Bear River Basin Water Plan Update
Groundwater Study Level II (2010 - 2014)

Available Groundwater Determination
Technical Memorandum No. 6

Executive Summary

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INTRODUCTION

Between 2001 and 2006 the Wyoming Water Development Commission (WWDC) completed individual water plans for each of Wyoming's seven major river basins. One of the first water plans completed during that period, for the Bear River Basin (Forsgren and Associates, 2001) included an available groundwater determination in **Appendix O** (Forsgren and Associates, 2001). The 2014 Available Groundwater Determination presented in this report updates and expands the previous technical memorandum with a new compilation of information and represents the most current assessment of the groundwater resources of the Bear River Basin. This technical memorandum has the following objectives:

- Identify the major (most widely used) aquifers in the Bear River Basin.
- Define the three-dimensional extent of the aquifers.
- Describe the physical characteristics, water chemistry, and potential contaminants of the aquifers and confining (hydrogeologic) units.
- Estimate the quantity of water in the aquifers.
- Describe the aquifer recharge areas.
- Estimate aquifer recharge rates.
- Estimate the "safe yield" potential of the aquifers and describe implications of hydrologically connected groundwater and surface water.
- Describe and evaluate existing groundwater studies and models.
- Identify future groundwater development opportunities to satisfy projected agricultural, municipal, and industrial demands.

BEAR RIVER BASIN DESCRIPTION

This report examines groundwater resources that underlie the Bear River drainage basin in Wyoming, as well as in areas in Idaho and Utah that are tributary to the Wyoming part of this basin. The Bear River is the major tributary to the Great Salt Lake. The mainstem of the Bear River begins at the confluence of Hayden Fork and Stillwater Fork in Summit County, Utah. Primary tributaries that confluence with the Bear River in Wyoming include Sulphur, Bridger, and Twin creeks and Thomas and Smith's forks. Woodruff Creek and Saleratus Creek are significant Utah tributaries to the Bear River. The hydrologic divides of these drainages define the limits of the Bear River Basin study area.

The Bear River Basin covers approximately 1,494 square miles (0.95 million acres) or 1.5 percent of Wyoming's surface area. The tributary watershed in southeastern Idaho is small, about 18 square miles (0.01 million acres). Approximately 1,112 square miles (0.71 million acres) of tributary watershed are located in northeastern Utah. In Wyoming, the Bear River Basin includes 23 percent of Uinta County and 24 percent of Lincoln County. In Utah, the tributary watershed covers 15 percent of Summit and 75 percent of Rich counties (**Fig. 3-1 main report**).

The Bear River Basin encompasses about 1.5 percent of Wyoming's total surface area; it serves as home to approximately 14,500 people or about 2.4 percent of the state's current population (2010 census). The Bear River Basin contains three incorporated municipalities (Evanston, Cokeville, and Bear River); a U.S. Census Designated Place (CDP), Taylor; approximately 2,000 people live in rural areas.

The landscape of the Bear River Basin consists of several mountain ranges of the middle Rocky Mountains, valleys, rolling plains, plateaus, escarpments, bluffs, hills, drainage ways, and structural basins. In Wyoming, elevations in the Bear River Basin range from 6,055 feet above mean sea level where the Bear River crosses the Wyoming-Idaho state line, to 10,761 feet at Mount Isabel (WWDO, 2012).

Climate types in the Bear River Basin range from semi-arid continental within the basin interior, to humid-alpine in the bordering mountains. The mountain ranges capture much of the atmospheric moisture through orographic uplift, increasing annual precipitation in the mountainous regions while substantially decreasing precipitation in the basin interiors. Air temperatures vary by season from well below 0°F in the winter, to more than 100°F in the summer. Annual precipitation increases with surface elevation (**Fig. 3-3, main report**) and can exceed 40 inches a year in the high mountain headwater areas near Smith's Fork; average annual precipitation for the entire basin is 21 inches (PRISM, 2013). Most precipitation within the basin occurs as snowfall during the winter and early spring and as convective thunderstorms during late spring and summer months (Ahern and others, 1981).

Land use in the Bear River Basin is controlled primarily by elevation, climate, the distribution of surface waters, precipitation, and the location of mineral resources. Above timberline, the alpine lands are generally used for recreational purposes. At lower elevations, thickly forested areas are utilized for recreation and limited (mostly historic) logging. Grazing is the dominant use for rangelands, foothills, and riparian areas. Agriculture plays a significant role in the basin; approximately 6.6 percent (63,900 acres) of its surface area consists of irrigated cropland (WWC Engineering, Inc. and others, 2007).

BEAR RIVER BASIN GEOLOGY

The Bear River Basin consists of two dominant structural features, the Thrust (or Overthrust) Belt and the Uinta Mountains. The Thrust Belt is a major continental feature, extending from British Columbia to the Uinta Mountains in Utah. The Uinta Mountains are an east-west trending range of Laramide age (35 – 80 million years ago (Ma)) that stretch eastward from the Wasatch Range in the west to the Sand Wash and Piceance basins in Colorado.

The Thrust Belt in the Bear River Basin consists of an expanse of on-strike valleys and ridges with significant topographic relief—up to 1,000 feet per mile in the north. Generally, Paleozoic and Mesozoic rocks were pushed eastward along a series of low-angle, westward-dipping, imbricated faults, creating significant thrust sheets. Stratigraphic displacement along the thrust faults range from 20,000 to 40,000 feet each. Numerous second-order thrusts exist within each sheet. The sediments within each thrust sheet are intensely folded, especially in the northern portion of the basin, and in some cases strata are overturned. Major breccia zones do not exist, and the rocks are not metamorphosed. The rocks generally maintain superposition, suggesting the thrusting occurred along bedding planes. The sub-parallel ranges are bound on the east by thrust faults and on the west by younger, high-angle normal or reverse faults that are down-drop to the west. Some of the normal faults show Holocene aged displacement, including the Bear River fault zone and the Rock Creek Fault.

The formation of the Thrust Belt began during the Sevier orogeny (140 – 50 Ma). Five main thrust systems exist within the Wyoming part of the Bear River Basin and the Utah and Idaho headwater areas (**Fig. 4-1, main report**). From oldest to youngest (west to east) they are the Paris-Willard, the Meade-Laketown, the Crawford, the Absaroka, and the Darby thrust systems.

The western Uinta Mountains in northeastern Utah are an east-west trending mountain range approximately 60 miles long in northeastern Utah. Rocks in the western Uinta Mountains range from Precambrian to Quaternary in age. The Uinta Mountains were emplaced as an asymmetric anticline in the late Cretaceous during the Laramide Orogeny. The Uinta anticline was thrust northward, forming the North Flank reverse fault. There are numerous subsidiary faults within the Uinta Mountains, creating broad zones of brecciated and fractured bedrock. Subsequent glacial activity in the high Uintas deposited large expanses of unconsolidated glacial debris across much of the western Uinta Mountains.

Mineral resources

Significant quantities of oil and natural gas have been developed in the Bear River Basin primarily in the areas around Evanston, including the Bear River Divide and drainages west of Evanston. Minimal coal, uranium, and metal mines exist in the Bear River Basin. Mapped coal mines are primarily historic pit mines, while a single historic uranium mine/pit was located near Sulphur Creek reservoir.

The Wyoming State Geologic Survey (WSGS) has evaluated numerous sites in the Bear River Basin for potential mineral deposits.

BASIN HYDROGEOLOGY

Groundwater circulation, availability and development

Complex Thrust Belt structures (Ahern and others, 1981), principally thrust, reverse, and normal faults, and fracture zones,

coupled with topography, control groundwater circulation in the Bear River Basin. Ahern and others (1981) discussed groundwater circulation by dividing Thrust Belt aquifers into three groups: 1) heavily fractured formations that pre-date the Upper Cretaceous deposition of the Hilliard Shale, 2) post-Hilliard Cretaceous and Tertiary units, and 3) Quaternary aquifers.
In terms of the volume of water withdrawn and the number of wells permitted, the most widely used aquifer system in the Bear River Basin is the Quaternary alluvial aquifer that lies along the Bear River and its tributaries (WWDO, 2012). Most of the basin's wells are located within the Quaternary system. Ahern and others (1981) report that the alluvial aquifer system is recharged primarily by direct infiltration of precipitation, discharge from bedrock aquifers, recharge from irrigation and infiltration of streamflows in losing reaches of headwater streams. Evapotranspiration, groundwater discharges into surface water flows, and withdrawals from wells constitute the principal forms of aquifer discharge. Groundwater flows within this system generally follow the topography of the watershed drainages, that is, toward or parallel to the channels of the Bear River and its tributary streams (Glover, 1990).

The Upper Cretaceous and Tertiary aquifers that formed after the deposition of the Hilliard Shale (89 – 84 Ma), constitute the most areally extensive bedrock aquifer exposures in the Bear River Basin, most notably in the southern half of the basin. The post-Hilliard group is extensively utilized and includes the Salt Lake, Fowkes, Wasatch, Evanston, and Adeville aquifers. Recharge to these aquifers consists of infiltration of rainfall and snowmelt and streamflow seepage in ephemeral streambed reaches. Natural discharge occurs primarily at gravity driven springs and seeps and as direct flows into alluvial sediments. Ahern and others, (1981) note that groundwater circulation in these aquifers is primarily controlled by local topography and that artesian discharge is common only along stream drainages.

Ahern and others (1981) noted that groundwater circulation in the highly fractured pre-Hilliard aquifers is heavily controlled by faults and fracture sets. Structural control of groundwater circulation is especially marked in the northern half of the Bear River Basin where numerous north-south parallel systems of reverse and normal faults typically lie in relatively close proximity to one another.

The Wyoming Statewide Framework Water Plan (WWC Engineering, Inc. and others, 2007) classified the Bear River Basin geologic units as follows:

Major Aquifer – Alluvial - Quaternary alluvium

Major Aquifer – Sandstone - Wasatch and Fowkes formations; Mesaverde Group; Nugget Sandstone; Gannett Group

Major Aquifer – Limestone - Wells Formation; Madison Group; Bighorn Dolomite; Flathead Sandstone

Minor Aquifer - Quaternary non-alluvial deposits; Twin Creek and Thaynes limestones; Evanston, Frontier and Phosphoria formations

Marginal Aquifer - Woodside Shale; Dinwoody Formation

Major Aquitard (Confining Unit) - Hilliard Shale; Bear River, Sage Junction, and Thomas Fork formations, Aspen Shale; Precambrian rocks

Natural groundwater quality and hydrogeochemistry
For this report, groundwater-quality data were gathered from the U.S. Geological Survey (USGS) National Water Information System (NWIS) database (USGS, 2012), the USGS Produced Waters Database (PWD) (USGS, 2010), the Wyoming Oil and Gas Conservation Commission (WOGCC) database (WOGCC, 2013), the University of Wyoming Water Resources Data System (WRDS) database, and other sources such as consultant reports prepared in relation to development of public water supplies.

Groundwater quality in the Bear River Basin varies widely, even within a single hydrogeologic unit. Water quality in any given hydrogeologic unit tends to be better near outcrop areas where recharge occurs, and tends to deteriorate as the distance from these areas increases (and residence time increases). Correspondingly, the water quality in a given hydrogeologic unit generally deteriorates with depth.

This report contains statistical analyses and trilinear diagrams of groundwater quality for both "environmental water" and for "produced water" samples. Environmental water samples are from wells of all types except those used for resource extraction (primarily oil and gas production) or those used to monitor areas with known groundwater contamination. Produced-water samples are from wells related to natural resource exploration and extraction (primarily oil and gas production). Physical characteristics, major-ion chemistry, nutrients, trace elements and radiochemicals are summarized for both environmental and produced waters in **Appendices E, F, G** and **H** of the main report.

Aquifer sensitivity and potential sources of groundwater contamination

This report uses Geographic Information Systems (GIS) analysis of aquifer sensitivity (Hamerlinck and Arneson, 1998) to evaluate potential contamination threats to groundwater resources in the Bear River Basin. Potential contaminant sites were identified from Wyoming environmental regulatory agency databases and include facilities that handle substantial volumes of substances that released to the environment could migrate to the water table. These facilities are generally located in and near municipal, manufacturing, and mineral resource areas in the basin.

Estimated recharge in the Bear River Basin

The hydrogeologic units in the Bear River Basin range in geologic age from Quaternary to Paleozoic and are variably permeable. The basin's complex geology does not permit the use of the general assumptions regarding aquifer geometry, saturated thickness and hydraulic properties commonly employed by hydrogeologists in other settings that would be required to calculate a plausible estimate of total and producible groundwater resources. In this report, groundwater resources are evaluated by using previous GIS based estimates of average annual recharge (Hamerlinck and Arneson, 1998) to the outcrop zones of the basin's identified aquifers. Aquifer recharge zones, based on geologic age were generated as GIS shapefiles; these are: 1) Quaternary, 2) Tertiary, 3) Mesozoic, and 4) Paleozoic aquifers. Total recharge volume for each aquifer recharge zone was calculated as the cell-by-cell product of the surface area within each aquifer recharge zone by the estimated average annual recharge.

Total average annual precipitation in the Bear River Basin for the 1981-2010 period of record was estimated as 1,398,195 acre-feet; the best estimate of average annual recharge to the Bear River Basin's sedimentary aquifers is 188,968 acre-feet per year.

Groundwater development potential in areas subject to the Amended Bear River Compact of 1978

The Amended Bear River Compact of 1978 divides water administration in the Bear River among three geographically defined divisions. The Upper Division encompasses the reach of the Bear River that extends from its headwaters in the Uinta Mountains to the Pixley diversion dam in Sec. 25, T. 23 N., R. 120 W. of the Sixth Principal Meridian in Wyoming. During a compact defined water emergency in the Upper Division, percentage allocations are made to the Utah and Wyoming sections and distribution of divertible flow is managed by diversion by the two states. The Central Division extends from below Pixley Dam to the Stewart diversion dam in Sec. 34, T. 13 S. R. 44 E. (Boise Base) and Meridian in Idaho; during a water emergency, divertible flow is allocated by percentage to Wyoming and Idaho. In the Lower Division, which extends from the Stewart Dam to the Great Salt Lake, divertible flows are allocated by a commission approved delivery schedule.

The portion of the Bear River drainage basin examined in this report consists of the entire Upper Division and those parts of the Central Division that are tributary to the Bear River upstream of the Idaho-Wyoming border (**Fig. 3-1, main report**). **Appendix D** (SEO, 2006) of the main report contains a copy of the Amended Bear River Compact (1978). The compact is administered by the Bear River Commission (http://www.bearrivercommission.org/), composed of three commissioners from each signatory state. The Interstate Streams Division of the SEO, in conjunction with the Water District IV staff, administers the provisions of the compact that fall under the authority of the state of Wyoming.

Along with the distribution of water specified for each of the divisions, Article VI of the compact allocates an additional 13,000 ac-ft annual total of surface and connected groundwater each to both Wyoming and that portion of Utah above Stewart Dam for beneficial uses applied on or after January 1, 1976. Historically, Wyoming has used only a small portion of this additional allocation, so it is likely that future groundwater development in the Bear River Basin will allow Wyoming to develop and utilize its 13,000 ac-ft allocation. In Wyoming, the State Engineer's Office (SEO) monitors surface water and connected groundwater depletions owing to the additional allocation.

GROUNDWATER USES AND BASINWIDE WATER BALANCE

Chapter 8 contains a discussion of current groundwater uses in the Bear River Basin. Six maps (**Figs. 8-1** through **8-6, main report**) were prepared for this study to illustrate the geospatial distribution of groundwater permits according to use in the

Bear River Basin. Only permits for wells that were likely to have been drilled (including abandoned wells) are included on the maps. Figures are provided for irrigation, stock watering, municipal, industrial, monitoring, and miscellaneous permits. Groundwater permits are mapped relative to their date of issue (before or after January 1, 2001) and by total well depths. The figures indicate the following trends for groundwater permits by use:

- Most **irrigation permits** appropriate water from wells located near the Bear River, likely targeting alluvial deposits adjacent to the river.
- **Livestock wells** are generally located in close proximity to the Bear River and other surface drainages.
- **Municipal wells** are located within or close to the municipalities that they supply and produce water from both bedrock and alluvial aquifers.
- Most **domestic wells** are located in rural areas, generally outlying population centers along surface drainages. Most wells are completed in Quaternary and Tertiary geologic units; however, domestic-use wells have also been permitted over a wide range of depths within virtually all hydrogeologic units, including confining units.
- **Industrial wells** are generally clustered in rural areas around conventional oil and gas fields, mining operations, and population centers.
- **Monitoring wells** are generally located near population centers, areas with industrial facilities, and along rivers and other large surface drainages, where facilities that require groundwater monitoring are concentrated.
- **Miscellaneous-use and test wells** are located throughout the basin in population centers, in mineral development areas, rural areas, and generally along rivers and larger surface drainages.

Chapter 8 (**Table 8-2a, main report**) also contains a basinwide water balance based on the mass balance equation: *Evapotranspiration = (precipitation + surface inflow + imported water + groundwater inflow) – (surface water outflow + groundwater outflow + reservoir evaporation + exported water + recharge) ± changes in surface water storage ± changes in groundwater storage.*

For this analysis, geospatial precipitation data was obtained from PRISM Climate Group (PRISM, 2013) for the Bear River Basin. The USGS Daily Streamflow website http://waterdata.usgs.gov/nwis/rt was accessed for surface water outflow data. Consumptive use estimates for irrigation and stock watering, industry, municipal, and domestic and recreational and environmental uses were obtained from previous Bear River Basin Water Plans (Forsgren and Associates, 2001; WWDO, 2012). Finally the water budget analysis used the annual recharge estimate calculated in **Chapter 6** of the main report. The results of the water balance analysis, shown in **Table 1**, indicate that evapotranspiration (ET) accounts for about 85 percent of precipitation losses in the basin; the USGS estimate places ET losses at 86 percent of precipitation. Current estimated consumptive uses of surface water and groundwater constitute about 6 percent of annual precipitation.

Table 1. Summary water balance statistics.

WATER BALANCE PARAMETERS [a]		*Average Annual Volume (ac-ft)*
Precipitation (1981 - 2010 - Figure 3-3) [b]		1,398,195
Total surface water inflows [c]	+	340,337
Total surface water outflows [c]	-	503,592
Evaporation from reservoirs [d]:	-	5,361
Surface water depletions from municipal/domestic, livestock, and industrial uses [d]	-	2,676
Groundwater depletions from municipal/domestic, livestock, and industrial uses [d]	-	1,574
Total estimated Bear River Basin recharge (Table 6-3)	-	188,968
Basin-wide evapotranspiration	=	1,036,361

Estimation evapotranspiration in the Bear River Basin using the USGS climate and land-cover data regression [e].

Total evapotranspiration 1,069,066 acre-feet

[a] Fetter , C. W., 2001
[b] PRISM Climate Group, 2012
[c] USGS, 2012
[d] Wyoming Water Development Commission, 2012
[e] Sanford and Selnick, 2013

FUTURE WATER DEVELOPMENT OPPORTUNITIES

Future groundwater development projects in the Bear River Basin are largely affected by the issues of water availability, funding, stakeholder involvement, water quality, environmental regulation and, perhaps most importantly, the court decrees and interstate agreements regulating the appropriation of water. **Table 2** summarizes the general potential for development of the state's major aquifers, grouped by geologic age.

Table 2. Generalized groundwater development potential for major regional aquifer systems in the Bear River Basin (modified from WWC Engineering and others, 2007; WWDO, 2012).

Age	*System*	*Location*	*Well yields*	*Major aquifers*	*General potential for new development*
Quaternary	Alluvial	Throughout Bear River Basin	Small to large	Unconsolidated deposits	Good to very good
	Non-alluvial	Throughout Bear River Basin	Small to moderate	Primarily unconsolidated terrace deposits*	Good to very good
Tertiary	Late	Scattered small outcrops west edge of basin	Small to moderate	Salt Lake	Good - little yield data
	Early	Widespread outcrops in south and central basin	Small to large	Fowkes, Wasatch, Evanston, and equivalents	Good to very good
Mesozoic	Late Cretaceous	Scattered outcrops south and central basin	Small to moderate	Evanston, Adaville, Frontier	Fair to very good – little yield data
	Early Cretaceous	Widespread outcrops throughout basin	Small to moderate	Bear River, Thomas Fork, Gannett	Fair to good - some marginal yields
	Triassic/Jurassic	Outcrops on uplands and flanks in central and north basin	Moderate to large	Twin Creek, Nugget, Thaynes	Good to very good
Paleozoic	Late	Exposed on uplifts in north basin	Small to large	Phosphoria, Madison, Amsden, Wells	Fair to very good – some marginal water quality
	Early	Outcrops largely absent	Unknown	Flathead, Bighorn, Gallatin	Fair – outcrops largely absent

*terraces are alluvial

CURRENT WWDC GROUNDWATER DEVELOPMENT PROSPECTS

As of November 2013, neither WWDC nor the State Engineer's Office (SEO) are conducting large scale groundwater development projects in the Bear River Basin. Applications submitted to the SEO are usually for domestic and stock well permits.

WWDC projects that were recently conducted in the Bear River Basin include:

- A feasibility study (Trihydro, 2003) of groundwater development and improvement for the Town of Bear River. A test well, Deer Mountain #6, was completed in the Wasatch Formation and subsequently converted to a municipal well and connected to the town's water distribution system.

- Sunrise Engineering (2005) conducted a Level II study under contract to the WWDC to examine the feasibility of implementing a regional water system with water supplied by the City of Evanston to the Town of Bear River. Subsequently, the regional system was constructed and is currently in operation. While the water supplied by this system comes from Bear River surface flows, this WWDC project eased groundwater demands in North Uinta County and is an example of successful regional water system development.

SUMMARY

This study evaluated available groundwater resources in the Bear River Basin of Wyoming and small upstream watersheds in Utah and Idaho. The potential for future groundwater development in the basin is fair to very good in late Tertiary through early Paleozoic aquifers.

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