cfs was conservatively used for the inlet flow rate. The settling analysis determined if a particle would reach the bottom of the pond by the time it had traveled through the pond's length. Table 5 summarizes the percentage of sediment that has settled and been removed by the time flow moves through the system. This assumes sediment must reach the pond bottom to be removed. The assumption leads to a conservative analysis since cleaner water on top will likely exit through the outlet first, and it may be unnecessary for sediment to reach the pond's bottom in order to settle in the pond. The table shows that the trial pond is mostly ineffective for the smallest particle size analyzed (0.01 mm), but the Bureau of Reclamation's sediment analysis indicates that silt sizes in the Beaverhead are greater than 0.02 mm. The pond system has an associated detention time of 7.6 hours.

Table 5. Settling velocities and percentage of sediment removed by the trial pond for silts of various sizes.

Particle Size (mm)	Settling Velocity (m/s)	Percentage Removed (%)
0.01	2.19E-05	23
0.02	8.74E-05	93
0.03	1.97E-04	100
0.04	3.50E-04	100
0.05	5.46E-04	100
0.06	7.87E-04	100

In addition to grading a trial pond, potential settling basin and terrace pond locations were further analyzed by describing the available runoff storage associated with a specific dam height. The average slope for each area was derived from the available 10 meter DEM, and a section was cut based on these average slopes. A 4 foot high dam with 2:1 side slopes was used to compare available storage on the sections. Care was taken to balance cut and fills for each section. The results are summarized in the next table and show the greater efficiency of flatter slopes to store runoff.

Table 6. Estimated pond storage for a 4 foot high dam.

	Ephemeral Outlet	Field Upstream of East Fork and Main Stem Confluence	East Fork
Average Slope %	14.2	5.7	8.1
Cubic Feet of Storage per Foot of Embankment Length	41	126	82

While it is believed that sediment ponds at any of the described locations would provide an effective mitigation method for the offending sediment, it is recommended that a single sediment pond is constructed and then monitored until an event occurs producing the offending sediment. This will help to define the nature and amount of problem sediment. If the problem sediment is a high percentage of hard gravel and rock, application of a sediment pond may be reconsidered, but if the sediment is a high percentage of mud and soft rocks, more sediment ponds are likely to be effective in preventing sediment loading in the Beaverhead River.

5.1.3 Estimated Cost

The estimated cost for implementing Alternative 1 Storage/Settling Pond ranges from \$150,000 to \$300,000. This estimated cost does not include purchase of any necessary easements or costs related to negotiations with private land owners. The cost range was estimated based on a conceptual construction cost estimate for the trial pond only, and the terrace ponds were not included. The estimate for the trial pond includes a 30% contingency. It is common to include this percentage of contingency in conceptual-level cost estimates. More detailed costs are listed in Appendix 4 Estimated Costs.

Based on the above estimated cost, the cost per acre foot of storage for the trial pond is roughly \$11,000/acre-feet. Terraced ponds are estimated to have an efficiency of 33% to 65% compared to a single pond when comparing earthwork required per storage volume. Therefore, terrace ponds may cost in the range of \$20,000/acre-feet to \$30,000/acre-feet.

Though the watershed may produce more sediment during problematic events, assuming the estimated annual average sediment load of 146 tons/year (for the entire Clark Canyon Creek basin) is deposited in a storage/settling pond, the estimated cost to remove this volume of material is on the order of \$5,000.

5.2 POTENTIAL FUNDING SOURCES

Several potential funding sources are described below. Detailed information about these potential funding sources including contact information is provided on the attached CD.

5.2.1 319 Grant

The 319 Grant was established to provide funding to projects addressing nonpoint source pollution. Funds are distributed by the Department of Environmental Quality and may be used for several purposes including watershed restoration, groundwater protection and education and outreach. In most cases, Watershed Restoration Plans are required.

5.2.2 RRGL Grant

The Montana Department of Natural Resources and Conservation (DNRC) Renewable Resource Grant and Loan Program offers RRGL Planning grants (\$25,000) and RRGL Project grants (\$100,000). Eligible projects must be for the conservation, management, development or

protection of a renewable resource in Montana. Planning grants have an open application cycle and project grants are due in May of even numbered years.

5.2.3 Other Grants

Other grant programs that should be considered include DNRC Conservation Districts Grant Program (223 Grants), DNRC Conservation District Technical Assistance grants and Montana Fish Wildlife & Parks Future Fisheries grants.

6.0 RECOMMENDATIONS

Based on the analysis conducted for the Clark Canyon Creek Sediment Reduction Project, the following recommendations are made:

1. Collect field samples of the problematic sediment deposits in the Beaverhead River and perform analysis on the samples to characterize the composition of the problem sediment;
2. Further evaluate Alternative 1 – Storage/Settling Pond. A minimum storage volume of 19-acre feet is recommended and would store the runoff from the estimated 20% exceedance probability annual peak flow. A maximum storage volume of about 49 acre-feet is recommended and would store the runoff from the estimated 4% exceedance probability annual peak flow.
 - a) Identify acceptable site(s) for placement of pond
 - b) Complete a detailed survey of settling pond sites
 - c) Complete preliminary designs based on detailed topographic survey data
3. A single sediment pond should be constructed and monitored before Alternative 1 is fully implemented. This will provide better understanding of the scale and type of problem sediment.
4. Conduct a thorough site reconnaissance to evaluate Alternative 5 – Check Dams and to evaluate the degree of gully erosion as a potential significant sediment source; and
5. Seek funding for detailed analysis and design.

7.0 REFERENCES

Atkins (2011), “Road Sediment Assessment & Modeling”, Bozeman, MT.

Beaverhead Watershed Committee (2012), “Clark Canyon Creek Sediment Reduction Project Limited Solicitation”, Dillon, MT.

Confluence (2011), “Beaverhead TMDL Planning Area Sediment Contribution from Hillslope Erosion”, Bozeman, MT.

Flynn, Kathleen M.; Kirby, William H.; and Paul R. Hummel (2006) “User’s Manual for Program PeakFQ, Annual Flood-Frequency Analysis Using Bulletin 17B Guidelines, U.S. Geological Survey Techniques and Methods 4-B4”, Reston, VA.

Khanna, S. (1997), “Effectiveness of Contour Bands and Gully Plugs as Tool for Watershed Treatment. A Case Study of Khabji Village of Bharuch District”, www.sswm.infor, accessed November, 2012.

Metropolitan Council (2012), “Sediment Control. Check Dams”, www.sswm.infor, accessed

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Ruffina, L. (2009), "Rainwater Harvesting and Artificial Recharge to Groundwater", Brussels, SAI Platform.

Tchobanoglous, George and Edward D. Schroeder (1987), "Water Quality", Addison-Wesley Publishing Company, Inc., Davis, CA.

Appendix 1. Conceptual Design and Analysis Information

Settling Pond Calculations

v_{sc} critical settling velocity

$$v_{sc} = \frac{Q}{A_s}$$

Θ_H hydraulic detention time

$$\theta_H = \frac{H}{v_{sc}}$$

v_s terminal settling velocity

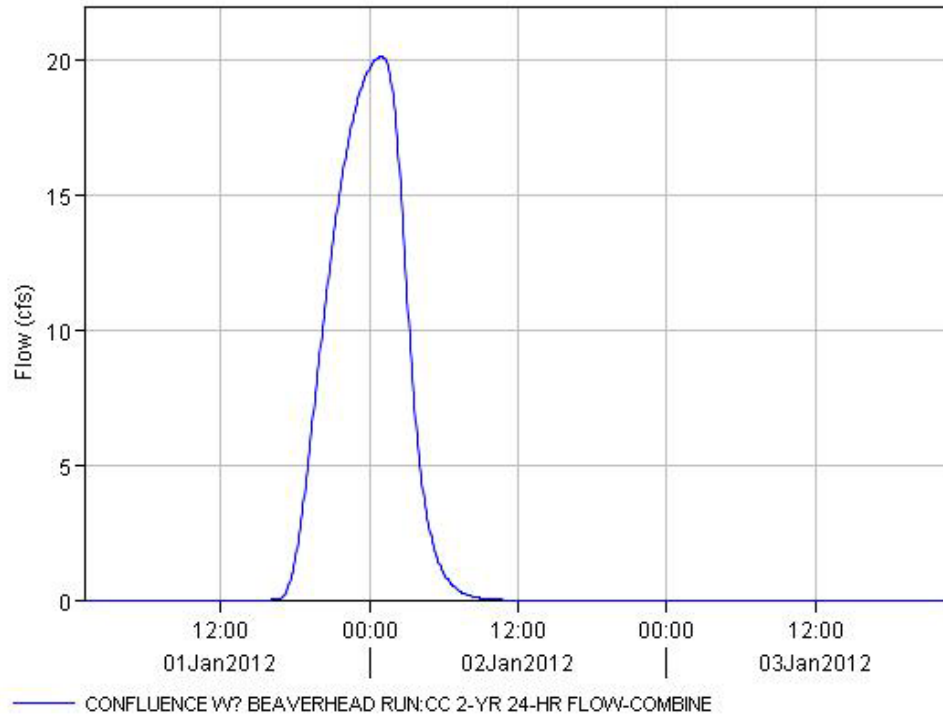
$$v_s = \frac{g(\rho_p - \rho_w)d_p^2}{18\mu}$$

Silt Density		Pond Parameters		Inflow	
1.4 g/cc		Length	360 ft	Q	29 cfs
1400 kg/m ³		Width	260 ft	Q	0.82 cms
		Depth (H)	8.5 ft		
		Area	93600 ft ²		
		Area	8695 m ²		

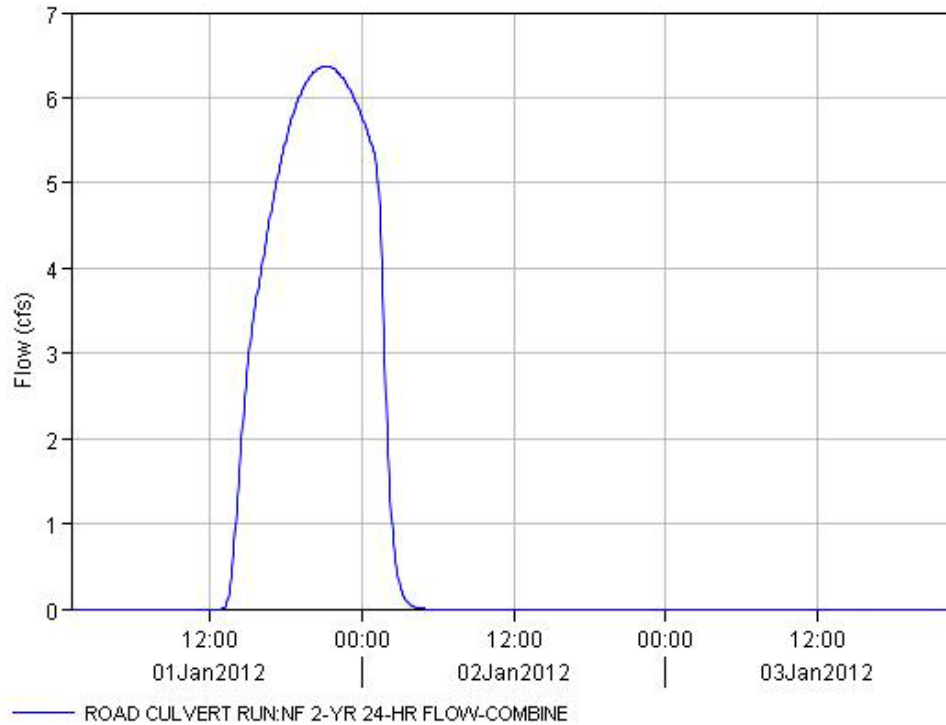
V _{sc}	Θ _H	Θ _H
m/s	s	hr
9.44E-05	27434	7.6

size	v _s	Reynolds Number	Proportion Removed
mm	m/s		%
0.01	2.19E-05	0.0002	23.1
0.02	8.74E-05	0.0015	92.6
0.03	1.97E-04	0.0050	100.0
0.04	3.50E-04	0.0118	100.0
0.05	5.46E-04	0.0231	100.0
0.06	7.87E-04	0.0400	100.0

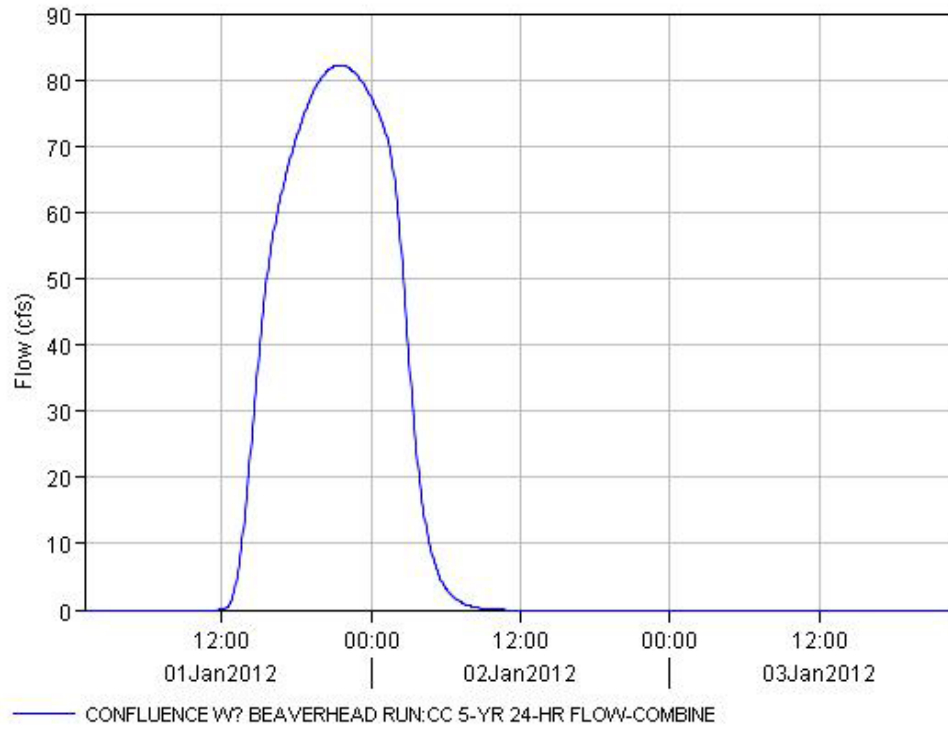
2YR-24HR STORM
CLARK CANYON CREEK



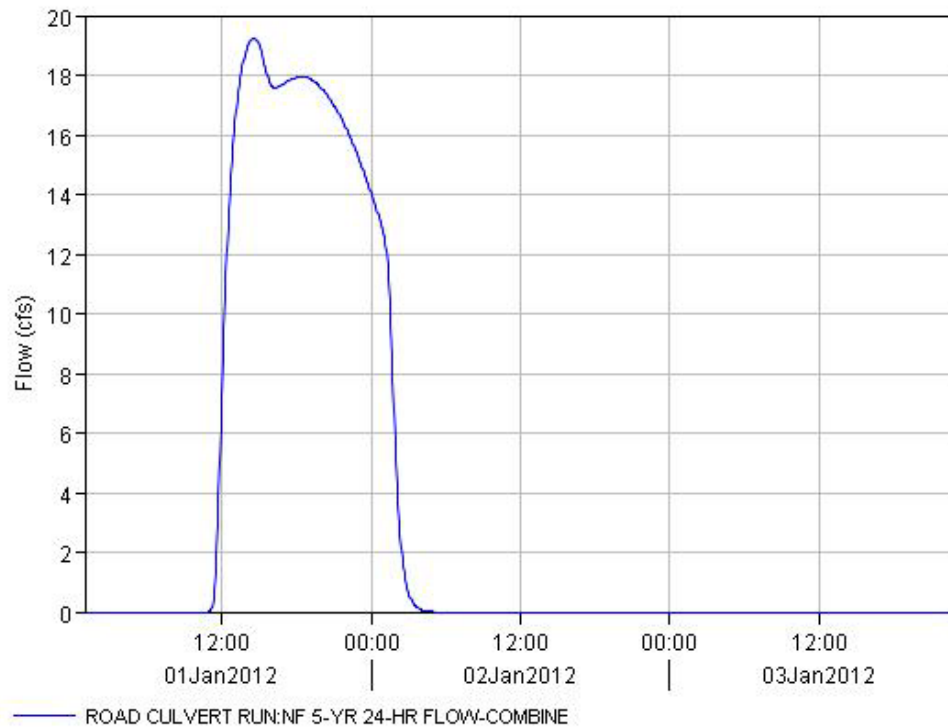
2YR-24HR STORM
NORTH FORK



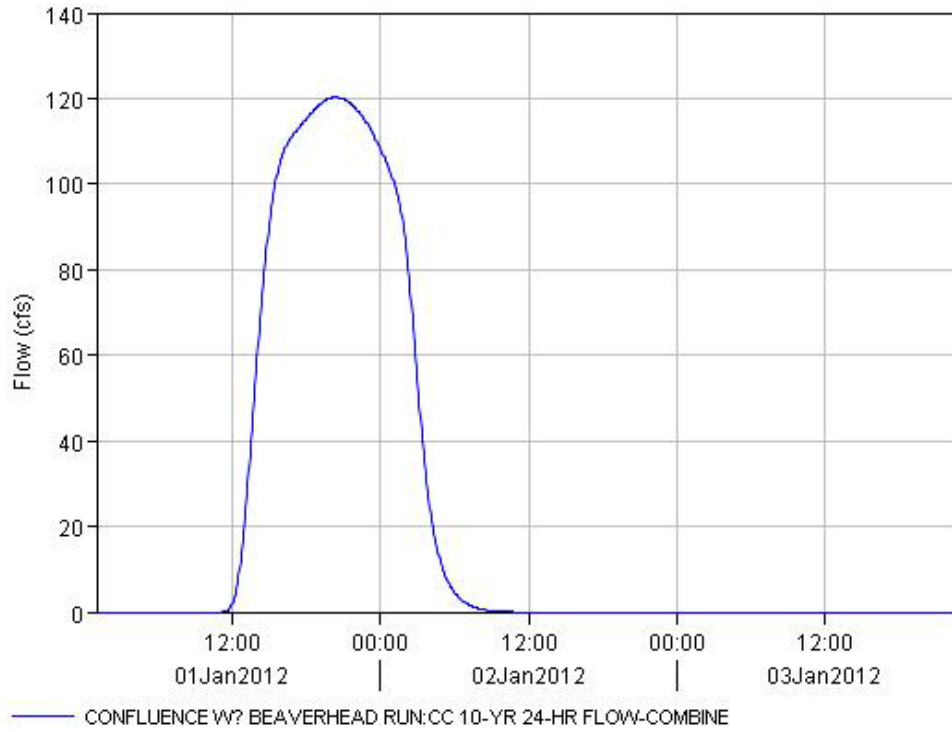
5YR-24HR STORM
CLARK CANYON CREEK



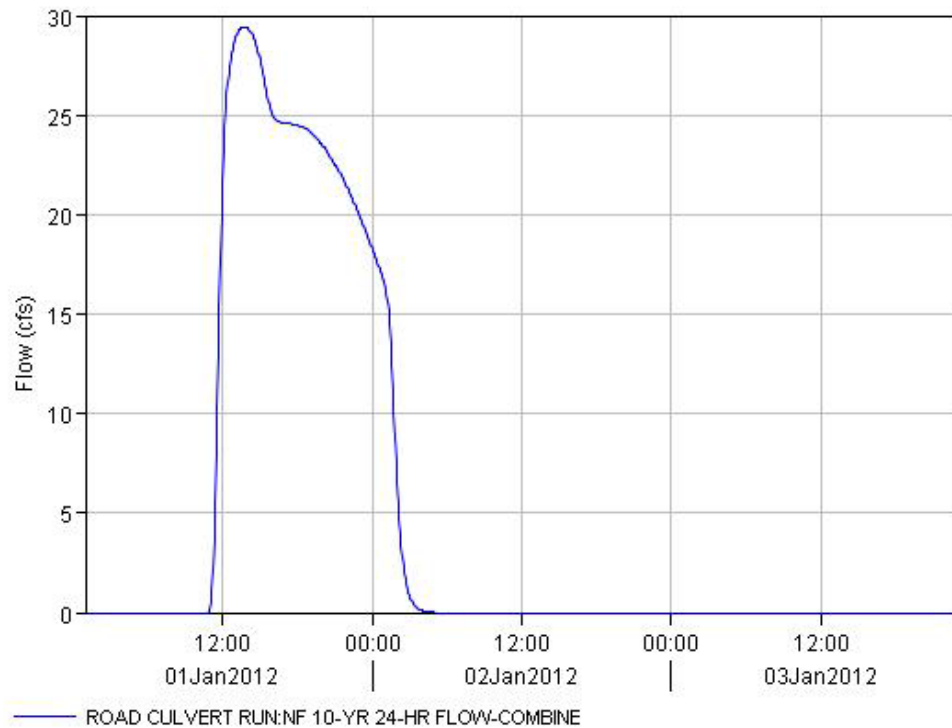
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NORTH FORK



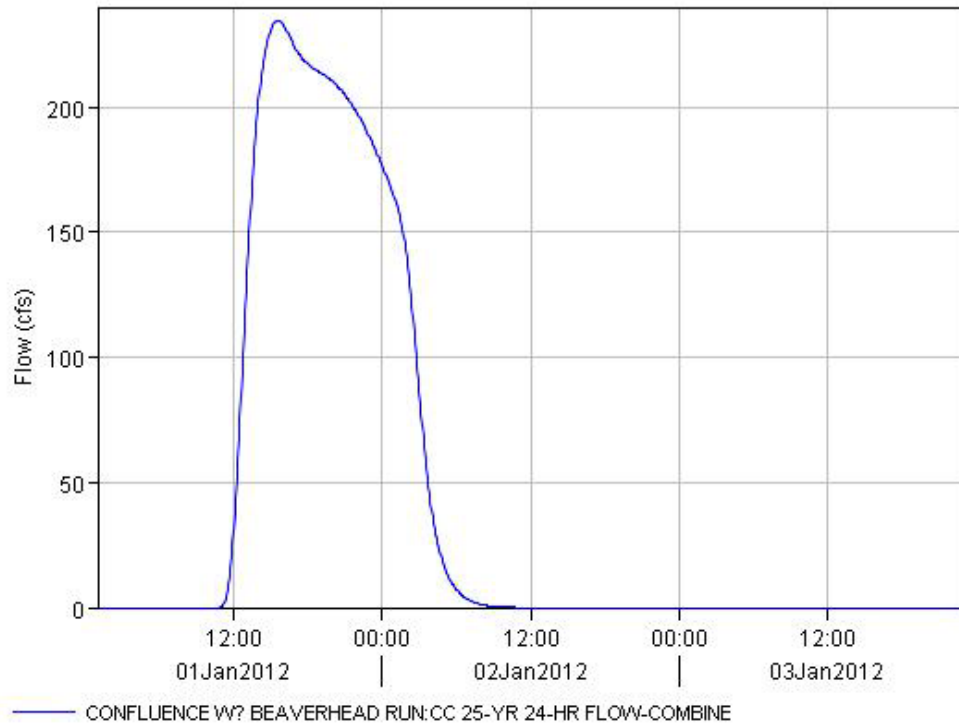
10YR-24HR STORM
CLARK CANYON CREEK



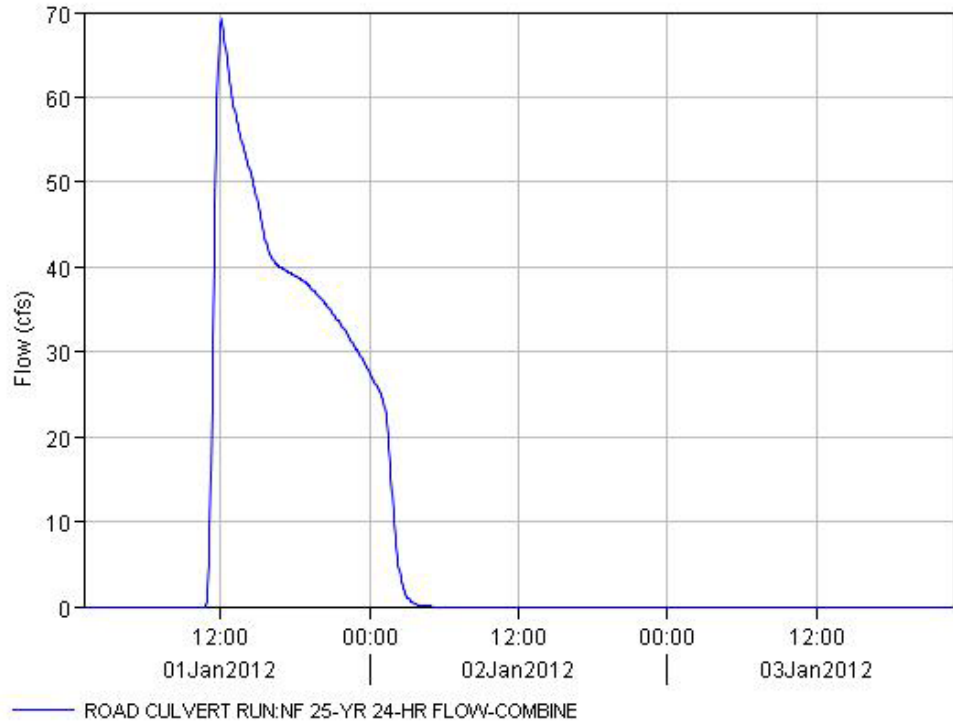
10YR-24HR STORM
NORTH FORK



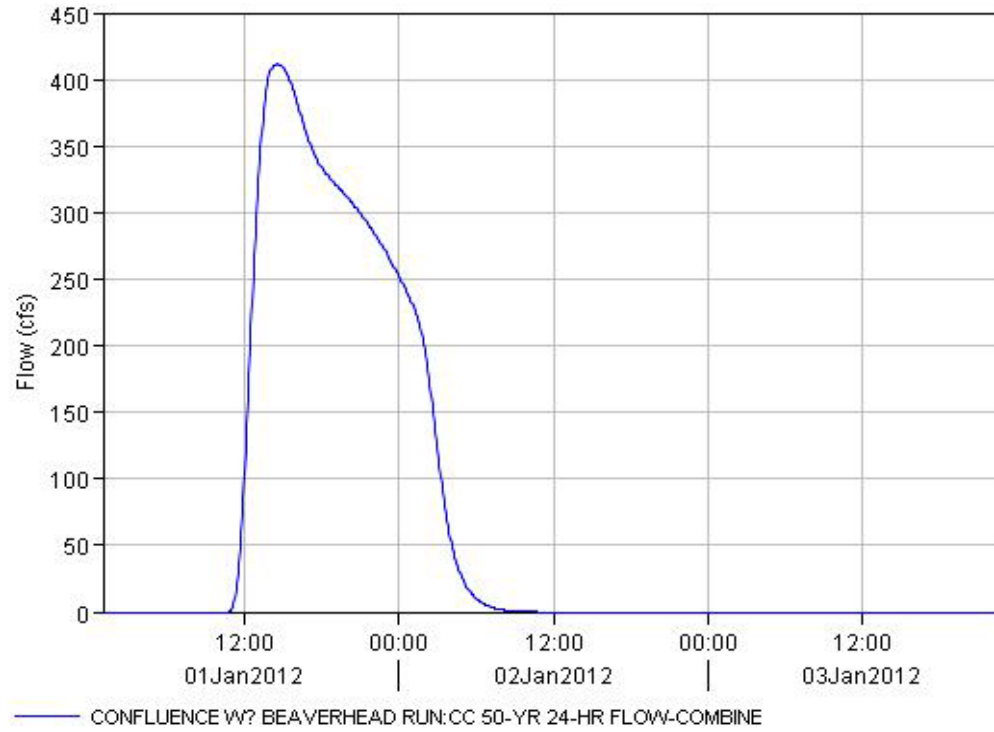
25YR-24HR STORM
CLARK CANYON CREEK



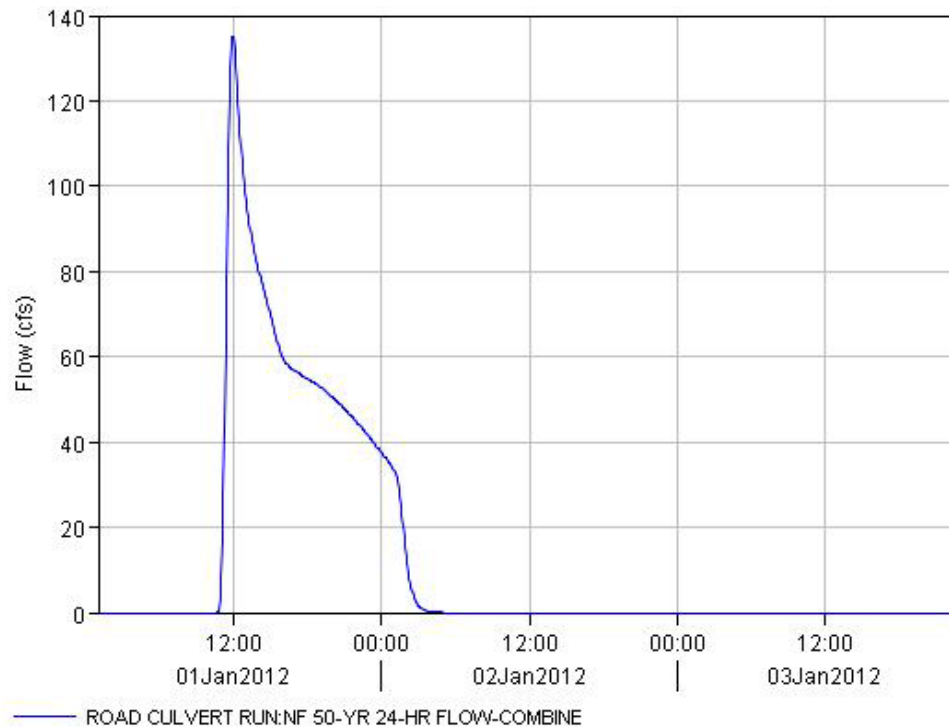
25YR-24HR STORM
NORTH FORK



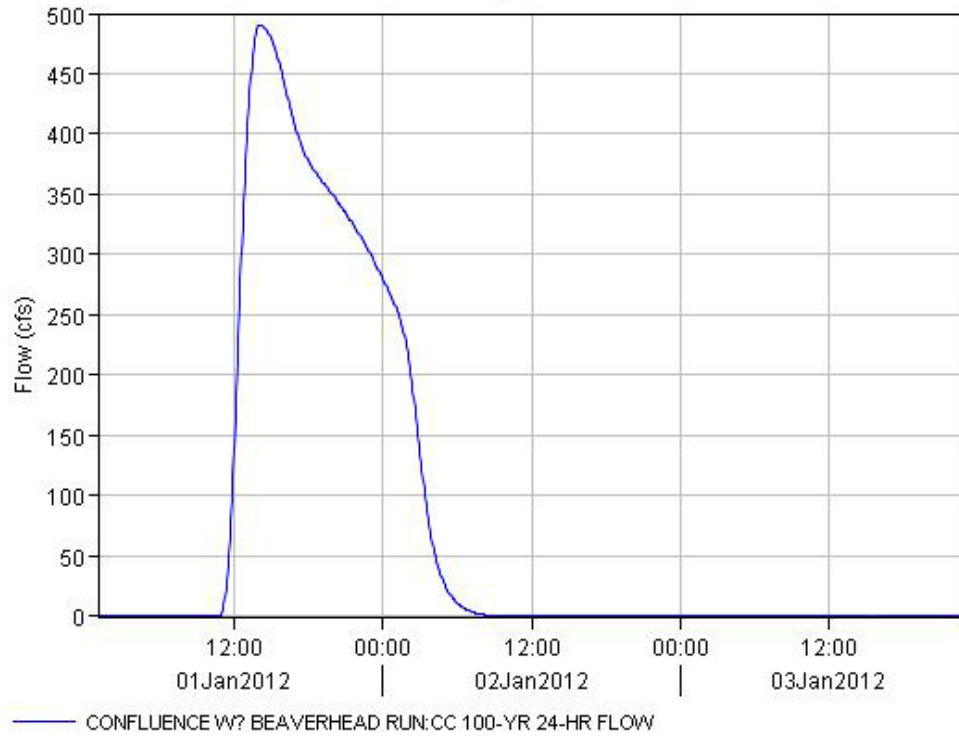
50YR-24HR STORM
CLARK CANYON CREEK



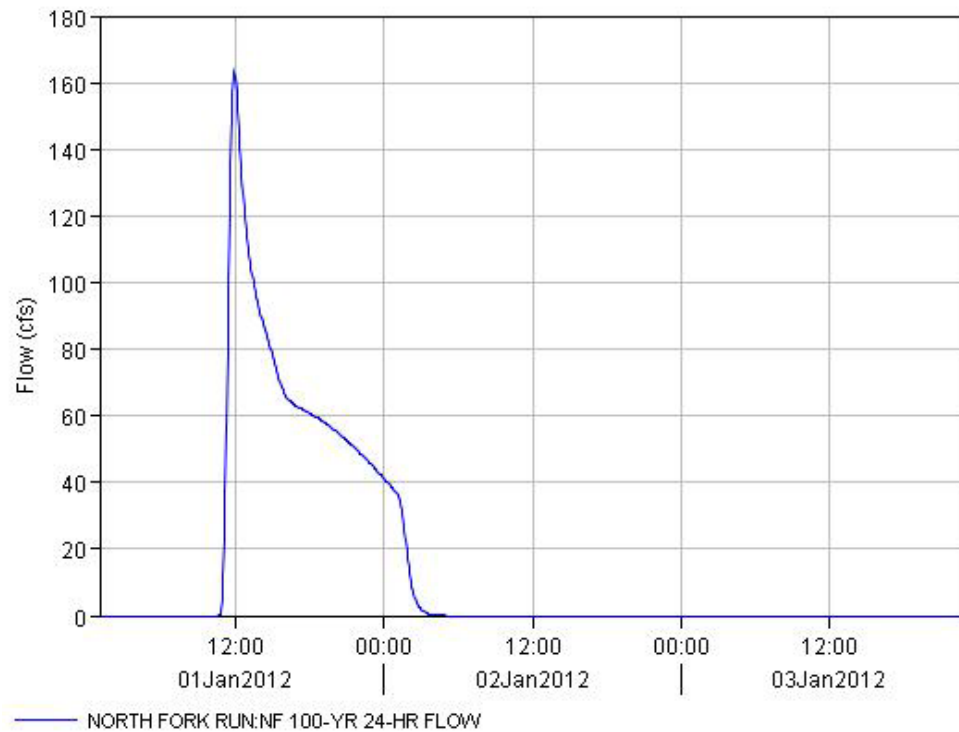
50YR-24HR STORM
NORTH FORK



100YR-24HR STORM
Clark Canyon Creek

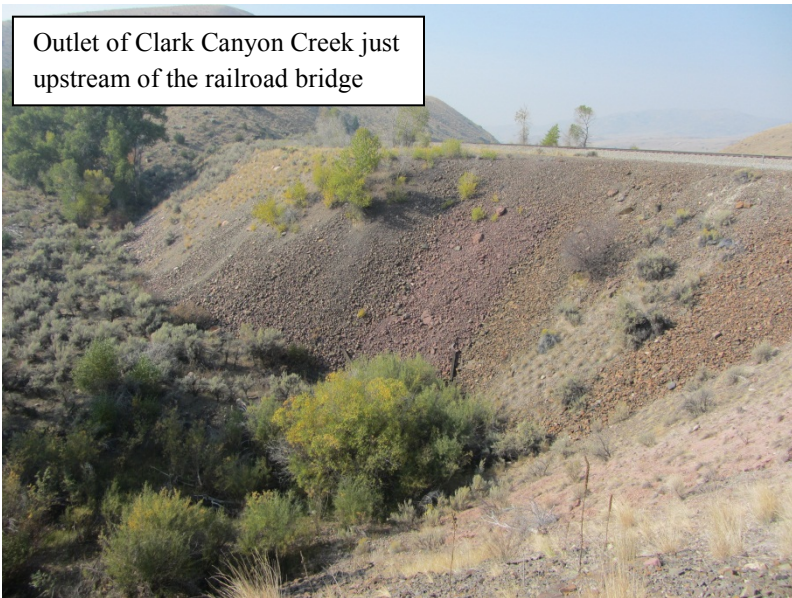


100YR-24HR STORM
NORTH FORK



Appendix 2. Photos

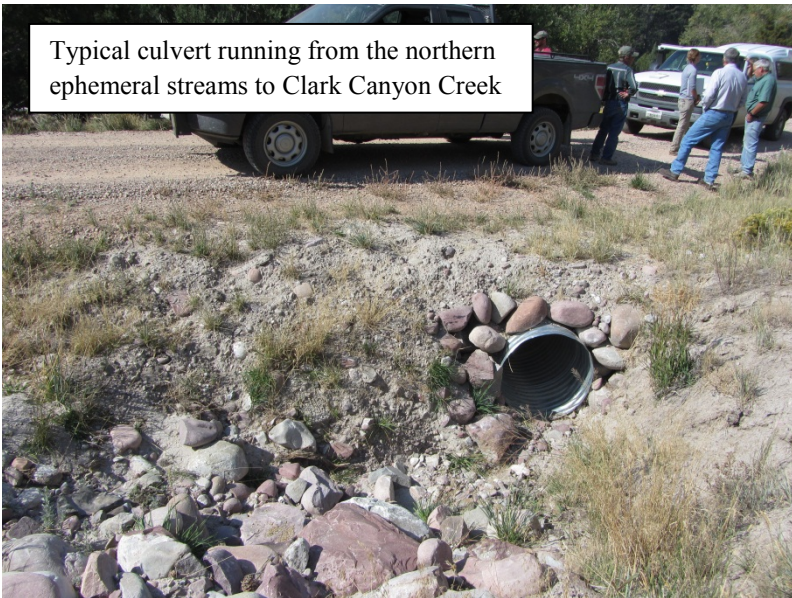
Outlet of Clark Canyon Creek just upstream of the railroad bridge



Outlet culvert of Clark Canyon Creek that runs under the railroad bridge



Typical culvert running from the northern ephemeral streams to Clark Canyon Creek

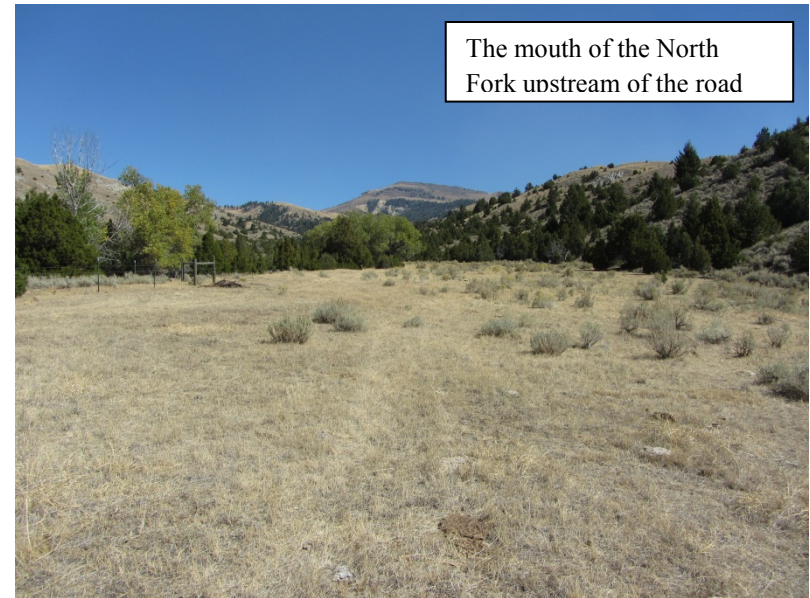


Clark Canyon Creek at an irrigation diversion

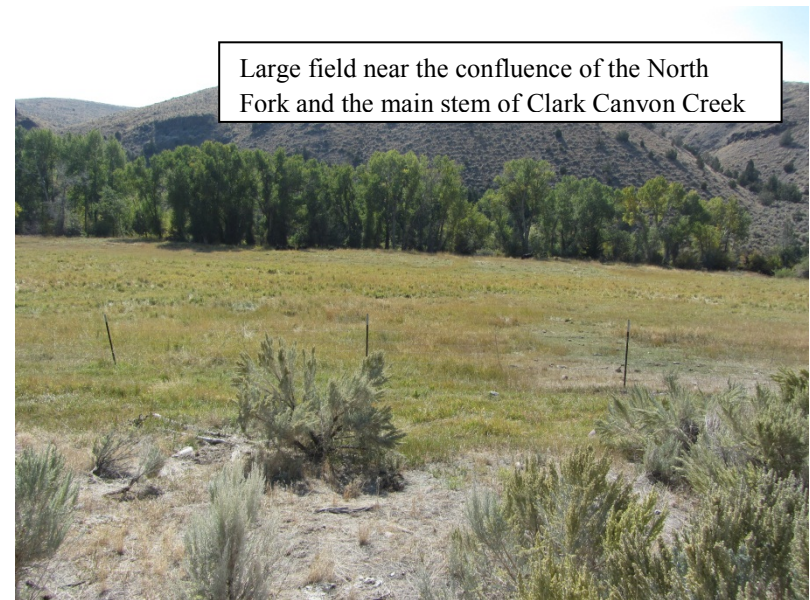




The North Fork near its outlet



The mouth of the North Fork upstream of the road



Large field near the confluence of the North Fork and the main stem of Clark Canvon Creek



Sediment laden water in the Beaverhead



Sediment build-up along the bank of the Beaverhead



High flow in Clark Canyon Creek

**Appendix 3. Excerpts from BOR
(sediment distribution and map of samples)**

Table 1-HEC-RAS results at select cross sections for an approximate discharge of 275 cfs

River	River Sta	Q Total	Min Ch El	W.S. Elev	Vel Chnl
		(cfs)	(ft)	(ft)	(ft/s)
Beaverhead	25550.6	277	5460.6	5463.81	2.22
Beaverhead	23172.0	277	5436.5	5439.31	3.5
Beaverhead	19788.5	277	5399.77	5402.88	2.03
Beaverhead	18719.1	277	5393.77	5397.24	2.96
Beaverhead	16527.4	277	5378.06	5380.73	3.4
Beaverhead	15075.9	277	5363.69	5367.14	2.79
Beaverhead	12853.3	277	5354.31	5357.1	3.29
Beaverhead	11341.2	277	5340.7	5342.92	3.07
Beaverhead	9492.8	277	5327.89	5330.3	2.64
Beaverhead	7021.2	277	5304.92	5307.46	2.13
Beaverhead	3097.1	277	5260.86	5264.4	1.76
Beaverhead	2321.8	277	5259.31	5261.89	2.86
Beaverhead	1173.3	277	5245.91	5250.76	1.12
Beaverhead	831.7	277	5245	5249.73	2.28

Table 2-HEC-RAS results at select cross sections for a discharge of 800 cfs

River	River Sta	Q Total	Min Ch El	W.S. Elev	Vel Chnl
		(cfs)	(ft)	(ft)	(ft/s)
Beaverhead	25550.6	800	5460.6	5465.27	3.74
Beaverhead	23172.0	800	5436.5	5440.95	5.13
Beaverhead	19788.5	800	5399.77	5403.66	3.27
Beaverhead	18719.1	799	5393.77	5399.26	4.42
Beaverhead	16527.4	800	5378.06	5381.78	5.59
Beaverhead	15075.9	800	5363.69	5368.86	4.36
Beaverhead	12853.3	800	5354.31	5358.24	4.39
Beaverhead	11341.2	800	5340.7	5343.91	4.83
Beaverhead	9492.8	800	5327.89	5331.39	3.63
Beaverhead	7021.2	800	5304.92	5308.7	3.15
Beaverhead	3097.1	800	5260.86	5266.32	2.71
Beaverhead	2321.8	800	5259.31	5263.26	4.22
Beaverhead	1173.3	801	5245.91	5254.89	1.41
Beaverhead	831.7	800	5245	5254.1	2.55

Bed Material Data

The Reclamation Montana Area Office collected bed material samples along the Beaverhead River in January 2010. The samples were taken at 4 locations near

the edge of the river. Because of the time of year and water temperature, shovel samples were taken rather than pebble counts. Dowl HKM Engineering (Material Laboratory for Dowl HKM Engineering, 2010) analyzed the samples. Dowl HKM also provided a particle size distribution report on the samples. Figure 14 shows bed material sampling locations. The river locations near Clark Canyon Dam and Pipe Organ contain the coarsest material (Figure 1515 through Figure 1818, Table 3). The finest material is coming out of Clark Canyon Creek. The average bed material size decreases in the downstream direction except where Clark Canyon Creek enters the river.

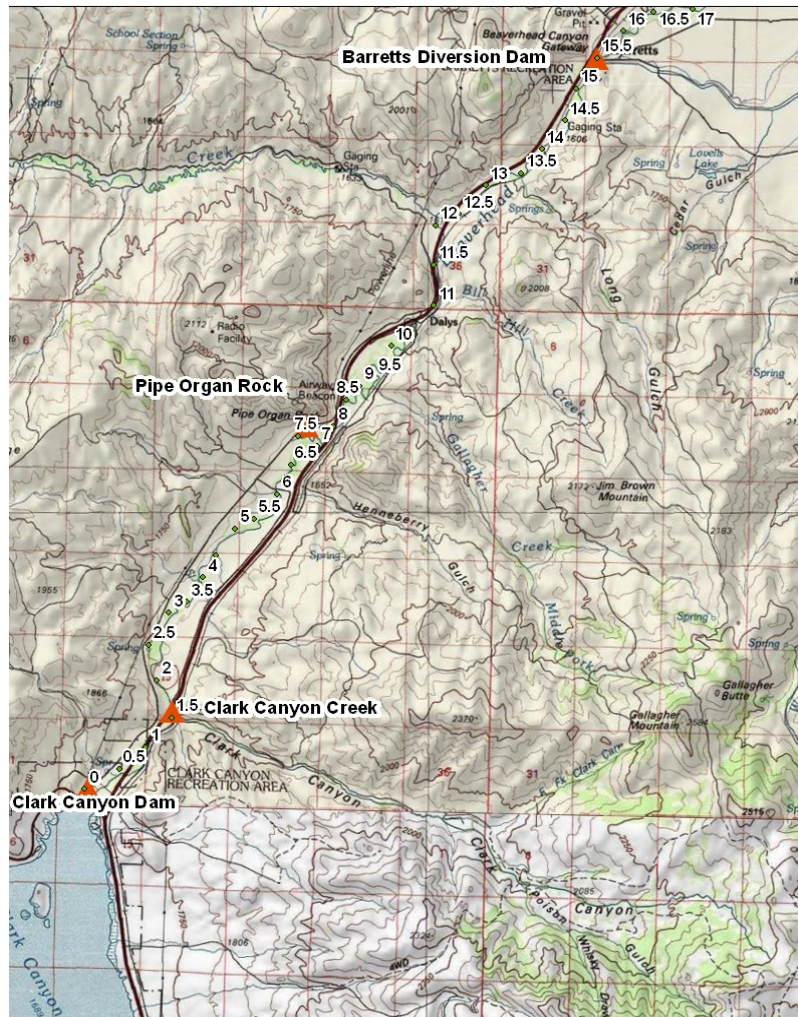


Figure 14-Bed material sampling locations

BUREAU OF RECLAMATION BED MATERIAL SEDIMENT SIZE ANALYSIS
BEAVERHEAD RIVER NEAR CLARK CANYON DAM

SAMPLE I.D.: Bed Material
Sample collected Jan. 2010

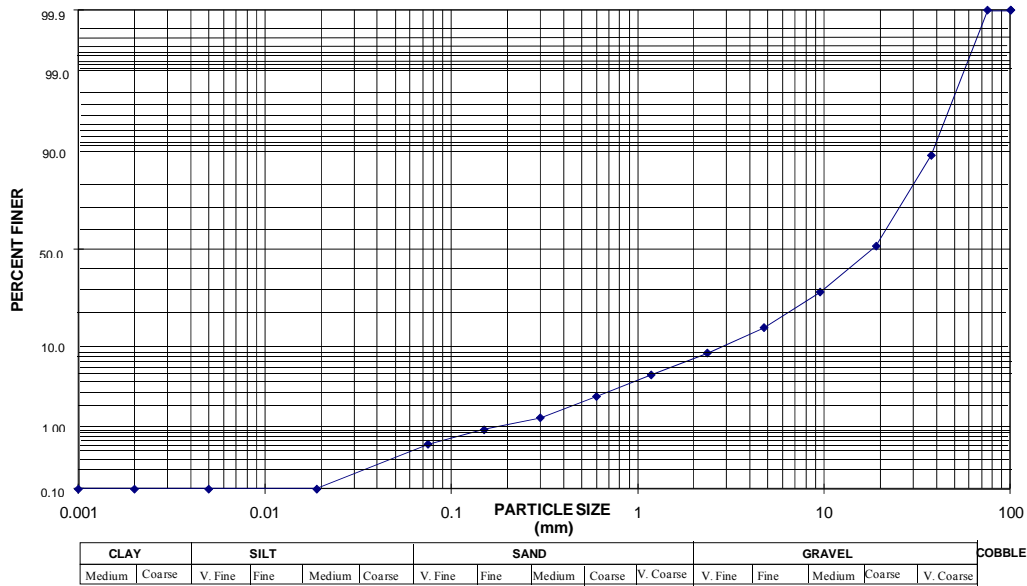


Figure 15-Bed Material Sediment Size Analysis near Clark Canyon Dam.

BUREAU OF RECLAMATION BED MATERIAL SEDIMENT SIZE ANALYSIS
CLARK CANYON CREEK NEAR BEAVERHEAD RIVER

SAMPLE I.D.: Bed Material
Sample collected Jan. 2010

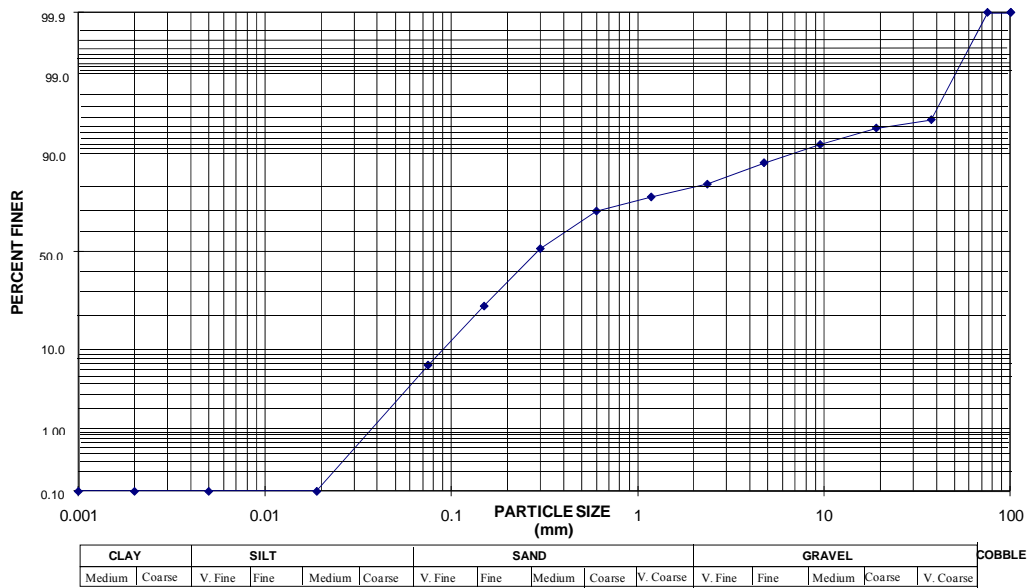


Figure 16- Bed Material Sediment Size Analysis near the mouth of Clark Canyon Creek .

Beaverhead River Flushing Flow Study

BUREAU OF RECLAMATION BED MATERIAL SEDIMENT SIZE ANALYSIS BEAVERHEAD RIVER NEAR PIPE ORGAN

SAMPLE I.D.: Bed Material
Sample collected Jan. 2010

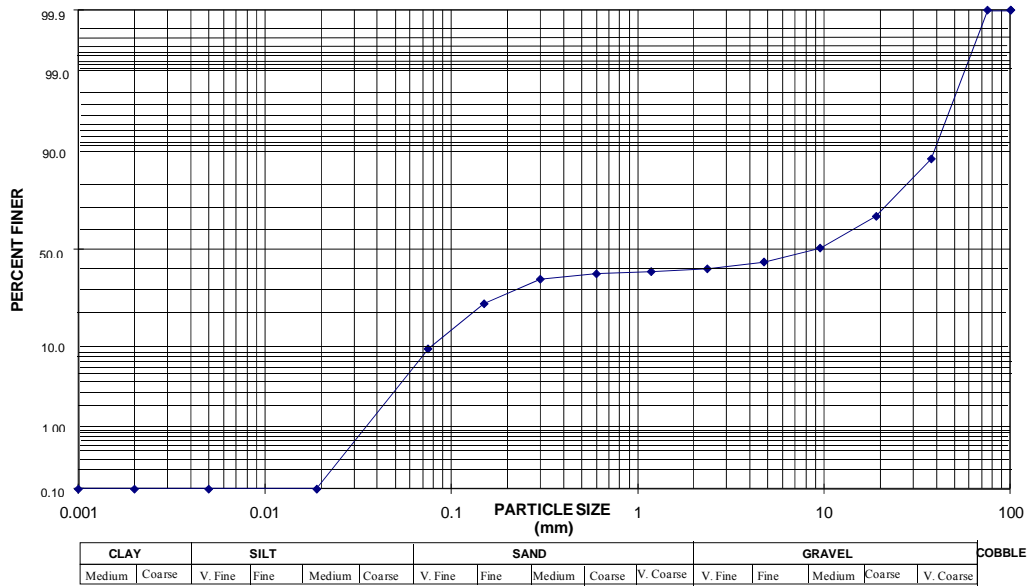


Figure 17- Bed Material Sediment Size Analysis near Pipe Organ

BUREAU OF RECLAMATION BED MATERIAL SEDIMENT SIZE ANALYSIS BEAVERHEAD RIVER NEAR BARRETTS DIVERSION DAM

SAMPLE I.D.: Bed Material
Sample collected Jan. 2010

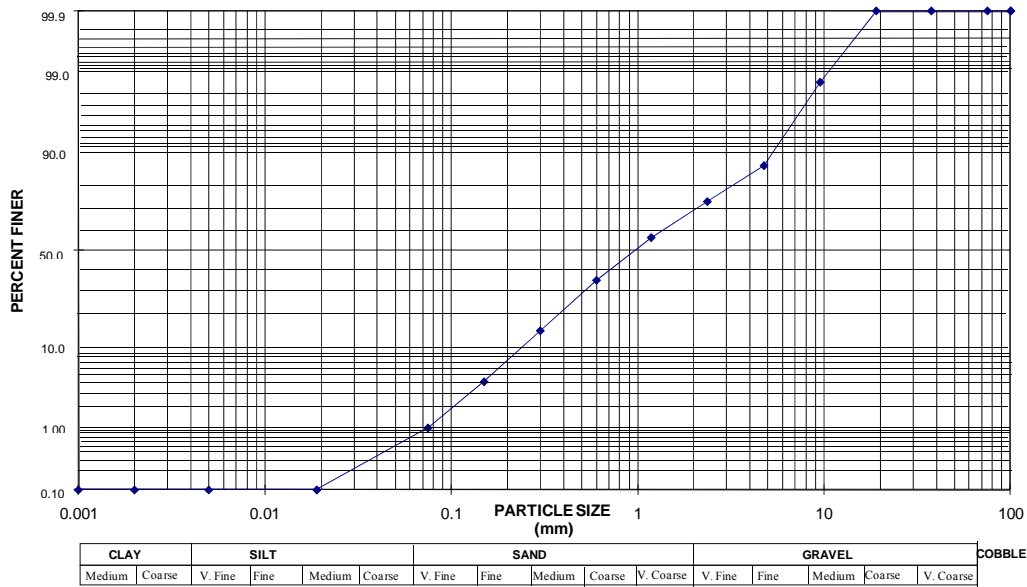


Figure 18- Bed Material Sediment Size Analysis near Barretts Diversion Dam.

Table 3-Bed Material Size Analysis

Location	D₅₀	D₉₀
Clark Canyon Dam	18.3	39.3
Clark Canyon Creek	0.3	6.7
Pipe Organ	9	41.4
Barrets	1	5.7

Initial Motion or Incipient Motion of Bed Material and Flushing Flow

Incipient motion or initial motion can be described as the point when a sediment particle will begin to move. The determination of incipient or beginning motion was utilized to determine the potential for different bed material sizes to move. The concept of beginning motion is difficult to quantify, but is dependent on a particle's location with respect to other different sized particles as well as bed forms. Clark Canyon Creek enters the Beaverhead River about 1.5 miles downstream from the dam. All of the particles from the creek are deposited in the upper layer of the sediment. The assumption is that if the underlying bed material will mobilize then it will also carry the smaller size particles downstream allowing flushing of the sediment.

The methodology used in this section is the determination of the particle size that would form an armor layer (Strand and Pemberton, 1982). The method includes the computation of a particle size for which any greater size particle would not move. After computing the particle size, the particle diameter was compared to the median size or 90th percentile size of the bed material data at each of the four locations in Table 3. If the measured bed material size data were smaller than the computed armoring size, then the particle would be able to move downstream. Several different methods were computed to determine initiation of movement including Shields Diagram, Meyer-Peter and Muller Bedload Transport Equation, Competent Velocity, and Yang's critical velocity criteria (Yang, 1996).

The methods utilize the hydraulic data from the HEC-RAS model (velocity, slope, hydraulic radius). The analysis utilized two reaches: Clark Canyon Dam to Pipe Organ (river miles 0 to 8) and Pipe Organ to Barrets Diversion Dam (8 to 16). The results were averaged on the reaches identified to equalize the results. The assumption seemed reasonable because of the coarseness of the geometry data.

The Shields Method utilizes the d_{50} particle size for the analysis. Meyer-Peter and Müller bed load equation is based on the d_{90} particle size. Competent Velocity and Yang's critical velocity criteria are based on hydraulics alone and do not use bed material information to solve for the critical sediment size.

Appendix 4. Estimated Costs

<div>Clark Canyon Creek - Alternative 1, Storage/Settling Pond</div> <div>Cost Estimate Date: 01/11/13</div> <div>Cost Estimate Description: Conceptual</div> <div>Total Estimated Construciton Cost With Contingency \$291,000</div> <div>Contingency Percent 30%</div> <div>Contingency Amount \$67,466</div>								
No.	Activity	Quantity	Unit	Unit Price	Cost	Percent of Total	Subtotal Cost	Assumptions and Comments
1.0	Site Preparation						\$42,200	
1.1	Mobilization and Demobilization	1	LS	\$8,000	\$14,000	6.3%		Adjusted to be about 8% of the estimated construction cost
1.2	Construction Staking	1	LS	\$2,000	\$2,000	0.9%		
1.3	Site Access and Staging Areas	1	LS	\$5,000	\$5,000	2.2%		
1.4	Clearing and Grubbing	4	ACRE	\$2,000	\$7,200	3.2%		Acerage based on the pond's footprint
1.5	Control of Water	1	LS	\$10,000	\$10,000	4.5%		Diverting streamflow during dam construction
1.6	Erosion Control	1	LS	\$2,000	\$2,000	0.9%		
1.7	Seeding	1	ACRE	\$2,000	\$2,000	0.9%		Acerage estimated based on the pond's footprint (excluding impoundment area)
2.0	Site Improvements						\$131,334	
2.1	Salvage Topsoil	2,822	CY	\$4	\$11,287	5.0%		This assumes 6 in. of topsoil will be salvaged
2.2	Replace Topsoil	2,822	CY	\$4	\$11,287	5.0%		
2.3	Gross Excavation	9,755	CY	\$4	\$39,020	17.5%		Cut and fills will be balanced.
2.4	Structural Backfill	9,755	CY	\$4	\$39,020	17.5%		
2.5	Rock for Spillway Channel	384	TON	\$60	\$23,040	10.3%		Assumes a spillway 20 ft wide for 160 ft with rock thickness of 2 feet. Volume = 6,400 ft^3
2.6	Rock on Upstream Face of Pond	192	TON	\$40	\$7,680	3.4%		Assumes about 10 feet of rock for 320 feet with rock thickness of 1.0 ft. Volume = 3,200 ft^3
3.0	Design and Construction Services						\$50,000	
3.1	Engineering Design	1	LS	\$25,000	\$25,000	11.2%		Adjusted to be about 10% of construction cost
3.2	Permitting	1	LS	\$10,000	\$10,000	4.5%		Adjusted to be about 5% of construction cost
3.3	Construction Assistance	1	LS	\$15,000	\$15,000	6.7%		Adjusted to be about 7% of construction cost