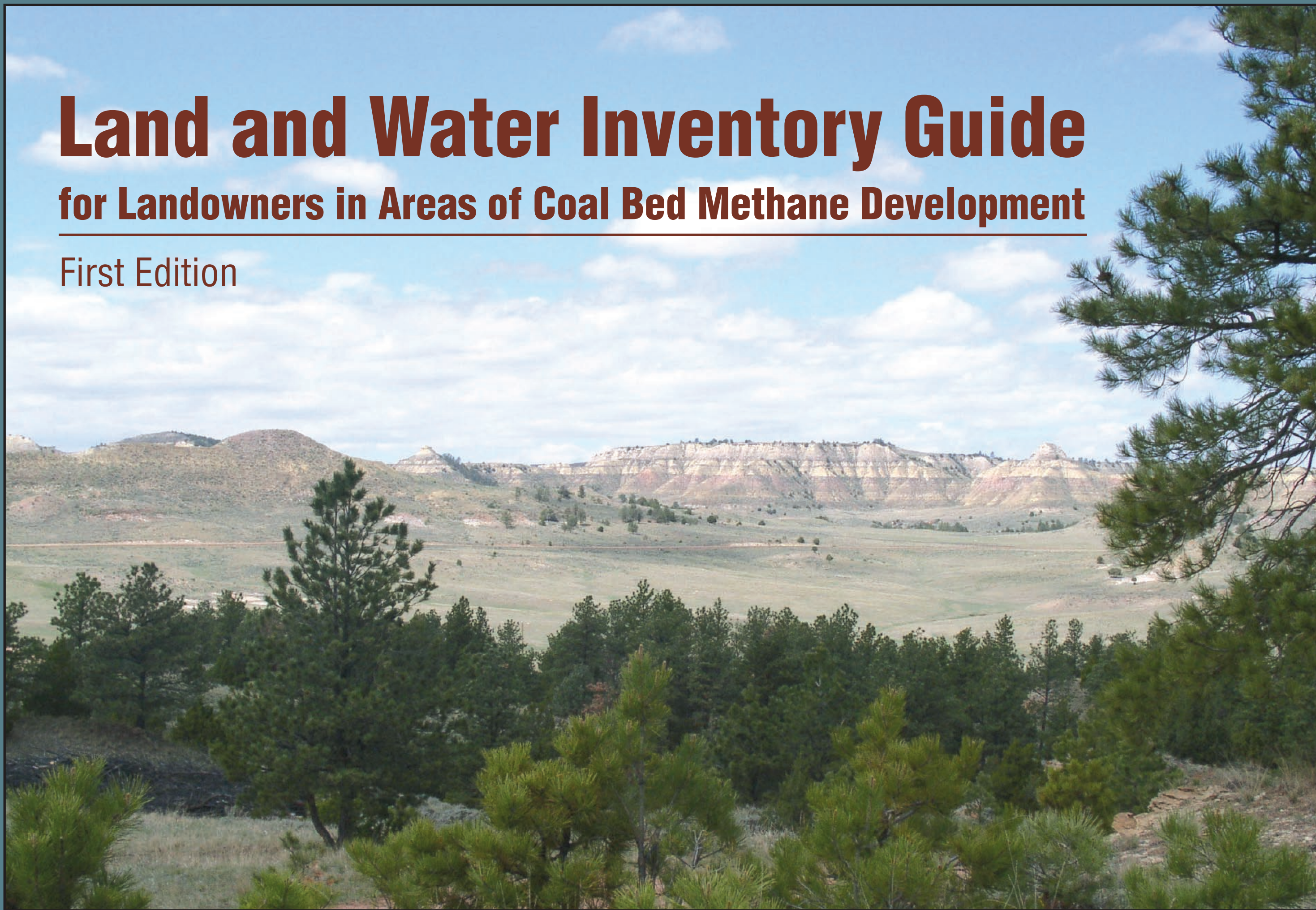
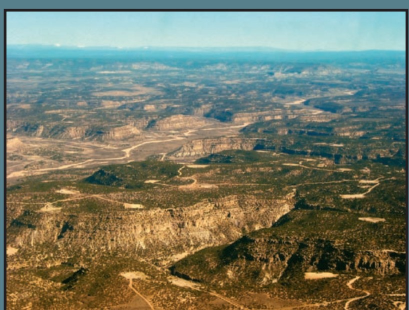


Land and Water Inventory Guide

for Landowners in Areas of Coal Bed Methane Development

First Edition



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Applying knowledge to improve water quality
Northern Plains & Mountains Regional Water Program
A Partnership of USDA CSREES & Land Grant Colleges and Universities

INSURE TOMORROW THROUGH CONSERVATION

EPA United States Environmental Protection Agency

LAND AND WATER INVENTORY GUIDE

FOR LANDOWNERS IN AREAS OF COAL BED METHANE DEVELOPMENT

Authors: Kristin Keith (Mont.), Holly Sessoms (Mont.), Matt Neibauer (Colo.), Quentin Skinner (Wyo.), James Bauder (Mont.), Reagan Waskom (Colo.), and Nancy Mesner (Utah)

About the Guide

This guidebook was developed and is being made available by the Region 8 Coordinated Regional Natural Resource Monitoring and Training Program team, a USDA-CSREES funded coordination team. As the U.S. domestic demand for natural gas grows, so has the coal bed methane industry. In an effort to enhance communication among water quality specialists in Montana, Wyoming, Colorado, and Utah and with our EPA Region 8 partners, we have co-developed this guide to address significant resource management issues encountered within the region.

As specialists, we have experienced a growing demand from landowners for guidance regarding soil and water resource management and stewardship as coal bed methane extraction has expanded across the region. This guidebook, made possible by funding from the US Environmental Protection Agency (EPA) Region 8 Geographic Initiative Program; Prairie County Conservation District (MT); the National Energy Technology Laboratory, Department of Energy (Tulsa, OK); and the USDA-CSREES, was developed in response to those demands.

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Introduction

This guide is a practical tool that provides guidelines for understanding and monitoring soil and water issues of concern in areas of coal bed methane (CBM) development. If CBM development is a new activity on your or your neighbor's property, your involvement in the planning process for development of this energy resource can have significant bearing on your satisfaction with how the natural resources are managed. Developers must understand your operation, its value to you and its importance for continuing your chosen lifestyle. As landowners, you should pursue and participate in opportunities for developing a strategy and plan which reflects your interests and substantiates your concerns. With your involvement, you and developers will initiate a planning process that will reflect your concerns and meet your expectations for managing your property values. For landowners with surface discharge of CBM product water, managing circumstances associated with the chemistry and volume of CBM product water is essential to maximizing benefits and minimizing impact of CBM development to land and water resources on your property.

Because CBM development occurs on a landscape scale, documenting condition of land and water resources of your farm or ranch before onset of CBM development is the foundation for planning a management strategy. Resource documentation is also important in resolving differences in opinion about resource values, developing goals and objectives, and monitoring change of your farm/ranch property use. Even without CBM development on your property, completing this resource inventory process is important. If CBM development is an anticipated use of your or your neighbor's property, it is to your benefit to document land use, resource values, and water resource information.

Purpose of this guide

The purpose of this guide is to empower landowners/tribal members in CBM development areas to:

- Understand the process of CBM development
- Understand potential benefits, possible impacts and issues of concern in areas of CBM development
- Understand the rights and responsibilities of landowners and CBM developers
- Inventory the current condition of land and water resources on your property or operation
- Use this inventory for negotiation during the CBM development process, and as a baseline for tracking impacts from CBM development
- Understand management practices to protect your land and water resources once CBM development begins
- Learn how to identify situations for more detailed monitoring, should the need arise.

Background Information

Coal bed methane

A primary component of natural gas is a substance called methane (CH_4). Coal bed methane (CBM) is the same compound as methane, but is found in water-filled coal seams. According to the United States Geological Survey, the Rocky Mountain region of the U.S. has about 30-58 trillion cubic feet of recoverable CBM gas (Decker, 2001). Commercially viable amounts of CBM are usually centered in coal seams or formations which are saturated with water. Although CBM extraction is relatively new to the Rocky Mountain region of the U.S., it is not exclusive to this area (**Figure 1**). Significant amounts of CBM have been extracted in the southern Gulf states and global distribution of CBM is well documented.

Figure 1 · Coal bed methane reserves in the United States (VanVoast, 2003).

Coal bed methane extraction process

Extraction of CBM starts by drilling a small bore well into the gas bearing coal seam, much like a residential groundwater well. Extraction then involves pumping some of the water from the coal, thereby forming an area around the well of reduced water pressure. By reducing pressure at the well, methane is free to flow from the remaining aquifer. Since methane has very low solubility in water, it separates from the water. The CBM flows and water is pumped to a single point on the landscape surface for collection, where the water and gas are routed to separate transmission pipes (**Figure 2**). The extracted water is called CBM product water. Generally, several wells will be connected to a common gas and water manifold system for gas and water collection within a local landscape area.

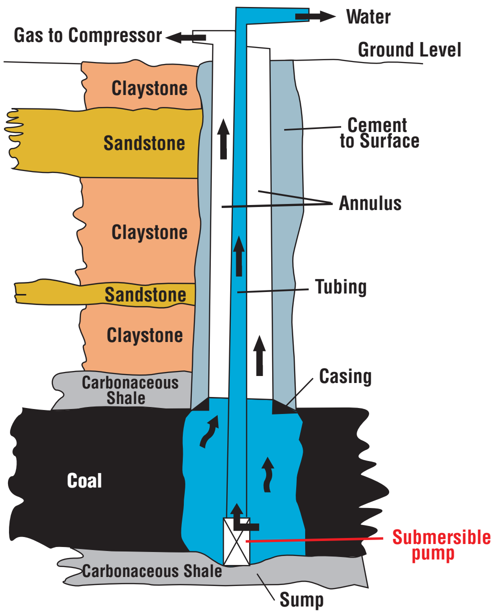

Figure 2 · Typical production schematic for a CBM well.

Possible benefits and impacts of coal bed methane development

Planning for CBM extraction and management of the associated product water requires consideration for possible benefits and impacts associated with CBM development. An important benefit of CBM development to the developer, society, and the landowner is a source of energy. In many cases, CBM development provides an additional source of income for a landowner. Additional income may come from royalties, fees associated with surface access agreements, or fees gained from contracted services. CBM development in Alabama and Virginia has yielded positive economic benefits including the creation of jobs in gas production, development of infrastructure, and revenue generation for state and local economies (EPA, 1994). Potential benefits and impacts vary with the region in which development is occurring. In the San Juan, Raton, and Uinta basins of Colorado, Utah, and New Mexico, environmental benefits and impacts are primarily related to landscape alteration. In the Powder River basin of Montana and Wyoming, environmental benefits and impacts are a result of CBM product water disposal to the surface along with landscape alteration. Some of the potential benefits of CBM development to ranchers and other landowners include (example illustration in **Figure 3**):

- Lease payments to owners of mineral rights
- Direct compensation payments for the disturbance of the land surface
- Expanded and year round road networks, cattle guard and gate installations
- Enhanced electrical service distribution
- Improved fencing
- Lease payments and access fees associated with surface use agreements
- Income associated with farm/ranch contracted services (fencing, road building, weed spraying, gravel)
- Improved water distribution for livestock and wildlife

Figure 3 · Careful placement of roads may result in better access, improved gates and improved fencing.

Figure 4 · Valley bottom with green vegetation in late summer due to enhanced water supply from CBM development. Longer season of green vegetation enhances the forage resource.

Figure 5 · Landscape dissected by roads supporting CBM infrastructure.

For landowners in areas where large volumes of CBM product water are discharged to the surface, additional benefits may include (example illustration in **Figure 4**):

- Enhanced wildlife/waterfowl habitat
- Enhanced livestock water supplies and livestock distribution
- More forage production along riparian areas
- Permanent pipeline water distribution system over the area of development
- Potential for improved forage utilization by livestock (if landowner implements a grazing system)
- Enhanced recreational opportunity

Potential impacts from CBM development facing ranchers and other landowners fall into three main categories:

1) Surface landscape issues arising from CBM development
2) Impacts of water withdrawals on groundwater resources
3) Impacts of product water on surface water, soil and vegetation resources that may occur due to quality of the water and/or from discharge of large volumes of water.

Possible impacts to the surface landscape include (examples illustrated in **Figures 5-6**):

- Disruption of livestock handling, resting, migration or traffic areas
- Increased traffic or maintenance of roads and stream crossings
- Impacts to wildlife habitat and ecologically sensitive areas
- Sedimentation resulting from erosion of disturbed areas
- Increased opportunity for weed encroachment, dust, litter, and noise associated with vehicle traffic and CBM infrastructure
- Flooded soil conditions from a rising water table
- Saline seep down slope of impoundment areas
- Disturbance from pipeline and powerline excavation and installation
- Need for additional fencing to exclude livestock from well operation areas
- Possible gas and water leaks

Figure 6 · CBM compressor station lacking an exterior structure and with an access road can be a source of noise pollution and traffic.

Possible impacts to surface water, soil, and vegetation include (example illustrations in **Figures 7-8**):

- Changes in flow downstream
- Overland or channel erosion caused by augmented flow where discharge or seepage is occurring
- Alterations to surface water quality
- Sedimentation caused by erosion from road and well pad construction or by augmented flow
- Flooding and ice damming at culverts or other areas not designed for conveying augmented flow
- Change in plant species composition due to changes in water quantity or quality (to less or more desirable species)
- Encouragement of noxious weed invasion such as salt cedar and Russian knapweed in riparian and disturbed areas
- Changes in soil conditions along stream channels
- Poor drainage, crusting and increased runoff on crop or rangeland receiving land application of product water
- Decreased yield on cropland receiving land application of product water

Possible impacts to groundwater may include:

- Change in flow of springs and streams supplied by coal seam aquifer
- Change in water level/productivity of wells supplied by coal seam aquifer
- Rising ground water table where significant surface infiltration is occurring
- Increased or decreased salinity, sodicity, or other impacts on groundwater quality

Coal bed methane product water

Since extraction of CBM initially involves pumping water from the coal seam to release gas (**Figure 2**), proper management of CBM product water needs to occur to minimize farm, ranch, and landscape resource impacts. Coal bed methane development may initially involve aggressively pumping water from many closely spaced wells to reduce coal seam water pressure and extract methane from the coal. In some cases, the volume of pumped water may be substantial (**Figure 9**). Depending on the basin, a well may produce up to 20 gallons of water per minute, or 28,800 gallons of water per day (about 1 acre inch), in the early stages of gas production. This amount of water does not remain constant over time;

Figure 7 · Sedimentation due to increased erodible surface or following release of CBM product water and flooding conditions from thunderstorm events.

Figure 8 · Flooding in a channel too small to convey augmented flow.

Figure 9 · CBM product water pumped from several wells is brought together to one outfall for disposal or management. This figure illustrates a CBM outfall releasing water into a constructed pond.

rather, it decreases with the life of the well. Because water production may decrease substantially over the life of the well, water use projects should be designed for sustainable water yields. Additionally, water production will eventually cease. Added benefits obtained from CBM water production cannot be guaranteed or sustained beyond the production life of CBM wells.

Water from many methane producing coal basins in the U.S. has salinity and sodicity levels greater than local surface water. In some instances, CBM product water salinity may be greater than that of shallow groundwater. In parts of the Powder River Basin, CBM product water may have lower salinity than surface water and shallow groundwater resources. The salinity of water is often referred to in terms of total dissolved solids (TDS). Salinity can also be estimated by measuring the electrical conductivity (EC) of water, which is expressed as deciSiemens per meter (dS/m) or less often in millimhos per centimeter (mmhos/cm) (the two units are numerically equivalent).

Water with an EC greater than 4 dS/m is considered by the U.S. Department of Agriculture to be saline. In saline conditions, plant growth is often stunted; crop, forage, and native plant species composition may also be altered to favor plants which are salt tolerant and to eliminate those that are not.

Sodic water exhibits a high concentration of sodium relative to concentrations of calcium and magnesium. The sodicity of water is expressed as the sodium adsorption ratio (SAR). Sodium in water may create soil conditions of poor drainage and soil crusting, and may result in surface runoff and erosion. Sodium-induced alterations to the soil may also affect hydrologic connections of streams (or impoundments) with riparian and groundwater systems.

Basin	State	Average water production per well (gal/day)	Average TDS (ppm)	Average EC (dS/m)	Average SAR
S. Powder River	WY	12,600	768	1.2	5
N. Powder River	MT	12,600	1,600	2.5	40
Raton	CO	8,379	2,200	3.4	100
S. San Juan	NM	788	19,000	29.7	280
N. San Juan	CO	788			150
Uinta	UT	6,773	15,000	23.4	60

Table 1 · Regional variability of CBM product water. Adapted from USGS Fact Sheet FS-156-00 and Van Voast 2003.

The salinity and sodicity of product water from methane producing coal seams varies across coal seams and varies regionally (**Table 1**). Information about product water quality in the Powder River Basin of MT and WY shows that it may be acceptable to drink and water grazing animals, but it may present a hazard with regard to irrigation suitability. Often times, the soil to which CBM product water is applied may be more sensitive than are the plants that are exposed to CBM product water. Product water in the San Juan, Raton, and Uinta basins of Utah, New Mexico, and Colorado may be unsuitable for drinking water and/or irrigation and is often injected deep underground.

Managing circumstances associated with the chemistry and volume of CBM product water is essential to maximizing benefits and minimizing impact of CBM development to land and water resources on your property. Proper management depends on the local hydrology, geology, and watershed/channel characteristics of local landscapes. It will also depend on the water chemistry at the site, which may be substantially different than the chemistry at the source (CBM well). Salinity and sodicity may increase or decrease as CBM product water mixes with subsurface and surface water moving through the watershed.

Management of coal bed methane product water

- ***Injection*** of CBM product water is one management approach which avoids surface disposal. It involves injecting the product water into geologic formations other than the CBM-bearing coal. Approximately 95% of produced water in Colorado is injected. Likewise, injection is the primary means of product water disposal in Utah at this time.

All other management approaches involve surface management or disposal of CBM product water. If there are proposals for surface disposal of CBM product water in your watershed, there may be some methods which are more beneficial and have less impact on resources on your property. Knowledge of the quantity and quality of product water to be managed either on your property or in the watershed can prove valuable in choosing the best option(s) for managing the water.

Currently, CBM product water dispersed at the land surface is managed by the following methods:

- ***Discharged into a stream channel or by overland flow.*** Only limited direct stream discharge is permitted on new wells, and this is generally regulated closely. In some instances, regulated discharges are permitted during certain flow conditions. If the product water quality is a salinity or sodicity hazard to plant and soil resources, an annual inventory (monitoring) of receiving water bodies on your property is recommended – ideally before development begins and continued once development commences.
- ***Impounded.*** This method involves constructing a pond (lined or unlined) in which CBM product water is stored either with the intent of evaporation, infiltration, injection, or subsequent use or discharge (**Figures 10 and 11**). Subsequent use may be regulated or dictated by prevailing water rights agreements. Although impoundments usually do not directly discharge water on the land surface, many impoundments are not lined and consequently do discharge to the subsurface; the fate of the water may be uncertain. Ponds that are lined rely on evaporation and/or irrigation (where permitted) to dispose of the water. If you choose to use impoundments to manage product water, an annual inventory of the impoundment sites, perimeter, and down gradient ephemeral channels or landscapes is recommended to document any changes.
- ***Treated.*** Several methane extraction companies are either currently using or are considering water treatment to remove the sodium and/or salts from product water before it is disposed on the land surface or used for irrigation. Treatment of large volumes of saline/sodic water is costly and may require special provisions for dealing with extracted salts.
- ***Applied to crop or range land.*** Irrigation or land-application of CBM product water will require management. Management options to consider include providing adequate drainage, managed leaching fractions, and alternative sources of water to periodically flush the salts that may accumulate in the root zone. If you are considering land application of CBM product water on crop fields or range, an annual inventory (monitoring) of

Figure 10 · CBM product water storage in an unlined pond.

Figure 11 · Lined evaporation pond to avoid discharge of CBM water to subsurface.

soils at the site and detailed crop and irrigation water management records are recommended.

- ***Recharge of aquifers and shallow alluvium.*** CBM product water stored in unlined evaporation ponds or discharged to the surface may infiltrate to aquifers and shallow alluvium.
- ***Other uses.*** CBM product water is also used in a number of industrial operations including dust suppression, road construction, and facilitating coal mining.

Product water management often includes combinations of the previously mentioned methods. Each decision made in the planning process regarding product water management will present advantages and disadvantages. Understanding the local conditions on your farm or ranch, their relationships with infrastructure development, and knowing the quantity and quality of CBM water to be managed can be useful information in deciding the best option(s) for management of the water. As you plan for CBM water management, locate targets of opportunity where additional water may be of beneficial use to you and/or your neighbors - where additional supply can augment your historical operation and landscape values. Keeping in mind product water quality and its risk to soil and plant resources, you can begin to identify areas where proper management of CBM product water may enhance your operations (**Figure 12**). Some additional water resource management and utilization opportunities currently being used include:

- Enhanced livestock distribution with extra water sources
- Wildlife habitat improvement and enhanced recreational opportunities (fee hunting, fishing, waterfowling)
- Increased yield by irrigation on crop or rangeland where permitted
- Conjunctive water use., i.e. blend, mix or supplement existing water supplies

Figure 12 *· CBM product water storage pond designed for waterfowl habitat.*

Rights and Responsibilities of Landowners and Developers

Coal bed methane development on your land may provide benefits to you as a landowner, but may also impact various aspects of your landscape and operation. Before CBM development occurs on your land, you and the developer should enter into negotiations that clearly define the parameters of development. It is critical that landowners determine:

1) Who owns the rights to minerals associated with their property
2) Whether the rights have been leased
3) Current status of the land and water resources of the property

Best engineering practices and best management practices will protect land and water resources from a number of impacts, but the landowner ultimately has the responsibility to be informed so that he or she can effectively negotiate extraction of minerals or the surface activities to be carried out by mineral lease holders on their land. Undertaking continued monitoring of CBM operations will further enable landowners to protect their resources. Many government agencies also have missions to protect natural resources and these agencies may be used as a resource in your efforts.

This section provides a general discussion of mineral ownership, surface versus subsurface rights, and what is involved during negotiation with an oil and gas company. It is important to note that this document does not constitute legal advice and you should contact an attorney if you have specific questions regarding mineral law as it applies to your property rights.

Mineral ownership

In the western U.S., property is divided into the "surface estate" and the "mineral estate," each of which can be owned by one individual or by different parties. Over time, mineral rights underlying surface ownership can be sold to individuals, companies, or numerous parties. Mineral rights can also be separated by mineral commodities in which one party can own the subsurface oil, while another company may own the coal. The owner or lessee of a *mineral estate* has a legal right to enter the property of someone who only owns the *surface estate* in order to drill wells, construct roads, and build infrastructure reasonably necessary to maintain drilling operations or other extraction procedures. In some states, these actions can be done even without consent or agreement from the surface owner.

In order to perfect title, the owner of a mineral estate has to file its interest in the official records of the county in which the property is located. Sometimes, however, the current ownership of the mineral estate may not be correctly recorded in the county records. In order to fully distinguish between the rights and responsibilities of landowners and CBM developers, it is important to determine who owns the mineral rights beneath your land and what minerals are included in the mineral deed.

Surface versus mineral rights

Surface and subsurface rights are separated by one of two legally binding documents. One is called a mineral deed and the other is a mineral reservation.

- Separation of surface and subsurface rights (ownership) by *mineral deed* occurs when all or part of the minerals are sold to another person or company.
- A separation by *mineral reservation* occurs when a person who owns both the surface and mineral rights sells his or her land, but reserves all or part of the mineral rights (example - Federal Reserve).
- Mineral rights owned by one party can be leased to a second party for development.

How mineral rights are legally obtained by oil and gas companies

- The mineral rights or mineral lease owner has the right to develop their minerals.
- The CBM company will research and identify who owns the mineral rights on a potential site or who holds a lease to the minerals on a potential site.
- The CBM company will then contact the current mineral owners and/or lease holder.
- The CBM company will negotiate with the mineral owner for the purchase or negotiate for leasing of the mineral rights.

Information to obtain prior to development

To effectively negotiate extraction of minerals and/or the associated surface activities, a landowner should research the current ownership and status of the mineral rights on their land. The following outlines information to obtain and considerations to be made by landowners prior to CBM development.

Landowner considerations for coal bed methane development

- If the surface owner does not own the mineral rights, the CBM company may contact the surface owner to negotiate terms of access and water management.
- Educate yourself before signing any agreements.
- Research your options and rights by investigating the following:
  - Time frames in which the mineral owner has to provide written notices
  - Surface entry stipulations
  - State requirements for compensating surface damages
- Research issues related to bonding.
- What is the oil/gas company's drilling plan?
- Consider contacting an attorney.

- Contact other people who have worked with the coal bed methane company or your state's oil and gas regulatory agency to research the company's history.
- Research who owns the mineral rights on your land.

Determining mineral ownership

- Locate your property deed or obtain your land title records from your county clerk office.
- Contact your county, state, or federal offices to determine if any mineral deeds, grants, or reservations are connected with your property.
- Hire a title insurance company to research the history of your property (i.e. deeds, contracts, court records, mortgages, tax records).

To learn whether the mineral rights on your land are in federal or state ownership, begin by contacting the appropriate state or federal agency (e.g. Bureau of Land Management or State Land Department) and ask the following (see ***References and Resources*** for contacts regarding oil and gas):

- Are the minerals beneath my property leased?
- Who leased these minerals?
- When were the minerals leased?
- What are the conditions and terms of the mineral lease?
- What is the time limit of the lease?

If the mineral estate below your land is leased or private, you will need to visit your county clerk to gain an understanding of how they maintain property records. State statutes dictate the method in which transfers are indexed (e.g. by tract index or by grantor/grantee).

Considerations for negotiations with the coal bed methane company

Experience has shown that negotiation, although not required, can play a very important role in meeting surface owner expectations for managing property. Ideally, negotiations may result in a Surface Use Agreement (SUA) that provides signed legal documentation outlining the issues agreed upon between landowner and developer. General issues to consider when negotiating a SUA include how product water will be disposed, approaches to minimize impacts to surface and groundwater resources, and locations of wells, compressors, roads and pipelines. For more information about SUA's, see the ***References and Resources*** section of this guide.

Mineral estate owner rights

It is important to contact your county or state government, such as your state oil and gas commission, to obtain accurate reports of mineral estate laws in your state. Depending on your state, the following is a list of rights entitled to owners of the mineral estate on your property.

- Mineral owners can enter your property for exploration and production of oil and gas (even areas with existing crop and/or animal production).
- Mineral owners can use the surface estate for constructing roads, drill pads, and other areas of development necessary for reasonable development of the mineral estate.
- Mineral owners can explore the geology of your land and perform seismic tests on the surface.
- Mineral owners may select appropriate drilling sites.
- Mineral owners may have the right to utilize available ground water for development and production of methane gas.
- Mineral owners can build and maintain roads, bridges, and other pathways necessary to transport employees, equipment, and materials to development sites.
- Mineral owners can harvest timber to clear the way for roads and other passage-ways.
- Mineral owners can install, maintain, and utilize pipelines for the transportation of gas and waste products associated with coal bed methane development.
- Mineral owners can build and/or install facilities involved in the production and storage of methane gas.

- Mineral owners have the right to proceed with gas development at a time of their choosing.

Surface estate owner rights

- Surface owners cannot deny access to the mineral estate, but may demand compensation for access and associated disturbance.
- In many states, the CBM operator is required to obtain a Surface Use and Damage Agreement with the surface owner.
- In some states, the oil and gas commissions are charged with protecting surface owner rights.

It is important to contact your state oil and gas commission to obtain accurate reports of surface estate laws in your state. Contact information and additional resources regarding surface owner rights can be found in the ***References and Resources*** section of this guide.

Negotiating with a coal bed methane company may involve the following:

- Agreements on appropriate compensation for activities involving gas extraction on your property
- Methods and timing of compensation
- Parameters (location, quality, size of property necessary) of development on your property
- Best management and engineering practices to be employed by the company on your property
- Dates and times of gas development
- Restoration of land and water resources impacted by gas exploration and development
- Length of time of contract to develop on property
- Land use agreements involving the infrastructure for gas extraction such as roads, pipelines, pumping stations, pods, power lines, reseeding, fences, cattle guards

Guidelines for negotiating with a coal bed methane company

- Negotiate all surface agreements before signing any document
- If possible, you and your attorney should write any surface agreements
- Know your ranch plan. In some cases, the oil and gas developer can offer improvements that you could not previously afford. Additionally, some oil and gas companies implement monitoring plans upon development, which may ease the burden of monitoring for you.

Landowners may consider having a qualified and objective lawyer review any Surface Use Agreements, lease agreements, or contracts developed with a development company before signing. For more information on rights and responsibilities please see the ***References and Resources*** section of this guide.

Documenting Current Condition of Land and Water Resources

To facilitate open communication, cooperation and negotiation between affected interests, you should inventory the extent, location, and condition of land and water resources on your property and in the area where CBM drilling is proposed. Although it is best if this process begins before CBM activity occurs, it is never too late to start your inventory. Any information collected will help you evaluate consequences of CBM development and management of your farm/ranch resources.

This guide details a method to document the condition of land and water resources and special areas on your property based primarily on photo documentation. For most ranchers, this will involve documenting the condition of rangelands and croplands, along with irrigated lands and riparian areas for landowners in areas with product water discharge to the surface. Essential elements of this inventory will include:

- A map of your farm or ranch detailing land uses and resources of concern on a landscape scale and important features such as pastures, wells, springs, streams, wetlands, ponds, and archeological sites
- Photographs representing key land uses and critical resources that may be impacted by CBM development
- Additional information on vegetation, soils, water quality and water quantity (many federal and state agencies collect information regarding the

quantity and quality of soil and water resources. See ***References and Resources*** for sources of information).

As you begin planning your inventory process, keep in mind there are many processes occurring on the landscape around you. Coal bed methane development is one piece of the whole picture; therefore, changes in condition of land and water resources caused by CBM development may not be easily identified. A carefully designed inventory will provide records that may help differentiate changes caused by CBM development, natural processes, or management.

As you plan your inventory, select sites which are

1) Representative of land uses, resources, and important areas you want to document.
2) Accessible in all times of the year and easily repeatable. Your inventory will require repeating some observations throughout the year to account for seasonal variations.

In addition, you may continue monitoring for many years to assess long-term, gradual changes in the condition of your resources and changes due to natural processes that sometimes are not easy to see with a single observation. After years of observations, trends (upward, stable, or downward) can be observed in the condition of resources. Identifying these trends will help you evaluate consequences of CBM development, decide if your farm/ranch management objectives are being met, and determine what management decisions need to be made.

Whether you choose to do only a baseline inventory of your resources or to make annual observations, making observations, gathering data, and keeping records on land activities is an important process. Recording livestock distribution patterns, grazing use, problem areas, climatic conditions, flooding, insect or weed infestations, and fire, is important for understanding background conditions on your property. It may be necessary to call on a professional such as your County Extension agent, a local Natural Resources Conservation Service (NRCS) employee, or Conservation District employee to help with any questions you might have on your inventory or other issues.

Farm and ranch inventory map

A farm or ranch inventory starts with a detailed map of your entire property or the land you manage. The map will be a visual tool for recording current land use and documenting condition of natural resources. If you enter into negotiations with a gas development company, this map will help in planning and coordinating locations for CBM activity such as roads, infrastructure, and product water management.

The first step is to contact your local NRCS, Conservation District, or Farm Service Agency office for aerial photos and soil survey maps of your property and land you manage (photos should be 1:24,000 scale or larger). These professionals, along with your local Extension personnel, can assist you in the mapping process. Begin by identifying and marking on the maps four broad land-use categories:

1) rangeland/uplands
2) irrigated, sub-irrigated, or dryland cropland or pasture

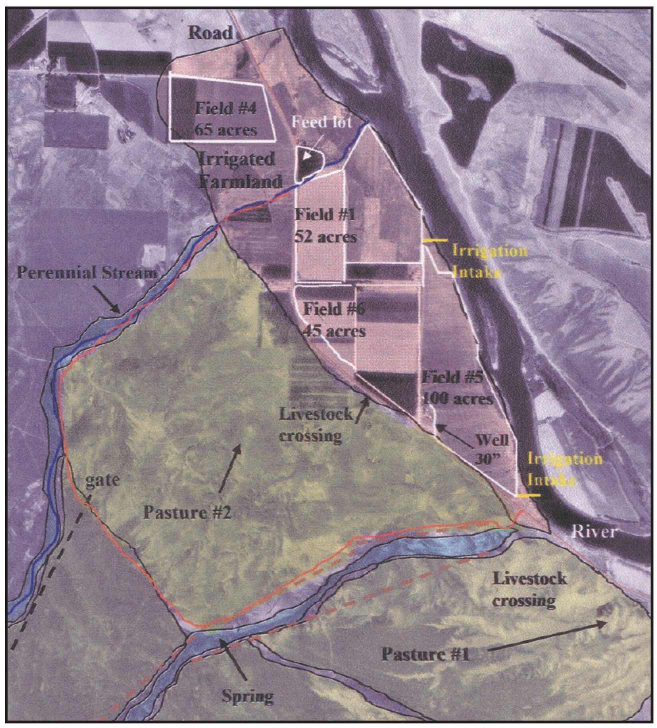

Figure 13 · Farm and ranch inventory map detailing land uses and resources of concern.

3) land areas that follow your channels and stream drainages (riparian areas)
4) residences, outbuildings, and associated facilities

Next, identify the following features on the maps (see **Figure 13, previous page** for an example map):

- Property boundaries
- Roads and fences
- Livestock pastures and livestock handling facilities
- Pasture rotation systems and dates of use
- Streams, springs and seeps
- Areas of channel debris damming
- Livestock crossings and access points
- Bridges, culverts, stream crossings
- Rangeland/Upland
- Wildlife habitat
- Cropland by field name and acres
- Irrigation structures
- Livestock and domestic housing and facilities
- Wells, including depth and aquifer type
- Other water development
- Timber assets
- Important geologic features
- Archeological and historic assets
- Areas of fire and safety concern
- Gas seeps
- Arrows indicating runoff and drainage patterns and directions of water flow onto and off the property
- Salt licks

When developing the resource map, landowners may consider obtaining historical aerial photos and references in addition to current data. Historical records reveal effects of land use practices, provide insight into riparian area condition, and may aid in establishing baseline conditions.

Photo monitoring and inventory

Once a detailed map of the development area and/or your property has been completed, the next step in your farm and ranch inventory is to document property resources. Permanent records using repeated photographs over time of a single scene and position can be used to observe and document change in water, range, and cultural resources through time, otherwise known as trend. Trend provides information needed to assess progress to or away from what is expected to happen. Thus, it is important to consider the reason for taking a photo in the first place, or the specific objective. A specific objective, or reason for taking a photo, should define the goal of photo-monitoring for a specific location. A photo to be used for inventorying resources should *never* be taken without developing its specific objective. For example, a specific objective of monitoring may be to document wildlife habitat conditions at the time of initial monitoring and to document changes that may occur following CBM development. Repeat photos of the same location should be taken as close to the same time of year and vegetation growth stage as possible each year.

Photo monitoring and the resulting inventory can be separated into 3 categories. Proceeding from the first category to the other categories requires an increase in your commitment in time and funding:

1. **Photo monitoring:** An initial photo inventory can be used to observe change through time without taking any additional resource measurements other than repeat photography of individual locations. For example, **Figure 14** provides visual evidence of change in stream channel conditions and vegetation across years

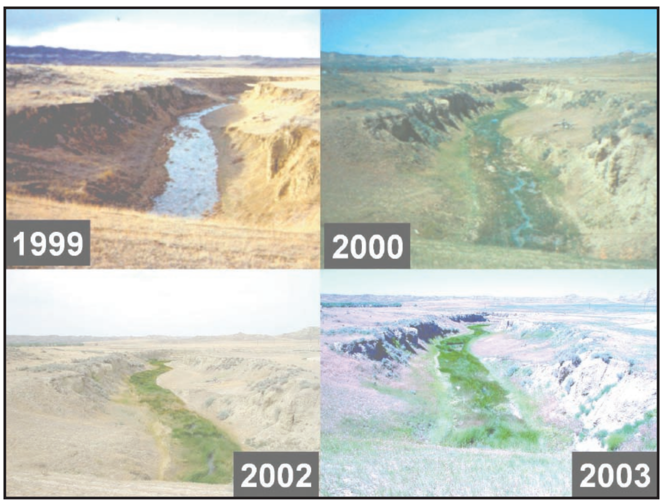

Figure 14 · Repeat photographs of stream channel with perennial CBM product water flow illustrate stabilization of stream channel by vegetation. Note however, that differences in time of day the photo is taken may hinder interpretation.

from a single location. Your photo inventory can be done using the ***Photo-monitoring record sheets***. Example record sheets and photographs are also provided in the section titled ***Monitoring instructions and record sheets***. Examples of locations to monitor are:

- land resources such as pastures, areas of cattle migration and crossing, wildlife habitat
- cultural resources such as buildings and archeological sites
- water resources such as springs, seeps, streams and wells
- critical areas requiring special attention due to the release or storage of CBM product water such as CBM storage ponds, points of product water outfall, stock ponds, and sites receiving land application of product water.

2. **Photo monitoring with additional field measurements:** On-site measurements of some form are taken within the photograph scene to verify change across time. For example, **Figure 15** provides visual evidence of change in stream channel conditions and vegetation across years along a measured distance. Plant cover and species recorded at every foot along the measured distance where the channel flow meets the channel bank is used to verify change when flow is released in the channel continuously instead of that produced by a single storm event. Other field measurements to consider in this level of monitoring include collecting information on:
   - quality and quantity (surface water flow, or depth to groundwater) of water resources using the ***Groundwater and surface water record sheets***
   - condition of well sites and associated infrastructure using the ***Well and infrastructure record sheet***
   - quality and quantity of CBM product water in ponds, outfalls, and land application sites using the ***Groundwater and/or Irrigation water record sheets***
   - soil physical and chemical data prior to and during the process of application of CBM product water to crop or range land using the ***Soil sample record sheet***
   - crop and irrigation water management information on sites intended for CBM product water application using the ***Crop production and irrigation water record sheets***

Resources and reference materials which might prove useful when preparing to collect soil, water, and vegetation field measurements are provided in the ***Reference and Resources*** section.

3. **Advanced monitoring:** Builds on photo

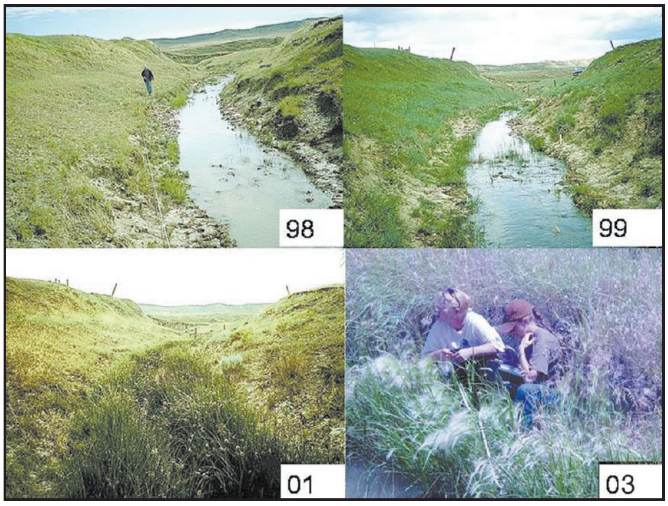

Figure 15 · Additional field measurements with photo monitoring are time comsuming, but provide valuable data to understand changes to resources with time.

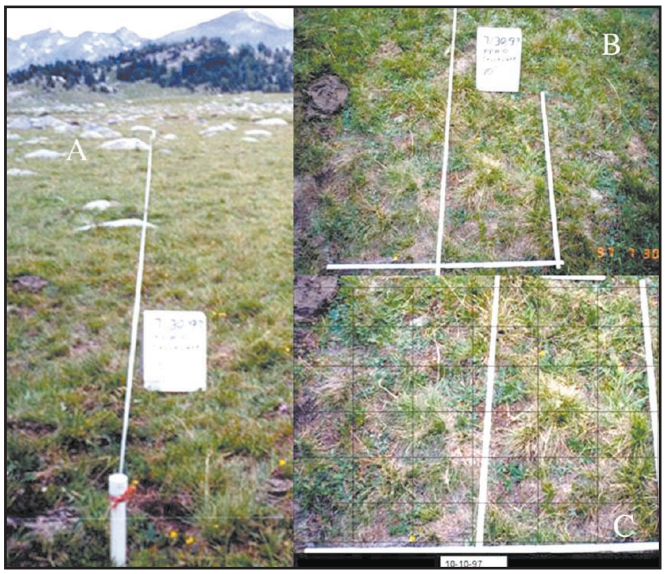

Figure 16 · Advanced photo monitoring of a range site designed to capture data on vegetation cover across the years. Collection of vegetation samples allows for species identification.

monitoring with additional field data by adding measurements taken from the photo itself and/or by collecting data using accredited data collection protocol with a quality assurance and quality control component. For example, **Figure 16, previous page,** illustrates that oblique and specific photos taken of square areas along a measurement transect in the photo can be used to measure vegetation cover by recording what lies under the cross-over points of the grid lines. These data increase sample numbers for future analysis and provide a visual description of conditions when field data was recorded. In addition, an analysis can be repeated later by a variety of audiences.

Advanced monitoring is designed for situations where legal or compliance issues are anticipated for the data. Many different rules and regulations, in addition to Oil and Gas Commission requirements, may influence coal bed methane water discharge. Some of these include, but are not limited to, state, federal, or tribal water quality protection requirements. These rules and regulations may be required by, or intended to supplement, the Clean Water and Safe Drinking Water Acts and may or may not require discharge permits and downstream monitoring. State and federal rules and regulations can also dictate or recommend Best Engineering Practices.

In addition, data gathered through photographic evidence may be suitable for determining the chemical, physical, and biological state of the water bodies or the watershed. This kind of data may be used in determining if streams are impaired or in need of restoration. The photos may be used in cases before official EPA, state, or tribal decision making bodies. Photos may be used to apply for grant funding from the NRCS, EPA, NOAA or other entities. For example, the photographic evidence may be requested by EPA, the state, or a tribal entity to be entered into STORET, a national water quality data base for waters of the U.S. (see ***References and Resources*** for the website address).

Advanced monitoring is a complex matter that requires high quality field and photo documentation approaches and is beyond the specific scope of this guide. However, there are many resources available that can help plan for this eventuality should it be needed and may be of interest to the users of this guide. One reference to consider is EPA's Clean Water Act, National Pollutant Discharge Elimination System, 2002 Draft Policy on the Use of Digital Cameras for Compliance Inspections which provides a basic understanding of advanced photo evidence gathering techniques (see ***References and Resources*** for the website address). Additional references for advanced monitoring are listed in the ***References and Resources*** section of this guide. Those considering legal action may want to hire an environmental consultant to conduct advanced monitoring or to verify the data gathered.

Well and infrastructure monitoring

In the San Juan, Raton, and Uinta basins (areas where product water is commonly injected), wells and associated infrastructure may be the primary concern regarding CBM development. To insure acceptable construction and maintenance of CBM infrastructure, landowners may assess conditions of the infrastructure during drilling and later during the production phase. Collecting photographs of structures and points of interest may substantiate the assessment.

Monitoring wells and infrastructure may require a couple of visits to assess the site during the drilling stage and again when the well is completed. Drilling the well involves the construction of pits. These pits store drilling mud and other by-products of the drilling process. A flare pit may be used to temporarily store drilling fluids until the fluid can be drained into the overflow pit. A berm is often constructed around the flare pit to intercept flares that may occur during the drilling process. When drilling is completed, the flare pit is drained into the overflow pit and both pits are filled in. The overflow pit may become the permanent storage place for drilling by-products and will be buried within a synthetic liner on-site. **Figures 17 and 18** depict a drilling operation with a flare and overflow pit and a berm constructed around a flare pit.

During the production phase of CBM extraction (where quality of pumped water limits surface discharge), produced water is generally stored in a water tank on site (**Figure 19**). The tank is constructed atop a gravel pad with berms around all sides. The bermed area should be sufficient in size to store water from accidental spills, and the bottom of the tank should be visible to observe any leaking that may occur. The top of the tank should be screened to prevent wildlife (bird) access. As gas is extracted, it may need to be dehydrated to remove any remaining water. The water and liquid hydrocarbons that are separated from the gas during the dehydration process are stored in a drip or condensate tank (**Figure 20**). This tank should be free of leaks, fenced, and covered by a screen to prevent livestock and wildlife access.

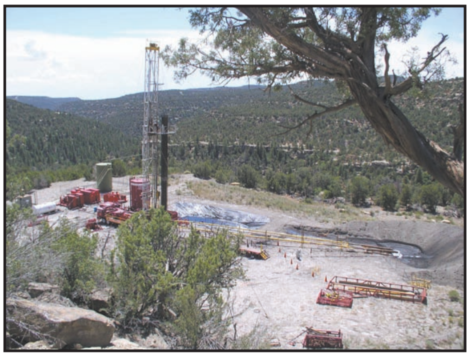

Figure 17 · The flare pit (left) and overflow pit (right) collect drilling fluid.

Figure 18 · A berm constructed around the flare pit blocks flares that may occur during drilling.

Figure 19 · A water tank is constructed atop a gravel pad with berms on all sides.

Figure 20 · A drip tank collecting condensate. The tank should be livestock and wildlife proof and should have no leaks.

The well itself is often constructed along side a compressor which compresses the gas before being transported off site via pipelines. Wells and compressors should be free or essentially free of leaks, should be in good condition, and preferably constructed to minimize noise and landscape disturbance. The entire well pad and infrastructure should be constructed within the perimeters originally agreed upon (marked by large stakes referred to as anchors).

Other points of interest potentially worth monitoring include road and culvert condition, presence of noxious weeds, pipeline and right of way (ROW) conditions, and placement of well pads outside of natural waterways. Common issues of concern are addressed in the ***Well and infrastructure record sheet*** on page 51.

Best Management and Best Engineering Practices for Your Land and Water Resources

A variety of best engineering practices (BEPs) and best management practices (BMPs) can be used to minimize impact of development and product water disposal on the landscape. By engaging the developer in a planning process, you may be able to identify and prevent potential impacts, negotiate effective engineering and/or management practices to minimize impacts, and influence the location of roads, fences, ponds or pipelines.

Development activities should be planned to avoid resource concerns such as disturbance to the landscape, erosion and sedimentation, degradation of stream banks, and changes to soil and vegetation due to salt and/or sodium. Listing and describing all BMPs and BEPs for resource protection in areas of CBM development are beyond the scope of this guide. For more comprehensive information on CBM BMPs, see the ***References and Resources*** section of this guide.

It is beneficial to involve an engineer or a resource professional from the NRCS or a private consulting firm in the planning process to understand options of engineering and management practices for the life of the development process. Below are a few examples of best engineering and/or management practices used in areas of CBM development.

Figure 21 · New road installed for CBM development. Edges of road where excavation was done were reseeded with hydro mulch cover for site stabilization and weed control.

Figure 22 · Drill seeding along roadway for site stabilization and weed control.

Considerations for development

Road construction: roads and travel corridors should be designed and located to minimize impact and optimize benefits to CBM operations, ranching operations, wildlife habitat, traffic and aesthetic values of the landowner. Maintenance and reclamation of road networks following completion of development should also be negotiated prior to development.

Pipeline and powerline installation: these activities should be planned and coordinated for minimal impact to the landscape and ranching operations during installation, and for proper reclamation to restore landscapes and ground surfaces close to their original condition following installation.

Wells and compressor station construction: equipment, wells, housing structures, and sheds should be designed to minimize impact to the landscape, ranching operations, wildlife habitat, aesthetic values and noise sensitivities of the landowner.

Land and vegetation resource BMPs

Reseeding: disturbed areas with minimal subsequent traffic after well drilling, pipeline, power line, and containment pond installation and other activities should be reseeded with an appropriate seed mix. Reestablishment of permanent vegetative cover will reduce wind and water erosion and aid in prevention of undesirable or noxious weed infestation (**Figures 21 and 22**).

Weed and pest management: weed and pest management should be planned for the life of the development process in areas of CBM development activity. Consult your local extension office and/or state land grant university for more information regarding invasive plant and pest species in your area.

Soil amendments: In some circumstances, soil amendments such as gypsum or sulfur can be added to land where CBM water is being applied to help manage effects of sodium contributions from CBM product water. When CBM product water is no longer being applied, adequate drainage and good water are necessary to leach accumulated sodium out of the soil and to keep the salinity low in the soil.

Alternative drilling practices: alternative drilling practices such as "closed-loop" drilling and directional drilling (**Figure 23**) can reduce surface impacts. Closed-loop, or pitless drilling, eliminates the need for earthen pits by storing drilling fluids in storage tanks. Directional drilling allows for a number of wells to be drilled from one well pad, thus reducing surface disturbance.

Water resource BMPs (for landowners in areas with significant water disposal to the surface)

Vegetative filter strips: Filter strips are a cost-effective and ecologically sensitive option for protecting resources on more gently sloping landscapes. Natural vegetation or planted/introduced vegetation can:

- reduce runoff volume and stream flow through transpiration
- enhance soil infiltration
- stabilize soils from wind and water erosion
- slow runoff and trap sediment
- enhance wildlife habitat and provide aesthetic benefits

Geotextiles: synthetic mats, webbing, and ground covers can be effective, but often expensive, tools to prevent surface or channel erosion, facilitate infiltration, retain soil moisture, and promote establishment of natural or planted vegetative cover. Geotextiles are porous fabrics typically made into a sheet which is rolled out and anchored onto exposed surfaces. Biodegradable material such as jute, wood fiber or straw can also be used for the same purposes, but they are designed to be less permanent than synthetic geotextiles. **Figure 24** illustrates an example of using geotextiles for surface or channel protection.

Riprap: is rock used to protect slopes or channels from erosion. Riprap can also be used for erosion control on stream banks, and below outlets of pipes, culverts, and ponds. **Figure 25** illustrates a method of using riprap for erosion control.

Drop structures: used to prevent accelerated head cutting on more sloped reaches of a stream channel or at the base of culverts and pond discharge sites. **Figures 26** illustrates headcutting (the process whereby stream channels gradually cut progressively deeper upstream).

Bridges and culverts: used for temporary or permanent stream crossings to prevent streambed and banks from degradation and erosion. Ice damming may occur at bridges and culverts, and could potentially result in flooding.

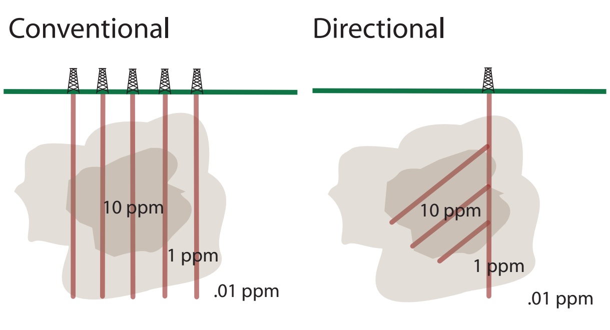

Figure 23 · Directional drilling allows wells to be drilled at an angle from a single bore hole.

Figure 24 · Erosion control for overland discharge using rock and geotextile fabric.

Figure 25 · Riprap used to protect the windward side and dam face of a CBM storage pond from erosion caused by wave action.

Figure 26 · Channel incision and headcutting.

Water bars: used to direct water across roads and travel corridors while minimizing erosion.

Terraces: used to prevent water erosion on long, steep slopes. Terraces are constructed at intervals along the face of a slope and they are designed to slow and divert runoff to a less erosive runoff flow path.

Conclusion

In summary, understanding the process of CBM development and appropriate landscape monitoring techniques will enable landowners to prepare for CBM development on their property. Prepared landowners, along with developers, may implement a monitoring program that reflects landowner interests and minimizes impacts of CBM development.

A farm or ranch map detailing land uses and resources of concern is an essential element of a monitoring plan. A basic photo inventory prior to CBM development serves to document resources and to determine where you need further detailed monitoring. Collection of additional vegetation, soil, water quality, and water quantity information as described in the following record sheets provides sound documentation of property conditions. Implementation of the following monitoring techniques will greatly aid in evaluation of consequences of CBM development on your property, as well as aid in overall management of your farm or ranch. However, if legal or compliance issues are foreseen, a more complete, technical program for collection of resource data must be followed. Consult the resources describing advanced monitoring techniques or hire a professional consultant.

References and Resources

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Coal Bed Natural Gas Alliance. Background and description of development in Montana and Wyoming. Available online at: http://www.cbnga.com.

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Surface and mineral estate rights, contacts regarding oil and gas

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Utah: Utah Division of Oil, Gas, and Mining http://ogm.utah.gov/oilgas/LINKS/oillinks.htm

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Glossary of terms

Abandoned well • A well no longer in use or operation, previous operator has purposely relinquished its interest in the well.

Alluvium • Eroded soil sediments deposited on the landscape by streams.

Basin • An area drained by rivers and tributaries or geologically formed, where sediments, typically waterborne, accumulate.

Best engineering practice (BEP) • Effective, practical, structural or nonstructural methods developed to achieve a balance between environmental protection and the production of coal bed methane within natural and economic limitations.

Best management practice (BMP) • See best engineering practice.

Bond • A financial guarantee supplied by a development company to ensure reclamation of disturbed lands. If the required reclamation is not completed, money supplied by the bond can be used by the landowner or government agency to complete reclamation.

Borehole • The hole created when a well is drilled or bored.

Casing • Steel pipe (or pipe of another material) that is inserted into the borehole to prevent the hole from collapsing and to prevent movement of drilling liquids into a formation or fluids movement from one formation to another.

Channelization • The straightening and/or deepening of a watercourse for purposes of augmented flow control. Channelization often includes lining of stream banks with a retaining material such as concrete or rock.

Compressor • A device that raises the pressure of methane gas, thereby creating a pressure differential to move gas through a pipeline.

Condensate • Liquid hydrocarbons condensed from gas and oil wells.

Damages • Compensation paid by a developer to the surface owner for actual or potential damages resulting to the land surface as a result of the installation and operation of a well.

Deed • A written document used for legal transfer or ownership.

Dehydration • Process of removing water from a substance.

Drip tank • The tank that collects condensate produced during dehydration of methane gas following extraction.

Easement • A temporary right given to a non surface owner for a specific purpose.

Electrical conductivity (EC) • A convenient estimate of total dissolved solids in soil or water. The larger the salt concentration in soil or water, the greater the electrical conductivity. Normally expressed as millimhos per centimeter (mmhos/cm) or deciSiemens per meter (dS/m).

Ephemeral stream • A stream that flows briefly and only in direct response to local precipitation, and whose channel is always above the water table.

Flaring • Burning of hydrocarbon gas during the drilling process.

Formation • An assemblage of rocks or series of strata having similar characteristics.

Head cutting • The process where-by a stream channel cuts progressively deeper upstream. Head cutting may result in erosion and channelization.

Hydrocarbons • Organic compounds composed of hydrogen and carbon. Liquid geologically-extracted hydrocarbons are referred to as petroleum while gaseous geologic hydrocarbons are referred to as natural gas.

Injection • Process of injecting CBM product water into geologic formations above or below the CBM bearing coal seam.

Leaching fraction • Indicates the additional water that must be added when irrigating to leach salt through the soil and to keep soil salinity below a predetermined concentration.

Lease • A legal agreement between a mineral owner (lessor) and another party (lessee) that grants exclusive rights to the lessee to explore for, drill, and remove oil or gas from a given area of land.

Methane • A hydrocarbon consisting of one carbon atom and four hydrogen atoms. Chemical formula is CH_4.

Mineral deed • Severance by mineral deed occurs when a party owning both surface rights and mineral rights sells or grants by deed all or a portion of the mineral rights underlying his/ her property. This deed, known as a mineral deed, is registered with the county register of deeds and will become a part of the abstract of title to the land involved.

Mineral estate • The ownership of minerals lying below the surface of the land. Mineral ownership may or may not be tied to surface ownership.

Mineral reservation • Severance by mineral reservation occurs when a party owning both surface rights and mineral rights sells or grants by deed the surface rights of his property, but retains all or a portion of the mineral rights. Severance of minerals by mineral reservation has been widely practiced by federal and state governments, land-grant railroads, and lending institutions, as well as by individuals. Mineral reservations are recorded with the county register of deeds and are included in any abstract of title to the land involved.

Natural gas • Flammable gaseous mixture consisting mostly of hydrocarbons. The primary constituent of natural gas is methane. Natural gas is usually found together with petroleum deposits in earth's crust.

Outfall • A discharge site of CBM product water onto the surface. An outfall is generally constructed of black or galvanized corrugated pipe, and discharges water from several wells.

Overflow pit • An excavated pit that may be lined with synthetic materials to prevent soil contamination. It is used to permanently store water, drilling fluid, or drilling by-products following drilling operations.

Perennial stream • A stream that flows continuously throughout the year.

Reserve pit • An excavated pit. May be lined with synthetic materials to prevent soil contamination. It is used to temporarily store water, drilling fluid, or drilling by-products during drilling operations.

Royalty • A payment made by a producer or purchaser of minerals to the owner of the mineral right; mineral owner receives a portion of the production from leased minerals.

Saline • Describes soil or water containing sufficient soluble salts to impair plant productivity. Saline soil and water is generally described as having an electrical conductivity greater than 4 deciSiemens per meter.

Saline seep • Emergence of saline water in a localized location on the landscape; generally a result of movement of water and salts in the subsoil at a higher location downslope, and a resulting accumulation of salt at the soil surface at the downslope location due to water evaporation and salt concentration.

Sedimentation • The accumulation of geological or organic material deposited by air, water, or ice. Sedimentation may be a result of increased erosion from disturbed surfaces, or may result from sediment entrapment by riparian vegetation.

Sodium adsorption ratio (SAR) • Relationship between the concentration of sodium (Na) in water relative to the concentration of calcium (Ca) and magnesium (Mg). It is used as an index for determining the sodium hazard of irrigation water that may lead to soil dispersion, crusting, and reduced permeability.

Sodic • A term applied to soil or water which is sodium-rich. Usually used to describe soil or water with sodium adsorption ratios exceeding 12. When applied to soil, sodic water may cause soil to disperse, resulting in reduced infiltration, increased runoff, and poor soil drainage.

Split estate • Mineral and surface estate owned by different parties.

Surface estate • The ownership of the surface of the land. Surface ownership may or may not be tied to mineral ownership.

Surface use agreement (SUA) • A surface use agreement is a legal document drawn between a surface owner and an oil and gas operator. It specifies the allowed impacts and uses of the surface for the purpose of extracting the mineral resource for which the operator has a right.

Total dissolved solids (TDS) • Refers to any minerals, salts, metals, cations or anions dissolved in water. This includes anything present in water other than the pure water (H_2O) molecule and suspended solids.

Trend • The direction of change in landscape or riparian condition. Generally described as upward (or improving) or downward (declining) or stable. Determined from repeated measures of landscape or riparian condition over time.

MONITORING INSTRUCTIONS AND RECORD SHEETS

Coal Bed Methane: Monitoring Instructions and Record Sheets

PHOTO-MONITORING INSTRUCTIONS

This manual emphasizes and provides guidelines for inventorying your ranch/farm resources using a photo-monitoring method. A conventional film camera can be used, however digital cameras are quickly replacing the need to use film. It is recommended that you use a digital camera as you can review your success as a photographer immediately after having taken a photo. It is important to select the date as a photo option or clearly indicate the date photos are taken as part of any photo you take. Be sure photos are of good resolution and high quality.

Site selection, identification, and access to the point from which photographs are taken at all times are important criteria to insure consistency in monitoring change in resource conditions. Repeat photographs should be taken from the same spot, season or year, and approximately the same time of day. The fixed location from which photos are taken is referred to as the "fixed landmark location" in the photo-monitoring record sheets and the location or site being photographed is referred to as the "specific permanent photo point". If necessary, use stakes or steel posts to permanently mark the photo location. If vegetation conditions are being recorded, it is critical to repeat photographs of a specific location when vegetation growth is at about the same stage and near the same time of day as when previous photos were taken.

You should have a reason for every photograph you take. This reason becomes your "monitoring objective". This objective, your expectations, and other pertinent data should be recorded according to the forms provided in this guide. If you do not own a GPS and would like to locate your photo-monitoring locations with a GPS, your local County Extension or Conservation District may have a GPS available for loan.

PHOTO-MONITORING RECORD SHEET

Site name: ____

Position of sun to the camera: __________________________

Direction of photo from camera: _________________

GPS Coordinates: _________________

Description and location of specific permanent photo point:

Fixed landmark location:

Distance and direction to specific permanent photo point from fixed land mark:

Location: ____

Camera: _________________

Monitoring objective:

Questions to be addressed by photo-monitoring:

Expected response to changes in landform associated with CBM extraction activities:

Record of repeat photo monitoring:

Date	Time	Photographer	Photo ID	Notes

Site location map: (sketch illustrating the location of the point from which photograph was first taken, distinguishing landmarks, and fixed (permanent) photo-points)

Attach photos:

Example: photo-monitoring

PHOTO-MONITORING RECORD SHEET

Site name: Flying Bar Ranch

Position of sun to the camera: high in the sky and to my right

Direction of photo from camera: downstream

GPS Coordinates: ____________________

Description and location of specific permanent photo point:

Edge of road facing downstream, centered on the channel

Fixed landmark location:

_ mile from Access Road 1 and junction with Country Road #123

Distance and direction to specific permanent photo point from fixed land mark:

_ mile northwest from County Road #123

Location: 1st access road culvert crossing at Muddy Creek

Camera: ____________________

Monitoring objective:

Record dry channel of Muddy Creek after CBM water is released as flow year round (perennial flow).

Questions to be addressed by photo-monitoring:

Will vegetation change when CBM water is released? Will livestock and wildlife prefer grazing Muddy Creek Channel after water is released? Will erosion occur within the channel?

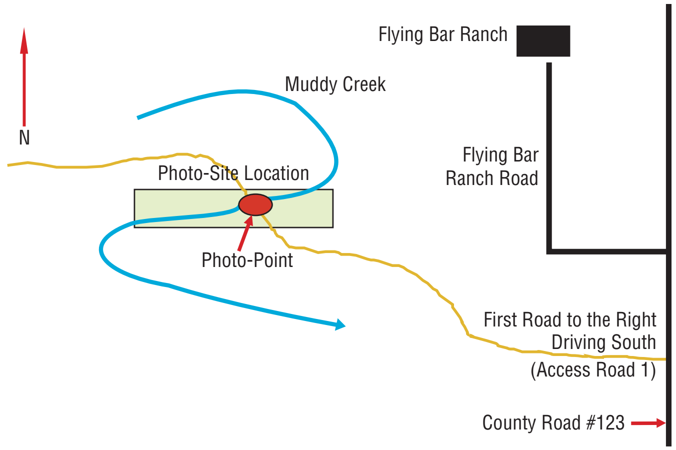
Expected response to changes in landform associated with CBM extraction activities:

Expect more erosion and downcutting of channel, change in vegetation color and species - not those that livestock will graze on.

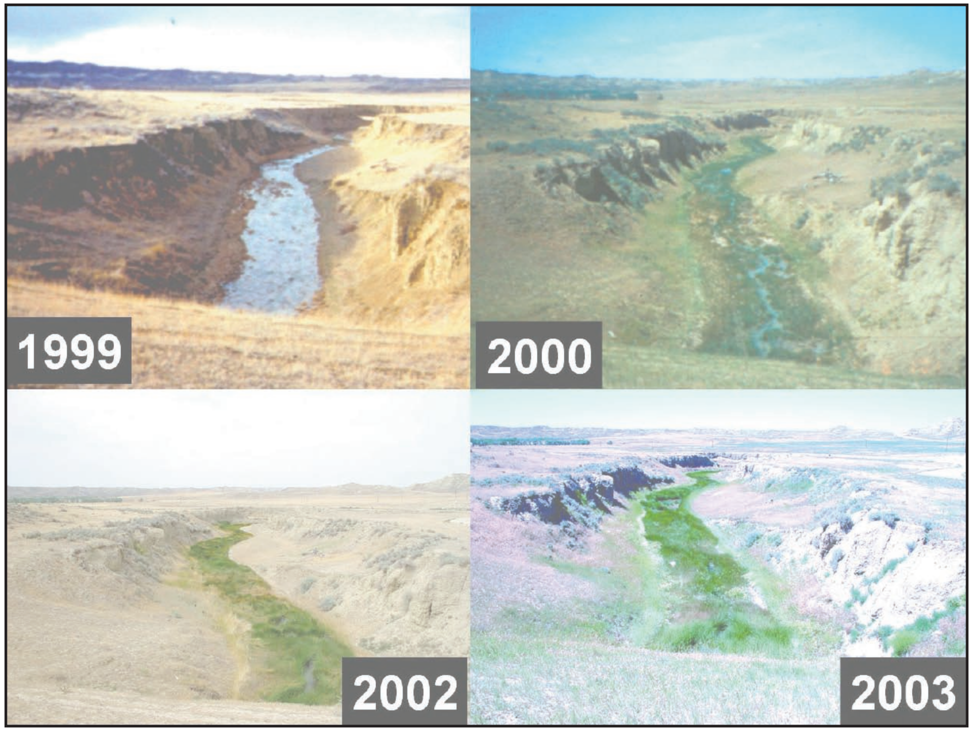
Record of repeat photo monitoring:

Date	Time	Photographer	Photo ID	Notes
7/13/99	9:30 am	Joe Doe	1999	Deep channel lined with grasses, little to no green vegetation.
7/13/00	10:00 am	Joe Doe	2000	No significant erosion or down-cutting of channel. Green vegetation growing in around channel.
7/13/02	9:30 am	Joe Doe	2002	Narrower channel appears to be occurring by bank building of deposited sediment. Green vegetation along banks appears to stabilize channel area.
7/13/03	9:30 am	Joe Doe	2003	Channel remains stable. Plant species different than those in other parts of Muddy Creek. Livestock not eating these plants. Collected plants to have identified by county agent or conservation district.

Site location map:



Attach photos:



Example: photo-monitoring with additional field data

PHOTO-MONITORING RECORD SHEET

Site name: 1st access road culvert crossing at Muddy Creek

Position of sun to the camera: high in the sky and to my right

Direction of photo from camera: downstream

GPS Coordinates: ____________________

Description and location of specific permanent photo point:
Left fence post looking downstream where fenceline crosses Muddy Creek

Fixed landmark location:
1 stream channel bend above culvert crossing Access Road 1 leaving County Road #123

Distance and direction to specific permanent photo point from fixed land mark:
300 ft. upstream of left fence post facing downstream where wire crosses Muddy Creek. Standing with left foot against white PVC stake and right foot in center of channel.

Location: Flying Bar Ranch

Camera: ____________________

Monitoring objective:
Observe response of dry channel of Muddy Creek after CBM product water is released year round.

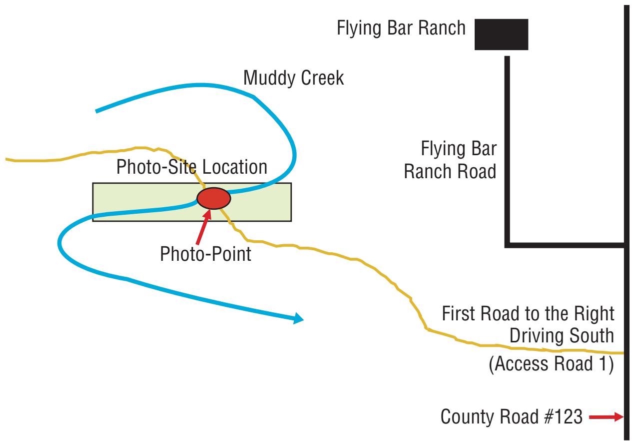
Questions to be addressed by photo-monitoring:
Will vegetation change when CBM water is released as channel flow? Will % bare ground decrease along channel because of growth of salt tolerant plant species?

Expected response to changes in landform associated with CBM extraction activities:
Expect increased vegetation along channel due to year round flow. Expect channel to narrow because of bank building. Expect salt tolerant species to grow along channel.

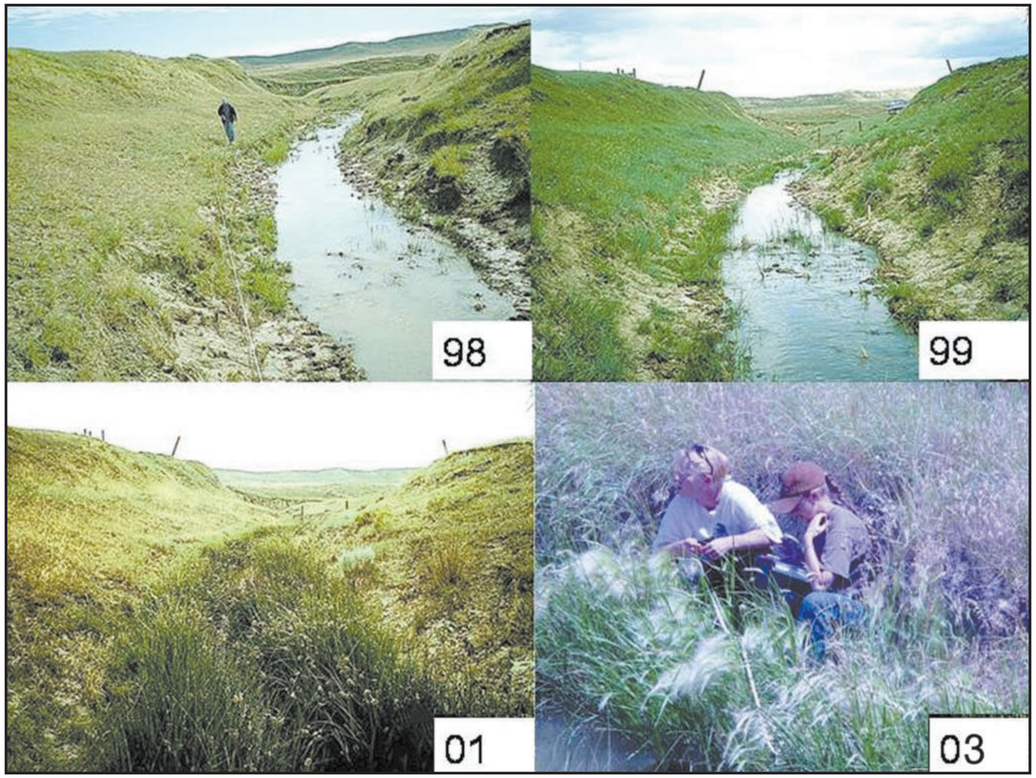
Record of repeat photo monitoring:

Date	Time	Photographer	Photo ID	Notes
7/13/98	10:30 am	Joe Doe	98	Average channel width of 15 ft. About 60% of channel bank is bare.
7/16/98	10:00 am	Joe Doe	99	Channel appears narrower. Some riparian plants starting to grow along banks and in the channel.
7/14/01	9:30 am	Joe Doe	01	Channel considerably narrower. Banks and channel densely covered with salt tolerant plants and riparian type plants (bulrush, sedges).
7/13/03	10:00 am	Joe Doe	03	Average channel width of 2 ft. About 3% bare ground along channel banks. ID'd American bulrush, Maritime bulrush, Inland saltgrass, Alkali cordgrass, Baltic rush, Foxtail barley growing along banks.

Site location map:



Attach photos:



Example: advanced photo-monitoring

PHOTO-MONITORING RECORD SHEET

Site name: Flying Bar Ranch

Position of sun to the camera: high in the sky and to the south

Direction of photo from camera: northeast

GPS Coordinates: ____________________

Description and location of specific permanent photo point:
Trail from cow camp to Jim Lake on open divide where first see Jim Creek

Fixed landmark location:
White PVC stake off to the left and trunk of large down tree to the right

Distance and direction to specific permanent photo point from fixed land mark:
300 ft. north from crown of tree trunk to white PVC stake. 2nd white PVC stake 100 ft. northeast of first stake with Victor Peak in the background.

Location: Forest Service high elevation livestock grazing allotment

Camera: ____________________

Monitoring objective:
Determine if grass/grasslike plants of upland high elevation meadows can be increased at the expense of forb cover by altering distribution of livestock.

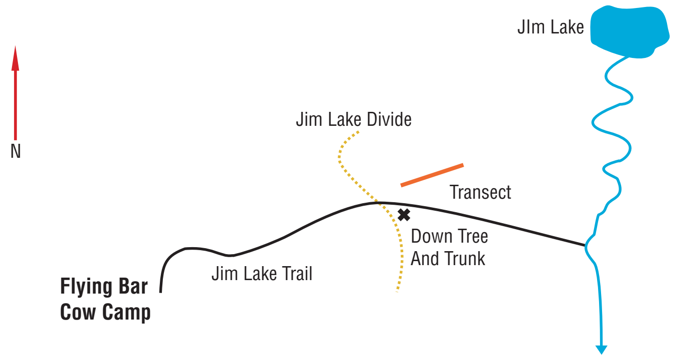
Questions to be addressed by photo-monitoring:
Will grass/grasslike cover increase at the expense of forb cover when grazing use is within F.S. standards?

Expected response to changes in landform associated with CBM extraction activities:
Scattering of cattle by herding will reduce utilization, and therefore, favor an increase in grasses over forbs. Photo-monitoring will provide a permanent record that can be reviewed by grazing permittees and federal land managers.

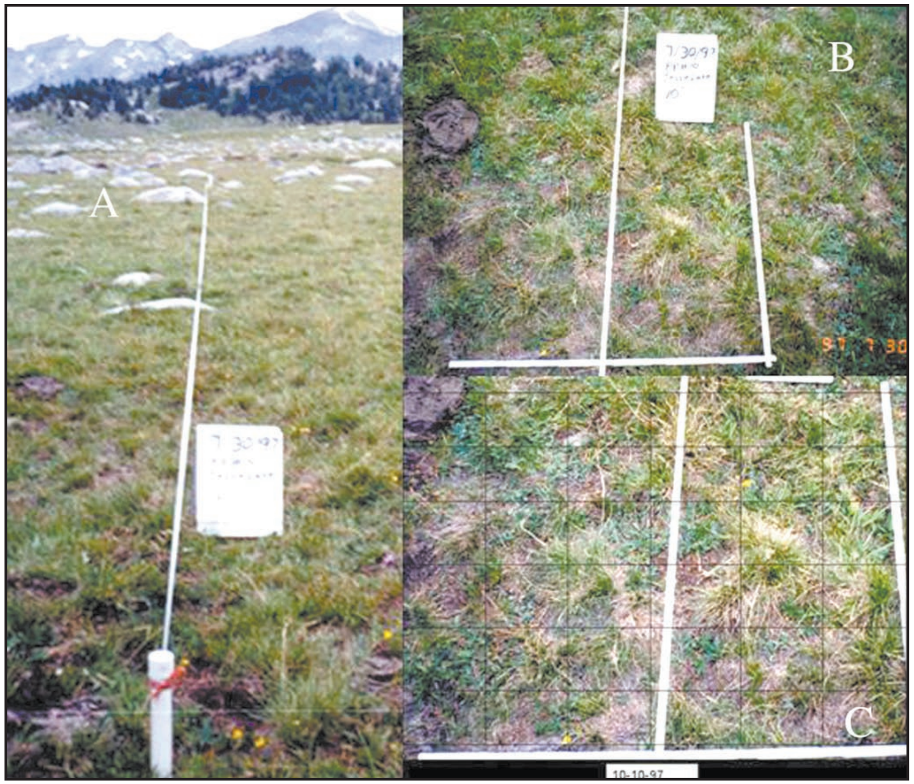
Record of repeat photo monitoring:

Date	Time	Photographer	Photo ID	Notes
7/30/01	1:00 p.m.	Joe Doe	Jim Cr. '01	Conducted vegetation transects to determine grass and forb cover. Determined that vegetation consists of 50% grasses and 50% forbs. Took photos of transects to serve as permanent record.
7/30/02	1:30 p.m.	Joe Doe	Jim Cr. '02	Conducted vegetation transects. Determined that vegetation consists of 60% grasses and 40% forbs. Took photos of transects.
7/30/03	1:00 p.m.	Joe Doe	Jim Cr. '03	Conducted vegetation transects. Determined that vegetation consists of 70% grasses and 30% forbs, and that grass cover has increased significantly while forb cover has decreased. Analysis of photo transects not significantly different than field transects and photos support conclusions.

Site location map:



Attach photos:



Although the Flying Bar Ranch Forest Service Allotment concerns are not associated with CBM development, this example illustrates an intensified photo-monitoring protocol and can be adapted to landscape issues where CBM development may occur.

WELL AND INFRASTRUCTURE RECORD SHEET (Developed from WORC, SJCA, and OGAP)

Well Name & Operator: ________________________________

Well Lease #: ___________________________________

Legal location: Sec_______ Twp______ Rng______

RESERVE PIT

Y N NA Site free of overspray?
Y N NA Level, away from drainage patterns?
Y N NA Minimum of 2 feet of berm?
Y N NA Fenced? Fence stretched and livestock proof?

OVERFLOW PIT

Y N NA Level, away from drainage patterns?
Y N NA Lined with a synthetic material liner?
Y N NA Fenced? Fence stretched and livestock proof?

DRIP/CONDENSATE TANK

Y N NA Labeled to identify contents?
Y N NA Level, away from drainage patterns?
Y N NA Area leak/contaminant free?
Y N NA Fenced? Fence stretched and livestock proof?
Y N NA Tank covered by a net or screen?
Y N NA Exterior base of tank visible?

PRODUCED WATER TANK

Y N NA Labeled to identify contents?
Y N NA Level, away from drainage patterns?
Y N NA Exterior base of tank visible?
Y N NA Area leak/contaminant free?
Y N NA Fenced? Fence stretched and livestock proof?
Y N NA Tank covered by a net or screen?

WELL PAD SITE

Y N NA Site free of visible/audible gas or fluid leaks?
Y N NA Exhaust stacks screened?
Y N NA Noise abatement provisions/equipment in place?
Y N NA Well pad, tanks, equipment level & on firm soil?
Y N NA Water runoff diverted around well pad?
Y N NA Earthen drilling pits filled in and re-seeded?
Y N NA Pad inside four anchors?
Y N NA Site avoids natural watercourses?
Y N NA Site free of overspray and noxious weeds?

PLUGGED AND ABANDONED WELL SITE

Y N NA All items removed from site?
Y N NA Site and access road re-contoured?
Y N NA Site re-vegetated or re-seeded?

ROADS

Y N NA Road surface well maintained & free of erosion?
Y N NA Roadside drainage water-barred?
Y N NA Culverts buried at sufficient depth?

PIPELINES

Y N NA Pipelines clearly marked?
Y N NA Trenches and right-of-ways (ROWs) backfilled and reseeded?
Y N NA Pipelines backfilled and reseeded?
Y N NA ROWs and pipelines free of erosion?
Y N NA ROWs and pipelines free of noxious weeds?

Comments: ____

____

SURFACE WATER MONITORING INSTRUCTIONS

For stream or spring flow and quality data collection, select sites which are representative of the entire stream or spring, or of a stretch of the stream or spring. The site you select for monitoring should be:

- accessible in all weather
- safe to sample during all stages of flow
- not near a road drainage influence
- well below tributaries or other discharge into the stream
- upstream from any culverts
- not on a bend in the stream
- not near obstructions

If flow is continuous year round, monitor flow (water quantity) 4 times during the year (Feb, May, July, Sept) to account for seasonal variations. While monitoring flow in May and September, collect 2 water quality samples. Collect the samples from the same place each time (see accompanying record sheet).

Water Quantity

Supplies needed for monitoring:

✔ hip waders or rubber boots
✔ camera and film

Water Quality

Supplies needed for monitoring:

✔ clean containers for sampling – 100 ml or more
✔ permanent ink pen
✔ hip waders or rubber boots

Collecting Water Samples:

❒ Collect water samples in a clean container after rinsing the container three times with the water. Laboratories will often provide sample bottles upon request. If bottles are obtained from a laboratory, inquire with the laboratory about the proper sample collection procedure. Samples from a spring should be taken from the headwaters of the spring. Unless instructed otherwise, fill the collection bottle to the brim.

❒ Be careful not to agitate stream/spring bottom before, or between samples; your intent is to collect samples representative of the flowing water. Avoid sampling immediately next to the bank if possible.

❒ If you must store the samples, do so for a short time in a dark, cold place.

❒ Label sample bottles with your name, date, and sample identification and send the sample to the laboratory right away. Ask for a routine irrigation water analysis, or at a minimum, ask for testing on electrical conductivity (EC), pH, sodium, calcium, and magnesium. Contact your local County Extension or Conservation District office for a list of laboratories in your area. If at all possible, continue to use the same laboratory for all future samples.

Continued on next page ➩

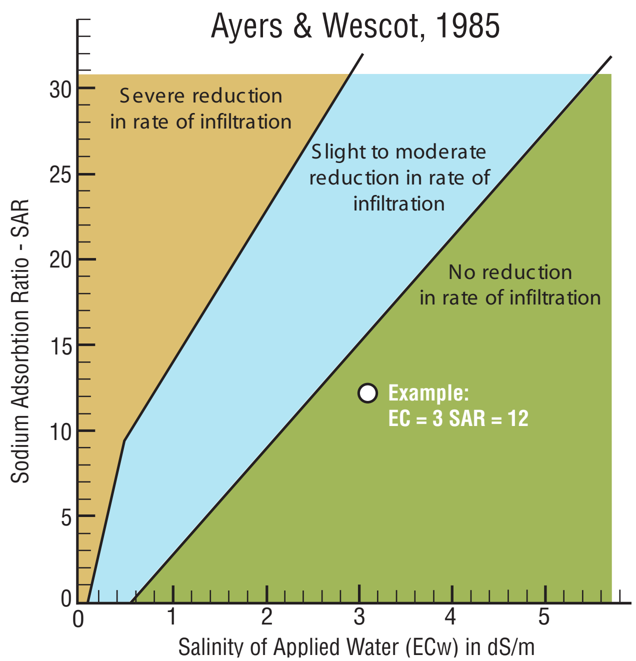
❒ At sites where coal bed methane product water is directly discharged into a stream, collect samples at 3 points on the stream:
a. Just upstream from the product water discharge site
b. Directly from discharge water before it reaches the stream
c. 25-50 feet downstream from product water discharge site. If the stretch of stream is quite long, you might also want to select another sampling site several hundred feet below the discharge site.

Evaluating the hazard of water to soil and plants

It is important to evaluate the salinity and sodicity of the water especially with regard to soil and plants. Salinity (salts) can adversely affect plants while the amount of sodium can affect soil. To gain appreciation for this significance, use the EC and SAR values from the water quality laboratory report to determine the water quality class, the salinity hazard to plants, and the potential reduction in soil infiltration using the guidelines below and record your results on the ***Surface water record sheet***.

Water Quality Rating

Saline (EC > 4 dS/m or 4 mmhos/cm)**:** potential hazard to growth of most plants and can affect survivability of many plants.
Sodic (SAR > 12)**:** may be a hazard to soil, causing reduced infiltration, increased runoff, and poor drainage.
Saline and Sodic: may be a hazard to soil and plants.
Acceptable: water quality not saline or sodic, or EC/SAR interaction deems water non-hazardous to soil and plants. Evaluate water for hazard to soil infiltration (see below).



Hazard to Soil Infiltration

Sodium in water can reduce soil permeability or the ability to infiltrate water (drain). This hazard must be determined from the SAR/EC interaction. Specific combinations of SAR and EC cause soil crusting, surface runoff and poor drainage. Plot the EC and SAR of your water on the graph to the right to determine the hazard to soil infiltration.

Calculating SAR

SAR (sodium adsorption ratio) is an index to determine the potential sodium hazard of soil or water. SAR is calculated in milliequivalents per liter (meq/l). Sodium (Na), calcium (Ca) and magnesium (Mg) concentrations may be reported by a laboratory in several ways including meq/l, milligrams per liter (mg/l), and parts per million (ppm). For practical purposes related to agricultural salinity and sodicity, 1 ppm is equal to 1 mg/l. If the laboratory reports Na, Ca, and Mg in ppm, it will be necessary to convert these units to meq/l.

Sodium (ppm): multiply by **.043** to get meq/l
Calcium (ppm): multiply by **.050** to get meq/l
Magnesium (ppm): multiply by **.083** to get meq/l

The equation to calculate SAR when Na, Ca, and Mg concentrations are expressed as meq/l is:

$$SAR = \frac{[Na]}{\sqrt{\frac{[Ca]+[Mg]}{2}}}$$

Example: A laboratory report received by John Doe on water samples he collected from a stock water pond supplied by CBM product water reported an **EC of 1.8**, a sodium concentration of **1080 ppm**, calcium concentration of **110 ppm**, and magnesium concentration of **40 ppm**. To calculate SAR, first convert results in ppm to meq/l:

1080 ppm sodium x .043 = 46.44 meq/l
110 ppm calcium x .050 = 5.50 meq/l
40 ppm magnesium x .083 = 3.32 meq/l

$$SAR = \frac{46.44}{\sqrt{\frac{5.50 + 3.32}{2}}}$$

$$SAR = \frac{46.44}{2.1}$$

SAR = 22.11

Laboratory results indicate the water in John's stock pond is not saline (EC < 4 dS/m), but is sodic with an SAR greater than 12. If applied to the soil, the water poses a slight to moderate hazard to infiltration (Ayers and Westcott figure, page 55).

SAR calculator available on-line at Colorado State University Extension Service website at:
http://www.coopext.colostate.edu/TRA/PLANTS/index.html#http://www.colostate.edu/Depts/CoopExt/TRA/PLANTS/sar.html

SURFACE WATER RECORD SHEET

Water source identification (name on inventory map): ________________________________

Description of water resource:

_ Ephemeral stream _ Pond/lake _ Irrigation canal
_ Perennial stream _ Spring _ Other

Climate Observations: Average annual precipitation at this site: ______________

Snow melt: Start Date: ____ End Date: ____ photos? _ yes _ no

Description of the snow year:

_ Dry winter only - snow drifts
_ Average winter, draws full of snow, exposed areas dry
_ Heavy snow year, draws and channels full and snow everywhere

Other observations:

Water Quality Inventory:

Laboratory name, address and phone number: ____

Location of laboratory reports: ____________________________

Record of repeat water quality samples:

Date	Days after precip event	Flow (dry, low, full, over bank)	# Photos (see below)	Sediment (clear, moderate, muddy)	EC* in dS/m or mmhos/cm	SAR**	Infiltration Hazard*** (none, slight, severe)

* EC = TDS in parts per million / 640 **see page 57 to calculate SAR ***see page 57 to determine infiltration hazard

Photographs documenting the volume of flow and sediment in the channel are recommended at the time of water sample collection.

PRODUCT WATER LAND APPLICATION MONITORING INSTRUCTIONS

If possible, collect soil and water data before any application of CBM product water or mixed water. Collect soil samples once annually (preferably before the growing season) from all pasture, range and crop fields where either CBM water or other water mixed with CBM water will be or has been applied. Collect water quality samples directly from the irrigation source at least one time during the irrigation period for each irrigated parcel.

Keep detailed records on annual crop yield and the amount of water applied to the site. Record the date, well ID (as identified on your map), and site location in the attached data sheets and store it and all laboratory reports in your inventory notebook.

Soil Sampling

Supplies needed for monitoring

- ✔ Soil sampling tool: tile spade, hand probe bucket auger, or open split tube sampler free of rust (your local County Extension, NRCS, or Conservation District office may have soil sampling tools)
- ✔ Clean plastic containers (3 to 4)
- ✔ Hand gardening shovel, stiff spatula, or old knife
- ✔ Soil sample bags or plastic bags that seal tightly
- ✔ Handheld GPS (your local County Extension or Conservation District may have a GPS available for loan)

To collect a representative soil sample from each site:

- ❒ Remove all litter and dead plant matter from the soil surface before sampling. If living plants are present, clip the plants at ground level and discard. Collect one sample from the 0 to 6 inch depth of soil and place in a bucket. Collect a second sample from the 6 to 18 inch depth and place in a second bucket. Repeat this process at a total of five locations in small fields or five samples per 100 acres in large fields. Each time you collect a sample, place the 0-6” sample and the 6-18” sample in the respective buckets. When you finish, you should have two buckets, each with a composite sample from a depth increment.
- ❒ Thoroughly mix the soil in each bucket.
- ❒ Remove a sub-sample of the soil mixture from the bucket and place it in a soil sample bag or a resealable plastic bag. This is a composite consisting of a mixture of the individual cores.
- ❒ Properly label each bag with the site location, sampling depth, and other descriptive characteristics.
- ❒ Take a GPS reading of where you took the soil sample and/or mark the location of the site with a stake and spray paint. Also mark your photo-monitoring inventory map.

Continued on next page ⇨

- ❒ Submit samples to the lab for a routine irrigation suitability test. Contact your local County Extension or Conservation District office for a list of laboratories in your area. If at all possible, use the same laboratory for all of your samples.
- ❒ Store results in your monitoring notebook.
- ❒ When re-sampling a field, make sure to collect samples at the same time of year and at the same locations previously sampled.
  - In fields with high variability, collect some samples from locations such as water turn out locations, ponded locations, or locations where crusting/cracking is observed.
  - However, don't sample only in "bad" spots in fields, and avoid unique or non-representative areas, such as fences, roads, or areas of high livestock traffic.

Irrigation Water Quality (land applied CBM water and mixed water)

Supplies needed for monitoring:

✔ clean containers for sampling with water tight lids– 100 ml or more (equivalent to a 12 oz. pop bottle)
✔ permanent ink pen

To collect a representative water sample from each irrigation source:

- ❒ Collect the sample in a clean container after rinsing the container three times with the water being sampled (irrigation stream). Laboratories will often provide sample bottles upon request. If bottles are obtained from a laboratory, inquire with the laboratory about the proper sample collection procedure. Unless instructed otherwise, fill the collection bottle to the brim.
- ❒ If you must store the samples, do so for a short time in a dark, cold place.
- ❒ Label the containers with your name, date, and water source and send the sample to the laboratory right away. Ask for a routine irrigation water analysis, or at a minimum, ask for testing on electrical conductivity (EC), pH, sodium, calcium, and magnesium. Contact your local County Extension or Conservation District office for a list of laboratories in your area. If at all possible, use the same laboratory for all future samples.
- ❒ When you get your results from the lab, identify *Water Quality Class* and the water's *Hazard to Soil Infiltration* (see page 57) and record this information in the attached ***Soil sample record sheet***.

SOIL SAMPLE RECORD SHEET

Field Name or Number: ______________________________

Soil Sampling:

Person/company performing soil sampling: ________________________

Laboratory name, address and phone number: ____

Location of laboratory reports: ________________________

Sample location or GPS coordinates: _________________________

Soil Sample Laboratory Data

Date of test	Sample depth	pH	EC* in dS/m or mmhos/cm	Na	Ca	Mg	SAR**	Infiltration Hazard*** (none, slight, severe)	Soil Amendments (since last soil test) i.e. gypsum, sulfur, etc.

* EC = TDS in parts per million / 640

**see page 57 to calculate SAR

***see page 57 to determine infiltration hazard

CBM IRRIGATION WATER QUALITY RECORD SHEET

(For CBM product water intended for land application)

Irrigation Water Quality:
Person/company performing soil sampling: ______________________________
Laboratory name, address and phone number: ____
Location of laboratory reports: ______________________________

CBM Water Laboratory Data

Water Source ID	Field ID	Sample Date	Inches irrigation water applied	EC* in dS/m or mmhos/cm	Na	Ca	Mg	SAR**	Infiltration Hazard*** (none, slight, severe)

* EC = TDS in parts per million / 640 **see page 57 to calculate SAR ***see page 57 to determine infiltration hazard

➩ It is important that CBM water intended for irrigation be sampled at the sprinkler nozzle or at the point of diversion to the field and not at the well head or pond site.

MIXED IRRIGATION WATER QUALITY RECORD SHEET

(For product water mixed with non-CBM water intended for land application)

Irrigation Water Quality:
Person/company performing soil sampling: ______________________________
Laboratory name, address and phone number: ____
Location of laboratory reports: ______________________________

Mixed Water Laboratory Data

Water Source ID	Field ID	Sample Date	Mixed water source: ratio CBM water to supplement water source	Inches irrigation water applied	EC* in dS/m or mmhos/cm	Na	Ca	Mg	SAR**	Infiltration Hazard*** (none, slight, severe)

* EC = TDS in parts per million / 640 **see page 57 to calculate SAR ***see page 57 to determine infiltration hazard

➩ It is important that CBM water intended for irrigation be sampled at the sprinkler nozzle or at the point of diversion to the field and not at the well head or pond site.

CROP PRODUCTION RECORD SHEET

(CBM product water and mixed water land application sites)

Keep detailed records of the crop yield, especially for sites receiving CBM product water or mixed water. Use the table below to document crop production on each field.

Crop Production Data

Year	Field ID	# Acres	Irrigation Method (pivot, flood, etc.)	Growing Season Rainfall	Crop	Planting Date	Harvest Date	Fertilizer Use (type, method, date applied)	Yield (bales/acre, tons/ acre, bu/acre)	Soil Amendments i.e. gypsum, sulfur, etc.

GROUND WATER MONITORING INSTRUCTIONS

Measure depth to groundwater and sample water quality in all agricultural and domestic wells on your property. Take four samples for testing and four measurements of depth during the first year (Dec, March, July, Sept). If taking 4 measurements is not possible, samples and measurements in March and September are recommended. In subsequent years, sampling depth to groundwater and water quality in March and September only are adequate, unless changes in water quality are detected (see accompanying record sheet).

Water Quantity (depth to groundwater)

Supplies needed for monitoring:

✔ Electronic water level meter. (These meters are expensive, but they are a critical investment to track changes in groundwater depth. Your state water resource agency, a local well driller, or the County Extension agent can direct you to a supplier.

Measuring the depth to groundwater using an electronic water level meter:

❒ Keeping the meter taught, lower the meter tape into the well until you hear the "beep" as the meter comes in contact with the water in the well.
❒ Measure the distance from the top of the well to the ground surface.
❒ Subtract the distance from the top of the well to the ground surface from the measured depth of ground water to get actual depth of ground water.

Water Quality

Supplies needed for monitoring:

✔ Clean containers for sampling with water tight lids (plastic is fine) – 100 ml or more (equivalent to a 12 oz. pop bottle)
✔ Permanent ink pen

Collecting water quality samples:

❒ Collect water quality samples in a clean container from all wells using an outside hydrant. Laboratories may provide sample bottles upon request. If bottles are obtained from a laboratory, inquire with the laboratory about the proper sample collection procedure. Unless instructed otherwise, fill the sample bottles to the brim. Either wait until the pump turns on or let the water run for 1 to 2 minutes before collecting the sample to be sure the pressure tank has drained and that the water sample is fresh. Rinse the jar three times with the water before collecting the sample.
❒ Label the sample bottles with your name, date, and sample identification. If you must store the sample, do so for a short time in a dark, cold place.
❒ Send the sample to the laboratory right away. Ask for a routine irrigation water analysis or at a minimum, ask for testing on electrical conductivity (EC), pH, bicarbonate, sulfate, sodium, calcium, and magnesium. Contact your local County Extension or Conservation District office for a list of laboratories in your area. If possible, use the same laboratory for all future samples.

Petroleum Hydrocarbons in the San Juan Basin

Petroleum hydrocarbons is a term used to describe a large family of chemical compounds that originally come from crude oil. Many hydrocarbons are used as fuels such as gasoline and methane. Some hydrocarbon compounds produce adverse health effects including central nervous system damage and may result in headaches, dizziness, and anemia. The hydrocarbon Benzene is a known carcinogen.

Water production associated with CBM development in certain areas, such as the San Juan Basin in southern Colorado and northern New Mexico, potentially result in the coproduction of petroleum hydrocarbons (**Figure 27**). This is not a common or known occurrence in the Powder River Basin at the present time. Hydrocarbons stored in unlined pits, spilled on the soil surface, or leaked from storage tanks and pipelines are potential sources of ground water contamination. Landowners in these areas may consider petroleum hydrocarbon monitoring a necessary component of a ground water monitoring plan.

Figure 27 · Liquid hydrocarbons and product water may be discharged to the surface during the drilling phase of CBM development.

Numerous laboratory techniques exist for testing the presence and make-up of petroleum hydrocarbons and interpretation of results can be difficult. Contact a laboratory in your area to determine if hydrocarbon sampling is necessary in your area, and if so, what the appropriate hydrocarbon analysis, sampling protocol, and associated costs will be. Although it is more expensive, you may consider hiring a professional consultant to collect samples and interpret the results. If you determine that hydrocarbon monitoring is appropriate for your situation/property, it may be necessary to establish periodic monitoring once every several years to provide adequate safeguard for your ground water resources.

For a list of analytical laboratories to contact, go to the following website: http://www.ext.colostate.edu/pubs/crops/00520.html.

For a list of petroleum hydrocarbon compounds, associated health effects, and acceptable contaminant level thresholds, go to the EPA Ground Water and Drinking Water website at: http://www.epa.gov/safewater/mcl.html#organic.

GROUND WATER RECORD SHEET

Well identification: ___________________________ **Location:** ____

Type of well: _ agricultural _ artesian, flowing _ spring
_ artesian, not flowing _ domestic _ other ________________

Source of well water: _ shallow aquifer _ coal seam aquifer _ deep aquifer _ unknown _ Other ___________

Water Quality Inventory:
Person/company performing soil sampling: ____
Laboratory name, address and phone number: ____
Location of laboratory reports: ____

Groundwater Quantity and Quality Data

Date	Time	Depth to Water Surface (ft)	EC* in dS/m or mmhos/cm	Na	Ca	Mg	SAR**	pH	Sulfate	Bicarb.	Cost

* EC = TDS in parts per million / 640 **see page 57 to calculate SAR