Atlantic Rim Natural Gas Project
Carbon County, Wyoming

July 2008

Muddy Creek Monitoring Plan

CDM

Contents

Section 1
Introduction

This monitoring plan has been prepared to guide geomorphic, aquatic habitat, and water quality monitoring on upper Muddy Creek in the Atlantic Rim Natural Gas Project area. The Atlantic Rim Natural Gas Project in Carbon County, Wyoming is a natural gas project to be developed on public and private land by Anadarko and other operators (Figure 1-1). Development will occur in a 270,080 acre area and requires construction of roads, pipelines, well pads, compressor stations and gas processing facilities, drilling 2,000 wells, and production of water (BLM, 2006). The portion of the upper Muddy Creek drainage where development will take place is shown in Figure 1-2. 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 affects the non-game, native fish population. The potential adverse effects caused by natural gas 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 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, 2007) 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. This monitoring plan addresses monitoring activities that will take place on upper Muddy Creek.

1.2 Project Organization

Monitoring of upper Muddy Creek described in this plan is the responsibility of Anadarko and its consultant. Additional monitoring tasks will be conducted on upper Muddy Creek as well as on lower Muddy Creek and Muddy Creek tributaries by various agencies. Water quality data will be collected throughout the Muddy Creek drainage by the Little Snake River Conservation District (LSRCD) as it has been in the past. The LSRCD will also measure flows at these stations. The Wyoming Game and Fish Department (WGFD) will continue fish distribution and population studies in the drainage as well. The BLM as the lead agency for the Atlantic Rim Development Project will coordinate the various monitoring efforts through the Muddy Creek Working Group.

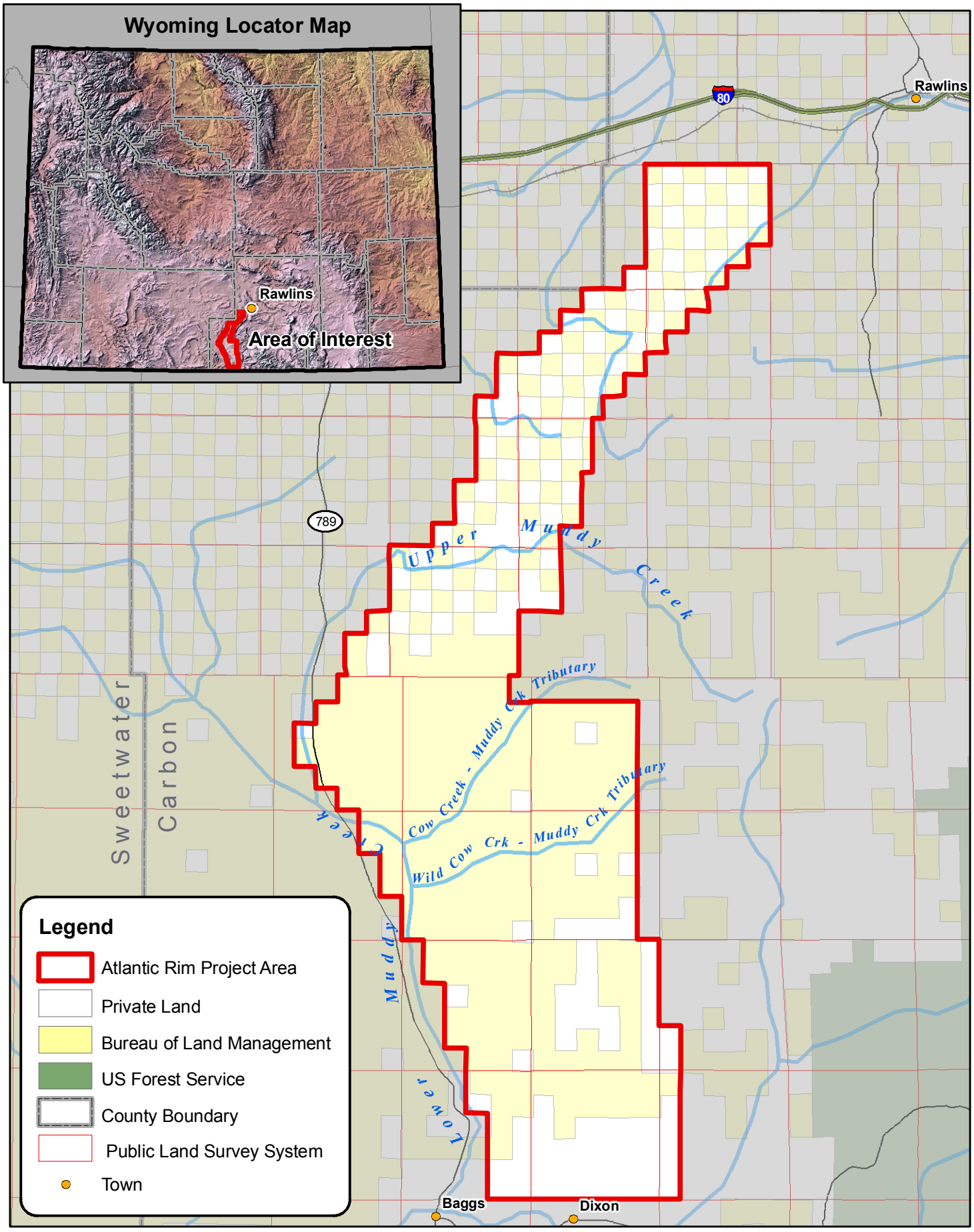

Figure 1-1.
Atlantic Rim Project Area
Carbon County, Wyoming

CDM

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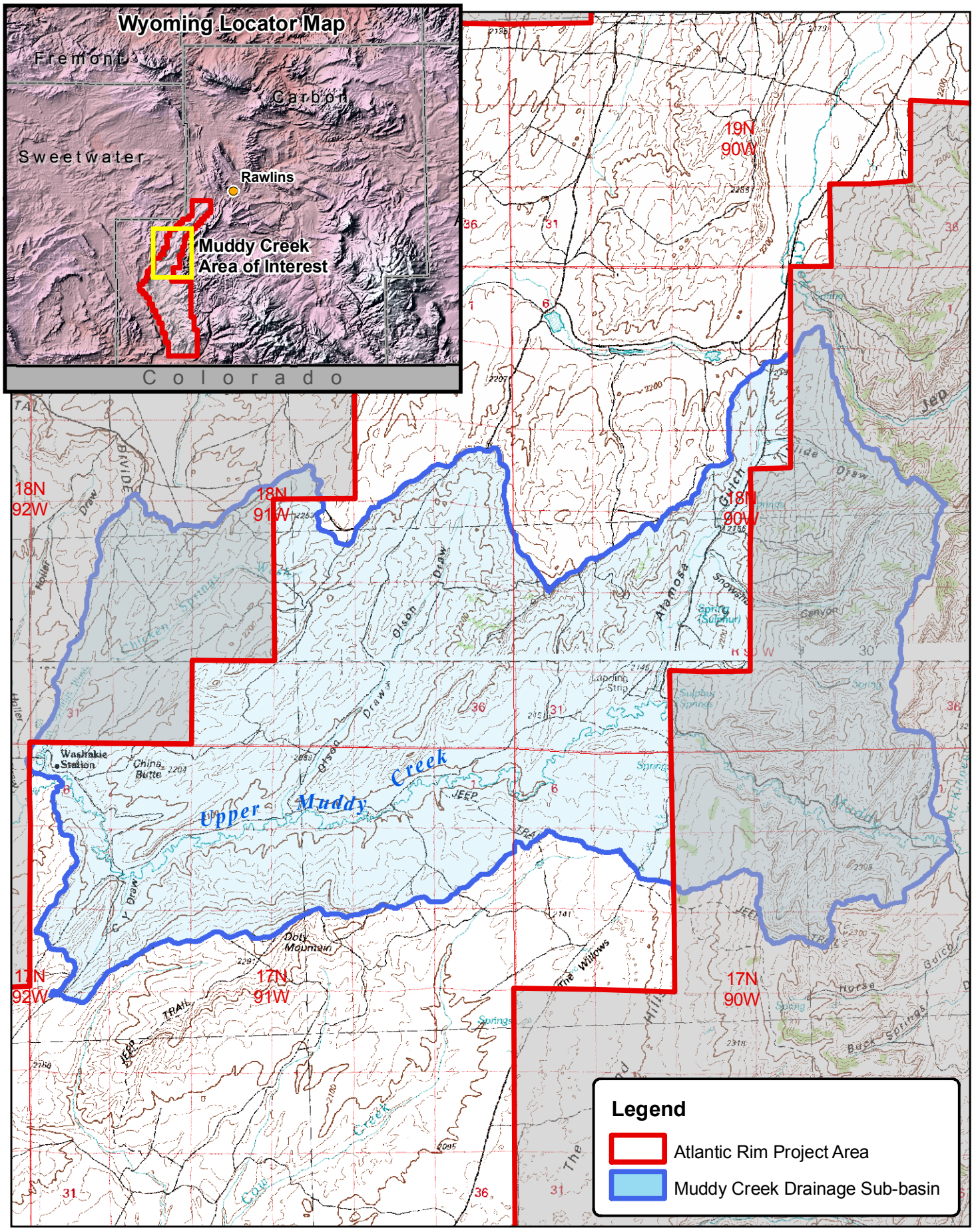

Figure 1-2. Muddy Creek Area
Atlantic Rim Project
Carbon County, Wyoming

0 0.5 1 2 3 4 5
Scale of Miles

CDM

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1.3 Monitoring Objectives

The primary concerns with development activities within upper Muddy Creek are the modification of flow regimes, potential increase in sediment delivery and transport, and potential impacts on channel stability. Increases in stream sediment load could adversely affect sensitive fish populations and distribution. Aquatic habitat and riparian habitat could also be degraded or lost.

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 is 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.

This monitoring plan focuses on upper Muddy Creek within or near the project boundaries because this segnment of Muddy Creek could potentially be directly affected by natural gas development. This segment of Muddy creek is also the best documented location of sensitive fish species.

Specific tasks that will be performed to accomplish the above objectives are listed below and developed in detail in Sections 2 and 3 of this plan.

For Streambank Erosion:

- Survey and monument cross-sections for repeated surveys in reaches of interest.
- Place bank pins at or near sections for verification of section data.

For Geomorphology and Habitat Features:

- Perform Rosgen Level II stream survey including bankfull determination, cross-section measurement, longitudinal profiles, pool/riffle length, spacing, and ratios.
- Measure residual pool depth.
- Evaluate bed material using Wolman pebble count, inventory of bedrock and other hard surfaces.
- Measure embeddedness using Platts' method.

- Evaluate bank stability using the Bank Erosion Hazard Index method.
- Survey vegetative stream cover.

For Sediment and Water Quality:

- Sample for total suspended solids, field parameters, and common ions using standard field sampling methods and laboratory analysis.
- Measure instantaneous discharge during sample collection.

Section2
Geomorphic and Aquatic Habitat Monitoring

This section describes the timing, location, and methods planned for monitoring of geomorphic and aquatic habitat features in upper Muddy Creek. The timing of water quality monitoring, which is described in the next section, will coincide with monitoring the geomorphic components and aquatic habitat features, but locations may differ because of differing objectives.

2.1 Monitoring Period and Frequency

Monitoring is initially planned to occur annually. It is likely that the monitoring protocols will be revised over time based on the results of data collected. Monitoring will take place in late summer during a period of low flow. Although low flow periods often exhibit the highest concentrations of dissolved constituents in water, higher sediment concentrations would be expected during spring high flows. However, the watershed is largely inaccessible during the high flow period because of snow and wet conditions. Other reasons for monitoring during the low flow period are that the geomorphic and aquatic habitat monitoring protocols are more easily and more accurately performed when flows are low.

Prior to the first monitoring event, currently planned for August 2008, a reconnaissance level assessment of the watershed will be undertaken by agency personnel and CDM to document the present watershed condition and identify reaches where monitoring is most needed. The initial assessment work will continue during the monitoring event in August, which will combine assessment work with monitoring. In following years, only monitoring tasks will be conducted. Section 2.3 clarifies which tasks are specific to 2008 and which are planned for annual monitoring.

2.2 Study Reach Locations

The objective of geomorphic and aquatic habitat monitoring is to monitor potential impacts of development on the stream geomorphology and habitat features of upper Muddy Creek. There may be some reaches of upper Muddy Creek that are well vegetated and relatively stable as well as some that are currently highly degraded. The impacts of development may scarcely change the quality of already degraded reaches, and it is also possible that the reaches in good condition may be stable enough to resist the potential impacts of development. It may be that marginally stable reaches will be the most sensitive to any future impacts. Therefore, it is recommended that stream conditions be monitored by selecting reaches that represent the range of stability and aquatic habitat conditions.

Another criterion for reach selection will be the presence of suitable habitat for sensitive native non-game fish species. Habitat for the species of interest will be consid-

ered with guidance of WGFD personnel. Up to six study reaches will be identified in upper Muddy Creek that fit these criteria. The study reaches will be of sufficient length to capture the range of physical and habitat parameters typical of that stream type and may be up to 600 feet in length.

2.3 Monitoring Methods

Monitoring methods for geomorphic and aquatic habitat have been selected based on the goals for the study, input from the agencies, and CDM's experience with watershed assessments in other areas. These methods include a Rosgen Level 2 survey, bed measurements, bank stability evaluation, and aquatic habitat feature measurements.

2.3.1 Initial Geomorphic Stream Survey

In 2008, the initial assessment of upper Muddy Creek will generally follow the methods of David Rosgen outlined in his book *Applied River Morphology* (Rosgen, 1996); specifically, the Level II method described in Chapter 5 will be followed. This method results in a stream classification according to the author's system but also develops many important stream parameters in the process. It requires surveys of longitudinal profile as well as surveys of cross-sections at riffle and pools. The purpose of this initial assessment is to determine the general geomorphic condition of the stream. In particular, the assessment will indicate the relative stability of the channel and what the probable evolution of the stream would be under natural conditions. Measurements to be taken at each study reach include:

- Longitudinal profile of thalweg, water elevation, bankfull indicators, terraces, bars.
- Cross-sections across the floodplain at riffle and pool locations within the reach (about six per study reach).
- Riffle–pool spacing and pool lengths.
- Bed material size using the Wolman (1954) pebble count method.

These measurements are supplemented by measurement of stream sinuosity, which will be measured from high resolution mapping rather than in the field.

Field measurements will be supplemented by photographs and a plan-view sketch of the features of each reach. Important geomorphic features such as bed rock outcrops will be noted on the field sketches.

The Level II analysis uses the aforementioned field measurements to calculate of a number of parameters:

- Channel (riffle to riffle) slope,
- Bankfull maximum depth,

- Floodprone area width,
- Bankfull surface width,
- Bankfull mean depth,
- Entrenchment ratio,
- Width/depth ratio, and
- Dominant bed material (D_{50} size).

In addition, for each pool, the residual depth will be calculated, a parameter not specifically included in the Level II method. Pool/riffle ratios will also be calculated based on the riffle spacing and pool length measurements.

Stream geomorphology measurements will generally follow those of Harrelson et al. (1994) although measurements will be taken with a total station to permit efficient data collection with a two-person team. Benchmarks will be set locally on a local datum and will be located horizontally with a resource grade Global Positioning (GPS) receiver. Bench marks will consist of iron rebar driven in the ground and guarded by a steel fence post.

2.3.2 Annual Geomorphic Stream Monitoring

The initial geomorphic assessment of upper Muddy creek is intended to determine the general geomorphic character of the stream and will not be repeated in its entirety every year because stream types change slowly over time, if at all. However, certain measurements will be repeated every year such as channel cross-section and residula pool depth because these characteristics are sensitive to short term change that could be induced by development. Bed particle sizes, embeddedness, bank stability, and overhanging vegetation will also be monitored on an annual basis. Table 2-1 summarizes the differences between initial monitoring and annual monitoring.

At each of the study reaches, an average of one cross-section will be monumented and surveyed in order to repeat the survey in the future. This section will generally be selected at a location that has the potential to indicate erosion and section change. However, the monumented sections at reference reaches, which represent the desired condition on the stream, would represent a more stable condition for comparison purposes. Note that generally only one section will be monumented and remeasured in each study reach. The other initial survey sections, which are selected to represent the riffle and pool sections of the stream, are not necessarily representative of conditions that indicate the stability of the channel.

Table 2-1. Monitoring Elements, Muddy Creek, Atlantic Rim Natural Gas Project

Task	2008	Annually
Level II Geomorphic Survey		
Longitudinal profile	yes	no
Cross sections	yes	no
Permanent cross sections	yes	yes
Riffle – pool spacing	yes	no
Residual pool depth	yes	yes
Bed Measurements		
Bed material size	yes	yes
Embeddedness	yes	yes
Bank Stability		
Erosion Pin Measurement	yes	yes
Bank Hazard Erosion Index	yes	yes
Aquatic Habitat Features		
Overhanging Vegetation Cover	yes	yes

Monuments will consist of steel fence posts at each end of the cross section. The purpose of the repeated measurements will be to allow estimation of the rate of streambank and bed erosion (or aggradation). If a permanent section established by the LSRCD is encompassed by a study reach and that section serves the goals of this study, that section will be used as the permanent section for this study reach. Photos of the monumented section as well as other noteworthy features of the study reach will be taken.

Residual pool depths throughout the study reaches will also be measured on an annual basis to monitor potential sedimentation or scour effects.

2.3.3 Bed Measurements

Bed measurements are important for evaluating geomorphic stability as well as habitat. Variations in bed particle size over time may indicate aggradation or erosion of the bed material. The standard method for evaluating materials with coarse grained beds is the Wolman pebble count mentioned above (Wolman, 1954) and is described in detail in Harrelson et al. (1994). Wolman pebble counts will be performed at three cross-sections within each study reach. One hundred sample pebbles will be taken from the stream bed using a standard method such as gathering the pebble at the toe of your boot at each step. The length of the intermediate axis of each pebble will be measured using a gravelometer, and the number of particles falling in standard size categories recorded on a field data sheet. The locations of the riffle reaches measured will be recorded with a GPS receiver. A typical field form for recording a pebble count is found in Appendix A.

During data analysis, the cumulative size distribution for each pebble count will be plotted and the D_{50} size (median size) calculated.

Embeddedness is an important aquatic habitat measurement because it measures the amount of siltation in a streambed. Normally siltation is undesirable because it reduces habitat for benthic macroinvertebrates and spawning areas for fish. Embeddedness measures the amount of silt in a coarse grained (gravel, cobble, boulder) bed. The methods laid out by the Wyoming Department of Environmental Quality in *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ, 2004) will be followed. Embeddedness is rated from 1 to 5, where 1 is more than 75 percent surface covered with silt. In this method, 50 particles are visually inspected at a riffle and the percentage of the particle that is covered in fine sediment is estimated. This is then repeated at another two riffles for a total of 150 particles. One 150 particle sample will be measured for each reach. Locations of these riffles will be documented with a GPS receiver. Appendix A contains the WDEQ method for embeddedness called "Silt Covering Rating."

2.3.4 Bank Stability

Several measures of bank stability will be employed. First, the annual remeasurement of the monumented cross-section for each study reach will indicate if banks are eroding. These monumented cross-sections will be selected at points where bank erosion is most likely to occur in the reach. To provide a more precise measurement of bank movement, erosion pins will be driven near the monumented cross sections at points most susceptible to bank erosion or collapse. Generally two bank pins will be placed near each permanent cross-section. Erosion pins are four foot steel bars driven horizontally in a bank until only several inches are protruding. The protrusion is measured and then remeasured in future monitoring events to determine if bank erosion or collapse has occurred. This method of measurement is described in Field Methods and Procedures part of the *Watershed Assessment of River Stability and Sediment Supply* website of EPA (http://www.epa.gov/WARSSS/monitor/method.htm).

Finally, bank stability will be rated semi-quantitatively at each cross-section according to the Bank Erosion Hazard Index (BEHI), which is presented in *Applied River Morphology* (Rosgen, 1996). This method 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 arrive at a qualitative descriptor of bank stability. The location of the bank on a straight reach or outside of bend is noted. Information on the BEHI method and a field rating sheet are included in Appendix A.

BEHI will be measured at the two banks with erosion pins within each study reach and up to eight additional banks that are susceptible to erosion within each study reach. These locations will not necessarily correspond to cross-section locations measured during the initial geomorphic stream assessment. However, the same bank

locations will be evaluated using BEHI in each annual monitoring event. Bank locations will be recorded with a GPS receiver, and photos of the banks will be taken.

2.3.5 Aquatic Habitat Features

Aquatic habitat features add complexity and heterogeneity to a stream, which are generally important to the health of aquatic life. These habitat features are varied and can include large rocks in the channel, drops, large woody debris, overhanging banks, vegetation cover that extends over the channel and any other feature that provides cover or other needed habitat for aquatic animal life. Also included as habitat features are drops and pools with adequate residual depths, which will be identified through the stream survey. It is not expected that the stream will contain significant amounts of large rock or large woody debris although, if found, these features will be noted on the field sketches. The most measurable aquatic habitat feature not addressed by the stream survey is expected to be vegetative cover that extends over the channel. In each study reach, overhanging vegetative cover will be approximately measured and its ratio to the bank length of the reach calculated.

Section 3
Water Quality Monitoring

3.1 Water Quality Monitoring Objectives

The objective of this surface monitoring program is to assess the water quality of upper Muddy Creek within or near the Atlantic Rim Project Area and compile a data set starting with a baseline. The data set will be used to identify trends in water quality within the stream potentially caused by coal methane development and to determine the effectiveness of BMPs and reclamation efforts. If the data shows undesired effects on the water quality that could impact sensitive fish species or aquatic habitat, Best Management Practices (BMPs) can modified to achieve the desired effects.

3.2 Sampling Locations and Frequency

As mentioned in the ROD, monitoring must occur for several years before any trends can be identified. Therefore, it is assumed that this sampling program will initially be performed annually.

Sampling will be conducted annually during low-flow conditions at three locations within the upper Muddy Creek project site; one upstream, one downstream and one approximately half way between the other two locations. Figure 3-1 shows the proposed sampling locations. The exact locations will be determined during the reconnaissance trip scheduled for July 2008. The sampling locations will be selected based on accessibility, current conditions and potential for channel changes in the future. Station locations will be recorded with a GPS receiver. The first surface water quality sampling activities are scheduled for August 2008 and will be conducted in conjunction with the geomorphic and aquatic habitat monitoring activities.

3.3 Sampling Parameters and Analytical Methods

Field parameters will be measured by using a Datasonde/Surveyor 4 System with integrated parameters measurement equipment or approved equal. The following parameters will be measures at each sampling location approximately in the middle of the stream and recorded in the project field logbook: pH, temperature, dissolved oxygen (DO), turbidity, and specific conductance. All parameter measurement sensors will be calibrated at the factory before bringing the instrument to the field for use. The pH and DO sensors will be calibrated in the field prior to use on a daily basis and the calibration noted.

Surface water samples will be collected in laboratory supplied containers containing preservatives as appropriate for calcium, magnesium, sodium, potassium, phosphate, chlorine, fluoride, sulfate and total alkalinity. These samples will be collected at each location by submerging the bottle by hand (dip) approximately in the middle of the stream and allowing the container to fill as the container is brought up to the surface.

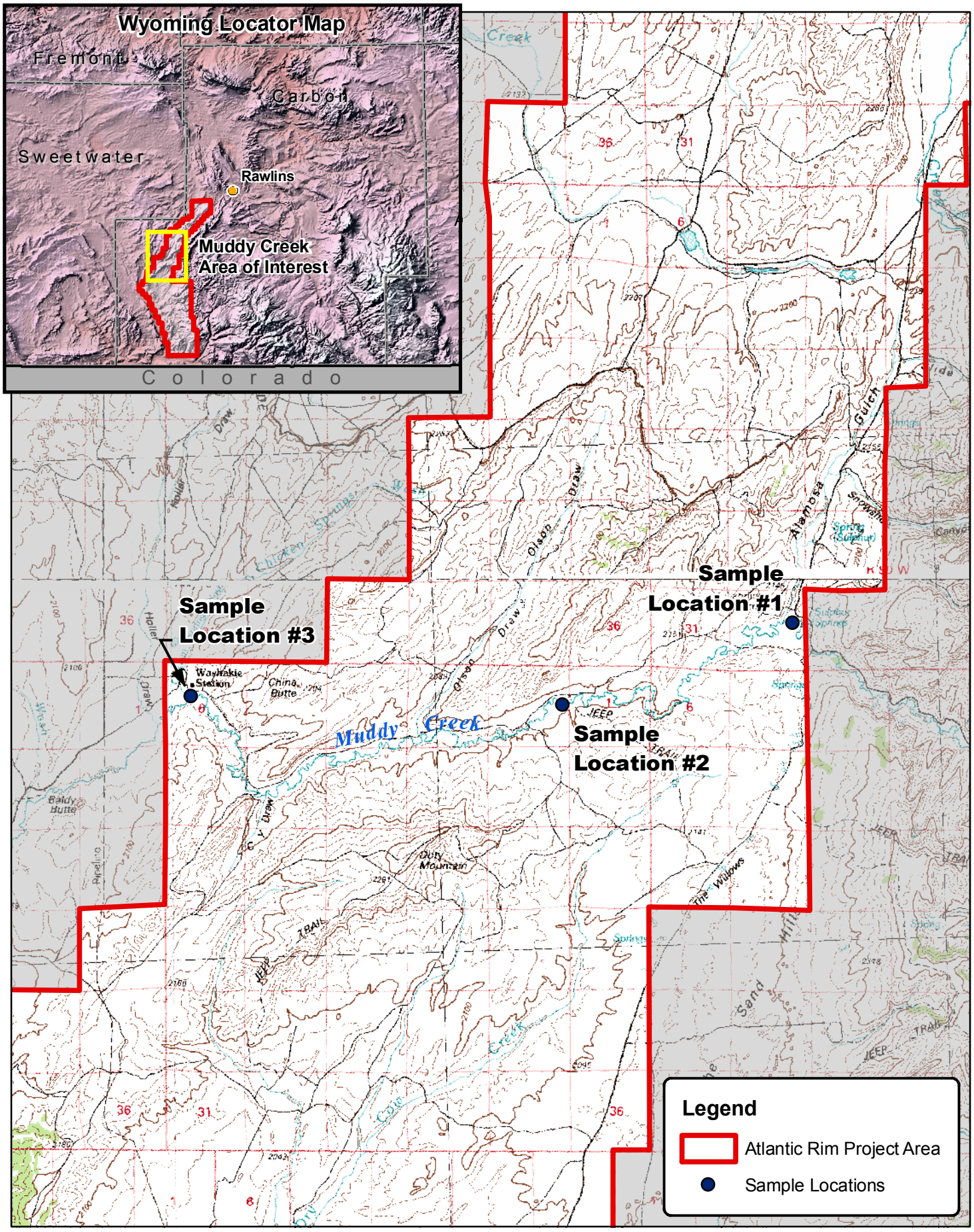

Figure 3-1. Proposed Upper Muddy Creek Sample Locations
Atlantic Rim Project
Carbon County, Wyoming

0 0.5 1 2 3 4
Scale of Miles

CDM

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In addition, Total Suspended Solids (TSS) samples will be collected in laboratory supplied containers according to the Sample Collection and Treatment Section of *Field Guidelines for Collection, Treatment, and Analysis of Water Samples, Montana District*. Appropriate pages of this method are included in Appendix B. To ensure representative TSS samples, integrated samples will be collected using the equal-discharge-increment (EDI) method along each channel cross section. This method requires that the field team determine at least five equal-discharge increments for each cross-section prior to commencing the sampling activities. The total flow in the creek will first be determined using the equal-width-increment (EWI) method which will be used to determine the location of each flow increment. All measurement will be recorded in the field logbook.

Each sampling container will be labeled with the following information:

- Project identification,
- Date,
- Time,
- Sampler's initials, and
- Sample identification number or location.

The samples will be placed in a container chilled with ice immediately after collection and submitted to Energy Laboratories for analysis. Chain-of-custody forms will be completed and accompany the samples to the laboratory.

Samples will be analyzed in accordance with the EPA analytical methods listed in Table 3-1. The selected methods should be appropriate for this study because the reporting limits are lower than the previously collected sample results reported by BLM and LSRCD. If, in the future, the reporting limits appear not to provide the necessary resolution, alternative methods will be used.

Table 3-1 summarizes the samples parameters, analytical methods, reporting limits, sample containers, preservatives, and holding times for each parameter.

3.4 Quality Control/Quality Assurance

One surface water field duplicate and one field blank will be collected during the surface water sampling activities and analyzed for the same parameters listed in Table 3-1.

The field duplicate precision criterion for water samples is 20 percent relative percent difference (RPD) for concentrations greater than five times the reporting limit. If a result of the duplicate sample exceeds the 20 percent RPD criterion for that parameter, the associated field sample will be qualified as estimated and flagged with a J or UJ, respectively.

Table 3-1. Analytical Methods and Reporting Limits

Parameter	Analytical Method (1)	Reporting Limit	Container Requirement	Preservative	Holding Times
Common Ions: Sulfate Chloride Fluoride	 EPA 300.0 EPA 300.0 A4500-F C	 1 mg/L 1 mg/L 0.1 mg/L	250 ml (P)	Cool, 4°C Not Required	28-days
Cations (Ca, Mg, Na, K)	ICP-MS (EPA 200.7-8)	1 mg/L	125 ml (P)	HNO_3 to pH < 2	6 months
Total Alkalinity	EPA 310.1/A2320B	1 mg/L	100 ml (P)	Cool, 4°C Not Required	14 days
Total Suspended Solids (TSS)	A 2540-D	10 mg/L	250 ml	Cool, 4°C Not Required	7 days

Notes:
ICP-MS – Inductively Coupled Plasma – Mass Spectrometry.
(P) – Plastic bottle
(1) – As described in USEPA (1993) and APHA (1992).

Section 4
Reporting

After completion of field activities and receipt and quality control of laboratory data, an annual data report will be prepared. The report for the initial monitoring year will also include information on the watershed and initial stream assessment information that will not be collected in future years. This information includes a description of the watershed, its existing sediment sources, and geomorphic stream classifications. The initial report will include interpretation of the assessment data such as determining Rosgen stream types, pool/riffle ratios, and bankfull flows. Monitoring data will be summarized in tabular form and a description of the existing condition provided. Based on monitoring results, recommendations for modifications to the monitoring program will be presented.

In following years, the annual report will summarize data collected in that year, compare it to the previous year's data, and note any significant changes in conditions. Recommendations for possible modification of BMPs and operations in the watershed will be presented as well as recommendations for modifications to the monitoring program. The reports will contain appendices presenting field data sheets, sketches, site photos, and laboratory data sheets.

Section 5
References

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APPENDIX A
Geomorphic and Aquatic Habitat Methods and Forms

APPENDIX B
Depth-Integrated Sampling Methods
From USGS Open File report 85-409