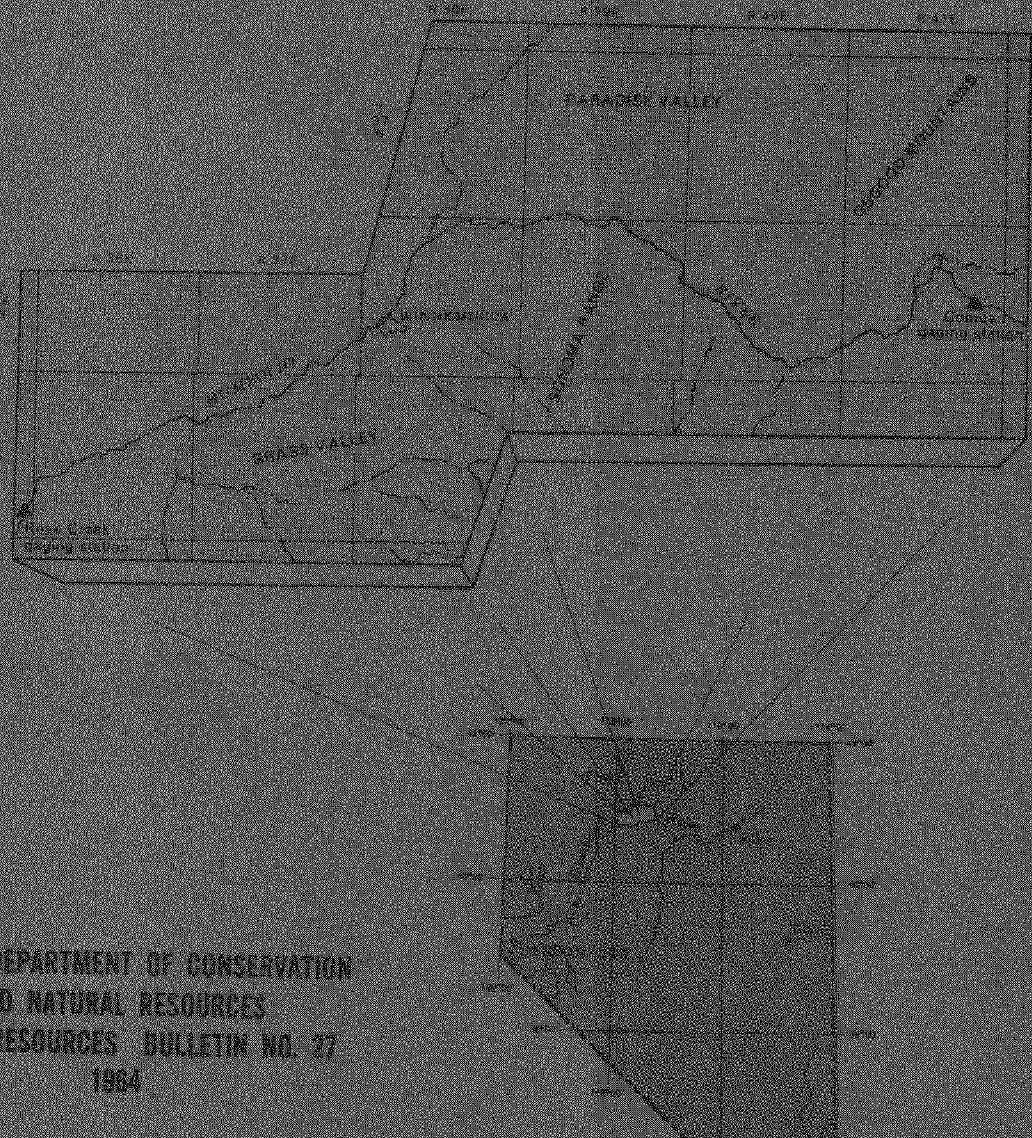
WATER IN THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEVADA



NEVADA DEPARTMENT OF CONSERVATION
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STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

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WATER IN THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEVADA

By Philip Cohen

A Summary of the Water-resources Studies of the Interagency Humboldt River Research Project in the Winnemucca Area

Prepared in cooperation with the

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

1964

SPO, Carson City, Nevada, 1964

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WATER IN THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEVADA

By PHILIP COHEN

ABSTRACT

Most of the work of the interagency Humboldt River Research Project in the Winnemucca reach of the Humboldt River valley has been completed. More than a dozen state and federal agencies and several private organizations and individuals participated in the study. The major objective of the project, which began in 1959, is to evaluate the water resources of the entire Humboldt River basin. However, because of the large size of the basin, most of the work during the first 5 years of the project was carried on in the Winnemucca area. The purpose of this report is to summarize briefly and simply the information regarding the water resources of the Winnemucca area, especially the quantative aspects of the flow system, given in previous reports prepared as a result of the project.

The Winnemucca reach of the Humboldt River valley, which is in north-central Nevada, is about 200 miles downstream from the headwaters of the Humboldt River, and includes that part of the valley between the Comus and Rose Creek gaging stations. Average annual inflow to the storage area (the valley lowlands) in the Winnemucca reach in water years 1949–62 was about 250,000 acre-feet. Of this amount, about 68 percent was Humboldt River streamflow as measured at the Comus gaging station, 23 percent was precipitation directly on the storage area, 6 percent was subsurface ground-water inflow, and about 3 percent was tributary streamflow. Average annual streamflow at the Rose Creek gaging station during the same period was about 155,000 acre-feet, or about 17,000 acre-feet less than that at the Comus gaging station. Nearly all the loss in streamflow was consumed by evapotranspiration in the project area. Total average annual evapotranspiration losses during the period were about 115,000 acre-feet, or about 42 percent of the total average annual outflow.

The most abundant ions in the ground and surface water in the area commonly are sodium and bicarbonate. Much of this water has a dissolved-solids content ranging from 500 to 750 ppm; however, locally, the dissolved-solids content of the ground water is more than 5,000 ppm. The chemical quality of the Humboldt River, especially during the low flow, reflects the chemical quality of ground-water inflow from tributary areas that discharge into the river. Almost all the water in the project area is moderately hard to very hard; otherwise it commonly is suitable for most uses.

Increased ground-water development, the conjunctive use of ground and surface water, and increased irrigation efficiency probably would conserve much of the water presently consumed by nonbeneficial evapotranspiration. However, intensive ground-water development, especially from the highly permeable medial gravel subunit, will decrease the flow of the Humboldt River to the extent that some of the pumpage may not be offset by a corresponding decrease in natural evapotranspiration losses. Such depletions of streamflow will therefore infringe upon downstream surface-water rights.

The results of this study indicate that the Humboldt River and ground water in the unconsolidated deposits beneath and adjacent to the river in the Winnemucca area are closely related. There is little doubt that, in general, somewhat similar conditions exist elsewhere in the Humboldt River valley. As was contemplated at the beginning of the project, additional detailed studies are needed —both upstream and downstream from the Winnemucca area—to define adequately the flow system and the interrelations among the components of the system in the remainder of the valley. Before proceeding with additional detailed studies, however, a 1-year overall appraisal of the water resources of the entire basin should be considered. A major objective of this study would be to provide information that would help select the next subarea of the valley to be studied in detail and to decide upon which of the methods of study developed or used in the Winnemucca area would be most effective in the future studies.

CHAPTER 1

INTRODUCTION

In recent years the nation has become increasingly aware of its water problems, both current and future. In Nevada, the most arid state in the nation, man has been keenly aware of water problems, notably the shortage of water, for at least the last several thousand years—he had to be aware of these problems to survive.

Largely as a result of increased agricultural development, major changes in the use of water have taken place in Nevada in the past 50 years; these changes have created and are creating local water shortages and related problems. Nevertheless, the major task for man has not changed since his earliest days in the area—that of obtaining sufficient water of suitable chemical quality for his needs.

Nevada has many other water problems, including those involving water rights and related legal matters, methods of storing and transporting water, water quality and pollution, flood control, hydroelectric power, and recreational use, just to mention a few. All these problems have one fundamental feature in common; they can be solved efficiently only when sufficient scientific information is available regarding the total water supply and its environment.

THE HUMBOLDT RIVER RESEARCH PROJECT

Recognizing the need for accurate technical information about water, the Nevada State Legislature authorized the Humboldt River Research Project in 1959 (Chap. 97, Stats. 1959). The major objective of the study was to evaluate the water resources of the Humboldt River valley as thoroughly as possible, and thus to provide the information that would be helpful in planning for the most effective use of these resources.

Choice of the Area to Be Studied and Objectives of the Study

The Humboldt River is the longest stream in Nevada and carries more water than any other stream entirely within the State. Moreover, about 265,000 acres in the Humboldt River valley, or about one-third the cultivated land in the State, is irrigated with water diverted from the river and its major tributaries. Inasmuch as almost the entire flow of the river has been appropriated, additional agricultural, industrial, and municipal development is legally possible only insofar as these developments do not infringe upon existing water rights. Thus, to protect the existing economy, to determine whether the available water supply is being used most effectively, and to investigate the possibility of developing additional water in this economically vital part of the State, the Humboldt River valley was chosen as the area for intensive study.

Because of the large size of the Humboldt River drainage basin (Fig. 1), almost 18,000 square miles, the agencies cooperating in the project decided that it would not be feasible to study the entire basin at one time. Accordingly, most of the work during the first 5 years of the project was carried on in the Winnemucca reach of the valley. This reach is in North-central Nevada, and extends from a point about 2 miles east of the

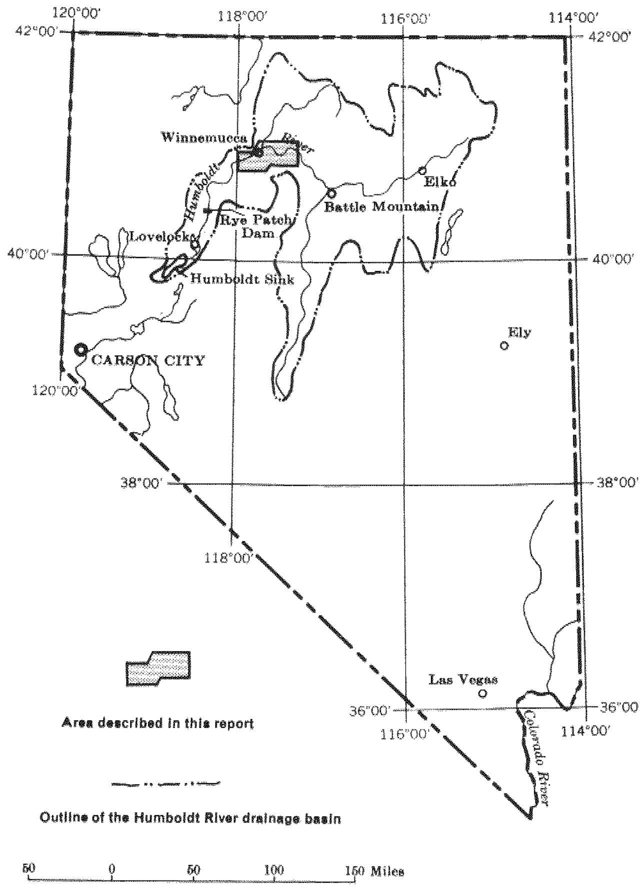


FIGURE 1. Map of Nevada showing location of the area described in this report.

Comus gaging station ("Humboldt River at Comus") downstream to the Rose Creek gaging station ("Humboldt River near Rose Creek"). (See cover illustration.) It is about 520 square miles in area and is almost entirely in Humboldt County; only about 17 square miles is in Pershing County.

Organization of the Study

The Nevada Department of Conservation and Natural Resources, the coordinating agency for the Humboldt River Research Project, requested and received the cooperation of almost every local, state, and federal agency, and many private organizations and individuals concerned with water in Nevada. It was agreed that each participating agency would evaluate those features of the water situation that it was best equipped to study—best equipped with regard to experience and available funds.

Inasmuch as water occurs above, on, and within the earth, many aspects of the atmosphere, the land surface, and the rocks beneath the surface were studied. Specialists in hydrology, geology, meteorology, the agricultural sciences, and biology were called upon to carry out the studies. The organizations participating in the project in the Winnemucca area and their principal responsibilities are outlined briefly in Table 1.

WHY THIS REPORT WAS WRITTEN AND WHAT IT CONTAINS

If a research project is to be truly successful, the information obtained as a result of the study must be made available to those who can benefit from it. Accordingly, the agencies participating in the study have completed many technical reports, some of them quite long and very detailed, describing the results of the Humboldt River Research Project in the Winnemucca area; most have been published or will be in the near future. (See pp. 67 and 68.) In 1962 the Nevada Department of Conservation and Natural Resources requested that the U.S. Geological Survey prepare the present report to summarize as briefly and simply as possible the results of the water-resources studies of all the participating agencies when those studies were completed, or nearly so.

To achieve ultimately the most effective use of the available water supply, those individuals and agencies concerned with utilizing and managing that supply indicated that they had to know as much as possible about the "flow system" in the study area—the movement of water into, within, and out of the area. They wanted to know how the system operated, how much water was in the system, what the chemical quality of the water was and how it changes as it moves through the flow system.

As is described in the previously prepared reports, the flow system in the Humboldt River valley near Winnemucca is moderately complex (Fig. 2). Most of the surface water reaching the area is derived from precipitation (Fig. 2, item 1), Humboldt River inflow (item 2), and tributary stream inflow (item 3). Additional surface water in the form of Humboldt River streamflow is derived from the zone of saturation by seepage gain (item 20). (See Chap. 3 for definitions of

TABLE 1. ORGANIZATIONS PARTICIPATING IN THE HUMBOLDT RIVER RESEARCH PROJECT NEAR WINNEMUCCA, NEVADA

Organization	Principal responsibilities
Nevada Agencies	
Nevada Department of Conservation and Natural Resources	Project coordinator; participated in field experiments involving the use of water by non-beneficial woody phreatophytes and evaporation of water from bare soil; collection of weather records.
Division of Water Resources	Supplied information on diversions for irrigation.
Division of Forestry	Gave technical advice on transplanting phreatophytes.
Nevada Bureau of Mines	Made geologic and geophysical studies.
University of Nevada	
Department of Geology	Made geologic and geophysical studies.
Desert Research Institute	Made geologic and geophysical studies.
Federal Agencies	
U.S. Agricultural Research Service	Made hydrologic studies and phreatophytes experiments.
U.S. Bureau of Land Management	Participated in replacement-vegetation studies.
U.S. Bureau of Reclamation	Cooperated in phreatophyte experiments.
U.S. Geological Survey	Made hydrologic studies, including evapotranspiration experiments.
U.S. Soil Conservation Service	Made soils and vegetation studies.
U.S. Weather Bureau	Gave technical advice regarding collection of weather data.
Other Organizations	
University of Illinois, Department of Geology	Made hydrogeologic and geophysical studies.
Southern Pacific Company	Supplied topographic and geologic maps.

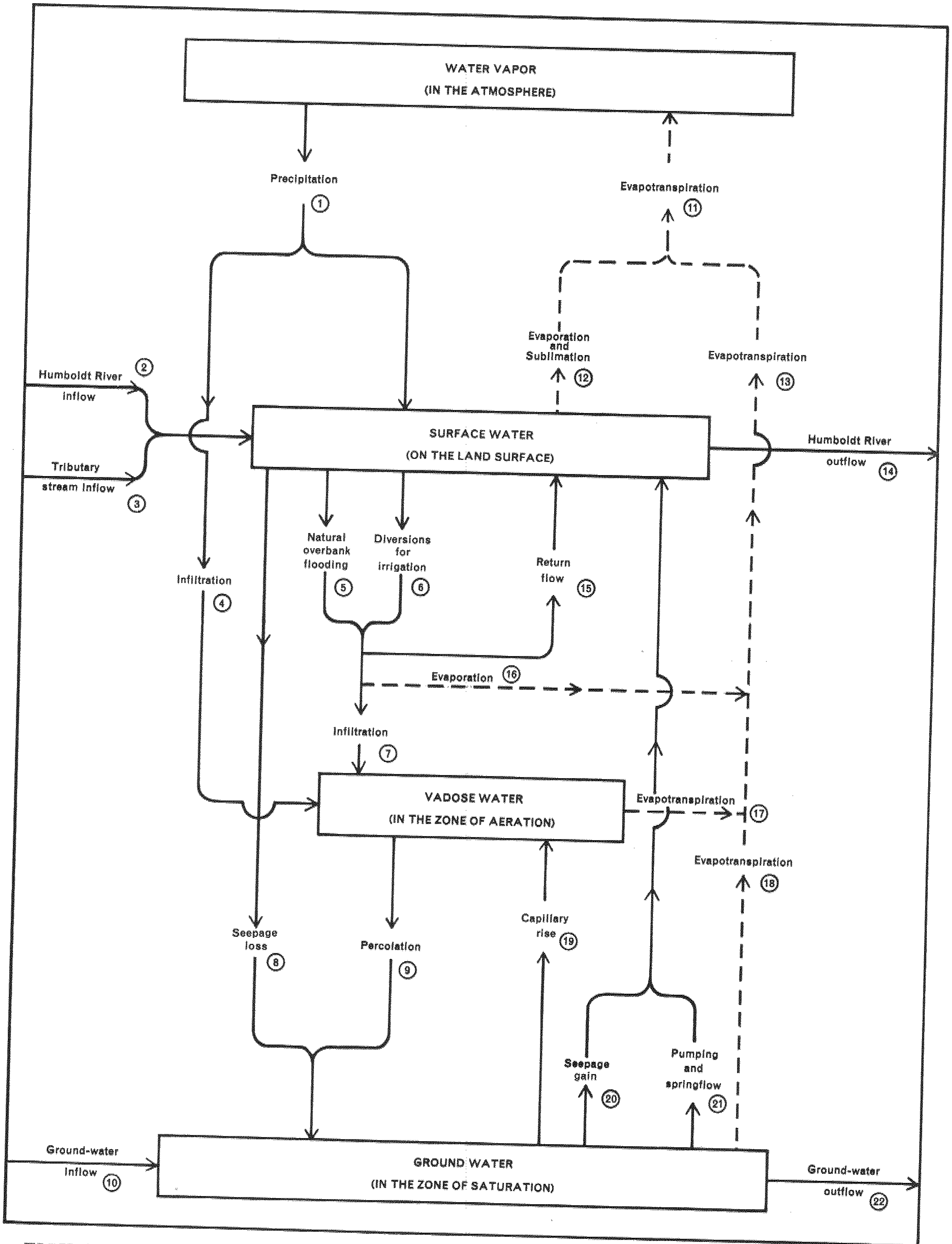


FIGURE 2. Generalized flow diagram showing the movement of water (the flow system) in the Humboldt River valley near Winnemucca, Nevada. Circled numbers are referred to in the text.

most of the technical terms used in this report.) Finally, ground water that is discharged from wells and by springflow (item 21) supplies the least amount of water to the land surface.

Most of the surface water is discharged from the area as Humboldt River streamflow at the Rose Creek gaging station (item 14). The second largest amount evaporates from free-water surfaces and is lost by sublimation (items 12 and 16). The remainder of the surface water infiltrates into the zone of aeration (item 7) or seeps into the zone of saturation (item 8).

The infiltration of precipitation (item 4) and surface water (item 7), plus capillary rise from the zone of saturation (item 19) are the sources of practically all the vadose water in the project area. Water is discharged from the zone of aeration by percolation into the zone of saturation (item 9) and by evapotranspiration (item 17).

Seepage loss of surface water (item 8) and the percolation of water from the zone of aeration (item 9) are the sources of some of the ground water in the area. The source of the remainder of the ground water is subsurface inflow (item 10). Ground water is discharged from the area mainly by evapotranspiration (item 18) and to a lesser extent by seepage to the Humboldt River (item 20), pumping and springflow (item 21), and ground-water outflow near the Rose Creek gaging station (item 22).

Because effective utilization and management of the water resources of the project area depend upon as thorough an understanding of the flow system as possible, much of the remainder of this report is directed toward a step by step analysis of the flow diagram shown in Figure 2, including quantitative estimates of inflow to, outflow from, and changes in the amount of water in storage in the system. Several aspects of the water quality of the area are reviewed briefly. In addition, water budgets for three selected periods are developed. Finally, the effects of man's activities on the flow system, and the achievement of the most effective use of the water resources of the valley are considered.

Practically all the mathematical derivations and calculations are omitted from this report; however, the more significant results of these calculations are given. For those who are interested in the mathematical derivations, the supporting basic data, theoretical considerations, or a more detailed discussion of a particular phase of the study, a list of reports containing this additional information is given in the selected bibliography at the end of this report.

The cooperation and assistance of personnel from the organizations listed in Table 1 and of the residents of the project area are gratefully acknowledged. Without their help and that of my colleagues in the U.S. Geological Survey this report could not have been written.

CHAPTER 2

GENERAL GEOGRAPHIC FEATURES

Geography is the science concerned with the description of the earth and its life, especially of the land, water, and air, and of the plants and animals, including man and his activities. Many geographic features affect the water resources of the Humboldt River valley; some of the more significant of these are summarized in this chapter.

LANDFORMS AND DRAINAGE

The major landforms in the study area are four mountain ranges, two large intervening valleys, and the Humboldt River and its flood plain.

Mountains

The mountain ranges trend roughly northward, their crests ranging in altitude from about 7,500 to 9,500 feet. They are, in downstream order, the Osgood Mountains and their southward extension, Edna Mountain, the Sonoma Range, Winnemucca Mountain, which is the southernmost extension of the Santa Rosa Mountains, and the East Range.

The ranges are the types that commonly are referred to as fault-block mountains. They are large blocks of consolidated rocks that have been uplifted relative to the intervening valleys along steeply dipping cracks, or faults, in the earth's crust. Earthquakes, which are common in and near the study area, are associated with movement along these faults.

Paradise and Grass Valleys

The south end of Paradise Valley and the north end of Grass Valley are included in the area described in this report. That part of Paradise Valley included in the study area is bounded by the Osgood Mountains on the east and Winnemucca Mountain on the west; Grass Valley is bounded by the Sonoma Range on the east and the East Range on the west. The floors of both valleys are remarkably flat and represent the bottom of a large and deep lake, known as Lake Lahontan, which covered the area some 10 to 70 thousand years ago. The floor of Paradise Valley is almost horizontal and that of Grass Valley slopes northwestward at about 3 to 4 feet per mile.

The maximum altitude of the level of Lake Lahontan was nearly 4,400 feet. Wave-cut terraces and scarps, beaches, gravel bars, and spits that were formed near the margins of the lake occur in both valleys at altitudes ranging from about 4,260 to 4,400 feet. After the final desiccation of Lake Lahontan, wind and stream action modified the former featureless bottom of the lake. Because of the recent age of the deposits, the drainage systems on the floors of Paradise and Grass Valleys are poorly developed; stream channels are only a few feet deep and can carry only small amounts of runoff. (See Russell, 1885, Cohen, 1962c, and Hawley and Wilson, 1964, for additional information regarding Lake Lahontan.)

Wind action has scoured shallow depressions in the deposits of the former lake and has formed sand dunes more than 20 feet high. Most of the dunes have been stabilized by vegetation, but some in Paradise Valley are actively moving eastward.

Alluvial Apron

The alluvial apron is the area of intermediate slope between the steep rugged mountains and the subdued valley floors. It is composed largely of coalescing alluvial fans, which are cone-shaped deposits of clay, silt, sand, and gravel that have formed where streams discharge from the mountains onto the valley floor. Pediments, which are erosional features that superficially resemble alluvial fans, also form part of the alluvial apron, especially along the northwest slope of the Sonoma Range. (See Hawley and Wilson, 1964, for a detailed description of the alluvial apron.)

Streams and Related Landforms

The Humboldt River is the largest stream in the area. The river heads in the mountains in northeastern Nevada and flows westward for about 200 miles before entering the Winnemucca area. After leaving the area at the Rose Creek gaging station, it flows southwestward for about 40 miles to Rye Patch Reservoir. From the reservoir, it continues southwestward for about 20 miles to the Humboldt Sink, which normally is a dry lake. The drainage area of the Humboldt River upstream from the Comus gaging station is 12,100 square miles; it is 15,200 square miles upstream from the Rose Creek gaging station, and 16,100 square miles upstream from Rye Patch Dam.

Probably the most striking feature of the Humboldt River is its winding, meandering course. The straight-line distance between the Comus and Rose Creek gaging stations is a little more than 35 miles; however, the distance measured along the meandering channel is about 92 miles. The river gradient averages about 1.7 feet per mile. The depth of the channel ranges from about 6 to 15 feet and averages about 10 feet; its width ranges from about 40 to 150 feet and averages about 80 feet.

The flood plain of the Humboldt River, which is the nearly flat surface bordering the river and which periodically is covered by flood water, ranges in width from about 0.2 mile to 5 miles. The flood-plain distance between the Comus and Rose Creek gaging stations, the distance measured along straight segments parallel to the main thread of the river, is about 45 miles. The average gradient of the flood plain is nearly 3.4 feet per mile, or about twice that of the river.

Two discontinuous terraces separate the flood plain from the floors of Paradise and Grass Valleys. Locally, both terraces have been removed by erosion, and scarps about 50 feet in height border the flood plain. The lower of the two terraces is best preserved downstream from Winnemucca, and the higher terrace is best preserved upstream.

The more significant tributary streams in the project area and their drainage areas are listed in downstream order in Table 2. Although all these streams on the alluvial apron and in the valley lowlands commonly are dry during most of the year, some in the mountains contain water for short distances during the entire year.

CLIMATE

The climate of the valley lowlands is arid to semiarid; it is characterized by low humidity and precipitation, and by an abundance of sunshine. Precipitation, which averages about 8 inches per year on the valley floor, increases with altitude (Fig. 3) and averages more than 20 inches per year on the highest peaks, where the climate is subhumid.

The U.S. Weather Bureau has collected weather records at and near Winnemucca since 1870. The significant temperature and precipitation data are summarized in Table 3 and Figures 4 and 5. The average daily temperature recorded on the valley floor is 49° F. The highest temperature ever recorded was 108° F., on July 20, 1931; the lowest temperature was –36° F., on January 21, 1937. Freezing temperatures have been recorded in every month of the year; however, they are not common in June, July, and August. The daily temperature commonly fluctuates 30° F. to 40° F., and sometimes more than 50° F.

The average annual precipitation for the period 1871–1962 was 8.40 inches. In an average year nearly half the precipitation occurs in the 4-month period December-March. On the other hand, less than 2 inches, or about 20 percent of the yearly precipitation, normally falls during the growing season of May-August. Because of the small amount of precipitation, all crops in the area must be irrigated.

Most of the precipitation occurs as snow in the winter, and as infrequent and scattered thunderstorms in the summer. The maximum daily precipitation ever recorded was 1.58 inches, on October 24, 1951; the maximum monthly precipitation, 5.23 inches, occurred in March 1884.

Only meager data are available regarding evaporation rates in the Winnemucca area. These are summarized in other reports and cannot be used reliably to estimate the long-term average annual rate of evaporation from free-water surfaces. Data given by Kohler, Nordenson, and Baker (1959) and data obtained in other parts of Nevada suggest that the long-term average annual rate of evaporation from free-water surfaces in this area is 4 to 5 feet.

TABLE 2. SMALLER STREAMS TRIBUTARY TO THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEVADA

Stream or canyon	Drainage area (square miles)	Point above which drainage area was measured
Kelly Creek	300	Where it joins the Humboldt River
Rock Creek	52	At U.S. Highway 40
Pole Creek	13	At U.S. Highway 40
Devils Canyon	5	At U.S. Highway 40
Little Humboldt River	1,800	Where it joins the Humboldt River
Harmony Canyon	9	At U.S. Highway 40
Water Canyon	7	At diversion ditch three-quarters of a mile south of Winnemucca
Thomas Canyon	11	At Grass Valley road
Clear Creek	480	At U.S. Highway 40
Rose Creek	8	Where it joins Clear Creek

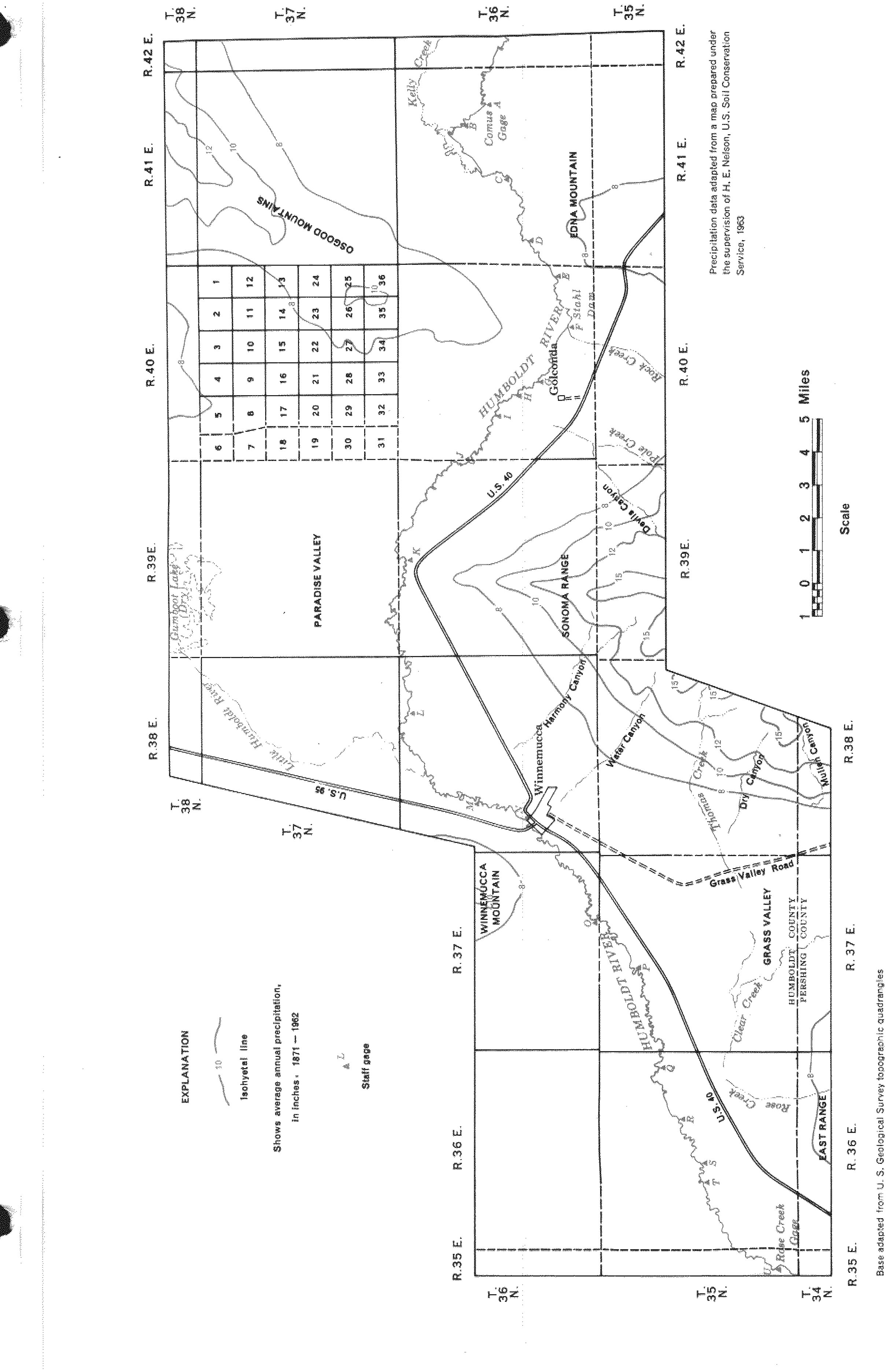


FIGURE 3. Map of the Humboldt River valley near Winnemucca, Nevada, showing the estimated average annual precipitation, in inches.

TABLE 3. SUMMARY OF CLIMATOLOGICAL DATA AT AND NEAR WINNEMUCCA, NEVADA, 1871–1962
(Data from published records of the U.S. Weather Bureau)

	Period (years)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	The year
Average monthly maximum temperature, degrees Fahrenheit	83	52	58	69	77	86	94	99	97	90	81	67	56	78
Average monthly minimum temperature, degrees Fahrenheit	83	—4	3	13	19	26	33	42	38	26	18	7	0	18
Average monthly temperature, degrees Fahrenheit	83	28	34	40	47	55	62	72	69	60	48	38	30	49
Highest temperature of record, degrees Fahrenheit	83	61	69	82	88	98	104	108	106	103	90	75	70	108
Lowest temperature of record, degrees Fahrenheit	83	—36	—26	—3	9	12	23	29	26	12	9	—9	—27	—36
Average monthly precipitation, inches	91	1.05	.92	.90	.78	.88	.68	.22	.18	.36	.67	.77	.99	.70
Maximum monthly precipitation, inches	91	3.08	2.75	5.23	3.34	2.82	2.86	1.55	1.26	1.53	2.93	3.78	3.40	5.23
Minimum monthly precipitation, inches	91	0	Trace	0	.06	.02	0	0	0	0	0	0	Trace	0
Maximum 24-hour precipitation, inches	82	1.45	.99	.97	.92	1.44	1.56	1.85	.59	1.00	1.58	1.56	1.08	1.85

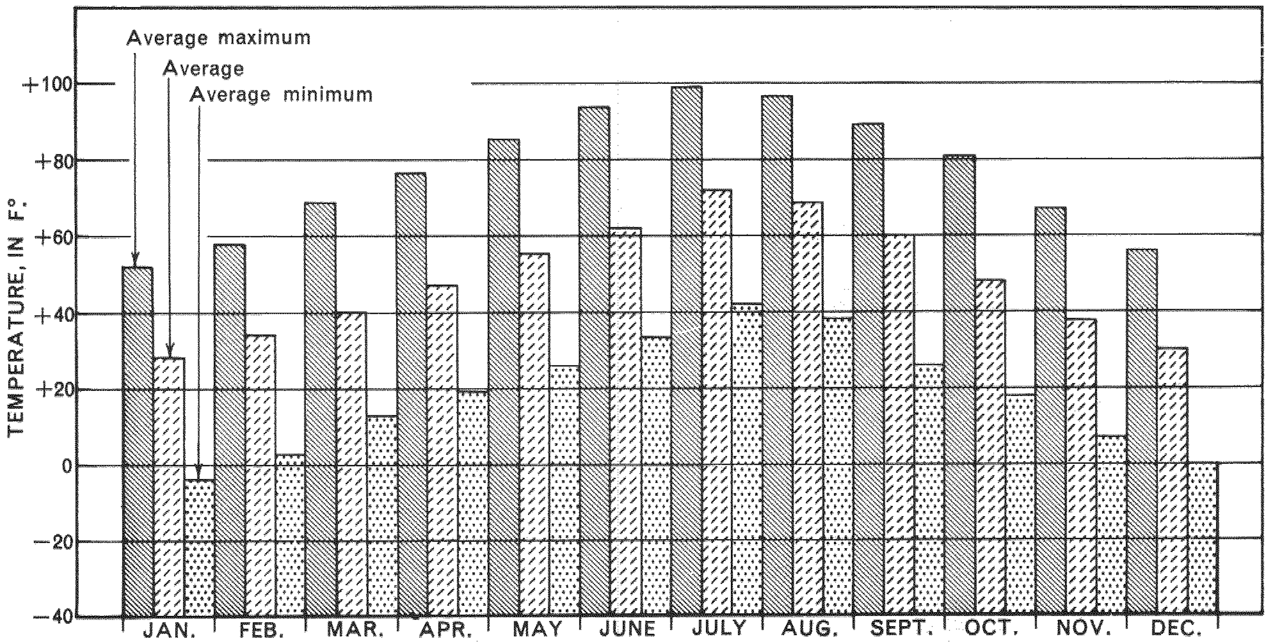


FIGURE 4. Average monthly temperature at and near Winnemucca, Nevada, 1872–1962.

VEGETATION

The native plants in the Winnemucca area are typical of those in the northern part of the Great Basin. Sagebrush and shadscale are the most abundant shrubs on the alluvial apron, and greasewood is the most abundant shrub in the valley lowlands. Native grasses cover much of the flood plain of the Humboldt River; however, willow and wildrose locally are the predominant plants on the flood plain, especially in abandoned channels of the Humboldt River. The most common varieties of trees are pinyon pine and juniper, which are found mainly in the mountains, and a few scattered cottonwood on the valley lowlands.

A vegetation map for the Winnemucca area has been prepared by the U.S. Soil Conservation Service under the supervision of E. A. Naphan (written communication, 1964). Twenty-nine vegetative types, which include the major species of plants in the area, were defined for the purpose of preparing the map.

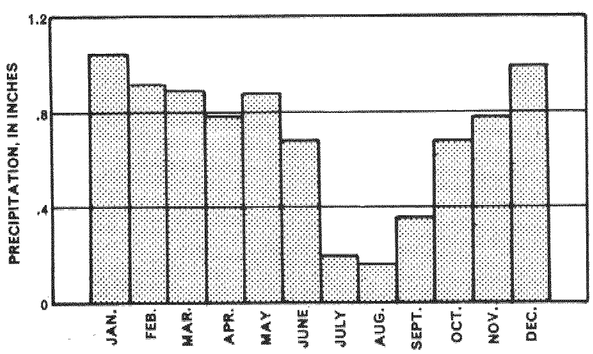


FIGURE 5. Average monthly precipitation at and near Winnemucca, Nevada, 1871–1962.

For the purpose of this report, the vegetative types defined by the Soil Conservation Service are grouped into five major units in Figure 6, and are listed below.

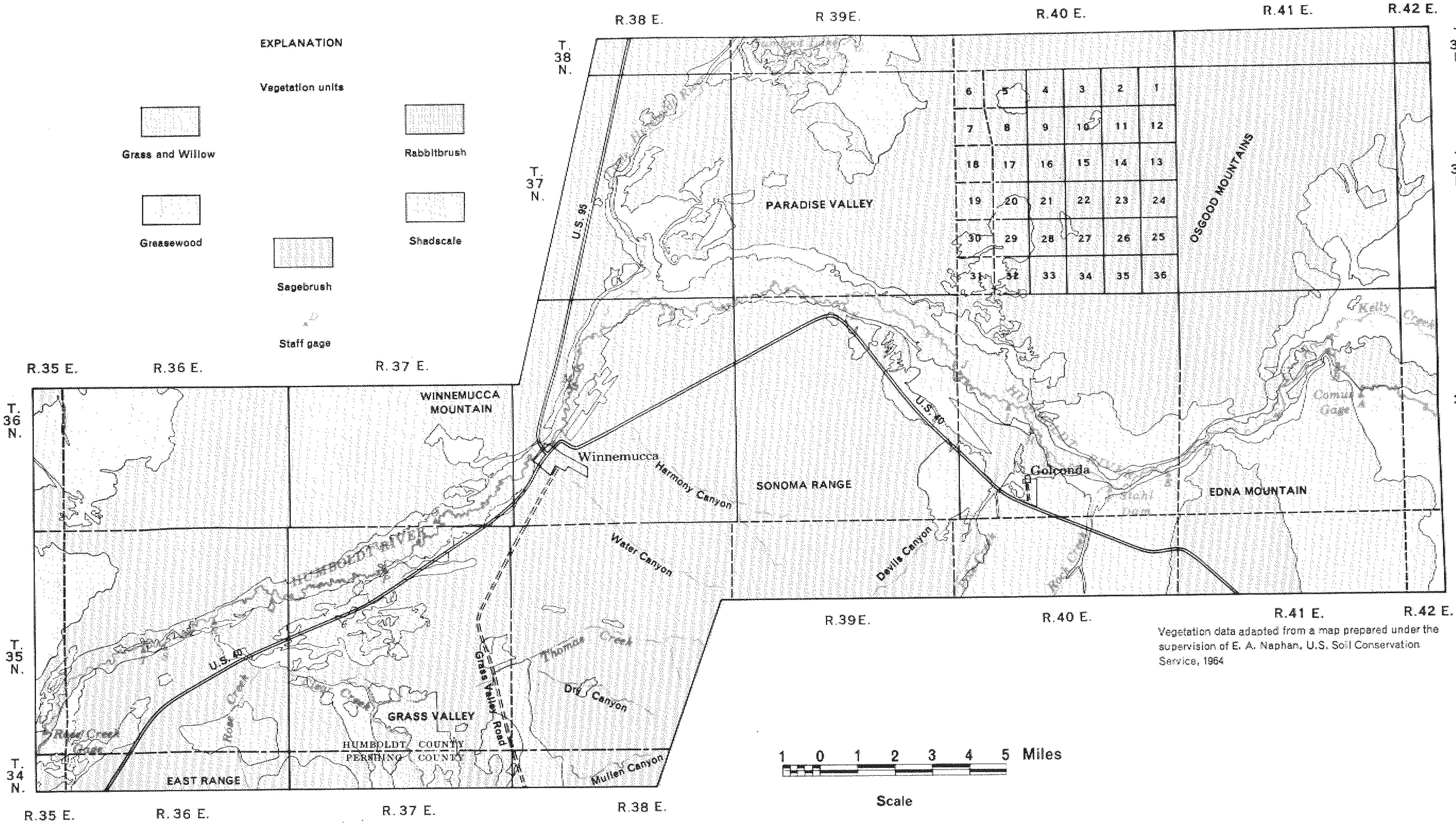
Vegetative units shown in Figure 6	Vegetative types defined by the U.S. Soil Conservation Service
Grass and Willow	Saltgrass Creeping wildrye Cattail and bulrush Willow and rose Buffaloberry
Rabbitbrush	Rabbitbrush Rabbitbrush and greasewood
Greasewood	Greasewood Greasewood and big sagebrush Greasewood and shadscale Greasewood and saltgrass Greasewood and spiny hopsage Greasewood and budsage Greasewood and Douglas rabbitbrush Greasewood and alkali blite
Shadscale	Shadscale
Sagebrush	Big sagebrush Big sagebrush and greasewood Big sagebrush and rabbitbrush Big sagebrush and spiny hopsage Big sagebrush and hairy horsebrush Big sagebrush and budsage Spiny hopsage Hairy horsebrush Crested wheatgrass seedings Annuals Big sagebrush and low sagebrush and shadscale Big sagebrush and low sagebrush Juniper

MAN AND HIS ACTIVITIES

Before the first white men explored the Humboldt River basin in the early 19th century, the area was sparsely inhabited by Shoshone and Paiute Indians. The early explorers were searching for a westward route through the inhospitable mountains and desert of the Great Basin. By the mid-19th century, a well-defined emigrant trail followed the Humboldt River and led to Oregon and California. Soon afterward, in the 1860's, a railroad closely paralleling the river and linking the Midwest and California was completed. By the late 19th century, mining towns, railroad junction points, and agricultural communities were well established in the valley. Winnemucca, the county seat of Humboldt County, formerly was the center of a prosperous mining industry. The principal metals recovered were gold, silver, tungsten, and mercury. Presently very few mines are in operation, and the economy of the area is based mainly on cattle raising and the tourist business. The population of Winnemucca in 1960 was about 3,500.

The activities of man that involve the use of water are, of course, of principal concern in this report. More than 95 percent of the beneficial use of water in the Humboldt River basin is for irrigation; forage crops, notably meadow grasses and alfalfa, are the principal crops. Along the main stem of the Humboldt River, the diversion of river water is virtually the sole source of irrigation water; ground-water development for irrigation is negligible.

In the Winnemucca area about 10,000 to 20,000 acres of the flood plain is irrigated with Humboldt River water, the acreage depending largely on the availability of streamflow. In 1962 nearly 2,000 acres, mostly in the mouth of Grass Valley, was irrigated with ground water. Most of the irrigation is accomplished by diversions through a network of unlined ditches and by overbank flooding onto unimproved meadows. All the diversionary structures in the project area are privately owned; the largest is the Stahl Dam about 15 miles east of Winnemucca.



Base adapted from U. S. Geological Survey topographic quadrangles

FIGURE 6. Generalized vegetation may of the Humboldt River valley near Winnemucca, Nevada.

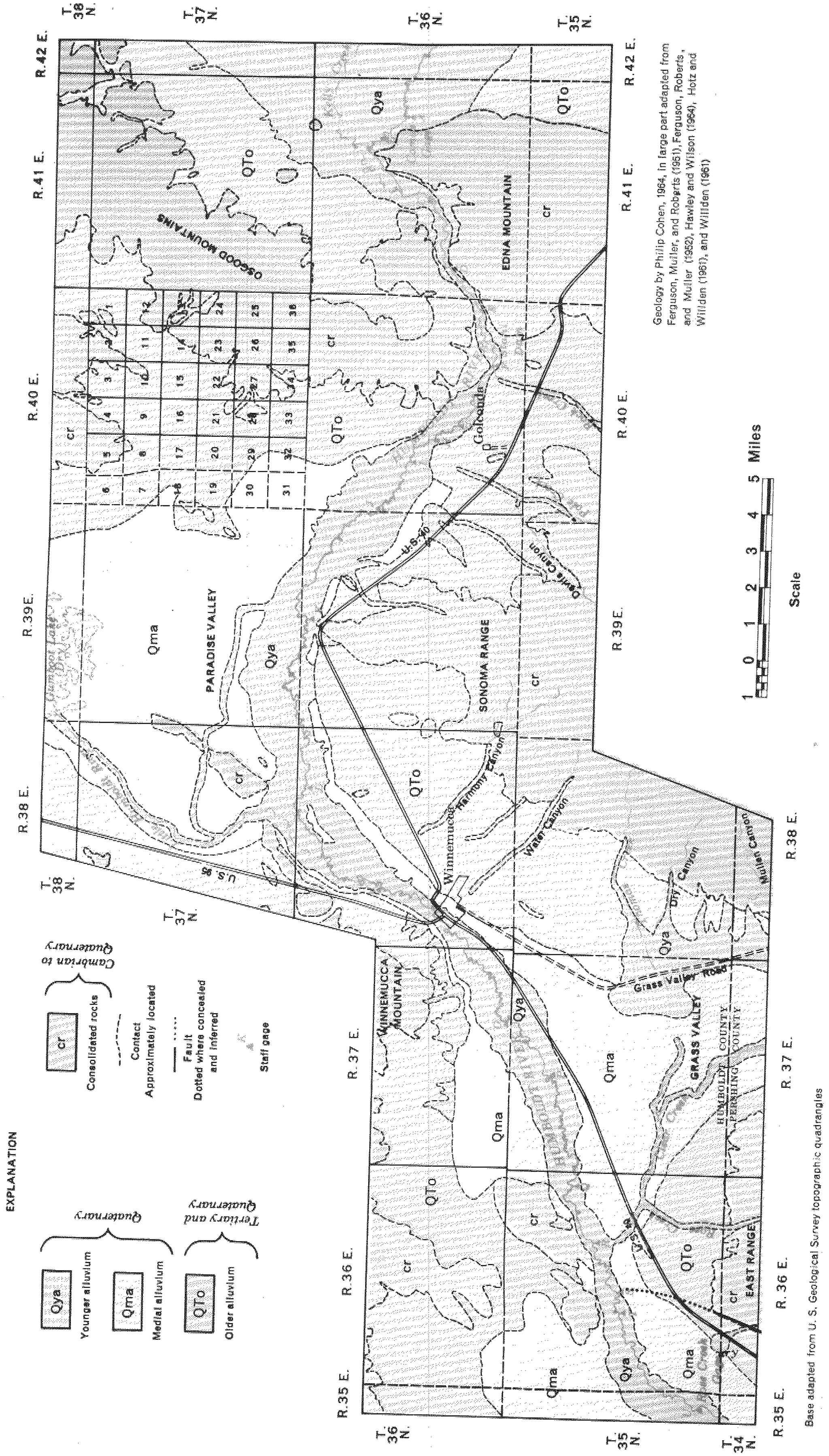


FIGURE 8. Generalized geologic map of the Humboldt River valley near Winnemucca, Nevada.

CHAPTER 3

HOW AND WHERE THE WATER OCCURS

Before additional consideration is given to such factors as how much water enters the project area, where it comes from, and what happens to it after it enters the area, some of the physical characteristics of the water and the environment in which it occurs are reviewed briefly in this section of the report. Water occurs in three forms or phases: as a gas (water vapor), as a solid (most commonly as ice and snow), and as a liquid. The liquid phase is the one that most people usually are concerned about; however, in this report all three phases are considered. Moreover, it is necessary to consider the three broad areas in which the water occurs—beneath the surface of the earth, on the land surface, and in the atmosphere.

SUBSURFACE WATER

The Geologic Environment

According to Meinzer (1923, p. 23), subsurface water occurs in three major zones within the earth—the zone of rock flowage, the zone of saturation, and the zone of aeration. (See Fig. 7.) Water in

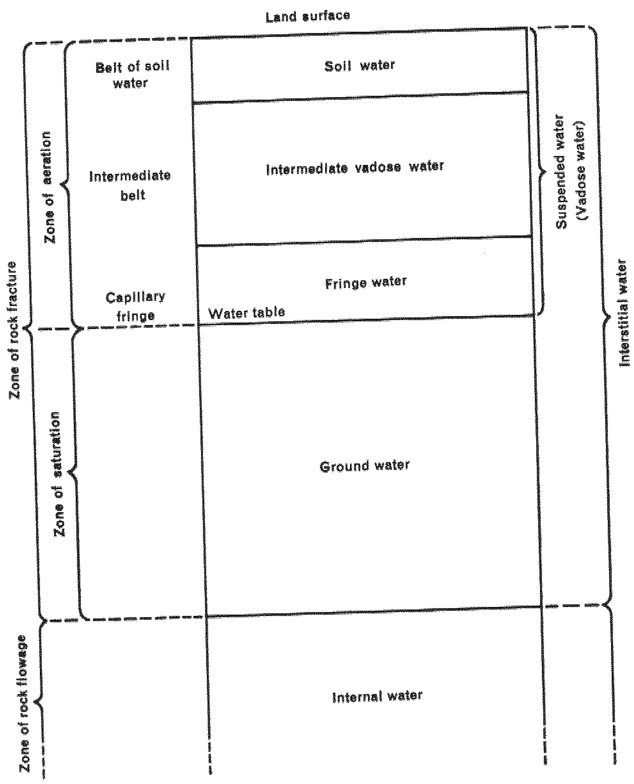


FIGURE 7. Diagram showing the divisions of subsurface water. (After Meinzer, 1923, p. 23.)

the zone of rock flowage is not considered in this report because it normally occurs at great depth, is not readily available for use by man, and even if it could be recovered, its chemical quality probably would not be suitable for most uses.

To evaluate such factors as the amount of subsurface water available, the rate, direction, and quantity of ground-water flow, and the chemical quality of the water, the distribution and the physical and chemical characteristics of the rock materials on and beneath the surface of the earth had to be studied. In other words, it was necessary to study many aspects of the geology of the area. The results of the geologic studies, including those of a detailed test-drilling program, are described in detail in other reports (pp. 67–68); a brief summary of the results of some of this work is given in the following paragraphs and, where pertinent, in other sections of the report.

In this report, the rock materials on and beneath the surface of the earth are grouped into four units: consolidated rocks, older alluvium, medial alluvium, and younger alluvium (Fig. 8). The last three units collectively are termed "valley-fill deposits." The geology of the valley-fill deposits is described in considerable detail in reports by Russell (1883, 1885), Cohen (1962c, 1963a, 1963b), and Hawley and Wilson (1964).

The consolidated rocks comprise most of the mountain ranges, and underlie the valley-fill deposits. In overall aspect, these rocks are dense and hard and, accordingly, store and transmit only small quantities of water. Locally, however, fractures resulting from structural deformation, solution openings in some of the carbonate rocks, and primary and secondary structures in some of the lava flows transmit moderately large quantities of water through these otherwise largely impermeable rocks.

The older alluvium includes some moderately consolidated lakebeds that for the most part are highly metamorphosed, cemented, and compacted. Therefore, these deposits do not store or transmit appreciable quantities of water. Also included in the older alluvium are thousands of feet of unconsolidated and partially consolidated strata of silt, sand, and gravel deposited mainly as alluvial fans and as stream-channel deposits in the valley lowlands; and clay and silt strata deposited in lakes that intermittently occupied the project area.

Wells in the study area that tap well-sorted and poorly compacted sand and gravel strata of the older alluvium yield more than 1,000 gpm (gallons per minute); however, wells that tap the predominantly fine-grained strata or the consolidated strata of the older alluvium yield only a few gallons per minute.

The medial alluvium was deposited within and around the margins of Lake Lahontan. The unit consists of at least five recognizable subunits (Cohen, 1963b, Table 3); however, only two of the subunits, the medial gravel and the upper silt and clay, are significant with regard to the water resources of the area. The approximate areal distribution and thickness of the medial gravel subunit is only slightly more than the distribution and thickness of the saturated portion of the subunit as shown in Figure 19. The top of the subunit is at a depth ranging from about 5 to 20 feet below land surface on the flood plain, and from about 2 to 15 feet on the bordering terraces. Throughout most of the remainder of the project area, the medial gravel is overlain by the upper silt and clay subunit, which ranges in thickness from a few inches to about 55 feet.

The medial gravel subunit consists mainly of moderately to well-sorted lenses of coarse sand and gravel; however, locally it contains thin beds of fine sand and silt. It is almost completely saturated with ground water and is highly permeable. Thus, it could yield large quantities of water, at least 2,000 gpm, to properly constructed and developed wells. The upper silt and clay subunit consists of fine-grained and moderately compacted silty and clayey strata that store moderately large quantities of water; however, because of the very low permeability of these strata, the subunit transmits only small quantities of water and yields negligible quantities to wells. Locally, the subunit confines water in the underlying medial gravel under artesian pressure.

The younger allvium is entirely of post-Lake Lahontan age and includes flood-plain and terrace deposits, alluvial-fan and stream-channel deposits, windblown silt and sand, and the deposits of Gumboot Lake. Commonly, these deposits are less than 50 feet thick, and their texture and water-bearing character range from highly permeable stringers of sand and gravel to lenses and layers of silt and clay of very low permeability.

Water in the Zone of Saturation

In the Winnemucca reach of the Humboldt River valley, most of the water in the zone of saturation (ground water) is in the pore spaces, or openings, in the unconsolidated sedimentary deposits. Some ground water also occurs in cracks and other openings in the consolidated rocks, but the amount is small as compared to that in the unconsolidated deposits. Moreover, most of the consolidated rocks yield little or no water to wells.

Practically all the ground water occurs as a liquid that is under greater than atmospheric pressure. If water is held in the zone of saturation by an overlying bed or layer of material through which it cannot pass readily, the water is said to be confined or under artesian pressure. Where the top of the zone of saturation is not separated from the atmosphere by a confining bed, the ground water is unconfined, and the top of the zone of saturation is referred to as the water table.

Water in the Zone of Aeration

Vadose water, or water in the zone of aeration, occurs largely in the liquid phase, but partly in the vapor phase and partly in the solid phase. Although pore spaces in the zone of saturation normally are completely filled with water, those in the zone of aeration commonly contain small to large amounts of air, the amount depending mainly on the size of the spaces. In addition, vadose water differs from ground water in that it is under less than atmospheric pressure and therefore will not enter a well. Most of the vadose water is held in the zone of aeration by capillary and molecular attraction, and does not move downward in response to gravity.

The capillary fringe is the lowest part of the zone of aeration. Most of the water in the capillary fringe is derived from the underlying zone of saturation by capillary attraction in much the same way that water rises in a wick partly immersed in a glass of water. The smaller the particles and the pore spaces in the material immediately above the water table, the thicker the capillary fringe.

In the Humboldt River valley, the thickness of the zone of aeration ranges from a few feet to more than several hundred feet. At times the capillary fringe locally extends to the land surface, especially on the flood plain where the zone of aeration commonly is only a few feet thick.

SURFACE WATER

Surface water is the water that occurs on the land surface; it mainly includes flowing water in streams, impounded water in lakes, ponds, and reservoirs, and ice and snow on the ground. The amount of water in the streams at a given time is referred to as channel storage. Channel storage normally represents the largest quantity of surface water in the Humboldt River valley, and water in the Humboldt River normally represents more than 95 percent of the total channel storage in the project area.

Gumboot Lake near the south end of Paradise Valley is the only natural lake in the project area. Prior to agricultural development in Paradise Valley, Gumboot Lake contained water when eastward-moving sand dunes blocked the channel of the Little Humboldt River, or when the river was in flood. At present, most of the flow of the Little Humboldt River is diverted for irrigation in Paradise Valley. As a result, Gumboot Lake currently is dry; it was dry during the entire period of this investigation.

Stahl Reservoir, the largest artificial lake in the area, covers an area of about 600 acres and has a storage capacity of less than 1,000 acre-feet. The reservoir was formed by the construction of a dam across the channel of the Humboldt River in the NW¼ sec. 35, T. 36 N., R. 40 E. Numerous other small dams, including both permanent and temporary structures, are used to impound and divert the flow of the Humboldt River during the irrigation season. The bodies of water behind these structures are small lakes or reservoirs, but for practical purposes they are considered to represent increases in the amount of water in storage in the river channel.

Although the depths of snow and ice in the project area were not measured, the snowpack that accumulates on the mountains during the winter probably contains an equivalent of at least 15 to 20 inches of liquid water locally. Accordingly, the snowpack represents an appreciable though unmeasured part of the total surface-water supply.

ATMOSPHERIC WATER

Almost all the water in the atmosphere occurs as a vapor. The vapor content of air commonly is expressed in terms of relative humidity, which is the ratio of the amount of water vapor in the air to the total amount the air can contain at a given temperature. According to U.S. Weather Bureau data, the average annual relative humidity in Winnemucca in the afternoon is slightly less than 40 percent, the humidity ranging from an average low of about 20 percent in the summer to an average high of about 60 percent in the winter.

The low summer humidity is very significant in the total water-supply picture for the area. It is one of the major factors that contribute to high evapotranspiration rates and, as described subsequently in the report, evapotranspiration consumes large quantities of water in the project area.

CHAPTER 4

WHERE THE WATER COMES FROM

The source and quantity of water entering the Winnemucca reach of the Humboldt River valley are considered in this chapter of the report. The inflow of water to the "storage area" outlined on Figure 9 is emphasized rather than the inflow of water to the entire project area, because most of the inflow, most of the changes in the amount of water in storage, and most of the discharge occur in the storage area. Estimates of inflow and most of the other quantitative estimates given in this report are for three time periods, water years 1949–62, water year 1962, and December-June of water year 1962. (The water year is defined as the 12-month period ending September 30 and is designated by the calendar year that includes 9 of the 12 months.) These three time intervals are emphasized mainly because of the availability of streamflow and other data needed for the purpose of water-budget analyses (p. 54) and because the estimates for the three periods illustrate many significant features of the water resources of the area.

The oceans bordering the western and northern coasts of North America are the sources of practically all the water in the project area. Water vapor derived from these oceans by evaporation generally moves in an eastward or southeastward direction across Nevada in response to the prevailing wind direction. Some of this moisture condenses over the Humboldt River drainage basin and falls as rain or snow. Much of the precipitation evaporates soon after it falls; some of it collects on the land surface in ponds and lakes and as streamflow; some of it infiltrates the zone of aeration; and some of it percolates downward into the zone of saturation. Eventually, in some instances after many hundreds or thousands of years, all the precipitation in the basin is returned to the atmosphere by evapotranspiration. Thus, not only is the atmosphere the medium through which all the water is transported to the Humboldt River basin, but also it is the medium that transports all the water that is discharged from the basin. Eventually, the water discharged from the basin finds its way back to the ocean, and the never-ending hydrologic cycle, the cycle of condensation, precipitation, and evapotranspiration, is repeated again.

STREAMFLOW

Humboldt River

The flow of the Humboldt River, measured at the Comus gaging station, is derived entirely from precipitation in the Humboldt River drainage basin upstream from the project area and is the source of most of the inflow to the storage area in the Winnemucca reach of the Humboldt River valley (Fig. 2, item 2). As shown in Figure 10, the average annual flow at the Comus gaging station in water years 1949–62 was about 172,100 acre-feet; the range was from a low of nearly 28,000 acre-feet in water year 1955 to a high of about 558,000 acre-feet in water year 1952.

The flow of the Humboldt River at the Comus gaging station during water years 1959–61 was markedly below average (Fig. 10). However, the river inflow to the storage area in water year 1962 was 297,200 acre-feet, or about 50 percent more than the long-term average (1895–1962). Similarly, the flow of the Humboldt River at the Comus gaging station in December-June of water year 1962 was 254,300 acre-feet, which also was considerably above the long-term average.

Table 4 shows the relation between streamflow for water years 1949–62 and comparable flow for the period of record water years 1895–1962. The average annual flow for the 14-year period was 14 percent less than the average annual flow for the entire period of record. Nevertheless, overall streamflow characteristics during the 14-year period were very similar to those of the long-term period. Moreover, a seemingly random distribution of years of below- and above-average streamflow characterized both the 14-year period and the long-term period.

TABLE 4. SUMMARY OF STREAMFLOW OF THE HUMBOLDT RIVER AT THE COMUS GAGING STATION FOR THE PERIOD OF RECORD AND FOR WATER YEARS 1949–62

Period (water years)	Average annual (acre-feet)	Water year	Maximum annual (acre-feet)	Water year	Minimum annual (acre-feet)
1895–1962*	199,100	1907	688,100	1920	26,700
1949–62	172,100	1952	558,500	1955	27,530

*Does not include water years 1910 and 1927–45 for which data were not obtained.

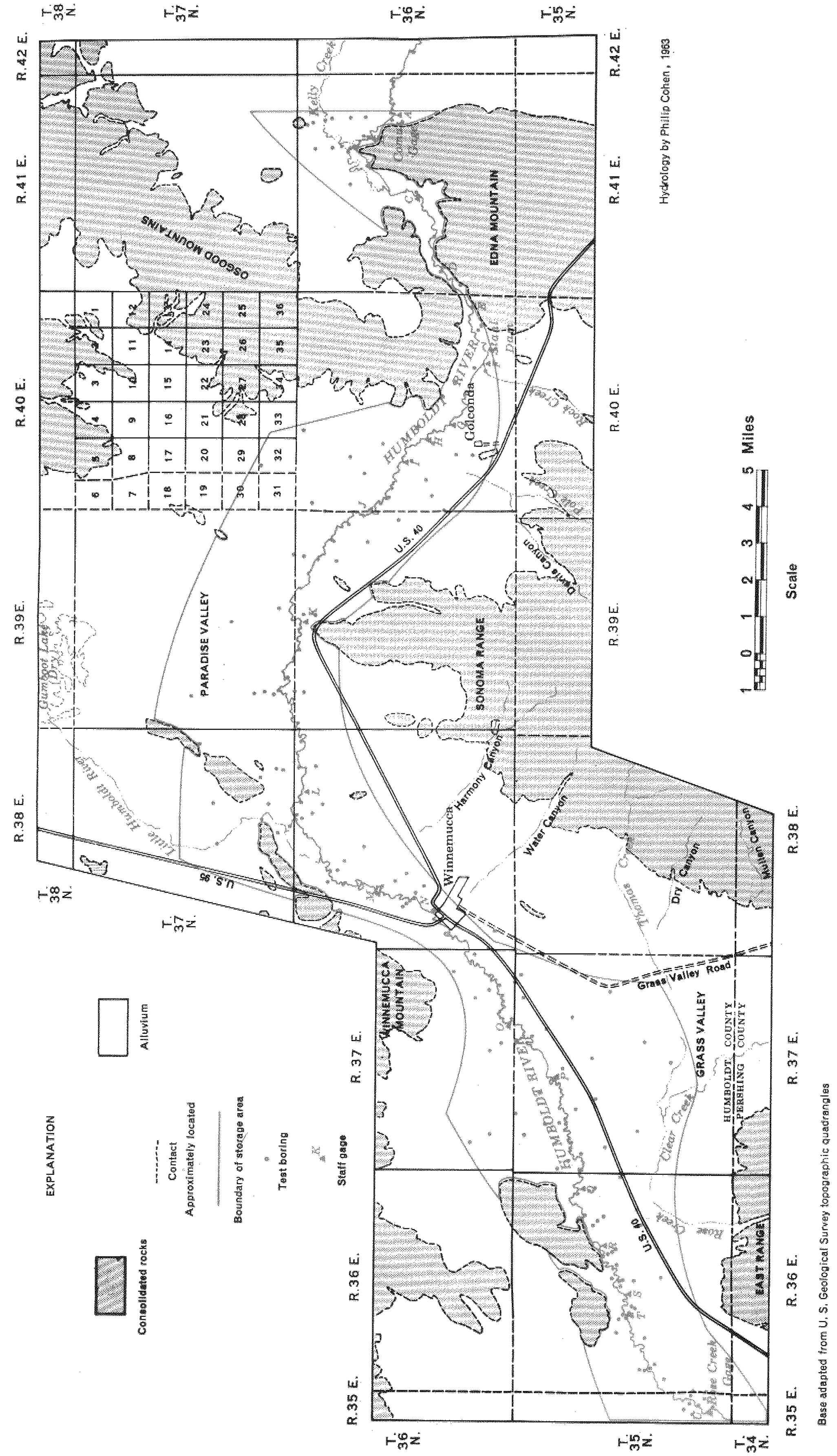


FIGURE 9. Map showing outline of storage area and locations of test borings and staff gages in the Humboldt River valley near Winnemucca, Nevada.

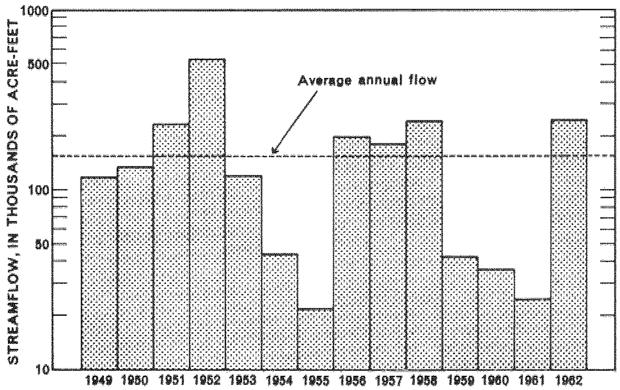


FIGURE 10. Annual flow of the Humboldt River at the Comus gaging station, water years 1949–62.

Inasmuch as there are no sizable upstream storage facilities, monthly streamflow at the Comus gaging station (Fig. 11) is largely a reflection of climatic conditions in the basin. The flow at the beginning of a water year normally is the lowest of the year. It increases gradually from November through January as the weather turns cold, causing the phreatophytes to consume less water and evaporation to decrease. The flow increases in January, February, and March because of winter storms. In April, as the weather begins to turn warm and as the snowpack that accumulated during the winter begins to melt, the flow of the Humboldt River increases markedly. It usually reaches a peak in May. By the end of June, when the snowpack is nearly depleted, the flow decreases abruptly and continues to decrease until the end of the water year. On the average nearly 65 percent of the total yearly flow at the Comus gaging station occurs in the months of April, May, and June.

An especially notable characteristic of the flow of the Humboldt River at the Comus gaging station, and for that matter in the entire basin, is the wide range in annual and monthly flows. This in part reflects the lack of major upstream storage facilities, but in the main is related to climatic variations. Intense thunderstorms and warm rain on frozen ground can, and have, caused severe and frequent flooding in the basin (Nevada Department of Conservation and Natural Resources and U.S. Department of Agriculture, 1962b, and Thomas and Lamke, 1962). Moreover, a year or a series of years of above- or below-normal precipitation in the basin corresponds very closely to a year or years of above- or below-average streamflow (Hanson, 1963, Fig. 13).

The percentage of time that the daily average rate of flow of the Humboldt River at the Comus gaging station equaled or exceeded a given rate of flow is shown in Figure 12. The graph shows, for example, that a daily average flow of 70 cfs was equaled or exceeded about 50 percent of the time. The daily average flow exceeded 2,000 cfs only about 1 percent of the time; the river was dry at the Comus gaging station also for about 1 percent of the time. The maximum instantaneous flow recorded was 5,860 cfs on May 6, 1952, and the maximum daily flow of 5,810 cfs occurred on the same day.

Tributary Streams

Tributary streamflow supplies the least amount of water of any of the significant sources of inflow to the storage area near Winnemucca (Fig. 2, item 3). All the streams in the project area, except the Humboldt River, are dry most of the time throughout most of their lengths. However, some of these streams contain water during the entire year for short distances in the mountains where they receive year-round springflow; nevertheless, even in the mountains most of the tributary streams normally flow only in the winter in response to increased rain and snow, and in the spring and early summer in response to the melting snowpack.

Very rarely does tributary streamflow discharge into the Humboldt River in the Winnemucca area. Rather, the flow evaporates (Fig. 2, item 12), is

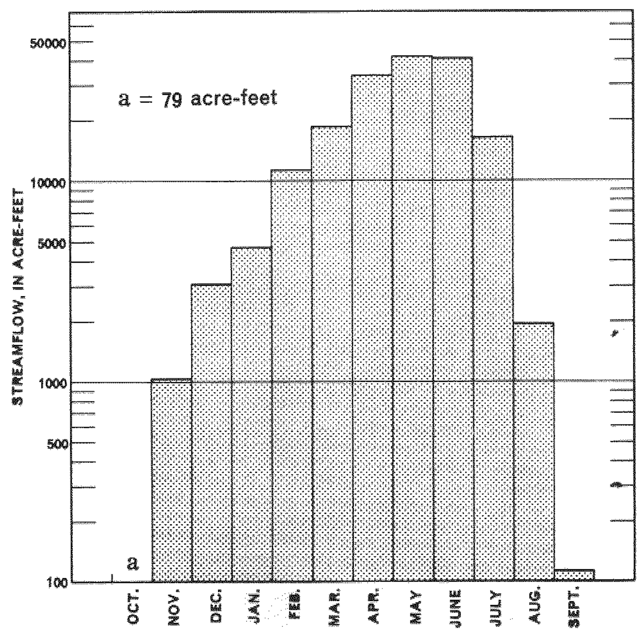


FIGURE 11. Average monthly flow of the Humboldt River at the Comus gaging station, water years 1949–62.

transpired (Fig. 2, item 13), infiltrates into the zone of aeration (Fig. 2, item 7), or percolates downward through the zone of aeration and eventually recharges the zone of saturation (Fig. 2, item 9).

Unusual weather conditions such as intense summer thunderstorms or warm rain on frozen ground may result in concentrated and large amounts of runoff in one or more of the tributary streams. Even then the amount of water that discharges into the Humboldt River in the project areas commonly is negligible, especially when compared to the total annual flow of the river.

In water years 1953 and 1958 a total of about 58,000 acre-feet of flood water from the Little Humboldt River was drained artificially from Gumboot Lake to the Humboldt River. Excluding this quantity of water, the estimated average annual tributary streamflow that reached the outer margins of the storage units in water years 1949–62 was about 4,500 acre-feet; it was about 5,800 acre-feet in water year 1962 and about 5,000 acre-feet in the period December through June of that year (Hanson, 1963, p. 41). On the average, very little of this water reached the Humboldt River as surface flow.

If the water that was drained from Gumboot Lake in water years 1953 and 1958 is added to the calculated average annual inflow from other tributary streams for the period water years 1949–62, the estimated total average annual inflow from all tributary streams for that period was about 8,600 acre-feet.

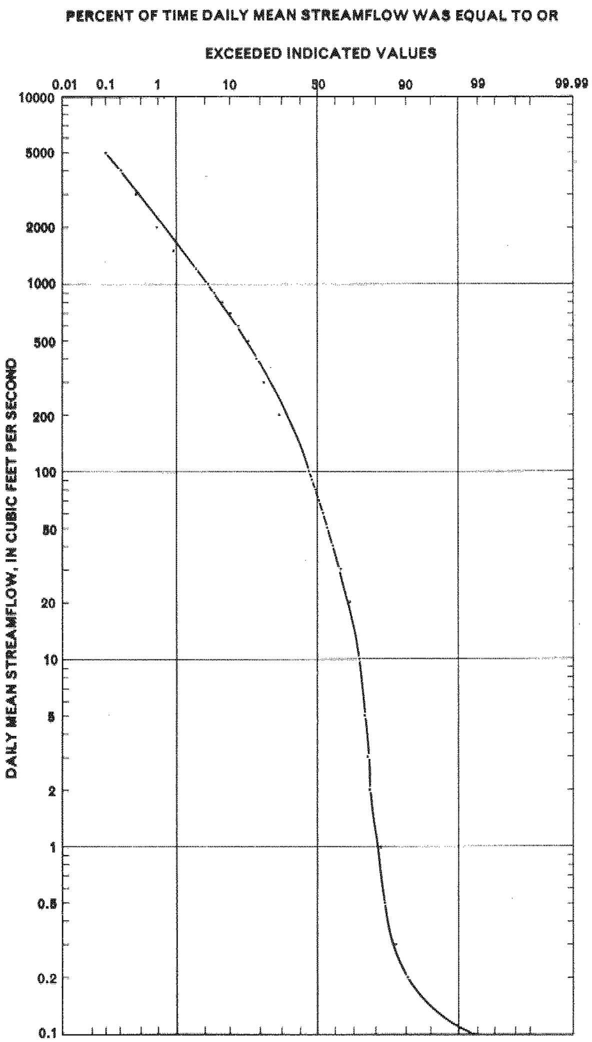


FIGURE 12. Duration curve of daily mean streamflow, Humboldt River at Comus, Nevada, water years 1918–26, 1946–62.

PRECIPITATION

Precipitation directly on the storage area (Fig. 9) is the second largest source of water in the area (Fig. 2, item 1). The average annual precipitation on the storage area in water years 1949–62 probably was nearly equal to that at the Winnemucca airport, about 7.6 inches. The storage area covers about 93,000 acres. Thus, the estimated average annual precipitation on the storage area in water years 1949–62 was 59,000 acre-feet; it was 60,000 acre-feet in water year 1962, and about 47,000 acre-feet in December-June of that year. As is described subsequently in the report, most of this precipitation is consumed by evapotranspiration soon after it falls (Fig. 2, items 12 and 13); very little percolates downward to the zone of saturation.

GROUND–WATER INFLOW

The fourth major source of water in the storage area near Winnemucca is subsurface ground-water inflow—that is, the movement of water from the saturated deposits bordering the storage area to the saturated deposits within the storage area (Fig. 2, item 10). Ground-water inflow to the storage area is indicated by the water-level contours in Figures 13 and 14, which are based on the altitude of water levels in observation wells and at springs, and the altitude of the Humboldt River at 21 staff gages (Fig. 9). The direction of ground-water flow is perpendicular to the water-level contours, and water moves from areas of higher to areas of lower water-level altitudes.

Four subareas supply almost all the ground-water inflow to the storage area; they are, in downstream order, the Humboldt River valley upstream from the storage area, the drainage basins of Pole and Rock Creeks, Paradise Valley, and Grass Valley including the northwestern slope of the Sonoma Range. The estimated average annual ground-water inflow from these subareas is listed in Table 5.

Unlike that of streamflow, the rate of subsurface ground-water movement into the storage area is very slow, on the order of a fraction of a foot to several feet per day, and remains almost constant. Thus, the amount of ground-water inflow to the storage area is independent of short-term climatic factors, and responds only slightly to long-term climatic trends, such as several consecutive years of above- or below-normal precipitation. Accordingly, subsurface ground-water inflow to the storage area in water year 1962 is inferred to have been equal to the long-term average annual inflow of 14,000 acre-feet; inflow during the 7-month period December-June of water year 1962 was equal to seven-twelfths of the annual inflow, or about 8,000 acre-feet.

TABLE 5. ESTIMATED AVERAGE ANNUAL SUBSURFACE GROUND-WATER INFLOW TO THE STORAGE AREA NEAR WINNEMUCCA, NEVADA.
(Adapted and generalized from Cohen 1963b, Table 17)

Subareas contributing ground-water inflow to the storage area (Fig. 9)	Average annual ground-water inflow (acre-feet)
Humboldt River valley upstream from the storage area	500
Drainage basins of Pole and Rock Creeks	4,000
Paradise Valley	3,500
Grass Valley and the northwestern slope of the Sonoma Range	6,000
Total	14,000

SUMMARY OF TOTAL INFLOW

The estimated average annual inflow to the storage area near Winnemucca in water years 1949–62 and the percentage of the total represented by each of the major sources are as follows:

Source	Average annual inflow (acre-feet)	Percentage of total
Humboldt River	172,100	68
Tributary streams	8,600	3
Precipitation	59,000	23
Ground-water inflow	14,000	6
Totals (rounded)	250,000	100

Because of legal considerations and because of several other factors that are described subsequently in the report, only a small percentage of the total inflow to the Winnemucca area is available for use by man within that area.

Average annual precipitation at Winnemucca and at Elko (near the headwaters of the Humboldt River) in water years 1949–62 was about 5 to 10 percent less than the average annual precipitation in the past 90 years. Furthermore, average annual streamflow at the Comus gaging station in water years 1949–62 was about 14 percent less than that for the entire period of record. Thus, these figures suggest that in water years 1949–62 the average annual inflow to the storage area near Winnemucca was on the order of 10 percent less than the average annual inflow for the past 90 years or so.

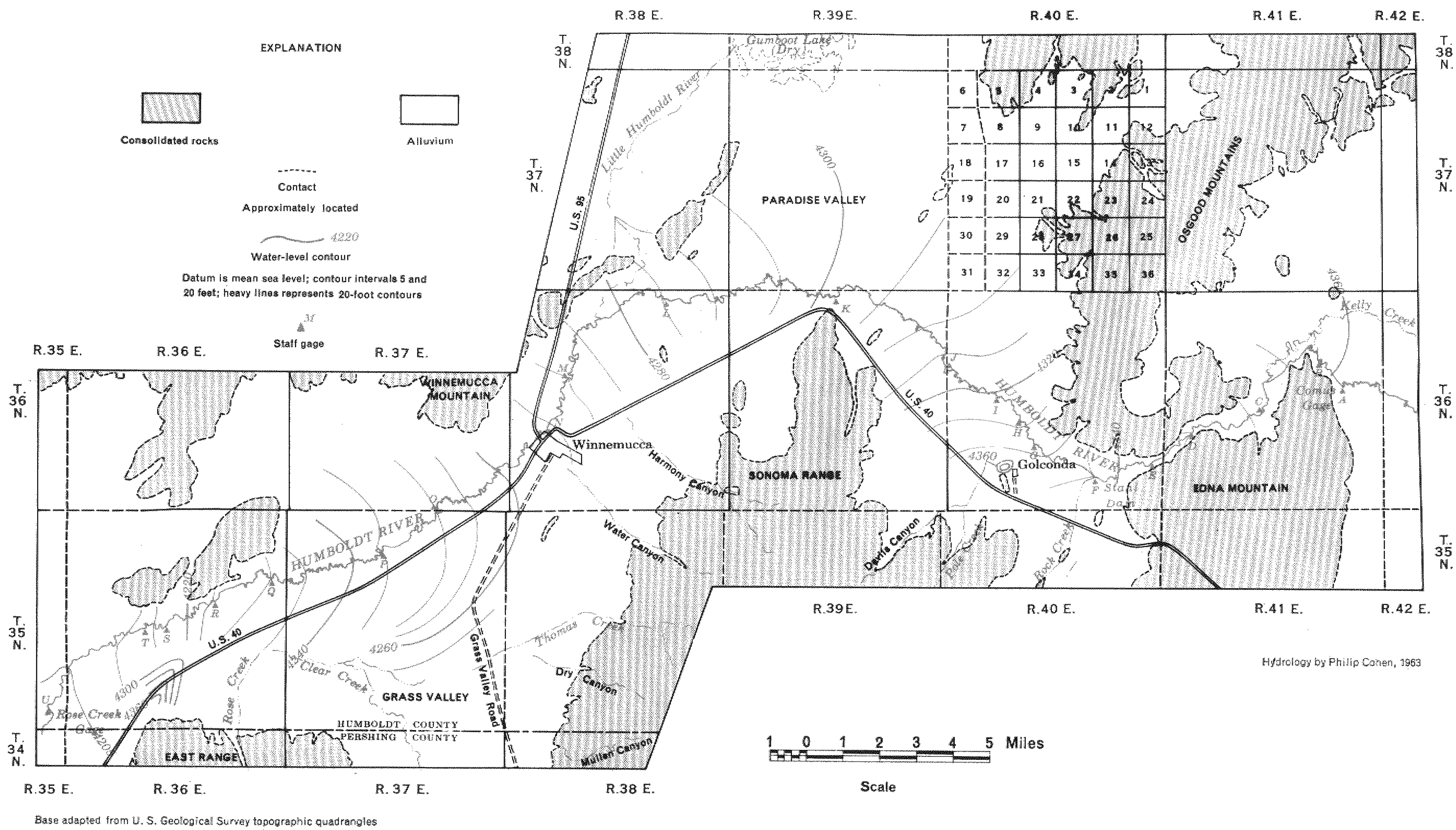


FIGURE 13. Map showing water-level contours in the Humboldt River valley near Winnemucca, Nevada, December 1961.

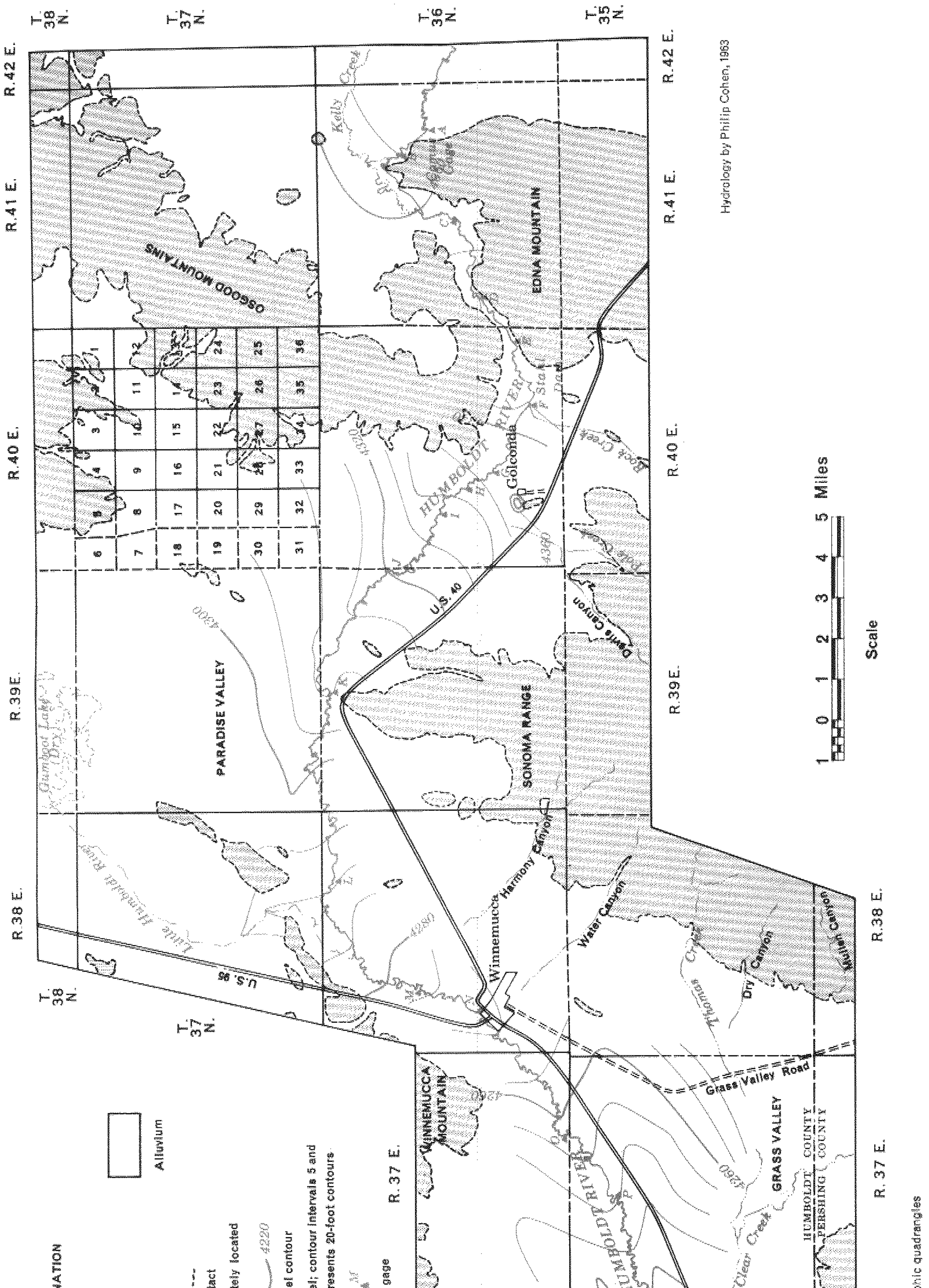


FIGURE 14. Map showing water-level contours in the Humboldt River valley near Winnemucca, Nevada, June 1962.

CHAPTER 5

MOVEMENT AND STORAGE OF WATER

What happens to the water after it enters the storage area and before it is discharged from the area? A drop of Humboldt River streamflow at the Comus gaging station may move downstream and be discharged from the area within a few days. On the other hand, another drop of Humboldt River streamflow may percolate into the ground and be stored there for tens or hundreds of years before reappearing at the land surface. Similarly, drops of rain or ground-water inflow may follow many diverse paths and may be stored in several different environments for differing periods of time before being discharged from the area as streamflow, as ground-water outflow, or by evapotranspiration.

HUMBOLDT RIVER STREAMFLOW

The movement and storage of Humboldt River streamflow are considered first inasmuch as the Humboldt River normally supplies most of the water moving into the area in a given year. Moreover, variations in the amount of water in the channel of the river usually represent the largest yearly changes in the total amount of water stored within the area.

Variations in the Rate and Quantity of Flow

The rate and quantity of water flowing in the channel of the Humboldt River varies with time and with increasing distance downstream from the Comus gaging station. As might be expected, these variations are caused by many complex factors, some of which are closely interrelated.

The velocity at which water moves in the channel ranges from an average high of about 3 feet per second, or about 2 miles per hour, when the river is in flood, to zero feet per second when the river is dry. During the period of record, the measured rate of flow past the Comus gaging station into the project area ranged from a high of 5,860 cfs (cubic feet per second) to a low of zero.

The amount of water flowing in the channel and the average velocity of flow vary seasonally. Some of the factors causing variations in flow at the Comus gaging station have been discussed in a previous chapter of the report (pp. 27–29). These factors also affect the flow downstream from the Comus gaging station. Moreover, irrigation practices, evapotranspiration, and seepage gains and losses also significantly affect the flow of the river in the project area.

The three sets of representative streamflow measurements plotted in Figure 15 show typical changes in the flow of the Humboldt River during periods of low, moderate, and high flow. In December 1961, no tributary streamflow discharged into the river between stations A and U (Fig. 9); the stage (level of the water surface) of the river was nearly constant, no water was diverted from the river, and evapotranspiration losses were negligible. Thus, the increase in flow from a fraction of a cubic foot per second at station A to about 14 cfs at station U was almost entirely the result of ground-water seepage into the river (Fig. 2, item 20). In February 1961, streamflow was moderately high at station A, about 21 cfs, mainly as a result of snow and rain on the headwaters of the basin during the preceding few weeks. Again, as the water moved downstream the flow increased as a result of seepage of ground water into the river.

On June 14–16, 1960, the flow decreased from a little more than 300 cfs at station A to about 150 cfs at station U. The decrease in flow was caused by seepage from the river to the ground-water reservoir (Fig. 2, item 8), diversions for irrigation (Fig. 2, item 6), and evaporation (Fig. 2, item 11). In addition, part of the decrease in flow probably was caused by increases in channel storage.

Variations in Channel Storage

Channel storage, the volume of water in the river at any given time, is directly related to flow of the river. As the flow increases the amount of channel storage increases. Figure 16 shows the relation of channel storage in the Humboldt River to the average of streamflow at the Comus and Rose Creek gaging stations. (See Hanson, 1963, p. 55.) Inasmuch as the average of the flow at the two gaging stations normally is the same at the beginning and end of a water year, the average annual net change in channel storage in the Humboldt River is zero. The flow of the Humboldt River at the Comus and Rose Creek gaging stations averaged 5 cfs at the beginning of water year 1962 and about 22 cfs at the end of the water year. Accordingly, from the graph (Fig. 16) the estimated net increase in channel storage for that period can be computed to be about 1,800 acre-feet.

The flow averaged 7 cfs on December 1, 1961, and about 1,170 cfs on June 30, 1962; the estimated net increase in channel storage for that period was approximately 22,000 acre-feet.

TRIBUTARY STREAMFLOW

During the spring and early summer, the flows of Rock, Pole, Thomas, and Rose Creeks and that of the stream in Harmony Canyon are diverted for irrigation. During the rest of the year the flows in most of these streams are insufficient to reach the outer margins of the storage area (Fig. 9). Tributary streamflow that does reach the outer margins of the storage area normally evaporates or percolates downward to the ground-water reservoir before reaching the Humboldt River.

Except for two farm ponds, there are no facilities for storing tributary streamflow in the project area. The combined storage capacity of the two ponds is less than 50 acre-feet.

PRECIPITATION

Most of the rain and snow on the storage area infiltrates to and is stored temporarily in the zone of aeration (Fig. 2, item 4), from where it eventually is returned to the atmosphere by evapotranspiration (Fig. 2, item 17). However, some precipitation percolates downward to the zone of saturation beneath the flood plain and recharges the ground-water reservoir, especially in the spring and summer when the water table locally is only a few feet below land surface and when the capillary fringe locally extends to land surface (Fig. 2, item 9). The estimated average annual ground-water recharge resulting from the infiltration of precipitation on the storage area is 2,000 acre-feet (Cohen, 1963b, p. 68).

On the basis of the average annual rate of precipitation at the Winnemucca weather station and on the average surface area of the Humboldt River, it is estimated that an average of about 600 acre-feet per year of rain and snow falls directly

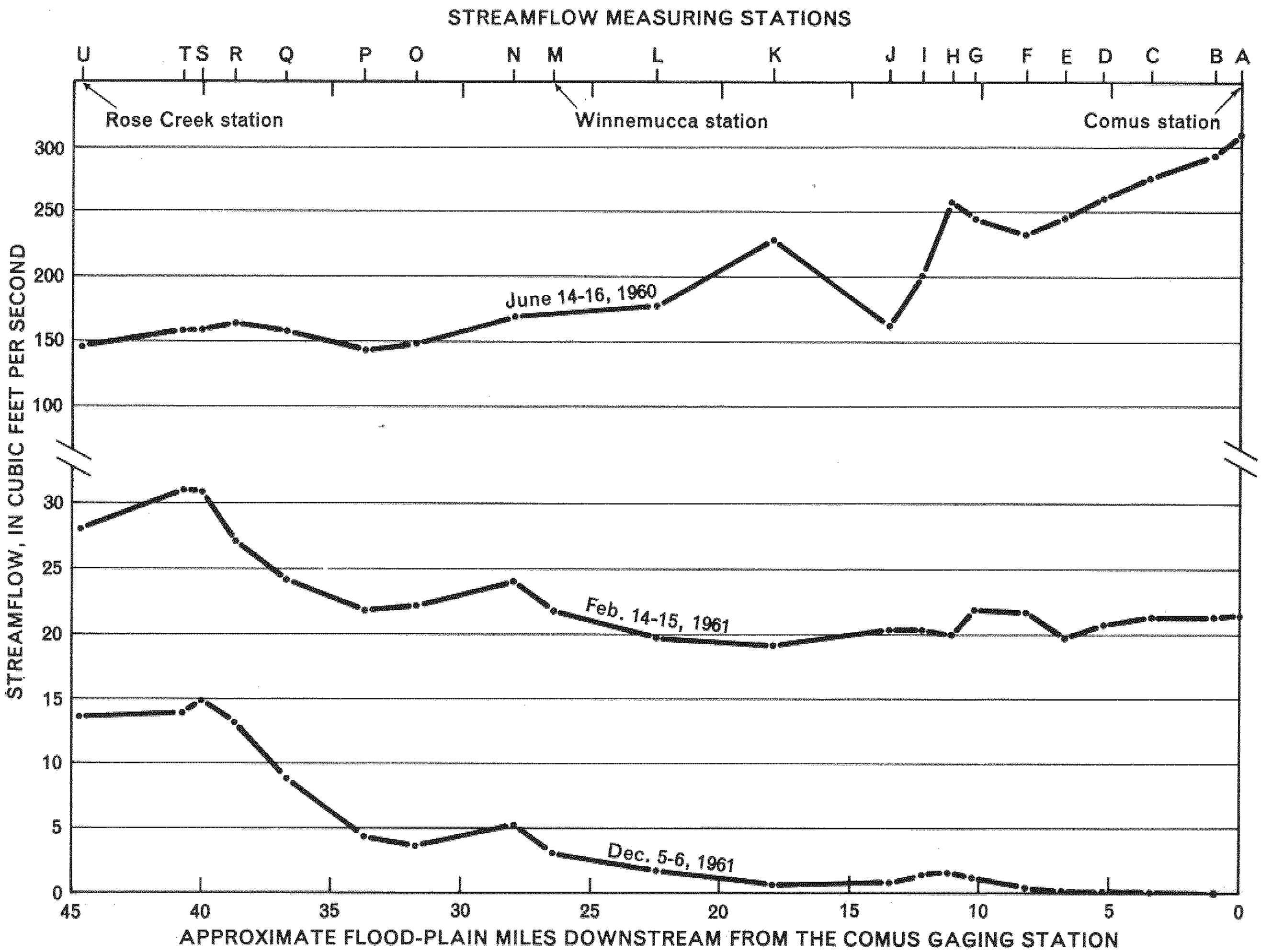


FIGURE 15. Representative streamflow measurements of the Humboldt River between the Comus and Rose Creek gaging stations.

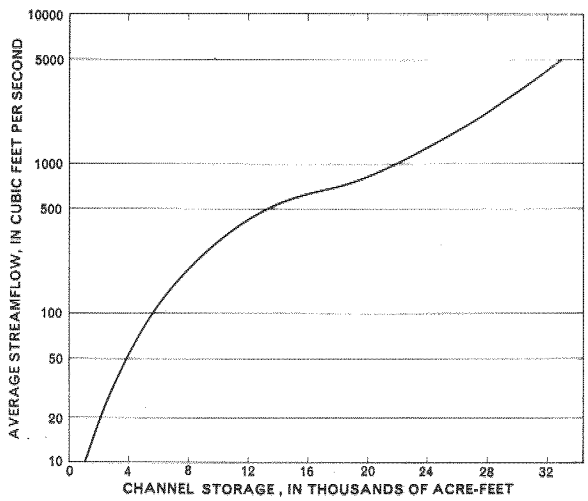


FIGURE 16. Relation of channel storage between the Comus and Rose Creek gaging stations to the average of streamflow at the two gaging stations. (After Hanson, 1963, Fig. 24.)

on the Humboldt River in the storage area near Winnemucca. The moment the precipitation falls on the free-water surface of the river it becomes, of course, part of the streamflow.

GROUND WATER

Direction and Rate of Movement

Throughout most of the year the general direction of ground-water movement is from the outer margins of the storage area (Fig. 9) toward the Humboldt River. Some of the water discharges into the river, some is discharged by evapotranspiration on the flood plain and bordering terraces and some moves westward and southwestward parallel to the river (Figs. 13 and 17).

In the spring and early summer when the stage rises and the flow of the river increases rapidly, a ground-water ridge or mound forms along the river as a result of seepage from the stream to the ground-water reservoir (Figs. 14 and 18).

At the same time ground water continues to move toward the river from the outer margins of the storage area; however, along most of the reach of the river in the storage area, ground water cannot discharge into the river because of the ground-water ridge. As a result, ground-water levels rise beneath the flood plain and the bordering terraces, and two troughs are formed in the water table, one on each side of the ground-water ridge. Ground water moves into these troughs and thence westward and southwestward downstream parallel to the river. In the late summer the ground-water ridge subsides because of evapotranspiration and

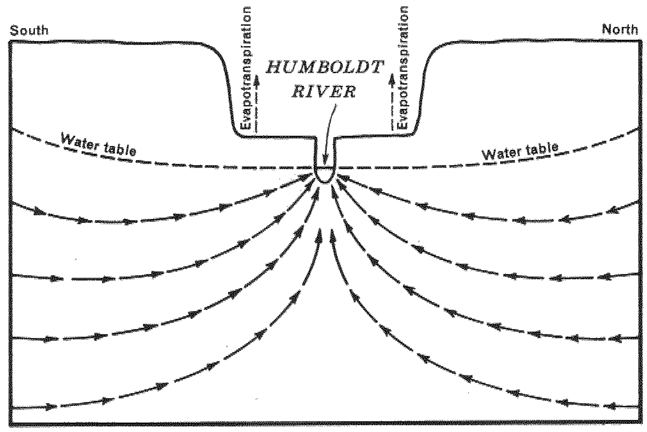


FIGURE 17. Schematic cross section showing the direction of ground-water movement in the Humboldt River valley near Winnemucca, Nevada, when the stage and flow of the river are low.

seepage to the river, and water levels again resemble those shown in Figures 13 and 17.

The velocity or rate of ground-water flow depends on three factors: the permeability or the ease with which water can move through the saturated deposits, the hydraulic gradient, and the porosity or the percentage of open spaces in the deposits. In general, the velocity of flow in coarse material such as sand and gravel is greater than in fine material such as silt and clay. Typical values for the velocity of ground-water flow in the project area range from a few tens of feet to about a thousand feet per year.

Storage

Ground water in storage is the water in the zone of saturation that will drain by gravity when water levels are lowered. It is less than the total

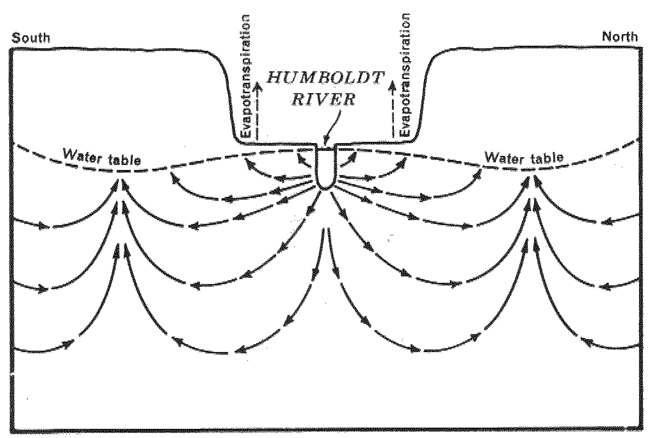


FIGURE 18. Schematic cross section showing the direction of ground-water movement in the Humboldt River valley near Winnemucca, Nevada, when the stage and flow of the river are high.

amount of water in the zone of saturation because some water will be retained in the deposits by capillary and other attracting forces. The amount of water that drains from the saturated deposits, expressed as a percentage of the total volume of the material, is known as the specific yield.

Figure 19 shows the approximate saturated thickness of the medial gravel subunit. The total saturated volume of the subunit is about 2.5 million acre-feet, and its estimated average specific yield is 20 percent (Cohen 1963b, p. 81). Thus, the total amount of ground water in storage in the subunit is about 500,000 acre-feet. The volume of the upper 100 feet of saturated unconsolidated deposits adjacent to the medial gravel subunit in the remainder of the project area is about 15 million acre-feet; the average specific yield of this material is presumed to be 10 percent. Accordingly, it is estimated that these deposits contain an additional 1.5 million acre-feet of ground water in storage. The total amount of ground water in storage in the upper 100 feet of the unconsolidated deposits in the zone of saturation in the project area alone, therefore, is estimated to be about 2 million acre-feet, or more than 10 times the capacity of Rye Patch Reservoir, the largest surface reservoir on the river.

The amount of ground water in storage varies from season to season and from year to year. Increases in the amount of ground water in storage are accompanied by rising ground-water levels; the converse is also true. Figure 20 shows that ground-water levels beneath the flood plain respond to and are related closely to changes in the stage of the Humboldt River; the higher the stage of the river, the higher the ground-water levels and the more ground water in storage.

The computed net changes of ground water in storage for four selected time intervals are listed in Table 6. (See Cohen, 1963b, p. 81.) As shown in the table, for the 14-year period 1949–62 the average annual net change of ground water in storage was zero, or very nearly zero. However, the estimated average annual net increase of ground water in storage from December through June of water years 1949–62, when ground-water levels were at or near their yearly lows and highs, respectively, was 10,000 acre-feet.

TABLE 6. ESTIMATED NET CHANGE OF GROUND WATER IN STORAGE IN THE STORAGE AREA NEAR WINNEMUCCA, NEVADA, FOR FOUR SELECTED TIME INTERVALS

Period	Net change of ground water in storage (acre-feet)
Water years 1949–62 (average annual)	0
December-June, water years 1949–62 (average)	+10,000
Water year 1962	+5,000
December-June, water year 1962	+26,000

Humboldt River streamflow into the storage area at the Comus gaging station was about 125,000 acre-feet above average in water year 1962 (Fig. 10). Ground-water levels beneath the flood plain rose markedly, locally more than 8 feet, in the late winter and spring as a result of the above-average streamflow. This, in turn, resulted in an estimated net increase of ground water in storage of 26,000 acre-feet in the period December through June of water year 1962, or about 16,000 acre-feet more than average. By the end of the water year much of the increased ground water in storage was consumed by evapotranspiration or had discharged into the river; however, even then there was still an estimated 5,000 acre-feet more ground water in storage than at the beginning of the water year.

Although the net increase of ground water in storage was substantial in December-June of water year 1962, it was only slightly more than 1 percent of the total amount of ground water in storage in the upper 100 feet of the zone of saturation in the project area. Considering the fact that the average thickness of the zone of saturation probably is more than 1,000 feet, seasonal changes in the amount of ground water in storage are almost negligible as compared to the total amount of ground water in storage.

VADOSE WATER

In 1961, A. O. Waananen of the U.S. Geological Survey began an investigation designed to evaluate the effectiveness of a neutron-scattering soil-moisture meter in studying the movement and storage of water in the zone of aeration in the shallow flood-plain deposits in the Winnemucca area. (See Waananen, 1963, p. 81–84.) Although these studies were not designed to yield quantitative answers for the entire storage area, the data developed as a result of the studies have been used to obtain a rough indication of the changes in moisture content in the zone of aeration (Cohen,

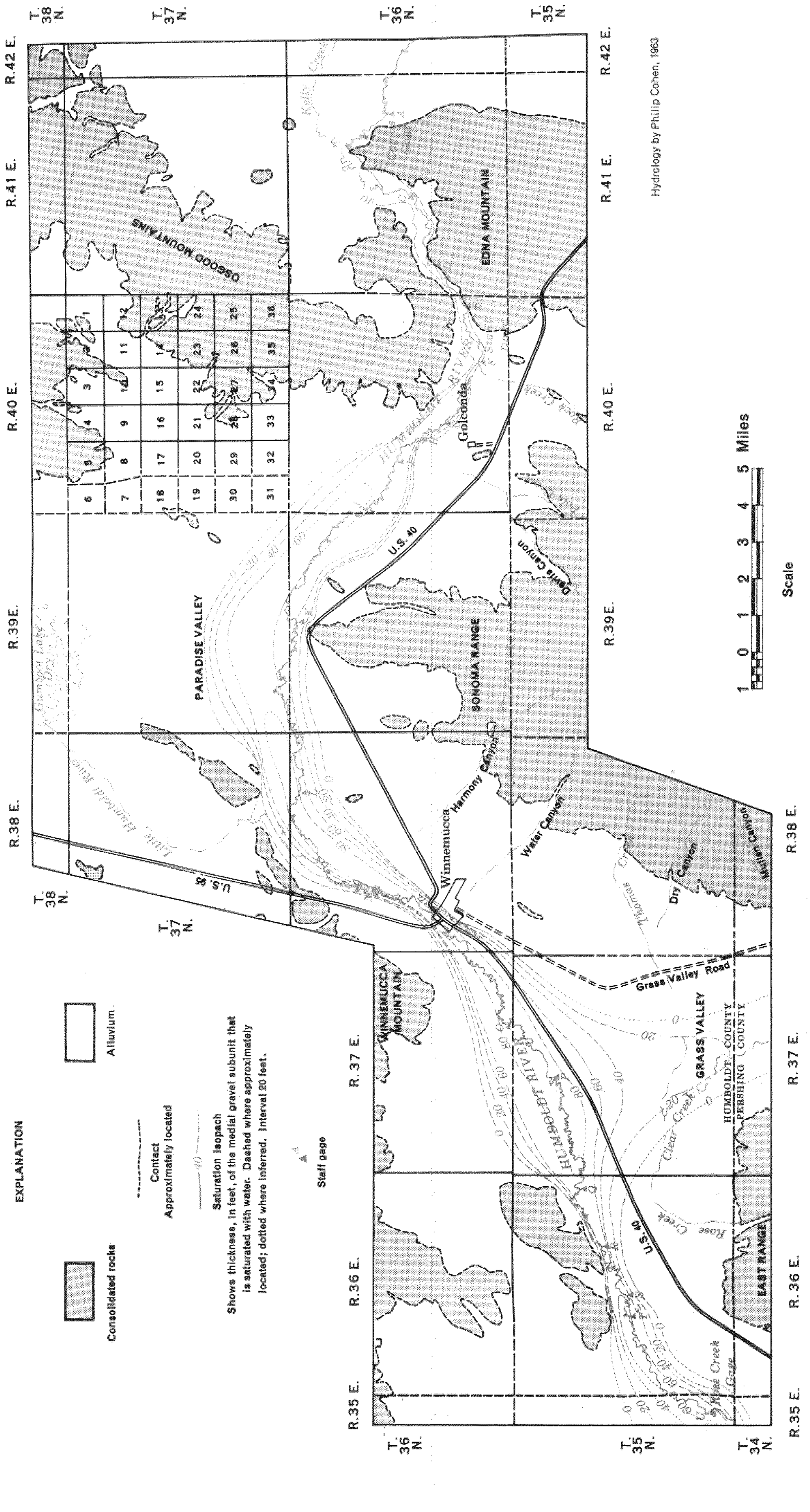


FIGURE 19. Map of the Humboldt River valley near Winnemucca, Nevada, showing the approximate saturated thickness of the medial gravel subunit.

1963b, p. 83–84). These changes, which are listed in Table 7, reflect differences in the amount of water moving into and out of the zone of aeration during a given period of time. When more water moves into the zone than is discharged from it, the moisture content increases; the converse, of course, is also true.

TABLE 7. ESTIMATED NET CHANGE IN MOISTURE CONTENT IN THE ZONE OF AERATION IN THE STORAGE AREA NEAR WINNEMUCCA, NEVADA, FOR THREE SELECTED TIME INTERVALS

Time interval	Net changes in moisture content (acre-feet)
Water years 1949–62 (average annual)	0
Water year 1962	+10,000
December-June, water year 1962	+17,000

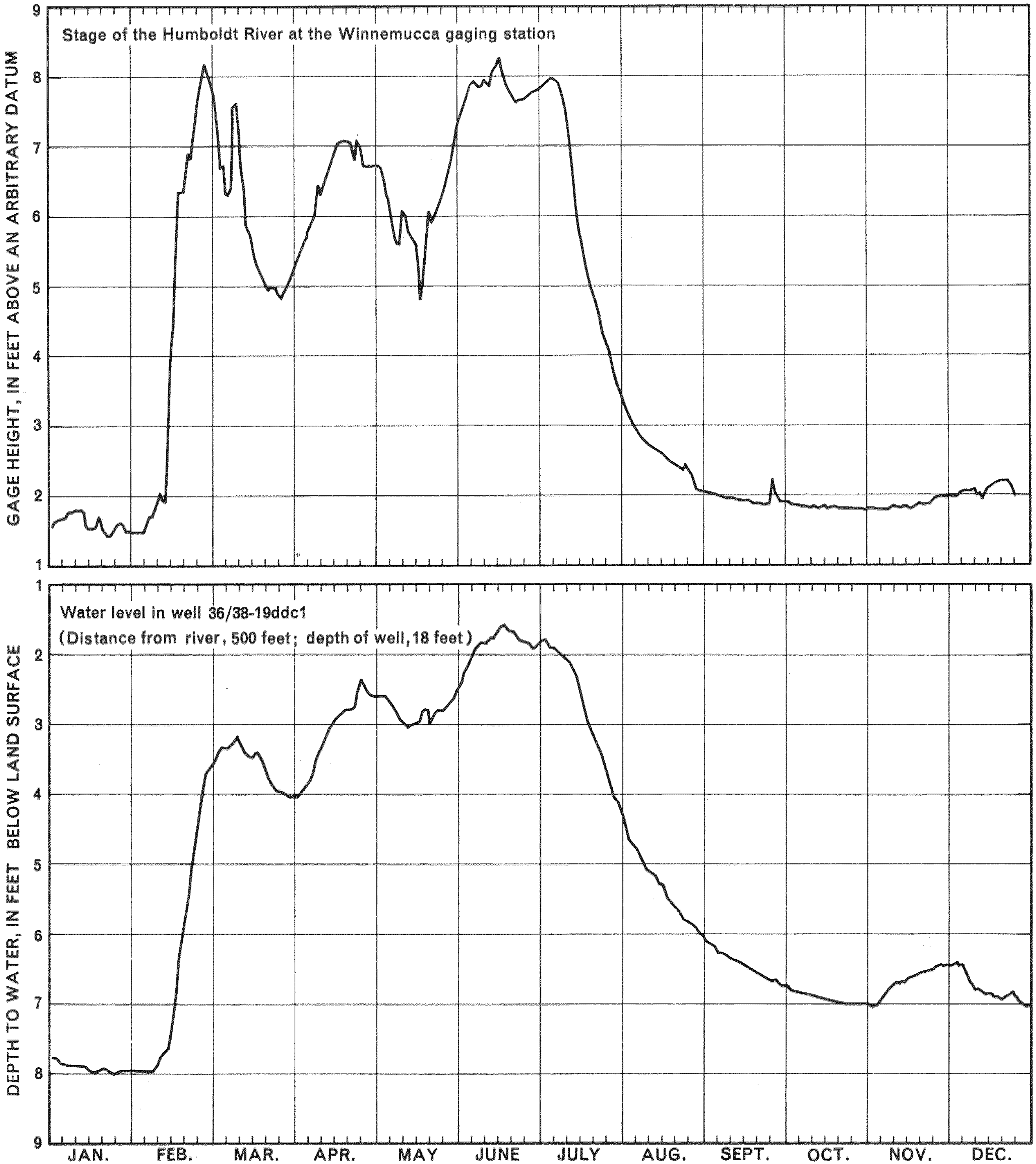


FIGURE 20. Hydrographs of the stage of the Humboldt River at the Winnemucca gaging station and the water level in a nearby well, calendar year 1962.

CHAPTER 6

DISCHARGE OF WATER

HUMBOLDT RIVER STREAMFLOW NEAR ROSE CREEK GAGING STATION

In previous chapters of this report the source and quantity of water entering the storage area (Fig. 9), and the movement and storage of water within the area have been emphasized. The discharge of water out of the storage area is summarized in this chapter of the report.

Humboldt River streamflow as measured at the Rose Creek gaging station (Fig. 2, item 14) normally represents the largest quantity of water discharged from the storage area in a given year. Since the beginning of the period of record (water year 1949), it has ranged from a high of about 536,000 acre-feet in water year 1952 to a low of about 22,000 acre-feet in 1955 (Fig. 21). The average annual flow for the period 1949–62 was 155,400 acre-feet; it was 242,900 acre-feet in water year 1962, and 187,800 acre-feet in December-June of that year.

As might be expected, overall yearly streamflow characteristics at the Rose Creek gaging station (Fig. 21) were very similar to those at the Comus gaging station (Fig. 10). However, streamflow in 10 of the 14 years of common record was less at the Rose Creek than at the Comus gaging station, ranging from nearly 5,200 acre-feet less in water year 1955 to about 54,000 acre-feet less in 1962 (Fig. 22). In the other 4 years, streamflow was greater at the Rose Creek gaging station than at the Comus gaging station, ranging from about 700 acre-feet more in 1954 to about 15,000 acre-feet more in 1958. In the 14-year period, 1949–62, average annual streamflow at the Rose Creek gaging station was nearly 17,000 acre-feet less than that at the Comus gaging station.

On the average, the flow of the Humboldt River decreased between the Comus and the Rose Creek gaging stations in the months of February-June of 1949–62. Table 8 shows that streamflow averaged about 28,000 acre-feet more at the Comus gaging station than at the Rose Creek gaging station during these months. In other words, the decrease in flow between the two stations in February-June was about 11,000 acre-feet more than the average annual decrease in flow.

As shown in Table 9, on the average the flow increased by about 11,000 acre-feet in July-January of 1949–62, thereby accounting for the difference between the average annual loss in streamflow and the loss in the months of February-June.

The decrease in flow between the Comus and Rose Creek gaging stations in February-June was a result of seepage from the river to the groundwater reservoir (Fig. 2, item 8), diversions for irrigation (Fig. 2, item 6), and evapotranspiration (Fig. 2, item 11). Inasmuch as tributary streamflow was almost negligible, practically the entire

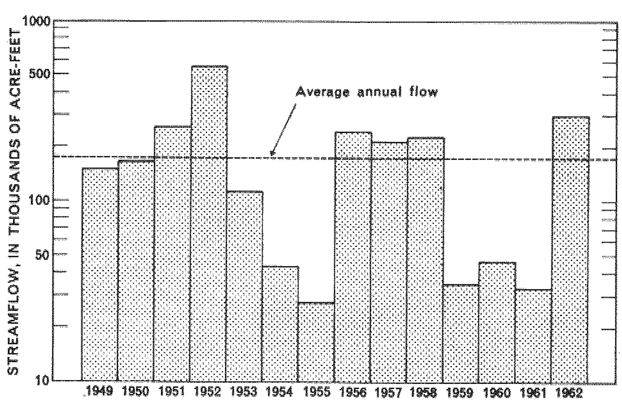


FIGURE 21. Annual flow of the Humboldt River at the Rose Creek gaging station, water years 1949–62.

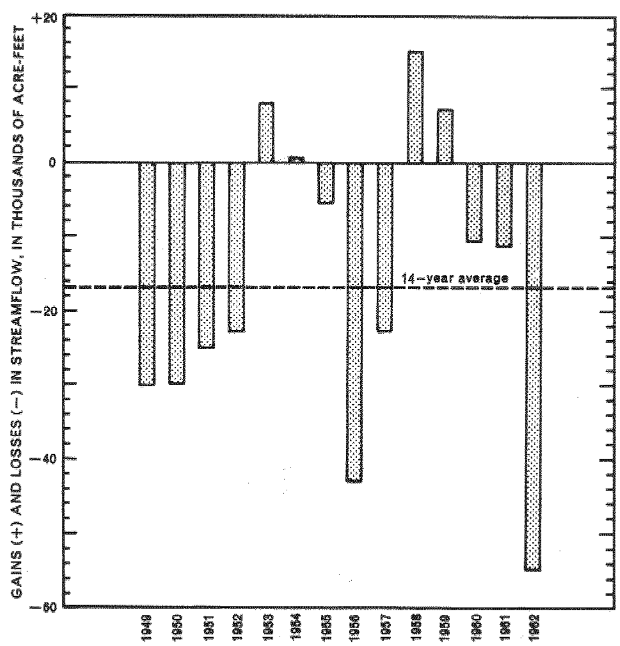


FIGURE 22. Gains and losses in streamflow between the Comus and Rose Creek gaging stations, water years 1949–62.

increase in flow in July-December was due to ground water discharging into the river between the two stations (Fig. 2, item 20). In July and August, most of the water that seeped into the river was ground water derived mainly from the river and stored in the flood-plain deposits during the previous high-water season. As the rate of seepage to the river decreased in September and October, the proportion of ground-water inflow from tributary areas discharging into the river increased. Normally, by December and January almost all the ground water discharging into the river was inflow from tributary areas.

EVAPOTRANSPIRATION OF PRECIPITATION

As previously noted (p. 30), of the approximately 59,000 acre-feet of average annual precipitation on the storage area near Winnemucca (Fig. 9), about 600 acre-feet fell on the Humboldt River and about 2,000 acre-feet recharged the ground-water reservoir. Almost all the remainder of the precipitation, an average of about 56,000 acre-feet per year, evaporated from the land surface soon after it fell, or was stored in the zone of aeration and subsequently was consumed by evapotranspiration (Fig. 2, items 12 and 13). In water year 1962, about 57,000 acre-feet of precipitation was consumed by evapotranspiration in the storage area in this manner; about 40,000 acre-feet of this amount was lost in December-June (Cohen, 1963b, p. 68).

Once precipitation falls on the Humboldt River or percolates downward into the zone of saturation it cannot be distinguished, of course, from the streamflow or the ground water with which it mixes. Thus, an unknown but fairly small quantity of water originating as precipitation on the storage area probably evaporates from the free-water surface of the Humboldt River and is lost by evapotranspiration from the zone of saturation. In addition, a very small percentage of the precipitation on the storage area probably is discharged from the area as Humboldt River streamflow and as ground-water outflow near the Rose Creek gaging station. These losses of precipitation cannot be computed separately; however, they are included in the estimates given in other sections of this chapter.

TRANSPIRATION BY PHREATOPHYTES AND EVAPORATION FROM BARE SOIL

Phreatophytes are plants that obtain a substantial part of their water supply from the zone of saturation (Fig. 2, item 18). The loss of water from areas covered by phreatophytes in the Winnemucca area, including the amount transpired by the plants and the amount evaporated from bare soil, is being investigated intensively as part of the Humboldt River Research Project. T. W. Robinson of the U.S. Geological Survey is in charge of studies involving the woody phreatophytes (Robinson, 1963), and A. S. Dylla of the U.S. Agricultural Research Service is in charge of studies involving the grasses.

TABLE. 8 AVERAGE DECREASE IN FLOW OF THE HUMBOLDT RIVER BETWEEN THE COMUS AND ROSE CREEK GAGING STATIONS, FEBRUARY THROUGH JUNE OF WATER YEARS 1949–62

Month	Average streamflow at the Comus gaging station (acre-feet)	Average streamflow at the Rose Creek gaging station (acre-feet)	Decrease in streamflow (acre-feet)
February	11,300	8,780	2,520
March	18,620	16,950	1,670
April	33,560	23,750	9,810
May	41,030	36,380	4,650
June	40,500	31,120	9,380
Totals (rounded)	145,000	117,000	28,000

TABLE 9. AVERAGE INCREASE IN FLOW OF THE HUMBOLDT RIVER BETWEEN THE COMUS AND ROSE CREEK GAGING STATIONS, JULY THROUGH JANUARY OF WATER YEARS 1949–62

Month	Average streamflow at the Comus gaging station (acre-feet)	Average streamflow at the Rose Creek gaging station (acre-feet)	Increase in streamflow (acre-feet)
July	16,220	19,570	3,350
August	1,940	4,590	2,650
September	131	2,100	1,970
October	79	1,670	1,590
November	1,040	2,030	990
December	3,080	3,650	570
January	4,660	4,840	180
Totals (rounded)	27,000	38,000	11,000

The phreatophyte studies are not yet completed; however, the available data permit fairly accurate preliminary estimates of these evapotranspiration losses. Inasmuch as most of the precipitation on the storage area evaporates from the land surface soon after it falls, the estimates given in the following table do not include these losses. The preliminary estimates of evapotranspiration losses from the areas covered by phreatophytes listed in Table 10 are based on unpublished data supplied by agencies cooperating in the project (Robinson, 1964, written communication; Dylla, 1964 written communication; and Naphan, 1964, written communication) and the interpretation and extrapolation of these data by the writer.

EVAPORATION FROM OPEN BODIES OF WATER

The amount of water evaporated from open bodies of water (Fig. 2, item 12) depends mainly on the rate of evaporation and on the area of the open bodies of water (commonly termed the area of "free-water surface"). Hanson (1963, pp. 53–55) studied the relation between the average flow of the Humboldt River at the Comus and Rose Creek gaging stations and the area of the free-water surface of the river (Fig. 23). For example, he found that when the flow of the river at the two gaging stations averaged 20 cfs, the area of the free-water surface was about 1,000 acres; when the flow averaged 5,000 cfs, the river was in flood and the area of the free-water surface was 12,000 acres.

Rates of evaporation from open bodies of water were estimated on the basis of limited evaporation-pan data available for the Winnemucca area, and data obtained in nearby areas. Using these data, the available streamflow data, and the relation shown in Figure 23, Hanson computed the relation between the annual flow of the Humboldt River at the Comus gaging station and the amount of water evaporated from the free-water surface of the Humboldt River in the Winnemucca area (Fig. 24). These estimated evaporation losses ranged from a high of 23,400 acre-feet in water year 1952, to a low of 4,650 acre-feet in water year 1955.

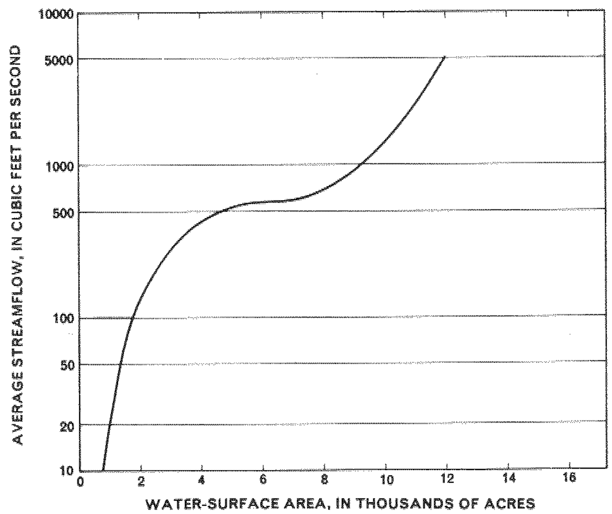


FIGURE 23. Relation of the total water-surface area of the Humboldt River between the Comus and Rose Creek gaging stations to the average of streamflow at the two stations. (After Hanson, 1963, Fig. 22.)

The estimated evaporation from the free-water surface of the Humboldt River for the three periods selected for water-budget analysis is summarized in Table 11.

Based on the work of Hanson, the estimates of evaporation from free-water surfaces include most but not all the evaporation losses from free-water surfaces in the storage area. During the irrigation season, thousands of acres on the flood plain are covered by water, commonly for days and sometimes for weeks at a time, as a result of artificial overbank flooding for irrigation. The amount of water lost by evaporation as a result of this method of irrigation was not studied and thus is not known; it is presumed to range from several

TABLE 10. PRELIMINARY ESTIMATES OF EVAPOTRANSPIRATION LOSSES FROM AREAS COVERED BY PHREATOPHYTES IN THE STORAGE AREA NEAR WINNEMUCCA, NEVADA[1]

General class of phreatopyhtes[2]	Acreage	Estimated Evapotranspiration Losses, in acre-feet: Water years 1949–62 (average annual)	Water year 1962	December-June of water year 1962
Grass	10,020	13,000	14,000	4,300
Willow and wildrose	5,470	20,000	22,000	7,000
Cattail and bulrush	460	2,100	2,300	700
Greasewood	16,780	6,000	6,700	2,100
Rabbitbrush	2,310	3,800	4,200	1,300
Totals (rounded)	35,000	45,000	50,000	15,000

[1]Does not include evapotranspiration losses of precipitation from the land surface and from the zone of aeration.

[2]Major vegetative type; includes lesser amounts of associated plants. Grass, willow, wildrose, cattail, and bulrush are included in the "grass and willow" vegetative unit shown in Figure 6.

hundred to several thousand acre-feet per year, depending largely on the availability of Humboldt River water for irrigation.

Almost all the remainder of the significant amount of water evaporated from free-water surfaces in the storage area is lost from ephemeral pools and puddles formed as a result of infrequent

TABLE 11. EVAPORATION LOSS FROM THE FREE-WATER SURFACE OF THE HUMBOLDT RIVER IN THE STORAGE AREA NEAR WINNEMUCCA, NEVADA

Time interval	Evaporation loss (acre-feet)
Water years 1949–62 (average annual)	14,000
Water year 1962	21,400
December-June, water year 1962	14,000

rain showers. It is very difficult to compute the amount of water evaporated in this manner; however, the amount is included in the estimates of the evapotranspiration of precipitation given in a previous section of this chapter.

GROUND-WATER OUTFLOW

All the subsurface ground-water outflow from the storage area (Fig. 2, item 22) occurs at the downstream margin of the project area. Available data are insufficient to calculate directly the amount of ground-water outflow in the vicinity of station U (the Rose Creek gaging station); however, it can be estimated by computing the underflow roughly parallel to the river near station S (Fig. 9).

Detailed geophysical, geologic, and hydrogeologic studies (Dudley and McGinnis, 1962, Hawley and Wilson, 1964, McGinnis and Dudley, 1964, Cartwright, Swinderman, and Gimlett, 1964, and Cohen, 1962a) have shown that a fault bordering the west side of the East Range extends northward beneath the Humboldt River near station S (Fig. 8). As a result of earth movement along the fault, virtually impermeable consolidated rock underlies the flood plain at a depth of about 40 to 50 feet; the consolidated rock, in turn, is overlain almost solely by the medial gravel subunit. Thus, nearly all the ground-water outflow roughly parallel to the Humboldt River near station S, about 2.5 to 3.5 cfs (Cohen, 1963b, Table 16), is through the medial gravel.

During most of the year the flow of the Humboldt River decreases by about 1 cfs between stations S and U, because water moves from the river to the ground-water reservoir as a result of the substantial increase in the cross-sectional area of the medial gravel subunit downstream from station S. Moreover, ground-water inflow moving toward the river between stations S and U is considered to be negligible. Thus, the estimated average annual underflow leaving the storage area near station U is equal to the underflow past station S, plus the 1 cfs of water derived from the river by seepage loss between stations S and U, or about 3.5 to 4.5 cfs, which is approximately 3,000 acre-feet per year. Ground-water outflow in water year 1962 was nearly equal to the average annual ground-water outflow, and outflow in the period December-June was about 1,800 acre-feet.

PUMPAGE AND SPRINGFLOW

"Gross pumpage" is the total amount of water removed from the ground-water reservoir by wells (Fig. 2, item 21). Some of the pumped water returns to the ground-water reservoir by infiltration, and a few hundred acre-feet discharges into the Humboldt River through the Winnemucca sewage plant. The remainder, termed the "net

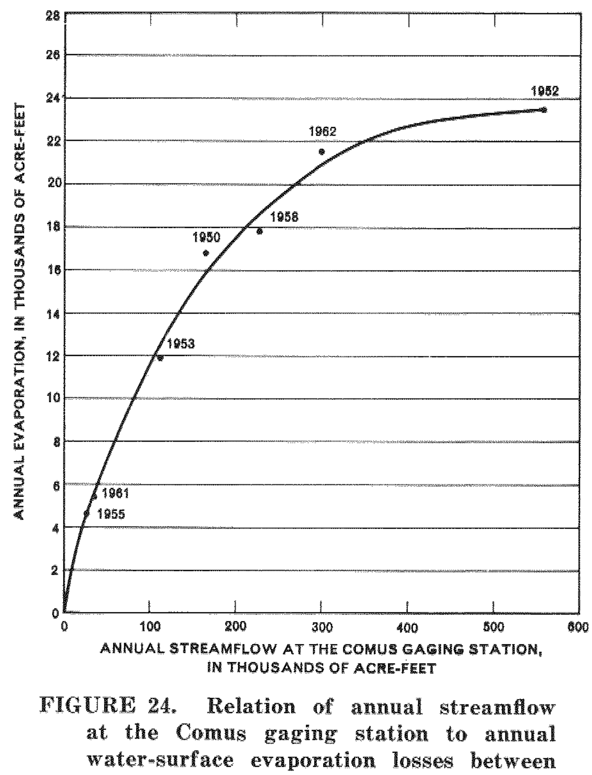


FIGURE 24. Relation of annual streamflow at the Comus gaging station to annual water-surface evaporation losses between the Comus and Rose Creek gaging stations. (After Hanson, 1963, Fig. 23.)

pumpage," is permanently removed from the storage area by evapotranspiration. The estimated net pumpage for the three time intervals of interest is as follows:

Time interval	Estimated net pumpage (acre-feet)
Water years 1949–62 (average annual)	1,500
Water year 1962	3,000
December-June of water year 1962	1,000

Average annual springflow in the storage area is about 250 gpm, or about 400 acre-feet per year. Most of this water is consumed by evapotranspiration; however, because all the springflow is thermal and because its ultimate source is not known, it is not included in either the inflow or outflow data listed in the water budgets (Table 13).

SUMMARY OF TOTAL OUTFLOW

The estimated average annual outflow from the storage area near Winnemucca in water years 1949–62 and the percentage of the total represented by each of the major outflow items are as follows:

Outflow item	Average annual outflow (acre-feet)	Percentage of total
Humboldt River	155,400	57
Evapotranspiration of precipitation	56,000	20
Transpiration by phreatophytes and evaporation from bare soil[1]	45,000	16
Evaporation from free-water surfaces	14,000	5
Ground-water outflow	3,000	1
Net pumpage	1,500	Less than 1
Total (rounded)	275,000	100

[1]Does not include the evapotranspiration of precipitation.

CHAPTER 7

CHEMICAL QUALITY OF THE WATER

Almost all the many thousands of compounds and elements above, on, and beneath the surface of the earth are soluble to some extent in water. Therefore, practically all naturally occurring water contains dissolved solids. In the small quantities in which they commonly occur, most of these dissolved solids are harmless; in fact, many of the substances found in water are necessary for the proper nutrition of plants and animals, including man. On the other hand, excessive amounts of some of the material dissolved in water can be harmful in quantities only slightly higher than the optimum amounts needed. Thus, one of the major objectives of the water-resources studies carried on as part of the Humboldt River Research Project was an evaluation of the chemical suitability of the water for use. (See Cohen, 1962d.)

In addition, water-quality data commonly are very helpful in evaluating many other features of the water resources of an area, such as the source and amount of water entering the area, and its rate and direction of movement. Water-quality data were used to study these and other features of the water resources of the Winnemucca area (Cohen, 1962d and 1963b).

Some of the significant results of the water-quality studies are summarized in the following paragraphs.

DEFINITION OF TERMS

"Dissolved solids" or "dissolved-solids content" refers to the substances dissolved in water. The values for dissolved-solids content given in this report are the sums of the constituents for which analyses were made, expressed in parts per million (ppm)—the weight of dissolved material in one million parts of water. Thus, water in the Winnemucca area is classified as follows:

Dissolved-solids content (ppm)	Classification
150– 300	Very low
300– 500	Low
500– 750	Moderate
750–1,000	Moderately high
1,000–2,000	High
>2,000	Very high

Most naturally occurring water will conduct an electrical current, depending mainly on the number and kinds of ions in solution and on the temperature of the water. "Specific conductance," expressed in micromhos per centimeter at 25° C., is a measure of the ease with which the electricity will pass through water, and therefore is a rough measure of the dissolved-solids content of water.

Hardness of water is caused principally by dissolved calcium and magnesium, and commonly is expressed in parts per million of calcium carbonate. The following numerical ranges and adjectives are used to classify water hardness in this report:

Hardness (ppm of $CaCO_3$)	Classification
0– 60	Soft
61–120	Moderately hard
121–180	Hard
>180	Very hard

VARIATIONS IN WATER QUALITY

Ground Water

Figure 25 shows the dissolved-solids content of the ground water in the area, based on 176 chemical analyses. (See Cohen, 1962d, Tables 1 and 2, for representative chemical analyses.) Many of the wells and springs were sampled more than once (during periods of low, moderate, and high ground-water levels in 1961 and 1962) to determine whether the water quality changed with time, especially from season to season. In addition, where possible, water samples were obtained from nearby wells of different depths to evaluate vertical changes in quality. Throughout most of the area, the water quality did not change appreciably with depth; however, marked changes were noted locally. Where appropriate, these changes are discussed in the following paragraphs.

As is shown in Figure 25, the dissolved-solids content and, accordingly, the chemical quality of the ground water vary considerably from place to place within the Winnemucca reach of the Humboldt River valley. Throughout almost the entire project area, most of the ground water beneath the flood plain of the Humboldt River and the immediately adjacent benchlands has a dissolved-solids content ranging from 500 to 750 ppm, and is a sodium bicarbonate type.

Ground water sampled from several small areas on the flood plain had a high to very dissolved-solids content. In most cases, these samples

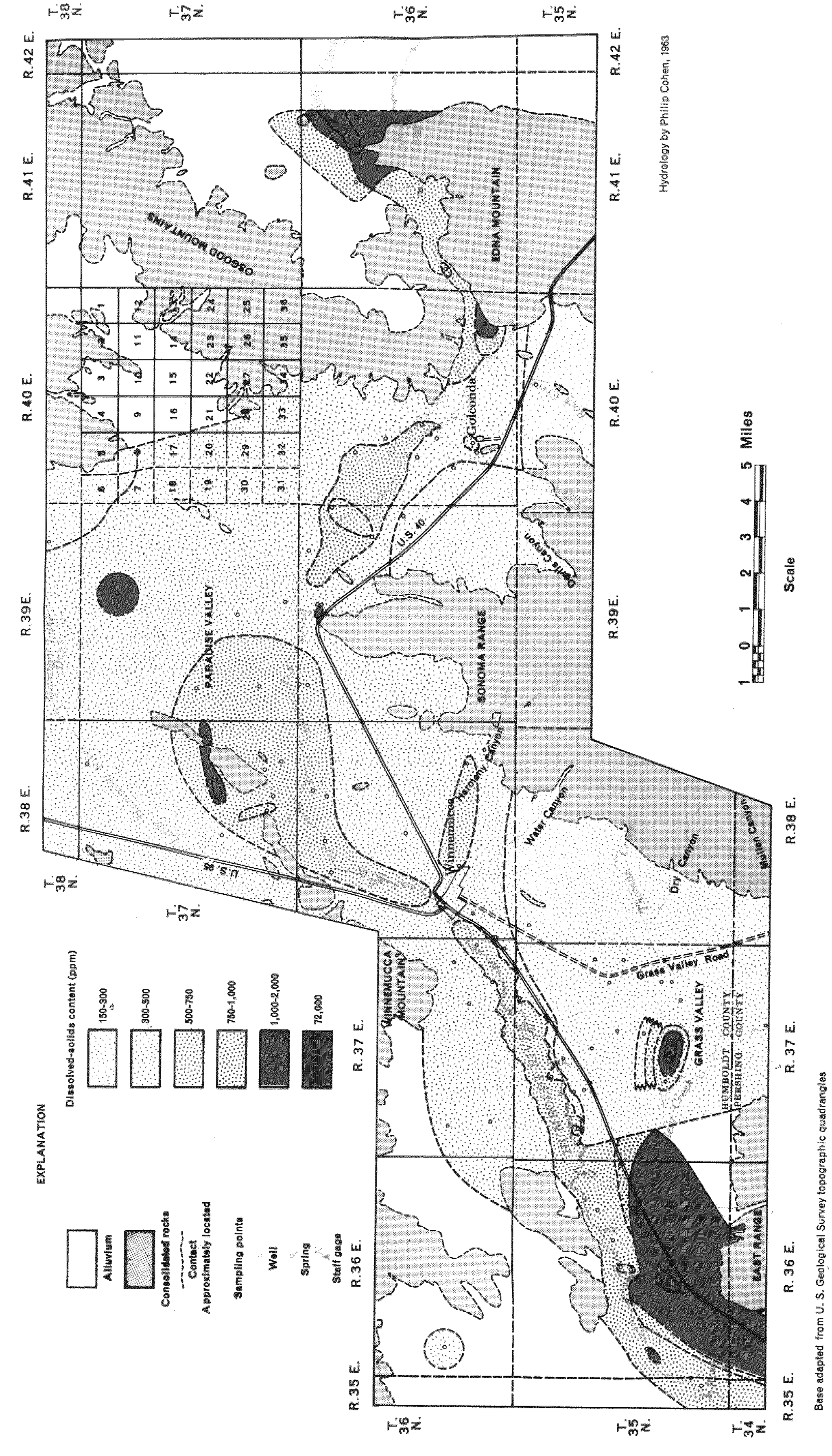


FIGURE 25. Map showing dissolved-solids content of ground water in the Humboldt River valley near Winnemucca, Nevada, 1961–62.

reflected highly localized conditions or the fact that they were obtained from shallow test borings, or a combination of the two factors. In many places on the flood plain large amounts of salts have accumulated as a result of evapotranspiration. Shallow wells tapping these highly saline flood-plain deposits or their subsurface equivalents yield sodium chloride or calcium sulfate water having a high or very high dissolved-solids content. Generally, however, wells tapping the deposits beneath these saline materials yield sodium bicarbonate water of moderate dissolved-solids content.

Ground water in most of that part of Paradise Valley shown in Figure 25 has a low dissolved-solids content. A small area in the northeastern part is underlain by ground water of very low dissolved-solids content; a 61-foot deep flowing well in sec. 39, T. 37 N., R. 39 E., yields thermal sodium bicarbonate water of high dissolved-solids content and having a temperature of 158° F. Finally, shallow wells tapping fine-grained saline, lacustrine deposits near the southwest corner of Paradise Valley yield sodium chloride and mixed-type water of high to very high dissolved-solids content.

Ground water in the drainage basins of Pole and Rock Creeks and most of the ground water in Grass Valley is calcium bicarbonate water of very low dissolved-solids content. This water is derived mainly from the infiltration of streamflow draining the Sonoma Range. Calcium and bicarbonate are the most abundant ions in this water because the Sonoma Range consists mainly of limestone ($CaCO_3$). Ground water in Grass Valley having a moderate to very high dissolved-solids content (Fig. 25) was obtained from shallow wells tapping highly saline silt and clay deposits of Lake Lahontan age.

Near the southwest margin of the project area, thermal calcium bicarbonate ground water associated with the East Range fault has a moderately high to very high dissolved-solids content. This water is similar to the thermal water issuing from the previously described flowing well in Paradise Valley and to the water issuing from the springs near the eastern margin of the project area. Thermal springs near the town of Golconda also discharge sodium bicarbonate water of similar chemical character. These widely spaced sources of thermal artesian ground water of similar chemical quality suggest the possibility of a single, widespread thermal ground-water system at depth.

The chemical quality of all the thermal ground water and of much of the rest of the ground water that was sampled more than once did not change significantly with time. However, the quality of the water from some of the shallow wells, notably from some of the shallow wells on the flood plain, changed markedly with time. Most of these shallow wells are fairly close to the Humboldt River and tap deposits that are in hydraulic continuity with the river; that is, during periods of high river stage water moves from the river into these deposits, and during periods of low river stage water moves from the deposits into the river.

Surface Water

The chemical quality of the Humboldt River and that of most of the ground water in the shallow deposits are closely related. As is shown in Figure 26, the specific conductance varies inversely with the flow of the Humboldt River. Thus, during periods of high flow the dissolved-solids content of the river and of most of the ground water in the shallow deposits adjacent to the river decreased markedly. Locally, however, the dissolved-solids content of the ground water increased during the same periods because the water table rose into highly saline silty and clayey flood-plain deposits.

Normally the stage and flow of the river are highest in the late winter and spring. At that time almost all the streamflow is derived from rain and snowmelt runoff, and therefore the specific conductance of the water commonly is the lowest of the year, about 475 to 500 micromhos at the Winnemucca gaging station (station M, Fig. 9). In the late summer and fall when the stage and flow of the river are at or near their lowest of the year, the flow of the river in the project area consists almost entirely of ground-water seepage, and the specific conductance of the water is the highest of the year, about 950 to 975 micromhos at the Winnemucca gaging station.

During periods of low streamflow in the late fall and early winter, the chemical quality of the river closely reflects the chemical quality of underflow from the tributary areas. Moreover, the flow and the chemical quality of the river change downstream because of the interchange between the river and the water in the ground-water reservoir. (See Cohen, 1963b, pp. 89–92.)

Changes in the chemical quality of the river between the Comus and Rose Creek gaging stations in December 1961 and estimates of ground-water inflow from Grass Valley based on water-quality data are considered in detail in other reports (Cohen, 1962d, pp. 18–20, and 1963b, pp. 89–92). Some of the more significant of these changes are summarized briefly in the following paragraphs.

The flow of the Humboldt River at station A was about 0.05 cfs and was a mixture of sodium chloride and sodium bicarbonate water of moderately high to very high dissolved-solids content derived from the deposits in the vicinity of and upstream from the Comus gaging station. At station B, the flow increased to 0.4 cfs and the dissolved-solids content decreased to 836 ppm as a result of seepage of ground water of moderate dissolved-solids content into the river. The river was dry at station C, but the dissolved-solids content of water from a pool in the bed of the stream was 585 ppm. The flow and dissolved-solids content increased to 0.21 cfs and 752 ppm at station E, as a result of seepage into the river of ground water of moderate to moderately high dissolved-solids content.

At station G, the flow increased to 1.23 cfs and the dissolved-solids content decreased to 559 ppm, mainly as a result of the inflow to the river of calcium bicarbonate ground water of low dissolved-solids content from the drainage basin of Rock Creek. The flow and dissolved-solids content increased at station H, owing to continued ground-water inflow. At station N, the flow increased to 5.07 cfs and the dissolved-solids content decreased to 489 ppm, mainly because of seepage to the river of ground-water inflow from the Pole Creek drainage basin and from Paradise Valley.

Between stations N and O, the width of the medial gravel unit increased markedly and caused the river to lose water to the ground-water reservoir; the dissolved-solids content of the river remained almost unchanged between the two stations in December 1961. The inflow of ground water of very low to low dissolved-solids content mainly from Grass Valley caused the flow of the river to increase to 14.8 cfs and the dissolved-solids content to decrease to 453 ppm between stations O and S. The flow decreased to about 13.5 cfs at station U and the dissolved-solids content was almost unchanged from that at station S.

SUITABILITY FOR USE

Inasmuch as the industrial use of water in the project area was negligible during the period of the investigation and because standards for the chemical quality of water for such use are extremely variable, only the chemical suitability of the water for domestic and agricultural use was studied in detail. (See Cohen, 1962d.) However, the available data indicate that, in general, most of the water in the Winnemucca area probably is chemically suitable for most industrial uses.

Table 12 summarizes the source of the chemical constituents for which analyses were made as part

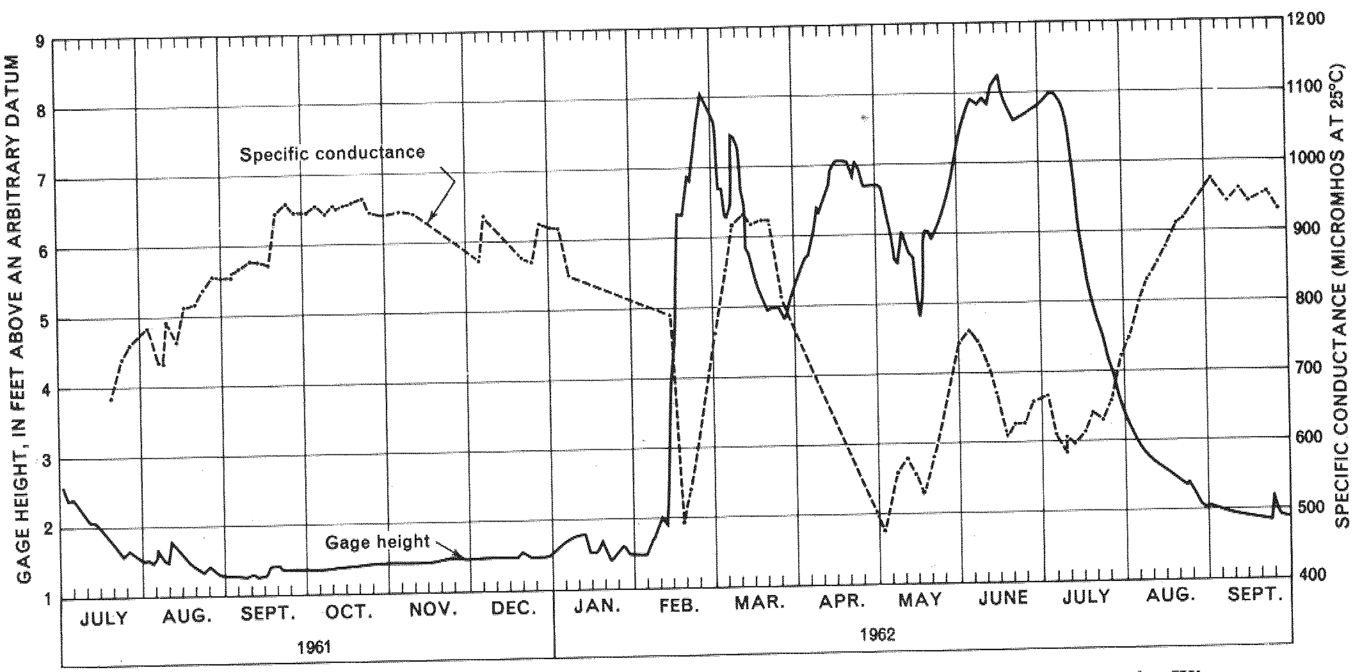


FIGURE 26. Relation between specific conductance and gage height of the Humboldt River at the Winnemucca gaging station (station M), 1961–62.

of the present investigation and the significance of these constituents with respect to the suitability of the water for use. Some of the thermal water near the Comus gaging station, the water issuing from the springs near Golconda, and much of the ground water in the vicinity of the East Range fault contains excessive amounts of boron and fluoride and, therefore, is not suitable for agricultural or domestic use. Likewise, some of the ground water in the shallow flood-plain deposits that has a high to very high dissolved-solids content is not suitable for many uses. Nevertheless, most of the ground water and almost all of the surface water in the area is of good to excellent quality and is chemically suitable for most agricultural and domestic uses.

TABLE 12. PRINCIPAL SOURCES AND SIGNIFICANCE WITH RESPECT TO SUITABILITY FOR USE OF SELECTED CHEMICAL CONSTITUENTS IN THE WATERS OF THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEVADA

Constituent	Principal sources	Significance with respect to suitability for use (U.S. Public Health Service, 1962)
Silica (SiO_2)	Silicate minerals abundant in nearly all the consolidated rocks and in all the unconsolidated deposits.	May form scale in pipes and boilers.
Iron (Fe)	Iron-bearing minerals that occur, at least in small amounts, in nearly all the consolidated rocks and in all the unconsolidated deposits.	More than about 0.3 ppm may stain laundry utensils and kitchen fixtures. Larger quantities may color and impart objectionable taste to water.
Calcium (Ca)	Calcium-bearing feldspars which constitute as much as 50 percent of some of the basic volcanic rocks such as basalt, andesite, and diorite; limestone. Calcium salts, especially $CaCO_3$ and $CaSO_4$ in the unconsolidated deposits.	Principal cause of hardness. Commonly a major constituent in scale deposits.
Magnesium (Mg)	Pyroxenes and amphiboles in igneous rocks. Magnesium salts in unconsolidated deposits.	Second most important cause of hardness.
Sodium (Na)	Sodium-bearing feldspars in the acidic volcanic rocks such as granite and rhyolite. Sodium salts, especially NaC1, Na_2CO_3, $NaHCO_3$, and Na_2SO_4 in the unconsolidated deposits. Ion exchange with sodium-bearing clay minerals.	Excessive amounts may reduce soil permeability. In combination with chloride, may cause water to taste salty.
Potassium (K)	Potash feldspars in acidic igneous rocks. Potassium salts probably are comparatively rare in the unconsolidated deposits.	Essential for proper plant nutrition.
Bicarbonate (HCO_3)	End product of the weathering of feldspars and many other common rock-forming minerals. $CaCO_3$, Na_2CO_3, and $NaHCO_3$ salts in the unconsolidated deposits.	Causes carbonate hardness in combination with calcium and magnesium. May be precipitated from boiling water to form scale and yield corrosive carbon dioxide. Locally forms "black alkali" (Na_2CO_3) crusts on the soil which are injurious to many plants.
Sulfate	Oxidation and hydration of sulfide minerals in the consolidated rocks. Solution of gypsum from the unconsolidated deposits.	May be precipitated from boiling water to form scale. Excessive amounts may have a laxative effect on humans and animals.
Chloride	Chloride salts, largely NaCl, in the unconsolidated deposits, especially in the lacustrine and flood-plain deposits.	Excessive amounts (more than 250 ppm) may cause salty taste. Precipitates locally on the Humboldt River flood plain where it is injurious to most plants.
Fluoride	Occurs in trace amounts in various consolidated rocks. Associated with thermal water near the East Range fault and near the Comus gaging station.	Essential for proper human nutrition. Excessive amounts (more than about 1.7 ppm) may cause mottled tooth enamel in children.
Nitrate (Na_3)	Nitrates in the soil and, locally, organic pollutants.	Nitrate in drinking water in excess of about 45 ppm may cause cyanosis, the so-called "blue-baby" disease, in infants.
Boron	Occurs in trace amounts in some of the consolidated rocks of the area. Associated with thermal water near the East Range fault and with water of high dissolved-solids content near the Comus gaging station.	Essential for proper plant nutrition in small amounts. Toxic to many plants in amounts only slightly more than the needed amounts. Unsuitable in quantities of more than 3.75 ppm, for even the most tolerant crops.

CHAPTER 8

SUMMARY OF THE FLOW SYSTEM

The quantitative aspects of the flow system in the storage area near Winnemucca are summarized in this chapter of the report by means of three water-budget analyses (Table 13). The storage area (Fig. 9) includes only about 28 percent of the project area—the area termed the "Humboldt River valley near Winnemucca"—which, in turn, represents only about 3 percent of the entire Humboldt River drainage basin. However, as is considered in Chapters 9 and 10 of this report, development in this fairly small part of the basin conceivably could affect the downstream supply of water and, because of established water rights, the upstream supply of water.

THE CONCEPT OF DYNAMIC EQUILIBRIUM

The flow system in the project area as summarized in Figure 2 is nearly in a state of long-term dynamic equilibrium. As used in this context, the term "dynamic" means a constant state of motion, and refers to the fact that water in the storage area is continually moving. The rate of movement of surface water ranges from a few feet per second when the Humboldt River is in flood to practically zero feet per second in pools of standing water. Nonetheless, even in these pools the water is moving. The word "equilibrium" refers to a state of balance of the flow system. Thus, when referring to the flow system as being in a state of long-term dynamic equilibrium, it is implied that over a long period of time the amount of water entering the system is balanced by or is equal to the amount of water leaving the system.

The flow system in the storage area was in a state of long-term dynamic equilibrium prior to the development of water by man. The equilibrium has been disturbed only slightly, if at all, as a result of the activities of man, because (1) the additional net draft has been very small as compared to the total amount of water entering and leaving the system, and (2) the additional draft in part has been compensated for by decreased natural losses from the system. Thus, for practical purposes the flow system of the storage area is still nearly in a state of long-term dynamic equilibrium.

WATER–BUDGET ANALYSIS

An analysis of the water budget for the storage area is a quantitative evaluation of the flow system of the area—a tally of all the items of inflow and outflow and of changes in the amount of water in storage. For any period of time, long or short, the water budget for a given area can be expressed by the equation:

$$I = O \pm St,$$

where I is equal to total inflow, O is equal to total outflow, and St is equal to the net change in the amount of water in storage. If the amount of water in storage increases, it is added to the right side of the equation; if it decreases, it is subtracted. Because the flow system in the storage area virtually is in long-term dynamic equilibrium, the long-term average annual net change in the amount of water in storage is practically zero.

Water-budget analyses were made for three periods: water years 1949–62, water year 1962, and December-June of water year 1962. The period 1949–62 was chosen because of the availability of Humboldt River streamflow data at both the Comus and Rose Creek gaging stations for that period. Water year 1962 was chosen because the largest measured loss in streamflow between the Comus and Rose Creek gaging stations, about 54,000 acre-feet, occurred during that year. Finally, December-June 1962 was chosen because the largest measured changes in storage occurred during the period. The three water budgets are shown in Table 13.

Not all the items shown on the flow diagram (Fig. 2) are included individually in the budget analyses. Rather, several of them are grouped together in the table. This grouping is necessary because it was impossible to estimate some of the items separately. For example, it was impossible to tell what proportion of the water lost from the zone of saturation was derived from the infiltration of precipitation, the infiltration of streamflow, and subsurface ground-water inflow. Similarly, the continual downstream interchange between the Humboldt River and the ground-water reservoir makes it impossible to identify the exact amounts of water in the river at the Rose Creek gaging station that are derived from the various sources contributing to the streamflow.

If all the amounts listed in Table 13 were accurate, the water-budget equation for each of the three periods would balance. The table shows that for each period the estimates of inflow are somewhat less than the sums of the outflow plus the net increases in storage, ranging from about 3 percent less for December-June of water year 1962 to about 10 percent less for the 14-year average of water years 1949–62. The imbalances reflect the cumulative errors in the estimates of all the components of the water budgets, and are to be expected, inasmuch as the components of the flow system could not be studied as precisely as desired within the realm of economic and technological feasibility.

TABLE 13. THREE WATER BUDGETS FOR THE STORAGE AREA NEAR WINNEMUCCA, NEVADA

Water-budget components	Water years 1949–62; 14-year average (acre-feet)	Water year 1962 (acre-feet)	December through June of water year 1962 (acre-feet)
Inflow:			
Humboldt River streamflow at the Comus gaging station (p. 27)	172,100	297,200	254,300
Precipitation (p. 30)	59,000	60,000	47,000
Ground-water inflow (p. 30)	14,000	14,000	8,000
Tributary streamflow (p. 30)	8,600†	5,800	5,000
(1) Total inflow	253,700	377,000	314,300
Outflow:			
Humboldt River streamflow at the Rose Creek gaging station (p. 41)	155,400	242,900	187,800
Evapotranspiration of precipitation (p. 42)[1]	56,000	57,000	40,000
Transpiration by phreatophytes and evaporation from bare soil (Table 10[2])	45,000	50,000	15,000
Evaporation from open bodies of water (Table 11)	14,000	21,400	14,000
Ground-water outflow (p. 44)	3,000	3,000	1,800
Net pumpage (p. 44)	1,500	3,000	1,000
(2) Total outflow	274,900	377,300	259,600
Net Increase in Storage:			
Surface water (p. 35)	0	1,800	22,000
Ground water (Table 6)	0	5,000	26,000
Vadose water (Table 7)	0	10,000	17,000
(3) Total increase in storage	0	16,800	65,000
(4) Sum: (2) + (3)	274,900	394,100	324,600
Difference: (1) — (4)	—21,200	—17,100	—10,300

[1]Mainly evaporation from the land surface; includes a small amount of evapotranspiration from the zone of aeration.
[2]Does not include evapotranspiration losses of precipitation from the land surface and from the zone of aeration; mainly includes evapotranspiration of water derived from the zone of saturation.
†Includes artificial drainage of Gumboot Lake, and accordingly is 4,100 acre-feet more than the value listed in table 27 of Nevada Water Resources Bulletin 24.

CHAPTER 9

HOW MAN HAS MODIFIED THE NATURAL FLOW SYSTEM

To achieve the most effective use of the water resources of the Winnemucca area and of the entire Humboldt River valley, the present flow system may have to be changed significantly. Before describing the possible modifications that are being considered and the possible results of these changes, the modifications of the natural flow system already affected by man are considered in this chapter of the report. In addition, some of the legal aspects regarding the use of water in the valley are reviewed briefly.

DIVERSIONS OF HUMBOLDT RIVER STREAMFLOW

The first and the most significant modification of the natural flow system in the Humboldt River valley was the diversion of Humboldt River streamflow for irrigation. The early settlers found that the natural grasses growing on the flood plain, which in part were subirrigated and in part were irrigated by natural flooding, made excellent hay for horses and cattle. Subsequently, in about 1870, as the larger cattle ranches became established and as the need for a more dependable and more substantial supply of winter feed for the expanding livestock industry increased, Humboldt River water was diverted for irrigation.

These early diversions were accomplished by means of artificial flooding resulting from the construction of temporary rock and brush dams in the channel. Eventually, a network of unlined ditches was completed. Most of the ditches were only a few miles long and many of them consisted of abandoned natural stream channels.

Gradually, additional diversionary structures of a somewhat more substantial and permanent nature were built. In 1912, the first and still the only major off-stream storage facilities, the Pitt-Taylor Reservoirs, were completed near the community of Humboldt, about 40 miles downstream from Winnemucca. The reservoirs, which have a combined storage capacity of 32,000 acre-feet, were constructed to supply supplemental irrigation water to the Lovelock area, about 30 miles farther downstream.

The largest and the only major storage facility on the Humboldt River, Rye Patch Dam and Reservoir, is about 50 miles downstream from Winnemucca. It was completed in 1936 to furnish supplemental irrigation water for 38,000 acres in the Lovelock area, and has a storage capacity of 179,100 acre-feet. Since construction of Rye Patch Dam, water has been diverted into the Pitt-Taylor Reservoirs only in years of unusually high streamflow. In these years, water is released from the Pitt-Taylor Reservoirs during the irrigation season through an outlet canal into Rye Patch Reservoir, from where it subsequently is released for irrigation in the Lovelock area. Water was not diverted into the Pitt-Taylor Reservoirs during the period 1958–62.

Except for the construction of the fairly large reservoirs that supply irrigation water to the Lovelock area, methods of irrigation using Humboldt River water upstream from the Lovelock area have not changed materially since the earliest diversions. Moderately frequent and severe natural flooding has discouraged most of the landowners from making major capital improvements on either the land or the irrigation systems. Thus, almost all the Humboldt River water, other than that used in the Lovelock area, is diverted to unimproved meadows on the flood plain by artificial overbank flooding. The water is used mainly to irrigate native grasses, which in turn are cut for hay or used for pasture.

In 1931 the Sixth Judicial District Court of Nevada adjudicated the rights of the various ranchers to divert the waters of the Humboldt River. The court determined that as of 1931 the total area of cultivated land for which water could legally be diverted from the river was slightly more than 285,000 acres, and that it required about 698,000 acre-feet of water to satisfy the irrigation rights for this land (Mashburn and Mathews, 1943, p. 27).

As part of the reclamation project which resulted in the construction of Rye Patch Dam and Reservoir, about 60,000 acres of ranching property along the Humboldt River in the Battle Mountain area (Fig. 1) was purchased; some of this land had decreed rights to divert Humboldt River water for irrigation, and these rights were transferred downstream for use in the Lovelock area. Since then, the purchased land in the Battle Mountain area has not been irrigated, except perhaps during the periods of natural flooding.

Accordingly, the total amount of land along the river having decreed rights to Humboldt River water currently is about 265,800 acres.

Data supplied by the Assistant State Engineer of Nevada (1964, written communication) indicate that, depending upon the availability of streamflow, a maximum of about 31,300 acre-feet of Humboldt River water legally may be diverted onto slightly less than 17,000 acres in the Winnemucca area. Very rarely is there sufficient streamflow to supply all of these water rights.

GROUND-WATER DEVELOPMENT

As previously noted, ground-water development for irrigation along the main stem of the Humboldt River is small as compared to the total amount of water diverted from the river. In the Winnemucca area, total (gross) ground-water pumpage was about 5,000 acre-feet in water year 1962, of which about 4,000 acre-feet was for irrigation and the remainder was for domestic and municipal use.

Data are not available to estimate accurately total pumpage in the remainder of the Humboldt River basin. Along the main stem of the Humboldt River, ground-water pumpage for irrigation probably is negligible. However, a few thousand acre-feet per year probably is pumped for municipal use, namely in the cities of Elko, Battle Mountain, and Lovelock. Ground-water development for irrigation in valleys tributary to the Humboldt River, especially upstream from the Winnemucca area, has been increasing rapidly in recent years. As is described subsequently in this report, such development eventually could modify the flow system of the basin.

EFFECTS OF MAN'S MODIFICATIONS OF THE FLOW SYSTEM

Under natural conditions a substantial part of the flow of the Humboldt River ultimately discharged into the Humboldt Sink, from where the water was lost by evapotranspiration. These losses were almost a complete waste inasmuch as they provided no significant economic benefits. As a result of the activities of man, only small quantities of streamflow currently reach the sink. Rather, nearly all the water that formerly flowed into the Humboldt Sink now is lost by evapotranspiration upstream—by natural evapotranspiration and as a result of agricultural practices. Thus, some of the increased upstream evapotranspiration losses are desirable, as the water is used to produce crops and is providing some economic return.

Manmade structures, ranging in size from Rye Patch Dam and Reservoir to small headgates and earthen dams, have increased the free-water surface of the river which, in turn, has resulted in increased losses upstream from the Humboldt Sink. Furthermore, upstream evaporation losses have increased as a result of the artificial flooding of meadows for irrigation. Diversions for irrigation and the resulting infiltration of water to the zone of saturation beneath the flood plain causes the water table to rise to within a few feet and, locally, to within a few inches of the land surface. This, in turn, results in substantial evaporation losses from bare soil and increased transpiration by phreatophytes. The increased upstream evapotranspiration losses locally have resulted in the accumulation of injurious amounts of salts that formerly would have been deposited in the Humboldt Sink. Many of the older residents in the area report that, since the advent of intensive artificial overbank flooding for irrigation, the character of the phreatophytes locally has changed from wildrye to willow, wildrose, and less nutritious grasses. These changes in the types of plants growing on the flood plain not only have decreased the productivity of the meadows, but also have increased the nonbeneficial evapotranspiration losses.

Ground-water development locally has increased the net draft on the hydrologic system; however, as total pumpage is very small in relation to the total average annual recharge to and discharge from the system, the losses from the system as a result of this development to date (1963) are negligible. In addition, although pumpage on the flood plain undoubtedly has decreased the flow of the river locally, the amount has been so small that it was not detected in the Winnemucca area during the course of this investigation.

LEGAL ASPECTS OF THE MODIFICATIONS OF THE FLOW SYSTEM

Many volumes of court testimony and legal decisions are available regarding man's modifications of the natural flow system of the Humboldt River valley. Much of this material is concerned with rights to divert Humboldt River water for irrigation. Those legal matters that have a direct bearing on the scope and content of this report are considered briefly in the following paragraphs.

Two of the fundamental features of Nevada water law are (1) that the water is public property and that, therefore, the State has the legal right to regulate its use, and (2) that the legal right to utilize the water resources of the State is based on the doctrine of prior appropriation, which states that the person who first uses beneficially a specific quantity of water from a given source has the highest priority for the perpetual use of that water. (See Hutchins, 1955.)

All rights to divert Humboldt River streamflow for irrigation were adjudicated largely on the basis of these two features of the state water law. (See Mashburn and Mathews, 1943, for details regarding the Humboldt River adjudications.) The earliest recognized rights in the basin and those having the highest priority were established for the year 1861. Rights were recognized and established for every year thereafter until 1921; the later the date of a recognized water right, the lower the priority to divert water. That is, earlier rights must be satisfied before water can be diverted onto land having later rights.

The highest priority rights to divert water in the Winnemucca area are for the year 1863; the lowest rights are for 1912. Some of the land downstream from the Winnemucca area, notably in the Lovelock area, has an earlier priority right to divert Humboldt River water than some of the land in the Winnemucca area. Accordingly, when there is insufficient streamflow to irrigate all the land in the valley that has established water rights, which is the case more often than not, diversions must be curtailed and commonly discontinued in the Winnemucca area to satisfy the higher priority water rights downstream.

The Nevada Department of Conservation and Natural Resources has been empowered by the State Legislature to enforce the regulatory statutes regarding the state water law. That agency has established several rules and regulations regarding the development of ground water in the State; some of these are especially pertinent with respect to the modification of the flow system in the Humboldt River valley. The department recognized that whenever a well is drilled near a stream, it is possible that pumping water from the well may affect the flow of the stream and thereby infringe upon established surface-water rights. In an attempt to minimize this possibility, regulations have been established regarding the required distance of a well from a stream and methods of constructing wells that are close to streams.

CHAPTER 10

ACHIEVEMENT OF THE MOST EFFECTIVE USE OF THE WATER RESOURCES

Achieving the most effective use of the water resources of the Winnemucca area, and for that matter of the entire Humboldt River valley, depends at least in part upon a general agreement as to the meaning of the phrase "the most effective use." Many of the people who presently are concerned with the economic well-being of the valley think in terms of using the available water supply more efficiently for irrigation, and, if possible, of increasing the total amount of water available for agricultural use. Some people are concerned primarily with flood control or the development of additional facilities for recreation. A few people have expressed the idea that allowing more water to discharge into the Humboldt Sink and thereby reestablishing a refuge for waterfowl would be a way of increasing significantly the effective use of Humboldt River water.

It is thus obvious that no general agreement exists at this time regarding what would constitute the most effective use of the water resources of the valley. Nevertheless, suggestions have been made by various individuals and agencies regarding possible changes in the water-use pattern. The effects on the flow system of the more commonly proposed changes and the effects of those changes that are of principal concern to the present residents of the valley are considered briefly in the following paragraphs.

CHANGES UPSTREAM FROM THE WINNEMUCCA AREA

Increased Precipitation and Runoff

The Nevada Department of Conservation and Natural Resources, the coordinating agency for the Humboldt River Research Project, is participating in research to evaluate the effectiveness of cloud seeding as a means of increasing precipitation in the headwaters of the Humboldt River valley. The study began in 1961, and as yet no data are available regarding the feasibility of increasing precipitation by this method. It is conceivable that the amount of inflow to the basin could be increased significantly in the future as a result of these studies. Accordingly, Humboldt River streamflow into the Winnemucca area also might be increased, the amount depending largely on how the increased streamflow in the upstream part of the basin is utilized. As Humboldt River streamflow currently supplies nearly 70 percent of the average annual inflow to the Winnemucca area, a substantial increase in this inflow would markedly affect the flow system in the area.

Upstream Storage Facilities

The feasibility of constructing major upstream storage facilities in and near the headwaters of the Humboldt River is being investigated intensively by the Nevada Department of Conservation and Natural Resources and by several federal agencies. These facilities probably would help prevent costly flood damage and could provide recreational areas. In addition, upstream reservoirs may significantly affect the agricultural industry by regulating the flow of the river and thereby increasing the timeliness of the delivery of irrigation water. The extent to which the operation of upstream reservoirs would infringe upon the established downstream water rights and the possibility of increased salinity of the water resulting from increased evaporation from the free-water surfaces of the reservoirs currently are being considered by several state and federal agencies. Any significant change in the flow of the Humboldt River at the Comus gaging station resulting from the construction and operation of upstream reservoirs could, as previously noted, significantly alter the flow system in the Winnemucca area.

Several additional changes can be made to the flow system and the water-use pattern upstream from the Winnemucca area. In general, these are similar to the possible changes that can be made in the Winnemucca area which are described in the following paragraphs.

CHANGES IN THE WINNEMUCCA AREA

Other than increasing the total amount of inflow to the system by artificially increasing precipitation in the upper Humboldt River valley, the only legal means of increasing the total available supply of water in the Winnemucca area is to decrease evapotranspiration losses, either in the project area or upstream from the area. The other means by which water is discharged from the Winnemucca area, ground-water and surface-water outflow, cannot legally be decreased by man's activities as this would infringe upon downstream water rights, notably in the Lovelock area.

In addition to increasing the total amount of water available for use, some modifications in the management of the water supply probably would result in the more effective use of the available supply. For example, improvement in the timeliness of the delivery of water and the conjunctive use of ground and surface water could be of significant economic value. As previously noted, the construction of upstream reservoirs might result in more timely delivery of Humboldt River water. In addition, as described in a subsequent section of the report, increased upstream development of ground water also might increase the timeliness of the delivery of irrigation water.

Decreased Evapotranspiration Losses

Beneficial evapotranspiration losses are an inherent part of growing crops. Accordingly, so long as farming continues in the area, some water will have to be consumed by evapotranspiration. Moreover, no matter what conservation methods are employed in the foreseeable future, it is probable that some precipitation will be lost by nonbeneficial evapotranspiration. However, improved irrigation practices could conserve much of the water currently consumed by nonbeneficial evapotranspiration. In terms of modern irrigation practices, overbank flooding onto unimproved meadows unquestionably is not the most efficient method of irrigation. If Humboldt River water were diverted onto level fields by means of a network of lined ditches, crops of higher economic value probably could be produced and at the same time less water would be lost by evapotranspiration.

Upstream storage facilities and the concurrent lessening of the danger of floods may encourage farmers to upgrade their farming activities on the flood plain, especially the improvement of irrigation practices and the leveling of fields. If this is the case, consideration might be given to channel improvement, notably straightening the channel. Not only would this lessen the frequency and severity of floods, but it also would decrease the area of the free-water surface which, in turn, would decrease evaporation losses from the river.

As it supplies little or no economic return, most of the substantial quantity of water transpired by the native phreatophytes, other than the grasses used as forage, is wasted. Of the estimated average of 45,000 acre-feet per year of ground and surface water lost by evapotranspiration from the areas covered by phreatophytes (Table 10), only 13,000 acre-feet was consumed in areas covered by grass. Accordingly, at least 30,000 acre-feet conceivably could be salvaged for beneficial use. As is described subsequently, ground-water development may help salvage some of this water. Moreover, increased efficiency in the use of Humboldt River water for irrigation will result in somewhat lower ground-water levels beneath the flood plain. This also would decrease nonbeneficial evapotranspiration losses from areas covered by phreatophytes. Finally, if it is deemed undesirable or found impractical to eradicate the native phreatophytes, it may be possible to replace these plants with more beneficial plants or crops.

As part of the Humboldt River Research Project, the U.S. Agricultural Research Service has been investigating the feasibility of replacing greasewood and rabbitbrush with more beneficial plants, such as tall wheatgrass and wildrye (Nevada Department of Conservation and Natural Resources, 1964, p. 9). In addition to economic feasibility, some of the major problems that will have to be resolved are the development of irrigation supplies to support the seedlings of the replacement plants, and the correction of locally adverse soil conditions.

Increased Ground-water Development

Development in tributary areas: The possibility of increased ground-water development is of major interest to almost everyone in the basin. Water users in the Lovelock area have long been aware of the fact that ground water from Grass and Paradise Valleys discharges into the Humboldt River. They have been concerned that ground-water development in these valleys would decrease the amount of seepage gain in the river and thereby decrease the downstream supply of surface water.

Their concern, of course, has been justified. Uncontrolled ground-water development in these valleys and in the drainage basin of Pole and Rock Creeks eventually could intercept the 14,000 acre-feet of ground-water inflow to the storage area (Table 5, and Cohen 1963b, pp. 98–100). This, in turn, could conceivably result in a decrease in Humboldt River streamflow of approximately an equal amount. Ultimately, however, the decrease in ground-water inflow to the storage area and to the Humboldt River will be less than the total pumpage in the tributary areas to the extent that some of the pumped ground water will return to the ground-water reservoir and some natural evapotranspiration losses will be salvaged as a result of the pumping.

The amount of natural evapotranspiration losses salvaged in the tributary areas will depend mainly on the location of future wells, the amount of pumpage, and the magnitude and extent of the resultant lowering of ground-water levels. If the increased ground-water development is carefully planned and the net pumpage (the amount of water permanently removed from the ground-water reservoir) is limited to the amount of natural evapotranspiration losses that are salvaged, the decrease in ground-water inflow to the storage area and into the Humboldt River may be negligible.

Development from the medial gravel subunit: The medial gravel subunit (Fig. 19) is highly permeable and contains a large amount of ground water in storage. Moreover, it occurs at shallow depth and will yield large quantities of water, at least 2,000 to 3,000 gpm, to adequately constructed and equipped wells. Water developed from the subunit could be used to supplement the surface-water supply during periods of deficient streamflow and thus could provide irrigation water at times when it is needed most.

If the medial gravel subunit was partly dewatered by pumping, at least some and perhaps much of the streamflow that currently is lost by nonbeneficial evapotranspiration during periods of natural flooding would recharge the subunit naturally or might be induced to recharge the subunit by artificial means. Moreover, increased ground-water development locally would lower ground-water levels sufficiently to conserve some of the ground water currently being wasted by nonbeneficial phreatophytes.

There is little doubt that increased ground-water development from the medial gravel subunit and from somewhat similar deposits upstream from the Winnemucca area (Bredehoeft, 1963, pp. 39–45) offers the possibility of significantly increasing the efficiency of use of the total water supply in the basin. However, in terms of present agricultural practices and legal restrictions, ground-water withdrawals from the medial gravel subunit that would not be compensated for by decreased natural evapotranspiration losses ultimately would decrease the flow of the Humboldt River and thereby infringe upon downstream surface-water rights. The amount of water that would be diverted from the river as a result of increased ground-water development would depend mainly on the quantity of the net ground-water withdrawal and on the distance between the wells and the river. (See Cohen, 1963b, pp. 99–100, and Fig. 38.)

During the spring and early summer when ground-water levels beneath the flood plain are fairly close to the land surface, crops locally are subirrigated—that is, they derive at least some of their moisture from the water table or from the overlying capillary fringe. Increased ground-water withdrawals from the medial gravel subunit locally could lower the water table sufficiently to decrease or eliminate the subirrigation of crops.

NEED FOR ADDITIONAL STUDIES

One of the objectives of the intensive interagency studies in the Winnemucca area was to test new and established methods of investigation and thus to determine how to evaluate the water resources of the entire Humboldt River valley most effectively. Now that most of the studies in the Winnemucca area are completed, consideration can be directed to an orderly and efficient investigation of the water resources of the remainder of the valley.

There is little doubt that before effective basin-wide plans for the most effective use of the available water supply can be formulated, the magnitude of that supply must be known. Moreover, the interrelations among the components of the flow system must be evaluated both qualitatively and quantitatively, and understood as thoroughly as possible. If these features are not known, the effectiveness of future water-resources planning and development activities may be less than optimum.

To take full advantage of the results of the studies in the Winnemucca area, it is suggested that an appraisal of the water resources of the entire Humboldt River valley should be undertaken and completed as soon as possible. The objectives of this study would be (a) to accumulate and analyze the available hydrologic data, particularly the surface-water data; (b) to evaluate the interrelation of surface and ground water; (c) to define those reaches of the valley in which additional intensive studies are needed; (d) to define the desired degree of intensity of future studies; (e) to define the salt balance for the basin; (f) to establish the order of priority of subareas in the valley in which future detailed studies should be undertaken; and (g) to decide upon the most effective methods of investigation in future detailed studies based on the results of the studies in the Winnemucca area. Such an appraisal should provide adequate information regarding the feasibility and location of future detailed studies in the Humboldt River valley.

Much of the information obtained in the Winnemucca area, such as the use of water by phreatophytes and the relation between specific yield and other geologic factors, can be adapted for use in other parts of the basin with a reasonable degree of accuracy. Accordingly, future detailed studies in the basin could be completed in a somewhat shorter time than the study described in this report.

CHAPTER 11

SUMMARY

The information in this report is summarized as follows:

CHAPTER 1

INTRODUCTION

1. The Nevada State Legislature authorized the Humboldt River Research Project in 1959; a major objective of the project was to evaluate the water resources of the Humboldt River valley as thoroughly as possible. Most of the work in the first 5 years of the study was carried on in the Winnemucca reach of the valley, the reach of the river between the Comus and Rose Creek gaging stations.

2. The Nevada Department of Conservation and Natural Resources is coordinating the project; other agencies and organizations participating in the study are the Nevada Bureau of Mines, the Department of Geology and the Desert Research Institute of the University of Nevada, the U.S. Agricultural Research Service, the U.S. Bureau of Land Management, the U.S. Bureau of Reclamation, the U.S. Geological Survey, the U.S. Soil Conservation Service, the U.S. Weather Bureau, the Department of Geology of the University of Illinois, and the Southern Pacific Company.

3. The flow system, the movement of water into, within, and out of the Winnemucca area, and related physical features have been described in considerable detail in reports prepared by the cooperating agencies. The purpose of this report is to summarize the hydrologic information given in those reports, especially the quantitative estimates of the components of the flow system.

CHAPTER 2

GENERAL GEOGRAPHIC FEATURES

1. The project area includes parts of four fault-block mountains and two intervening valleys, Grass and Paradise Valleys, and part of the valley of the Humboldt River. The flat and poorly drained floors of those parts of Grass and Paradise Valleys that are within the project area were covered by ancient Lake Lahontan, which had a maximum altitude of about 4,400 feet.

2. The Humboldt River is the largest stream entirely within Nevada, having a total drainage area of about 18,000 square miles. Its drainage area upstream from the Rose Creek gaging station is 15,200 square miles. The distance measured along the meandering channel of the river in the project area is 92 miles, but its flood plain length is only about 45 miles; the average width and depth of the channel are about 80 and 10 feet, respectively.

3. All the smaller streams in the project area are usually dry on the alluvial apron and in the valley lowlands; some are perennial for short distances in the mountains.

4. The climate of the project area ranges from arid to semiarid in the valley lowlands to subhumid in the higher mountains. The average daily temperature and average annual precipitation on the valley floor are 49° F. and 8.40 inches, respectively. Evaporation from free-water surfaces averages about 4 to 5 feet per year.

5. Sagebrush and shadscale are the most abundant shrubs on the alluvial apron, and greasewood is the most abundant shrub in the valley lowlands. Native grasses and lesser amounts of willow, wildrose, and rabbitbrush cover most of the flood plain.

6. The present economy of the area is based largely on cattle raising and the tourist business. The principal crops, mainly native grasses used for forage, are irrigated almost entirely with Humboldt River water. About 2,000 acres of farmland was irrigated with ground water in 1962.

CHAPTER 3

HOW AND WHERE THE WATER OCCURS

1. Water occurs as a gas, liquid, and solid beneath the surface of the earth, on the land surface, and in the atmosphere. The rock materials on and beneath the earth's surface in the project area are grouped into four units in this report—consolidated rocks, older alluvium, medial alluvium, and younger alluvium. Most of the consolidated rocks do not store or transmit appreciable amounts of water; rather, most of the water is stored in and transmitted through the three alluvial units. The medial gravel subunit of the medial alluvium occurs at fairly shallow depths beneath the flood plain and bordering terraces, is highly permeable, and will yield at least 2,000 gpm to adequately constructed and equipped wells.

2. Ground water is the water in the zone of saturation; the top of this zone commonly is termed the water table. The water table is overlain by the zone of aeration. Most of the water in

the zone of aeration (vadose water) is held by capillary and other attraction, and does not move downward in response to gravity. Water in the lowermost part of the zone of aeration, the capillary fringe, is derived mainly from the underlying zone of saturation.

3. Water in storage in the channels of the Humboldt River and the smaller streams in the area normally represents the largest quantity of surface water in the area at any given time. The snowpack that accumulates in the mountains in the winter also represents an appreciable part of the total surface-water supply.

CHAPTER 4

WHERE THE WATER COMES FROM

1. Estimates of the inflow, outflow, and changes in the amount of water in storage are made for the storage area outlined in Figure 9 rather than for the entire project area. These estimates are made for three periods, water years 1949–62, water year 1962, and December-June of water year 1962. Inasmuch as the estimates for water years 1949–62 are more nearly representative of the long-term averages, these values are emphasized in this summary.

2. Humboldt River streamflow as measured at the Comus gaging station supplied most of the water to the storage area—an average of about 172,100 acre-feet per year in water years 1949–62. Precipitation directly on the storage area supplied the second largest amount of water—an average of about 59,000 acre-feet per year in water years 1949–62. Tributary streamflow supplied an average of about 8,600 acre-feet of water per year to the storage area in water years 1949–62. Finally, ground-water inflow to the storage area from the Humboldt River valley upstream from the storage area, from the drainage basins of Pole and Rock Creeks, from Paradise Valley, and from Grass Valley and the northwestern slope of the Sonoma Range supplied about 14,000 acre-feet per year.

3. Total inflow to the storage area in water years 1949–62 averaged slightly more than 250,000 acre-feet per year.

CHAPTER 5

MOVEMENT AND STORAGE OF WATER

1. Humboldt River streamflow moves at average rates ranging from zero to about 3 feet per second. The amount of water in the channel of the Humboldt River varies from season to season and from place to place. In the spring and early summer, when the flow commonly is high, the amount of water in storage in the channel is large, and the river loses water between the Comus and Rose Creek gaging stations. In the late summer and early fall the flow and the amount of water in storage in the channel of the river commonly are the lowest of the year, and the river gains water in the project area.

2. An average of about 2,000 acre-feet per year of precipitation on the storage area recharges the ground-water reservoir; about 600 acre-feet per year falls on the Humboldt River and becomes streamflow. Most of the remainder of the precipitation, about 56,000 acre-feet, is lost by evapotranspiration from the land surface and from the zone of aeration.

3. Most of the time the direction of ground-water movement is from the outer margins of the storage area toward the Humboldt River, and thence downstream roughly parallel to the river. In the spring and early summer, hydraulic gradients locally are reversed and water moves from the river to the ground-water reservoir.

4. The estimated total amount of ground water in storage in the upper 100 feet of saturated alluvium in the project area is about 2 million acre-feet. Of this amount about 500,000 acre-feet is stored in the medial gravel subunit. The average annual net change of ground water in storage in the water years 1949–62 was zero, or very nearly zero.

5. Estimates based on meager soil-moisture data and on theoretical considerations indicate that the average annual net change in moisture content in the zone of aeration in the storage area was zero in water years 1949–62.

6. Most of the tributary streamflow that discharges into the storage area is consumed by evapotranspiration or recharges the ground-water reservoir before reaching the Humboldt River as surface flow.

CHAPTER 6

DISCHARGE OF WATER

1. Humboldt River streamflow as measured at the Rose Creek gaging station represents the largest quantity of water discharged from the storage area—an average of about 155,400 acre-feet per year in water years 1949–62. Streamflow at the Rose Creek gaging station ranged from 54,000 acre-feet less than that at the Comus gaging station in water year 1962, to 15,000 acre-feet more

in water year 1958; it averaged nearly 17,000 acre-feet per year less in the period water years 1949–62.

3. Only a few thousand acre-feet of precipitation on the storage area is discharged from the area as Humboldt River streamflow and as ground-water outflow. In addition, a small undetermined amount was discharged from the zone of saturation by evapotranspiration. In water years 1949–62 an estimated average of about 95 percent of the total precipitation was lost by evapotranspiration from the land surface and from the zone of aeration.

4. In water years 1949–62 an average of about 45,000 acre-feet per year, excluding that derived from precipitation, was consumed by evapotranspiration in areas covered by phreatophytes. In addition, the estimated average annual evaporation loss from open bodies of water was 14,000 acre-feet.

5. The estimated average annual ground-water outflow from the storage area was about 3,000 acre-feet per year in water years 1949–62, and the estimated average annual net pumpage during the same period was about 1,500 acre-feet. The computed total outflow from the storage area near Winnemucca for the period 1949–62 averaged about 275,000 acre-feet per year.

CHAPTER 7

CHEMICAL QUALITY OF THE WATER

1. Most of the ground water beneath the flood plain of the Humboldt River is the sodium bicarbonate type and has a dissolved-solids content of 500 to 750 ppm. Ground water in the mouth of Paradise Valley is mainly sodium bicarbonate water having a low dissolved-solids content; ground water in the drainage basins of Pole and Rock Creeks and most of the ground water in Grass Valley is calcium bicarbonate water having a very low dissolved-solids content.

2. The specific conductance and, therefore, the dissolved-solids content of the Humboldt River is inversely proportional to the flow of the river. During periods of low streamflow the flow and the chemical quality of the river change between the Comus and Rose Creek gaging stations because of the interchange of streamflow with water in the ground-water reservoir.

3. Most of the ground water and almost all the surface water in the area are chemically suitable for agricultural and domestic uses.

CHAPTER 8

SUMMARY OF THE FLOW SYSTEM

1. The flow system, or the movement of water into, within, and out of the storage area, is virtually in long-term dynamic equilibrium. The equilibrium may be expressed by the following equation: I (inflow) $=$ O (outflow) $\pm$ St (net change in storage).

2. Solutions of the water-budget equation for three periods, water years 1949–62, water year 1962, and December-June of water year 1962, yield results that balance within 3 to 10 percent.

CHAPTER 9

HOW MAN HAS MODIFIED THE NATURAL FLOW SYSTEM

1. The diversion of Humboldt River streamflow for irrigation is the most significant of man's modifications of the natural flow system in the Humboldt River valley.

2. About 265,000 acres in the entire basin may legally be irrigated with Humboldt River water; nearly 700,000 acre-feet of water, more than twice the average annual flow, would have to be diverted from the river to supply all the adjudicated water to this land. A maximum of about 31,300 acre-feet of Humboldt River water may legally be diverted onto slightly less than 17,000 acres in the Winnemucca area.

3. The activities of man, mainly agricultural practices, have decreased nonbeneficial evapotranspiration losses in the Humboldt Sink, and have increased both beneficial and nonbeneficial losses upstream from the sink. The small amount of ground-water development has not appreciably altered the flow system in the Winnemucca area or in the entire basin.

4. Almost the entire flow of the Humboldt River is appropriated. Any future activities of man that might infringe upon these rights are illegal according to the present state law and regulatory provisions.

CHAPTER 10

ACHIEVEMENT OF THE MOST EFFECTIVE USE OF THE WATER RESOURCES

1. In the future, increased precipitation in the upper Humboldt River basin resulting from cloud seeding may increase the downstream supply of water.

2. Increased upstream storage facilities (a) probably will decrease the hazard of floods; (b) may provide recreational facilities; and (c) may increase the timeliness of the delivery of Humboldt River water for irrigation.

3. Decreasing evapotranspiration losses, both beneficial and nonbeneficial, by more efficient methods of irrigation, by the development of ground water for irrigation, and by other methods of conservation are the significant ways that the total available supply of water can be used more effectively. A total of at least 30,000 acre-feet could be salvaged if economically and technologically feasible methods can be found to recover all the water now being wasted in areas covered by nonbeneficial phreatophytes.

4. Ground-water development would increase the timeliness of the delivery of irrigation water; however, the consumptive use of ground water that is not compensated for by decreases in natural evapotranspiration losses ultimately will decrease the flow of the Humboldt River and thereby infringe upon established surface-water rights.

5. Additional studies are needed to evaluate the hydrology of the remainder of the basin. Consideration now should be given to an overall appraisal of the water resources of the entire Humboldt River valley. This appraisal would evaluate the need and establish the guidelines for additional detailed studies, such as the one described in this report.

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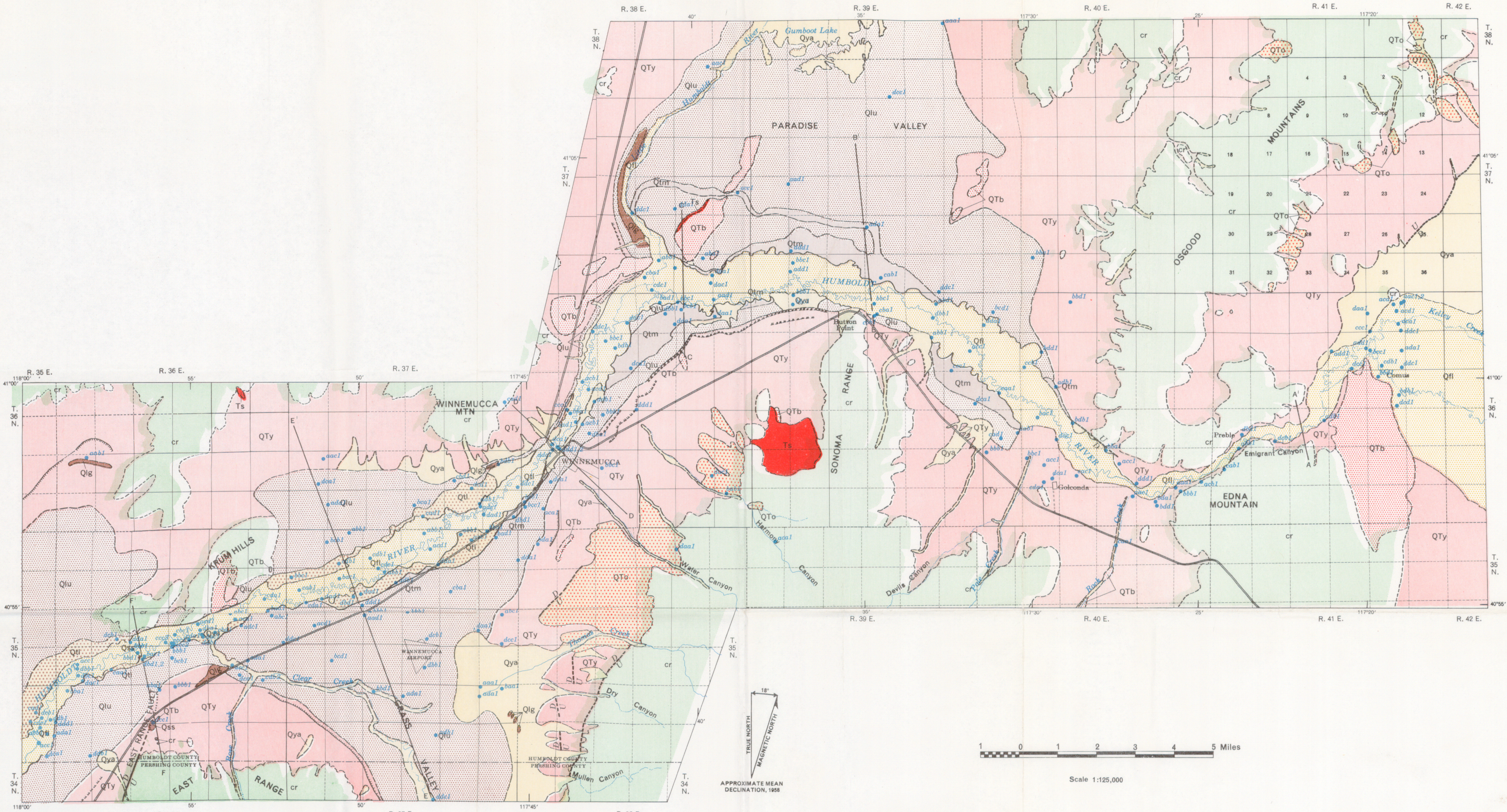


EXPLANATION

(Lithology, thickness, occurrence, hydrologic features and other pertinent characteristics are listed in table 3)

QUATERNARY

Recent

- Qya — Younger alluvium
- Qfl — Flood-plain deposits
- Qtl / Qtm — Terrace deposits
  Qtl, deposits of the lower terrace
  Qtm, deposits of the middle terrace; also includes deposits in the abandoned channel in the mouth of Paradise Valley

Pleistocene or Recent

- Qss — Spring sinter

Pleistocene — Lake Lahontan deposits

- Qlu — Upper silt and clay
- Qlg — Gravel-bar deposits
- Qlm — Medial gravel. *Recognized only in the subsurface*
- Qla — Older alluvium. *Recognized only in the subsurface*
- Qll — Lower silt and clay. *Recognized only in the subsurface*

TERTIARY OR QUATERNARY

Pliocene or Pleistocene

- QTy — Younger fanglomerate
- QTo — Older fanglomerate
- QTb — Basalt
- QTa — Alluvium, undifferentiated. *Recognized only in the subsurface*

TERTIARY

Miocene or Pliocene

- Ts — Older sedimentary deposits

CAMBRIAN TO TERTIARY

- cr — Consolidated rocks, undifferentiated

A —— A′ Location of geologic sections shown on plate 2

Contact
Dashed where approximately located

Wave-cut scarp
Dashed where questionable

Fault
Dashed where approximately located, dotted where concealed and inferred. U, upthrown side; D, downthrown side

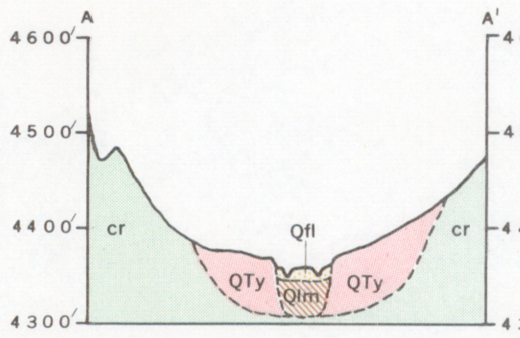
dda1 Well or test boring

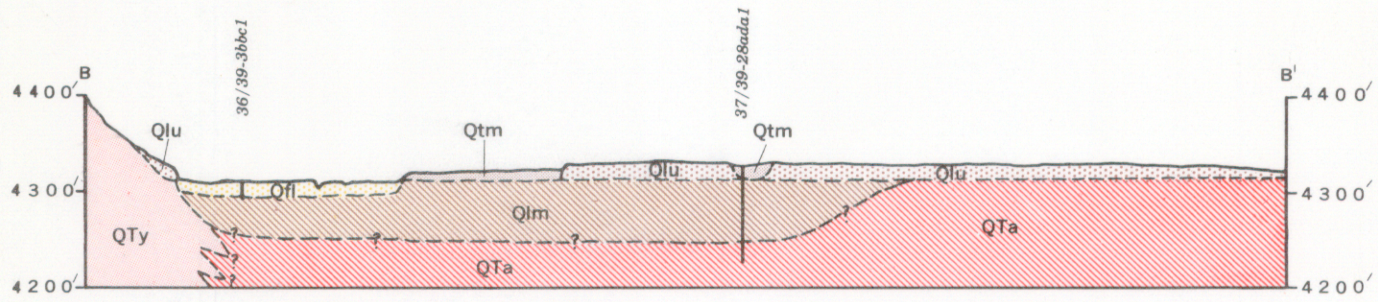
cad1 Spring

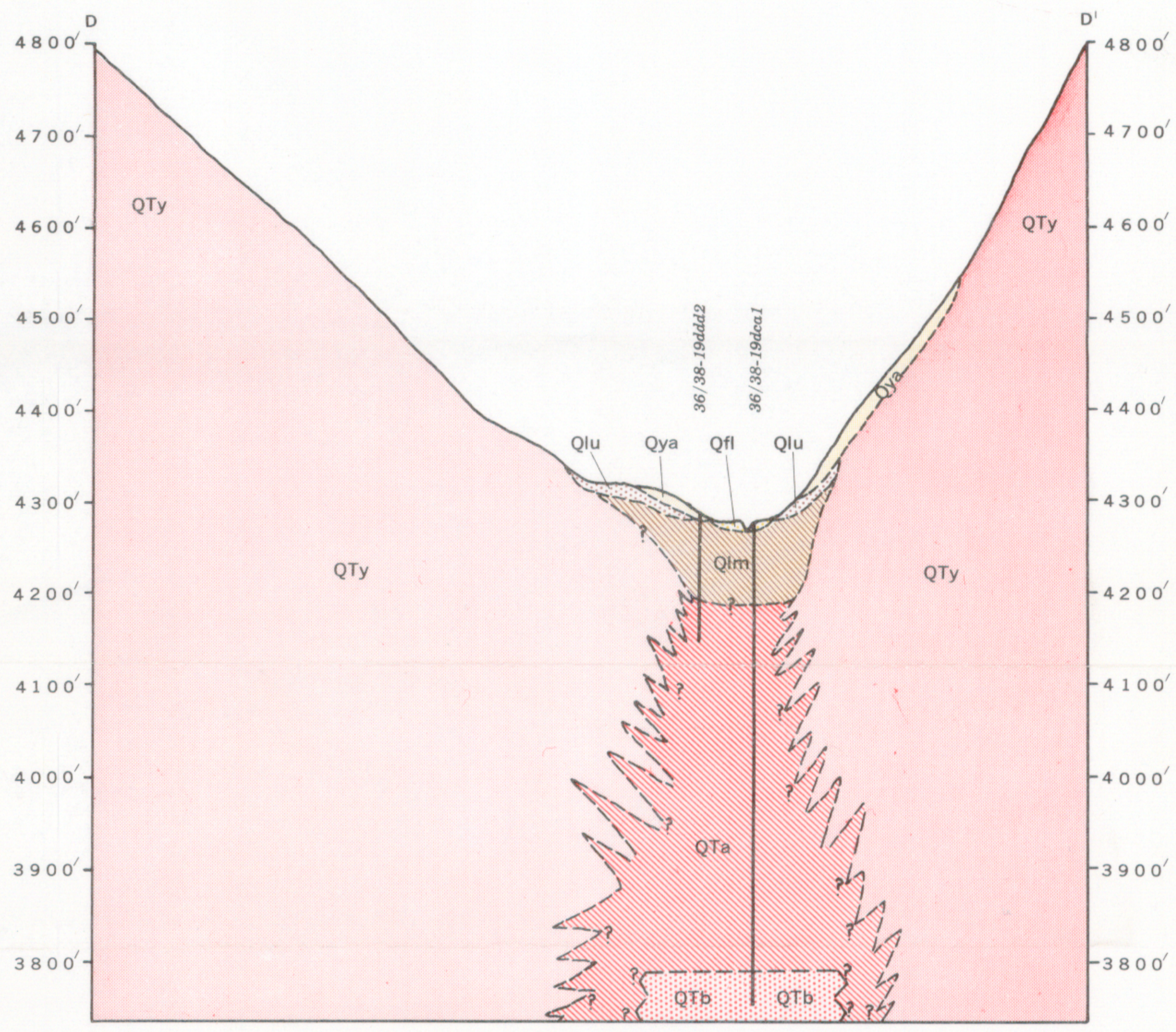
GENERALIZED GEOLOGIC MAP OF THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEV.

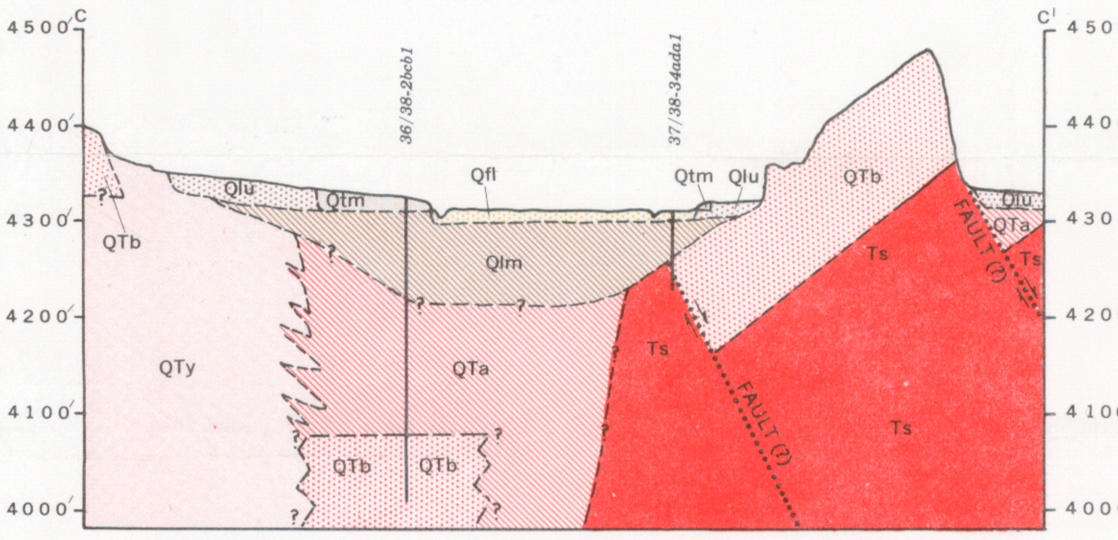
Base from U.S. Geological Survey topographic maps and from the Southern Pacific Company

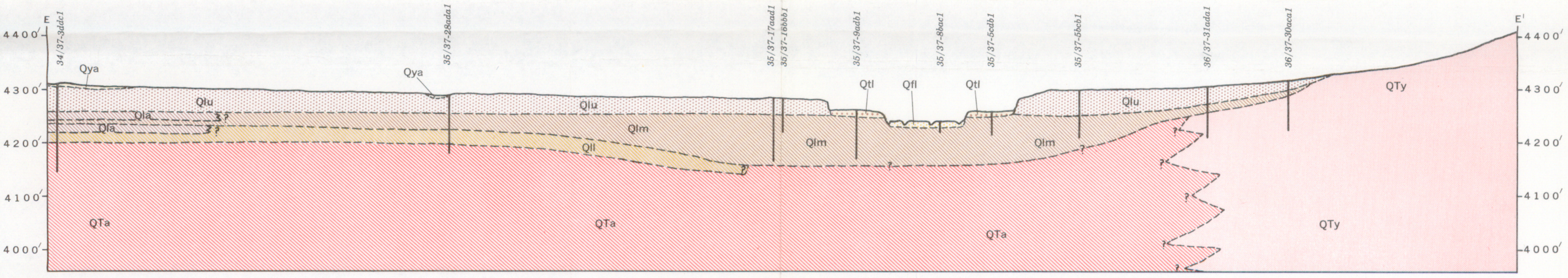
Geology by Philip Cohen, 1963; in large part adapted from Cartwright, Keros (1960); Ferguson, H. G., Muller, S. W., and Roberts, R. J. (1951); Ferguson, H. G., Roberts, R. J., and Muller, S. W. (1952); Hawley, J. W. (1962); Hotz, P. E., and Willden, Ronald (1961); Maxey, G. B., and Shamberger, H. A. (1961); Willden, Ronald (1961); and Wilson, W. E. (1962)

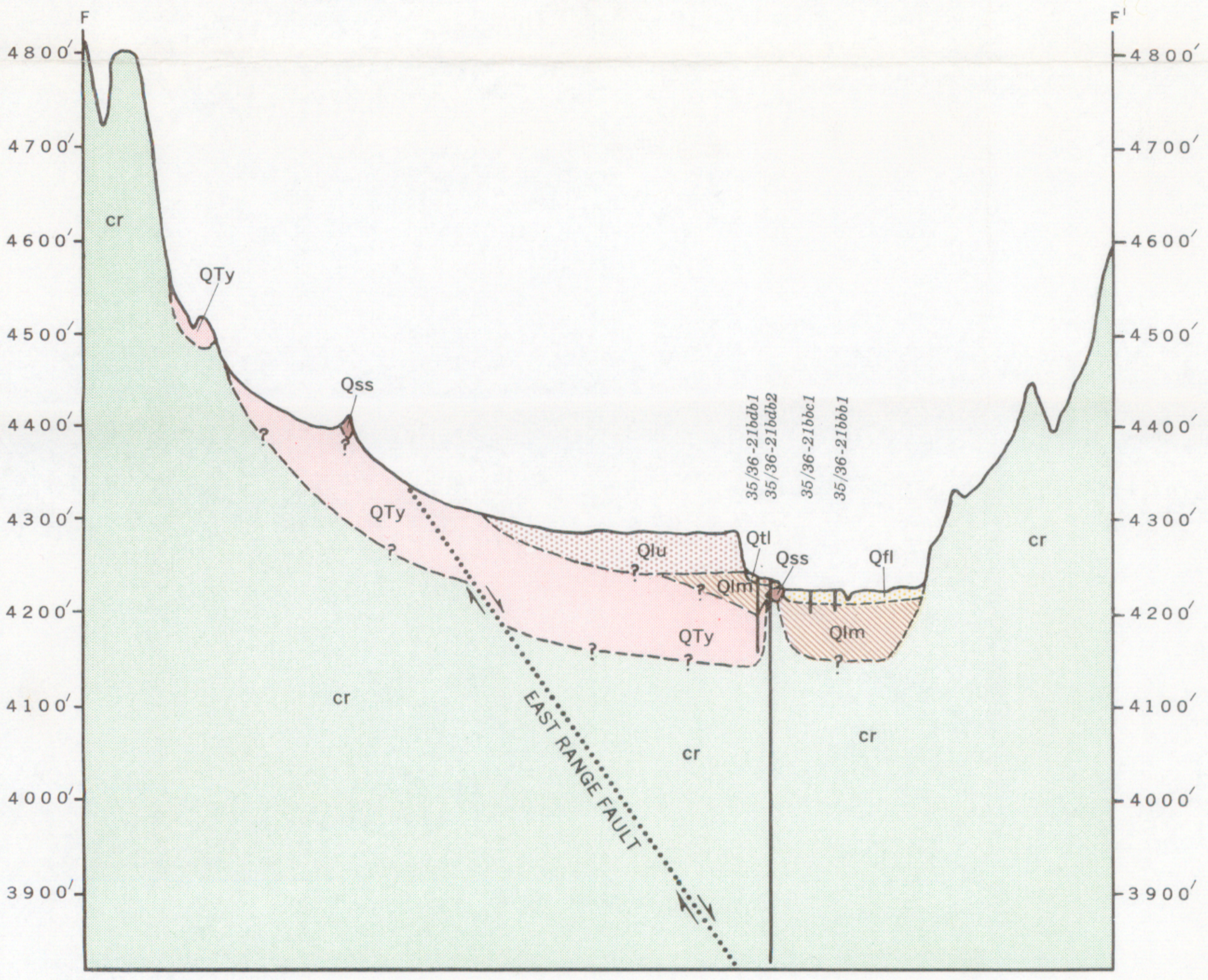












EXPLANATION

Contact

Dashed were approximately located, querried where inferred

Fault, inferred

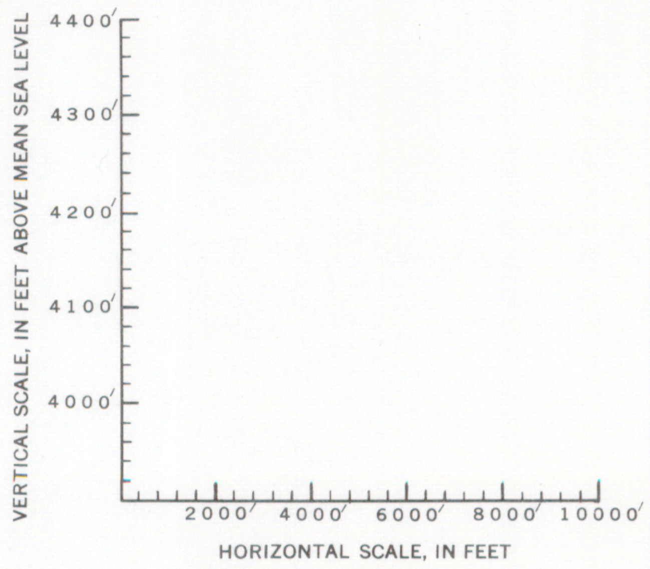
Arrows indicate relative movement

36/37-31ada1

Well or test boring

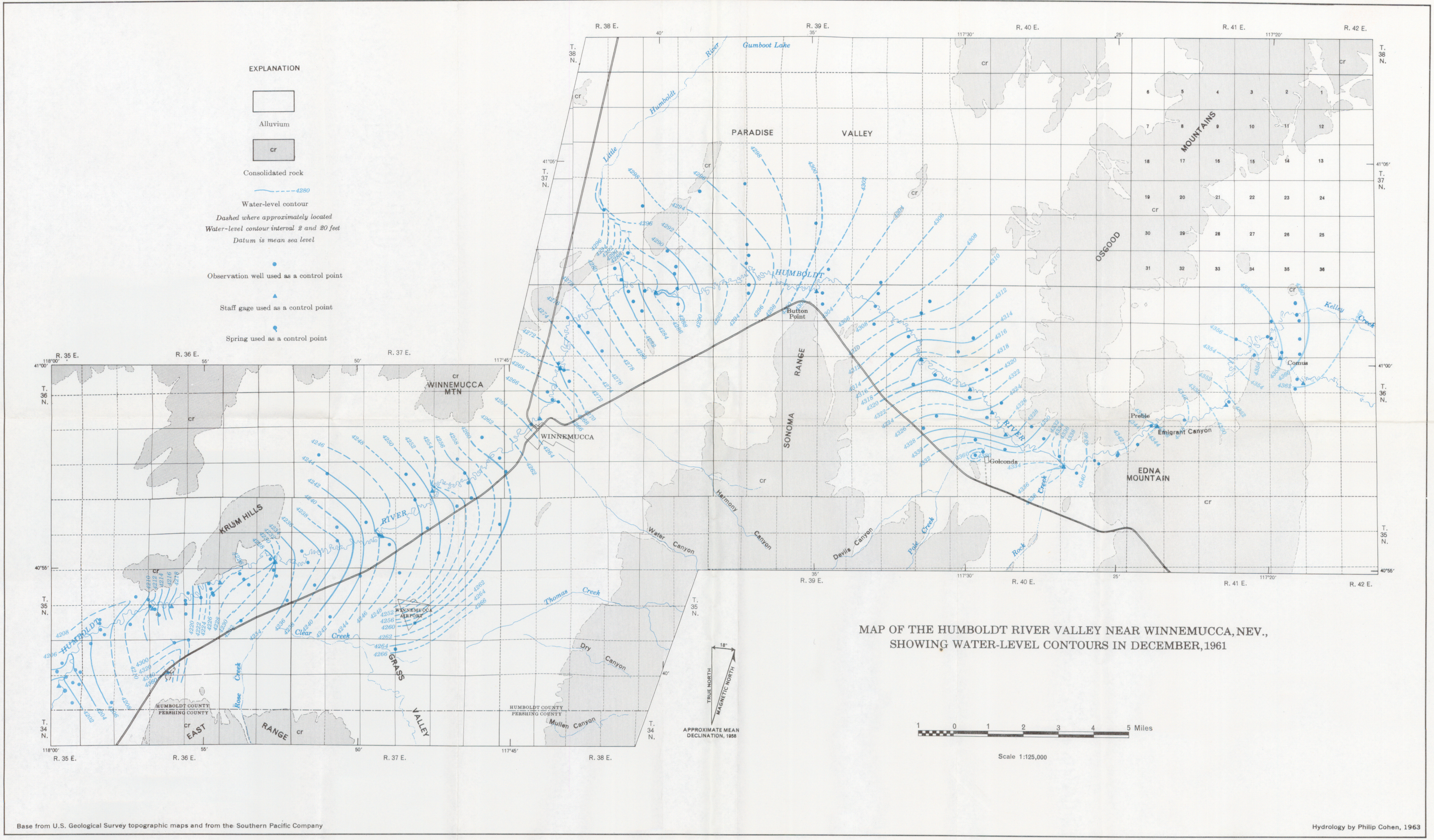
Length of line indicates depth of well

For explanation of geologic symbols and location of sections see Plate 1.
Sections viewed from upstream.

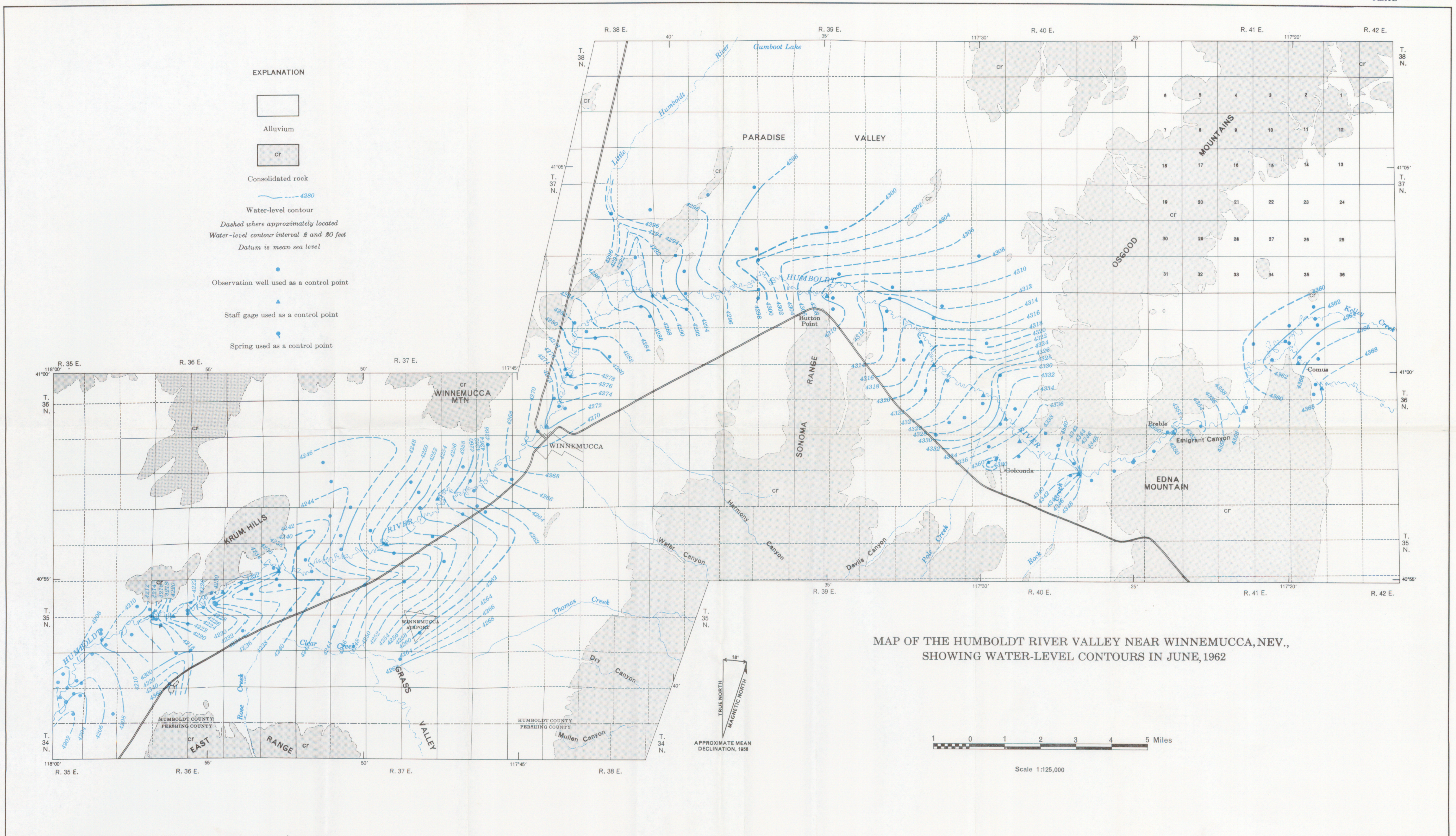


Geology by Philip Cohen, 1963

GENERALIZED GEOLOGIC SECTIONS IN THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEV.



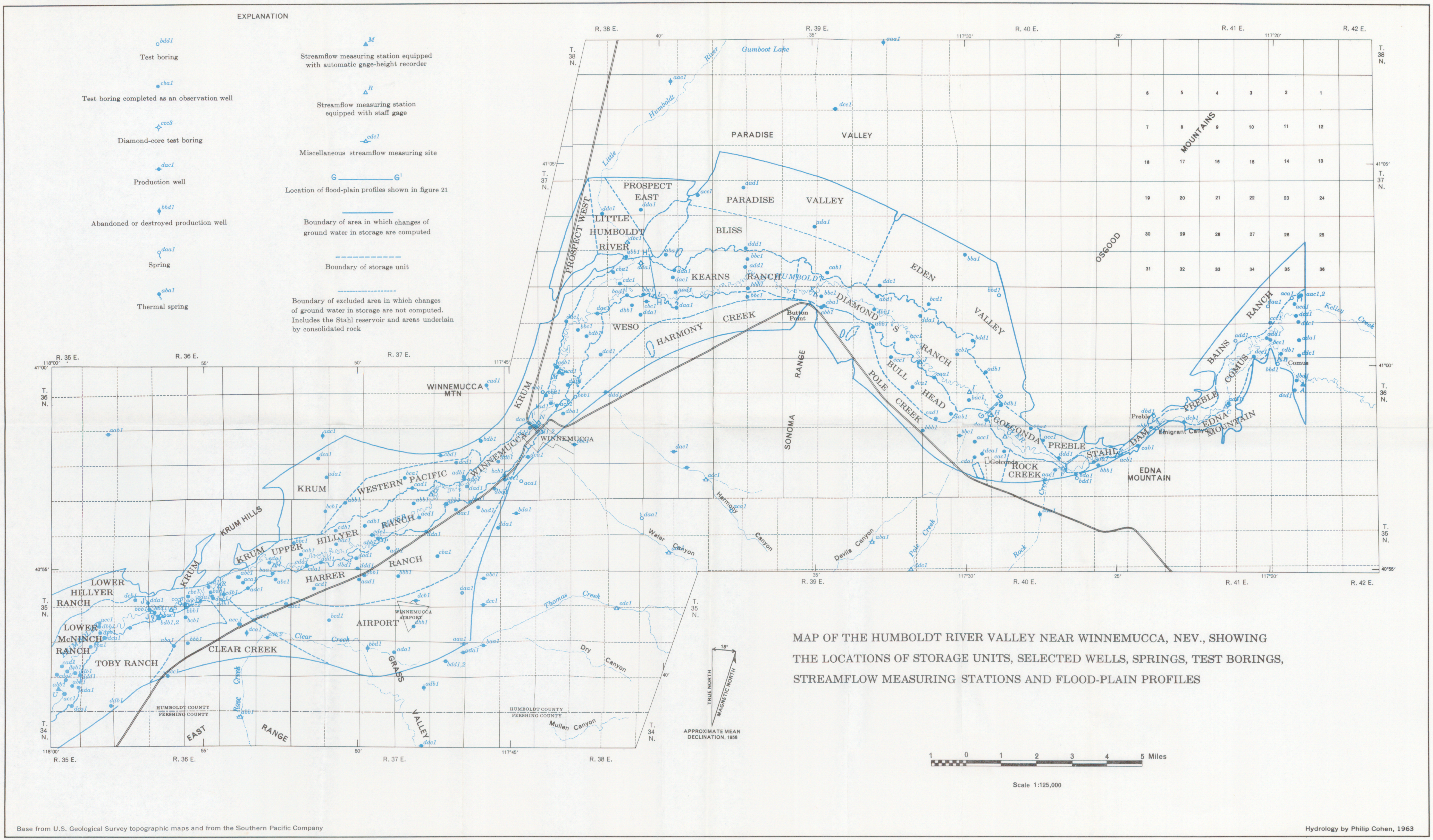
MAP OF THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEV., SHOWING WATER-LEVEL CONTOURS IN DECEMBER, 1961



MAP OF THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEV., SHOWING WATER-LEVEL CONTOURS IN JUNE, 1962

Base from U.S. Geological Survey topographic maps and from the Southern Pacific Company

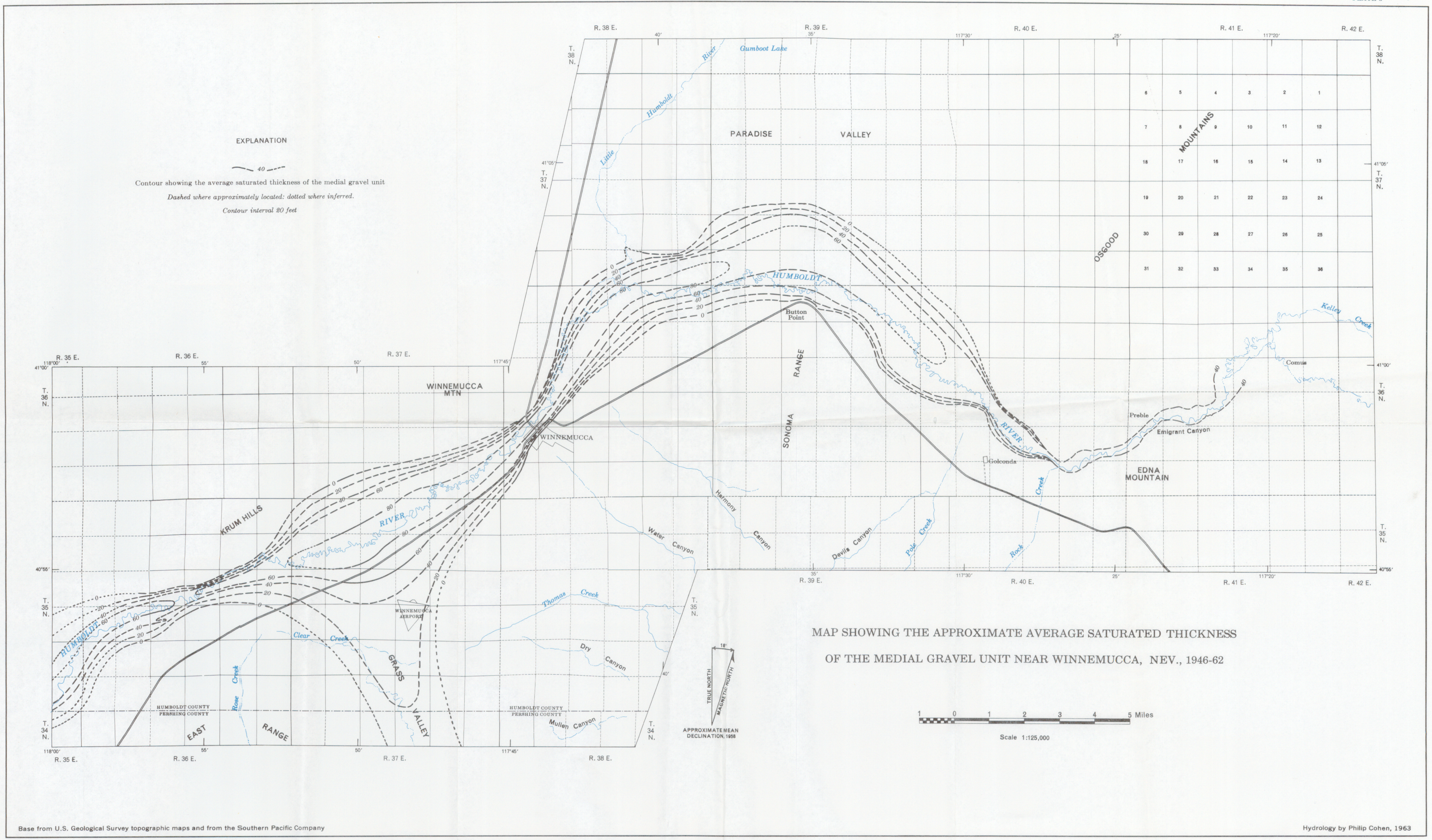
Hydrology by Philip Cohen, 1963



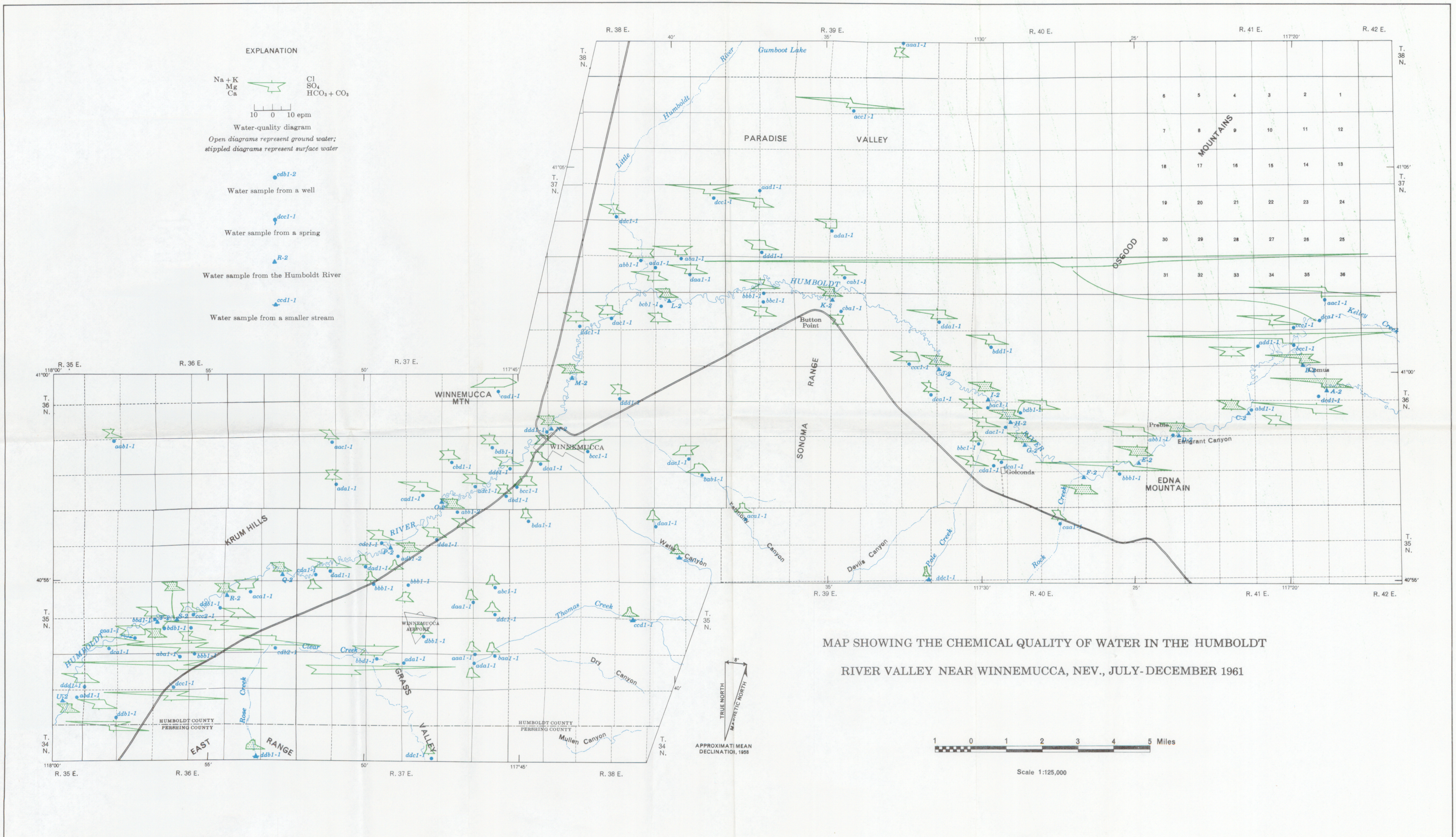
MAP OF THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEV., SHOWING THE LOCATIONS OF STORAGE UNITS, SELECTED WELLS, SPRINGS, TEST BORINGS, STREAMFLOW MEASURING STATIONS AND FLOOD-PLAIN PROFILES

Base from U.S. Geological Survey topographic maps and from the Southern Pacific Company

Hydrology by Philip Cohen, 1963



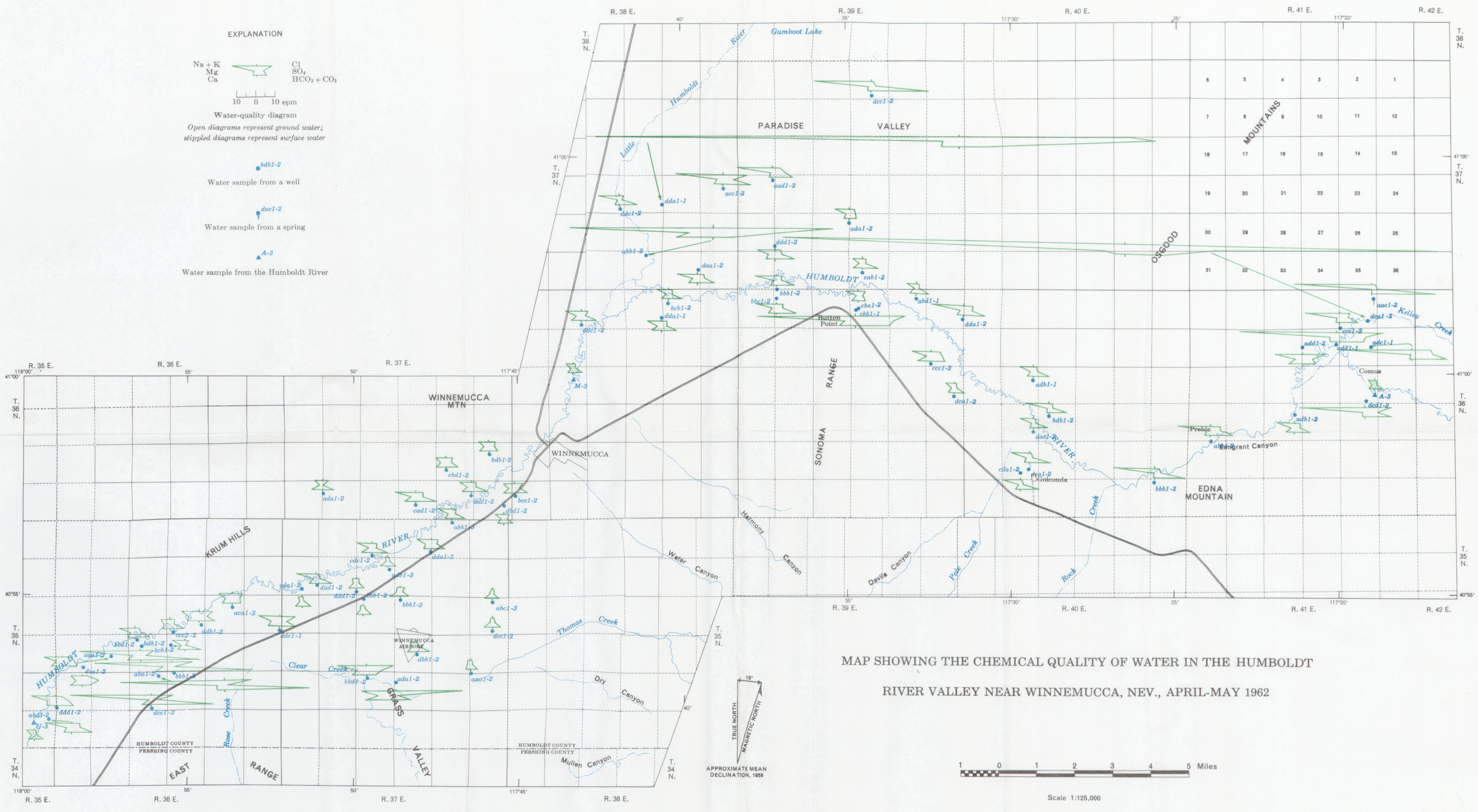
MAP SHOWING THE APPROXIMATE AVERAGE SATURATED THICKNESS OF THE MEDIAL GRAVEL UNIT NEAR WINNEMUCCA, NEV., 1946-62



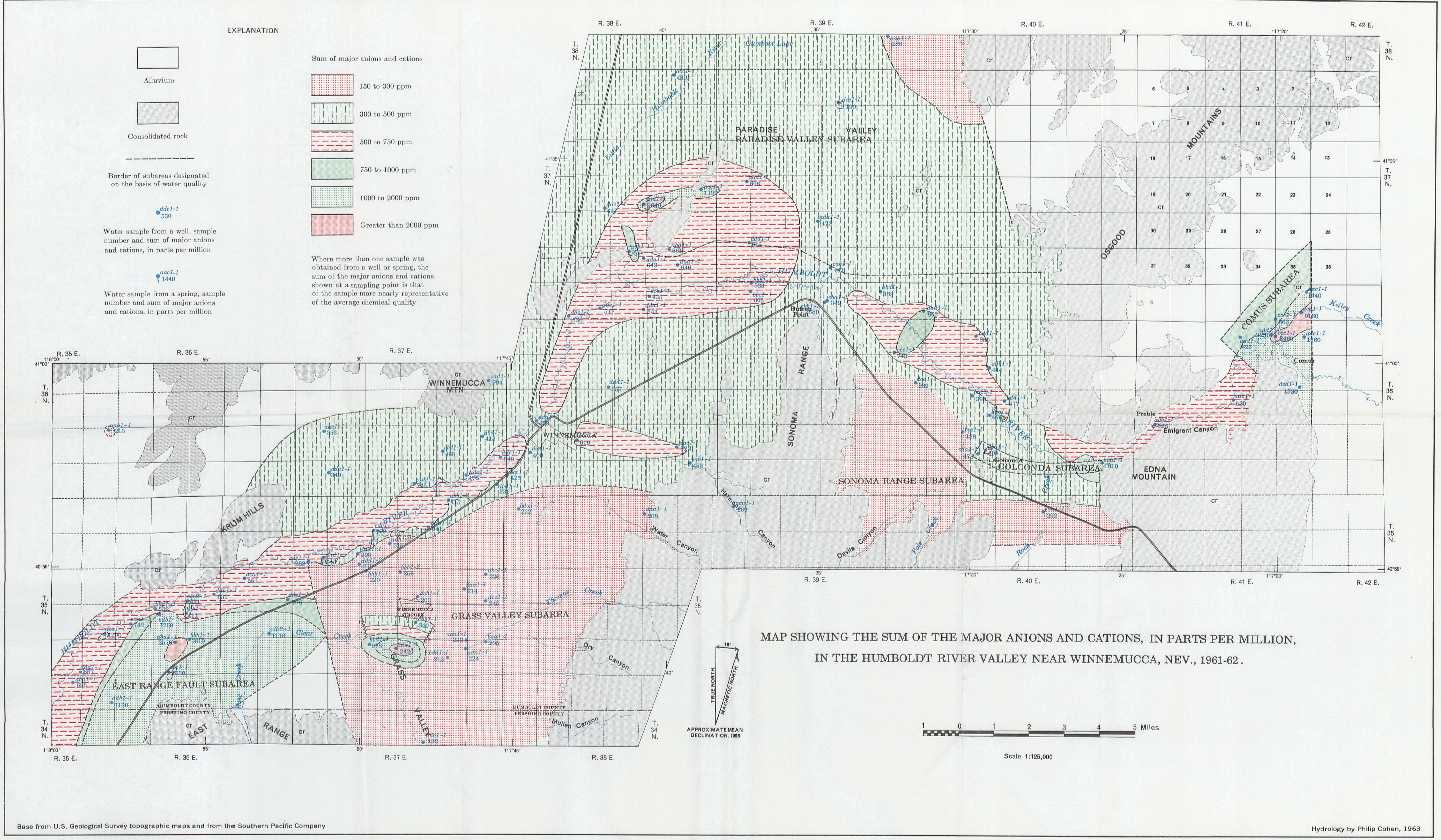
MAP SHOWING THE CHEMICAL QUALITY OF WATER IN THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEV., JULY-DECEMBER 1961

Base from U.S. Geological Survey topographic maps and from the Southern Pacific Company

Water-quality diagrams by Philip Cohen, 1963



MAP SHOWING THE CHEMICAL QUALITY OF WATER IN THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEV., APRIL-MAY 1962


EXPLANATION
Alluvium
Consolidated rock
Border of subareas designated on the basis of water quality
ddc1-1 530
Water sample from a well, sample number and sum of major anions and cations, in parts per million
aac1-1 1440
Water sample from a spring, sample number and sum of major anions and cations, in parts per million
Sum of major anions and cations
150 to 300 ppm
300 to 500 ppm
500 to 750 ppm
750 to 1000 ppm
1000 to 2000 ppm
Greater than 2000 ppm
Where more than one sample was obtained from a well or spring, the sum of the major anions and cations shown at a sampling point is that of the sample more nearly representative of the average chemical quality
PARADISE VALLEY
PARADISE VALLEY SUBAREA
OSGOOD MOUNTAINS
COMUS SUBAREA
SONOMA RANGE
SONOMA RANGE SUBAREA
GOLCONDA SUBAREA
EDNA MOUNTAIN
WINNEMUCCA MTN
WINNEMUCCA
KRUM HILLS
GRASS VALLEY SUBAREA
GRASS VALLEY
EAST RANGE FAULT SUBAREA
EAST RANGE
HUMBOLDT RIVER
Preble
Emigrant Canyon
Comus
Kelley Creek
Golconda
Button Point
Water Canyon
Harmony Canyon
Devils Canyon
Pole Creek
Rock Creek
Clear Creek
Thomas Creek
Dry Canyon
Mullen Canyon
HUMBOLDT COUNTY
PERSHING COUNTY
R. 35 E.
R. 36 E.
R. 37 E.
R. 38 E.
R. 39 E.
R. 40 E.
R. 41 E.
R. 42 E.
T. 38 N.
T. 37 N.
T. 36 N.
T. 35 N.
T. 34 N.
TRUE NORTH
MAGNETIC NORTH
18°
APPROXIMATE MEAN DECLINATION, 1958
1 0 1 2 3 4 5 Miles
Scale 1:125,000
MAP SHOWING THE SUM OF THE MAJOR ANIONS AND CATIONS, IN PARTS PER MILLION, IN THE HUMBOLDT RIVER VALLEY NEAR WINNEMUCCA, NEV., 1961-62.
Base from U.S. Geological Survey topographic maps and from the Southern Pacific Company
Hydrology by Philip Cohen, 1963