GROUND-WATER RECONNAISSANCE OF THE GREEN RIVER BASIN SOUTHWESTERN WYOMING

by George E. Welder

INTRODUCTION

This report describes the occurrence and quality of ground water in the Green River structural basin of Wyoming. Some general information concerning surface water has been included because of the close relationship of ground water to surface water in parts of the basin. The report gives the results of one of several ground-water reconnaissance investigations of large areas in Wyoming that are being conducted in cooperation with the Wyoming State Engineer. Each area generally coincides with one or more structural features that form relatively independent ground-water systems. The purpose of these studies is to obtain a general knowledge of ground water in previously unstudied parts of the State in order to locate potential water supplies for future development.

The area of this investigation consists of approximately 10,000 square miles, and includes all of the Green River structural basin, which is about 60 percent of the Wyoming part of the Green River drainage basin. It does not include the Wyoming thrust belt along the western side of the drainage basin, nor the Rock Springs uplift, the Washakie Basin, and the Sierra Madre uplift in the eastern part of the drainage basin. (See structural feature map.) Almost all of Sublette County and substantial parts of Lincoln, Sweetwater, and Uinta Counties are in the area studied.

Major uplifts border the Green River structural basin on all sides. Much of the bordering highlands consist of high rugged mountains and, except for the Uinta Mountains in Utah on the south, are shown on the structural feature map. The high mountain areas in the north and south support pine and aspen, but the ridges and hills in the eastern and southwestern parts of the area are nearly barren. The basin floor, which ranges from about 6,000 to about 7,500 feet above sea level, is typified by treeless plains, mesas, and badlands. Altitude extremes are 13,785 feet at Gannett Peak in the Wind River Mountains in the northern part of the basin, and about 6,000 feet where the Green River leaves Wyoming in the southern part of the basin.

The Green River and its major tributaries are shown on the streamflow map. Most of these streams flow nearly all year and reach their peak-flow stage in late spring. The numerous intermittent streams shown on the geologic map, but not on the streamflow map, flow for only short periods in response to precipitation.

Climatic conditions in much of the south half of the area are arid and similar to those at the town of Green River which has an average annual precipitation of 7.9 inches. The temperature extremes for 60 years of record at Green River are -40° and +104°F, and the average annual temperature is about 44°F. Average annual precipitation at Pinedale near the foot of the Wind River Mountains and at Kendall near the head of the Green River are 10.6 and 16.9 inches, respectively. Monthly distribution of precipitation at Green River and Kendall is illustrated with the map showing streamflow. Precipitation in some years might be as much as 35 inches at higher altitudes in the Wind River Mountains.

The principal known mineral resources of the area are water, trona, natural gas, oil, and oil shale; all except the latter are being developed. Other activities that support the economy are transportation, tourist trade, and agriculture. Agricultural activities include sheep and cattle raising throughout much of the area and the growing of native hay along the major stream valleys. About 385,000 acres of land is irrigated with surface water on the flood plains of the Green River and its tributaries.

Much of the land in the Green River Basin is still public domain administered by the U. S. Bureau of Land Management. The Union Pacific Railroad controls nearly all odd-numbered sections for 20 miles north and south of the railroad.

Very little hydrologic work of a detailed nature has been done in the Green River Basin. A study in the Eden-Farson irrigation area by the U. S. Bureau of Reclamation includes some quantitative ground-water work. Considerable information about the geohydrology, but little quantitative information, is given by C. J. Robinove and T. R. Cummings (1963) in their report on a 300 square-mile area in the vicinity of Lyman. Other hydrologic reports have only very general information. They include publications by Gordon and others (1960), Iorns and others (1964, 1965), and several unpublished studies of range well sites made by the U.S. Geological Survey for the U.S. Bureau of Land Management.

WELL-NUMBERING SYSTEM

The well-numbering procedure used in this report is based on the U.S. Land Grant System. The first segment of the number is the township (north); the second number segment is the range (west); the third number segment is the section, which is followed by a first letter designating quarter section, a second letter, if shown, designating quarter-quarter section, etc., (a - NE¼, b - NW¼, c - SW¼, d - SE¼). Well 30-110-15dbc2, for example, is in the SW¼ of the NW¼ of the SE¼ of section 15, Township 30 North, Range 110 West. The number 2 indicates a second well in the quarter-quarter-quarter section.

GENERAL GEOLOGY

The rocks that underlie the area of this investigation range in age from Precambrian to Recent. Rocks at the surface are divided as follows: 82 percent of Tertiary and Quaternary age, 2 percent of Paleozoic and Mesozoic age, and 16 percent of Precambrian age. (See geologic map.) The greatest thickness of sedimentary rocks (about 30,000 feet) in the basin is in the deep syncline that trends northwest through T. 30 N., R. 108 W. parallel to the Wind River Mountains (Krueger, 1960). Individual rock units are described in the generalized section of the geologic formations.

The structure of the Green River Formation is shown on the geologic map by contours drawn on a horizon near the base of the Fontenelle Tongue and Tipton Shale Member of the Green River Formation. The mapping horizon is persistent and detectable on electric logs in the north and east, but is difficutlt to trace in the southwest and along the south margin of the area because of facies changes (Culbertson, 1965) and insufficient well control.

The structure of the Cretaceous and older rocks is more complex than the structure at the base of the Green River Formation. Along the Wind River Mountain front the Continental fault and Pinedale anticline are associated with a great thrust fault and the deep syncline mentioned above (Berg, 1961, and Krueger, 1960). In addition, thrust faults parallel to the Wyoming thrust belt and the Uinta Mountains have pushed older rocks basinward over younger rocks. The geologic section shows the structure across the middle of the basin between the Rock Springs uplift and the Wyoming thrust belt. A broad arch of low relief not shown on the section extends from Church Buttes gas field (T. 16 N., R. 113 W.) to La Barge Ridge (T. 27 N., R 113 W.) and involves rocks principally older than Tertiary age (Hallock, 1960).

GENERAL HYDROLOGY

Ground-water conditions in the Green River Basin are controlled chiefly by climate, topography, geology, and man. The activities of man have been concentrated mainly along the larger streams where irrigation and dams have created artificial conditions. (See reservoir locations on the map showing streamflow.)

Recharge to ground-water reservoirs in the Green River Basin is mainly by seepage from precipitation and streams. Discharge is mainly by evaporation, seepage to streams and lakes, transpiration by plants, and pumpage from wells. Evaporation, which is excessive in this arid area, removes more water from the basin than any other means of discharge.

A balance between ground-water recharge and discharge in much of the area is indicated by water-level fluctuations observed in 11 wells. Wells tapping bedrock aquifers, such as the Wasatch Formation, at locations several miles from perennial streams generally had annual water-level fluctuations of less than 3 feet. Shallow wells tapping bedrock near perennial streams and wells in alluvial and terrace deposits had fluctuations of as much as 7 feet. Annual fluctuations of the water table in gravel deposits in sec. 1, T. 31 N., R. 107 W. were as much as 16 feet, but this area is exceptional. (See map of the East Fork River area.) In general, the water table is relatively stable, except in a few areas of heavy pumpage such as the Big Piney public well field. Withdrawals of ground water at stock and domestic wells in the basin are small.

Ground water occurs in the area under water-table (unconfined) or under artesian (confined) conditions. Under water-table conditions, the zone of saturation is overlain by permeable material, and water seeps downward from the surface to the saturated zone. A number of unconfined aquifers are present in the area. They are generally unconsolidated alluvial, windblown, glacial, and gravel deposits of Quaternary age. Many of the thicker and widespread consolidated formations of Tertiary age, however probably have an upper zone of unconfined water that extends from near the surface to depths possibly as much as 300 feet.

Artesian aquifers are confined by relatively impermeable rocks. Water may enter an artesian aquifer at the outcrop where water-table conditions prevail or it may move in from adjacent rocks. Water in an artesian aquifer is under hydrostatic pressure and will rise above the base of the overlying confining bed when the bed is pierced or broken. The piezometric surface of an artesian aquifer is the surface to which the water in the aquifer would rise under its full head. If the pressure is sufficient, water from a well tapping an artesian aquifer will flow even though the aquifer is deeply buried. The Green River, Wasatch, Fort Union, and older formations generally contain water under artesian pressure in the Green River Basin. Individual water-bearing units within the formations may differ greatly in thickness and extent, but they are probably interconnected sufficiently to permit indirect or partial hydrologic connection in varying degrees. The depth to the water surface in both water-table and artesian wells is generally less than 200 feet, but the drilling depth to artesian aquifers exceeds 1,000 feet in the deeper parts of the basin.

The slope of the water table in the unconfined aquifers in the Green River Basin generally follows the topography and the drainage pattern. (See configuration of water table on map of the East Fork River area.) The piezometric surface of deep artesian aquifers, however, may not conform as closely to the topography and drainage. Water-table maps of the entire basin could not be prepared because of the sparseness of well control and the heterogeneous nature of the aquifers.

QUANTITY AND QUALITY OF GROUND WATER

The maximum yields of existing wells in the Green River Basin probably range from about 1 to about 500 gpm (gallons per minute), but yields of most wells range from about 10 to 100 gpm. Yields greater than 500 gpm could probably be obtained from deep wells (2,000 to 5,000 feet) penetrating thick sandstone sections in the Wasatch and Fort Union Formations, and from shallow wells tapping some of the well-sorted alluvial and gravel deposits near Pinedale and east of Boulder. (See column on ground-water possibilities in the generalized section of geologic formations.)

The quality of ground water in the Green River Basin ranges from very poor to excellent. Water in the alluvial and gravel deposits and in the more permeable sandstone of the Wasatch Formation near the surface in the northern two-thirds of Sublette County generally contains less than 500 ppm (parts per million) total dissolved solids. In southern Sublette County and southward, water ranging from 500 to 3,500 ppm is generally available from at least one aquifer; other aquifers may contain water with a higher mineral content. In general, ground water in the Green River Basin becomes more mineralized with increased depth.

The alluvial and gravel deposits in the north and southwest, in the Wasatch Formation in the north, and rocks mapped as Tertiary undivided in the north and northeast would probably yield water suitable for irrigation if adequate quantities could be obtained. Because of the high sodium content, water in the Green River Formation and water in the Wasatch Formation in the southern two-thirds of the basin is not suitable for irrigation.

The high fluoride content of water in some wells tapping the Wasatch, Green River, and Bridger Formations south of T. 29 N. (table of chemical anaylses) exceeds the recommended maximum limits of the U.S. Public Health Service (1962) for fluoride in drinking water. (See footnote "a" on the table of chemical analyses.) Prolonged drinking of this water could be detrimental. The source of the fluoride is probably volcanic ash and tuff that were incorporated in the rocks at the time of deposition.

Additional information on the quality of ground water is given on the map showing specific conductance, the generalized section and table of chemical analyses. Approximately 100 chemical analyses and 80 specific-conductance measurements of water from wells and springs were used with geologic data to delineate the areas shown on the specific-conductance map. The boundaries of the water quality areas are approximate, owing to the complexity of the geology and the small amount of data available.

QUANTITY AND QUALITY OF SURFACE WATER

According to the Wyoming State Engineer (Bishop, 1966), there is an abundance of surface water in the Green River Basin, and Wyoming is entitled by interstate compacts to much more water than it is currently using. Shortages of surface water, however, do occur locally because of the variation in streamflow during the growing season and because of the long distances of some irrigation projects from the water source. Average annual discharge at stream-gaging stations in the basin is shown on the streamflow map. The discharge figures are based on data collected by the U.S. Geological Survey. The figures do not necessarily reflect natural streamflow conditions because storage reservoirs and irrigation diversions and return flows locally alter the natural flow of the streams. Reservoir capacities on the map are from Iorns and others (1965) and Martin and Hanson (1966); the precipitation data are from the U.S. Department of Commerce. As shown by the streamflow map, most of the surface water leaving Wyoming from the area enters the Green River above the town of Green River and comes principally from the Wind River Mountains and from the northern half of the Wyoming thrust belt.

The water in most of the perennial streams in the basin contains less than 500 ppm total dissolved solids. Two important exceptions are the reaches of Big Sandy Creek below the Eden-Farson irrigation project and Blacks Fork below the Lyman irrigation project. Total dissolved solids in the surface water of these reaches generally exceed 1,500 ppm. Additional information and data concerning the quality of the surface water in the Green River Basin are given in the report by Iorns and others (1964), in the regular series of U.S. Geological Survey water-supply papers, and in the annual reports "Water Resources Data for Wyoming, Part 2."

WATER USE

The predominant use of ground water in the Green River Basin is for stock and domestic purposes. A few wells are used by small businesses along the highways and by oil companies for water flooding and drilling in the La Barge and Big Piney areas. Ground water is not used for irrigation except on lawns and small gardens.

Surface water is used for all crop irrigation in the basin and for public supplies at the towns of Green River and Pinedale, which obtain water from the Green River and Fremont Lake, respectively.

Big Piney and Lyman have public water supplies obtained from ground-water sources; Lyman also uses a spring. Residents of Daniel, Eden, Farson, Granger, and La Barge use ground water from privately owned water wells. Water use for each well is given with the well data on the geologic map.

EAST FORK RIVER AREA

East Fork River extends about 30 miles from its source in the Wind River Mountains to its mouth at New Fork River. (See map of the East Fork River area and geologic map.) Crops of native hay are grown on terrace deposits along East Fork River and Muddy Creek in much of the area. The hay is subirrigated in summer after the water table rises to the root zone; surface-water diversions, which are principally from East Fork River, cause an artificial mounding of ground water in the vicinity of the hay meadows. (See hydrograph on map of the East Fork River area.) When diversions cease in later summer, the water table gradually declines until diversions are resumed the following spring.

Although the water in the terrace deposits is very good in quality (total dissolved solids are less than 300 ppm), most water wells are drilled below the terrace sand and gravel to the first sandstone in the Wasatch Formation. The water is slightly more mineralized in the Wasatch, but danger of pollution from the surface is reduced.

Saturated thicknesses of sand and gravel in the terrace deposits exceed 40 feet at several places in the area, and wells having yields of 500 gpm or more can probably be developed.

The U.S. Geological Survey, in cooperation with the Wyoming Natural Resource Board, began collecting hydrologic data in the East Fork area in July 1965. Objectives are to define the ground- and surface-water conditions and to determine whether or not surplus water is available. The results of these studies, which will be continued, should be useful in planning investigations of similar irrigated areas in the Green River Basin.

GENERAL CONCLUSIONS

The chief water-bearing material in the Green River Basin is sandstone. The Fort Union and Wasatch Formations, which underlie most of the basin, contain many lenticular fine to coarse-grained sandstone beds. Widespread single aquifers having uniform characteristics, however, are not known to be present in the basin except possibly in the Tipton Shale Member of the Green River Formation. Sandstone in the Tipton Shale Member is discernible on electric logs over an area of about 4,000 square miles, but the degree and continuity of permeability in the sandstone are not known.

Water-table conditions generally exist above a depth of about 300 feet in much of the basin but below that depth artesian conditions prevail.

Water is available to wells in most of the basin within a depth of 2,000 feet except possibly for outcrop areas of Precambrian rocks in the Wind River Mountains and the Bridger Formation in the south.

Most water wells are less than 1,000 feet in depth, but a few wells tapping the Wasatch Formation in the south-central part of the basin range from 2,000 to 3,000 feet in depth.

The maximum yields of wells in the basin probably range from about 1 to about 500 gpm, but yields of most wells generally are in the range of 10 to 100 gpm. Yields greater than 500 gpm could probably be obtained from deep wells (2,000 to 5,000 feet) penetrating thick sandstone sections of the Wasatch and Fort Union Formations and from shallow wells in the alluvial and gravel deposits near Pinedale and east of Boulder.

Water in the alluvial and gravel deposits and in the permeable sandstone of the Wasatch Formation near the surface in Sublette County generally contains less than 500 ppm dissolved solids. Ground water in the basin becomes more mineralized with increased depth.

Rocks mapped as Tertiary undivided, the Wasatch Formation, the Tipton Shale Member of the Green River Formation, and gravel and alluvial deposits are the most promising aquifers with regard to both quality and quantity of ground water. Larger quantities of water having a lower total dissolved-solids content can generally be obtained in the northern one-third of the basin.

Ground water in most of the basin is virtually untapped. The predominant use of ground water is for stock and domestic purposes, which require relatively small quantities of water. Large withdrawals, however, would probably lower the pressures in the deeper fine-grained aquifers.

Water from sandstone in the Tipton Shale Member of the Green River Formation (J. R. Rapp and W. T. Stuart, written communication, 1966) and possibly from sandstone in the Wasatch Formation is a nuisance to trona mining. These aquifers and sandstone aquifers in the laney Shale Member of the Green River Formation could be a hindrance to the future development of oil shale. Trona occurs in the Wilkins Peak Member of the Green River Formation, and oil shale occurs in the Tipton Shale, Wilkins Peak, and Laney Shale Members.

Detailed studies, particularly in Sublette County, are needed to evaluate the quality, quantity, and availability of ground water. Additional studies should be made to determine the effects that ground water might have on trona and oil shale mining.

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