Chapter 2

Background

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The data contained in this basin groundwater update were obtained from regional and area-specific studies conducted by state and federal agencies in Nebraska, Montana, South Dakota, and Wyoming. This chapter discusses the data sources, approach, organization, and mapping through Geographic Information Systems (GIS) used in this study, and compares these points to the previous Groundwater Technical Memoranda contained within the 2002 Powder/Tongue (HKM Engineering and others, 2002a) and Northeast River Basin Water Plans (HKM Engineering and others, 2002b).

The 2002 Powder/Tongue (HKM Engineering and others, 2002a) and Northeast River Basin Water Plans (HKM Engineering and others, 2002b) and the 2007 Wyoming Framework Water Plan (WWC and others, 2007) are cited frequently in this study. In this report, online links are provided to these earlier studies and other sources of data.

2.1 SOURCES OF DATA

Agencies that contributed data and information for this study include:

BLM	U.S. Bureau of Land Management
EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UW	University of Wyoming Libraries
WRDS	University of Wyoming Water Resources Data System
WDEQ	Wyoming Department of Environmental Quality
WyGISC	Wyoming Geographical Information Science Center
WOGCC	Wyoming Oil and Gas Conservation Commission
WRRI	Wyoming Water Resources Research Institute
SEO	State Engineer's Office (Wyoming)
WSGS	Wyoming State Geological Survey
WWDC	Wyoming Water Development Commission
WWDO	Wyoming Water Development Office

2.2 PREVIOUS REGIONAL-SCALE INVESTIGATIONS

Numerous surface water and groundwater management studies have been conducted for areas contained wholly or partly within the combined Powder, Tongue, and Northeast river basins. The geographic scale of these earlier projects varies considerably. This study builds on these previous compilations. Primary hydrogeologic studies and associated supporting geologic investigations of the basin area are listed below in approximate chronologic order by agency and author(s). Notes have been included in italics to explain relevant content for some citations, as well as online links to agency websites where full content publications may be found.

- *U.S. Geological Survey Hydrologic Investigation Atlases (https://pubs.er.usgs.gov/)*

1973 - Hodson, W.G., Pearl, R.H., and Druse, S.A., 1973, Water resources of the Powder River Basin and adjacent areas, northeastern Wyoming: U.S. Geological Survey Hydrologic Atlas 465, 4 pl., scale 1:250,000. Study area of HA-465 encompasses all river basins examined in this groundwater memorandum excepting the Niobrara River Basin.

1980 - Gutentag, E.D., and Weeks, J.B., 1980, Water table in the High Plains aquifer in 1978 in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey Hydrologic Atlas 642, 1 pl., scale 1:2,500,000. Includes Niobrara and parts of Cheyenne River basins.

1981 - Weeks, J.B., and Gutentag, E.D., 1981, Bedrock geology, altitude of base, and 1980 saturated thickness of the high plains aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey Hydrologic Atlas 648, 2 pl., scale 1:2,500,000. Includes Niobrara and parts of Cheyenne River basins.

1982 - Kroethe, N.C., Oliver, J.W. and Weeks, J.B., 1982, Dissolved solids and sodium in water from the High Plains aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey Hydrologic Atlas 658, 2 pl., scale 1:2,500,000. Includes Niobrara and parts of Cheyenne River basins.

Luckey, R.R., Gutentag, E.D. and Weeks, J.B., 1982, Water-level and saturated-thickness changes, predevelopment to 1980, in the High Plains aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey Hydrologic Atlas 652, 2 pl., scale 1:2,500,000. Includes Niobrara and parts of Cheyenne River basins.

1990 - Bedinger, M.S., and Langer, W.H., 1990, Reconnaissance study of the thickness of the unsaturated zone in the western conterminous United States: U.S. Geologic Survey Hydrologic Investigations Atlas HA-715, 1 pl., scale 1:2,500,000. Includes thickness data for Bighorn Mt. headwaters of Powder, Tongue and Little Bighorn rivers.

1996 - Whitehead, R.L., 1996, Groundwater atlas of the United States, segment 8, Montana, North Dakota, South Dakota, Wyoming: U.S. Geologic Survey Hydrologic Investigations Atlas HA-730-I, 24 p.

2002 - Bartos, T.T., Hallberg, L. L., and Ogle, K.M., 2002, Potentiometric surfaces, altitudes of the tops, and hydrogeology of the Minnelusa and Madison aquifers, Black Hills area, Wyoming: U.S. Geologic Survey Hydrologic Investigations Atlas HA-748, [variously paged].

Carter, J.M., Driscoll, D.G., Williamson, J.E., and Lindquist, V.A., 2002, Atlas of water resources in the Black Hills area, South Dakota: U.S. Geological Survey Hydrologic Investigations Atlas HA–747, 120 p.

- *Basin studies (http://library.wrds.uwyo.edu/) by the University of Wyoming, Water Resources Research Institute, and the Wyoming Natural Resource Board*

1961 - Dana, G.F., 1961, Underground water report for the city of Sundance, Wyoming: report prepared by Wyoming Natural Resources Board, Cheyenne, Wyoming, [variously paged].

1962 - Dana, G.F., 1962, Groundwater reconnaissance study of the State of Wyoming—Introduction and seven basin reports: Prepared for Wyoming Natural Resource Board, Cheyenne, Wyoming, 355 p.

1972 - Wyoming State Engineer's Office, 1972, Water & related land resources of northeastern Wyoming: Wyoming Water Planning Program, Cheyenne, Wyoming, Report No. 10, 180 p.

1977 - Davis, R.W., and Rechard, P.A., 1977, Effects of surface mining upon shallow aquifers in the eastern Powder River Basin, Wyoming: Laramie, University of Wyoming, Water Resources Research Institute Water Resources Series no. 67, 47 p.

Wyoming State Engineer's Office, 1977, Report on the Gillette project—A system of water wells in the Madison Formation and pipeline transmission to the Gillette area: Wyoming Water Planning Program, Cheyenne, Wyoming, 59 p.

1979 - Wells, D.K., 1979, Chemical analyses of water from the Minnelusa Formation and equivalents in the Powder River Basin and adjacent areas, northeastern Wyoming—A basic-data report: Wyoming Water Planning Program, Cheyenne, Wyoming, Report No. 18, 31 p.

1980 - Brown, J.D., 1980, Regional hydrogeology of the Gillette, Wyoming area (with a discussion of cumulative regional impacts of surface coal mining and reclamation), in Proceedings, Second Wyoming Mining Hydrology Symposium: Laramie, University of Wyoming, Water Resources Research Institute, p. 10–42.

Eisen, C., Feathers, K.R., and Kerr, G., 1980, Preliminary findings of the Madison baseline study: Laramie, University of Wyoming Water Resources Research Institute: report prepared for Wyoming State Engineer's Office and ETSI, 72 p.

1981 - Eisen, C., Feathers, K.R., and Kerr, G., 1981, Progress report on phase 2 of the Madison baseline study: Laramie, University of Wyoming Water Resources Research Institute: report prepared for Wyoming State Engineer's Office and ETSI, 29 p.

Feathers, K.R., Libra, R., and Stephenson, T.R., 1981, Occurrence and characteristics of ground water in the Powder River Basin: Report to U.S. Environmental Protection Agency, contract number G-008269-79, by Water Resources Research Institute, Laramie, Wyoming, 239 p., 8 pl., scale 1:500,000. Does not include Niobrara River Basin or some parts of Cheyenne River Basin.

Libra, R.D., Collentine, M., and Feathers, K.R.. 1981. Occurrence and characteristics of ground water in the Denver-Julesburg Basin, Wyoming. Report to U.S. Environmental Protection Agency, contract number G-008269-79, by Water Resources Research Institute, Laramie, Wyoming, 122 p., 8 pl., scale 1:500,000. Includes Niobrara River Basin and some portions of Cheyenne River Basin.

Richter, H.R., Jr., 1981, Occurrence and characteristics of groundwater in the Wind River Basin, Wyoming: Laramie, University of Wyoming Water Resources Research Institute, v. IV–A [variously paged] and v. IV–B (11 pls).

1997 - Wyoming Water Resources Center, 1997, A study of techniques to assess surface and groundwater impacts associated with coalbed methane and surface coal mining, Little Thunder Creek drainage, Wyoming: Laramie, University of Wyoming, Wyoming Water Resources Center [variously paged].

- *Wyoming State Geological Survey (http://sales.wsgs.wyo.gov/) and Wyoming Geological Association (http://www.wyogeo.org/) reports*

1958 - Wyoming Geological Association, 1958, Powder River Basin, Wyoming: Wyoming Geological Association 13th Annual Field Conference Guidebook, 341 p.

1968 - Wulf, G.R., 1968, Lower Cretaceous Muddy Sandstone in the northern Rockies: Wyoming Geological Association 20th Annual Field Conference Guidebook, p. 29–34.

1971 - Curry, W.H. III, 1971, Laramide structural history of the Powder River Basin, Wyoming: Wyoming Geological Association 23rd Annual Field Conference Guidebook,, p. 49–60.

1976 - Davis, R.W., 1976, Hydrologic factors related to coal development in the eastern Powder River Basin: Wyoming Geological Association 28th Annual Field Conference Guidebook, p. 203–207.

Glass, G.B., 1976, Update on the Powder River coal basin: Wyoming Geological Association 28th Annual Field Conference Guidebook, p. 209–220.

Law, B.E., 1976, Large-scale compaction structures in the coal-bearing Fort Union and Wasatch formations, northeast Powder River Basin, Wyoming: Wyoming Geological Association 28th Annual Field Conference Guidebook, p. 221–229.

1977 - WSGS, 1977, Preliminary geologic map of the Buffalo area, northwest Powder River Basin, Wyoming: Wyoming State Geological Survey Preliminary Geologic Map MF-806, scale 1:50,000.

1980 - Flores, R.M., 1980, Fluvial coal setting of the Tongue River member of the Fort Union Formation in the Powder River-Clear Creek area, Wyoming: Geological Survey of Wyoming Publication Information Circular 14, p. 71–95.

Glass, G.B., 1980, Coal resources of the Powder River basin coal basin: Geological Survey of Wyoming Public Information Circular 14, p. 97–131.

1985 - Rasmussen, D.L., Jump, C.J., and Wallace, K.A., 1985, Deltaic systems in the Early Cretaceous Fall River Formation, southern Powder River Basin, Wyoming: Wyoming Geological Association 36th Annual Field Conference Guidebook, p. 91–111.

1990 - Jones, R.W., and De Bruin, R.H., 1990, Coalbed methane in Wyoming: Wyoming State Geological Survey Public Information Circular 30, 15 p.

Pierce, F.W., Johnson, E.A., Molnia, C.L., and Sigleo, W.R., 1990, Cross sections showing coal stratigraphy of the southeastern Powder River Basin, Wyoming: U.S. Geological Survey Miscellaneous Investigations Series Map I–1959–B, scale 1:500,000, 2 sheets.

1991 - Pierce, F.W., and Johnson, E.A., 1991, Stratigraphic cross section showing upper Paleocene coal-bearing rocks of the Tongue River member of the Fort Union Formation in the Piney Canyon NE and Piney Canyon NW quadrangles, Campbell and Weston Counties, southeastern Powder River Basin, Wyoming: U.S. Geological Survey Miscellaneous Investigations Series Map I–2011, scale 1:24,000.

1992 - Nichols, D.J., and Brown, J.L., 1992, Palynostratigraphy of the Tullock member (lower Paleocene) of the Fort Union Formation in the Powder River Basin, Montana and Wyoming: U.S. Geological Survey Bulletin 1917–F, 35 p.

1993 - Love, J.D., Christiansen, A.C., and Ver Ploeg, A.J., 1993, Stratigraphic chart showing the Phanerozoic nomenclature for the state of Wyoming: Wyoming State Geological Survey Map Series MS-41, no scale, 1 sheet.

1994 - Flores, R.M., Roberts, S.B., and Perry, W.J., Jr., 1994, Paleocene paleogeography of the Wind River, Bighorn, and Powder River basins, Wyoming: Wyoming State Geological Survey Public Information Circular 33, p. 1–16.

Nichols, D.J., 1994, Palynostratigraphic correlation of Paleocene rocks in the Wind River, Bighorn, and Powder River basins, Wyoming: Wyoming State Geological Survey Public Information Circular 33, p. 17–29.

1997 - Keystone Coal, 1997, Coal geology of Wyoming: 1997 Keystone Coal Industry Manual, 21 p. (Reprint 1997, Wyoming State Geological Survey).

Heffern, E.L., and Coates, D.A., 1997, Clinker—its occurrence, uses, and effects on coal mining in the Powder River Basin: Wyoming State Geological Survey Public Information Circular 38, p. 151–165.

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Heffern, E.L., and Coates, D.A., 1999, Hydrogeology and ecology of clinker in the Powder River Basin, Wyoming and Montana: Wyoming Geological Association 50th Annual Field Conference Guidebook, p. 231–252.

Hunter, J., 1999, Fluvial architecture and paleo-groundwater infiltration of the Fort Union Formation near the Highland Uranium Mine, southern Powder River Basin, Wyoming: Wyoming Geological Association 50th Annual Field Conference Guidebook, p. 119–139.

Meyer, J., 1999, General drawdown map of the Wyodak-Anderson coal bed, 1980 to 1998: Wyoming Geological Association 50th Annual Field Conference Guidebook, p. 87–88.

2005 - Frost, C.D., and Brinck, E.L., 2005, Strontium isotopic tracing of the effects of coalbed natural gas development on shallow and deep groundwater systems in the Powder River Basin, Wyoming: Wyoming State Geological Survey Report of Investigations 55, p. 93–107.

2006 - Jones, N.R., Quillinan, S.A., Hays, R.J., and Rodgers, J.R., 2006, Net coal thickness within the Powder River watershed, Wyoming: Wyoming State Geological Survey Open File Report 06-9, 1 sheet, scale 1:200,000.

2007- Surdam, R.C., Jiao, Z., and Heasler, H.P., 2007, Origin of thermogenic and biogenic natural gas in the Tongue River Member coals of the Fort Union Formation, northeastern Powder River Basin, Wyoming: Wyoming State Geological Survey Report of Investigations 58, 43 p.

2008 - Jones, N.R., 2008, Coal bed nomenclature and distribution: Wyoming State Geological Survey Exploration Memoir 2, p. 45–108.

2009 - Clarey, K.E., 2009, 1990–2006 coalbed natural gas (CBNG) regional groundwater monitoring report, Powder River Basin, Wyoming: Wyoming State Geological Survey Open File Report 09-10, 126 p. This series (see next four reports, examines water level changes related to coal bed methane development.

2010 - Clarey, K.E., Gribb, N.W., Hays, R.J., and McLaughlin, J.F., 2010, 1993–2006 coalbed natural gas regional groundwater monitoring report, Powder River Basin, Wyoming: Wyoming State Geological Survey Open File Report 10-2, 96 p.

2012 - McLaughlin, J.F., Rodgers, J.R., Gribb, N.W., Hays, R.J., and Cottingham, K.D., 2012, 2009 coalbed natural gas regional groundwater monitoring update, Powder River Basin, Wyoming: Wyoming State Geological Survey Open File Report 12-5, 391 p.

Quillinan, S.A., and Frost, C.D., 2012, Spatial variability of coalbed natural gas produced water quality, Powder River Basin, Wyoming—implications for future development: Wyoming State Geological Survey Report of Investigations 64, 56 p.

2013 - Stafford, J.E., and Wittke, S.J., 2013, 2012 coalbed natural gas regional groundwater monitoring update, Powder River Basin, Wyoming: Wyoming State Geological Survey Open File Report 13-1, 347 p.

2014 - Taboga, K.G., and Stafford, J.E., 2014, 2013 coalbed natural gas regional groundwater monitoring update, Powder River Basin, Wyoming: Wyoming State Geological Survey Open File Report 14-1, 353 p.

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- *Wyoming State Geological Survey maps (http://sales.wsgs.wyo.gov/)*

1987 - Ver Ploeg, A.J., and Greer, P.L., 1987, Preliminary geologic map of the Mayoworth quadrangle, Johnson County, Wyoming: Wyoming Geological Survey Open File Report 87-4, 2 sheets, scale 1:24,000.

Ver Ploeg, A.J., and Greer, P.L., 1987, Preliminary geologic map of the Red Fork Powder River quadrangle, Johnson County, Wyoming: Wyoming State Geological Survey Open File Report 87-5, 2 sheets, scale 1:24,000.

1988 - Ver Ploeg, A.J., De Bruin, R.H., and Greer, P.L., 1988, Preliminary geologic map of the Barnum quadrangle, Johnson County, Wyoming: Wyoming State Geological Survey Open File Report 5, scale 1:24,000.

Ver Ploeg, A.J., De Bruin, R.H., and Greer, P.L., 1988, Preliminary geologic map of the Fraker Mountain quadrangle, Johnson County, Wyoming: Wyoming State Geological Survey Open File Report 88-4, scale 1:24,000.

1991 - Ver Ploeg, A.J., and Greer, P.L., 1991, Preliminary geologic map of the Monument Hill quadrangle, Washakie and Johnson Counties, Wyoming: Wyoming State Geological Survey of Wyoming Open File Report 91-5, scale 1:24,000.

Ver Ploeg, A.J., and Greer, P.L., 1991, Preliminary geologic map of the Beartrap Meadows quadrangle, Johnson County, Wyoming: Wyoming State Geological Survey Open File Report 91-4, scale 1:24,000.

1992 - Ver Ploeg, A.J., and Greer, P.L., 1992, Preliminary geologic map of the Packsaddle Canyon quadrangle, Johnson County, Wyoming: Wyoming State Geological Survey Open File Report 92-1, scale 1:24,000.

1995 - Ver Ploeg, A.J., and Greer, P.L., 1995, Geologic map of the Beartrap Meadows quadrangle, Johnson County, Wyoming: Wyoming State Geological Survey Map Series 45, scale 1:24,000.

Ver Ploeg, A.J., and Greer, P.L., 1995, Geologic map of the Monument Hill quadrangle, Washakie and Johnson Counties, Wyoming: Wyoming State Geological Survey Map Series 44, scale 1:24,000.

1998 - Boyd, C.S., and Ver Ploeg, A.J., 1998, Geologic map of the Gillette 30' x 60' quadrangle, Campbell, Crook, and Weston Counties, Wyoming: Wyoming State Geological Survey Map Series 49, scale 1:100,000.

Case, J.C., Arneson, C.S., and Hallberg, L.L., 1998, Preliminary 1:500,000-scale digital surficial geology map of Wyoming: Wyoming State Geological Survey, Geologic Hazards Section Digital Map 98–1, scale 1:500,000.

Ver Ploeg, A.J., 1998, Preliminary geologic map of the Hole-In-The-Wall Quadrangle, Johnson County, Wyoming: Wyoming State Geological Survey Preliminary Geologic Map 98-2, scale 1:24,000.

1999 - Hallberg, L.L., and Case, J.C., 1999, Preliminary surficial geologic map of the Sundance 30' x 60' quadrangle, Crook and Weston Counties, Wyoming, and southwestern South Dakota: Wyoming State Geological Survey Hazards Section Digital Map 01-6, scale 1:100,000.

Hallberg, L.L., and Case, J.C., 1999, Preliminary digital surficial geologic map of the Buffalo 30' x 60' quadrangle, Johnson and Campbell Counties, Wyoming: Wyoming State Geological Survey Hazards Section Digital Map 00-2, scale 1:100,000.

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Hallberg, L.L., and Case, J.C., 1999, Preliminary digital surficial geologic map of the Lusk 30' x 60' quadrangle, Converse and Niobrara Counties, Wyoming and northwestern Nebraska: Wyoming State Geological Survey Hazards Section Digital Map 01-5, scale 1:100,000.

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Hallberg, L.L., and Case, J.C., 2000, Preliminary surficial geologic map of the Newcastle 30' x 60' quadrangle, Weston and Niobrara Counties, Wyoming: Wyoming State Geological Survey Hazards Section Digital Map 00-5, scale 1:100,000.

Hallberg, L.L., and Case, J.C., 2000, Preliminary surficial geologic map of the Worland 30' x 60' quadrangle, Johnson, Washakie, and Big Horn Counties, Wyoming: Wyoming State Geological Survey Hazards Section Digital Map 00-6, scale 1:100,000

2001 - Hallberg, L.L., and Case, J.C., 2001, Preliminary digital surficial geologic map of the Devils Tower 30' x 60'quadrangle, Crook County, Wyoming and western South Dakota, southeastern Montana: Wyoming State Geological Survey Hazards Digital Map 01-3, scale 1:100,000.

Hallberg, L.L., and Case, J.C., 2001, Preliminary digital surficial geologic map of the Lance Creek 30' x 60' quadrangle, Niobrara and Converse Counties, Wyoming, southwestern South Dakota, and northwestern Nebraska: Wyoming State Geological Survey Hazards Section Digital Map 01-4, scale 1:100,000.

Ver Ploeg, A.J., and Boyd, C.S., 2001, Preliminary digital geologic map of the Sheridan 30' x 60' quadrangle, Sheridan, Johnson and Campbell Counties Wyoming and southeastern Montana: Wyoming State Geolological Survey Hazards Section Digital Map 1, 1 sheet, scale 1:100,000.

2002 - Hallberg, L.L., and Case, J.C., 2002, Preliminary surficial geologic map of the Nowater Creek 30' x 60' quadrangle, Washakie, Hot Springs, and Johnson Counties, Wyoming: Wyoming State Geological Survey Open File Report 04-3, 11 p., scale 1:100,000.

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2006 - McLaughlin, J.F., and Ver Ploeg, A.J., 2006, Geologic map of the Newcastle 30' x 60' quadrangle, Weston and Niobrara Counties, Wyoming, and Pennington and Custer Counties, South Dakota: Wyoming State Geological Survey Map Series 71, scale 1:100,000.

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- *Wyoming Water Development Commission Project Reports are listed in Appendix B and are available online at: http://library.wrds.uwyo.edu/wwdcrept/wwdcrept.html. Project reports are listed in Appendix B, alphabetized by location, and include brief project descriptions and summary project recommendations. Separate associated publications (executive summaries, interim reports and appendices) are also available on the WRDS website, and are noted in italics following each citation.*

2.3 CURRENT WWDC AND USGS HYDROGEOLOGIC INVESTIGATIONS IN THE POWDER/TONGUE/NORTHEAST RIVER BASINS

Currently, the WWDO is updating the 2002 Powder/Tongue (HKM Engineering and others, 2002a) and Northeast River Basin Water Plans (HKM Engineering and others, 2002b). Additionally, WWDO is presently conducting groundwater studies in Buffalo, Clearmont, Lusk, and Newcastle. WWDO is also studying the feasibility of connecting the Buckskin, Fox Ridge, and Grace Land communities to the Gillette Regional Water Supply. The U.S. Geological Survey (USGS) is not currently conducting specific hydrogeologic investigations in the NERB. However, recent USGS reports which discuss the

hydrogeology of the Powder River and Williston structural basins (Long and others, 2014; Thamke and others, 2014) in detail can be obtained from the USGS publications website: http://pubs.er.usgs.gov/. Additionally, the USGS continues to collect real time streamflow data and periodic water quality at twenty-one USGS gaging stations located in the NERB: http://waterdata.usgs.gov/wy/nwis/current/?type=flow.

2.4 CURRENT AVAILABLE GROUNDWATER DETERMINATION

The above noted previous investigations examined the hydrogeology of geographic areas of varying scale that fall partly or entirely within the NERB. The study area of this and the previous memoranda (HKM Engineering, 2002a, b) include the surface drainages of the NERB that lie within the borders of the state of Wyoming, as well as watersheds that are tributary to the Wyoming NERB in Montana, South Dakota, and Nebraska (fig. 3-1).

A detailed hydrostratigraphy of the NERB was developed by the USGS for this study based on stratigraphic regions by Love and others (1993). Development of the updated hydrostratigraphy is described in chapter 7 and summarized on hydrostratigraphic nomenclature charts (pls. 4-6), and on plate 2.

This Available Groundwater Determination provides expanded information on several topics to more fully characterize the groundwater resources of the NERB, including:

- Effects of structure on groundwater distribution and flow (section 5.4 and chapter 7)
- Potential hydrothermal resources (chapter 4)
- Aquifer vulnerability and potential sources of groundwater contamination (section 5.6)
- Comparisons of calculated aquifer(s)—specific recharge volumes with updated precipitation data, and current and projected beneficial uses (section 6.2)
- A basin-wide water balance (chapter 8)
- A detailed listing and summary of historic groundwater development studies by the WWDC in the NERB (Appendix B)

2.5 MAPS

Progressive improvements in GIS technology have enhanced the geologist's ability to process and present large, complex geospatially linked datasets for natural resource evaluations. To meet the objectives of this updated Available Groundwater Determination, the WSGS and USGS developed a series of maps to present and evaluate the extensive digital data resources available on NERB groundwater resources. Several maps were generated wholly or primarily from existing GIS databases compiled specifically for this study. Some of the maps and layers were supplemented with information scanned or digitized from existing hard copy maps into GIS-supported formats.

The accuracy of any map or figure depends on the accuracy of the original data and the methods used to process it. Frequently, data processing for large compilations requires correlations between multiple disparate datasets. The limitations of the data used in digital mapping make it necessary for the analyst to provide the reader with interpretive qualifications regarding the reliability of the produced maps and figures. This memorandum provides discussions of data limitations and cites data sources for each map and figure presented.

Additionally, metadata (qualifying information on the GIS datasets) is commonly furnished along with the GIS data. Metadata provides structured and detailed descriptive information about the data resources used to develop GIS map layers. Metadata facilitates the understanding, use, and management of the data by defining its sources, locations, formats, attributes, processing, limitations, disclaimers, etc. Where appropriate, the metadata includes contact information to obtain additional information. The metadata associated with the NERB maps are provided online at http://waterplan.state.wy.us/.

WSGS and USGS generated the maps for this study in two formats. Plate-scale maps use 1:380,000 scale (1 inch = 6 miles). Figure-scale maps use variable scales that allow the maps to fit either 8½ × 11-inch, or 11 × 17-inch sheets.