

# Chapter 3

*Description of the study area*

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This study examines groundwater resources that underlie the aggregated Powder/Tongue/Northeast River Basins (collectively designated in this report by the acronym “NERB”) in Wyoming, as well as tributary areas in Montana, South Dakota, and Nebraska (fig. 3-1). The NERB in Wyoming covers approximately 23,223 mi<sup>2</sup> (14.86 million acres), or 23.75 percent of Wyoming’s surface area. Tributary watersheds in the neighboring states are small, about 613 mi<sup>2</sup> (0.39 million acres). In Wyoming, the NERB includes all of Sheridan, Campbell, Crook, and Weston Counties, 98 percent of Johnson, 93 percent of Niobrara, 50 percent of Converse, 33 percent of Natrona, and 4 percent of Goshen counties. In Montana, the tributary watershed covers 3 percent of Bighorn, 1 percent of Powder River, and 4 percent of Carter Counties. In South Dakota, the NERB encompasses 6 percent of Custer County, and 5 percent of both Lawrence and Pennington Counties. The NERB covers 1 percent of Sioux County in Nebraska. Unless specific references are made to the tributary areas outside of Wyoming, references to the NERB in this memorandum refer only to the Wyoming portion.

The NERB encompasses about 23.75 percent of Wyoming’s total surface area and serves as home to approximately 102,000 people, or about 17 percent of the state’s population (Wyoming Department of Administration and Information Economic Analysis Division, 2016). The NERB contains 19 incorporated municipalities, 17 unincorporated communities, 11 U.S. Census Designated Places (CDP; table 3-1), and a substantial rural population. The map in figure 3-1 shows townships, major roads, and incorporated municipalities within the NERB.

### 3.1 GEOGRAPHIC EXTENT, PHYSIOGRAPHY, GEOMORPHOLOGY, AND SURFACE DRAINAGE

The NERB consists of eight contiguous river drainages located in the northeastern quarter of Wyoming and small tributary areas in neighboring states (table 3-2). Streamflows from all eight rivers move from Wyoming into neighboring states, and ultimately discharge to the Missouri River. Data from several decades of USGS stream gauge stations tracking average annual streamflows out of Wyoming are also shown in table 3-2 (Stafford and Gracias, 2009).

**Table 3-1.** Communities located in the NERB.

Municipalities	Unincorporated communities	Census designated places
Buffalo	Aladdin	Antelope Valley
Clearmont	Alva	Arvada
Dayton	Arminto	Beulah
Edgerton	Banner	Big Horn
Gillette	Beulah	Hill View Heights
Hulett	Bill	Lance Creek
Kaycee	Four Corners	Osage
Lusk	Hiland	Parkman
Manville	Leiter	Powder River
Midwest	Linch	Sleepy Hollow
Moorcroft	Natrona	Story
Newcastle	Recluse	----
Pine Haven	Rozet	----
Ranchester	Saddlestring	----
Sheridan	Weston	----
Sundance	Wolf	----
Upton	Wyarno	----
Van Tassell	----	----
Wright	----	----

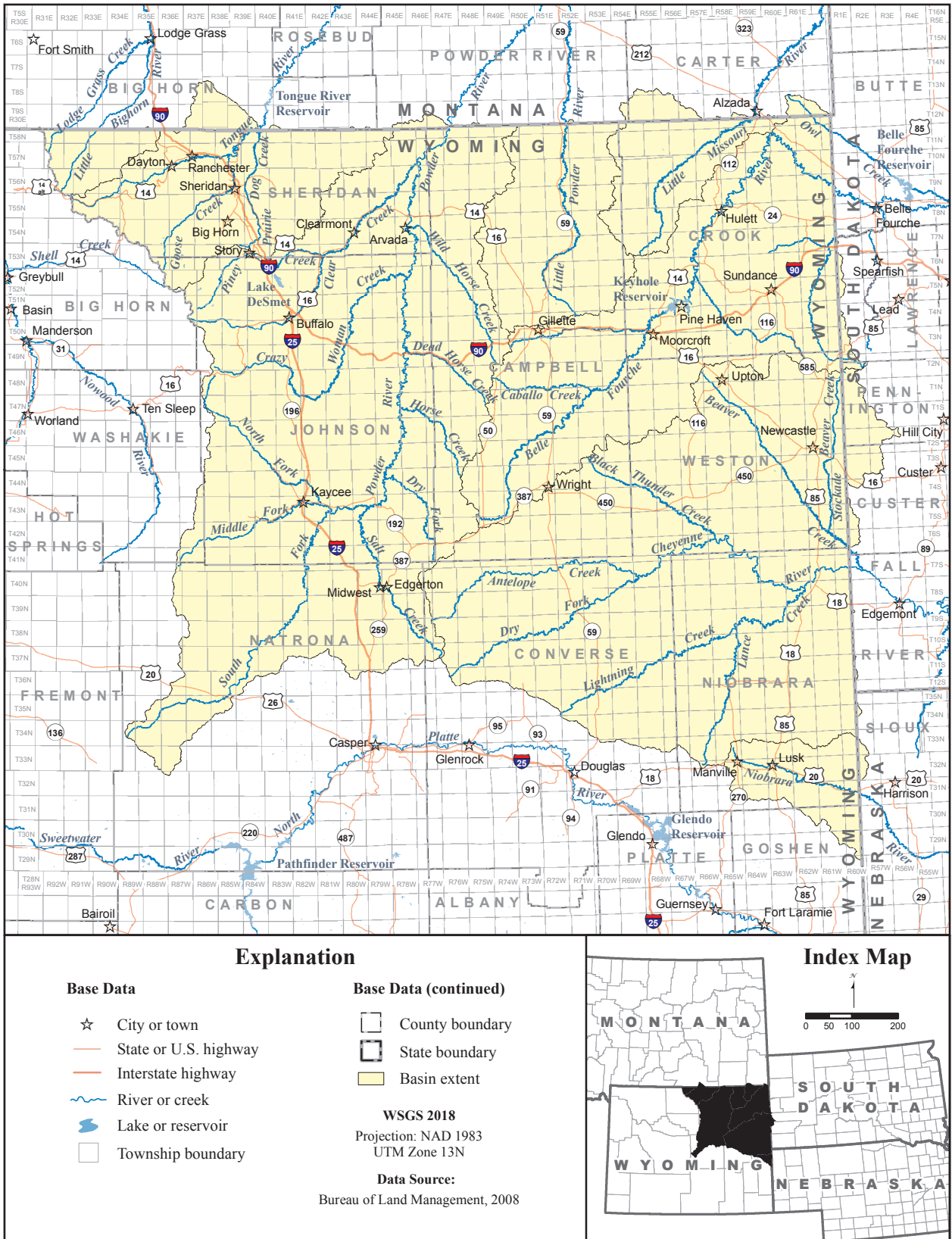


Figure 3-1. Municipality, road, township, and range index map, NERB, Wyoming.

**Table 3-2.** Physical characteristics of the river drainages that compose the NERB.

River Drainage <sup>1</sup>	Total surface area (mi <sup>2</sup> ) covered by this report <sup>1</sup>	Drainage surface area (mi <sup>2</sup> ) located in Wyoming <sup>1</sup>	Neighboring states with tributary areas <sup>1</sup>	Average annual streamflows (CFS) out of Wyoming <sup>2</sup>
Little Bighorn River	302	299	Montana	173
Tongue River	1,737	1,609	Montana	430
Powder River	7,979	7,951	Montana	438
Little Powder River	1,381	1,378	Montana	20
Little Missouri River	828	725	Montana	80
Belle Fourche River	3,968	3,881	Montana, South Dakota	116
Cheyenne River	7,043	6,813	South Dakota	85
Upper Niobrara River	550	532	Nebraska	4

<sup>1</sup> NRCS, 2016

\*NRCS, 2016, Watershed Boundary Dataset overview, history of hydrologic units and supporting documents: <http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/ngce/>.

<sup>2</sup> Stafford and Gracias, 2009

Stafford, J.E., and Gracias, T., 2009, Surface water resource map of Wyoming—Streamflows and storage: Wyoming State Geological Survey Map Series 91, scale 1:500,000.

The NERB is located within the Great Plains, Middle Rocky Mountain, and Wyoming Basin Physiographic Provinces. Major physiographic features, drainages, and reservoirs of the NERB are shown on figure 3-2 and plate 1. A map of the physiographic provinces of Wyoming is available online at: <http://www.wsgs.wyo.gov/products/wsgs-1989-es-1.pdf> (Roberts, 1989).

The geomorphology of the NERB (fig. 3-2) is dominated by heavily eroded Laramide-aged uplifts that border deep intermountain structural basins, which are filled with sediments eroded from the uplifts. The Laramide uplifts are composed of large anticlines that have crystalline basement cores. Erosion of the uplifts has exposed older geologic formations at higher elevations. Precambrian basement rocks crop out along the ridges of the Bighorn Mountains and Hartville uplift. Paleozoic sedimentary units are exposed in the Black Hills and Rattlesnake Hills. Mesozoic formations are exposed in the Casper Arch. The Black Hills and Rattlesnake Hills contain igneous rocks formed during brief periods of early Tertiary volcanic activity that likely occurred in the waning stages of the Laramide orogeny.

The largest geologic structure is the Powder River Structural Basin (PRSB), an elongate Laramide foreland basin measuring 200 miles north to south by nearly 120 miles east to west. The structural basin is asymmetric—it dips gently westward ( $-1.5^\circ$ ) from its eastern margin for about 90 miles to the basin's axis, where it reaches its greatest depths ( $\sim 18,000$  ft below the surface). The basin axis is within 10 miles of its western edge and generally

parallels the ridge of the Bighorn Mountains. Earliest formation of the PRSB likely occurred in the middle Paleocene when rapid subsidence (Curry, 1971) created Lake Lebo, which was subsequently in-filled by fluvial, deltaic, paludal (marshy), and lacustrine deposition of eroded sediments from nearby uplifts. The Paleocene Fort Union Formation crops out along the basin margins and is overlain by the Eocene Wasatch Formation (plate 1).

A small portion of the NERB extends onto the northeast margin of the Wind River Structural Basin (plate 1, fig. 3-2) where the South Fork of the Powder River drains the northern flank of the Rattlesnake Hills. Additionally, the Upper Niobrara River drainage of the NERB extends into the northern Denver-Julesburg Structural Basin.

Detailed discussion of the geology of the NERB is provided in chapters 4 and 7 of this study.

The area of the NERB is bound by the Bighorn Mountains on the west, the Casper Arch and Rattlesnake Hills to the southwest, the Hartville Uplift to the southeast, and the Black Hills in the northeast. The NERB is open to the north where the PRSB continues into Montana, and also along the eastern border of Wyoming between the Black Hills and the Hartville uplift. The Little Bighorn, Tongue, Powder, Little Powder, and Little Missouri Rivers flow out of Wyoming from the northern PRSB into Montana. The Cheyenne and Upper Niobrara Rivers enter South Dakota and Nebraska, respectively, across Wyoming's eastern border between the Black Hills and the Hartville uplift. The Belle Fourche River flows

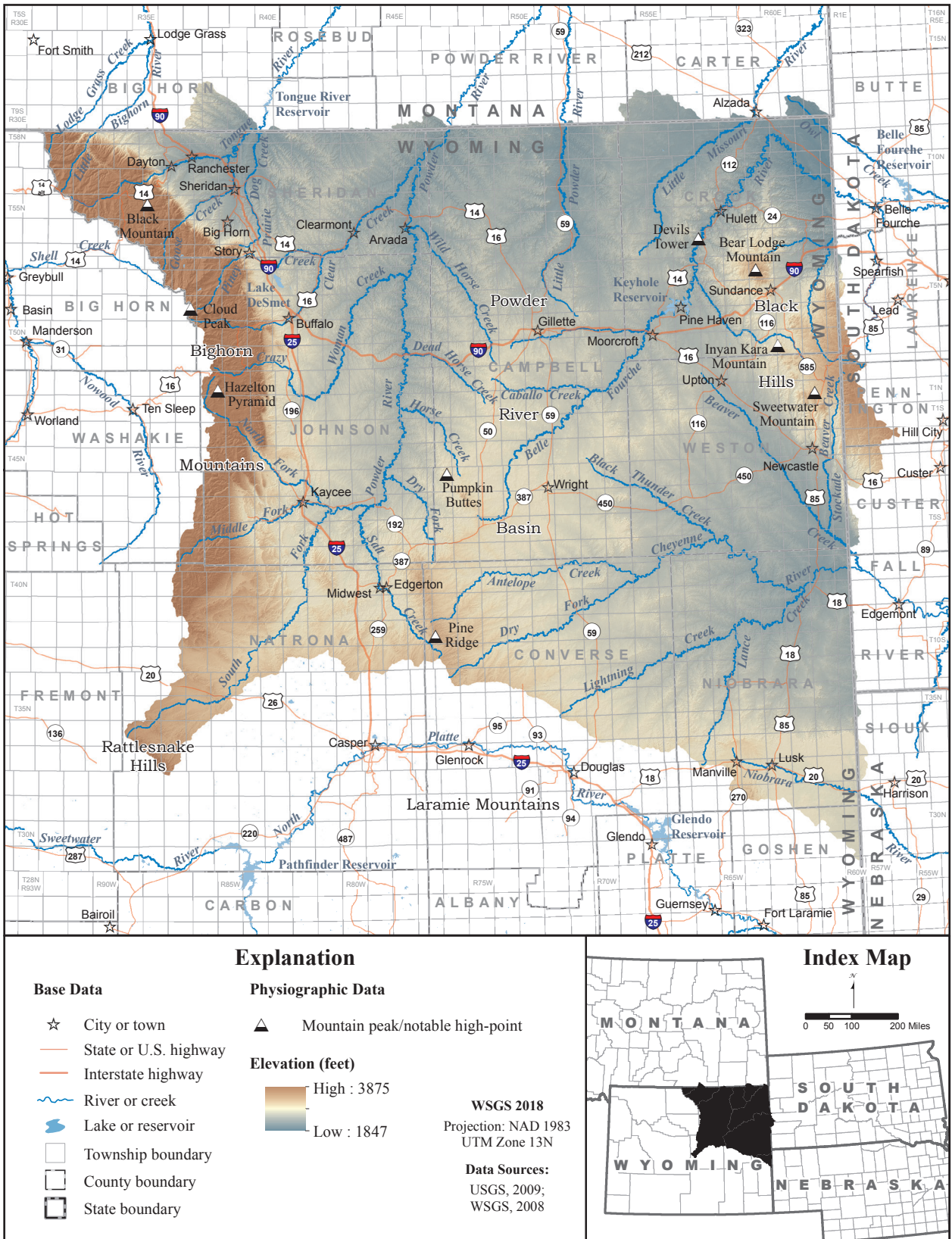


Figure 3-2. Physiographic features, drainages, and bodies of water, NERB, Wyoming.

northeast around the northern end of the Black Hills, then makes an abrupt turn to flow southeastward into South Dakota.

Perennial streams in the NERB receive a large percentage of their source waters from overland flow associated with snowmelt and rainfall that originates in semi-humid mountains and highlands, headwater regions, and from persistent baseflow. Most ephemeral flow occurs in response to springtime snowmelt and to intense, short duration, rainfall events characteristic of transient, convective thunderstorms. Streamflows are also affected by vegetation, temperature, artificial diversions, and complex interconnections with groundwater.

### **3.2 CLIMATE, PRECIPITATION, AND VEGETATION**

Climate within the NERB is primarily a function of elevation, though latitude and topography play lesser roles. Climate types range from semi-arid continental within the interior basins to humid-alpine in the bordering mountain ranges. The Bighorn Mountains capture much of the atmospheric moisture through orographic uplift, resulting in increased annual precipitation while substantially decreasing precipitation in the basin interiors. Temperature varies 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) and can exceed 41 inches a year in the high mountain headwater areas of the Powder River and Tongue River drainages. Annual precipitation averages 15 inches over the entire basin (PRISM, 2016). Most precipitation within the basin occurs as snowfall during the winter and early spring, and as convective thunderstorms during late spring and summer months (Feathers and others, 1981).

The diversity and distribution of vegetation within the NERB is primarily influenced by elevation and the availability of water. The abundance of grasses, shrubs, woodland trees (primarily conifers), and other species generally increases with elevation and corresponding precipitation up to timberline, above which, alpine tundra species of lichens, low shrubs, and grasses dominate flora. The dominant ecological zones are, generally, sagebrush steppe/shrubland (mixed prairie grasses and shrubs, primarily sagebrush) on the plains, mixed deciduous and coniferous forest along drainages, sub-alpine spruce-fir forest on mountain flanks, and alpine tundra at the highest elevations.

### **3.3 POPULATION DISTRIBUTION, LAND USE, AND LAND OWNERSHIP**

The Wyoming Department of Administration and Information Economic Analysis Division (WDAIEAD) estimates 102,000 people, or about 17 percent of the state's population (WDAIEAD, 2016), reside in the Wyoming portion of the NERB. The basin contains 19 municipalities and 11 U.S. Census Designated Places (U.S. Census Bureau, 2010) in Wyoming; most of these communities are located along or within a few miles of rivers or creeks (fig. 3-1).

Land use in the NERB is controlled primarily by elevation, climate, precipitation, and land ownership. Above timberline, the alpine areas are generally used for recreational purposes. At lower elevations, densely forested areas are utilized for recreation and limited logging. Grazing is the dominant use for rangelands, foothills, and riparian areas. Agriculture plays a significant role in the basin; approximately 1.7 percent (256,523 acres) of the basin's surface area consists of irrigated cropland (HKM and others, 2002a, b). Crop-producing areas in the Powder River Basin are located mainly along the Upper Tongue River, Clear Creek, Crazy Woman Creek, Powder River, and Little Powder River (HKM and others, 2002a, b). Other drainages in the NERB with significant irrigated acreages include the Little Missouri, Belle Fourche, Cheyenne, and Niobrara Rivers (HKM and others, 2002a, b). A map illustrating the distribution of the broad categories of land cover in the northwestern United States, with downloadable GIS land cover data, is provided online by the USGS at: [https://gis1.usgs.gov/csas/gap/viewer/land\\_cover/Map.aspx](https://gis1.usgs.gov/csas/gap/viewer/land_cover/Map.aspx).

Privately owned lands constitute about 70.4 percent of the land in the NERB, approximately 21 percent is federally owned, and 8.3 percent is owned by the State of Wyoming. Federal land in the basin is managed by the Bureau of Land Management (-1.68 million acres), the U.S. Forest Service (-1.45 million acres), and the National Park Service (1,361 acres). A map of state, federal, and private land ownership in Wyoming can be found online in Chapter 3 of the Wyoming Water Development Office's 2007 Statewide Water Plan (WWC Engineering and others, 2007) at <http://waterplan.state.wy.us/frameworkplan-index.html>.

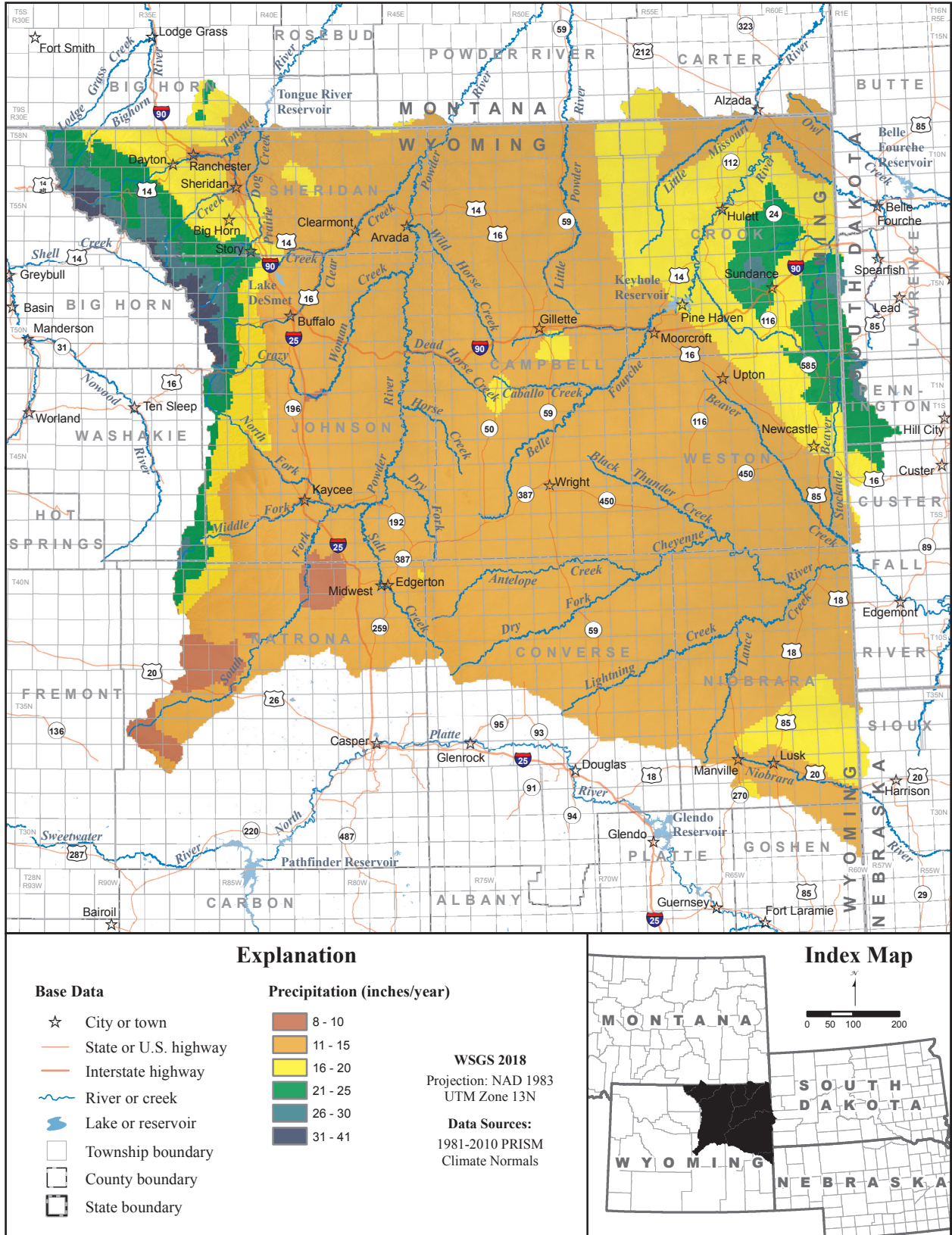


Figure 3-3. Average annual precipitation (1981–2010), NERB, Wyoming.

