

Chapter 9

Looking to the future

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The purpose of this chapter is to discuss future water use opportunities in the NERB. This issue was examined in detail in previous NERB water plans (HKM and others, 2002a, b) and the Wyoming Framework Water Plan (WWC Engineering and others, 2007). This study provides the most current information available about the future focus and direction of NERB groundwater development projects.

The technical concepts and geology previously discussed in this study provide the background required to understand the practical considerations that shape the conceptualization and design for a successful completion of a water resource development project. Chapter 5 opened with the definition of several hydrogeologic concepts crucial to understanding basic groundwater science. Section 5.1.3 introduced the dynamics of groundwater recharge, discharge, and flow, and summarized the hydrogeologic characteristics of the complex geologic settings in the NERB. Future groundwater development in the NERB is physically limited by hydrogeology. Specific groundwater development projects are discussed in section 9.1, and recommendations for future updates of this groundwater determination technical memoranda are presented in section 9.2.

Additional supporting information for the project assessments contained in this chapter can be found in previous chapters of this study:

- Basin hydrogeology is discussed at length in chapters 5 through 7 and illustrated in plates 4, 5, and 6.
- Groundwater chemical characteristics are summarized in chapter 7 and appendices E and F.
- Recent and historic development patterns specified by beneficial use are examined in chapter 8. These patterns were provided by the Wyoming State Engineer's Office.
- Studies published by the USGS (chap. 7) and Wyoming Water Development Office (WWDO) (appendix B) examine the development potential of specific aquifers.
- The 2002 Water Plan for the NERB (HKM and others, 2002), the 2017 Water Plan (RESPEC, 2019) and associated technical memoranda, as well as the 2007 State Water Plan (WWC Engineering and others, 2007), identify potential groundwater development projects considered prior to the completion dates of those studies. Many of the opportunities examined in those publications may be

under current development or will become more viable in the future as financial factors and technological improvements allow.

- The Water Resources Data System (WRDS) library, specifically the WWDC Projects and Studies webpage (<http://library.wrds.uwyo.edu/wwdcrept/wwdcrept.html>), contains hundreds of water development reports for projects completed in the last 40 years for localities throughout Wyoming.

This chapter discusses development projects designed with the primary objective of producing potable groundwater. Projects that may produce groundwater as a value-added byproduct of other activities, such as oil and gas production or in-situ mineral extraction, are not considered.

9.1 FACTORS THAT AFFECT GROUNDWATER DEVELOPMENT

- Water availability—A groundwater resource must be legally, economically, and physically available. In the semi-arid west, the significance of the last two factors cannot be overstated. Large sources of good quality groundwater exist in most Wyoming river basins, but in many cases they are located at such distances from population centers that development is uneconomical. In the NERB, there are few legal constraints on groundwater development and availability is controlled primarily by hydrogeology. Fortunately, most of the basin's communities are located in proximity to productive aquifers.
- Funding—Groundwater development projects are expensive and most Wyoming municipalities lack the funds required to plan, carry out, and complete development programs. Therefore, funding for some projects has to be obtained from other governmental agencies. The primary water development funding agencies in Wyoming are the WWDC, DEQ, and the U.S. Department of Agriculture.
- Stakeholder involvement—The successful completion of any groundwater project requires the involvement of stakeholders who have interests in the development or preservation of a particular water resource. Stakeholders include: municipal, state, and federal regulatory agencies; current and future water users; landowners; business representatives; attorneys; scientists; engineers; environmental groups; sportsmen; and holders of competing water rights. Stakeholder support

for a water development project depends on the nature, benefits, costs, and perceived impacts of the particular project. The project will likely incur substantial cost increases and time delays if legal challenges are filed by stakeholders opposed to development.

- **Interstate compacts**—In the NERB, interstate compacts regulate surface water uses on the Belle Fourche (1943), Yellowstone (1950), and Upper Niobrara (1962) rivers. However, only the Upper Niobrara River Compact of 1962 recognizes the interconnection between groundwater and surface water resources and lays the foundation for groundwater apportionment in the future. The Interstate Streams Division of the SEO administers all interstate stream compacts for the State of Wyoming (<https://sites.google.com/a/wyo.gov/seoi/interstate-streams>). Currently, there is no interstate regulation of groundwater use in the basin.
- **Water quality**—Groundwater produced must meet the water quality requirements of the intended use(s). State and federal laws mandate water quality requirements for certain beneficial uses. These benchmarks may or may not be used as reference measures for water acquired by other means. For example, the National Primary Drinking Water Regulations (table 5-1), established by the Environmental Protection Agency (EPA) under provisions of the Safe Drinking Water Act, are legally enforceable standards for public water systems (PWS), but do not regulate water quality in private groundwater wells that serve fewer than 25 people. Still, water quality in private wells is frequently evaluated in comparison to the Maximum Contaminant Levels (MCL) contained in the EPA regulations.
- **Environmental regulation**—Water development projects in Wyoming are subject to regulation under the provisions of state and federal environmental laws including:
 - **Wyoming Environmental Quality Act**—the principal state environmental law that created the Wyoming Department of Environmental Quality, repealed the state's existing environmental laws (in 1973) and replaced them with the provisions of the new act.
 - **Endangered Species Act**—a federal environmental law designed to protect imperiled plant and animal species. The ESA is administered under the Endangered Species Program of the U.S. Fish and Wildlife Service and the National

Marine Fisheries Service of the National Oceanic and Atmospheric Administration (NOAA).

- **National Environmental Policy Act (NEPA)**—the main federal law that established national environmental policy. It requires federal agencies in the executive branch to write Environmental Impact Statements (EIS) and Environmental Assessments (EA) that examine anticipated impacts to the environment resulting from proposed federal agency actions.
- **Clean Water Act**—the principal federal law that governs pollution in the nation's surface waters. The CWA does not regulate groundwater pollution directly. The Water Quality Division of DEQ regulates the discharge of pollutants to surface waters under the CWA.
- **Safe Drinking Water Act (SDWA)**—the primary federal law that ensures safe drinking water supplies for the public. The SDWA covers public water supplies but does not apply to private wells that serve less than 25 people. The EPA administers and enforces provisions of the SDWA.

9.1.1 Groundwater development projects in the NERB

Appendix B contains a chronological summary of groundwater development related projects sponsored by the WWDC in the NERB since 1973. Information contained in many of these studies was used to detail the physical and chemical characteristics of the basin's hydrogeologic units in chapter 7. Appendix B summarizes the following groundwater development information for WWDC projects in the NERB:

- **References to the study(s)**—full citations are included
- **Location**—name of the community, county, rural area, irrigation district, well site, etc.
- **Aquifers involved in the study**
- **Descriptions of development project(s) and aquifer development potential**
- **Summary of results**
- **Current project status**

9.1.2 Future water use opportunities

Technical memoranda (Memorandum “S”) of the 2002 Powder/Tongue River Basin Water Plan (HKM, 2002a) and the Northeast Wyoming River Basin (HKM, 2002b) provide detailed discussions of future water use opportunities that could expand water supplies to meet current and future demands. These water use opportunities were initially developed by the respective Basin Advisory Groups (BAGs) for these river basins in 2002 and can be reviewed online at: <http://waterplan.state.wy.us/basins/basins.html>.

The BAGs evaluated four categories of promising water development projects on the basis of availability, financial feasibility, public acceptance, number of beneficiaries, legal constraints, and environmental benefits. These four categories are:

- Category 1: Rehabilitation projects that preserve existing uses
- Category 2: Projects that rectify existing shortages
- Category 3: Projects that meet projected future demands
- Category 4: Projects that enhance uses in other Wyoming basins

Most of the opportunities discussed in Technical Memoranda “S” for both the Powder/Tongue and the Northeast Wyoming river basins (HKM and others, 2002a, b) involve Category 2 and 3 surface water projects, particularly improvements to existing reservoirs or construction of new reservoirs. Groundwater projects include:

- Generally increasing groundwater development in both river basins
- Exploring the feasibility of CBM aquifer storage and retrieval
- Studying the feasibility of trans-basin groundwater diversions to Gillette

This chapter discusses potential new groundwater development in the NERB by examining the basin’s major aquifer systems (sec. 9.1.3) and overviews of recent WWDC groundwater development projects (sec. 9.1.4).

9.1.3 Groundwater development potential by aquifer system

Currently, the Belle Fourche, Upper Niobrara and Yellowstone interstate river compacts (app. D) do

not restrict groundwater development in the NERB. Thus, future groundwater development projects will be designed and completed based on the location and magnitude of future water demands, groundwater availability and quality, funding, stakeholder involvement, and environmental regulations. Table 9-1 summarizes further groundwater development potential in the basin’s main hydrogeologic units.

Virtually all aquifers and some confining units in the NERB have some physical potential for development (pl. 2 and table 9-1), depending on the needed quantity, the quality required by the specified beneficial use(s), and technical limitations. The Tertiary Wasatch/Fort Union aquifer system remains available for future groundwater development. Additionally, Mesozoic and Late Paleozoic bedrock aquifers are underutilized and may be prime targets for future development, especially within or in close proximity to exposures where recharge is actively occurring, where residence times are low, and where water quality is good. Although well yields could be expected to range from 10 to 500 gpm in these aquifers, water quality and susceptibility to surface sources of contamination (e.g. irrigation return flows and leachates from septic systems) should be considered in evaluating development prospects.

9.1.4 Groundwater development potential—an economic perspective

Table 9-1 indicates that large sources of good quality groundwater can be found in the NERB. However, these resources may be located at such distances from population centers that development is uneconomical. The cost of constructing the pipelines necessary to convey water to an urban area may far exceed the cost of installing municipal wells in a productive aquifer. For example, projected costs for the Gillette Regional Water System (HDR and others, 2009) were estimated at \$19.36 million for the installation of 11 Madison aquifer wells and \$69.08 million for the construction of the 41-mile long transmission pipelines.

Given the complexities encountered in determining when and where groundwater development is economically feasible, examinations of recent WWDO groundwater projects and existing public water systems in the NERB provide the most realistic evaluations of future groundwater development potential. The consultant reports associated with WWDO projects (app. B) carefully consider how the various factors discussed in section 9.1 will impact the economic development of groundwater resources in each project area. The following section examines the aquifers most frequently targeted for municipal/domestic uses.

Table 9-1. Generalized groundwater development potential for major regional aquifer systems in the NERB (modified from WWC Engineering and others, 2007; chap. 7, this report).

Age	System	Outcrop location	Well yields	Major aquifers	General potential for new development
Quaternary	Alluvial	Scattered throughout NERB	Small to large	Unconsolidated deposits	Fair to good. Water quality may be poor
	Non-alluvial	Scattered throughout NERB	Small to moderate	Primarily unconsolidated terrace deposits but locally can include glacial deposits	Poor to fair. Most deposits located above stream channels exc. W Sheridan County
Tertiary	Volcanic Rocks	Black Hills	Small	Undifferentiated volcanic deposits	Poor to fair—deposits of limited extent located distant from population centers
	Late	Niobrara R. basin	Small to large	Arikaree	Good to very good
	Early	Tongue, Powder, Little Powder, Upper Belle Fourche, Upper Cheyenne	Small to large	Lower Tertiary aquifer system (Wasatch and Fort Union Formations) including coal aquifers	Good to very good—varying water quality
Mesozoic	Upper Cretaceous	Widespread along perimeter of PRSB	Small to moderate	Upper Cretaceous aquifer system (Lance Formation and Fox Hills Sandstone), Locally Mesaverde, and Frontier formations	Fair to good—varying water quality
	Lower Cretaceous	Widespread along perimeter of PRSB; flanks of Black Hills and Bighorn Mts.	Small to moderate	Muddy, Newcastle, Cloverly, Inyan Kara	Poor to good—varying water quality
	Jurassic/Triassic/Permian	Outcrops flanks of Black Hills	Small	Sundance, Spearfish, Minnekahta	Fair in some local areas—poor to good water quality
Paleozoic	Upper	Widespread along perimeter of PRSB; flanks of Black Hills and Bighorn Mts.	Small to very large	Madison/Pahasapa, Tensleep/ Minnelusa	Good to very good—poor to good water quality
	Lower	Widespread along perimeter of PRSB; flanks of Black Hills and Bighorn Mts.	Small to large	Flathead, Bighorn, Deadwood	Fair to good—some marginal water quality

Summary information for WWDC funded water development projects is listed in appendix B under the name of the community, watershed, or locale served by the project. Projects for subdivisions may be found under the subdivision name or, in some cases, the name of the neighboring municipality. Complete project reports can be accessed by the public at: <http://library.wrds.uwyo.edu/wwdcrept/wwdcrept.html>.

9.1.4.1 Economic development of potable groundwater

Economic groundwater development of domestic and public supplies in the NERB has been largely determined by geographic location (table 9-2). Generally, communities near or along the eastern margin of the Powder River Structural Basin have targeted the Madison aquifer, its equivalents, and associated Paleozoic formations. Dayton and Kaycee, two towns on the western margin of the PRSB, also obtain their water from the Madison aquifer where it dips steeply along the eastern flank of the Bighorn Mountains. Most public water systems for communities in the interior PRB utilize groundwater from the Wasatch/Fort Union or Lance/Fox Hills Aquifer systems. The Inyan Kara aquifer, the stratigraphic equivalent of the more widely occurring and named Cloverly Formation, provides municipal water to Lance Creek, a Census Designated Place in western Niobrara County. Lusk and Manville in southern Niobrara County obtain their municipal water, in part, from wells recently installed in the Tertiary Arikaree aquifer.

The Madison aquifer and its equivalent, the Pahasapa Limestone, and the Tensleep Limestone and its Minnelusa equivalent are the most frequently accessed units in the Paleozoic aquifers. WWDC development projects associated with the Paleozoic aquifers include exploration wells in the communities of Aladdin, Dayton, Hulett, Kaycee, Moorcroft, the Newcastle area, Pine Haven, Sundance, and Upton. Several WWDC development projects evaluate water system improvements for communities served by the Gillette Regional Water Supply System which is partially supplied from the Madison aquifer. Projected or actual community well yields in the Paleozoic units range from 25 to 1500 gpm. Water quality is usually good to excellent, and generally meets EPA standards. Exceedances for sulfate, TDS, and iron were observed in water samples from some community wells. Access to the Paleozoic aquifers in some locations requires that municipal wells be drilled to depths greater than 3,400 ft.

The WWDC has funded groundwater exploration projects in the Tertiary aquifer system for Antelope Valley-

Crestview, Cook Road, Gillette, Pine Butte, Sleepy Hollow, and Wright. WWDC also funded a hydraulic evaluation of existing wells in Clearmont. Actual municipal well yields in the Tertiary aquifer system range from 5 to 500 gpm. Groundwater quality generally meets the EPA drinking water standards. The most commonly observed exceedances include fluoride, radium, iron, and TDS. Generally, the best quality water is found in the lenticular sandstones of the Tongue River Member of the Fort Union Formation (Soda Butte Services, Inc. and others, 1994; Wester-Wetstein & Assoc., Inc., 2004). Groundwater from the Tullock Member is generally higher in fluoride, sodium, and TDS (Wester-Wetstein & Assoc., Inc., 2004). Total depths of Tertiary system municipal wells may be as high as 3,000 ft.

In the Upper Niobrara Basin communities of Lusk and Manville, groundwater is obtained from the Arikaree Formation of the High Plains aquifer system. WWDC exploration wells in the Arikaree yield up to 400 gpm and are completed at depths of less than 500 ft. Groundwater from the Lusk #9 Test Well did not meet EPA standards for uranium and gross alpha particle levels.

9.1.5 Current WWDO, USGS, and SEO projects

In addition to the previous studies summarized in appendix B, the WWDO is updating the previous Powder/Tongue and Northeast River Basin water plans (HKM Engineering and others, 2002a, b) and constructing a hydrological model for surface flows in the basins (RESPEC and others, 2019 a, b). WWDO is also conducting groundwater projects in Buffalo, Lusk, and Clearmont (http://wwdc.state.wy.us/planning_program/all_projects.html) Additionally, the USGS continues to collect real-time streamflow data and periodic water quality at 21 USGS stream gaging stations located in the basins (<http://waterdata.usgs.gov/wy/nwis/current/?-type=flow>).

9.1.6 Groundwater interference and interconnection with surface water

Other factors that must be considered for new groundwater projects are the potential for interference between wells or well fields completed in the same aquifer, excessive drawdowns in over-utilized aquifers, and interconnections between groundwater and surface water. Wells alone do not necessarily present significant problems to a public water system depending on several factors, including the physical and hydrogeologic properties of the target aquifer, construction of the production wells, and the timing and rate(s) of well production. In aquifers possessing high degrees of secondary (fracture) permeability, well interference may occur over the scale of several

miles. In many cases, municipal water supply personnel are aware of well interference effects in their facilities, and effectively manage them by adjusting well pumping times and rates, or by periodically switching to other sources of municipal water.

Excessive drawdown, or groundwater depletion, in over-utilized aquifers has become a national concern (Stanton and others 2011; Konikow, 2013). It is a concern in parts of the Powder River Structural Basin where coalbed natural gas (CBNG) production was extensive. Groundwater declines of more than 100 ft have been documented in some PRB coal seam aquifers (Taboga and others, 2015) and in adjacent sandstone strata (Taboga and others, 2017) during CBNG production. Further monitoring is needed to quantify groundwater level responses to subsequent declines in CBNG production in the affected aquifers. Further monitoring may also reveal how these changes may impact adjacent aquifers that provide potable water to basinward communities (WSEO, 1995; Weston Engineering, 2008).

Large declines in hydraulic head from over-pumping can reduce aquifer water levels to the point where groundwater discharges to surface water bodies are reduced, thereby diminishing streamflow volumes (Barlow and Leake, 2012). In extreme cases, groundwater levels may decline below the elevation of the streambed, causing streamflows to recharge the aquifer. This effect, called pumping-induced recharge, may dry up spring flows or turn gaining streams into losing streams (Winter and others, 1998; Barlow and Leake, 2012).

9.2 RECOMMENDATIONS FOR FUTURE UPDATES

The quality of the Wyoming State River Basin water plans is limited by the availability of data and the institutional resources used to develop the compiled information into a readily accessible and useful format for stakeholders. While some information (e.g., hydrogeology studies, SEO groundwater permits, data from the DEQ and other agencies) is generally available for all basins, other information (e.g. regional groundwater modeling) does not exist. The quantity, accuracy, and completeness of available groundwater information vary between the major drainage basins of Wyoming.

The purpose(s) of updating an available groundwater determination memorandum can be to include new information, to include older information not initially provided, or to utilize continuously improving technology to maximize the value of the information presented. While information in some areas will grow slowly (e.g.

mapping of geologic and hydrogeologic units), other information (e.g., SEO and other agency data) requires regular updates to maintain its utility.

9.2.1 Data challenges

Computing capabilities will continually improve but will always be limited by the availability and reliability of the input data. The quality of a compilation study such as this relies on the quality of the available data. The development of a comprehensive statewide database for water quality and aquifer physical characteristics would greatly assist Wyoming water professionals to manage and protect the state's valuable water resources.

Currently, hydrogeologic and hydrogeochemical data exist that could be integrated into a more comprehensive and evolving groundwater database for Wyoming. For example, DEQ collects copious amounts of groundwater data for site-specific investigations of contaminated sites, for issuing industrial permits (e.g. mining, underground injection control, waste and wastewater management), and for monitoring for potential impacts. The SEO collects groundwater information from selected wells. The USGS, WOGCC, BLM, EPA, counties, municipalities, other agencies, and private entities all collect hydrologic information for a variety of activities and purposes. However, coordination between the various entities collecting groundwater information is generally lacking, and clearly there is abundant relevant information that was not and is not accessible for this study and groundwater determinations in other basins. While the quality of some of this information may not be consistent with the standards described in chapter 7, those data could be qualified. Some data (e.g., on contaminated samples), however, would not be representative of natural groundwater, and some water quality analyses (e.g., for contaminated sites and industrial site monitoring) would be for constituents not commonly used to characterize natural groundwater quality; nevertheless, a comprehensive database would be useful.

Ongoing revision and maintenance of a comprehensive groundwater information database where data are continually being generated by numerous entities would be a substantial project, requiring a continuing commitment of resources by federal, state, and local agencies, and is certainly easier described than done. As interest in groundwater resources increases, so will justification for such a program.

9.2.2 Current and future research efforts

This study is a compilation of previous investigations conducted primarily by state and federal agencies and

consultants. Any significant advancements in the development of the conceptual model of the hydrogeology of the northeast river basins require further original research, most likely conducted by academic investigators, USGS water scientists, or by consultants employed by the WWDC, SEO, or Wyoming municipalities. The recent formation of the Wyoming Center for Environmental Hydrology and Geophysics (WyCEHG) should prove to be particularly valuable to developing a better understanding of groundwater resources in NERB. Funded for a five-year period by the National Science Foundation, WyCEHG efforts are specifically targeted to advancing research in western hydrologic systems using advanced geophysics and remote sensing technologies. The stated goals of WyCEHG are:

- To improve understanding of mountain front hydrology by characterizing the processes that partition water into streams, soils, plants, rivers, and aquifers in several locations throughout the state
- To improve understanding of how disturbances affect water flux by studying effects on hydrological systems from climate change, bark beetle infestations, and energy extraction
- To improve integrated modeling of the fate and transport of water by creating integrated computer models that will provide the scientific knowledge and tools for improved prediction of hydrological processes

- To provide cutting edge resources and tools for educators and watershed managers in the state

Further information for WyCEHG can be accessed at: <http://www.uwyo.edu/epscor/wycehg/>.

The recharge calculations contained in section 6.2, went beyond summarizing existing information by using the data to estimate the groundwater resource. The recharge evaluation in this study could easily be updated and the results refined as new data is collected, with a relatively low-level commitment of resources. The estimation of recharge can be enhanced by numerical modeling in selected areas that include additional variables that affect infiltration and recharge (sec. 5.1.3).

Finally, there are several areas where additional geologic mapping would develop useful information for future water plan updates. More detailed geologic mapping would better define the hydrogeologic role of the basin's geology, further identify areas where groundwater and surface water may be interconnected, and determine areas where vertical recharge may be enhanced by fracture permeability.