

**Atlantic Rim Coal Bed Methane and Natural  
Gas Project  
Carbon County, Wyoming**

October 19, 2010



*Muddy Creek Monitoring  
Report - 2010*

**CDM**



# Executive Summary

This monitoring report presents data collected on upper Muddy Creek in the Atlantic Rim area in 2010. Camp, Dresser, and McKee, Inc., (CDM) is under contract with Anadarko to provide annual monitoring for geomorphology, aquatic habitat, and water quality on this project. The Atlantic Rim Coal Bed Methane and Natural Gas Project in Carbon County, Wyoming is a coal bed methane and natural gas project being developed on public and private land by Anadarko and other operators. A particular concern on upper Muddy Creek is the maintenance of populations of non-game, native fish species, particularly the roundtail chub, bluehead sucker, and flannelmouth sucker (BLM, 2007). The general goal of monitoring on upper Muddy Creek is to determine if activities associated with the Atlantic Rim Project have an impact on upper Muddy Creek that adversely affects the non-game, native fish population.

Monitoring objectives for upper Muddy Creek have been developed based on the performance goals in the Record of Decision (BLM, 2007) for the Atlantic Rim Coal Bed Methane and Natural Gas Project. The performance goal for sensitive fish species is to “maintain adequate water quality, water quantity, species distribution, and aquatic habitat components.” To determine if the Atlantic Rim Project has adverse impacts on the sensitive fish populations in the stream, a multi-parameter approach that encompasses geomorphology, hydrology, habitat features and water quality has been recommended. All of these disciplines relate to sediment transport in the system, which is key to the health of the benthic macroinvertebrate populations and fish that feed on them. The objectives of this monitoring effort include:

- Measurement of sediment delivery from eroding streambanks.
- Measurement of habitat features and stream morphology.
- Measurement of in-stream sediment concentrations and other water quality parameters.

Field work in August 2010 included geomorphic and habitat measurements and water quality sampling. The six reference cross-sections (one at each site) were remeasured using a total station. Comparing the cross sections to those obtained in previous years, most reference cross-sections had only minor changes. The only changes observed were continued erosion of deposits that remained from the higher runoff that occurred in 2009.

Bed measurements were taken using Wolman pebble count methods (Wolman, 1954) and embeddedness measurements (Sennatt et al, 2006). The small riffles previously observed at the lower three sites were inundated with this year’s higher flow and no longer functioning as riffles. Four of nine measured riffles retained their original particle distributions, while the bed materials from four more became coarser this

year. This pattern of change appears to be due to patterns of deposition of finer sediments and subsequent removal of finer sediments while the large gravel and cobble remain in place. One riffle is continually becoming finer grained and may not effectively control water elevations in the near future.

The embeddedness measurements are also similar to those collected in previous years. In general, pools are 100% embedded and the riffles are 0% embedded. To attain intermediate numbers areas just upstream or downstream of riffles were sampled, but the selection of these areas was targeted to obtain a reasonable count and did not represent the condition of the stream well.

Erosion pins set in 2008 were remeasured this year. Of the nine erosion pins, three showed bank erosion in the last year although the amounts of erosion are all 0.10 ft. or less and generally less than found from 2008 to 2009.

Bank stability was evaluated using the Bank Erosion Hazard Index (BEHI) and Near Bank Stress metrics developed by Rosgen (1996). Ratings for 2010 were very similar to those obtained in 2008 and range from high to extreme. This indicates that the existing condition on Muddy Creek is highly erosive and produces large amounts of sediment.

Residual pool depths were measured at all sites and compared to previous depths. Previously measured pools at the three downstream sites were not measured because higher streamflow this year inundated the downstream riffles. All measured pools showed some variation in residual depth compared to the previous years with depths being sometimes greater and sometimes less.

Water quality of upper Muddy Creek in August 2010 was very similar to that observed in previous years. Flows were similar to those observed in 2009 but higher than those observed in 2008. This year's flows ranged from 4.85 to 5.09 cfs. Common ions concentrations were similar to those measured previously, but total suspended sediment concentrations were higher than previously recorded presumably due to recent rains. Total selenium was less than 0.005 mg/L at all three sites, which is below the chronic aquatic life standard. The chemical water quality does not appear to have changed from 2008 in spite of the higher flows.

In summary, only small changes in erosion rates and stream morphology were observed this year compared to the two previous years. We concur with BLM's opinion that BEHI measurements are only needed every five years unless there is a channel altering event because of the minor changes observed over the last three years. We also recommend that embeddedness no longer be measured because the patterns of siltation observed in Muddy Creek are not conducive to this metric.

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# Section 1 Introduction

This monitoring report presents data developed or collected on Upper Muddy Creek in the Atlantic Rim area in 2010. Camp, Dresser, and McKee, Inc., (CDM) is under contract with Anadarko to provide annual monitoring for geomorphology, aquatic habitat, and water quality on this project. The Atlantic Rim Coal Bed Methane and Natural Gas Project in Carbon County, Wyoming is a coal bed methane and natural gas project being developed on public and private land by Anadarko and other operators (Figure 1-1). Development is occurring in a 270,080 acre area and requires construction of roads, pipelines, well pads, compressor stations and gas processing facilities, drilling up to 2,000 wells, and production of water (BLM, 2007). In 2010 there was no new road building or new drilling in the project area in the Muddy Creek drainage.

A particular concern on Upper Muddy Creek is the maintenance of populations of non-game, native fish species, particularly the roundtail chub, bluehead sucker, and flannelmouth sucker (BLM, 2006). The general goal of monitoring on Upper Muddy Creek is to determine if activities associated with the Atlantic Rim Project have an impact on upper Muddy Creek that adversely affect the non-game, native fish population. The potential adverse effects caused by development will need to be compared to potential impacts due to other factors such as recreation and livestock grazing.

## 1.1 Background

The Atlantic Rim Coal Bed Methane and Natural Gas Project was proposed by Anadarko and other operators in 2001. The responsible agency for permitting the development is the Bureau of Land Management (BLM), which initiated scoping for an Environmental Impact Statement (EIS) in 2001. The Record of Decision (BLM, 2006) for the project was signed in 2007 and includes specific performance goals for the project. The performance goal for Muddy Creek sensitive fish is to “maintain adequate water quality, water quantity, species distribution, and aquatic habitat components.” This is to be accomplished through use of Best Management Practices (BMPs), performance-based monitoring, and adaptive management. The monitoring program currently in place addresses activities that will take place on Upper Muddy Creek. The Muddy Creek Monitoring Plan (CDM, 2008a) describes the monitoring objectives developed by CDM for the Muddy Creek Working Group in 2008 to guide annual monitoring activities on the Upper Muddy Creek.

Initial monitoring activities for geomorphology, aquatic habitat and water quality were conducted by CDM between August 18 and 23, 2008. The results are summarized in the 2008 Muddy Creek Monitoring Report (CDM, 2008b). The second monitoring event occurred between August 4 and 6, 2009, and results of this monitoring event are summarized in the 2009 Muddy Creek Monitoring Report (CDM, 2009).

Water year 2010 had higher precipitation than average at the Divide Peak SNOTEL site, which is a nearby precipitation gage with 29 years of record (<http://www.wcc.nrcs.usda.gov/snotel/Wyoming/wyoming.html>). The 2010 precipitation at this site was 39.9 inches and the mean for the period of record is 33.8 inches. However, the precipitation was not as great as water year 2009 especially in the winter and spring suggesting that the 2010 runoff was less pronounced than the 2009 runoff. This decrease in probable runoff corresponds with relatively little channel change observed in 2010 compared with 2009.

In July 2010, the US Geological survey (USGS) installed a new stream gage in the project area at the bridge located between Stations UMC2 and UMC3. This gage is designated USGS 09258050 Muddy Creek above Olson Draw, near Dad, Wyoming. At this time no rating curve has been established for this site and only stage information is available. However, this station will be very useful for tracking stream flow in the project area in future years.

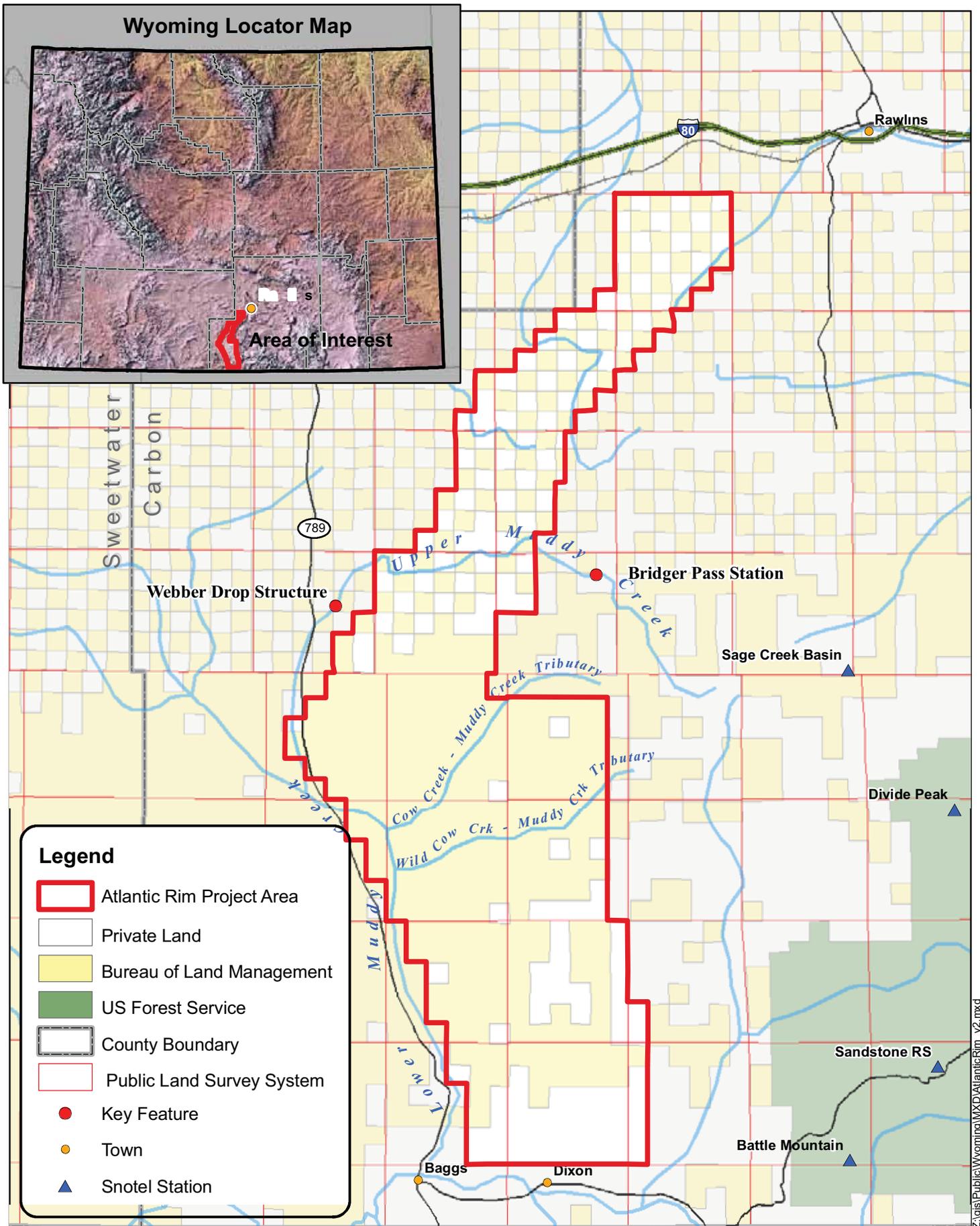
## 1.2 Project Organization

Monitoring of Upper Muddy Creek is the responsibility of Anadarko and its consultant. The BLM as the lead agency for the Atlantic Rim Coal Bed Methane and Natural Gas Development Project coordinates the various monitoring efforts through the Muddy Creek Working Group.

## 1.3 Report Organization

This is the third annual report of monitoring activities conducted by Anadarko on the Atlantic Rim Coal Bed Methane and Natural Gas Project. Section 2 of this report presents the results of the geomorphic and aquatic habitat monitoring, and Section 3 presents the water quality monitoring results. Appendices A through D present the data developed or collected in 2010 as part of this assessment and monitoring effort.

Final comments were received from the agencies (BLM, 2010) on the 2009 Monitoring Report on September 1, 2010, after the 2010 monitoring occurred. Most modifications to field procedures were implemented during the sampling event based on previous discussions with the agencies. However, because we did not have final notification on the recommendation only to repeat the Bank Erosion Hazard Index (BEHI) measurements if a channel altering event had occurred, we collected BEHI information this year as well. We have incorporated the agencies' recommendations for changes in report presentation in this year's monitoring report.



**Figure 1-1.**  
**Atlantic Rim Project Area**  
**Carbon County, Wyoming**



# Section 2 Geomorphic and Aquatic Habitat Monitoring

## 2.1 2010 Monitoring Event

Monitoring activities were conducted in Upper Muddy Creek during the period of August 17 through 20, 2010. The same six sites monitored during the previous monitoring activities were monitored during the 2010 event and work included geomorphic and aquatic habitat monitoring as well as water quality monitoring. The locations of the monitored sites are shown on Figure 2-1. Maps of each individual site are found in Appendix A.

Monitoring activities performed at each site are described in the Muddy Creek Monitoring Plan (CDM, 2008a). In summary, the following activities for geomorphic and aquatic habitat monitoring were performed:

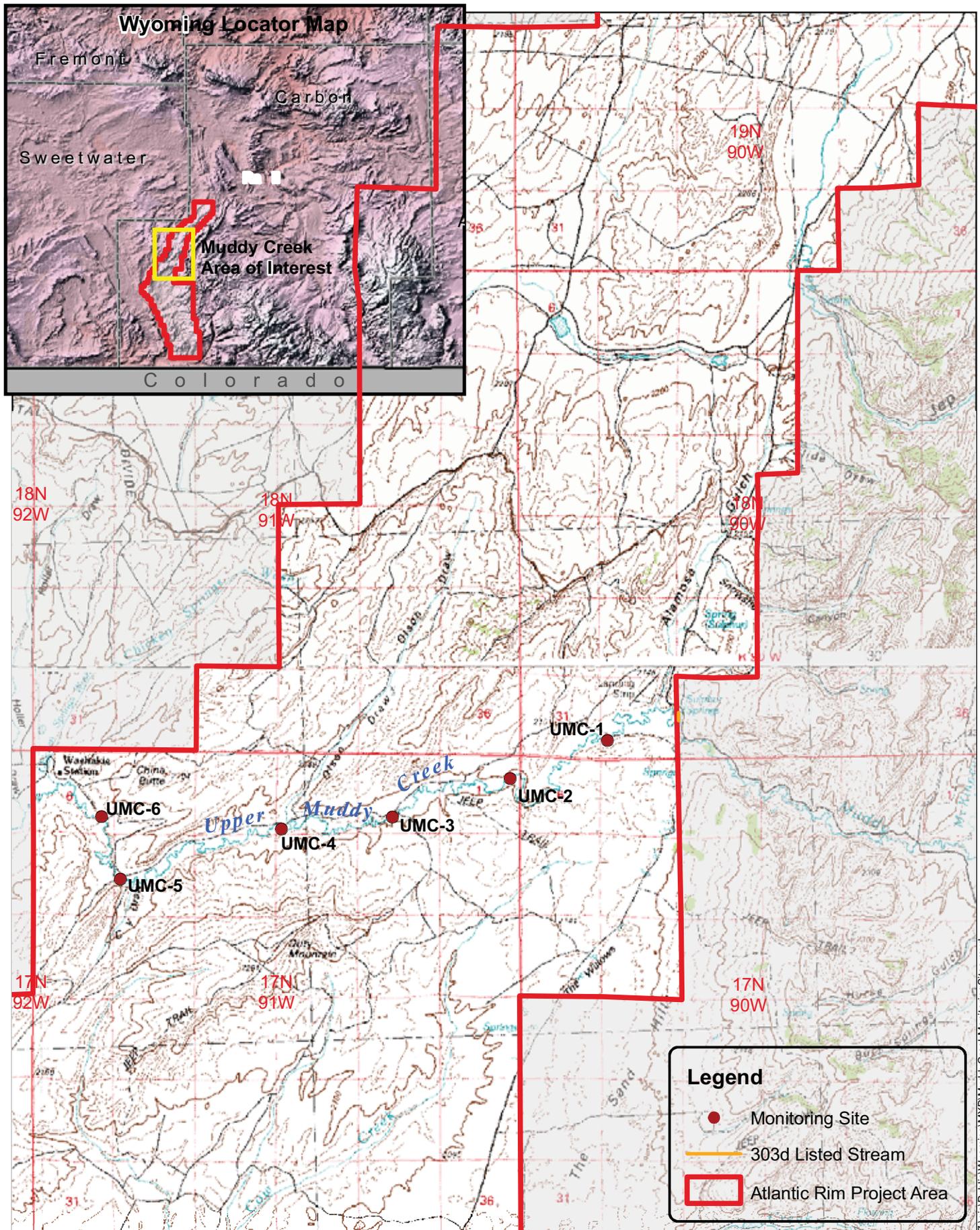
- The monumented, reference cross-sections located during the 2008 monitoring activities were re-surveyed. Cross-section information was collected to allow measurement of channel changes over time.
- Banks selected for evaluation using the Bank Erosion Hazard Index (BEHI) (Rosen, 1996) were evaluated and photographed.
- Wolman pebble counts and embeddedness measurements were performed at riffles and other areas with appropriate bed material conditions.
- The bank erosion pins were measured and compared to the previous year and then pounded flush with the bank face.
- Residual depths of pools were measured.

## 2.2 Geomorphic Monitoring

### 2.2.1 Cross-sections

The reference cross-section at each site was surveyed and compared to the previous year's survey. The remaining cross-sections were not surveyed during the 2010 field activities. The cross-sections surveyed during the previous field seasons are compared to the 2010 cross-sections in Appendix A. Appendix A contains reference section photographs, as well as typical and panoramic photographs of the sites. The relevant changes in the sections are described here.

The reference sections at stations UMC1, UMC2, and UMC6 have remained generally unchanged since 2008, although the section at UMC1 (XS-4) has shown some erosion at the toe of the right bank. At UMC3 XS-3, a large amount of left bank erosion occurred in 2009, and a smaller amount of erosion occurred here in 2010. At UMC4 XS-3, there was some erosion of the right bank at the toe in 2009, which con



**Figure 2-1. Upper Muddy Creek Monitoring Locations**  
**Atlantic Rim Project**  
**Carbon County, Wyoming**



tinued in 2010 and lowered the bed elevation. The apparent variations on the first overbank terrace of the right bank are due to the difficulty of measuring ground elevations through a large debris pile and are probably not actual ground changes.

At UMC5 XS-3 a large amount of deposition occurred on the left bank in 2009, which had largely eroded away by 2010. The 2009 deposition was accompanied by deposition in the bed. In 2010 the bed degraded but still has not reached its 2008 level. This cross-section experienced the greatest change since 2009. Generally the channel adjustments observed from 2009 to 2010 are much less than those observed from 2008 to 2009, probably due to a less intense spring runoff.

## 2.3 Bed Measurements

Wolman pebble counts (Wolman, 1954) and embeddedness measurements were performed at the same three locations measured during the 2008 field activities. Pebble counts were performed by measuring approximately 100 individual pebbles at each location with a gravelometer. The pebbles were sorted into standard size classes and then a cumulative size distribution was plotted (Appendix C). Pebble counts were only performed at riffles because pool materials were generally sand and silt and not amenable to this measurement.

In 2010, three pebble counts were performed at UMC1, UMC2 and UMC3 at the same locations as previously sampled. At the downstream stations (UMC4, UMC5, and UMC6) there are no stable gravel-cobble riffles although there are some clay bed riffles. In places, the clay beds have caught smaller gravel sizes (5.6 to 22.6 mm) and these areas have had pebble counts in the past. We have determined that these areas do not meet the criteria of being gravel-cobble riffles and that pebble counts for these sites are not meaningful for all of the following reasons:

- Any stability in these apparent riffles is due to the presence of underlying clay beds; the gravel sizes found on these beds are small and easily mobilize even during low flows.
- In 2010 the previously measured sites were inundated and not acting as riffles.
- In 2010, turbid water conditions made it difficult to identify the locations of the previously sampled, inundated sites. Figure 2-2 shows the inundated condition of the lower portion of UMC4 in August 2010.

In Table 2-1,  $D_{50}$  (median diameter) values for all pebble counts are displayed.



Figure 2-2. Lower section of UMC4, August 2010.

Table 2-1: D<sub>50</sub> Values at Pebble Count Cross-sections.

Site	Cross-Section	D <sub>50</sub> range (mm)		
		2008	2009	2010
UMC1	XS-1	22.6-32	22.6-32	45-64
	XS-4	90-128	90-128	90-128
	XS-6	64-90	45-64	64-90
UMC2	XS-1	32-45	22.6-32	45-64
	XS-3	22.6-32	11-16	8-11
	XS-6	8-11	8-11	11-16
UMC3	XS-1	45-64	32-45	45-64
	XS-4	45-64	22.6-32	45-64
	XS-6	45-64	32-45	32-45

Pebble counts were taken at nine sections and four of them show relatively little change from previous years, as seen in the comparative graphs in Appendix C. Four other sections have coarsened notably this year (UMC1 XS-1, UMC1 XS-6, UMC2 XS-1, and UMC3 XS-4) and one (UMC2 XS-3) became finer in 2009 and has remained

that way this year. Of the four that coarsened this year, two (UMC1 XS-6 and UMC2 XS-1) became finer in 2009 and returned to their 2008 condition this year. One possible explanation for this change is that smaller size fractions were deposited at these two riffles on the receding limb of the high 2009 spring runoff and these sediments may have been removed during the 2010 spring runoff. A similar explanation may explain the coarsening of the other two riffles if the 2008 runoff had also left an excess of finer gravels in these beds. Based on the appearance and solidity of the cobbles and small boulders in these riffles, we do not think that the coarse materials are moving through the system; rather, the coarse fraction in the pebble counts changes as the amount of finer gravel varies.

The consistent decrease in pebble size at UMC2 XS-3 is indicative of a systematic change at this location and this riffle may not effectively control water elevations in the near future. Figure 2-3 shows the condition of this riffle in 2010.



**Figure 2-3. Riffle at UMC2 XS-3, August 2010.**

The embeddedness measurement method followed the U.S. Geological Survey's National Water-Quality Assessment Program as described in Sennatt et al (2006). Embeddedness was measured by collecting 15 pebbles at each transect. The percent of the clast's height that was buried in silt was estimated. These percentages were then averaged to estimate embeddedness at that transect. At UMC2, UMC5, and UMC6, all areas were either clean gravel or larger clasts with no siltation or the bed was entirely silt. Therefore, embeddedness measurements were not taken at these

sites. The results of embeddedness measurements are shown in Table 2-2. It is important to note that these measurements were largely taken in transitional zones between riffles and pools. Almost all of the pools throughout the study reach were 100% embedded and, likewise, almost all of the riffles were 0% embedded.

**Table 2-2: Average Embeddedness Values.**

		2008	2009	2010
UMC1	30' below XS-1 Riffle	32.0%	58.0%	63.7%
	50' downstream of XS-2	52.7%	61%	66.7%
	Immediately below XS-5	52.7%	40.7%	45.3%
UMC3	Downstream of XS-1 Riffle	38%	51.3%	52.7%
	Upstream of XS-6	31%	42%	46.8%
UMC4	Upstream of XS-4 <sup>(1)</sup>	--	44%	--

<sup>(1)</sup> No measurement in 2008; in 2010 this location was silted in and only unembedded fine gravel was observed.

## 2.4 Bank Stability

### 2.4.1 Erosion Pins

Erosion Pins were installed near the monumented cross-section at each site during the 2008 field investigation. An erosion pin is a four-foot steel bar driven horizontally into the bank. Pins were placed in vertical sections of bank that are likely to erode (for example, outside of bends) that are difficult to monitor using surveyed cross-sections.

The visible pins were measured during the 2009 and 2010 field activities and were compared to the measurements taken in previous years. The measurements and differences are shown in Table 2-3 below. The measurements indicate that erosion occurred at UMC1 XS-4, UMC3 XS-3, and Rocky Crossing although the amounts of erosion are all 0.10 ft. or less and generally less than experienced from 2008 to 2009. Other stations with erosion pins did not erode and the pin on the right bank above Webber Drop experience slumping of the bank over the pin. This site is outside the project area, not representative of the geomorphic conditions within the site, and will not be sampled in future monitoring events.

Bank pins were pounded flush after measurement this year to minimize any potential for pins influencing the rate of bank erosion.

### 2.4.2 Bank Erosion Hazard Index

Bank Erosion Hazard Index (BEHI) and Near-Bank Stress (NBS) methods are presented in *Applied River Morphology* (Rosgen, 1996). BEHI looks at five indices of bank stability and assigns numeric values to the observed conditions. The index values are summed and subjected to adjustment for bank material type and stratification to

**Table 2-3: Locations and Protruding Lengths of Bank Erosion Pins for 2008 and 2009.**

Site	Location	Length (ft)- Apr 2008	Length (ft)- Aug 2008	Length (ft)- Aug 2009	Length (ft)- Aug 2010	Difference 2008-2009	Difference 2009-2010
UMC1	XS-4, Right bank		0.33	0.30 top 0.42 bottom	0.52	0.09	0.10
UMC2	XS-5, Right bank		0.24	0.30 top 0.25 bottom	0.29	0.06	-0.01
UMC3	XS-3, Right bank	0.22	0.27	0.35	0.39	0.13	0.04
UMC4	XS-3, Right bank		0.37	0.42	0.41	0.05	-0.01
UMC5	XS-3, Right bank		0.38	0.35	0.35	-0.03	0.00
UMC5	XS-2, Right bank		NM	0.33	0.33	--	0.00
UMC6	XS-3, Right bank		NM	0.33	0.32	--	-0.01
Webber drop - Right bank		0.31	0.24	0.25	0.16	0.01	-0.09
Rocky Crossing - Left bank		0.43	0.51	1.23	1.32	0.72	0.09

NM – Not measured.

arrive at a qualitative descriptor of bank stability. At each site, BEHI evaluations were performed on the more susceptible bank at that cross-section unless neither bank was applicable. As requested by BLM in its final comment response letter (BLM, 2010) on the 2009 monitoring report, the BEHI bank angles were measured from the base flow water level to the top of the bank. Previously, a weighting method was used to calculate compound bank angles.

Appendix B contains the evaluation of BEHI at each evaluated bank and the corresponding photos for 2008 and 2010. Table 2-4 summarizes the BEHI and Near Bank Stress ratings for all the evaluated banks. The 2010 BEHI ratings range from “high” to “extreme”, with most banks rating as “high” or “very high”. These ratings indicate that most of the measured banks had a high potential for erosion. When compared to the 2008 ratings, the rating decreased at six sites and increased at two sites.

### 2.4.3 Near Bank Stress

NBS evaluates the rate at which a bank is expected to supply sediment to a stream based on the local hydraulic conditions. Several options are available for estimating the effects of bank stress in the *Watershed Assessment of River Stability and Sediment Supply* website of EPA (<http://www.epa.gov/WARSSS/monitor/method.htm>). The method chosen in 2008 was the width to radius of curvature ratio. Because the planform of the stream did not change between 2008 and 2010, no change in the NBS ratings occurred. Therefore, the NBS evaluations calculated for the 2008 monitoring activities and are included in Table 2-4.

The comparison of 2010 to 2008 data shows a slight preponderance of improved ratings (decreased indices), which is linked to the change in methods of bank angle measurement. No bank ratings changed more than one rating step. BEHI ratings

are generally in the high to extreme range. This suggests that the baseline condition of this stream is one of considerable bank erosion.

**Table 2-4: BEHI Rating and NBS Ratings in Upper Muddy Creek**

Site	Location	BEHI Rating (2008)	BEHI Rating (2010)	NBS Rating	Photo Nos. in Appendix B
UMC1	XS1, Left bank	High	High	Straight Reach	1 & 2
	XS2, Right bank	High	High	Extreme	3 & 4
	XS4, Right bank	High	High	Straight Reach	5 & 6
	XS6, Right bank	Very high	High	Inside of bend	7 & 8
UMC2	XS1, Left bank	Very high	High	Extreme	9 & 10
	XS2, Right bank	High	High	Very high	11 & 12
	XS4, Left bank	High	High	Extreme	13 & 14
	XS5, Right bank	Very high	Very high	Moderate	15 & 16
	XS6, Right bank	Very high	Very high	Extreme	17 & 18
UMC3	XS1, Left bank	Very high	Very high	Moderate	19 & 20
	XS2, Right bank	High	High	Extreme	21 & 22
	XS3, Right bank	Very high	High	Straight Reach	23 & 24
	XS5, Left bank	High	High	Extreme	25 & 26
	XS6, Right bank	High	High	Very high	27 & 28
UMC4	XS1, Left bank	High	High	Low	29 & 30
	XS3, Right bank	High	High	Very low	31 & 32
	XS6, Right bank	Very high	High	Moderate	33 & 34
UMC5	XS1, Right bank	High	High	Straight Reach	35 & 36
	XS2, Right bank	High	Very high	Straight Reach	37 & 38
	Below XS3, Right bank	Very high	High	Low	39 & 40
	XS5, Right bank	High	High	Straight Reach	41 & 42
	XS6, Right bank	High	High	Very low	43 & 44
UMC6	XS1, Left bank	Extreme	Extreme	NA	45 & 46
	XS3, Right bank	High	Very High	NA	47 & 48
	XS4, Right bank	Extreme	Extreme	Straight reach	49 & 50
	XS6, Left bank	Extreme	Very High	N/A	51 & 52

NA – Not available

Shading indicates reference section.

## 2.5 Residual Pool Depths

Residual pool depth refers to the depth of the pools remaining when water stops flowing, leaving water only in the pools. The depth was obtained by subtracting the water depth at the riffle crest downstream of the pool from the water depth at the deepest portion of the pool. Measured depths may not always be maximum pool depths because turbid water prevented visual identification of the deepest pool location. As discussed in Section 2.3, riffles at sites UMC4, UMC5, and UMC6 were generally not identifiable this year because of the higher flows and higher turbidity and therefore residual depths could not be measured at some locations. At UMC6 cross-section 4 beavers have a constructed dam (Figure 2-4), which creates the residual pool measured at this section.



**Figure 2-4. Beaver dam at UMC6 XS-4, August 2010.**

Measured residual pool depths are shown in Table 2-5. All pools showed some variation in residual depth compared to the previous year with depths being sometimes greater and sometimes less. However, the average residual depths were similar to previous years.

**Table 2-5. Summary of Residual Pool Depth Measurements in Upper Muddy Creek.**

Site	Downstream Riffle Section	2008 Residual Pool Depth (ft)	2009 Residual Pool Depth (ft)	2010 Residual Pool Depth (ft)
UMC-1	XS-3	1.9	2.2	2.3
UMC-1	XS-6	1.7	1.2	0.6
UMC-2	XS-3	0.9	0.7	Not visible
UMC-2	XS-5	2.0		1.6
UMC-2	55' downstream of XS-6	1.4		Not visible
UMC3	XS-2		2.2	2.3
UMC-3	XS-3	1.3	0.6	0.6
UMC-3	XS-6	2.4	1.9	1.8
UMC-4	XS-3	0.5	1.6	Not visible
UMC-4	XS-5	1.7	2.4	Not visible
UMC-5	XS-3	0.3	Not visible	Not visible
UMC-5	XS-6	2.0	0.9	Not visible
UMC6	XS-3		2.1	Not visible
UMC6	XS-4		1.6	2.0
UMC6	XS-5		1.4	Not visible
UMC6	XS-6		1.5	Not visible
Average		1.5	1.6	1.6

# Section 3 Water Quality Sampling

## 3.1 Measurement Methods

During the 2008, 2009 and 2010 site monitoring events, water quality samples were collected along with field measurements at three sites, UMC1, UMC3 and UMC6. These sites represent the upstream, middle and downstream portions of the project area on Upper Muddy Creek. As described in the Muddy Creek Monitoring Plan (CDM, 2008a), measurements were taken for discharge, pH, electrical conductivity, dissolved oxygen, temperature and turbidity. Discharge was measured with a Marsh-McBirney flow meter and pH, dissolved oxygen, temperature, and electrical conductivity were measured with a YSI Multiparameter meter.

Water quality samples were collected for common ions, total suspended solid (TSS), and dissolved selenium. Common ions and the metals sample were grab samples. The Muddy Creek Monitoring Plan (CDM, 2008a) called for depth integrated TSS sampling; however, the water depths were too shallow to permit sampling with the DH-48 sediment sampler. As an alternative, grab samples were collected at the center of the quartile flow sections and composited for the TSS sample.

Samples were delivered to Energy Laboratories in Helena, Montana in a chilled shipping container following chain-of-custody procedures on August 23, 2010.

## 3.2 Water Quality Sampling Results

Field measurements measured during the August 2008, 2009 and 2010 sampling events are summarized in Table 3-1.

Flow in the Upper Muddy Creek project area in August 2010 appeared to be continuous although the discharge decreased in the downstream direction. The constant flow compared to previous years was due to the frequent precipitation events that were maintaining high stream flows. Electrical conductivities were lower than observed in 2009, perhaps also a result of the recent precipitation. Turbidity was higher than previously observed because of the recent rains and generally clarity was too low to observe the stream bed. Dissolved oxygen values and pH values were similar to previous levels. The variation in water temperature with the previous years' data can be explained by ambient air temperatures on the day of observation.

Table 3-2 presents the laboratory analytical data for 2008, 2009 and 2010, and Appendix D contains the laboratory data sheets for 2010.

**Table 3-1. Field Parameters from Upper Muddy Creek Water Quality Sampling.**

Sample Site	Year	Discharge (cfs)	pH	Temp. (°C)	EC (mS) - Field	EC (mS) - Lab	DO (mg/L)	Turbidity*
UMC1	2008	2.29	7.77	14.4	0.548	0.556	7.32	14.9
	2009	5.66	8.23	20.85	0.74	0.664	8.74	16 <sup>(1)</sup>
	2010	4.9	7.59	15.8	0.548	-	7.5	40.8
UMC3	2008	1.68	8.02	14.8	0.57	0.578	7.81	13.5
	2009	5.74	8.43	22.54	0.738	0.66	8.66	6.15 <sup>(1)</sup>
	2010	4.85	9.16	21.2	0.565	-	7.7	30.4
UMC6	2008	1.46	8.02	22.6	0.607	0.616	7.5	14.8
	2009	4.64	8.05	18.03	0.763	0.688	7.92	6.88 <sup>(1)</sup>
	2010	5.09	8.76	18.74	0.589	-	8.22	32.5

\* Nephelometric Turbidity Units (NTU)

(1) Lab measurement.

**Table 3-2. Laboratory Analytical Data for Upper Muddy Creek Water Quality Sampling.**

Sample	Year	Ca	Mg	K	Na	Alkalinity*	Cl	SO <sub>4</sub>	Diss. Se	TSS
UMC1	2008	61	17	3	20	150	5	140	0.002 <sup>(1)</sup>	10
	2009	76	25	4	29	170	6	180	<0.005	23
	2010	69	25	4	29	180	6	170	<0.005	28
UMC3	2008	60	19	3	25	150	6	150	0.002 <sup>(1)</sup>	11
	2008Dup	61	19	3	25	150	6	150	0.002 <sup>(1)</sup>	<10
	2009	71	26	4	32	160	6	180	<0.005	<10
	2009Dup	72	26	4	30	160	6	180	<0.005	10
	2010	70	27	4	32	180	6	180	<0.005	19
UMC6	2008	58	19	4	31	150	7	180	0.001 <sup>(1)</sup>	12
	2009	73	27	4	34	160	7	200	<0.005	11
	2010	71	27	4	36	170	7	190	<0.005	29
	2010Dup	73	28	4	36	170	7	190	<0.005	20
UMC-Blank	2008	<1	<1	<1	<1	<4	<1	<1	<0.001 <sup>(1)</sup>	<10
	2009	<1	<1	<1	<1	<4	<1	<1	<0.005	NA

Note: All units are mg/L.

<sup>(1)</sup> Samples analyzed for total selenium.

Common ions collected during the 2010 sampling activities were generally consistent between the three sampling sites. The dissolved selenium concentrations were less than 5 µg/L, which is below the chronic aquatic life standard of 5 µg/L. Total

suspended solids (TSS) concentrations were in the range of 20 to 29 mg/L at the three sites and were higher than previously recorded. This correlates with the higher turbidity measurements and is due to the precipitation runoff. With the exception of TSS, the water quality appears similar to previous sampling events.

### 3.3 Quality Assurance/Quality Control

Laboratory quality assurance/quality control (QA/QC) reports are included in Appendix D. All method blank water quality parameters were below detection limits and all other quality assurance requirements were within accepted values.

A field duplicate sample was collected at site UMC6 and analysis results for this sample are presented in Table 3-2. All parameters had zero relative percent difference between the duplicate and natural sample except for calcium, magnesium, and TSS. The natural sample for calcium was 71 mg/L while the duplicate was 73 mg/L with a percent difference of 2.8. The natural sample for magnesium was 27 mg/L and the duplicate sample was 28 mg/L with a percent difference of 3.6. percent difference between +/- 20 percent area considered acceptable. The natural TSS sample measured 29 mg/L and the duplicate was 20 mg/L. Because the measurements are near the detection limit, which is 10 mg/L, this relative percent difference is acceptable.



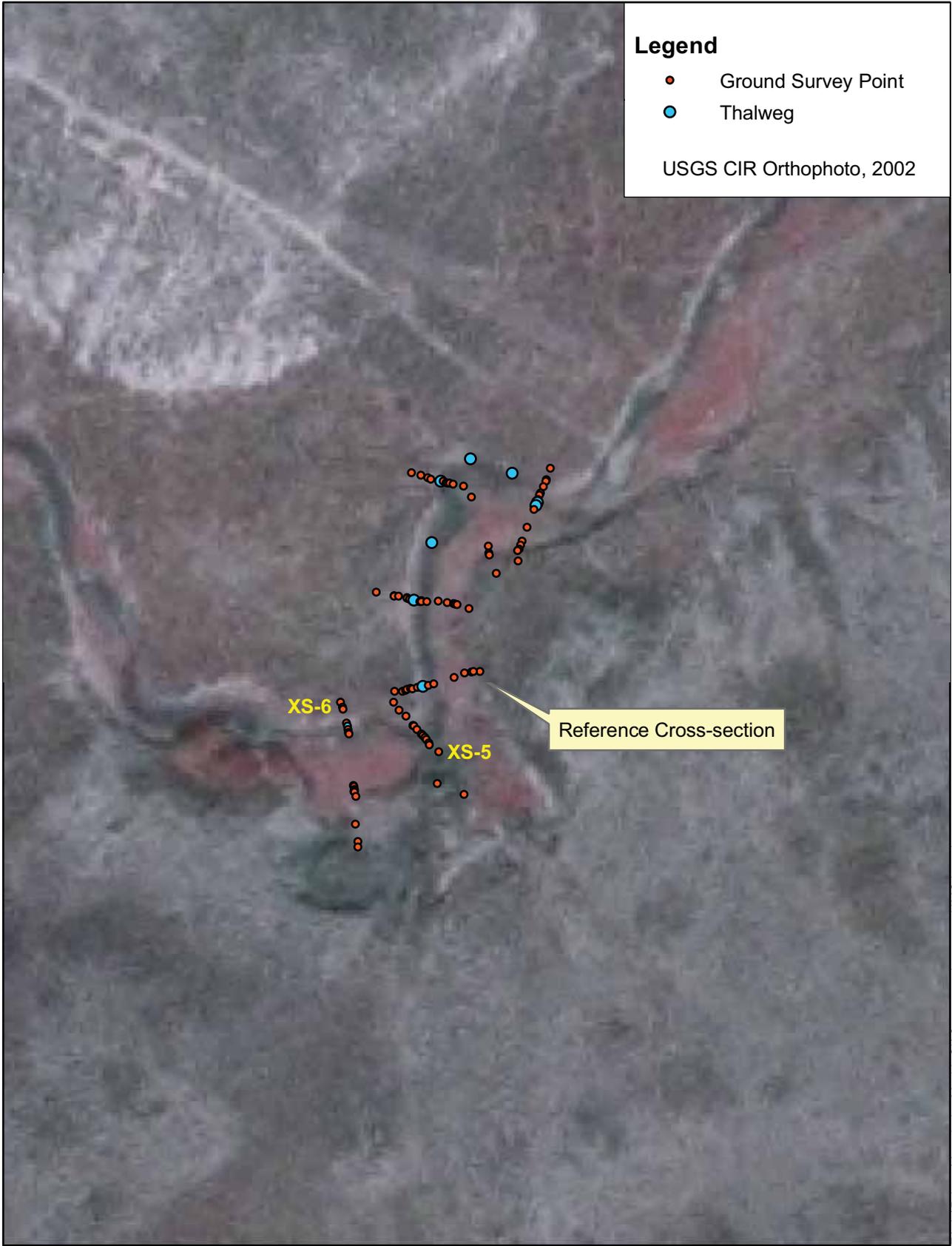
## Section 4 References

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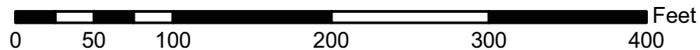
**Appendix A**  
**Monitoring Site Maps, Reference Section Photos and Cross-**  
**Sections, Typical and Panoramic Photos**





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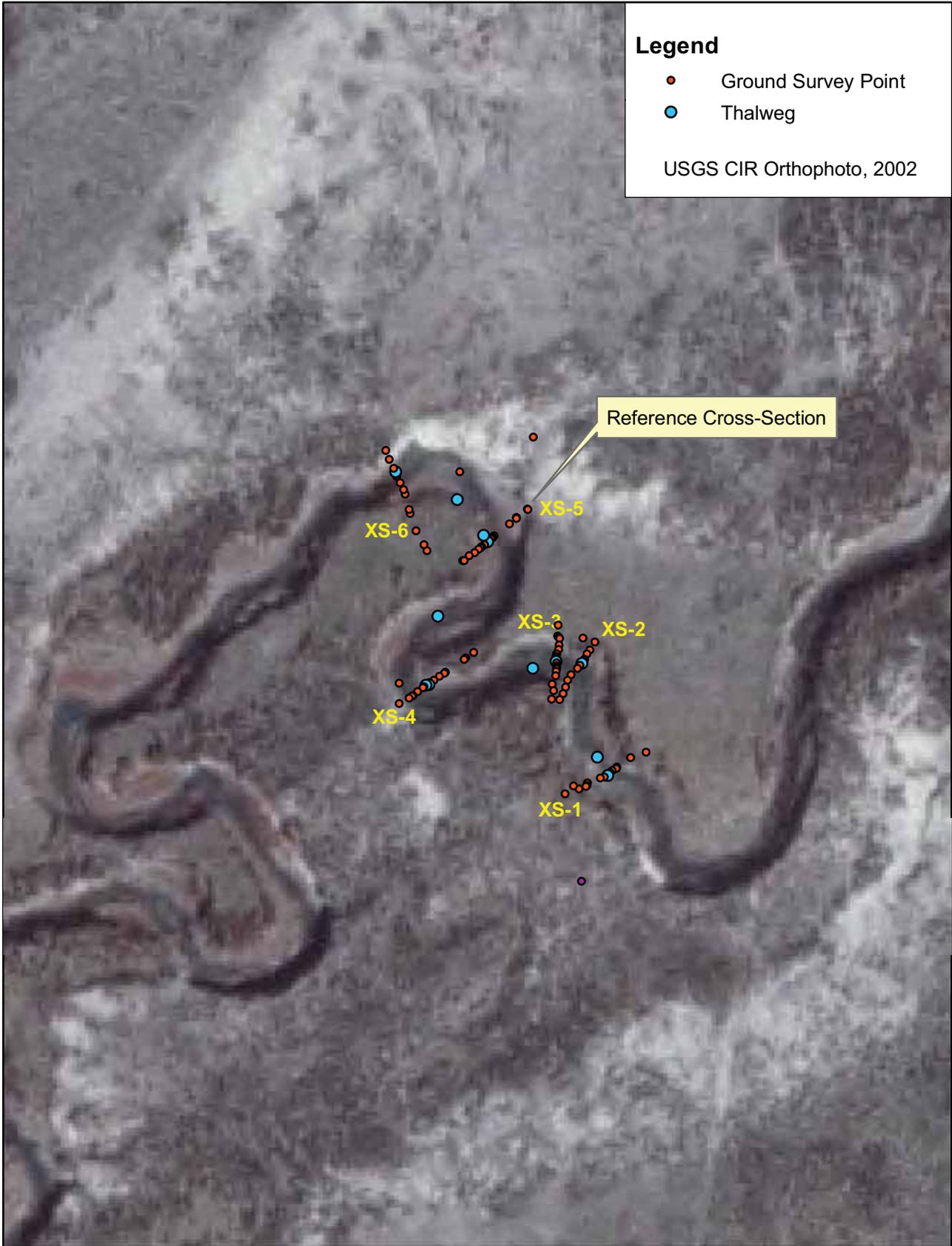
**Monitoring Site UMC-1**  
**Plan View**  
**Upper Muddy Creek**  
**Atlantic Rim Project**  
**Carbon County, Wyoming**



**Legend**

- Ground Survey Point
- Thalweg

USGS CIR Orthophoto, 2002



Z:\gis\Private\Anadarko-Muddy\Ck\Cross-section\_map-UMC2.mxd

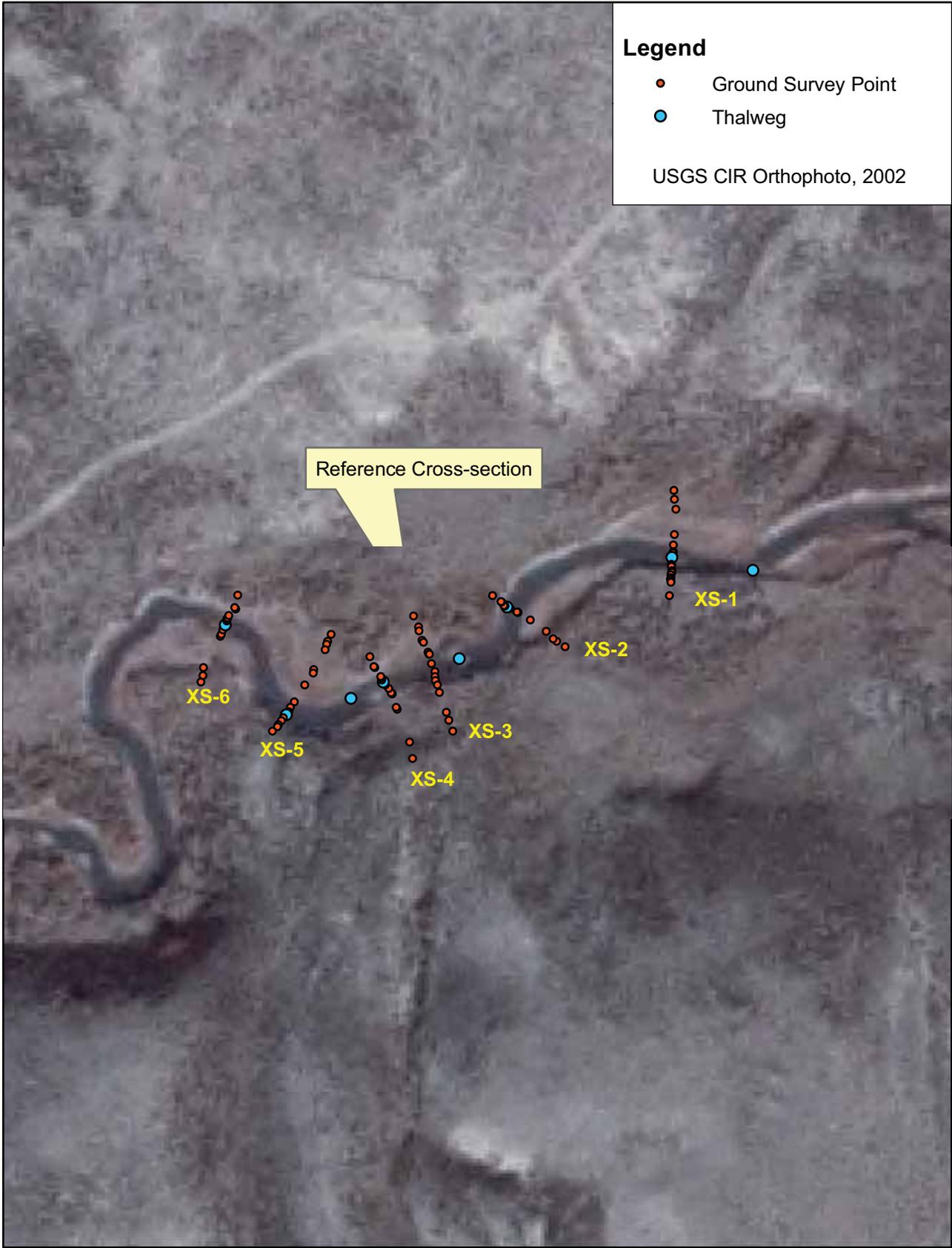
**Monitoring Site UMC-2**  
**Plan View**  
**Upper Muddy Creek**  
**Atlantic Rim Project**  
**Carbon County, Wyoming**



**Legend**

- Ground Survey Point
- Thalweg

USGS CIR Orthophoto, 2002



Z:\gis\Private\Anadarko-Muddy\Ck\Cross-section map-UMC3.mxd

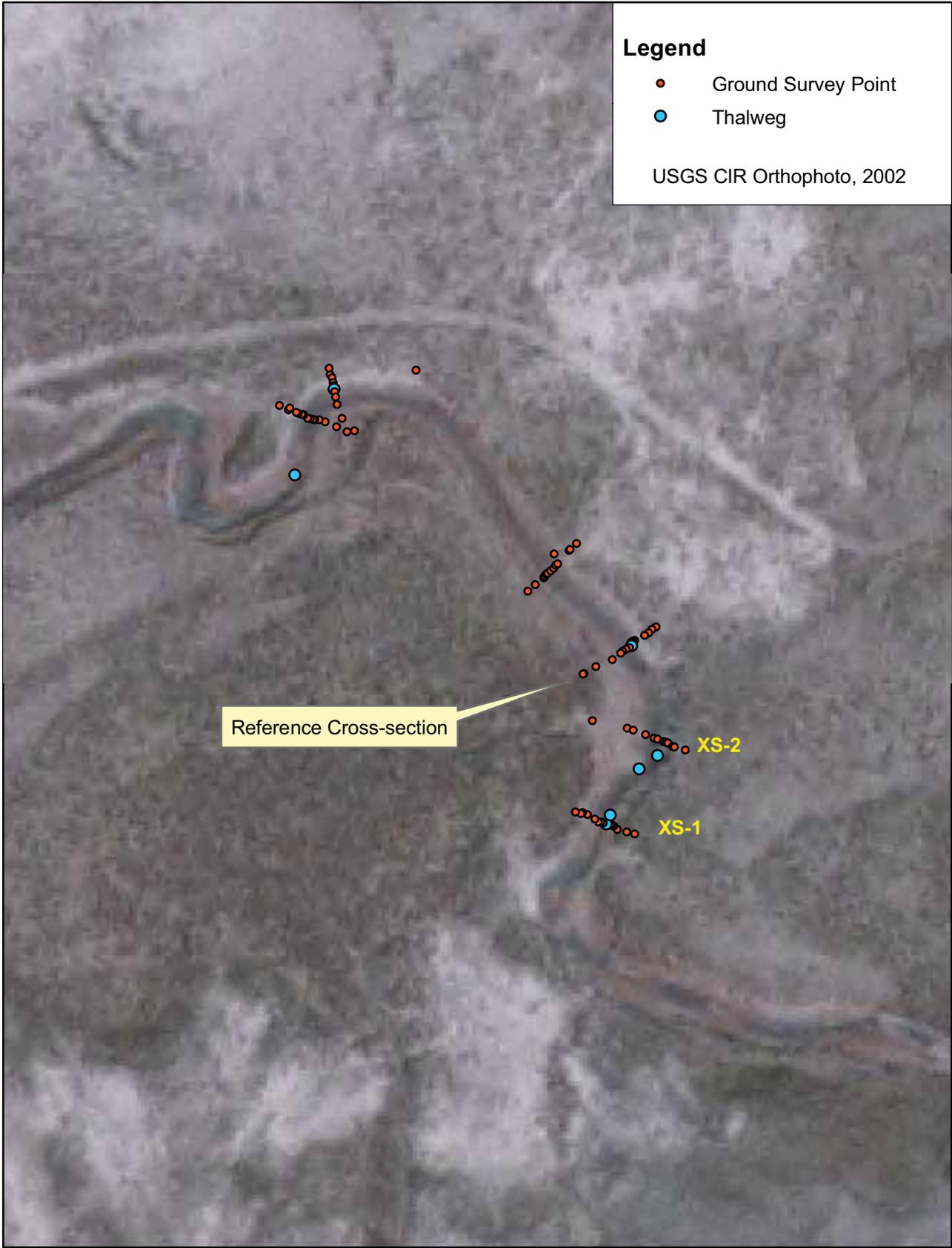
**Monitoring Site UMC-3**  
**Plan View**  
**Upper Muddy Creek**  
**Atlantic Rim Project**  
**Carbon County, Wyoming**



**Legend**

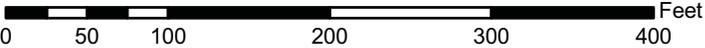
- Ground Survey Point
- Thalweg

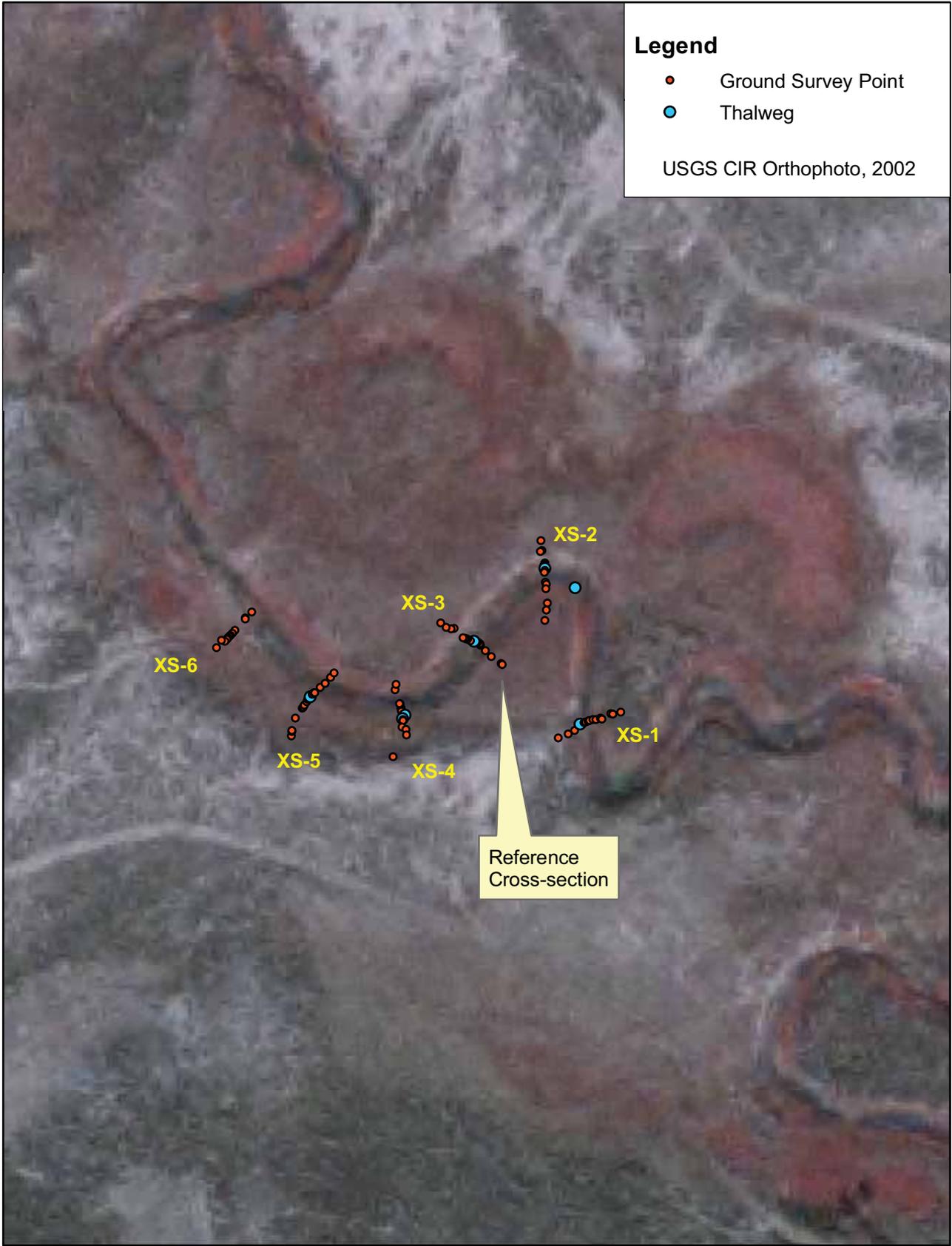
USGS CIR Orthophoto, 2002



Z:\gis\Private\Anadarko-Muddy\Ck\Cross-section\_map-UMC4.mxd

**Monitoring Site UMC-4**  
**Plan View**  
**Upper Muddy Creek**  
**Atlantic Rim Project**  
**Carbon County, Wyoming**





Z:\gis\Private\Anadarko-MuddyCk\Cross-section\_map-UMC5.mxd

**Monitoring Site UMC-5**  
**Plan View**  
**Upper Muddy Creek**  
**Atlantic Rim Project**  
**Carbon County, Wyoming**





**Legend**

- Ground Survey Point
- Thalweg

USGS CIR Orthophoto, 2002

Reference Cross-section

XS-3

**Cross Section UMC-6  
Plan View  
Upper Muddy Creek  
Atlantic Rim Project  
Carbon County, Wyoming**



Z:\gis\Private\Anadarko-Muddy\CK\Cross-section\_map-UMC6.mxd

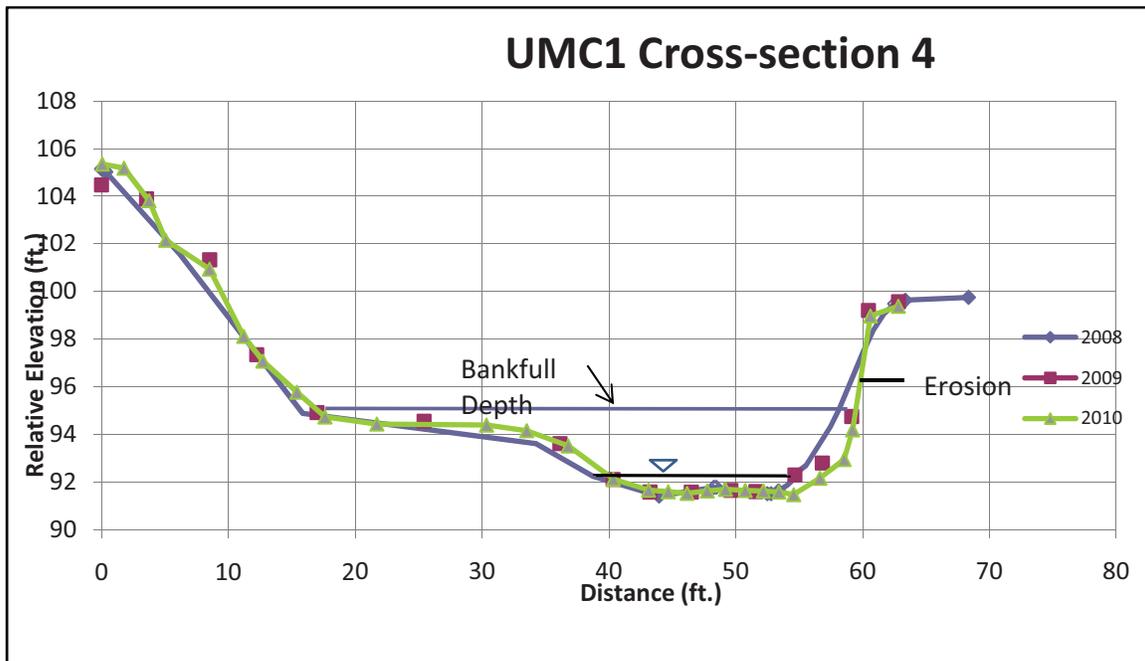


2008



2010

UMC-1 XS-4, Right Bank





2008



2010

UMC-1, XS-4, View Upstream



2008



2010

UMC1, XS-4, View Downstream

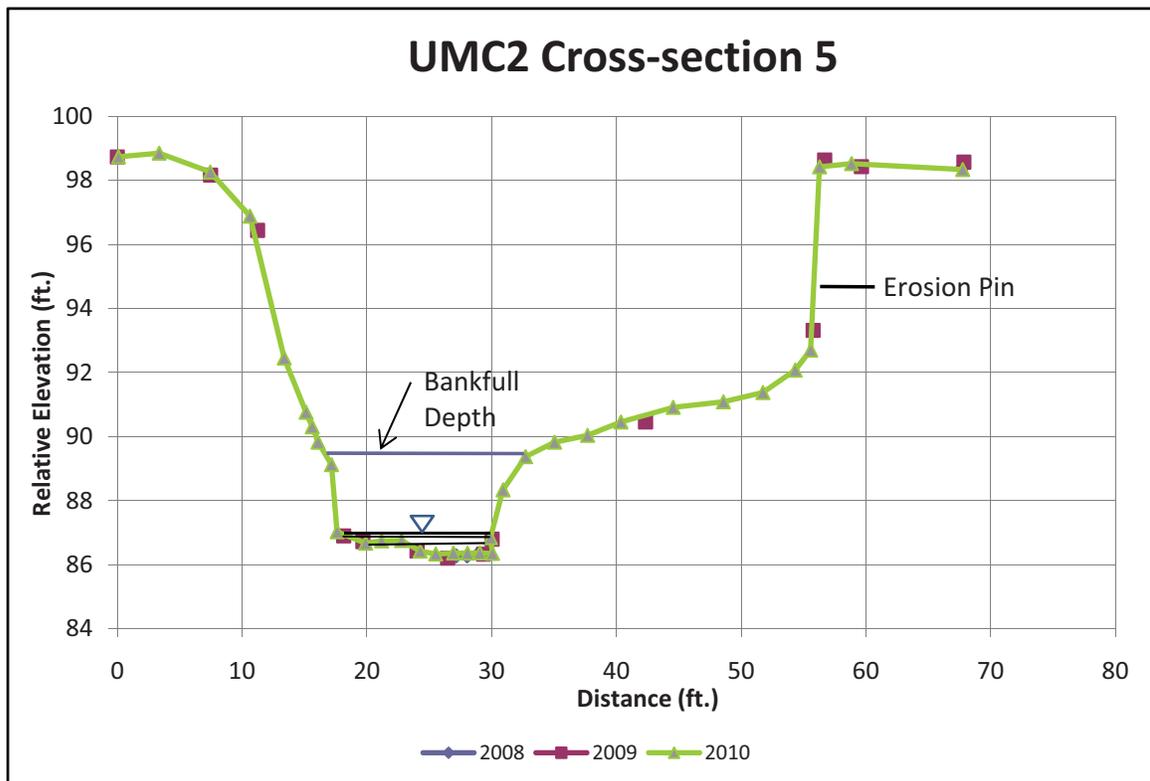


2008



2010

UMC-2, XS-5, Right Bank





2008



2010

UMC2, XS-5, View Upstream



2008



2010

UMC2, XS-5, View Downstream

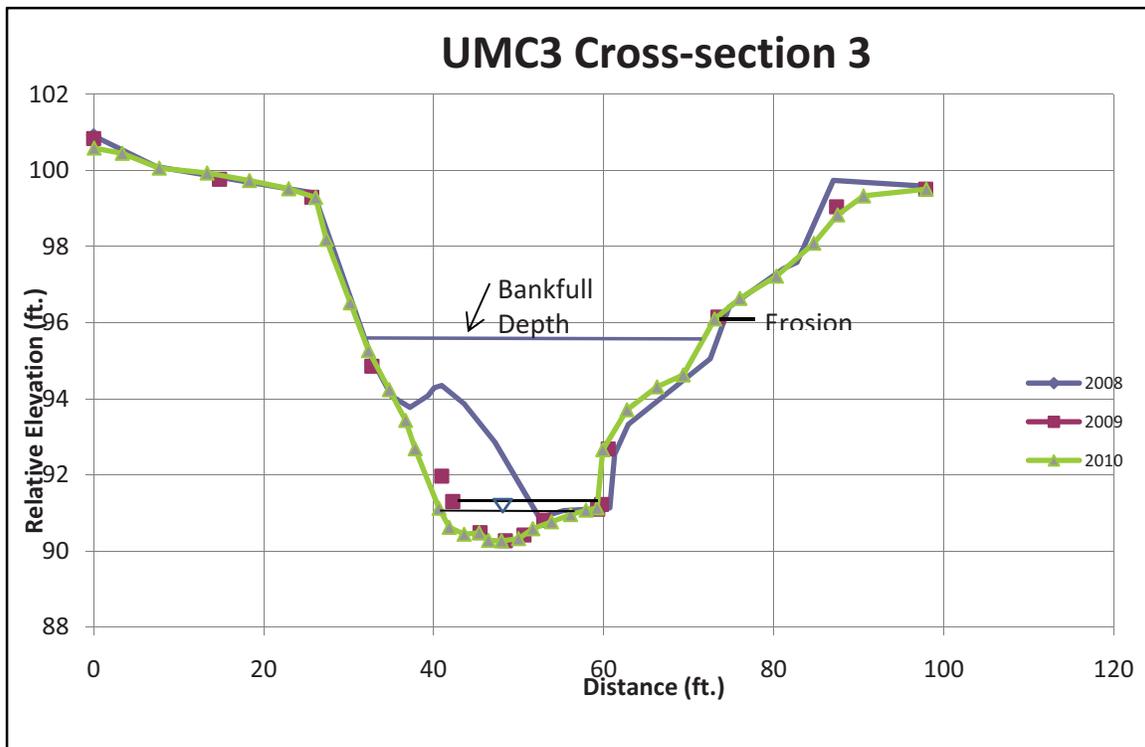


2008



2010

UMC3, XS-3 Right Bank





2008



2010

UMC 3, XS-3, View Upstream



2008



2010

UMC3, XS-3, View Downstream

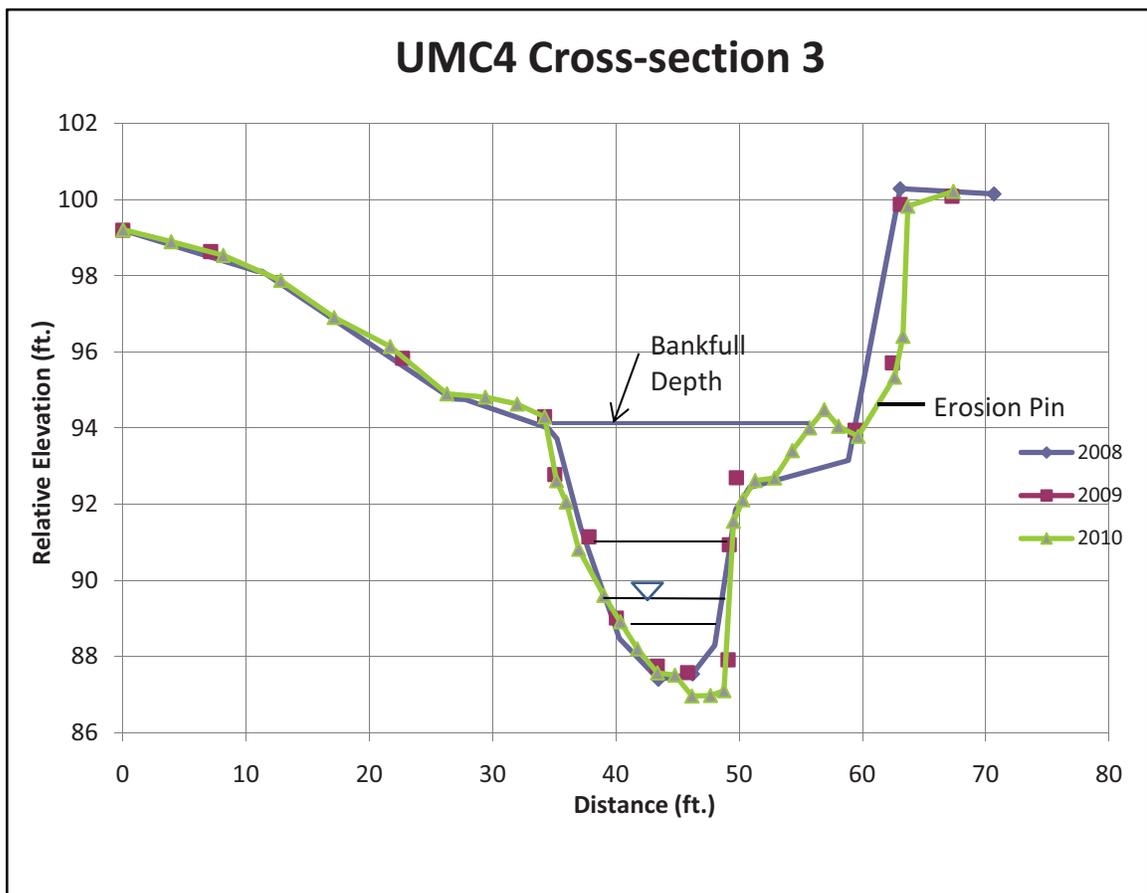


2008



2010

UMC4, XS-3, Left Bank





2008



2010

UMC4, XS-3, View Upstream



2008



2010

UMC4, XS-3, View Downstream

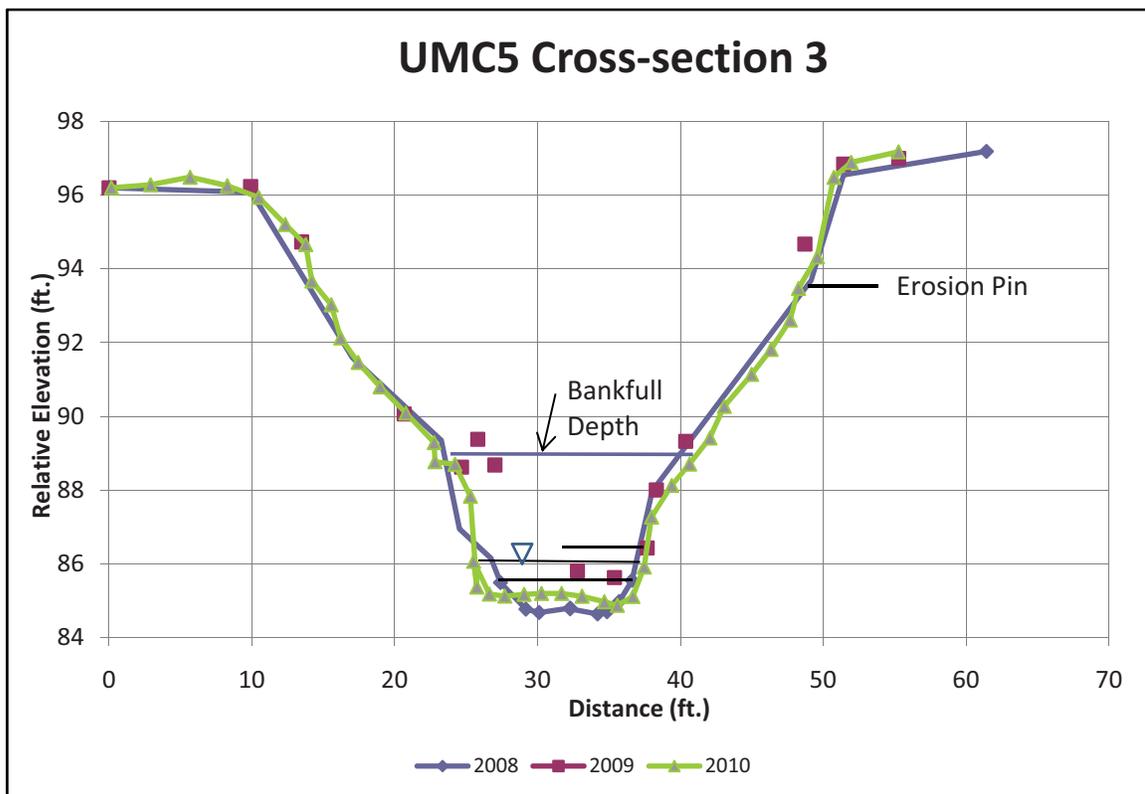


2008



2009

UMC5, XS-3, Right Bank





2008



2010

UMC5, XS-3, View Upstream



2008



2010

UMC5, XS-3, View Downstream

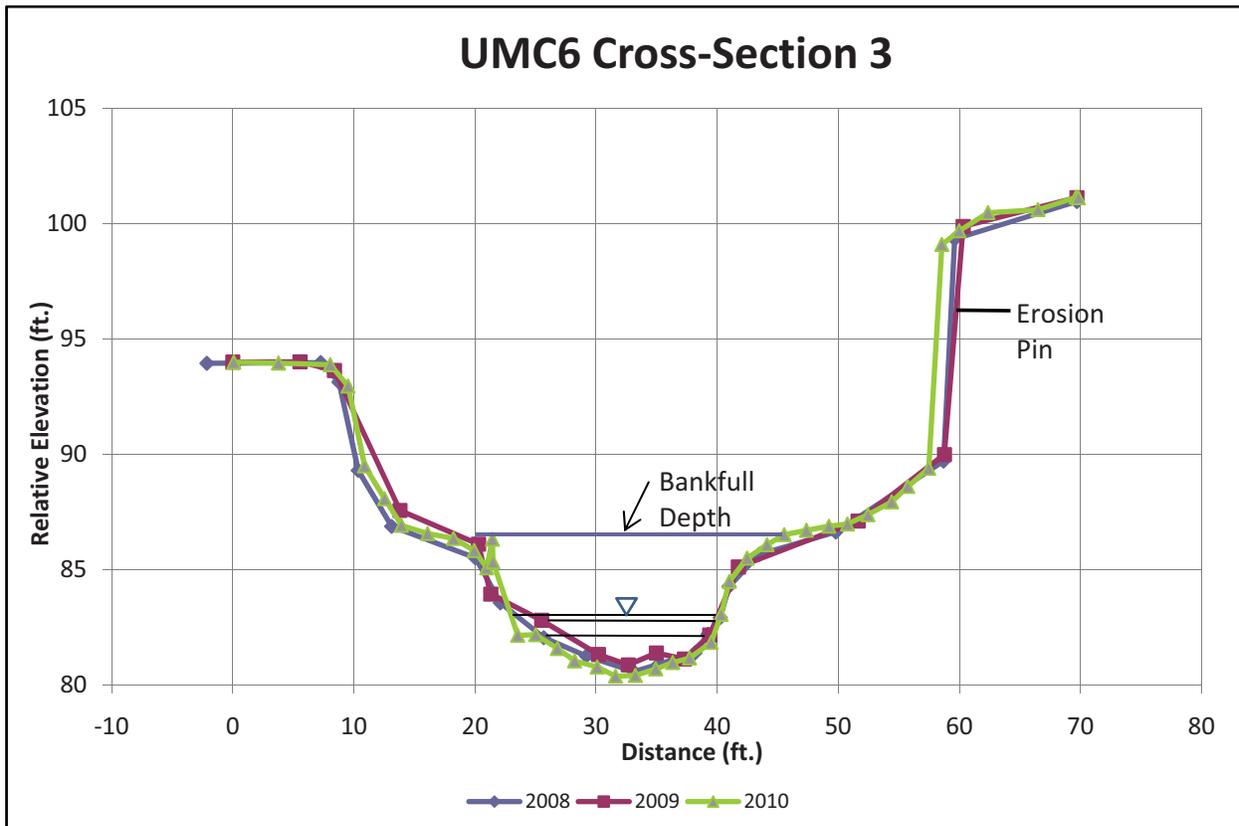


2008



2010

UMC6, XS-3, Right Bank





2008



2010

UMC6, XS-3, View Upstream



2008



2010

UMC6, XS-3, View Downstream

**UMC1**



**XS-1 Looking Downstream to XS-2**



**XS-6 Looking Downstream**

**UMC2**



**XS-5 Looking Upstream**



**XS-5 Looking Downstream to XS-6**

**UMC3**



**XS-2 Looking Upstream**



**XS-4 Looking Downstream**

**UMC4**



**View upstream from XS-3**



**View downstream from XS-4**

**UMC5**



**XS-3 Looking Downstream to XS-4**



**XS-5 Looking Downstream**

**UMC6**



**XS-3 Looking Upstream**



**XS-3 Looking Downstream**



**Panorama of UMC1- XS1.**



**Panorama of UMC2- XS3**



Panorama of UMC2- XS5



Panorama of UMC3- XS2



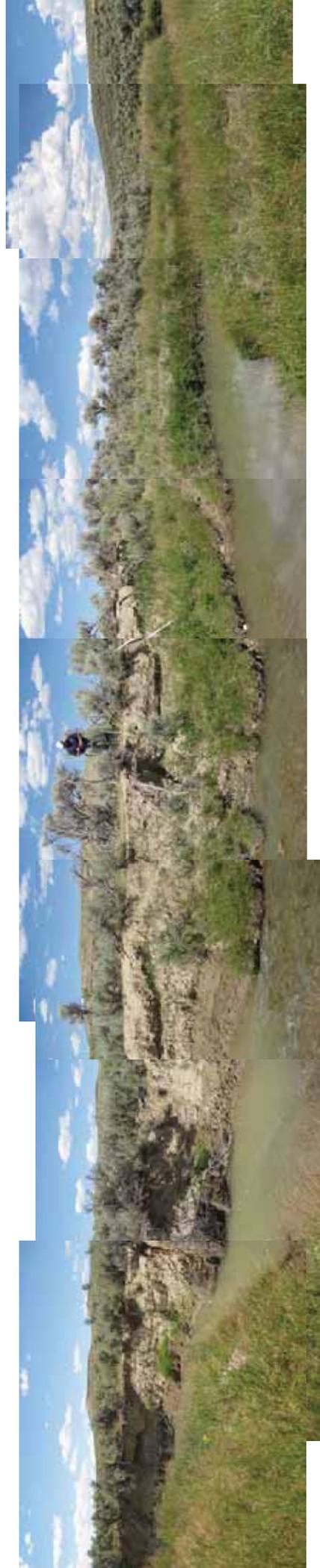
Panorama of UMC3- XS3



Panorama of UMC3- XS4



Panorama of UMC3- XS5



Panorama of UMC3- XS6



**Panorama of UMC4- X3**



**Panorama of UMC6- X1**



Panorama of UMC6- X3



Panorama of UMC1- XS1.



Panorama of UMC2- XS3



Panorama of UMC4- X3



Panorama of UMC6- X1

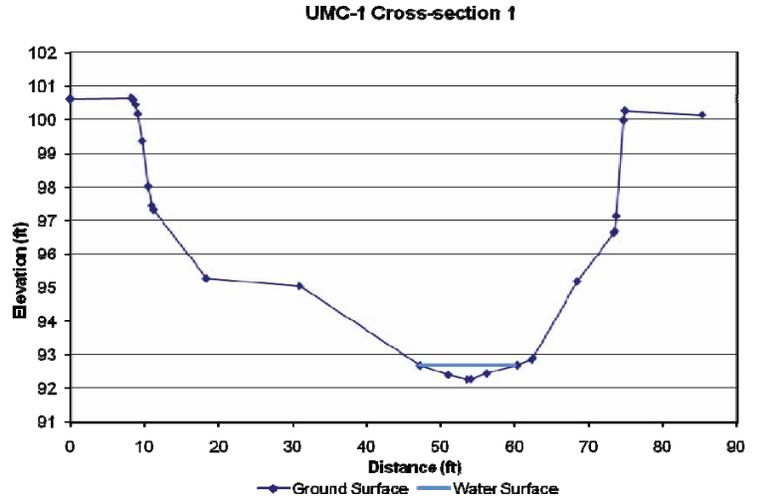


Panorama of UMC6- X3

**Appendix B**  
**BEHI Data and Bank Photos**



Photo 1. UMC 1, XS-1, Left Bank (2008).



UMC1, Cross-section 1, Left bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	2.25	8.2	8.6
Root Depth/Bank ht	0.2	7	7
Root Density	<5%	10	10
Bank Angle	13.2	1.1	3.8
Surface Protection	0%	10	10
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	36.3	39.4
BEHI Rating	--	High	High
Radius of Curvature	Straight	--	--
Bankfull Width	--	--	--
NBS Rating	--	N/A	N/A



Photo 2. UMC 1, XS-1, Left Bank (2010).

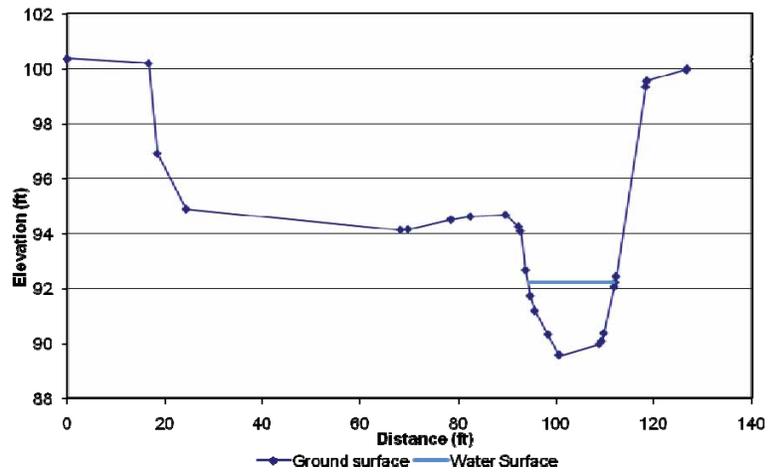
**Note:**

Cross section was surveyed during the 2008 field activities.



Photo 3. UMC1, XS-2, Right Bank (2009).

UMC-1 Cross-section 2



UMC1, Cross-section 2, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	1.9	5.01	6.2
Root Depth/Bank ht	0.2	10	6.5
Root Density	<5%		10
Bank Angle	60		4.3
Surface Protection	20%		10
Bank Material	Silt		0
Stratification	None		0
Index sum	--		37.0
<b>BEHI Rating</b>	--		<b>High</b>
Radius of Curvature			--
Bankfull Width			--
Rc/W			--
<b>NBS Rating</b>			<b>Extreme</b>

Note:

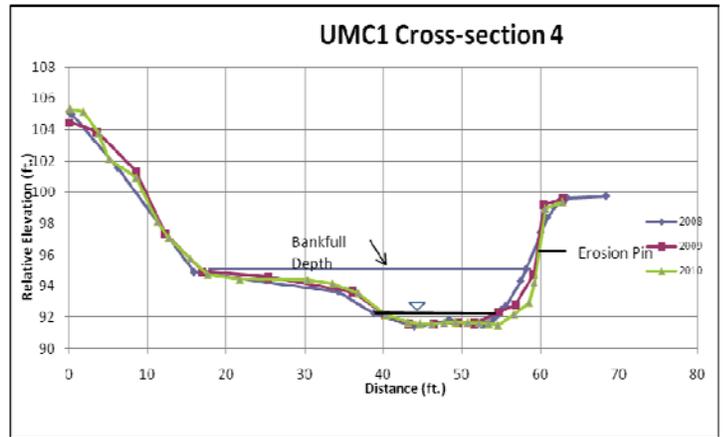
Cross section was surveyed during the 2008 field activities.



Photo 4. UMC1, XS-2, Right Bank (2010).



Photo 5. UMC1, XS-4, Right Bank (2008).



UMC1, Cross-section 4, Right bank

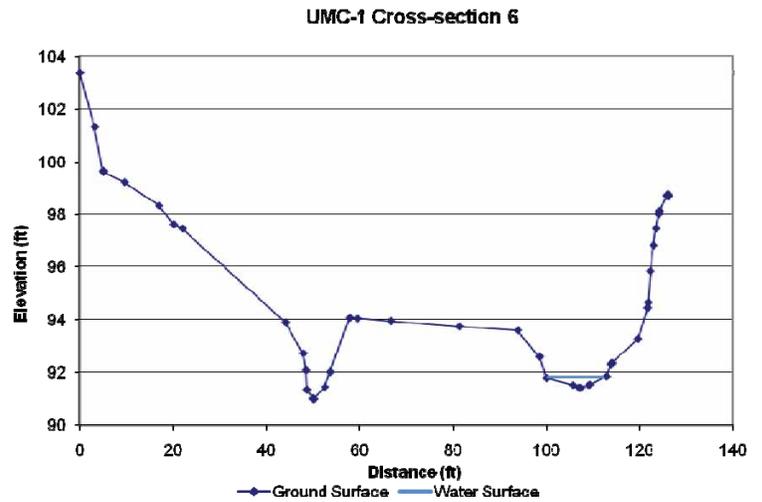
Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	1.5	5.9	5.9
Root Depth/Bank ht	0.2		7
Root Density	<5%		10
Bank Angle	80		7
Surface Protection	20%		10
Bank Material	Silt		0
Stratification	None		0
Index sum	--		39.9
<b>BEHI Rating</b>	--	<b>High</b>	<b>High</b>
Radius of Curvature	Straight		--
Bankfull Width	--		--
<b>NBS Rating</b>	--		<b>N/A</b>



Photo 6. UMC1, XS-4, Right Bank (2010).



Photo 7. UMC1, XS-6, Right Bank (2008).



UMC1, Cross-section 6, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	2.5	8.57	8.5
Root Depth/Bank ht	0.4		5
Root Density	<5%		10
Bank Angle	63		7
Surface Protection	5%		10
Bank Material	Silt		0
Stratification	None	0	0
Index sum	--		40.5
<b>BEHI Rating</b>	--	<b>High</b>	<b>Very High</b>
Radius of Curvature	Inside of bank		--
Bankfull Width	--		--
<b>NBS Rating</b>	--		<b>N/A</b>

Note:

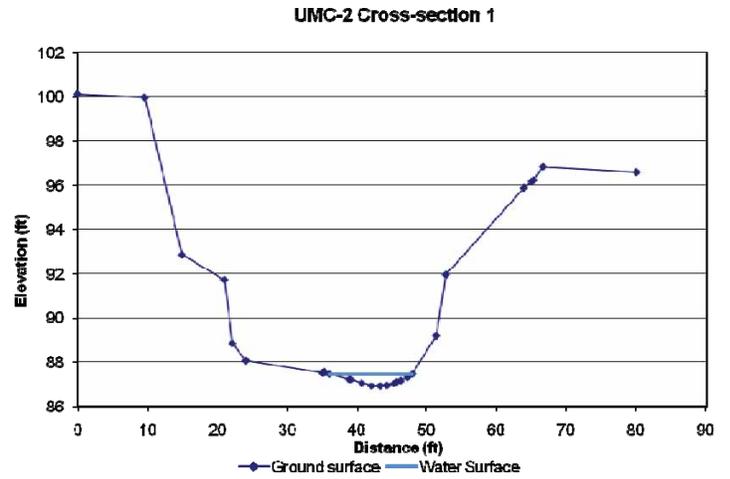
Cross section was surveyed during the 2008 field activities.



Photo 8. UMC1, XS-6, Right Bank (2010).



Photo 9. UMC2, XS-1, Left Bank (2008).



UMC2, Cross-section 1, Left Bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth			
Depth	2.6	8.8	8.5
Root Depth/Bank ht	0.1		8.5
Root Density	<5%		10
Bank Angle	64		7
Surface Protection	17%		10
Bank Material	Silt		0
Stratification	None		0
Index sum	--		44
<b>BEHI Rating</b>	--	<b>High</b>	<b>Very High</b>
Radius of Curvature			--
Bankfull Width			--
Rc/W			--
<b>NBS Rating</b>			<b>Extreme</b>

Note:

Cross section was surveyed during the 2008 field activities.



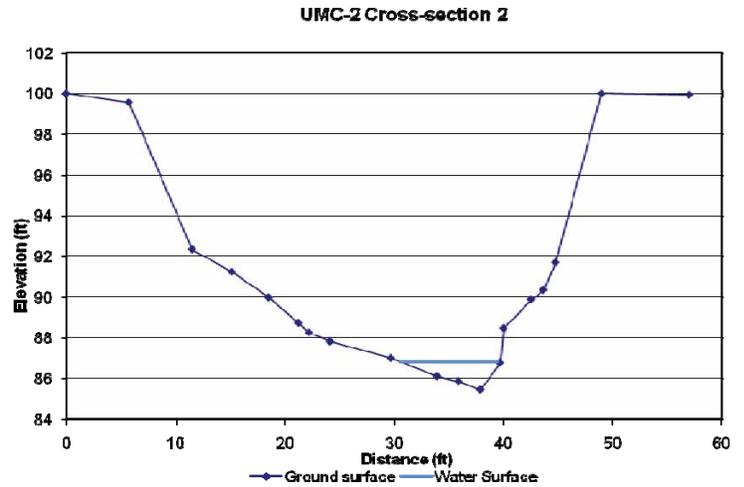
Photo 10. UMC2, XS-1, Left Bank (2010).



Photo 11. UMC2, XS-2, Right Bank (2008).



Photo 12. UMC2, XS-2, Right Bank (2010).



UMC2, Cross-section 2, Right bank

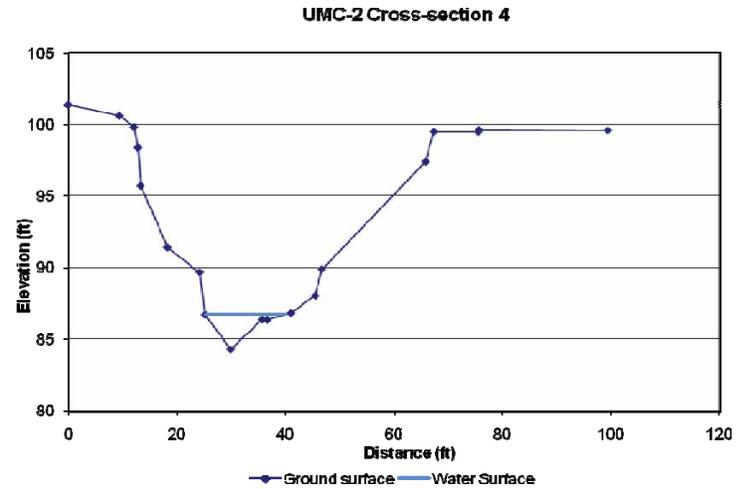
Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	2.4	8.44	8.5
Root Depth/Bank ht	0.3		5.9
Root Density	<5%	10	10
Bank Angle	54		5
Surface Protection	<5%		10
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--		39.4
<b>BEHI Rating</b>	--	<b>High</b>	<b>High</b>
Radius of Curvature	37		--
Bankfull Width	24		--
Rc/W	1.5		--
<b>NBS Rating</b>	--		<b>Very High</b>

Note:

Cross section was surveyed during the 2008 field activities.



Photo 13. UMC2, XS-4, Left Bank (2008).



UMC-2, Cross-section 4, Left bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth			
Depth	2.2	2	5.9
Root Depth/Bank ht	0.2		7
Root Density	<5%		10
Bank Angle	64.3		5
Surface Protection	<5%		10
Bank Material	Silt		0
Stratification	None		0
Index sum	--		37.9
<b>BEHI Rating</b>	--	<b>High</b>	<b>High</b>
Radius of Curvature			--
Bankfull Width			--
Rc/W			--
<b>NBS Rating</b>			<b>Extreme</b>

Note:

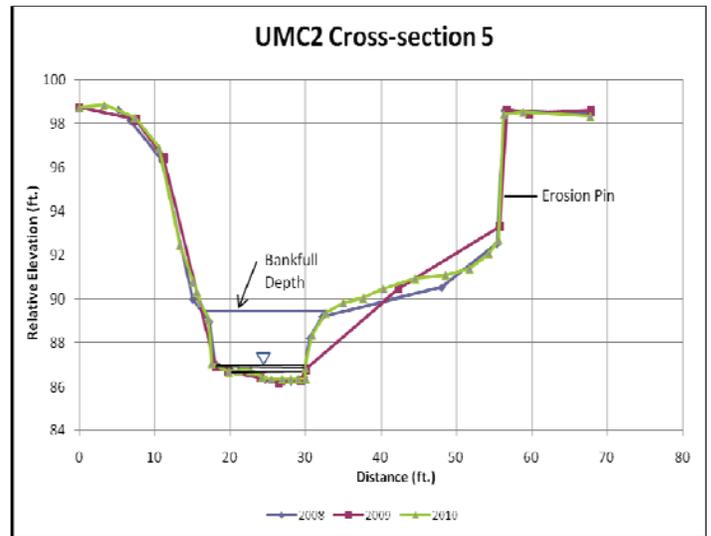
Cross section was surveyed during the 2008 field activities.



Photo 14. UMC2, XS-4, Left Bank (2010).



Photo 15. UMC2, XS-5, Right Bank (2008).



UMC-2, Cross-section 5, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	2.4	8.57	8.2
Root Depth/Bank ht	0.1		8.5
Root Density	<5%	10	10
Bank Angle	66		5.2
Surface Protection	0%		10
Bank Material	Silt		0
Stratification	None		0
Index sum	--		41.9
<b>BEHI Rating</b>	--	<b>Very High</b>	<b>Very High</b>
Radius of Curvature			--
Bankfull Width			--
Rc/W			--
<b>NBS Rating</b>			<b>Moderate</b>

Note:

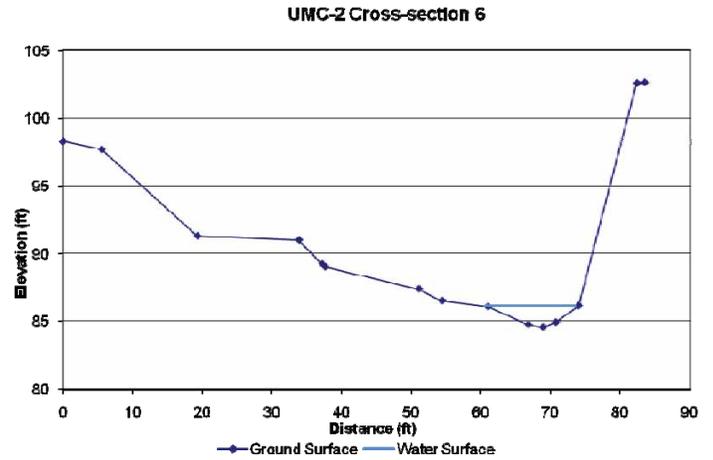
Cross section was surveyed during the 2008 field activities.



Photo 16. UMC2, XS-5, Right Bank (2010).



Photo 17. UMC2, XS-6, Right Bank (2008).



UMC-2, Cross-section 6, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth			
Depth	3.2	10	10
Root Depth/Bank ht	0.1		8.5
Root Density	<5%		10
Bank Angle	63		7
Surface Protection	0%		10
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--		45.5
<b>BEHI Rating</b>	--	<b>Very High</b>	<b>Very High</b>
Radius of Curvature	45		--
Bankfull Width	37		--
Rc/W	1.2		--
<b>NBS Rating</b>	--		<b>Extreme</b>

Note:

Cross section was surveyed during the 2008 field activities.



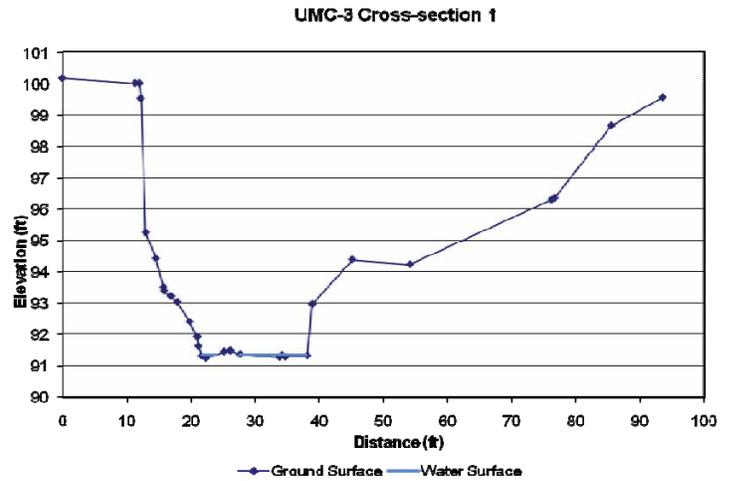
Photo 18. UMC2, XS-6, Right Bank (2010).



Photo 19: UMC3, XS-1, Left Bank (2009).



Photo 20: UMC3, XS-1, Left Bank (2010).



UMC-3, Cross-section 1, Left bank

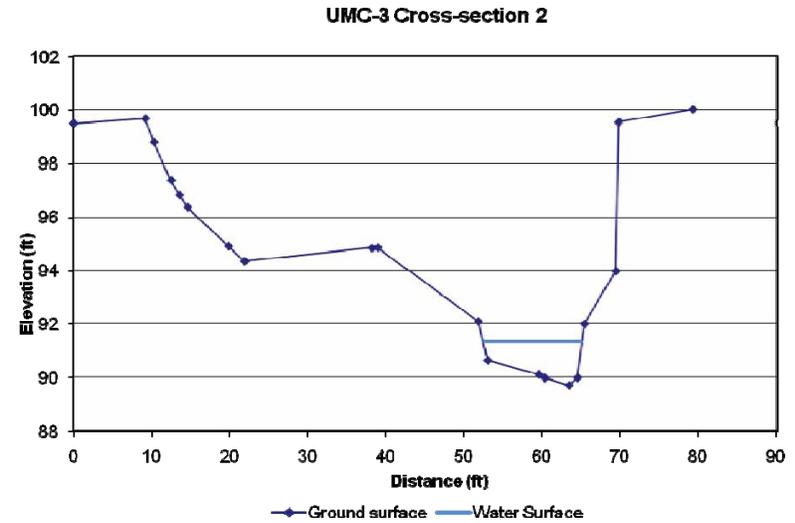
Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	3.0	10	8.2
Root Depth/Bank ht	0.3		9.5
Root Density	<5%		10
Bank Angle	49		5
Surface Protection	<5%		10
Bank Material	Silt		0
Stratification	None		0
Index sum	--		42.7
<b>BEHI Rating</b>	--	<b>Very High</b>	<b>Very High</b>
Radius of Curvature	86		--
Bankfull Width	42		--
Rc/W	2.1		--
<b>NBS Rating</b>	--		<b>Moderate</b>

Note:

Cross section was surveyed during the 2008 field activities.



Photo 21: UMC3, XS-2, Right Bank (2008).



UMC-3, Cross-section 2, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	1.9	7.4	1.9
Root Depth/Bank ht	0.7		3
Root Density	<5%		10
Bank Angle	57	3.75	7
Surface Protection	0%		10
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	34.15	31.9
<b>BEHI Rating</b>	--	<b>High</b>	<b>High</b>
Radius of Curvature			--
Bankfull Width			--
Rc/W			--
<b>NBS Rating</b>			<b>Extreme</b>

Note:

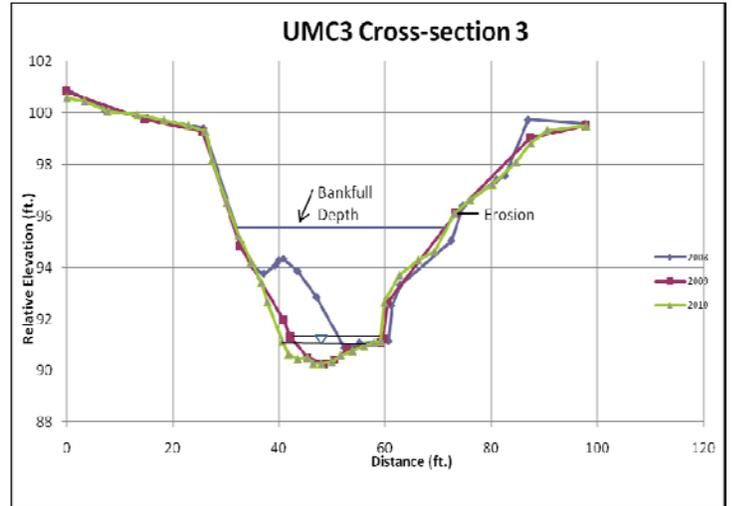
Cross section was surveyed during the 2008 field activities.



Photo 22: UMC3, XS-2, Right Bank (2010).



Photo 23: UMC3, XS-3, Right Bank (2008).



UMC-3, Cross-section 3, Right bank

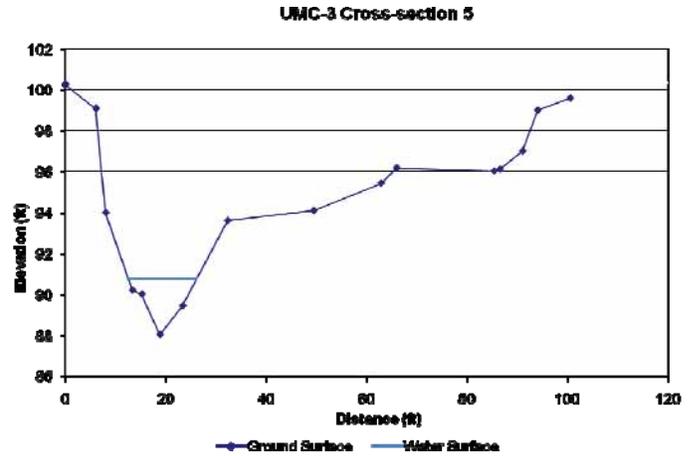
Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	1.6	6	6.5
Root Depth/Bank ht	0.2		7
Root Density	<5%	10	10
Bank Angle	75.3	5.43	7
Surface Protection	0%		10
Bank Material	Silt		0
Stratification	None		0
Index sum	--		40.5
<b>BEHI Rating</b>	--	<b>High</b>	<b>Very High</b>
Radius of Curvature			--
Bankfull Width			--
<b>NBS Rating</b>			<b>N/A</b>



Photo 24: UMC3, XS-3, Right Bank (2010).



Photo 25: UMC3, XS-5, Left Bank (2008).



UMC-3, Cross-section 5, Left bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth			1.9
Depth	1.5	5.9	
Root Depth/Bank ht	0.2		7
Root Density	<5%	10	10
Bank Angle	53		5
Surface Protection	0%		10
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--		33.9
<b>BEHI Rating</b>	--	<b>High</b>	<b>High</b>
Radius of Curvature			--
Bankfull Width			--
Rc/W			--
<b>NBS Rating</b>			<b>Extreme</b>

Note:

Cross section was surveyed during the 2008 field activities.



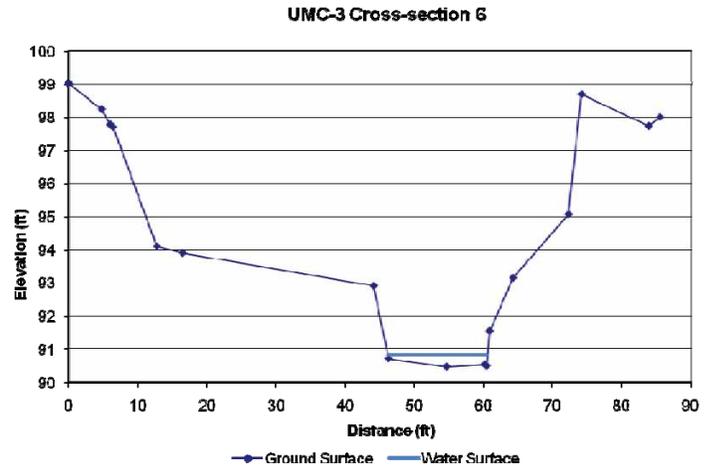
Photo 26: UMC3, XS-5, Left Bank (2010).



Photo 27: UMC3, XS-6, Right Bank (2008).



Photo 28: UMC3, XS-6, Right Bank (2010).



UMC-3, Cross-section 6, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	2.3	8.3	5.5
Root Depth/Bank ht	0.2		7
Root Density	<5%		10
Bank Angle	57		4.5
Surface Protection	0%		10
Bank Material	Silt		0
Stratification	None		0
Index sum	--		37
<b>BEHI Rating</b>	--	<b>High</b>	<b>High</b>
Radius of Curvature			--
Bankfull Width			--
Rc/W			--
<b>NBS Rating</b>			<b>Very High</b>

Note:

Cross section was surveyed during the 2008 field activities.

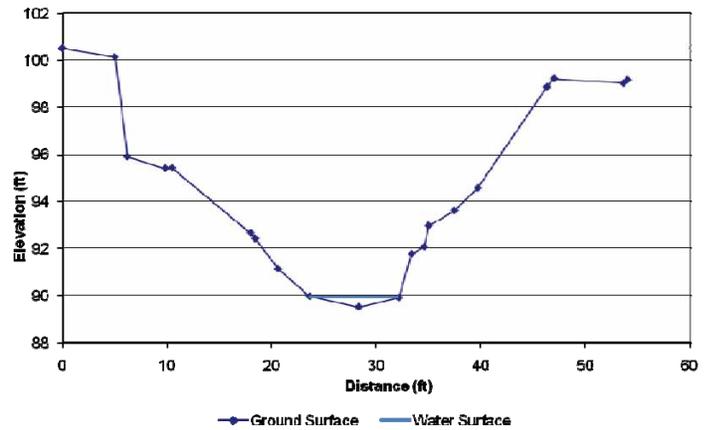


Photo 29: UMC4, XS-1, Left Bank (2009).



Photo 30: UMC4, XS-1, Left Bank (2010).

UMC-4 Cross-section 1



UMC-4, Cross-section 1, Left bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	2.3	8.57	7.9
Root Depth/Bank ht	0.3		5.9
Root Density	<5%	10	10
Bank Angle	61	4	5
Surface Protection	0%	10	10
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	38.47	38.8
<b>BEHI Rating</b>	--	<b>High</b>	<b>High</b>
Radius of Curvature	57		--
Bankfull Width	22		--
Rc/W	2.6		--
<b>NBS Rating</b>	--		<b>Low</b>

Note:

Cross section was surveyed during the 2008 field activities.



Photo 31: UMC4, XS-3, Right Bank (2008).

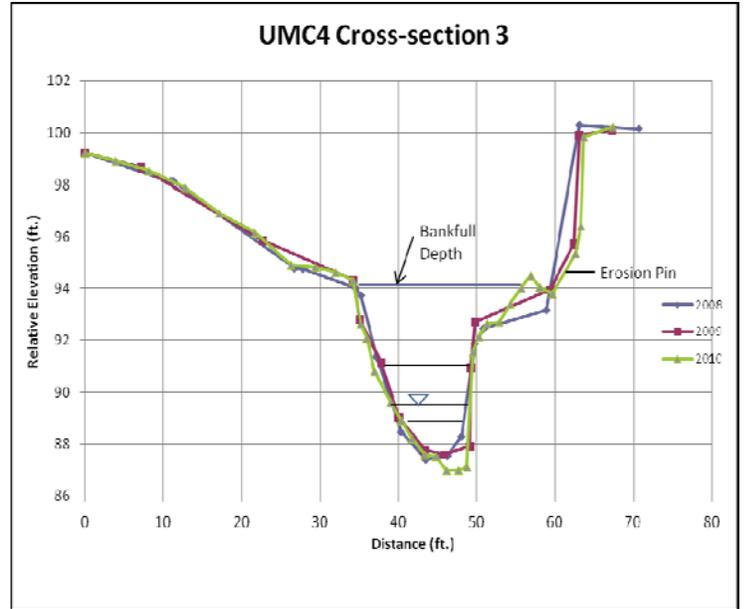


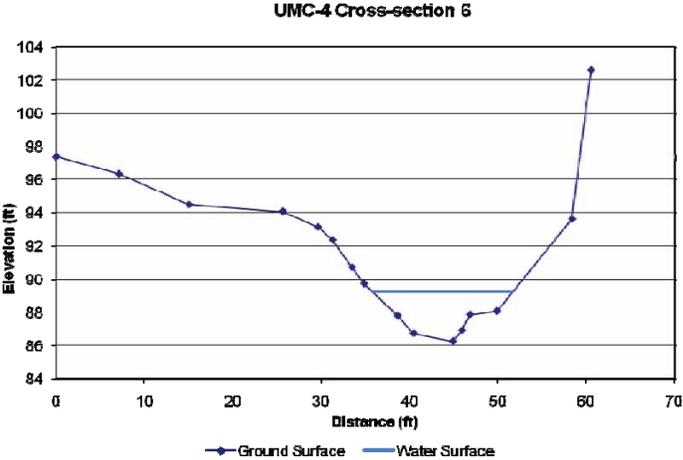
Photo 32: UMC4, XS-3, Right Bank (2010).

UMC-4, Cross-section 3, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	1.7	6.5	4.5
Root Depth/Bank ht	0.3		5.9
Root Density	<5%		10
Bank Angle	54		8.5
Surface Protection	0%		10
Bank Material	Silt		0
Stratification	None		0
Index sum	--	36	38.9
<b>BEHI Rating</b>	--	<b>High</b>	<b>High</b>
Radius of Curvature			--
Bankfull Width			--
Rc/W			--
<b>NBS Rating</b>			<b>Very Low</b>



Photo 33: UMC4, XS-6, Right Bank (2008).



UMC-4, Cross-section 6, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	2.5	8.6	8.5
Root Depth/Bank ht	0.2		7
Root Density	<5%	10	10
Bank Angle	58.5	3.8	6
Surface Protection	0%	10	10
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	39.4	41.5
<b>BEHI Rating</b>	--	<b>High</b>	<b>Very High</b>
Radius of Curvature			--
Bankfull Width			--
Rc/W			--
<b>NBS Rating</b>			<b>Moderate</b>

Note:  
Cross section was surveyed during the 2008 field activities.



Photo 34: UMC4, XS-6, Right Bank (2010).

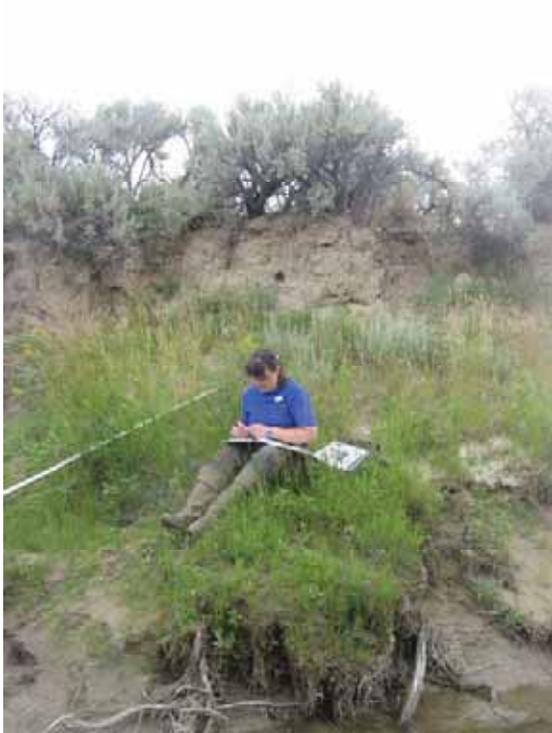
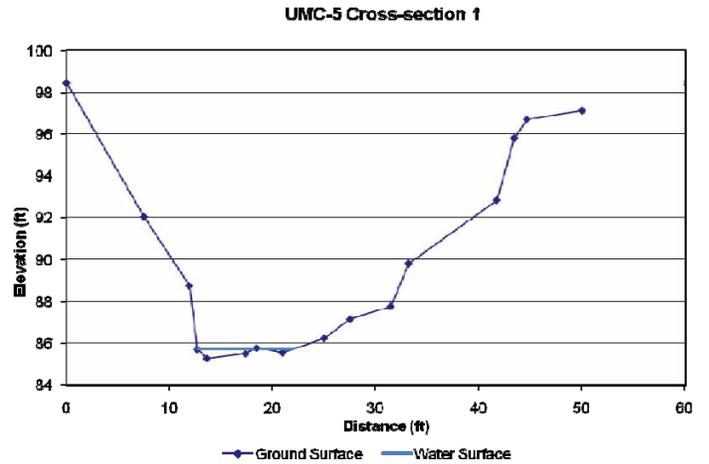


Photo 35: UMC5, XS-1, Right Bank



Photo 36: UMC5, XS-1, Right Bank (2010).



UMC-5, Cross-section 1, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	2.6	8.8	10
Root Depth/Bank ht	0.3		5.9
Root Density	<5%	10	10
Bank Angle	52	3.5	3.6
Surface Protection	35%	5.5	6.5
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	33.7	36
<b>BEHI Rating</b>	--	<b>High</b>	<b>High</b>
Radius of Curvature			--
Bankfull Width			--
<b>NBS Rating</b>			<b>N/A</b>

Note:

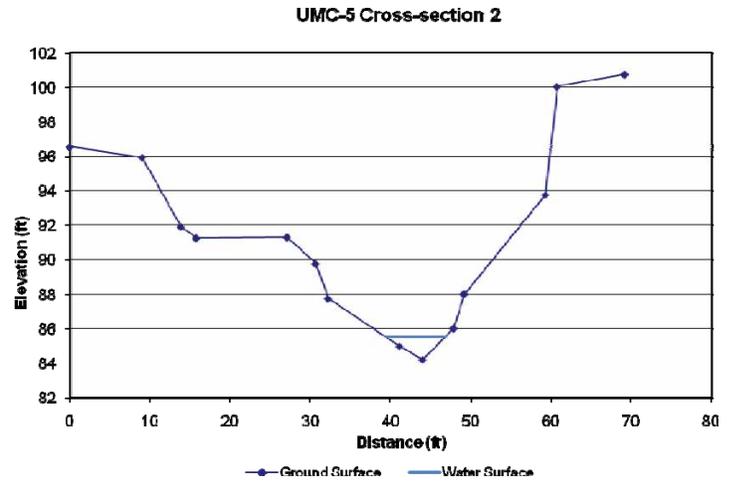
Cross section was surveyed during the 2008 field activities.



Photo 37: UMC5, XS-2, Right Bank (2009).



Photo 38: UMC5, XS-2, Right Bank (2010).



UMC-5, Cross-section 2, Right bank.

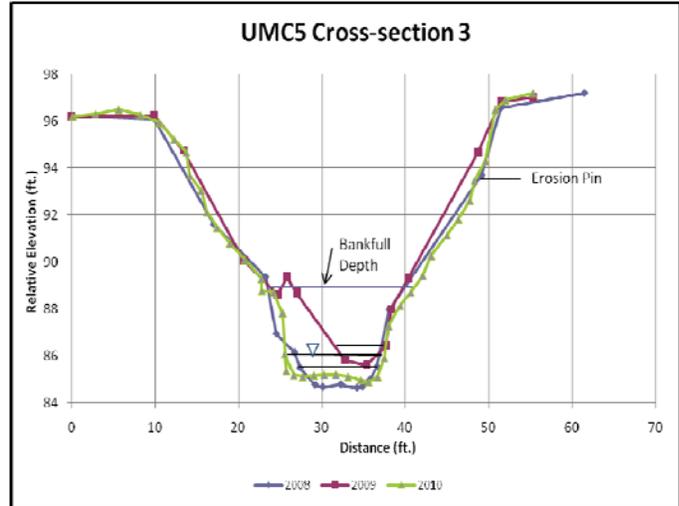
Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	2.8	9.0	8.3
Root Depth/Bank ht	0.1	8.5	8.5
Root Density	<5%	10	10
Bank Angle	52	3.5	5.2
Surface Protection	10%	9.0	6.5
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	40	38.5
<b>BEHI Rating</b>	--	<b>Very High</b>	<b>High</b>
Radius of Curvature	Straight		--
Bankfull Width	--		--
<b>NBS Rating</b>	--		<b>N/A</b>

Note:

Cross section was surveyed during the 2008 field activities.



Photo 39: UMC5, XS-3, Right Bank (2008).



UMC-5, Cross-section 3, Right bank

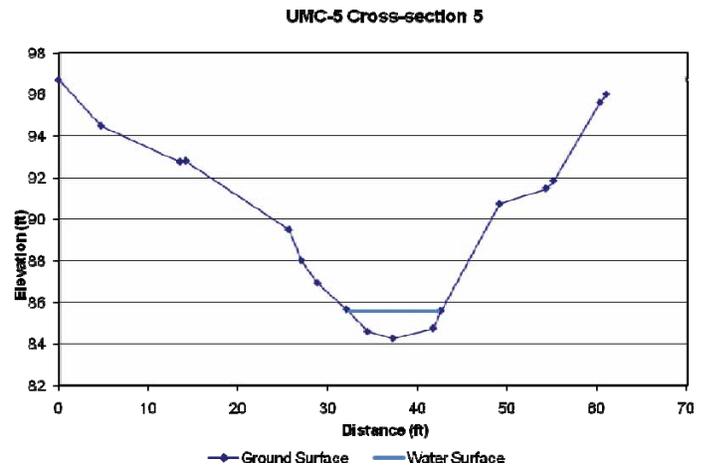
Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	3	10	8.7
Root Depth/Bank ht	0.2	7.4	7.4
Root Density	<5%	10	10
Bank Angle	53	3.55	5
Surface Protection	43%	4.9	10
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	35.85	41.1
<b>BEHI Rating</b>	--	<b>High</b>	<b>Very High</b>
Radius of Curvature			--
Bankfull Width			--
Rc/W			--
<b>NBS Rating</b>	--		<b>Low</b>



Photo 40: UMC5, XS-3, Right Bank (2009).



Photo 41: UMC5, XS-5, Right Bank (2008).



UMC-5, Cross-section 5, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	1.9	7.5	7.5
Root Depth/Bank ht	0.2	7.5	7.5
Root Density	<5%	10	10
Bank Angle	60	3.9	4
Surface Protection	56%	3.85	5.5
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	32.75	34.5
<b>BEHI Rating</b>	--	<b>High</b>	<b>High</b>
Radius of Curvature		--	--
Bankfull Width		--	--
<b>NBS Rating</b>		<b>N/A</b>	<b>N/A</b>



Photo 42: UMC5, XS-5, Right Bank (2010).

Note:

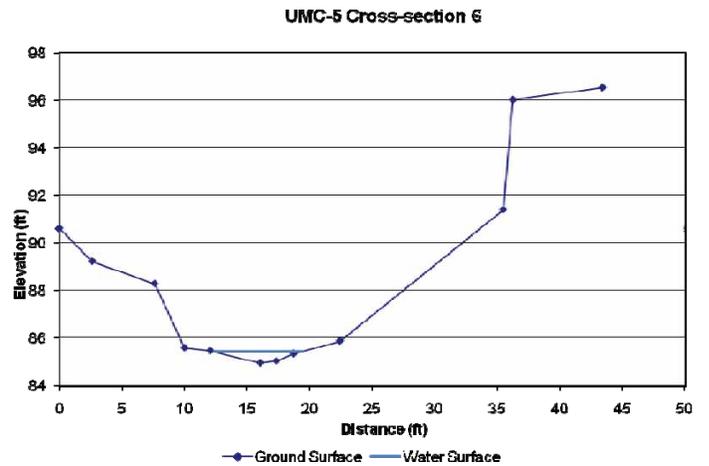
Cross section was surveyed during the 2008 field activities.



Photo 43: UMC5, XS-6, Right Bank (2008).



Photo 44: UMC5, XS-6, Right Bank (2010).



UMC-5, Cross-section 6, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	2.4	8.5	8.5
Root Depth/Bank ht	0.1	8.5	8.5
Root Density	<5%	10	10
Bank Angle	58	3.8	5
Surface Protection	13%	8.25	6.1
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	39.05	38.1
<b>BEHI Rating</b>	--	<b>High</b>	<b>High</b>
Radius of Curvature			--
Bankfull Width			--
Rc/W			--
<b>NBS Rating</b>			<b>Very Low</b>

Note:

Cross section was surveyed during the 2008 field activities.



Photo 45: UMC6, XS-1, Left Bank (2009).



Photo 46: UMC6, XS-1, Left Bank (2010).

UMC-6, Cross-section 1, Left bank

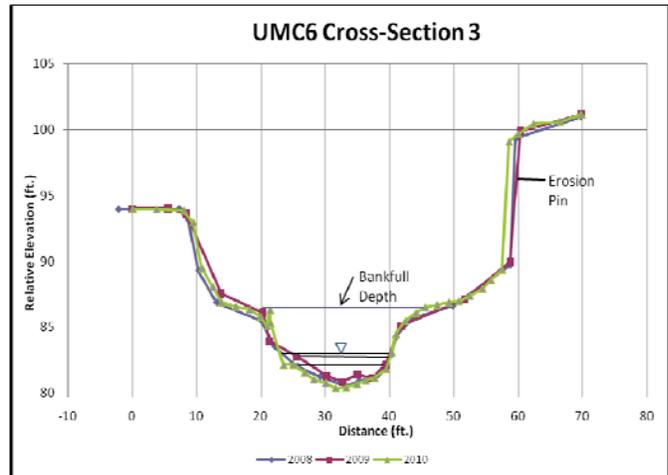
Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	3.3	10	10
Root Depth/Bank ht	0.1	8.5	8.5
Root Density	<5%	10	10
Bank Angle	>90	8.5	8.5
Surface Protection	0%	10	10
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	47	47
<b>BEHI Rating</b>	--	<b>Extreme</b>	<b>Extreme</b>

Notes:

No cross section available – angle was estimated.  
 Cross section was surveyed during the 2008 field activities.



Photo 47: UMC6, XS-3, Right Bank (2008).



UMC-6, Cross-section 3, Right bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth			10
Root Depth/Bank ht	2.7	8.9	8.5
Root Density	<5%	10	10
Bank Angle	48	5.3	4.1
Surface Protection	15%	7.9	6.2
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	40.6	38.8
<b>BEHI Rating</b>	--	<b>Very High</b>	<b>High</b>



Photo 48: UMC6, XS-3, Right Bank (2010).



Photo 49: UMC6, XS-4, Right Bank (2008).



Photo 50: UMC6, XS-4, Right Bank (2010).

UMC-6, Cross-section 4, Right bank

Category	2010 Value	2010 Index	2010 Index
Bank ht/Bankfull Depth	2.6	8.8	10
Root Depth/Bank ht	0.05	10	10
Root Density	<5%	10	10
Bank Angle	>90	8.5	8.5
Surface Protection	0%	10	10
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	47.3	48.5
<b>BEHI Rating</b>	--	<b>Extreme</b>	<b>Extreme</b>

Notes:

No cross section available – angle was estimated.

Cross section was surveyed during the 2008 field activities.



Photo 51: UMC6, XS-6, Left Bank (2008).



Photo 52: UMC6, XS-6, Left Bank (2010).

UMC-6, Cross-section 6, Left bank

Category	2010 Value	2010 Index	2008 Index
Bank ht/Bankfull Depth	3.8	10	10
Root Depth/Bank ht	0.17	7.7	7.7
Root Density	<5%	10	10
Bank Angle	80	5.9	7.9
Surface Protection	0%	10	10
Bank Material	Silt	0	0
Stratification	None	0	0
Index sum	--	43.6	45.6
<b>BEHI Rating</b>	--	<b>Very High</b>	<b>Extreme</b>

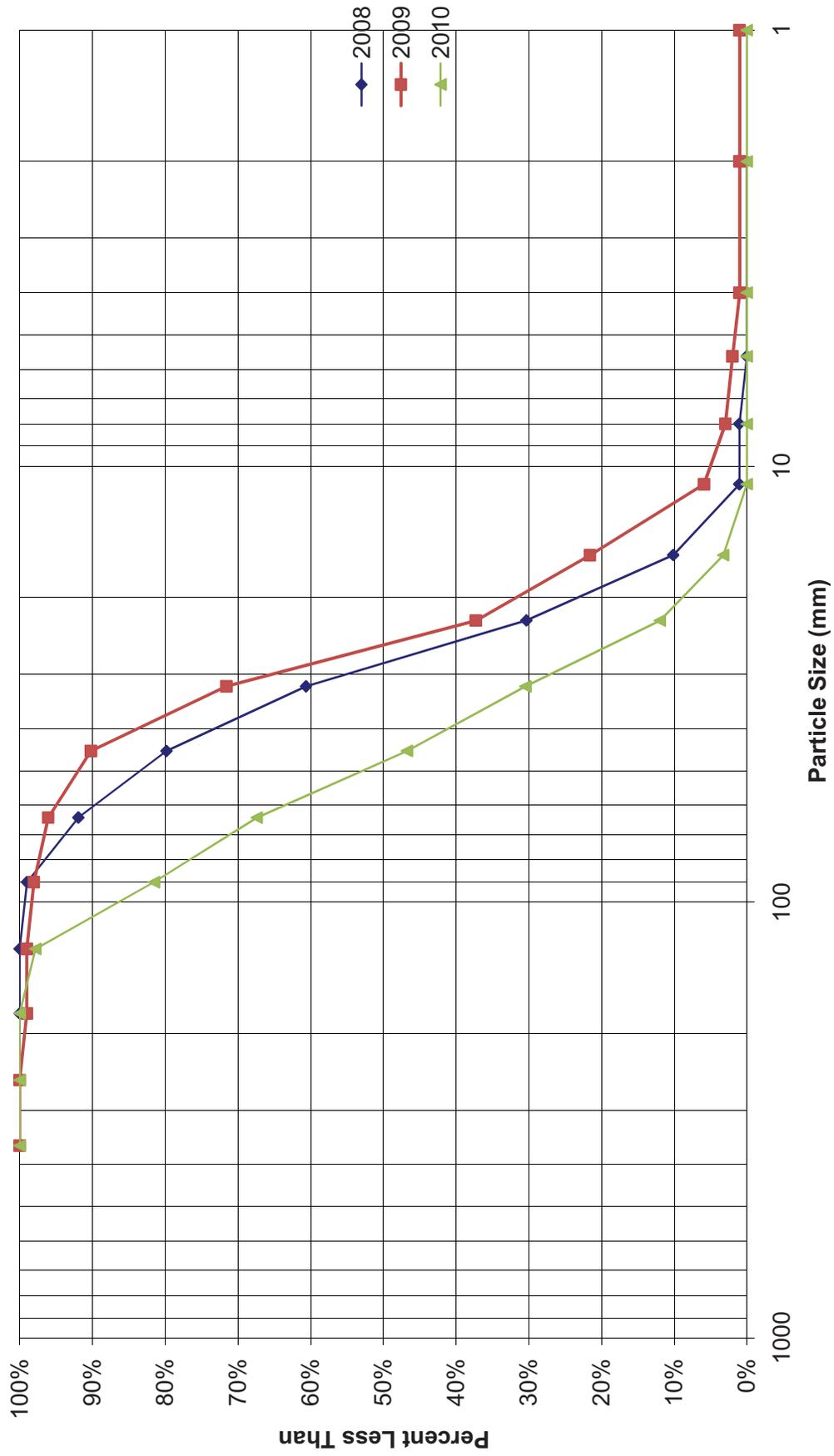
Notes:

No cross section available – angle was estimated.  
 Cross section was surveyed during the 2008 field activities.

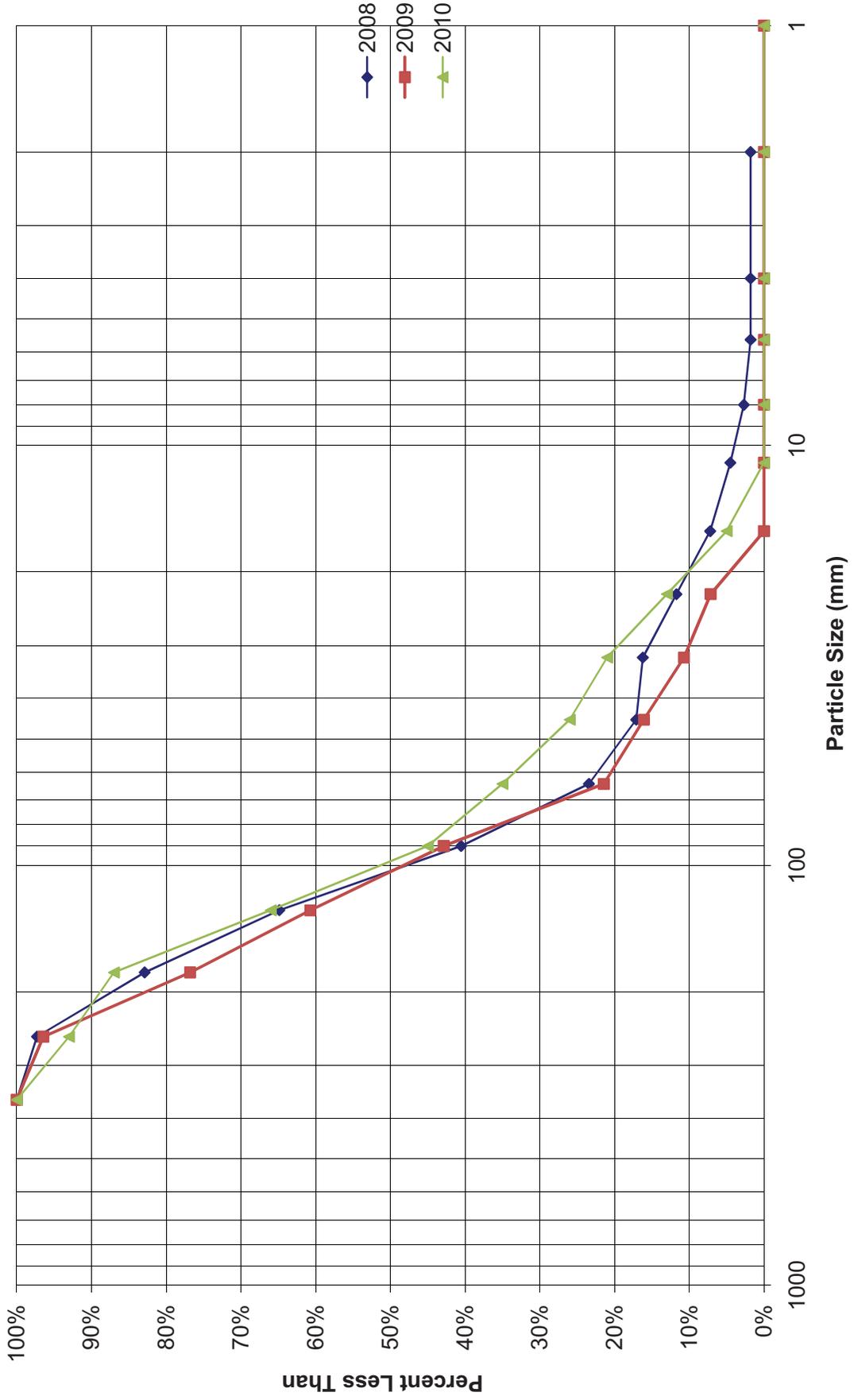
# **Appendix C**

## **Cumulative Sediment Size Distributions**

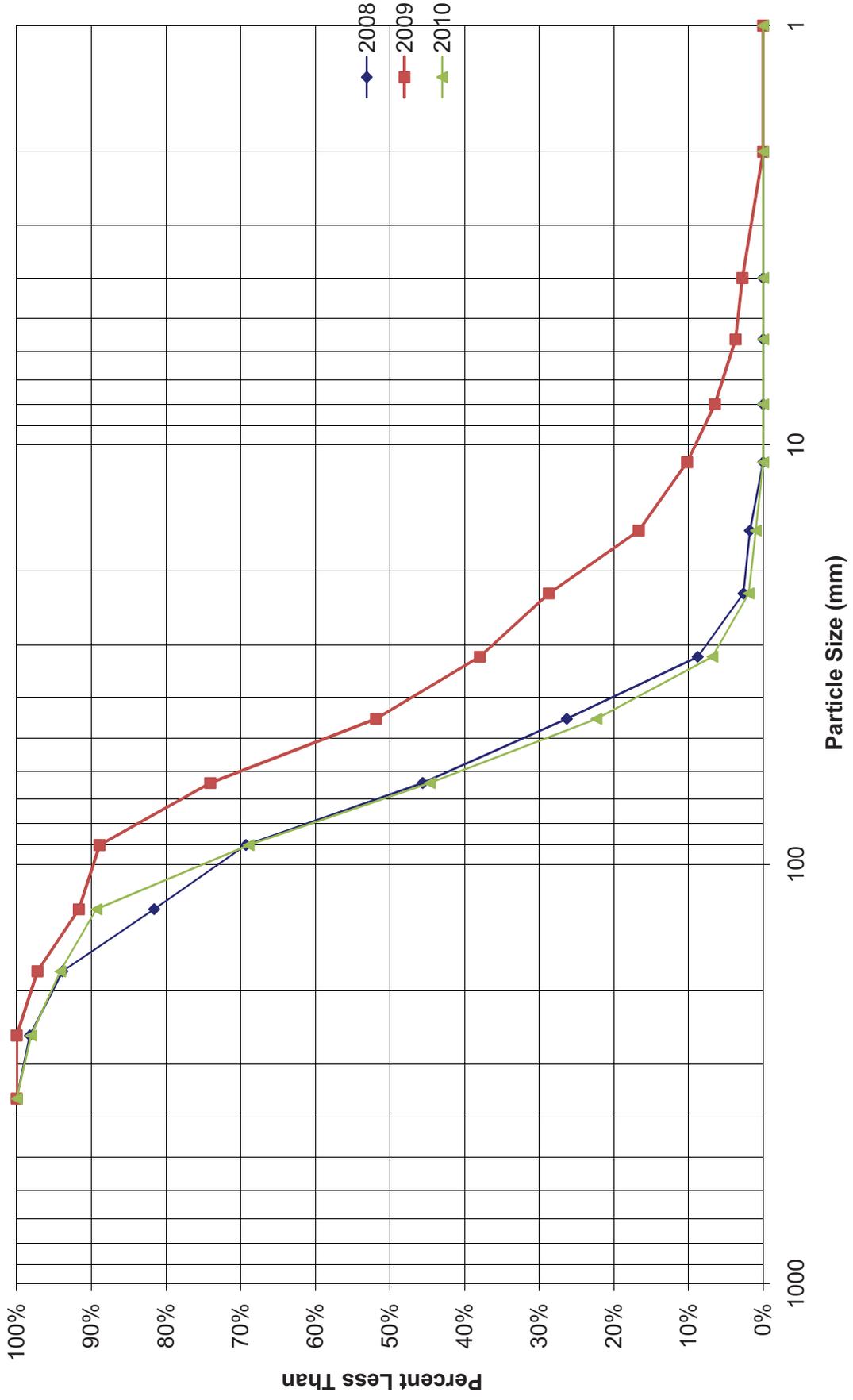
UMC1 - XS-1  
Pebble Count Cumulative Size Distributions  
Upper Muddy Creek, Carbon County, Wyoming



UMC1 - XS-4  
Pebble Count Cumulative Size Distributions  
Upper Muddy Creek, Carbon County, Wyoming

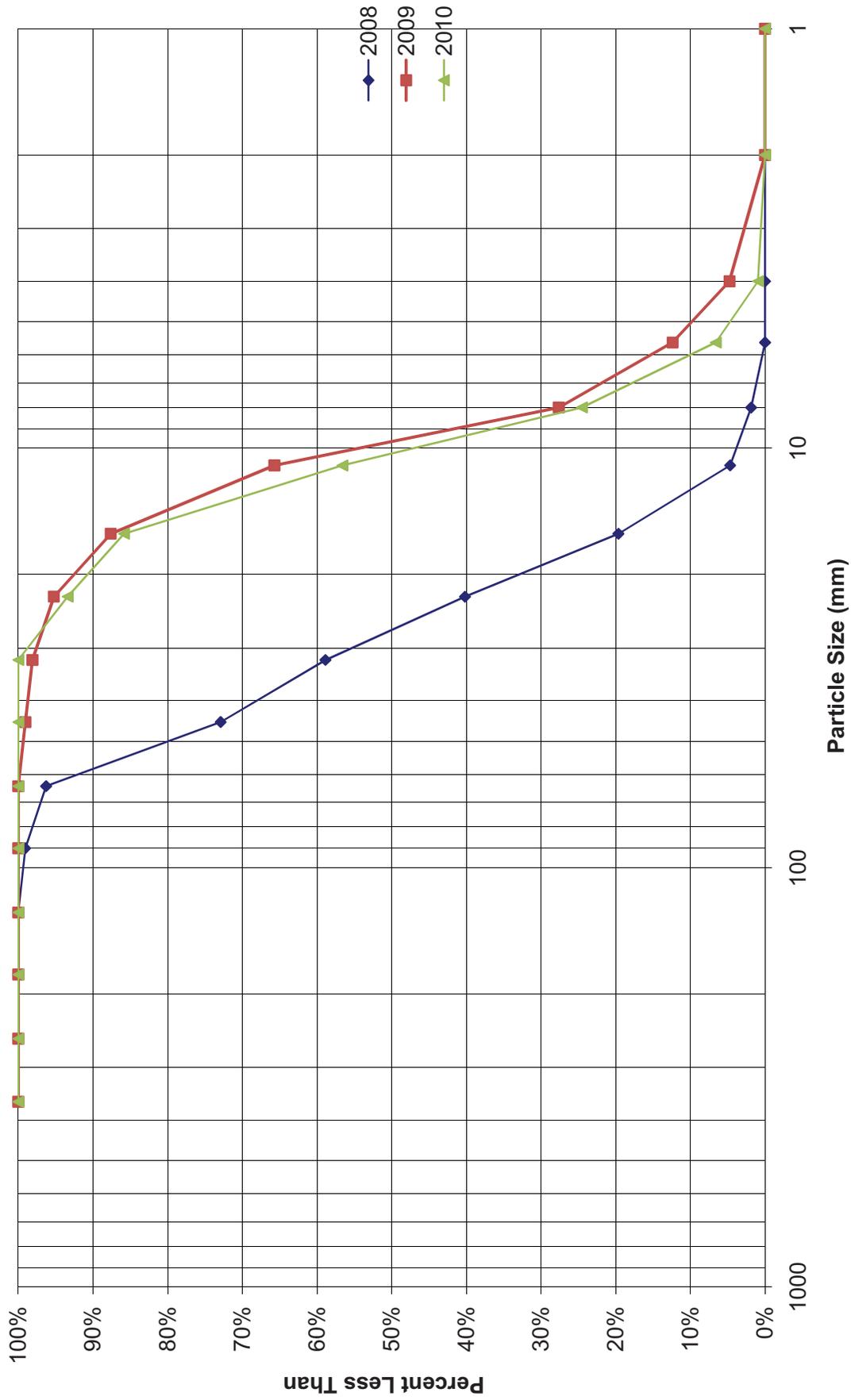


UMC1 - XS-6  
Pebble Count Cumulative Size Distributions  
Upper Muddy Creek, Carbon County, Wyoming

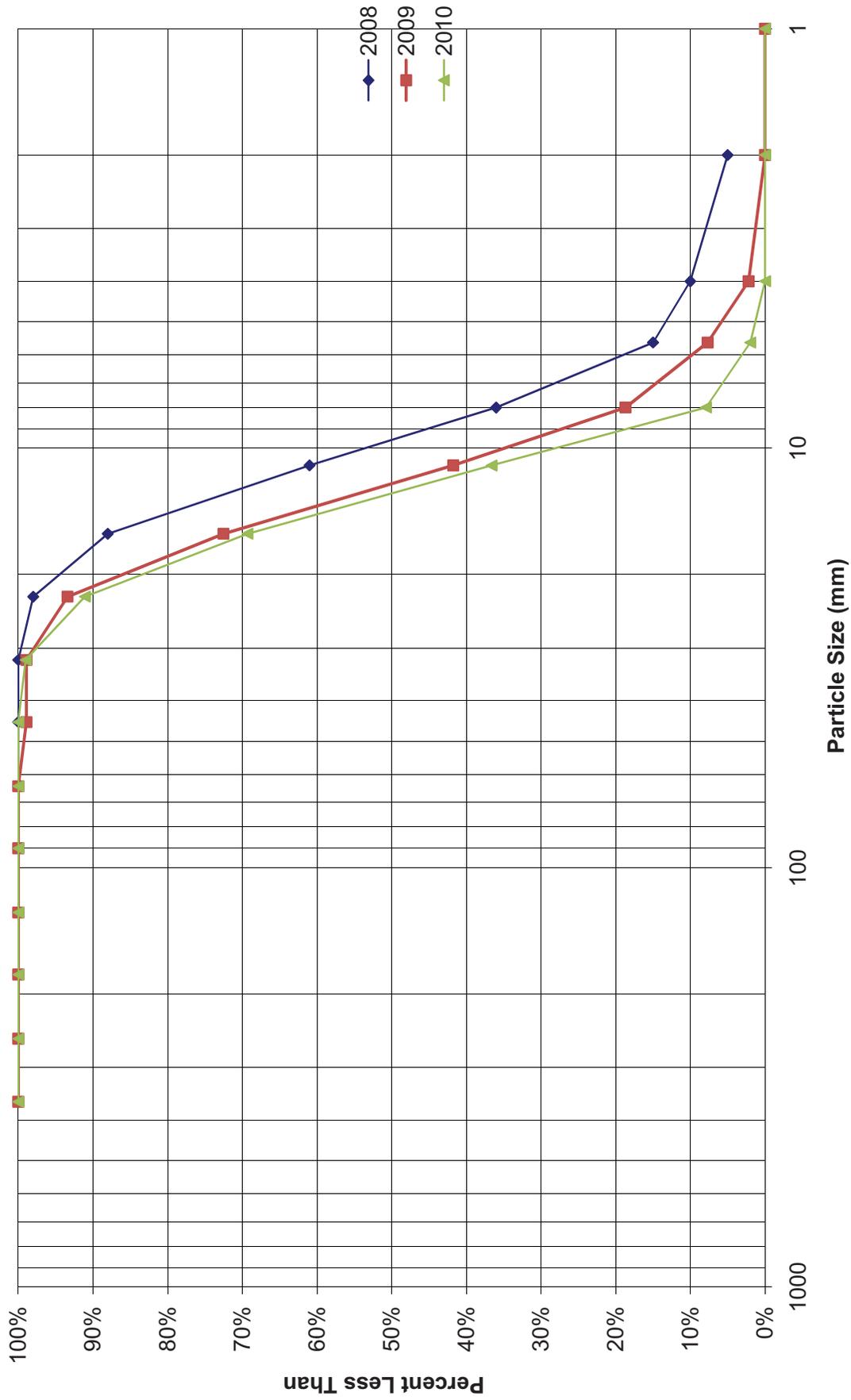




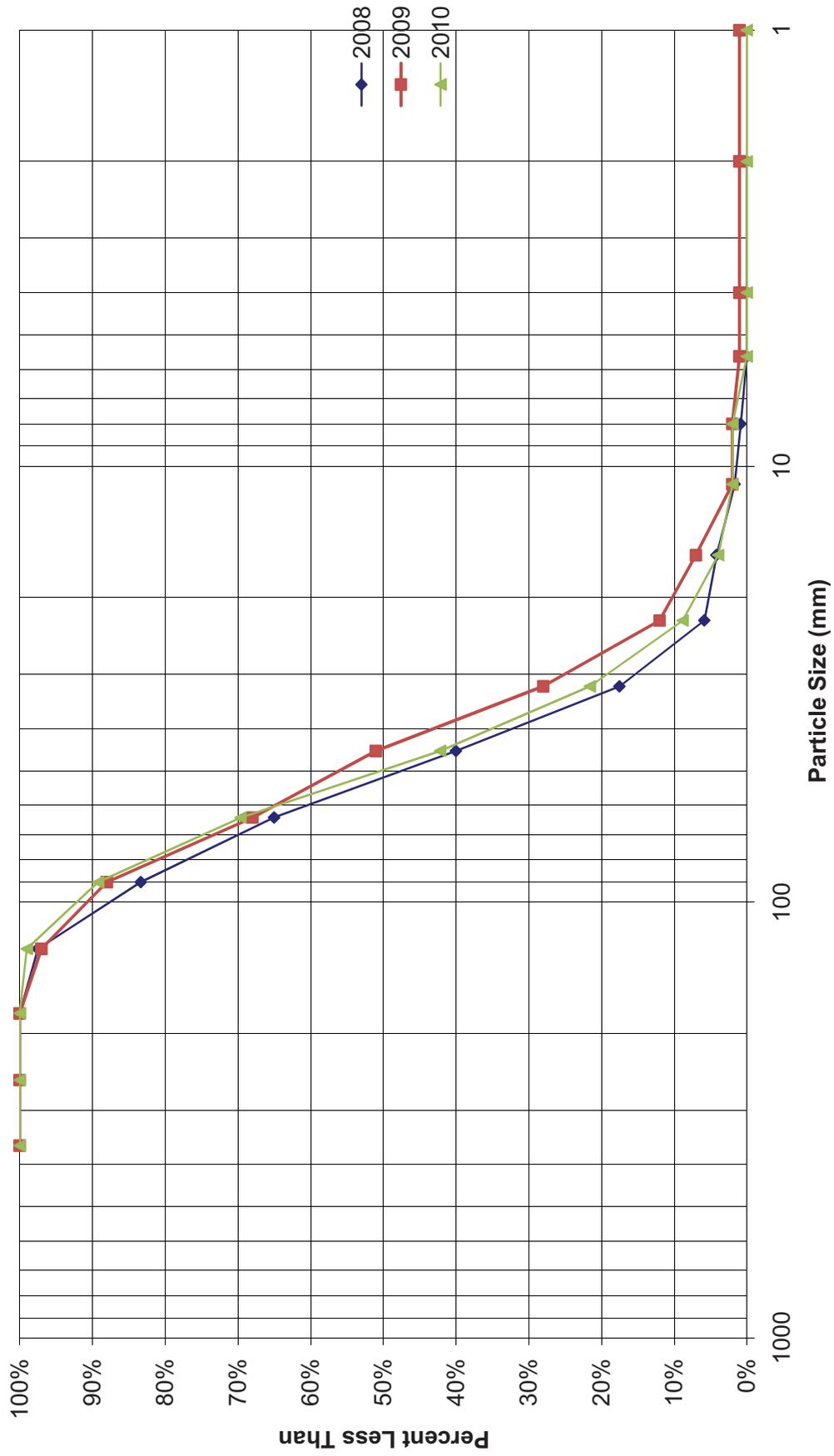
UMC2 - XS-3  
Pebble Count Cumulative Size Distributions  
Upper Muddy Creek, Carbon County, Wyoming



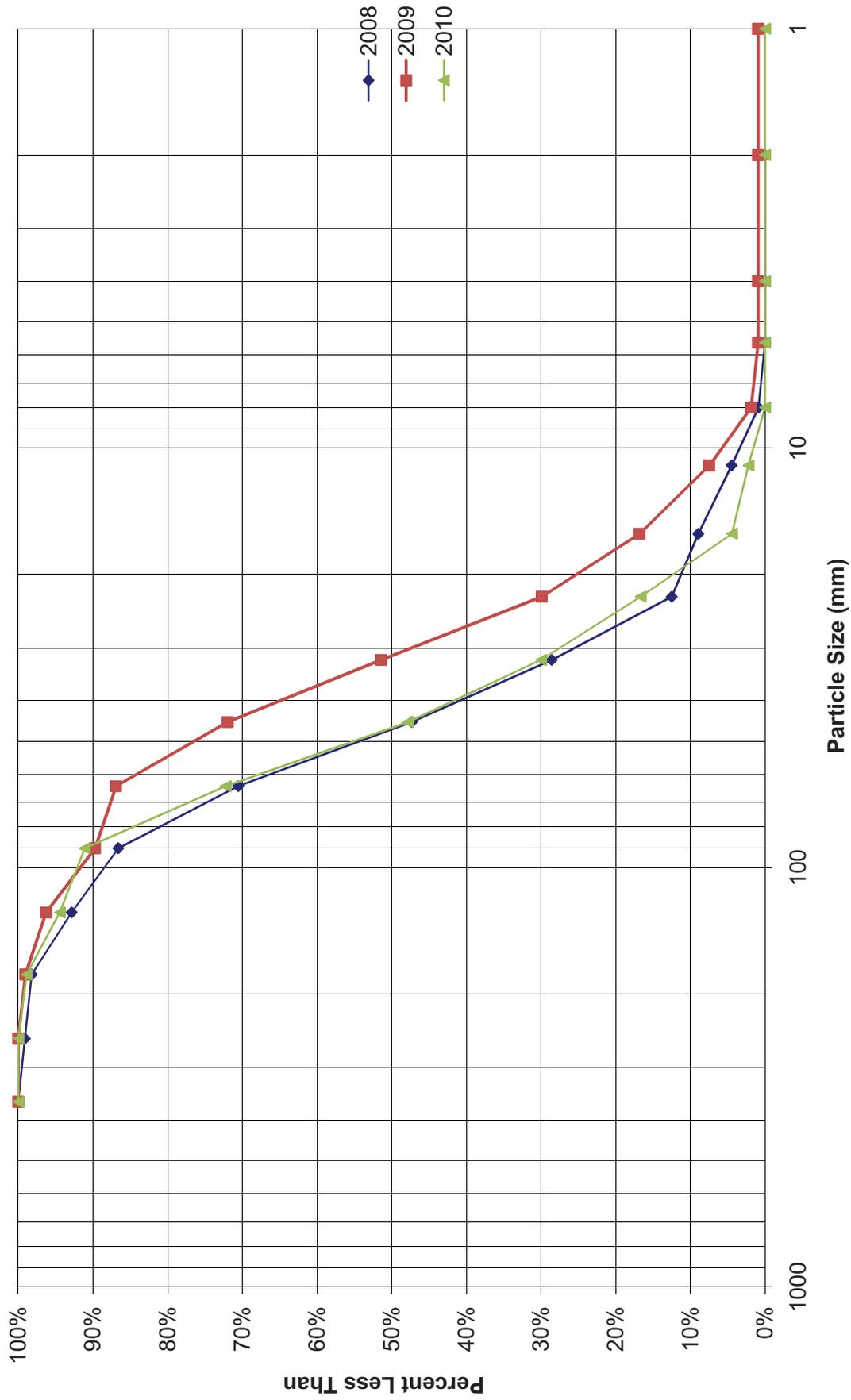
UMC2 - XS-6  
Pebble Count Cumulative Size Distributions  
Upper Muddy Creek, Carbon County, Wyoming



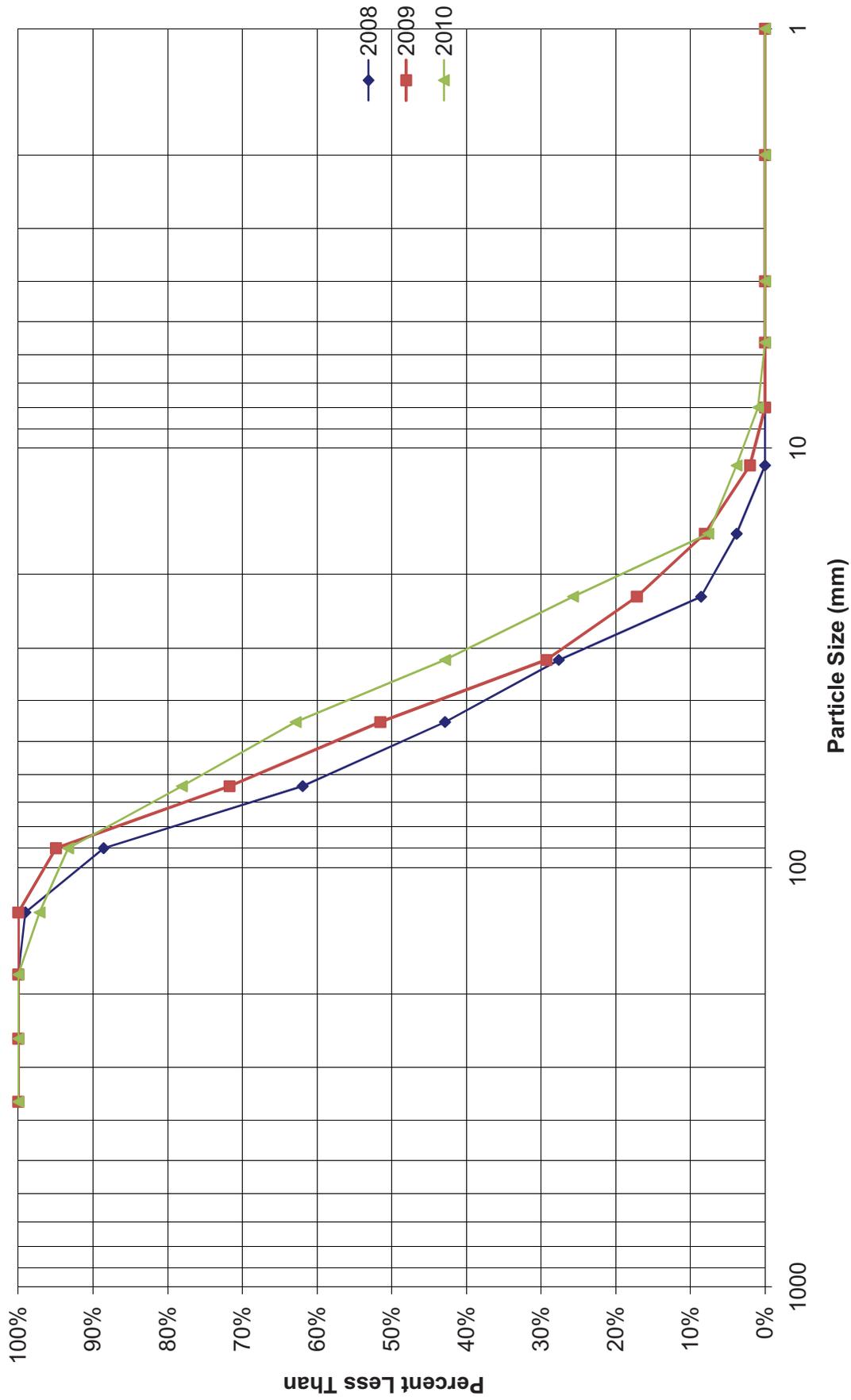
UMC3 - XS-1  
Pebble Count Cumulative Size Distributions  
Upper Muddy Creek, Carbon County, Wyoming



UMC3 - XS-4  
Pebble Count Cumulative Size Distributions  
Upper Muddy Creek, Carbon County, Wyoming



UMC3 - XS-6  
Pebble Count Cumulative Size Distributions  
Upper Muddy Creek, Carbon County, Wyoming



**Appendix D**  
**Laboratory Data Sheets**

## ANALYTICAL SUMMARY REPORT

September 01, 2010

Bill Bucher  
Camp Dresser and McKee Inc  
50 W 14th St Ste 200  
Helena, MT 59601

Workorder No.: H10080327

Project Name: Anadarko - Muddy Creek

Energy Laboratories Inc received the following 4 samples for Camp Dresser and McKee Inc on 8/23/2010 for analysis.

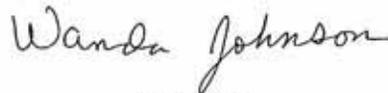
Sample ID	Client Sample ID	Collect Date	Receive Date	Matrix	Test
H10080327-001	UMC-1	08/19/10 12:00	08/23/10	Aqueous	Metals by ICP/ICPMS, Dissolved Alkalinity Conductivity Anions by Ion Chromatography Preparation for TSS Solids, Total Suspended
H10080327-002	UMC-3	08/17/10 16:15	08/23/10	Aqueous	Same As Above
H10080327-003	UMC-6	08/20/10 13:20	08/23/10	Aqueous	Same As Above
H10080327-004	UMC-6D	08/20/10 13:30	08/23/10	Aqueous	Same As Above

This report was prepared by Energy Laboratories, Inc., 3161 E. Lyndale Ave., Helena, MT 59604. Any exceptions or problems with the analyses are noted in the Laboratory Analytical Report, the QA/QC Summary Report, or the Case Narrative.

The results as reported relate only to the item(s) submitted for testing.

If you have any questions regarding these test results, please call.

Report Approved By:



Login Supervisor

Digitally signed by  
Wanda Johnson

Date: 2010.09.01 19:05:52 -06:00

### LABORATORY ANALYTICAL REPORT

**Client:** Camp Dresser and McKee Inc  
**Project:** Anadarko - Muddy Creek  
**Lab ID:** H10080327-001  
**Client Sample ID** UMC-1

**Report Date:** 09/01/10  
**Collection Date:** 08/19/10 12:00  
**Date Received:** 08/23/10  
**Matrix:** Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
<b>PHYSICAL PROPERTIES</b>							
Solids, Total Suspended TSS @ 105 C	28	mg/L		10		A2540 D	08/23/10 15:19 / glj
<b>INORGANICS</b>							
Alkalinity, Total as CaCO3	180	mg/L		4		A2320 B	08/31/10 12:04 / zeg
Chloride	6	mg/L		1		E300.0	08/26/10 10:02 / zeg
Sulfate	170	mg/L		1		E300.0	08/26/10 10:02 / zeg
<b>METALS, DISSOLVED</b>							
Calcium	69	mg/L		1		E200.7	08/26/10 14:46 / sid
Magnesium	25	mg/L		1		E200.7	08/24/10 12:31 / sid
Potassium	4	mg/L		1		E200.7	08/24/10 12:31 / sid
Selenium	ND	mg/L		0.005		E200.8	08/28/10 03:50 / dck
Sodium	29	mg/L		1		E200.7	08/24/10 12:31 / sid

**Report Definitions:** RL - Analyte reporting limit.  
QCL - Quality control limit.

MCL - Maximum contaminant level.  
ND - Not detected at the reporting limit.

### LABORATORY ANALYTICAL REPORT

**Client:** Camp Dresser and McKee Inc  
**Project:** Anadarko - Muddy Creek  
**Lab ID:** H10080327-002  
**Client Sample ID** UMC-3

**Report Date:** 09/01/10  
**Collection Date:** 08/17/10 16:15  
**Date Received:** 08/23/10  
**Matrix:** Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
<b>PHYSICAL PROPERTIES</b>							
Solids, Total Suspended TSS @ 105 C	19	mg/L		10		A2540 D	08/23/10 15:19 / glj
<b>INORGANICS</b>							
Alkalinity, Total as CaCO3	180	mg/L		4		A2320 B	08/31/10 12:14 / zeg
Chloride	6	mg/L		1		E300.0	08/26/10 10:54 / zeg
Sulfate	180	mg/L		1		E300.0	08/26/10 10:54 / zeg
<b>METALS, DISSOLVED</b>							
Calcium	70	mg/L		1		E200.7	08/26/10 14:55 / sld
Magnesium	27	mg/L		1		E200.7	08/24/10 12:40 / sld
Potassium	4	mg/L		1		E200.7	08/24/10 12:40 / sld
Selenium	ND	mg/L		0.005		E200.8	08/28/10 04:24 / dck
Sodium	32	mg/L		1		E200.7	08/24/10 12:40 / sld

**Report Definitions:** RL - Analyte reporting limit.  
QCL - Quality control limit.

MCL - Maximum contaminant level.  
ND - Not detected at the reporting limit.

### LABORATORY ANALYTICAL REPORT

**Client:** Camp Dresser and McKee Inc  
**Project:** Anadarko - Muddy Creek  
**Lab ID:** H10080327-003  
**Client Sample ID** UMC-6

**Report Date:** 09/01/10  
**Collection Date:** 08/20/10 13:20  
**Date Received:** 08/23/10  
**Matrix:** Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
<b>PHYSICAL PROPERTIES</b>							
Solids, Total Suspended TSS @ 105 C	29	mg/L		10		A2540 D	08/23/10 15:19 / glj
<b>INORGANICS</b>							
Alkalinity, Total as CaCO <sub>3</sub>	170	mg/L		4		A2320 B	08/31/10 13:04 / zeg
Chloride	7	mg/L		1		E300.0	08/26/10 11:11 / zeg
Sulfate	190	mg/L		1		E300.0	08/26/10 11:11 / zeg
<b>METALS, DISSOLVED</b>							
Calcium	71	mg/L		1		E200.7	08/26/10 14:59 / sld
Magnesium	27	mg/L		1		E200.7	08/24/10 12:49 / sld
Potassium	4	mg/L		1		E200.7	08/24/10 12:49 / sld
Selenium	ND	mg/L		0.005		E200.8	08/28/10 04:30 / dck
Sodium	36	mg/L		1		E200.7	08/24/10 12:49 / sld

**Report Definitions:** RL - Analyte reporting limit.  
QCL - Quality control limit.

MCL - Maximum contaminant level.  
ND - Not detected at the reporting limit.

### LABORATORY ANALYTICAL REPORT

**Client:** Camp Dresser and McKee Inc  
**Project:** Anadarko - Muddy Creek  
**Lab ID:** H10080327-004  
**Client Sample ID:** UMC-6D

**Report Date:** 09/01/10  
**Collection Date:** 08/20/10 13:30  
**Date Received:** 08/23/10  
**Matrix:** Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
<b>PHYSICAL PROPERTIES</b>							
Solids, Total Suspended TSS @ 105 C	20	mg/L		10		A2540 D	08/23/10 15:19 / glj
<b>INORGANICS</b>							
Alkalinity, Total as CaCO3	170	mg/L		4		A2320 B	08/31/10 13:12 / zeg
Chloride	7	mg/L		1		E300.0	08/26/10 12:04 / zeg
Sulfate	190	mg/L		1		E300.0	08/26/10 12:04 / zeg
<b>METALS, DISSOLVED</b>							
Calcium	73	mg/L		1		E200.7	08/26/10 15:02 / sld
Magnesium	28	mg/L		1		E200.7	08/24/10 12:52 / sld
Potassium	4	mg/L		1		E200.7	08/24/10 12:52 / sld
Selenium	ND	mg/L		0.005		E200.8	08/28/10 04:57 / dck
Sodium	36	mg/L		1		E200.7	08/24/10 12:52 / sld

**Report Definitions:** RL - Analyte reporting limit.  
QCL - Quality control limit.

MCL - Maximum contaminant level.  
ND - Not detected at the reporting limit.

## QA/QC Summary Report

**Client:** Camp Dresser and McKee Inc  
**Project:** Anadarko - Muddy Creek

**Report Date:** 09/01/10  
**Work Order:** H10080327

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
<b>Method:</b> A2320 B								Batch: 100831A-ALK-W		
<b>Sample ID:</b> MBLK1_100831A	Method Blank					Run: TITTR_100831A		08/31/10 11:46		
Alkalinity, Total as CaCO3	2	mg/L	1							
<b>Sample ID:</b> LCS1_100831A	Laboratory Control Sample					Run: TITTR_100831A		08/31/10 11:51		
Alkalinity, Total as CaCO3	620	mg/L	4.0	103	90	110				
<b>Sample ID:</b> H10080327-002ADUP	Sample Duplicate					Run: TITTR_100831A		08/31/10 12:52		
Alkalinity, Total as CaCO3	170	mg/L	4.0					5.7	20	
<b>Sample ID:</b> H10080327-004AMS	Sample Matrix Spike					Run: TITTR_100831A		08/31/10 13:23		
Alkalinity, Total as CaCO3	740	mg/L	4.0	95	90	110				

**Qualifiers:**

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

## QA/QC Summary Report

**Client:** Camp Dresser and McKee Inc  
**Project:** Anadarko - Muddy Creek

**Report Date:** 09/01/10  
**Work Order:** H10080327

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
<b>Method: A2540 D</b>										Batch: 9630
<b>Sample ID: LCS-9630</b>										
Laboratory Control Sample										Run: ACCU-124 (14410200)_100823 08/23/10 15:17
Solids, Total Suspended TSS @ 105 C		1810	mg/L	10	91	70	130			
<b>Sample ID: MB-9630</b>										
Method Blank										Run: ACCU-124 (14410200)_100823 08/23/10 15:18
Solids, Total Suspended TSS @ 105 C		1	mg/L	1						

**Qualifiers:**

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

## QA/QC Summary Report

**Client:** Camp Dresser and McKee Inc  
**Project:** Anadarko - Muddy Creek

**Report Date:** 09/01/10  
**Work Order:** H10080327

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual	
<b>Method: E200.7</b>								Analytical Run: ICP1-HE_100824A			
<b>Sample ID: ICV</b>	3	Initial Calibration Verification Standard									08/24/10 11:35
Magnesium		38.4	mg/L	1.0	96	95	105				
Potassium		39.0	mg/L	1.0	97	95	105				
Sodium		40.9	mg/L	1.0	102	95	105				
<b>Sample ID: CCV-1</b>	3	Continuing Calibration Verification Standard									08/24/10 11:41
Magnesium		23.9	mg/L	1.0	95	95	105				
Potassium		25.2	mg/L	1.0	101	95	105				
Sodium		25.7	mg/L	1.0	103	95	105				
<b>Sample ID: ICSA</b>	3	Interference Check Sample A									08/24/10 11:54
Magnesium		528	mg/L	1.0	106	80	120				
Potassium		0.113	mg/L	1.0		0	0				
Sodium		0.131	mg/L	1.0		0	0				
<b>Sample ID: ICSAB</b>	3	Interference Check Sample AB									08/24/10 11:57
Magnesium		552	mg/L	1.0	110	80	120				
Potassium		21.2	mg/L	1.0	106	80	120				
Sodium		21.2	mg/L	1.0	106	80	120				
<b>Sample ID: CCV</b>	3	Continuing Calibration Verification Standard									08/24/10 12:01
Magnesium		25.2	mg/L	1.0	101	90	110				
Potassium		25.2	mg/L	1.0	101	90	110				
Sodium		25.6	mg/L	1.0	103	90	110				
<b>Sample ID: CCV</b>	3	Continuing Calibration Verification Standard									08/24/10 12:43
Magnesium		24.1	mg/L	1.0	96	90	110				
Potassium		24.9	mg/L	1.0	99	90	110				
Sodium		25.4	mg/L	1.0	101	90	110				
<b>Sample ID: ICSA</b>	3	Interference Check Sample A									08/24/10 14:56
Magnesium		518	mg/L	1.0	104	80	120				
Potassium		0.116	mg/L	1.0		0	0				
Sodium		0.123	mg/L	1.0		0	0				
<b>Sample ID: ICSAB</b>	3	Interference Check Sample AB									08/24/10 14:59
Magnesium		517	mg/L	1.0	103	80	120				
Potassium		20.8	mg/L	1.0	104	80	120				
Sodium		21.8	mg/L	1.0	109	80	120				
<b>Method: E200.7</b>								Batch: R64814			
<b>Sample ID: ICB</b>	3	Method Blank									08/24/10 12:12
Magnesium		ND	mg/L	0.02							
Potassium		ND	mg/L	0.04							
Sodium		ND	mg/L	0.1							
<b>Sample ID: LFB</b>	3	Laboratory Fortified Blank									08/24/10 12:15
Magnesium		9.70	mg/L	1.0	97	85	115				

**Qualifiers:**

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ND - Not detected at the reporting limit.

## QA/QC Summary Report

**Client:** Camp Dresser and McKee Inc  
**Project:** Anadarko - Muddy Creek

**Report Date:** 09/01/10  
**Work Order:** H10080327

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
<b>Method: E200.7</b> <span style="float: right;">Batch: R64814</span>										
<b>Sample ID: LFB</b>	3	Laboratory Fortified Blank								08/24/10 12:15
Potassium		10.3	mg/L	1.0	103	85	115			
Sodium		9.96	mg/L	1.0	100	85	115			
<b>Sample ID: H10080327-001BMS2</b>	3	Sample Matrix Spike								08/24/10 12:34
Magnesium		43.2	mg/L	1.0	89	70	130			
Potassium		24.5	mg/L	1.0	105	70	130			
Sodium		50.7	mg/L	1.0	109	70	130			
<b>Sample ID: H10080327-001BMDS2</b>	3	Sample Matrix Spike Duplicate								08/24/10 12:37
Magnesium		43.0	mg/L	1.0	88	70	130	0.5	20	
Potassium		24.9	mg/L	1.0	107	70	130	1.5	20	
Sodium		48.5	mg/L	1.0	98	70	130	4.5	20	
<b>Method: E200.7</b> <span style="float: right;">Analytical Run: ICP1-HE_100826D</span>										
<b>Sample ID: ICV</b>		Initial Calibration Verification Standard								08/26/10 12:56
Calcium		41.4	mg/L	1.0	103	95	105			
<b>Sample ID: ICSA</b>		Interference Check Sample A								08/26/10 13:13
Calcium		504	mg/L	1.0	101	80	120			
<b>Sample ID: ICSAB</b>		Interference Check Sample AB								08/26/10 13:16
Calcium		501	mg/L	1.0	100	80	120			
<b>Sample ID: CCV</b>		Continuing Calibration Verification Standard								08/26/10 14:40
Calcium		25.0	mg/L	1.0	100	90	110			
<b>Sample ID: ICSA</b>		Interference Check Sample A								08/26/10 17:00
Calcium		500	mg/L	1.0	100	80	120			
<b>Sample ID: ICSAB</b>		Interference Check Sample AB								08/26/10 17:03
Calcium		515	mg/L	1.0	103	80	120			
<b>Method: E200.7</b> <span style="float: right;">Batch: R64893</span>										
<b>Sample ID: ICB</b>		Method Blank								08/26/10 14:19
Calcium		ND	mg/L	0.1						
<b>Sample ID: LFB</b>		Laboratory Fortified Blank								08/26/10 14:22
Calcium		8.88	mg/L	1.0	89	85	115			
<b>Sample ID: H10080327-001BMS2</b>		Sample Matrix Spike								08/26/10 14:49
Calcium		91.0	mg/L	1.0	110	70	130			
<b>Sample ID: H10080327-001BMDS2</b>		Sample Matrix Spike Duplicate								08/26/10 14:52
Calcium		86.8	mg/L	1.0	90	70	130	4.7	20	

**Qualifiers:**

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## QA/QC Summary Report

**Client:** Camp Dresser and McKee Inc  
**Project:** Anadarko - Muddy Creek

**Report Date:** 09/01/10  
**Work Order:** H10080327

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual	
<b>Method:</b> E200.8										Analytical Run: ICPMS204-B_100827A	
<b>Sample ID:</b> ICV STD		Initial Calibration Verification Standard								08/27/10 12:24	
Selenium		0.0501	mg/L	0.0050	100	90	110				
<b>Sample ID:</b> ICSA		Interference Check Sample A								08/27/10 12:31	
Selenium		6.00E-05	mg/L	0.0050							
<b>Sample ID:</b> ICSAB		Interference Check Sample AB								08/27/10 12:38	
Selenium		0.0102	mg/L	0.0050	102	70	130				
<b>Sample ID:</b> ICV STD		Initial Calibration Verification Standard								08/28/10 00:34	
Selenium		0.0508	mg/L	0.0050	102	90	110				
<b>Sample ID:</b> ICSA		Interference Check Sample A								08/28/10 00:40	
Selenium		4.10E-05	mg/L	0.0050							
<b>Sample ID:</b> ICSAB		Interference Check Sample AB								08/28/10 00:47	
Selenium		0.0103	mg/L	0.0050	103	70	130				
<b>Sample ID:</b> ICV STD		Initial Calibration Verification Standard								08/28/10 12:58	
Selenium		0.0499	mg/L	0.0050	100	90	110				
<b>Sample ID:</b> ICSA		Interference Check Sample A								08/28/10 13:05	
Selenium		4.60E-05	mg/L	0.0050							
<b>Sample ID:</b> ICSAB		Interference Check Sample AB								08/28/10 13:12	
Selenium		0.0102	mg/L	0.0050	102	70	130				
<b>Method:</b> E200.8										Batch: R64906	
<b>Sample ID:</b> ICB		Method Blank								Run: ICPMS204-B_100827A	08/27/10 14:11
Selenium		ND	mg/L	3E-05							
<b>Sample ID:</b> LFB		Laboratory Fortified Blank								Run: ICPMS204-B_100827A	08/27/10 14:18
Selenium		0.0494	mg/L	0.0050	99	85	115				
<b>Sample ID:</b> H10080327-003BMS		Sample Matrix Spike								Run: ICPMS204-B_100827A	08/28/10 04:37
Selenium		0.0506	mg/L	0.0050	98	70	130				
<b>Sample ID:</b> H10080327-003BMSD		Sample Matrix Spike Duplicate								Run: ICPMS204-B_100827A	08/28/10 04:44
Selenium		0.0499	mg/L	0.0050	97	70	130	1.4	20		

**Qualifiers:**

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ND - Not detected at the reporting limit.

## QA/QC Summary Report

**Client:** Camp Dresser and McKee Inc  
**Project:** Anadarko - Muddy Creek

**Report Date:** 09/01/10  
**Work Order:** H10080327

Analyte	Count	Result	Units	RL	%REC	Low Limit	High Limit	RPD	RPDLimit	Qual
<b>Method: E300.0</b>								Analytical Run: IC101-H_100825A		
<b>Sample ID: ICV082510-12</b>	2	Initial Calibration Verification Standard								08/25/10 16:54
Chloride		23	mg/L	1.0	92	90	110			
Sulfate		91	mg/L	1.0	91	90	110			
<b>Sample ID: CCV082510-44</b>	2	Continuing Calibration Verification Standard								08/26/10 06:15
Chloride		24	mg/L	1.0	95	90	110			
Sulfate		95	mg/L	1.0	95	90	110			
<b>Sample ID: CCV082510-72</b>	2	Continuing Calibration Verification Standard								08/26/10 10:19
Chloride		24	mg/L	1.0	94	90	110			
Sulfate		95	mg/L	1.0	95	90	110			
<b>Method: E300.0</b>								Batch: R64854		
<b>Sample ID: ICB082510-13</b>	2	Method Blank								08/25/10 17:11
Chloride		ND	mg/L	0.2						
Sulfate		ND	mg/L	0.07						
<b>Sample ID: LFB082510-14</b>	2	Laboratory Fortified Blank								08/25/10 17:29
Chloride		23	mg/L	1.0	93	90	110			
Sulfate		91	mg/L	1.1	91	90	110			
<b>Sample ID: H10080316-004AMS</b>	2	Sample Matrix Spike								08/26/10 08:52
Chloride		24	mg/L	1.0	94	90	110			
Sulfate		96	mg/L	1.1	93	90	110			
<b>Sample ID: H10080316-004AMSD</b>	2	Sample Matrix Spike Duplicate								08/26/10 09:09
Chloride		24	mg/L	1.0	94	90	110	0.3	20	
Sulfate		96	mg/L	1.1	94	90	110	0.6	20	
<b>Sample ID: H10080327-003AMS</b>	2	Sample Matrix Spike								08/26/10 11:29
Chloride		31	mg/L	1.0	98	90	110			
Sulfate		300	mg/L	1.1	104	90	110			
<b>Sample ID: H10080327-003AMSD</b>	2	Sample Matrix Spike Duplicate								08/26/10 11:46
Chloride		31	mg/L	1.0	98	90	110	0.3	20	
Sulfate		300	mg/L	1.1	104	90	110	0.1	20	

**Qualifiers:**

RL - Analyte reporting limit.

ND - Not detected at the reporting limit.

# Workorder Receipt Checklist



H10080327

Camp Dresser and McKee Inc

Login completed by: Tracy L. Lorash

Date Received: 8/23/2010

Reviewed by: BL2000\ablackburn

Received by: abb

Reviewed Date: 8/25/2010

Carrier name: Hand Del

Shipping container/cooler in good condition?	Yes <input checked="" type="checkbox"/>	No <input type="checkbox"/>	Not Present <input type="checkbox"/>
Custody seals intact on shipping container/cooler?	Yes <input type="checkbox"/>	No <input type="checkbox"/>	Not Present <input checked="" type="checkbox"/>
Custody seals intact on sample bottles?	Yes <input type="checkbox"/>	No <input type="checkbox"/>	Not Present <input checked="" type="checkbox"/>
Chain of custody present?	Yes <input checked="" type="checkbox"/>	No <input type="checkbox"/>	
Chain of custody signed when relinquished and received?	Yes <input checked="" type="checkbox"/>	No <input type="checkbox"/>	
Chain of custody agrees with sample labels?	Yes <input type="checkbox"/>	No <input checked="" type="checkbox"/>	
Samples in proper container/bottle?	Yes <input checked="" type="checkbox"/>	No <input type="checkbox"/>	
Sample containers intact?	Yes <input checked="" type="checkbox"/>	No <input type="checkbox"/>	
Sufficient sample volume for indicated test?	Yes <input checked="" type="checkbox"/>	No <input type="checkbox"/>	
All samples received within holding time?	Yes <input checked="" type="checkbox"/>	No <input type="checkbox"/>	
Container/Temp Blank temperature:	3.2°C		
Water - VOA vials have zero headspace?	Yes <input type="checkbox"/>	No <input type="checkbox"/>	No VOA vials submitted <input checked="" type="checkbox"/>
Water - pH acceptable upon receipt?	Yes <input checked="" type="checkbox"/>	No <input type="checkbox"/>	Not Applicable <input type="checkbox"/>

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Contact and Corrective Action Comments:

Sample UMC-1 has a collection time of 12:00 on COC - 12:10 on bottles. Rcv'd 250ml unpreserved bottle with no sample ID on it with a collection date of 8/20/10 and collection time of 13:30, which matches information for sample UMC-6D.

