Water from oil and gas?

Produced Water
Encouraging Sustainable Development: Redefining Beneficial Use of Produced Water

Jim Kaipers, P.E. – Kaipers and Associates, Butte, MT

Drake Engineering Inc.’s CBNG onsite water treatment system engineering process unit in Johnson County, Wyoming. Photo courtesy of Drake Engineering.

Trillions of gallons of water will be produced as a byproduct of coal bed natural gas (CBNG) development in the Powder River Basin and similar areas of the intermountain western United States during the coming years. Industry and public interest groups have been clashing over this development in regards to the ultimate fate of the water. While “beneficial use” has been used in the past to justify different discharge methods, many would argue that the use or disposal of CBNG-produced water should be considered in light of sustainable development.

Numerous definitions of sustainable development are currently in use, with the most often cited definition from the Brandtland Report (WCED, 1987), which defines it as “…development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.”

Sustainability can be particularly difficult to apply when dealing with natural resources extraction issues such as CBNG. First, the concept itself is an oxymoron when dealing with a finite resource since it cannot be indefinitely sustainable. Second, in some situations, such as where produced water is used for crop water, some might benefit (farmers), while others might lose (ranchers who own land above the CBNG resource and end up with a lowered water table). Sustainable development implies that society must recognize future limitations and remain flexible to change.

Presently the CBNG industry appears to primarily design operations with little thought given to post-operation impacts. Other industries such as mining have seriously grappled with closure and post-closure implications for water quality, quantity, and other issues. Mining companies have been faced with questions about their social license to operate in light of the problems they have historically created. This suggests that CBNG companies, if they are serious about their future, must move beyond merely complying with regulations and address produced-water disposal within a framework of sustainable development.

Seven Questions for Addressing Sustainability

A list of seven questions (below) developed by the International Institute for Environment and Development (IIED) and the World Business Council for Sustainable Development (WBCSD) provides a set of practical principles for considering CBNG-produced water disposal. These principles can be employed during the exploration, development, and post-development stages when considering the compatibility of various produced-water disposal methods with the concept of sustainable development.

Seven Questions for Assessing Sustainability

1. Are engagement processes in place and working effectively?
2. Will people's well-being be maintained or improved?
3. Is the integrity of the environment assured over the long term?
4. Is the economic viability of the project or operation secured, and will the economy of the community and beyond be better as a result?
5. Are traditional and non-market activities in the community and surrounding area accounted for in a way that is acceptable to the local people?
6. Are rules, incentives, programs, and capacities in place to address project or operational consequences?
7. Does a full synthesis show that the net result will be positive or negative in the long term, and will there be periodic reassessments?

IIED and WBCSD (2002)
### Receptors of Produced Water

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<td>Loss of native species</td>
<td>Loss of recreation</td>
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### Least Sustainable Practices
- Expiration of water resulting in loss of resource
- Injection or percolation into aquifers where water quality is deteriorated and negative hydrologic impacts occur
- Land applications that create negative impacts on soils and water quality
- Direct discharges that degrade water quality and negatively impact downstream users or result in loss of resource

### Most Sustainable Practices
- Reinjection to original formation
- Injection or percolation into depleted aquifers with water treatment as required to protect or enhance water quality
- Crop, livestock, municipal, or industrial uses with water treatment and other mitigations as required to prevent negative impacts
- Surface discharges with water treatment as required, resulting in improved stream flows with adequate mitigations against negative impacts

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**Produced Water Benefits and Impacts**

CBNG-produced water can be disposed to groundwater, surface water, land or by other means. Depending on the method, various potential benefits and impacts may result, as identified in the table above.

Although many of the uses may be in some way beneficial, negative impacts can still occur. Using water that contains a high salinity or sodium adsorption ratio (SAR) for irrigating crops may bring short-term benefits, but long-term irrigation will damage the soil structure by deflocculating the clays within the soil, thereby reducing the soil's capacity to absorb water.

**Sustainability and Produced Water**

What is the most sustainable practice for CBNG-produced water? From the perspective of produced water alone, the primary questions deal with benefits versus impacts to agriculture. As a result, neighboring farmers and ranchers are often pitted against each other.

Sustainable development will require cooperation among the various parties to ensure that those enjoying short-term benefits do not do so at the expense of future users whose water rights may be impacted. The most and least sustainable practices listed above right are based on human and environmental values.

However, it should be noted that CBNG development currently lacks engagement processes, economic viability measures (such as financial assurance), and rules, incentives, and capacities (governance) to steer the industry in the direction of sustainable development. Until the industry itself embraces the concept of sustainable development and is willing to recognize the concerns of legitimate parties, it cannot expect widespread support for its activities.

Contact Jim Kuipers at jkuipers@kuipersassoc.com.

**References**


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**Innovative Solutions in Hydrology**

- Vadose Zone Characterization and Modeling
- Groundwater Recharge Investigations
- Water Resources Management
- Mine Reclamation Studies
- Copper and Gold Heap Leach Optimization
- Hydrologic Testing Laboratory
  - Saturated and Unsaturated Flow Properties
  - Calibration of Monitoring Instruments
  - Large Core Testing
  - Custom Testing and Research
Desalinating Brine From Oil and Gas Operations in Texas

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As part of its Water for Texas initiative, the Texas Water Resources Institute at Texas A&M University created a program to study the feasibility of recovering fresh water from wastewater and oil-field produced brines. The goals have been to find new sources of potable water in arid regions of the state and to avoid the loss of potentially valuable water resources by unnecessary byproduct water re-injection into oil and gas reservoirs. Led by the Department of Petroleum Engineering, research now includes activity on three different A&M campuses.

Management and disposal of produced water is a major operating expense because of the volumes involved. Currently, large producers re-inject the brine to enhance production, at a cost of about $10 to $15 per 1,000 gallons ($3,000 to $5,000 per acre-foot). In Texas alone, more than 31,000 oil-field injection wells are used to dispose over 700,000 acre-feet of brine fluids each year. Services that transport brine from the oil or gas lease to commercial disposal facilities charge as much as $50 per 1,000 gallons (about $16,000 per acre-foot) for the service.

Commercial reverse osmosis (RO) desalination technology offers the opportunity to turn some of this produced water into a useful freshwater commodity at less cost than transporting it to disposal sites. And as demand for fresh water continues to climb, the value of the resource becomes greater and greater.

Produced Water as Source Waters
Texas oil and gas production, and hence its water production, occurs primarily in the semi-arid western part of the state. While most of the produced water is too saline for cost-effective desalination, almost one-third of the fields produce brine of less than 10,000 parts per million total dissolved solids. We estimate that there are more than 1,000 sites in West Texas with brines amenable to treatment with RO. As shown in the map at left, produced water operations are active in counties across much of Texas and could provide new water sources.

The A&M Technology
The peculiarities of oil field brine, particularly with respect to the mix of heavy metals, dissolved and precipitated petroleum compounds, and dissolved salts, make RO desalination of this byproduct a challenge. The process developed by Texas A&M differs from commercial systems in three main ways.

Including pretreatment and waste disposal costs, the total cost of producing fresh water should range from about $4.00 to $8.00 per 1,000 gallons, including disposal costs.

Pretreatment: Until recently, pretreatment has not been a part of most commercial desalination processes, but the characteristics of oil field brine make it an important step in this application. The pretreatment used to protect RO membranes is based upon techniques used in the oil industry to maintain the injectivity of wells that are used to force water under high pressure into the formation to aid recovery, a process known as water flooding. The injected water must be essentially free of suspended solids and treated to minimize biological activity, and chelating agents must be employed to avoid scaling.

Texas A&M’s portable desalination testing unit uses microfiltration membranes to remove substances that might plug the RO membranes. Reject brine is dumped back into petroleum storage where it is either hauled to disposal.
wells or returned to the formation from which it was produced. As much as 70 percent fresh water can be recovered from brackish brine produced water.

**RO Desalination:** The desalination train has a dual-stage recirculating process that provides higher fresh water recovery than one-pass systems used elsewhere, producing less waste.

**Disposal Practices:** The process returns brine concentrate to the formation, avoiding transportation and disposal costs. Unlike commercial disposal facilities, oil field injection wells operate with an exemption that permits disposal of fluids (generally brine) associated with oil and gas production. Attaining this Class II permit requires a relatively simple and inexpensive filing with the Texas Railroad Commission, which oversees oil production in Texas.

The capital cost of drilling a disposal well is approximately $500,000 (for a deep well) with brine disposal costs of approximately $1.00 per 1,000 gallons of concentrate injected (W.A. Baker, Key Energy, Midland, Texas).

**Cost of Produced Brine Desalination**
Although RO treatment of highly saline produced water may not yet be practical, desalination of brackish produced water can be less expensive than RO desalination of seawater. More expensive pretreatment is offset by reduced disposal costs, since less waste is produced and it can be disposed of onsite. Our trials have found the operating costs of the portable units range from $2.40 to $2.90 per 1,000 gallons of fresh water delivered, based on 7 cents per kWh power cost. Maintenance and capital costs to build and lease the unit add about 10 percent to the cost over the expected three- to five-year use period. Including pretreatment and waste disposal costs, the total cost of producing fresh water should range from about $4.00 to $8.00 per 1,000 gallons, including disposal costs, based on a 10-year lifetime and allowing for maintenance and replacement. This does not include transference costs of water to and from a facility.

**Users of Produced Water**
Because of the dispersed locations of produced water, the most promising applications for its use are to fulfill local industrial, agricultural (such as livestock watering), and environmental needs. For example, produced water is planned to be used to enhance habitat at the McFadden Ranch in Goliad County, Texas, by improving wetlands.

**Legislation is Encouraging**
The Governor of Texas and the Texas Legislature have supported desalination technology as one solution to meet the state's future water needs. A recent initiative provides funding for studies of the feasibility of inland desalination facilities. Since one of the obstacles to inland desalination is the disposal of brine concentrate, researchers are investigating whether disposal into oil and gas operations is a practical option. The Texas Water Development Board found that such disposal practices are technically sound. Texas A&M and the city of Andrews are now planning a pilot desalination project using brackish groundwater with disposal of concentrate into an adjacent water flooding operation operated by ExxonMobil.

**Advancing Desalination**
Cooperation, collaboration, and consultation will make desalination a more viable solution to meet future water needs of the Southwest. In addition to adopting produced-water management practices, the petroleum industry may provide other cross-cutting technologies and means to facilitate advancement of desalination operations, including:

- identifying other geological formations that would allow safe and effective deep-well disposal;
- tracking compositional fronts of brines injected at depth with seismic techniques now used to identify and monitor oil and gas in porous zones;
- investigating the use of offshore high-rate injection well technology for use with deep onshore disposal wells and aquifer storage and recharge;
- disposing of solid waste slurries generated in water treatment operations by slurry injection into friable formations.

It is encouraging to see how the combined efforts by many people and companies over the last ten years have brought desalination of non-resource brines from an idea to reality. The future is even more promising.

For more information, visit www.gpri.org. Contact David Burnett at burnett@spindletop.tamu.edu.

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Produced Water Reuse at the Kern River Oil Field

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Located along the southeastern edge of the San Joaquin Valley is the giant Kern River oil field. With humble origins — it was discovered in 1899 in a 45-foot shaft dug with shovels — this oil field originally contained approximately 4 billion barrels of oil (1 barrel = 42 gallons). The discovery of the field started an oil boom in Kern County that continues today.

Much of the field’s high-viscosity “heavy” oil is produced from shallow fluvial deposits of the late Miocene to Pleistocene Kern River Formation. The productive oil interval ranges from less than 100 feet deep to approximately 1,600 feet deep. Through 2003, approximately 1.8 billion barrels of oil had been produced. Production has remained relatively constant for the past five years, at more than 100,000 barrels per day (DOGGR, 2003). More than 90 percent of the estimated ultimate 2-billion barrel recovery will have been accomplished with steam-assisted, secondary recovery production processes. The Kern River oil field is one of the world’s largest steam-flood oil projects and the sixth largest oil field in the United States.

Kern Hydrology

Hydrologically, the field is located near the mouth of Kern River Canyon on the Kern River alluvial fan, a huge fan-shaped wedge of sand and gravel on the east side of the San Joaquin Valley that forms where the bicarbonate-rich waters of the Kern River exit the Sierra Nevada foothills. This is the main gateway through which much of the water that recharges the valley’s shallow aquifers flows.

The principal aquifer in the Kern River field is an unconfined aquifer comprised of the lower Kern River and upper Chanae formations. This aquifer is overlain by several perched aquifers within the upper Kern River Formation. Underlying the unconfined aquifer are several confined aquifers in the lower Chanae and Santa Margarita formations that do not appear to be hydraulically connected to the unconfined aquifer (Coburn, 1997). The potentiometric surface in the regional unconfined aquifer and the smaller perched aquifers dip westwardly and are parallel to the structural dip of the Kern River Formation.

Extensive fluid depletion in zones along the up-dip edge of the field and the lack of a potentiometric gradient showing flow outward from the Kern River suggest there is minimal groundwater recharge in the Kern River field from natural sources, including the Kern River (Coburn, 1997).

With Oil Comes Water

In mature oil fields with high water-to-oil recovery ratios that use steam as the primary recovery technique, water is the result — lots of it! Steam is injected as vapor into the Kern River Formation, where it heats the oil to lower the viscosity. The steam condenses and occupies part of the pore space that is effectively produced on a daily basis. Because the steam and the produced water are geochemically equivalent, it is difficult to know how much recycling actually takes place. But about nine barrels of water are produced along with every barrel of oil. Therefore, over 900,000 barrels, or 116 acre-feet of water are produced each day. Chevron reclamns about half of this water to generate new steam to enhance oil production and for other in-field uses. However, the remaining water, approximately 58 acre-feet, represents what would normally be a costly disposal problem and potentially wasteful use of water.

Through a long-term contract ..., the water district is able to buy millions of barrels of water at a very reasonable price.

Various degrees of treatment of produced water are often required prior to any discharge for agricultural use. But produced water from the Kern River oil field is uniquely of very high quality and contains a minimal amount of dissolved solids...
and metals. To treat any hydrocarbons that may be left in the water after flotation and mechanical separation, the produced water is filtered through large walnut shell-filled filters. The shells have exceptional surface characteristics for coalescing and filtration, plus excellent resilience to wear and tear. Chevron conducted a rigorous water-monitoring program to ensure the quality of its produced water prior to discharge. Discharge is governed by National Pollutant Discharge Elimination System permits overseen by the California State Water Resources Control Board. Any deviation from the standards can result in a substantial fine by the state.

Two discharge points currently exist for the excess produced water: the Beardsley Canal, operated by the North Kern Water Storage District, and a pipeline to the Cawelo Water District. Both discharge points convey excess produced water strictly for agricultural use. Historically, the Beardsley Canal was the sole discharge point for all water leaving the oil field; however, in the early 1990s it became apparent that another discharge point would be required to handle the ever-increasing volume of produced water.

A User is Found

Just a few miles from the oil field, Chevron (then Texaco) learned that valley farmers needed additional water for irrigation. After lengthy discussions, the Cawelo Water District recognized that Chevron’s excess produced water was a safe and reliable source of agricultural water and in 1994 signed a long-term conservation agreement with Chevron. Cawelo then had an 8.5-mile pipeline permitted and built to connect its local reservoir with the Kern River oil field. Chevron spent about $1.8 million to build a pump station to deliver the water into the pipeline. Through a long-term contract that was signed in 1996 and runs through 2011, the water district is able to buy millions of barrels of water at a very reasonable price. Chevron and Cawelo are also jointly exploring the innovative use of constructed wetlands to further treat produced water for agricultural reuse. This pilot project is in its third year and shows great promise in reducing residual organic compounds to very low or nondetectable levels.

Local farming interests in this semi-arid region of California use blended excess produced water to irrigate over 46,000 acres of crops, including grapes, citrus, almonds, and pistachios. Blending with fresh water sources is required to lower the concentration of boron from naturally occurring levels of about 1.0 milligram per liter (mg/l) to below 0.5 mg/l, to avoid any leaf or plant damage. This unique and novel venture creates a long-term, economical use of excess produced water and achieves the mutual goals of Chevron and Cawelo. The project also stresses the importance of maximizing fresh-water resources through cooperative efforts among public agencies and private industries. John Jones, former manager of the Cawelo Water District, stated, “This is a major conservation project for us. It’s a resource that we knew was there.” It is a “win-win” situation for both entities.

References


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America’s oil producers must contend with the fact that their oil production often yields about 10 barrels of water for each barrel of oil produced. Put another way, produced water comprises 98 percent of all waste generated by oil and gas exploration and production in the United States.

Coalbed natural gas (CBNG) development has been the fastest-growing new source of produced water in recent years. America’s production of CBNG grew more than tenfold from 2000 to 2003, to a total of 1.6 trillion cubic feet (TCF) in 2003, about 8.5 percent of domestic natural gas production that year.

The handling, treatment, and disposal of produced water is the single greatest environmental impediment to the nation’s oil production, contends the U.S. Department of Energy’s National Energy Technology Laboratory (NETL). Concerns over produced water threaten to hobble the growth of the CBNG industry as well.

Options for managing produced water include discharge to stream beds, surface storage and evaporation ponds, treatment, and reinjection. Some landowners and environmental groups have expressed concerns that the CBNG-produced water used in irrigation or discharged onto the land could alter the soil’s structure and chemistry by raising salinity and sodicity levels—a particular concern for crop irrigation. For example, studies in Montana showed that repeated wetting and drying with CBNG-signature water resulted in salt injury to common crops in the area. If rendered suitable, however, CBNG-produced water could help western states solve their perennial water shortages, especially during summer months. Overarching these issues is a complex welter of federal and state land, resource, and environmental regulations with which producers must contend.

Therefore, it behooves CBNG producers to promote beneficial uses for their produced water in a cost-effective way without damaging ecosystems.

**NETL’s Interest**

Accordingly, produced water is a major focus of NETL’s Strategic Center for Natural Gas and Oil environmental program research. NETL, an arm of DOE’s Office of Fossil Energy, partners with other federal and state agencies to assess produced water resources and demonstrate how to beneficially manage them. NETL currently manages 26 recently completed or active produced-water management projects. Major focus areas are:

- streamlining regulatory processes;
- water-treatment technologies using reverse osmosis (RO);
- innovative filtration methods, including biologic processes;
- best-practices management of coalbed natural gas (CBNG);
- analysis of water toxicity;
- long-term monitoring of surface water and groundwater as related to wetlands; and
- beneficial uses for produced water.

**Putting Produced Water To Use**

Finding beneficial uses for produced water is an especially daunting hurdle for CBNG producers in the western states, where ranchers and farmers depend on often-limited water supplies and worry about potential groundwater and soil contamination by produced water—but otherwise would welcome new water supply sources.

That’s why DOE-funded research is seeking to sustain the growth of CBNG production while resolving another critical issue in western states—chronic water shortages—in an environmentally friendly way.

For example, Tulsa-based ALL Consulting Inc., working on a DOE-funded project, is studying the potential use of surface ponds and reservoirs—which it estimates account for 50 percent of the CBNG-produced water that is managed in the Powder River Basin—for beneficial uses such as livestock watering and crop irrigation. Water statistical data have been collected and geochemical models are being analyzed in order to
develop risk-based analyses for pond placement, construction, and minimized impacts to soil and water resources.

At Montana State University's Extension Water Quality (EWQ) program, DOE-funded research focuses on how produced water with a characteristic saline-sodic fingerprint will interact with oil and water resources in CBNG-production areas of the Powder River Basin. Among the projects of the EWQ program are:

- studying environmentally sustainable methods of dispersing or land-spread CBNG-produced water, such as using salt-tolerant riparian species in constructed wetlands for salt uptake in a CBNG-produced water management scheme;
- using wetland plants to phytoremediate saline-sodic water. This entails selecting wetland plant species identified for their natural filtration capabilities and using them in an artificial or modified natural wetlands to reduce levels and negative effects of salinity and sodicity in CBNG-produced water and thus allow safe surface discharge;
- examining the potential for CBNG-produced water to enhance wildlife habitat and livestock forage, including opportunities for carbon sequestration through increased biomass. This entails the concept of “greening” the western landscape with salt-tolerant species in constructed wetlands built with CBNG-produced water, thus providing opportunities for animals to forage and plants to take up carbon dioxide; and
- engineering on-site CBNG-produced water treatment facilities. Under an MSU subcontract, Drake Engineering of Helena, Montana, designed and developed a fluid-bed resin exchange treatment system for removing sodium from CBNG-produced water; the system is now being field-tested in the Powder River Basin.

A DOE-funded project at the New Mexico Institute of Mining and Technology aims to develop a new RO technology through molecular sieve zeolite membranes to efficiently treat produced water with high levels of total dissolved solids. Zeolite membranes are easy to clean, have a longer life, and are chemically more stable than conventional polymer RO membranes, and they can clean CBNG-produced water to a level suitable for irrigation. This project would improve zeolite membrane synthesis and optimize operating conditions for water and ion exchange in order to produce a long-term, cost-effective membrane.

DOE-funded researchers at Texas A&M University (see pages 24-25) are developing advanced membrane technology for desalination of oil field brine, and new cleaning agents for membrane filters used to treat oil field-produced water for beneficial purposes. The latter project aims to use micellar solutions to reduce membrane cleaning time from all night to less than three hours.

A new NETL-managed project will look at the removal of emulsified oil, particulates, and TDS from produced water. The goal is to develop new coatings that dramatically improve the fouling resistance of polymer membranes in RO filtration.

It behooves CBNG producers to promote beneficial uses for their produced water in a cost-effective way without damaging ecosystems.

Advancing RO Technology

Other NETL projects focus on advanced membrane research to make RO, the most aggressive water treatment method, more cost-effective. The typical cost for this approach, when trucking residual concentrated brine to EPA-specific disposal sites is included, can be 12 times that of surface discharge. The key to cost-effectively desalinating the produced water via RO is pretreatment to remove particulates and heavy minerals and reduce saline content, allowing for on-site reinjection.

More details on NETL's produced water program and the individual projects can be found at the lab's website at www.netl.doe.gov. Contact David Alleman at dawhl.alleman@netl.doe.gov.
3,000 milligrams per liter (mg/l), but is generally lower than surface waters in the upgradient (southern and eastern) portions of the PRB and higher than the Tongue and Powder rivers in the downgradient (northern and western) portions. SAR ranges from 6 along the eastern edge of the basin to over 50 in the northern portion.

The variation in water quality creates a challenge among the interested parties in these two regions to quantify and apportion the available assimilative capacity for salinity and SAR. In both watersheds and in both states, direct and indirect discharge of CBNG water to these streams is limited by the EC and SAR standards set by Montana to protect downstream irrigators. A further complication is that seven-day, 10-year low flows of the Powder River in late summer are at or near zero, providing no assimilative capacity.

Treating produced water is not always a panacea. When the Wyoming Department of Environmental Quality recently planned to issue a discharge permit for 100 cubic feet per second (cfs) from a series of proposed ion-exchange treatment systems, the state's Game and Fish Department objected that too much clean water could adversely affect the unique aquatic ecology of the sediment-rich Powder River. As a result, the permit was scaled back to 20 cfs.

Although CBNG water is often of better quality than that of the shallow groundwater system, soils and surface sediments of the semi-arid PRB often contain abundant soluble salts that can drive TDS of infiltrating produced water to high levels. Groundwater monitoring beneath one CBNG reservoir revealed TDS levels in excess of 70,000 mg/l (Healy et al., 2004). Seepage quality beneath some sites can meet existing groundwater standards if site lithology and salt content are favorable. Wyoming's Groundwater Pollution Control Division has taken a regulatory approach similar to that used at underground storage tank sites, requiring baseline characterization of shallow aquifers and groundwater quality, generally three monitoring wells around impoundments, a defined monitoring and reporting schedule, and a compliance plan if adverse impacts are observed.

Management Options

Staying on top of produced water management requires keeping one foot firmly rooted in good earth science and the other skating at high speed through an array of technical, financial feasibility, regulatory, legal, and political traffic cones. Environmental and agricultural advocacy groups and CBNG companies have gone to state legislatures, regulatory bodies, and the courts with petitions, studies, and lawsuits over produced water issues, resulting in some major shifts in produced water management. Water management options that result in direct or indirect discharge of untreated CBNG-produced water to the surface have become more difficult or impossible to permit. Increasingly popular options include treatment and discharge, on-channel storage with controlled releases, injection wells, managed irrigation, and water marketing or other off-site use. A trend is evolving to fewer but larger water management facilities, which require greater capital investment but which producers hope will provide more technical and regulatory certainty.

Existing and alternative technologies are also being evaluated. Watershed modeling studies help predict water quality after mixing treated and untreated CBNG water with runoff or streamflow under various statistical scenarios. Preconstruction hydrogeologic studies evaluate impoundment sites for baseline groundwater conditions, seepage migration pathways, and the potential need for engineered pond liners. The geology and hydrology of the upper several hundred feet of the earth's surface, once thought irrelevant for production, is now examined for suitability for CBNG-water injection and impoundments. Industry and agencies are adapting information technology and geographic information systems to utilize results of groundwater and surface water monitoring programs and improve the science and understanding of the hydrogeologic systems of the PRB.

Perspective

In the early years of the play, management of CBNG-produced water in the PRB was driven by traditional economics and practices. More recently, challenging basin-wide water quality issues, environmental regulations that transcend state borders, and an array of complex sociopolitical forces have squeezed out some practices and stimulated innovations. The outlook for sustained higher gas prices is driving development of new but costlier methods of water management, such as treatment, managed irrigation, deep injection and water re-use/marketing. The intensity surrounding regulation and management of CBNG-produced water is likely to affect many aspects of water resource management throughout the West.

References