Chapter 6

Platte River Basin Hydrogeology and Groundwater Resources

Paul Taucher and Karl Taboga

Wyoming's groundwater resources occur in both unconsolidated deposits and bedrock formations. The hydrogeologic units in the Platte River Basin consist of saturated strata and fractured crystalline rocks that store and convey groundwater. These units range in geologic age from Quaternary to Precambrian (**Plates 1** and **2**) and are variably permeable. Generally, aquifers store and transport useable amounts of groundwater while less permeable confining units impede groundwater flow. In practice, the distinction between aquifers and confining units is not so clear. A geologic unit that has been classified as confining at one location may act as an aquifer at another. Virtually all of the geologic units in the Platte River Basin, including confining units, are capable of yielding at least small quantities of groundwater to wells. For example, although the Mowry Shale and Niobrara Formation are classified as confining units throughout the Platte River Basin, several domestic supply and stock wells have been completed in these units (**Figures 8-6** and **8-15**), according to the records of the Wyoming State Engineer's Office (SEO). Permeability can vary widely within an individual geologic unit depending on the lithology in the unit and geologic structure present. For example, intergranular permeability in the unfractured limestone strata of the Casper aquifer is estimated to be only one hundredth to one thousandth of the measured permeabilities of the unit's sandstone members. In another case, the Precambrian formations commonly found in the mountainous regions of Wyoming generally function as confining units except near the surface where these formations have developed extensive sets of joints, cracks, and fractures as the result of tectonic uplifting and weathering. The great differences in permeability between geologic units account, in part, for the observed wide variation in the available quantity and quality of a basin's groundwater resources.

One of the primary purposes of this study is to evaluate the groundwater resource of the Platte River Basin through the following tasks (**Chapter 1**):

- Estimate the quantity of water in the aquifers.
- Describe the aquifer recharge areas.
- Estimate aquifer recharge rates.
- Estimate the "safe yield" potential for the aquifers.

Although an enormous quantity of groundwater is stored in the Platte River groundwater basin, 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. The data required for a basin-wide aquifer-specific assessment of groundwater resources is not available and is unlikely to ever be developed. Therefore, groundwater resources are evaluated in this study by using previous estimates of recharge (Hamerlinck, J.D. and Arneson, 1998) to the outcrop zones of the basin's identified aquifers (**Figures 6-1 through 6-6**) and the formulation of a basin-wide water balance (**Chapter 8**). The technical and conceptual issues concerning recharge are discussed in **Section 5.1.3**.

In theory, safe yield would be equal to the amount of recharge that exceeds the total discharge from an aquifer with groundwater in storage remaining essentially static or, stated another way, the amount of water that can be withdrawn from an aquifer without causing an unacceptable decline in the potentiometric surface. Lacking accurate data for either recharge or discharge it is difficult to evaluate safe yield. However, the total recharge estimated in this chapter can be used as an upper limit of safe yield for the Platte River Basin aquifers. Technical and conceptual issues concerning safe yield are discussed in **Section 5.1.4**.

6.1 Hydrostratigraphy and recharge to aquifer outcrop areas

The first step in recharge evaluation requires the identification of the specific aquifers and groups of aquifers to which the recharge calculations will be applied (**Figures 6-1** through **6-6**). Several previous groundwater resource studies **(Section 2.2)** have grouped the Platte River Basin's hydrogeologic units into various combinations of aquifers, aquifer systems, and confining units. The hydrostratigraphy developed for this study is based on previous regional assessments and is summarized in the **Plate 2** hydrogeology map**,** in the hydrostratigraphic charts in **Plates J, K, M, S, T, U, Figure** 7-2, and in **Chapter 7**. The hydrostratigraphic charts provide a detailed description of the hydrogeologic nomenclature used in previous studies, including the aquifer classification system from the Statewide Framework Water Plan (WWC Engineering, Inc. and others, 2007), and for the subregions defined in **Chapter 2**. **Appendix A** provides detailed descriptions of the geologic units used to develop the surface hydrogeology shown on **Plate 2**.

Section 5.2 discusses how the "map" units of Love and Christiansen (1985), previously compiled into a Geographic Information Systems (GIS) database by the U.S. Geological Survey and Wyoming State Geological Survey (WSGS) were used to develop **Plate 2**. Love and Christiansen (1985), however, were not able to distinguish all of the stratigraphic units present in Wyoming and the Platte River Basin due to the sheer size of the data set and cartographic limitations. Therefore, some geologic units were not mapped as individual hydrogeologic units but, instead, are shown on **Plate 2** as undifferentiated. To address this, the outcrops of hydrogeologic units assigned as aquifers or aquifer groups **(Plate 2)** were aggregated by geologic age **(Plate 2 – inset).** These aggregated aquifers, or *aquifer recharge zones,* were generated as GIS shapefiles that were used to calculate recharge volumes and rates:

- **Quaternary Aquifers (Figure 6-1)**
- **Lower Tertiary Aquifers (Figure 6-2)**
- **Upper Tertiary Aquifers (Figure 6-3)**
- **Mesozoic Aquifers (Figure 6-4)**
- **Paleozoic Aquifers (Figure 6-5)**
- **Precambrian Aquifer (Figure 6-6)**

6.2 Average annual recharge

Although the saturated geologic units in the groundwater basins function as reservoirs that store enormous volumes of groundwater, with the exception of unconfined aquifers (primarily Quaternary and Tertiary strata) only a small fraction of the groundwater in storage can be withdrawn for beneficial use while most will be retained within the porosity of the aquifers. If only the volume of producible water in storage is considered, it would clearly be a non-renewable resource. The amount of groundwater that can be sustainably withdrawn from a typical aquifer system is controlled by recharge and total discharge, especially as withdrawal approaches or exceeds recharge. Under natural conditions, a state of dynamic equilibrium exists in which natural discharge to surface waters are counterbalanced by recharge. If natural discharge and groundwater withdrawals approach or exceed recharge, springs, streams and wetlands will dry up, holders of surface water rights will not receive their appropriations and riparian ecosystems will collapse. This fact has long been recognized by ranchers and farmers and was incorporated into Wyoming's water law from its initiation.

The availability of estimated average annual recharge data from the Spatial Data and Visualization Center (SDVC) study (Hamerlinck and Arneson, 1998) and WSGS maps of the outcrop areas of the hydrogeologic units in the Platte River Basin (**Figure 5-2, Figures 6-1 through 6-6, Plate 2**) are used in this study to evaluate recharge on a regional scale. This section describes how the volume of average annual recharge within the Platte River groundwater basin was estimated.

Average annual recharge restrained by best estimates of annual discharge (both natural and by pumping) establishes a limit on how much development can be sustained without unacceptably depleting the groundwater held in storage, depleting natural discharges below acceptable levels, or causing permanent structural damage to an aquifer by irreversible compression of its rock matrix. While aquifer-specific recharge can be reasonably estimated, aquifer-specific discharges are difficult to estimate. Estimates of annual groundwater withdrawals and consumptive uses from the previous Platte River Basin Water Plan (Trihydro Corporation and others, 2006a) and Statewide Framework Water Plan (WWC Engineering, Inc. and others, 2007) are discussed later in this study (**Chapter 8**). Other analyses of Platte River Basin groundwater resources in **Chapter 8** include a basin-wide water balance, and analyses of recharge as a percentage of: 1) precipitation; 2) other water balance statistics; 3) estimates of current groundwater consumptive uses; and 4) estimated future groundwater requirements.

Estimated average annual recharge (**Figure 5-2)** in the Platte River Basin ranges from less than 1 inch per year in interior areas of the drainage sub-basins to 28 inches per year in the surrounding mountains (Hamerlinck and Arneson, 1998). Mountain and foothill areas receive higher

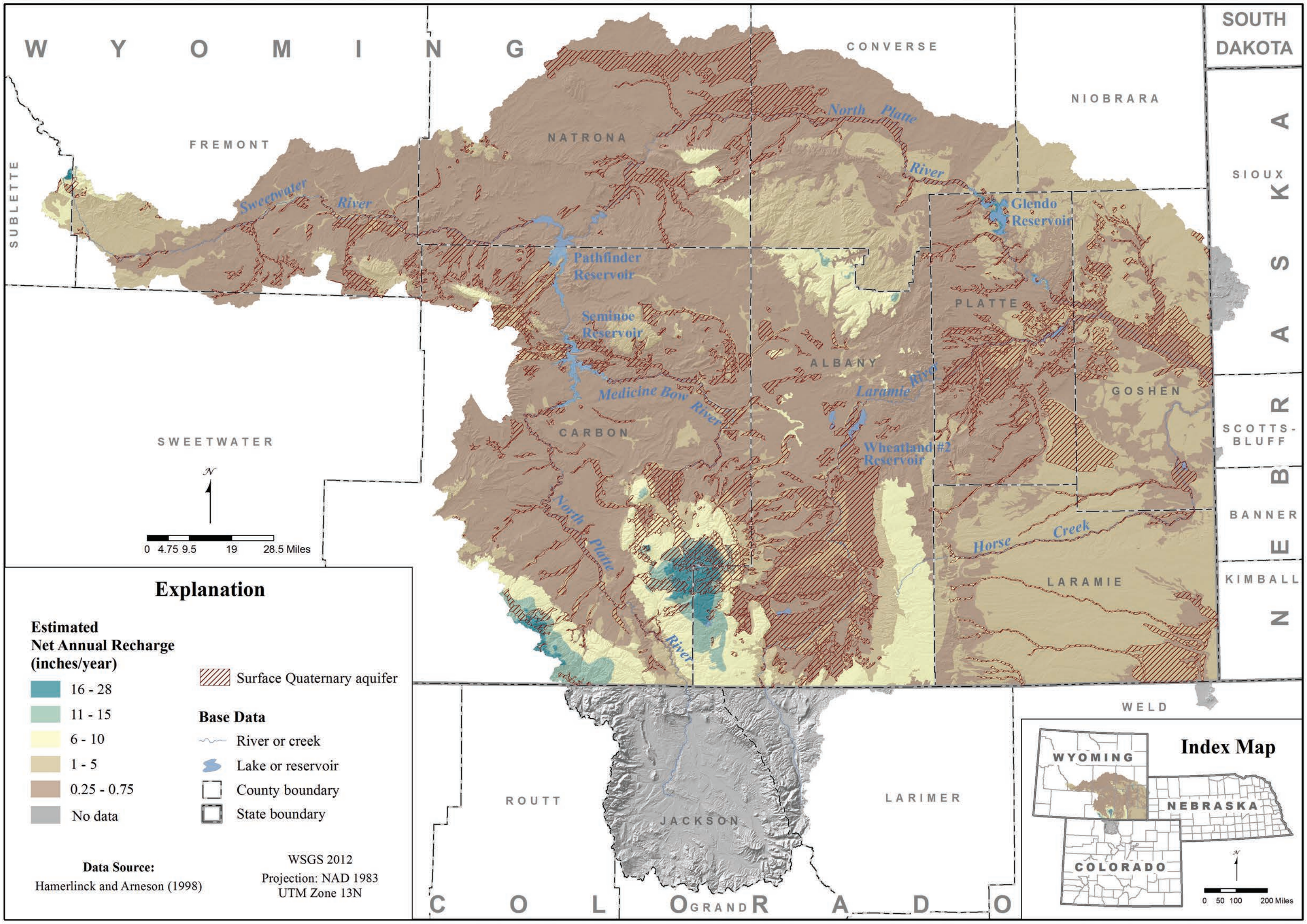

Figure 6-1. Estimated net annual aquifer recharge – surface **Quaternary** Aquifer, Platte River Basin, Wyomingg.

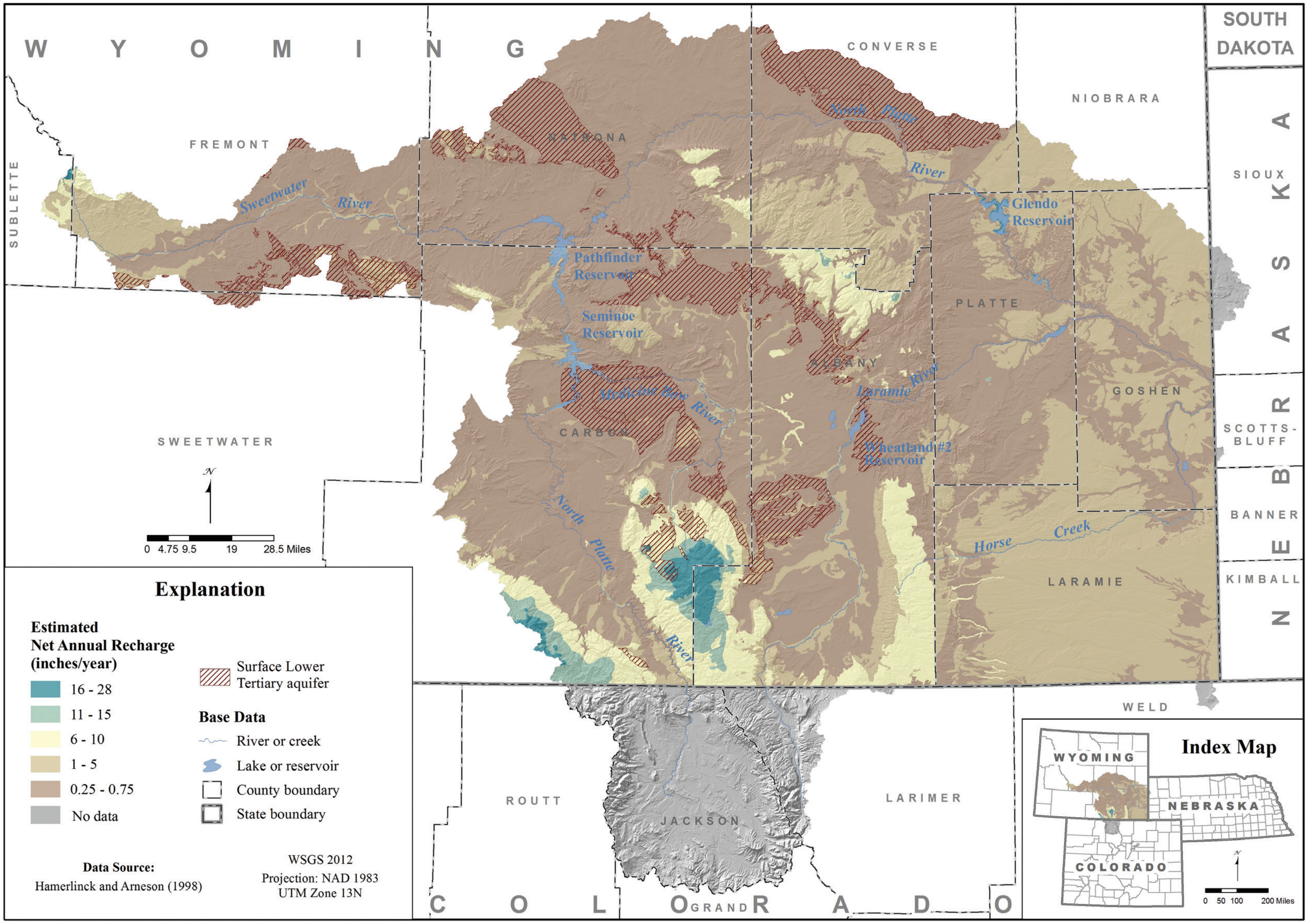

Figure 6-2. Estimated net annual aquifer recharge – surface **Lower Tertiary** Aquifer, Platte River Basin, Wyoming.

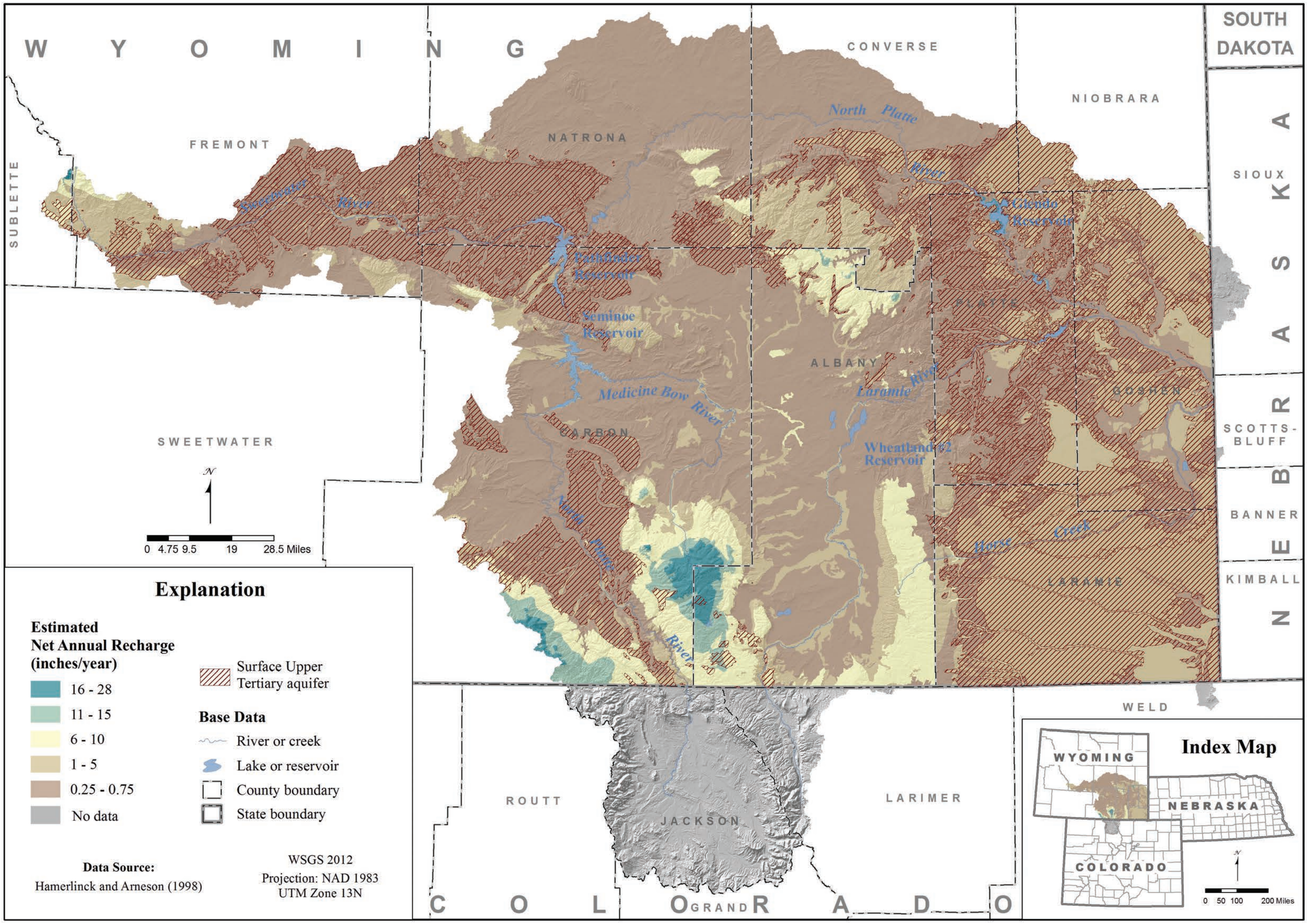

Figure 6-3. Estimated net annual aquifer recharge – surface **Upper Tertiary** Aquifer, Platte River Basin, Wyoming.

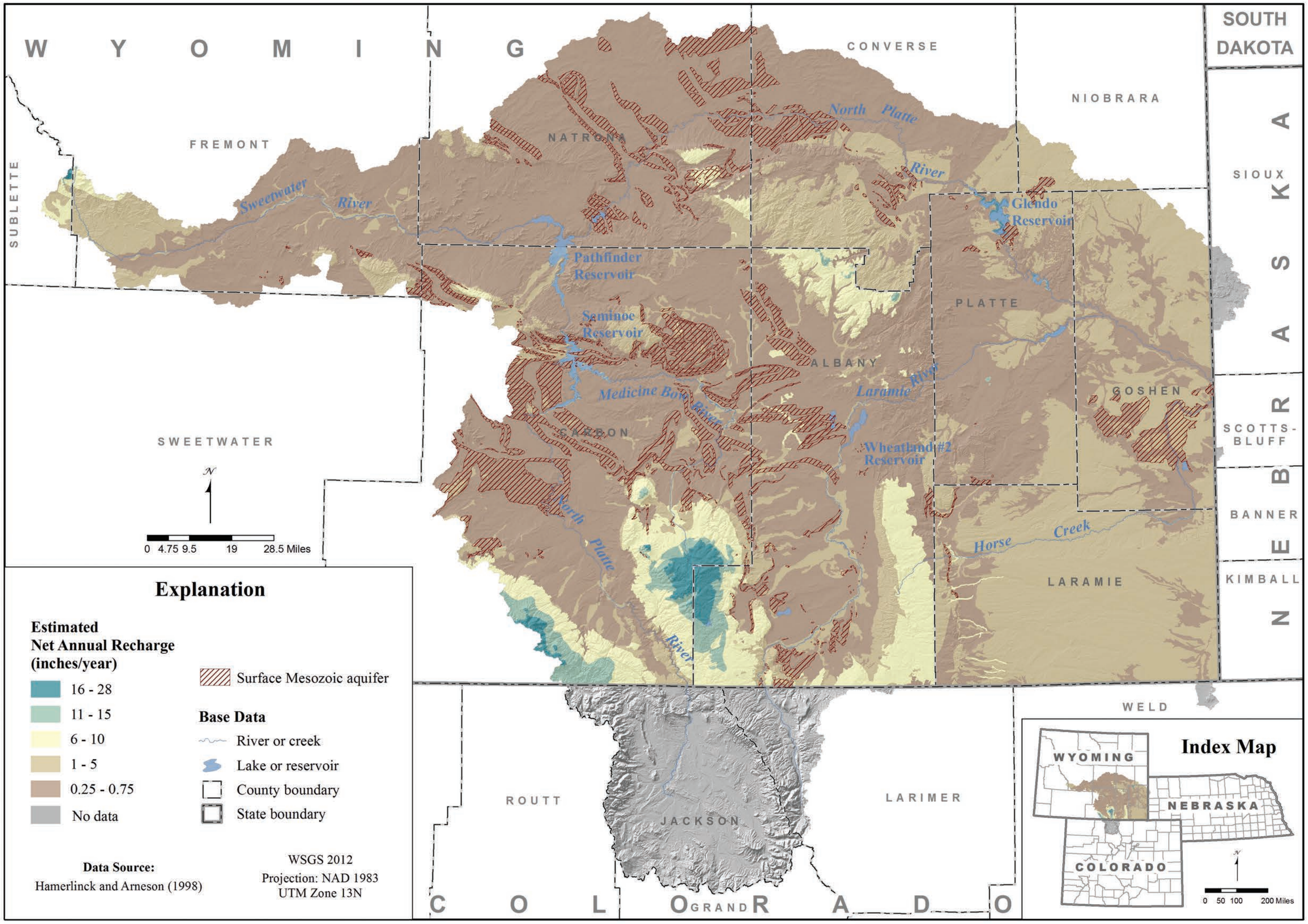

Figure 6-4. Estimated net annual aquifer recharge – surface **Mesozoic** Aquifer, Platte River Basin, Wyoming.

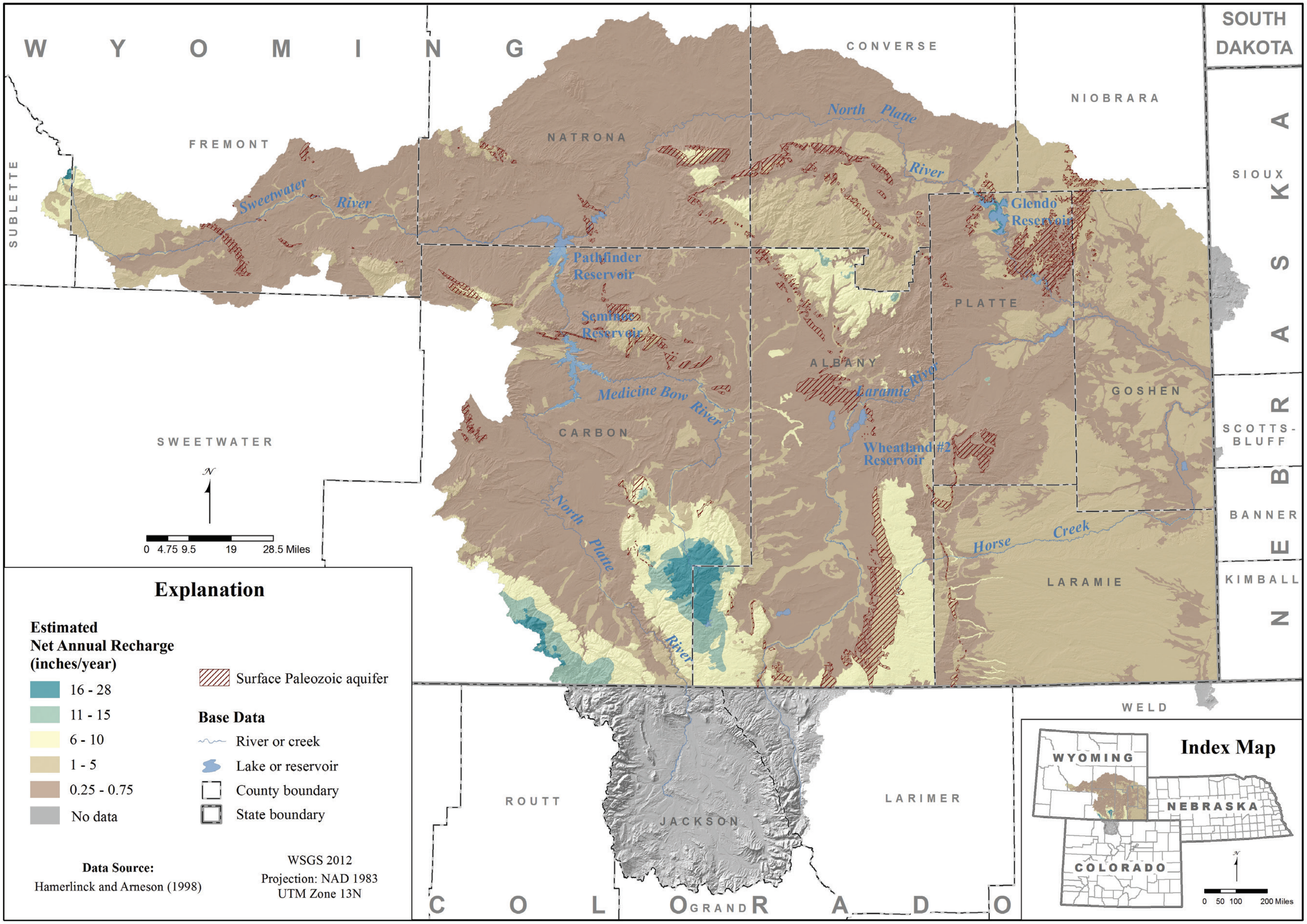

Figure 6-5. Estimated net annual aquifer recharge – surface **Paleozoic** Aquifer, Platte River Basin, Wyoming.

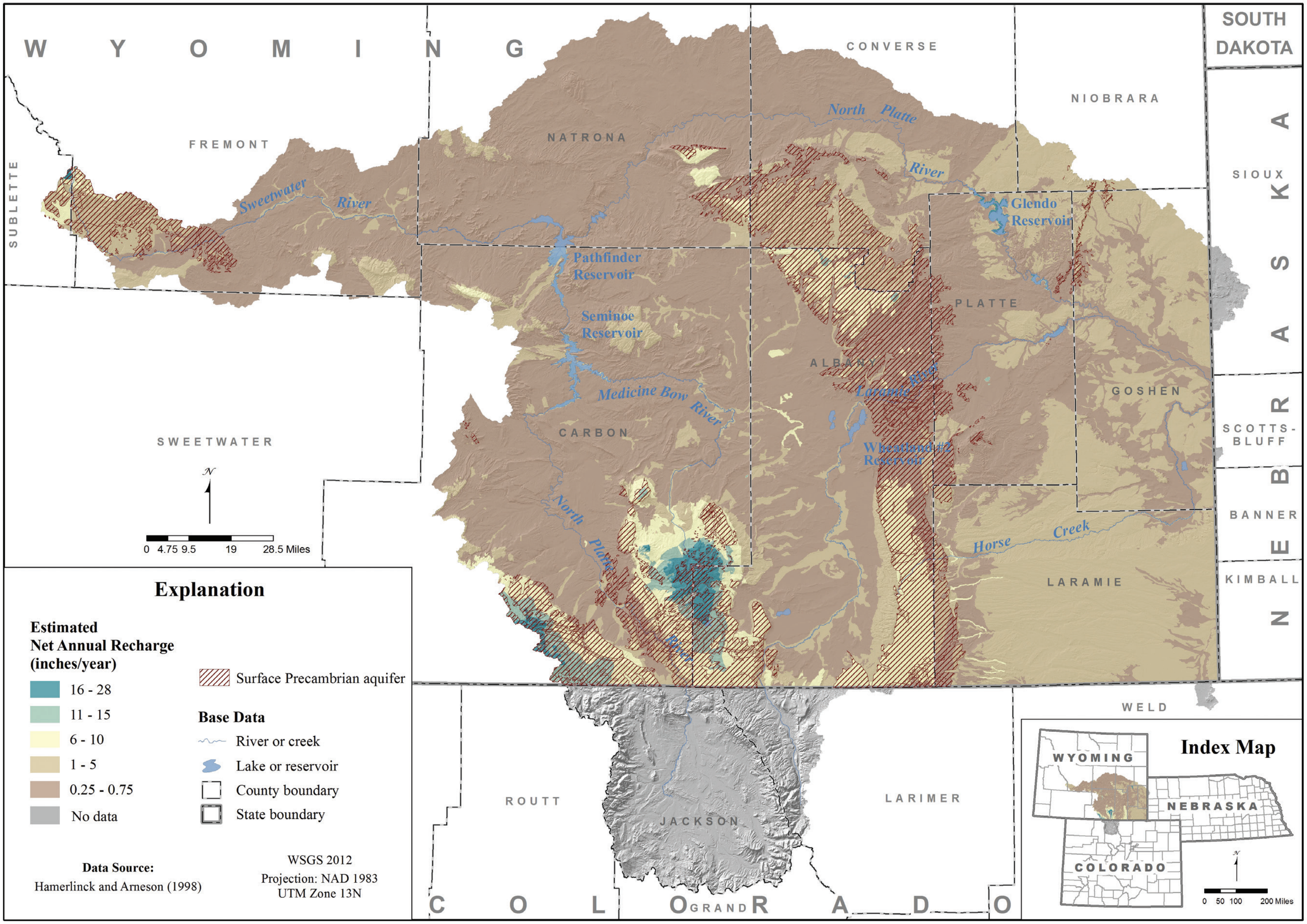

Figure 6-6. Estimated net annual aquifer recharge – surface **Precambrian** Aquifer, Platte River Basin, Wyoming.

amounts of recharge than basin lowlands due to environmental attributes characteristic of highland zones:

- Greater amounts of precipitation and more persistent snow pack.
- More abundant vegetation.
- Soil and vegetation combinations that are more favorable to infiltration.
- Lower rates of evapotranspiration.
- Better exposure of the upturned and weathered edges of hydrogeologic units along upland basin margins and associated greater permeability parallel to bedding.
- The presence of geologic structural features that enhance recharge (e.g., faults, fractures, joints, fault/fracture-controlled surface drainages).

Figure 6-7 shows how recharge efficiency, defined as a percentage of average annual precipitation (R/P), varies throughout the Platte River Basin and suggests what environmental factors exert control on recharge. Recharge takes place most efficiently in the mountain and highland areas, but recharge rates are also elevated around the Platte River's large reservoirs, in the outcrops of Paleozoic formations located south of Casper, Glenrock, and Douglas and in the outcrops of the High Plains Aquifer in the eastern part of the basin. The data set for **Figure 6-7** was generated by dividing 4,000-meter grid cells of average annual aquifer recharge shown in **Figure 5-2** (Hamerlinck and Arneson, 1998) by average annual precipitation (**Figure 3-3**) for the 30 year period of record from 1992-2010 (PRISM Climate Group, 2012). The average annual recharge rates depicted in **Figure 5-2** are based on percolation percentages for different soil/vegetation combinations. (Note that the PRISM data for the two 30 year periods of record (1961-1990 and 1992-2010) indicate that the precipitation volumes for the two periods are essentially equivalent as discussed in **Section 5.1.3.1**). Although this approach does not take into consideration all of the factors that affect recharge, initial infiltration and precipitation levels are probably the most important factors in a regional sense. Consideration of the other factors listed above and in **Section 5.1.3.1** should confirm the general pattern of recharge efficiency displayed in **Figure 6-7**. As discussed previously (**Sections 5.1.3.1 and 5.4**), local recharge rates may be dominated by site-specific hydrogeologic conditions (e.g., solution-enhanced fracture permeability).

Hamerlinck and Arneson (1998) indicated that most areas in the basin interior receive zero or, in some cases, negative amounts of recharge. This contradicts well-documented observations of the presence of shallow groundwater in both alluvial and bedrock aquifers throughout the subbasin interior lowlands of the Platte River Basin. In the absence of any recharge, the presence of shallow groundwater could not be sustained in these regions. So, during the development of **Figure 6-7**, minimal positive annual recharge values were assigned to lowland areas where Hamerlinck and Arneson, (1998) indicated that recharge is less than or equal to zero. A conservative low range of recharge (0.25 to 0.75 inches) was used for volume calculations and for developing **Figure 5-2** and the average of that range (0.5 inches) was used for developing **Figure 6-7**. This adjustment, while reasonable, does exert an influence on the appearance of both the recharge (**Figure 5-2)** and recharge efficiency maps (**Figure 6-7** and **Tables 6-1** through**6-3)**.

Table 6-1 shows the percent of surface area by specified range of recharge efficiency, as R/P, for each of the six age-classified *aquifer recharge zones* (**Plate 2 – inset, *Figures 6-1 through 6-6***). Calculations were made by GIS analysis. These *aquifer recharge zones* are also used to calculate recharge volumes in **Chapter 8**.

Table 6-1 shows that most recharge to all *aquifer recharge zones* in the Platte River Basin occurs at the lowest range of recharge efficiency (2 percent to 10 percent of precipitation). Higher proportions of Paleozoic and Precambrian aquifers receive recharge at efficiencies greater than 10 percent than do younger units. This is likely due to the higher elevation exposures of older aquifers in upland areas where recharge is delivered more efficiently. The consistent low recharge efficiencies seen in the Tertiary and Mesozoic aquifer zones may reflect the relatively low variation in elevation and associated precipitation (**Figure 3-3**) in the subbasin interiors of the Platte River Basin. Areas of slightly higher recharge in the

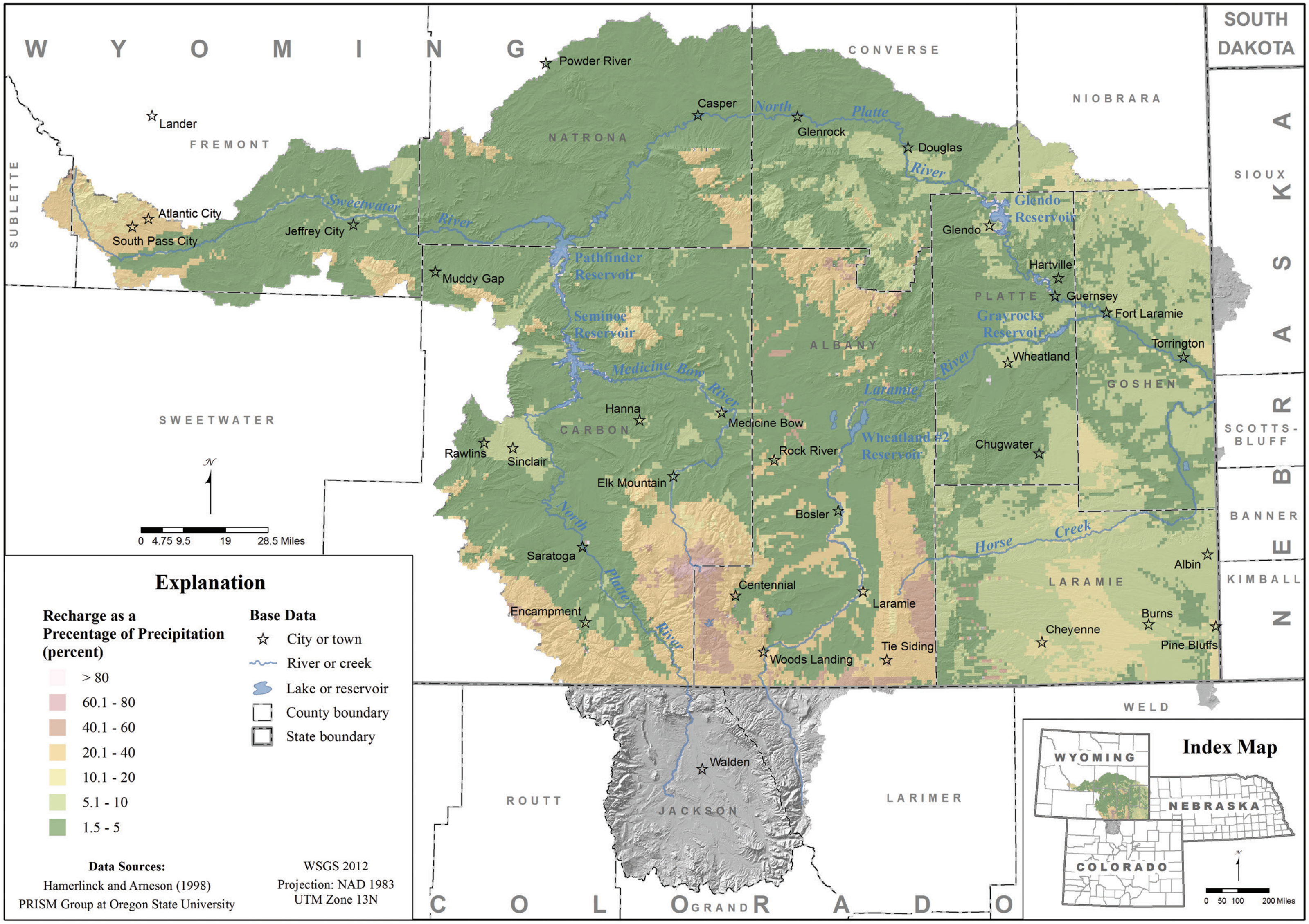

Figure 6-7. Aquifer recharge as percentage of precipitation using 1981 – 2010 precipitation normals, Platte River Basin, Wyoming.

Table 6-1. Platte River Basin Aquifers and Groups of Aquifers.

Percent of aquifer recharge zones recharging at varying efficiencies									
Recharge Efficiency as Annual Recharge / Annual Precipitation, in percent	2-10	11-20	21-30	31-40	41-50	51-60	61-70	71-100	>100
Quaternary	81.1	6.2	6.6	3.1	1.4	1.0	0.38	0.23	0.08
Upper Tertiary	89.2	8.3	1.2	0.67	0.34	0.06	---	---	0.16
Lower Tertiary	89.2	2.4	5.3	1.4	0.79	0.36	---	0.56	---
Mesozoic	92.7	1.2	3.7	1.1	1.0	0.19	---	0.22	0.01
Paleozoic	69.2	13.2	11.0	5.4	0.68	0.20	---	---	0.24
Precambrian	69.2	13.2	11.0	5.4	0.68	0.20	---	---	0.24

High Plains aquifer in eastern part of the basin may be due to more favorable soil/vegetation conditions. **Figure 6-7** also shows that elevated recharge efficiencies in excess of 80 percent are limited to those areas bordering the Seminoe, Pathfinder, and Glendo reservoirs. **S**ome of these areas have apparent recharge efficiencies above 100 percent.

Recharge volumes for the established *aquifer recharge areas* were calculated using the following general equation:
Average annual recharge volume (acre-feet) = ***Aquifer recharge area*** (acres) × Average annual recharge (feet)

The outcrop areas of the exposed aquifer groups used in the recharge calculations **(Figures 6-1 through 6-6)** were determined from the hydrogeologic map **(Plate 2)** developed for this study. As discussed above, average annual rates of recharge throughout the Platte River Basin (mapped in 100-meter cells), adapted from the Wyoming Groundwater Vulnerability Assessment Handbook (Hamerlinck and Arneson, 1998) are shown in **Figure 5-2**. Recharge rates were grouped into the five ranges to make **Figure 5-2** more readable, and to mitigate the uncertainties associated with the recharge calculations. Recharge rates for the *aquifer recharge zones*, mapped as polygons, were converted from inches to feet, and the average annual recharge volumes (in acre-feet) were calculated using the equation above.

With the exception of the Precambrian aquifer group, these recharge calculations do not consider confining unit outcrop areas (**Plate 2**). Although Precambrian hydrogeologic units are generally classified as confining, the Precambrian group was included as an aquifer because it provides useable amounts of groundwater in outcrop areas as a result of the formation of shallow secondary permeability from fracturing and weathering. As noted in **Section 5.2,** undifferentiated geologic units were included in the established *aquifer recharge areas* of the same era. Recharge calculations that exclude confining-unit outcrop areas provide a more conservative and probably more realistic estimate of available groundwater resources. Leakage from adjacent confining layers was not considered in this evaluation.

Table 6-2 summarizes calculated recharge for the Platte River Basin over the ranges of average annual recharge mapped on **Figure 5-2** and the *aquifer recharge zones* on **Figures 6-1 through 6-6.** Low and high recharge values were calculated by multiplying the surface area of each aquifer recharge zone by the lowest and highest recharge rate observed for each group. A “best total” amount for each range of recharge over the outcrop area of each aquifer group is also provided in **Tables 6-2** and **6-3** based on the recharge area for each integral inch of recharge in the database

Table 6-2. Platte River Basin Average Annual Recharge Calculations.

ERA	Range of Average Recharge per year: Inches	Feet	Outcrop Area Receiving Recharge: Acres	Range - Average Annual Recharge: Acre-feet		Best Total (Acre-feet)
Quaternary	0.25	0.02	1,561,546	32,532		65,064
	0.75	0.06			97,597	
	1	0.08	614,963	51,247		85,728
	5	0.42			256,235	
	6	0.50	87,854	43,927		54,450
	10	0.83			73,212	
	11	0.92	48,861	44,789		52,127
	15	1.25			61,077	
	16	1.33	42,048	56,064		73,173
	28	2.33			98,112	
Low TOTAL			2,355,272	228,560		330,542
High TOTAL					586,231	

ERA	Range of Average Recharge per year: Inches	Feet	Outcrop Area Receiving Recharge: Acres	Range - Average Annual Recharge: acre-feet		Best Total (acre-feet)
Mesozoic	0.25	0.02	1,073,053	22,355		44,711
	0.75	0.06			67,066	
	1	0.08	112,934	9,411		19,555
	5	0.42			47,056	
	6	0.50	13,627	6,813		8,359
	10	0.83			11,356	
	11	0.92	592	542		580
	15	1.25			739	
	16	1.33	442	589		873
	28	2.33			1,031	
Low TOTAL			1,200,647	39,711		74,077
High TOTAL					127,248	

ERA	Range of Average Recharge per year: Inches	Feet	Outcrop Area Receiving Recharge: Acres	Range - Average Annual Recharge: acre-feet		Best Total (acre-feet)
Upper Tertiary	0.25	0.02	3,125,337	65,111		130,222
	0.75	0.06			195,334	
	1	0.08	2,562,974	213,581		268,817
	5	0.42			1,067,906	
	6	0.50	53,554	26,777		31,122
	10	0.83			44,628	
	11	0.92	7,452	6,831		7,224
	15	1.25			9,315	
	16	1.33	3,852	5,136		5,644
	28	2.33			8,988	
Low TOTAL			5,753,169	317,436		443,029
High TOTAL					1,326,171	

ERA	Range of Average Recharge per year: Inches	Feet	Outcrop Area Receiving Recharge: Acres	Range - Average Annual Recharge: acre-feet		Best Total (acre-feet)
Paleozoic	0.25	0.02	259,420	5,405		10,809
	0.75	0.06			16,214	
	1	0.08	178,378	14,865		51,450
	5	0.42			74,324	
	6	0.50	19,302	9,651		11,170
	10	0.83			16,085	
	11	0.92	445	408		469
	15	1.25			556	
	16	1.33	296	395		499
	28	2.33			691	
Low TOTAL			457,841	30,723		74,397
High TOTAL					107,870	

ERA	Range of Average: Inches	Feet	Outcrop Area Receiving Recharge: Acres	Range - Average Annual Recharge: acre-feet		Best Total
Lower	0.25	0.02	1,259,709	26,244		52,488
	0.75	0.06			78,732	
	1	0.08	121,767	10,147		33,180
	5	0.42			50,736	
	6	0.50	32,889	16,444		20,724
	10	0.83			27,407	
	11	0.92	6,655	6,100		6,640
	15	1.25			8,318	
	16	1.33	4,980	6,641		9,573
	28	2.33			11,621	
Low TOTAL			1,425,999	65,576		122,606
High TOTAL					176,814	

ERA	Range of Average: Inches	Feet	Outcrop Area Receiving Recharge: Acres	Range - Average Annual Recharge: acre-feet		Best Total
Precambrian (+ Qt & Tert)	0.25	0.02	710,375	14,799		29,599
	0.75	0.06			44,398	
	1	0.08	609,478	50,790		126,470
	5	0.42			253,949	
	6	0.50	731,226	365,613		461,534
	10	0.83			609,355	
	11	0.92	141,798	129,982		148,784
	15	1.25			177,248	
	16	1.33	60,381	80,507		105,995
	28	2.33			140,888	
Low TOTAL			2,253,259	641,691		872,382
High TOTAL					1,225,839	

Platte River Basin TOTAL	13,446,188	1,323,698		1,917,033
			3,550,173	

Conversion Factors:

$1 ft^3$ =	7.480519	gal
1 acre-ft =	325,829	gal
$1 m^2$ =	10.76391	ft^2

compiled for this study. Although these values fall between the high and low results, the "best total" is not an average of the high and low values but rather a "weighted average" calculated directly from the detailed (cell-by-cell) recharge data and the corresponding surface area.

Table 6-3 summarizes calculated average annual recharge statistics for the Platte River Basin from the more detailed calculations provided in **Table 6-2** and provides a "best total" average recharge depth. This last statistic, equivalent to the depth of recharge that would be delivered over the entire surface area of each aquifer recharge zone, provides a measure of recharge that is independent of surface area. An analysis of the values of "best total" average recharge depths shows that high elevation Precambrian aquifers collect four times the depth of recharge received by the basinward Tertiary and Mesozoic zones. Paleozoic aquifers, typically located in upland settings, and predominantly alluvial Quaternary age aquifers receive twice the depth of recharge as the basin aquifers.

Table 6-2 illustrates that, predictably, the percentages of recharge volumes are generally consistent with the surface areas of the *aquifer recharge zones.* However, while the *Upper Tertiary Aquifers* (**Figure 6-3**) constitute the largest *aquifer recharge area* in the Platte River Basin, they receive the second largest volume of recharge. The *Precambrian Aquifer* (**Figure 6-6**) with less than half the outcrop area of the *Upper Tertiary Aquifers* stands out as receiving more recharge than any of the other *aquifer recharge areas* (34 percent to 49 percent of all annual recharge). The *Quaternary Aquifers* (**Figure 6-1**) receive the third most recharge in the Platte River Basin. Although the *Paleozoic Aquifers* (**Figure 6-5**) are a very important source of groundwater, especially in the Laramie Basin, they constitute by far the smallest *aquifer recharge area* and receive the smallest recharge volume in the Platte River Basin.

For the most part, the high rates of recharge over the mountainous Precambrian outcrop areas do not translate into large quantities of stored groundwater. The hydrogeology of the Precambrian aquifers differs markedly from the sedimentary aquifers that overlie the crystalline basement rocks along the margins of uplifted areas and in structurally downwarped areas of the Platte River Basin. With low intercrystalline permeability the Precambrian basement complex in Wyoming typically functions as a confining unit except where it is exposed in uplifted areas and extensive joints, fractures and faults have developed as the result of tectonic activity and weathering. Groundwater is stored and transported through the "secondary porosity" formed by these shallow fractures, typically to depths of less than 300 feet below the lowest elevation of erosion along drainages. Aquifers dominated by secondary porosity are characterized by low storage and rapid transport times in contrast to the high storage coefficients but longer flow times exhibited by sedimentary aquifers with higher intergranular

Table 6-3. Annual recharge statistics[1] for Platte River Basin aquifer recharge zones.

Aquifer Recharge Zone	Recharge zone surface area (acres)	Percent of total basin surface area	Range - Average annual recharge (acre-feet)		"Best total" annual recharge volume (acre-feet)	"Best total" recharge as percent of basin total	"Best total" average recharge depth (feet)
			Low	High			
Quaternary	2,355,272	17.52%	228,560	586,231	330,542	17.24%	0.140
Upper Tertiary	5,753,169	42.79%	317,436	1,326,171	443,029	23.11%	0.077
Lower Tertiary	1,425,999	10.61%	65,576	176,814	122,606	6.40%	0.086
Mesozoic	1,200,647	8.93%	39,711	127,248	74,077	3.86%	0.062
Paleozoic	457,841	3.40%	30,723	107,870	74,397	3.88%	0.162
Precambrian	2,253,259	16.76%	641,691	1,225,839	872,382	45.51%	0.387
Total, all recharge zones	**13,446,188**	**100.00%**	**1,323,698**	**3,550,173**	**1,917,033**	**100.00%**	**0.143**
Total, sedimentary zones, Paleozoic through Quaternary zones	**11,192,929**	**83.24%**	**682,006**	**2,324,334**	**1,044,651**	**54.49%**	**0.093**
[1] adapted from Hamerlinck and Arneson, 1998							

porosities. This characteristic is illustrated by the rapid seasonal decreases in mountain spring flows. Most groundwater in the Precambrian aquifers discharges to and sustains flows to lakes and mountain streams. As these streams flow basinward, they cross and recharge the younger sedimentary geologic units that crop out along the margins of the structural groundwater basins. The observed high rates of recharge in the Precambrian aquifers are offset by high rates of natural discharge which means that the volume of recharge stored in the Precambrian units is quite low. Groundwater development in the Precambrian aquifer is limited to local springs and low-yield wells.

When all of the Platte River Basin's estimated recharge is considered, it constitutes 7 to 17 percent of total precipitation. If recharge to the Precambrian terrain is discounted, because much of the recharge to these aquifers is discharged to surface waters, total recharge ranges from approximately 4 to 11 percent (**Table 8-2b**) of total precipitation. These estimates encompass the "rule-of-thumb" frequently cited by water resource professionals that 10 percent of precipitation eventually becomes recharge. Finally, the volumes of recharge that enter groundwater storage are further reduced in areas where recharge is "rejected" or discharged as spring flow. Once rejected, it may be evaporated, beneficially used or discharged as streamflow.

6.3 Summary

- Recharge ultimately controls the availability and sustainability of regional groundwater resources, and recharge is controlled directly and indirectly by precipitation. Total average annual precipitation in the Platte River Basin for the 1981-2010 period of record has been estimated as 19,677,577 acre-feet (**Table 8-2a**).
- Recharge controlled by precipitation and soil/vegetation combinations in the Platte River Basin ranges from 0 to 28 inches (Hamerlinck and Arneson, 1998), with the lowest values occurring in the interior basins and the highest in the surrounding mountain ranges.
- Recharge efficiency (recharge as a percentage of precipitation, or R/P) varies based on the factors used the Wyoming Groundwater Vulnerability Assessment Handbook (Hamerlinck and Arneson, 1998) to estimate recharge throughout Wyoming.
- Other factors also control recharge and may dominate locally (e.g., solution enhanced fractures); however, the consideration of these factors should confirm the overall pattern of recharge and recharge efficiency from Hamerlinck and Arneson (1998).

Recharge from precipitation to the flat-lying Tertiary, and Mesozoic aquifers in the interior basin areas is generally less efficient than to the upturned Paleozoic and fractured Precambrian aquifers in the uplifted and mountainous areas and the typically alluvial Quaternary aquifers. Recharge is more efficient in some areas of the High Plains Upper Tertiary aquifer. Recharge in the Platte River Basin is most efficient in the higher mountain Precambrian terrains; however, most of the groundwater in this shallow fracture-control aquifer is rejected and discharged to surface waters.

- Because recharge from the Precambrian aquifer is mostly rejected, the best estimate for overall recharge in the Platte River Basin discounts Precambrian recharge volumes and considers only the younger sedimentary aquifers.
- Estimates of average annual recharge in the Platte River Basin is presented as a high/low range consistent with the range of recharge rates mapped over the aquifer outcrop areas and as a "best total" based on the cell-by-cell product of area and rate of recharge.
- Future analyses of recharge may incorporate some of the significant additional factors discussed in **Sections 5.1.3.1 and 5.4** such as the distribution and character of fractures, recharge from surface water bodies and improved quantification of ET rates. Current computational technology and data may allow these analyses on small geospatial areas but cannot yet extend studies of this detail over the entirety of the Platte River Basin.