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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HYDROLOGY OF THE SAN LUIS VALLEY, SOUTH-CENTRAL COLORADO

By

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OPEN-FILE REPORT

WATER
RESOURCES
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Prepared in cooperation with the
COLORADO WATER CONSERVATION BOARD
Felix L. Sparks, Director

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INTRODUCTION

An investigation of the water resources of the Colorado part of the San Luis Valley was begun in 1966 by the U.S. Geological Survey, in cooperation with the Colorado Water Conservation Board. (See index map, fig. 1). The purpose of the investigation is to provide information for planning and implementing improved water-development and management practices. The major water problems in the San Luis Valley include (1) waterlogging, (2) waste of water by nonbeneficial evapotranspiration, (3) deterioration of ground-water chemical quality, and (4) failure of Colorado to deliver water to New Mexico and Texas in accordance with the Rio Grande Compact.

This report describes the hydrologic environment, extent of water-resource development, and some of the problems related to that development. Information presented is based on data collected from 1966 to 1968 and on previous studies. Subsequent reports are planned as the investigation progresses.

The San Luis Valley extends about 100 miles from Poncha Pass near the northeast corner of Saguache County, Colo., to a point about 16 miles south of the Colorado-New Mexico State line. The total area is 3,125 square miles, of which about 3,000 are in Colorado. The valley is nearly flat except for the San Luis Hills and a few other small areas. The Colorado part of the San Luis Valley, which is described in this report, has an average altitude

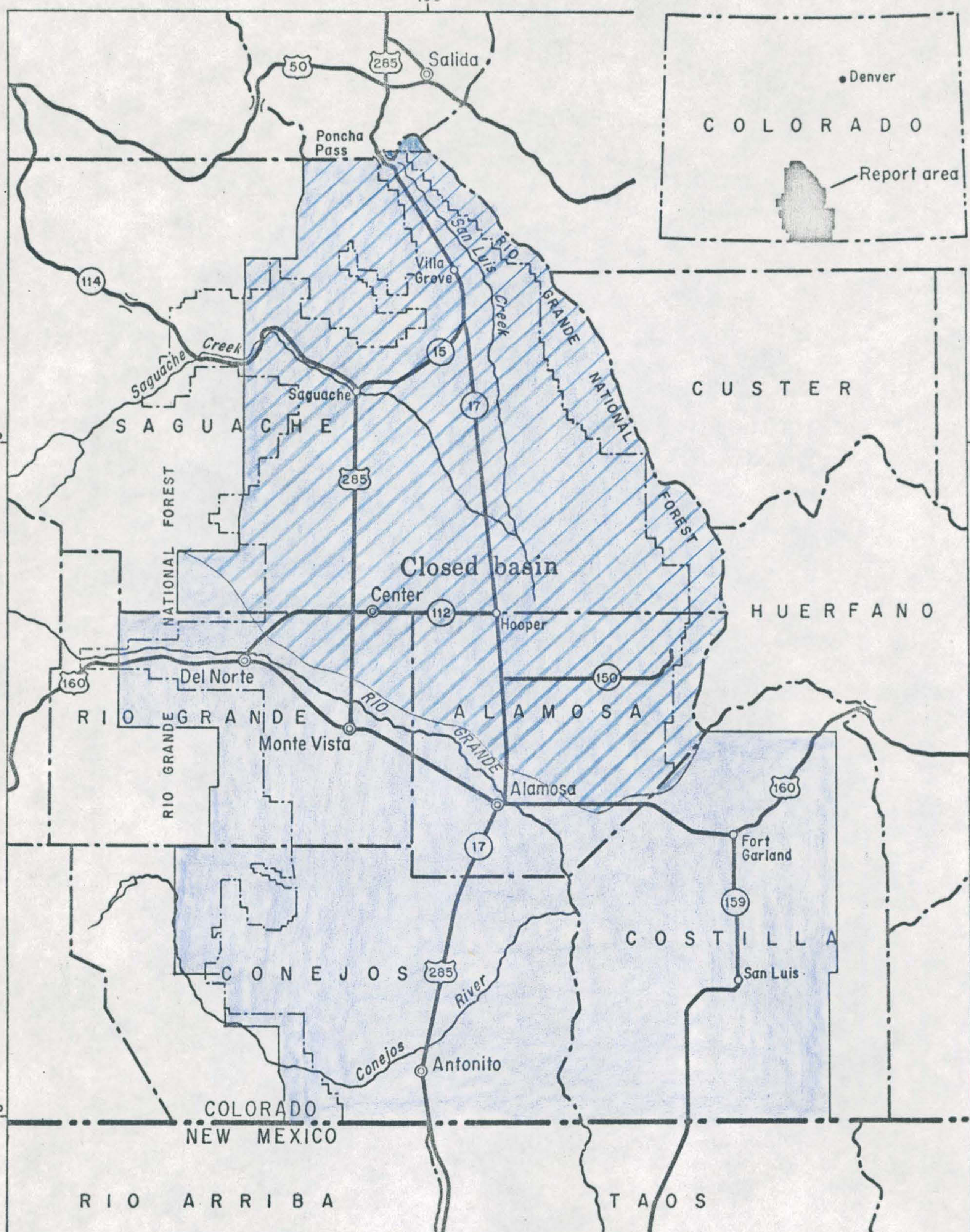

Figure 1. Index map showing location of report area (shaded) and extent of closed basin (ruled pattern).

of about 7,700 feet. Bounding the valley on the west are the San Juan Mountains and on the east the Sangre de Cristo Mountains. Most of the valley floor is bordered by alluvial fans deposited by streams originating in the mountains, the most extensive being the Rio Grande fan (see block diagram, fig. 2 in pocket).

Most of the streamflow is derived from snowmelt from 4,700 square miles of watershed in the surrounding mountains. The northern half of the San Luis Valley is internally drained and is referred to as the closed basin. The lowest part of this area is known locally as the "sump." The remainder of the valley is drained by the Rio Grande and its tributaries.

The climate of the San Luis Valley is arid, and a successful agricultural economy would not be possible without irrigation. It is characterized by cold winters, moderate summers, and much sunshine. The average annual precipitation on the valley floor ranges from 7 to 10 inches. More than half the precipitation occurs from July to September. Moisture deficiency in the valley is shown by the graph comparing pan evaporation and precipitation (fig. 3). For the years 1961-67 average pan evaporation for the period April through September was 52.25 inches, but average precipitation for the period was only 5.02 inches. Average annual precipitation was 7.8 inches. Owing to the short growing season (90-120 days), crops are restricted mainly to barley, oats, potatoes, and other vegetables.

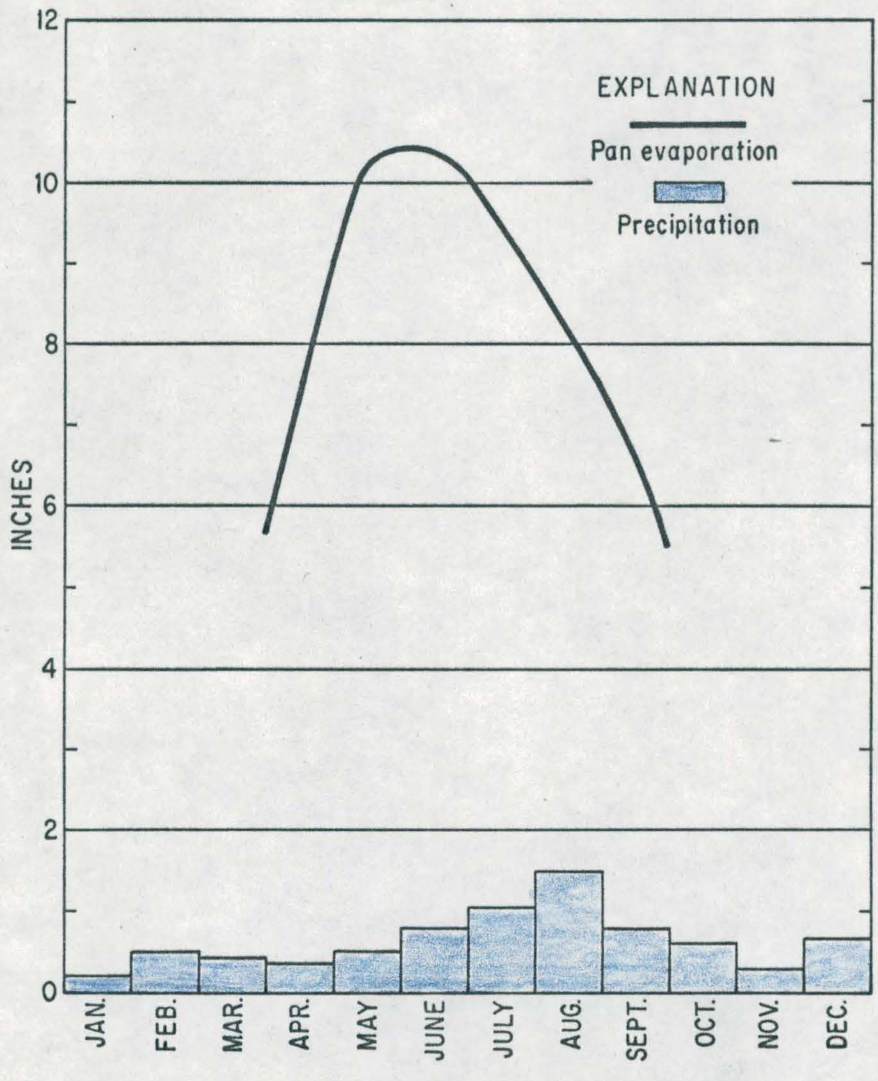

Figure 3. Pan evaporation and mean monthly precipitation at Alamosa, 1961-67.

HYDROGEOLOGY

The San Luis Valley is a large north-trending structural depression that is downfaulted on the eastern border and hinged on the western side (see fig. 2). The valley is underlain with as much as 30,000 feet (Gaca and Karig, 1966, p. 1) of alluvium, volcanic debris, and interbedded volcanic flows and tuffs of Oligocene to Holocene age. Although Siebenthal (1910, p. 39-47) subdivided the deposits into the Santa Fe and Alamosa Formations, later information indicates that it is impossible to differentiate the formations except very locally. In this report, all deposits above the Precambrian crystalline rocks are referred to as valley fill (see table 1).

The Sangre de Cristo Mountains are composed of igneous, metamorphic, and sedimentary rocks, whereas the San Juan Mountains are composed mainly of volcanic flows, tuffs, and breccias (Larson and Cross, 1956, p. 62). Many of the lava flows and tuffs from the San Juans dip eastward under the valley floor, and in the southwestern part of the valley, restrict the vertical movement of ground water. Geophysical and drillers' logs indicate that a "clay series" 10 to 80 feet thick occurs throughout much of the central and northern parts of the valley at depths ranging from 50 to 130 feet below land surface. The clay beds also restrict the vertical movement of ground water.

Table 1.--*Summary of geologic units and their hydrologic character*

System or series	Geologic unit	Hydrologic unit	Thickness (feet)	Physical character	Hydrologic character	Water supply
Holocene to Oligocene	Valley fill	Unconfined aquifer	0-200	Unconsolidated clay, silt, sand, and gravel.	Transmissivity ranges from 1,000 to 250,000 gallons per day per foot. Specific yield is estimated to be 0.20.	Yields as much as 3,000 gallons per minute.
		Confined aquifer	50-30,000	Unconsolidated clay, silt, sand, and gravel interbedded with volcanic flows and tuffs.	Transmissivity ranges from 4,000 to 300,000 gallons per day per foot in zone tapped by existing wells. Storage coefficient is estimated to be 0.0001. Water is under artesian pressure.	Yields as much as 4,000 gallons per minute.
Precambrian	Crystalline rocks			Granite, gneiss, and schist.	Not water bearing.	None.

Total annual water supply to the San Luis Valley averages about 2,500,000 acre-feet. About 1,500,000 acre-feet is streamflow derived chiefly from snowmelt in the surrounding mountains and 1,000,000 acre-feet is from precipitation on the valley floor. The streamflow stations shown on the water-table map (fig. 4 in pocket) measure runoff from 80 percent of the drainage area. Runoff from the remainder of the area is estimated by correlation with these stations. Discharge of water from the valley averages about 2,000,000 acre-feet per year by evapotranspiration and about 500,000 acre-feet per year as flow across the State line. The streamflow at the State line averages 445,000 acre-feet and ground-water underflow accounts for a small amount currently estimated as 55,000 acre-feet. About half of the evapotranspiration is nonbeneficial, that is, it does not contribute to the growth of plants having economic value. Much of the nonbeneficial consumption is by phreatophytes in areas where the depth to water is less than 12 feet. The curve on the evapotranspiration graph (fig. 5) shows an estimate of the relation of depth to water to annual evapotranspiration from the water table in these areas.

Ground water in the San Luis Valley is obtained from unconfined and confined aquifers. These aquifers contain at least 2 billion acre-feet of water in storage. They are separated by a "clay series" or by a layer of volcanic rocks. These confining beds are discontinuous and lenticular so it is difficult to differentiate

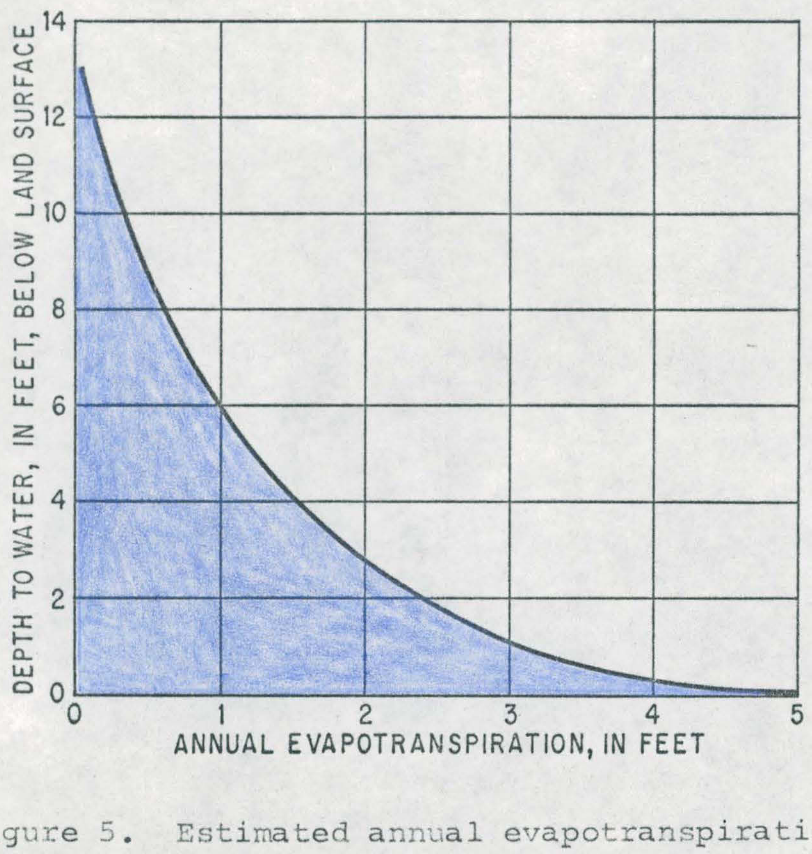

Figure 5. Estimated annual evapotranspiration from the water table in phreatophyte areas.

between unconfined and confined aquifers except locally. This discontinuity in the "clay series" causes varying degrees of hydraulic connection between the aquifers.

Shallow unconfined ground water occurs almost everywhere in the valley and extends 50 to 200 feet beneath the land surface. The depth to water in the valley is less than 12 feet except along the edges and in most of Costilla County (see fig. 4).

Recharge to the unconfined aquifer is mainly by infiltration of applied irrigation water and leakage from canals and ditches. Some water percolates from the many streams flanking the valley and precipitation on the valley floor also recharges the unconfined aquifer. Discharge from this aquifer is by evapotranspiration and seepage to streams. Flow lines show the direction of ground-water movement in the unconfined aquifer in several areas (see fig. 4). A slight flexure of the water-table contours shows a ground-water divide north of and parallel to the Rio Grande. The divide, which is marked on the map, is caused by recharge from canal leakage and applied irrigation water. The flow lines show that ground water south of the divide moves toward the Rio Grande and that ground water north of the divide moves into the closed basin where it is discharged by evapotranspiration.

The principal source of recharge to the confined aquifer is seepage from mountain streams that flow across the alluvial fans flanking the valley floor. At the edge of the valley the clay series is absent permitting recharge to beds that constitute the confined aquifer in the main part of the valley. The mountain streams show significant losses as they cross the porous surface of the fans. For example, seepage measurements made July 6, 1967, on Deadman Creek south of Crestone (northeast part of valley) showed that the 7 cfs (cubic feet per second) measured at the canyon mouth was completely dissipated within about 8 miles; all but 1 cfs was lost in the first 3.7 miles. The confined aquifer underlies most of the valley and the water has sufficient head to flow at the land surface. The major discharge from the confined aquifer is by wells, springs, and upward leakage through the confining beds into the unconfined aquifer. A small amount may discharge as underflow into New Mexico.

The quality of water in the artesian aquifer generally is better than that in the unconfined aquifer according to Powell (1958). The concentration of dissolved solids in 41 samples from the artesian aquifer ranged from 70 to 224 mg/l (milligrams per liter) and in 271 samples from the unconfined aquifer ranged from 52 to 13,800 mg/l. The least mineralized water in the unconfined aquifer occurs on the west side of the valley. The mineral concentration increases toward the sump area of the closed basin probably because of solution from the rocks and by concentration by evapotranspiration in areas having a shallow water table.

DEVELOPMENT

The principal source of water for irrigation in the San Luis Valley between 1880 and 1950 was surface water. A large network of canals was built in 1880-90 to irrigate lands in the eastern and central parts of the closed basin. By 1915 most of the area around Mosca and Hooper became waterlogged because of this irrigation. Drainage systems constructed between 1911 and 1921 to reclaim waterlogged lands alleviated some of the problems but created waterlogging in areas downgradient. Waterlogging in other areas is caused by subirrigation because the water table is intentionally raised to the plant root zone. The practice continues because it is considered locally to be essential to successful growth of crops.

In 1967 there were about 2,800 wells in the San Luis Valley that yielded more than 300 gallons per minute each. Of this total, 2,160 tap the unconfined aquifer. The graph (fig. 6) showing large-capacity well installation indicates that the greatest rate of installation occurred during the drought years when about 1,200 wells were installed from 1950 to 1957. The greatest concentration of large capacity wells is in the Rio Grande fan area (see map showing distribution of irrigation wells, fig. 7 in pocket).

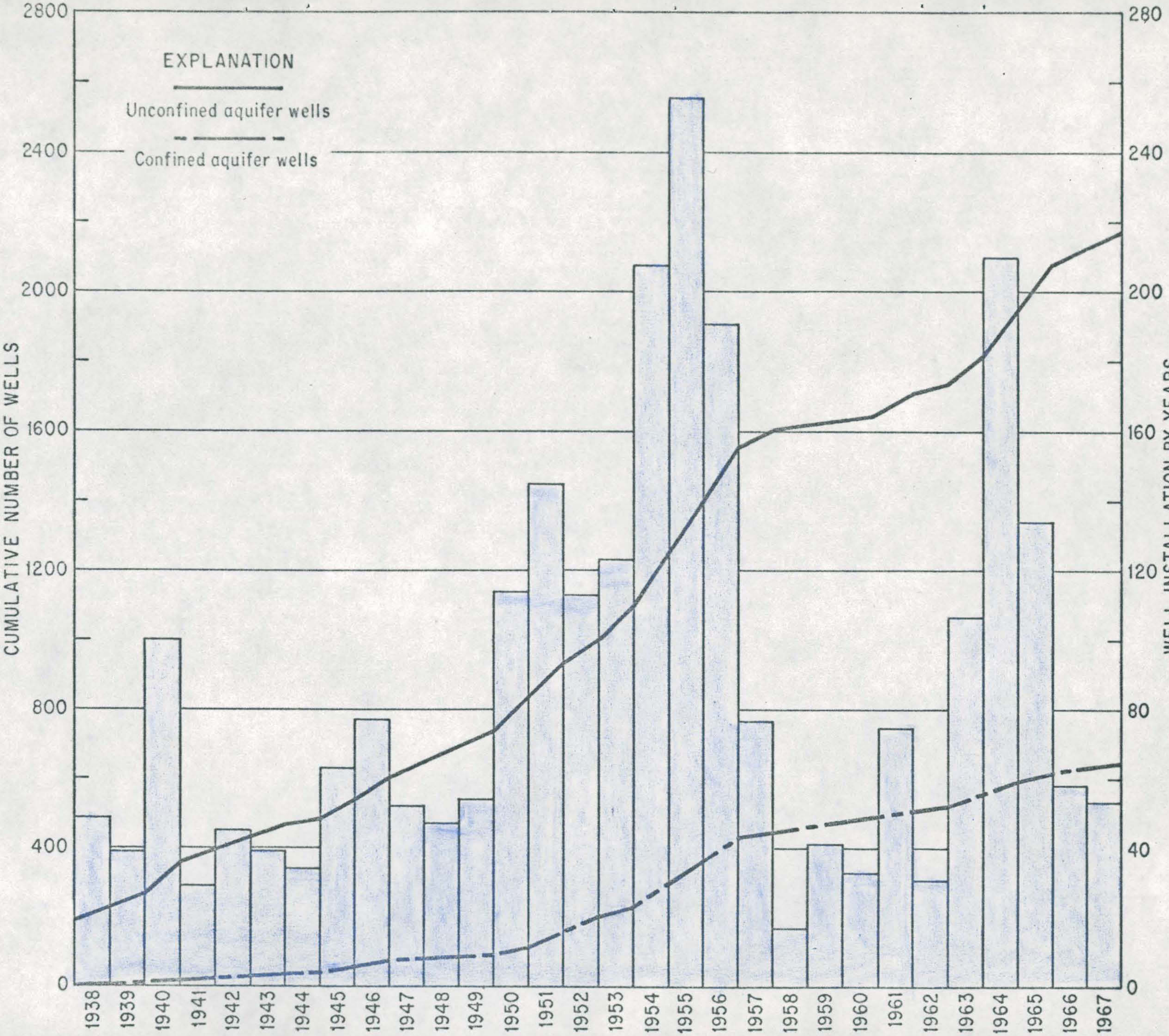

Figure 6. Large-capacity well installation by years.

In addition to the large capacity wells, there are more than 7,000 small capacity flowing wells. In 1890 Carpenter (Siebenthal, 1910) estimated there were 2,000 flowing wells; in 1904 Siebenthal (1910) counted 3,234; and in 1936 Robinson and Waite (1938) (counted) estimated 6,074. [Counted every other section and multiplied by 2. zm]

Ground-water withdrawal for recent years (1962-67) averaged about 1,100,000 acre-feet per year. Withdrawal by large capacity irrigation wells was about 800,000 acre-feet per year (see graph showing ground-water withdrawal, fig. 8) and withdrawal by small capacity wells tapping the confined aquifer was 300,000 acre-feet per year. In 1967 the unconfined aquifer accounted for 71 percent of the ground water withdrawn from large capacity wells. A large number of the small capacity confined wells continue to flow throughout the year and an estimated 150,000 acre-feet per year might be considered waste because it does not contribute to crop production. In fact, it causes additional waterlogging.

The Rio Grande fan contains much more ground water today than it did before the beginning of irrigation. About 1900, the water table was reported as 50 to 100 feet below land surface (Powell, 1958, p. 56). Since then recharge by canal leakage, applied irrigation water, and uncontrolled flow from artesian wells has filled the valley fill of the Rio Grande fan to within 5 to 20 feet of the land surface.

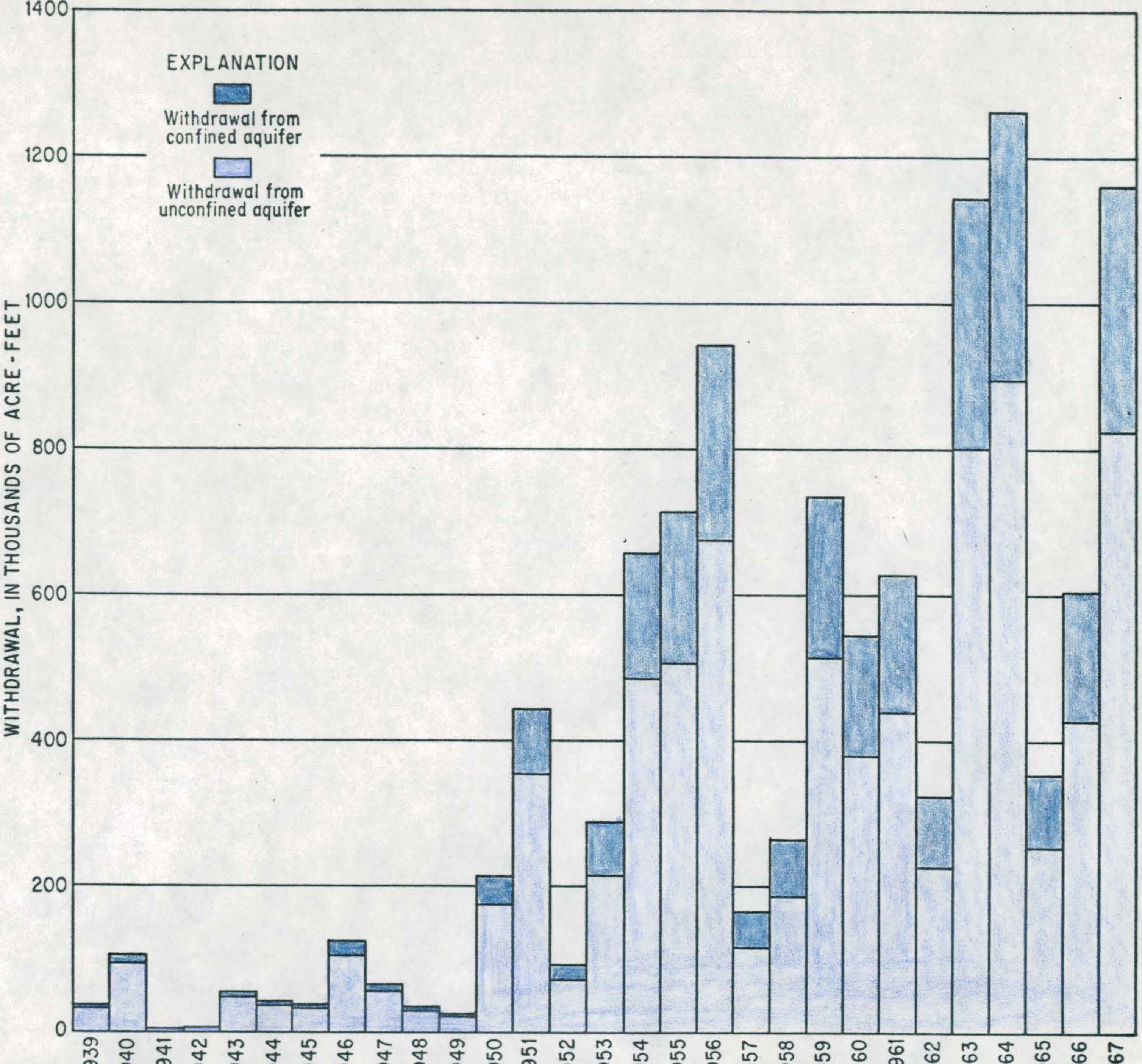

Figure 8. Estimated ground-water withdrawal by large-capacity irrigation wells.

The unconfined aquifer underlying the Rio Grande fan helps to regulate the water supply in the closed basin. Ground water withdrawn during periods of low surface-water supply is replenished during periods of abundant supply. The lowering of the water table (see fig. 9) in 1955, 1956, 1963, and 1964 corresponds with years of above-average pumping. When excess surface water was available, it was used to replenish ground-water storage.

The rise of the water level in the Rio Grande fan has changed the upper reaches of the Rio Grande from a losing to a gaining river. Measurements made during the period 1896-1903 (Carpenter, 1911) indicated seepage losses from the Rio Grande of as much as 53 cfs between Del Norte and Monte Vista. However, measurements in the summer of 1967 indicated a loss of only 2 cfs in the same reach and a gain from Monte Vista to the State line. The rise of the water level has also created the ground-water divide shown on figure 4. It is sustained by canal leakage and by the water diverted into the closed basin.

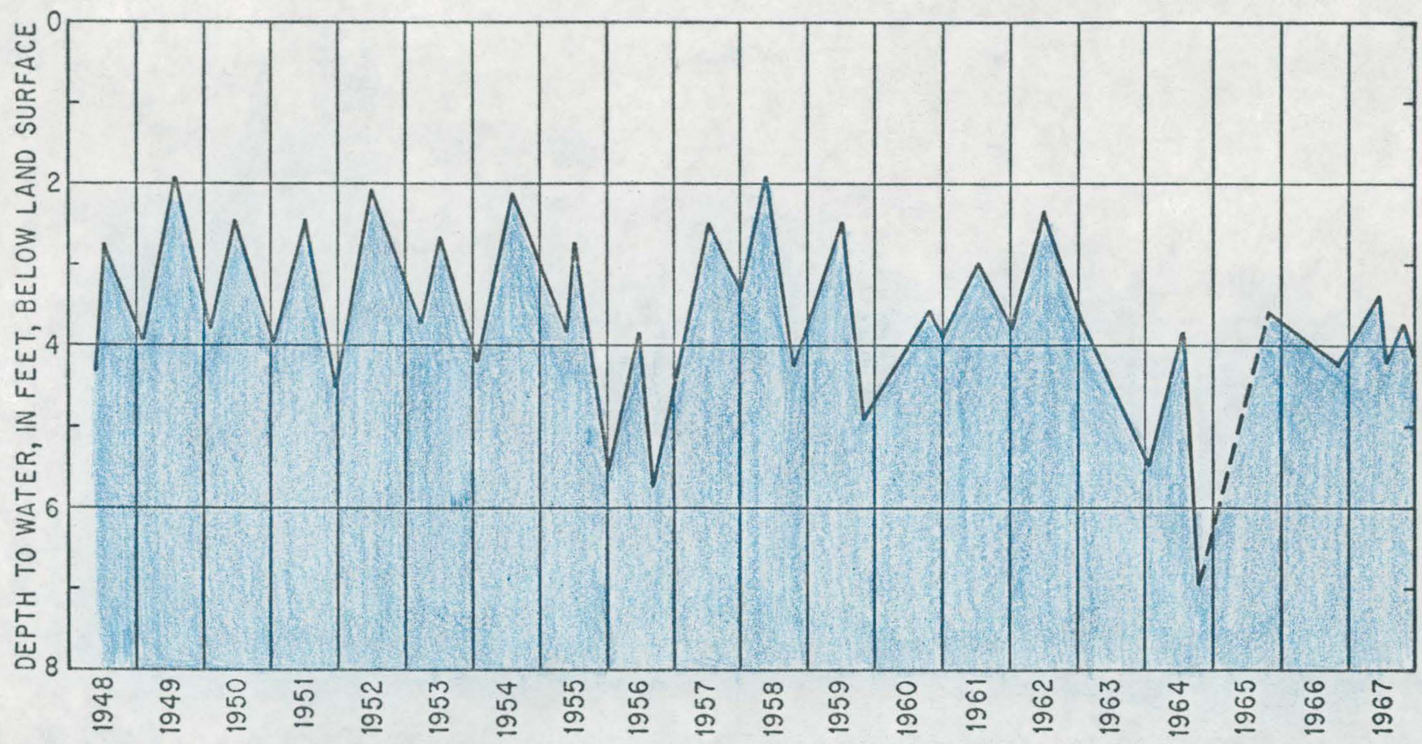

Figure 9. Hydrograph of typical observation well in the unconfined aquifer of Rio Grande fan.

CONCLUSIONS

The San Luis Valley is endowed with a plentiful supply of ground water and surface water. The surface-water supply averages 1,500,000 acre-feet per year, and ground-water withdrawals have averaged 1,100,000 acre-feet per year in recent years (1962-67). This annual supply is substantial but could be supplemented by additional development of the more than 2 billion acre-feet of ground water stored in the deposits underlying the valley. The stored water is sufficient to supply current consumptive use for 1,000 years. Although only a small part of the stored water could be withdrawn at costs competitive with surface supplies, the potential ground-water supply still staggers the imagination. Despite the abundant supply, water-use practices over the past 100 years have created water problems. The following is a summary of the major problems.

Surface water use has resulted in the waterlogging of a large part of the valley. The valley-fill deposits in the northern part of the valley are filled with water from the tributary watersheds and from the Rio Grande diversions. The results are good crop production in part of the area, but waterlogging and high nonbeneficial consumptive use of water in most of the area. Furthermore the soils in some areas have become alkaline and the ground water has become highly mineralized because of concentration of salts by evapotranspiration. A major part of the valley south and west of Alamosa likewise is waterlogged, suffering from an abundance of water and poor drainage. Nonbeneficial vegetation consumes half (about 1 million acre-feet) of the total water available annually for use in the valley.

Deliveries of water under the Compact with New Mexico and Texas have been deficient, accruing a deficit of 944,000 acre-feet by the end of 1967. The graphs (fig. 10) showing index inflow and Compact accruals show that for 11 years after January 1, 1940, when the Compact became effective, deliveries to New Mexico were in accord with the agreement. The accumulation of the debit since 1952 corresponds with a period when the flow was generally below normal at the stations used for allocating water for the Compact. In the winter of 1967, and summer of 1968, the State Engineer controlled Colorado diversions in an attempt to halt further accumulation of the debit. A solution more satisfactory to Colorado water users is being sought. The U.S. Bureau of Reclamation proposed a plan for obtaining water to satisfy Compact requirements (U.S. Bureau of Reclamation, 1963). The plan envisions salvaging water being consumed non-beneficially in the closed basin and transporting it to the Rio Grande to satisfy Compact requirements. Other plans for satisfying the deficit from salvaged water have subsequently been proposed. None of the plans have been adopted at this time (1969).

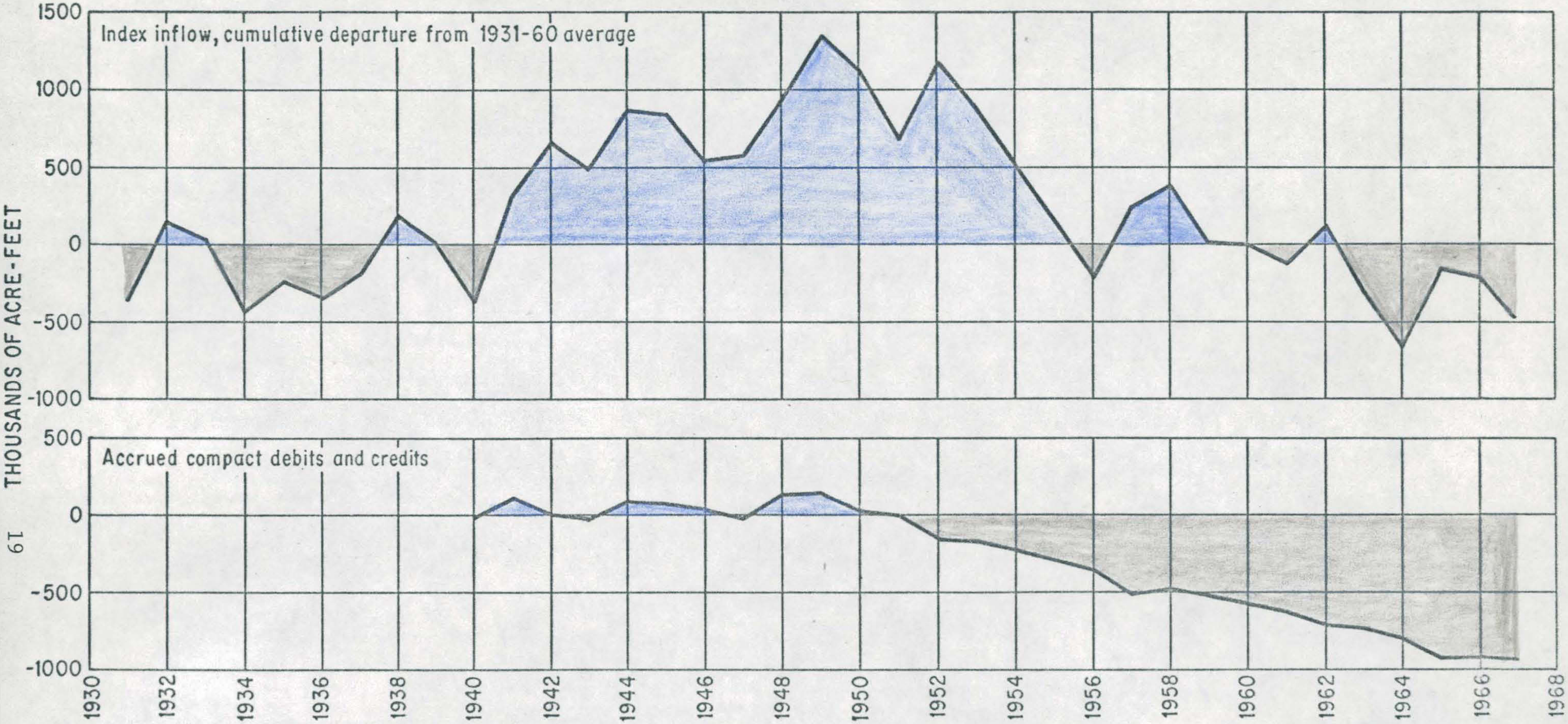

Figure 10. Relation between index inflow and Compact accurals.

Colorado legislators are attempting to enact new water laws that will encourage improved water-management practices. Their aim is to utilize more fully the supply by reducing waste and to provide better regulation by using ground-water storage. Facts gained from studies such as this one are being used to make the law compatible with the physical framework. This study should be useful in devising plans that will eliminate or substantially alleviate most of the water problems in the San Luis Valley. Analog and digital models of the hydrology in the valley will be used in testing these plans. An analog model of the unconfined aquifer has been constructed and is presently (1969) being tested.

Continued study of the water resources is needed to define further the many complex relations among the confined aquifer, unconfined aquifer, and their effect on the regimen of streams. Further measurements and refinement of measurements of surface and ground water are prerequisite to formulating plans for effecting improved water management. The continuation of this study will be oriented toward these refinements which should provide a basis for improved water utilization.

SELECTED REFERENCES

Carpenter, L. G., 1911, Seepage and return waters, detailed measurements: Colorado Agr. Coll. Expt. Sta. Bull. 180, pt. 3, 145 p.

Gaca, J. R., and Karig, D. E., 1966, Gravity survey in the San Luis Valley area, Colorado: U.S. Geol. Survey open-file report, 21 p.

Johnson, R. B., 1967, The great sand dunes of southern Colorado: Art. in U.S. Geol. Survey Prof. Paper 575-C, p. C177-C183.

Larson, E. S., Jr., and Cross, Whitman, 1956, Geology and petrology of the San Juan region, southwestern Colorado: U.S. Geol. Survey Prof. Paper 258, 303 p.

McConaghy, J. A., and Colburn, G. W., 1964, Records of wells in Colorado: Colorado Water Conserv. Board Basic-Data Release 17, 384 p.

Powell, W. J., 1958, Ground-water resources of the San Luis Valley, Colorado: U.S. Geol. Survey Water-Supply Paper 1379, 284 p.

Robinson, T. W., Jr., and Waite, H. A., 1938, Ground water in the San Luis Valley, Colorado, in Regional Plan., pt. 6, Upper Rio Grande: U.S. Nat. Resources Comm., p. 226-267.

Siebenthal, C. E., 1910, Geology and water resources of the San Luis Valley, Colorado: U.S. Geol. Survey Water-Supply Paper 240, 128 p.

U.S. Bureau of Reclamation, 1963, Plan for development of Closed Basin Division, San Luis Valley project, Colorado: Amarillo, Tex., U.S. Bur. Reclamation, Region 5, Project Plan Rept., 87 p.

U.S. Geological Survey, 1966, pt. 2, Quality of water records: U.S. Geol. Survey open-file report, p. 45-46.

Upson, J. E., 1939, Physiographic subdivisions of the San Luis Valley, southern Colorado: Jour. Geology, v. 47, no. 7, p. 721-736.

Winograd, I. J., 1959, Ground-water conditions and geology of Sunshine Valley and western Taos County, New Mexico: New Mexico State Engineer Office Tech. Rept. 12, 70 p.

Woodward-Clyde-Sherard and Associates, 1967, Geo-hydrologic study of the Closed Basin, San Luis Valley, Colorado: Denver, Colo., 21 p.