Frequently Asked Questions

Coal Bed Methane (CBM)

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John Wheaton, Montana Bureau of Mines and Geology (2003)

- What is coal bed methane (CBM)?
- Where does CBM exist?
- How much methane gas is estimated will be extracted from the Powder River Basin?
- How do they estimate the amount of methane gas which will come from a region underlain by coal?
- How do gas companies extract methane from a coal seam?
- Are coal seams aquifers?
- I've heard people talk about aquifer drawdown from CBM development. What does this mean?
- Some individuals say that the depleted aquifers in the Powder River Basin will be recharged within a matter of years, while others think the time might be more on the scale of a thousand years or more. Who is right?
- I heard that almost all CBM product water discharged to the land surface eventually reaches the aquifer from which it was pumped. Is this true?
- Will CBM devlopment reduce flow to streams, springs and wells?
- Why are people concerned with CBM product water?
- What is saline water and why is it considered saline?
- What is sodic water and why is it considered sodic?
- Is CBM product water in Montana saline or sodic?
- Are some soils more sensitive than others to saline and/or sodic water?
- Is it true you can irrigate crops with CBM water?
- What are the current management practices for disposal of CBM product water?
- How can holding ponds hold all that water being produced from CBM development?
- Can CBM product water be treated to make it more usable?

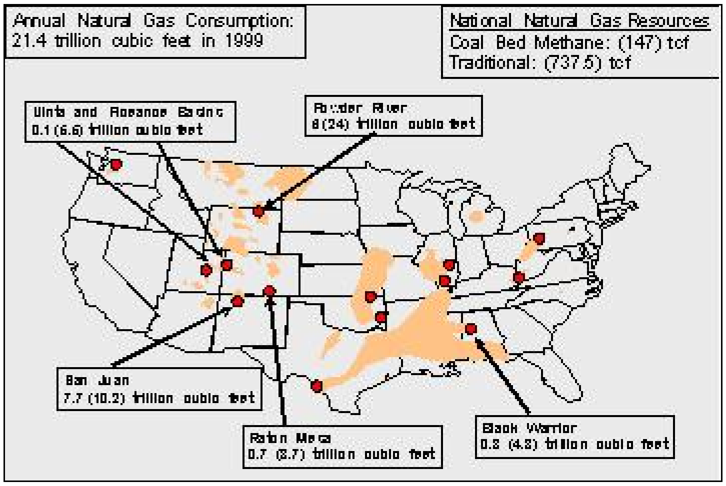
What is coal bed methane?

The primary energy source of natural gas is a substance called methane (CH_4). Coal bed methane (CBM) is simply methane found in coal seams. It is produced by non-traditional means, and therefore, while it is sold and used the same as traditional natural gas, its production is very different. CBM is generated either from a biological process as a result of microbial action or from a thermal process as a result of increasing heat with depth of the coal. Often a coal seam is saturated with water, with methane is held in the coal by water pressure. Currently, natural gas from coal beds accounts for approximately 7% of total natural gas production in the United States.

Where does coal bed methane exist?

According to the CBM Association of Alabama, 13% of the land in the lower 48 United States has some coal under it, and some of this coal contains methane - either in the form we know as traditional natural gas or as CBM. According to the United States Geological Survey, the Rocky Mountain Region has extensive coal deposits bearing an estimated 30-58 trillion cubic feet (TCF) of recoverable CBM. While impressive, this represents only one third of the total 184 TCF of natural gas in the Rocky Mountain region (Decker, 2001).

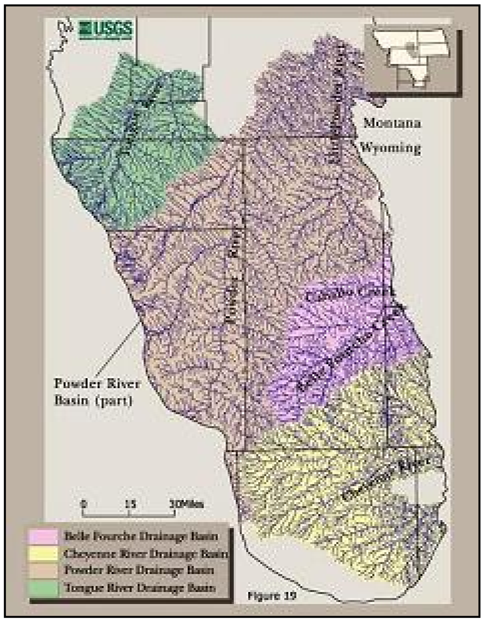
Within the Rocky Mountain Region, untapped sources of CBM exist in the Powder River Basin of Wyoming and Montana, the Greater Green River Basin of Wyoming, Colorado, and Utah, the Uinta-Piceance Basin of Colorado and Utah, and the Raton and San Juan Basins of Colorado and New Mexico. An estimated 24 TCF of recoverable CBM resources may lie below the Powder River basin of Montana and Wyoming (Decker, 2001).



How much methane gas is estimated will be extracted from the Powder River Basin?

Estimates of amounts of methane gas in the Powder River Basin vary and are often re-calculated. There are several methods to estimate the amount of recoverable gas from a coal seam, all having varying degrees of accuracy.

According to the U. S. Geological Survey (2001), the amount of recoverable CBM in the Powder River Basin ranges from 8.24 - 22.42 TCF. The Wyoming Oil and Gas Conservation Commission (2002) estimates 31.8 TCF of recoverable CBM in the Powder River Basin of Wyoming alone. The Montana Bureau of Mines and Geology and the U.S. Department of Energy have



separately estimated 0.8 - 1.0 TCF of recoverable CBM in the Powder River Basin of Montana. The Environmental Impact Statement for coal bed methane development in the Powder River Basin of Montana reports 2.5 TCF of recoverable gas.

How do they estimate the amount of methane gas which will come from a region underlain by coal?

There are two popular methods of estimating recoverable methane gas from a coal seam. One method requires estimating methane reserves by boring to the top of the coal seam, then extracting a core from the coal. The amount of methane recovered from the coal core is used to estimate gas content per unit volume of coal. If a number of cores are drilled and methane gas release is observed, one can estimate the amount of gas available in a region. The limitations to this method are: 1) there is much disturbance to the coal seam core before gas release is measured; 2) it is expensive and 3) not every region of potential CBM development has been drilled and explored.

Another method of estimation is through a series of calculations based on information already known about the coal in the region and the feasibility of CBM development. For instance, the Montana Bureau of Mines and Geology estimated the amount of recoverable CBM in the Powder River Basin using the following information:

- A coal seam has favorable reserves if it produces 50-70 ft^3 per ton of coal.
- CBM extraction is economical at 50 ft^3 per ton of coal when a coal seam is 20 feet thick or more.
- Coal bed methane exists only in areas where the dominant chemistry of the water in the coal seam is sodium bicarbonate and where the coal seam is buried deeply enough to maintain sufficient water pressure to hold the gas in place.

The Environmental Impact Statement for CBM development in the Powder River Basin estimated the amount of coal in the region based on the total reported tonnage of coal in the region multiplied by 50 ft^3 of methane per ton of coal, irregardless of seam thickness, depth or proximity to outcrop.

How do gas companies extract methane from a coal seam?

Since CBM travels with ground water in coal seams, extraction of CBM involves pumping available water from the seam in order to reduce the water pressure that holds gas in the seam. CBM has very low solubility in water and readily separates as pressure decreases, allowing it to be piped out of the well separately from the water. Water moving from the coal seam to the well bore encourages gas migration toward the well.

CBM producers try not to dewater the coal seam, but rather seek to decrease the water pressure (or head of water) in the coal seam to just above the top of the seam. However, sometimes the water level drops into the coal seam.

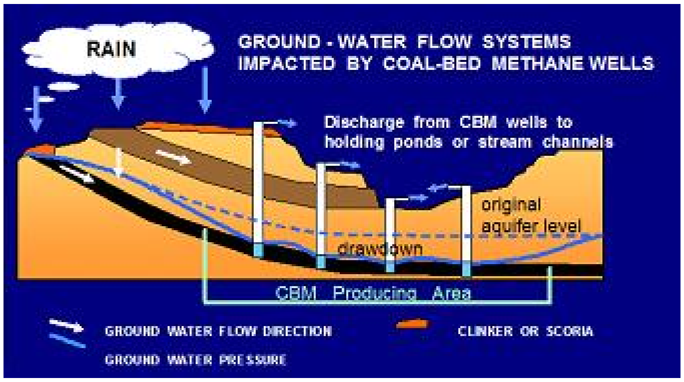
Are coal seams aquifers?

Yes. Water flows through fractures (or cleats) in the coal seam and if the cleat system is well developed and has enough water to pump and produce an economically viable and feasible water supply, the seam can be an aquifer. Coal seams are the most regionally continuous geologic unit in the Powder River Basin and have aquifer characteristics equal to or better than sandstones, so are frequently targeted for water-well completions.

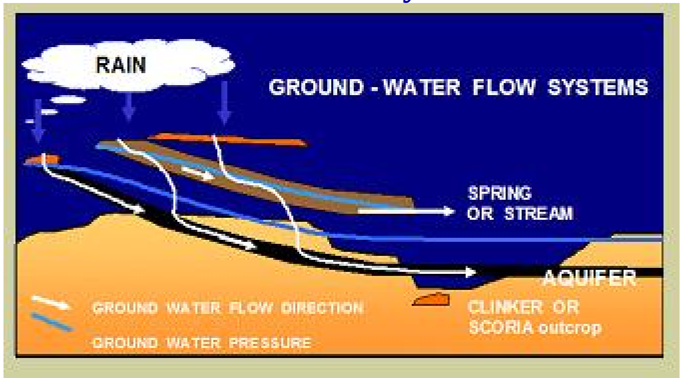
I've heard people talk about aquifer drawdown from CBM development. What does this mean?

Ground water flows through coal seams due to water pressure, or hydrostatic head. When the pump in a well is turned on, the amount of water than can be produced is controlled in part by the static water level, which is the original hydrostatic head in the well. As the pump withdraws water from the aquifer and discharges it at the surface (whether it is to a stock tank, house, or CBM discharge point) the water pressure (head) in the aquifer is reduced. The greatest reduction in water pressure is near the well, with progressively less change at increasing distances from the well. If we could see this reduction in water pressure it would be shaped like a funnel or cone with the spout in the well. This area of reduced water pressure is called the cone-of-depression. When the pump is turned off, water flowing through the coal aquifer replaces the discharged water, and the water pressure returns to static conditions. An idealized ground-water flow system, and one where the head shows the drawdown associated with CBM production are shown in the following figures.

Within the cone-of-depression, there is less water pressure in the aquifer, and therefore less water can be produced from a well (or spring). The percentage change is greatest near the central or deepest part of the cone-of-depression. The amount of change in water pressure and the distance from the producing well to the limit of change depends on many factors, including the static water level, pumping rate, aquifer characteristics, and how long water is produced. Also, the time needed for water pressure to return to static conditions is dependent on the same parameters. In cases with a field of producing wells, as is the case with CBM, the size of the cone-of-depression and recovery time are both increased significantly.



Some individuals say that the depleted aquifers in the Powder River Basin will be recharged within a matter of years, while others think the time might be more on the scale of a thousand years or more. Who is right?



Aquifer recharge is the process whereby precipitation or surface water infiltrates below land surface and begins to flow in an aquifer system. Ground water flowing through coal seams in the Powder River Basin has infiltrated along clinker or scoria ridges, in stream valleys, and in some cases in sandy soils during years of heavy precipitation. In the case of CBM product water, recharge occurs many miles away from development sites.

According to the Montana Bureau of Mines and Geology, monitoring and groundwater modeling indicates somewhere between a few years and 20 years for recharge to occur. The question of recharge time is a challenging one. In coal mining areas, recharge occurs within a few years (typically 3 to 4). However, open pit or strip coal mines normally cover an area of only a few square miles, and because the area of impact is relatively small, recharge can occur rapidly. With CBM extraction, the area of impact may be as large as many adjacent townships (1 township=36 mi^2). In such large geographic areas recharge depends on the time it takes recharge at the coal seam outcrop to move to the CBM developed area (Wheaton, 2002).

I heard that almost all CBM product water discharged to the land surface eventually reaches the aquifer from which it was pumped. Is this true?

MSU scientists contend that most likely only a small percentage of CBM water returns to the aquifers from which it was pumped. Rather, the water recharges shallow alluvium and coarse soil material aquifers near the land surface, less than 200 feet deep, or is lost to evaporation. If CBM product water is directly discharged into a stream channel (this is no longer allowed, but there are sites that were "grandfathered") it can flow downstream, evaporate, or percolate to groundwater through the stream channel. Land applied or stored CBM product water evaporates or percolates to shallow groundwater.

Once water reaches a shallow aquifer, where it goes is very site specific. The aquifer water pressure (head) may increase, and/or the water may flow laterally to a spring or become baseflow to a nearby stream. There are reports in the Powder River Basin that some stream channels are carrying more flow than before CBM development, and there are reports that some streams have no increase in flow. With our current level of knowledge, it is very difficult to predict what will happen to the water once it reaches the shallow aquifer system.

In Gillette, WY, the Pennaco company is reinjecting water back into the depleted aquifer which supplies water for the city of Gillette. Pennaco, and other companies in the Powder River Basin, are investigating the feasibility of injecting CBM product water at several sites in the area.

Will CBM devlopment reduce flow to streams, springs and wells?

As a result of the large amount of water being pumped from coal seam aquifers, there is concern of impact to springs and streams and to the level of water in drinking and livestock wells. The answer to this question is very location specific. If a spring or stream is fed by a coal seam aquifer (the coal seam surfaces and discharges water into a stream or spring), CBM development in the local area may decrease flow to those water bodies. If a spring or stream is not fed by a coal seam aquifer, decreases in flow would be minimal. However, if CBM product water is land applied or impounded in a holding pond (most often these ponds are not lined and discharge to the subsurface), streams down slope may have increased flow during development due to subsurface flow.

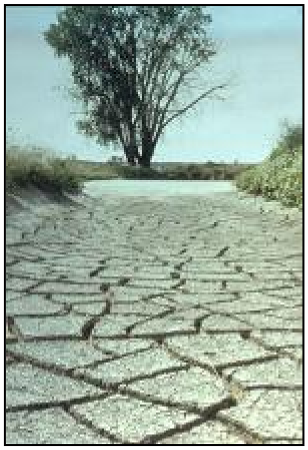
If a drinking water or livestock well gets water directly from a coal seam, then CBM development in the local area may decrease the water level in that well. Duration of impacts to spring flow and water available from wells will depend on the total area developed and timing.

Why are people concerned with CBM product water?

There are several concerns about CBM development and how to manage the water co-produced with methane.

The quantity of the CBM product water:

Extraction of CBM involves pumping large volumes of water from the saturated coal seam in order to release the water pressure holding the gas in the coal seam. What to do with this volume of often marginal-quality CBM product water is a source of much debate. Each well produces 5 to 20 gallons of water per minute. At 12 gallons per minute, one well produces a total of 17,280 gallons of water per day. It is common to have to have one well every 80 acres, and in the Powder River Basin, there are up to three methane-bearing coal seams. Therefore, there may be up to three wells per 80 acres.



The quality of CBM product water and its effects on soil:

CBM product water has a moderately high salinity hazard and often a very high sodium hazard based on standards used for irrigation suitability. Irrigation with water of CBM product water quality on range or crop lands should be done with great care and managed closely. With time, salts from the product water can accumulate in the root zone to concentrations which will affect plant growth. Saline conditions stunt plant growth because plants must work harder to extract water from the soil.

The sodium hazard of CBM product water poses additional threats to certain soil resources. Sodic irrigation water causes soil crusting and impairs soil hydraulic conductivity, adversely affecting water availability and aeration and subsequent crop growth and yield. Upon wetting of soils containing swelling clay, sodium causes the degree of swelling in the clay to increase, leading to dispersion and migration of clay particles. Current research at Montana State University shows that water with sodium levels equal to typical Montana CBM product water can degrade the physical and chemical properties of heavier, clay soils, making such soils completely unsuitable for plant growth.

The risk of sodium degradation has been observed in other soil textures. Jim Oster (personal com.) observed crusting, poor soil tilth, hardsetting and aggregate failure on a sandy loam soil irrigated with water with EC ~ 1 and SAR ~ 7. Minhaus (1994) saw irreversible and severe reduction in infiltration on sandy loam soil with long term irrigation under high SAR water followed by monsoon rain.

There are many factors in addition to soil textures that affect infiltration rates. Mineralogy, lime, sesquiozides, organic matter content, cultivation, irrigation method, wetting rate, antecedent water content and time since cultivation all play a roll in infiltration. The only way to be certain of the impacts of saline/sodic irrigation water on the soil is to periodically sample and test the irrigation water and the soil.

The quality of CBM product water and its effect on plants:

Disposal of the quantities of CBM product water into stream channels and on the landscape poses a risk to the health and condition of existing riparian and wetland areas. High salinity and sodium levels in product water may alter riparian and wetland plant communities by causing replacement of salt intolerant species with more salt tolerant species. It is well recognized that encroachment of such noxious species as salt cedar, Russian olive, and leafy spurge is enhanced by saline conditions.

Impounded CBM discharge in an ephemeral channel. Die-off of plants within weeks of release.

Encroachment of halophytic weed species within one season.

Left: An example of soils of eastern Montana that are high in swelling (montmorillonitic) clay.
Right: Complete dispersion of the same soil following a season of exposure to high saline/sodic water.

What is saline water and why is it considered saline?

Saline water has a relatively high concentration of dissolved salts. Salt is not just "salt" as we know it - sodium chloride (NaCl) - but can be dissolved calcium (Ca^{2+}), magnesium (Mg^{2+}) sulfate ($S0_4^{2-}$), bicarbonate ($HC0_3^-$) and Boron (B).

Salinity of water is referred to in terms of Total Dissolved Solids (TDS) and can be estimated by measuring Electrical Conductivity (EC), expressed as decisiemen per meter (dS/m), or less often in millimhos per centimeter (mmhos/cm) (the two measurements are numerically equivalent). EC is also reported in microsiemens or micromhos per centimeter, equal to 1,000 times dS/m. TDS is approximately related to EC by the following equations:

- TDS (parts per million, ppm or milligrams per liter, mg/l) = 640 x EC (dS/m)
- TDS (milliequivalents per liter) = 10 x EC (dS/m)

Water is considered saline when it becomes a risk for crop growth and yield. The U.S. Department of Agriculture defines water with an EC greater than 3.0 dS/m as saline.

What is sodic water and why is it considered sodic?

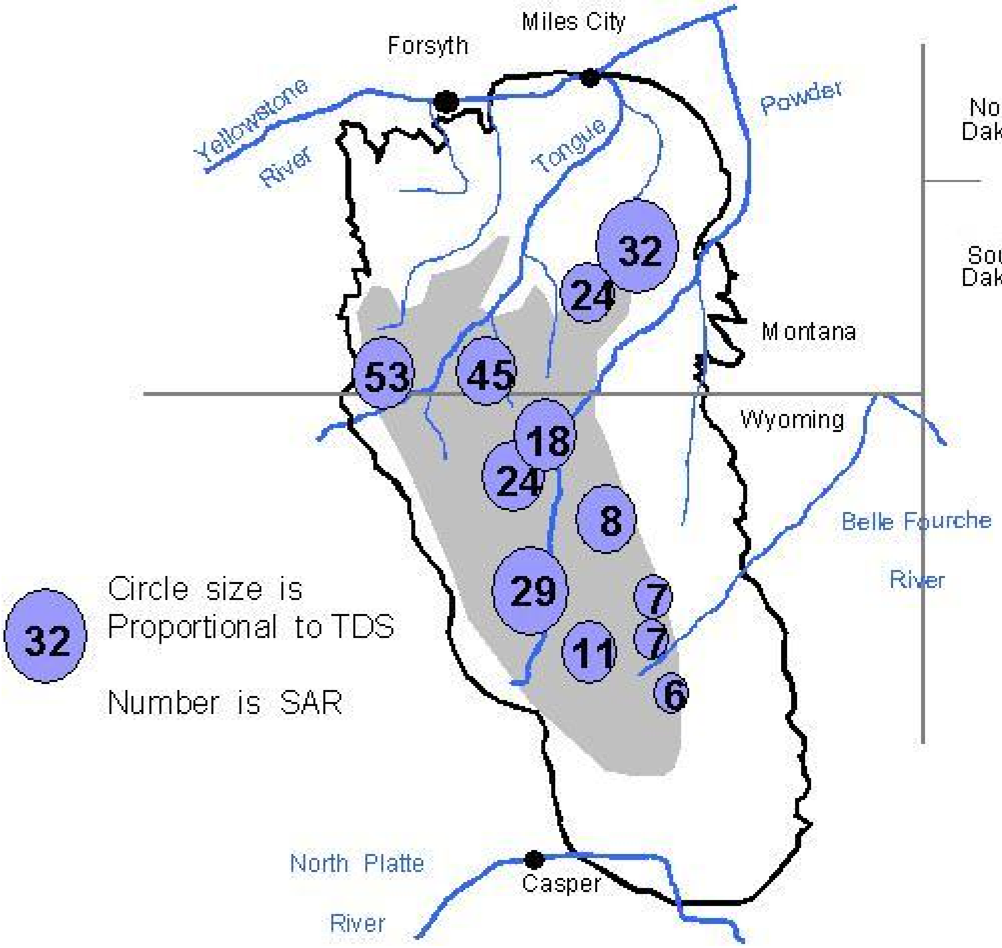
Sodic water is high in the sodium (Na^+) concentration relative to concentrations of calcium (Ca^{2+}) and magnesium (Mg^{2+}). Sodicity of water is expressed as the Sodium Adsorption Ratio (SAR) which is:

$SAR = Na \sqrt{[(Ca + Mg) / 2]}$ (These values are in meq/L)

The U.S. Department of Agriculture defines water with a SAR greater than 12 as sodic.

Is CBM product water in Montana saline or sodic?

In the Powder River Basin, CBM product water becomes increasingly saline and sodic moving north and west through the basin.



Are some soils more sensitive than others to saline and/or sodic water?

Yes. Irrigation water that is suitable for one soil may not be for another. Use of saline and/or sodic water for irrigation can be risky business on soils predominated by silt or clay. Just 1 acre-foot of moderately saline irrigation water (EC = 3 dS/m - the upper end of suitability for irrigation water) will introduce 1.8 tons of salt to an acre of land. Soluble salts do not leach as readily through fine textured soils as through sandy soils. Therefore, when irrigating fine textured soils with moderately saline water, it is critical to add enough water to meet crop water requirements and to maintain a net downward movement of water through the soil.

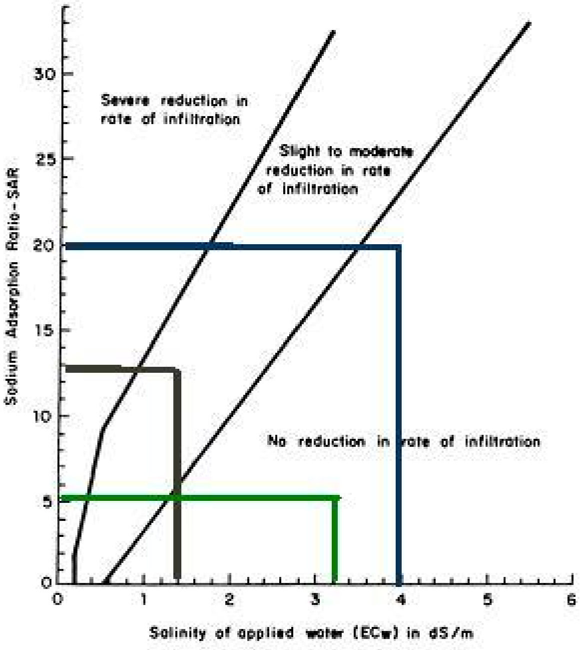
In addition to being a salinity component of irrigation water, sodium poses a more troublesome problem in soils with more than 30% clay. On such soils, sodium degrades soil physical properties, leading to poor drainage and crusting. Irrigation of sandy soils with sodic water on sandy soils does not cause such problems, as the sodium is more readily leached from the soil profile.

Sodium risk to soil infiltration cannot be determined solely from the USDA definition of sodic water (SAR = 12). Therefore, the sodium hazard of irrigation water on soil infiltration must be determined from the SAR/EC interaction. Ayers and Wescot (1985) outline guidelines for evaluating sodium risk to soil infiltration. The risk is soil texture independent. The three examples below illustrate the need to evaluate the risk to soil infiltration based on the EC/SAR interaction. It is important to understand that rainfall or irrigation with non-saline water on soils previously irrigated with saline sodic water can increase the sodium hazard by lowering the EC much faster than the SAR.

Saline Irrigation Water: EC = 3.2 dS/m, SAR = 5.0 slight risk

Sodic Irrigation Water: EC = 1.4 dS/m, SAR = 13 slight to moderate risk

Saline-Sodic Irrigation Water = EC 4.0 dS/m, SAR = 20 slight risk



Ayers & Wescot, 1985

Is it true you can irrigate crops with CBM water?

Irrigation of crops with water of CBM quality can be risky if not managed closely. With time, salts accumulate in the root zone to concentrations which will affect crop growth. Saline conditions stunt plant growth because the plants must work harder to extract water from the soil. Table 1 illustrates salt tolerance levels for some common Montana crops.

Elevated sodium and chloride concentrations can harm some woody plants as they are taken up by the root cells or directly applied to plant leaves. Either way, ions can accumulate in the leaves, causing leaf burn along the outer leaf edges.

Sodium can indirectly affect crop growth by causing calcium, potassium, and magnesium deficiencies or by adversely affecting soil physical properties. If irrigation water is sodic, physical properties of heavier soils (predominantly silt or clay) may be altered, affecting the soil's ability to drain. Poorly drained soils can compromise crop growth and yield.

To avoid build-up of salt in the soil, annually leach the soil with enough non-saline water so the salts are moved below the root zone. Adequate drainage is absolutely necessary for this procedure to be successful. Research in the western United States has shown that substantial volumes are needed to leach salt from the soil.

Table 1. Salt tolerance of common Montana crops.

	Tolerant **EC = 10-16 dS/m**	**Semi-Tolerant** **EC = 4-10 dS/m**	**Sensitive** **EC < 4 dS/m**
Crops	Barley Sugarbeet Sunflower	Wheat Oats Safflower Corn	Potatoes Field Bean Peas Lentils
Forages	Tall wheatgrass (Alkar) Bearless wildrye (Shoshone) Altai wildrye (Prairieland) Slender wheatgrass (Revenue) Western wheatgrass (Rosana) Russian wildrye (Commercial) Barley (Steptoe)	Yellow Sweetclover (Commercial) Alfalfa (ladak 65) Tall fescue (Kenmont) Wheat (hay) Orchardgrass Cicer milkvetch Crested Wheatgrass (Nordan)	White clover Meadow Foxtail Alsike clover Red clover Ladino clover

Sources: MSU Extension MontGuide #8382 *Salinity Control Under Irrigation*; MontGuide #8321 *Salt Tolerant Forages for Saline Seep Areas*

What are the current management practices for disposal of CBM product water?

Currently, CBM product water in the Powder River Basin is managed by the following methods:

- **Discharged into a stream channel** - Although direct stream discharge is no longer permitted on new wells, existing operations were "grandfathered" and are still discharging directly into streams. Also, proposals are being advanced to allow regulated discharges during certain flow conditions.
- **Impounded** - This method involves constructing a pond in which CBM product water is stored or allowed to infiltrate to the subsurface. There are several terms for these impoundments: "holding ponds", "zero discharge ponds" or "infiltration ponds". Although they do not directly discharge water on the land surface, most impoundments are not lined and do discharge to the subsurface. Some percentage of seepage flow from impoundments is likely to reach stream channels via subsurface flow.

- **Land applied to crop or rangeland** - through some form of irrigation equipment.
- **Other uses** - CBM product water is also used for dust control and, in some cases, is being used by coal mines.

Another option proposed for disposal of CBM product water in eastern Wyoming and Montana is to reinject the CBM product water back into an aquifer(s). This practice occurs in the southwest U.S., where CBM product water is injected into formations below CBM-bearing coal. This approach avoids surface discharge. Many opinions exist, and the feasibility - economic, physical, and environmental - of either reinjecting CBM product water to the coal seam from which it was pumped or injecting it into an aquifer above or below the CBM-bearing coal seam is being investigated.

How can holding ponds hold all that water being produced from CBM development?

CBM product water holding ponds (also called infiltration ponds, evaporation ponds, or zero discharge ponds) are designed to hold CBM water and avoid any discharge onto the ground surface. Typical holding ponds are not lined and therefore discharge water to the subsurface. Some MT Bureau of Mines and Geology shallow monitoring wells show rising water levels in response to pond leakage in an area where CBM product water is being stored. This phenomenon was similarly reported by the Bureau of Land Management scientists monitoring relatively shallow aquifers near holding ponds in the upper Powder River Basin. In addition, seepage flow from impoundments is likely to reach stream channels via subsurface flow.

Can CBM product water be treated to make it more usable?

The only ways to lower the salt concentration in saline and/or sodic water are through dilution with non-saline water, reverse osmosis, or salt precipitation with an evaporation process that leaves salt behind and traps evaporated water. Reverse osmosis is expensive, and evaporation and salt precipitation treatment is neither economical nor feasible with large quantities of saline CBM water. Dilution of CBM product water is only possible if there is a large source of non-saline water with which to dilute the saline water.

It is possible to alter the chemistry of sodic water by adding calcium and magnesium. This does not eliminate or reduce sodium, but changes the ratio of sodium to other salts, thus decreasing the sodium adsorption ratio (SAR). The net result is more saline water with the sodium salt still dissolved in the water. This approach is not likely to work with CBM product water because the added calcium will combine with carbonate from the CBM water and precipitate out as calcium carbonate (lime). To make this process work, CBM product water must be de-gassed of carbonate by addition of acid, or additional calcium must be made available in the soil by acidification from sulfur additions. Unfortunately, addition of more salts to water or soil may result in conditions too saline for plant growth.