

Sedimentation and Chemical Quality of Water in Salt Creek Basin Nebraska

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CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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GLOSSARY

Equivalents per million (epm) is a unit for expressing the concentration of chemical constituents in terms of the interreacting values of the electrically charged particles, or ions, in solution. One equivalent per million of a positively charged ion will react with one equivalent per million of a negatively charged ion. Parts per million are converted to equivalents per million by multiplying by the reciprocal of the combining weight of the ion.

<i>Cations</i>	<i>Factor</i>	<i>Anions</i>	<i>Factor</i>
Calcium (Ca^{+2})	0. 04990	Carbonate (CO_3^{-2})	0. 03333
Magnesium (Mg^{+2})	. 08226	Bicarbonate (HCO_3^{-1})	. 01639
Sodium (Na^{+1})	. 04350	Sulfate (SO_4^{-2})	. 02082
Potassium (K^{+1})	. 02557	Chloride (Cl^{-1})	. 02821
		Fluoride (F^{-1})	. 05264
		Nitrate (NO_3^{-1})	. 01613

Fluvial sediment is sediment that is transported by, suspended in, or deposited from water.

Parts per million (ppm) is a unit for expressing the concentration of chemical constituents by weight, usually as grams of constituents per million grams of solution. Parts per million for suspended sediment is computed as one million times the ratio of the weight of sediment to the weight of the mixture of water and sediment.

Particle-size classification is the classification recommended by the American Geophysical Union Subcommittee on sediment terminology (Lane and others, 1947, p. 937). According to this classification, a particle having a diameter between 0.0002 and 0.004 mm is clay, a particle having a diameter between 0.004 and 0.062 mm is silt, and a particle having a diameter between 0.062 and 2.0 mm is sand.

Percent sodium is the ratio, expressed in percentage, of sodium to the sum of the positively charged ions (calcium, magnesium, sodium, and potassium)—all ions given in equivalents per million.

Specific conductance is a measure of the ability of a water to conduct an electrical current and is expressed in micromhos per centimeter at 25°C. Because the specific conductance is related to the number and specific chemical types of ions in solution, it can be used for

approximating the salinity of the water. The following general relations are applicable:

Specific conductance $\times (0.65 \pm 0.05) = \text{ppm dissolved solids};$

$$\frac{\text{Specific conductance}}{100} = \frac{\text{total epm}}{2}$$

Suspended sediment is the sediment that at any given time is maintained in suspension by the upward components of turbulent currents or that exists in suspension as a colloid.

Water discharge of a stream is the flow of the stream and includes the sediment and dissolved solids that are contained in the water.

Water type, in this report, indicates the predominant cation and anion present.

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

SEDIMENTATION AND CHEMICAL QUALITY OF WATER IN SALT CREEK BASIN, NEBRASKA

By L. R. KISTER and J. C. MUNDORFF

ABSTRACT

Salt Creek basin occupies about 1,655 square miles of the dissected till plains of eastern Nebraska. Surficial deposits in the basin range from alluvial and eolian deposits of Recent age to limestones and shales of Pennsylvanian age. Deposits of Pleistocene age, mainly loess and glacial till, mantle nearly the entire basin; scattered bedrock outcrops are mainly along the major stream valleys. Sedimentary rocks of the Dakota group of Early Cretaceous age immediately underlie deposits of Pleistocene age in most of the basin. In about 40 square miles in the western part of the basin, the Greenhorn limestone and (or) Graneros shale of Late Cretaceous age immediately underlie deposits of Pleistocene age. Limestones and shales of Permian age compose the uppermost bedrock in the southeastern part of the basin. Limestones and shales of Pennsylvanian age compose the uppermost bedrock in and bordering Salt Creek valley from Lincoln to the mouth of Salt Creek.

The climate of the basin is continental and subhumid. Average annual precipitation at Lincoln is 25.73 inches; during 1921-55 annual precipitation ranged from 14.09 inches in 1936 to 40.1 inches in 1951.

Most of the total annual suspended-sediment discharge of Salt Creek occurs on a few days of each year. In most years, 75 percent or more of the total annual discharge occurs on 15 or less days.

Flow-duration data for 1950-59 and sediment-discharge data for 1951-54 indicated that the total suspended-sediment discharge at Lincoln for 1950-59 was about 18.7 million tons. A layer of soil 1 foot thick and about 13 square miles in area would be required to yield this estimated discharge.

Computations of total sediment discharge indicated that bedload discharge is a minor part of the total sediment discharge over wide ranges of water and sediment discharges. The suspended sediment transported by Salt Creek is predominantly clay and silt.

Water from most wells in the Dakota group contained high concentrations of dissolved solids and was of the sodium chloride type. The water from some of the wells, however, contained less than 500 ppm (parts per million) of dissolved solids and was of the calcium bicarbonate type; such water generally overlies the water containing higher concentrations of dissolved solids.

Water from the sands and gravels of Pleistocene age in the southern half of the basin contained generally less than 1,000 ppm of dissolved solids, and water in

the northern half contained generally less than 500 ppm. Locally in the southern half of the basin, water from the Dakota probably infiltrates the sands and gravels of Pleistocene age. Except where the water from the Dakota affects the water in the sands and gravels of Pleistocene age, the water is of the calcium bicarbonate type.

Not much information is available on the quality of the water in the alluvium; however, the water probably is of the calcium bicarbonate type and has less than 1,000 ppm of dissolved solids, except where water of the sodium chloride type has infiltrated the alluvium.

During low discharge the water in the upstream parts of Salt Creek and its tributaries is similar in chemical quality to the water from sands and gravels of Pleistocene age, and the water in the vicinity of Lincoln is similar in chemical quality to the water from the Dakota group.

Nearly all the water used in the Salt Creek basin for domestic, public, and industrial supplies is produced from wells; surface water of adequate quantity and quality is not available. Water from most public supplies contained less than 500 ppm of dissolved solids but was very hard. Iron and manganese in many of the supplies exceeded recommended maximum concentrations. The water from the Dakota group is either unsatisfactory for irrigation or is insufficient for large-scale irrigation. Most of the water from the deposits of Pleistocene age and from the alluvium can be used for irrigation if drainage is adequate and if plants having good salt tolerance are grown.

INTRODUCTION

The U.S. Geological Survey began studies of water quality in the Salt Creek drainage basin in 1950 as a part of the program of the Department of the Interior for the development of the Missouri River basin. Chemical-quality studies have been made of the water from Salt Creek and its tributaries and from three types of water-bearing deposits—the Dakota group of Early Cretaceous age, the sands and gravels of Pleistocene age, and the alluvium of Recent age. Fluvial-sediment studies have been made only at one site, Salt Creek at Lincoln. The interpretive results of these studies are presented in this report.

These studies were made under the supervision of P. C. Benedict, regional engineer, who was succeeded by D. M. Culbertson, district engineer. The geology section of the report was prepared from information furnished by E. C. Reed, Director of the Conservation and Survey Division, University of Nebraska.

GENERAL FEATURES OF THE BASIN

Salt Creek basin, a part of the dissected till plains of eastern Nebraska, is about 1,655 square miles in area and comprises parts of six counties. (See fig. 1.) Of the total area, about 75 percent is cultivated, about 20 percent is pasture, and about 5 percent is urban and wasteland. The estimated population of the basin is about 150,000, of which about 80 percent is urban. Although the population is pre-

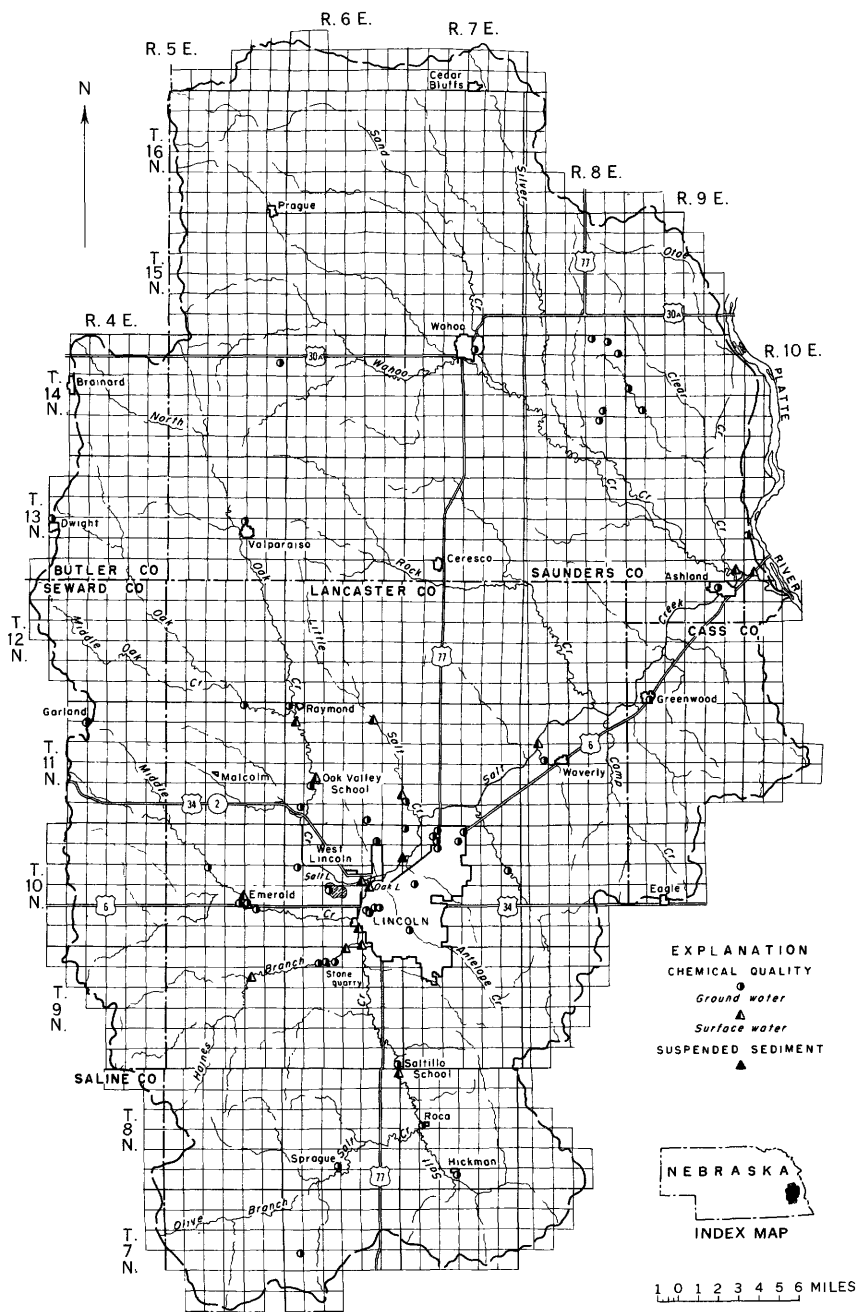


FIGURE 1.—Map showing sampling sites in the Salt Creek basin, Nebraska.

dominantly urban, the economy of the basin is based mainly on agriculture; other significant economic enterprises include manufacturing industries, transportation industries, and military installations.

CLIMATE

The climate of Salt Creek basin is continental and subhumid. An annual temperature range of 110°F and winter temperatures of 0° to -10°F and summer temperatures of 100° to 105°F are common. Weather Bureau records show that the minimum was -29°F and the maximum was 115°F during the period 1900 to 1960.

Average annual precipitation at Lincoln for 1921-55 was 25.73 inches (reported by the U.S. Weather Bureau) and for 1950-58 was about 28.7 inches (computed from U.S. Weather Bureau records); the minimum was 14.09 inches in 1936, and the maximum was 40.1 inches in 1951. Although U.S. Weather Bureau records for 1956 show that the total precipitation at Lincoln was about 23.8 inches, which is near normal, the total at Valparaiso, in the northern part of Salt Creek basin, was only 12.7 inches.

Generally, about 55 percent of the total precipitation occurs between May and August, and about 75 percent occurs between April and September. Annual snowfall averages about 24 inches. The variability of precipitation from year to year and from place to place in the basin is apparent from data shown in table 1.

TABLE 1.—*Annual precipitation, in inches, during 1950-58 at some locations in Salt Creek basin, Nebraska*

[From U.S. Weather Bureau records]

Location	1950	1951	1952	1953	1954	1955	1956	1957	1958
Lincoln.....	24.8	40.1	32.0	21.2	30.6	¹ 17	23.8	34.6	33.9
Raymond.....	18.0	-----	28.6	17.5	24.7	21.0	18.5	36.0	36.7
Malcolm.....	20.6	41.2	26.8	19.4	26.8	17.6	20.4	35.6	32.6
Valparaiso.....	-----	-----	27.9	19.9	22.2	19.7	12.7	30.6	27.8
Wahoo.....	26.0	40.0	29.6	22.4	28.1	18.3	14.3	34.2	21.2
Sprague.....	32.2	41.4	30.7	20.2	32.1	14.5	27.1	31.4	29.1

¹ Partly estimated.

VEGETATION AND LAND USE

In preagricultural time, the vegetation consisted mainly of tall grass, such as little bluestem, big bluestem, needlegrass, and side-oats grama; trees were restricted to stream valleys. Before about 1870 only a minor part of the land in Salt Creek basin was cultivated; between about 1870 and 1900 a major part was placed in cultivation. Since 1900 changes in cultivated acreage have been relatively minor. The principal crops include corn, sorghums, wheat and other small grains, and legumes.

During recent years considerable progress has been made in instituting land-use practices to reduce erosion and surface runoff. Some marginal land has been retired from production of cultivated crops and has been seeded to grass. Contour farming and terrace farming are common on much of the cultivated land.

GEOLOGY

Deposits exposed at the surface in the Salt Creek basin range from alluvial and eolian deposits of Recent age to limestones and shales of Pennsylvanian age. Unconsolidated deposits of Pleistocene age mantle nearly the entire basin; the scattered outcrops of rocks of Pennsylvanian, Permian, or Cretaceous age are limited to steep valley-side slopes, mainly along the major streams. Only the rocks of Pennsylvanian age or younger significantly affect the ground-water hydrology, water quality, and runoff in the basin. Rocks older than Pennsylvanian age therefore, are not discussed in this report.

Rocks of Pennsylvanian and Permian age consist mainly of interbedded limestones and shales and, in general, have low permeability except where highly weathered or fractured. Limestones and shales of Permian age compose the uppermost bedrock (fig. 2) in the southeastern part of the basin but crop out only along the valley of Salt Creek. Limestones and shales of Pennsylvanian age compose the uppermost bedrock in and bordering Salt Creek valley from Lincoln to the mouth of Salt Creek but crop out only in a few places near Ashland.

The sandstones and shales of the Dakota group immediately underlie glacial till in most of the basin. (See table 2.) The rocks of the Dakota group differ widely in permeability; the sandstones have high permeability, and the shales have low permeability. Rocks of the Dakota group crop out at many places along the valleys, mostly in Lancaster County. The Dakota group has a maximum thickness of about 400 feet in the western part of the basin and thins progressively eastward.

In about 40 square miles in the western part of the basin, the Dakota group is overlain by rocks of Late Cretaceous age, the Graneros shale and the Greenhorn limestone; the Graneros shale is overlain by the Greenhorn limestone. The Graneros shale is as much as 70 feet thick, and the Greenhorn limestone is as much as 30 feet thick. The Greenhorn crops out about 3 miles north-northeast of Garland in a small area along the valley of Middle Oak Creek.

Deposits of Pleistocene age are at or near the surface in most of the basin and differ greatly in thickness, composition, and lateral extent. The surface material and topography of the basin have re-

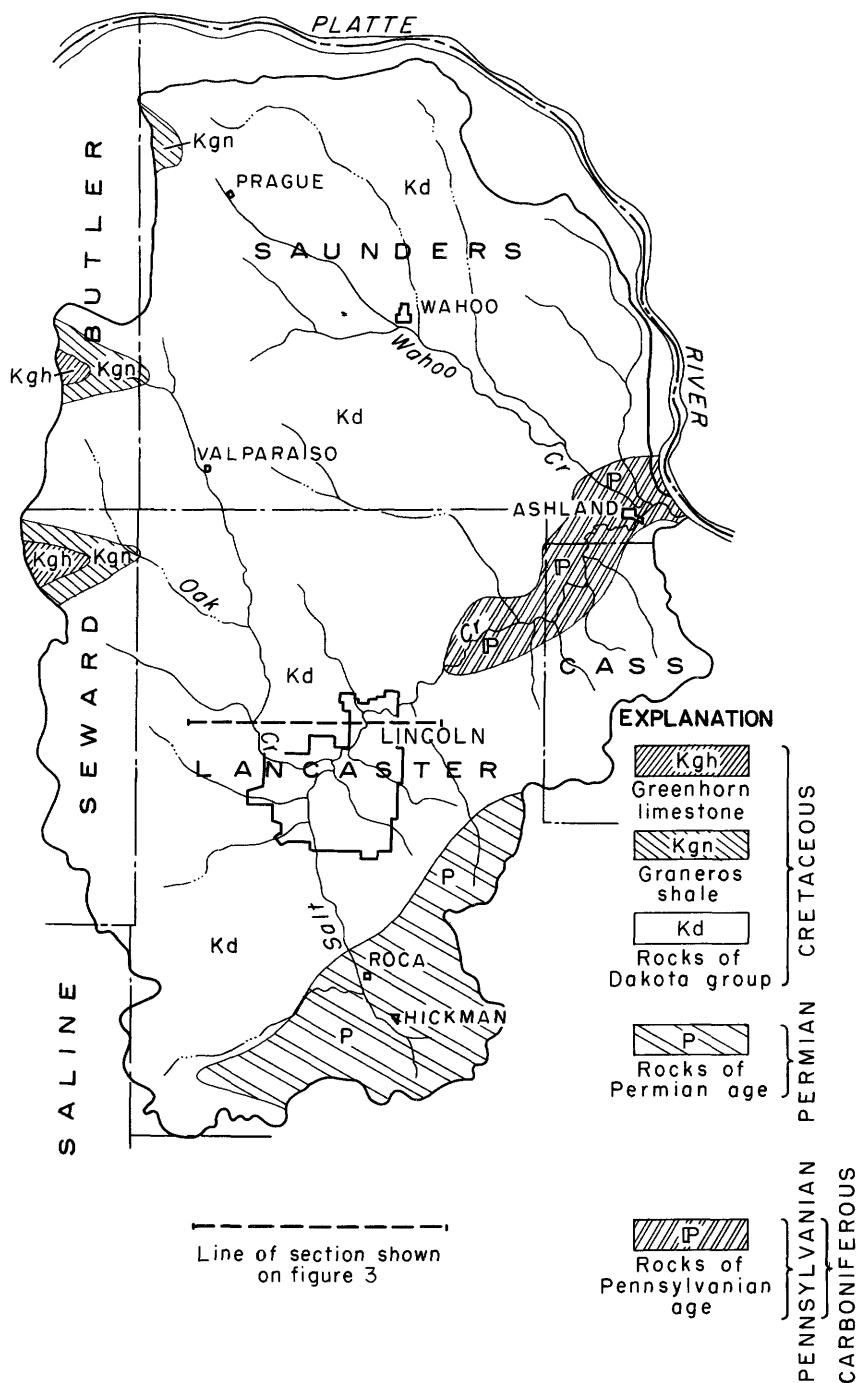


FIGURE 2.—Bedrock geology of Salt Creek basin (from Reed, 1951).

sulted almost entirely from deposition and erosion since the beginning of the Pleistocene epoch.

As the earliest Pleistocene continental glacier (Nebraskan) advanced from the northeast, the sands and gravels of the David City formation were deposited in the lower parts of the valleys. The eastward-flowing streams were dammed or were deflected southward by the advancing ice sheet, which overrode the channel fills of sand and gravel. When the glacier receded northward, the Nebraskan drift, a poorly sorted boulder-clay deposit from the melting ice, remained as a mantle over the surface. The streams that were formed in this surface by melt water from the receding glacier deposited the sands, gravels, silts, and clays of the Aftonian formation (E. C. Reed, written communication).

A similar sequence of events occurred as the second continental glacier (Kansan) advanced over and receded from the area. Sands and gravels of early Kansan age, Kansan drift, sands and gravels of the Grand Island formation, and the silts and clays of the Sappa formation remain as evidence of the advance and recession of the Kansan glacier. At the end of Kansan time the present valleys of the basin began to be formed. The Grand Island formation is closely associated with present major valleys, because no glaciers advanced over the basin after Kansan time. However, variation in the climate during the advance and recession of the Illinoian, early Wisconsin, and late Wisconsin glaciers, which were north and east of the basin, caused three principal cycles of deposition that were separated by periods of weathering and soil development. During Illinoian time, the Crete formation and the Loveland loess were deposited; during early Wisconsin time, the Todd Valley formation and the Peorian loess were deposited; during late Wisconsin time, localized alluvium and the Bignell loess were deposited. During interglacial periods the Sangamon or Loveland soil developed on the Loveland loess, and the Brady soil developed on the Peorian loess.

The alternate degradation and aggradation of the valleys in post-Kansan time resulted in at least four terrace levels. Some of the terrace levels are indistinct because successive cuts removed parts of the previous terrace levels, which were then replaced by younger terrace fills. Some of the highest levels are indistinct because of valley-side erosion.

Valley alluvium of Recent age was deposited along the streams during floods. The presence of natural levees 2 to 3 feet higher than the adjoining bottom land is evidence of repeated flooding in the past. The natural levees and the flood plains indicate that floods have been common in Salt Creek valley.

TABLE 2.—*Summary of rock formations younger than Permian age in the Salt Creek basin, Nebraska*

[E. C. Reed, written communication]

Period	Epoch	Stage	Stratigraphic unit	Remarks
Quaternary	Recent		Superficial alluvium, loess, and topsoil	Clays, silts, and sands, generally thin; deposited during floods; isolated wind deposits of clay, silt, and sand; widespread soils.
			Unconformity	
	Pleistocene	Late Wisconsin	Bignell loess	Associated with some sand and gravel; typically found on and in the lower terrace levels; occurs as thin mantles in the upland edges adjacent to the larger valleys; ranges in thickness from a few feet to about 20 ft.
			Unconformity	
		Early Wisconsin	Peorian loess	Gray to brownish-gray silt; upper part leached; extensive over the uplands and on the higher terrace levels; Brady soil that was developed on the surface of this loess is present where preserved by the younger Bignell loess; 0 to 25 ft thick.
			Todd Valley formation	Light-gray to white; upper surface in many places shows action of wind; underlies the Todd Valley drainage basin in northeast Saunders County, also present under some scattered terrace remnants; absent in the uplands; 0 to 50 ft thick.
		Illinoian	Unconformity	
			Loveland loess	Reddish-brown silt, weathered and leached; occurs as a comparatively thin mantle over Kansan drift and under Peorian loess in the uplands; is thicker under Peorian loess in the high terraces; capped by the well developed "Loveland soil."
			Crete formation	Reddish-brown sand and gravel that occur in the high terraces as channel fills under the Loveland loess; 0 to 10 ft thick.
		Kansan	Unconformity	
			Sappa formation	Greenish-gray silts and clays and interstratified sand and volcanic ash; generally has a soil at the top; absent or very thin under the surface of the uplands but generally present under the Loveland loess or under the sand and gravel of the Crete formation in the higher terraces; 0 to 20 ft thick.
			Grand Island formation	Gray to brown sand and gravel; fine grained in the upper part, which is transitional to the Sappa formation; coarse grained in the lower part, which in many places includes boulders of quartzite and granite from the underlying drift; absent in uplands; 0 to 50 ft thick.
			Unconformity	
			Kansan drift	Boulder clay, generally oxidized to a yellowish color; leached in the upper part, and locally altered to gumbotil; composed of boulders of quartzite and granite in a matrix of poorly sorted clays and silts; present in the uplands and generally present in the valleys; 0 to 100 ft thick.
			Kansan sand and gravel	Brownish-gray sand and gravel, generally fine grained; only rarely exposed; occurs as restricted channel fills along stream channels of early Kansan age that were later covered by Kansan drift; 0 to 50 ft thick.

Cretaceous		Nebraskan	Unconformity	
			Aftonian formation	Light-gray silts and clays locally grading to fine sand; in many places leached at top; comparatively extensive in the subsurface; crops out along the valley sides at low levels in the southern part of the basin and at progressively higher levels northward; 0 to 60 ft thick.
			Nebraskan drift	Dark-gray boulder clay that contains fewer and smaller boulders and pebbles than are in the Kansan drift; upper surface weathered and leached and some gumbotil has formed locally; locally crops out in the northern part of the basin but is largely limited to the subsurface; 0 to 50 ft thick.
			David City formation	Sand and gravel that occur as channel fills; do not crop out at the surface but are known to inter-finger with Kansan drift in the subsurface; 0 to 50 ft thick.
			Unconformity	
			Greenhorn limestone	Light-gray to white dense to chalky limestone; contains numerous clam shells; crops out northeast of the town of Garland and is limited to the northwestern part of the basin; 0 to 30 ft thick.
			Graneros shale	Dark-gray shale, chalky in upper part, sandy in lower part; limited to the subsurface of a small area in the northwestern part of the basin; 0 to 70 ft thick.
			Dakota group	Sandstones and shales; upper 150 ft is generally sandstone but may grade laterally to gray or varicolored clay shales; middle 60 ft is red and varicolored clay shales; lower 100 ft is mostly sandstone.

Much of the terrace and upland surface of the basin is mantled with Peorian loess or Bignell loess except in western Lancaster County and southwestern Saunders County, where these loesses are extremely thin or absent. In such areas, Kansan drift is at or near the surface. The thickness of Peorian loess and Bignell loess ranges from 0 feet in some areas to about 40 feet in the northern part of the basin.

RELIEF AND DRAINAGE

The present surface of Salt Creek basin conforms, in major aspects, to the Kansan drift surface. Prior to deposition of Loveland loess, the Kansan drift surface was subjected to erosion and dissection, which produced a rolling to hilly topography. The irregularities of the dissected drift surface were somewhat subdued by subsequent loess deposition. Either most of the Loveland loess was removed by erosion prior to deposition of the Peorian loess or the Loveland loess deposited in this area was thin. In many areas erosion has removed both the Loveland and Peorian loess and has exposed the underlying glacial drift.

The greatest relief in Salt Creek basin is in northwestern Lancaster County, in southeastern Butler County, in the headwaters of Wahoo Creek, and in the "Bohemian Alps" in east-central Seward County. Local relief generally ranges from 100 to 200 feet in these areas. Altitudes range from about 1,040 feet at the mouth of Salt Creek to about 1,620 feet in the extreme northwestern part of the basin.

The most extensive terraces are mainly along Salt Creek in the vicinity of Lincoln and Waverly and in Todd Valley in the northeastern part of the basin. These terraces generally have a loess or silt mantle that is underlain by a variable thickness of sand and gravel.

The basin is generally well drained, and drainage problems are minor. The only poorly drained areas of significance are in the alluvium bordering some of the large streams; in some of these areas the high concentration of salts in the soil retards or prohibits plant growth. Salt efflorescence may occur during dry periods. The upland areas are well drained except for scattered small depressions.

The stream system of Salt Creek basin has a dendritic pattern, which is, however, not ideally formed. The effect of bedrock in the control of the detailed drainage pattern is very minor. The downstream two-thirds of Salt Creek and long reaches of some of the major tributaries, however, are in bedrock-defended valleys; the channels are at a lower elevation than is the bedrock along the valley sides.

Throughout most of the length of Salt Creek and in the downstream reaches of the major tributaries, the natural channels are meandering. The sinuosity indexes of these channels, computed as

the ratio of channel length to valley length, range from about 1.5 to about 2.0. Leopold and Wolman (1957) arbitrarily classified streams having sinuosity indexes greater than 1.5 as meandering streams. Between Lincoln and Ashland, the Salt Creek channel has been straightened and enlarged to increase its capacity. The channel had a sinuosity index of about 1.9 before straightening and about 1.2 after straightening. The gradient of Salt Creek was increased from about 1.7 feet per mile before straightening to about 2.7 feet per mile after straightening.

SOILS

Salt Creek basin is usually described as being in the Prairie soil region of the United States, although most of the basin occupies a transitional zone between the Prairie and Chernozem soil zones. All the soils have developed under the influence of tall-grass vegetation except those soils occupying part of the bottom lands and part of the most steeply sloping uplands.

Each soil type occupies a rather characteristic topographic position. (See fig. 3.) Where loessial and glacial soils are associated within

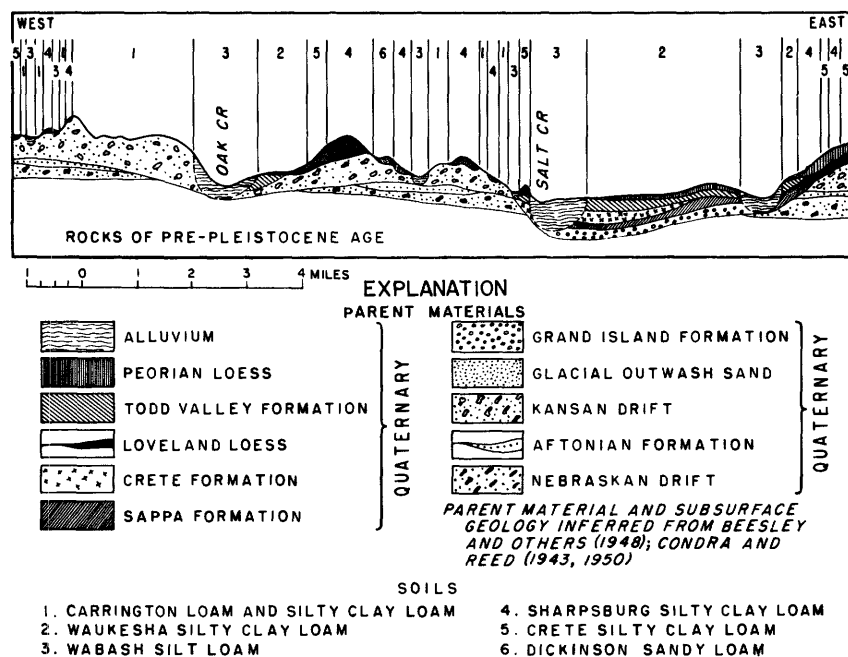


FIGURE 3.—Relations among topography, parent materials, and soil types in Salt Creek basin. Line of section is from sec. 3, T. 10 N., R. 5 E., to sec. 1, T. 10 N., R. 7 E. Vertical scale is exaggerated.

relatively small areas, the loessial soils are commonly developed along the upper slopes and ridge tops, and the glacial soils are generally some distance downslope. In most of the eastern and northern parts of the basin, however, soils are developed on a nearly unbroken mantle of loess.

Soils of the Butler, Crete, Sharpsburg, and Knox series are developed on the loessial uplands of the basin. Soils of the Carrington, Burchard, Pawnee, and Steinauer series are developed on the glacial uplands. The Waukesha and Rokeby series occupy terrace positions. The Wabash, Lamoure, Bremer, Judson, and Sarpy series are developed on alluvial and colluvial materials of the bottom lands. The soils of the basin are differentiated on the basis of texture of the different horizons in the profile, depth of solum, character of the parent material, and topographic position. Detailed soils maps are available only for part of the basin, and accurate computations cannot be made for the percentage of the basin occupied by different soils. On the basis of a soil survey of Lancaster County (Beesley and others, 1948), geologic information, and reconnaissance throughout the basin, the following estimates were made: Loessial soils, predominantly of the Sharpsburg and the Crete series, about 60 percent of the basin; glacial till soils, predominantly of the Carrington¹ and Burchard series, about 20 percent; and terrace and bottom-land soils, predominantly of the Waukesha and the Wabash series, about 20 percent. Musgrave (1957) classified some of the major soils of the United States into "hydrologic soil groups." The classification is based on the premise that soils with similar profiles will respond in a similar manner under a long storm of appreciable intensity. Musgrave includes the Carrington, Sharpsburg, and Waukesha soils in the group described as "mostly sandy soils * * * and loess * * * [that have] above-average infiltration after thorough wetting"; the Burchard, Shelby, Butler, Crete, Steinauer, and Bremer soils in the group described as "shallow soils and soils containing considerable clay and colloid * * * [that have] below-average infiltration after pre-saturation"; and the Pawnee and Wabash soils in the group described as "mostly clays of high swelling percent [highest runoff potential]." Comparisons between the different soils are made with the assumption that the soils have minimum cover, that maximum swelling has taken place, and that the applied rainfall exceeds potential infiltration (Musgrave, 1957). The classification of hydrologic soil groups can be used to estimate runoff from a given area and to estimate roughly the erosion and sediment yield from a given area.

¹ In November 1959, the term Carrington soil series was discontinued; the present (1961) equivalent of the Carrington in eastern Nebraska is generally the Shelby series (A. R. Aandahl, oral communication).

FLUVIAL SEDIMENT

Investigation of fluvial sediment in Salt Creek at Lincoln was begun in May 1950. From May 1950 to March 1951 and from October 1951 to March 1952, suspended-sediment samples were obtained infrequently, usually during high stages. From March to September 1951 and from March 1952 to September 1954, samples were obtained daily or at such frequency necessary to compute the daily suspended-sediment discharge. Analyses for most of the samples have been published by the U.S. Geological Survey in the annual series of water-supply papers entitled, "Quality of Surface Waters of the United States." The sampling location is shown on figure 1.

Suspended-sediment discharge is computed as the product of the measured suspended-sediment concentration, the total water discharge, and a constant for converting the units to a weight per unit time, generally tons per day. Suspended-sediment concentrations for computing sediment discharges were determined from depth-integrated samples collected with standard samplers. The suspended-sediment concentration, in parts per million by weight, was determined in the laboratory. Particle-size distribution of the sediment was determined by the sieve method or by methods based on the fall velocity of the sediment particles.

Table 3 is a monthly and annual summary of suspended-sediment data for Salt Creek at Lincoln for March to September 1951 and for March 1952 to September 1954. Most of the total annual suspended-sediment discharge of Salt Creek occurs on a few days of each year. During March to September 1951 the suspended-sediment discharge for 15 days was about 78 percent of the total discharge for the period. During March to September 1952 the suspended-sediment discharge for 12 days accounted for about 75 percent of the total for the period. In 1953 the suspended-sediment discharge for 5 days accounted for about 75 percent of the total annual discharge. In 1954 the discharge for 12 days accounted for about 87 percent of the total annual discharge. The combined suspended-sediment discharge for 5 days in June 1951 was about the same as the combined suspended-sediment discharge for the entire 1952, 1953, and 1954 water years.

During the period March 1951 to September 1954, the measured suspended-sediment concentrations ranged widely (from 9 to 69,100 ppm). The daily mean concentrations did not range as widely (from 10 to 34,000 ppm). The daily mean concentrations for the period March 1951 to September 1954, if regarded as representative of long-term conditions, can be used to estimate the percentage of time that specific daily mean concentrations would be exceeded. The data for this period indicate that a daily mean suspended-sediment concentra-

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TABLE 3.—*Monthly and annual summary of water and suspended-sediment discharge, Salt Creek at Lincoln, Nebr.*

Month	Water discharge (cfs-days)	Suspended sediment			
		Load (tons)	Daily load (tons)		Maximum daily concentration (ppm)
			Maximum	Minimum	
1951					
Mar. 16-31.....	3,313	59,358			
April.....	9,804	277,154	136,000	34	21,600
May.....	14,341	555,074	178,000	118	22,500
June.....	91,834	4,326,702	857,000	562	34,000
July.....	7,687	45,233	12,000	11	11,000
August.....	12,308	312,440	79,600	15	22,000
September.....	8,098	59,817	20,000	3	4,850
Total, Mar. 16 to Sept. 30.....	147,385	5,635,778			
1952					
Mar. 16-31.....	10,863	410,310	199,000		
April.....	19,129	469,145	120,000	99	24,500
May.....	9,528	102,462	35,200	50	10,500
June.....	22,948	838,405	662,000	10	20,500
July.....	16,380	332,110	184,000	10	13,500
August.....	5,921	88,468	27,000	9	18,000
September.....	2,171	1,274	796	6	1,170
Total, Mar. 16 to Sept. 30.....	86,940	2,242,174			
October.....	1,755	197	9	4	58
November.....	2,085	664	368		846
December.....	2,302	490			
1953					
January.....	2,683	1,160	1 500		
February.....	4,152	5,029			
March.....	3,394	1,156	103	10	350
April.....	3,229	4,041	1,750	9	3,080
May.....	4,724	22,208	10,600	11	6,300
June.....	2,299	7,158	6,060	1	5,670
July.....	2,509	48,774	44,900		14,400
August.....	1,950	568	1 200		
September.....	1,410	585	383		
Total, water year 1952-53.....	32,492	92,030			
October.....	1,099	160	44		160
November.....	1,703	1,138	800		1,000
December.....	1,700	605	1 200		
1954					
January.....	1,271	155			
February.....	1,885	751	1 260		
March.....	1,658	306	1 60		
April.....	1,916	5,720	4,770		5,800
May.....	6,674	119,455	60,900		10,900
June.....	17,550	420,256	263,000	12	13,400
July.....	4,221	115,030	103,000		12,700
August.....	17,604	191,265	60,800	1 15	6,380
September.....	1,673	215			
Total, water year 1953-54.....	58,954	855,056			

¹ Estimated.

tion of 50 ppm would be exceeded about 70 percent of the time; a concentration of 100 ppm, about 43 percent of the time; a concentration of 500 ppm, about 23 percent of the time; a concentration of 1,000 ppm, about 17 percent of the time; a concentration of 5,000 ppm, about 6

percent of the time; and a concentration of 15,000 ppm, only about 1 percent of the time.

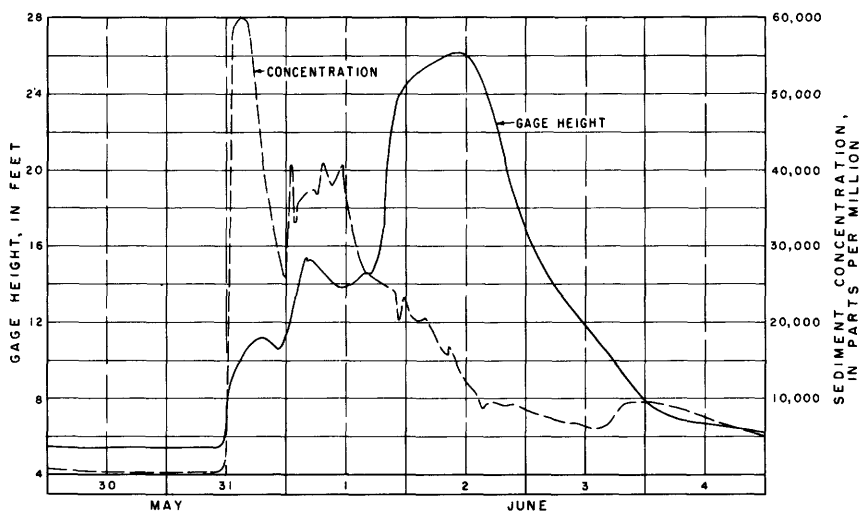


FIGURE 4.—Stage hydrograph and concentration curve, Salt Creek at Lincoln, May 30 to June 4, 1951.

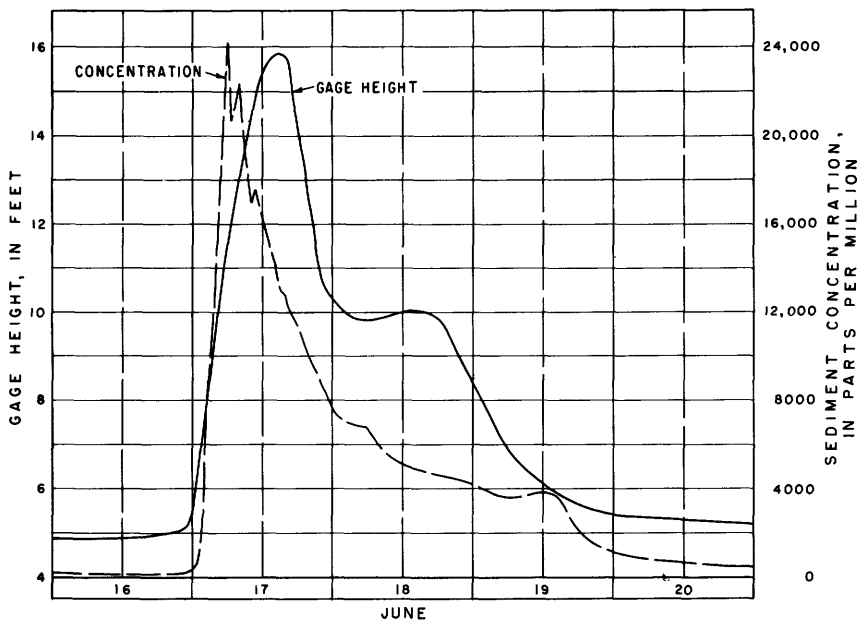


FIGURE 5.—Stage hydrograph and concentration curve, Salt Creek at Lincoln, June 16–20, 1954.

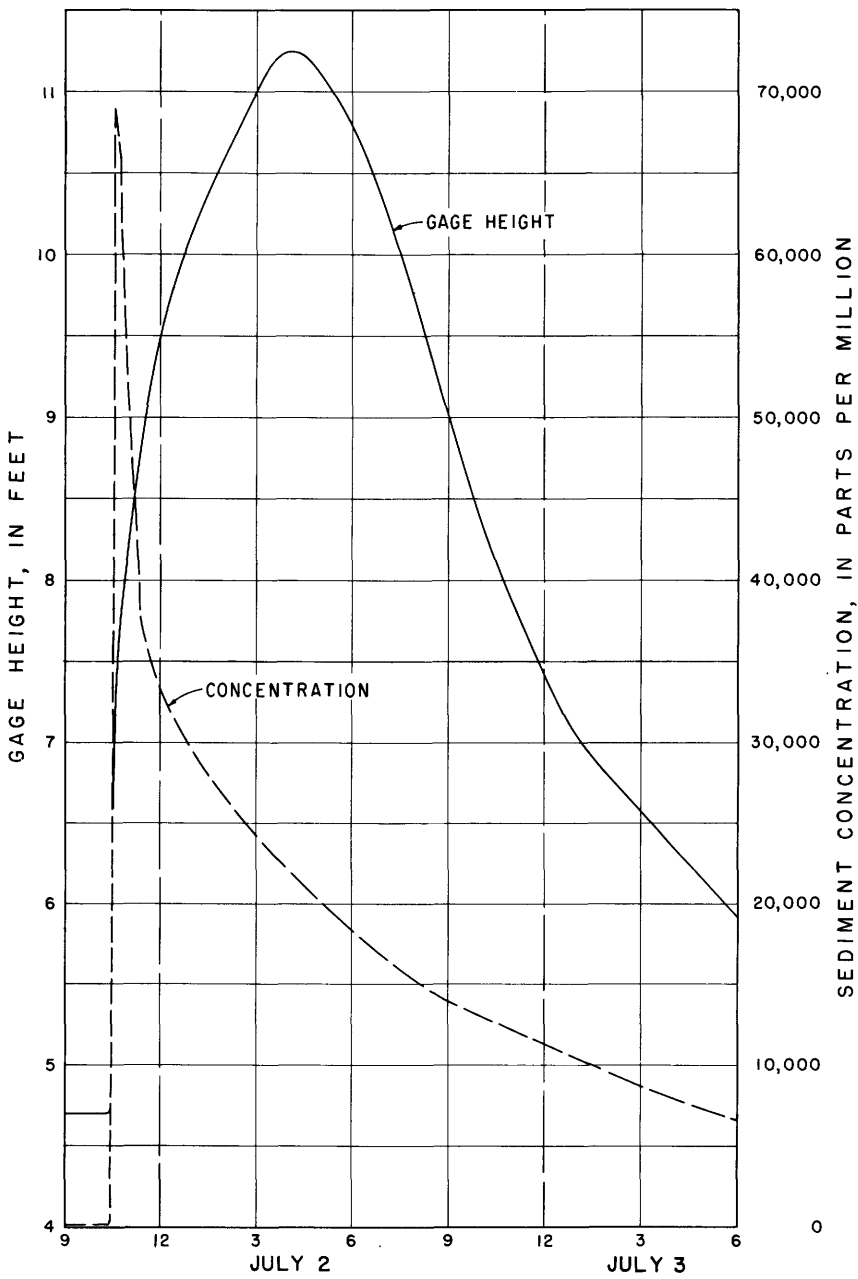


FIGURE 6.—Stage hydrograph and concentration curve, Salt Creek at Lincoln, July 2-3, 1954.

Hydrographs and concentration curves for selected periods of major flow of Salt Creek at Lincoln are shown in figures 4 to 6. During the flood of May 31 to June 4, 1951 (fig. 4), about 1,800,000 tons of suspended sediment was discharged; in contrast, during the entire 1953 water year only 92,000 tons of suspended sediment was discharged. Figure 7 shows Salt Creek at Lincoln on June 2, 1951, at a discharge of 28,100 cfs, and figure 8 shows Salt Creek at a discharge of about 70 cfs.

The rapid rise at Lincoln on July 2, 1954 (fig. 6), was caused by heavy rain in the vicinity of Valparaiso, about 28 channel miles upstream, on the evening of July 1. Suspended-sediment samples were obtained immediately before the arrival of the flood wave and at frequent intervals during and after the passing of the flood wave. The suspended-sediment concentration increased from 75 ppm about 1 minute before the flood wave arrived to 69,100 ppm at a discharge of 1,200 cfs (cubic feet per second) about 10 minutes after the arrival of the flood wave. The suspended-sediment concentration then decreased gradually, although the maximum water discharge of 4,160 cfs was not reached until about 6 hours after the maximum concentration occurred.

Possible reasons for the maximum concentration to precede the maximum water discharge are (1) the early runoff carries the most easily eroded weathered material from the drainage area, and (2) the sediment deposited in the channel during low-flow periods is eroded and placed in suspension by the initial flood wave as it moves downstream.

Runoff and sediment yield from any given area are controlled by many variables, such as geology, soil characteristics, slope, land use, type and density of channels, amount and intensity of precipitation, and flood- and erosion-control structures. The suspended sediment discharged by Salt Creek at Lincoln is composed of material derived from the western half of Salt Creek basin; for any given rise in stage, the exact part of the basin from which the transported sediment was derived is rarely known. The sediment discharge at Lincoln, therefore, cannot be correlated with any single one of these variables or with any combination of the variables.

The relation of water discharge to sediment discharge at Salt Creek at Lincoln is fairly well defined. The curve in figure 9, based on both



A



B

FIGURE 7.—Salt Creek at Lincoln, June 2, 1951, at discharge of 28,100 cfs. *A*, Stage recorder (downstream side of bridge); *B*, Sampling installation (upstream side of bridge).



A



B

FIGURE 8.—Salt Creek at Lincoln, at discharge of about 70 cfs. *A*, Stage recorder (downstream side of bridge); *B*, Sampling installation (upstream side of bridge).

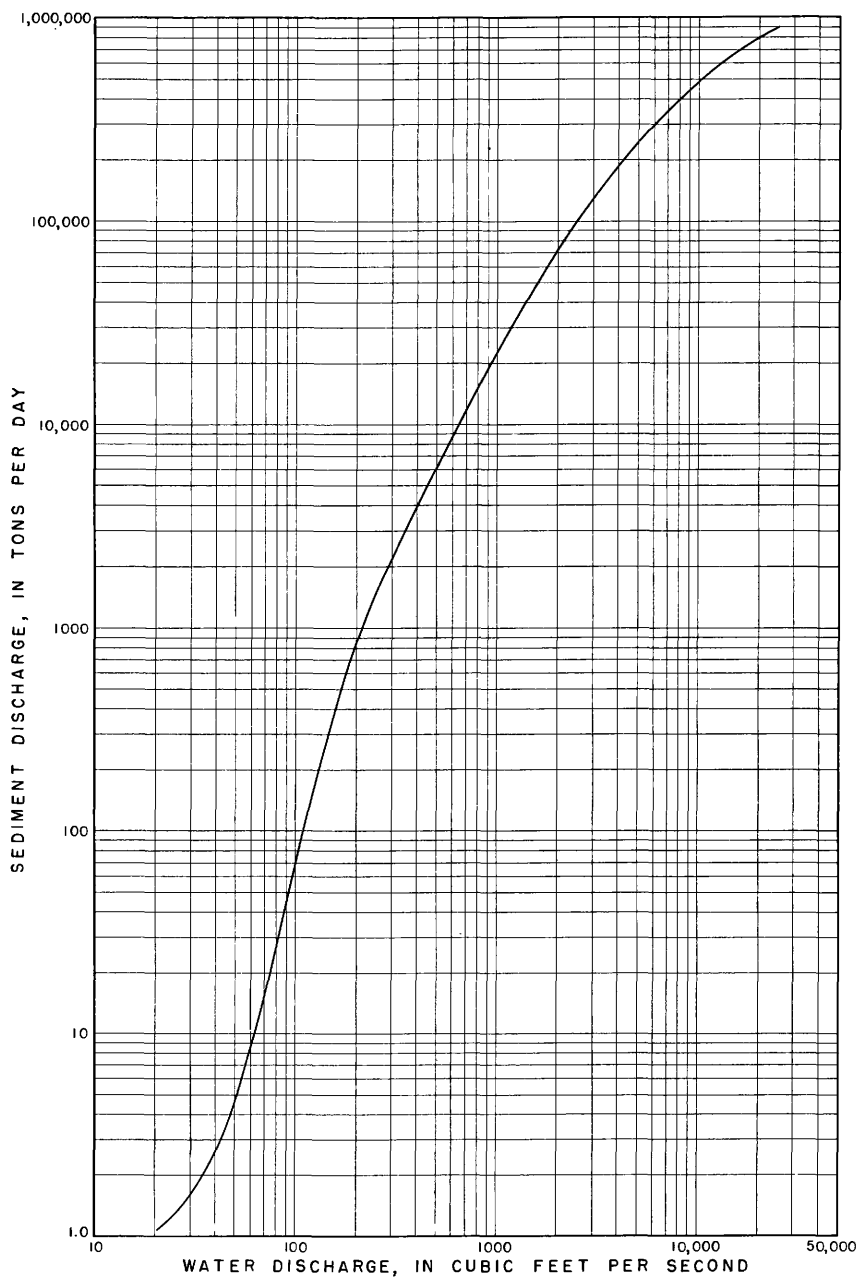


FIGURE 9.—Relation of sediment discharge to water discharge, Salt Creek at Lincoln.

instantaneous discharge and on daily mean discharge, indicates that, on the average, sediment discharge increases as water discharge increases. An appreciable range in sediment discharge, however, can be expected at any given water discharge. For example, on Salt Creek the suspended-sediment concentration at a given water discharge is generally considerably higher on the rising stage than on the receding stage; therefore, the sediment discharge at a given water discharge may be considerably greater on the rising stage than on the falling stage. Nevertheless, the curve indicates the sediment discharge that, on the average, can be expected at any given water discharge.

The relation of sediment discharge to water discharge can be used in conjunction with a flow-duration curve or with streamflow data to estimate the probable suspended-sediment discharge during periods before and after sediment data are obtained on a stream. Figure 10 is a flow-duration curve based on streamflow data obtained on Salt Creek at Lincoln during the period 1950-59. The total suspended-sediment discharge of Salt Creek at Lincoln for this period, computed from figures 9 and 10, was about 18.7 million tons and, computed from figure 9 and daily streamflow data, about 18.6 million tons.

If a specific weight of 100 pounds per cubic foot is assumed for the soil in place, a layer of soil about 1 foot thick and slightly more than 1 square mile in area would yield about the same amount of sediment as that transported by Salt Creek at Lincoln in 1952. For the period 1950-59, a layer of soil 1 foot thick and about 13 square miles in area would yield the estimated suspended-sediment discharge of Salt Creek at Lincoln.

The suspended-sediment discharge is generally most of the total sediment discharge for streams such as Salt Creek; however, some sediment not included in the measured suspended-sediment discharge may be transported either as bedload or as part of the suspended-sediment discharge in the unsampled zone near the streambed. A method devised by Colby (1957, p. 708-717) was used to compute the unmeasured sediment discharge at selected times on Salt Creek at Lincoln. The data in table 4 indicate that the measured sediment discharge is most of the total sediment discharge (measured discharge plus computed unmeasured discharge) over a wide range of water and sediment discharges.

The suspended sediment transported by Salt Creek is predominantly silt and clay, and the particle-size data shown in figure 11 represent water discharges ranging from 652 to 24,200 cfs.

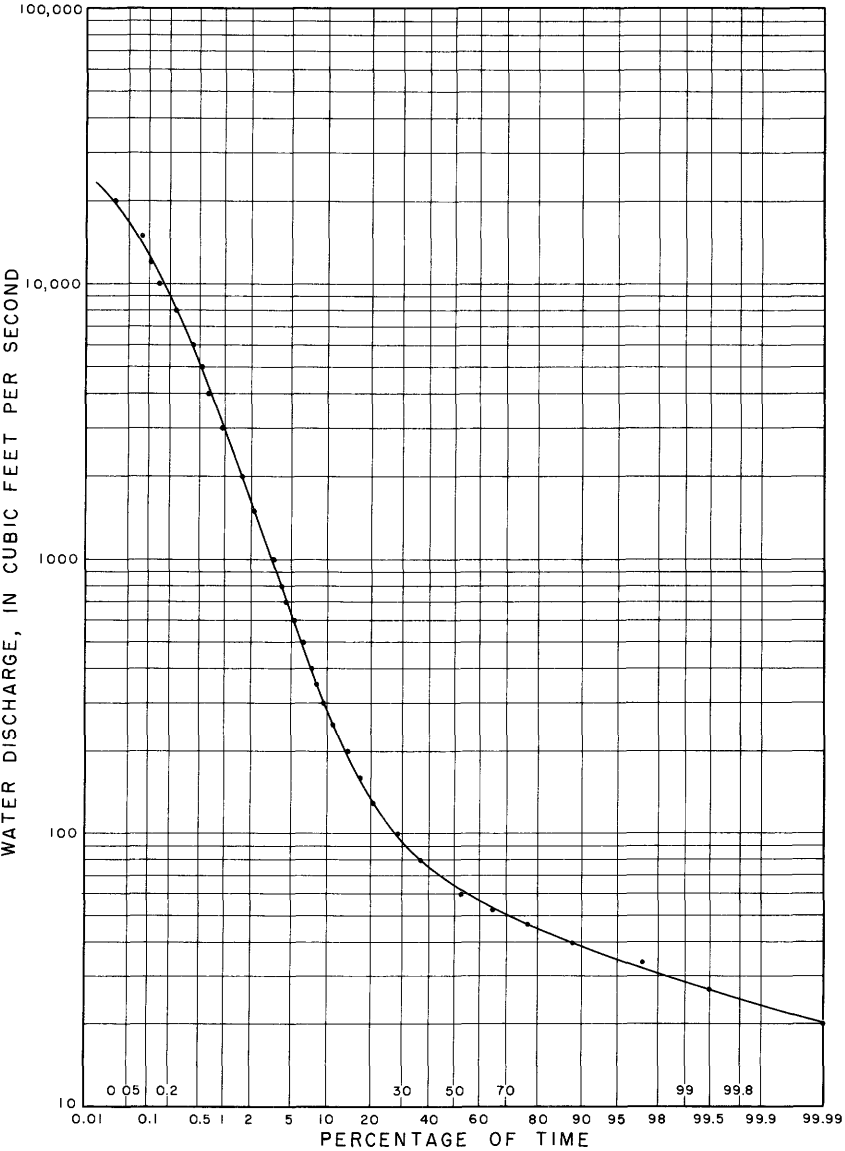


FIGURE 10.—Flow-duration curve, Salt Creek at Lincoln, 1950-59.

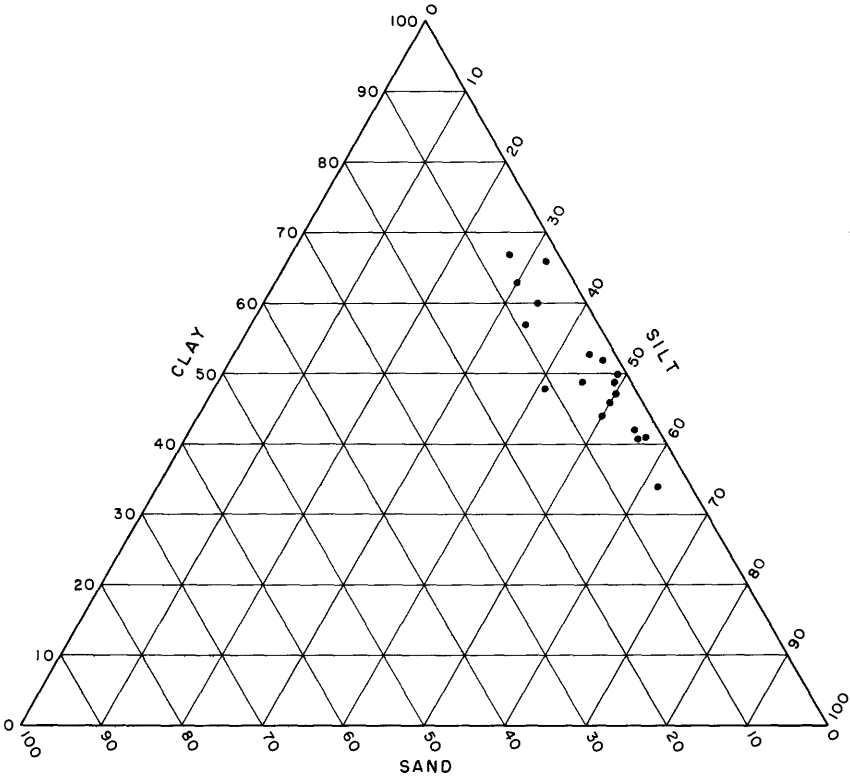


FIGURE 11.—Percentage of sand, silt, and clay in suspended-sediment samples, Salt Creek at Lincoln.

TABLE 4.—Measured suspended-sediment discharge, total sediment discharge, and hydraulic data for selected dates at Salt Creek at Lincoln, Nebr.

Date	Discharge (cfs)	Suspended sediment		Total sediment discharge (tons per day)	Mean velocity (fps)	Mean depth (ft)	Width (ft)
		Discharge (tons per day)	Concen- tration (ppm)				
1951							
Apr. 22-----	652	16,300	9,250	16,650	2.20	1.96	169
Apr. 25-----	2,860	187,000	24,200	189,100	2.75	4.53	231
May 1-----	3,430	139,000	15,000	141,000	2.39	6.15	234
May 31-----	3,110	319,000	36,600	323,600	3.04	7.05	237
1954							
June 9-----	2,760	93,200	12,500	94,900	2.54	4.60	237
June 17-----	11,800	436,000	13,700	443,400	3.57	12.75	255
Aug. 8-----	1,930	16,500	3,170	17,080	1.86	4.30	236
Aug. 23-----	4,180	62,000	5,490	64,000	2.73	6.60	234

CHEMICAL QUALITY OF THE WATER

As water falls through the air and percolates through the soil, it absorbs carbon dioxide and becomes an effective solvent for many of the minerals in the earth's crust. The kinds and amounts of minerals dissolved by the water depend mainly on the types of minerals with which the water has contact and on the length of time of contact. Therefore, water that travels rapidly over the land does not ordinarily become as mineralized as water that infiltrates slowly through the ground.

Analyses of water from the Salt Creek basin were studied to determine the relations between water quality and geology and to evaluate the suitability of the water for domestic, industrial, and irrigation uses.

GROUND WATER

Large variations in the quality of water from an individual well are not common. Waters from different aquifers or from different parts of the same aquifer, however, are commonly different in chemical quality. The quality of the ground water in the Salt Creek basin was determined from analyses of samples representative of the three major sources of supply. Results of analyses are given in table 5.

The location of wells is shown in this report by numbers and letters. (See fig. 12.) The first number indicates the township; the second, the range; and the third, the section. The first lowercase letter following the section number indicates the quarter section; the second, the quarter-quarter section; and the third, the quarter-quarter-quarter section. These letters are arranged counterclockwise and begin with "a" in the northeast quarter. If more than one well is within the 10-acre tract, an additional number follows the lowercase letters.

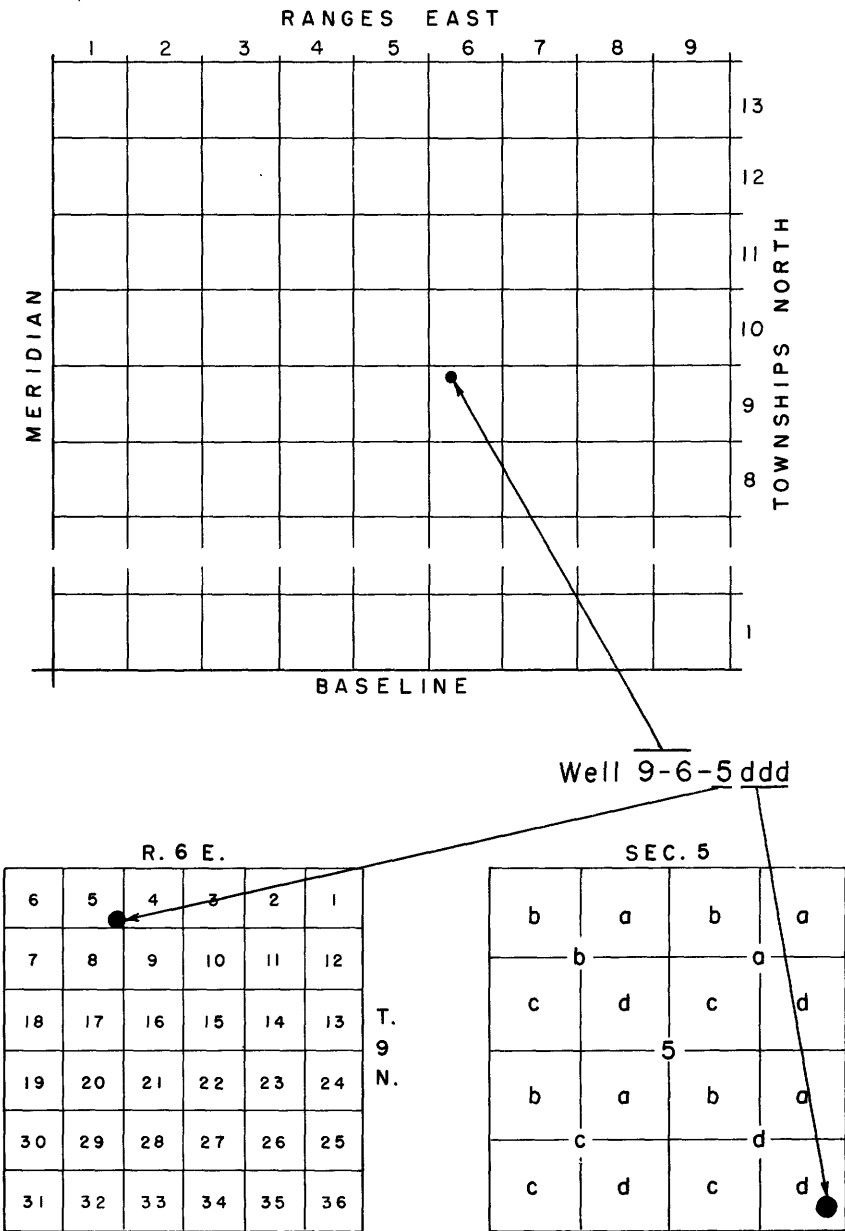


FIGURE 12.—Well-numbering system.

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TABLE 5.—Chemical analyses of ground

[Use: D, domestic; Ind., industrial; Irr., irrigation; N., none; O, observation; PS,

Location	Depth (ft)	Use	Date of collection	Temperature (° F)	Silica (SiO ₂)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO ₃)
Allu											
9-6-4db.....	17	D	May 24, 1951..	58	38	1.2	147	41	153	5.0	456
36d.....	40.5	D	May 31, 1950..	54	15	.14	111	15	62	4.8	350
10-5-16b.....	36	O	May 24, 1951..	56	24	7.0	82	20	135	5.3	638
10-6-26b.....	72	Ind	June 10, 1950..	56	30	.06	222	53	570	7.6	280

Sands and gravels											
7-6-19a.....	{ 1 350 2 380 3 380	T T T	Dec. 13, 1955..	52	26	2.4	292	95	1,890	9.7	382
			Dec. 14, 1955..	51	33	.72	79	29	30	4.4	373
			do.	55							
8-6-28dd.....	80	PS	May 31, 1950..	57	28	.12	111	13	47	3.8	419
8-7-17cc.....	40	N	do.	57	23	.16	125	32	63	3.2	412
33ad.....	42	PS	do.	54	32	.14	115	27	58	5.4	360
9-6-5d.....	30	T	July 10, 1953..	41	5.5		49	13	108	3.4	384
10-6-18ab.....	25	D, S	June 1, 1950..	57	53		150	28	74	11	538
10-7-3bc.....		D	do.	57	24		124	30	81	5.2	365
4d.....	63	D	do.	61	9.4		44	10	32	2.6	110
5db1.....	4 35	T	Apr. 26, 1950..	53		1.0			765		481
5dda.....		T	June 27, 1951..	22			22	9.0	148	2.9	288
8aa.....	4 100	Ind	1948.				42	14	76		207
11-4-8aa.....	396	PS	Mar. 29, 1945..	57			50	20	103		452
11-5-3aa.....	4 105	T	May 24, 1948..	54	45	2.6	46	8.5	245	9.6	508
11-6-6b.....	45	D	May 31, 1950..	60	22	.12	118	20	46	4.3	376
29ba.....	30.5	D	May 23, 1951..	55	27	1.3	181	36	380	8.3	460
31a.....		D	May 25, 1950..	56	34		142	25	143	6.2	445
35c.....	190	D	Dec. 30, 1955..	82		4.4			1,180		480
11-7-30c.....	4 25	D	June 1, 1950..	58	26		116	29	116	8.4	466
11-8-17d.....	91	Irr	May 25, 1950..	54	22	.12	73	21	45	3.8	326
12-9-2ac.....	73	PS	do.	55	41	.12	58	12	29	7.8	220
32c.....	108	PS	do.	54	26	.12	74	18	31	5.3	372
13-4-19bb.....	392	PS	Sept. 26, 1952..	66	45	1.7	88	29	21	11	432
13-5-22aa.....	180	PS	May 29, 1952..	59	39	1.2	102	21	12	5.4	376
13-10-19ccd.....		PS	May 29, 1951..	24		.09	55	10	32	8.0	202
14-5-12ac.....		D	June 29, 1948..	45			47	23	20	5.6	234
14-7-3db.....	85	PS	July 2, 1952..	55	32	.02	79	17	34	4.3	324
14-8-1bc.....	123	D	Apr. 9, 1957..	65	43	.05	83	17		27	302
1dce.....	118	D	Jan. 8, 1957..	52	43	.16	94	17		27	309
2ba.....	122	D	Oct. 8, 1957..	54	53	.10	80	13		32	349
23da.....	130	D	May 13, 1958..	56	43	3.9	40	12		18	170
26aba.....	122	D	June 12, 1956..	55	48	.07	52	11		20	215
14-9-18cbc.....	110	D	Mar. 8, 1957..	50	40	.23	86	16		27	313
19da.....	103	D	Feb. 11, 1958..	55	41	.56	59	12		24	237

Dakota group of											
9-6-4cbd.....	{ 55 99 151	T T T	July 1939.....				82	0.4	488		123
			do.				126	17	2,410		
			do.				147	18	4,230		
5dd.....	2,000	N	Aug. 8, 1959..	61	9.8		183	143	9,990	35	448
10-5-22dc.....	95	D	Jan. 28, 1960..	54	37	.02	77	16	36	6.1	370
23cc.....		PS	May 20, 1953..	19		.98	41	14	460	7.6	322
26ab.....	85	D	Dec. 5, 1949..	19	3.3		78	16	109	7.2	412
10-6-2dc.....	187	D	January 1957..	41	3.4		140	2.6	137	7.1	390
21bd.....	4 2,650	N	Nov. 19, 1951..	60	9.6		184	145	9,410	98	437
26aab.....		Ind	Oct. 17, 1959..	30			147	152	5,540		407
26ab.....	143	Ind	Apr. 24, 1951..	58	17	.11	415	205	16,100	17	547
26ab2.....	159	Ind	do.	60	22	.16	298	122	8,660	11	419
26bdd.....		Ind	Oct. 17, 1959..	30			347	140	9,360		405
10-7-5ada.....	140	T	June 29, 1951..	57	13		285	135	11,900	44	763
6b.....	4 180	T	August 1953..	16		2.8	283	124	10,600	53	764
13bd.....	80	D	July 6, 1950..	54	28	.06	66	14	33	3.6	286
18dc.....	4 192	Irr	May 9, 1955..	56	23	.04	62	13	68	3.7	266
31bab1.....	141.5	PS	August 1951..	55	25	.07	66	14	30	4.0	239

¹ Water from 350 ft.

² Water from 260-270 ft.

³ Water from 290-300 ft.

⁴ Estimated.

SEDIMENTATION, QUALITY OF WATER, SALT CREEK, NEBR. H27

water, Salt Creek basin, Nebraska

public supply; S, stock; T, test. Results in parts per million except as indicated]

Carbonate (CO ₂)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Boron (B)	Dissolved solids		Hardness as CaCO ₃	Noncarbonate hardness as CaCO ₃	Percent sodium	Sodium-adsorption-ratio	Specific conductance (microhmios per cm at 25° C)	pH
						Calculated	Residue on evaporation at 180° C						
vium													
0	175	202	0.8	40	0.14	1,020	1,100	536	162	38	2.9	1,610	7.2
0	193	10	.2	.4	.30	-----	640	339	52	28	1.5	884	7.1
0	18	27	.7	.0	.25	-----	636	288	0	50	3.4	981	7.4
0	423	893	.2	116	.30	2,450	2,630	772	542	61	8.9	3,980	6.8

of Pleistocene age

0	617	3,030	1.6	2.7	0.50	6,150	6,350	1,120	807	78	25	10,300	7.9
6	54	7.5	.3	.1	.01	-----	424	317	11	17	.7	663	8.2
0	47	16	.2	.25	.13	-----	546	331	0	23	1.1	1,120	7.2
0	83	52	.3	.130	.30	-----	730	444	106	23	1.3	806	7.3
0	116	35	.2	.84	.37	-----	658	398	103	24	1.3	1,060	7.4
13	13	44	.3	1.1	.08	-----	490	177	0	56	3.5	949	7.4
0	142	46	.3	8.3	.20	-----	958	490	49	24	1.5	765	8.4
0	188	51	.3	32	.20	716	1,010	433	134	29	1.7	1,130	7.5
0	18	84	.2	.6	.30	-----	318	151	61	31	1.1	1,070	7.1
0	193	820	.9	-----	-----	-----	90	0	95	35	3.4	477	6.8
0	48	87	.2	1.2	.15	-----	504	92	0	77	6.7	3,500	7.2
0	61	67	-----	-----	-----	-----	404	162	0	50	2.6	836	7.2
0	49	5.0	.6	.2	-----	-----	404	162	0	50	2.6	682	8.2
0	126	115	.8	.4	.25	-----	830	207	0	52	3.1	766	-----
0	91	46	.3	35	.25	-----	622	377	69	21	1.0	1,310	7.3
0	110	655	.4	2.5	.23	1,630	1,780	598	221	58	6.7	894	7.0
0	49	192	.2	131	.18	-----	972	458	93	40	2.9	2,790	7.2
0	280	1,680	.4	5.3	.20	3,390	3,670	502	108	84	23	1,490	7.6
0	114	110	.2	3.2	.07	-----	862	409	27	38	2.5	6,210	7.4
0	60	16	.4	6.2	.20	-----	408	269	2	26	1.2	1,190	7.5
0	40	20	.2	28	.12	-----	352	194	14	24	.9	621	7.1
0	20	6.0	.2	.7	.30	-----	370	259	0	20	.8	509	7.1
0	37	7.5	.3	.7	.08	-----	448	338	0	11	.5	575	7.3
0	44	6.0	.3	14	.11	-----	434	342	34	7	.3	696	7.4
0	83	8.0	.4	.5	-----	-----	336	180	14	27	1.0	673	7.4
0	68	6.0	.2	.0	.06	-----	328	212	20	16	.6	492	7.5
0	46	15	.2	20	.13	-----	406	268	2	21	.9	483	8.0
0	47	15	.5	21	.10	-----	415	277	29	18	.7	647	7.3
0	96	3.5	.3	4.3	.08	-----	455	304	51	16	.7	630	7.9
0	33	1.5	.5	.5	-----	-----	382	255	0	21	.9	661	7.3
0	23	3.8	.4	21	-----	-----	257	148	9	21	.6	590	7.4
0	25	5.0	.2	11	-----	-----	277	176	0	19	.7	374	7.0
0	45	16	.5	13	.09	-----	417	279	22	17	.7	427	7.6
0	40	5.5	.5	4.2	-----	-----	305	196	2	21	.8	634	7.5
												467	7.1

Cretaceous age

-----	99	748	-----	-----	-----	-----	206	105	84	15	-----	-----	-----
-----	471	3,610	-----	-----	-----	-----	384	-----	93	53	-----	-----	-----
-----	826	6,200	-----	-----	-----	-----	439	-----	95	88	-----	-----	-----
0	3,150	13,800	2.4	2.9	5.5	27,500	28,200	1,040	673	96	134	38,000	7.4
0	16	11	.4	7.4	.10	-----	389	259	0	23	1.0	626	6.9
0	68	590	.2	.6	.34	1,360	1,360	159	0	86	16	2,470	7.6
0	29	101	.2	.0	-----	-----	597	261	0	47	2.9	1,010	7.5
0	18	314	.1	.8	.07	-----	945	456	136	39	2.8	1,560	7.8
0	2,950	13,200	2.4	10	3.5	26,200	26,600	1,050	692	95	126	38,900	6.9
0	1,250	8,080	-----	-----	-----	15,400	16,200	995	661	92	76	62	7.2
0	2,280	24,400	2.3	32	.83	43,800	43,800	1,880	1,430	95	184	62,700	7.0
0	1,340	12,800	2.2	35	.69	23,500	23,700	1,250	906	94	108	36,100	7.0
0	1,790	13,900	-----	-----	-----	25,800	26,700	1,440	1,110	93	107	-----	6.8
0	2,570	16,700	.9	21	4.8	32,000	32,100	1,270	644	95	146	45,800	7.1
0	2,280	15,100	1.7	3	4.1	28,800	29,100	1,170	544	95	135	43,000	8.1
0	50	13	.3	1.6	.30	-----	348	222	0	24	1.0	540	7.1
0	44	71	.2	1.7	.11	-----	422	208	0	41	2.0	707	7.1
0	42	14	.1	9.6	-----	-----	336	196	0	25	.9	500	7.0

* From analysis by Layne Research Div., Memphis, Tenn.

WATER FROM THE DAKOTA GROUP

The quality of ground water and surface water in parts of the basin is affected by the Dakota group, which characteristically yields water that contains large amounts of dissolved solids—principally sodium and chloride. However, most of the salts have been leached from some parts of the Dakota, and water from these parts is relatively low in dissolved solids.

Most of the available data on the chemical quality of water from the Dakota group are for wells in and near Lincoln, where in places the Dakota is at or near the surface. The water from most of these wells was of the sodium chloride type and contained high concentrations of dissolved solids. (See table 5.) The water from some of the wells, however, was of the calcium bicarbonate type and contained less than 500 ppm of dissolved solids; such water generally overlies water containing higher concentrations of dissolved solids.

The data indicate that, in places, the concentration of dissolved solids increases with depth; for example, the concentration of chloride in the water from test hole 9-6-4cbd increased from 748 ppm at a depth of 55 feet to 6,200 ppm at 151 feet. Therefore, the rate of pumping can affect the quality of the water obtained, particularly if the rate is high for prolonged periods; the water level can be lowered so much that the wells begin to yield salty water. Before 1933 the water supply of Lincoln was obtained in the city limits from about 20 wells that could produce a combined total of 10 million gallons per day for short periods. Some of these wells, however, began to produce salty water and were abandoned. Since 1933, the city of Lincoln has been supplied principally by water from a well field near Ashland. Some of the wells in the city limits are used during periods when the demand for water is exceptionally high.

Figure 13 shows diagrammatically (Stiff, 1951) the relations of dissolved solids to chloride and to water type. The water from the Dakota group as represented by analyses in table 5, has either a fairly low or an extremely high dissolved-solids content. As the dissolved-solids content increases, the water type changes from calcium bicarbonate to sodium chloride, and the concentration of chloride increases. In waters that contain more than about 900 ppm of dissolved solids, the amount of chloride increases almost proportionally with the increase in dissolved solids.

At some places, water from the Dakota issues from springs and adversely affects the quality of the surface waters, especially when stream discharges are low. Also, at some places, infiltration of water from the Dakota adversely affects the quality of the adjacent water-bearing deposits.

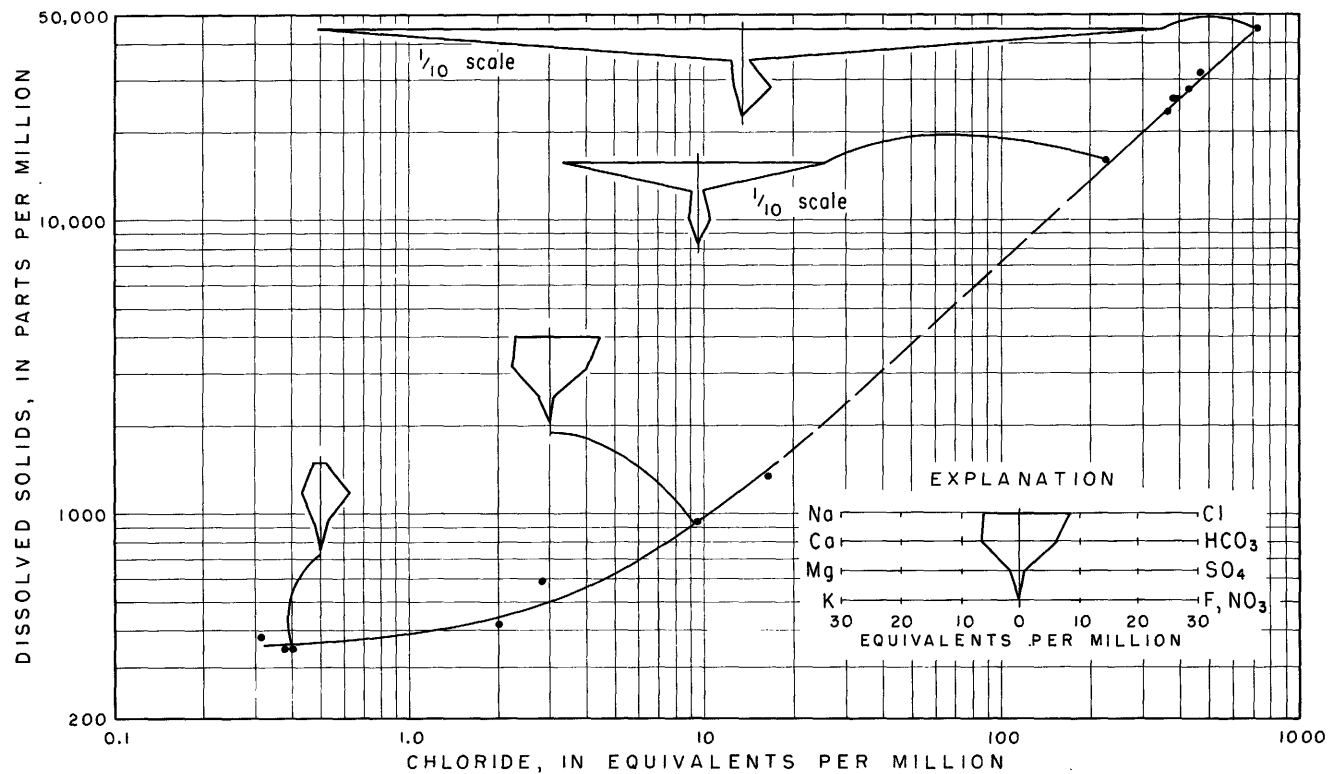


FIGURE 13.—Relation of chloride, dissolved solids, and type of water from the Dakota group, Salt Creek basin.

WATER FROM THE SANDS AND GRAVEL OF PLEISTOCENE AGE

Most of the water for domestic, industrial, and irrigation uses in the basin is from sands and gravels of Pleistocene age of variable thickness and extent. In the southern half of the basin, the deposits are not capable of yielding the large quantities of water required for the city of Lincoln; therefore, Lincoln has developed its supplies in the deposits east of Ashland in the Platte River valley.

Dissolved solids in the water from the sands and gravels of Pleistocene age were generally less than 1,000 ppm in the southern half of the basin and less than 500 ppm in the northern half. Locally in the southern half the dissolved solids were higher than 1,000 ppm. (See table 5.) In test hole 7-6-19a, the dissolved solids were 424 ppm at a depth of 260 to 270 feet, about 800 ppm (estimated) at 290 to 300 feet, and 6,350 ppm at 350 feet. Water from the Dakota evidently has infiltrated into the deep sands and gravels because the increase in dissolved solids was due principally to increases in sodium and chloride. Except where water from the Dakota affects water in the sands and gravels of Pleistocene age in the southern half of the basin, the water is of the calcium bicarbonate type. Concentrations of iron are greater than 1 ppm in water from many of the wells.

WATER FROM THE ALLUVIUM

The alluvium in most of the basin does not yield large quantities of water, although in a few places, such as near Ashland, some wells have produced enough water for irrigation. Not much information on the quality of water in the alluvium is available (see table 5); however, the water probably is of the calcium bicarbonate type and has less than 1,000 ppm of dissolved solids, except where water from the Dakota has infiltrated the alluvium, such as in the vicinity of well 10-6-26b.

SURFACE WATER

Streamflow consists of both overland flow and effluent from the ground-water reservoir. If the chemical composition of the overland flow differs significantly from that of the ground-water effluent, the chemical composition of the streamflow will vary with changes in discharge. When the discharge is high, the chemical quality of the streamflow is similar to that of the overland flow; when the discharge is low, the chemical quality of the streamflow is similar to that of the ground water.

Most of the analyses in table 6 are representative of low discharge. The water in the upstream parts of Salt Creek and its tributaries is similar to the water from sands and gravels of Pleistocene age; it is of the calcium bicarbonate type and contains about 600 ppm or less

TABLE 6.—*Chemical analyses of surface water, Salt Creek basin, Nebraska*

[Results in parts per million except as indicated]

Date of collection	Discharge (cfs)	Silica (SiO ₂)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO ₃)	Carbonate (CO ₂)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate NO ₃)	Boron (B)	Dissolved solids			Hardness as CaCO ₃	Noncarbonate hardness as CaCO ₃	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos per cm at 25°C)	pH
															Calculated	Residue at 180°C							
																Parts per million	Tons per acre-foot						
Salt Creek, near Saltillo School																							
May 23, 1951-----	-----	12	0.08	56	13	29	211	0	59	12	0.5	3.8	0.06	-----	304	0.41	193	20	25	0.9	475	7.4	
Salt Creek, above confluence of Haines Branch																							
May 24, 1951-----	-----	11	0.06	53	15	30	211	0	60	12	0.3	4.4	0.07	-----	314	0.43	192	19	25	0.9	479	7.5	
Haines Branch, 3½ miles south of Emerald																							
July 14, 1951-----	-----			122	16	55	394	0	141	16	-----	-----	-----	-----	616	0.84	372	49	24	1.3	889	8.1	
Haines Branch, above confluence with Salt Creek																							
May 24, 1951-----	-----	20	0.05	136	32	205	438	0	168	270	0.4	2.6	0.14	1,050	1,120	1.52	472	113	49	4.1	1,700	8.0	
Salt Creek, downstream from Haines Branch																							
May 25, 1950-----	-----	21	0.06	89	20	112	300	0	102	135	0.4	5.6	-----	-----	722	0.98	305	59	44	2.8	1,050	7.4	

TABLE 6.—*Chemical analysis of surface water, Salt Creek basin, Nebraska—Continued*

[Results in parts per million except as indicated]

Date of collection	Discharge (cfs)	Silica (SiO ₂)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO ₃)	Carbonate (CO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Boron (B)	Dissolved solids			Hardness as CaCO ₃	Noncarbonate hardness as CaCO ₃	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos per cm at 25°C)	pH
															Calculated	Residue at 180° C							
																Parts per million	Tons per acre-foot						
Middle Creek, near Emerald																							
July 14, 1951.....	-----	---	-----	118	15	65	405	0	110	37	-----	-----	-----	-----	606	0.82	357	25	28	1.5	920	7.9	
Salt Creek, south of Oak Lake																							
May 25, 1950.....	-----	22	0.04	90	25	761	246	0	185	1,120	0.3	9.5	-----	2,330	2,480	3.37	328	126	83	18	4,080	7.3	
Oak Creek, 1 mile south of Raymond																							
July 14, 1951.....	-----	---	-----	112	24	41	417	0	84	29	-----	-----	-----	-----	574	0.78	380	38	19	0.9	843	7.9	
Oak Creek, near Oak Valley School																							
May 23, 1951.....	-----	16	0.03	97	26	176	382	0	105	217	0.9	1.2	0.15	-----	856	1.16	350	37	52	4.1	1,410	8.0	
Oak Creek, near West Lincoln																							
May 23, 1950.....	-----	25	0.06	119	29	627	413	0	164	898	0.5	4.3	-----	2,070	2,150	2.92	417	78	77	13	3,520	7.8	

Salt Creek, at Lincoln

May 9, 1950-----	26,500	12	-----	12	2.7	22	54	0	17	17	0.5	1.5	0.20	-----	114	0.16	41	0	53	1.5	172	7.4	
Do-----	16,700	13	-----	11	2.3	23	47	0	18	20	.5	1.5	.10	-----	124	.17	37	0	58	1.7	170	7.4	
May 23-----	98	30	0.04	108	32	1,080	357	0	245	1,560	.5	6.6	-----	3,240	3,340	4.54	401	108	85	24	5,460	7.4	
May 23, 1951-----	137	-----	-----	-----	-----	1,100	282	0	255	1,600	-----	-----	.32	-----	-----	-----	366	135	87	25	5,560	7.2	
May 20, 1953-----	178	24	.01	102	32	985	12	388	0	230	1,420	.1	8.0	.33	3,000	3,000	4.08	386	68	84	22	5,250	8.0
May 27-----	915	-----	-----	36	8.5	226	7.8	-----	-----	-----	-----	-----	-----	-----	764	1.04	125	-----	78	8.8	1,390	6.9	
July 3, 1956-----	3,840	-----	-----	16	4.4	56	4.4	96	0	-----	-----	-----	-----	-----	241	.33	58	0	66	3.2	428	7.1	
July 10, 1958-----	18,500	-----	-----	-----	-----	21	-----	106	0	6.8	23	-----	.8	-----	167	.23	74	0	36	1.1	259	6.9	

Little Salt Creek, 8 miles north of Lincoln

Feb. 26, 1952-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1,310	-----	-----	-----	-----	3,110	4.23	458	-----	-----	-----	5,250	-----
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Little Salt Creek, 4 miles north of Lincoln

Feb. 26, 1952-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2,360	-----	-----	-----	-----	5,140	6.99	520	-----	-----	-----	8,580	-----
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Salt Creek, west of Waverly

May 23, 1951-----	-----	15	0.05	83	23	588	275	0	190	816	0.8	2.1	0.30	1,850	1,860	2.53	300	74	81	15	3,160	7.4
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Wahoo Creek, near Ashland

May 23, 1951-----	-----	18	0.01	90	26	112	346	0	158	87	0.7	1.7	0.20	-----	680	0.92	330	46	43	2.7	1,120	7.8
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Salt Creek, near Ashland

May 23, 1950-----	-----	24	0.02	91	23	484	300	0	142	688	0.4	12	-----	1,610	1,820	2.48	322	76	77	12	2,790	7.3
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¹ Daily mean discharge.

of dissolved solids. The water in the vicinity of Lincoln is similar to the water from the Dakota group; it is of the sodium chloride type and contains more than 1,000 ppm of dissolved solids.

Partial analyses indicate that the water in Little Salt Creek during periods of low discharge is high in dissolved solids and is probably of the sodium chloride type. Saline soils are fairly common in the downstream two-thirds of Little Salt Creek valley and reflect both the quality of water and the poor drainage in parts of the flood plain. Some very small areas completely devoid of vegetation were observed. The bare areas were fringed with scattered saltwort that graded into saltbush; a little farther out the saltbush graded into saltgrass and western wheatgrass.

Figure 14 shows diagrammatically the increases in the concentrations of dissolved solids and chloride as the water in the streams becomes affected by the water from the Dakota. As the water in Haines Branch (3 and 4) and in Oak Creek (8, 9, and 10) moves downstream, the concentrations of sodium chloride increase to such a degree that the water type changes from calcium bicarbonate to sodium chloride. Downstream from Lincoln, concentrations of dissolved solids and chloride in Salt Creek decrease somewhat, but the effects of the water from the Dakota are still noticeable at Ashland. The underlying bedrock in most of this reach of Salt Creek consists of limestones and shales of Pennsylvanian age.

The dissolved-solids content in the water from Salt Creek at Lincoln decreases as the discharge increases, and the water type changes from sodium chloride at low discharge to sodium bicarbonate at high discharge. (See fig. 15.)

WATER QUALITY AND USE

Water supply is of prime consideration in the growth of either an industrial or an agricultural economy. The use of the available water for specific purposes, however, may be restricted by the amounts and kinds of dissolved material in the water. For some uses the water must meet strict quality standards.

Nearly all the water used in the Salt Creek basin for domestic, public, industrial, and agricultural supplies is produced from wells; surface water of adequate quantity and quality is not available. Surface water, however, is used for pollution abatement, recreation, and some livestock needs.

DOMESTIC AND PUBLIC SUPPLIES

Water for domestic and public supplies should have no unpleasant odor or taste, be free from sediment and color, and contain no pathogenic organisms or excessive quantities of minerals. Standards have

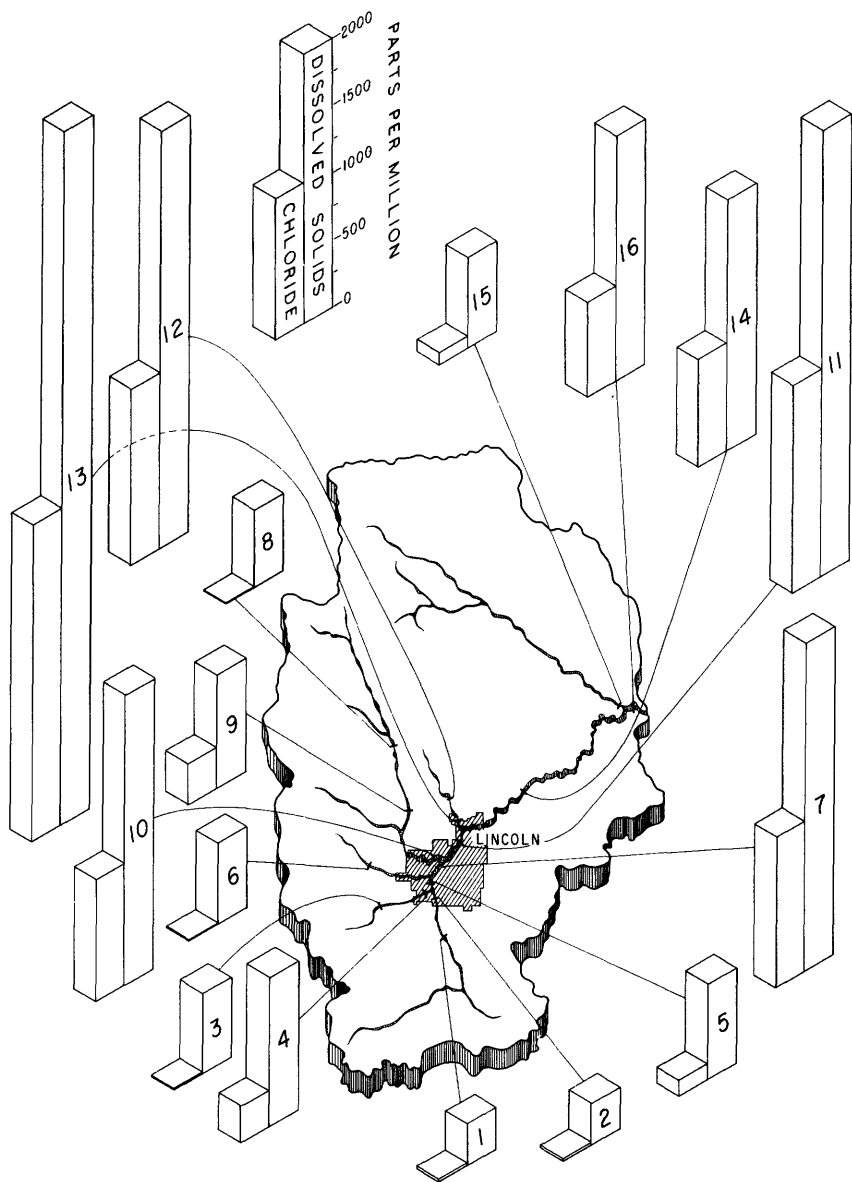


FIGURE 14.—Concentrations of dissolved solids and chloride in surface water during periods of low discharge, Salt Creek basin. Explanation: 1, Salt Creek near Saltillo School; 2, Salt Creek above confluence of Haines Branch; 3, Haines Branch, $3\frac{1}{2}$ miles south of Emerald; 4, Haines Branch above confluence with Salt Creek; 5, Salt Creek downstream from Haines Branch; 6, Middle Creek near Emerald; 7, Salt Creek south of Oak Lake; 8, Oak Creek, 1 mile south of Raymond; 9, Oak Creek near Oak Valley School; 10, Oak Creek near West Lincoln; 11, Salt Creek at Lincoln; 12, Little Salt Creek, 8 miles north of Lincoln; 13, Little Salt Creek, 4 miles north of Lincoln; 14, Salt Creek west of Waverly; 15, Wahoo Creek near Ashland; 16, Salt Creek near Ashland.

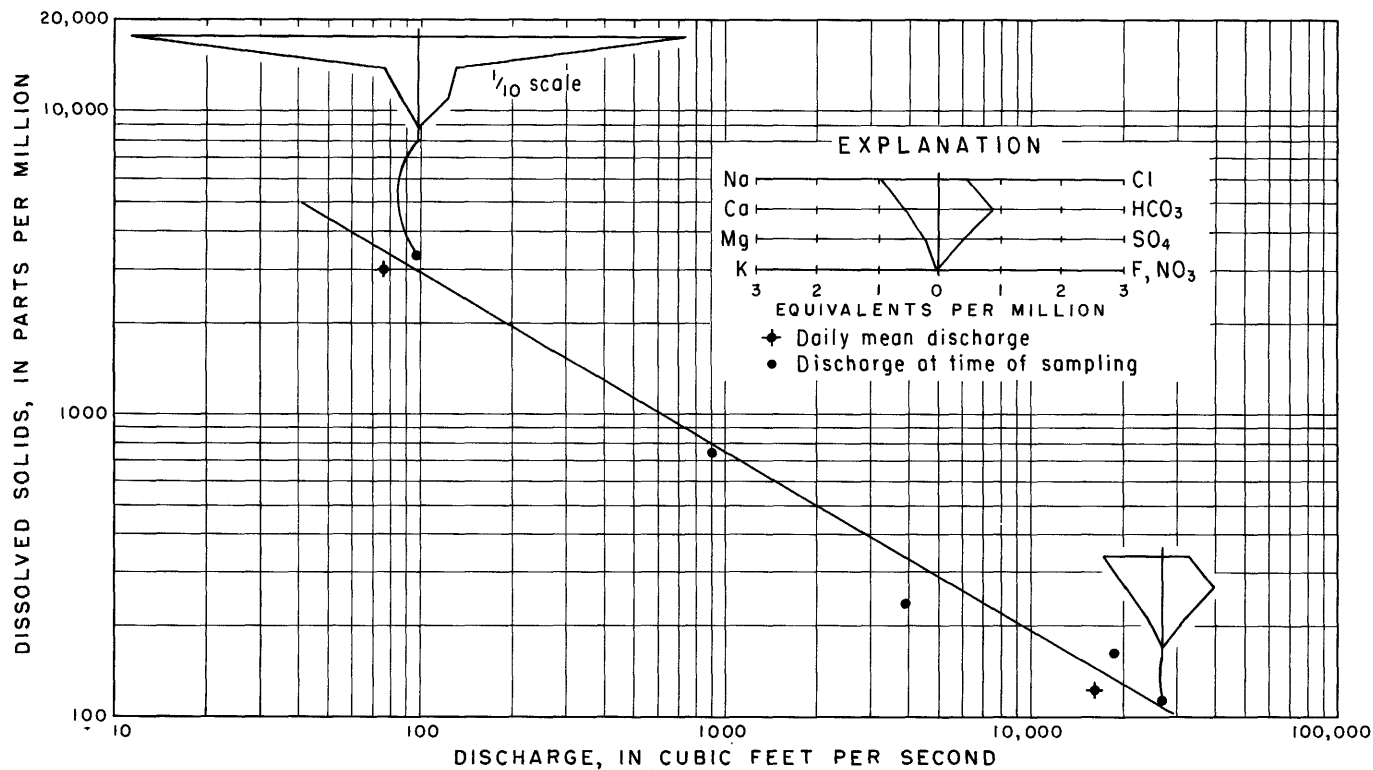


FIGURE 15.—Relation of dissolved solids, discharge, and water type, Salt Creek at Lincoln.

been established by the U.S. Public Health Service (1961) for drinking water used on interstate carriers and should be applicable to all public water supplies in the United States. Some of these standards for the chemical constituents of the water are as follows:

<i>Constituent</i>	<i>Recommended maximum (ppm)</i>
Iron (Fe)-----	0.3
Manganese (Mn)-----	.05
Lead (Pb)-----	¹ .05
Arsenic (As)-----	¹ .01
Sulfate (SO ₄)-----	250
Chloride (Cl)-----	250
Fluoride (F)-----	^{1,2} 1.3
Dissolved solids-----	500

¹ Mandatory.
² Based on long-term annual average of maximum daily air temperatures at Lincoln, Nebr.

The standards for lead, arsenic, and fluoride are mandatory because these constituents in sufficient quantity are toxic to human beings. According to Welsh and Thomas (1960), excessive amounts of arsenic may cause chronic arseniasis, which is characterized by small eruptions on the hands and feet; and excessive amounts of fluoride may cause fluorosis or "mottled enamel" of children's teeth. In most natural water the concentration of these constituents is low. Studies have shown, however, that fluoride in concentrations between 0.6 and 1.2 ppm in drinking water have a beneficial effect on children's teeth.

Excessive concentrations of iron and manganese in the water stain fabrics and porcelain or enamelware, produce unsavory flavors in coffee and tea, and discolor vegetables during cooking. Micro-organisms, which thrive in water containing iron, may cause disagreeable tastes and odors in the water. Magnesium and sulfate in high concentrations in water may have a laxative effect on some people and cause an unpleasant taste, and large quantities of chloride in water may cause a salty taste.

Nitrate is an end product in the decomposition of organic wastes; therefore, high concentrations of nitrate may indicate pollution of the water. Maxcy (1950, p. 265) reported that water containing more than 44 ppm of nitrate should be regarded as unsafe for infants because it may cause cyanosis.

Hardness is caused principally by calcium and magnesium in water. It impairs the quality of the water because of curd that forms when soap is added and because of scale that is deposited in water pipes, heaters, and boilers. No standards for hardness have been established, but the following gradations are generally recognized:

Hardness as CaCO ₃ , in ppm	Rating	Suitability
<60-----	Soft-----	Suitable for many uses without further softening.
60-120-----	Moderately hard-----	Usable except in some industrial applications.
121-200-----	Hard-----	Softening required by laundries and some other industries.
>200-----	Very hard-----	Requires softening for most uses.

The analyses in table 7 indicate that the water from most public supplies is very hard but contains less than 500 ppm of dissolved solids. Iron and manganese in many of the supplies and chloride in one analysis exceeded the maximum concentrations recommended by the U.S. Public Health Service (1961). High concentrations of nitrate indicated possible pollution of the water from three of the supplies.

INDUSTRY

In industries, the quality requirements for water depend on the specific use of the water. The requirements for water used for cooling or waste disposal are not so strict as those for water used in processing or incorporated in the final product. Generally, water that is of satisfactory quality for domestic and public supply is also satisfactory for many industrial uses or can be made satisfactory with a reasonable amount of treatment. Table 8 shows the water-quality tolerances for some industrial uses (American Water Works Association, 1950).

IRRIGATION

The amount of precipitation is sufficient for successful dryland farming, except during the growing season in some years. Recently, however, ground water has been used for irrigation, particularly in Salt Creek basin northeast of Lincoln and in Wahoo Creek valley. According to the Conservation and Survey Division, University of Nebraska, there were 208 irrigation wells in Lancaster and Saunders Counties in 1958; most of them were in Salt Creek basin. Although many applications for the use of surface water have been filed with the Nebraska Department of Water Resources, little of the surface water in the basin is used for irrigation. Streamflow is generally low when the need for irrigation is the greatest.

Water used for irrigation should be of such quality that it will not adversely affect the productivity of the land to which it is applied. The suitability of the water for irrigation, however, depends not only on the quality of the water but also on such conditions as climate, soil structure and drainage, type of crop, and farm-management

practices. Methods have been suggested for classifying irrigation water so that its long-term effect on soil productivity can be forecast (Wilcox, 1948; Scofield, 1936; Eaton, 1950; U.S. Salinity Laboratory Staff, 1954). The method used in this report was proposed by the U.S. Salinity Laboratory Staff (1954).

Properties of principal importance in determining the suitability of water for irrigation are the total concentration of the dissolved salts, the relative proportion of sodium to calcium and magnesium, the concentration of boron or other elements that may be toxic, and the concentration of bicarbonate as compared with the concentrations of calcium and magnesium.

High concentrations of dissolved salts in irrigation water may cause an accumulation of salts in the soil solution and may make the soil saline. Because all plants absorb water by osmosis, a favorable balance must be maintained between salts within a plant and salts in the soil solution. When the total concentration of salts in the soil solution becomes too high for plants to get an adequate amount of water or when the concentration of certain salts in the soil solution becomes so high as to be toxic, the growth of the plants is adversely affected. The tendency of irrigation water to cause an accumulation of salts in the soil is called the salinity hazard of the water. The specific conductance of the water is used as an index of the salinity hazard.

High concentrations of sodium relative to the concentrations of calcium and magnesium in irrigation water may change soil structure. Cations in the soil water become fixed on the surface of fine soil particles; calcium and magnesium tend to flocculate the particles, whereas sodium tends to deflocculate them. Flocculation gives the soil looseness, provides good penetration by water and air, and generally gives the soil good tillage properties. Deflocculation promotes packing and prevents free movement of air and water. The adverse effect on soil structure caused by high sodium concentrations in the irrigation water is called the sodium hazard of the water.

An index used for predicting the sodium hazard of a water is the sodium-adsorption-ratio (SAR), which is defined by the equation

$$SAR = \frac{Na^{+1}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

where Na^{+1} , Ca^{+2} , and Mg^{+2} are in equivalents per million (U.S. Salinity Laboratory Staff, 1954).

TABLE 7.—*Chemical analyses of water from public supplies, Salt Creek basin, Nebraska*

[Analyses by Nebraska Department of Health. Results in parts per million except as indicated. Point of collection: D, distribution system; S, source]

Municipality	Point of collection	Depth of well (feet)	Date of collection	Iron (Fe)	Manganese (Mn)	Lead (Pb)	Arsenic (As)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO ₃)	Carbonate (CO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Dissolved solids (residue on evaporation at 105°C)	Hardness as CaCO ₃	Noncarbonate hardness as CaCO ₃	Percent sodium	Sodium-adsorption-ratio	pH
Ashland (well 1) ¹	S	74	8-13-57	0.1	0.1	---	---	64	19	25	13	176	0	64	37	0.3	<44	480	236	92	18	0.7	6.9
Ashland (well 2) ¹	S	73	8-13-57	.0	.2	---	---	62	15	27	10	234	0	40	19	.4	<44	420	216	24	20	.8	7.2
Ashland (well 3) ¹	S	100	8-13-57	.0	.1	---	---	64	13	22	9	244	0	52	14	.3	<44	370	212	12	18	.7	7.3
Brainard	S	324	8- 8-52	.1	.54	0	0.004	---	---	9.0	---	417	0	163	5.7	.2	<44	782	500	158	4	.2	7.5
Cedar Bluffs	---	116-140	5- 9-57	.5	.3	---	---	104	22	17	---	346	0	80	11	.1	<44	480	348	64	10	.4	7.5
Ceresco	S	93	---	.0	.0	---	---	89	37	98	5	417	0	69	85	.3	40	700	376	34	36	2.2	7.2
Do.	S	95	8- 9-55	.3	.01	---	---	---	---	153	---	388	0	115	112	.4	<44	686	264	0	56	.4	---
Colon	S	110	9-11-56	1.9	.40	---	---	81	25	24	10	368	0	50	1.9	.2	<44	458	308	0	14	.6	7.1
Davey	S	---	12-17-57	.2	.0	---	---	---	---	32	5	322	0	4	6	---	<44	302	212	0	24	1.0	---
Denton	S	160+	5-16-56	8.5	.27	---	---	85	12	198	6	351	0	130	193	.2	<44	850	262	0	62	5.3	7.4
Do.	D	---	---	1.1	---	---	---	---	---	---	---	106	294	---	---	.2	<44	920	---	---	---	---	7.4
Dwight ²	S	376	---	2.1	.4	---	---	---	---	20	10	434	0	55	11	---	<44	452	---	---	---	---	7.3
Do. ²	S	376	12- 8-52	1.3	.57	0	.005	---	---	---	---	44	0	44	8.5	.4	<44	394	358	2	10	.5	7.7
Eagle (east well)	S	244	2-23-56	1.1	.24	---	---	106	21	56	3	161	0	135	22	.2	<44	614	352	220	26	1.3	7.4
Emerald ³	S	---	2- 8-57	.1	.0	---	---	2	5.6	161	---	351	0	50	27	.2	<44	470	28	0	93	13	7.7
Garland ⁴	D	396	---	.05	.24	---	---	---	---	112	---	456	0	66	6.6	.4	<44	480	210	0	54	3.3	8.2
Greenwood ⁵	D	108	---	.0	.01	---	---	---	---	---	---	---	---	29	6.0	.2	<44	377	283	---	---	---	7.5
Do. ⁵	S	108	9-27-54	.4	.05	0	.004	74	22	28	4	371	0	23	6.5	.2	<44	356	274	0	18	.7	7.3
Hallam	S	265	---	1.3	.35	---	---	---	---	38	4	388	0	55	18	.3	<44	794	346	28	19	.9	7.1
Hickman (well 1) ⁶	S	45	2-14-55	.05	.02	0	---	130	34	56	6	398	0	134	41	---	75	734	464	138	21	1.1	7.2
Hickman (well 2) ⁶	S	38	5-23-55	3.1	.55	---	---	79	20	35	3	317	0	57	35	.3	<44	458	280	20	21	.9	7.6
Hickman ⁶	D	---	---	.01	.0	---	---	---	---	70	5.6	403	0	131	39	.2	75	753	478	148	24	1.4	7.1
Lincoln	D	---	---	.01	.01	---	---	46	21	30	9	203	0	70	14	.4	<44	336	200	34	24	.9	7.3
Do.	D	---	4-12-55	.06	---	---	---	54	12	---	---	206	0	54	23	.4	---	* 319	184	15	30	1.1	7.7
Do.	D	---	5-14-58	.04	---	---	---	53	11	---	---	201	0	54	11	.5	2.4	* 297	179	14	25	.9	7.5

Malmö.....	D	65	4-21-53	.0	.0	0	.01	64	28	32	3	346	0	37	5.7	.2	<44	404	276	0	20	.8	7.3
Mead (new well).....	S		10- 3-58	1.9	.5			104	19	26	12	400	0	56	6	.4	<44	532	336	8	14	.6	7.4
Mead (well 1).....	S	72	5-20-58	2.0	.2			85	18	18	13	234	0	24	24	.5	40	558	284	92	11	.5	7.4
Mead (well 2).....	S	132	5-20-58	.5	.0			93	18	21	12	312	0	40	2	.3	<44	470	304	48	12	.5	7.4
Mead.....	D			.05	.05						36	398	0	54	3.8	.3		416	310	0	20	.9	7.3
Morse Bluff.....	D	65	12- 5-51	.0	.0	0	.01				46	461	0	145	8.6	.3	64	656	494	116	17	.9	7.2
Prague (new well).....	S		1-19-59	7.3	2.5			88	23	31	10	239	0	60	30	.2	<44		316	120	17	.8	
Prague (filtered water).....	S		6-23-59	.0	<.05			90	19	53	8	395	0	32	44	.7	<44	490	304	0	27	1.3	7.7
Roca.....	S	60	11-24-50	.49	.05	0	.012				34	393	0	112	13	.1	<44	616	384	62	16	.7	7.2
Valparaiso ¹	D	180	4-21-53	1.2	.0	0	.02	91	35	11	4	381	0	55	3.8	.3	<44	486	370	58	6	.2	7.7
Wahoo ¹⁰	S	80		.0	.0			72	28	32	3	322	0	50	19	.3	<44	438	294	30	19	.8	7.2
Waverly.....	D		9-26-52	.02	.1	0	.008			35	11	359	0	90	28	.3	<44	468	330	36	18	.8	7.2
Weston.....	S	80±	2-24-53	.0	.2	0	.02	67	28	18	5	325	0	38	13	.2	<44	406	282	16	12	.5	7.3
Yutan (well 1).....	S	144	10-26-56	.0							36	200	0	32	9.6		<44	260	132	0	37	1.4	

¹ See also table 5, well location 12-9-2ac.² See also table 5, well location 13-4-19bb.³ See also table 5, well location 10-5-23cc.⁴ See also table 5, well location 11-4-8aa.⁵ See also table 5, well location 12-9-32c.⁶ See also table 5, well location 8-7-33ad.⁷ Analysis by U.S. Geol. Survey.⁸ Residue on evaporation at 180°C.⁹ See also table 5, well location 13-5-22aa.¹⁰ See also table 5, well location 14-7-3db.

¹ American Water Works Association (1950).

² A, No corrosiveness; B, No slime formation; C, Conformance to Federal drinking-water standards necessary; D, NaCl, 275 ppm.

³ Waters with algae and hydrogen sulfide odors are most unsuitable for air conditioning.

⁴ Some hardness desirable.

⁵ Water for distilling must meet the same general requirements as for brewing (gin and spirits mashing water of light-beer quality; whiskey mashing water of dark-beer quality).

⁶ Clear, odorless, sterile water for syrup and carbonization. Water consistent in character. Most high quality filtered municipal water not satisfactory for beverages.

⁷ Hard candy requires pH of 7.0 or greater, as low value favors inversion of sucrose, causing sticky product.

⁸ Control of corrosiveness is necessary as is also control of organisms, such as sulfur and iron bacteria, which tend to form slimes.

⁹ $\text{Ca}(\text{HCO}_3)_2$ particularly troublesome. $\text{Mg}(\text{HCO}_3)_2$ tends to greenish color. CO_2 assists to prevent cracking. Sulfates and chlorides of Ca, Mg, Na should each be less than 300 ppm (white butts).

¹⁰ Uniformity of composition and temperature desirable. Iron objectionable as cellulose adsorbs iron from dilute solutions. Manganese very objectionable, clogs pipelines and is oxidized to permanganates by chlorine, causing reddish color.

¹¹ Excessive iron, manganese, or turbidity creates spots and discoloration in tanning of hides and leather goods.

¹² Constant composition; residual alumina 0.5 ppm.

¹³ Calcium, magnesium, iron, manganese, suspended matter, and soluble organic matter may be objectionable.

The salinity hazard and sodium hazard of the water may be evaluated by use of a diagram by the U.S. Salinity Laboratory Staff (1954). (See fig. 16.) Interpretation of the diagram is as follows:

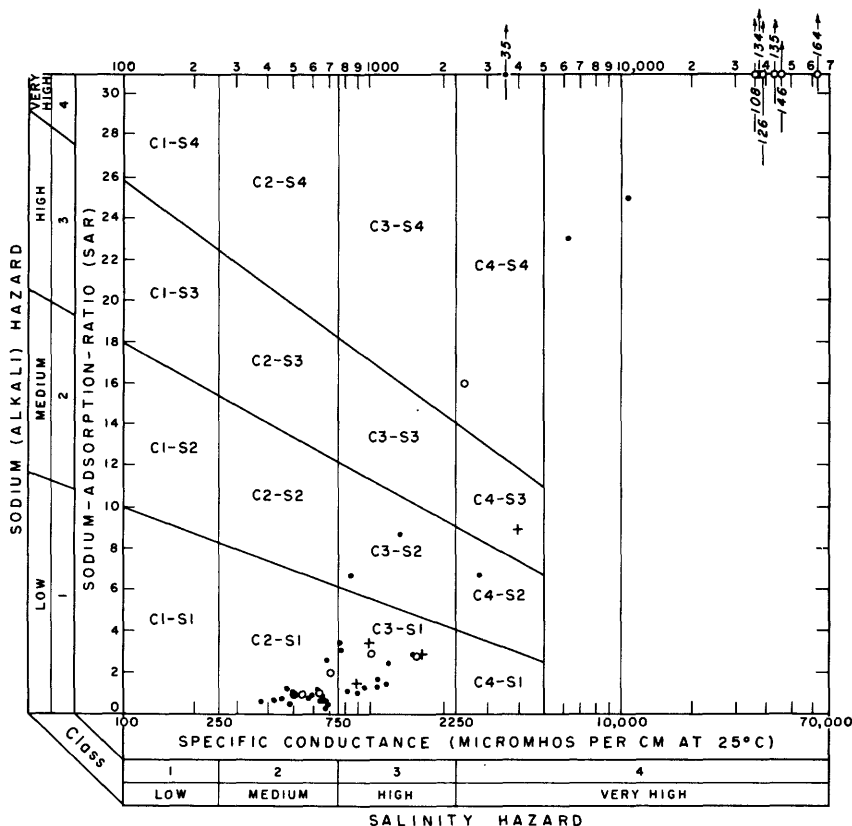


FIGURE 16.—Classification of water for irrigation. Diagram after U.S. Salinity Laboratory Staff (1954).

Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

High-salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required, and plants with good salt tolerance should be selected.

Very high salinity water (C4) is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium-sensitive plants may, however, suffer injury as a result of sodium accumulation in plant tissues when exchangeable-sodium values are lower than those effective in causing deterioration of the physical condition of the soil. **Low-sodium water (S1)** can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.

Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management—good drainage, high leaching, and organic-matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

In the Salt Creek basin most of the water from the Dakota group is unsatisfactory for irrigation because both the salinity hazard and the sodium hazard are very high. Some of the water is suitable for irrigation, but such water is insufficient for large-scale development. Most of the water from the deposits of Pleistocene age and the alluvium can be used for irrigation if drainage is adequate and if salt-tolerant plants are grown. In some places the water is unsatisfactory for irrigation, because it has been contaminated by the water from the Dakota.

Boron is essential to the normal growth of all plants; however, if present in excessive concentrations, it may be highly toxic to some species. According to Wilcox (1955, p. 6), "Plants usually show no symptoms of boron deficiency if irrigated with water containing at least 0.1 ppm of boron, but injury may develop on the more sensitive plants when irrigated with water containing boron in excess of 1 ppm." According to the California Water Pollution Control Board (California Institute of Technology, 1957, p. 149), "It is doubtful whether more than 0.5 ppm can be applied continuously to soils without ultimately producing some plant injury." The concentrations of boron

in most of the water from sands and gravels of Pleistocene age and from alluvium are between 0.1 and 0.5 ppm, and the concentrations in most of the water from the Dakota group are more than 0.5 ppm.

High concentrations of bicarbonate in irrigation water may cause the pH of the soil to increase and may lead to the development of "black alkali" soil. As the water evaporates and the calcium and magnesium precipitate, any remaining bicarbonate combines with sodium to form sodium carbonate, which raises the pH of the soil. Wilcox, Blair, and Bower (1954) concluded that if concentrations of bicarbonate do not exceed those of calcium and magnesium by more than 1.25 epm, the water probably is safe for use. The concentrations of bicarbonate in most of the water in Salt Creek basin do not exceed those of calcium and magnesium by more than 1.25 epm.

SUMMARY

Suspended-sediment data obtained from 1951 to 1954 on Salt Creek at Lincoln, Nebr., indicate that 75 percent or more of the total annual suspended-sediment discharge is transported by flow that is exceeded 5 percent or less of the time each year. Estimates from sediment data for 1951-54 and flow-duration data for 1950-59 indicate that the sediment discharge for the period 1950-59 was about 18.7 million tons.

Suspended-sediment concentrations varied widely. From March 1951 to September 1954 the minimum measured concentration was 9 ppm, and the maximum was 69,100 ppm.

Computations indicate that the measured sediment discharge is most of the total sediment discharge over a wide range of water and sediment discharges.

Water from most wells in the Dakota group contains high concentrations of dissolved solids and is of the sodium chloride type. Water from the sands and gravels of Pleistocene age in the southern half of the basin generally contains less than 1,000 ppm of dissolved solids, and water in the northern half generally contains less than 500 ppm. The water in the alluvium probably is of the calcium bicarbonate type and has less than 1,000 ppm of dissolved solids except where water of the sodium chloride type has infiltrated the alluvium.

During low discharge the water in the upstream parts of Salt Creek and its tributaries is similar in chemical quality to the water from sands and gravels of Pleistocene age, and water in the vicinity of Lincoln is similar in chemical quality to the water from the Dakota group.

Water from most public supplies contains less than 500 ppm of dissolved solids but is very hard; iron and manganese in many of the supplies exceeded recommended maximum concentrations. The water from the Dakota group is unsatisfactory for irrigation, and most of

the water from the deposits of Pleistocene age and from the alluvium can be used for irrigation if drainage is adequate and if plants having good salt tolerance are grown.

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