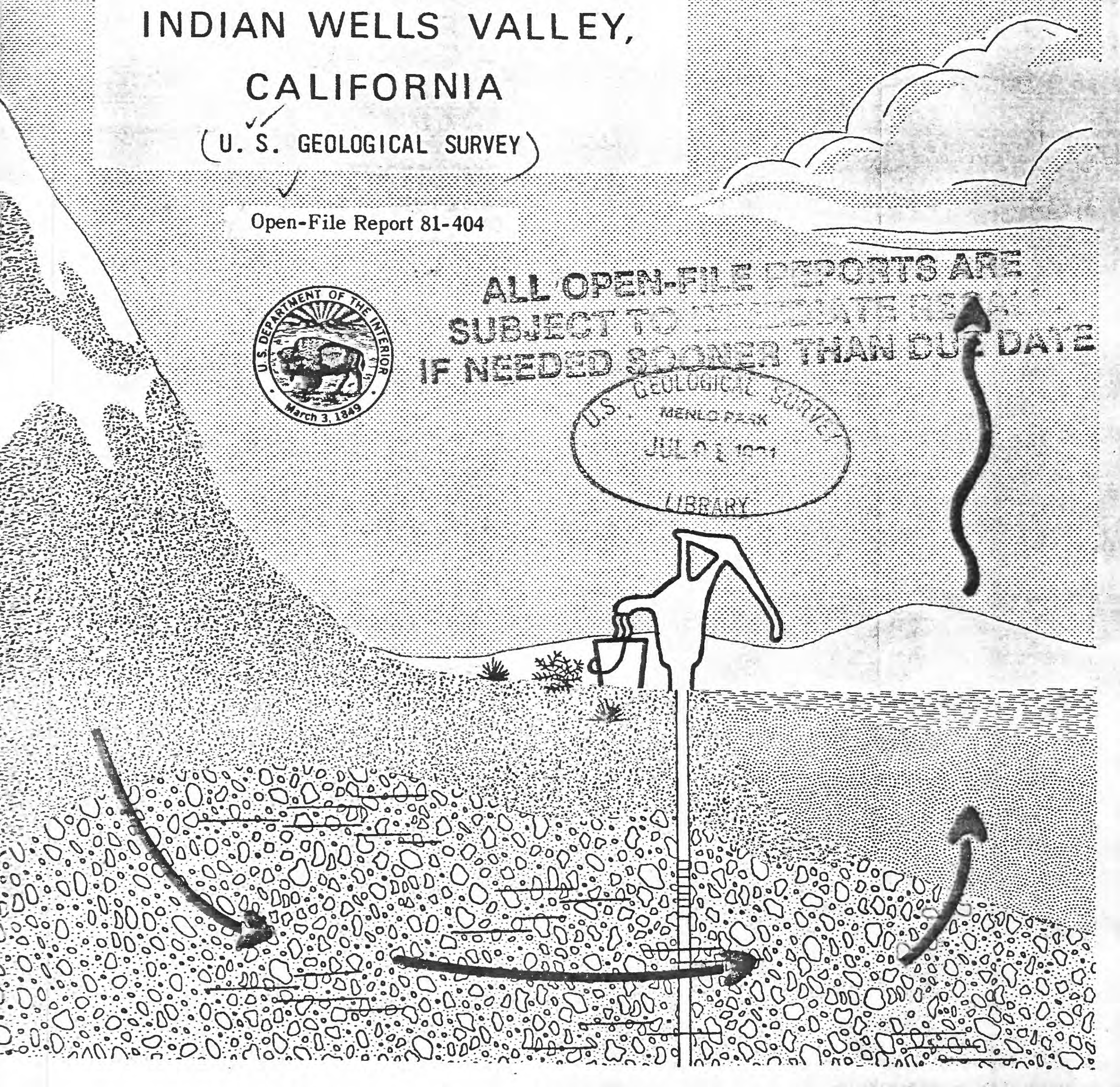
Prepared in cooperation with the U.S. DEPARTMENT OF THE NAVY and the INDIAN WELLS VALLEY WATER DISTRICT

A 10-YEAR PLAN TO STUDY THE AQUIFER SYSTEM OF INDIAN WELLS VALLEY, CALIFORNIA

(U. S. GEOLOGICAL SURVEY)

Open-File Report 81-404



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CONVERSION FACTORS

The inch-pound system of units is used in this report. For readers who prefer metric (SI) units, the conversion factors for the terms used are listed below:

Multiply	By	To obtain
acre-feet	0.001233	cubic hectometers
cubic yards	0.7646	cubic meters
feet	0.3048	meters
inches	25.4	millimeters
miles	1.609	kilometers
square miles	2.590	square kilometers

A 10-YEAR PLAN TO STUDY THE AQUIFER SYSTEM OF INDIAN WELLS VALLEY, CALIFORNIA

By Paul Lipinski and Darwin D. Knochenmus

ABSTRACT

Water needs of the population of Indian Wells Valley must be met through further development of ground-water resources. Studies show that annual ground-water pumpage there has increased since 1945 and has exceeded mean annual recharge since 1966. Continued and increased stress on the aquifer system of the valley is expected because population in the valley is predicted to double by 1998 and triple by 2020, based on 1977 population figures. The U.S. Geological Survey proposes a 10-year program to develop a data base to aid in evaluation of future water-management alternatives. A study plan has been developed that describes present and potential problems and objectives of the program, and outlines work items to be undertaken in the study area.

INTRODUCTION

Indian Wells Valley is a structural and topographic depression east of the Sierra Nevada escarpment, which in this area reaches altitudes of 6,000 to 8,000 feet. The valley floor, most of which is between 2,175 and 2,400 feet in altitude, occupies an area of about 300 square miles. Indian Wells Valley is bounded by the Sierra Nevada on the west, the Argus Range on the east, the El Paso Mountains on the south, and low volcanic hills and the Coso Range on the north (fig. 1). Topography of the valley floor is subdued, with broad alluvial fans extending from the Sierra Nevada and coalescing into alluvial plains several miles wide that slope with gradually decreasing steepness toward China Lake, a large playa at the east-central margin of the basin. An area of about 900 square miles drains into Indian Wells Valley where drainage is entirely internal. As there is no perennial surface flow on the valley floor, current water needs of the valley's populace are met through development of ground-water resources.

Two ground-water bodies occur in Indian Wells Valley: a shallow aquifer that is locally perched on lenses of clay of low permeability near and around China Lake, and a deep aquifer that underlies most of the valley. The deep aquifer is unconfined over most of its extent but was considered by Kunkel and Chase (1969) to be confined beneath the shallow aquifer in the eastern part of the ground-water basin. The generalized flow scheme (fig. 2) shows that the main source of ground-water recharge to the valley is from the Sierra Nevada. This recharge is conveyed eastward to China Lake, where evapotranspiration constitutes the only natural discharge from the aquifer system. Typical of areas where much evapotranspiration is taking place, water quality in the China Lake area is generally poor due to the increased concentration of dissolved solids. Water quality throughout the remainder of the basin is comparatively good (fig. 3).

Subsurface flow in Indian Wells Valley is controlled by several ground-water barriers of varying effectiveness that have been formed by episodic faulting of the basin's sedimentary fill. The most effective of these is the China Lake barrier (Bloyd and Robson, 1971), a zone of very low transmissivity that restricts flow between the pumping centers near Ridgecrest and the China Lake area where water is of poor quality (fig. 2). Restricted flow normally takes place across the barrier toward the north and east from recharge areas of higher head south and west of the barrier toward evapotranspiration areas of lower head on the north and east side of the barrier. Water-level relations to depth of wells in the China Lake vicinity indicate that water moves from the deep aquifer up through the partly confining lenses of clay into the shallow aquifer.

Pumpage in Indian Wells Valley has increased gradually since 1945, and U.S. Geological Survey studies indicate that since 1966 pumpage has exceeded mean long-term annual recharge, resulting in a condition of overdraft in the ground-water basin (Dutcher and Moyle, 1973). Development of ground water in the valley is concentrated in the Ridgecrest and Inyokern areas. Major users include the Indian Wells Valley Water District, the Naval Weapons Center, Kerr-McGee Chemical Corp., and numerous farms.

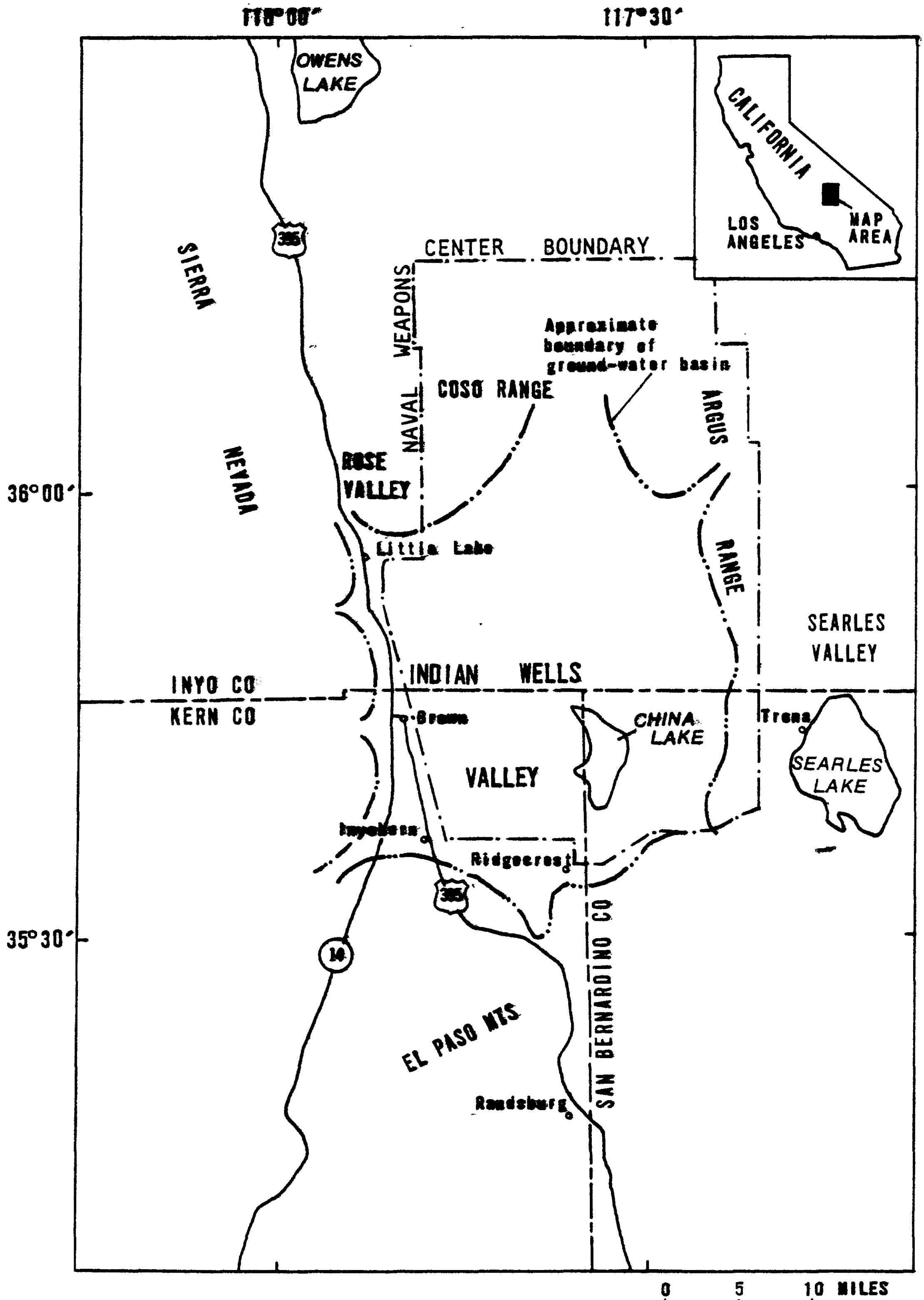


FIGURE 1.--Location of Indian Wells Valley ground-water basin.

The economy of Indian Wells Valley (population about 23,000) is based on the presence of the Naval Weapons Center. Ridgecrest, the valley's largest city (population about 16,000), has grown as a community providing housing and services for Navy employees and their families. Kerr-McGee Chemical Corp. is another major economic factor, employing about 1,200 people in the area who also utilize the community's various support services. Projected growth figures for the area served by the Indian Wells Valley Water District indicate that, relative to 1977 figures, population will double by 1998 and triple by 2020. Such growth cannot be achieved without commensurate increases in water supply.

The future economy of Indian Wells Valley and adjacent Searles Valley will depend on the availability of fresh water, and efficient ground-water management programs will require a more complete understanding of the Indian Wells Valley aquifer system. Even considering the possibility of future water importation, efficient conjunctive use of water from within the basin will be necessary.

Problems

The concentration of pumping in small areas in the Indian Wells Valley ground-water basin combined with projected need for more water for the area may cause several hydrologic problems. The ground-water problem of most immediate concern is the possible reversal of flow across the China Lake barrier near Ridgecrest. Northeastward flow is maintained by virtue of head differences across the barrier; that is, water is forced across the barrier in the direction of China Lake and the water of poor quality. Lowering the water table in the Ridgecrest area could result in a reduction of the natural pressure head and a reversal of flow. In the event of such a reversal, water of poor quality would move toward water of good quality and could contaminate the aquifer. A water-level change map of Indian Wells Valley (Lipinski, 1980) shows that water levels declined as much as 32 feet near Ridgecrest in the 15-year period, 1963-78. According to a general plan for water supply and distribution (Krieger and Stewart, 1977, p. III-5), the water table could decline as much as 100 feet by the year 2020 in areas of concentrated pumping. On the basis of analyses, using a mathematical ground-water model for the valley, Mallory (1979, p. 22) predicted that the direction of flow may be locally reversed as early as 1984 and that a pronounced southwestward gradient would be established by 2020.

The community sewage ponds northeast of the China Lake barrier could further contribute to a reversal of the hydraulic gradient by applying back pressure to the flow system through recharge to the shallow aquifer. Although the ponds are primarily evaporation sites lined with bentonite to minimize percolation, a recharge mound does exist in the area (Lipinski, 1980). Located in the area where the shallow aquifer occurs, the ponds are somewhat isolated from the deep aquifer, but the degree of hydraulic interconnection between the deep and shallow zones, and thus the capacity for transmittal of pressure and of effluent, is not well understood.

Reversal of the ground-water gradient near Ridgecrest would be the most serious problem created by continued lowering of water levels, but would not be the only adverse consequence. Flow patterns indicate that the movement of water of poor quality from the southeastern part of the basin toward the Ridgecrest well fields would be accelerated by increased pumping at these fields. Water quality in this southeastern part of the valley is poor because of the geologic framework through which the water flows. Slow flow velocities in this area allow the water much contact time in which to dissolve various minerals from the aquifer. This is also the site of the former Ridgecrest Sanitation District sewage ponds, a now defunct facility for evaporation and reclamation of sewage from which some effluent was used to irrigate alfalfa in the area. Some of this effluent may have percolated to the water table and may now be moving slowly toward the pumping centers.

Warner (1975) suggested that the lower part of the deep aquifer contains water of poorer quality than the upper part and that lowered water levels would mean that production wells would be drawing an increasing proportion of their water from the lower part. This situation has been recognized in other desert basins, but on the basis of E-log interpretation, Krieger and Stewart (1977, p. III-19) stated that "existing data are not really sufficient to substantiate a clear-cut vertical distribution of the magnitude proposed by Warner." This insufficiency of data could be overcome by a data-gathering program aimed at determining relations among hydrologic parameters, including the relation between water quality and depth within the aquifer system.

Ground-water problems and potential problems in Indian Wells Valley are related directly or indirectly to possible overdraft of specific areas within the basin. Public attitude regarding the overdraft is mixed. Most water producers in the valley agree with U.S. Geological Survey findings that the basin is in a state of continuing depletion, but this acceptance is by no means unanimous. Some producers dispute ground-water recharge values estimated by the Survey, and some contend that actual recharge is more than 110 percent greater than that estimated (Carl Austin, written commun., 1978). This situation points out the need for additional studies to determine more accurately the inflow to the ground-water basin so that the general public, with whom the ultimate responsibility for management lies, can be made aware of the state of their water resources. Indeed, public awareness and cooperation are absolute requirements for development and implementation of workable water-resources programs.

Purpose and Scope

The purpose of this report is to provide a study plan to develop a data base of sufficient breadth to help evaluate future water-management alternatives. The two-dimensional mathematical ground-water-flow model currently in use for Indian Wells Valley has been verified and has proved to be a useful predictive tool. In the 10 years since it was developed, however, it has become apparent that the complex three-dimensional aspects of the deep and shallow aquifers need to be more fully understood for development of efficient ground-water resource programs.

The objectives of the study are to determine more accurately the quantities of ground-water recharge to Indian Wells Valley and to gain an understanding of flow patterns in three dimensions and of water-quality trends within the basin. The scope of the plan includes work in the four general subject areas listed below:

1. Design and implementation of a comprehensive ground-water-level and quality monitoring network.
2. Construction of observation wells where they are needed.
3. Studies of ground-water recharge from Rose Valley, the Freeman Gulch area, and the Coso and Argus Ranges.
4. Study of effects on ground-water flow and quality from community sewage ponds.

Although the data base will take 10 years to complete, useful information will be gained almost immediately from implementation of the program through retrieval of water-quality and water-level information.

Previous Work

Hydrologic work in Indian Wells Valley was begun by Lee (1913), who estimated the perennial yield, and continued by Thompson (1929), who included the area in a general investigation of the Mojave Desert region. During the period 1952-55, Kunkel and Chase (1969) studied the geology and hydrology of Indian Wells Valley and estimated recharge, discharge, and perennial yield. Moyle (1963) prepared a reconnaissance geologic map and assisted Zbur (1963) in a seismic refraction investigation of the area. Geologic and hydrologic features of the valley were discussed by Dutcher and Moyle (1973). Bloyd and Robson (1971) used previous estimates of recharge, discharge, and perennial yield to develop a mathematical ground-water-flow model, which was used later by Mallory (1979) to make predictions regarding ground-water flow in Indian Wells Valley. Warner (1975) reported on water-quality trends and distribution within the basin.

The U.S. Geological Survey has made ground-water studies in cooperation with the Naval Weapons Center in Indian Wells Valley since 1952. In the current program, the U.S. Geological Survey cooperates with the Naval Weapons Center and the Indian Wells Valley Water District to monitor water levels annually in 115 wells and water quality in 37 wells. Water quality is monitored twice a year through analyses for the following constituents and properties:

- Boron (dissolved)
- Calcium (dissolved)
- Chloride (dissolved)
- Fluoride (dissolved)
- Iron (dissolved)
- Magnesium (dissolved)
- Nitrite plus nitrate (dissolved)
- Potassium (dissolved)
- Silica (dissolved)
- Sodium (dissolved)
- Sulfate (dissolved)
- Alkalinity
- Arsenic (total)
- Bicarbonate
- Carbonate
- Dissolved carbon dioxide
- Dissolved solids
- Non-carbonate hardness
- Percent sodium
- pH
- Sodium adsorption ratio
- Temperature
- Total hardness

The wells in the present network are not evenly distributed in space nor are all strategically located to represent the hydrologic conditions in all areas of specific features such as ground-water barriers (faults) and pumping depressions. For example, the 37 wells in the water-quality network are predominantly in T. 26 S., and R. 40 E. (fig. 3), and do not sufficiently monitor the effects of pumping and the effectiveness of ground-water barriers.

PLAN OF STUDY

Work Item 1: Design and Implementation of a Monitoring Network

The best approach to gathering comprehensive ground-water information is through the use of a basinwide well-monitoring network. An ideal network would consist of wells evenly spaced throughout the basin for determining water levels, hydraulic gradients, flow directions, and water quality. A network of closely spaced wells would yield more representative data than a network of widely spaced wells, but in practicality such a network in Indian Wells Valley could involve a virtually unlimited number of wells, many of which would duplicate data from neighboring wells. Spacing for this basin is proposed for a 2-mile separation of data points, so that one well would represent an area of 4 square miles (fig. 4). This arrangement might in some cases cause duplication of information and in others it could miss pertinent data, but adjustments in spacing through addition or deletion of wells would take place as the network evolves. Drilling of new wells in areas of low well density where information is lacking will be necessary and is discussed separately as Work Item 2.

A canvass of existing wells to determine their suitability as observation wells would be undertaken as a basis for designing the network. Criteria for selecting wells to be incorporated into the network would include: (1) Proper areal distribution to provide lateral continuity of data, (2) well depths and perforated intervals that will give data representative of the upper zone of the shallow aquifer and the upper zone of the deep aquifer in their respective areas, (3) availability of previous records and logs, (4) future availability of observation site, (5) accessibility of site, (6) ease of sampling and measurement, (7) permission to sample and measure, and (8) possibility of recorder installation.

Selection of areas for beginning a canvass of existing wells is somewhat flexible but should include the study areas listed under Work Item 3. These areas are shown in figure 4.

The following is a summary of the sequence of steps in designing and implementing a monitoring network:

1. Define purpose of network, such as to determine recharge or flow near ground-water barriers.
2. Modified canvass of wells.
3. Select wells.
4. Collect water-level and water-quality data.
5. Design network, and drill new wells where needed.
6. Implement network.

Variations in concentrations of the constituents analyzed under the ongoing program provide a good index to water quality in certain parts of the basin. Although present sampling takes place semiannually, under the comprehensive program networkwide sampling need not occur so often. Instead, index wells shown to be representative of water quality in given hydrologic sectors of the network would be sampled annually, with the remainder of the wells sampled every 3 years at first, then every 5 years after implementation of the network. State health requirements are such that wells producing water for public use must undergo yearly water-quality analyses. Some of the wells chosen for the network will be of this type and information from these annual samplings will become part of the record.

Measurement of water levels within the basin would also follow an index-well approach, that is, annual measurements would be made in index wells for information on the water level in that particular hydrologic sector. Every 5 years all the wells in the network would be measured. Where more frequent measurements are needed to determine seasonal and manmade water-table fluctuations, water-level recorders will be installed on some wells for retrieval of continuous water-level information.

Work Item 2: Construction of Observation Wells

Where ground-water information is lacking, new observation wells will have to be drilled. Two types of observation wells are proposed: (1) single-well installations, and (2) multiple-well installations. Single-well installations will be used to gain water-level and water-quality information where areal gaps in the network occur, and multiple-well installations will be used to relate water level and water quality to depth within the aquifer.

Single-Well Installations

The purpose of single observation wells will be to monitor water quality and water levels which are representative of the upper part of the deep aquifer. The wells should penetrate about 100 feet of the saturated thickness of the aquifer to insure contact with the water table in the event of moderate water-level decline. The lowermost 10 feet of each well would be perforated or screened to provide hydraulic continuity between aquifer and well bore. Inasmuch as depths to the water table average 100 to 200 feet, most of the wells will probably be less than 300 feet in total depth. The wells will be cased with steel, plastic (PVC), or fiberglass and have a minimum diameter of 6 inches to allow for possible installation of water-level recorders. PVC casing will be necessary at some sites where the water is so corrosive that steel casing would have a short lifespan. PVC casing is suitable for all proposed observation wells because it is generally cheaper and less reactive with ground-water chemicals, but the choice of PVC versus steel casing should be stated as a contract option. Approximately 10 percent of the wells would be gravel packed and used for aquifer testing, while those not gravel packed would be developed by pumping to ensure that water-level and water-quality data are representative of the aquifer. Aquifer testing at gravel-packed installations should be done following the development of the well while the pump apparatus is still in place.

The highest drilling priority for observation wells would be in those areas where recharge studies may need additional data-collection installations as discussed under Work Item 3.

Multiple-Well Installations

The purpose of multiple-well installations is to allow observation of differences in water quality and water levels with respect to depth within the aquifer system. The installations will consist of two or three wells of varying depths at a single location. There are different ways to construct such installations. One way would be to drill separate holes close to each other. Another method would be nesting the wells in a single large-diameter hole and sealing the annular space between the screened intervals of each well (piezometer). The contractor should be given the option of bidding on separate hole or multipiezometer approaches to construction of the installations. Functional specifications of the wells would be the same as described for single observation installations in terms of diameter, casing, and perforated intervals. Gravel packing would not be necessary for multilevel installations.

Three of the six proposed multilevel observation wells would be located in the area where the deep aquifer is partly confined beneath the shallow aquifer and where the China Lake barrier intercepts ground-water flow. Figure 4 shows how the installations would be arranged along east-west and north-south rays intersecting in the area of China Lake. This deployment would minimize the number of installations necessary to provide three-dimensional information in the areas of interest. At the multidepth installations indicated, the number of wells at each site (2 or 3 wells) will depend on hydrologic conditions at that location.

Security or safety precautions involving design of the finished well installation (well vaults, for example) may be necessary at some locations, but determination of the need for these measures would result from an informal risk assessment for each installation.

The depths, diameters, and purpose of the proposed wells suggest that an air-rotary drilling method would be preferred for installation, although a mud-rotary or cable-tool method is acceptable. The bid package will be assembled by the Indian Wells Valley Water District and the Naval Weapons Center, using functional specifications provided by the U.S. Geological Survey.

Recent bids accepted by the U.S. Geological Survey in southern California for drilling projects similar to the one proposed here indicate that the cost for each observation installation would be $10,000. A breakdown of bids received in 1979 and 1980 follows:

Specification	Cost	Cost for an average 300-foot hole
Drilling	$16.00 per foot	$4,800
6" blank casing	10.00 per foot	2,900
6" perforated casing (lowermost 10 feet)	12.00 per foot	120
Gravel pack (optional)	50.00 per cubic yard	250
Development	1,200.00 per well	1,200
Set up	1,000.00 per site	1,000
		$10,270

Obtaining permission to drill observation wells should pose no serious problems because many of the installations would be on land owned by parties cooperating in the study. Wells drilled on the Naval Weapons Center will require an Environmental Impact Statement (EIS) for Navy files. Some installations will be on land controlled by the Bureau of Land Management who will require a similar statement in addition to application for right-of-way. Bureau of Land Management cooperation is expected in light of their Master Desert Plan, of which hydrologic knowledge will be an integral part. A 4 to 6 month lead time is required for filing an application, and for Bureau of Land Management to write and approve the EIS.

Work Item 3: Studies of Ground-Water Recharge

Studies of ground-water inflow to Indian Wells Valley will be made in three areas: Rose Valley, Freeman Gulch area, and the Coso and Argus Ranges (fig. 4). These areas deserve special attention regarding their capabilities for providing water for recharge because currently little is known about their contribution to the total recharge to Indian Wells Valley. Past quantitative estimates of recharge have been questioned as discussed in the Problems section of the report.

Rose Valley

Subsurface flow and limited surface flow from Rose Valley provide recharge to Indian Wells Valley at Little Lake. The U.S. Geological Survey estimates that this flow contributes about 45 acre-feet per year (Bloyd and Robson, 1971), although this figure has been challenged as being far too small (Carl F. Austin, written commun., 1978). A study to quantify this recharge would consist of five phases:

1. Canvass existing wells and obtain drillers' logs.
2. If suitable wells do not exist along the axis of the valley south of Little Lake, drill two or three wells to determine ground-water gradients. At least one well should be drilled to bedrock.
3. Carry out a gravity survey of the valley to determine configuration of the bedrock surface.
4. Test the aquifer to determine hydraulic characteristics of the sedimentary fill.
5. Estimate the volume of ground-water recharge from Rose Valley by using Darcy's Law and data obtained from phases 2 through 4.

Data from wells in southern Rose Valley and northwestern Indian Wells Valley would indicate the ground-water gradients in the vicinity of Little Lake. The canvass could be undertaken as a high priority phase of the design of the monitoring network as described under Work Item 1. If too few wells are located along the axis of the narrow valley south of Little Lake, a priority phase of Work Item 2, new observation wells should be drilled for determination of ground-water gradients. At least one hole should be drilled to bedrock to provide a control for gravity measurements of the valley. An aquifer test in the area, or information available from any previous pumping test, would yield transmissivity values that can be used together with hydraulic gradient and cross-sectional area figures to determine recharge values through use of Darcy's law:

$$Q = T/b \times A \times dh/L$$

where:
- Q = volume of flow,
- T/b = hydraulic conductivity,
- T = transmissivity,
- b = saturated thickness of aquifer,
- A = cross-sectional area,
- dh/L = hydraulic gradient,
- dh = difference in water-level elevation between two points parallel to flow direction, and
- L = distance between the two points.

Freeman Gulch Area

A quantitative study of recharge from the Freeman Gulch area should be undertaken because that area contributes more than 20 percent of the estimated recharge to Indian Wells Valley (Bloyd and Robson, 1971, p. 15). A study in this area would be similar to the one outlined for Rose Valley, beginning with a thorough canvass of wells to determine ground-water gradients. Alluvial cover in the area is so shallow that gravity surveying could be eliminated and the cross-sectional area of the inlet approximated through analysis of drillers' logs and topographic maps. Aquifer-test data would then be used in conjunction with gradient and profile data to evaluate the volume of underflow into Indian Wells Valley. Additional observation wells are not expected to be drilled specifically for this study, but in the event of sparse data points, at least one well may have to be installed as a priority phase of Work Item 2.

Coso and Argus Ranges

A study to quantify recharge from the Coso and Argus Ranges is suggested because (1) recharge from these areas is estimated to be 30 percent of the total recharge and (2) a widespread area exists in this part of the valley where little is actually known about ground-water movement. Again, the recharge study would be similar to the one proposed for Rose Valley. It would involve application of flow equations to data collected from a network of observation wells combined with measurements or estimates of thickness and transmissivity of the aquifer to provide the volume of underflow. Because few wells exist in the northeastern part of the valley, four to six new wells may have to be drilled, depending on the success of the well canvass of the area.

Work Item 4: Study of Effects on Ground-Water Flow and Quality from Community Sewage Ponds

The sewage ponds in T. 26 N., R. 40 E., sec. 14, were constructed by the Navy for Navy use. Their capacity has since been expanded to include sewage disposal for the city of Ridgecrest. Currently the ponds are downgradient from the well fields at Ridgecrest, but with the potential for a reversal in gradient, the present and potential effect of the ponds on the ground-water gradient and water quality should be analyzed.

In the study to determine the hydrologic impact of the ponds, attention should be paid to (1) the mechanisms of flow between the deep and shallow aquifers and (2) flow across the China Lake barrier separating the areas of pumping from the area of waste disposal. The nature of flow will be determined through analyses of water-quality and water-level data collected from multidepth observation wells in the area. Where shallow observation wells exist singly, deeper wells augered or drilled to tap the deep aquifer would provide information on possible downward migration of sewage effluent percolating from the ponds or infiltrating from irrigation of the golf course. Head effects on the deeper aquifer created by recharge to the shallow aquifer would also be indicated by monitoring of multidepth piezometers in the area.

Flow across the China Lake barrier would be studied through the use of multidepth installations described in Work Item 2. Four of these installations bracketing the barrier would give information relating head to depth within the deep aquifer which could be interpreted to indicate the nature of flow across the barrier.

SUMMARY AND OUTLINE OF PROGRAM

The proposed 10-year program is intended to gather detailed hydrologic data that can be used to infer three-dimensional flow patterns in Indian Wells Valley. Data will be collected through a basinwide well-monitoring network that will be designed and implemented by means of a thorough canvass of existing wells and by drilling additional wells where none are present or suitable. Wells used for the network should have an average spacing on 2-mile centers, with wells farther apart where additional data would be redundant, and closer together where flow conditions are changing.

New wells should consist of PVC-, fiberglass-, or steel-cased holes of minimum 6-inch diameter with the lowermost 10 feet screened or perforated. Two types of observation sites are planned, single-well installations and multiple-well (piezometer) installations. Single-well installations are planned to monitor water quality and water levels in the upper 100 feet of the deep aquifer, and multiple-well installations are planned to monitor the quality and water levels at various depths within the deep aquifer, in the confined area, and near the China Lake barrier. Information gathered at multiple-well observation sites will be used to determine the hydrologic effects of the community sewage ponds.

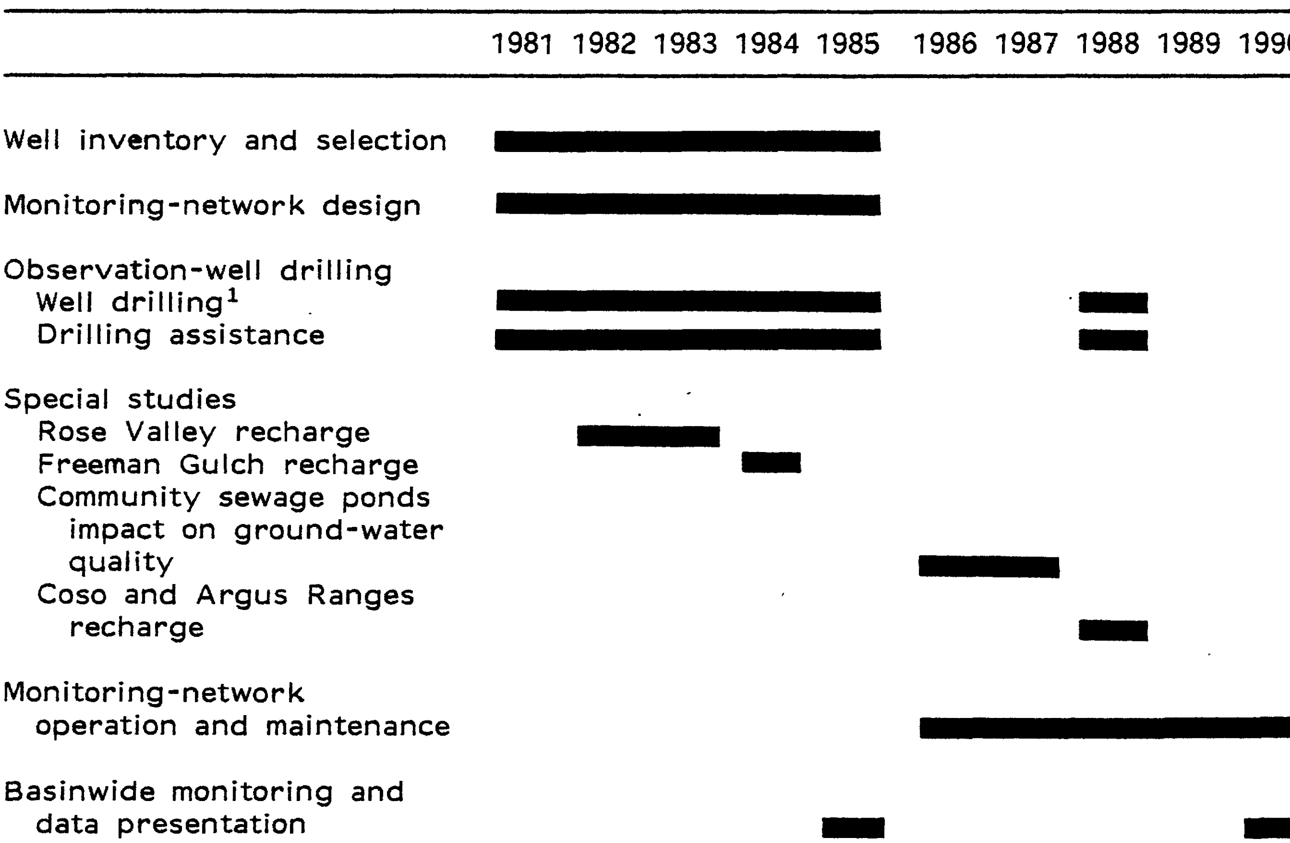
Recharge to Indian Wells Valley from Rose Valley, the Freeman Gulch area, and the Coso and Argus Ranges will be studied. Hydraulic gradients determined through measurements of the well-monitoring network will be used, together with measured or estimated values of transmissivity and cross-sectional data, as a basis for estimating flow.

The program is scheduled to be completed in 10 years. Canvassing of wells for development of the network will begin in 1980 and proceed at the rate of about two townships per year. Well canvassing is also the first stage of the special studies portion of the program; thus the special study areas, especially Rose Valley, the Freeman Gulch area, and the sewage pond-China Lake barrier area will be areas of high priority for well canvassing.

As canvassing progresses, locations where new wells are needed will be determined. It is not known now how many observation wells will have to be installed, but between 20 and 30 single observation site network wells will probably have to be drilled, with the actual number depending on the spacing required. In order to spread out the workload, it is proposed to drill five network wells per year for 4-5 years beginning in 1981. If more than the minimal number of wells (20) are required, the few additional wells would be drilled sometime after 1986.

The special studies listed as Work Items 3 and 4 would be undertaken on a part-time basis and take about a year each to complete, although work could progress simultaneously on separate phases of the different study projects, so that the four projects would not necessarily take 4 years to complete. The results of the studies will be presented in the form of open-file reports written individually for each investigation and one water-resources investigation report describing design of the monitoring network including the well data. In addition to these reports, annual statements will be presented describing the progress of the program and the data resulting from the network monitoring.

The work schedule follows:



[1]Drilling costs not to be included as part of the cooperative program.

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