Chapter 10

Energy development and groundwater

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The NERB encompasses most of the Wyoming portion of the Powder River Basin Province (PRBP), one of the most prolific areas of fossil fuel production in the United States (Anna and others, 2009). The Powder River Basin's extensive deposits of coal as well as most of its oil and natural gas resources are located in the NERB. Moreover, during the period from 2002 to 2016, the Powder River Structural basin produced nearly 5.6 trillion mcf (thousand cubic feet, a standard measure of natural gas) of coalbed methane gas (CBM). In comparison, CBM production during the same period in the rest of Wyoming was a little more than 188 million mcf (WOGCC, 2017). Interactive online maps, available from the Wyoming Department of Environmental Quality (WDEQ) (http://deq.wyoming.gov/lqd/coal) and the Wyoming Oil and Gas Conservation Commission (WOGCC) (http://wogccms.state.wy.us/flexviewers/unitmap/), show the extent and location of active coal mines and oil and gas wells in the NERB, respectively. The WSGS provides an overview of energy resources in Wyoming structural basins at: http://www.wsgs.wyo.gov/energy/energy.

10.1 ENERGY PRODUCTION AND GROUNDWATER IMPACT

Energy resource development usually affects groundwater resources in some manner. Coal mines must be de-watered when mining extends into saturated geologic units. Groundwater must be pumped from saturated coal seams to extract coalbed methane. Oil and gas wells typically discharge co-produced groundwater present within the targeted hydrocarbon reservoir(s) during production; (see http://www.wsgs.wyo.gov/energy/oil-gas-resources for an explanation of how oil, gas, and water exist together within a petroleum reservoir). Groundwater recharge may be enhanced or decreased by surface disturbances related to development. The practices employed to manage co-produced waters can substantially alter surface water and groundwater volumes (Taboga and others, 2015; 2017) and hydrochemistry (Healy and others, 2011; Clark, 2012).

10.1.1 Energy production and co-produced groundwater

Table 10-1 and figure 10-1 illustrate hydrocarbon and groundwater production volumes in the NERB for 2002–2016. Annual water production volumes for traditional oil and gas (TOG), coalbed methane (CBM), and injection/disposal wells were obtained from operator-supplied data, as reported to the WOGCC (2018). Groundwater production volumes associated with coal mining were calculated by multiplying annual coal production (U.S. Energy Information Administration, 2018) by groundwater production rates per short ton of coal mined (Lovelace, 2009).

Groundwater produced from all forms of energy development (fig. 10-1) in the NERB has declined from a peak of more than 184,000 ac-ft in 2008 to about 90,000 ac-ft in 2016. The observed decline is due largely to a four-fold decrease (from 88,000 to 22,000 ac-ft) in CBM water production from 2008 to 2016. In comparison, the less variable groundwater volumes produced from coal mining and traditional oil and gas development have declined at relatively modest rates (fig. 10-**1**).

Injection and disposal wells pump water and other fluids into deep geologic units. Disposal wells are for disposing hydrocarbons, brines, or other fluids produced in conjunction with oil and gas production. Injection wells inject water, gases such as CO_2, or a combination of water and gases into petroleum reservoirs to achieve secondary recovery of oil and natural gas. Injection and disposal wells are regulated by the WOGCC as Class II underground injection control permits.

In most cases, injection and disposal wells pump fluids into deep geologic units where depth and water quality would prevent future withdrawal. Although disposal volumes have remained relatively constant at about 3,500 ac-ft/yr (table 10-1) between 2002 and 2016, annual injected water volumes (fig. 10-1) have been steadily declining since 2002.

10.1.2 Produced groundwater management

Managing co-produced groundwater is a critical environmental issue that must be addressed in any energy development project. In some cases, the costs and logistics of water management have hampered or halted project development. Produced water extraction and management were, and have remained, pivotal issues in the Powder River Basin during the accelerated development of surface coal mining (Bloyd and others, 1986) that began in the 1970s, and the more recent period (1999–present) of CBM development (Peterson and others, 2010; Bern and others, 2013).

The WDEQ and WOGCC are the principal regulators of produced water in Wyoming. However, developing a produced water management program frequently requires close coordination with other state and federal environmental agencies. Depending on the location of production and the management strategies proposed, developers may be required to comply with regulations and/or obtain permits from the Bureau of Land Management

(BLM), SEO, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency (EPA), U.S. Forest Service (USFS), and U.S. Fish and Wildlife Service (FWS).

The produced water management methods most commonly employed in the NERB include:

- Discharging produced water to receiving waters (streams, waterways) of the state, closed basins, playas, headwater reservoirs, and on-channel containment units. These projects require permits from the WDEQ Wyoming Pollutant Discharge Elimination System (WYPDES) Program.
- Using produced waters for other uses such as irrigation, livestock watering, wildlife watering, dust suppression on roadways, and some on-site industrial processing. These projects also require WYPDES permits, as the produced waters are likely to enter waters of the state.
- Storing produced water in off-channel pits or sending it to designated disposal and injection wells requires permits from the WOGCC (chaps. 4, secs. 1, 5, and 7 in http://wogcc.state.wy.us/wogcchelp/commission.html).

These water management methods are largely consumptive. Evapotranspiration consumes much of the produced water discharged to surface waterways and impoundments, as well as that used for agriculture and dust suppression. Injection and disposal wells pump produced water into deep geologic units, many of which are saline petroleum reservoirs.

10.1.3 Additional information

Further information about produced water management and its impacts can be found at the following websites:

- WDEQ WYPDES Program: http://deq.wyoming.gov/wqd/wypdes/
- WOGCC injection and disposal wells: http://wogcc.state.wy.us/legacywogcce.cfm
- WDEQ Cumulative Hydrologic Impact Assessments (CHIA) for coal mines: http://deq.wyoming.gov/lqd/coal/resources/chia/
- BLM Wyoming Resource Management Plans: https://www.blm.gov/programs/planning-and-nepa/plans-in-development/wyoming
- WSGS groundwater publications: http://www.wsgs.wyo.gov/water/groundwater
- The USGS Publications Warehouse: https://pubs.er.usgs.gov/

Table 10-1. Commodity and produced groundwater from energy production during 2002–2016.

	Traditional oil and gas production[1]			CBM production[1]		Injected/disposed water[1]			PRB coal production		Energy development
Year	Oil (BBLS) x 1,000	Natural gas (MCF) x 1,000	Produced water (ac-ft)	Coal Bed Gas (MCF) x 1,000	Produced water (ac-ft)	Injected Water (ac-ft)	Disposed Water (ac-Ft)	% Produced water injected/ disposed	Coal[2] (Short tons) x 1,000	Produced[3] water (ac-ft)	Total Produced water (ac-ft)
2002	20,842	81,163	58,593	326,411	74,621	47,916	2,596	38%	212,059	28,341	161,555
2003	19,567	75,637	57,406	345,749	73,001	44,321	2,960	36%	211,792	28,305	158,712
2004	18,690	76,447	54,031	332,123	69,349	41,543	3,042	36%	225,856	30,185	153,565
2005	18,670	64,373	55,535	337,142	71,876	37,403	3,088	32%	235,318	31,449	158,861
2006	18,940	54,905	49,436	377,796	87,225	31,133	3,361	25%	264,457	35,344	172,005
2007	18,581	48,036	57,749	429,935	84,559	29,056	3,514	23%	277,740	37,119	179,426
2008	17,958	48,667	57,705	536,996	88,391	26,033	3,467	20%	285,194	38,115	184,211
2009	17,592	44,522	55,211	559,046	73,295	23,972	3,634	21%	273,059	36,493	165,000
2010	19,251	39,277	58,248	539,395	68,663	25,434	4,084	23%	276,303	36,927	163,838
2011	20,855	41,383	54,466	480,556	63,241	25,292	3,846	25%	284,064	37,964	155,671
2012	23,666	47,702	51,195	401,966	48,308	21,051	4,080	25%	260,977	34,879	134,382
2013	30,835	63,564	47,820	312,910	38,951	20,290	3,798	28%	242,330	32,387	119,157
2014	41,872	82,328	43,665	246,761	33,102	18,936	3,847	30%	247,166	33,033	109,800
2015	50,668	98,754	41,443	198,996	25,568	16,699	4,193	31%	228,771	30,574	97,585
2016	38,901	94,231	42,344	155,567	22,140	14,600	3,724	28%	189,652	25,346	89,831
Total	**376,888**	**960,990**	**784,848**	**5,581,347**	**922,290**	**423,677**	**53,234**		**3,714,737**	**496,461**	**2,203,599**

[1] WOGCC, 2018

[2] U.S. Energy Information Administration, 2018

[3] Lovelace, 2009

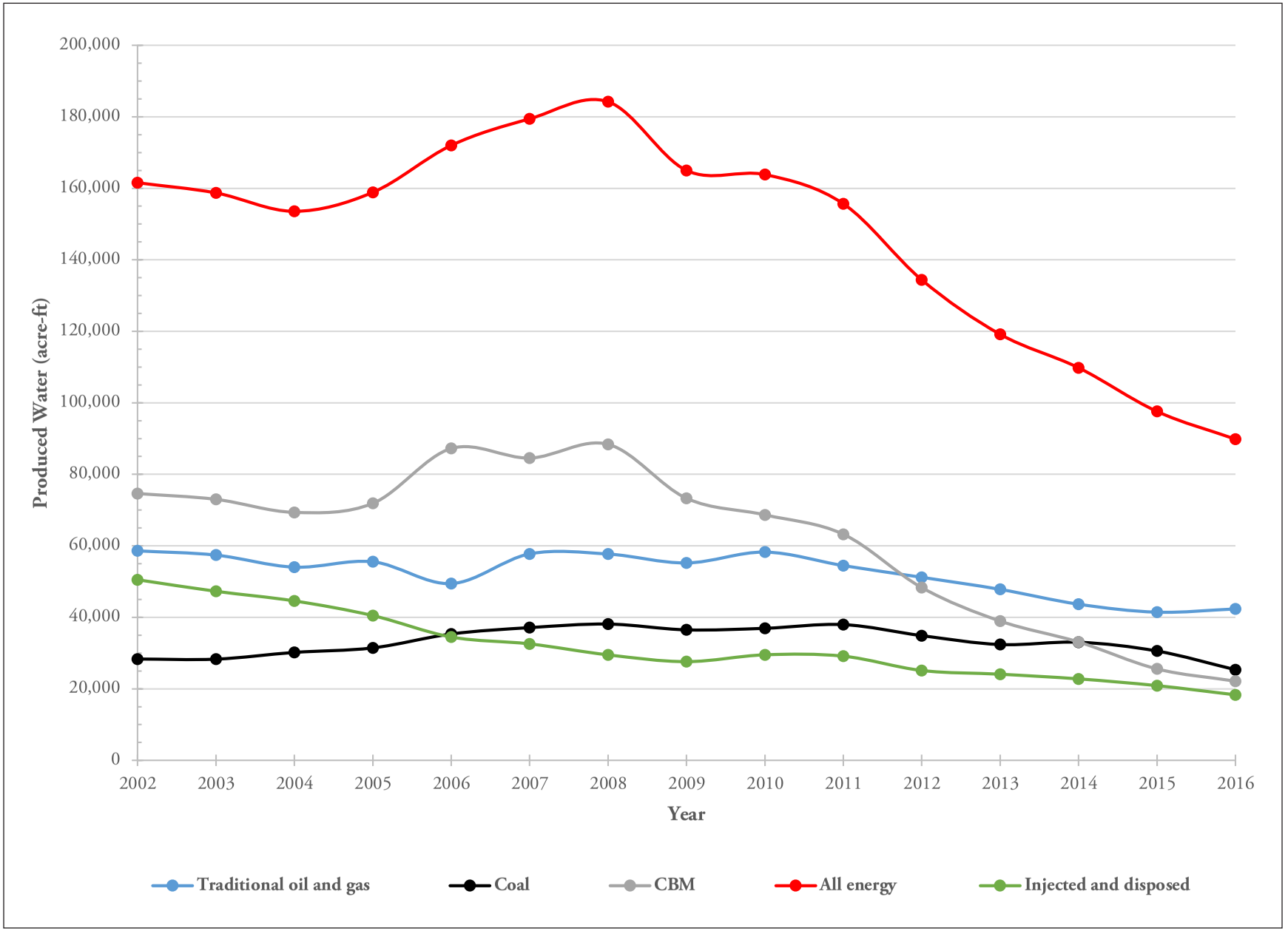

Figure 10-1. Produced water volumes from energy production during 2002–2016.