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# PRELIMINARY RESULTS OF HYDROGEOCHEMICAL STUDIES IN THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEVADA

By

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# PRELIMINARY RESULTS OF HYDROGEOCHEMICAL STUDIES IN THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEVADA

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## ABSTRACT

As part of the interagency Humboldt River Research Project, the U. S. Geological Survey is studying the hydrogeochemistry of the Humboldt River valley between the Comus and Rose Creek gaging stations near Winnemucca, Nevada. The water-bearing sedimentary deposits of the area include three units: older alluvium of Miocene or Pliocene and Pleistocene age, medial alluvium of Lake Lahontan (Pleistocene) age, and younger alluvium of post-Lake Lahontan (Pleistocene and Recent) age.

The Humboldt River is perennial downstream from Winnemucca, and is ephemeral between Winnemucca and the Comus gaging station. The smaller streams in the area are ephermeral and rarely discharge into the Humboldt River.

Most of the ground-water recharge to the Humboldt River valley is by underflow from tributary areas including the Humboldt River valley upstream from the study area, the drainage basins of Pole Creek and Rock Creek, Paradise Valley, and Grass Valley and the northwestern slope of the Sonoma Range. Most of the ground-water discharge is by seepage to the Humboldt River and evapotransporation.

Sodium and bicarbonate are the most abundant ions in the ground and surface waters of the area. However, the most abundant ions in solution in the streams draining the Sonoma range and in the ground water of Grass Valley are calcium and bicarbonate. The dissolved-solids content of most of the water in the area is less than 600 ppm; however, locally, as in the Comus area, the Golconda area, and the East Range fault area, the dissolved-solids content of the ground water is more than 2,000 ppm. Thermal water in these areas contains comparatively large amounts of boron and fluoride, and therefore the water is not suitable for agricultural or domestic use.

In December 1961, practically all the water in the Humboldt River between the Comus and Rose Creek gaging stations was seepage from the ground-water reservoir. The chemical quality of the river largely reflected the chemical quality of ground water from the tributary areas.

# INTRODUCTION

A number of governmental agencies, including the Water Resources Division of the U.S. Geological Survey, are cooperating with the Nevada Department of Conservation and Natural Resources in the Humboldt River Research Project. One of the major objectives of the project is to determine the disposition of the water resources of the Humboldt River valley, one of the most important agricultural areas in Nevada. Each cooperating agency is studying one or more aspects of the hydrogeologic environment of the valley. Initially, most of the agencies are concentrating their work in the segment of the Humboldt River valley near the city of Winnemucca in Humboldt County. (See fig. 1)

## Scope and Objectives of the Study Described in this Report

The Geological Survey is studying the following aspects of the hydrogeology of the area: (1) changes of ground water in storage, (2) ground-water underflow into and out of the area, (3) the relation between surface water and ground water, and (4) the hydrogeochemistry of the area.

The three objectives of the hydrogeochemical phase of the investigation are to determine the suitability of the water in the area for domestic and agricultural use; to utilize geochemical data to make a qualitative and, if possible, a quantitative evaluation of the source and direction of movement of the water; and to determine whether there are seasonal changes in the chemical quality of the water.

## Purpose and Content of the Report

The purpose of this report is to make most of the basic hydrogeochemical data obtained to date (December 1961) available to the cooperating agencies and to others who are interested in the hydrology of the study area and to make a preliminary interpretation of these data. (See tables 1 and 2). A qualitative appraisal is made of the variations in the chemical quality of the water by areas. The source and direction of movement of water are considered on the basis of geochemical factors, and the chemical suitability of the water for domestic and agricultural use is discussed. Seasonal changes in the chemical quality of the water and a more detailed quantitative analysis of the geochemical data will be given in a subsequent report.

Some geologic and hydrologic features of the area are discussed briefly as a basis for the description of the hydrogeochemistry of the area.

## Location of the Study Area

The area described in this report is in Humboldt and Pershing Counties in north-central Nevada (fig. 1). It includes the Humboldt River valley between the Geological Survey's gaging station at Comus in the SE 1/4 NE 1/4 SE 1/4 sec. 14, T. 36 N., R. 41 E., and the gaging station near Rose Creek in the NW 1/4 SE 1/4 NW 1/4 sec. 36, T. 35 N., R. 35 E. The gaging stations are respectively about 22 miles east and 15 miles southwest of the city of Winnemucca. Also included in the study area are parts of Grass Valley and Paradise Valley, and the mountain ranges bordering these valleys.

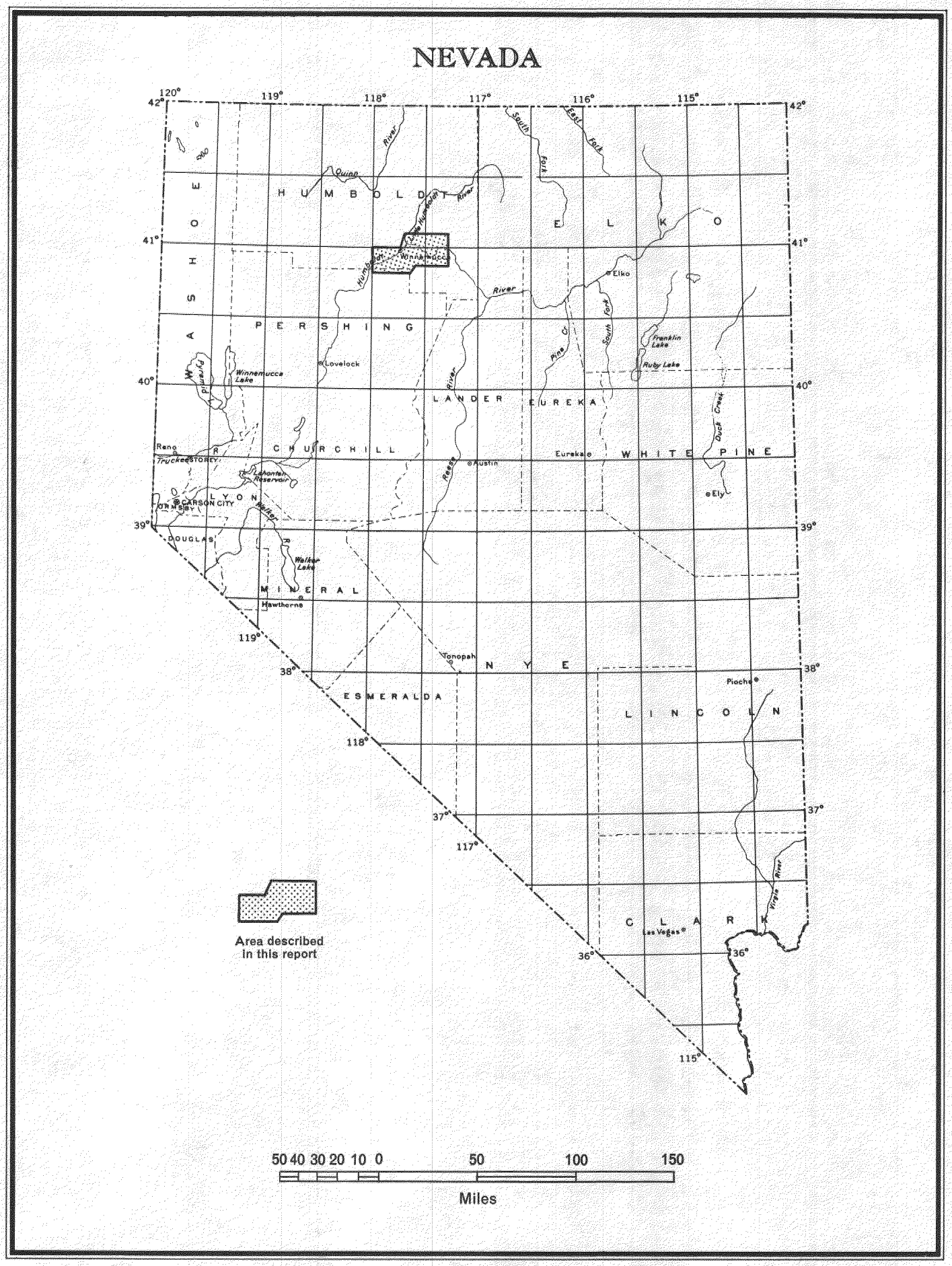


FIGURE I. — Map of Nevada showing the location of the area described in this report.

## Previous Investigations

King (1878) investigated the geology of part of the study area during his exploration of the 40th Parallel. The deposits and geomorphic features of Pleistocene Lake Lahontan, which occupied much of north-central and northwestern Nevada were mapped by Russell (1885). His report described the distribution and character of some of the surficial deposits in the study area.

The geology of the Winnemucca and Golconda quadrangles was mapped by Ferguson, Muller, and Roberts (1951) and Ferguson, Roberts, and Muller (1952). Willden (1961) prepared a reconnaissance geologic map of Humboldt County, and Hotz and Willden (1961) prepared a preliminary geologic map of part of the Osgood Mountains near the eastern margin of the study area. The latter two reports refer to a number of other studies concerned principally with local mining districts. A report describing ground water in Paradise Valley, which is tributary to the Humboldt River valley east of Winnemucca, was prepared by Loeltz, Phoenix, and Robinson (1949).

Recently completed reports describing the results of the Humboldt River Research Project include a general description of the project by Maxey and Shamberger (1961), an evaluation of geophysical studies in the area by Dudley and McGinnis (1962), and analyses of several aspects of the hydrogeology by Cohen (1961a, b, and c; and 1962a, b, and c).

## Numbering of Water Samples and Sampling Sites

Identification and location numbers of water-sampling sites are shown in figure 2. The numbers indicate the position of the sampling sites in the rectangular system for the subdivision of public lands. The first unit indicates the township north of the Mount Diablo base line. The second unit, separated from the first by a slant, indicates the range east of the Mount Diablo meridian. The third unit, separated from the first two units by a hyphen, lists the section number followed by three letters that designate the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section, respectively. The three letters are followed by a number that shows the order in which the sampling site was recorded within the subdivision. The letters a, b, c, and d designate respectively the northeast, northwest, southwest, and southeast quarters of each unit. For example, well number 35/37-2abb1, designates the first well recorded in the NW 1/4 NW 1/4 NE 1/4 sec. 2, T. 35 N., R. 37 E., Mount Diablo base line and meridian. Because of the limitation of space, only that part of the number designating the subdivision of the section and the order in which the sampling site was recorded is shown in figure 2, and section numbers are shown only in T. 37 N., R. 41 E.

Samples are given the same number as the site at which they were obtained. If more than one sample was obtained at a given site, a number preceded by a hyphen is added to the site number to designate the order in which the sample was obtained. For example, water sample 35/37-2abb1-2 is the second water sample obtained from the previously described well.

For the sake of clarity, staff gages and gaging stations along the Humboldt River are designated by capital letters. The corresponding identification and location numbers are given in table 2.

Acknowledgments

The assistance and cooperation of various local, State, and Federal agencies, private companies, and residents of the study area are gratefully acknowledged. Personnel of the Nevada Department of Conservation and Natural Resources helped in virtually every phase of the study. Maps and aerial photographs were provided by agencies of the U.S. Department of Agriculture. The Southern Pacific Co. and Western Pacific Railroad Co. provided access to their lands. The Southern Pacific Co. also provided topographic and geologic maps of part of the project area. Local residents permitted test drilling and access to their property and their cooperation is especially appreciated.

## GEOLOGIC FEATURES

The project area is in the Great Basin section of the Basin and Range physiographic province. The Great Basin is characterized by generally north-trending fault-block mountains separated by structural basins of approximately equal width. The ranges of the study area, from east to west, are the Osgood Mountains and their southern extension, Edna Mountain, the Sonoma Range, Winnemucca Mountain, and the East Range. For the most part, the internal structure of the ranges was caused by thrust faulting and folding. However, the gross form of the ranges is a result of relative uplift along north-trending, high-angle, normal faults.

Streams draining the mountains are either consequent upon the steep frontal slopes of the ranges, which are moderately eroded fault scarps, or are consequent upon the gentler back slopes of the ranges, which are modifications of the topography prior to faulting. The Humboldt River flows westward and southwestward at an oblique angle to the ranges of the project area. Cutoff meanders, meander scrolls, and floodflow channels characterize its flood plain. The flood plain is bordered by two prominent but discontinuous river-cut terraces that range in height from less than 5 feet to about 50 feet above the river.

In this report, the rocks of the area are divided into four generalized units: undifferentiated consolidated rocks, older alluvium, medial alluvium, and younger alluvium. (See fig. 3) The last three units are collectively termed "valley fill".

Consolidated rocks constitute the bulk of the mountain ranges of the area, underlie the valley fill, and form isolated bedrock highs within the valley fill. These rocks range in age from Cambrian to Pleistocene (?) and include several sedimentary, metamorphic, and igneous types. Fractures resulting from structural deformation, solution of some of the carbonate rocks, and primary igneous structures such as scoriaceous zones in some of the lava flows, locally allow water to move through these otherwise dense and impermeable rocks. In overall

aspect, however, most of the consolidated rocks probably do not store or transmit appreciable amounts of water.

The older alluvium includes unconsolidated and partly consolidated silt, sand, and gravel deposited largely as alluvial fans by streams draining the mountains, and clay and silt deposited in lakes that intermittently occupied the area. The older alluvium ranges in age from Miocene or Pliocene to Pleistocene and constitutes most of the unconsolidated deposits of the valley fill. It ranges from lenses of well-sorted highly permeable sand and gravel to beds of dense, relatively impermeable clay and silty clay. Wells in the study area that tap well-sorted sand and gravel strata of the older alluvium yield as much as 2,000 gpm (gallons per minute), whereas wells that tap only the predominantly clayey or deposits yield only a few gallons per minute.

Three major lithologic units deposited within and near the shore of Lake Lahontan compose most of the medial alluvium. These units are termed lower silt and clay, medial gravel, and upper silt and clay (Cohen, 1961a, p. 5). The lower unit consists largely of beds of clay, silt, and silty clay of low permeability. It is not exposed within the study area, and its estimated maximum thickness is about 20 to 30 feet. The medial gravel unit, which overlies the lower silt and clay, consists largely of well-sorted, highly permeable sand and gravel. Only a few feet of this deposit are exposed along the bases of some of the river-cut scarps, and its estimated maximum thickness is about 150 feet. The upper silt and clay unit ranges in thickness from less than a few inches to about 55 feet, and consists largely of clay, silty clay, silt, and fine sand. It is relatively impermeable and, although it contains a considerable amount of ground water in storage, does not yield appreciable amounts of water to wells.

The younger alluvium includes alluvial fans of post-Lake Lahontan age, flood-plain and terrace deposits, windblown deposits, and the deposits of Gumboot Lake, an ephermeral lake in Paradise Valley. These deposits commonly are less than 50 feet thick, and their texture and water-bearing character range from highly permeable stringers of sand and gravel to lenses of silt and clay of very low permeability.

## HYDROLOGIC FEATURES

Practically all the water within the study area originates as precipitation within the Humboldt River drainage basin. Some precipitation evaporates or transpires soon after it falls. The remainder either runs off as streamflow, is stored in the zone of soil moisture and subsequently evaporates or transpires, or percolates downward through the soil mantle to the ground-water reservoir.

The Humboldt River is the longest river in Nevada, heading near the eastern border of the State and flowing westward and southwestward about 275 miles to the Humboldt Sink, about 75 miles southwest of Winnemucca. The river is perennial downstream from Winnemucca, but is ephemeral in the reach between Winnemucca and the Comus gaging station. The following data summarize some of the streamflow records of the Humboldt River at the Comus gaging station.

| Streamflow<br>Water years 1895-1909, 1911-26, 1946-60<br>(acre-feet per year) | |
|---|---|
| Maximum . . . . . | 688,100 |
| Minimum . . . . . | 26,700 |
| Average . . . . . | 200,500 |
| Median . . . . . | 149,500 |

(Data from U.S. Geological Survey Water-Supply Papers.)

The smaller streams in the project area discharge into the Humboldt River only during periods of unusually large runoff. Normally, most of the flow of these streams evaporates, transpires, or infiltrates into the valley fill and percolates downward to the water table.

Ground water in the study area moves downgradient from recharge areas bordering the mountain ranges toward the flood plain of the Humboldt River where it either evaporates, transpires, discharges into the Humboldt River, or discharges as underflow out of the study area near the Rose Creek gaging station. Most of the ground-water recharge to the study area is by underflow from the Humboldt River valley upstream from the study area, the drainage basins of Pole Creek and Rock Creek, Paradise Valley, and Grass Valley and the northwestern slope of the Sonoma Range. The preliminary estimate of the average annual ground-water underflow from these areas to the valley of the Humboldt River in the period 1949-60 is about 14,000 to 19,000 acre-feet (Cohen, 1961a, p. 6). Approximately 10,000 to 12,000 acre-feet per year of underflow is from Grass Valley and the northwestern slope of the Sonoma Range.

Estimates of ground-water discharge by evapotranspiration are currently being made. The estimated average annual ground-water discharge into the Humboldt River in the period 1949-60 is 11,000 acre-feet (Cohen, 1961a, p. 6). The estimated average annual ground-water underflow out of the study area in the same period is about 4,000 to 9,000 acre-feet (Cohen, 1961b, p. 154).

Figure 4 shows generalized water-level contours in December 1961, based on the altitude of water levels in about 160 observation wells and the altitude of the Humboldt River at 21 staff gages. Ground water flows perpendicular to the water-level contours. Thus, the surface defined by the contours of figure 4 shows the direction of ground-water movement in the study area in December 1961. Details of the water-level surface change from day to day, season to season, and year to year; however, the changes do not materially

affect the overall shape of the surface. For example, a ground-water mound commonly forms along the Humboldt River as a result of the rapidly rising stage of the river during the spring runoff. Within a few months, usually in July or August, the mound begins to subside.

## HYDROGEOCHEMISTRY

There are about 100 elements, and many compounds of these elements, in the rocks of the project area that are somewhat soluble in water. The chemical quality of the water is variable largely because of differences in the abundance and solubility of these elements and compounds and because of the complex stratigraphy and structure of the aquifers. The rate of movement of water and the depth of burial and temperature of the rocks are among some of the other factors that also affect the quality of the water.

Nearly all dissolved constituents in the water are in ionic form, but some occur as un-ionized colloidal particles. These ionic and colloidal constituents impart to the water of the project area most of the chemical and some of the physical properties that are discussed in this report.

### Collection of Data

In July and August 1961, 48 water samples were obtained from selected wells and springs, from the Humboldt River, and from some of the streams tributary to the Humboldt River valley. After a preliminary evaluation of the analyses of these samples, 51 additional samples were obtained in November and December 1961.

Because it was important to know where the casing was perforated, most of the ground-water samples were obtained from wells for which drillers' logs were available and from small-diameter observation wells constructed as part of the current study. Virtually all the small-diameter wells tap only the upper few feet of the zone of saturation. Samples were obtained from these wells partly to help define the chemical quality of ground water in areas where there are no other wells and partly to help evaluate the relation between ground water and the Humboldt River. In most areas, the chemical quality of water from shallow wells did not differ significantly from the quality of water from nearby deeper wells. However, in some areas, as in the Grass Valley area (p. 14 ), the chemical quality of the ground water did differ with depth. Those differences that were observed are appropriately indicated in the following descriptive text.

### Reporting of Data

Dissolved Solids: The Geological Survey uses the term "dissolved solids" or "dissolved-solids content" to refer either to the residue of a known quantity of a sample dried at 180°C or to the sum of the determined constituents. The dissolved-solids content values given in this report are the sums of the determined constituents and were calculated by converting the bicarbonate content to carbonate and adding this amount to the sum of the other determined constituents. (See Rainwater and Thatcher, 1960, p. 272).

The units used in this report to express dissolved-solids content are parts per million (ppm) and equivalents per million (epm). Parts per million are calculated by determining the number of milligrams of solute in 1 kilogram of solution. Usually, the number of milligrams of solute in 1 liter of solution are determined. The error involved in assuming that one liter of naturally occurring water weighs 1 kilogram ordinarily is small and commonly is disregarded. Equivalents per million are computed by dividing the concentration of an ion in parts per million by its combining weight, which is defined as the atomic or molecular weight divided by the valence.

For the purpose of this report the waters have been classified according to dissolved-solids content as follows:

| Dissolved-solids content (ppm) | Classification |
|---|---|
| 200-300 | Very low |
| 300-500 | Low |
| 500-750 | Moderate |
| 750-1,000 | Moderately high |
| 1,000-2,000 | High |
| Greater than 2,000 | Very high |

Specific Conductance: Specific conductance or, more simply, conductivity is a measure of the ease with which an electrical current will pass through a solution. It is expressed in micromhos per centimeter at 25°C. Conductivity increases with increasing number of ions in solution and with increasing temperature. Therefore, if conductivity is referred to a constant temperature it is a rough measure of the dissolved-solids content in parts per million. It is only a rough measure because some of the substances reported as part of the dissolved solids, silica for example, may not be ionized, and the ionized constituents have differing relations between concentration and conductance (Hem, 1959, p. 39-42).

Figure 6 shows the relation between the dissolved-solids content and the conductivity of water in the study area. On the basis of this relation, dissolved-solids content can be estimated from conductivity fairly accurately. By this method, field approximations of dissolved-solids content are being obtained with use of a portable conductivity meter.

Hardness: Hardness values given in this report are expressed in terms of an equivalent quantity of calcium carbonate in parts per million. This is done merely as a convenience and does not necessarily indicate that calcium carbonate occurs in the solution. Hardness is caused by several different constituents, but most commonly by calcium and magnesium. If it is assumed that the total hardness is caused by calcium and magnesium, the equivalents per million of calcium plus magnesium may be calculated from hardness data as follows:

$$\text{epm Ca + Mg} = \frac{\text{total hardness (in ppm } CaCO_3)}{50}$$

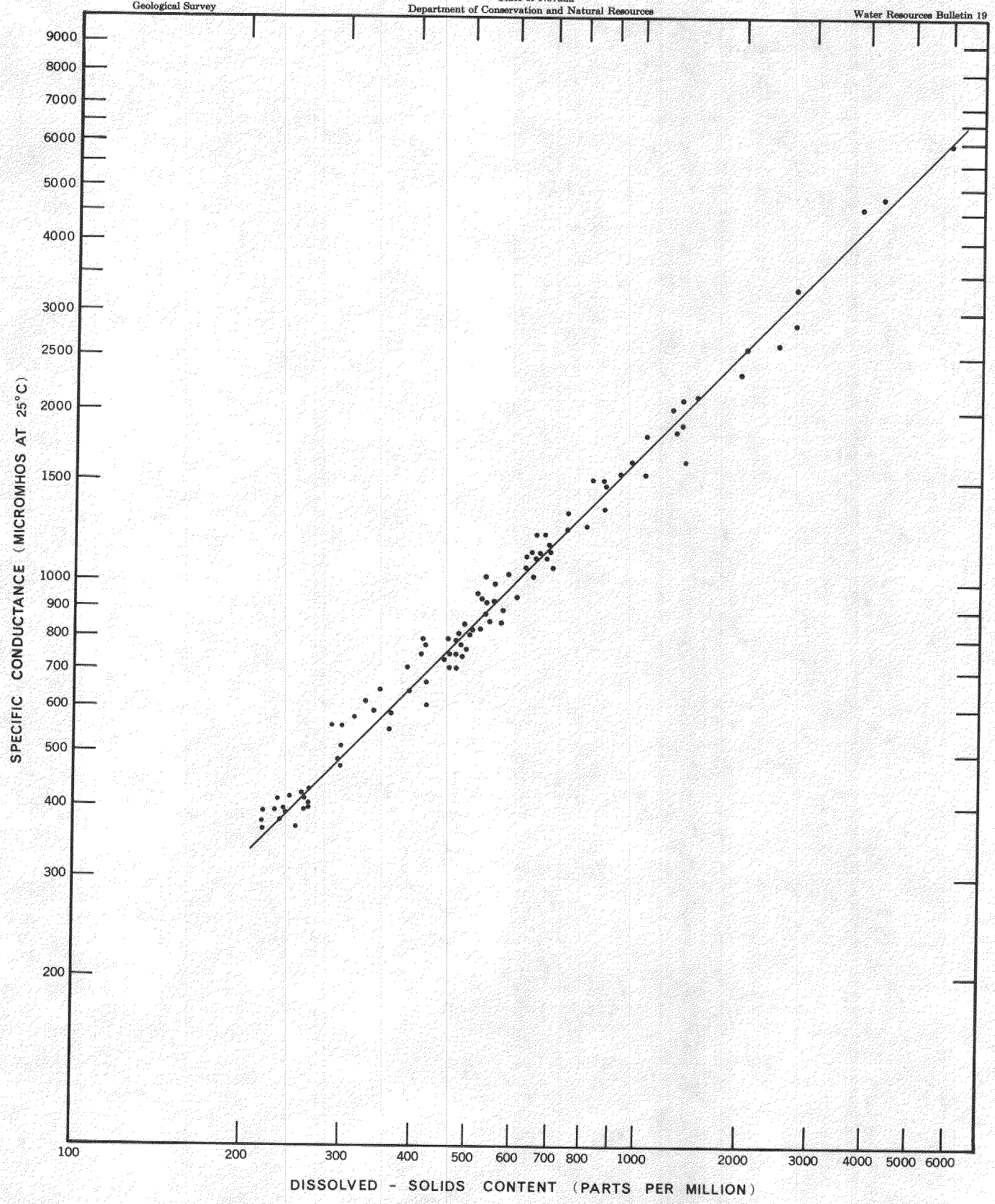


FIGURE 6. — Relation between dissolved-solids content and conductivity of water in the Humboldt River Valley near Winnemucca, Nevada.

Hydrogen Ion Concentration (pH): The pH is the negative logarithm of the hydrogen-ion concentration of a solution. All the pH values given in tables 1 and 2 were determined in the laboratory. The pH of a ground-water sample may change soon after the sample is obtained, largely because of the loss of carbon dioxide from the sample. Thus, the laboratory pH values of the samples given in the tables probably are not representative of pH values of the water in the aquifers. Although the pH values of ground water as determined in the laboratory may not represent natural conditions, they probably are fairly indicative of the pH values of the water when it is being used (Hem, 1959, p. 47). There probably is no significant difference between the pH values of the surface-water samples determined in the laboratory and those determined in the field.

Pure water has a pH of 7.0 and is regarded as neutral. Water having a pH less than 7.0 is acidic, and water having a pH more than 7.0 is alkaline. The pH values of the water of the study area range from 7.1 to 9.2, indicating that all the water is slightly to moderately alkaline.

Ionic Concentration Factor: The term "ionic concentration factor," as used in this report, is defined as the ratio of one or more cations to the sum of the major cations (expressed in equivalents per million) multiplied by 100, or the ratio of one or more anions to the sum of the major anions multiplied by 100. For example, the calcium ionic concentration factor is defined as:

$$\text{Ca ionic concentration factor} = \frac{\text{epm Ca}}{\text{epm Ca} + \text{epm Mg} + \text{epm Na} + \text{epm K}} \times 100$$

## Major Chemical Constituents

The most abundant ions in the water of the project area are the cations sodium, potassium, calcium, and magnesium, and the anions carbonate, bicarbonate, sulfate, and chloride. These ions are termed "major chemical constituents".

Calcium: Minerals containing compounds of calcium are abundant in the consolidated rocks of the area. The feldspars, which constitute about 50 to 60 percent of the igneous rocks, are rich in calcium. Most of the igneous and metamorphic rocks also contain pyroxenes and amphiboles that are relatively rich in calcium. Weathering of these minerals yields many calcium compounds that readily are dissolved by water. Accordingly, the calcium ionic concentration factors of the streams draining the Sonoma Range are about 50 to 70 percent. The calcium ionic concentration factor of the water in Rose Creek is 45 percent.

Calcium salts, especially calcium carbonate and calcium sulfate, are abundant in the deposits of the valley fill. Practically all the samples tested reacted vigorously to dilute hydrochloric acid, indicating abundant calcium carbonate, which in the presence of carbon dioxide is readily soluble in water. Gypsum and selenite, two common varieties of calcium sulfate, also are moderately soluble in water and are abundant in the upper silt and clay and lower silt and clay units of the medial alluvium.

Largely as a result of the solution of the calcium compounds referred to above, ground water in the area contains relatively large amounts of calcium, ranging from 2 to 186 ppm and averaging about 58 ppm.

Magnesium: Magnesium is moderately abundant in the consolidated rocks of the area, but not as abundant as calcium. Expressed in equivalents per million, about three times more calcium than magnesium is in solution in the streams draining the Sonoma Range, and slightly more calcium than magnesium is in solution in Rose Creek. The difference in the ratio of calcium to magnesium in solution in the streams draining the Sonoma Range and in Rose Creek is largely a result of the difference in the character of the rocks of the ranges; limestone ($CaCO_3$) is abundant in the Sonoma Range and is not common in the East Range.

Magnesium salts, probably largely magnesium carbonate or magnesium bicarbonate, occur in the deposits of the valley fill, and are dissolved by ground water. Brines near the eastern margin of the study area (p. 13), have the greatest concentration of magnesium, about 90 ppm.

Sodium: Sodium compounds are not as abundant as calcium compounds in the consolidated rocks of the area and sodium is not abundant in the streams draining the mountains. (See table 2.) Sodium is common in the deposits of the valley fill, especially in the lacustrine deposits where it occurs in comination with other elements, probably largely as a sodium chloride, sodium carbonate, and sodium sulfate. Water in contact with these deposits dissolves the salts. In addition, ion exchange, the process by which sodium in some of the clay minerals is exchanged for calcium or magnesium in the water, increases the sodium content of some of the ground water. The sodium ionic concentration factors of most of the ground water of the area are greater than 50%. The ground water of the Grass Valley area (p. 14) is an exception; the sodium ionic concentration factors of ground water in this area ranges from about 10 to 40 percent and averages about 20 percent. (See fig. 7).

Potassium: Potassium compounds probably are less abundant than sodium in the consolidated rocks of the area, and potassium is less abundant than sodium in solution in the streams draining the mountains. Samples of water from Rose Creek, Thomas Creek, and the stream in Water Canyon contained about 2 to 3 ppm potassium, and the potassium ionic concentration factors of these samples were about 1 or 2 percent. There was slightly more potassium in the sample from Pole Creek.

Most of the ground water of the area contains less than 10 ppm potassium but water from some of the thermal springs contains as much as 90 ppm potassium. The potassium ionic concentration factors of the ground water generally are less than 2 percent. Water in the Golconda area (p. 13) has the highest potassium ionic concentration factor, about 7 percent.

Bicarbonate and Carbonate: The bicarbonate ionic concentration factors of most of the water in the area are more than 60 percent. Although most of the water sampled contained about 200 to 300 ppm bicarbonate, the thermal water associated with the East Range fault contained about 1,500 to 2,000 ppm bicarbonate (p. 15). As previously stated (p. 9), calcium carbonate is abundant in

the deposits of the valley fill, and in the presence of carbon dioxide calcium bicarbonate is formed and is readily dissolved in water.

Carbonate is not common in the water of the area. Carbonate cannot occur in water if the pH is less than about 8.2, and because the pH of most of the samples was less than 8.2 at the time of analysis, most of the samples did not contain carbonate.

Sulfate: Sulfide compounds occur in some of the hydrothermally altered rocks and some of the consolidated sedimentary rocks in the mountains. As a result of the oxidation and hydration of the sulfide compounds by weathering, sulfate compounds are formed and are dissolved by water draining the mountains. The sulfate ionic concentration factors of the four tributary streams sampled ranged from about 10 to 20 percent; the sulfate content ranged from 15 to 31 ppm.

As previously stated (p. 9 ), gypsum and selenite are abundant in the deposits of the valley fill. Solution of these minerals contributes sulfate to the ground water of the area. The sulfate ionic concentration factors of most of the ground water are about 20 to 25 percent, but the sulfate ionic concentration factors of three samples (35/36-19dca1, 35/36-20caa1, and 36/37-cad1) are about 40 percent or greater. The highest sulfate concentration, 1,530 ppm, was noted in sample 36/41-2dca1 from a shallow well near the eastern margin of the study area.

Chloride: Soluble chloride compounds are rare in most of the rocks of the mountain ranges, and accordingly, chloride is the least abundant major anion in the streams draining the mountains. Chloride compounds, especially sodium chloride deposited as an evaporite, are moderately abundant in the deposits of the valley fill, and these compounds are readily dissolved by water. The chloride content of the ground water of the area is extremely variable, ranging from about 10 to 15 ppm in some of the water in Grass Valley to 3,880 ppm in sample 36/41-2dca1. The chloride ionic concentration factors of most of the water in the area are about 25 percent or less.

## Minor Chemical Constituents

Only the major chemical constituents were determined in somewhat more than half the samples. In the remainder of the samples, analyses also were made for the more common minor constituents: silica, iron, fluoride, nitrate, and boron.

Silica: The element silicon (Si) is reported as the molecule silica ($SiO_2$). Silica in most natural water is considered to be in a colloidal or subcolloidal state, but not in an ionic state. Silica is one of the most abundant compounds in the rocks of the area, but because it normally is not very soluble in water, it constitutes less than 10 percent of the dissolved-solids content of most of the water. The silica content ranges from 10 to 81 ppm and averages about 37 ppm.

Iron: Iron is abundant in the rocks of the area, but is not common in the water. The presence of iron in water depends on a number of complex interrelated

factors such as pH, availability of oxygen, other chemical constituents, and, in some cases, the presence of bacteria. A sample containing abundant dissolved iron at the time of collection may contain little or no dissolved iron at the time of analysis. Commonly, the dissolved iron is precipitated in the sample container as ferric hydroxide soon after the sample is collected. Therefore, the data in tables 1 and 2 relative to iron have only limited use for geochemical interpretation, but greater use in evaluating the suitability of the water for various purposes (p. 20 & p. 24).

Fluoride: Fluoride is comparatively rare in the rocks of the area, and occurs in concentrations of less than 1 ppm in most of the water. The highest concentrations of fluoride, 12 to 16 ppm, occur in the water of some of the thermal springs. (See p. 20)

Nitrate: Some of the plants in the area have the property of adding nitrate to the soil. In addition, some of the nitrate in the shallow ground water probably is derived from the downward infiltration of organic pollutants. The nitrate content of most of the samples tested was less than 0.1 ppm. The maximum nitrate content, 40 ppm, was noted in sample 36/38-28bcc1.

Boron: Boron also is a rare element in the rocks and occurs in concentrations of less than 1 ppm in most of the water of the area. The highest concentration, 15 ppm, was noted in sample 35/36-28aba1 from a thermal spring associated with the East Range fault. Other water associated with the fault also is relatively rich in boron. (See p.22 ). In this report, the following qualitative terms are used to describe boron content in relation to its effect on the usefulness of water for irrigation.

| Boron content (ppm) | Classification |
|---|---|
| Less than 0.1 . . . . . | Very low |
| 0.1 - 0.5 . . . . . | Low |
| 0.5 - 1 . . . . . | Moderate |
| 1 - 5 . . . . . | Moderately high |
| 5 - 10 . . . . . | High |
| 10 - 15 . . . . . | Very high |

## Chemical Quality of Ground Water by Areas

Except near the eastern margin of the study area, the chemical quality of most of the ground water in the flood plain of the Humboldt River and the immediately adjacent benchlands is similar. The chemical quality of ground water in six areas outlined on figure 2 and in the flood plain and benchlands bordering the Humboldt River is described in the following text. The six areas are of interest because (1) they contribute practically all the ground-water underflow to the study area, (2) they contain water of high dissolved-solids content, or (3) they contain thermal water.

Comus Area: All the ground and surface water in the Comus area has a very high to moderately high dissolved-solids content. (See figs. 2 and 5). All but one of the ground-water samples from this area were obtained from shallow small-diameter observation wells. Sample 36/41-2dca1, from a well 22 feet deep, has the highest dissolved-solids content of any of the samples tested, 9,160 ppm. Sample 36/41-11bcc1, from a well 26 feet deep about a mile downgradient from well 36/41-2dca1, has the second highest dissolved-solids content, about 3,500 ppm. Sodium and chloride are the most abundant ions in the two samples, their ionic concentration factors being 92 and 71 percent, respectively. Sodium also is the most abundant cation in the other ground-water samples from the Comus area, but bicarbonate is the most abundant anion. In sample 36/41-2aac1, which is from a thermal spring issuing from alluvium near the base of a limestone hill, the bicarbonate plus carbonate ionic concentration factor is 84 percent and the chloride ionic concentration factor is 5 percent. The sodium ionic concentration factor of sample 36/41-14dcd1, which is a mixture of sodium chloride and sodium bicarbonate water, is 90 percent. The water contains almost an equal number of equivalents per million of bicarbonate plus carbonate and chloride, the ionic concentration factors of these constituents being 44 and 37 percent, respectively.

The very high concentration of sodium chloride in the water of the area probably is a result of the solution of this compound from the shallow sedimentary deposits. Sodium chloride accumulated in these deposits at least partly because of the shallow ground-water table, which is less than 15 feet below land surface in much of the area. Evaporation from the capillary fringe and transpiration cause salts to be concentrated in the alluvium. In addition, sodium chloride and other salts are deposited in the area as a result of relatively frequent flooding. In some areas, flooding leaches salts from the soil. This is not the case in the Comus area nor, for that matter, in many areas on the flood plain of the Humboldt River. Commonly, many of the abandoned channels of the river are filled with water during periods of high river stage. After the stage of the river declines, these abandoned channels, or oxbow lakes, retain water for several weeks. Some of the water percolates downward to the water table, but most of the water evaporates or is transpired, causing the salts to be deposited.

The source of the water issuing from spring 36/41-2aac1 is not known. However, because the spring is near a limestone hill, and because of the above-normal temperature of the water, it is possible that the water is moving at considerable depth through solution openings in the limestone. If the water were issuing directly from limestone, the dominant ions should be calcium and bicarbonate. As noted above, the spring issues from alluvium and the dominant ions are sodium and bicarbonate. If the hypothesis that the water is coming from limestone is correct, then the calcium probably is exchanged for sodium as the water moves through the alluvium.

Golconda Area: Sample 36/40-29dca1 is from a spring pool at the Golconda Hot Springs immediately west of the town of Golconda. The temperature of the water at the bottom of the pool is 148°F. Although the spring pool is bordered by consolidated siliceous sinter, the water in this and adjacent pools issues from

alluvium. Sample 36/40-29cda1 is from an observation well 18 feet deep, about 500 feet southwest of the spring; the temperature of the water in the well is 80°F. The thermal water, which is under artesian pressure, forms a ground-water mound that rises about 50 feet above the regional water table. (See fig. 4). The chemical quality of the water from the spring is very similar to that from the well although the sample from the spring contains about 100 ppm more dissolved solids. The sodium ionic concentration factors of the water from the spring and well are 68 & 64 percent, respectively, and the bicarbonate ionic concentration factors are 81 and 82 percent, respectively. Both samples have ionic concentration factors similar to the spring sample from the Comus area (p. 13); however, the dissolved-solids content of the thermal water in the Golconda area is about one-third the dissolved-solids content of the thermal water in the Comus area.

Sample 36/40-36bba1 is from a well 19 feet deep near the eastern margin of the Golconda area; the temperature of the water in the well is 59°F. The chemical quality of the water from the well is similar to that from spring 36/41-2aac1 in the Comus area. It is a sodium bicarbonate water having a dissolved-solids content of 1,860 ppm. The sodium and bicarbonate-plus-carbonate ionic concentration factors are 93 and 65 percent, respectively. Thus, the sample differs slightly from sample 36/41-2aac1 in that the percentage of bicarbonate plus carbonate is lower. The well taps poorly sorted unconsolidated flood-plain deposits. The uppermost 5 feet of the deposits penetrated by the well reacted vigorously to dilute hydrochloric acid, indicating the presence of abundant calcium carbonate. However, the strata opposite the perforated section of casing, which are dominantly silt and clay, reacted very weakly to dilute hydrochloric acid, indicating little or no calcium carbonate. Because of the comparatively impermeable character of these deposits, and because there is no evidence of thermal activity at or near the well site, it is concluded that the high dissolved-solids content of the water is a result of the solution of salts, notably sodium bicarbonate, from the silt and clay.

Paradise Valley Area: All the samples from the Paradise Valley area, except sample 38/39-35aaa1, are sodium bicarbonate water. Sample 38/39-35aaa1 has the lowest dissolved-solids content, 288 ppm. Although the most abundant anion is bicarbonate, the sodium and calcium ionic concentration factors are about equal--37 and 36 percent, respectively. Sample 37/39-3dcc1 is from a flowing well 61 feet deep; the temperature of the water is 158°F. Water from this well has the second highest dissolved-solids content, 1,190 ppm, of the samples from the Paradise Valley area. The sodium and bicarbonate ionic concentration factors are 88 and 93 percent, respectively. The dissolved-solids content of sample 37/38-24acc1 is 1,200 ppm. The well is 38 feet deep and taps partly consolidated fine-grained Tertiary (?) deposits. Well 37/38-34abb1 is only 9 feet deep and taps fine-grained, unconsolidated, highly saline flood-plain deposits. The dissolved-solids content of the water is 970 ppm.

Grass Valley and Sonoma Range Areas: All but two samples from the Grass Valley and Sonoma Range areas are calcium bicarbonate water of very low dissolved-solids content. The two exceptions are samples 35/37-28ada1 and 35/37-28bbd1. These are sodium chloride water, containing 2,420 and 1,020 ppm dissolved-solids, respectively. The wells from which the samples were

obtained tap highly saline silt and clay of the upper silt and clay unit. All the other wells in the area tap fluviatile deposits of the older alluvium or the medial gravel unit beneath the upper silt and clay unit.

East Range Fault Area: The hydrogeologic evidence of the northward extension of the East Range fault in T. 35 N., R. 36 E. (fig. 3) is described in a previous report (Cohen 1962a). The evidence includes a ground-water mound along the fault as shown in figure 4, a buried bedrock high penetrated by test borings and wells, hydrothermal alteration of the alluvium penetrated by some of the wells, a deposit of siliceous sinter on the flood plain of the Humboldt River, thermal water in springs and observation wells near the faul, and the chemical quality of the ground water in the area.

Figure 5 shows that ground water in the area adjacent to the fault has a high dissolved-solids content. Samples 35/36-28aba1 and 35/36-28dcc1 are from thermal springs along the fault which have temperatures of 82 and 83°F, respectively. The springs discharge sodium bicarbonate water, having dissolved-solids contents of 2,650 and 1,740 ppm, respectively. The sodium ionic concentration factors are 86 and 82 percent, respectively, and the bicarbonate plus carbonate ionic concentration factors of both samples are 71 percent. The dissolved-solids content of sample 35/36-31ddb1, from an observation well 88 feet deep which taps hydrothermally altered fanglomerate about a mile west of the fault, is 1,140 ppm. This content is less than the dissolved-solids content of the water from the springs, and the temperature of the water from the well is 62°F, or about 20° lower than that of the water from the springs. The ionic concentration factors of the major constituents of the water from the well are very similar to those of the water from the springs. The water in the well in downgradient from the fault, and although it is slightly diluted, it undoubtedly is derived, at least in part, from the fault system.

Sample 35/36-21bdb1, from an observation well 29 feet deep about 1 mile northwest of spring 35/36-28aba1, taps strata of the medial gravel unit that have been altered by hydrothermal solutions. The water from this well has a slightly higher dissolved-solids content, 1,260 ppm, than the water from well 35/36-31ddb1, but in most other respects it is similar. The sodium ionic concentration factor of the water from well 35/36-24cdb2, 55 percent, is less than the sodium ionic concentration factor of the other samples associated with the fault system. However, in most other respects the chemical quality of the water from this well closely resembles that of the other water associated with the fault.

Flood Plain and Benchlands Bordering the Humboldt River: Except in the Comus area and the eastern part of the Golconda area, the dissolved-solids content of most of the ground water from the flood plain and the benchlands immediately adjacent to the Humboldt River is between 500 and 750 ppm. The dissolved-solids content of ground water in four relatively small areas along the flood plain is between 300 and 500 ppm. (See fig. 5). Ground water in the shallow aquifers underlying the flood plain and river-cut terraces of the Humboldt River is in hydraulic continuity with the river, and the chemical quality of the ground

water is very similar to that of the river. Sodium and bicarbonate have the highest ionic concentration factors, about 40 to 50 and 50 to 60 percent, respectively. Calcium and chloride are the second most abundant ions in most of the ground-water samples.

Other Areas: There are other less well defined areas where the chemical quality of the ground water is of interest because of unusual concentrations of some constituents. Although it is not feasible in this report to describe all these areas, some are discussed in the following text.

Expressed in equivalents per million, sulfate is the most abundant anion in samples 35/36-19dca1, 35/36-20caa1, and 36/37-13cad1. The first two samples are from wells 18 feet deep near the base of a river-cut scarp formed in the upper silt and clay unit. The wells penetrate silt and clay strata that were at least partly derived from the upper silt and clay unit. As stated above (p. 9) the upper silt and clay unit contains abundant calcium sulfate. The sulfate in these two samples probably is derived from this deposit.

Sample 36/37-13cad1 is from a spring near the base of Winnemucca Mountain. The mountain is composed largely of granitic rocks containing secondary sulfide minerals. The sulfate in this sample probably is derived from the oxidation and hydration of the sulfide minerals.

The most abundant ions in samples 36/38-26dac1 and 36/38-28bcc1 are calcium and chloride. With respect to the available water analyses, this is the only calcium chloride water in the valley. The samples also are somewhat unusual in that they have the highest dissolved-solids content of the ground water along the slope of the Sonoma Range. (See fig. 5). The moderate dissolved-solids content is due, almost entirely, to the abundance of calcium and chloride.

## Movement and Mixing of Water

Figure 5 shows the dissolved-solids content of the ground water in the project area based on water samples collected in July and August and November and December 1961. (See table 1.) Although there are some slight differences in the chemical quality of these samples, the changes are not large enough to invalidate the premise that the distribution of dissolved solids as shown in figure 5, as well as the distribution of the parameters shown in figures 7, 8, and 9, are fairly representative of the average chemical quality of the ground water sampled.

Figures 7, 8, and 9 were prepared largely to describe the chemical suitability of the water for various uses. However, the illustrations also are useful in the following discussion of the movement and mixing of water. In most areas the distribution of the parameters shown on these maps closely agrees with the distribution of the dissolved solids. Thus, these maps complement and verify each other with respect to the source and the direction of water movement.

Ground water in the Comus area moves southward and southwestward roughly parallel to the Humboldt River. The source of the sodium bicarbonate

water from spring 36/41-2aac1 is not known (p. 13). Most of this water mixes with sodium chloride water of moderate to very high dissolved-solids content, and during most of the year, practically all the mixture discharges into the Humboldt River.

The source of most of the ground water in the flood plain of the Humboldt River between the western margin of the Comus area and the eastern margin of the Golconda area is seepage from the Humboldt River. Therefore, the chemical quality of the ground water in this area probably does not differ substantially from the average chemical quality of the Humboldt River during periods of moderate to high river stage, when most of the recharge to the aquifers beneath the flood plain occurs.

Ground water in the flood plain of the Humboldt River near the eastern margin of the Golconda area has a high dissolved-solids and boron content (figs. 5 and 8), a high sodium ionic concentration factor (fig. 7), and a high sodium-adsorption ratio (p. 22 and fig. 9). Ground water in this area also is derived largely from the Humboldt River. The high dissolved-solids and boron content, and the relatively high sodium ionic concentration factor and sodium-adsorption ratio probably are a result of the solution of salts, largely sodium bicarbonate or sodium carbonate, from the flood-plain deposits. The dissolved-solids content, sodium ionic concentration factors, and sodium-adsorption ratios decrease in the ground water of the central part of the Golconda area largely as a result of the underflow of calcium bicarbonate water of very low dissolved-solids content from the drainage basin of Pole Creek northward toward the Humboldt River.

The chemical quality of the ground water near the western margin of the Golconda area is affected by the Golconda hot springs system. Recently completed geophysical studies (Dudley and McGinnis, 1962) suggest that faults cut the bedrock underlying the hot springs area. The high temperature of the water probably is associated with the faults. The chemical quality of the water is interpreted as being a result of the solution of mineral matter partly from the bedrock and partly from the overlying alluvium. Considering the chemical reactivity of the water because of the high temperature, it is somewhat surprising that the dissolved-solids content of the water from the spring is only 571 ppm. One possible explanation for the comparatively low dissolved-solids content might be that the hot water removed most of the relatively soluble compounds from the bedrock and alluvium during the early history of the spring system leaving behind only the more insoluble compounds.

The source of most of the ground water in the Sonoma Range and Grass Valley areas is the infiltration of streamflow draining the Sonoma Range. Water moves from the Sonoma Range and Grass Valley areas northward and northwestward toward the Humboldt River. Some of the water is discharged by wells and springs and by evapotranspiration, but most discharges into the Humboldt River (p. 6). The geochemical evidence for this movement in the Sonoma Range area is limited, but is considerable in the Grass Valley area. The chemical-quality data shown on figures 5, 7, 8, and 9 clearly suggest ground-water movement from Grass Valley northwestward toward the Humboldt River.

Ground water of low to very low dissolved-solids content moves southward through the eastern one-third of the Paradise Valley area toward the Humboldt River near station K. In addition, ground water of low dissolved-solids content moves parallel to the Little Humboldt River southward toward the Humboldt River. Ground water of moderately high to high dissolved-solids content from the SE 1/4 T. 37 N., R. 38 E., mixes with the ground water of low to very low dissolved-solids content from the eastern part of the Paradise Valley area and moves toward the Humboldt River.

The source of the sodium bicarbonate water of high dissolved-solids content in the East Range fault area is not known precisely. The moderately high temperature of the water probably is related to the fault. Water may be moving through fractures in the bedrock at considerable depth, and the high temperature may be due to the geothermal gradient, the normally expected increase in temperature with depth. On the other hand, it is possible that the temperature of the rock, and thus the temperature of the water in contact with the rock at fairly shallow depth, is abnormally high, owing to heat generated as a result of the faulting. The warm water associated with the fault moves perpendicular to the contours of the ground-water mound in T. 35 N., R. 36 E. (fig. 4). The water moves westward, northward, and eastward and mixes with ground water from the Grass Valley area and with ground water moving southwestward parallel to the Humboldt River.

In December of most years, the Humboldt River at the Comus gaging station is practically dry. Downstream, at the Rose Creek gaging station, the flow usually is about 14 to 15 cfs. The increase in flow between the two gaging stations results largely from the seepage of ground-water underflow from tributary valleys into the Humboldt River. Normally, no surface-water inflow occurs between the gaging stations. Thus, changes in the chemical character of the river in December help to show the relation between surface water and ground water and to define the source of the water in the river.

Figure 10 shows streamflow measurements and the chemical character of the Humboldt River in December 1961. The water at station A was a mixture of sodium chloride and sodium bicarbonate water of high to moderately high dissolved-solids content derived largely from the aquifers in the Comus area. The dissolved-solids content of the river at station B decreased about 440 ppm, and the flow increased about 0.2 cfs. The decrease in dissolved-solids content probably was a result of seepage to the river of sodium bicarbonate water of moderate dissolved-solids content from the flood-plain deposits.

The river was dry at station C, but the dissolved-solids content of a sample from a pool near the station was 585 ppm. The pool probably was caused by the intersection of the bed of the river and the water table. There was very little evaporation of the water and consequently very little increase in concentration of the dissolved solids. The chemical character of the water from the pool probably was similar to that of the water discharging into the river between stations A and B.

From station C to station E, the flow and dissolved-solids content of the river increased 0.21 cfs and 167 ppm, respectively, as a result of seepage to the river of sodium bicarbonate water of moderately high to moderate dissolved-solids content from the aquifers beneath the flood plain of the river.

Because of the underflow of calcium bicarbonate water of low dissolved-solids content from the drainage basin of Rock Creek, the flow of the Humboldt River at station G increased to about 1.2 cfs, and the dissolved-solids content decreased to 559 ppm. The flow increased to about 1.4 cfs at station H, and the dissolved-solids content increased to 642 ppm. The increase in flow and dissolved-solids content resulted largely from ground-water underflow from the Golconda hot springs system and the adjacent shallow aquifers to the river.

The flow of the Humboldt River decreased from about 1.4 cfs at station H to about 0.6 cfs at station J. The water-level contours of figure 4 suggest that there was ground-water underflow toward the river from the southeast, and that there was ground-water underflow away from the river toward the northwest, the net result being a decrease in the flow of the river. The dissolved-solids content of the river decreased from 642 ppm at station H to 538 ppm at station J, because ground water discharging into the river was mostly calcium bicarbonate water of very low dissolved-solids content from the Sonoma Range area.

There was an increase in streamflow of about 1.1 cfs and a decrease in dissolved-solids content of 112 ppm between stations J and L. The increase in streamflow and the decrease in dissolved-solids content resulted from the underflow of calcium bicarbonate water of low to very low dissolved-solids content from the Sonoma Range area and the northwestern slope of the Sonoma Range, and from the underflow of sodium bicarbonate water of high to low dissolved-solids content from the Paradise Valley area.

Streamflow increased about 1.3 cfs and the dissolved-solids content increased 83 ppm between stations L and M, largely as a result of the underflow of sodium bicarbonate water of moderately high to moderate dissolved-solids content to the Humboldt River from the western margin of the Paradise Valley area (underflow roughly parallel to the Little Humboldt River). Between stations M and N, streamflow increased about 2.1 cfs and dissolved-solids content decreased 20 ppm, largely because of the underflow of calcium bicarbonate water of low dissolved-solids content from the northwestern slope of the Sonoma Range.

Largely as a result of the marked increase in the width of the aquifers beneath the flood plain, there was a net loss of streamflow of about 1.3 cfs between stations N and O. The dissolved-solids content decreased because of underflow of calcium bicarbonate water of very low dissolved-solids content from the Grass Valley area. The dissolved-solids content of the river continued to decrease (except at station P) between stations O and R, and the streamflow increased mostly because of ground-water underflow from the Grass Valley area discharging into the Humboldt River. The largest flow, 14.8 cfs, occurred at station S. The dissolved-solids content increased 30 ppm between stations R and S. The increase in dissolved-solids content and some of the increase in flow

between these stations resulted partly from ground-water seepage from the East Range fault area to the Humboldt River.

Streamflow decreased between stations S and U as a result of the increased width and thickness of the aquifers beneath the flood plain. The dissolved-solids content remained virtually constant. This suggests that the quantity of water of very high dissolved-solids content from the East Range fault area seeping into the river between the stations probably was small.

## Suitability of the Water for Use

Most of the water used in the area is for domestic and agricultural purposes; very little is used for industrial purposes. The following section of the report describes only the chemical suitability of the water of the area for domestic and agricultural use. Although sediment and bacterial content also are important criteria for determining the suitability of water for use, these factors were not studies, and therefore are not discussed in this report.

Domestic Use: Excessive amounts of some dissolved constituents in drinking water may be harmful to humans. In most water-quality studies, standards established by the U.S. Public Health Service (1962) for drinking water supplied by common carriers are used to evaluate the suitability of water for human consumption.

According to the Public Health Service, fluoride should not be present in drinking water in excess of 1.7 ppm. Excessive fluoride causes mottled tooth enamel in children. The California State Water Pollution Control Board (1952, p. 257) indicated that water containing less than 1.0 ppm fluoride will seldom cause mottled enamel in children. Mitchell and Edman (1953) estimated that a daily intake of 15 to 20 milligrams of fluoride over a long period of time, which would be equal to drinking about a quart of water per day containing about 22 ppm fluoride, might produce endemic fluorosis in adults.

Fluoride in excess of 1.7 ppm occurs in the East Range Fault area, in the Golconda area, and in the Comus area. The highest concentrations of fluoride, 12 ppm and 16 ppm, occur in the water from springs 35/36-28aba1 and 36/41-2aac1, respectively. Thermal water associated with the Golconda hot springs system contains about 2 ppm fluoride. None of the water from the areas mentioned above is currently being used for domestic purposes, and care should be exercised in any future attempts to develop ground water in these areas for domestic use.

The U.S. Public Health Service also places the following upper limits, for drinking water, on the constituents listed in tables 1 and 2:

| | ppm |
|---|---|
| Magnesium . . . . . | 125 |
| Chloride . . . . . | 250 |
| Sulfate . . . . . | 250 |
| Total dissolved solids (good quality) . | 500 |
| Total dissolved solids (where no better water is available). . . . . | 1,000 |

The limits placed on these constituents for satisfactory drinking water are not as restrictive as the limits placed on fluoride. Many people can drink water containing more than the above amounts of dissolved constituents without any apparent adverse effects. Chloride concentrations of about 250 ppm, especially in the presence of an equivalent amount of sodium, may cause water to taste salty to some people, and similar concentrations of sulfate may have a laxative effect on some people.

Excessive hardness of water, which is caused principally by calcium and magnesium, adversely affects the suitability of water for domestic use, especially for cooking and washing. The U.S. Geological Survey uses the following numerical ranges and adjective ratings for classifying water hardness:

| Hardness range (ppm) | Classification |
|---|---|
| 0 - 60 . . . . . | Soft |
| 61 - 120 . . . . . | Moderately hard |
| 121 - 180 . . . . . | Hard |
| Greater than 181 . . . . . | Very hard |

Hardness data are given in tables 1 and 2. Nearly all the water sampled was hard or very hard, most of the hardness probably resulting from the solution of calcium carbonate from the deposits of the valley fill. Most of the residents of the study area reportedly do not find the water used for domestic purposes objectionably hard and very few people use water softeners.

Excessive amounts of iron are objectionable in water used for laundering. The iron is oxidized and commonly is deposited on clothing and plumbing fixtures, causing rust-colored stains. All the water tested contained only a few hundredths of a part per million of iron and, in this respect, should cause little or no difficulty in domestic use.

Nitrate in drinking water in excess of about 44 ppm may be harmful to infants, causing cyanosis or the so-called "blue-baby" disease (Hem, 1959, p. 239). Practically all the water tested contained less than 4 ppm nitrate; none contained more than 44 ppm.

Agricultural Use: Stock watering and irrigation are the principal agricultural uses of water in the area.

With respect to the chemical constituents listed in tables 1 and 2, all the surface water and practically all the ground water sampled is suitable for stock watering. Water from well 36/41-2dca1, having a dissolved-solids content of 9,160 ppm, is the only water sampled that may have adverse effects on livestock.

Boron is one of the most critical constituents in irrigation water. It is essential for proper plant nutrition in small quantities but is toxic to many plants in amounts only slightly more than the needed amounts. Most of the crops raised in the area are classified by the U.S. Salinity Laboratory Staff (1954) as semitolerant and tolerant with respect to boron. The semi-tolerant crops include most small grains, potatoes, and some other vegetables. The tolerant crops include alfalfa, which is one of the important crops raised in the area. Scofield (1936) showed permissible boron concentrations for semi-tolerant and tolerant crops as follows:

| Classes of water | | Boron content | |
|---|---|---|---|
| Rating | Grade | Semitolerant crops (ppm) | Tolerant crops (ppm) |
| 1 | Excellent | less than 0.67 | less than 1.00 |
| 2 | Good | .67 to 1.33 | 1.00 to 2.00 |
| 3 | Permissible | 1.33 to 2.00 | 2.00 to 3.00 |
| 4 | Doubtful | 2.00 to 2.50 | 3.00 to 3.75 |
| 5 | Unsuitable | more than 2.50 | more than 3.75 |

Most of the surface water sampled contained boron in concentrations that are classed as permissible to excellent for semitolerant and tolerant crops (table 2). The boron content of the ground water of the area is shown in figure 8. Excessive amounts of boron occur in the Comus area and in the East Range fault area. Moderately high amounts of boron occur also in the Golconda area and locally in the Paradise Valley area.

Some of the water in the project area may have an adverse effect on soils because of ion exchange. Sodium in the water may be exchanged for calcium or magnesium in the soil, thus causing a decrease in the permeability of the soil. This effect becomes important when the percent sodium (which is virtually identical to the sodium ionic concentration factor as defined on p. 9 is considerably above 50 percent (Hem, 1959, p. 148). Figure 7 shows that the sodium content of the ground water is considerably above 50 percent in parts of the Comus, Golconda, Paradise Valley, and East Range fault areas.

The sodium-adsorption ratio (SAR) of irrigation water, which is related to the experimentally determined adsorption of sodium in the water by soil, is more directly significant than the percent sodium in determining the suitability of water for irrigation (Hem, 1959, p. 149). SAR is defined by the equation

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

where all concentrations are expressed in equivalents per million. Figure 9 shows the SAR values for ground water in the area. The highest values of SAR correspond closely with the high percent sodium values as shown in figure 7. Wilcox (1955, p. 7) gives the following classification system for irrigation water on the basis of SAR or "sodium hazard" (fig. 11):

1. "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.

2. "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.

3. "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.

4. "Very high-sodium water (S4) is generally unsatisfactory for irrigation purposes except under special circumstances."

Wilcox also gives the following classification of irrigation water with respect to the salinity hazard as expressed in terms of specific conductance (fig. 11):

1. "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.

2. "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.

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

4. "Very high salinity water (C4) is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances."

High concentrations of dissolved solids in water may be toxic to plants, but more commonly cause excessive accumulations of salts in the soil and thus are indirectly harmful to plants. Where the water table is close to the land surface, as on the flood plain of the Humboldt River, there is insufficient leaching of the soil and salt encrustations are common. Transpiration by phreatophytes, evaporation of excess irrigation water, evaporation from the capillary fringe, and poor drainage contribute to the accumulation of salts in the soil. "Black alkali" or sodium carbonate occurs in the soil in parts of the study area. The characteristic brown or black color of the crusts on the soil results from the solution of organic material by water rich in sodium carbonate. These soils characteristically have high pH values and as a result the solubility of some plant nutrients is decreased, causing considerable injury to plants. Accumulations of calcium carbonate, calcium sulfate, and sodium chloride also are common in the soil of the flood plain of the Humboldt River. Only the most salt-tolerant shrubs, such as greasewood, rabbitbrush, and the native grasses, grow in areas where the salt content of the soils is high.

A modified form of a diagram prepared by the U.S. Salinity Laboratory staff (1954, p. 80) is shown as figure 11. SAR is plotted as the ordinate, and specific conductance as the abscissa. On the basis of this diagram, water in the study area is classified with respect to suitability for irrigation. (See tables 1 and 2).

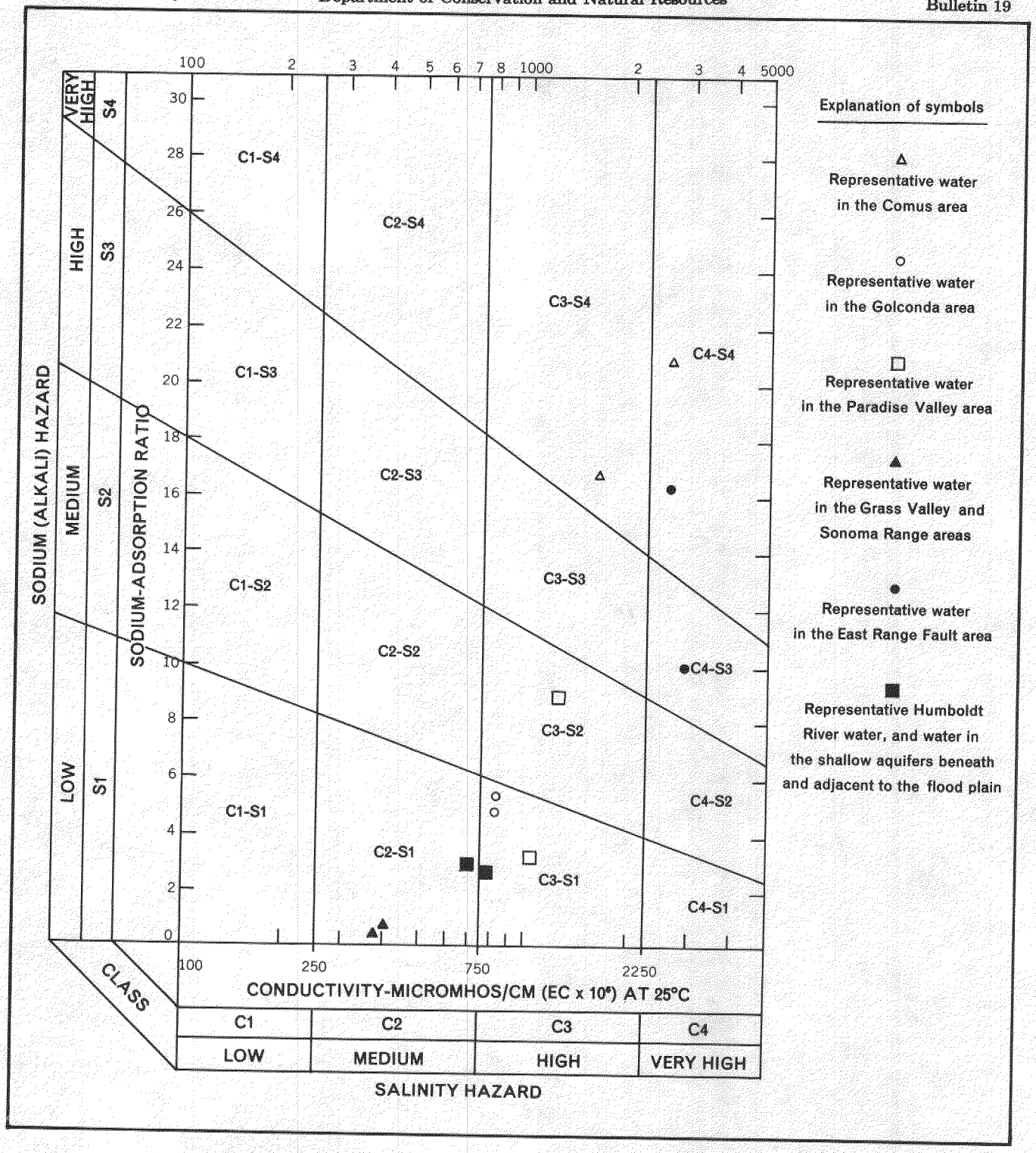


FIGURE II.— Classification of irrigation water on the basis of conductivity and sodium-adsorption ratio. Symbols denote representative water in areas described in text.

## SUMMARY AND CONCLUSIONS

During the spring and early summer of 1961 the stage of the Humboldt River was relatively high because of the spring runoff. As a result, there was seepage from the river to the aquifers beneath and immediately adjacent to the flood plain. In August, and to a lesser extent in December 1961, some of the ground-water recharge resulting from seepage from the river during the spring and early summer discharged into the river. Also, there was ground-water underflow into the river from tributary areas. Nearly all the flow in the Humboldt River between the Comus and Rose Creek gaging stations in August and December resulted from ground-water seepage to the river.

The chemical quality of the ground water discharging into the river in August was partly a reflection of the quality of the water stored in the shallow aquifers during the previous spring and early summer, and partly a reflection of the quality of the ground water from tributary areas. By December, most of the ground water stored in the shallow aquifers during the previous spring and early summer had been discharged by evapotranspiration or by seepage to the river. Thus, the quality of the ground water discharging into the river in December was more nearly a reflection of the quality of the ground water from the tributary areas.

The chemical quality of the ground-water underflow from the major tributary areas is distinctive. The source of the ground water discharging into the river as suggested by water-level contours is corroborated by the water-quality data.

Although nearly all the water in the area is hard to very hard, and locally some of the thermal water contains excessive amounts of fluoride and boron, most of the water in the project area is suitable for domestic and agricultural use.

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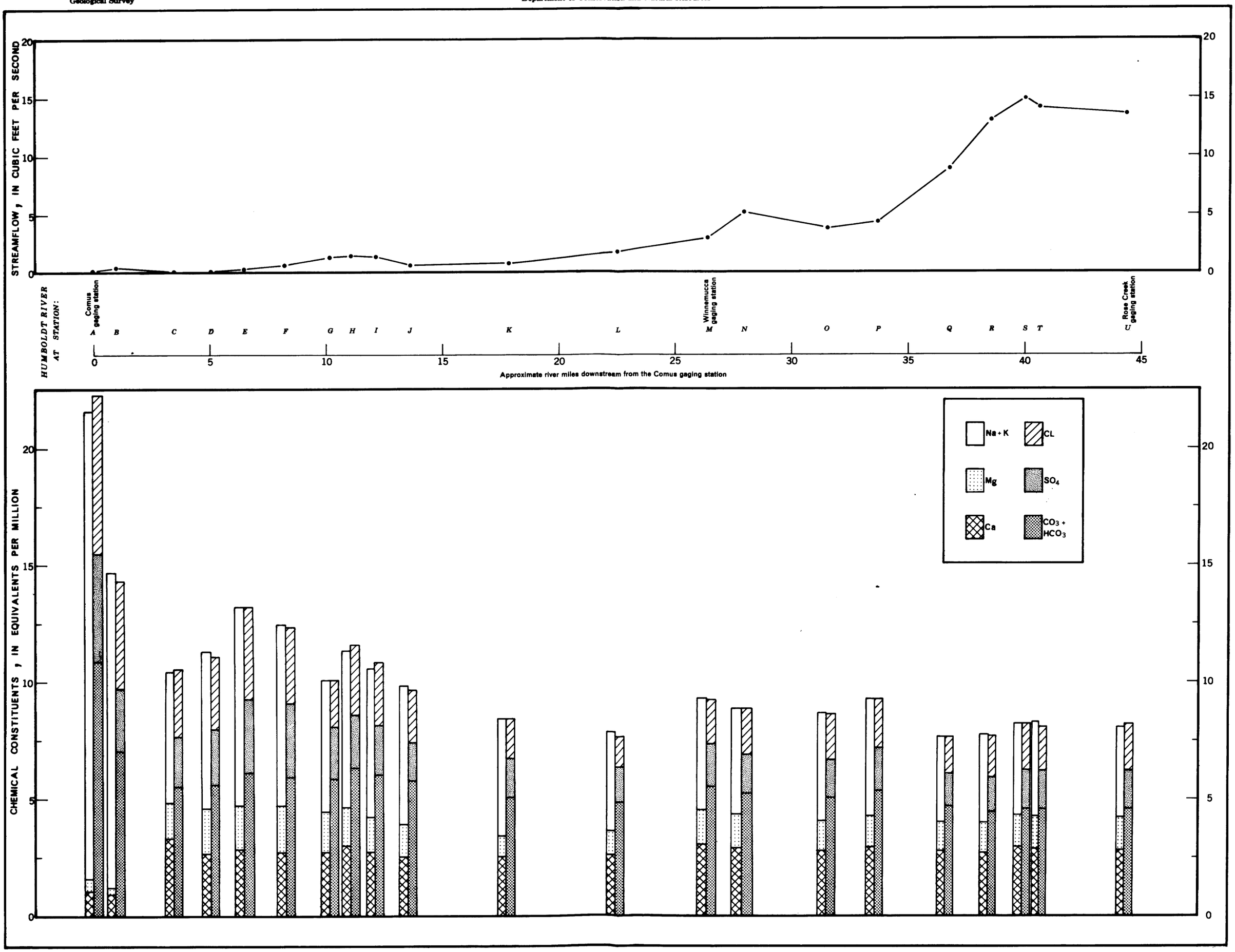
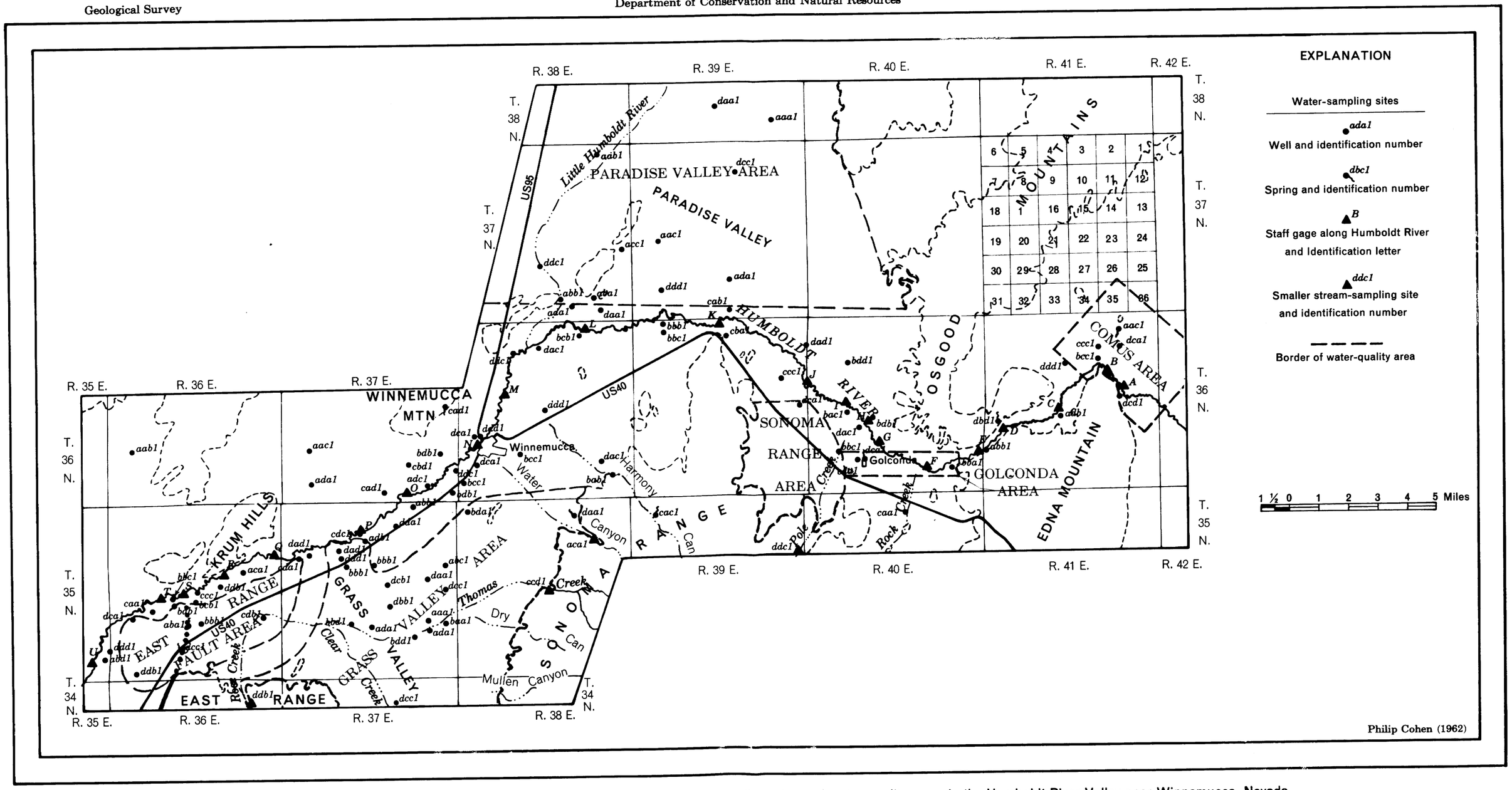
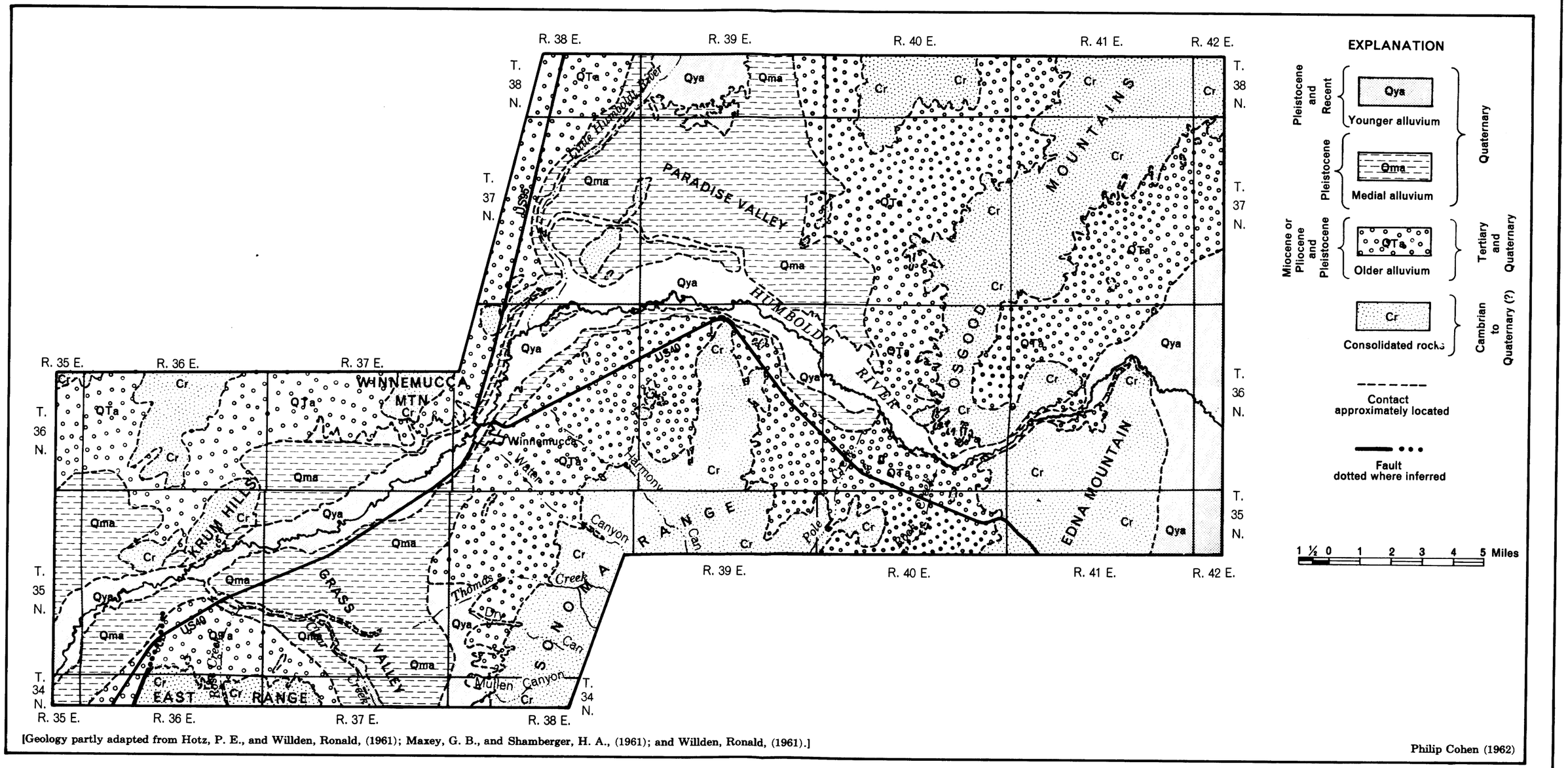



FIGURE 10.— Streamflow and chemical quality of the Humboldt River near Winnemucca, Nevada December 4-6, 1961.




Philip Cohen (1962)

FIGURE 2. — Map showing the location and identification numbers of water-sampling sites and water-quality areas in the Humboldt River Valley near Winnemucca, Nevada.




[Geology partly adapted from Hotz, P. E., and Willden, Ronald, (1961); Maxey, G. B., and Shamberger, H. A., (1961); and Willden, Ronald, (1961).]

Philip Cohen (1962)

FIGURE 3. — Generalized geologic map of the Humboldt River Valley near Winnemucca, Nevada.

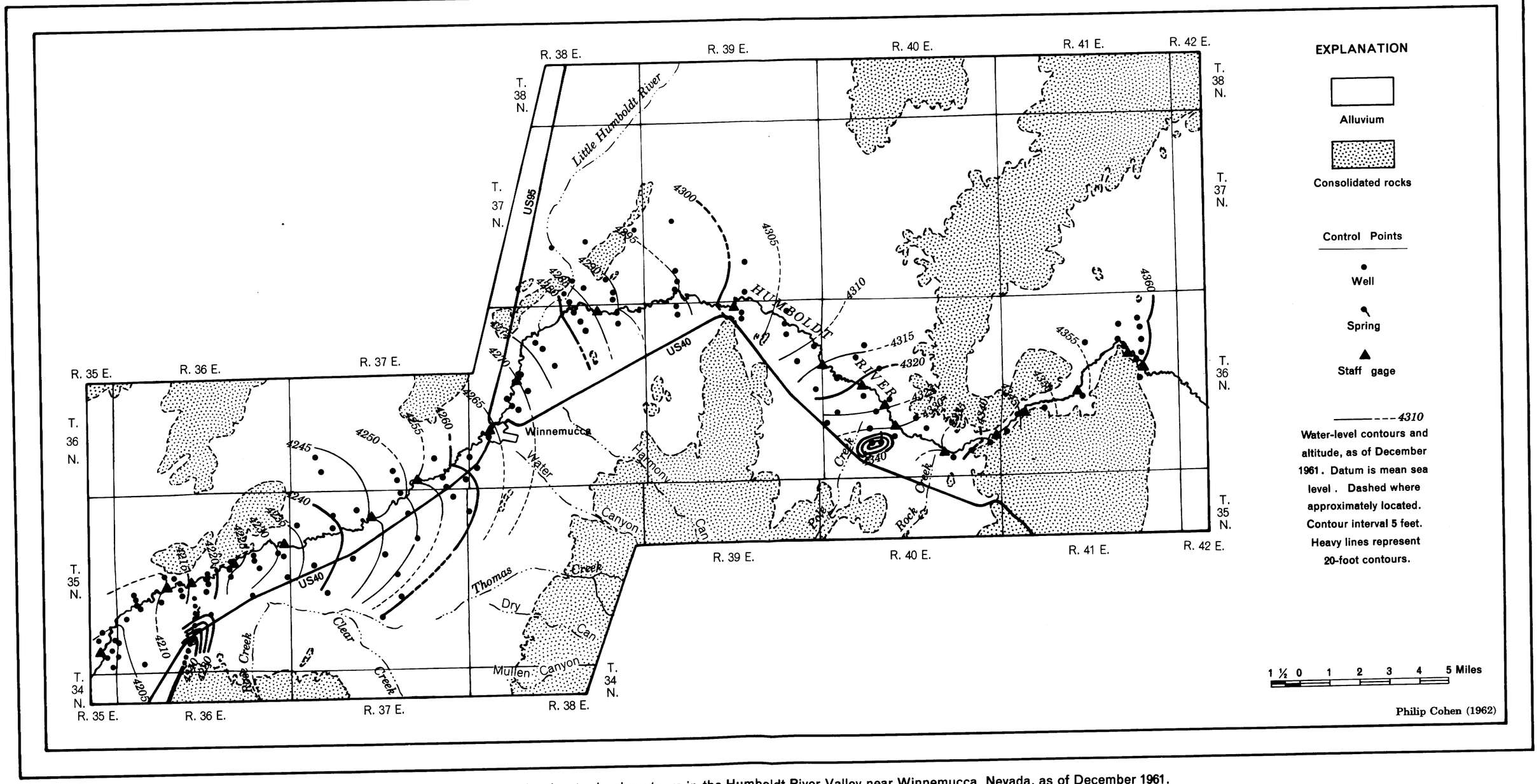



FIGURE 4. — Map showing generalized water-level contours in the Humboldt River Valley near Winnemucca, Nevada, as of December 1961.

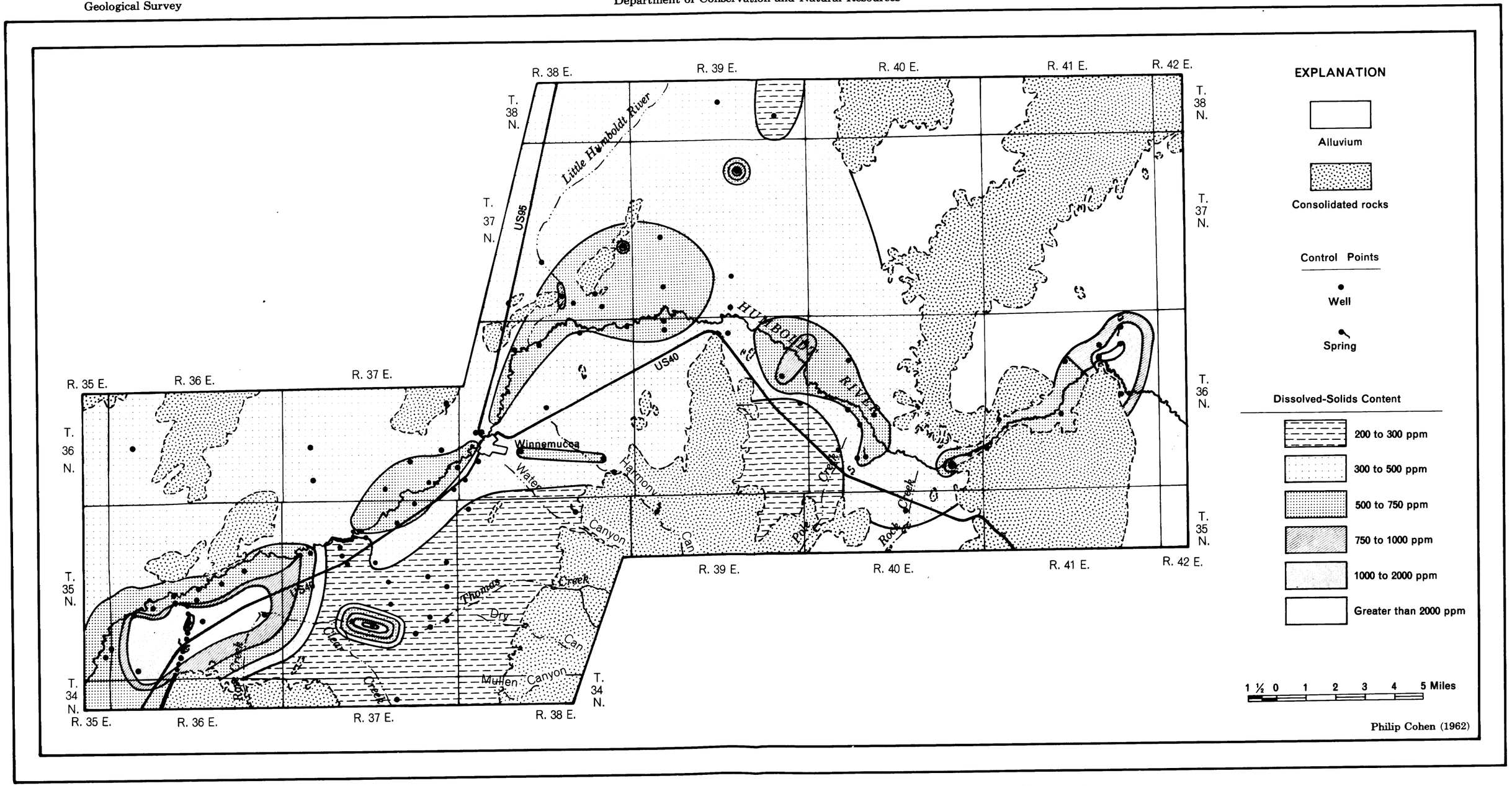



FIGURE 5. — Map showing dissolved-solids content of ground water in the Humboldt River Valley near Winnemucca, Nevada., July-December 1961.

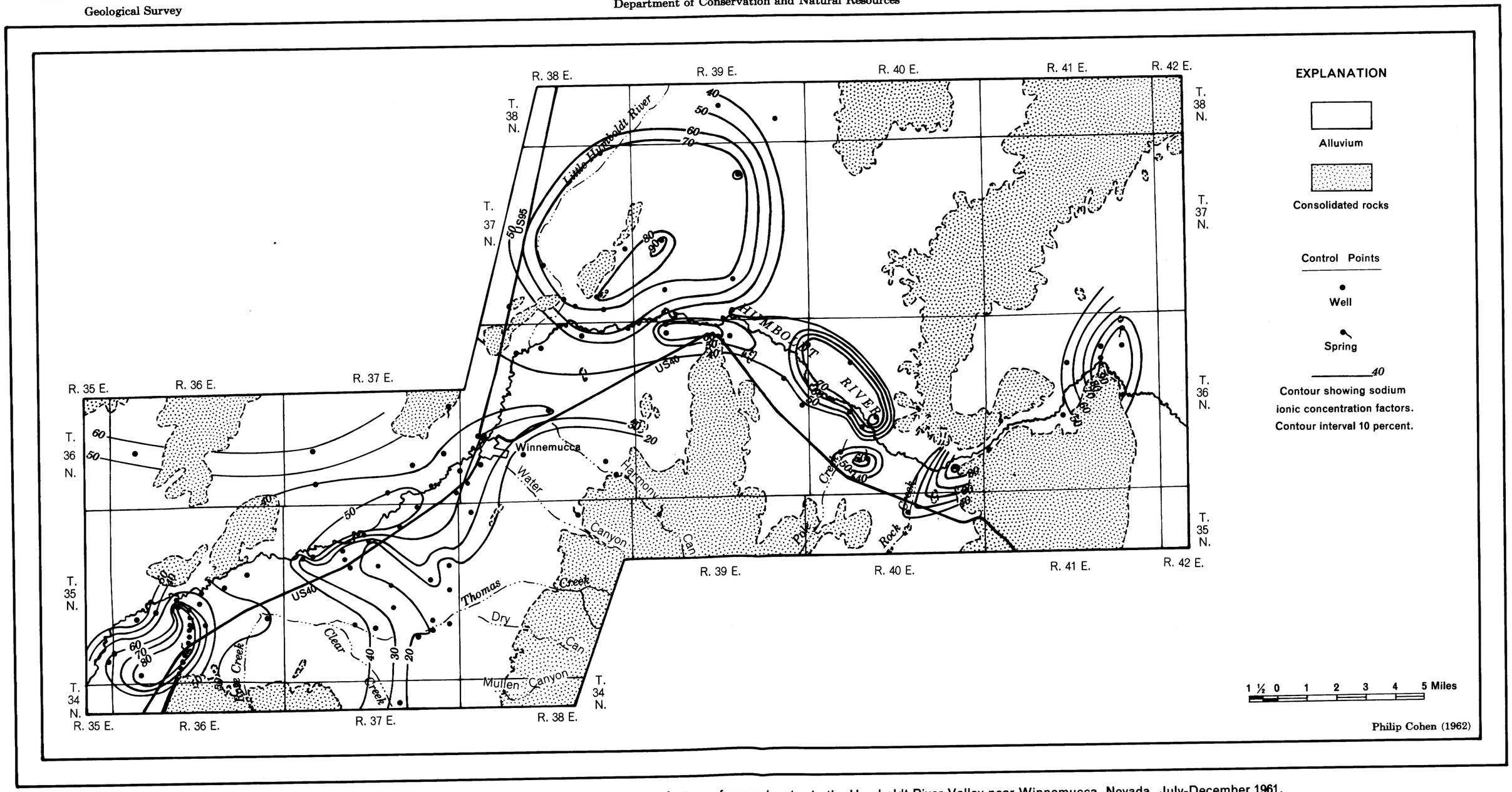



FIGURE 7. — Map showing the sodium ionic concentration factors of ground water in the Humboldt River Valley near Winnemucca, Nevada., July-December 1961.

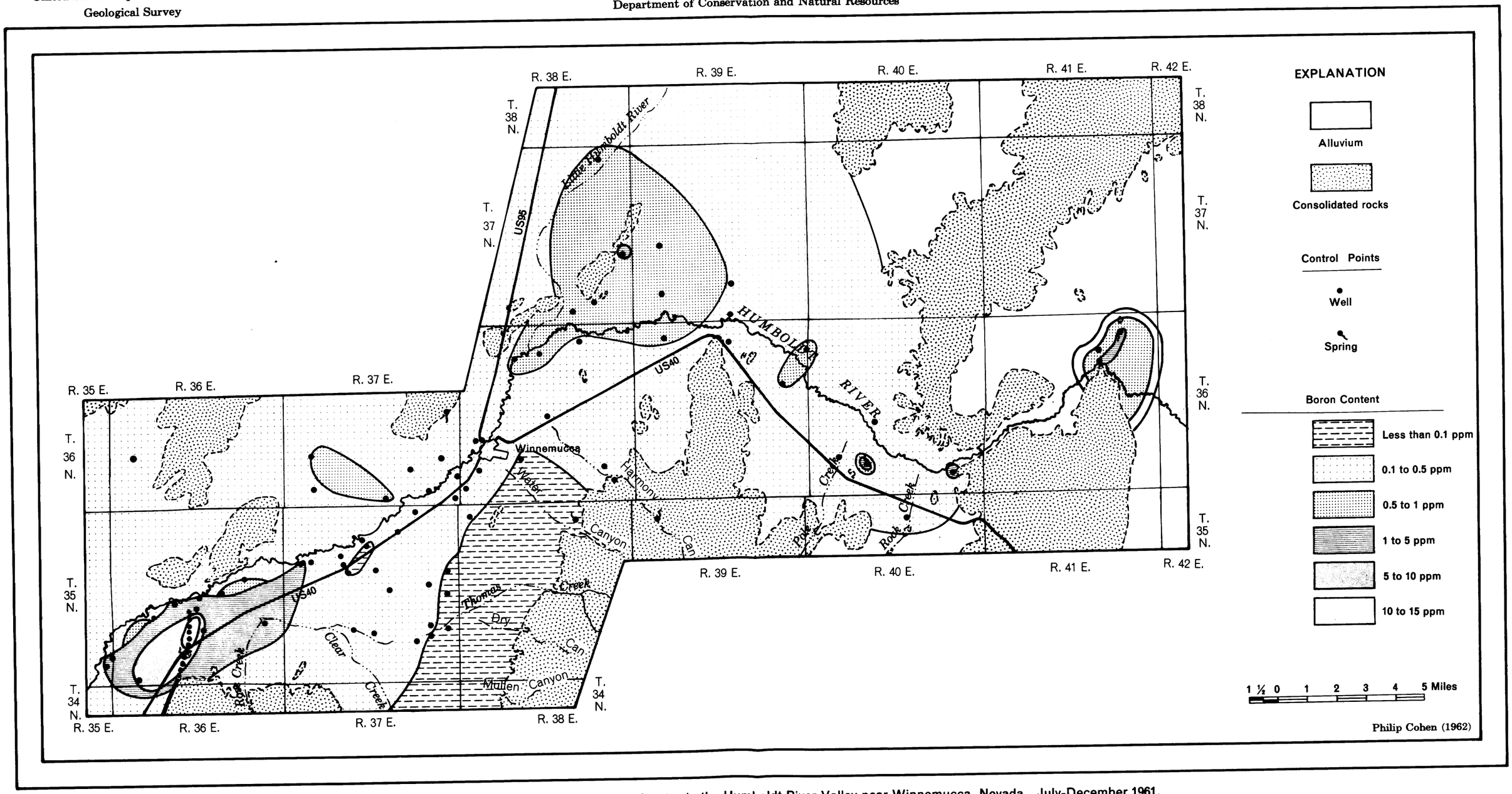



FIGURE 8. — Map showing the boron content of ground water in the Humboldt River Valley near Winnemucca, Nevada., July-December 1961.

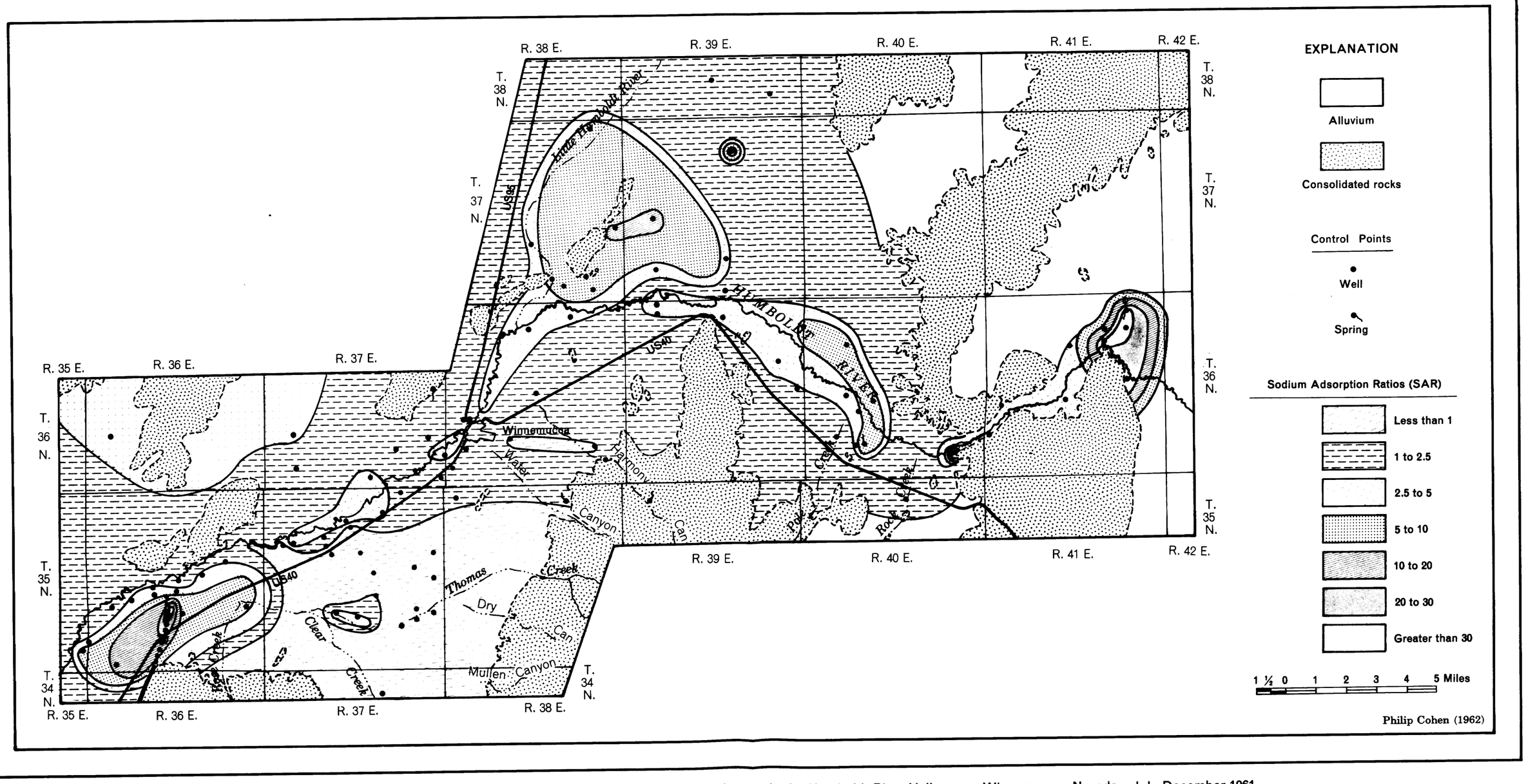



FIGURE 9. — Map showing sodium adsorption ratios (SAR) of ground water in the Humboldt River Valley near Winnemucca, Nevada., July-December 1961.

Table 1.--Chemical analyses of ground water in the Humboldt River valley near Winnemucca, Nev.

[Analyses by the U.S. Geological Survey, except as indicated.]

| Sample number and location | Source | Depth (feet) | Date of collection | Temperature (°F) | Chemical constituents, in parts per million (ppm): 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 (sum of determined constituents) | Hardness as $CaCO_3$: Total | Hardness as $CaCO_3$: Noncarbonate | Specific conductance (micromhos at 25°C) | Percent sodium | Sodium adsorption ratio (SAR) | pH | Suitability for irrigation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 34/37-3ddc1 | Well | 160 | 7-26-61 | 59 | 25 | 0.00 | 37 | 11 | 21 | 1.4 | 138 | 0 | 29 | 26 | 0.1 | 1.7 | 0.00 | 219 | 272 | 160 | 363 | 25 | 0.8 | 8.2 | $C_2$-$S_1$ |
| 35/35-25ddd1 | do | 18 | 11-29-61 | 59 | -- | -- | 55 | 21 | 161 | 7.1 | 376 | 12 | 158 | 68 | -- | -- | 2.0 | 669 | 222 | 0 | 1,120 | 60 | 4.7 | 8.4 | $C_3$-$S_1$ |
| 35/35-36abd1 | do | 15 | 11-29-61 | 57 | -- | -- | 50 | 20 | 177 | 16 | 432 | 4 | [a] 141 | 75 | -- | -- | 3.2 | 698 | 208 | 0 | 1,120 | 63 | 5.3 | 8.3 | $C_3$-$S_1$ |
| 35/36-14aca1 | do | 18 | 11-29/61 | 55 | -- | -- | 66 | 26 | 90 | 17 | 161 | 3 | 110 | 160 | -- | -- | .1 | 551 | 270 | 133 | 997 | 40 | 2.4 | 8.3 | $C_3$-$S_1$ |
| 35/36-15ccc2 | do | [b] 60 | 7-19-61 | 64 | 33 | .00 | 59 | 23 | 69 | 3.3 | 312 | 0 | 60 | 56 | .4 | 1.9 | 1.1 | 461 | 243 | 0 | 751 | 38 | 1.9 | 8.1 | $C_3$-$S_1$ |
| 35/36-15ddb1 | do | 24 | 11-29-61 | 56 | -- | -- | 30 | 41 | 135 | 58 | 382 | 0 | [a] 65 | 115 | -- | -- | .6 | 632 | 292 | 0 | 1,110 | 49 | 3.8 | 8.1 | $C_3$-$S_1$ |
| 35/36-19dca1 | do | 18 | 7-19-61 | 58 | -- | -- | 186 | 62 | 106 | 20 | 166 | 0 | 685 | 63 | -- | -- | -- | 1,200 | 720 | 584 | 1,640 | 24 | 1.7 | 8.1 | $C_3$-$S_1$ |
| 35/36-20caa1 | do | 18 | 11-29-61 | 56 | -- | -- | 92 | 24 | 144 | 6.8 | 294 | 6 | 235 | 96 | -- | -- | .6 | 749 | 328 | 77 | 1,230 | 48 | 3.5 | 8.4 | $C_3$-$S_1$ |
| 35/36-21bbc1 | do | 19 | 11-29-61 | 54 | -- | -- | 53 | 15 | 128 | 12 | 335 | 0 | [a] 115 | 65 | -- | -- | 1.4 | 554 | 192 | 0 | 926 | 57 | 4.0 | 8.1 | $C_3$-$S_1$ |
| 35/36-21bdb1 | do | 29 | 7-19-61 | 84 | -- | -- | 43 | 15 | 420 | 29 | 974 | 0 | 88 | 185 | -- | -- | -- | 1,260 | 170 | 0 | 2,120 | 82 | 6.9 | 7.9 | $C_3$-$S_2$ |
| 35/36-22bcb1 | do | 78 | 11-29-61 | 62 | -- | -- | 52 | 23 | 85 | 4.1 | 384 | 0 | 3.0 | 55 | -- | -- | 2.1 | 413 | 225 | 0 | 749 | 45 | 2.5 | 8.1 | $C_2$-$S_1$ |
| 35/36-24cdb2 | do | [b] 212 | 7-18-61 | 60 | 30 | .00 | 88 | 58 | 268 | 9 | 1,120 | 0 | 70 | 58 | .2 | .1 | 2.8 | 1,140 | 460 | 0 | 1,830 | 55 | 4.3 | 7.6 | $C_3$-$S_1$ |
| 35/36-27bbb1 | do | 99 | 7-19-61 | 82 | 52 | .05 | 117 | 48 | 512 | 60 | 1,610 | 0 | 59 | 225 | 4.8 | 1.0 | 7.8 | 1,880 | 490 | 0 | 3,030 | 66 | 10.1 | 7.8 | $C_4$-$S_2$ |
| 35/36-28aba1 | Spring | -- | 7-18-61 | 82 | 50 | .01 | 17 | 40 | 920 | 94 | 1,940 | 41 | 121 | 381 | 12 | .8 | 15 | 2,650 | 207 | 0 | 4,080 | 86 | 27.8 | 8.3 | $C_4$-$S_4$ |
| 35/36-28dcc1 | do | -- | 6-18-61 | 83 | 73 | .08 | 61 | 12 | 550 | 51 | 1,270 | 10 | 100 | 237 | 6 | 3.5 | 9.2 | 1,740 | 200 | 0 | 2,640 | 82 | 16.8 | 8.3 | $C_4$-$S_4$ |
| 35/36-31ddb1 | Well | 88 | 11-29-61 | 62 | -- | -- | 30 | 18 | 392 | 28 | 820 | 10 | [a] 16 | 235 | -- | -- | 5.7 | 1,140 | 148 | 0 | 2,020 | 82 | 12.3 | 8.3 | $C_3$-$S_3$ |
| 35/37-2abb1-1 | do | 22 | 7-16-61 | 55 | 42 | .03 | 50 | 16 | 97 | 11 | 282 | 18 | 77 | 52 | .8 | .0 | .4 | 503 | 191 | 0 | 805 | 51 | 1.4 | 8.4 | $C_3$-$S_1$ |
| 35/37-2abb1-2 | do | 22 | 11-30-61 | 55 | 44 | .00 | 44 | 13 | 90 | 11 | 293 | 5 | 68 | 40 | .8 | .4 | .4 | 461 | 165 | 0 | 706 | 52 | 2.6 | 8.3 | $C_2$-$S_1$ |
| 35/37-3dda1 | do | 12 | 11-30-61 | 55 | -- | -- | 53 | 22 | 102 | 4.4 | 278 | 10 | [a] 105 | 68 | -- | -- | .4 | 541 | 222 | 0 | 851 | 49 | 3.0 | 8.4 | $C_3$-$S_1$ |
| 35/37-4cdc1 | do | 50 | 7-24-61 | 54 | 37 | .06 | 67 | 16 | 102 | 8.6 | 366 | 0 | 67 | 59 | .8 | .4 | .4 | 538 | 234 | 0 | 875 | 48 | 2.9 | 7.8 | $C_3$-$S_1$ |
| 35/37-7cda1 | do | 16 | 11-30-61 | 56 | -- | -- | 44 | 10 | 26 | 3.9 | 177 | 9 | [a] 38 | 9.8 | -- | -- | .1 | 228 | 152 | 0 | 394 | 26 | .9 | 8.4 | $C_2$-$S_1$ |
| 35/37-7dad1 | do | [b] 97 | 7-26-61 | 56 | 49 | .00 | 98 | 23 | 170 | 7.6 | 580 | 0 | 154 | 75 | 1.1 | 4.2 | 2.6 | 870 | 340 | 0 | 1,480 | 51 | 4.0 | 7.8 | $C_3$-$S_1$ |
| 35/37-8dad1 | do | 78 | 8- 7-61 | 58 | 39 | .00 | 54 | 11 | 30 | 2.2 | 204 | 0 | 41 | 20 | .1 | 1.2 | .2 | 299 | 181 | 14 | 469 | 26 | 1.0 | 8.2 | $C_2$-$S_1$ |
| 35/37-8ddd1 | do | [b] 83 | 9-21-54 | -- | 43 | .04 | 56 | 15 | 31 | 3.3 | 194 | 0 | 76 | 21 | .3 | .8 | -- | 299 | 201 | 42 | 513 | 25 | 1.0 | -- | $C_2$-$S_1$ |
| 35/37-9adb1-1 | do | 19 | 8- 7-61 | 58 | -- | -- | 54 | 12 | 17 | 3.1 | 194 | 0 | 34 | 16 | -- | -- | -- | 231 | 182 | 23 | 414 | 17 | .5 | 7.9 | $C_2$-$S_1$ |
| 35/37-9adb1-2 | do | 19 | 11-28-61 | 58 | -- | -- | 52 | 11 | 15 | 3.1 | 181 | 5 | 29 | 14 | -- | -- | .0 | 218 | 175 | 19 | 392 | 15 | .5 | 8.4 | $C_2$-$S_1$ |
| 35/37-13abc1 | do | 107 | 7-25-61 | -- | 16 | .01 | 51 | 13 | 16 | 1.2 | 168 | 0 | 36 | 26 | .3 | 1.4 | .0 | 244 | 181 | 43 | 413 | 16 | .5 | 8.1 | $C_2$-$S_1$ |
| 35/37-13dcc1 | do | [b] 300 | 7-25-61 | -- | 16 | .00 | 59 | 12 | 13 | 1.2 | 182 | 0 | 51 | 19 | .4 | .6 | .0 | 262 | 198 | 49 | 428 | 12 | .4 | 8.0 | $C_2$-$S_1$ |
| 35/37-14daa1 | do | [b] 276 | 7-25-61 | 62 | 20 | .00 | 38 | 16 | 21 | 1.1 | 170 | 0 | 38 | 15 | .2 | 2.2 | .1 | 236 | 162 | 23 | 395 | 22 | .7 | 8.2 | $C_2$-$S_1$ |
| 35/37-15bbb1 | do | 57 | 11-29-61 | 54 | -- | -- | 72 | 16 | 19 | 5.3 | 193 | 0 | 44 | 61 | -- | -- | .1 | 312 | 244 | 86 | 579 | 14 | .5 | 8.1 | $C_2$-$S_1$ |
| 35/37-15dcb1 | do | [b] 159 | 11-17-50 | -- | 44 | .02 | 42 | 11 | 19 | 1.9 | 183 | 0 | 30 | 12 | .5 | 1.2 | .05 | 252 | 150 | 0 | 364 | 21 | .7 | 7.8 | $C_2$-$S_1$ |
| 35/37-16bbb1 | do | [b] 100 | 7-25-61 | 64 | 50 | .01 | 46 | 9.2 | 20 | 3.3 | 178 | 0 | 28 | 13 | .3 | .8 | .0 | 259 | 153 | 7 | 394 | 22 | .7 | 8.2 | $C_2$-$S_1$ |
| 35/37-22dbb1 | do | 52 | 11-28-61 | 54 | -- | -- | 60 | 19 | 41 | 5.9 | 252 | 8 | 60 | 22 | -- | -- | .2 | 340 | 228 | 8 | 594 | 27 | 1.2 | 8.4 | $C_2$-$S_1$ |
| 35/37-25baa1 | do | [b] 620 | 7-25-61 | 60 | 32 | .00 | 40 | 15 | 17 | 2.2 | 175 | 0 | 30 | 14 | .3 | 1.1 | .0 | 238 | 162 | 18 | 390 | 18 | .6 | 8.2 | $C_2$-$S_1$ |
| 35/37-26aaa1 | do | [b] 360 | 7-25-61 | 59 | 29 | .00 | 47 | 15 | 18 | 2.5 | 188 | 2 | 28 | 17 | .3 | 3.1 | .1 | 255 | 179 | 22 | 422 | 18 | .6 | 8.3 | $C_2$-$S_1$ |
| 35/37-26ada1 | do | [b] 800 | 7-25-61 | 58 | 32 | .00 | 40 | 17 | 20 | 3.1 | 193 | 0 | 35 | 14 | .3 | 2.1 | .0 | 250 | 168 | 10 | 406 | 20 | .7 | 8.1 | $C_2$-$S_1$ |
| 35/37-26bdd1 | do | [b] 630 | 6-16-53 | 58 | 44 | .03 | 36 | 20 | 18 | 2.9 | 198 | 0 | 30 | 10 | .3 | 2.6 | .2 | 261 | 172 | 10 | 396 | 18 | .6 | 7.9 | $C_2$-$S_1$ |
| 35/37-28ada1 | do | 58 | 11-28-61 | 55 | -- | -- | 304 | 160 | 388 | 15 | 243 | 0 | 56 | 1,300 | -- | -- | .1 | 2,420 | 1,420 | 1,220 | 4,630 | 37 | 4.5 | 7.6 | $C_4$-$S_2$ |
| 35/37-28bbd1 | do | 73 | 7-26-61 | 59 | 39 | .04 | 102 | 40 | 192 | 5.2 | 204 | 0 | 213 | 385 | .1 | 2.4 | .1 | 1,020 | 420 | 253 | 1,810 | 49 | 3.7 | 8.1 | $C_3$-$S_1$ |
| 35/38-3daa1 | Spring | -- | 7-27-61 | 56 | 17 | .00 | 47 | 13 | 15 | .9 | 166 | 0 | 32 | 18 | .3 | .6 | .0 | 226 | 170 | 34 | 374 | 16 | .5 | 7.8 | $C_2$-$S_1$ |
| 35/38-6bda1 | Well | [b] 120 | 7-26-61 | -- | 36 | .00 | 38 | 9.5 | 30 | 1.8 | 133 | 6 | 39 | 32 | .3 | 3.8 | .1 | 262 | 134 | 15 | 401 | 32 | 1.1 | 8.3 | $C_2$-$S_1$ |
| 35/39-6cac1 | Spring | -- | 7-27-61 | 55 | 24 | .00 | 64 | 10 | 25 | 1.3 | 216 | 0 | 35 | 28 | .0 | 1.7 | .1 | 295 | 202 | 25 | 484 | 21 | .8 | 7.8 | $C_2$-$S_1$ |
| 35/40-3caa1 | Well | [b] 240 | 8- 8-61 | -- | 70 | .05 | 44 | 10 | 51 | 5.3 | 203 | 0 | 51 | 31 | .2 | .2 | .3 | 363 | 152 | 0 | 547 | 41 | 1.8 | 7.5 | $C_2$-$S_1$ |
| 36/36-30aab1 | do | -- | 7-20-61 | 62 | 15 | .01 | 45 | 4.3 | 76 | 4.2 | 265 | 0 | 3 | 50 | .1 | .0 | .4 | 329 | 130 | 0 | 618 | 55 | 2.9 | 7.5 | $C_2$-$S_1$ |
| 36/37-13cad1 | Spring | -- | 7-20-61 | 93 | 25 | .00 | 179 | 58 | 74 | 2.0 | 211 | 0 | 390 | 191 | .3 | 20 | .4 | 1,040 | 685 | 512 | 1,540 | 19 | 1.2 | 7.7 | $C_3$-$S_1$ |
| 36/37-25bdb1 | Well | 31 | 11-30-61 | 56 | -- | -- | 62 | 16 | 76 | 4.3 | 210 | 4 | 72 | 75 | -- | -- | .4 | 413 | 220 | 41 | 797 | 42 | 2.2 | 8.3 | $C_3$-$S_1$ |
| 36/37-25ddc1 | do | 19 | 11-27-61 | 52 | -- | -- | 59 | 22 | 110 | 12 | 365 | 0 | 91 | 66 | -- | -- | .4 | 540 | 239 | 0 | 924 | 48 | 3.1 | 8.1 | $C_3$-$S_1$ |
| 36/37-26cbd1 | do | 87 | 7-20-61 | 60 | 54 | .00 | 69 | 19 | 72 | 6.8 | 247 | 9 | 91 | 80 | .3 | .0 | .3 | 523 | 252 | 35 | 822 | 38 | 2.0 | 8.4 | $C_3$-$S_1$ |
| 36/37-30aac1 | do | [b] 400 | 7-20-61 | 63 | 66 | .00 | 34 | 7.8 | 84 | 6.9 | 234 | 6 | 77 | 22 | .6 | 2.5 | .5 | 424 | 117 | 0 | 605 | 59 | 3.4 | 8.4 | $C_2$-$S_1$ |
| 36/37-31ada1 | do | 86 | 11-30-61 | 60 | -- | -- | 54 | 13 | 57 | 8.4 | 220 | 0 | [a] 24 | 84 | -- | -- | .4 | 349 | 190 | 10 | 644 | 38 | 1.8 | 7.4 | $C_2$-$S_1$ |
| 36/37-34cad1 | do | 18 | 11-30-61 | 56 | -- | -- | 71 | 21 | 177 | 23 | 430 | 14 | 129 | 99 | -- | -- | .7 | 746 | 264 | 0 | 1,240 | 57 | 4.8 | 8.4 | $C_3$-$S_1$ |
| 36/37-35adc1 | do | 72 | 7-20-61 | 60 | 32 | .02 | 76 | 15 | 78 | 6.8 | 342 | 0 | 74 | 57 | .5 | .0 | .2 | 508 | 249 | 0 | 821 | 40 | 2.1 | 7.9 | $C_3$-$S_1$ |
| 36/37-36dbd1 | do | [b] 465 | 7-24-61 | -- | 35 | .01 | 43 | 12 | 60 | 6.1 | 188 | 0 | 60 | 57 | .3 | 1.1 | .2 | 368 | 156 | 2 | 589 | 44 | 2.1 | 8.1 | $C_2$-$S_1$ |
| 36/38-2bcb1 | do | [b] 314 | 7-28-61 | 54 | 48 | .01 | 56 | 14 | 86 | 8.3 | 313 | 0 | 66 | 50 | .6 | 1.4 | .3 | 485 | 198 | 0 | 741 | 47 | 2.7 | 7.9 | $C_2$-$S_1$ |
| 36/38-4dac1 | do | 208 | 7-29-61 | 61 | 58 | .00 | 65 | 19 | 103 | 8.2 | 342 | 0 | 86 | 67 | .6 | 1.3 | .5 | 577 | 240 | 0 | 893 | 47 | 2.9 | 7.7 | $C_3$-$S_1$ |
| 36/38-5dda1 | do | 22 | 12- 1-61 | 55 | -- | -- | 65 | 20 | 106 | 1.9 | 290 | 8 | 99 | 88 | -- | -- | .8 | 531 | 246 | 0 | 938 | 48 | 2.9 | 8.4 | $C_3$-$S_1$ |
| 36/38-16ddd1 | do | 319 | 7-27-61 | 62 | 50 | .00 | 52 | 11 | 65 | 6.4 | 260 | 0 | 48 | 46 | .3 | .8 | .3 | 408 | 176 | 0 | 664 | 43 | 2.1 | 8.2 | $C_2$-$S_1$ |
| 36/38-19daa1 | do | [b] 525 | 11-17-50 | 65 | 44 | .03 | 59 | 16 | 78 | 4.6 | 287 | 0 | 72 | 61 | .6 | .1 | .2 | 477 | 213 | 0 | 748 | 44 | 2.3 | 7.7 | $C_2$-$S_1$ |
| 36/38-19ddd1 | do | [b] 150 | 7-24-61 | 56 | 43 | .00 | 66 | 16 | 66 | 5.7 | 274 | 0 | 73 | 58 | .3 | .6 | .3 | 464 | 231 | 6 | 748 | 38 | 1.9 | 7.9 | $C_2$-$S_1$ |
| 36/38-26dac1 | do | 55 | 7-27-61 | 73 | 10 | .04 | 102 | 30 | 42 | 3.5 | 166 | 0 | 85 | 178 | .3 | 2.9 | .1 | 536 | 379 | 243 | 1,020 | 19 | .9 | 8.0 | $C_3$-$S_1$ |
| 36/38-28bcc1 | do | [b] 245 | 7-27-61 | 62 | 21 | .00 | 142 | 41 | 30 | 1.5 | 128 | 0 | 108 | 233 | .2 | 40 | .0 | 680 | 525 | 420 | 1,210 | 11 | .6 | 7.9 | $C_3$-$S_1$ |
| 36/38-30dca1 | do | [b] 495 | 7-24-61 | 73 | 51 | .00 | 56 | 19 | 60 | 6.5 | 260 | 0 | 72 | 58 | .3 | .3 | .4 | 452 | 218 | 5 | 728 | 37 | 1.8 | 7.9 | $C_2$-$S_1$ |
| 36/38-31bcc1 | do | [b] 78 | 7-24-61 | -- | 29 | .02 | 68 | 20 | 59 | 2.2 | 243 | 0 | 75 | 82 | .1 | 5.4 | .2 | 460 | 252 | 53 | 792 | 34 | 1.6 | 7.9 | $C_3$-$S_1$ |
| 36/38-36bab1 | do | 68 | 7-27-61 | 52 | 24 | .00 | 94 | 21 | 34 | 2.5 | 245 | 0 | 141 | 45 | .0 | 3.1 | .2 | 486 | 321 | 120 | 778 | 19 | .8 | 7.8 | $C_3$-$S_1$ |
| 36/39-1dad1 | do | 18 | 7-31-61 | -- | 41 | .00 | 46 | 12 | 252 | 10 | 453 | 14 | 149 | 120 | .8 | .0 | .8 | 869 | 166 | 0 | 1,340 | 75 | 8.5 | 8.4 | $C_3$-$S_2$ |
| 36/39-3cba1 | do | 82 | 7-31-61 | -- | 42 | .00 | 37 | 7.7 | 80 | 2.1 | 145 | 0 | 67 | 82 | .6 | 2.2 | .2 | 392 | 124 | 5 | 638 | 58 | 3.1 | 8.2 | $C_2$-$S_1$ |
| 36/39-5bbb1 | do | 18 | 7-29-61 | 62 | -- | -- | 68 | .1 | 163 | 11 | 458 | 0 | 44 | 72 | -- | -- | -- | 583 | 170 | 0 | 1,030 | 66 | 5.5 | 7.5 | $C_3$-$S_1$ |
| 36/39-5bbc1 | do | 39 | 7-29-61 | 59 | 42 | .09 | 47 | 17 | 157 | 12 | 380 | 0 | 93 | 92 | .8 | 1.0 | .5 | 649 | 188 | 0 | 1,020 | 63 | 5.0 | 7.8 | $C_3$-$S_1$ |
| 36/39-12ccc1 | do | 18 | 7-31-61 | 61 | 53 | .00 | 100 | 17 | 138 | 5 | 299 | 5 | 210 | 126 | .4 | 11 | .8 | 808 | 320 | 75 | 1,250 | 48 | 3.4 | 8.3 | $C_3$-$S_1$ |
| 36/39-13dca1 | do | 27 | 7-31-61 | -- | -- | -- | 42 | 6.3 | 64 | 4.8 | 237 | 4 | 23 | 28 | -- | 9.1 | -- | 298 | 131 | 0 | 554 | 49 | 2.4 | 8.5 | $C_2$-$S_1$ |
| 36/40-8bdd1 | do | 18 | 8- 1-61 | -- | -- | -- | 27 | 7.9 | 196 | 14 | 420 | 8 | 106 | 65 | -- | -- | -- | 630 | 100 | 0 | 1,060 | 78 | 7.0 | 8.3 | $C_3$-$S_2$ |
| 36/40-20bac1 | do | 17 | 7-31-61 | 56 | -- | -- | 41 | 8.5 | 85 | 10 | 292 | 0 | 56 | 45 | -- | -- | -- | 390 | 162 | 0 | 707 | 51 | 2.9 | 8.2 | $C_2$-$S_1$ |
| 36/40-20dac1 | do | 18 | 8- 1-61 | -- | -- | -- | 49 | 14 | 119 | 12 | 373 | 12 | 61 | 46 | -- | -- | -- | 496 | 180 | 0 | 846 | 57 | 3.9 | 8.5 | $C_3$-$S_1$ |
| 36/40-21bdb1 | do | 18 | 7-31-61 | 61 | 35 | .00 | 20 | 6.3 | 200 | 9.2 | 392 | 10 | 83 | 55 | 1.1 | .5 | .4 | 614 | 76 | 0 | 939 | 83 | 10.1 | 8.4 | $C_3$-$S_2$ |
| 36/40-29bbc1 | do | [b] 256 | 8-18-61 | -- | 36 | .00 | 43 | 6.9 | 20 | 2.0 | 139 | 0 | 25 | 23 | .0 | 9 | .1 | 233 | 136 | 22 | 375 | 24 | .7 | 7.4 | $C_2$-$S_1$ |
| 36/40-29cda1 | do | 18 | 8- 7-61 | 80 | -- | -- | 40 | 6.8 | 126 | 22 | 434 | 0 | 50 | 20 | -- | -- | -- | 478 | 128 | 0 | 811 | 64 | 4.8 | 7.7 | $C_3$-$S_1$ |
| 36/40-29dca1 | Spring | -- | 12- 2-61 | 148 | 59 | .00 | 35 | 8.4 | 146 | 23 | 448 | 0 | 56 | 20 | 2.0 | .4 | 1.3 | 571 | 122 | 0 | 845 | 68 | 5.8 | 8.2 | $C_3$-$S_1$ |
| 36/40-36bba1 | Well | 19 | 8- 7-61 | 59 | 44 | .00 | 26 | 11 | 690 | 5 | 1,210 | 18 | 284 | 179 | 1.8 | 1.4 | 2.3 | 1,860 | 110 | 0 | 2,830 | 93 | 27.3 | 8.4 | $C_4$-$S_4$ |
| 36/41-2aac1 | Spring | -- | 8- 8-61 | 70 | 34 | .00 | 2 | .0 | 620 | 3.5 | 1,080 | 143 | 98 | 46 | 16 | .0 | 4.6 | 1,500 | 5 | 0 | 2,340 | 99 | 117.3 | 9.2 | $C_4$-$S_4$ |
| 36/41-2ccc1 | Well | 29 | 11-27-61 | 52 | -- | -- | 23 | 7.4 | 320 | 2.5 | 648 | 0 | 22 | 170 | -- | -- | .9 | 864 | 88 | 0 | 1,510 | 88 | 16.9 | 7.9 | $C_3$-$S_4$ |
| 36/41-2dca1 | do | 22 | 8- 8-61 | -- | -- | -- | 76 | 86 | 3,160 | 23 | 816 | 0 | 1,530 | 3,880 | -- | -- | -- | 9,160 | 542 | 0 | 14,400 | 92 | 59.3 | 8.1 | $C_4$-$S_4$ |
| 36/41-9add1 | do | 32 | 8- 8-61 | 59 | -- | -- | 87 | 25 | 186 | 7.6 | 300 | 0 | 101 | 268 | -- | -- | -- | 822 | 320 | 74 | 1,520 | 55 | 4.5 | 8.0 | $C_3$-$S_1$ |
| 36/41-11bcc1 | do | 26 | 11-27-61 | 52 | 37 | .00 | 58 | 36 | 1,210 | 10 | 518 | 0 | 570 | 1,320 | 2.8 | 1.8 | 1.7 | 3,500 | 292 | 0 | 5,980 | 90 | 31 | 8.1 | $C_4$-$S_4$ |
| 36/41-14dcd1 | do | 19 | 8- 9-61 | 61 | -- | -- | 20 | 17 | 545 | 14 | 675 | 23 | 228 | 351 | -- | -- | -- | 1,530 | 121 | 0 | 2,580 | 90 | 21.5 | 8.4 | $C_4$-$S_4$ |
| 36/41-19dbd1 | Spring | -- | 10-20-58 | 60 | 15 | -- | 102 | 24 | 110 | 10 | 534 | 0 | 146 | 13 | 1.1 | .0 | -- | 684 | 356 | -- | 1,090 | 40 | 2.5 | 7.1 | $C_3$-$S_1$ |
| 36/41-21adb1 | Well | 19 | 8- 9-61 | 56 | -- | -- | 58 | 18 | 116 | 7.4 | 365 | 0 | 67 | 75 | -- | -- | -- | 520 | 220 | 0 | 954 | 50 | 3.4 | 8.0 | $C_3$-$S_1$ |
| 36/41-30abb1 | do | 27 | 8- 8-61 | 64 | -- | -- | 46 | 28 | 256 | 10 | 510 | 0 | 190 | 144 | -- | -- | -- | 925 | 230 | 0 | 1,550 | 70 | 7.3 | 8.2 | $C_3$-$S_2$ |
| 37/38-2aab1 [c] | do | 79 | 8-15-45 | -- | -- | -- | 27 | 8.0 | 120 | -- | 232 | -- | 74 | 67 | -- | -- | .5 | 430 | -- | -- | -- | 72 | 5.2 | -- | -- |
| 37/38-21ddc1 | do | 13 | 8- 1-61 | -- | -- | -- | 34 | 7.1 | 116 | 9.6 | 255 | 11 | 52 | 62 | -- | -- | -- | 417 | 114 | 0 | 773 | 67 | 4.7 | 8.5 | $C_3$-$S_1$ |
| 37/38-24acc1 | do | 38 | 12- 1-61 | 55 | -- | -- | 55 | 26 | 378 | 15 | 702 | 0 | [a] 51 | 322 | -- | -- | 2.9 | 1,200 | 240 | 0 | 2,100 | 76 | 11.4 | 8.1 | $C_3$-$S_3$ |
| 37/38-34abb1 | do | 9 | 8- 1-61 | -- | -- | -- | 66 | 27 | 242 | 12 | 370 | 0 | 226 | 215 | -- | -- | -- | 970 | 275 | 0 | 1,630 | 64 | 6.3 | 8.2 | $C_3$-$S_2$ |
| 37/38-34ada1 | do | 40 | 12-28-61 | 54 | 14 | .00 | 40 | 14 | 184 | 8.0 | 368 | 0 | 111 | 104 | .7 | .4 | .8 | 658 | 159 | 0 | 1,100 | 70 | 6.4 | 8.1 | $C_3$-$S_2$ |
| 37/38-35aba1 | do | 57 | 12- 1-61 | 55 | -- | -- | 25 | 11 | 214 | 9.2 | 209 | 0 | 106 | 194 | -- | -- | .6 | 662 | 106 | 0 | 1,210 | 80 | 9.0 | 8.0 | $C_3$-$S_2$ |
| 37/38-35daa1 | do | 11 | 8- 1-61 | -- | -- | -- | 44 | 14 | 182 | 9.6 | 385 | 6 | 102 | 99 | -- | -- | -- | 646 | 168 | 0 | 1,130 | 69 | 6.1 | 8.4 | $C_3$-$S_2$ |
| 37/39-3dcc1 | do | 61 | 8-10-61 | 158 | -- | -- | 30 | 7.1 | 450 | 26 | 1,240 | 0 | 52 | 14 | -- | -- | -- | 1,190 | 104 | -- | 1,900 | 88 | 19.2 | 7.4 | $C_3$-$S_4$ |
| 37/39-19aac1 | do | 29 | 12- 1-61 | 54 | -- | -- | 18 | 5.6 | 238 | 11 | 382 | 18 | [a] 135 | 82 | -- | -- | .9 | 697 | 68 | 0 | 1,160 | 86 | 12.2 | 8.5 | $C_3$-$S_3$ |
| 37/39-28ada1 | do | 40 | 12- 1-61 | 56 | -- | -- | 25 | 13 | 124 | 8.2 | 166 | 0 | [a] 128 | 91 | -- | -- | .3 | 472 | 118 | 0 | 788 | 68 | 4.9 | 8.0 | $C_3$-$S_1$ |
| 37/39-30ddd1 | do | 22 | 8- 1-61 | -- | 55 | .00 | 57 | 28 | 126 | 34 | 423 | 8 | 109 | 75 | .8 | .0 | .5 | 701 | 258 | 0 | 1,060 | 48 | 3.4 | 8.3 | $C_3$-$S_1$ |
| 37/39-34cab1 | do | 27 | 8- 1-61 | -- | 51 | .00 | 66 | 17 | 72 | 8.4 | 329 | 11 | 65 | 40 | .6 | .0 | .3 | 493 | 236 | 0 | 765 | 39 | 2.0 | 8.4 | $C_3$-$S_1$ |
| 38/39-28daa1 | do | [b] 420 | 11-14-61 | -- | 81 | .03 | 56 | 9.8 | 72 | 11 | 156 | 0 | 91 | 79 | .4 | 1.7 | .1 | 479 | 180 | 52 | 703 | 45 | 2.3 | 8.0 | $C_2$-$S_1$ |
| 38/39-35aaa1 | do | 64 | 8-10-61 | 62 | -- | -- | 40 | 16 | 45 | 5.8 | 202 | 0 | 16 | 66 | -- | -- | -- | 288 | 166 | 0 | 557 | 36 | 1.5 | 7.9 | $C_2$-$S_1$ |

[a] Calculated.

[b] Reported

[c] Analysis by the Nevada State Department of Health.

Table 2.--Chemical analyses of surface water in the Humboldt River valley near Winnemucca, Nev.

[Analyses by the U.S. Geological Survey]

| Sample number and location | Source | Streamflow, in cubic feet per second (cfs) | Date of collection | Temperature (°F) | Chemical constituents, in parts per million (ppm): 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 (sum of determined constituents) | Hardness as $CaCO_3$: Total | Noncarbonate | Specific conductance (micromhos at 25°C) | Percent sodium | Sodium adsorption ratio (SAR) | pH | Suitability for irrigation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Humboldt River at: | | | | | | | | | | | | | | | | | | | | | | | | |
| 36/41-14dad1-1 | Station A | 0.22 | 8-8-61 | 83 | -- | -- | 15 | 7.2 | 425 | 10 | 548 | 23 | 166 | 213 | -- | -- | -- | 1,130 | 67 | 0 | 1,920 | 92 | 23 | 8.6 | $C_3$-$S_4$ |
| 36/41-14dad1-2 | do | .15 | 12-4-61 | 35 | -- | -- | 21 | 6.7 | 455 | 7.5 | 620 | 20 | 221 | 242 | -- | -- | 2.3 | 1,280 | 80 | 0 | 2,040 | 92 | 22 | 8.5 | $C_3$-$S_4$ |
| 36/41-11cdc1-1 | Station B | .33 | 8-8-61 | 85 | -- | -- | 22 | 9.1 | 460 | 11 | 565 | 28 | 201 | 250 | -- | -- | -- | 1,260 | 92 | 0 | 2,080 | 90 | 21 | 8.7 | $C_3$-$S_4$ |
| 36/41-11cdc1-2 | do | .40 | 12-6-61 | 38 | -- | -- | 19 | 3.5 | 305 | 6.5 | 404 | 14 | 126 | 162 | -- | -- | 1.5 | 836 | 62 | 0 | 1,430 | 90 | 17 | 8.5 | $C_3$-$S_4$ |
| 36/41-21aac1-1 | Station C | .20 | 8-8-61 | 83 | -- | -- | 55 | 16 | 88 | 8.2 | 322 | 0 | 59 | 61 | -- | -- | -- | 445 | 204 | 0 | 788 | 47 | 2.7 | 8.1 | $C_3$-$S_1$ |
| 36/41-21aac1-2 | do | .00 | 12-6-61 | 42 | -- | -- | 66 | 19 | 126 | 3.3 | 336 | 0 | 101 | 104 | -- | -- | .5 | 585 | 242 | 0 | 991 | 53 | 3.5 | 8.2 | $C_3$-$S_1$ |
| 36/41-19ddc1-1 | Station D | .84 | 8-8-61 | 60 | -- | -- | 58 | 20 | 120 | 10 | 347 | 0 | 91 | 82 | -- | -- | -- | 552 | 228 | 0 | 943 | 52 | 3.4 | 8.1 | $C_3$-$S_1$ |
| 36/41-19ddc1-2 | do | .02 | 12-6-61 | 42 | -- | -- | 54 | 24 | 147 | 8.9 | 340 | 0 | 113 | 110 | -- | -- | .5 | 625 | 232 | 0 | 1,070 | 57 | 4.2 | 8.1 | $C_3$-$S_1$ |
| 36/40-25dcb1-1 | Station E | -- | 8-9-61 | -- | -- | -- | 50 | 18 | 98 | 10 | 332 | 0 | 57 | 56 | -- | -- | -- | 452 | 201 | 0 | 814 | 50 | 3.0 | 7.9 | $C_3$-$S_1$ |
| 36/40-25dcb1-2 | do | .21 | 12-6-61 | 42 | -- | -- | 56 | 23 | 190 | 8.1 | 360 | 6 | [a]151 | 140 | -- | -- | .6 | 752 | 236 | 0 | 1,260 | 63 | 4.9 | 8.3 | $C_3$-$S_1$ |
| 36/40-35bbc1-1 | Station F | 3.05 | 8-8-61 | 81 | -- | -- | 53 | 15 | 82 | 9.3 | 333 | 0 | 47 | 40 | -- | -- | -- | 410 | 192 | 0 | 737 | 47 | 2.6 | 8.1 | $C_2$-$S_1$ |
| 36/40-35bbc1-2 | do | .48 | 12-6-61 | 44 | -- | -- | 54 | 24 | 174 | 7.2 | 332 | 14 | 152 | 113 | -- | -- | .5 | 702 | 233 | 0 | 1,190 | 61 | 5.0 | 8.5 | $C_3$-$S_1$ |
| 36/40-28bad1-1 | Station G | 4.55 | 8-8-61 | 80 | -- | -- | 45 | 14 | 76 | 9.6 | 296 | 0 | 51 | 38 | -- | -- | -- | 380 | 171 | 0 | 671 | 47 | 2.5 | 8.0 | $C_2$-$S_1$ |
| 36/40-28bad1-2 | do | 1.23 | 12-6-61 | 44 | -- | -- | 54 | 21 | 126 | 5.0 | 338 | 9 | 105 | 72 | -- | -- | .6 | 559 | 221 | 0 | 956 | 55 | 3.8 | 8.4 | $C_3$-$S_1$ |
| 36/40-21bcc1-1 | Station H | 5.21 | 8-8-61 | 83 | -- | -- | 54 | 16 | 97 | 9.6 | 338 | 0 | 70 | 58 | -- | -- | -- | 471 | 200 | 0 | 811 | 50 | 3.0 | 8.1 | $C_3$-$S_1$ |
| 36/40-21bcc1-2 | do | 1.37 | 12-6-61 | 42 | -- | -- | 59 | 20 | 152 | 5.4 | 382 | 0 | 112 | 105 | -- | -- | .8 | 642 | 230 | 0 | 1,110 | 58 | 4.4 | 8.2 | $C_3$-$S_1$ |
| 36/40-17cdd1-1 | Station I | 5.66 | 8-8-61 | 83 | -- | -- | 54 | 16 | 91 | 10 | 338 | 0 | 54 | 54 | -- | -- | -- | 445 | 199 | 0 | 788 | 48 | 2.8 | 8.2 | $C_3$-$S_1$ |
| 36/40-17cdd1-2 | do | 1.28 | 12-6-61 | 42 | -- | -- | 54 | 18 | 143 | 5.6 | 364 | 0 | 102 | 96 | -- | -- | .8 | 598 | 210 | 0 | 1,050 | 59 | 4.3 | 8.1 | $C_3$-$S_1$ |
| 36/39-13aaa1-1 | Station J | 3.16 | 8-8-61 | 82 | -- | -- | 51 | 13 | 91 | 12 | 324 | 0 | 59 | 52 | -- | -- | -- | 437 | 182 | 0 | 758 | 50 | 2.9 | 8.0 | $C_3$-$S_1$ |
| 36/39-13aaa1-2 | do | .55 | 12-6-61 | 40 | -- | -- | 50 | 17 | 130 | 10 | 333 | 8 | 79 | 80 | -- | -- | .6 | 538 | 194 | 0 | 932 | 58 | 4.1 | 8.3 | $C_3$-$S_1$ |
| 36/39- 4aad1-1 | Station K | 3.76 | 8-9-61 | 73 | -- | -- | 46 | 13 | 91 | 10 | 298 | 3 | 61 | 52 | -- | -- | -- | 423 | 169 | 0 | 740 | 52 | 3.0 | 8.3 | $C_2$-$S_1$ |
| 36/39- 4aad1-2 | do | .70 | 12-5-61 | 43 | -- | -- | 50 | 14 | 103 | 8.5 | 282 | 12 | [a] 80 | 60 | -- | -- | .5 | 467 | 184 | 0 | 794 | 53 | 3.4 | 8.5 | $C_3$-$S_1$ |
| 36/38- 2bac1-1 | Station L | 4.82 | 8-9-61 | 74 | -- | -- | 46 | 11 | 91 | 9.6 | 288 | 0 | 66 | 50 | -- | -- | -- | 416 | 161 | 0 | 716 | 53 | 3.1 | 8.1 | $C_2$-$S_1$ |
| 36/38- 2bac1-2 | do | 1.65 | 12-4-61 | 38 | -- | -- | 51 | 13 | 94 | 3.9 | 296 | 0 | 70 | 48 | -- | -- | .4 | 426 | 180 | 0 | 742 | 53 | 3.0 | 8.2 | $C_2$-$S_1$ |
| 36/38-17aca1-1 | Station M | 4.90 | 8-9-61 | 76 | -- | -- | 47 | 9.7 | 91 | 9.1 | 276 | 0 | 64 | 55 | -- | -- | -- | 412 | 158 | 0 | 732 | 54 | 3.2 | 8.2 | $C_2$-$S_1$ |
| 36/38-17aca1-2 | do | 2.94 | 12-5-61 | 38 | -- | -- | 60 | 18 | 104 | 8.8 | 335 | 0 | [a] 85 | 68 | -- | -- | .5 | 509 | 222 | 0 | 873 | 49 | 3.0 | 8.2 | $C_3$-$S_1$ |
| 36/38-20ccb1-1 | Station N | 5.69 | 8-9-61 | 74 | -- | -- | 48 | 13 | 98 | 9.4 | 286 | 0 | 74 | 61 | -- | -- | -- | 444 | 174 | 0 | 770 | 53 | 3.2 | 8.1 | $C_3$-$S_1$ |
| 36/38-20ccb1-2 | do | 5.07 | 12-5-61 | 40 | -- | -- | 58 | 17 | 99 | 8.8 | 316 | 0 | 81 | 69 | -- | -- | .5 | 489 | 214 | 0 | 805 | 49 | 2.9 | 8.1 | $C_3$-$S_1$ |
| 36/37-34dda1-1 | Station O | 6.46 | 8-9-61 | 71 | -- | -- | 57 | 14 | 100 | 10 | 316 | 0 | 78 | 65 | -- | -- | -- | 480 | 200 | 0 | 831 | 51 | 3.1 | 8.2 | $C_3$-$S_1$ |
| 36/37-34dda1-2 | do | 3.72 | 12-5-61 | 40 | -- | -- | 55 | 16 | 100 | 8.2 | 286 | 9 | 78 | 70 | -- | -- | .4 | 477 | 204 | 0 | 836 | 50 | 3.0 | 8.4 | $C_3$-$S_1$ |
| 35/37- 9abb1-1 | Station P | 7.81 | 8-9-61 | 70 | -- | -- | 56 | 14 | 100 | 10 | 322 | 0 | 69 | 62 | -- | -- | -- | 469 | 199 | 0 | 826 | 51 | 3.1 | 8.2 | $C_3$-$S_1$ |
| 35/37- 9abb1-2 | do | 4.28 | 12-5-61 | 41 | -- | -- | 58 | 16 | 109 | 8.8 | 281 | 21 | [a] 90 | 72 | -- | -- | .4 | 513 | 212 | 0 | 860 | 51 | 3.2 | 8.6 | $C_3$-$S_1$ |
| 35/36-12dcb1-1 | Station Q | 12.7 | 8-9-61 | 72 | -- | -- | 55 | 15 | 84 | 9.0 | 304 | 0 | 58 | 54 | -- | -- | -- | 424 | 197 | 0 | 758 | 47 | 2.6 | 8.0 | $C_3$-$S_1$ |
| 35/36-12dcb1-2 | do | 8.84 | 12-5-61 | 47 | -- | -- | 55 | 15 | 80 | 5.4 | 269 | 8 | [a] 65 | 54 | -- | -- | .3 | 415 | 200 | 0 | 728 | 46 | 2.5 | 8.5 | $C_2$-$S_1$ |
| 35/36-14bcc1-1 | Station R | 16.3 | 8-9-61 | 72 | -- | -- | 55 | 15 | 80 | 8.6 | 288 | 0 | 69 | 60 | -- | -- | -- | 430 | 200 | 0 | 766 | 45 | 2.5 | 8.1 | $C_3$-$S_1$ |
| 35/36-14bcc1-2 | do | 13.0 | 12-5-61 | 46 | -- | -- | 53 | 16 | 82 | 6.7 | 260 | 4 | 71 | 62 | -- | -- | .3 | 423 | 198 | 0 | 739 | 46 | 2.5 | 8.3 | $C_2$-$S_1$ |
| 35/36-21abb1-1 | Station S | 17.8 | 8-9-61 | 73 | -- | -- | 56 | 17 | 84 | 7.4 | 293 | 0 | 76 | 60 | -- | -- | -- | 444 | 211 | 0 | 786 | 45 | 2.5 | 8.2 | $C_3$-$S_1$ |
| 35/36-21abb1-2 | do | 14.8 | 12-6-61 | 39 | -- | -- | 58 | 17 | 86 | 6.0 | 263 | 8 | [a] 79 | 69 | -- | -- | .5 | 453 | 214 | 0 | 782 | 46 | 2.5 | 8.4 | $C_3$-$S_1$ |
| 35/36-21bbb1-1 | Station T | 17.9 | 8-9-61 | 75 | -- | -- | 56 | 16 | 84 | 8.8 | 298 | 0 | 62 | 63 | -- | -- | -- | 437 | 205 | 0 | 786 | 46 | 2.5 | 8.1 | $C_3$-$S_1$ |
| 35/36-21bbb1-2 | do | 14.0 | 12-6-61 | 39 | -- | -- | 57 | 17 | 90 | 3.3 | 260 | 8 | 78 | 69 | -- | -- | .5 | 451 | 212 | 0 | 787 | 48 | 2.7 | 8.5 | $C_3$-$S_1$ |
| 35/35-36bdb1-1 | Station U | 17.3 | 8-9-61 | 82 | -- | -- | 54 | 17 | 84 | 8.8 | 290 | 0 | 76 | 64 | -- | -- | -- | 447 | 203 | 0 | 783 | 46 | 2.6 | 8.1 | $C_3$-$S_1$ |
| 35/35-36bdb1-2 | do | 13.5 | 12-6-61 | 39 | -- | -- | 56 | 17 | 84 | 6.9 | 256 | 12 | 77 | 70 | -- | -- | .5 | 449 | 210 | 0 | 782 | 45 | 2.5 | 8.5 | $C_3$-$S_1$ |
| 34/36- 2ddb1 | Rose Creek | 0.03 | 7-18-61 | 77 | 23 | 0.00 | 49 | 26 | 20 | 2.1 | 273 | 0 | 28 | 17 | 0.1 | 1.6 | 0 | 301 | 228 | 4 | 505 | 16 | 0.6 | 7.9 | $C_2$-$S_1$ |
| 35/38-15ccd1 | Thomas Creek | .01 | 7-20-61 | 62 | 21 | .00 | 58 | 11 | 11 | 2.7 | 208 | 4 | 25 | 4.5 | .5 | .2 | .1 | 240 | 191 | 14 | 403 | 11 | .3 | 8.4 | $C_2$-$S_2$ |
| 35/38-11aca1 | Stream in Water Canyon | .03 | 7-27-61 | 62 | 20 | .00 | 48 | 12 | 12 | 1.9 | 180 | 2 | 31 | 7.0 | .4 | 1.1 | .0 | 224 | 168 | 17 | 358 | 13 | .4 | 8.3 | $C_2$-$S_1$ |
| 35/39-12ddc1 | Pole Creek | .04 | 8- 8-61 | 64 | 17 | .00 | 22 | 5.1 | 14 | 6.5 | 102 | 0 | 15 | 8.0 | .3 | .1 | .1 | 138 | 76 | 0 | 216 | 27 | .7 | 7.1 | $C_1$-$S_1$ |

[a] Calculated