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DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

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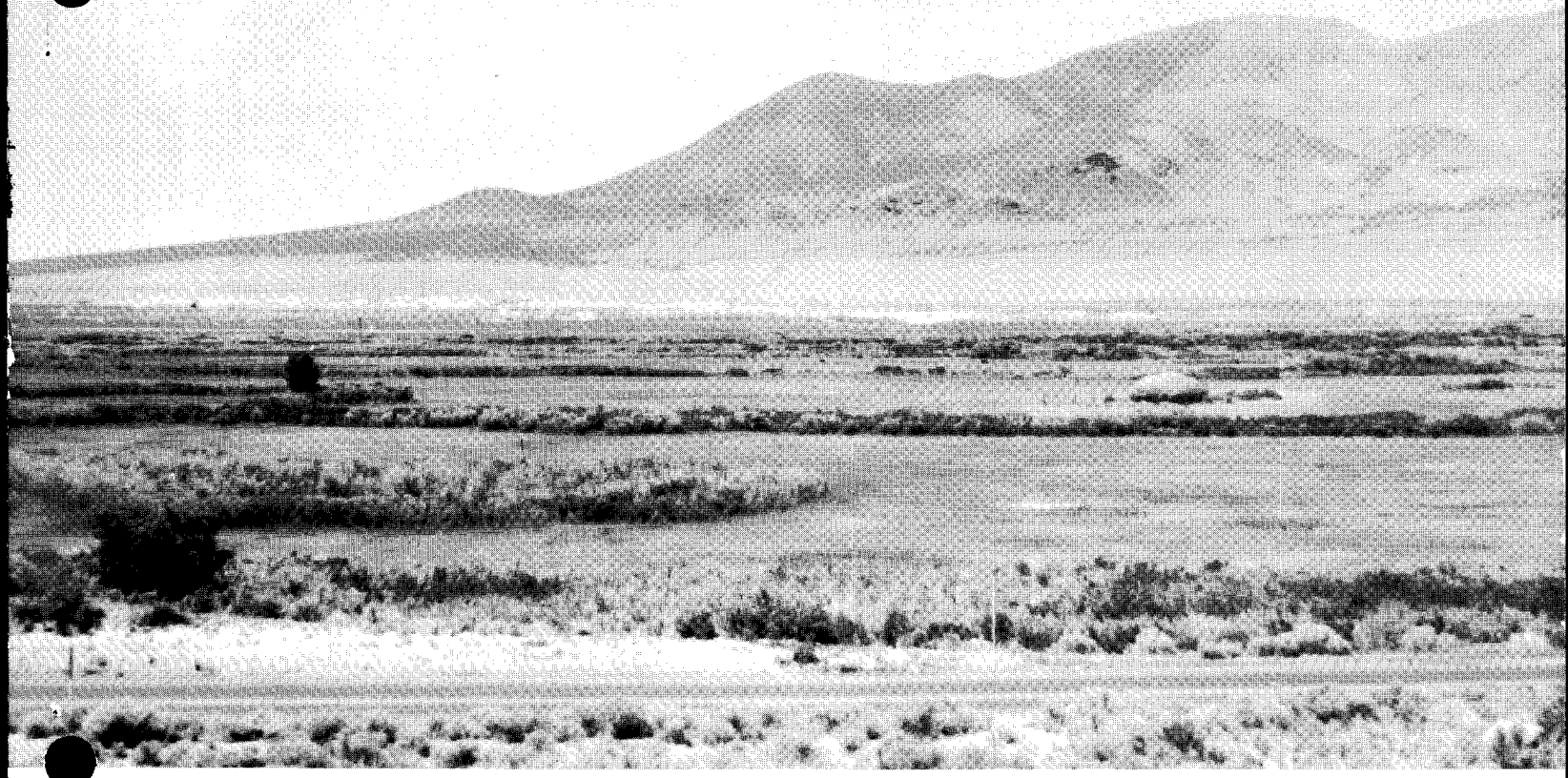

Flood Plain of Humboldt River near Winnemucca, Nevada—Photo by T. W. Robinson

GROUND-WATER RESOURCES — INFORMATION SERIES

REPORT 11

A Preliminary Evaluation of the Ground-Water Hydrology of the Valley of the Humboldt River, near Winnemucca, Nevada

A Summary

and

Specific Yield of Sediments of the Humboldt River Valley, Humboldt County, Nevada

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By

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Prepared cooperatively by the

Geological Survey, U. S. Department of the Interior

JANUARY 1962

STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

Carson City

A PRELIMINARY EVALUATION OF THE GROUND-WATER HYDROLOGY OF THE VALLEY OF THE HUMBOLDT RIVER, NEAR WINNEMUCCA, NEVADA; A SUMMARY

By

Philip Cohen
Geologist

Reprint from the Proceedings of the

Fifteenth Annual Nevada Water Conference

September 1961

Prepared Cooperatively by the

Geological Survey, U. S. Department of Interior

FOREWORD

This is the second report under the ground-water resources information series. The first report covered the ground-water situation in Nevada 1960 by O. J. Loeltz and G. T. Malmberg of the U. S. Geological Survey, Ground Water Branch.

This report contains two papers prepared by Philip Cohen, geologist of the U. S. Geological Survey, both pertaining to certain phases of the Humboldt River Research Project, in which the Geological Survey is one of the major participants.

Both of these papers, "A Preliminary Evaluation of the Ground-Water Hydrology of the Valley of the Humboldt River, near Winnemucca, Nevada; A Summary" and "Specific Yields of Sediments of the Humboldt River Valley, Humboldt County, Nevada" are worthwhile contributions to the overall study of the hydrology of the Humboldt River.

It will be the policy of this Department to print such papers in the "Information Series" in order to record them in a more permanent manner and make the information readily available.

Hugh A. Shamberger, Director
Department of Conservation and Natural Resources

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A PRELIMINARY EVALUATION OF THE GROUND-WATER HYDROLOGY OF THE VALLEY OF THE HUMBOLDT RIVER, NEAR WINNEMUCCA, NEVADA: A SUMMARY [1/]

By
Philip Cohen
U. S. Geological Survey
Carson City, Nevada

Introduction

The Ground-Water Branch of the U. S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources is participating in the Humboldt River Research Project. One of the major objectives of the Research Project is to determine the disposition of the water resources of the area. In order to help meet this objective, the Ground Water Branch is studying a number of aspects of the ground-water hydrology of the area including (1) ground water underflow into and out of the study area, (2) the relation of the Humboldt River and the ground-water reservoir, (3) the specific yield of the unconsolidated sedimentary deposits in the zone of water-level fluctuations in and near the flood plain of the Humboldt River, (4) changes of ground water in storage, and (5) the hydrogeochemistry of the area.

The purpose of this paper is to summarize some of the preliminary results of our investigations to date. Because intensive hydrogeochemical studies were begun only recently, this phase of the investigation is not discussed in this report.

Figure 1 shows the location of the study area. The Humboldt River, the longest river in the State, and one of the longest rivers in North America that is characterized by internal drainage, heads in northeastern Nevada, flows westward and southwestward for about 275 miles, and discharges into the Humboldt Sink south of Lovelock.

The flood plain of the Humboldt River and the benchlands bordering the river constitute one of the most important agricultural areas in the State.

Figure 2 shows the study area in more detail. The city of Winnemucca is roughly midway in the segment of the valley of the Humboldt River currently being studied. The gaging station at Comus, about 22 miles east of Winnemucca, is at the upstream margin of the study area, and the gaging station near Rose Creek, about 15 miles southwest of Winnemucca, is at the downstream margin of the study area.

The Hydrologic Problem

Streamflow of the Humboldt River is closely related to the ground-water system of the study area. Streamflow at the Comus gaging station during each of the water years 1949-60, the common period of record of both the Rose Creek and Comus gaging stations is shown in figure 3. During this period, the average

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1/ Presented at the Fifteenth Nevada Water Conference, September 28-29, 1961. Publication authorized by the Director, U. S. Geological Survey.

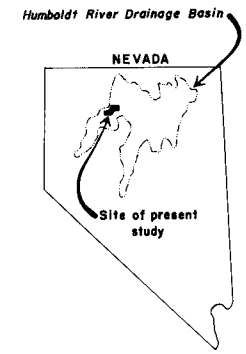

Fig. 1 LOCATION OF STUDY AREA

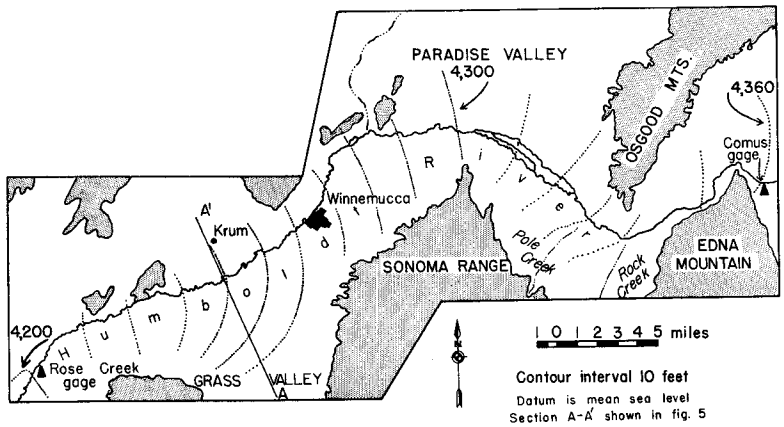

Fig. 2 MAP SHOWING GENERALIZED WATER-LEVEL CONTOURS IN DECEMBER, 1960

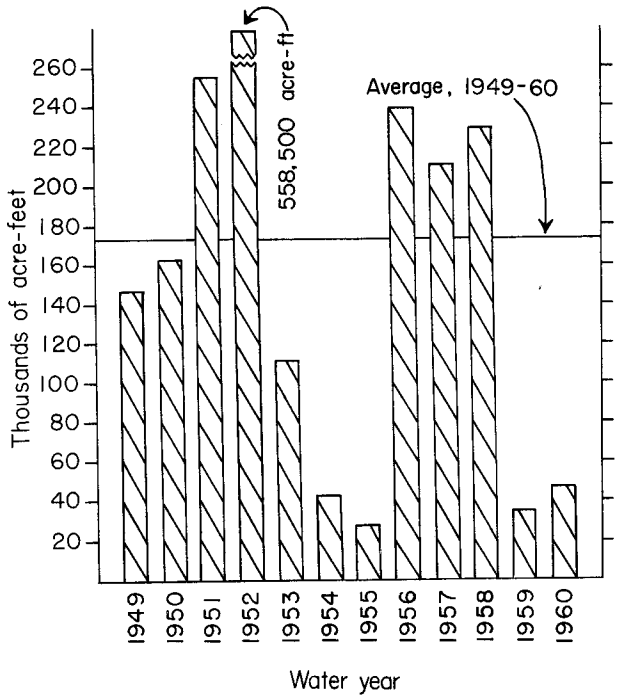

Fig. 3 STREAMFLOW OF THE HUMBOLDT RIVER AT THE COMUS GAGING STATION, 1949-60

streamflow at the Comus gaging station was about 173,000 acre-feet per year. Note the extreme range of annual flow, from a maximum of about 558,500 acre-feet in water year 1952, to a minimum of about 27,500 acre-feet in water year 1955, a ratio of more than 20 to 1.

Figure 4 shows the average amount by which streamflow at the Rose Creek gaging station differed from streamflow at the Comus gaging station. During the water years 1949-52, the decreases of flow within the study area were rather uniform, ranging from about 30,000 acre-feet in 1949 to about 23,000 acre-feet in 1952. Losses of streamflow also occurred in water years 1955, 1956, 1957, and 1960. The maximum loss of streamflow during the 12-year period, about 43,000 acre-feet, occurred in water year 1956.

Increases of flow occurred in the water years 1953, 1954, 1958, and 1959, ranging from a high of about 14,000 acre-feet in 1958 to a low of about 700 acre-feet in 1954. During the 12-year period, flow at the Rose Creek gaging station averaged about 14,000 acre-feet per year less than at the Comus gaging station.

The decrease of streamflow within the study area have been a matter of concern and conjecture for many years. An evaluation of the ground-water hydrology of the area in part helps to account for the losses. Changes of the amount of ground water in storage, ground-water underflow into and out of the area, and the close relation between surface water and ground water within the study area significantly affect the flow of the Humboldt River.

The Hydrogeologic Environment

Figure 5 is a diagramatic geologic section across the valley of the Humboldt River from the mouth of Grass Valley northwestward to about the vicinity of the abandoned railroad siding at Krum.

The lithologic units of principal hydrologic concern in the study area are unconsolidated sedimentary deposits of late Tertiary and Quaternary age. The upper Tertiary and lower Pleistocene units are moderately permeable fluviatile deposits which form the alluvial fans bordering the valley and which underlie the younger fluviatile and lacustrine deposits of the valley floor. The bulk of the younger fluviatile and lacustrine units was deposited near the margins of, and within, Lake Lahontan, a large, relatively deep Pleistocene lake, which covered much of northwestern Nevada. Fluctuations of the level of the lake, related largely to changes in climate, are manifested by well-developed shoreline features and changes in the character of the sediments deposited within the study area. The shoreline features include wave-cut scarps and benches, beaches, bars, and spits.

The classical threefold division of the deposits of Lake Lahontan, as described by Russell in 1885 and verified by others in many parts of the State, cannot be observed at land surface within the study area. However, as a result of the recently completed test-drilling program, during which about 175 test holes were drilled and about 160 observation wells were established, the three major

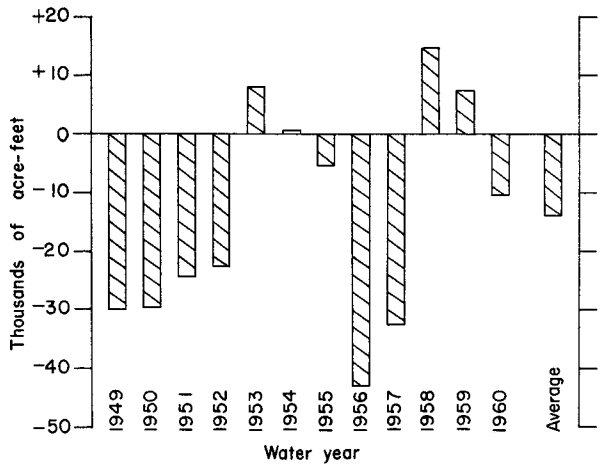

Fig. 4 GAINS AND LOSSES IN THE HUMBOLDT RIVER BETWEEN THE COMUS AND ROSE CREEK GAGING STATIONS, 1949-60

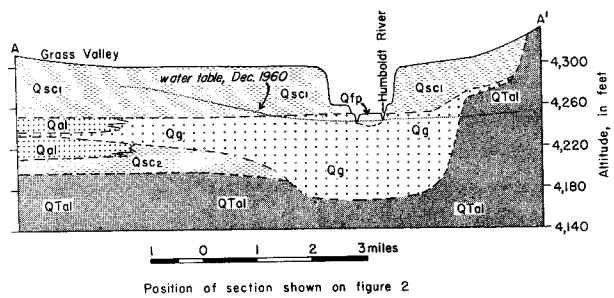

Fig. 5 DIAGRAMMATIC GEOLOGIC CROSS SECTION OF THE HUMBOLDT RIVER VALLEY NEAR THE MOUTH OF GRASS VALLEY

EXPLANATION

Qfp
Gravel, sand, silt and clay
Recent flood-plain deposits of the Humboldt River

Qsc1
Silt and clay
Upper lacustrine deposits of Lake Lahonton age

Qg
Sand and gravel
Medial lacustrine and fluviatile deposits of Lake Lahonton age

Qal
Gravel, sand, silt and clay
Fluviatile deposits of Lake Lahonton age; partly of the same age and partly younger than Qg and Qsc2

Qsc2
Silt and clay
Lower lacustrine deposits of Lake Lahonton age

QTal
Gravel, sand, silt and clay
Undifferentiated fluviatile Quaternary and Tertiary deposits

lithologic units of Lake Lahontan age, the so-called lower silt and clay, medial gravel, and upper silt and clay were recognized.

The oldest lithologic unit of Lake Lahontan consists of beds of silt and clay of undetermined thickness, but probably no more than 50 feet thick, that were deposited in the relatively quiet waters of the first deep stage of the lake. The time of accumulation of this deposit is tentatively correlated with wave-cut scarps that occur at an altitude of about 4,400 feet along the northern slope of the Sonoma Range. This was probably the maximum altitude of the lake. Its maximum eastward extent was in the vicinity of the Comus gaging station.

Following the first deep-lake stage, Lake Lahontan completely receded from the study area and relatively thin fluviatile deposits buried the lake deposits. Subsequently, probably in response to a change in climate, the level of the lake again began to rise. Initially, a relatively shallow lake was formed within the study area and the topography was such that minor fluctuations of the level of the lake resulted in rapidly transgressing and regressing shorelines. Largely as a result of these rapidly moving shorelines, a mass of sand and gravel, the so-called medial gravel, whose maximum thickness is about 150 feet, was deposited within the study area. The medial gravel was derived partly by reworking of the older alluvium by waves and currents, and partly by reworking of stream deposits of the Humboldt River. During Lake Lahontan time the flow of the Humboldt River was considerably greater than at present, and the stream probably carried considerably more coarse material. Large volumes of sediments were deposited within the study area as the river flowed into the lake. As the shoreline receded and advanced these sediments were reworked by waves and currents, largely removing the fine-grained sediments and forming the medial gravel.

After the deposition of the medial gravel, the lake level rose to an altitude of about 4,360 feet and the gravel was covered by beds of silt and clay very similar to the silt and clay that underlies the gravel. This upper silt and clay now forms the floors of Grass and Paradise Valleys and the upper benchlands adjacent to the Humboldt River.

The lower and upper silty clay units are relatively porous but of very low permeability. Thus, they yield very little water to wells. The intervening gravel is porous and highly permeable. Preliminary data suggest that these gravel strata constitute one of the most permeable aquifers in Nevada. Results of recently completed short-term pumping test suggest that the gravel may have a higher coefficient of transmissibility than any aquifer previously tested in Nevada--about 700,000 gallons per day per foot.

Following the final desiccation of Lake Lahontan within the study area, the Humboldt River cut through the upper silty clay unit to about the top of the underlying medial gravel unit. Subsequently, the Humboldt River deposited a 10- to 15-foot thick layer of Recent flood-plain deposits on top of the gravel unit. The flood-plain deposits vary considerably in texture, and range from lenses of highly permeable sand and gravel to beds of relatively impermeable clay and clayey silt. The present channel of the Humboldt River is cut in these deposits.

Partly because of the permeable lenses within the flood-plain deposits, and partly because the deposits are relatively thin, the Humboldt River is in hydraulic continuity with the medial gravel. When the stage of the Humboldt River rises in spring and early summer, the river loses water to the flood-plain deposits and the medial gravel. After the stage of the river declines in middle and late summer, the river tends to gain water from the ground-water body. Thus, although there are small segments of the river within the study area that lose water throughout the year, the river tends to lose water in April, May, and June and tends to gain water throughout the remainder of the year.

Preliminary Quantitative Results

Grass Valley and the northwestern slope of the Sonoma Range, Paradise Valley, the drainage basins of Pole Creek and Rock Creek, and the valley of the Humboldt River above the Comus gaging station contribute underflow to the valley of the Humboldt River within the study area. Preliminary estimates based upon (1) the increase of streamflow of the Humboldt River during periods of low flow, (2) the estimated underflow within the valley of the Humboldt River, and (3) the seasonal and long-term range of water-table gradients suggest that the average annual underflow from these areas for the period 1949-60 was on the order of 14,000 to 19,000 acre-feet. Probably somewhat more than 50 percent of this underflow was derived from Grass Valley. An estimated average of about 11,000 acre-feet per year of this underflow discharged into the Humboldt River, and the remainder left the study area as subsurface outflow through the medial gravel.

As previously mentioned, the average annual measured loss of streamflow between the Comus and Rose Creek gaging stations for the period 1949-60 was about 14,000 acre-feet. Because about 11,000 acre-feet per year was contributed to the river by lateral ground-water inflow between the two gaging stations, and because there was no significant intervening surface-water contribution, the estimated total loss from the Humboldt River between the two gaging stations during the 12-year period was equal to the measured surface-water loss of 14,000 acre-feet plus the lateral ground-water inflow of 11,000 acre-feet, or a total loss of about 25,000 acre-feet per year.

For the period 1949-60, more than 65 percent of the average annual streamflow of the Humboldt River occurred in the months of April, May, and June. During these months, the computed average total decrease of streamflow of the Humboldt River was about 23,000 acre-feet. Based in part upon laboratory specific-yield data, and upon ground-water level data collected during the past 12 years, the average net increase of ground water in storage in the shallow aquifers underlying and adjacent to the Humboldt River during April, May, and June is estimated to have been about 10,000 acre-feet. As previously indicated, the source of much of this recharge to the shallow aquifers was seepage from the river during periods of high river stage. In addition, some recharge to the shallow aquifers resulted from infiltration of some of the water diverted for irrigation from the Humboldt River. Some of the water that was stored in the shallow aquifers subsequently seeped back into the river as the stage of the river declined, but most of it was lost by evapotranspiration. Thus, the increase of

ground water in storage and subsequent evapotranspiration is estimated to have accounted for about 10,000 acre-feet of the average annual decrease of streamflow. The remaining 15,000 acre-feet of the estimated 25,000 acre-feet of average annual loss of streamflow was partly evaporated from open bodies of water and the zone of soil moisture, and was partly transpired by vegetation.

Conclusions

The flow of the Humboldt River within the study area is closely related to the ground-water system, especially the ground water in the deposits underlying and bordering the flood plain of the river. Gains and losses of streamflow coincide with changes of ground water in storage in these shallow aquifers. Because of the close relation between the ground-water reservoir and the river and because of the extremely permeable character of the medial gravel, both the ground-water and surface-water systems must be considered conjunctively in any planning to utilize most effectively the water resources of the area.

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Specific Yield of Sediments of the Humboldt River Valley, Humboldt County, Nevada

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Philip Cohen
Geologist

Prepared Cooperatively by the

Geological Survey, U. S. Department of Interior

January, 1962

SPECIFIC YIELD OF SEDIMENTS OF THE HUMBOLDT RIVER VALLEY, HUMBOLDT COUNTY, NEVADA [1/]

by
Philip Cohen
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Two hundred and nine sediment samples were collected in the fall of 1959 from the Humboldt River Valley near the city of Winnemucca in north-central Nevada, and were analyzed for specific yield and particle-size distribution in the Hydrologic Laboratory of the Geological Survey, Denver, Colo. The specific yields are needed to compute changes in ground-water storage within the area.

The specific yield of a rock or sediment was defined by Meinzer (1923, p. 28) as "*** the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume." This ratio multiplied by 100 expressed specific yield as a percentage. The definition does not state how long the sample should be allowed to drain; however, it is generally assumed that sufficient time is required to allow for complete gravity drainage.

Specific yields were determined in the laboratory by the indirect centrifuge-moisture-equivalent method. First, the porosities of the samples, expressed in percentages of the volume of the samples, were determined. Then the centrifuge-moisture equivalents, or the amounts of water retained by the samples after they were subjected to a force equal to 1,000 times the force of gravity for 1 hour, were determined, and were expressed, also, in percentages of the volume of the samples. Using a method described by Piper and others (1939, p. 118-119), the centrifuge-moisture equivalents were converted to specific retentions. The specific yields of the samples then were determined by the formula --

Specific yield = porosity - specific retention

The results of the laboratory analyses are summarized in table 164.1.

1/ Article 164 - Reprint from U. S. Geological Survey Paper 424-C, Titled "Geological Survey Research 1961" Sub-title "Short Papers in the Geologic and Hydrologic Sciences, Articles 147-292" , p. C-43.

Table 164-1 -- Specific yield of sediment samples from the Humboldt River Valley, Humboldt County, Nev.

	Range of median diameters (millimeters)								All samples
	0.004-0.0625	0.0625-0.125	0.125-0.25	0.25-0.5	0.5-1	1-2	2-4	4-8	
Number of samples	121	15	17	23	6	19	7	1	209
Mean specific yield percent	19.1	21.4	25.9	25.9	22.2	20.8	17.4	17.4	20.7
Range of specific yield percent	1.0-34.1	2.5-36.5	7.0-35.4	7.2-39.5	10.7-35.3	4.6-36.2	4.9-27.4	--- ---	1.0-39.5

From these data it can be seen that there is a large range in specific yield within each median particle-size class. All other factors being equal, specific yields should tend to approach a constant value within each particle-size class and should increase as the median particle sizes increase. The large range in specific yields within each particle-size class for the sediments sampled probably is due to the presence of sedimentary structures (especially in some of the fine-grained sediments), differences in the degree of compaction of the sediments, and complex interrelationships among specific retention, median particle size, porosity, and sorting coefficient. The observed relations among these parameters for the sediments of the Humboldt River Valley are: (a) specific retention tends to increase as median particle size decreases; (b) porosity tends to increase as median particle size decreases; (c) porosity tends to be independent of the sorting coefficient; and (d) sorting coefficient tends to increase as median particle size decreases.

Table 164.1 shows that the mean specific yields for samples whose median particle sizes fall within the silt-size range is exceptionally high -- about 19 percent. Piper and others (1939, p. 121) determined that the average specific yield of samples of very fine sand, silt, and clay is 4.2 percent. Kues and Twogood (1954, p. 33) found that the average specific yield of clay, clayey silt, and silt ranges from about 2 to 14 percent. The relatively high specific yields associated with the fine-grained sediments of the Humboldt River Valley probably is due to the fact that most of the sediment samples whose median particle sizes fall within the silt-size range were collected from recently deposited soil of the flood plain of the river. These sediments commonly are characterized by a moderately high secondary porosity caused by plant roots and burrowing invertebrate animals.

In addition, because of the relatively shallow depth of burial, most of the fine-grained sediments have not been subjected to significant compaction by the weight of overlying sediments.

The mean specific yield of the 209 sediment samples is about 21 percent. While it is true that for some of the size classes the mean specific yields are somewhat lower or higher than 21 percent, it is significant that, for most size classes, these values do not differ substantially from 21 percent. The tendency for the mean specific yield to approach 21 percent probably is a consequence of relations (a) and (b) described above. As the median particle size changes, the porosity and specific retention tend to change in the same direction, and because porosity and specific retention tend to change at the same rate, the difference between the two (specific yield) tends to approach a constant value.

Terzaghi (1949, p. 352-353) indicated that specific yields determined by the centrifuge-moisture-equivalent method are related to time by the equation

$$t = (N^2)\,(\bar{t})$$

According to this equation, the degree of drainage of a saturated sample of thickness H, subjected to a centrifugal force equal to N times the force of gravity for a time $\bar{t}$ is equal to the degree of drainage due to gravity from a bed of the same material of NH thickness in time t. The method used to obtain the laboratory data presented in this paper involves subjecting samples approximately 1/2-inch thick to a centrifugal force equal to 1,000 times the force of gravity for 1 hour. Thus, the laboratory specific yields are indicative of the degree of drainage that would occur in a layer of sediments approximately 40 feet thick during a period of about 100 years.

Within the limitations imposed by the variability of the data and the complexity of the geology, the laboratory data can be used to arrive at an approximation of the total amount of ground water in storage. The laboratory method must be modified to evaluate changes in ground-water storage that occur during relatively short periods of time at shallow depths. The problems involved are especially critical for fine-grined sediments but also are serious for coarser sediments.

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