Oil & Natural Gas Technology

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Final Progress Report

Water and Energy Sustainability: A Balance of Government Action and Industry Innovation

Submitted by:

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Prepared for:

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National Energy Technology Laboratory

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Office of Fossil Energy

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Final Quarterly Progress Report

Grant Instrument No.: DE-FG26-08NT07134

TITLE: Water and Energy Sustainability: A Balance of Government
Action and Industry Innovation

Project Director: Ben Grunewald
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STATEMENT OF PROJECT OBJECTIVES

Ground Water Protection Council, Inc.

Water and Energy Sustainability:

A Balance of Government Action and Industry Innovation

A. PROJECT OBJECTIVES

By completing the tasks and subtasks of the project, the Ground Water Protection Council (GWPC) through its state regulatory agency members and oil and gas industry partners, will bring attention to water quality and quantity issues and make progress toward water and energy sustainability through enhanced water protection and conservation thus enhancing the viability of the domestic fossil fuel industry.

B. PROJECT SCOPE

This project contains 4 major independent Tasks. Each task has a specific scope (see detail below)

C. TASKS TO BE PERFORMED

Task 1 – Work Plan

Water-Energy Sustainability: “A Symposium on Resource Viability”

Background

As the recognition of water and energy interdependency has emerged, the relationship between the availability of water and the development and use of energy point to the need for better strategies to assure that both resources will remain available even as demand for them grows substantially in the coming years. The implementation of resource management processes and programs will be critical tools in assuring the continued viability of water and energy resources.

The Ground Water Protection Council is an association of state water quality, underground injection control and oil and gas regulatory agencies. Our mission includes the protection of ground water for all beneficial uses. In order to accomplish this mission we must ensure that the development of water resources is conducted in coordination with the development and use of energy. In order to develop strategies for water and energy sustainability, the GWPC will hold a Water-Energy Sustainability Symposium in September, 2009. The symposium will be held over a 2 day period in conjunction with the GWPC Annual Forum to enhance participation by state regulatory agencies that will ultimately be responsible for implementing many of the strategies to be discussed and to provide for the most efficient management of time and resources for holding a major conference of this type. The location for the symposium will be in close proximity to a major city in the western United States. The GWPC will partner with numerous organizations such as the National Ground Water Association, Sandia National Laboratory, Argonne National Laboratory, the American Public Power Association and others to cover the myriad areas of water-energy interaction.

In addition to providing a forum for the exchange of ideas between water and energy providers, state regulatory program managers, and researchers, a major goal of the symposium will be to acquire information for the development of a Water Energy Sustainability Report. Consequently, the symposium will be held concurrently with the development of the report; which is being conducted under another task within the DOE/ NETL grant.

Task 1 Scope

This symposium will inform participants about the latest studies, research, processes and programs designed to coordinate the use of water and energy in a manner that recognizes the interdependent nature of these resources. The symposium will cover some or all of the following topical areas:

1. Water usage in the exploration for and development of energy resources
2. Water availability as a consequence of shifting energy usage patterns
3. Beneficial re-use vs. disposal of produced water
4. How water and energy are related in the real world
5. Energy usage in the treatment and delivery of high quality water
6. Consumptive vs. non consumptive water usage
7. Water/ Energy Interactions in specific industries such as:
 - a. Oil and Gas Exploration and Production
 - b. Biofuels and Renewable Energy
 - c. Nuclear Energy
 - d. Water and Power Utilities

Deliverables

The GWPC will conduct a 2 day symposium in conjunction with the 2009 GWPC Annual Forum and will post the proceedings of the symposium on the GWPC website. The symposium will also be used to inform participants, provide a forum for participant interaction and provide information for the development of a report on Water/ Energy Sustainability.

Timetable

This project will be conducted in 4 phases:

Phase 1: Coordinate the logistics for the symposium including hotel, travel and meeting space, and sign a contract to acquire meeting facilities by October 2008.

Phase 2: Develop an agenda and acquire speakers for the symposium by July, 2009

Phase 3: Hold the symposium by September, 2009

Phase 4: Post the proceedings of the symposium on the GWPC website by December, 2009

Participants

The following is a list of potential organizations/ persons who may participate in this project as contributors or contractors:

Ground Water Protection Council
National Ground Water Association
U.S. Department of Energy
Argonne National Laboratory
Sandia National Laboratory
American public Power Association
State Oil and Gas Agencies
State Drinking Water Protection Agencies

Accomplishments & Discussion:

- **11/15/08 Event facility was selected and contract was signed: Hilton Salt Lake City**
- **11/15/08 Planning committee was established**
- **12/10/08 Call for abstracts flyer was created**

- 12/10/08 Permission was granted from NETL and DOE to use logos
- 12/15/08 online submission function was established.
- 12/15/08 e-mail announcements and announcement flyers were distributed.
- 3/30/09 54 abstracts were received
- 4/21/09 The planning committee evaluated the abstracts and placed appropriately depending on quality
- 4/30/09 those who submitted abstracts were notified as to the status of their abstract
- In June/09 an event press release was developed and distributed
- In June/09 a printable flyer was developed and distributed
- In June/09 a comprehensive outreach e-mail was developed and distributed
- As of 6/30, including the presentations that have been solicited, a total 86 presenters make up the symposium preliminary agenda.
- As of 6/30 18 National/Regional organizations have agreed to be Partners for the event including:
Western States Water Council; Association of Safe Drinking Water Administrators; National Rural Water Association; National Ground Water Association; Alliance for Water Efficiency; Petroleum Technology Transfer Council; Interstate Oil & Gas Compact Commission; National Oil Shale Association; Water Environment Research Foundation; Groundwater Management Districts Association; The Groundwater Foundation; State Review of Oil & Natural Gas Environmental Regulations; Women's Council on Energy & the Environment; National Association of Clean Water Agencies; Geological Society of America; Purpose Focused Alternative Learning; Western Governors Association; Water Research Foundation
- As of mid-August/09: The following is a summary of the planned event...

An Opportunity for Dialog on Integrated Energy-Water Planning

On September 13-16, 2009, in Salt Lake City, the DOE is sponsoring the Water/Energy Sustainability Symposium as a forum through which energy and water planners can address challenges in meeting future water and energy needs. The focus of this event is not just on water requirements and efficiency within the energy sector, or energy requirements and efficiency within the water sector, but also on opportunities for the energy and water sectors can collaborate, co-locate, reuse and otherwise augment one another's supplies, and work jointly towards energy and water conservation and management of our nation's water resources.

To ensure a well-rounded discussion that includes state water agencies, as well as other water, energy, and power providers and researchers, DOE has teamed with GWPC as the host organization for the September 2009 symposium. Several other "Water-Energy Sustainability Partner" organizations have been invited to broaden the discussion at the symposium, including both water organizations and energy/power organizations. Organizations that have joined as partners or are scheduled to provide speakers include: Western States Water Council; Association of Safe Drinking Water Administrators; National Ground Water Association; National Rural Water Association; Alliance for Water Efficiency; National Association of Clean Water Agencies.

The Water-Energy Symposium will bring together leaders from government, energy and water industries, academia, water organizations and other stakeholders to explore the complex water/energy relationship and help chart a collaborative course to provide clean, affordable energy and water in a sustainable manner.

At the symposium, overviews of the latest research on “Water for Energy” will be provided by DOE, the USGS, and other energy researchers, while information on “Energy for Water” will be provided in a session featuring work by the American Water Works Association and California Energy Commission (invited), National Association of Clean Water Agencies, Water Research Foundation (invited), and National Rural Water Association.

Technical sessions have been organized in two parallel tracks featuring the latest research and case studies related to various aspects of the water-energy interrelationships. One track will focus on research on more traditional energy and power production, and ways in which energy-produced water can be conserved, treated, and reused. The other track focuses on the ways in which energy needs effect water uses, including water for public water supplies in larger and smaller systems, and impacts of water and energy on agriculture, and on opportunities to reduce both water and energy demands through end use efficiency (“green buildings, green cities”). Also considered will be the water demands associated with alternative energy sources, including wind, solar, nuclear, hydropower, biofuels, geothermal/underground energy, and “microhydro.” At the end of the program, there will be representatives from several regions of the country to discuss the results of the DOE “Energy-Water Nexus Roadmap” workshops, reviewing issues in four different regions of the country. This event will conclude with a discussion of recent federal legislative initiatives and new directions for integrated water-energy planning.

- On September 12-16 GWPC held the Water Energy Sustainability Symposium at the GWPC Annual Forum.

- The official title of the event was Water/Energy Sustainability Symposium: Water & Energy Policy in the 21st Century.

The event contained the following sessions...

- ⦿ Water needs for energy development
- ⦿ Water needs for power generation
- ⦿ Energy and power needs for water supply and wastewater treatment
- ⦿ Treatment and reuse applications of energy water for other water uses
- ⦿ Water needs for unconventional oil & gas
- ⦿ Water needs for renewable energy supplies
- ⦿ Water, energy and agriculture
- ⦿ Global water-energy issues and food security
- ⦿ Water and energy underground part 1 (geothermal)
- ⦿ Water and energy underground part 2 (carbon sequestration and hydraulic fracturing)
- ⦿ Water-energy policies, agency programs, and legislative initiatives
- ⦿ The DOE roadmapping process, regional issues, and integrated water-energy planning approaches

- The following is a breakdown of participants.

Total Number -310

Presenters-124

Partner Organizations-26

- Symposium Follow-up.

GWPC is in the process of receiving permission from presenter to post their presentation on the symposium site. Additionally, GWPC will post and distribute a series of articles resulting from information acquired at the event. 10/27/09 representatives of the GWPC and DOE were invited to the Council on Environmental Quality Listening Session. A synopsis of the Water Energy Symposium was presented and the following document was made available describing the event, listing partner organizations and announcing the article series to follow...

www.gwpc.org

Understanding Water-Energy Sustainability Fall 2009

On September 13-16, 2009, in Salt Lake City, the Ground Water Protection Council, US Department of Energy and National Energy Laboratories were joined by 26 water, power, and energy organizations as “sustainability partners” for a 4-day Symposium dedicated to understanding the water-energy inter-relationships and the science, technology, and policy needs identified by the participants as steps towards integrated water-energy planning and sustainability. This article series summarizes the findings of that Symposium. While these findings do not constitute recommendations by the sponsors and partners, they are intended to support a more informed dialogue on these important issues.

Water-Energy Sustainability Partners:

Topics in Water-Energy Sustainability: Water needs for energy development * Water needs for power generation * Energy and power needs for water supply and wastewater treatment * Treatment and reuse applications of energy water for other water uses * Water needs for unconventional oil & gas * Water needs for renewable energy supplies * Water, energy and agriculture * Global water-energy issues and food security * Water and energy underground part 1 (geothermal) * Water and energy underground part 2 (carbon sequestration and hydraulic fracturing) * Water-energy policies, agency programs, and legislative initiatives * The DOE roadmapping process, regional issues, and integrated water-energy planning approaches

For the complete agenda and PowerPoint presentations, go to www.gwpc.org

Understanding Water-Energy Sustainability

Water and energy are critical resources that are inextricably and reciprocally linked. Meeting our energy needs depends upon the availability of water, often in large quantities. The pumping, conveyance, treatment, and distribution of water (and wastewater) are all likewise dependent upon readily available, affordable energy. Through integrated water-energy planning and co-location of facilities, there are also opportunities to maximize the benefits and minimize the impacts on both our water and energy resources for a more sustainable future – environmentally, socially, and economically. Particularly with the increasing understanding of the need to adjust to climate change, the security and economic health of the United States depends upon maintaining a sustainable supply of both energy and water.

Recognizing the critical nature of both water and energy (including both energy resource development and power generation), the **Ground Water Protection Council (GWPC)** hosted a four-day Symposium in Salt Lake City, Utah, September 13-16, 2009. Co-sponsored by USDOE and the national energy laboratories, the Symposium brought together more than 300 participants, including more than 80 presentations, and had 26 “sustainability partner” organizations with missions related to water, power, and energy, who came to discuss issues related to the science, technology, and policy of the relationships between water and energy.

The Symposium was held in conjunction with the Annual Forum for the GWPC, which is the association of state ground water protection and underground injection control agencies. GWPC held parallel sessions on related topics such as carbon capture and sequestration, and hydraulic fracturing for natural gas production. Since 1983, GWPC has worked extensively with USDOE, USEPA, and other Federal agencies, industries, and other stakeholders on water and energy issues, as well as issues related to ground water availability and sustainability and ground water quality.

USDOE initially asked GWPC to host the Symposium to present findings of research at the national energy laboratories, and other USDOE-funded work on water and energy. The Energy Policy Act of 2005 directed the DOE to develop an Energy and Water program to include “research, development, demonstration, and commercial application.” Congress had also directed DOE to improve the understanding of the interdependencies and challenges between water and energy, and identify opportunities for improved management of both energy demands for water and water demands for energy, by integrating the management of water and energy – including the development of a water-energy “roadmap.” DOE completed a series of “roadmapping meetings” in 2005-2006. Several of the roadmapping meeting participants were present at the Symposium. To ensure the Symposium would address the full array of water-energy issues, the Sustainability Partners were invited to participate and assist in distribution of Symposium findings.

The Symposium was well-timed, as the ramifications of competing demands for water and energy, and the need for integrated water energy planning as part of climate change adaptation, are being addressed at a national level. The White House Council on Environmental Quality (CEQ), the Office of Science and Technology Policy (OSTP), and the National Oceanic and Atmospheric Administration (NOAA) are working with Federal agencies, including the U.S. Department of Energy, to develop recommendations for adapting to climate change. As part of this effort, a workgroup was created, composed of representatives from relevant Federal agencies to consider climate change adaptation challenges specifically related to water resources. This Federal water resources workgroup is convening a series of “listening sessions” to hear views on water resources and climate change adaptation issues from a range of stakeholders, including representatives from the energy industry (October 27); states, utilities, and tribes (October 28), environmental and coastal organizations (October 28), and agricultural and transportation industry (November 2). US EPA has also created a new State and Tribal Climate Change Council within the National Water Program, which will bring together program managers at State, Tribal, and Federal levels, with representatives from the **Ground Water Protection Council**, the Association of State and Interstate Water Pollution Control Administrators, Association of State Drinking Water Administrators, Association of State Wetlands Managers, and National Tribal Water Council.

To help provide a better understanding of the inter-relationships between planning and management of water and energy resources, this article series is being produced summarizing the various topics addressed at the Symposium. Developed as a public education tool, this article series presents an overview of the findings presented and policy issues raised at the Symposium, which featured sessions on a wide array of topics where water and energy interconnect. See www.gwpc.org for article series and copies of Symposium presentations.

Cost Status:

- **\$239.2K was spent including staff time, as well as travel for event site, and other meeting related costs. This is \$89K over the original cost estimate by. The reason for this is due to the fact that the event was much larger than originally projects.**

Schedule Status:

- **Task was completed on schedule. The following schedule was been established.**
 - **The announcement of the on-line proceeding went out in early November/09**
 - **The follow-up articles was developed and distributed via e-mail.**

Changes to Work Plan Needed:

- **The follow-up activities were added.**

Actual or Anticipated Problem:

- **Although we went over budget, we had sufficient capacity to complete the task with the modification of Task 4.**

Personnel Involvement:

- **GWPC staff has remained the same**
- **In addition to staff working on the effort, 30 individuals volunteered to serve on the planning committee.**

Products:

- **E-mail version of the call for abstracts and online event announcement was active prior to the event.**
- **The event handbook that included the agenda, abstracts and list of attendees was made available to each participant.**
- **The online proceedings containing the majority of the presentations can be viewed at www.gwpc.org/meetings/proceedings.htm**
- **A summary document was developed and will be made available at www.gwpc.org and www.waterenergy2010.com in June, 2010. Attachment #1 is the current Draft of the summary document**

Task 2 - Work Plan**A Regional Assessment of Water and Energy Sustainability****Background**

It was not until the 1970's that those engaged in water planning and water resource appropriation fully faced the stark reality that a sustainable supply of surface and ground water, particularly the latter, may not be possible in all regions of the United States. For example, many of the ground water management laws and stricter concepts of water appropriation were formulated and instituted after significant "mining" of ground water had occurred through injudicious irrigation and industrial use practices that failed to incorporate water conservation techniques or applied water to crops according to set schedule without regard to natural rainfall events. Many water users disregarded the early predictions of water, particularly ground water, as being "finite" or at the very least, unplenishable at the rate it was being withdrawn. "Sustainability" a word of more recent generation, just by definition, carried a warm feeling of the having a "forever available" supply of water for whatever consumptive use was intended.

The realization that oil, gas and coal might be finite, at least in terms of the United States being able to supply its own energy needs without appreciable dependence on imported resources preceded the concern over water by a couple of decades. The concept of conservation of oil resources began in the 1930's when the price of overproduced oil depressed the price to four cents per barrel and continued production to a market that did not exist was correctly viewed as economic waste. The Interstate Oil Compact Commission (IOCC) was formed in 1935 by a group of Mid-Continent governors to develop a method of producing oil in an orderly manner that took into account market demand based on some type of formula, which balanced available supply versus predicted consumer use. This formula worked very well until the 1970's when domestic oil production declined and the demand for oil gradually increased to the point where today the United States imports over 60% of its oil needs and the current price for gallon of gasoline reflects both the imbalance of demand over supply and the lack of control the United States has over importing nations. The assurance of sustainability has shifted to those with uncertain agendas. During the earlier years of the United State producing history, much gas was wasted and flaired to the environment and was considered a nuisance to clean oil production. Gas production conservation practices began in the 1960's for larger fields and slowly became a companion source of fuel to oil. Many traditional gas reservoirs have now matured and are in steady decline, however the interest in developing reserves of Coal Bed Methane (CBM) gas has regenerated exploration in many of the old oil and coal producing areas of the U.S.

In 2006-7, the Department of Energy sponsored three Energy/Water Nexus Workshops designed to have a comprehensive mix of stakeholders discuss the relationships between energy resources and water availability. Simply stated, the focus was on two questions. (1) What sustainable water resources are needed currently and in the future to support all of the development of different sources of produced energy? (2) What short and long-term sources of dependable energy are needed to provide a sustainable source of water for all consumptive uses? For example, ethanol blends will reduce the amount of gasoline by a certain percentage, but if the ethanol is from corn, the amount of water used to grow it and then refine the ethanol may actually use more water than fuel derived from petroleum sources. These workshops revealed not only the intensely competitively complex relationship between energy and water in its availability and use but also the feeling among many that a sustainable supply should continue to be a guaranteed entitlement.

There is an old saying that "many states have sufficient ground water resources to conduct activities and populations dependent upon water; unfortunately 95% is in the wrong place". Kansas and Nebraska are examples of where ground water resources are in the unpopulated part of the state while the major urban areas have to depend upon purchases of water from surface reservoirs. The same bromide is applicable to the various sources of energy, particularly those dependent upon petroleum production, when one views the major sources of domestic oil and gas production being regionally in parts of the country while the major population centers of the U.S. and energy consumers are in areas devoid of petroleum reserves.

Project Scope

The purpose of this study will be to conduct an initial water management assessment in selected states comprising a northern Rocky Mountain basin. This effort will be a microcosm of the problems existing for energy/water in more populated areas. The assessment will compare availability and need and will be accomplished by evaluating information obtained by interviews relating to the following subjects.

1. Gather and compile information from state oil and gas and water resource agencies to determine how much water is produced by each petroleum related activity (e.g. oil/gas production, Coal Bed Methane (CBM), and the amount of water estimated in storage in surface reservoirs and ground water aquifers.
2. Gather and compile information on the overall quality of the water, with emphasis on that water derived from petroleum and CBM sources.

3. Determine through review of state water data files and interviews with state water regulatory and water planning agency personnel, what water needs projections have been made for each state or region.
4. Identify through review of appropriate statutes, regulations, water quality standards and through interviews with appropriate state agency personnel and water users what barriers exist to deter the use and reuse of produced water for augmentation of supplies from other water sources.

Additionally, the GWPC will review appropriate peer published documents, reports and studies and will conduct internet based research to compile relevant information that, in conjunction with the information obtained from agency interviews and supplied materials, will be used to prepare two reports:

1. An initial report focusing on the quantitative and qualitative information gained during the contact with oil, gas and water resource regulatory agencies. This report will include information from all petroleum related water sources.
2. A comprehensive report covering all aspects the assessment of water needs and the issues that affect sustainability of both energy and water for each state in the region.

Project Timetable

- Phase 1: Develop, distribute and compile the results of the initial assessment and state questionnaire by Fall 2008.
- Phase 2: Prepare a draft summarizing the findings of the assessment to stakeholders for review by Summer, 2009.
- Phase 3: Hold a symposium on Water/Energy Sustainability by Fall 2009
- Phase 4: Prepare a final comprehensive report and submit to DOE by, Fall 2009

Project Stakeholders

The following is a list of organizations that may participate with GWPC in this project as advisors, reviewers or subcontractors: State Oil and Gas Agency staff; State Water Quality Agency staff; State Water Quantity Agency staff; Federal Agency staff with water and energy information; and representative of the oil and gas industry.

Accomplishments & Discussion:

- Consultant was selected: ALL Consulting
- The area for the study was defined as the Montana portion of the Powder River Basin. This area was chosen because there is a well-developed set of oil and gas produced water data available and the relatively small study area allowed us to concentrate on methodology rather than being consumed by data management.
- Data gathered for the included water availability and water use from surface and ground water sources as well as oil and gas produced water data. The data came from a combination of state and federal agencies. Data were standardized on a county-level basis using the four predominant counties in the Montana portion of the Powder River Basin: Big Horn, Rosebud, Custer, and Powder River. The state does not have water use projections. To compensate for this, researchers took

population growth projection data and, using water use projections from other states, created a simple methodology to estimate future water needs.

- Data on oil and gas produced water in the study area were gathered and a projection methodology was developed. To make oil and gas water projections, the volume of the recoverable resource in the study area has been evaluated and gas production/water production model has been created using an algorithm based on historic gas price/production data and future gas price projections.

Cost Status:

- ~180.1K including ~140 to All Consulting. The task was completed within budget.

Schedule Status:

- The task was completed ahead of schedule. A paper for this effort was presented at the GWPC Water-Energy Symposium and a final task report was completed on December 8, 2009. No problems were encountered, and no changes to the approved work plan were needed during the course of the task.

Changes to Work Plan Needed:

- None

Actual or Anticipated Problem:

- None

Personnel Involvement:

- GWPC staff has remained the same as well as the consultant

Products:

- Report entitled, "Regional Water Assessment: A Sustainability Analysis of the Potential for Using Produced Water in the Montana Portion of the Powder River Basin"

Task 3 - Work Plan

**Risk Based Data Management System-Water
Water and Energy Module**

Overview

The Ground Water Protection Council (GWPC) and the Nebraska Oil and Gas Conservation Commission (NOGCC) recently updated NOGCC's data mining application to include information pertaining to surface and ground water quality in the state of Nebraska. These enhancements serve as a prototype for an all encompassing ground water quality monitoring application that links geographically referenced water quality information with oil and gas regulatory data.

These enhancements place GWPC in a unique position to be the sole source for all water quality data from an array of governmental agencies and other stakeholders. GWPC has the capacity to compile, update, and maintain water quality from various agencies and make them available in a single, central repository. Additionally, by placing these data in the context of existing state-level oil and gas data, GWPC will be able to provide valuable analytical tools to assist in the protection and conservation of ground water.

Task 1 – Data Acquisition, Transformation, and Data Mining Integration -

- A. Acquire entire water quality datasets from NE, USGS (2 datasets), and USEPA, transform and normalize the data into an extended version of the RBDMSW database in use in Ohio.
- B. Modify full text search in the RBDMS Data Mining application and generate full text searchable tables in the RBDMSW database to return results for Projects, Sites, Observations, and Results from the RBDMSW database.
- C. Modify details display templates in the RBDMS Data Mining application to display detailed results for Projects, Sites, Observations, and Results from the RBDMSW database.
- D. Modify advanced search in the RBDMS Data Mining application to return results for Projects, Sites, Observations, and Results from the RBDMSW database.

Task 2 – Design and Implement *Water Sample Result Selection Dialog* -

- A. Generate up to 10 use case documents to clarify detailed input (provided by user) and output (provided by system).
- B. Implement *Water Sample Result Selection Dialog* as necessitated by use cases.

Task 3 – Design and Implement Thematic Analysis Using GIS -

- A. Modify the GIS component of the RBDMS Data Mining application to facilitate thematic mapping of results returned by the *Water Sample Result Selection Dialog* (e.g. thematically mapping sample locations shaded based on nitrate levels).

Task 4 – Design and Implement Report-Based Analysis Using RDLC Reports

- A. Develop RDLC report to display trend graph of results returned by the *Water Sample Result Selection Dialog*.

Project Timetable

- Phase 1: Design phase to be completed by Spring, 2009.
- Phase 2: Implementation by Fall, 2009.
- Phase 3: Analysis of product by Fall 2009

Project Stakeholders

Stakeholders include: State Oil and Gas Agency staff; State Water Quality Agency staff; State Water Quantity Agency staff; Federal Agency staff with water and energy information; and representative of the oil and gas industry.

Accomplishments & Discussion:

- **State, USGS and EPA ground water sampling sites and data have been imported into the Nebraska RBDMS data mining application in Nebraska. This map can be overlain with oil and gas production and injection wells. The application can be viewed at <http://coordinatesolutions.com/rbdmswebwq>**
- **Water quality analysis can be retrieved and compared. This is the first time that state and federal water quality data can be displayed on the same GIS interface. For screens shot displaying this application please contact Paul Jehn at pauljehn@roadrunner.com**
- **April 30, 2009: Historic water quality results for acid mine drainage compliance monitoring have been entered into RBDMS water for Ohio. Programming has been completed to enable laboratories to electronically submit data to RBDMS water. A web interface is also underdevelopment to**

allow volunteer monitoring programs the ability to upload data to the web. All these data will be posted on a public internet site.

- The GWPC is partnering with the ODNr to create a data management system to store and analyze the laboratory data provided by coal operators to comply with requirements for pre-mining characterization of background hydrologic conditions, quarterly monitoring, and NPDES reporting. The internal agency portion of the RBDMS for Water application is a desktop application that encompasses the laboratory information management system, water quality, source water assessment components, and links to the other databases. Deployed in 2006, this application features an integrated GIS and statistical and graphical reporting system.
- In Phase 2 of application development, which is underway now, industry operators' third-party laboratories will be able to upload electronic data deliverables via the Web in a format compatible with the EPA's schema for water quality (<http://www.epa.gov/storet/wqx.html>). The submitted information will be replicated to internal agency servers after passing several tiers of quality control checks. The Web application also will feature secure data entry screens for watershed volunteers and field inspectors to use in collecting organic, inorganic, and physical water quality parameters and water source data such as well and spring construction details, water well test data, surface sample source details, surface water flow measurements, waste stream source details, and abandoned and active mine source details such as seeps, impoundments, sediment ponds, and underground mine intercepts. Aquifer, watershed, usage categories for ground and surface water, and geographic information also will be tracked, as will laboratory and field test methods and observations. Sophisticated workflow and automated notifications will flag the occurrences of regulatory deadlines, permit violations, and analytical parameter exceedances. The status of electronic submittals and the resulting data will be queryable via the Web and accessible to both industry and to the public.

Cost Status:

- ~\$7.2K has been spent including consulting fees, staff time and overhead

Schedule Status:

- Task is generally on schedule.

Changes to Work Plan Needed:

- None at this time

Actual or Anticipated Problem:

- None at this time

Personnel Involvement:

- GWPC staff has remained the same

Products:

- Website enhancements to the site at the Nebraska Oil and Gas Conservation Commission and the Ohio DNR web site

NEW: Task 4 – Work Plan

**Identification and Assessment of States Regulatory Programs Regarding
Geothermal Heating and Cooling Systems**

Background

Nationally, installations of geothermal heat pump systems are estimated to have increased more than 33 % in each of the last two years as reported by the federal government. In the interest of protecting ground

water, the Ground Water Protection Council (GWPC) will conduct a inventory and assessment of current regulatory practices regarding geothermal heating and cooling systems among the various states of the United States of America. GWPC will team with the Geothermal Heat Pump Consortium, the International Ground Source Heat Pump Association, and the National Ground Water Association.

Scope

GWPC will work with partners, including the Geothermal Heat Pump Consortium, the International Ground Source Heat Pump Association, and the National Ground Water Association to develop a questionnaire appropriate to capture the status of regulatory controls that currently exist regarding geothermal heating and cooling systems. A third party technical consulting company will be retained to assist with the technical aspects of the online voluntary reporting form, data display and analysis and final report/display functions. GWPC will work with all appropriate state agencies to ensure their participation in this fact finding activity. GWPC will develop a summary report of the findings and distribute to appropriated entities. The total costs for this effort is estimated to be ~10K.

Deliverables

The GWPC will:

- Develop and finalize agreement with partners,
- Select technical consulting group,
- Finalize voluntary reporting form,
- Develop and implement online voluntary reporting form, and
- Develop and distribute final summary report.

Timetable

This project will be completed by 12/31/2009

Participants

The following is a list of potential organizations/ persons who may participate in this project as contributors or contractors:

Heat Pump Consortium

International Ground Source Heat Pump Association

National Ground Water Association

Accomplishments & Discussion:

- an agreement was developed and signed

The technical consulting group, Industry Insight was retained to assist with development and implementation of the online voluntary reporting form and data analysis tool function.

Cost Status:

- ~7.1K has been spent including consulting fees, staff time and overhead

Schedule Status:

1 Changes to Work Plan Needed:

- **Discussions regarding a project shift were held in June/09 with Project Officer, Michael Bednarz as well as other NETL officials, and GWPC Executive Director, Mike Paque in the Pittsburgh office. Mr. Paque proposed that at least some of the resources be directed to a study regarding regulatory information pertaining to the geothermal energy practices. GWPC began the process of working with key players across the country to develop a specific project plan.**

Actual or Anticipated Problem:

- **None at this time**

Personnel Involvement:

- **The staff assigned to the project when first developed in the original proposal stage is no longer an employee of GWPC. Staff assigned to this revised task has been identified.**

Products:

- **The FINAL voluntary reporting form was completed with input from partners and several state regulatory agencies**
- **The FINAL reporting form was developed into electronic format and posted on the Consultant's webpage for online internet response. State participants were identified by project partners and received an email notice of the online form.**
- **The preliminary response has been concluded with 34 participants providing regulatory information. Consultant analysis and FINAL written report are underway and expected to be completed by mid-April**

Project Management and Reporting

In addition to the aforementioned deliverables, reports and other required deliverables will be provided in accordance with the Federal Assistance Reporting Checklist following the instructions included therein.

Attachment #1

WHAT IS THE WATER-ENERGY NEXUS?

Water and energy are linked:

- **Water for Energy:** Developing energy resources and converting energy to power depends upon the availability of water, often in large quantities.
- **Energy for Water:** Pumping, conveyance, treatment, and distribution of water (and wastewater) are all likewise dependent upon available, affordable energy.
- **Integrated Water-Energy Resource Management:** Sustainable management of water resources (e.g. rivers and aquifers) and energy and power resources (e.g. petroleum reserves and electric power grids) requires integrated planning, coordinated policies, co-location of infrastructure, and “strategies for synergies”

*The Ground Water Protection Council (GWPC)
hosted a four-day “Water-Energy Sustainability Symposium”
in Salt Lake City, Utah, September 13-16, 2009.*

*Co-sponsored by the U.S. Department of Energy (USDOE),
this Symposium, drew more than 300 participants.
Planners, policymakers, managers, and researchers
in the energy, power, and water sectors
explored ways to coordinate approaches to resource management.*

Strategies for Improving Coordination on Water and Energy Sustainability

While it is clear that water and energy resources are linked (see left), the government agencies, companies, utilities, and other organizations that manage water and energy resources have, for the most part, developed and operated separately in the United States, and often have had different cultures and approaches to resource planning and management. Given the linkages between water and energy, however, it is clear that sustainable resource planning and management efforts will require a more coordinated and collaborative approach.

The 2009 Water-Energy Sustainability Symposium provided a forum in which policymakers, planners, researchers, and water managers could come together and discuss issues and perspectives as well as roles and activities related to coordinated policy and integrated planning for water and energy sustainability. Representatives from more than two dozen water, power, and energy associations, as well as academics and other stakeholders, also provided their perspectives on how the water-energy nexus affected them.

This Prospectus provides an understanding of the federal and state government agencies, companies and utilities, and other stakeholders involved in water and energy management and impacted by the linkages between water and energy. 2009 Water-Energy Sustainability Symposium participants worked to develop understanding of the need for strategies to integrate water and energy policies and identify opportunities for integrated planning approaches, policies and programs to promote water conservation and efficient energy use.

By creating “strategies for synergies” in the development and use of water and energy at the building, farm, river basin, and regional scale, we can maximize the benefits and minimize the impacts on both our water and energy resources for a more sustainable future – environmentally and economically.

Broadening the Perspective of the Global Balance of Water and Energy Needs

The 2009 Water-Energy Sustainability Symposium began with presentations by water and energy government agency representatives at the federal and state level, who discussed programs and policies to support better integration of water and energy management. Water and energy were both tied to other important agency initiatives, such as energy security, green jobs creation and economic recovery, and climate change adaptation and mitigation. Industry representatives, water and power utilities also discussed how the linkages between water and energy impact their sectors.

A more global understanding of the importance of water and energy was provided by organizations that bring clean water to developing countries using low-carbon or zero-carbon footprint methods. These discussions were kicked off by actor and humanitarian Don Johnson and the Director of the Centre for Affordable Water and Sanitation Technologies (CAWST) Camille Dow Parker. Manna Energy provided a downlink from flight engineers aboard the International Space Station on the importance of clean water and energy for the planet, and the conservation and efficiency methods used in space (www.youtube.com/watch?v=zJsfevC2liQ).

The Symposium breakout sessions (shown in the box to the right) explored several areas where water-energy linkages exist. The Symposium ended with a dialogue between the attendees and a panel of congressional staff on legislative opportunities to support further integration of planning and management of water and energy resources.

In each of the many linkages between water and energy (shown here), different regulatory agencies, technical assistance programs, utility companies, and other stakeholders decide how energy and water supplies are used, as well as how those uses can impact rivers and aquifers.

Source: Electric Power Research Institute

WATER-ENERGY TOPICS EXPLORED

Water for Energy

- Water for traditional oil and gas
- Water for unconventional oil and gas (oil shale, shale gas, coalbed methane) - hydraulic fracturing/in-situ technologies
- Water for thermoelectric power generation and carbon sequestration
- Water for renewable energy and nuclear
- Geothermal, heat pumps and storage

Energy for Water

- Power for water and wastewater utilities
- On-site renewable power production at water/wastewater utilities
- Carbon footprint reduction by water and wastewater utilities

Green Building and Green Cities

- Building/community scale efficiency
- Energy and sustainable water infrastructure

Water, Energy and Agriculture

- Bioenergy production
- Low-head dams & other “microhydro”
- Agricultural/municipal partnerships and rural water-energy concerns
- Water-energy-food security (US & Iraq)

Integrated Water Resources Planning

- Decision support tools and data sharing
- Regional examples: New York City (NY); Snake River Basin (ID), Colorado River Basin (CO), Cumberland River (TN).

INTERACTIONS BETWEEN ENERGY AND GROUND WATER

In addition to the direct impacts on aquifers associated with energy resource development, energy and ground water interact in many other ways. A few examples:

- Increased power demands for pumping from deeper aquifers as ground water levels fall
- Opportunities to use aquifers for thermal energy storage
- Impacts to ground water levels and quality from energy-related activities on the land surface, particularly at ground water recharge zones
- The development of rain gardens and other ground water infiltration methods to manage and treat storm water –and recharge aquifers—while reducing energy costs for storm water collection as part of the development of sustainable “green” communities

The Ground Water Protection Council (GWPC) is the national association of state ground water and underground injection control agencies. Its mission is to promote the protection and conservation of ground water resources for all beneficial uses, recognizing ground water as a critical component of the ecosystem.

The GWPC seeks to provide a forum for stakeholder communication and research to improve governments’ role in the protection and conservation of all aspects of ground water protection and management.

As an association of state agencies, GWPC frequently works with federal agencies, such as USDOE and USEPA, on state agency implementation of federal regulations, and on how state and federal regulatory and technical assistance programs can be implemented in a more coordinated manner.

Energy issues have been an essential focus of the GWPC since the association’s founding in 1983. Much of our nation’s energy resources lay underground in proximity with ground water aquifers. The GWPC has long been a partner with the USDOE on studies to protect groundwater during energy-related activities, playing a central role in issues such as the following:

- Underground injection
- Source water protection
- Coalbed natural gas and produced water
- Carbon capture and sequestration
- Shale gas development and hydraulic fracturing

Many fresh water aquifers nationwide are under stress from over-pumping and salt water intrusion. Energy production may involve withdrawals from aquifers as well as injection into aquifers.

USDOE has played an increasing role in broadening the understanding of the water-energy nexus. As shown in the table below, several of the USDOE program offices and related national laboratories have missions related to water and energy linkages.

The Energy Policy Act of 2005 directed the USDOE to develop an Energy and Water program to include “research, development, demonstration, and commercial application” to meet the following needs:

- Address energy-related issues associated with provision of adequate water supplies, optimal management, and efficient use of water
- Address water-related issues associated with the provision of adequate supplies, optimal management, and efficient use of energy
- Assess the effectiveness of existing programs within USDOE and other federal agencies to address these energy and water related issues.

USDOE submitted a 2006 Report to Congress which described the “interdependency of energy and water focusing on threats to national energy production resulting from limited water supplies.”

Information on water-energy activities underway by the USDOE and National Energy Labs, including a copy of the 2006 Report to Congress, are available online at www.sandia.gov/energy-water/.

The Symposium was the latest of several USDOE-supported initiatives, including a report to Congress and series of “road-mapping” workshops held with water-energy stakeholders to assess research needs (see www.sandia.gov/energy-water/).

USDOE Programs	Mission	Related National Laboratories
Energy Efficiency and Renewable Energy	Providing clean, abundant, reliable, and affordable renewable energy.	National Renewable Energy Laboratory National Energy Technology Laboratory
Environmental Management	Mitigating the risks and hazards posed by the legacy of nuclear weapons production and research.	Savannah River National Laboratory
Fossil Energy.	Ensuring clean, affordable energy from fossil fuels.	National Energy Technology Laboratory
Nuclear Energy	Supporting the nation’s diverse nuclear energy programs.	Idaho National Laboratory
National Nuclear Security Administration	Enhance national security through the military application of nuclear energy, and maintaining and enhancing the safety, reliability, and performance of the United States nuclear weapons stockpile.	Lawrence Livermore National Laboratory Los Alamos National Laboratory Sandia National Laboratory
Science	Basic research in the physical sciences.	Argonne National Laboratory Brookhaven National Laboratory Oak Ridge National Laboratory Pacific Northwest National Laboratory

Department of Energy Program Offices with Water-Energy Nexus-Related Missions

Modified from: Sehlke and Wichlacz, Journal of Contemporary Water Research and Education, December 2009, www.ucowr.siu.edu

2009 WATER ENERGY SUSTAINABILITY PARTNERS

Concern about the availability of water for future competing demands is growing.

NEEDS IDENTIFIED IN ROAD-MAPPING MEETINGS

Better resources planning and management

- Integrated regional energy and water resource planning and decision support tools
- Infrastructure and regulatory and policy changes for improved energy/water efficiency
- Improved water supply and demand characterization, monitoring, and modeling

Improved water and energy use efficiency

- Improved water efficiency in thermoelectric power generation
- Improved biofuels/biomass water use efficiency
- Reduced water intensity for emerging energy resources

Development of alternative water resources and supplies

- Oil and gas produced water treatment for reuse
- Energy efficiency and assessment of treatment and use of “impaired” water (produced, brackish, and wastewater)

U.S. energy sustainability is a complex puzzle of interlocking parts. Federally supported research and development (R&D) is being carried out to address key pieces of this puzzle including advanced fossil and nuclear energy technologies, energy efficiency, infrastructure systems, pollution control and prevention, and renewable and alternative energy. However, one critical component of the R&D mix is missing: **water**. Currently, no national research program is directed specifically at understanding the intimate relationship between energy and water.

In 2005 and 2006, with funding by Congress, USDOE and the NETL held a series of needs assessment workshops to assess gaps between existing national programs and emerging issues and to identify research innovations, needs, and priorities. The workshops obtained input from 350 participants from over 40 states and tribal nations. Participants included water managers, industrial users, regulators, public interest groups, and policymakers. A preliminary summary is available from <http://www.sandia.gov/energy-water/>.

Concern about the availability of water for future competing demands is growing. In some regions, power plants have had to limit generation because of insufficient water supplies, and citizens and public officials concerned about the availability of water have opposed new power generation and fuel processing facilities. Most state water managers expect shortages of water over the next decade. Water supply availability is already affecting existing and proposed power plants and nonconventional transportation fuel production in various locations.

- Current directions in energy development and production will significantly increase water consumption through 2035, making energy the largest non-agricultural water consumer.
- Availability of freshwater resources is limited without new storage capacity, so water reclamation and reuse are becoming major sources of future supplies.
- If growth in water reuse continues, overall national water availability could be sufficient to support water demand growth, though regional shortages are likely to occur, especially through 2015.
- Energy sector processes for cooling, scrubbing, refining, etc. will need to become compatible and cost-effective for use with reclaimed/nontraditional waters.
- Through 2015, water supplies development will be under significant pressure to keep pace with emerging water demands
- Siting priorities of energy facilities may change to use large reclaimed water sources in urban areas.
- Energy planning will become increasingly dependent on interactions between regional water, wastewater, and agricultural water managers and planners. Regional energy and water concerns will continue to emerge.

Participant Observations on Emerging Issues

More than one-third of the Symposium participants provided responses to a questionnaire on emerging issues in water-for-energy; energy for water, and integrated water-energy planning, and what roles different organizations and levels of government can play in addressing these issues. These perspectives and recommendations do not represent a “consensus,” nor do they represent the views of the GWPC or USDOE, but provide important contributions to the ongoing water-energy dialogue, and support the need for continued dialogue and integrated planning for water and energy:

- Energy uses 27 percent of non-agricultural fresh water.
- Fossil energy will remain a large part of the US energy portfolio for the foreseeable future. Even with a doubling of the use of renewable energy supplies, the US would continue to rely on oil, gas, and coal for more than three-quarters of its energy supplies. Continued efforts are needed to increase water efficiency during fossil energy production, including water use from production on nontraditional fossil energy sources, will be critical.
- New water challenges and opportunities accompany new energy sources. Domestic energy supplies are critical for national security and for rebuilding our economy. Accessing energy from nonconventional sources such as shale gas requires techniques such as hydraulic fracturing that require additional water supplies; although lower quality water can sometimes be used for these purposes. Produced water from extraction of energy sources such as coalbed methane can also provide opportunities for water supplies for agriculture and other water uses.
- The demand for natural gas is increasing. The US has abundant natural gas supplies, which have fewer emissions than coal (50%) or gasoline (30%). Natural gas is increasingly being used for power plants, and is also used directly in homes, for manufacturing and industrial processes, and for transportation fuel.
- Nuclear energy needs greater consideration. Currently 74% of U.S. emission-free electricity is produced by nuclear energy. Nuclear energy plant operation and development is being impacted by water availability.

U.S. Freshwater Consumption, 100 Bgal/day

Energy uses 27 percent of non-agricultural fresh water.

U.S. Energy Demand 2006

U.S. Energy Demand 2030

Fossil energy will remain a large part of the US energy portfolio for the foreseeable future.

The U.S. is the world's second largest producer of natural gas and the third largest producer of oil. Nearly every region of the country has oil and natural gas potential.

New water challenges and opportunities accompany new energy sources.

Participant Observations on Emerging Issues, Continued

- Alternative energy and water solutions are an important sector for creation of new jobs.
- Interruptible energy supplies such as wind and solar need to be operated jointly with hydropower or gas to meet both peak and baseload power demands. The power grid needs to be developed to ensure greater water reliability. Wind power can increase overall electricity availability while decreasing water demands. However, scenarios that would provide water savings also would require regulations and permitting requirements that would increase consumer electricity costs.
- Low-head hydraulic control structures can be a critical source of energy and income for agriculture. Many irrigation systems are appropriate for kinetic hydro applications, which could provide local energy to support enhanced water savings irrigation technologies. Licensing through the Federal Energy Regulatory Commission (FERC) and US Bureau of Reclamation needs to support these activities.
- Geography plays important role in fuel source water efficiency. We need to understand the water footprint of fuel production, including different types of bioenergy. We also need to consider the energy demands of fuel transport and the impacts on navigation channels, which reduce the water efficiency of imported fuels (foreign oil, Alaskan or off-shore oil and gas).
- Electric cars have a water cost. As electric vehicles are considered as a means of replacing vehicles requiring gas and ethanol, the “water cost” for creating the electricity for these vehicles is often overlooked.
- Water use numbers vary largely by power plant design, even within a single technology. Newer technologies often (but not always) have lower water use (e.g., air-cooled vs. water-cooled; geothermal binary vs. flash). Once-through systems consume 1% of water withdrawn. Cooling-tower systems consume 70%-90 % of water withdrawn. Different plant designs within a given technology should be assessed so that water use needs can be better understood and managed.

Drought affecting nuclear plants

Twenty-four of the nation's 104 nuclear reactors are in areas experiencing the most severe levels of drought. Rivers and lakes supply power plants with the cooling water necessary to operate.

Nuclear energy plant operation and development is being impacted by water availability

Participant Observations on Emerging Issues, Continued

- The Water-Energy-Agriculture connection is not just about biofuels. The water demand for biofuels is high for fuel produced from irrigated corn, but other sources of biofuels are available. Agricultural lands and irrigation infrastructure also provides opportunities to produce energy through “microhydropower,” algae, and non-irrigated crops for biofuels. The energy requirement to supply water to rural communities is also an important consideration, and greater resources are needed to support rural community water conservation.
- Power plant development is being limited by limited water supplies. US energy infrastructure depends heavily on the availability of water. There is growing concern about the availability of water for future competing demands once limited water resources are considered. In some regions, power plants have had to limit generation because of insufficient water supplies, and citizens and public officials concerned about the availability of water have opposed new power generation and fuel processing facilities. Regulatory mandates for closed-cycle vs. open cycle cooling need to be reviewed on site-specific bases.

Interruptible energy supplies such as solar need to be operated jointly with hydropower or gas to meet both peak and base load power demands.

Alternative energy and water solutions are an important sector for creation of new jobs.

The water cost of driving electric cars also must be considered.

The energy demands of fuel transport and the impacts on navigation channels reduce the water efficiency of imported fuels.

Agricultural lands and irrigation infrastructure also provides opportunities to produce energy through "microhydropower," algae, and non-irrigated crops

Biogas and biosolids are an underutilized resource for energy.

Participant Observations on Emerging Issues, Continued

- Electricity demands are significant for water utilities. Water utilities require power to pump, treat, deliver, collect, treat and clean water. The amount of electricity needed varies depending on the water source location and quality. Increased drinking water treatment requirements and increased populations are expected to increase the demand for energy to supply drinking water even further.
- On-site power generation is increasing at water utilities. Water utilities are developing wind, solar, and methane capture on-site. Water facilities need to be sited with consideration of energy requirements.
- The financial sector is an important player in the water-energy dialogues. The costs for electricity and carbon emissions reduction need to be considered in water and energy infrastructure discussions. Water use for power plant construction/manufacturing values is not well documented and is not often calculated in Lifecycle Cost Analysis. Lifecycle Cost Assessments should estimate water consumption for the life cycle of the plant, including water needed for transportation and distribution.
- Wastewater facilities can be an important generator of energy. There are 16,000 wastewater treatment plants in the U.S., of which 3,500 plants use anaerobic digestion. It has been determined that just over half of them recover biogas for use on-site. Additional energy is being generated at some wastewater utilities (e.g. East Bay, California) using food scraps. Biogas and biosolids are an underutilized resource for energy, and needs to be included as a renewable energy resource in climate change and energy legislation.
- Green buildings and green communities save both energy and water. More sustainable water infrastructure not only saves water, but also saves energy to heat water, and reduces the demand for electricity. Green infrastructure includes rain gardens that trap stormwater and sustain trees and plants, restoring beauty and improving air quality in cities, moderating energy flows, and providing potential food sources. On-site stormwater management and rain gardens can reduce energy costs for collection and treatment of stormwater. Energy savings need to be studied for decentralized water systems, with new performance standards developed.

Participant Observations on Emerging Issues, Continued

- Integrated regional resource planning and management is critical. Water and energy sectors and agencies use different words and acronyms. Decision support tools and collaborative approaches are needed to support greater interaction on very expensive water and energy infrastructure decisions, as well as policy and regulatory issues. We can't make stovepipe decisions. We need good data for modeling monitoring, and decision making. More support is needed to develop data and make that data widely accessible. We need to consider co-location of energy facilities with water and wastewater facilities. More integrated and tiered planning is needed with appropriate tools at appropriate levels. Bottom up approaches are necessary but not sufficient for sustainability. Risk management should consider the combined influences of population growth, land use change, technological advances, and climate variability. Scoping level analysis can be applied nationally, while more detailed management area water budget and dynamic watershed modeling can be used at the regional and local level.
- Agencies with energy expertise and agencies with water expertise need to work closely together. The US Department of the Interior (USDOI) has announced several programs and funding opportunities as part of its commitment to supporting the "New Energy Frontier," including improved coordination among the USDOI agencies on monitoring and managing climate change impacts and challenge grants for water reuse, including the US Bureau of Reclamation (USBR) Title XVI grants for reuse in western states. The USGS provides data on water use, including water use for thermoelectric power generation, as well as assessments of energy resources, including the ongoing national oil and gas assessments and oil shale and tar sands. Water and energy agencies need to work together to encourage more sustainable solutions and provide regulatory oversight for safe use of new technologies. Federal agencies need to initiate partnerships with states and local communities that focus on energy-water relationships. EPA and state drinking water programs need to market the Water Sense and Energy Star programs jointly, and to work in conjunction with local governments and associations such as homebuilders.

Green infrastructure includes rain gardens that trap storm water and sustain trees and plants.

EPA and state drinking water programs need to market the Water Sense and Energy Star programs jointly, and to work in conjunction with local governments and associations such as homebuilders.

Supporting international needs for water and energy can be critical to providing food for other nations and security for our own.

Participant Observations on Emerging Issues, Continued

- We need national ground water baseline studies and use parameters in each basin for ground water protection. Revised standards for some parts of the Underground Injection Control (UIC) program may be needed as more injection (ASR, CO₂) is being proposed. More research is needed on opportunities for reuse of energy wastewater as an alternative to injection.
- There will be many stakeholders involved in water-energy planning, including agencies at several levels. State agencies are often at the front lines of planning and implementation of water-energy program coordination. Regulations and interagency coordination need to be reviewed to ensure barriers are not created to water-energy sustainability.
- There is no centralized effort for coordination of policy and research on water and energy within the Executive Branch or in Congress, where legislation is divided among different committees.
- New research is needed to accelerate innovation. R&D is critical, bringing together expertise from the energy industry and DOE/National Energy Laboratories with water providers. Continuous technology innovation can strengthen our capability to meet the Nation's energy demands, and protect and conserve valuable water resources.
- The value of wetland ecosystem and vegetation needs to be considered for energy savings as a means of improving water quality.
- Supporting international needs for water and energy can be critical to providing food for other nations and security for our own. Modeling of water, energy, and food resource management has been a part of the US support for the Iraqi people and other diplomatic and international development efforts. The water-energy nexus is a global issue. US technologies can help developing countries to meet basic needs for water and food.
- Reuse of water is needed to meet water demands. Research is needed to support development of water reuse technologies that are sustainable and use less energy.

Participant Observations on Emerging Issues, Continued

- Research & Development (R&D) needs greater flexibility and broader input: R&D programs need to be developed with input from multiple stakeholders in order to ask the right questions. Federal and state agencies need to work more closely with non-governmental organizations, universities, and associations to put R&D “on the ground.” We need regulatory flexibility to encourage R&D, breaking down compartmental regulation that stifles innovation.
- More sustainable water-energy approaches need to be part of the climate change efforts. Carbon emissions reduction requirements will impact our water infrastructure as well as our energy infrastructure. Use of lower quality water to meet water supplies (brackish water, recycled water, produced water) can require higher energy treatment methods. Increasing drinking water requirements also increase power demands for water utilities. Decisions on energy and water efficiency should be driven by regional considerations. For example, some technologies will work better in some areas, such as desalination on the coast.

ADAPTING TO CLIMATE CHANGE

The White House Council on Environmental Quality (CEQ), the Office of Science and Technology Policy (OSTP), and the National Oceanic and Atmospheric Administration (NOAA) are working with Federal agencies, including the U.S. Department of Energy, to develop recommendations for adapting to climate change. As part of this effort, a workgroup was created, composed of representatives from relevant Federal agencies to consider climate change adaptation challenges specifically related to water resources. This Federal water resources workgroup is convening a series of "listening sessions" to hear views on water resources and climate change adaptation issues from a range of stakeholders, including representatives from energy; states, utilities, and tribes; environmental and coastal organizations; and agricultural and transportation industry.

US EPA has created a new State and Tribal Climate Change Council within the National Water Program. Participants include State, Tribal, and Federal program managers, the GWPC, the Association of State and Interstate Water Pollution Control Administrators, Association of State Drinking Water Administrators, Association of State Wetlands Managers, and National Tribal Water Council.

We need to translate:

Improving systems analysis approaches and information sharing techniques will result in better resource forecasting and management.

Improving power plant intake cooling systems, updating the grid structure, and assessing alternative fuels are priorities for the R&D program.

Three Areas of Concentrated Research

An integrated resource development of R&D program and planning tools

- Accelerate water resources forecasting and management
- Evaluate impacts of climate variability and improve hydrological forecasting
- Improve common decision support tools
- Generate new data and overcome obstacles to data sharing
- Develop system analysis approaches for co-location of energy and water facilities; improved national transmission capabilities to support renewables, and distributed generation of biofuels

Research Program for Electric Power Sector

- Improve dry and hybrid cooling system performance
- Improve ecological performance of intake structures for hydro and once-through cooling
- Improve materials and cooling approaches compatible with use of degraded water
- Electric grid infrastructure upgrades to improve low water use renewable technology integration

Research Program for Alternative Fuels Sector

- Reduce water use for cooling in biofuels and alternative fuels production
- Reduce water use in processing
- Develop low fresh water use technologies such as algal biodiesel
- Assess non-traditional water use for fuels applications
- Assess hydrologic impacts of large cellulose biofuels scale-up and oil shale

2010 Water-Energy Sustainability Symposium: Water and Energy in Changing Climates

Please join us in Pittsburgh, PA, September 25-29, 2010
to continue the dialogue:

www.WaterEnergy2010.com

Call for Presentations:

- Integrated Water/Energy Planning in a Changing Climate
- The Legal Framework: Water Allocation, Quality, & Energy
- Water, Energy, Climate Change
- The Water-Energy Relationship
- Water Needs for Energy
- Energy Needs for Water
- Climate Variability & Impacts on Water / Energy Resources
- Water / Energy Sustainability Best Practices at Regional, Local Community
- Water, Energy, Biofuels & Ground Water Impact
- Water, Energy & Agriculture
- Water Issues Related to Unconventional Oil & Gas Production
- Water/Energy Public Outreach & Education
- Green Infrastructure for Clean Water
- Water & Power Generation / Power Storage
- Treatment Technology of Energy Byproduct Water for Reuse / Disposal
- Use of Energy Byproduct Water for Water Supply

U.S. DEPARTMENT OF
ENERGY

Attachment #2

Regional Water Assessment: A Sustainability Analysis of the Potential for Using Produced Water in the Montana Portion of the Powder River Basin

Regional Water Assessment:

A Sustainability Analysis of the Potential for Using Produced Water in the Montana Portion of the Powder River Basin

Prepared For:
U.S. Department of Energy
National Energy Technology Laboratory

Prepared By:
Ground Water Protection Council
ALL Consulting, LLC

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ACRONYMS

bbl	barrel
bpd	barrels per day
CBNG	Coal Bed Natural Gas
cfs	cubic feet per second
CWS	Community Water System
DOE	U.S. Department of Energy
EC	Electrical Conductivity
gpm	gallons per minute
L	Liter
MBOGC	Montana Board of Oil and Gas Conservation
mg	milligram
NTNCWS	Non-Transient Non-Community Water Systems
PDSI	Palmer Drought Severity Index
PRB	Powder River Basin
SAR	Sodium adsorption ratio
SDI	Subsurface Drip Irrigation
SWSI	Surface Water Supply Index
Tcf	Trillion cubic feet
TDS	Total Dissolved Solids
TNCWS	Transient Non-Community Water Systems
UIC	Underground Injection Control
USEPA	U.S. Environmental Protection Agency

INTRODUCTION

An abundant supply of clean water is vital for our overall economic prosperity and quality of life. At the same time, the Nation's fossil energy resources are critical to our country's economy and energy security, and the production and use of these fossil fuels are intricately linked to water availability.¹ The lack of available water costs is already causing rationing for cities and limiting the production of fossil fuels on a regional basis. Increasing populations, heightened *per capita* water demands, regional droughts, and concerns over climate change have combined to make water issues even more pressing. Given the confluence of increasing energy demands, tightening water supplies, expanding domestic production, and more water-intense emerging energy resources, the availability of useable water supplies for energy production and human use is a looming national concern. This concern needs to be addressed by carefully planning the way we use our traditional water resources and by identifying new sources of water.²

Many states and cities have developed water use plans. These plans typically use models that predict future water needs and devise strategies to meet those demands through conservation and development of new water projects. While these plans are very useful, they rely on the use of traditional sources of water such as fresh groundwater and surface water in the form of rivers or reservoirs. This reliance on traditional sources of water may unnecessarily limit the options available for meeting future water demands. Oil and gas production in the United States generates over 600 million gallons of produced water each year.³ Most of that water is simply pumped back underground and never captured for human use.

Because much of this produced water is saline or brackish water, it has not been, for the most part, seriously considered as a potential water resource. However, as water demands grow and treatment technologies improve, it makes sense to consider the possibility of using this water on a regional basis to supplement traditional sources. While, as noted above, much of this water is unusable without treatment, some of this produced water, especially produced water associated with Coal Bed Natural Gas (CBNG) production, is relatively high quality water and would require minimal treatment before use. By using this relatively high quality water as a starting point, it is possible to build models and plans that will incorporate this water into regional plans and that will set the stage for broader use of produced water as demands grow, traditional supplies tighten, and technology improves.

This study examined the potential benefits of using CBNG produced water to supplement regional water supplies in the Montana portion of the Powder River Basin (PRB). The study applied the common water planning approaches of examining current supplies and uses and predicting future needs based on population and industry growth projections. In addition to these conventional approaches, this study identified the amount of water that is currently available from CBNG production and developed models for predicting future CBNG production and the water that would be available associated with that production.

¹ Sandia National Laboratory. "Energy Demands on Water Resources, Report to Congress on the Interdependency of Energy and Water." (February 2007).

² Ibid.

³ National Energy Technology Laboratory. Produced Water Management Information System. <http://www.netl.doe.gov/technologies/pwmis/intropw/index.html> (Accessed November, 2009).

This approach provides an assessment of the potential for harnessing an alternative water source from CBNG production in the study area. More importantly, this approach provides a model that can be applied to other regions of the country as water needs grow. As people become aware of this potential resource, new ways of viewing this water may create options that have previously not been considered. For example, as some wells become uneconomic for traditional oil and gas production, it is possible that the remaining production would be enough to pay for pumping and treating the water, thus providing a low-cost source of water. By creating a method for identifying the amount of water that could potentially be captured and used on a regional basis, this model can serve a basis for informed public discussion and to support sound planning and policy decisions by government.

It was not until the 1970s that those engaged in water planning and water resource appropriation fully faced the stark reality that a sustainable supply of surface water and groundwater may not be possible in all regions of the United States. Many water users disregarded the early warnings that water, particularly ground water, is “finite” and in many cases cannot be replenished at its current rate of withdrawal.

In addition, recognition of the interdependency of water and energy has emerged in recent years. The relationship between the availability of clean water and the development and use of energy point to the need for better strategies to assure that both resources will remain available even as demand for them grows substantially in the coming years. The implementation of resource management processes and programs will be critical tools in assuring the continued viability of water and energy resources.

In 2006-07, the U.S. Department of Energy (DOE) sponsored three Energy/Water Nexus Workshops designed to have a comprehensive mix of stakeholders discuss the relationships between energy resources and water availability. The focus of these workshops was on two questions:

- (1) What sustainable water resources are needed currently and in the future to support all of the development of different sources of produced energy?
- (2) What short- and long-term sources of dependable energy are needed to provide a sustainable source of water for all consumptive uses?

For example, ethanol blends will reduce the amount of gasoline needed by a certain percentage, but if the ethanol is corn-based, more water may be used to grow corn and refine the ethanol than is used for fuel derived from petroleum sources. These workshops revealed not only the intensely complex relationship between energy and water in relation to the availability and use of water, but also a feeling among many of the attendees that a sustainable supply of water should continue to be a guaranteed entitlement.

However, water resources are being increasingly threatened by human population growth, which has resulted in increasing demands for more high quality water for domestic use and economic pursuits.⁴ These concerns over the availability of fresh water for future use have been rising throughout the world, including in the U.S. As the concern for future supplies of fresh water grows, the search for alternative sources to supplement traditional water sources appears to be an essential step to sustain our current standard of living in the U.S.

⁴ United Nations Environment Programme, “Water Quality for Ecosystem and Human Health,” Prepared and published by the United Nations Environment Programme Global Environmental Monitoring System (GEMS)/Water Programme (Ontario, Canada: 2006).

REGIONAL WATER ASSESSMENT PROCESS AND OBJECTIVES

As part of the process to find and evaluate supplemental water sources, a water sustainability model was developed to assess multiple components of the water system of the Powder River Basin (PRB) of Montana. The assessment process involved developing a model to compare water demands in the project area from municipal, agricultural and industrial sources with the availability of traditional surface and groundwater sources. The assessment then examined the water demands and availability of water from the production of oil and gas resources in the project area. The primary focus was to evaluate the potential for oil and gas produced water to be used to supplement the traditional sources of water in the project area as a means to support water sustainability.

Water sustainability models evaluate the movement of water through the hydrologic cycle with a focus on the volumes of water in key stages of the cycle. The keys to a sustainability model are to identify the stages that include waters that are accessible for human use and management of the ecological health of these waters while maintaining a reasonable level of control on the permanent withdrawals from these stages. Part of the purpose of a sustainability model is the understanding of how each stage of the water cycle relates to the transfer and storage of water on the level being modeled and the evaluation of inputs or withdrawals at both short- and long-term durations for the project area. For example, human water consumption through domestic and public water supplies is a principal assessment point of a water sustainability model and can be a major consumptive withdrawal of groundwater and surface resources in populated regions. However, for a sustainability model for an area like the PRB where the population is small, human water consumption does not take a primary role in water withdrawal because the region is predominantly rural.

Human consumption is only one facet of a water sustainability model. Other facets include agricultural withdrawals for uses such as including irrigation of crops and water for livestock; industrial withdrawals for uses such as mining, power generation, and oil and gas development; and other withdrawals such as those for wildlife, recreation, and fire suppression. Beyond identifying the potential water withdrawal sectors, sustainability models also are used for assessing current water uses, estimating future water needs, and predicting water availability. Water sustainability models provide municipal and land-use planners the opportunity to take a proactive approach to future water needs. In evaluating future water needs it may also be necessary to identify new sources for future water supplies in order to maintain existing uses or to facilitate the expanding water needs of a growing population. Otherwise, it may be necessary to change existing water plans and uses to meet future needs.

Oil and gas produced water has the potential to become an alternative water source to meet future water needs in select areas such as the PRB. The concept of transitioning oil and gas development and production activities from being a water consumer to using oil and gas produced water as a resource to meet regional water needs is one option for meeting future water sustainability objectives. Produced water from oil and gas operations is estimated at approximately 14 billion barrels (bbl) of water per day in the U.S. Oil and gas produced water varies in quality from relatively fresh water with Total Dissolved Solids (TDS) concentrations below 500 milligrams per Liter (mg/L) to highly saline waters with TDS levels

exceeding 100,000 mg/L.⁵ In certain regions of the U.S., oil and gas produced water is beginning to be used to address water shortages from regional drought conditions.

In the Montana portion of the PRB, oil and gas development, primarily coal bed natural gas (CBNG) development, has created a unique water availability alternative. Coal bed natural gas reserves have been estimated as high as 90 trillion cubic feet (Tcf) in the basin, but in order to produce these reserves water must first be produced from these coal seams, lowering the hydrostatic head present in the coals, which then releases the methane gas. According to the Montana Supplemental Environmental Impact Statement for the PRB, as many 18,275 CBNG wells could be drilled in the Montana portion of the PRB over the next 20 years.⁶ To date, the anticipated level of development has not been achieved. Because of uncertainty in the pace of development, a range of water volumes that may be available is analyzed in this document.

Project Area

The study area is a subset of the Montana portion of the PRB, which is anticipated to have the greatest potential for CBNG development. In developing the boundary, it was decided that following township outlines provides a means to encompass the desired area while providing a distinct boundary. The study area includes portions of three different counties (Big Horn, Powder River, and Rosebud) and consists of a diverse variety of surface ownership, including the Northern Cheyenne Indian Reservation, the Crow Indian Reservation, and the Custer National Forest, as well as private lands (Figure 1). By choosing an area with such varied surface ownership, the project area provides a diverse set of options, which may help to guide implementation of the model to other basins throughout the United States. The study area for this water sustainability model was selected, in part, because of the large volume of data that has been collected on water resources in the area over the last 10 years. Since the inception of CBNG development in Montana, multiple ongoing studies have been conducted on groundwater, water quality, and beneficial use opportunities for produced water. The large volumes of available data make this area ideal starting point for development of a model for water sustainability.

The PRB in its entirety covers approximately 12,000 square miles in southeastern Montana.⁷ The basin is bounded to the west by the Bighorn Uplift, to the southwest and south by the Casper Arch, Laramie Mountains and Hartville Uplift, and to the east by the Black Hills Uplift. There is separation from the Williston Basin to the north by the Miles City Arch and the Cedar Creek Anticline. The basin is comprised of several thousand feet of sediments, including sands, coals and fine-grained sediments. Surface outcrops within the basin consist largely of the Paleocene Fort Union Formation and Wasatch Formation. The stratigraphic column in Figure 2 illustrates the sequence of Upper Cretaceous and Lower Tertiary sediments that are present within the Montana PRB. The study area for this water sustainability model covers approximately 4,304 square miles of the southern portion of the Montana PRB (Figure 1). Although there are a few small communities, the area is predominantly rural with most of the land being used for agricultural or mineral development activities.⁸

⁵ Argonne National Laboratory, "Produced Water Volumes and Management Practices in the United States" (September 2009).

⁶ Bureau of Land Management, "Final Supplement to the Montana Statewide Oil and Gas Environmental Impact Statement and Proposed Amendment of the Powder River and Billings Resource Management Plans" (October 2008).

⁷ Ibid.

⁸ U.S. Geological Survey, "Ecological Assessment of Streams in the Powder River Structural Basin, Wyoming and Montana, 2005-06," *Scientific Investigations Report 2009-5023*, U.S. Department of the Interior (2009).

Figure 1 - Project Location Map: Powder River Basin Water Sustainability Project Area

Figure 2 - Stratigraphic Column of the Tertiary, Mesozoic, and Part of the Paleozoic Sediments in the Montana, Powder River Basin

ERATHEM	SYSTEM, SERIES, AND OTHER DIVISIONS		POWDER RIVER BASIN, MONTANA AND WYOMING	
CENOZOIC	Quaternary		Alluvium	
	Tertiary	Pliocene
		Miocene		
		Oligocene		
		Eocene	Wasatch Formation
		Paleocene	Fort Union Formation	Tongue River Member
				Lebo Shale Member
				Tullock Member
MESOZOIC	Cretaceous	Upper	Hell Creek Formation	
			Fox Hills Sandstone	
			Lewis Shale	Pierre Shale
			Judith River	
			Cody Shale	Niobrara Formation
			Frontier Formation	Carlile Shale
				Greenhorn Formation
				Belle Fourche Shale
			Mowry Shale	
		Lower	Muddy Sandstone	Newcastle Sandstone
			Thermopolis Shale	Skull Creek Shale
			Inyan Kara Group	Fall River Formation
				Lakota Formation
	Jurassic		Morrison Formation	
			Sundance Formation	Upper Part
				Lower Part
			Gypsum Spring Formation
		Jurassic (?) or Triassic (?)
		Triassic
PALEOZOIC	Permian	Goose Egg Formation	Upper part	Spearfish Formation (Upper part)
			Lower Part	(Lower part)
		Tensleep Sandstone		Minnekahta Limestone
	Pennsylvanian	Amsden Formation		Opeche Formation
	Mississippian			Minnelusa Formation
		Madison Limestone	Madison Group	

The column includes formations that map up CBNG reservoirs and sources of water in the basin.

WATER AVAILABILITY

Precipitation is principal form of recharge for the groundwater aquifers in the region, but is quite variable and seasonal. The PRB contains groundwater in unconfined surface aquifers as well as confined bedrock aquifers. Water quality within these aquifers varies widely from water with less than 300 mg/L TDS to waters with more than 30,000 mg/L TDS.⁹ While both rainfall and snowfall occur in the study area, most of the precipitation falls as rain during the spring and summer months (Figure 3). The seasonality of precipitation affects surface water, as flow in the streams and rivers in the study area vary throughout the year. The seasonality of the precipitation as it is reflected in the flows of the rivers also affects the manner in which irrigation water has historically been withdrawn from these streams. Many of the surface waters have small impoundments constructed on their tributaries and diversion dams on their larger stems to feed water to irrigation fields when flows in the rivers are high.

Figure 3 - Mean Monthly Total Precipitation for Colstrip, MT, 1927-2009

Source: National Climate Data Center

Groundwater Resources

Groundwater resources in the PRB are diverse, a result of the pronounced geologic structures, semi-arid climate, and sculptured terrain. Water resources are often tied to local sedimentary basins, which contain significant portions of the groundwater in the study area. This groundwater often occurs in isolated zones where sandstones or silt beds are present but may also be found in areas where there is localized fractured bedrock. Coal seams in the area have also been developed for groundwater resources. Groundwater in the PRB is principally recharged by the infiltration of runoff from

⁹ R.N. Bergantino, "Hardin Groundwater Sheet MA-2B," Montana Bureau of Mines and Geology (1980).

precipitation at the outcrop, except for the alluvial formations bordering the surface waters, which are recharged in the losing portions of the streams.

Regional aquifers located within the study area include:

Quaternary Alluvium – shallow sub-surface to 90 feet

Wasatch Formation – approximately 100 feet

Tongue River Coal Seams – 50 feet to 400 feet

Lebo/Tulloch Coal Seams – 100 feet to 400 feet

Hell Creek/Fox Hills – 100 feet to 500 feet

Judith River – 2,500 feet

Eagle – 2,700 to 5,700 feet

Dakota/Lakota – 5,600 to 8,600 feet.¹⁰

Groundwater supplies water for several sectors within the study area. Stock water is the primary use of groundwater in the study area with more than 2,200 stock water wells active in the project area. Due to the rural nature of the project area, most households are supplied by private water wells; thus, domestic water supply wells represent the second largest number of groundwater wells in the project area. Agriculture is the principal industry for the study area and represents the largest number of water wells with stock water and irrigation wells accounting for more than 53 percent of the total groundwater wells in the study area. Water supply wells for domestic and public supply account for 20 percent of the total number of wells. Monitoring wells associated with coal mining and development activities, research wells, and test wells account for an additional 17 percent of the total groundwater wells. Of the remaining 10 percent of the groundwater wells in the area, 6.3 percent are either unused or of unknown use, and 0.5 percent are used for industrial and commercial supply wells. Geotechnical wells comprise another 1.7 percent and other groundwater wells account for 1.2 percent. Table 1 identifies the total number of groundwater wells for each use within the project area.

Uses	Well Count
STOCKWATER	2,243
DOMESTIC	858
MONITORING	429
RESEARCH	284
UNKNOWN	170
UNUSED	107
IRRIGATION	87
GEOTECH	75
OTHER	52
PUBLIC WATER SUPPLY	36
TEST WELL	27
INDUSTRIAL	16
COMMERCIAL	5
WILDLIFE	2
FIRE PROTECTION	1

¹⁰ ALL Consulting, "Water Resources Technical Report," prepared for the Montana Statewide Oil and Gas Environmental Impact Statement and Amendment of the Powder River and Billings Resource Management Plans (2001).

Surface Waters

Two major surface water drainage basins are located within the study area: the Tongue River and the Powder River. The Tongue River furnishes water for over 16,000 irrigated acres in the study area. The Powder River and its tributaries furnish water for over 27,153 irrigated acres in the study area. The two largest tributaries to the Powder River – the Little Powder River and Mizpah Creek – furnish irrigation water for 1,124 acres and 5,412 acres, respectively.

Tongue River

The Tongue River is a principal tributary of the Yellowstone River, with its headwaters in the Bighorn Mountains of northern Wyoming, and its confluence with the Yellowstone River near Miles City, Montana.¹¹ The Tongue River's headwaters originate in north-central Wyoming and flow generally to the northeast into southeastern Montana through the study area. The highly variable flow of the Tongue River can be seen in the average annual discharge plot for the state line gauging station (Figure 4). The Tongue River State Line station had an average annual discharge of approximately 436 cubic feet per second (cfs), a maximum annual discharge of 862 cfs and a minimum annual discharge of 138 cfs from

Figure 4 - Average Annual Discharge for the Tongue River at the State Line Station

Source: USGS National Watershed Information Center

¹¹ HydroSolutions, Inc., "2007 Tongue River Hydrology Report," prepared for the Montana Board of Oil & Gas Conservation (May 2007). http://bogc.dnrc.mt.gov/PDF/TRIPpdfFiles/MBOGC01_TongueR_HydroRpt_053107.pdf (accessed June 22, 2009).

1961 through 2008. Surface water runoff from the eastern part of the Crow Indian Reservation eventually accumulates in the Tongue River.¹² The Tongue River Dam and Reservoir are situated approximately 10 miles from the Wyoming-Montana state line.

Tongue River Reservoir

The total capacity of the Tongue River Reservoir is 79,071 acre-feet at normal full pool¹³ and covers 3,700 surface acres.¹⁴ The reservoir capacity was increased in 1999 as part of a dam rehabilitation project over its prior storage capacity of 68,040 acre-feet. The average reservoir accumulation for 1968-2008 was 45,169 acre-feet. Currently the reservoir's holdings are approaching 60,000 acre-feet. The reservoir provides reserved water rights for a number of the project area's rights holders, including a portion of the Northern Cheyenne Indian Reservation's reserved water right.¹⁵ The delivery period for waters from the reservoir run from May 1 to September 30,¹⁶ but water users typically do not call for water until July, except in cases of water shortages and droughts. Figure 5 depicts the outfall of the Tongue River Dam showing the discharge gates and the area just south of the dam. Current water use under contract includes 39,300 acre-feet for irrigation and 20,000 acre-feet reserved for use by the Northern Cheyenne Tribe.¹⁷ Additional water is contracted for the fish hatchery near Miles City and the St. Labre Mission in Ashland. The remaining volume of water contained in the reservoir is minimal.

Figure 5 - Tongue River area just below the Tongue River Dam

Source: Montana Fish, Wildlife and Parks

¹² Crow Indian Tribe, "Hydrology Resources Report" (April 15, 2002).

¹³ The Montana Drought Advisory Committee, "The Governor's Report: The Potential for Drought in Montana 2009." http://www.dnrc.mt.gov/wrd/water_mgmt/planning_reports/pdfs/gov_drt_rpt_2009.pdf (accessed June 23, 2009).

¹⁴ Montana Department of Natural Resources and Conservation Water Resources Division, "Water Storage in Montana," report submitted to 61st Legislature (January 2009). http://www.dnrc.mt.gov/wrd/water_mgmt/planning_reports/pdfs/govs_rpt_waterstorage_09/govrpt_waterstorage2009.pdf (accessed June 23, 2009).

¹⁵ Ibid.

¹⁶ Yellowstone River Compact Commission, "Technical Committee Discussions Notes," (April 25, 2005). <http://yrcc.usgs.gov/.../Tech%20Comm%204%2005%20Final%20minutes.doc> (accessed August 14, 2009).

¹⁷ HydroSolutions, Inc., "2007 Tongue River Hydrology Report."

Figure 6 - Average Annual Discharge for the Powder River at Moorehead, Montana, Station

Source: USGS National Watershed Information Center

Powder River

The Powder River is a warm prairie river that originates in the eastern slopes of the Big Horn Mountain Range in Wyoming and flows 220 miles north until it converges with the Yellowstone River near Terry, Montana. One tributary of the Powder River, the Little Powder River, feeds into the main river in the study area, while a second tributary, Mizpah Creek, originates in the project area. Surface water flows in the Powder River and its tributaries depend on early spring runoff and summer showers which flow through these rivers and creeks and supply much of the irrigation water used from these rivers.¹⁸ The Little Powder River merges with the Powder River near Broadus, Montana, within the project area. The Powder River at Moorehead station had an average annual discharge of approximately 439 cfs, a maximum annual discharge of 1,091 cfs, and a minimum annual discharge of 110 cfs from 1930 through 2008 (Figure 6). The monthly flow regime for the Powder River can fluctuate even more significantly with mean monthly discharges ranging from 5,553 cfs during spring runoff to less than one cfs in warm summer months. Figure 7 is a photograph taken during the spring runoff period showing the flow of the Powder River overrunning the banks.

¹⁸ Montana State Engineer's Office, "Water Resources Survey Powder River County, Montana Part I: History of Land and Water Use on Irrigated Areas" (June 1961).

Figure 7 - Powder River during the Spring Snowmelt

Source: Montana Fish, Wildlife and Parks

Yellowstone River Compact of 1950

The development and use of water from the Tongue River, Powder River, and the Little Powder River are all subject to the terms of the Yellowstone River Compact of 1950.¹⁹ Conflict has surrounded the use of waters in these rivers as the resource is shared by parties in both Wyoming and Montana. Issues related to the rights and needs for the waters of these rivers have led to numerous court hearings and lawsuits.

The Yellowstone River Compact, signed in 1950, dictates how water is distributed between the states from these two watersheds.²⁰ After existing water rights have been met, the remaining unappropriated water and unused diverted water that has been returned to the flow of the Tongue, Powder, and Little Powder Rivers are allocated to Wyoming and Montana on the following basis:

- (1) Tongue River: 60 percent goes to Wyoming, 40 percent goes to Montana
- (2) Powder and Little Powder Rivers: 42 percent goes to Wyoming, 58 percent goes to Montana.

New diversions from any of the rivers in the compact's jurisdiction require unanimous approval from all three signatory states: Montana, Wyoming, and North Dakota.²¹

Drought

Drought conditions can have a significant impact on the general economy, but in the PRB, which is predominantly made up of agricultural land, drought can be catastrophic. While the impacts of drought are evident to varying degrees on all lands, the effects are primarily seen on non-irrigated croplands first.²² As drought conditions persist, the effects of a lack of rainfall eventually spread to irrigated agriculture land and rangeland. Crop yields can be significantly decreased and, as drought conditions

¹⁹ United States Geological Survey, "Yellowstone River Compact Commission" (1950). <http://yrcc.usgs.gov/YRCC%20-%20Compact%20and%20Commission%20Information.htm> (accessed September 23, 2009)..

²⁰ Ibid.

²¹ Ibid.

²² Resource Management Services, Inc., Land & Water Consulting, Inc., and Big Sky Hazard Management, "State of Montana Multi-Hazard Mitigation Plan and Statewide Hazard Assessment," prepared for the State of Montana, Department of Military Affairs Disaster and Emergency Services (October 2004).

persist, insect infestation can further reduce usable forage for rangeland and negatively impact crop quality and quantity.

Water plays an integral role in maintaining the health of the economy in the PRB and at no time is it more evident than in times of drought. Montana is known for extreme weather patterns and conditions that can compound drought scenarios. Extreme high temperatures, low humidity, wind, rainfall, and snowfall all affect the health of the area.

In 1985, all 56 counties in Montana received disaster declarations for drought for an estimated economic loss of \$3 billion.²³ Cattle herds were reduced by 33 percent and the year brought the smallest wheat crop in 45 years. In 2000, \$4.2 billion in damages were experienced as a result of drought.

Table 2- Surface Water Supply Index Definitions	
Extremely Dry	-4.0 to -3.0
Moderate Dry	-2.9 to -2.0
Slightly Dry	-1.9 to -1.0
Near Average	-0.9 to 0.9
Slightly Wet	1.0 to 1.9
Moderately Wet	2.0 to 2.9
Extremely Wet	3.0 to 4.0

As drought patterns fluctuate across the state, it is essential to monitor and analyze data to predict future droughts while analyzing the effectiveness of drought mitigation plans. Drought monitoring can be used to assess and at least identify conditions indicative of a potential drought. Two methods commonly used to assess drought potential are the Surface Water Supply Index (SWSI), which assesses streamflow in individual basins, and the Palmer Drought Severity Index (PDSI), which assesses precipitation deficits by analyzing soil moisture data. These indices are the foundation to identifying potential drought conditions and the triggering mechanisms for the drought response plan in Montana.²⁴

The SWSI is useful for forecasting water availability for irrigated agriculture, fisheries, and other uses of runoff water.²⁵ The index is a culmination of snowpack, mountain and valley precipitation, soil moisture, and reservoir storage. The index is partially calculated using statistics generated from historic data, which also allows the index to be used to forecast future water supplies. Table 2 shows the range of Surface Water Supply Indices and the relation of the values to the relative moisture conditions. By reviewing past trends in SWSI and evaluating how water excesses and shortages were handled in the past, it may be possible to ease the transition between availability fluctuations in the future. Figure 8 presents an example of the SWSI values for the Powder River showing the annual SWSI values including the multiple instances of fluctuations throughout the last 20 years from extremely dry periods with water shortages to moderately wet periods with water availability.

²³ Ibid.

²⁴ Montana Drought Advisory Committee, "The Montana Drought Plan" (1985, revised 1988 and 1995). <http://www.nris.state.mt.us/drought/committee/DroughtP07.pdf> (accessed August 18, 2009).

²⁵ Ibid.

Figure 8 - SWSI Trend Plots for the Project Area, March 1992 to August 2009

A second method of analyzing historical drought conditions is the PDSI. The Palmer index is a standardized index for the local climate. As such, it can be applied to any region of the country to show relative drought or rainfall conditions. The PDSI is a long-term assessment index that looks to measure the duration and intensity of a long-term drought.²⁶ Table 3 shows the range of Palmer Drought Severity Indices and the relation of the values to the relative moisture conditions. As part of the PDSI process and in effort to categorize

historical trends, scientists analyzed 835 tree ring chronologies throughout North America to create drought reconstructions over the last 1,992 years.²⁷ Point-by-Point Regression, or the sequential, automated fitting of single-point principal components regression models to a grid of climate variables was the method used to generate the PDSI trend in Figure 9. As expected, similar trends are represented by SWSI and PDSI values for the time period shown in the figure, with the PDSI plot showing a more relaxed trend without the fluctuations seen in the SWSI trend.

Table 3 - Palmer Drought Severity Index Definitions

Extreme Drought	-4.0 or less
Severe Drought	-3.0 to -3.99
Moderate Drought	-2.0 to -2.99
Mild Drought	-1.0 to -1.99
Incipient Dry Spell	-0.5 to -0.99
Near Normal	0.49 to -0.49
Incipient Wet Spell	0.5 to 0.99
Slightly Wet	1.0 to 1.99
Moderately Wet	2.0 to 2.99
Very Wet	3.0 to 3.99

²⁶ National Climate Data Center, "Climate of 2009- August U.S. Palmer Drought Indices" (last updated 10 September 2009).

²⁷ E.R. Cook and P.J. Krusic, "The North American Drought Atlas," Lamont-Doherty Earth Observatory and the National Science Foundation. <http://iridl.ldeo.columbia.edu/SOURCES/.LDEO/.TRL/.NADA2004/.pdsi-atlas.html> (accessed August 19, 2009).

Figure 9 - SWSI and PDSI Trend Plots for the Tongue River, January 2003 to July 2009

The State of Montana included a Drought Response Plan in the Natural Hazards Mitigation Plan that was issued statewide in November 2001. The plan utilized a combination of SWSI and PDSI thresholds (triggers) for classifying droughts throughout the state. A PDSI value of -3.0 or less concurrent with a SWDI value of -2.5 or less represents a “Drought Alert.” A PDSI value less than or equal to -4.0 or a SWSI less than or equal to -3.5 indicates a “Severe Drought.” Both of these values indicate trigger conditions that allow impacted citizens to pursue federal assistance programs.

Drought conditions cause depletions in surface water reserves, but droughts also impact groundwater levels as surface waters and groundwater in the PRB are connected. The deep coal seams in Wyoming thin as they extend into Montana and eventually outcrop at the surface where water recharges the coal seam through precipitation around the edges of the basin.²⁸ Groundwater flows along the alluvial channels of the rivers mimic the flow of surface water with groundwater flowing northward from Wyoming to Montana where it discharges to rivers and springs or evaporates as it slowly seeps out of the coal seams.²⁹ Drought conditions have impacted the project area since 2000 with drought-related groundwater level declines having been observed across Montana.³⁰

Every area within the study area can be considered vulnerable to drought. The ability to have adequate stores of water and to implement conservation measures during drought periods is essential to

²⁸ United States Geological Survey, “Yellowstone River Compact Commission Fifty-sixth Annual Report” (2008). <http://yrcc.usgs.gov/support.docs/YRCCAnnualReport2007.pdf> (accessed September 22, 2009)..

²⁹ Montana Bureau of Mines and Geology, “Critical Resource Assessment, Alluvial Aquifers of Northern Big Horn County: Biennial Report of Activities and Programs, 2004-2006,” p. 63.

³⁰ Ibid.

minimize the negative effects associated with water shortages brought on by drought conditions. Supplementing traditional water storage needs with alternatives such as oil and gas produced water can decrease the gap associated with droughts.

CURRENT WATER USES

Industrial

Industrial water users within the PRB include coal mining, coal bed natural gas development, construction withdrawals, lumber mills and the road construction. The largest withdrawals are coal bed natural gas development and coal mining at the Spring Creek and Decker coal mines located within the Big Horn County portion of the project area.

Coal Bed Natural Gas

Coal bed natural gas development is the most water-intensive industrial use in the study area. However, it can also be considered a significant source of water availability if put to beneficial use. St. Mary Land and Exploration Company holds a permit allowing for the diversion of produced water at 20 gallons per minute (gpm), up to 22.55 acre-feet per annum, from one of two producing CBNG wells in the project area.³¹ Produced water is diverted from a water collection and delivery pipeline system and stored in a stock tank and transferred for use by water trucks. The appropriation includes 2.55 acre-feet per year for livestock and incidental wildlife watering on the Porter Ranch and 20 acre-feet for other industrial purposes such as dust abatement, construction operations and soil compaction. Fidelity Exploration and Production Company has applied for a water marketing permit which would allow for up to 3,863 acre-feet of CBNG-produced water to be marketed to potential users in Big Horn County, Montana, for beneficial use.³² The permit was initially issued in 2007 but subsequent litigation posed by the Northern Plains Resource Council and Tongue River Water Users' Association has resulted in a court ordered reversal, remanding the case to the Montana Department of Natural Resources for further proceedings.

Coal Mines

Most of the water consumed by active coal mines is for dust suppression on the mine and haul roads. Other water uses include aquifer restoration, sanitation and domestic purposes.³³ Discussions with mining operators indicated that large mines typically utilize anywhere from 70 to 2,900 gpm, depending on the mine size and the season.³⁴ Water availability for use at the Spring Creek and Decker Coal Mines (see Figure 1) is currently being supplemented by CBNG-produced water. The Spring Creek Mine receives between 200 gpm and 800 gpm of CBNG-produced water from the CX Ranch.

Two separate provisional permits to appropriate water are on record for the aforementioned mining operations with the Montana Department of Natural Resources and Conservation. The permits allow for a combined maximum of 300 gpm up to 481 acre-feet per annum to be produced from five total

³¹ Montana Department of Natural Resources and Conservation, Provisional Permit 42B-30026121.

³² Montana First Judicial District Court Lewis and Clark County, "Memorandum and Order on Petition for Judicial Review Cause No. CDV-2007-425."

³³ National Academy of Sciences, "Rehabilitation Potential of Western Coal Lands" (1974).
<http://www.fordfound.org/archives/item/0301> (accessed October 30, 2009).

³⁴ ALL Consulting, "Feasibility Study of Expanded Coal Bed Natural Gas Produced Water Management Alternatives in the Wyoming Portion of the Powder River Basin" (January 2006).

wells into one of two 400,000-gallon capacity bladder type reservoirs (storage tanks).³⁵ Water from the reservoirs is used for multiple industrial purposes, including mining operations, dust suppression and drinking water at the location. A third groundwater development appropriates 35 gpm, up to 44.8 acre-feet maximum, for industrial purposes (primarily dust control).³⁶ Each of the mines has several additional water right permits for various uses, including domestic and stock water.

Other industrial water uses in the study area include a Rosebud County withdrawal of 30 gpm up to a maximum volume of 8.47 acre-feet from May through November for construction purposes.³⁷

Northern Cheyenne Pine Company has a provisional permit to appropriate 500 gpm up to a maximum volume of 331.43 acre feet per annum to prevent lumber from blueing and to prevent potential fire hazard conditions during warmer months when natural precipitation is not sufficient.³⁸ The Northern Cheyenne Pine Company well is pumped into a 15,000-gallon storage tank with two permanent distribution lines that supply hydrants throughout the 60 acre mill property. The water is also used for dust and fine sawdust suppression during dry and windy conditions. Empire Sand and Gravel Company holds four groundwater certificates appropriating 35 gpm each up to 40 acre-feet total per year for highway construction operations in Powder River County.³⁹ Powder River County Road Department also has a provision permit for 3,000 gpm up to a maximum volume of 25 acre feet per year.⁴⁰ Of all the industrial water users listed in this section, only Powder River County depends on surface water for its water supply (Table 4).

Water Right Number	County	Purpose	Source Type	Means of Diversion	Max Rate (GPM)	Max Volume (acre-ft)	Source
42B 20510 00	Big Horn	INDUSTRIAL	GROUNDWATER	WELL	120	193	GROUNDWATER
42B 30026121	Big Horn	INDUSTRIAL		PIPELINE	20	22.55	CBNG-PRODUCED WATER
42B 31324 00	Big Horn	INDUSTRIAL	GROUNDWATER	WELL	180	288	GROUNDWATER
42B 68353 00	Big Horn	INDUSTRIAL	GROUNDWATER	WELL	35	44.8	GROUNDWATER
42C 104964 00	Powder River	INDUSTRIAL	GROUNDWATER	WELL	35	10	GROUNDWATER
42C 104979 00	Powder River	INDUSTRIAL	GROUNDWATER	WELL	35	10	GROUNDWATER
42C 104980 00	Powder River	INDUSTRIAL	GROUNDWATER	WELL	35	10	GROUNDWATER
42C 104981 00	Powder River	INDUSTRIAL	GROUNDWATER	WELL	35	10	GROUNDWATER
42J 30000561	Powder River	INDUSTRIAL	SURFACE	PUMP	3,000	25	POWDER RIVER
42A 115202 00	Rosebud	INDUSTRIAL	GROUNDWATER	WELL	30	8.47	GROUNDWATER
42A 115203 00	Rosebud	INDUSTRIAL	GROUNDWATER	WELL	30	8.47	GROUNDWATER
42C 71409 00	Rosebud	INDUSTRIAL	GROUNDWATER	WELL	500	331.43	GROUNDWATER

In many areas with oil and gas development throughout the country, oil and gas producers are not only major groundwater producers, but also users of large volumes of water for secondary oil recovery operations such as water flooding. Water that is produced from one operation is often injected into a commercial oil producing formation to aid in the displacement and ultimate recovery of additional hydrocarbons. Although this is not a current practice within the PRB study area, it could be instrumental in other areas where this type of model may be implemented.

³⁵ Montana Department of Natural Resources and Conservation, Provisional Permit 42B-31324 and Provisional Permit 42B-20510.

³⁶ Montana Department of Natural Resources and Conservation, Ground Water Certificate 42B-6835300.

³⁷ Montana Department of Natural Resources and Conservation, Ground Water Certificate 42A-115203.

³⁸ Montana Department of Natural Resources and Conservation, Provisional Permit 42C-71409.

³⁹ Montana Department of Natural Resources and Conservation, Ground Water Certificate 42C-104964, 42C-104979, 42C-104980, and 42C-104981.

⁴⁰ Montana Department of Natural Resources and Conservation, Provisional Permit 42J 30000561.

The maximum industrial water allocation for the project area is 4,025 gpm (1,025 gpm from groundwater and 3,000 gpm from surface water sources) up to 943.25 acre-feet per year based on industrial water rights search. However, not all of the appropriated water is likely to be utilized during any given year and is not fully indicative of actual water consumption patterns.

Commercial water usage, like industrial usage, occurs throughout the study area. However, upon review of the water rights permits identified in Table 4 and Table 5, it became evident that there is overlap between what is identified as “industrial” and what is termed “commercial.” The coal mines in the area have permits for both industrial and commercial water rights for similar applications such as dust suppression. However, in addition to coal mine operations, smaller entities such as a honey processing facility and a cemetery also have commercial permits. In total, 46 permits for commercial water appropriations exist in the study area. Like the industrial permits in the county, only one exists that diverts water for commercial use from surface waters. The maximum appropriated water for commercial use is approximately 4,702 gpm, up to 1,260 acre-feet per year. Table 5 below identifies the commercial water permits in the project area.

Table 5 - Commercial Water Rights within the Project Boundary

Water Right Number	County	Purpose	Source Type	Means of Diversion	Max Rate (GPM)	Max Volume (acre-ft)	Source
42A 30042299	Big Horn	COMMERCIAL	GROUNDWATER	WELL			GROUNDWATER
42B 12657 00	Big Horn	COMMERCIAL	GROUNDWATER	WELL	80.79	128.3	GROUNDWATER
42B 12658 00	Big Horn	COMMERCIAL	GROUNDWATER	WELL	80.79	128.3	GROUNDWATER
42B 20059 00	Big Horn	COMMERCIAL	SURFACE	PUMP	3590	750	TONGUE RIVER
42B 58019 00	Big Horn	COMMERCIAL	GROUNDWATER	WELL	25	3	GROUNDWATER
42B 7097 00	Big Horn	COMMERCIAL	GROUNDWATER	WELL	50		GROUNDWATER
43O 184973 00	Big Horn	COMMERCIAL	GROUNDWATER	WELL	30	20	GROUNDWATER
43O 185194 00	Big Horn	COMMERCIAL	GROUNDWATER	WELL	30	0.08	GROUNDWATER
43O 185724 00	Big Horn	COMMERCIAL	GROUNDWATER	WELL	10		GROUNDWATER
43O 30028503	Big Horn	COMMERCIAL	GROUNDWATER	WELL			GROUNDWATER
43O 4227 00	Big Horn	COMMERCIAL	GROUNDWATER	WELL	10		GROUNDWATER
42C 38178 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	10	0.3	GROUNDWATER
42C 52512 00	Powder River	COMMERCIAL	GROUNDWATER	DEVELOPED SPRING	8	2	GROUNDWATER
42I 4880 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	5	4.5	GROUNDWATER
42I 5587 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	25	40	GROUNDWATER
42I 7253 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	10	4.5	GROUNDWATER
42J 10350 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	20		GROUNDWATER
42J 104953 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	35	6.12	GROUNDWATER
42J 1125 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	25	2.4	GROUNDWATER
42J 116110 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	10	3.99	GROUNDWATER
42J 15628 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	80	2	GROUNDWATER
42J 15628 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	80	2	GROUNDWATER
42J 177 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	60	6.5	GROUNDWATER
42J 17776 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	20	3.5	GROUNDWATER
42J 17815 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	17	39	GROUNDWATER
42J 1927 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	10	5.5	GROUNDWATER
42J 2004 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	10	10	GROUNDWATER
42J 227 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	10	7.5	GROUNDWATER
42J 231 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	11	1.5	GROUNDWATER
42J 3320 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	10	3	GROUNDWATER
42J 337 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	8	4	GROUNDWATER
42J 42959 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	15	1.7	GROUNDWATER
42J 4393 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	30	0.4	GROUNDWATER
42J 46925 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	10	1.5	GROUNDWATER
42J 548 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	15	9	GROUNDWATER
42J 5967 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	30	8.4	GROUNDWATER
42J 5968 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	35	26.5	GROUNDWATER
42J 6663 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	10	5.5	GROUNDWATER
42J 7243 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	10	6	GROUNDWATER
42J 80614 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	8	0.38	GROUNDWATER
42J 9387 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	5	3	GROUNDWATER
42J 9531 00	Powder River	COMMERCIAL	GROUNDWATER	WELL	10	3	GROUNDWATER
42C 10599 00	Rosebud	COMMERCIAL	GROUNDWATER	WELL	50	3	GROUNDWATER
42C 174619 00	Rosebud	COMMERCIAL	GROUNDWATER	WELL	10	1.5	GROUNDWATER
42C 32644 00	Rosebud	COMMERCIAL	GROUNDWATER	WELL	10	12	GROUNDWATER
42C 9832 00	Rosebud	COMMERCIAL	GROUNDWATER	WELL	84		GROUNDWATER

Public Water Use

The U.S. Environmental Protection Agency (USEPA) classifies Public Water Supplies by the number of people that they serve, the frequency of reoccurring customers, and the water source. A Community Water System (CWS) is one which supplies water to the same group of people year round, such as in homes or businesses. In the project area, three Community Water Systems exist:

- (1) Ashland Water and Sewer District in Rosebud County serves approximately 400 people (Groundwater).
- (2) St. Labre Indian School in Rosebud County serves approximately 650 people through groundwater sources (Groundwater).
- (3) The town of Broadus in Powder River County serves approximately 450 people (Groundwater).

The second USEPA classification for public water systems is Non-Transient Non-Community Water System (NTNCWS), which regularly supplies water to at least 25 of the same people at least six months per year, but not year round as in the CWS system discussed previously.⁴¹ Some examples include schools, factories, office buildings, and hospitals that have their own water systems. In the study area, USEPA has identified four water systems that meet the criteria for NTNCWS:

- (1) East Decker Coal Mine (Groundwater)
- (2) Spring Creek Coal Domestic (Groundwater)
- (3) Spring Creek Mine (Purchased Surface Water)
- (4) West Decker Coal Mine (Groundwater).

Transient Non-Community Water Systems (TNCWS) include water systems that do not consistently serve the same people such as campgrounds, rest areas, and gas stations. In the study area, these are

- (1) Kirby Saloon in Big Horn County (Groundwater)
- (2) Tongue River Pee Wee Point (Groundwater)
- (3) Tongue River Campers Point (Groundwater).

Groundwater provides for almost all of the public water supply in the project area.

Agriculture

Agriculture in the PRB study area is the most prominent industry, representing over 99 percent of the total surface water diversions and 61 percent of groundwater withdrawals in the entire Yellowstone River Basin.⁴² A variety of crops are developed in the PRB. Table 6 presents a summary of the crop distribution by county for seven crops. Forage represents the largest crop grown in the study area, with wheat being the second largest. After forage and wheat, the next largest crop is barley, which is grown on approximately one-tenth the land that is used for forage (Table 6).

⁴¹ Environmental Protection Agency, "Public Drinking Water Systems: Facts and Figures." <http://www.epa.gov/ogwdw000/pws/factoids.html> (accessed October 19, 2009).

⁴² HydroSolutions, Inc., "2007 Tongue River Hydrology Report" (May 2007). http://www.tongueriverampp.com/news/MBOGC01_TongueR_HydroRpt_061507-final%20jr.pdf (accessed July 31, 2009).

Table 6 - Crop Distribution for Powder River Basin in Acres

Counties	Wheat for Grain	Forage	Barley for Grain	Sugar beets	Corn for Silage	Field & Grass Seed Crops	Oats
Big Horn	102,081	83,429	18,048	9,744	1,935	0	0
Powder River	12,828	91,666	1,759	0	0	2,187	408
Rosebud	40,788	50,763	1,999	1,494	5,253	0	0
TOTAL	155,697	225,858	21,806	11,238	7,188	2,187	408

In the three counties that encompass the study area, a total of 7,233,172 acres (or 85 percent of the total county area) is classified as farmland. While this area includes portions of these counties outside of the study area, the numbers are an indication of the important role agriculture plays in the economics of the PRB. Of the farmland present, most is forage pasture, land used for all hay and haylage, grass silage, and greenchop.

Irrigated crop acreage is a small percentage of total acreage classified as cropland in the PRB (Figure 10).

Figure 10 - Irrigated Acreage in the Powder River Study Area

Source: ALL Consulting

Within the study boundary, 54,724 acres are irrigated farmland. Total water consumption for irrigated farmland is represented by the crop water need, or the amount of water needed by various crops to grow optimally.⁴³ Crop water need is a factor of the crop type, climate (sunshine, temperature, wind speed, and humidity), and the growth stage of the crop.

Typically, crops require more water during warmer weather than during the cooler months. In addition, crops with longer growing time consume more water than short growing season crops. Table 7 presents a comparison of the growing seasons for some of the common crops in the PRB. As shown, beans have the shortest growing periods while the grain crops alfalfa and small grains have longer growing seasons therefore requiring more water.

Table 7 - Growing Period for Crops	
Crop	Total growing period (days)
Alfalfa	100-365
Barley/Oats/Wheat	120-150
Bean green	75-90
Bean dry	95-110
Grain/small	150-165
Lentil	150-170
Soybean	135-150
Sugarbeet	160-230

Alfalfa, a crop that is prevalent throughout the state, is a high water use crop due to its lengthy growing season, deep root system, and dense vegetation mass.⁴⁴ While governed by the 4 criteria identified previously for crop water needs, commonly cited water requirements for alfalfa range between 18 and 36 inches per year. By contrast, both winter and spring wheat, the most widely planted crops in the study area, are grown during cooler temperatures, decreasing the amount of water necessary for a successful harvest. Typical seasonal water requirements range from 18 to 21 inches per year, significantly less than is needed for alfalfa. In eastern Montana, optimal crop yields and efficient, scheduled irrigation for a 1,000 acre alfalfa plot requires 2,000 acre-feet per year, or 1.8 million gallons per day.⁴⁵

FUTURE WATER NEEDS

Population Projections

The PRB is predominantly rural country. Future population projections for Rosebud, Big Horn, and Powder River County, Montana, are shown in Figure 11.⁴⁶ The projections are for the entire counties, not just the portions identified as part of the study area.

Future population increases do not necessarily directly correlate to proportionate water demand increases. Migration can also significantly alter population projections for many regions, but do not significantly account for population fluctuations in this study area. Population can also be heavily impacted by the economy and potential economic opportunities as well as unforeseen events such as weather.

⁴³ Food and Agriculture Organization of the United Nations, "Irrigation Water Management: Irrigation Water Needs." <http://www.fao.org/docrep/S2022E/s2022e07.htm> (accessed November 12, 2009).

⁴⁴ James W. Bauder, "Irrigating Alfalfa: Some Guidelines." <http://waterquality.montana.edu/docs/irrigation/alfguidelines.shtml> (accessed October 20, 2009).

⁴⁵ Paul Cartwright, Memo regarding Coal conversion and water use (June 5, 2007).

⁴⁶ NPA Data Services, Inc., "Montana Population Projections" (November 2008). http://ceic.mt.gov/Demog/project/proj_mt_pop_total_08.pdf (accessed October 22, 2009).

Figure 11 - Population Projections for the Three Counties in Study Area

Source: NPA Data Services, Inc.

For Rosebud County, the towns of Forsyth and Colstrip are both included in the projections, but neither is within the study boundary. While the projections are not necessarily indicative of population growth in numbers within the project area, the trend can be applied. The cumulative population growth for the entire three-county area is estimated at approximately 9 percent.⁴⁷ With the relatively small anticipated population increases in this area, population change is not predicted to play a significant role in this particular model application and will not be analyzed in detail.

Agricultural

Predicting future water demands for irrigation purposes is not as straightforward as it is for municipal or industrial water demands. Irrigations demands are differentiated from municipal and industrial needs by the fact that irrigation demands are measured in relationship to price of water⁴⁸. Municipal water uses are typically not dependent on price and reasonable price fluctuations do not influence the volume of water needed to service the population. Industrial water demands are typically a small percentage of costs associated with an operation, so price fluctuations for water are generally viewed as normal components of operations.

Irrigation activities are sensitive to water price fluctuations, and there is a very strong inverse relationship between the price of water and demand. However, one element tends to hold true within

⁴⁷ Ibid.

⁴⁸ "Wyoming Powder/Tongue River Basin Plan: Irrigation Water Needs and Demand Projections," Technical Memorandum (February 2002).

the study area: most irrigators could benefit from additional irrigation water, particularly in years when drought reduces the volume available. As discussed earlier, drought has plagued the PRB area to varying degrees for the last decade. Water shortages have been recurring in the Tongue River Basin for the past several years. In 2001, the Tongue River Reservoir could meet only 48 percent of its contracts for water and in 2004, only 65 percent could be met. Additional water availability from alternative water sources could supplement supplies during these shortages, including drought years, stabilizing forage production and allowing ranchers to operate more profitably.⁴⁹ In addition, increased forage production could benefit livestock grazing patterns, allowing an increase in the number of cattle and a decrease in the amount of forage a rancher would need to purchase to maintain existing numbers. If a significant amount of water were available at a reasonable price, forage production that is sold to outside markets could also increase.

As the PRB experiences continued periods of drought, the use of more efficient irrigation systems such as subsurface drip irrigation will help to sustain current land use patterns without additional water availability. Subsurface Drip Irrigation (SDI) using CBNG-produced water has been successfully used to grow crops in the Wyoming portion of the PRB and could be utilized in Montana portions of the PRB. SDI is an irrigation method that applies water directly to the crop root zone below the ground surface (at depths ranging 18 to 48 inches)⁵⁰ by small emission points called emitters that are strategically placed in a series of plastic lines between crop rows.⁵¹ Unlike surface irrigation technologies, SDI eliminates soil crusting on the surface, dispersion, and salt accumulation in the root zone, all of which hinder productivity of agricultural lands when sodic water is utilized.

Selection of suitable lands for SDI application is typically limited to mixed alluvium and colluvium soils with high porosity. Electrolyte boosters are sometimes needed to increase infiltration rates. Water quality limitations would apply to SDI as well, but can typically be mitigated through amendments such as gypsum which reduce the sodium adsorption ratio (SAR). Irrigation through this technique is not limited to the growing season. Water is typically applied year round, utilizing the non-growing months to flush the salts below the root zone.

While irrigation through sprinkler and furrow irrigation is prevalent along rivers and reservoirs, it is difficult to find sources of water in sufficient quantity as the distance from surface water sources increases. Use of CBNG-produced water through SDI techniques opens the door to new areas of irrigated agricultural development. There is an increased flexibility in field shape and size selection as well as decreased energy costs.

Subsurface drip irrigation systems are not without limitations. Crop selection is typically limited to perennial crops such as alfalfa and refined grasses. Alfalfa has high crop water needs and a longer growing period, so it benefits greatly from high efficiency irrigation. Furthermore, crop selection for SDI should be limited to salt tolerant or moderately tolerant grass species or mixes of grass.

In SDI systems that are currently in operation in Wyoming, up to 60 inches of water per acre per year are applied. For a 115-acre alfalfa field in a fairly porous alluvium and colluvium soils with high porosity, about 38,800 barrels of water per acre per year, or about 106 barrels per day (bpd) per acre, are

⁴⁹ Ibid.

⁵⁰ BeneTerra, LLC., "BeneTerra Subsurface Drip Irrigation for Dispersal of Produced Coalbed Water."

⁵¹ ALL Consulting, "Feasibility Study of Expanded Coal Bed Natural Gas Produced Water Management Alternatives in the Wyoming Portion of the Powder River Basin Phase I."

utilized, although BeneTerra indicates a well designed and maintained system will accept approximately 90 bpd per acre.⁵² Estimated costs for equipment installation can range between \$1,500 and \$4,000 per acre with an estimated life span of 10 years. Lifetime costs for the system installation and design are around \$0.004 to \$0.01 per barrel, \$0.04 to \$0.06 per barrel for soil amendments, and \$0.02 to \$0.04 per barrel for operations and monitoring.⁵³

Industrial Needs

The Spring Creek and Decker coal mines lie within the project boundary. These industries are frequently lacking water for dust abatement and aquifer restoration. A large mine can require between 2,400 bpd and 100,000 bpd for operations, depending on the season.⁵⁴ Water is typically stored for dust control in on-site pits and settling ponds and utilized during dry and/or windy periods during summer and fall months.

Oil and gas development can often require water for drilling, completion, and testing operations and in CBNG-specific operations, water flushes are frequently performed.

A collection of coal-related projects have been proposed within the study area that would increase water needs in the area if implemented. Governor Brian Schweitzer has become an avid supporter of utilizing coal-to-liquids technology or coal gasification in Montana. Several sites have been selected as potential candidates for implementing the technology, including Otter Creek and Decker Coal Mines, both of which lie within the PRB study area. Decker has been identified as a potential source of future advanced coal development, which includes such technologies as coal-to-liquids and coal gasification. The location of the mine relative to a major petroleum pipeline and the Tongue River Reservoir makes it an ideal candidate for these water intensive operations. However, the reservoir water usage would have to be secured through the Northern Cheyenne tribe, which has a water reservation of 20,000 acre-feet.

The Otter Creek tracts, owned by the State of Montana and Great Northern Properties, are estimated to contain over 1.2 billion tons of coal.⁵⁵ While this is a vast resource, its high sodium content precludes it from modern thermal generation plants. However, it is a prime target for coal gasification. Diesel oil and gasoline can be made from solid coal through gasification and Fischer-Tropsch hydrocarbon synthesis.⁵⁶ Two plants in South Africa utilize the technology to supply approximately 25 percent of the fuel necessary for South Africa. These plants utilize approximately 5 barrels of water for every barrel of fuel that is produced, a comparable number to the anticipated Montana processes. In the case of Otter Creek, it is estimated that 4 million barrels of fuel can be economically produced each year, resulting in a net annual water need of 20 million barrels (assuming an 11,000 barrel per day plant). It has been noted that obtaining water in this area would be difficult. The total amount of water necessary for a coal

⁵² BeneTerra, LLC., "BeneTerra Subsurface Drip Irrigation for Dispersal of Produced Coalbed Water."

⁵³ Personal conversation between Dr. Bruce Langhus of ALL Consulting and Bill DeLapp of JM Huber Corporation (October 28, 2005).

⁵⁴ ALL Consulting, "Feasibility Study of Expanded Coal Bed Natural Gas Produced Water Management Alternatives in the Wyoming Portion of the Powder River Basin."

⁵⁵ Montana Conservation Voters, "Otter Creek Coal 'Not Ready to Be Developed'." http://www.mtvoters.org/land_board_article/article/2006/otter_creek_coal_not_ready_to_be_developed (accessed September 23, 2009).

⁵⁶ Tad W. Patzek, "Problems with Coal to Liquids in Montana" (May 23, 2007). <http://petroleum.berkeley.edu/papers/Biofuels/TWPCoal052307.pdf> (accessed September 23, 2009).

conversion facility varies based on conversion technology, cooling technology, type of coal, elevation of the facility, and the climate of the facility's vicinity.⁵⁷

In August 2008, the Crow Indian Tribe signed an agreement with Australian-American Energy Co. to build and operate the Many Stars Coal-to-Liquids plant on the reservation.⁵⁸ It is projected to convert 38,000 tons per day of coal to syngas and produce 50,000 gallons per day of liquid fuel.⁵⁹ Sources indicate an anticipated 15,000 acre-feet/year water usage for the plant. This is 3 percent of the total 500,000 acre-feet/year that the tribe is allocated from the Bighorn River and Bighorn Lake.⁶⁰ The exact location of the project within the reservation has not been finalized, but coal presence is greatest in the southern and easternmost portions. Therefore, it is highly likely that this project will be within the Powder River Basin study area or directly adjacent.

Aquifer Storage and Recovery

Aquifer storage and recovery allows the use of oil and gas produced water at a future time by injecting the water into aquifers with adequate storage capacity, such as those that have experienced several years of pumping (e.g., aquifers used for domestic or municipal supplies.)⁶¹ The water can be injected and recovered from a single well and used for multiple beneficial uses such as public drinking water, agriculture uses, and industrial uses. Water treatment may be necessary before injecting, upon retrieval, or both, depending on the regulatory requirements and beneficial uses.

This technology has been utilized successfully in the Powder River Basin. The city of Gillette, Wyoming, was experiencing depletion in their public water supply.⁶² A CBNG operator installed Class V injection wells for aquifer storage and recovery that were sufficient to manage all of the produced water from a nearby gas producing project. The CBNG-produced water became a vital component in the public water supply.

In the future, aquifer storage and recovery using previously developed coal seams may become a feasible and necessary use of coal bed natural gas produced water. This is not feasible while CBNG is being produced because injecting water increases the pressure in the formation, which was previously intentionally reduced in order to produce the gas from the coal seam.

⁵⁷ Flathead Conservation District, "Coal Conversion and Water Use." <http://www.flatheadcd.org/content/view/135/59/> (accessed September 23, 2009).

⁵⁸ "Crow Tribe Signs Deal for Coal-To-Liquids Plant," *Coal Gasification News* (November 28, 2008). <http://coalgasificationnews.com/2008/11/24/crow-tribe-signs-deal-for-coal-to-liquids-plant/> (accessed September 23, 2009).

⁵⁹ Bill Reid, "New CTL Montana Project Announced," *Coal News* 5, no. 10 (October 2008). http://commerce.mt.gov/energy/Includes/NewsArticles/2008Articles/100808_New_CTL_Montana_Project_Announced.pdf.

⁶⁰ Crow Agency, "The Crow Tribe – State of Montana Water Compact," presented to Tribal-State Relations Committee, 60th Montana Legislature on October 16, 2007.

⁶¹ ALL Consulting, "Feasibility Study of Expanded Coal Bed Natural Gas Produced Water Management Alternatives in the Wyoming Portion of the Powder River Basin."

⁶² IOGCC and ALL Consulting, "A Guide to Practical Management of Produced Water from Onshore Oil and Gas Operations in the United States," prepared for U.S. Department of Energy, National Energy Technology Laboratory (October 2006). <http://www.all-llc.com/IOGCC/ProdWtr/ProjInfo.htm>.

Fish and Wildlife

The Custer National Forest Plan identifies development of new water sources and development of cold and warm water fisheries as two of the management objectives for the forest. The plan also outlines the possibility of utilizing stock water ponds for fisheries when possible. Both alternatives present unique possibilities to coordinate oil and gas produced water with Montana's blue ribbon fisheries while improving water availability for livestock in the area. At the time of the forest plan, 406,250 catchable trout were available. Estimates based on existing cold water reservoirs and impoundments as well as new cold water fishery development concluded approximately 126,000 additional catchable trout could be available if management plans were implemented. Warm water fish habitat management is primarily done through the creation of stock ponds. In 1986, approximately 150 acres of ponds had been developed which provided habitat for approximately 22,500 fish. If additional habitat generation would occur, it was anticipated that 97,500 additional fish could be harvested. Oil and gas produced water and ponds constructed as part of coal bed natural gas development activities were not considered in the forest management plan; thus, the estimates could be increased to even more available trout with suitable habitat construction utilizing suitable quality water from oil and gas operations in the basin.⁶³

PRODUCED WATER AS A WATER RESOURCE

Produced water is defined as water brought to the surface in conjunction with oil and gas operations. It is sometimes referred to as brine, saltwater, or formation water.⁶⁴ The quality of produced water varies by basin, geological formation and even well level. Produced water use is dependent upon the quality of water recovered and the water must be evaluated to determine its potential use as a water source.

Initial water production in conventional oil or gas wells is typically a small percentage of total production, but can increase over time until the well becomes uneconomical to produce. However, in the study area the main source of produced water is not from conventional oil and gas but from CBNG. In CBNG operations, water production is often greatest at initial completion of the well rather than later in the life of the well. For production to occur in a CBNG well, water is produced, which decreases the pressure in the formation surrounding the wellbore and allows the natural gas to escape or become mobile and be produced through the wellbore. As the pressure decreases, less water is available to be produced by the well and the volume of produced water decreases in the later phases of the well's life. As a result, less produced water may be available as a CBNG play matures.

Availability in Study Area

To estimate the volume of produced water available for use requires an estimate of the number of current and future wells producing in the study area and an assumption of the volumes of water produced by each well. The following presents a review of existing production and three estimates developed for produced water availability based on the current producing history in the study area. The three well activity estimates selected for the study are

- (1) Current Observed Activity – This estimate takes current trends on drilling and completion activity in the study area and applies them to the future development.

⁶³ United States Department of Agriculture, "Custer National Forest Management Plan" (October 1996). http://www.fs.fed.us/r1/custer/projects/planning/Management_plan.pdf (accessed October 12, 2009).

⁶⁴ Argonne National Laboratory, "Produced Water Volumes and Management Practices in the United States."

- (2) Historic Match Activity – This estimate assumes that current well counts of producing wells will be maintained at a constant level in the study area.
- (3) Increased Activity – This estimate assumes that interest in drilling in the study area will increase to the maximum observed historic activity level and will be maintained over the estimated life of the study.

In addition, the number of wells that could be developed in the study area was assessed to see if the CBNG resource play could ultimately support the three estimated activity levels. A review of the study area was performed based on current well development and available coal with the potential to be developed and an estimated number of wells that could be drilled in the study area. This work was previously performed for the Supplemental Environmental Impact Statement⁶⁵ and it was determined that a total of 16,400 wells (9,000 wells in unrestricted locations and 7,000 wells in restricted Indian/Forest Service lands) have been estimated as a potential development level in the study area (Figure 12).

Figure 12 - Estimated Well Potential in Study Area

Source: ALL Consulting based on BLM, Data from Supplemental Environmental Impact Statement

⁶⁵ Bureau of Land Management, "Final Supplement to the Montana Statewide Oil and Gas Environmental Impact Statement and Proposed Amendment of the Powder River and Billings Resource Management Plans" (2008). Miles City Field Office. BLM/MT/PL-08/016.

Current Well Counts and Production

A review of current producing CBNG wells in the study area was performed to determine past and current performance of the wells and to provide information for predictions of produced water into the future.⁶⁶ A total of 2,300 wells were identified in the study area with 1,746 identified specifically associated with CBNG production. Not all of the wells can be classified as producing wells. Table 8 presents well counts developed on the identified CBNG wells relative to their mineral interest in the study area.

Table 8 - Count of CBNG Wells in Study Area by Mineral Interest

Source: MBOGC production database August 2009

Mineral Interest	Well Count
Federal Land Wells	321
State Land Wells	195
Indian Land Wells	0
Fee Land Wells	1,230
Total	1,746

An estimate of a CBNG well's life expectancy was developed through an interview with Montana Board of Oil and Gas Conservation (MBOGC) personnel and a review of the data provided from the MBOGC database. From the interview with MBOGC personnel it was learned that the current well life prognosis presented to the Board from industry was approximately seven years. A seven-year well life appears to

Figure 13 - Plot of Well Activity in Study Area from January 1998 to August 2009

Source: MBOGC Production Database August 2009

⁶⁶ Montana Board of Oil and Gas Conservation, Production Database (retrieved August 2009).

be consistent with a review of the information contained in the MBOGC database on more recently completed wells.

A review of the activity levels of the wells in the study area produced on the plot presented in Figure 13. This plot shows applications for permit to drill and completion counts as well as averaged yearly gas prices over the life of CBNG production in the study area. In addition, the plot has been annotated with regulatory activities that occurred during the time period. As shown in Figure 13, current activity in the study area relative to CBNG has significantly decreased since 2006. The well completion levels identified over the past 4 years and first two-thirds of 2009 are presented in Table 9.

Table 9 - Listing of Well Completion Counts for CBNG Wells in Study Area over past 4 years	
Source: MBOGC Production Database August 2009	
Year	Count Completions
2005	167
2006	324
2007	70
2008	42
2009	2

An analysis of water production per CBNG well was conducted by reviewing past production in the study area. From production data reviewed, the current average water production per active producing well

Figure 14 - Plot of Averaged Monthly Production Values by Well Count and Count of Wells Calculated from MBOGC Database August 2009

in the study area is 3,900 bbl/month. This is based on an average active well count of 836 wells over the past two-plus years of production data. This averaged value for produced water per month per well accounts for both initial and later life production from the CBNG wells. Figure 14 presents past water and gas production averaged on a per well basis for the wells in the study area.

Using the above determined information of average well life equaling 7 years and 836 current active wells in the area, it is estimated that 120 wells per year would need to be drilled in the study area to

maintain current produced water volumes. As shown in Figure 13, current activity in the study area is not matching this identified metric. Produced water volumes would be expected to be decreasing in the study area following the currently trend. The following scenarios were developed to predict produced water availability based on the three options presented above and the identified metrics developed from existing data.

Current Observed Activity

This estimate takes the current trends in well drilling activity observed in the study area and applies them to the future development of CBNG. As presented in Table 9, the number of well completions over the past 3 years has significantly decreased. Based on this observation, it was assumed that 25 producing wells would be drilled each year for CBNG in the study area proceeding into the future. The number of active wells in the area would decrease and produced water availability would decline. Using the life expectancy of the average well in the area and the observed average of 3,900 bbl/month of produced water per well, the following schedule of wells and available produced water was developed.

As can be seen in Table 10, the number of active wells in this scenario would decline in the project area to 175, and the available produced water per month would decline to 682,500 bbl/month within 7 years. The water availability stabilizes at this level and, as long as the predicted 25 wells are drilled annually, the water availability would continue at this level. Figure 15 presents a comparison of the water availability for the flat-line case versus the

Year	Well Count	Water Available/ Month (BBLs)
2009	836	3,260,400
2010	741	2,889,900
2011	646	2,519,400
2012	551	2,148,900
2013	456	1,778,400
2014	361	1,407,900
2015	266	1,037,400
2016	175	682,500
2017	175	682,500
2018	175	682,500
2019	175	682,500

Figure 15 - Predicted Water Availability for the Flat Line CBNG Well Development Case

current observed activity trend, showing the greater volume of water available under the flat line case for the years 2010 to 2016.

Under this scenario, a total of 500 additional wells are projected to be drilled in the study area over the next 20 years. The addition of these 500 wells to the 1,746 wells already drilled yields a number that is well below the predicted number of available wells that can be drilled in the area (2,246 drilled vs. 16,400 potential).

Historic Match Activity

This estimate assumes that the current producing well count will be maintained in the study area and that an active well count will be maintained at 836 producing CBNG wells. A total of 120 new wells would need to be drilled annually to maintain this activity level based on assumed well life. This assumption means that water availability would remain constant at 3,260,400 bbls of water per month (836 wells times 3,900 bbls/month). The number of wells to be drilled over the projected 20 year life of the study is 2,400 wells. This well count is within the projected availability of wells in the study area ($2,400 + 1,746 = 4,146$ drilled versus 16,400 potential).

Increased Activity

The increased activity estimate assumes that fluctuations in gas prices and limitations relative to infrastructure, drilling rigs and regulatory restrictions will not adversely limit the drilling of CBNG wells in the study area and that increased drilling will occur. The assumption is made that drilling in the study area will increase to the maximum level observed from historic activity levels and be maintained over the estimated life presented in this study.

The maximum annual completion activity was in 2006 when 324 wells were completed. Using this number and the estimated life of 7 years for wells in the area, the number of wells is estimated to increase by 204 wells per year. It is predicted that an additional 6,480 wells would be drilled over the next 20 years. This is still within the projected number wells to be drilled under the Supplemental Environmental Impact Statement ($6,480 + 1,746 = 8,226$ drilled vs. 16,400 potential).⁶⁷

The water availability in the study area is expected to increase by 795,600 bbls/month (204 added wells * 3,900 bbl/month) under this scenario. Table 11 presents the increased water schedule from this option and Figure 16 presents this increased water schedule.

Year	Well Count	Water Available/ Month (BBLS)
2009	836	3,260,400
2010	1,040	4,056,000
2011	1,244	4,851,600
2012	1,448	5,647,200
2013	1,652	6,442,800
2014	1,856	7,238,400
2015	2,060	8,034,000
2016	2,264	8,829,600
2017	2,468	9,625,200
2018	2,672	10,420,800
2019	2,876	11,216,400
2020	3,080	12,012,000
2021	3,284	12,807,600
2022	3,488	13,603,200
2023	3,692	14,398,800
2024	3,896	15,194,400
2025	4,100	15,990,000
2026	4,304	16,785,600
2027	4,508	17,581,200
2028	4,712	18,376,800
2029	4,916	19,172,400
2030	5,120	19,968,000

⁶⁷ Bureau of Land Management, "Final Supplement to the Montana Statewide Oil and Gas Environmental Impact Statement and Proposed Amendment of the Powder River and Billings Resource Management Plans."

Figure 16 - Predicted Water Availability for the Highest CBNG Well Development Case

BARRIERS TO BENEFICIAL USE OF OIL AND GAS PRODUCED WATER

Water Quality

The quality of the produced water from CBNG operations in the PRB varies considerably from well to well. Generally, water quality has been shown to decrease with depth and as development has progressed north and west through the basin.⁶⁸ However, some produced water in the basin is safe for human consumption and several groundwater wells in the basin utilize coal bed aquifers as a water source for domestic and agricultural uses.

The state of Montana has nine classifications for surface water in order to maintain the quality of water for domestic, fish and wildlife, recreational, agricultural, and industrial uses.⁶⁹ Montana's surface water quality standards are located in Montana Administrative Register Chapter 30, subchapter 6, ARM 17.30.621 through 17.30.629.

The state of Montana has also established classifications for groundwater which outline the maximum allowable changes in groundwater. The classifications serve as the basis for limiting discharges into groundwater. Montana's groundwater quality standards are located in Montana Administrative Register Chapter 30, subchapter 10, ARM 17.30.1005 through 17.30.1006.

In general, CBNG-produced water is characterized by elevated levels of sodicity, sodium, barium, bicarbonates, Electrical Conductivity (EC), and iron. The concentration of all of these constituents is a

⁶⁸ ALL Consulting, "Handbook on Coal Bed Methane Produced Water: Management and Beneficial Use Alternatives," prepared for Ground Water Protection Research Foundation, U.S. Department of Energy, National Petroleum Technology Office, and Bureau of Land Management (July 2003).

⁶⁹ Ibid.

function of multiple variables including depth of the coal seam, peat metabolism processes, aquifer recharge, source water, and many other factors. The ability to utilize CBNG water with elevated sodicity as irrigation water depends primarily on the characteristics of the soil and the ability of the crop being grown to tolerate the high sodium. Sodic water applied to soils with significant amounts of clay can alter the soils' physical properties, leading to poor drainage and crusting. However, the same water applied to sandy soils does not alter drainage properties. Calcium-enriched soils are essential to utilizing sodic water for irrigation.⁷⁰

Water treatment is currently being utilized in the study area to reduce the sodicity of the CBNG-produced water. The primary treatment currently being used is an ion exchange process which effectively removes arsenic, heavy metals, nitrates, radium, salts, uranium, and other elements from the produced water.⁷¹ Concentrated brine volumes account for approximately 1 percent of the total feed volume and are disposed of offsite by trucking the brine to a Class I disposal well. Reverse osmosis is currently being tested in the Wyoming portion of the PRB, with brine byproducts comprising up to 10 percent of the feed volume that would need to be disposed via injection or by developing an alternative use.

Subsurface drip irrigation operations use design considerations that take into account water quality, which ultimately determines the flushing requirements for the system and other design criteria.⁷² The primary concern with SDI systems is the clogging of the emitters, which can be the result of physical hazards such as sand and silt, chemical hazards such as mineral precipitation, and biological hazards such as slime and algae accumulations in the equipment. Water quality from CBNG development is known to change over time, so testing water quality is essential to managing a successful SDI system. Source water that is slightly acidic is ideal, since lower pH values typically result in the lower probability of mineral precipitates.⁷³ However, water associated with CBNG production is typically basic rather than acidic, which can cause calcium carbonate (lime) precipitation.

As in traditional irrigation operations, treatment may be necessary to remove or alter contaminants in the feed water and, of particular concern to SDI systems, treatment can aid in the removal of clogging agents from the source water. An advantage to SDI systems is the ability to inject chemicals directly into the system, such as acids to lower the pH to a point where mineral precipitates become soluble and can then be flushed from the system. Acid and other chemical treatments can be applied intermittently or continuously, depending on the water quality and constituents present in the soil and source water. Another major advantage with SDI systems is the ability to apply water soluble fertilizers to the root

⁷⁰ James W. Bauder, "Frequently Asked Questions on Saline and/or Sodic Water and Soils." http://waterquality.montana.edu/docs/methane/saline-sodic_faq.pdf.

⁷¹ ALL Consulting, "Feasibility Study of Expanded Coal Bed Natural Gas Produced Water Management Alternatives in the Wyoming Portion of the Powder River Basin."

⁷² Graham Harris, "Sub-surface Drip Irrigation: System Maintenance" (2005). http://www.nrw.qld.gov.au/rwue/pdf/factsheets/sdi_system_maintenance.pdf (accessed October 20, 2009).

⁷³ The University of Georgia, Ft. Valley State University, and the U.S. Department of Agriculture, "Considerations for Subsurface Drip Irrigation Application in Humid and Sub-humid Areas" (October 2009). <http://pubs.caes.uga.edu/caespubs/pubcd/c903/c903.htm> or <http://pubs.caes.uga.edu/caespubs/pubs/pdf/c903.pdf> (accessed October 20, 2009).

zone of the crop while irrigating by feeding the chemicals directly into the water supply line carrying the source water into the formation.⁷⁴

Regulatory Barriers

Obtaining permits for the beneficial use of produced waters, especially relative to CBNG-produced water in Montana is a tedious and lengthy process. Fidelity Exploration and Production Company applied for a beneficial use permit for the water that is produced through CBNG production in 2006.⁷⁵ This application has undergone numerous public objections and protests including several legal briefs; as a result, the permit has been stalled and has still not been issued in late 2009.

Permits for subsurface drip irrigation systems in Wyoming require a Class V injection permit and a WDEQ 5C5 Underground Injection Control (UIC) permit. No CBNG operator or rancher in Montana has implemented an SDI system to date, and, from discussions with regulators in Montana, it is not clear how Montana would handle this type of operation from a regulatory standpoint. What is known is that the utilization of CBNG-produced water for irrigation purposes in Montana would require a beneficial use permit similar to the permit which Fidelity has been trying to acquire since 2006. In contrast, in Wyoming, obtaining an SDI permit takes up to 8 months.⁷⁶

Gas Prices

Gas prices play a significant role in the volume of produced water that will be available in the future as well as the flexibility operators have in finding ways to manage produced water. In years when prices are down, new development may be postponed or halted indefinitely and operators will be pursuing the most cost effective means of managing produced water. Low gas prices can have a major role in a company's ability to operate, and new development is typically the first element of operating budgets to be eliminated. Without new CBNG development, water production declines at a greater rate because without new wells there is not the corresponding increase in water production volumes typical of newly developed wells. As a result, future water availability will fluctuate, making the exact volume available for beneficial use uncertain. This uncertainty is part of the barrier to development of resources which can utilize CBNG-produced water. Users of produced water are looking to avoid having to develop multiple options to supplying water in the event there is an unanticipated decline in produced water availability.

Costs

The costs associated with utilizing CBNG-produced water to supplement water shortages in the PRB vary depending on the beneficial use, economic factors, and distances for water transportation. Utilizing oil and gas produced water for secondary recovery operations or water flooding would require the installation of a pipeline or the trucking of large volumes of water to one of the nearest oil-producing fields. Water pipelines have been noted to cost approximately \$43,000 per inch-mile.⁷⁷ However, operating costs associated with water transport for secondary recovery operations is limited to pumping

⁷⁴ Bob Schultheis, Bob, "Maintenance of Drip Irrigation Systems," University of Missouri Extension Service. http://extension.missouri.edu/webster/irrigation/Maintenance_of_Drip_Irrigation_Systems.HDT.pdf (accessed october 20, 2009).

⁷⁵ Montana Department of Natural Resources, Application No 42B-30011045 and Application No. 42B-30014358.

⁷⁶ ALL Consulting, "Feasibility Study of Expanded Coal Bed Natural Gas Produced Water Management Alternatives in the Wyoming Portion of the Powder River Basin."

⁷⁷ Ibid.

costs, which is typically less than \$0.10/bbl.⁷⁸ Depending on the water availability and needs, length of pipeline necessary, and size of the water flooding project, using PRB-produced water may or may not be economically feasible. As such this option would need to be reviewed by operators on a case by case basis.

Implementing water treatment technologies such as those described in this report do not come without a cost. Costs have been estimated between \$0.25/bbl to over \$2.00/bbl. These costs take into consideration capital investment for the facility, operating expenses, brine disposal, monitoring expenses and regulatory expenses. Depending on the volumes of water being produced and the price of gas these costs are typically too great for a CBNG developer, but for some industrial uses these costs may be economically justifiable for the volume of water being supplied.

COAL BED NATURAL GAS PRODUCED WATER AS A WATER SOURCE

There are many future opportunities for using CBNG-produced water in the PRB. The economy of southeastern Montana is driven by agriculture; therefore, droughts and water shortages have a large impact on local economies. The drought patterns that have been experienced across the basin over the last decade, paired with the fact that surface water appropriations may soon exceed water availability for both the Tongue and Powder Rivers has created a need for water and the potential to put the produced water to beneficial use. New technologies, such as subsurface drip irrigation and emerging water treatment technologies, are making the use of produced water feasible in situations where, in the past, these uses would not have been possible.

Table 12 - Comparison of Water Availability from CBNG Development to Water Needs in the Study Area

Water Use	Volume of Water Used (bbls/day)	Days of Total Water Needs Met by Annual CBNG Produced Water		
		Current Decline Scenario (year 1/ year 10)	Historic Average Scenario (all years)	Increased Development Scenario (year 1 /year 20)
Agricultural	23,940,000	1.63 / 0.34	1.63	1.63 / 9.6
Industrial	138,000	284 / 59	284	284 / 1,667
Coal to Liquids	20,318,000	1.93 / 0.40	1.93	1.93 / 11
Totals	44,396,000	0.88 / 0.18	0.88	0.88 / 5

CBNG-produced water has the potential to supplement water supplies in the Montana portion of the PRB. Table 11 provides the average daily water requirements for the two largest water use categories in the PRB, Agricultural and Industrial, and presents potential future water needs for the coal-to-liquids industry. The table provides a summary of the number of days annual CBNG-produced water could supplement these industries under the three CBNG development scenarios detailed in this report. The Table illustrates that water sustainability is not easily achieved by finding a single source of water. However, the Table shows that CBNG-produced water could meet over 75 percent of the annual industrial water needs today and, under the Increased Development Scenario, could supply all of the industrial water needs in the years to come.

⁷⁸ Ibid.

The potential for CBNG-produced water to sustain the total water needs for the study area are limited to short durations and would require a large storage reservoir. However, CBNG-produced water has the potential to supplement the water supply needs of users in the area. For these water users, the benefit of the water supplied by CBNG development would be in addition to the ongoing benefits of production of energy resources in the study area.

SUMMARY AND RECOMMENDATIONS

As shown above, the current water needs for the study are dominated by agricultural use, with industrial use and municipal or domestic use consuming substantially less water. With limited population increases projected for the area, these use patterns are expected to continue for at least the next 20 years.

One possible significant change to these patterns would be the introduction of a coal-to-liquids plant with in the study area. This new industry would potentially require 20 million barrels of water per day to operate. This is about as much water as agriculture is expect to use by 2020 (Table 12), and the development of this industry would seem to be dependent on identifying new sources of water.

This study examined historic CBNG production in the area in order to determine the factors, such as natural gas prices and regulatory events, that affect the pace of development. Future development and the water that would result from that development were then forecast using models for three different scenarios: Current Decline, Historic Average and Increased Development.

The models indicate that under the Current Decline and Historic Average scenarios, CBNG produced water would provide a limited amount of additional water for the region. However, under the Increased Development scenario there would be enough water from CBNG production to meet all of the industrial water use needs in the study area.

While hurdles such as transportation and water quality must still be overcome, information about the availability of a new water source can be vital to those responsible for regional water planning. Knowing that this water source exists allows planners to consider whether policies should be developed to encourage both production and use of this water.

This study area was chosen in large part because it was known that substantial data exist on the quantity and quality of the produced water. The availability of this data coupled with the relatively small size of the study area, allowed researchers to focus on developing the appropriate methodology and models rather than spending an undue amount of time on data collection and data management. The methodology and models developed in this study can now be applied to other oil and gas producing regions.

It is recommended that additional regional water assessments be conducted in a variety of oil and gas producing basins. The additional assessments will allow the models to be refined for different resources and geographic settings. Expanding this study into oil and gas basins that are known to generate large volumes of produced water will allow an evaluation of the full potential of using oil and gas produced water to supplement regional water supplies and will provide federal, state, and local agencies to make informed policy decisions. Developing a water source that would otherwise be deemed a waste could put informed decision makers at the forefront for partnering energy development and traditional water uses, resulting in a win-win situation for all parties involved.