Ground Water in Cedar Rapids Division of Lower Platte River Basin Nebraska

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1779-H

Prepared as part of the program of the Department of the Interior for the development of the Missouri River basin

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By JAMES B. HYLAND *and* CHARLES F. KEECH

With section on CHEMICAL QUALITY OF THE WATER

By PHILIP G. ROSENE

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1964

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

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[Plates are in pocket]

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GROUND WATER IN CEDAR RAPIDS DIVISION OF LOWER PLATTE RIVER BASIN, NEBRASKA

By JAMES B. HYLAND and CHARLES F. KEECH

ABSTRACT

The Cedar Rapids Division of the lower Platte River basin, an area proposed for irrigation development by the U.S. Bureau of Reclamation, is largely in the drainage basin of the Cedar River, a tributary of the Loup River, but also includes a part of the drainage basin on the north side of the Loup River between the mouths of Cedar River and Beaver Creek. The area includes, in downstream order, parts of Wheeler, Greeley, Boone, and Nance Counties.

The investigation covered an area that was formerly a nearly level to rolling plain but in which minor relief has been produced by stream erosion and wind action. The upper fifth of the area is in the Sand Hills region of Nebraska, and the lower four-fifths is in the Loess Plains region. Semiconsolidated deposits of Pleistocene age underlie the dune sand and loess. These deposits range from fine-textured sand, silt, and clay to coarse-textured sand and gravel. The parts of the semiconsolidated deposits that are below the water table yield water to wells. Ground water in these deposits is discharged naturally along the courses of the principal streams.

In three localities—the upper part of the Cedar Rapids Division, the vicinity of the north boundary of Nance County, and the lower part of the Division—only small amounts of water can be obtained from wells. At other places, wells will yield as much as 200 gallons per minute; and in a few localities as much as 1,800 gallons per minute. Irrigation wells have been installed in those areas where yields of 200 gallons per minute or more can be obtained. Ninety-four irrigation wells irrigated about 8,000 acres in 1960.

The ground water is generally of low mineralization and is of the calcium bicarbonate type. It is suitable for irrigation, domestic use, and many industrial uses.

INTRODUCTION

The Cedar Rapids Division of the lower Platte River basin, an irrigation project proposed for development by the U.S. Bureau of Reclamation, is largely in the drainage basin of the Cedar River, a tributary of the Loup River, but it also includes that part of the drainage basin on the north side of the Loup River between the mouths of Cedar River and Beaver Creek. Parts of Wheeler, Greeley, Boone, and Nance Counties, Nebr., are included in the project area, as is shown in figure 1.

At the request of the Bureau of Reclamation, the U.S. Geological Survey determined the depth to water and the configuration of the

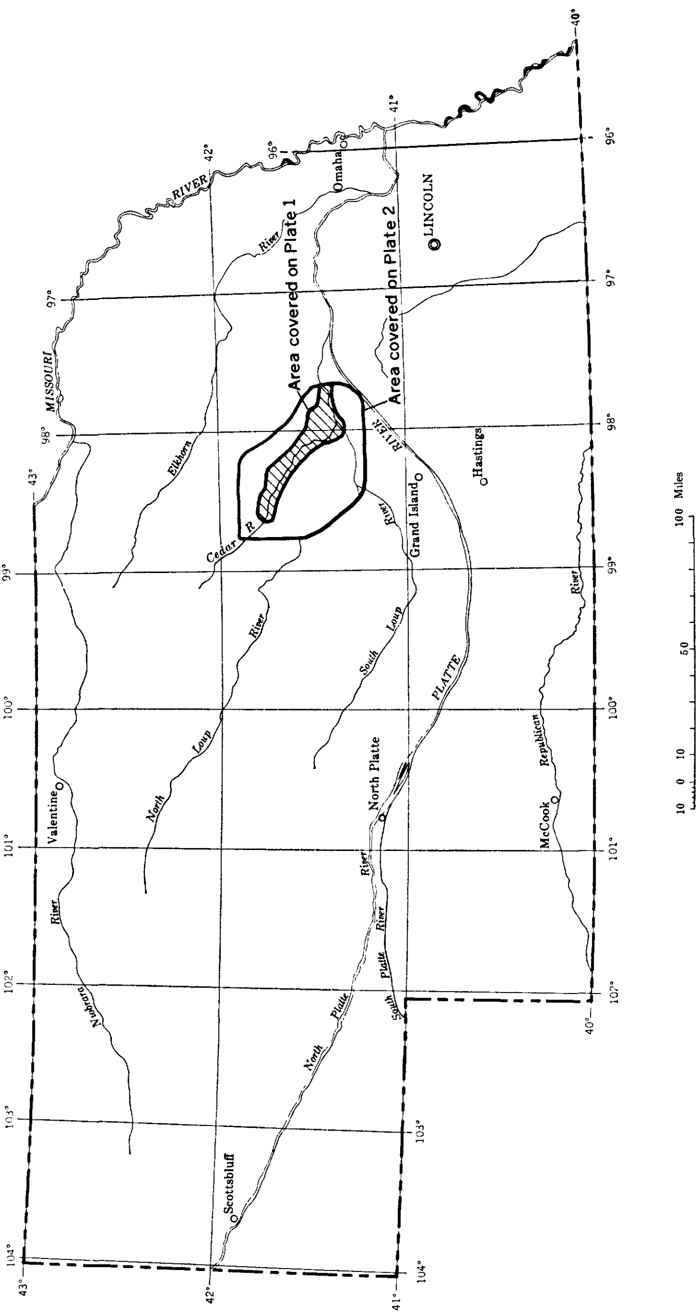

FIGURE 1.—Index map of Nebraska showing areas described in this report.

water table in the proposed project area and the configuration of the water table throughout the region that drains into the area. This report embodies the results of the study, which was made as part of the program of the Department of the Interior for development of the Missouri River basin.

The principal fieldwork was done during the summer and fall of 1959. All the irrigation wells in the proposed project area were visited, and pertinent data on the wells were obtained, in part by inspecting the wells and in part by interviewing the owners and operators of the wells. Fifty-three observation wells were installed. The altitude and location of measuring points of most wells were estimated from topographic maps, but a few had previously been established by instrumental levels. Plate 1, showing the depth to water and the configuration of the water table, was based on water-level data collected during the inventory. Chemical analyses of the water from 22 wells and 3 surface-water points were made in the Geological Survey laboratory in Lincoln, Nebr. The location of points of collection and graphs of chemical constituents are shown on plate 3. The basic data collected and compiled for this investigation have been published cooperatively by the U.S. Geological Survey and the Conservation and Survey Division of the University of Nebraska as Nebraska Water Survey Paper 10.

This report is based not only on the information obtained specifically for this investigation but also on hydrologic data collected during earlier studies. As part of the statewide program of ground-water studies made cooperatively between the U.S. Geological Survey and the Conservation and Survey Division, University of Nebraska, 29 test holes had been drilled in or near the area. Also, as part of the State-Federal program, water-level measurements had been made for about 25 years in several wells.

Reports of ground-water investigations in or adjacent to the present area of study include those by Lugn and Wenzel (1938), Connor (1951), Sniegocki (1955, 1959), Keech and Carlson (1959), and Smith (1959).

GEOGRAPHY AND CLIMATE

The Cedar Rapids Division is in east-central Nebraska in the High Plains section of the Great Plains physiographic province, as described by Fenneman (1931, p. 11–25). It is in an area that was formerly a nearly level to rolling plain but in which minor relief has been produced by stream erosion and wind action. In the upper fifth of the Cedar River basin, the surface material is wind-deposited sand, whereas in the lower four-fifths it consists of light-gray flourlike silt known geologically as Peorian Loess. The upland is nearly level to strongly rolling and hilly. The Cedar River, which flows in a southeasterly direction, has cut a broad valley through the loessial material and has formed a flood plain on the underlying water-laid sands.

The flood plain of the Cedar River is bordered by terraces that are remnants of the flood plain of the river at earlier stages in the formation of the valley. The terrace lands range in size from small scattered areas in the upper part of the valley to continuous strips as much as 3 miles wide in the lower part of the valley.

The altitude of the Cedar River is 2,000 feet above mean sea level at a point just below Lake Ericson and 1,605 feet at the confluence of the Cedar with the Loup. The average gradient of the stream is nearly uniform at about 8 feet per mile except in a short reach about 2 miles downstream from the city of Ericson where the stream drops nearly 35 feet in a mile.

The Cedar River, a tributary of the Loup River, flows northeastward in a broad shallow channel through a valley occupied by bottomland and low terraces that together range in width from less than 1 mile to more than 3 miles. The general surface of the Loup River valley is flat to gently undulate but is modified in places by shallow stream channels, depressions, and old cutoffs, and by extensive deposits of windblown sand which have produced a hummocky relief.

Also included in the area of this report is the part of the Loup River valley that lies northwest of the river between the Cedar River valley and the east Nance County line.

The discharge of the Cedar River has been recorded at a station 10½ miles northwest of Spalding for a total period of 12 years prior to September 1960 and at a station 3 miles northwest of Fullerton, 5¾ miles upstream from the mouth, for a period of 20 years. The location of these stations is shown on plate 3. Average yearly discharge was 109,300 acre-feet per year at the upstream station and 173,800 acre-feet per year at the Fullerton station. About nine-tenths of the discharge at the upstream station and about three-fourths of the average annual discharge at Fullerton is from ground-water discharge.

The principal cities and villages in the area and their population in 1960 are listed below in downstream order:

City or village	*Population*
Ericson	157
Spalding	683
Primrose	117
Cedar Rapids	512
Belgrade	224
Fullerton	1,475
Genoa	1,009

The climate is continental and is characterized by rather wide extremes in temperature. Winters are fairly cold, and periods of excessively low temperatures are short. Springs are generally cool, wet, and windy. Summers are characterized by hot days and warm nights, both of which are especially favorable to the growth of corn, the principal cultivated crop. Normally, the periods of extreme heat are brief. The autumns are normally long and pleasant. The last killing frost usually occurs in May; and the first, in October. The mean annual temperature is about 50° F.

The amount and distribution of precipitation differ greatly from year to year, but the mean annual precipitation ranges from about 21 inches in the upper part of the basin to about 23 inches at the lower end. The greater part of the precipitation occurs as thundershowers during the period April through September. Lack of rain in late summer occasionally causes reduced crop yields, but total crop failures are rare because the soil is light and retains moisture.

The prevailing wind is from the south and southeast during the summer and from the northwest during the winter. The average wind velocity is 9–10 miles per hour.

INDUSTRIES

Agriculture is the chief occupation; downvalley from the Sand Hills, the principal crops are corn, wheat, and oats, most of which are used locally for feeding cattle and hogs.

In the upper part of the basin, the grass-covered sand dunes are used for grazing and the numerous meadows between the dunes are used for hay and, in a few places, for field crops.

Where an adequate supply of water can be obtained, irrigation is practiced in both upland and valley areas. In addition to the farmers who irrigate with ground water, about 125 landowners have appropriative rights to water of the Cedar River and its tributaries. Water is pumped from the stream to irrigate an estimated 6,000 acres of valley land.

Three small hydroelectric plants on the Cedar River are near Ericson, Spalding, and Fullerton, respectively, and a dam on the Loup River between Fullerton and Genoa diverts water into the Loup River Public Power Co. Canal. Only the Ericson plant has a storage reservoir above the dam.

Sand and gravel deposits along both the Cedar and Loup Rivers are mined with dredging machines.

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WELL-NUMBERING SYSTEM

Each well referred to in this report has been assigned a number that is based on the location of the well within the system of land subdivision used by the U.S. Bureau of Land Management. The first numeral in the number indicates the township, the second the range, and the third the section. The lowercased letters that follow the section number indicate the position of the well within the section. The 160-acre and 40-acre subdivisions of the section are lettered a, b, c, and d in a counterclockwise direction beginning in the northeast quarter. If more than one well is located within a 40-acre tract, consecutive numbers, beginning with 1, follow the lowercased letters. (See fig. 2.)

GEOLOGY

SUMMARY OF TERTIARY AND QUATERNARY GEOLOGIC HISTORY

The end of the Cretaceous Period was marked by the uplifting of the Rocky Mountains and the retreat of the last great sea that inundated the interior of the North American continent. These events account for the character of the deposits of Late Cretaceous and Tertiary age in the area described in this report. During the Tertiary deposition, a broad alluvial plain was built up by the eastward-flowing streams that drained the rising mountains. Gradually, the alluvial sediments encroached on the area that had been vacated by the Late Cretaceous sea and buried the marine sediments that, in the meantime, had been exposed to subaerial erosion. The present easternmost extent of the Tertiary sediments, as determined by test drilling, is a northeast-trending sinuous line that lies just east of the area of study. As pointed out by Keech and Carlson (1959), the lack of deposits of Tertiary age east of that line may be due either to nondeposition or to removal by post-Tertiary erosion.

With the advent of the great continental ice sheets of Pleistocene time, the regimen of the streams that had been flowing eastward across and off the alluvial plain was changed radically. The first ice sheet, the Nebraskan, formed an effective dam across the existing drainages and created lakes into which the streams carried and deposited tremendous quantities of sand and gravel. As the Nebraskan ice sheet melted away, the Aftonian Interglaciation began; and during this interglaciation, eolian and fluvial sands, silts, and clays were deposited over the area. When the second ice sheet, the Kansan, advanced into Nebraska and similarly dammed the streams, the deposition of more sand and gravel resulted. The melting of the Kansan ice sheet was followed by the Yarmouth Interglaciation, which also was characterized by the deposition of eolian and fluvial silt and clay. Two later glaciations, the Illinoian and the Wisconsin, affected the report area to a lesser extent because the Illinoian glacier advanced into only the northeasternmost part of Nebraska, and the Wisconsin did not enter the State at all. During these two later glaciations, thick blankets of eolian silt (loess) were deposited over the entire area. Deposition during the Pleistocene was not continuous as erosion was concurrent with, and at times predominant over, deposition. In a few places in the Loup River valley between Fullerton and Genoa, all the Tertiary and Pleistocene deposits may

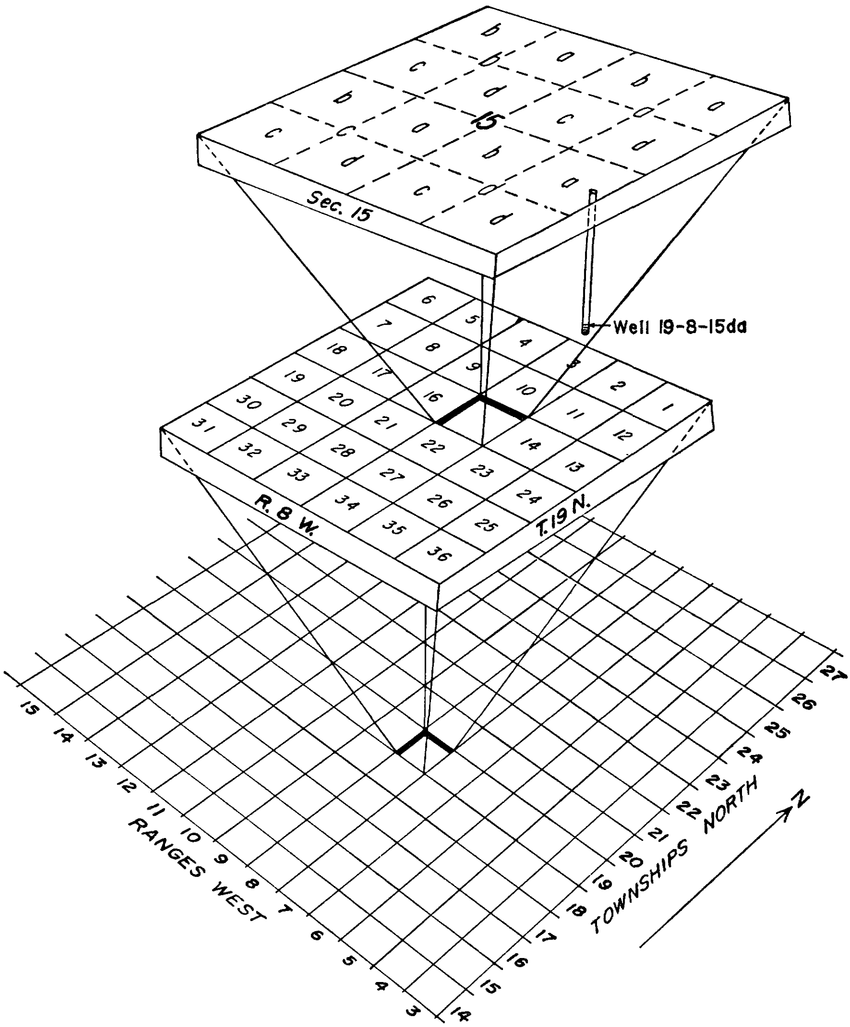

FIGURE 2.—Sketch showing well-numbering system.

have been removed by erosion and Recent deposits may lie in contact with the Cretaceous bedrock.

TERTIARY SYSTEM—OGALLALA FORMATION

The only formation of Tertiary age underlying the area is the Ogallala Formation of the Pliocene Series. It consists of interbedded hard and soft layers of sandy gravel, sand, silt, and clay. Some layers are cemented by calcium carbonate, but others are unconsolidated. The formation also contains minor amounts of marl, volcanic ash, and opaline sandstone that resembles quartzite. Gradations, both laterally and vertically, from one lithologic type to another within short distances are characteristic of the formation. Some beds in the Ogallala Formation are so like some of the Quaternary deposits that it is almost impossible to determine, when drilling, the exact depth at which the bit first enters the Ogallala Formation. Generally, the first cemented bed penetrated is considered to be at the top of the Ogallala.

In test hole 16–16–7bb, drilled at the northwest corner of Sherman County about 40 miles west of Fullerton, 551 feet of the Ogallala Formation was penetrated. The formation thins eastward and has a thickness of 395 feet in test hole 21–10–32cc. This is probably the maximum thickness, within a few feet, of the formation in the proposed project area. Only 39 feet of the Ogallala was penetrated during the drilling of test hole 16–6–2aa. Rock exposed in the bed of Beaver Creek, a short distance from Genoa (NW¼NE¼NW¼ sec. 23, T. 17 N., R. 4W) is probably of Tertiary age and possibly represents an outlier completely separated from the main body of the formation. The formation is covered almost everywhere in the area by Pleistocene or Recent sediments. There are a few reports of exposures of the formation in the Cedar River Valley, but none were seen by the authors.

QUATERNARY SYSTEM

Although the deposits of Pleistocene age have been differentiated into formations in parts of eastern Nebraska, it is not possible to identify those formations in the report area without first doing extensive fieldwork that would involve a correlation of surface observations with data obtained by test drilling. Therefore, in this report, the Pleistocene deposits are treated as if they constituted a stratigraphic unit. The deposits vary in texture both vertically and horizontally. In parts of the area, thick layers of sand and gravel are present; for example, a total of 260 feet of sand and gravel was penetrated in test hole 19–7–5aa, and 140 feet of sand and gravel was penetrated in test hole 20–11–36dd. The deposits of sand and gravel seem to be channel fills, but additional test drilling is needed to define the channels.

Detailed information on the lithology of the Pleistocene deposits is given in the basic-data report of the lower Cedar River drainage basin (Hyland, 1961).

OCCURRENCE OF GROUND WATER

The saturated sand and gravel formations of Tertiary and Quaternary age are recharged by direct infiltration of precipitation and by influent seepage from streams. No attempt was made during this investigation to determine the amount of water that reaches the water table, but probably it is only a small percentage of the total precipitation. Some ground water moves into the area as underflow.

Ground water percolates through the saturated deposits in a direction down the slope of the water table. Plate 2 illustrates the configuration of the water table in the lower Cedar River drainage basin and vicinity and shows that ground water is moving toward the streams. Along the Cedar River valley, north of the river between Ericson and Spalding, the close spacing of the contours indicates a steep gradient. The steep slope of the water table is the result of the river's having cut a deep valley into sediments which are not as permeable as those in most other areas. The depth to the water table in the Cedar River basin, as observed in nonflowing wells, ranges from less than 2 feet to as much as 244 feet below land surface. As shown by patterns on plate 1, the depth of water is generally greatest on the uplands and least in the valleys.

Ground water is discharged naturally along the courses of the principal streams within the area. In areas where the water table is near the land surface, probably the greatest consumptive use is evaporation. Along the flood plains of the principal streams, the ground water supports a luxuriant growth of meadow grass, rushes, willow, and cottonwood. Springs occur at the north end of Pibel Lake, and a few of the wells in that vicinity flow but their total discharge is small. Most of the ground water in the report area, however, probably is under water-table conditions.

GROUND WATER FOR IRRIGATION

Irrigation wells generally have been installed in those areas where the transmissibility of the aquifer is adequate. Ninety-four irrigation wells were canvassed in the project area during this investigation. The yields of the irrigation wells range from less than 2 gpm (gallons per minute) to more than 1,800 gpm and average about 800 gpm. Approximately 8,000 acres is irrigated with ground water. Plate 1 shows the location of the wells in the project area.

POTENTIAL DEVELOPMENT

In favorable localities, where the saturated sand and gravel is sufficiently thick, additional wells of moderate to large yields can be developed.

The aquifer will yield only small amounts of water to wells in the Cedar River valley between Ericson and a point about 4 miles upstream from Spalding. Wells can be obtained which will furnish enough water for domestic and livestock supplies, but wells capable of yielding adequate supplies for irrigation generally cannot be obtained.

Upvalley, from a point about 1.0 mile south of the town of Cedar Rapids, wells producing 1,000 gpm generally can be developed; but downvalley from that point, large-capacity wells cannot be obtained. In an area where the valley crosses the north boundary of Nance County, wells yield only a few gallons per minute. Downvalley, from Belgrade to a point about 3 miles northwest of Fullerton, the aquifer is more productive, and wells that will produce 200 to 500 gpm can be obtained; but from that point to the southeastern end of the study area, wells yield only small supplies. The city of Fullerton has had considerable difficulty in obtaining an adequate water supply from wells but obtains a moderate amount by pumping from a large number of wells of small yield.

At the time this investigation was in progress a new public-supply well was being installed on the terrace land across the Cedar River from the city. Tests indicate that this well will produce about 400 gpm.

CHEMICAL QUALITY OF THE WATER

By Philip G. Rosene

Water from 22 wells in the Cedar Rapids Division was analyzed to determine its chemical quality and to evaluate its suitability for use. In addition, analyses of 32 samples of water from the Cedar River were studied to correlate the surface water with the ground water. Results of the analyses are given by Hyland (1961, tables 2, 3). All sampling locations are shown on plate 3.

The mineralization of the water (represented by the specific conductance) ranged from 148 to 658 micromhos per centimeter at 25°C; the minimum was observed in the western end of the report area, and the maximum was observed in the eastern end. The trend of increasing mineralization from west to east is general throughout the area.

Both surface and ground waters are of the calcium bicarbonate type; in all samples the percentages of composition were nearly identical, regardless of degree of mineralization. Locally, the surface water is generally less mineralized than the ground water. The chemical quality and type of the waters are shown graphically by modified Stiff diagrams (1951). (See pl. 3.)

The abscissa dimensions of the Stiff diagram are proportional to the concentrations of the major-mineral ions in the water. The ordinate dimension of the Stiff diagram was modified so that it is proportional to the degree of mineralization of the water. Division of the ordinate dimension into equal segments maintains the geometric similarity of the diagrams for waters of the same type, regardless of the degree of mineralization.

The chemical quality of the water is generally acceptable for public supply and many industrial uses. Because of the concentrations of silica, calcium, magnesium, and bicarbonate ions, the water has a tendency to form hard scale and ranges from soft (less than 60 ppm $CaCO_3$) to very hard (more than 180 ppm $CaCO_3$). Concentrations of iron and manganese exceed the recommended maximums of 0.3 ppm and 0.05 ppm, respectively, (U.S. Public Health Service, 1962) in 20 percent or more of the samples collected. Treatment to remove the hardness, iron, and manganese may be required for public supply and some industrial uses. Water that is of satisfactory quality for public supply is also satisfactory for domestic and stock uses.

The water is rated as very good for irrigation (U.S. Salinity Laboratory Staff, 1954, p. 80–81). The water has a low to medium salinity hazard and an extremely low sodium (alkali) hazard. Concentrations of boron (an element toxic to certain plants) are much below the concentration limit of 0.33 ppm for boron-sensitive crops. The water contains less than 0.56 equivalents per million of residual sodium carbonate and is not likely to produce black alkali soils.

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