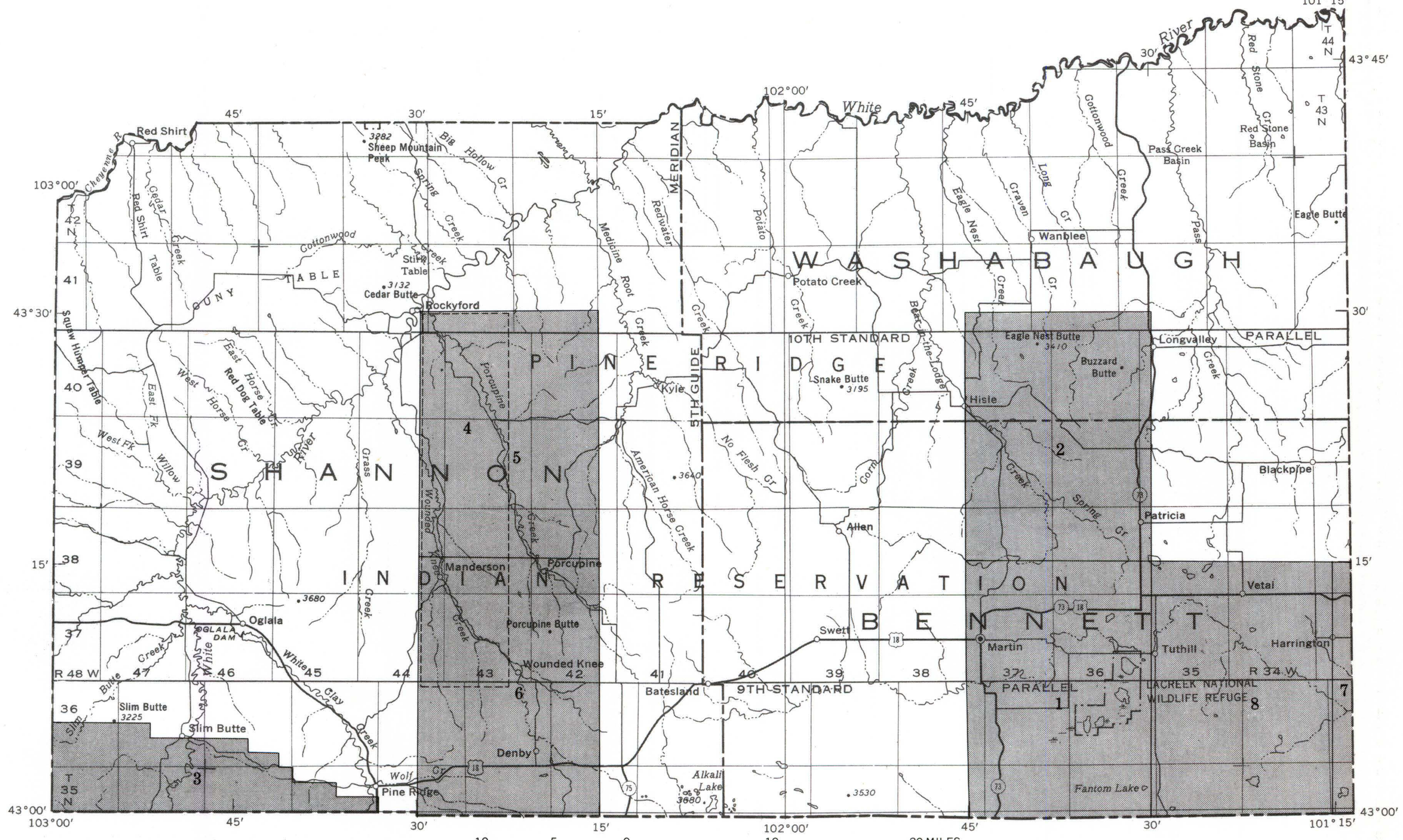

MAP SHOWING AREAS MAPPED PRIOR TO THIS INVESTIGATION

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INTRODUCTION

An investigation of the geology and ground-water resources of the Pine Ridge Indian Reservation, South Dakota, was made at the request of the Bureau of Indian Affairs as part of the U.S. Department of the Interior's program for the development of the Missouri River basin. The area of investigation (about 3,930 square miles) includes all the land within the original boundaries of the Reservation, except for that part of Bennett County south of the U.S. Highway 18, where there are only small tracts of Indian land.

Emphasis in the study was placed on mapping major rock units and on determining their potential as sources of water for domestic and stock use. The geologic map on sheet 1 shows the areal extent of the major rock units, and a summary of the stratigraphy and physical characteristics of the exposed geologic formations is given in the table on this sheet.

The writers appreciate the cooperation of the personnel of the South Dakota State Geological Survey, who provided most of the well data for Bennett County, information about the stratigraphy and geology of selected areas, and copies of published and unpublished geologic maps. (See map showing areas mapped prior to this investigation.) Also, they appreciate the cooperation of ranch owners and tenants, who permitted access to their lands, and the personnel of the Bureau of Indian affairs, who supplied soils maps and other data.

Data on which this report is based, including logs of wells and test holes, chemical analyses of water and records of wells and springs, have been summarized by the authors in a basic-data report published jointly by the South Dakota Geological Survey and the South Dakota Water Resources Commission (Water Resources Report 4, Basic hydrogeologic data—Pine Ridge Indian Reservation, South Dakota). A selected bibliography of reports pertaining to the geology of the area has been included in the basic-data report. This atlas will be more useful if studied in conjunction with a copy of the basic-data report.

HYDROLOGY

Ground water, from wells and springs, is the main source of supply for domestic, stock, and municipal use on the Pine Ridge Indian Reservation. Surface water from stock dams, streams, and lakes is used for stock supplies to supplement ground-water supplies or where shallow water-bearing deposits are not present. (See map showing areas underlain by shallow water-bearing deposits.)

Ground Water—Ground water in the project area is obtained, at least locally, from all the rock units shown on the geologic map (sheet 1) except the Pierre and Carlile Shales. None of the units, however, have a uniform potential for yielding water because of variation in their lithology, water-bearing properties, and thickness. The more significant variations are noted in the table summarizing the stratigraphy and physical characteristics of the exposed geologic formations.

In the area underlain by the Arikaree Formation, and including all of the younger units that overlie the Arikaree, there is a single continuous water table. The configuration of this water table is somewhat similar to that of the land surface, but is much smoother and has less relief. Depth to the water table is usually greatest beneath hills and ridges (150 to 275 feet) and shallowest beneath stream valleys and other low areas (0 to 50 feet).

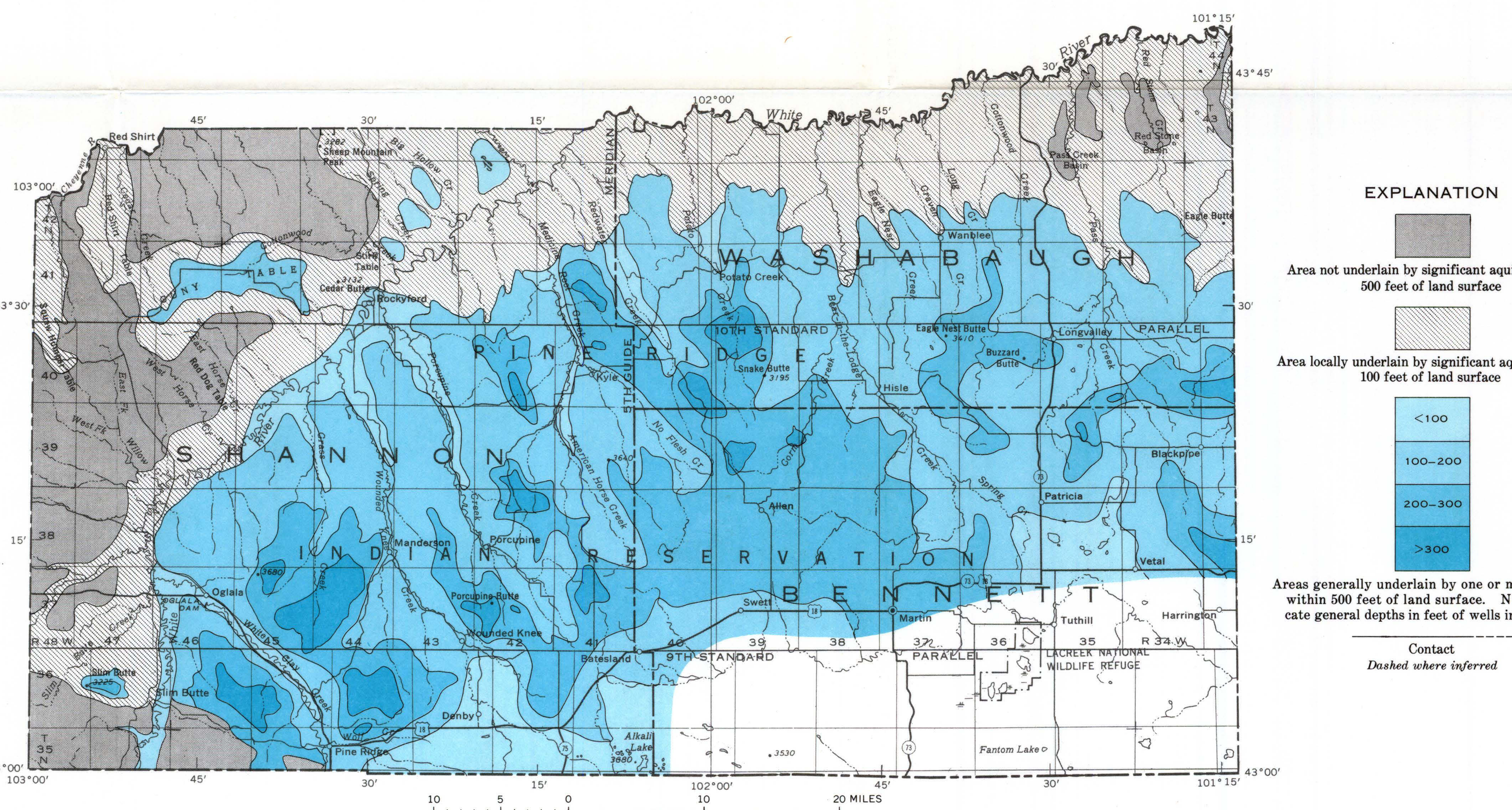
In a few places,discontinuous beds of impervious clay above the water table in terrace alluvium that overlies the Arikaree Formation obstruct downward percolation of water. Water that remains above such a clay barrier is called perched water. Although a few bodies of perched water may persist even in the driest seasons, most are temporary and not dependable sources of supply even for domestic purposes.

In the northern and western parts of the project area, where the Arikaree Formation has been removed by erosion, there is no continuous aquifer. Because of the relief and presence of many permeable beds overlying relatively impermeable clay and shale, there are many isolated, local, shallow aquifers. Water in those local aquifers is not considered to be perched water because there is no underlying water table. The extent of a local aquifer is governed by the extent of permeable beds overlying impermeable beds. Depth to water in these local aquifers varies with the thickness of the permeable beds, but is usually less than 50 feet.

Depth to water, especially in the Arikaree and the Ogallala Formations, is not necessarily an indication of the depth to which a well must be drilled to obtain an adequate water supply. Many of the rocks are not highly permeable and it may be necessary to drill a well through 100 feet or more of saturated material to insure an adequate supply. The areal extent of aquifers commonly used and the depth to which wells generally must be drilled to obtain sufficient water for domestic and stock use are shown on the map of areas underlain by shallow water-bearing deposits.

Springs occur most commonly in the northern and western parts of the project area where the deeply eroded land surface intercepts local water tables. Most of the springs are found along hillsides or in gullies, and are usually marked by a brush thicket or by a small grove of trees in an area normally devoid of vegetation other than grass, cactus, and sagebrush. Springs with the largest yields occur at the contact between wind-blown sand deposits or gravel in old terrace deposits and underlying clay of low permeability in the White River Group or the Pierre Shale. Seeps and springs with small yields often occur at the contact between the Arikaree Formation and the White River Group.

There are no deep artesian wells on the Reservation. Sandstones of Early Cretaceous age, which serve as aquifers around the Black Hills and in central South Dakota, underlie the entire area, but their potential is unknown. North of the Reservation, in the southern part of Pennington and Jackson Counties, water is obtained from wells completed in rocks of Early Cretaceous age at depths ranging from 2,500 to 3,000 feet.



MAP SHOWING AREAS UNDERLAIN BY SHALLOW WATER-BEARING DEPOSITS AND THE GENERAL WELL DEPTHS REQUIRED TO INSURE ADEQUATE YIELDS FOR DOMESTIC AND STOCK USE

Surface Water—Surface water impounded in small reservoirs or "stock ponds" is commonly used to supply water for cattle, especially in areas of the Reservation where shallow water-bearing deposits are absent or unproductive. These areas are generally underlain by either the Pierre Shale or the White River Group, both of which consist predominantly of soft shale and clay of low permeability. Precipitation that cannot infiltrate into the impermeable soils, can be salvaged for use in small stock reservoirs. Because the shale and clay are sufficiently impermeable to prevent significant seepage losses, the greatest loss of water from the reservoirs is by evaporation. Runoff resulting from local thunderstorms, however, is usually enough to make the reservoirs a reliable source of water.

Streams in the project area usually are not reliable sources of water. Most streamflow occurs in response to precipitation, however, during the spring and early summer when water levels are high, some seepage from ground water and discharge from springs supplement surface runoff in the streams. (See average monthly precipitation and runoff map.) Most precipitation occurs during the late spring and summer, with the largest amounts falling in May and June. The distribution of runoff is directly related to the distribution of precipitation, except during March when runoff is due primarily to snow melt.

The average monthly distribution of runoff is more uniform for the Little White River than for the White River. Flow in the White River is highest during March, May, and June, and low or erratic in response to storms the rest of the year. The more uniform flow in the Little White is due to very permeable sand formations in its drainage area. As a result, most of the precipitation seeps into the ground and then moves laterally into the streams through springs and seeps instead of running overland.

Flows in the numerous small streams that drain the project area are intermittent, except for short reaches of Bear-in-the-Lodge, Porcupine, Wounded Knee, and White Clay Creeks where the streambeds intercept the water table. Flows in the major streams (Cheyenne, White, and Little White Rivers) are usually perennial. During the summer, however, discharges often decrease to only a few cubic feet per second; and during extended dry periods there have been many days when no flow occured.

A few small lakes are in the southern and eastern parts of the project area. These lakes form in depressions, usually caused by wind erosion of sandy material when the water table is high enough to intercept the land surface. Usually, the lakes dry up or become marshy during the late summer months.

Quality of Water—Ground water throughout the Reservation is of satisfactory quality for most uses. Hardness ranged from 8 mg/l (milligrams per liter) to 1,120 mg/l in the 51 samples analyzed. The range of hardness is summarized in the following table:

Degree of hardness	Number of samples	Percent
Soft (0-60 mg/l)	13	25.5
Moderately hard (61-120 mg/l)	10	20
Hard (121-180 mg/l)	15	29
Very hard (181 mg/l or more)	13	25.5

Water from windblown sand deposits, old terrace deposits, and Tertiary deposits usually contains less than 500 ppm dissolved solids. Water from alluvial deposits, especially those underlain by Cretaceous formations, generally contains more than 500 ppm dissolved solids and in some places more than 2,000 ppm. (See geologic map.)

A summary of the quality of water from the Reservation in relation to the 1962 U.S. Public Health Service drinking water standards is given in the following table:

Substance	U.S. Public Health Service maximum recommended concentration[1]	Percent of 51 samples analyzed that exceeded maximum recommended concentration
Iron (Fe)	0.3 mg/l	27
Manganese (Mn)	.05	12
Sulfate (SO_4)	250	13
Chloride (Cl)	250	0
Nitrate (NO_3)	45	4
Total dissolved solids	500	35

[1]U.S. Public Health Service, 1962, Drinking water standards—1962: U.S. Public Health Service Pub. 956, 61 p.

Although some of the samples exceed one or more of the recommended maximum concentrations, most ground water from the Pine Ridge Indian Reservation is of acceptable quality for most uses.

Development—Present (1968) development of the water resources on the Reservation is not extensive. Wells have been completed in shallow rocks of Tertiary and Holocene age, and only the amounts of water necessary for domestic, stock, and municipal use are being withdrawn. Springs have been developed to increase their yields where natural flow was insufficient to meet the demands for domestic and stock use. Surface water is used only for livestock, except for small amounts withdrawn for irrigation from the White River and from White Clay Creek.

Large-capacity wells (more than 100 gallons per minute) have been constructed only for municipal supplies in the project area. However, the potential for large-capacity wells for irrigation and industrial use probably exists in much of the area underlain by the Arikaree Formation. The successful completion of wells depends largely upon their location and method of construction. The wells should be drilled where there is an adequate thickness of saturated permeable beds as determined by test drilling and electric logging. The method of well construction will depend upon the materials penetrated by the drill at a particular location. At all locations where the well penetrates the Arikaree Formation, the well should be screened and gravel packed at each water-yielding zone.

One method of constructing large-capacity wells is described by Gries[1] as follows:

"The newest city well at Martin starts in the lower Harrison and probably bottoms in the Sharps. It was drilled 30 inches in diameter; 10-inch casing was gravel-packed with minus ¼-inch road gravel. On the basis of sample study and electric log, screened sections were placed at 281-286, 366-378, 438-458, and 478-498 feet. The well was test pumped at rates up to 474 gallons per minute, and had an indicated specific capacity of 4.0 gallons per foot of drawdown. This method of continuous gravel packing, although expensive, is strongly recommended for wells in these Tertiary formations where large yields are desired, but no sharply defined permeable zones are encountered during drilling."

[1]Gries, J. P., 1964, Mineral resources and their potential on Indian lands—Pine Ridge Reservation, Shannon, Washabaugh, and Bennett Counties, S. Dak.: U.S. Bur. Mines Prelim. Rept. 153, 66 p.

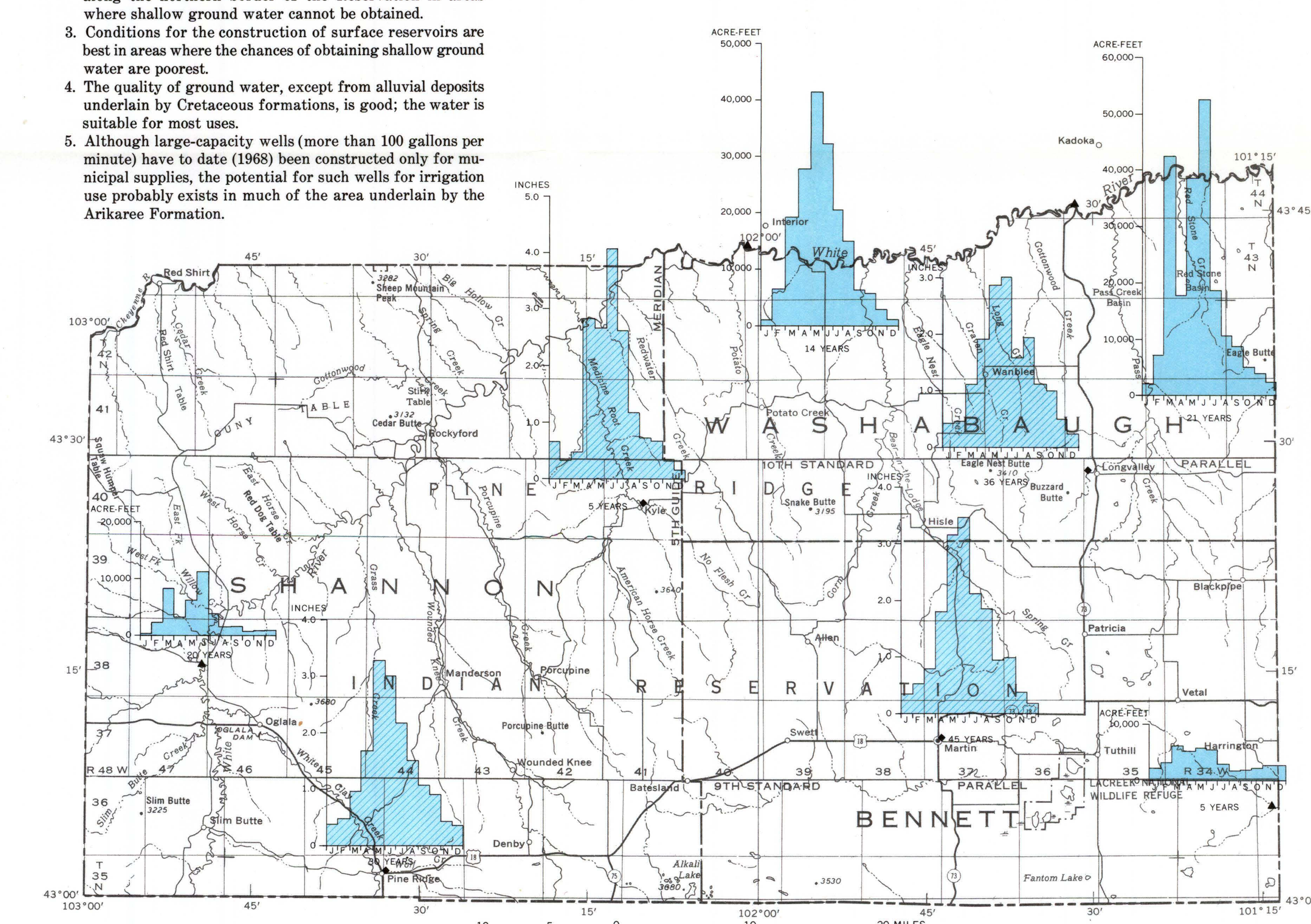
SUMMARY OF CONCLUSIONS

1. Adequate amounts of shallow ground water for domestic and stock use can be obtained throughout much of the Reservation, particularly in those areas underlain by the Arikaree Formation, Ogallala Formation, old terrace deposits, and windblown sand deposits.
2. Deep artesian wells, completed in Lower Cretaceous water-bearing rocks, are a potential source of supply, especially along the northern border of the Reservation in areas where shallow ground water cannot be obtained.
3. Conditions for the construction of surface reservoirs are best in areas where the chances of obtaining shallow ground water are poorest.
4. The quality of ground water, except from alluvial deposits underlain by Cretaceous formations, is good; the water is suitable for most uses.
5. Although large-capacity wells (more than 100 gallons per minute) have to date (1968) been constructed only for municipal supplies, the potential for such wells for irrigation use probably exists in much of the area underlain by the Arikaree Formation.

GENERALIZED STRATIGRAPHY AND PHYSICAL CHARACTERISTICS OF EXPOSED GEOLOGIC FORMATIONS

System	Series	Mapped unit	Recognizable subdivisions (not mapped)	Thickness (in feet)	Lithology	Topography and geology	Hydrology
QUATERNARY	Holocene	Flood-plain alluvium		0-40	Light-brown to gray clay, silt, and fine sand; discontinuous sandy and clayey gravel beds in lower part.	Flatlands adjacent to stream channels; composed of sediments deposited during present erosional cycle of streams. Generally thicker along White and Cheyenne Rivers (average thickness 25 to 35 feet) than along tributaries. Grades laterally into terrace alluvium.	Generally water bearing. Yields are adequate for domestic and stock needs, but differ because deposits are not uniform. Along some small tributaries deposits are thin, and wells commonly go dry in late summer or early fall. Water levels, especially along rivers, respond rapidly to changes in streamflow. Quality of the water is good where alluvium is underlain by Tertiary deposits and generally poor where underlain by Cretaceous rocks.
	Holocene and Pleistocene	Terrace alluvium		0-60	Light-brown clay, silt, and fine sand; thin discontinuous beds of medium to coarse gravel at or near the top. Clayey and sandy gravel common in the basal few feet, especially along the White River.	Flat terraces adjacent to, but higher than, present flood plains; remnants of flood plains formed during earlier erosional cycle of streams. As many as five distinct terraces are present at some locations. Small deposits of terrace alluvium along tributaries, especially in Washabaugh and Bennett Counties, are mapped as flood-plain alluvium.	Water bearing where deposits extend below the water table of adjacent flood-plain alluvium, or where water table is perched. Yields and water quality similar to those of flood-plain alluvium.
		Windblown sand deposits		0-200	Tan unconsolidated very fine to medium quartz sand.	Dune topography, characterized by small hills as much as 120 feet high and by closed depressions. Dunes are partly stabilized by vegetation. Sand probably derived from the Arikaree and Ogallala Formations.	Water table generally is near the base of sand. Some deep depressions contain ponds because the water table intersects the land surface. Springs are common along the margins of the deposits. Yields commonly more than adequate for domestic and stock needs. Quality of water is good (dissolved-solids content generally less than 350 Mg/l).
	Pleistocene	Old terrace deposits		0-80	Brown to light-brown silt, clay, sand, and gravel; sandy and silty layers often partly cemented by calcium carbonate; gravel and sand beds commonly interbedded with laminated silty clay.	Underlie nearly flat isolated terraces from about 80 to more than 200 feet above present stream. The terraces generally are alined parallel to the courses of the present White and Cheyenne Rivers and have a gentle slope towards the rivers. Only those deposits that are hydrologically significant are mapped.	Generally water bearing in the basal few feet. Springs and seeps are common along the river-side margins. Yields generally adequate for domestic and stock needs. Quality of water is good (dissolved-solids content generally less than 500 Mg/l.
TERTIARY	Pliocene	Ogallala Formation	Upper unit	0-150	Light-tan to light-gray calcareous, massive sandstone; thin discontinuous beds of limestone common near the base. Beds of volcanic ash as much as 11 feet thick locally occur near the top.	Thin caprock on isolated buttes and ridges in Shannon and Washabaugh Counties; caps high elevations in northeastern Bennett County, where it erodes to low but prominent bluffs. Mapped as the Ash Hollow Formation of the Ogallala Group by the Nebraska and South Dakota State Geological Surveys.	Relatively impermeable; water bearing only locally because of high topographic position.
			Lower unit	0-200	Light-gray to light-olive-green fine to medium, unconsolidated or poorly consolidated sand; lower part locally cemented with calcium carbonate.	Forms gentle slopes between bluffs of underlying Arikaree. Small blowouts are common in sandy areas. Mapped as the Valentine Formation of the Ogallala Group by the Nebraska and South Dakota State Geological Surveys.	Generally water bearing where areally extensive. Springs and seeps common at contact with underlying Arikaree. Yields of most wells adequate for domestic and stock needs. Quality of the water is good (dissolved-solids content generally less than 250 Mg/l).
	Miocene	Arikaree Formation	Unit E	0-235	Light-tan to brown, interbedded calcareous sand, silt, and clay; contains gray to pinkish-gray tabular concretions and small light-brown and greenish clay balls.	Rolling hills; easily erodible by wind. Small blowouts and thin, isolated deposits of windblown sand are common. Mapped by the South Dakota State Geological Survey as the Rosebud Formation, and probably equivalent to units mapped as the Hemingford Group by the Nebraska State Geological Survey.	Lack of detailed subsurface information makes it impossible to determine the water-bearing properties of individual units. However, the Arikaree is the most common source of ground water on the Reservation. Yields vary, probably because of well location and method of completion, but are usually adequate for domestic and stock needs. Large yields have been obtained for municipal use (Martin and Pine Ridge). Springs and seeps occur at the contact between the Arikaree and the underlying White River Group, and at contacts between permeable and impermeable zones within the Arikaree. The quality of water is generally good (dissolved-solids content generally less than 500 Mg/l). The few instances where dissolved-solids content is almost 1,000 Mg/l may be due to contamination from the surface or from local mineralized zones).
			Unit D	0-125	Gray, massive, poorly consolidated, fine to very fine sand; commonly contains layers of light-gray sandy marl, large pipey concretions, and small spherical concretions. Formation becomes silty toward the east; concretions in the lower part present only in discontinuous zones. Unit is difficult to differentiate from underlying units.	Rolling hills except along valleys where it forms steep slopes interrupted by small ledges; erodes to gently undulating hills in east part of reservation. Mapped by the South Dakota State Geological Survey as the Harrison Formation.	
			Unit C	0-90	Buff siltstone and very fine-grained sandstone; sandier toward the east. Difficult to distinguish from overlying and underlying units.	More resistant to erosion than other units of the Arikaree; forms cliffs along major tributaries, but forms a rolling, hummocky topography where exposed in the upland areas. Mapped as the Monroe Creek Formation by the South Dakota State Geological Survey.	
			Unit B	0-375	Pinkish-tan poorly consolidated silt and very fine-grained sand; gray, small (2-4 inches) calcareous concretions are common. Lenses of limestone and channel sand and gravel occur locally throughout the unit in the central and western parts of the reservation.	Gently rolling grass-covered hills. [Called the Sharps Formation by Harksen and others (1961).[1]] Mapped as the Sharps Formation by the South Dakota State Geological Survey.	
			Unit A	0-45	White, tan, buff, and reddish-brown silty volcanic ash; interbedded with thin layers of silt.	Forms prominent light-colored cliff between the Arikaree and White River; caps buttes and tables in northwestern part of Reservation. Called the Rockyford Ash Member of the Sharps Formation by Nicknish and McDonald (1962)[2]	
	Oligocene	White River Group	Brule Formation	0-450	Gray, yellowish-gray, and buff sandy clay and silt; distinct zones of calcareous concretions ("nodular layers") and channel sandstone or conglomerate. Horizontal color banding in shades of red, brown, and green is common, especially in the lower half of the formation.	Most common exposure is in the steep fluted cliffs and bluffs typical of the White River Badlands. On tables and other level surfaces the gently rolling topography is similar to that formed on the Sharps Formation.[1]	Generally too impermeable to serve as a source of ground water; local fractured zones and channel sands yield some water, which generally contains less than 500 Mg/l dissolved solids.
			Chadron Formation	0-110	Pale-gray-green bentonitic clay alternating with layers of greenish-gray siltstone. Thin limestone beds common in the northwestern part of the Reservation; a thin, discontinuous basal sandstone occurs locally in the northeastern part of the Reservation.	Forms low, rounded, barren "haystack" knolls. Contact between Chadron and Brule is transitional, but is probably best picked at the break in slope between the gentle rise of the Chadron and the steeper slope of the overlying Brule.	Generally too impermeable to serve as a source of ground water. Local basal sandstones in the northeastern part of the Reservation yield small amounts of water. The quality of the water is fair (dissolved-solids content mostly between 600 and 1,000 Mg/l).
CRETACEOUS	Upper Cretaceous	Pierre Shale		0-1,200±	Dark-gray marine shale and mudstone, containing several zones characterized by bentonitic beds, concretions, or differences in lithology. The upper part of the Pierre, where it is in contact with the overlying Chadron Formation, is deeply weathered (as much as 55 feet) and the dark shale has been altered to red, yellow, and orange claystone. Basal 75 to 100 feet of the formation (Sharon Springs Member) consists of a very dark-gray fissile shale with numerous beds of bentonite.	Generally erodes to rolling topography with deeply incised streams. The upper weathered zone is commonly referred to as the "Interior beds." Basal part weathers to form low unvegetated bluffs that rise above the less resistant beds of the underlying Niobrara.	Not a source of ground water. Very small seeps occur locally in sandy zones, but the water is highly mineralized. Water from alluvium that is composed in part of Pierre Shale fragments or is in contact with the Pierre generally has a dissolved-solids content of 2,000 Mg/l or more.
		Niobrara Formation		0-325±	Upper third consists of yellowish-gray to pale-yellow shaly limestone. At the few locations where the Niobrara is in contact with the Chadron Formation, the upper 20 to 25 feet of the Niobrara is deeply weathered to a red, yellow, and orange noncalcareous claystone. Lower two-thirds consists of light-grayish-yellow to brownish-yellow very calcareous shale, with scattered thin interbeds of dark-gray noncalcareous shale.	Upper third of the Niobrara forms steep bluffs with thin limestone ledges, and lower two-thirds erodes to gently rolling grasslands. Light-yellow coloring of the formation is due primarily to weathering; unweathered Niobrara generally is a light-bluish-gray.	Normally not a source of ground water; however, in areas where the limestone part of the formation is fractured, small yields of mineralized water may be obtained.
		Carlile Shale		100-325±	Dark-gray to brownish-gray marine shale and mudstone. Large septarian concretions common in the upper third of formation. Middle part of formation is sandy and contains thin limestone ledges locally.	Gently rolling grass-covered hills.	Not a source of ground water.

[1] Harksen, J. C., McDonald, J. R., and Sevon, W. D., 1961, New Miocene formation in South Dakota: Am. Assoc. Petroleum Geologists Bull., v. 45, no. 5, p. 674-678. (Also reprinted as South Dakota Geol. Survey Misc. Inv. No. 3.)
[2] Nicknish, J. M., and McDonald, J. R., 1962, Basal Miocene ash in White River badlands, South Dakota: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 5, p. 685-690. (Also reprinted as South Dakota Geol. Survey Misc. Inv. No. 7.)



MAP SHOWING AVERAGE MONTHLY PRECIPITATION AND RUNOFF

EXPLANATION

Gaging station

Precipitation station

Precipitation

Runoff

(Number of years of record are given below graphs.)

The following four gaging stations have sufficient records for computation average annual discharge:

1. White River near Oglala (SW¼NE¼ sec. 24, T. 38 N., R. 47 W.). Drainage area about 2,200 square miles. Records available for water years 1944–63. Average annual discharge 44,740 acre-feet.
2. White River near Interior (SE¼ sec. 12, T. 4 S., R. 17 E.). Drainage area about 4,120 square miles. Records available for water years 1904–06, 1912–18, 1928–31, and 1939–44. Average annual discharge 185,340 acre-feet.
3. White River near Kadoka (SE¼SE¼ sec. 30, T. 3 S., R. 22 E.). Drainage area about 5,000 square miles. Records available for water years 1943–63. Average annual discharge 210,000 acre-feet.
4. South Fork White River near Vetal (NW¼ sec. 17, T. 36 N., R. 33 W.). Drainage area about 590 square miles. Records available for water years 1960–64. Average annual discharge 38,660 acre-feet.

Base from U.S. Geological Survey State base map, 1961

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1971

HYDROGEOLOGY OF THE PINE RIDGE INDIAN RESERVATION, SOUTH DAKOTA

By
M. J. Ellis and D. G. Adolphson

1971