Coalbed Natural Gas Resources: Beneficial Use Alternatives

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Coalbed natural gas production, commonly called coalbed methane or CBM, is of vital interest in the search for new natural gas resources in the United States. Coalbed methane resources in the Rocky Mountain states have generated an industry drilling boom during the past decade. The output reached 4 billion cf/d in 2002 with production from 20,000 wells. This represents 8% of all natural gas produced in the United States. Interest in CBM development is high, particularly in Wyoming, Montana and New Mexico. However, development brings with it a growing concern about how to handle the produced water. Argonne National Laboratory estimates for 2002 indicate more than 14 billion bbl/year of produced water must be handled in the United States, with an increasing amount coming from coalbed natural gas development.

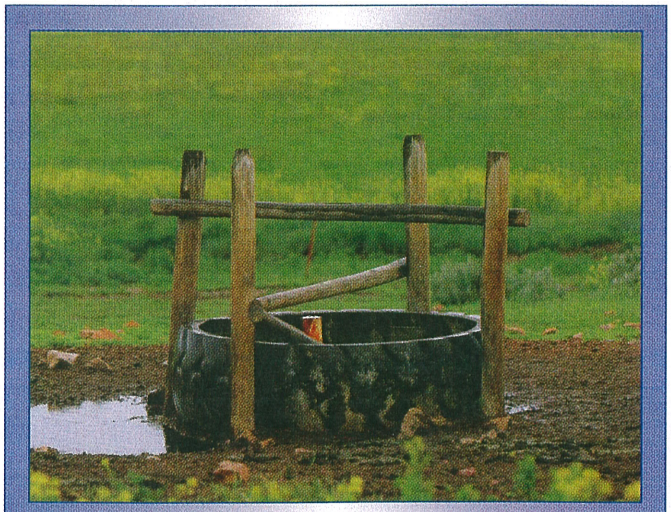

Figure 1: *The quality of coalbed methane produced water in much of the Rocky Mountain region meets standards for wildlife and livestock watering.*

Economics of CBM production depend on reducing the cost of handling produced water. Beneficial uses for produced water offer the best alternative to high-cost re-injection procedures. Various treatment or pretreatment applications (see *Coalbed Natural Gas Produced Water: Water Rights and Treatment Technologies, GasTIPS,* Fall 2003, Vol. 9, No. 4, p. 13-18) may be necessary before produced water can be funneled for alternative uses. However, much of the water from CBM development in the Rocky Mountain region is of high quality and requires no or only moderate treatment prior to agricultural or industrial use.

Alternatives to re-injection of CBM produced water fall in five main categories: water impoundments for stock and wildlife, irrigation, surface discharge, and recreational and industrial uses. These categories have some overlap because of drainage characteristics and storage requirements.

Water impoundments

Wildlife and Livestock Water Impoundments—Wildlife watering ponds are perhaps one of the simplest alternative uses for CBM and benefits the general public most. Wildlife watering ponds provide adequate drinking water during drought periods, create or expand suitable habitat for wildlife and may improve water quality. Because the arid western states have broad areas with inadequate surface water and prolonged periods of drought, creation of ponds using CBM produced water can be highly beneficial to resident species of deer, pronghorn, coyotes, bobcats, upland game and shore bird species. Ponds also can be constructed to provide breeding areas for waterfowl or wintering areas for migratory waterfowl and other transient bird species. The ponds also can provide habitat for fish. Ponds can be used to increase the range of certain wildlife species into areas that previously did not have sufficient surface water.

The Natural Resource Conservation Service (NRCS) has nationwide standards and design guidelines for wildlife watering facilities. Simple water tanks for remote areas where produced water of acceptable quality is available can be constructed from PVC pipe and a small tank or impoundment pit. Ponds for year-round water impoundment for wildlife, migratory birds and fish must be at least 40 acres in size with 25% of the area more than 9ft deep. Other requirements, such as fencing to protect livestock, water valves and maintenance, are provided by the NRCS. Construction and maintenance of CBM produced water wildlife watering impoundments are low-cost, and benefit private land owners as well as federal and state lands and services.

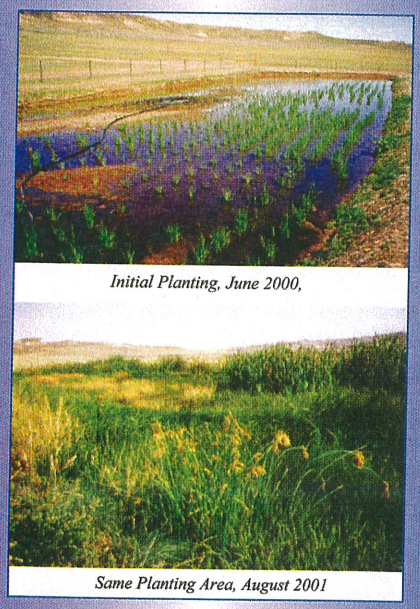

Figure 2: *Wetlands may have an additional benefit in sequestering carbon dioxide, and in a minor way help moderate global climatic changes.*

Livestock watering practices often rely on access to natural streams and lakes. In many areas, this has caused erosion and destabilization of stream banks, increased sediment load and contamination caused by increased nutrients and resulting algae bloom. Using off-channel watering facilities and CBM produced water ponds could provide additional water sources, allow the expansion of livestock grazing to areas otherwise not suitable because of limited surface water and reduce negative impacts of livestock on natural streams. Figure 1 shows a simple stock watering setup using a large equipment tire.

Fisheries—Construction of fisheries is another beneficial use for CBM produced water related to wildlife impoundments and recreational uses. Off-channel ponds of sufficient size to be maintained as fish breeding habitat range in size from small private ponds to large reservoirs and lakes. When conditions of size, depth and accessibility are met, state agencies will stock the ponds with the appropriate species of fish for the region. State, federal and commercial fisheries are established to provide fish for restocking as well as commercial resale and consumption. The state and federal fisheries are an important aspect of recreational programs. Location of fishponds is dependent on available quantities of useable water. The Bureau of Land Management manages more than 85,000 miles of fishery habitat on public lands in the United States. Coalbed methane produced water has the potential to expand the number of fisheries and areas where they can be established.

Requirements for fishponds differ from state to state but primarily specify pond size, depth, year-round water capacity, erosion prevention, livestock fencing and control of flow. Consideration of CBM produced water for fishponds and hatcheries depends on dissolved oxygen and nutrient content. Coalbed methane produced water is typically low in dissolved oxygen, but the content may be increased through surface water transport, agitation or aeration. High salt or metal content could be harmful to fish populations and if present must be removed prior to use in ponds. Untreated CBM produced water in Wyoming has been used to establish ponds for rainbow trout, blue gill and small-mouth bass. Some previous stocking operations in Wyoming were halted because there was a lack of available water, but CBM produced water is used to supplement natural water in these ponds.

Recharge Ponds—Recharge ponds are reservoirs constructed as off- or on-channel holding ponds, frequently called storm water ponds, retention ponds or wet extended detention ponds. Recharge ponds function as a permanent water management effort for seasonal surface water discharge. They may serve to restore depleted groundwater by water infiltration into the subsurface or primarily to improve water quality or minimize peak flow periods and flooding. Recharge ponds lower the total dissolved solid (TDS) content and thus can serve as a CBM produced water treatment in addition to beneficial use of the impounded water.

Design of recharge ponds has five areas of specification: pretreatment, treatment, conveyance, maintenance reduction and landscaping. Pretreatment involves filtration or an interval to allow the sediment to settle prior to input into the recharge pond. Various treatments may be used to eliminate pollutants. Control of water flow and volume in the pond, pond size and spillway design falls into the conveyance category. Landscaping ponds increase the aesthetic appeal and may contribute to improved maintenance of slopes and reduced erosion. They often also improve local wildlife habitat. Because CBM development has the potential to draw down local aquifers, it is vital to maintain surface impoundments to support local water use.

Recreation—Recreational use of large manmade water bodies has become an important secondary function of lakes and water sources created or expanded for urban and industrial water supplies. Fishing, swimming, boating and camping facilities are the most common recreational uses for impounded water. Coalbed methane water can be used to supply artificially constructed impoundments or supplement natural lakes during seasonal low periods. Wildlife habitat for migratory birds also may be classified as recreational use for hunters. A potential problem with constructing large recreational lakes is the relatively short-term nature (10 years to 20 years) of CBM development, which could result in water starved lakes.

Evaporation Ponds—Evaporation ponds constructed in off-channel areas provide storage for CBM water. As evaporation occurs, the remaining water becomes concentrated into high TDS brine. The pond may need to be lined with bentonite clays to prevent water infiltration into the soil. In arid climates in the West, evaporation rates from 28 in. to 52 in. annually have been recorded. In the Gulf Coast region, evaporation rates may reach 48 in. to 70 in. per year. Evaporative ponds provide a relatively low-cost disposal

method for CBM produced water if the proper stratigraphic layers of sediment are present. These include layers of sand and shales, which form impermeable seals or barriers to infiltration.

Constructed Wetlands—Wetlands are designated by saturated soil conditions, which determine the vegetation that may grow in a given region. Wetlands can be constructed in areas where frequent and long periods of soil inundation occur using CBM produced water to soak the site in arid off-channel areas. Wetland systems provide dual benefits as a means of naturally treating CBM produced water and to enhance and increase wildlife habitat. Wetland construction requirements are specific to locality but in general require a gentle gradient to prevent water runoff and soils with silt, loam, clay and fine sand that are able to hold water. Plant species should be selected given consideration to the local climate, tolerance levels to possible TDS concentration in the CBM produced water, and their value as food and habitat for fish and wildlife. Early stages in wetland construction and the resulting increased vegetation are shown in Figure 2.

Figure 3: *Local soils, pasture and agricultural needs must be considered before setting up coalbed methane irrigation systems.*

Surface discharge

The release of CBM produced water into surface water may be considered a beneficial use to augment stream water flow. The key to surface discharge is management of discharge amounts, timing and impact on the surface streams. The Clean Water Act requires permits for all water discharges. Permits to discharge water, including CBM produced water, specify the requirements on each site including volumes of water, TDS content and the body of water receiving the discharge. The effluent content of water discharged must be determined prior to discharge, and the period of discharge time is controlled to protect seasonal requirements of local streams, fish and wildlife. Surface discharge of CBM produced water can be intertwined with water rights issues. After discharge, the water becomes part of the "waters of the state" and is subject to all regulations applicable to surface water. Federal, state and Indian lands water rights must be considered for any use of the water once it has been discharged into a stream.

Individual states have specific regulations for discharge of water, which were discussed in article 2 of this series. Some of the typical considerations require:

- characterization of the stream;
- the total maximum daily load of pollutants in a stream segment;
- the base flow;
- the biological environment potentially affected;
- the primary source of water;
- the type of point source for any pollutants;
- the size and type of stream (perennial, intermittent or ephemeral); and
- the effect of snowmelt on stream flow.

There are three methods of surface discharge: discharge to surface water; discharge to land surface, with possible runoff; and discharge to land surface, with possible infiltration into subsurface aquifers. Direct discharge by pipelines avoids the potential erosion affects of open-channel discharge. Erosion causes local problems and increases the sediment load of the stream. The volume of direct discharge must also be considered so abrupt changes in the height of the water in a channel does not cause adverse effects on plant life, bank stability, aquatic vegetation, fish or invertebrates – all of which have particular depth and flow requirements.

Water discharge to land surfaces is commonly used for irrigation. Center-pivots, side-rolls and fixed or mobile water guns are irrigation systems used in the arid western states to spread water over a maximum area. All three have been used with CBM produced water in the Powder River Basin of Wyoming. Figure 3 shows the side-roll irrigation system.

Discharge of CBM produced water to surface impoundments having the potential of infiltration into subsurface aquifers requires determination of on- or off-channel water bodies. On-channel discharge includes ponds

or dry drainages managed to encourage infiltration into alluvial channel fill. The volume and TDS content of the CBM water can easily be monitored. Discharge into off-channel constructed containment structures is designed to reduce the volume of produced water through infiltration and evaporation, leaving remaining water for beneficial use like stock or wildlife watering or fisheries.

Agricultural Uses— In addition to livestock and wildlife watering, CBM produced water for crops or to support pasture growth is an effective use in the arid western states where CBM produced water is normally high quality. Agricultural water sources in the west are limited by low rainfall and snowmelt, normally a cumulative amount of less than 20 in. per year. The runoff into ephemeral streams is seasonal, and marginal dry land farming can be improved with increased water supplies. Storage of CBM produced water in impoundments can alleviate the seasonal problems and provide irrigation water as needed for crops.

Coalbed methane produced water often has high sodium adsorption ratio (SAR) values – the ratio of sodium, calcium and magnesium concentrations – high concentrations of metals – iron, manganese and barium – and variable salt content. These minerals may affect soil permeability or be toxic to certain plant species. Ideal conditions for CBM produced water for irrigation are areas with coarse-textured soil and salt-tolerant crops. Several studies have been conducted and comparisons made to other arid parts of the world to identify the plants best suited to CBM irrigation.Use of salt-tolerant species utilizing CBM produced water is a land management option. Cooperation with CBM producers, land owners and mineral rights holders is necessary to optimize management of produced water for agricultural uses.

The suitability of saline water for irrigation is dependent on numerous factors, including the type and relative abundance of ions in solution, soil texture and mineralogy, sensitivity threshold and growth stages of plant species, as well as the amount of CBM produced water during each irrigation event. Plant sensitivity research can be used to select agricultural crops, which grow in areas of limited rainfall, colder temperatures and shorter growing seasons found in most of the Rocky Mountain states. The U.S. Department of Energy-sponsored studies at Montana State University have found barley, wheat, sugar beets, sorghum and cotton are best suited to irrigation by CBM produced water in the Powder River Basin. Native high salt-tolerant grasses and forbs can be planted around impoundments and discharge sites to maximize the use of CBM produced water and reduce erosion, as well as being used in bioremediation of brine contaminated soils.

Irrigation in the Powder River Basin using CBM produced water began in the 1990s. However, produced water from coalmines in portions of the Powder River Basin has been used for livestock and human consumption for more than 100 years. Sprinkler systems are used to provide a slow discharge of water over a wide area. Selection of the best irrigation system for a given area looks at several criteria:

- soil type (infiltration rate);
- system size or length;
- sprinkler head and capacity (spray nozzle or oscillating);
- area of coverage;
- elevation differential from pivot point to end of system;
- water pressure (pump capacity);
- speed of rotation; and
- peak daily evaporation.

Flood irrigation, using a series of constructed channels to divert water to native grass pastures, also has been applied. One advantage of flood irrigation is that less water is lost through evaporation, but it is more difficult to spread the effects of the water over wide areas.

Mixing CBM produced water with natural runoff may improve the quality of irrigation water. Use of on-channel and off-channel impoundments for storage and mixing can improve the suitability of irrigation water by balancing the levels of salts and mineral in subsurface and surface waters. Soil amendment procedures may be used to improve soils prior to irrigating with CBM produced water. Additives include cultivating gypsum or sulfur compounds into the soil to reduce clays and minimize the precipitation of calcite. Cultivation further encourages the growth of microbial bacterial, which are beneficial to the soil when sufficient water is available.

Industrial use

Water management options for CBM produced water include use in the operational activities of industries in the producing region. Common industrial uses include coal mines, animal feedlots, cooling towers, car washes, enhanced oil recovery and fire protection.

Coal Mines— As CBM produced water is frequently available close to coal mining operations, coalmines are a prime industrial user of CBM produced water. Coalmines can use CBM water for drilling operations, dust abatement, support on conveyor belts, crushing and grinding, assistance in restoring abandoned mine sites, and preventing spontaneous combustion of coal in the subsurface and storage areas.

Animal Feedlots—Using CBM produced water for animal feedlots has two applications, livestock watering and management of animal wastes. Water is used to dilute animal wastes prior to discharge or disposal. The U.S. Environmental Protection Agency regulates the disposal of animal waste streams based on the number of animals held in a given facility. If the pollutants are discharged into navigable waters, the waste stream must be reduced to specified limits by adding fresh water.

Cooling Towers—Numerous industries, chemical plants and municipal power generating plants require large quantities of water as a cooling agent. Cool water enters

the system and is recycled through heat exchanges and cooling ponds, removing heat generated by the activities of the industrial complex. Constant input of water is necessary because of loss by evaporation. Only CBM produced water with relatively low TDS content can be used because high TDS content could result in mineralization, which would clog the cooling system.

Figure 4: *This figure shows a pond in the Powder River Basin supplied by coalbed methane produced water that facilities wildlife and recreational uses.*

Field and Car Wash Facilities— Construction activities require washing vehicles to avoid spreading noxious plants to other areas. This is particularly important when equipment is being used for reclamation of disturbed sites. Field sites and car washes in rural areas can be supplied with CBM produced water. Because there is a discharge of water to the soil, only CBM produced water with acceptable TDS and SAR levels can be used for this purpose.

Enhanced Oil Recovery— When oil and gas fields are in proximity to CBM producing areas, the use of produced water from CBM activities for waterflooding or secondary recovery is possible. Waterfloods are a common practice that can be performed with varying quality water and may be able to use low-quality CBM produced water.

Fisheries—Commercial fisheries in the western United States obtain water rights to divert water into their operational ponds from surface waters, and CBM produced water could be economically used in place of diverted surface or groundwater. This option is applicable if the fisheries are in or near the CBM fields where water can be easily transported or accessed through natural drainage systems. The water must be of sufficiently high quality not to be toxic or hazardous to the fish.

Fire Protection—Supplies of water for nearby municipal fire hydrants and sprinkler systems are a valuable use of CBM produced water. Fighting fires does not require high quality water and could benefit from the use of CBM produced water by not depleting drinking water supplies. Wildfires in the western United States are becoming larger and more dangerous because of the drought conditions that exist in many states, and normal supplies of water for fire fighting are becoming depleted. Supplies of CBM produced water stored in impoundments could provide accessible water for fighting fires in remote western areas.

Other Industrial Uses—In some of the western states, CBM produced water is beginning to be used in industries like sod farming, solution mining for minerals, production of bottled drinking water and water for breweries. Sod farming using CBM produced water in the San Juan Basin is helping supply the public's increasing demand for sod in new developments in municipal areas. Uranium mines in Wyoming are using CBM produced water in solution mining of uranium ore, and companies in Nebraska, Texas and Oklahoma have submitted permits for similar operations. Some CBM produced water already falls into the range of bottled drinking water and can be sold in stores, while other CBM water would require minimal treatment to make it suitable for drinking water. Drinking water quality CBM water can be used in breweries, and less high-quality CBM water can be used to irrigate barley, hops and other grains used in the manufacturing process.

Domestic and Municipal Water Use—Coalbed methane produced water that meets drinking water standards can be used for public, residential and municipal water use and supply. Many of the western states have a rural population in which individual landowners could benefit from a residential supply of CBM produced water, while other states have large municipalities in or near existing and potential CBM development. Coalbed methane produced water may also be used for watering lawns and in swimming pools, washing machines and plumbing.

Conclusions

Many coalbed natural gas operators are pursuing beneficial uses for CBM produced water where they are producing. The developers are undertaking a variety of new water management feasibility studies for new uses for CBM produced water that meet state and federal regulations and provide cost-effective water management for the CBM producers as well as low-cost, readily available water for public, residential and industrial uses. The handbook provides several case studies, which discuss strategies used for managing CBM produced water in the western United States. The strategies often employ a combination of several methods including impoundment, livestock and wildlife watering (Figure 4), irrigation and dust abatement. ✧

Acknowledgement

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