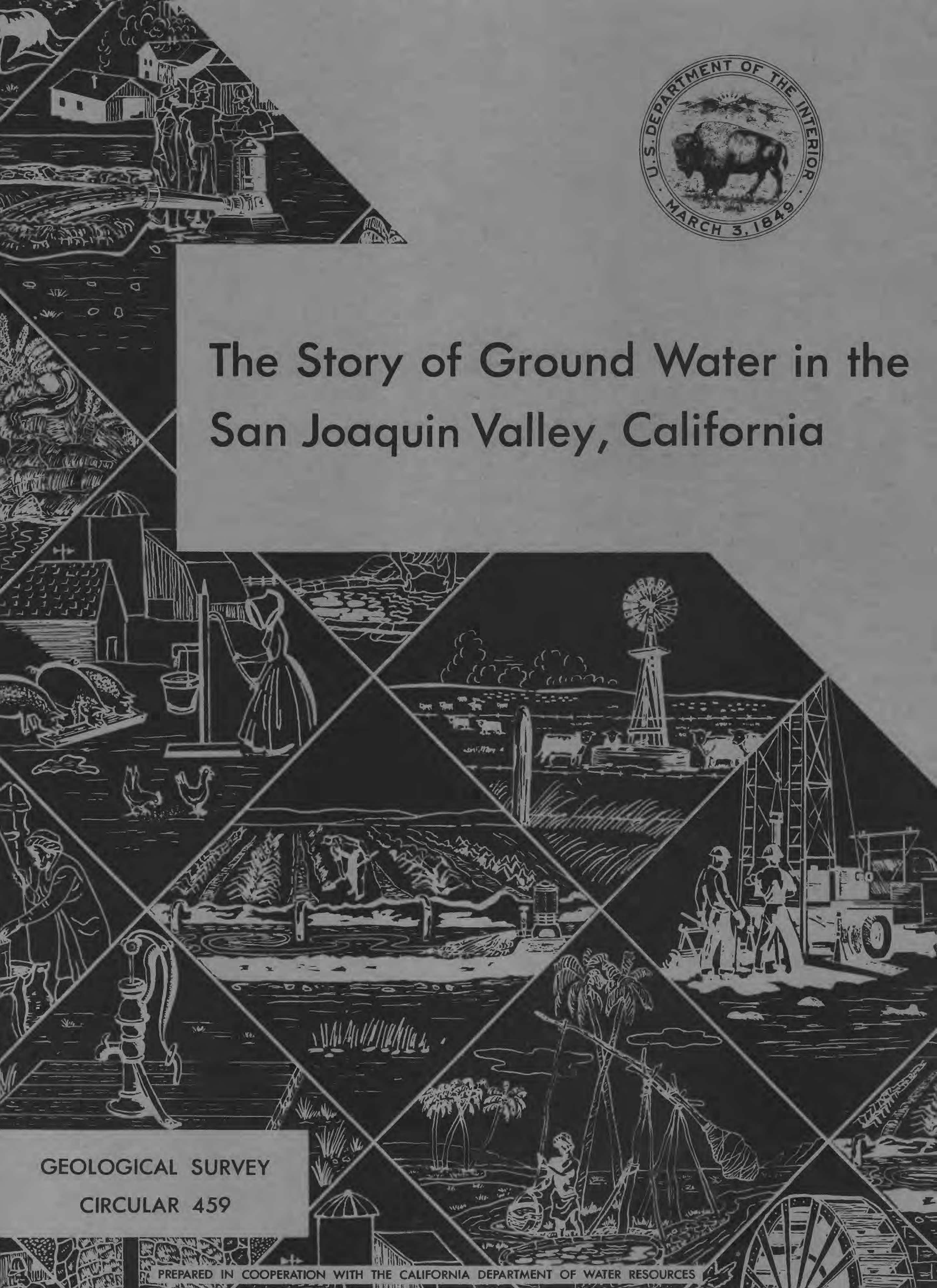
The Story of Ground Water in the San Joaquin Valley, California



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The Story of Ground Water in the San Joaquin Valley, California

By R. H. Dale, J. J. French, and H. D. Wilson, Jr.

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THE UNDERGROUND LAKE OF SAN JOAQUIN VALLEY

The underground lake of the San Joaquin Valley stretches from the Sierra Nevada to the Coast Ranges and from the Tehachapi Mountains to the San Francisco Bay area. Fantasy? No, fact! The San Joaquin Valley is really like a huge lake that is clogged with alluvium (clay, silt, sand, and gravel). The amount of water in this lake is tremendous—93 million acre-feet contained in the upper 200 feet alone—enough to cover the entire 10,000-square-mile valley with a layer of water 14½ feet deep. In comparison, Lake Isabella (fig. 1) at full capacity holds only 570,000 acre-feet; thus, the "lake" in the San Joaquin Valley holds more water than 163 Lake Isabellas!

This lake is not a mysterious subterranean cavern complete with rushing channels, whirlpools, sightless fish, and the like. It is a large porous body of loosely packed sand and gravel that is saturated with water. To get an idea of what this lake is like, fill a bucket brimful with dry sand and begin pouring water into it. You'll be surprised how much water you can pour into this bucket. This is also true of the alluvial fill of the San Joaquin Valley.

But where does the water come from to fill this alluvium? The answer is stated in a court decision that regarded the San Fernando Valley as a "great lake filled with loose detritus, into which the drainage from the neighboring mountains flows, and the outlet of which is the Los Angeles River." The San Joaquin Valley is very similar. In the southern part of the valley, for example, the major drainage from the mountains is the Kern River, which begins high on the slopes of Mount Whitney and then winds its tortuous 155-mile journey to recharge the underground lake of the San Joaquin Valley. Melting snow in the mountains is the chief source of water; most of the runoff is in late spring and early summer. The water flows over very hard crystalline granite from its source to the mouth of Kern Gorge (fig. 2), and virtually none seeps into the ground. However, once the river bursts out of the confining gorge, it flows over highly permeable sand and gravel that soak up the water just as our "full" bucket of sand did. This water becomes ground water—a part of the 93 million acre-feet lake—and continues its journey seaward through the pores between the sand grains.

Replenishment of recharge of the "lake" similarly occurs along the other streams of the valley, such as the Tule, Kaweah, Kings, San Joaquin, Merced, Tuolumne, and Stanislaus Rivers. For simplicity, however, the hydrologic discussion that follows is limited to the Kern River area (fig. 3).

Figure 1.—Lake Isabella.

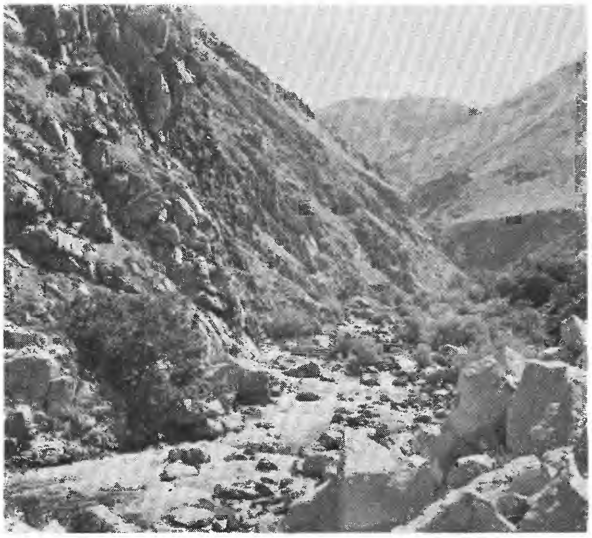


Figure 2.—Kern River Canyon.

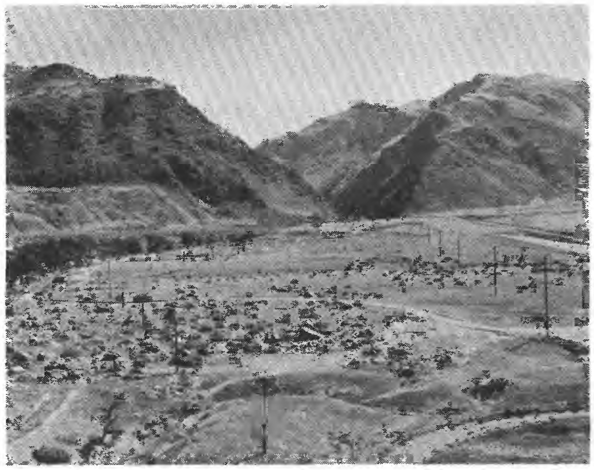


Figure 3.—Mouth of Kern Canyon.

FUTURE OF THE LAKE

The average annual runoff in the Kern River is estimated at about 700,000 acre-feet. That is almost three-fourths of a million acre-feet of water that pours into the Kern County section of the "lake" each year. Yet in this same area about 2 million acre-feet of ground water is pumped annually—three times the flow of the river! Much of the ground water, however, returns to the underground reservoir.

Back in the days of the Indians (fig. 4) the river and the "lake" had a nice sort of working agreement. In dry years when the river was low, the "lake" still contained plenty of water to keep much of the valley green. In fact the valley generally was so brimfull of water that the ground water spilled out into two visible surface lakes, Kern and Buena Vista. In wet years when the river brought in more water than usual, it simply evaporated or flowed over the low barrier to the north into the San Joaquin River and on out to the sea (fig. 5).

Along came the white men who drilled wells and dug canals to spread the water around. This spreading of water over the surface of the ground permitted a steady agricultural growth that required more and more water. Eventually, as more water was spread, less reached the two surface lakes. This increase in water use did not create much of a problem until about 1946. Until then the amount of ground water pumped was about the same as the recharge from the river. The postwar period brought about a tremendous increase in the amount of pumping for irrigation, and as shown by figure 6, water levels declined as the pumpage of ground water increased.

With about 2 million acre-feet of ground water being pumped yearly, water levels in wells are declining in much of the area. What is going to happen? Unless the present trend is changed, water levels would continue to decline and the cost of pumping would increase. Will this happen? and can something be done? Two possibilities come to mind: using the present supply of water more efficiently or providing a new supply. Greater use of ground-water storage would be one means of reducing the present water loss by evaporation. Some large scale water-spreading experiments to increase ground-water storage have been carried out in the Kern River area, but serious problems are involved.

The rainfall might be increased through cloud seeding, but that is an uncertain operation. The most practical solution would be to import new supplies of water, and the State of California and the U.S. Bureau of Reclamation have offered specific solutions—namely large imports via canals.

Many things can be done to alter the trend, but the most effective choice depends on a full understanding of the hydrologic system at hand. For this reason the U.S. Geological

Figure 4.—The river in Indian times.

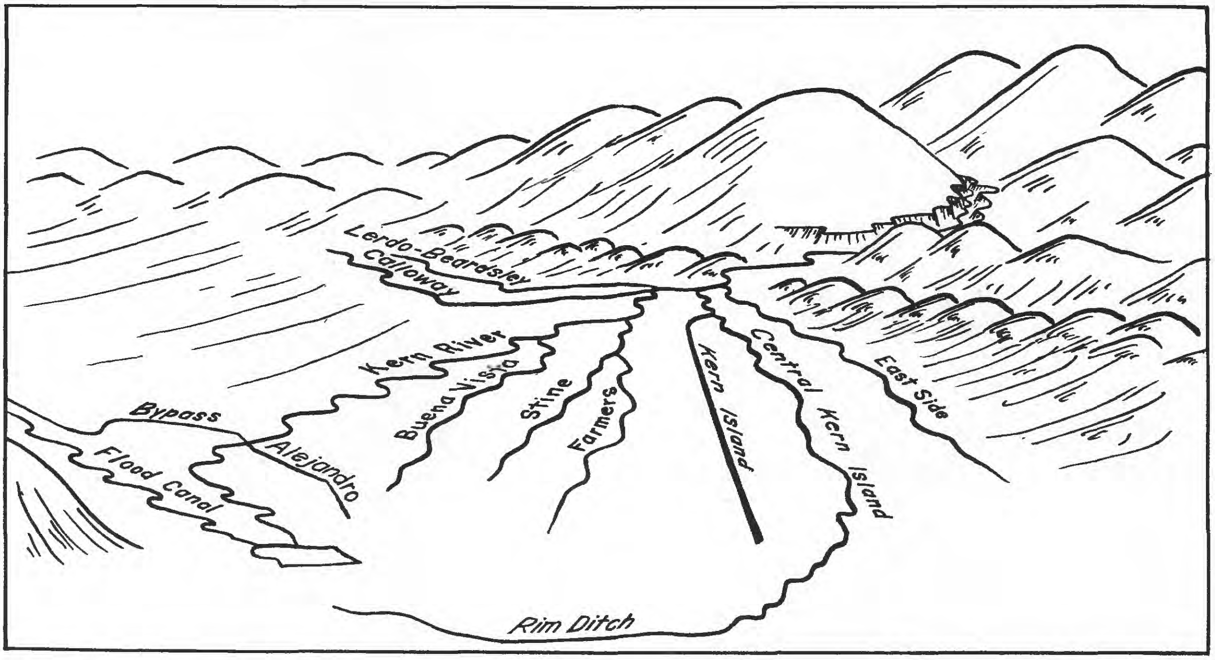


Figure 5.—The river today.

Survey is investigating the Kern River fan area and other parts of the San Joaquin Valley. In each investigation the goal is to understand the geology and hydrology of the area so choices and decisions may be made intelligently by those who must make them.

To understand how the desired objectives might be accomplished one must have a general basic knowledge about water and specific knowledge about the geology and hydrology of the alluvial fans in which the ground water occurs. First, water is not consumed

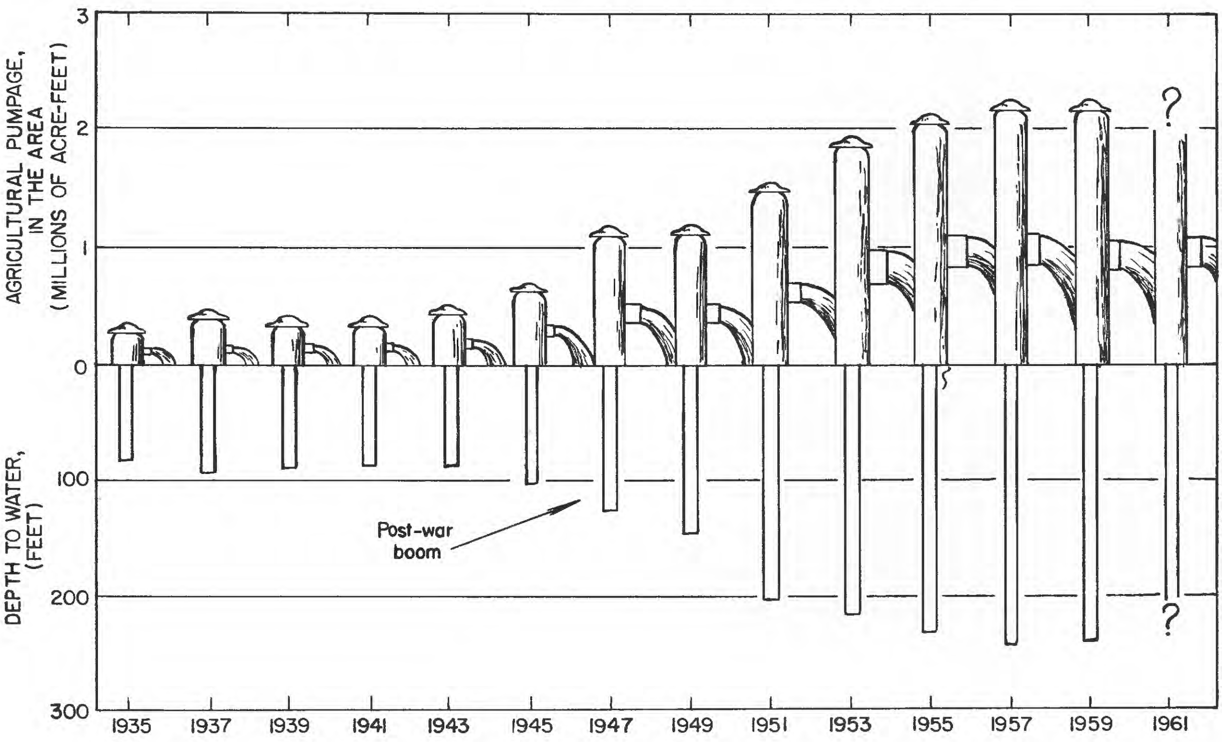


Figure 6.—The effect of increased area-wide pumping on the water level in a well near Wasco, Calif.

like coal or oil, water is employed. Also, unlike petroleum, ground water is not stationary. Petroleum, except for a moderate amount of movement, is trapped and is stationary in a body of rock, the pores of which are saturated with crude oil. Ground water is not commonly trapped, but rather it is constantly on the move from places of recharge to places of discharge. Where trapped, it is generally known as connate water and is commonly of poor quality and thus will not be suitable for domestic or irrigation uses.

The surface water flowing down the Kern River, for example, is in one phase of the hydrologic cycle. After it leaves the Kern Gorge it infiltrates into the ground and becomes ground water (another phase in the cycle). The movement of the ground water is in accordance with the same law that applies to surface water: it seeks the lowest level possible. These low areas may be natural such as the low central part of the valley including Buena Vista and Tulare Lakes toward which most of the ground water of the area eventually moved prior to man's interference with the hydrologic cycle or they may be man made, as in the vicinity of a pumped well where the water level is drawn down by pumping.

Under natural conditions the flow of the ground water didn't stop at Buena Vista Lake because there is a still lower level—the ocean. The flowing water collected at Buena Vista Lake continued underground down the San Joaquin Valley past Tulare Lake and the San Joaquin River to San Francisco Bay, where the surface water and the ground water discharged into the sea. From there it eventually evaporated into the atmosphere, was transported as clouds, and precipitated as rain or snow to begin the cycle all over. This is a constantly occurring and never-ending sequence called the hydrologic cycle (fig. 7).

This underground flow is present throughout part of the San Joaquin Valley, but in the example area of Buena Vista Lake the water levels have been lowered by pumping so that now there is no underground flow from here to the ocean.

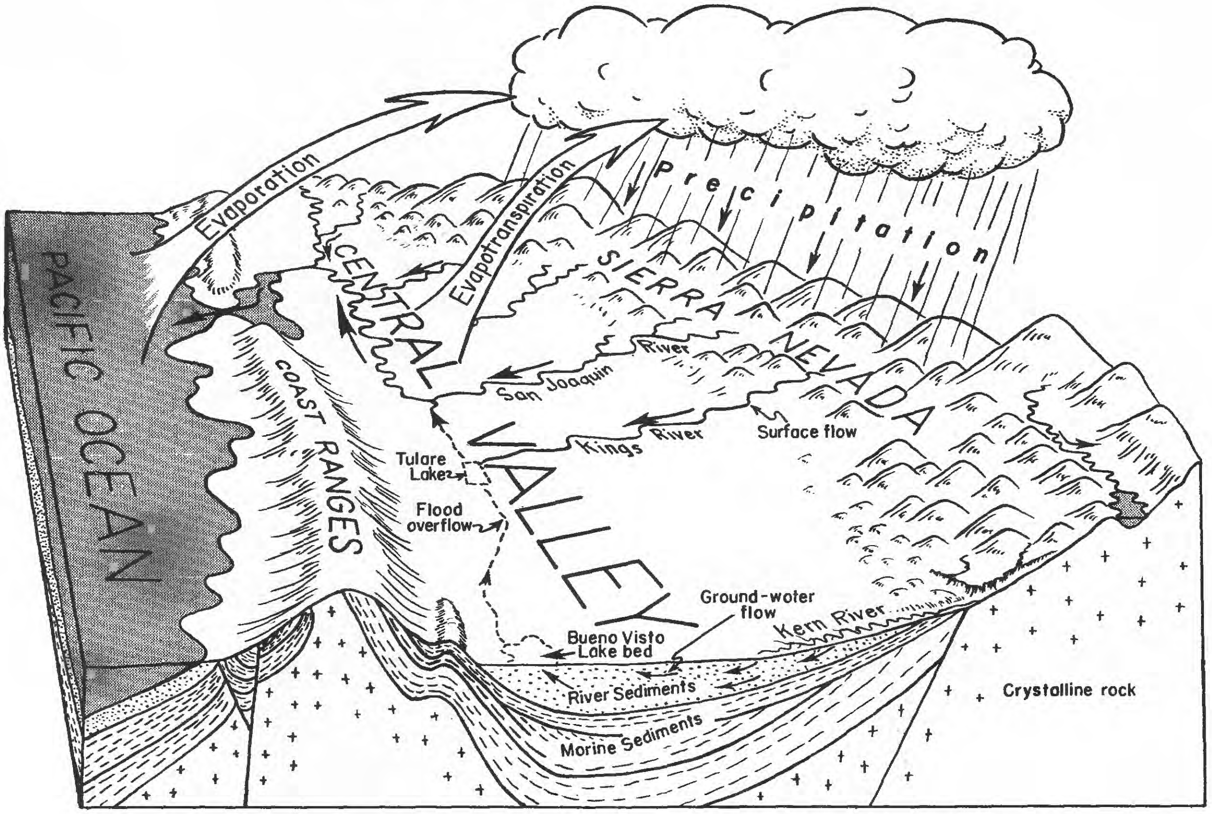


Figure 7.—The hydrologic cycle.

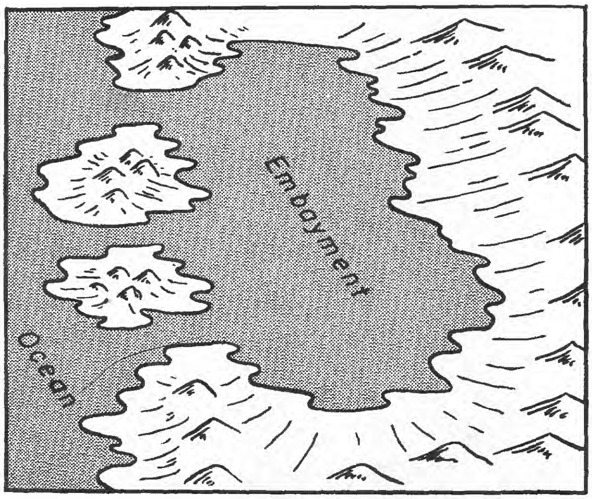


Figure 8.—Generalized shape of the embayment of the ancient Central Valley of California.

THE SAND AND GRAVEL FRAMEWORK OF THE LAKE

Let's take a closer look at the underground lake. What is it and how did it get there?

The San Joaquin Valley is a great structural trough (fig. 8) or downwarp in the earth's crust, having a bedrock floor of hard granitic and metamorphic or altered rocks. When it assumed its general shape, about 60 million years ago, the bottom of the trough was below the level of the sea, creating a huge embayment connected to the ocean. The rivers from the mountains to the east and west brought down great amounts of clay, silt, sand, and gravel and deposited them in this salt-water bay. These sediments were eventually consolidated into shale, sandstone, and conglomerate that retained some salt water and trapped large reserves of petroleum. The low rounded hills, Sharktooth, Pyramid, and Round Mountain, which border the valley, are surface outcrops of these consolidated rocks.

The debris from the rivers (fig. 9) continued to fill the valley, and as more sediments were added the embayment became shallower and the sea withdrew.

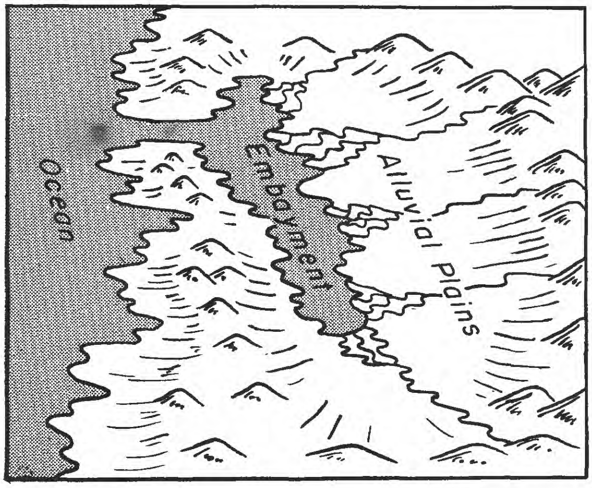


Figure 9.—Debris from surrounding mountains progressively filled up the embayment, forcing out the sea.

Deposition of sediments from the rivers, however, did not stop when the sea was crowded out. As long as rain and snowmelt drained from the mountains, debris was carried along and deposited in the valley, and this deposition of debris is occurring even today.

The latest of these accumulations are the beds of clay, silt, sand, and gravel that are penetrated today by wells drilled in the exploration for water. They are like the earlier underlying sediments but are not yet consolidated into rock. It is these latest deposits, fed by the fresh-water streams from the mountains, that make up the "lake" from which usable ground water is obtained.

THE RIVER FANS

The Kern and other rivers, by serving as transporters of sediment, have done most of the filling and building in the valley. During times of heavy runoff from melting snow, for example, the rivers carry much debris. As the water careens down the steep, narrow gorge, the power to carry this load becomes very great. Any casual traveler to the gorge of the Kern River has noticed the huge boulders which were moved there by the power of the river (figs. 2 and 3). Shooting out of this steep canyon and onto the wide flat expanse of the San Joaquin Valley, the river, no long confined in its narrow chute, spreads out and loses much of its velocity. As the velocity is reduced the load is dropped—right at the mouth of the gorge. Sand and gravel clog the river, forcing it to cut new channels just as in a delta. Each new channel spreads the finer grained debris farther into the valley to form a fan-shaped deposit (fig. 10) of clay, silt, sand, and gravel—a process that has been going on for many million years. Today the Kern fan reaches from the Kern Gorge to the Elk Hills near Tupman.

About a million years ago—the beginning of the Pleistocene epoch or great ice age—the Sierra Nevada was uplifted. This uplift tilted the alluvial fans slightly and increased the gradient or steepness of the rivers. This steepening caused the rivers to flow more swiftly and gave them greater erosive power. With its new power the Kern River, for example, began to cut into the old alluvial fan and produced the steep bluffs along Panorama Drive northeast of Bakersfield (fig. 11). A little farther downstream the river again

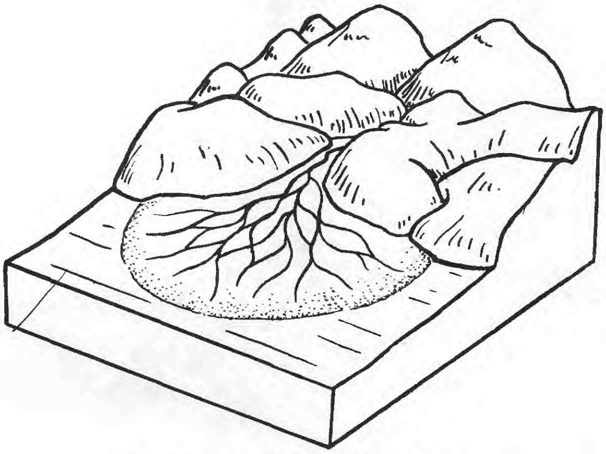


Figure 10.—An idealized alluvial fan.

Figure 11.—Bluffs along Panorama Drive. At right, is the old fan surface. Uplift in mountains renewed the power of the river enabling it to cut into the old fan.

broke away from the bluffs of the old alluvial fan and swept out into the valley, where a new alluvial fan was formed on the surface of the old one.

The other rivers of the valley also have been building alluvial fans, and they have overlapped, so that the whole valley floor today is made up of these merged, or coalescing, alluvial fans.

Searching above and below the land surface, the Geological Survey seeks information about the ground water and materials through which it moves. Where is the ground water? How far below the surface is it? How much is there? How much can be removed? How and where does it move? How much can be replaced? Is it of good quality? These are some of the many questions asked. Geologic, hydrologic, and chemical studies provide these answers.

INVESTIGATING GROUND WATER IN THE ALLUVIAL FANS

Geologic maps, which show the materials exposed on the surface, indicate the areas in which the pore spaces of sedimentary rocks are large enough to store water. In effect, these maps delineate the upper surface of the ground-water reservoir fans whose thickness can be determined from study of well logs.

To find out how much water the alluvial fans hold it is necessary to estimate how much pore space there is in relation to the total volume of the ground-water reservoir. Remember our sand-filled bucket? The water poured into the bucket infiltrated into millions of tiny air spaces or pores between the sand grains. The ground water in the alluvial fan does the same thing, only on a much larger scale. There are billions and billions of pores in the fan, each capable of storing water.

The pore space can be estimated on the basis of laboratory examination of sand-grain samples from many different locations and from many different depths. These samples are collected from bore holes drilled specifically for exploration, or they may be acquired more economically during the drilling of a water-supply or oil well. The size and shape of the grains are an indication of the pore spaces between them. Where the grains are large, the pore spaces are large. Where the grains are very small, as in clay, the pore spaces may be so small that the free flow of ground water is restricted.

Water contained in the pore space, however, is not all recoverable. If we were to punch a hole in the bottom of our sand-filled bucket, we would drain off a little less water than we poured into it. Why? Because very thin films of water, resisting the pull of gravity, will cling to the surface of the sand grains. When you wash your hands, some of the water clings to your skin in the same manner. They must be dried with a towel before all the water can be removed. Gravity is not enough to pull the film from either our hands or the sand grains. The amount of water to be yielded from an aquifer, then, is something less than the total water stored between the sand grains.

The yield characteristics of the alluvial-fan deposits may be studied in the laboratory using samples of the materials, or they may be studied in the field using a pumping-test procedure on wells (fig. 12). In this procedure one well is pumped for a period of time while water-level drawdowns are measured in other wells nearby. Information gained from such tests is useful in selecting new well sites, in planning multiple-site developments so as to avoid mutual interference between pumping wells, in planning optimum pumping schedules for existing well fields, and for locating and identifying hydrologic features that may contribute to or withdraw water from the system.

MAPPING THE WATER TABLE

If all the pore spaces in the alluvial fan were filled with water, we would have a vast swampy area, and in the past there were large swampy areas on the floor of the valley. For this reason the early Spanish explorers called the San Joaquin Valley the valley of the tules, or bull rushes.

Now, of course, there is no swamp. This is because the alluvial fans do not contain all the water they are capable of holding. This brings up the question how much water is in an alluvial fan at a given time? To find the answer the Geological Survey measures the water level in wells.

When water infiltrates into the ground from the rivers, it percolates downward through the empty pores until it reaches the zone

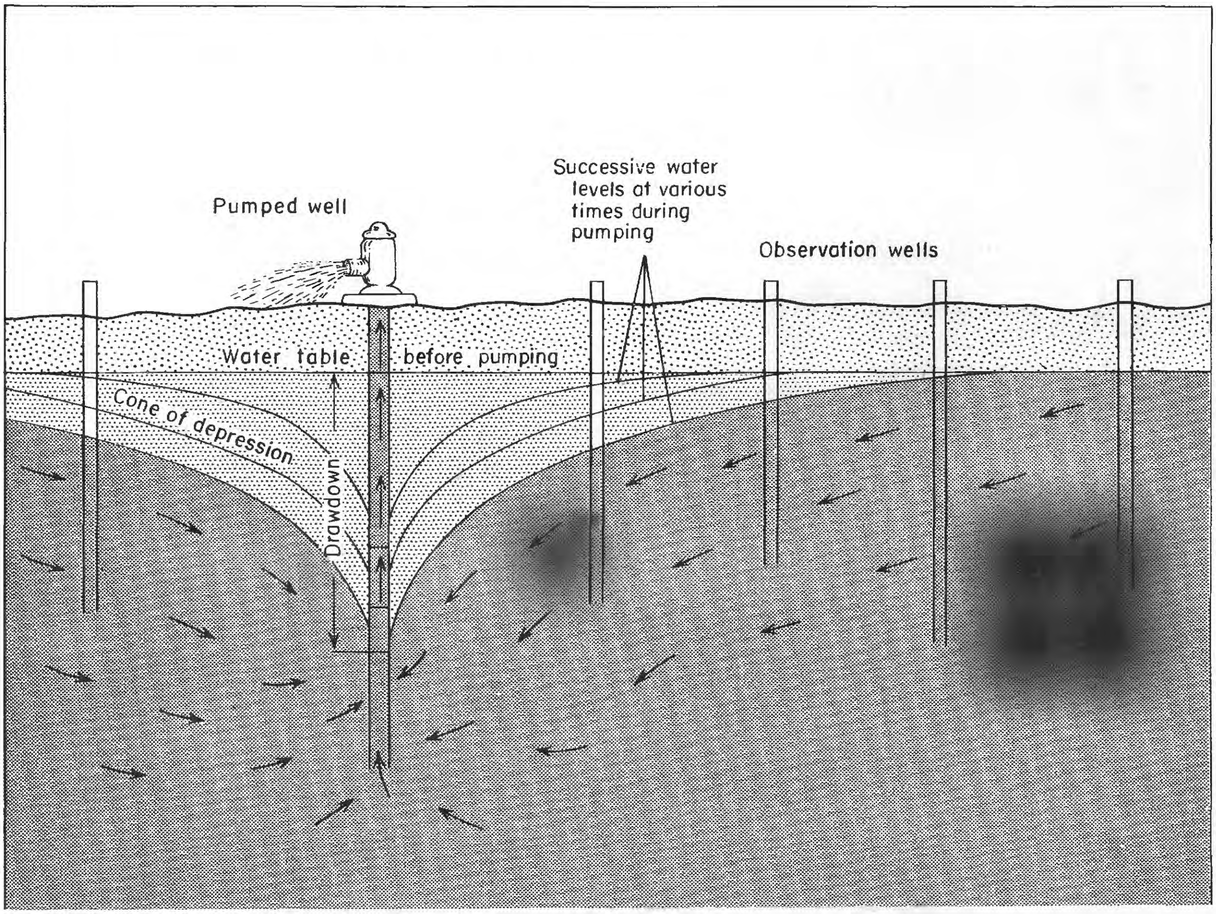


Figure 12.—The pumping test.

where the pores are already filled with water. As more water trickles downward the level of filled pores rises, just as adding water to any container will raise its water level. This upper level of saturation is called the water table, and its surface can be shown graphically by preparing a contour map that is based on water-level measurements in wells.

Of course, the water table is not static. Water put in the ground during rainy seasons raises the water table and pumping for human use lowers the water table. These changes are continuous, and the level in any well can change from day to day—even minute to minute!

Some farmers, like Elie Crettol (fig. 13) have made monthly measurements of the depth to water in their wells for many years, providing an invaluable long-term record of water-level fluctuations. The U.S. Geological Survey, California Department of Water Resources, and other government and private agencies make similar measurements and also install and maintain water-level recorders, similar to the one shown in figure 14, to provide a continuous record of fluctuations in key wells. The information from water-level measurements is used to make the water-level maps that show changes in ground-water storage, depth to water, and the direction of movement.

UNDERSTANDING THE HYDROLOGIC SYSTEM

In most areas of the San Joaquin Valley, ground water does not occur as simply as it does in the sand-filled bucket. Generally there are two or more water-bearing zones or aquifers, commonly sand and gravel, separated by beds of clay that restrict the movement of water from one aquifer to another. Water-level measurements and well data collected from individual well owners permit the study of the relation of one aquifer to another.

Figure 13.—Measuring the water level in an irrigation well. Elie Crettol, Wasco farmer, has made monthly measurements of this well for the past 30 years.

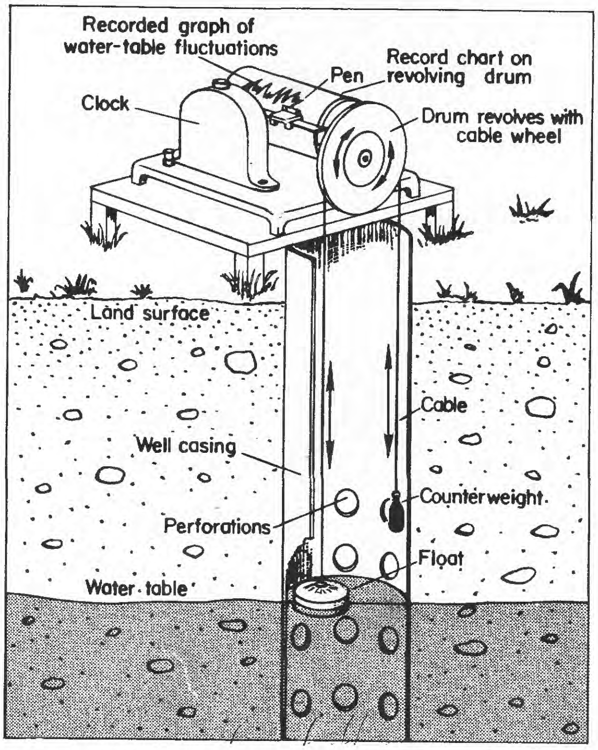


Figure 14.—Operation of a water-level recorder.

Figure 15 depicts a ground-water situation common in the San Joaquin Valley. Static water levels in all three wells shown are different because the wells tap different aquifers. For the same reason water-level fluctuations in these wells will differ also. Well 3 is of particular interest because its type of construction introduces the problem of "falling water," which may greatly reduce the efficiency of the pump. In addition, it permits the lower zone of good-quality water to be contaminated by poor-quality water from the shallow zone. Because large withdrawals have lowered water levels in many deep aquifers, the situation depicted in figure 15 is not uncommon in the San Joaquin Valley.

QUALITY OF WATER

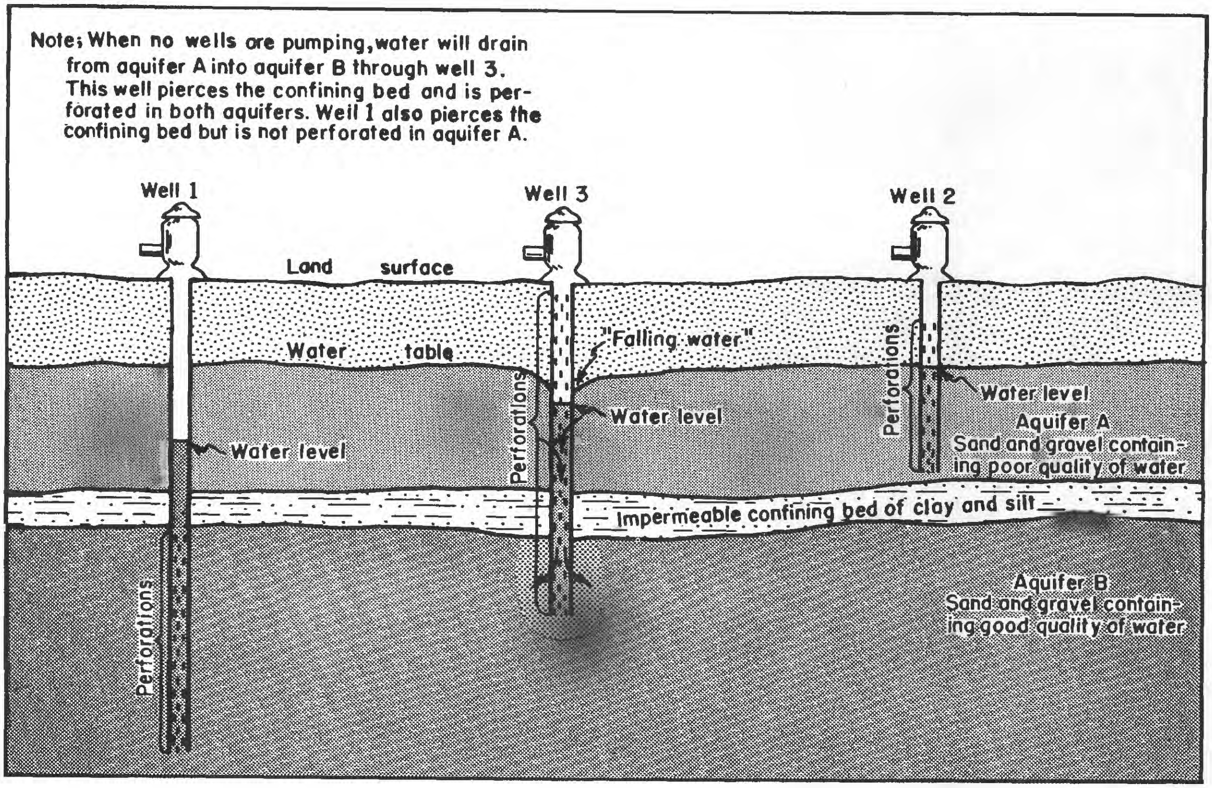
"Water, water, everywhere, and not a drop to drink," is an appropriate saying for the thirsty man who is adrift upon the open sea. It is also appropriate for a final consideration of our ground-water reservoir, because, unless the water is of suitable quality for our intended use, it is not worth developing. Some forms of contamination are harmless, others merely inconvenient or unpleasant, but in those areas in which only waters of marginal quality exist, development can be costly (fig. 16).

The U.S. Geological Survey collects samples of water for analysis from many pumping wells in the project area. Interpretation of these analyses permits the Survey to delineate the areas in which the water is of poor chemical quality and to identify the nature and source of the contamination.

CONCLUSION

This is the story of the San Joaquin "lake" and the U.S. Geological Survey's—and your own—interest in it. This tremendous reservoir of water is the life blood of the valley, but like the blood in our body, it must be replenished. When something happens to our blood supply, we need a transfusion. The San Joaquin Valley needs a transfusion now, and through pumping tests, water-level measurements, geologic, hydrologic, and chemical-quality studies, the necessary data on which to base intelligent water-management decisions will be accumulated.

Reports on these findings have been prepared for several areas in the San Joaquin Valley (fig. 17). Those now available pertain to the Edison-Maricopa, Avenal-McKittrick, and Mendota-Huron areas. More general reports covering the whole valley are available also. Studies in progress in 1961 include the Terra Bella-Lost Hills, Kern Fan, Kings Fan, and Kaweah-Tule areas. It is the joint plan of the U.S. Geological Survey and the



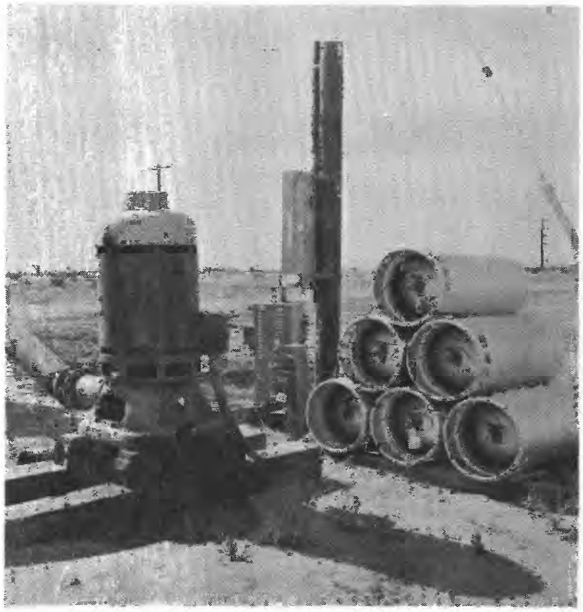


Figure 16.—Carbon dioxide tanks at a well near Oildale. The gas is injected into the well to prevent calcium deposits from choking off the flow of water.

State of California to initiate studies in additional areas of the valley.

Investigations of this type are invaluable for long-range, Statewide planning, but to the farmer, rancher, and ordinary citizen, they have even more tangible worth. Among the findings of benefit to you are accurate up-to-date information on the rate of water-table decline in your area, present position and average yearly rise and fall of the water table, chemical quality of the waters in various localities and at various depths, expected yield of wells, and information on correct depths for best yield in various areas.

More information may be obtained by writing for the book "Publications of the Geological Survey," address: Superintendent of Documents, Government Printing Office, Washington, D. C. 20402. This book lists all publications on water investigations by the Geological Survey. Most of the California investigation reports are available at local public libraries.

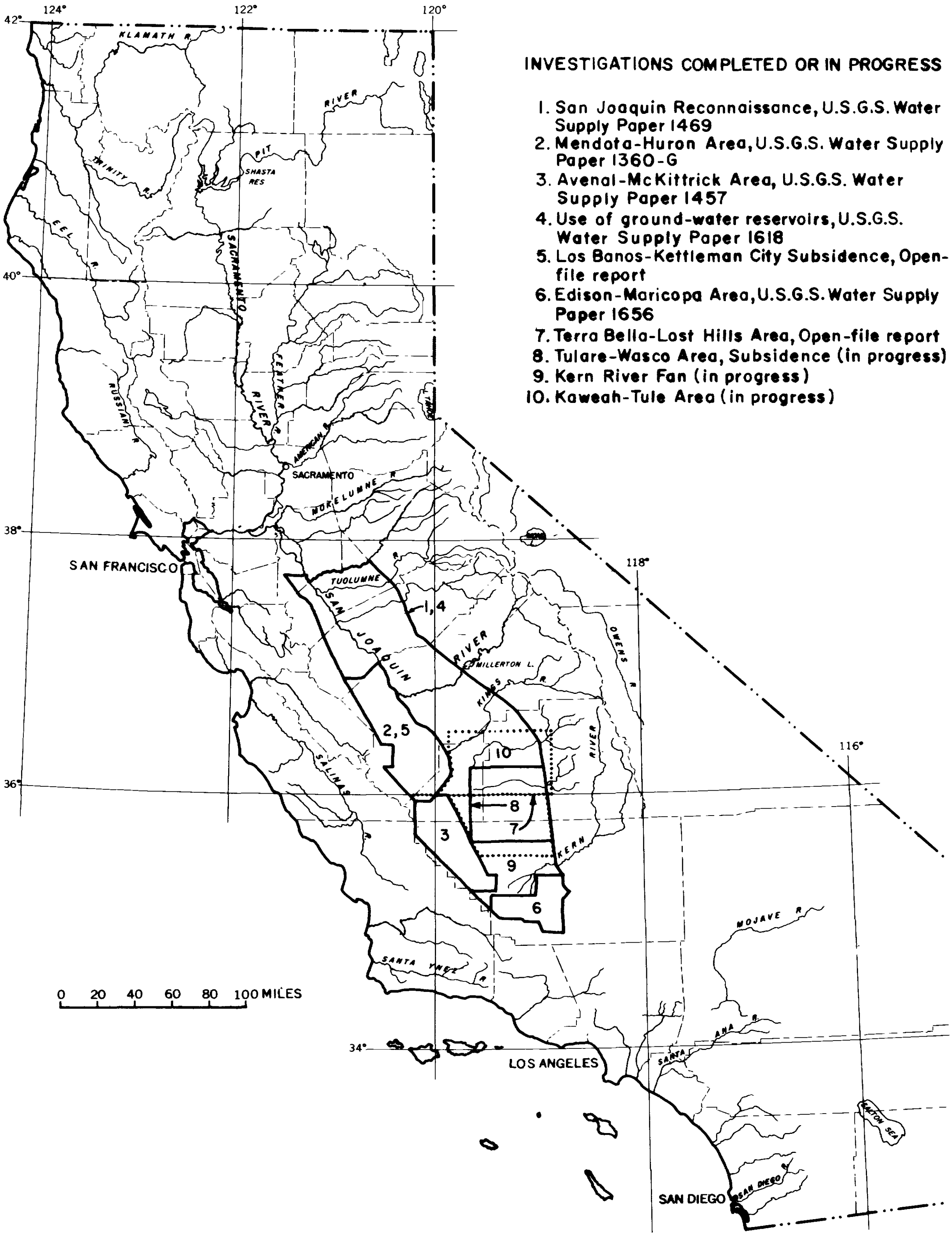


Figure 17.—Ground-water work by the U.S. Geological Survey in San Joaquin Valley.

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