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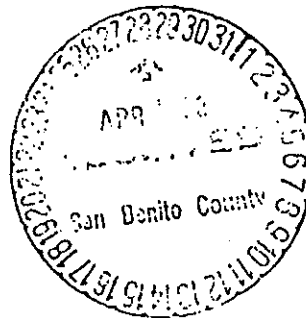


*San Benito County  
Ground-Water Investigation*



**LUHDORFF & SCALMANINI**  
Consulting Engineers

Eugene E. Luhdorff, Jr., P.E.  
Joseph C. Scalmanini, P.E.



April 24, 1992  
File No. 90-1-084

Mr. Rob Mendiola, Director of Planning  
County of San Benito  
3220 Southside Road  
Hollister, CA 95023

**SUBJECT: EVALUATION OF GROUND-WATER CONDITIONS  
AROMAS AREA, SAN BENITO COUNTY**

Dear Mr. Mendiola:

As indicated at the completion of our report **San Benito County Ground-Water Investigation**, we have prepared a letter report on an evaluation of ground-water conditions in the Aromas area of San Benito County. That letter report, addressed to Supervisor Graves as Chairman of the Water Committee and to Supervisor Kesler as the Water Committee member most interested in the Aromas area, is intended to supplement our final report to the County; and a copy is enclosed for your use and reference.

We trust that the enclosed summary of ground-water conditions in the Aromas area completes the County ground-water investigation. If you wish to discuss any of the enclosed, please advise.

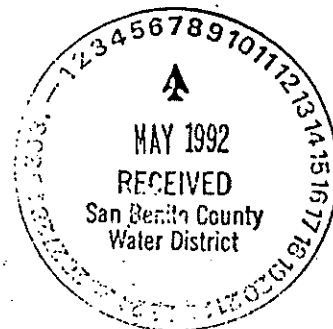
Sincerely,

**LUHDORFF AND SCALMANINI  
CONSULTING ENGINEERS**

Joseph C. Scalmanini

JCS:js

Enclosure





**LUHDORFF & SCALMANINI**  
Consulting Engineers

Eugene E. Luhdorff, Jr., P.E.  
Joseph C. Scalmanini, P.E.

April 24, 1992  
File 90-1-084

The Honorable Curtis Graves, Water Committee Chairman  
The Honorable Ruth Kesler  
San Benito County Board of Supervisors  
498 Fifth Street, Second Floor  
Hollister, CA 95023

**SUBJECT: EVALUATION OF GROUND-WATER CONDITIONS  
AROMAS AREA, SAN BENITO COUNTY**

Dear Supervisors Graves and Kesler:

As a supplement to our report *San Benito County Ground-Water Investigation*, this letter presents our completed analysis of the Aromas area. As discussed at several of the County Water Committee meetings and in our report, the Aromas area was included in a ground-water model of the Pajaro Valley Water Management Agency developed by James M. Montgomery Engineers (JMM) for the U.S. Bureau of Reclamation; and throughout the County ground-water study, we had intended to address the yield of the aquifer system in the Aromas area via use of the JMM model. However, due to constraints with the model as expanded below, our analysis ultimately consisted of reviewing the limited available ground-water level data in the area, reviewing model input and output in the Aromas area, and interpreting all the information and data into conclusions and recommendations regarding current basin yield and future ground-water use and development in the area.

**Review of Data**

Data on ground-water levels, ground-water quality, pumpage, etc. are extremely limited in the Aromas area. Ground-water level data for four wells northwest of Aromas, in Monterey County, were obtained from Monterey County. There are no available ground-water level data for the San Benito County portion of the study area. Hydrographs of the four wells are plotted on Figure 1. It is important to note that no data apparently exist past 1988, and three of the hydrographs are limited to available data through 1983. The general lack of monitoring data prevents any ability to assess the effects of the current drought and the effects of any changes in ground-water use associated with changes in land use or the drought.

In general, the data presented on Figure 1 suggest that the ground-water storage in the area has declined during drought periods (notably the 1976-77 drought) and recovered during wet periods (1978-1983). It is apparent that no overall long-term decline in ground-water storage has occurred during the period of record.

### Pajaro Valley Ground-Water Model

The ground-water model developed for the U.S. Bureau of Reclamation is a four-layer finite-element model containing 483 total elements, with 22 of the elements at least partially in western San Benito County as shown on Figure 2. Note that Figure 2 also depicts the location of the four wells for which we were able to obtain ground-water level data. The model has reportedly been calibrated for the period 1964 to 1988.

Input to the model in the Aromas area included agricultural pumpage, urban pumpage, and precipitation. The model assumed no subsurface inflow into or subsurface outflow out of the San Benito portion of the area from areas outside of the model. Figure 3 depicts the estimated pumpage (agricultural, urban and total) for the Aromas area of the model from 1964 to 1988. Urban pumpage was estimated to increase steadily during this period, and fluctuations in agricultural pumpage mirror the precipitation pattern.

The JMM model was run in order to obtain monthly ground-water level estimates in the Aromas area. Errors in model input or model code prevented running the model past December 1982. Discussions with the U.S. Bureau of Reclamation regarding this problem indicated that Bureau staff had not attempted to run the model, so this problem remains unresolved.

A comparison of model estimated ground-water level from node 422 and the actual ground-water level data from nearby well T12S/R3E-16C2 is presented in Figure 4. The match between actual data and model result is poor. The actual recovery of ground-water levels after 1978 is not apparent in the model results which suggests that model estimates of storage change in the area may not be accurate.

Another model result of considerable concern is illustrated in Figure 5, which depicts a cross-section of model estimated ground-water levels in 1978 and 1982. Note that the left side of the graph depicts the model estimate of ground-water level at node 428, which is near the town of Aromas, and the right side of the graph depicts the model estimate of ground-water level at node 474 which is located approximately 5 miles southeast of Aromas. The extremely steep gradient that is depicted on Figure 5 is difficult to conceptualize relative to typical ground-water conditions and suggests that the model is not well calibrated in this area.

The results for the Aromas area based on our run of the model are presented in Table 1. The estimated total pumping that was input to the model was assumed to be the only component of discharge; the model calculated water level changes were multiplied by the area and storativity to obtain an estimate of ground-water storage change in the area; recharge was assumed to be the difference between discharge and storage change.

Note that estimates of storage change and recharge for the period 1964 to 1982 are based on model output. In an attempt to estimate recharge and storage change for the period 1983 to 1988, Figure 6 depicts the 1964 to 1982 correlation between precipitation and storage change. Based on this analysis, Table 1 presents the estimated storage change and precipitation for the 1982 to 1988 period.

As a check on the validity of the method of analysis to estimate recharge to the area, the recharge estimate was divided by the total rainfall each year to estimate the percentage of rainfall that recharged ground water in the area. The result is consistent with generally accepted estimates that 10 percent of the rainfall will recharge aquifers, and that this percentage will increase in drought years and decrease in wet years.

The annual ground-water storage change data presented in Table 1 can be plotted in order to evaluate the cumulative ground-water storage change in the area (Figure 7). Note that the shape of this graph is similar to that of the hydrograph of node 422 discussed above (Figure 4). If the graph of cumulative ground-water storage change were evaluated without regard to its accuracy relative to actual data, it could be concluded that "safe-yield" pumping in the Aromas area is being exceeded and that ground-water storage is being depleted over the long term. This observation, however, is inconsistent with the admittedly limited ground-water level data which suggest that no long term decline in storage is occurring.

### Conclusions and Recommendations

The actual ground-water level data indicate that, in the Aromas area, ground-water storage declines in dry years in response to higher than average pumping and lower than average precipitation and recharge; and ground-water storage recovers in wet years in response to lower than average pumping and higher than average precipitation and recharge. Overall, the data suggest that there is no long term trend, downward or upward, in terms of ground-water levels. This suggests that, over the long term, recharge and discharge have been approximately equal.

The Pajaro Valley ground-water model prepared for the U.S. Bureau of Reclamation, part of which covers the Aromas area, suggests that an overdraft is occurring, and that "safe-yield" pumping is being exceeded. However, a comparison of model results to actual data indicates that the model is probably not a good representation of the Aromas area's ground-water conditions, and should not be relied upon for such conclusions, at least in that area.

Based on the unreliability of the model, and the trends depicted in the hydrographs of actual data, we can tentatively conclude that "safe-yield" pumping is not being exceeded in the area. If the agricultural and urban pumpage values in the JMM model are correct, "safe-yield" pumping would then be approximately 675 acre-feet per year.

Supervisors Graves and Kesler  
April 24, 1992  
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The general lack of actual ground-water level data in the area seriously limits the ability to evaluate ground-water conditions in the Aromas area, and is largely the reason for our "tentative" conclusion regarding safe yield in the area. A regular monitoring program (ground-water level measurement at least twice a year in at least eight wells in the area, complemented by data on annual agricultural and urban pumping) should be implemented if the County wishes to have an ability to update "safe-yield" estimates in the future. As more data become available either through such a monitoring program or through other possible sources of data, the conclusion about apparent safe yield can be re-evaluated.

As to the ability of the County to evaluate any proposals to change land use that would cause increased ground-water use in the Aromas area, we would expect that small or incremental increases (less than 10 percent of JMM reported average total pumpage, i.e. less than about 65 acre-feet) should not pose a problem, but detailed information as to the historical water use in the area and a detailed plan regarding water use of a proposed project should be outlined with particular attention paid to the hydrologic impacts of the proposal.

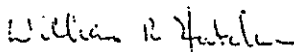
Large increases (greater than 10 percent of JMM reported average total pumpage) in pumping in the Aromas area should be avoided until or unless detailed water level information can be adequately evaluated and a more accurate basis can be developed to evaluate ground-water conditions and "safe yield" in the area.

Sincerely,

LUHDORFF AND SCALMANINI  
CONSULTING ENGINEERS



Joseph C. Scalmanini



William R. Hutchison

JCS/WRH:js

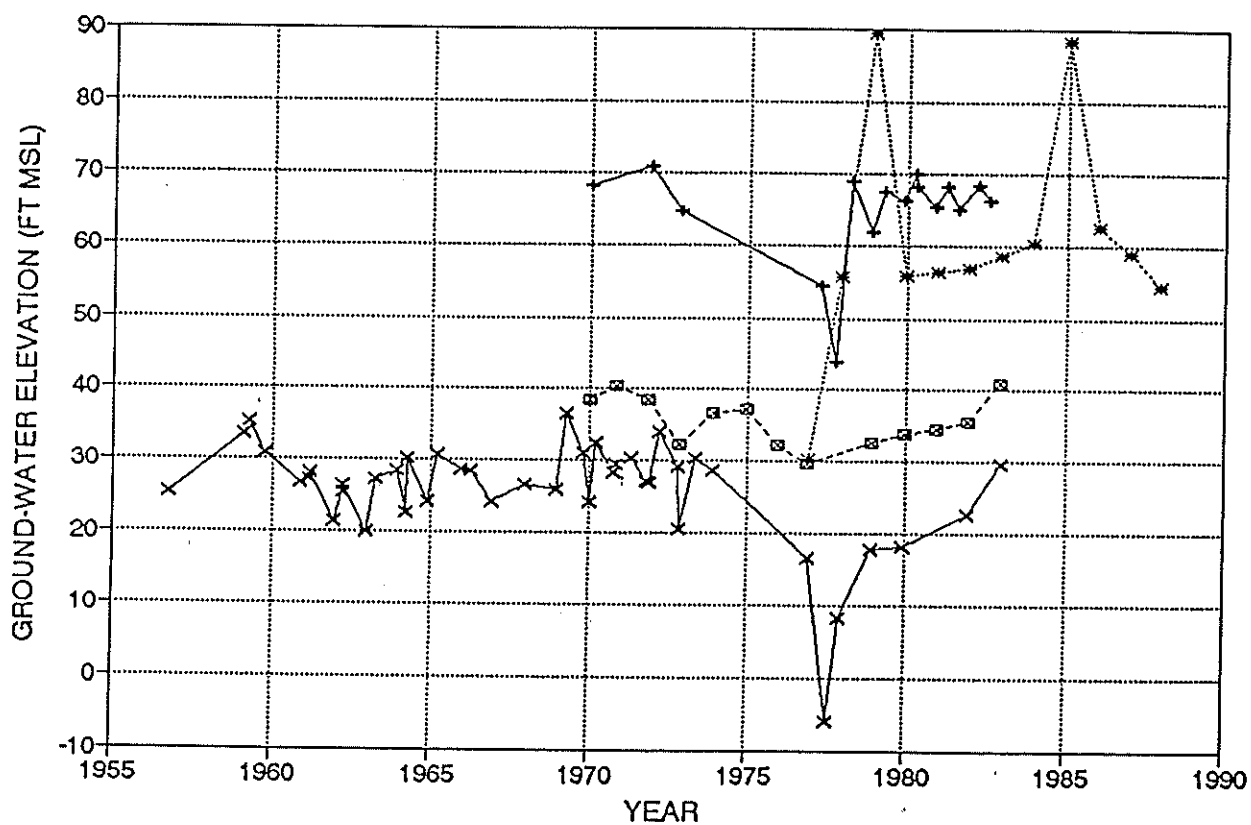
TABLE 1: AROMAS AREA WATER BUDGET  
BASED ON PAJARO VALLEY HYDROLOGIC MODEL

| Year    | Ag<br>Pumping<br>(AF) | Urban<br>Pumping<br>(AF) | Total<br>Discharge<br>(AF) | Total<br>Precip<br>(AF) | Storage<br>Change<br>(AF) | Total<br>Recharge<br>(AF) | Recharge<br>As % of<br>Precip |
|---------|-----------------------|--------------------------|----------------------------|-------------------------|---------------------------|---------------------------|-------------------------------|
| 1964    | 532                   | 88                       | 620                        | 4737                    | -33.5                     | 586                       | 12.4                          |
| 1965    | 446                   | 91                       | 537                        | 7835                    | 4.9                       | 542                       | 6.9                           |
| 1966    | 539                   | 96                       | 635                        | 4731                    | -24.8                     | 610                       | 12.9                          |
| 1967    | 409                   | 100                      | 509                        | 10858                   | 28.7                      | 538                       | 5.0                           |
| 1968    | 484                   | 106                      | 590                        | 5502                    | -23.0                     | 567                       | 10.3                          |
| 1969    | 482                   | 111                      | 593                        | 10837                   | 36.0                      | 629                       | 5.8                           |
| 1970    | 526                   | 116                      | 641                        | 8039                    | -4.7                      | 637                       | 7.9                           |
| 1971    | 514                   | 119                      | 634                        | 7010                    | -13.8                     | 620                       | 8.8                           |
| 1972    | 612                   | 136                      | 748                        | 3862                    | -32.6                     | 716                       | 18.5                          |
| 1973    | 575                   | 129                      | 703                        | 10365                   | 12.0                      | 715                       | 6.9                           |
| 1974    | 463                   | 126                      | 589                        | 10642                   | 16.6                      | 606                       | 5.7                           |
| 1975    | 527                   | 130                      | 657                        | 6802                    | -12.1                     | 645                       | 9.5                           |
| 1976    | 646                   | 147                      | 793                        | 4373                    | -53.9                     | 739                       | 16.9                          |
| 1977    | 628                   | 143                      | 772                        | 3627                    | -62.8                     | 709                       | 19.5                          |
| 1978    | 519                   | 146                      | 665                        | 10005                   | 13.3                      | 678                       | 6.8                           |
| 1979    | 552                   | 159                      | 711                        | 6244                    | -11.6                     | 700                       | 11.2                          |
| 1980    | 461                   | 152                      | 613                        | 9573                    | 10.5                      | 623                       | 6.5                           |
| 1981    | 547                   | 155                      | 702                        | 6001                    | -9.0                      | 693                       | 11.6                          |
| 1982    | 464                   | 150                      | 615                        | 12128                   | 23.2                      | 638                       | 5.3                           |
| 1983    | 479                   | 160                      | 638                        | 15026                   | 56.5 *                    | 695 *                     | 4.6 *                         |
| 1984    | 573                   | 167                      | 740                        | 6269                    | -14.2 *                   | 726 *                     | 11.6 *                        |
| 1985    | 553                   | 159                      | 713                        | 7305                    | -4.0 *                    | 709 *                     | 9.7 *                         |
| 1986    | 570                   | 162                      | 732                        | 9417                    | 11.9 *                    | 744 *                     | 7.9 *                         |
| 1987    | 644                   | 178                      | 822                        | 4676                    | -34.6 *                   | 787 *                     | 16.8 *                        |
| 1988    | 714                   | 170                      | 884                        | 3725                    | -50.4 *                   | 834 *                     | 22.4 *                        |
| Average | 538                   | 136                      | 674                        | 7584                    | -7.2 **                   | 642 **                    | 9.9 **                        |

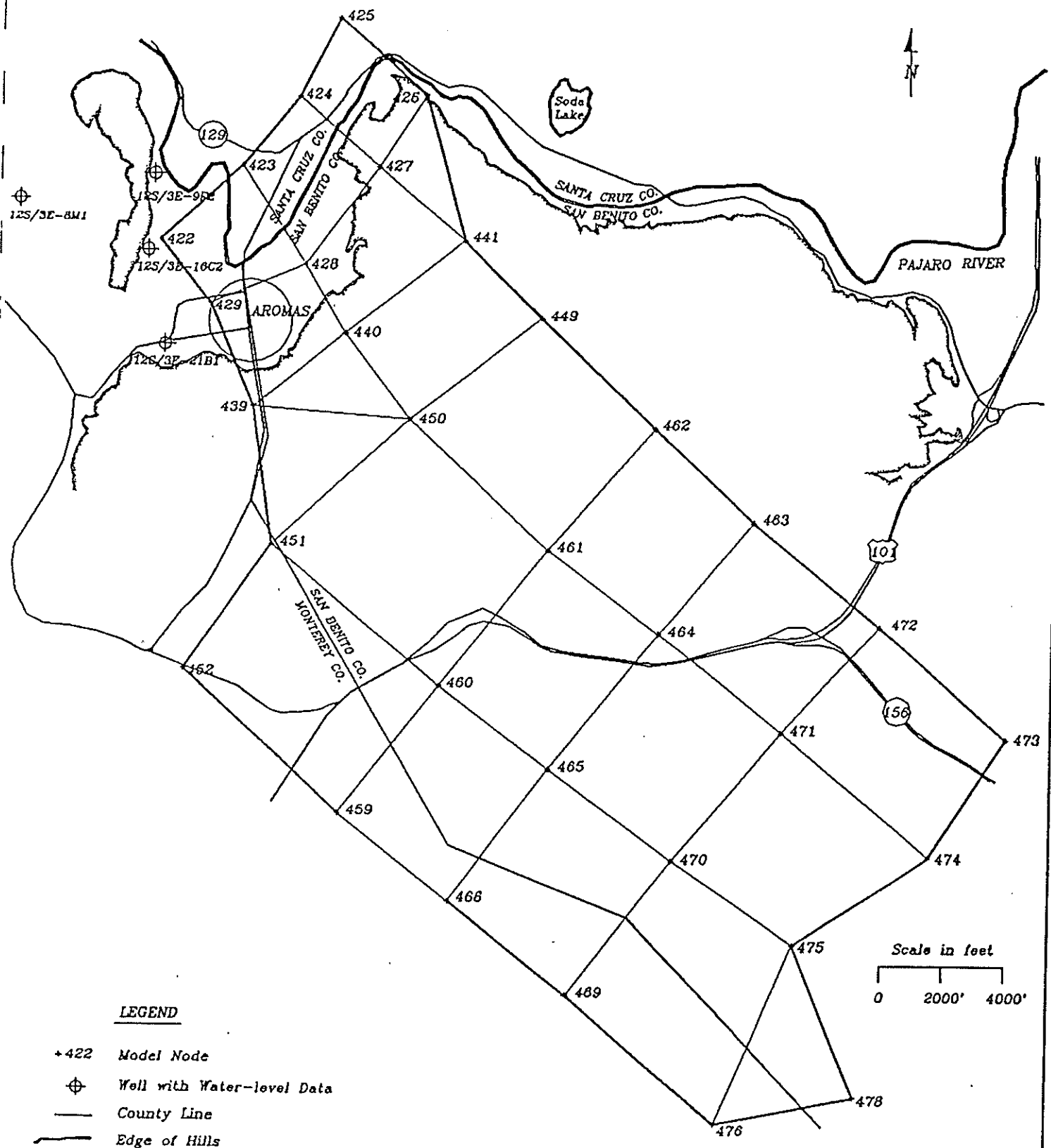
\* Projected

\*\* Average through 1982

FIGURE 1  
HYDROGRAPHS OF AROMAS AREA WELLS



+ 12S/3E-9F2    □ 12S/3E-16C2    x 12S/3E-8M1    \* 12S/3E-21B1



Map of Aromas Area Showing Model Nodes Used in Study

FIGURE

2

FIGURE 3: AROMAS AREA  
AGRICULTURAL AND URBAN PUMPING

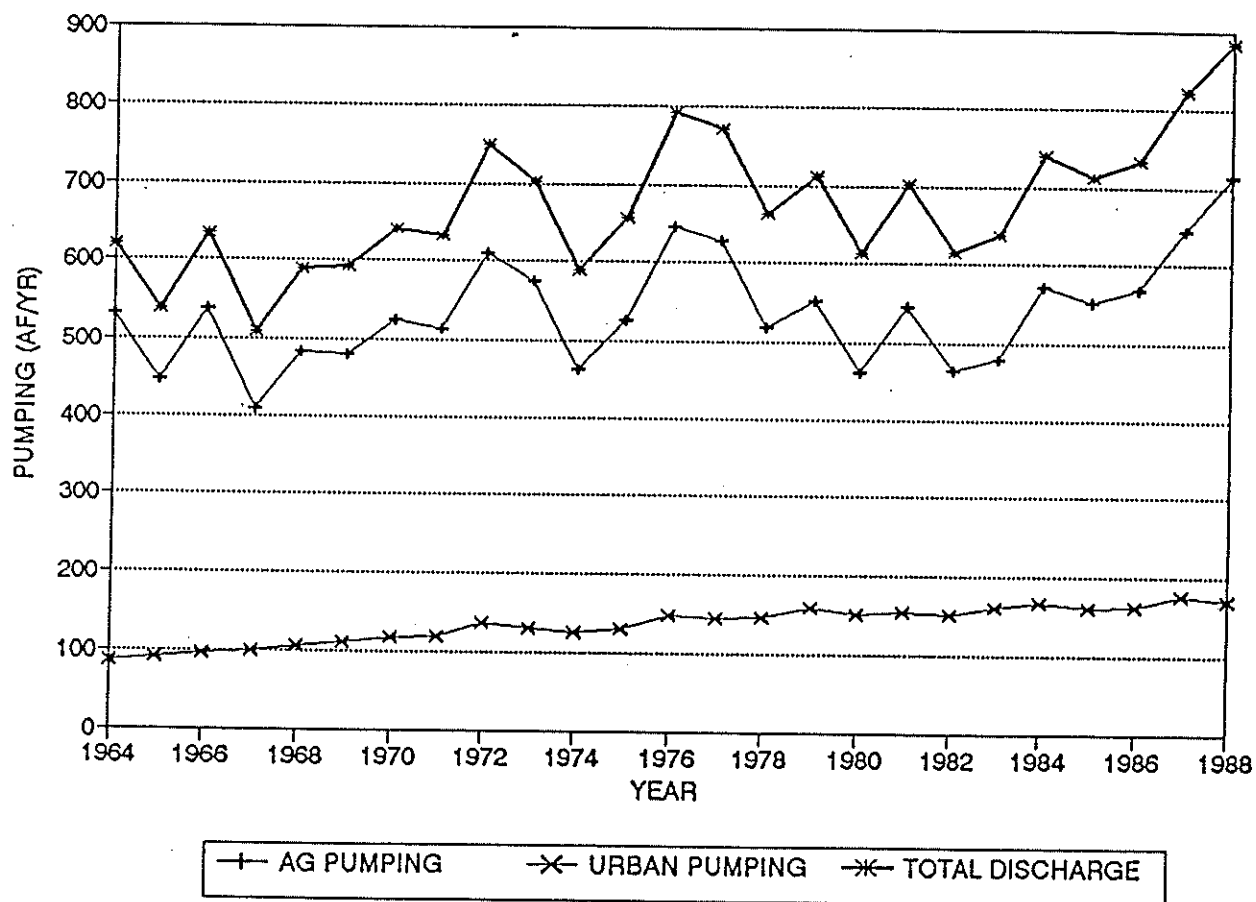


FIGURE 4: AROMAS AREA  
ACTUAL AND SIMULATED HYDROGRAPHS

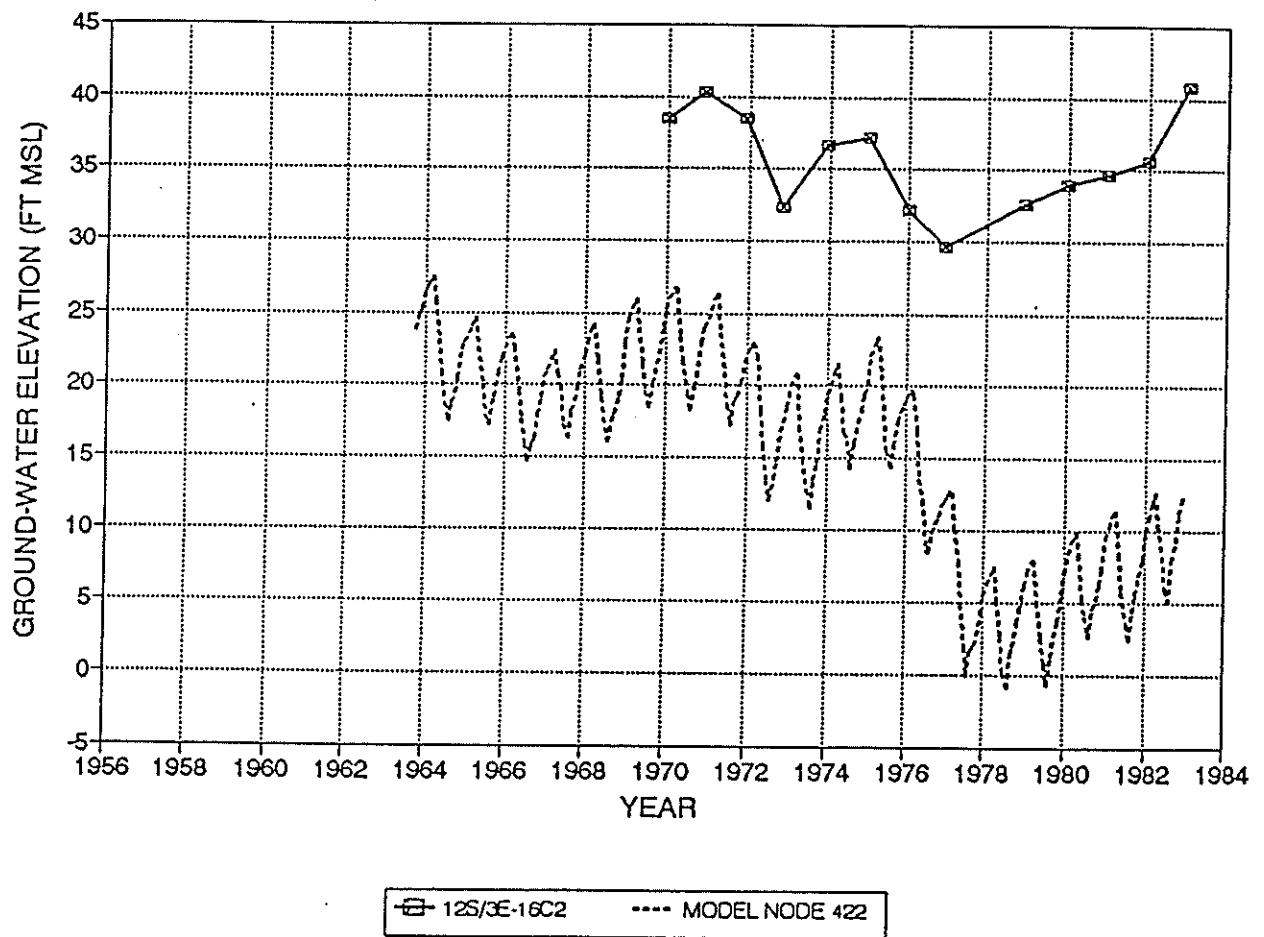


FIGURE 5  
SIMULATED WATER-LEVEL TRANSECT

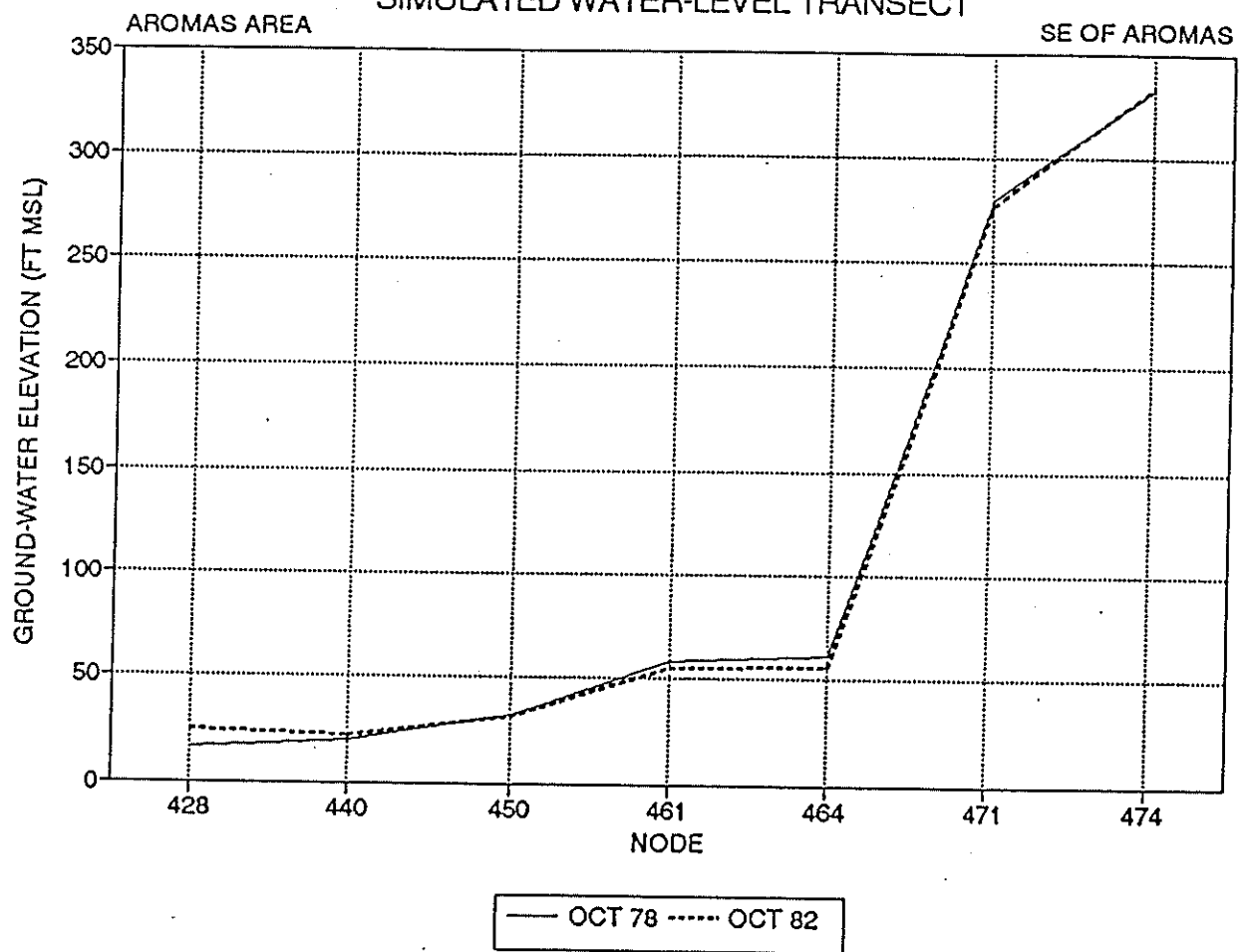


FIGURE 6: AROMAS AREA  
GROUND-WATER STORAGE CHANGE VS. PRECIPITATION

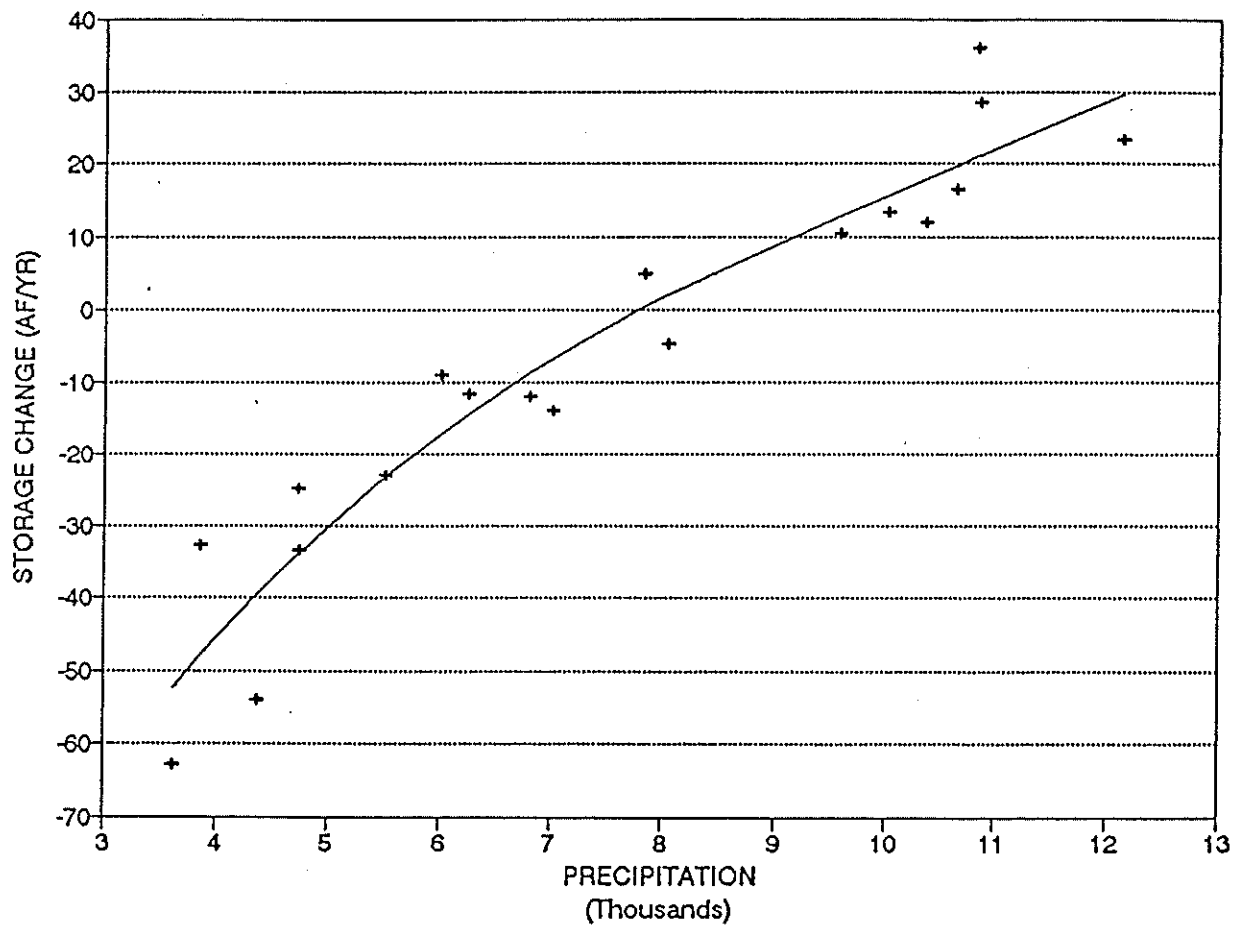
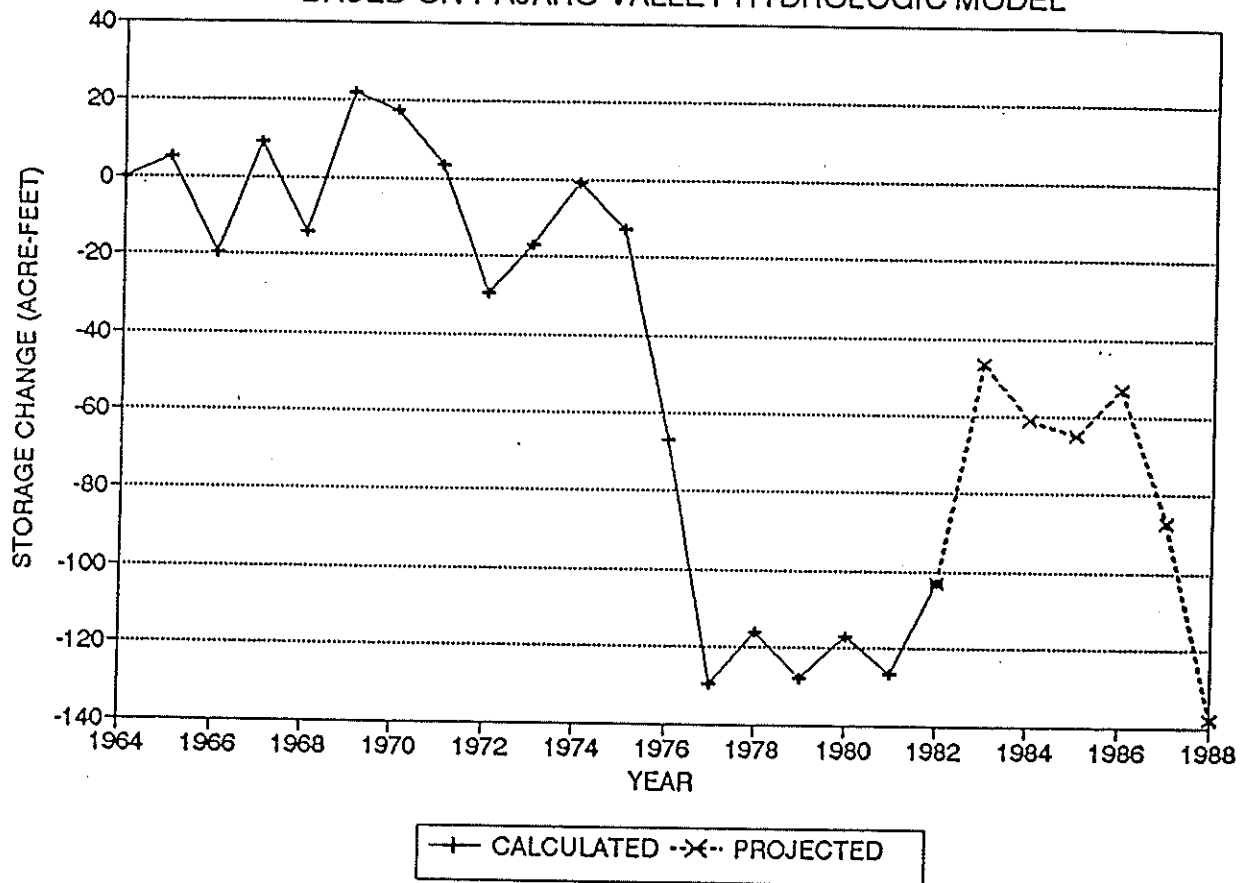


FIGURE 7: AROMAS AREA  
CUMULATIVE GROUND-WATER STORAGE CHANGE  
BASED ON PAJARO VALLEY HYDROLOGIC MODEL



*San Benito County  
Ground-Water Investigation*

Prepared for:  
County of San Benito

Prepared by:  
Luhdorff and Scalmanini  
Consulting Engineers

LUHDORFF & SCALMANINI



October, 1991  
Consulting Engineers

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*SAN BENITO COUNTY*  
*GROUND-WATER INVESTIGATION*

*Prepared for*  
*County Of San Benito*

*Prepared by*  
*Luhdorff and Scalmanini*  
*Consulting Engineers*

*October, 1991*



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## *Executive Summary*

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At the request of the San Benito County Board of Supervisors and the San Benito County Water Advisory Commission, Luhdorff and Scalmanini, Consulting Engineers have completed an analysis of ground-water conditions in various parts of San Benito County.

The objective of this investigation was to develop "safe-yield" ground-water pumping estimates in each of the basins. The underlying basis for all safe yield discussions and estimates in this report fundamentally involve the concept of no long-term change in ground-water storage over some specified period of time.

The lack of detailed geologic and hydrologic data in the smaller and relatively remote basins prevents preparation of estimates of safe yield. In these basins, a review of geologic conditions is presented, and recommendations regarding hydrologic data needs are presented for consideration if the County desires to proceed further in the direction of quantifying safe yield in those small basins.

The safe yield of the North County Basins (Hollister, San Juan, Bolsa, and Pacheco) was analyzed with a numerical ground-water model, after a review of geologic and hydrologic data. The ground-water level data that has been collected since the 1930's indicate that substantial ground-water storage depletions have been observed in varying degrees throughout the North County area. The importation of San Felipe water, which began in September 1987, has had the beneficial effect of adding a "new" source of ground-water recharge and has caused a reduction in agricultural pumpage. The net result of the importation of San Felipe water into the area has been a rise in ground-water levels in various areas, even through the current drought.

Based on the results of the development, calibration and application of the North County model, it can be concluded that, under average precipitation conditions (13.25 inches per year), and with the current rate and pattern of San Felipe deliveries (approximately 16,000 acre-feet per year), and at the current rate and pattern of average urban, suburban, and agricultural pumpage (approximately 38,000 acre-feet per year), no further long-term ground-water storage declines over the entire area would be expected. It is reasonable to expect, however, that as San Felipe deliveries increase toward the contract entitlement, and as agricultural pumping decreases in response to the use of the supplemental water, ground-water storage will increase and ground-water levels will recover.

The safe yield of the Tres Pinos and Paicines areas was analyzed by estimating historical pumpage and evaluating ground-water conditions as affected by that pumping. Pumpage in the area was estimated through an evaluation of the historical land use in the area, and through evaluation of Pacific Gas and Electric records of energy usage for pumping. The analysis of ground-water levels demonstrates that, during the historical period of limited available data, no long term depletion in ground-water storage has occurred. Therefore, it can be concluded that, as a first estimate, the historical pumpage of about 2,000 acre-feet per year in the Tres Pinos area, and 6,000 to 7,000 acre-feet per year in the Paicines area represent safe yield values.

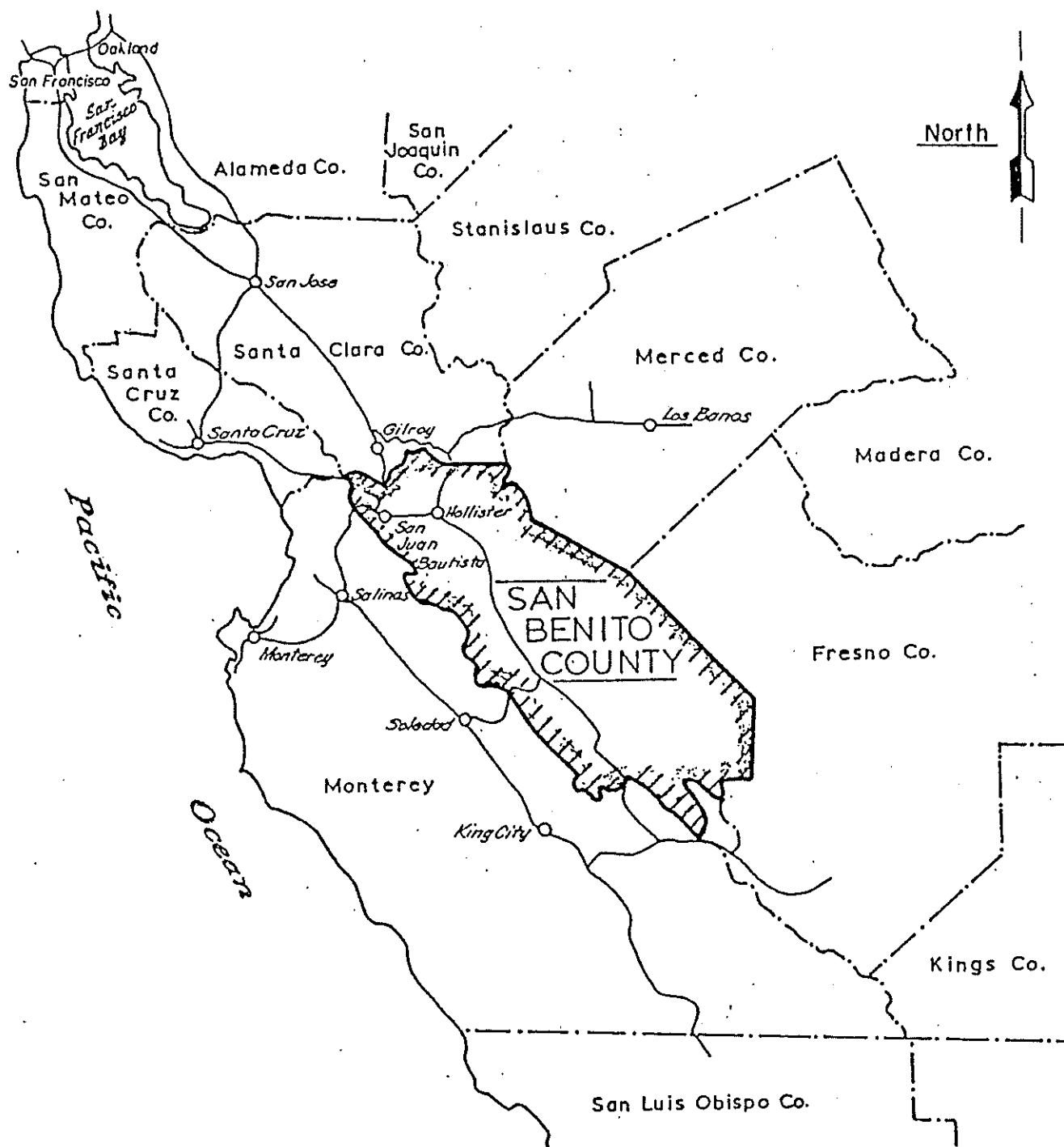
## *I. Introduction*

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At the request of the San Benito County Board of Supervisors (Board) and the San Benito County Water Advisory Commission (Commission), Luhdorff and Scalmanini, Consulting Engineers (LSCE) have completed an analysis of ground-water conditions in various parts of San Benito County (Figure 1.1). The Board and the Commission had identified a need to quantify ground-water conditions in the form of safe yield estimates through a hydrologic study of various ground-water basins in the County. The scope-of-work proposed by the Board and Commission outlined a three phase approach to the study, and called for the individual evaluation of all ground-water basins in the County.

There are approximately 28 ground-water basins in San Benito County as shown in Plate 1 (in pocket). Most of these identified basins are small and located in relatively remote areas, and are not considered likely areas for growth in the near future. There is also little data as to ground-water conditions in most of these areas.

In contrast, areas that have already experienced a great deal of growth (agricultural and urban) over the last century are also the areas with hydrologic data that permit a thorough analysis of basin yield. These areas include the Aromas, Bolsa, Hollister, Pacheco, Paicines, San Juan and Tres Pinos basins. These basins were originally listed by the Board and Commission as the primary basins of investigation. The other basins lack data (both geologic and hydrologic) to evaluate yield with any degree of confidence. An effort to develop both geologic and hydrologic data would have to begin and data collection would have to extend for at least a few years before any confidence could be placed in yield estimates.



From Creegan And D' Angelo Consulting Engineers,  
Consultants To San Benito County Water District.



Lubdorff & Scalmanini  
Consulting Engineers

Location Map

San Benito County  
Ground-Water Investigation

FIGURE

1.1

90-1-084  
October 1991

The basins listed by the Board and Commission can be grouped into two categories based on previous work: 1) basins that have been the subject of intensive study through the development and application of ground-water flow models by the U.S. Geological Survey (USGS), and 2) basins that have no models. The modeled basins are Hollister (including Pacheco), San Juan, Bolsa, and Aromas. The Hollister, San Juan, and Bolsa basins were modeled separately by the U.S. Geological Survey, and the Aromas area was included in a model of the Pajaro Valley Ground-Water Basin developed by Montgomery Engineering.

The basins can also be grouped according to the need for detailed analysis in the context of proposed development. Development in the Bolsa, San Juan, Hollister, Paicines, and Tres Pinos areas has been proposed. Development plans in other areas are non-specific at this time.

Early in the study, the efficacy of evaluating individual basins that are hydrologically connected was discussed with the Commission. Since the critical area of interest (Bolsa, Pacheco, Hollister, and San Juan basins) were hydrologically and hydraulically connected, this analysis looked at all four basins as a unit rather than individually.

Because the previous studies of the Hollister, San Juan, and Bolsa Basins relied upon the assumption that these basins were separated by faults which acted as completely impermeable barriers to ground-water flow, the initial analyses of this investigation sought to test that assumption by reviewing geologic and hydrologic data in those areas. Based on this initial work, the major portion of the County (Bolsa, San Juan, Hollister, Pacheco "basins") was analyzed in detail through the development, calibration, and application of a single numerical ground-water model. This effort was the primary focus of the overall investigation since most of the hydrologic data that has been collected in San Benito County are in these areas. The use of a single model relaxes the assumption that these areas are distinct basins which was fundamental to the U.S. Geological Survey work in the 1970's. Application of the model yielded results upon which conclusions could be drawn as to future ground-water management options.

The Tres Pinos and Paicines areas were not included in the model due to the geologic complexity of the areas, and the general lack of data. The limited available geologic and hydrologic data were analyzed to develop conclusions regarding the historic yield of the ground-water basin and the response of the aquifer system (ground-water level changes) to that level of development.

Since the most of the work of this investigation focused on the northern portion of the County (Hollister, Pacheco, San Juan, and Bolsa Basins), this report covers the development and analysis of data, the development, calibration, and application of the North County ground-water model, and the analysis of safe yield for these basins in separate subsections. The analyses associated with the Paicines and Tres Pinos areas are covered in a separate section.

Prior to a detailed discussion of the hydrologic analyses, a brief discussion of safe yield concepts and a description of the geologic setting are presented.

## *II. Discussion of Safe Yield Concepts*

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The objective of many ground-water resource investigations is focused on addressing the amount of water that can be pumped. A review of the evolution of the term "safe yield" as an indicator of how much water can be pumped from an area was presented by Domenico (1972), and is summarized below.

Lee (1915) first defined safe yield as "the limit to the quantity of water which can be withdrawn regularly and permanently without dangerous depletion of the storage reserve". Meinzer (1923) defined safe yield as "the rate at which water can be withdrawn from an aquifer for human use without depleting the supply to the extent that withdrawal at this rate is no longer economically feasible". Meizer's definition was expanded by Conkling (1946), who described safe yield as an annual extraction of water which does not: 1) exceed average annual recharge, 2) lower the water table so that the permissible cost of pumping is exceeded, and 3) lower the water table so as to permit intrusion of water of undesirable quality. Banks (1953) added a fourth condition, protection of existing water rights. Todd (1959) defined safe yield as "the amount of water which can be withdrawn from a ground water basin without producing an undesirable result".

It is clear that the term "safe yield" in its various forms ambiguously encompasses hydrologic, economic, legal, environmental, and water quality constraints, and as such requires the evaluation of those issues in conjunction with each other. What may be "safe" from a purely hydrologic or water supply view may adversely impact adjoining water rights or the environment. In all cases, developing estimates of safe yield cannot be done on a purely technical level since many of the constraints are legal and policy issues. Moreover, since the concept of safe yield involves non-quantitative fields such as public policy and law, it is generally recognized that quantification of safe yield is a difficult (and often impossible) task

unless the preconditions or hydrologic objectives that need to be met are well articulated.

Based on several meetings with the Commission, the details of an overall policy as to hydrologic objectives have not yet been established. Since it is extremely difficult to begin the formulation of some of these objectives in a vacuum, one of the objectives of this section and the section entitled "Synthesis of Results" is to place some of the possible alternative approaches into perspective using results of this investigation.

The underlying basis for all safe yield discussions and estimates in this report fundamentally involves the concept of no long term net change in storage over some specified period of time. This concept is somewhat different than past ground-water management of the area since ground-water storage has significantly declined over the last 50 years. This more or less tacit decision, which has resulted in ground-water overdraft, is not necessarily "unsafe" since recent activities (importation of San Felipe water) have reversed the long term trend and caused storage gains in some areas, even during the current drought.

Methods of determining safe yield usually begin with the concept of identifying annual pumping which will cause no net change in ground-water storage over some specified period of time. This can be done using a variety of methods which require, as a starting point, the choice of a time period of analysis. This choice of time period is critical, especially in the northern portion of San Benito County, since documented ground-water storage depletion has occurred for several decades. In San Benito County, future management options range from 1) attempting to correct the past storage depletion by managing future pumping to correct past depletions, to 2) establishing a policy that simply ignores the past depletions and attempts to cause no future long-term change in storage.

The importation of San Felipe water into San Benito County since 1987 has had a dramatic effect on the hydrology of the area. In essence, the imported water is "new" water which has had the net effect of increasing ground-water recharge and causing ground-water levels to stabilize in some areas and rise in other areas, even during the current drought.

Continuation and expansion of the importation of water will continue to have beneficial effects, and will have a direct influence on "safe yield" of the area.



### *III. Geologic Setting*

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San Benito County lies in the central California Coastal Range geologic province which consists of subparallel northwest-southeast trending, moderate relief mountain ranges of less than 4,000 feet elevation. In the County, two main mountain ranges are present: the Diablo Range to the east, which borders further east the San Joaquin Valley section of the Great Valley province, and the Gabilan Range to the west (Plate 1). Separating these two ranges is the dominate structural feature of the County, the San Andreas Fault Zone.

The San Andreas Fault Zone is an active transform fault whose movement is largely horizontal with the west side having moved northward hundreds of miles relative to the east side. The geology of the County contrasts sharply across the San Andreas Fault Zone. West of the San Andreas Fault Zone, the Gabilan Range is composed of Mesozoic granitic rocks intruded into older metamorphic rocks and overlain by late Tertiary marine sedimentary and volcanic rocks (Plate 1). East of the San Andreas Fault Zone, the Diablo Range is composed of strongly deformed, weakly metamorphosed, deep-marine sedimentary and igneous rocks overlain by less deformed early to late Tertiary marine to non-marine sedimentary rocks with some volcanic rocks. On both sides of the fault zone, Tertiary and Quaternary, weakly consolidated to unconsolidated gravel, sand and mudstone deposited by stream systems occur in stream valleys, basins, and down-dropped fault blocks. It is within these younger sedimentary deposits in which most ground water occurs within the County (Plate 1).

The purpose and scope of this section is to briefly review previous geologic investigations performed within the County, to summarize the various geologic units present, and to outline the geologic history of the County. The last portion of this section addresses the various ground-water basins and summarizes the extent of available geologic and

hydrogeologic information for each basin. The major ground-water basins in the County occur in the north, at the southern end of the Santa Clara Valley and in the San Juan Valley (Plate 1). South of the Hollister area, minor ground-water basins occur mostly along stream valleys and are limited in areal extent and thickness of water-bearing geologic units (Plate 1). Emphasis is placed on the northern basins where most of the urban and agricultural development of ground water has historically occurred.

### Previous Geologic Investigations

There is fairly extensive number of geologic reports and maps which cover various aspects of the County. The earliest reports were used to compile the only County-wide map by the California Division of Mines and Geology (CDMG) (Jennings and Strand, 1958). Some of the significant early geologic reports were of the San Juan Bautista quadrangle (Allen, 1946), the Hollister quadrangle (Taliaferro, 1948), the Quien Sabe quadrangle (Leith, 1949), and the San Benito quadrangle (Wilson, 1943).

The entire County was mapped by U.S. Geological Survey (USGS) geologist, Thomas Dibblee, Jr. during the 1970's and early 1980's at 15 and 7-1/2 minute quadrangle scale (Dibblee, see references). Because these maps were made by one geologist, they are the most consistent and detailed maps available for the County.

Other significant geologic maps of the County include the Central Diablo Range (Dibblee, 1979), basement rocks of the Gabilan Range (Ross, 1972), geologic and gravity map of San Juan Bautista area (Clark, 1970), and geology and gravity map of Hollister quadrangle (Robbins, 1982). The U.S. Soil Conservation Service has also published a County-wide soil survey map (U.S.S.C.S., 1969).

A large number of topical or limited area geologic studies, including forty Masters of Ph.D. theses on the geology of the County, also exist; these primarily address seismic hazards and earthquakes. Many other regional maps cover the County in larger scale geologic studies as

indicated in the CDMG and USGS Geologic Map Indexes for California.

California Department of Water Resources (DWR) defined and summarized the ground-water basins of the County in Bulletin 118 and 118-80 (DWR, 1975 and 1980). Other topical reports have been prepared by DWR's State and Regional District Offices.

### Regional Geology and Geologic History

This summary of the regional geology of San Benito County is based largely on the CDMG Santa Cruz map sheet (Jenning and Strand, 1958), the various detailed maps of Dibblee, and tectonic synthesis or regional geologic histories (Bartow, 1987 a,b; and other reports). The purpose of this section is to give a brief overview of the geologic units present in the County and their relationship and evolution through time. The water bearing and water yielding characteristics of these geologic units is also discussed.

East of the San Andreas Fault Zone, the two most extensively exposed rock units in the Diablo Range are the Mesozoic Franciscan Assemblage and the Great Valley Sequence. These units are roughly equivalent in time, although representing differences in depositional and tectonic setting. Their geologic history is related by plate tectonic theory to the interaction between the oceanic crust of the Pacific plate to the west and the continental crust of the North American Plate to the east. In Jurassic time, 144 to 208 million years ago (m.y.) a volcanic island arc and subduction zone of the Pacific plate collided with and was accreted to the continental crust in the vicinity of the present Sierra Nevada mountains. The Pacific plate west of this zone formed a new, east-dipping subduction zone down which the oceanic crust descended into the upper mantle of the earth. As this oceanic plate descended, it melted because of the increasing temperatures and pressures, generating large volumes of granitic magma which migrated upwards. The volcanic magmas broke through the continental crust forming a volcanic mountain chain along the trend of the Sierra Nevada. Magma chambers feeding these volcanos ultimately would crystalize into the granitic rocks now exposed in the Sierra Nevada.

Between the volcanic mountains in the Sierra Nevada and the subduction zone in the west, along the trend of the Coastal Ranges, a remnant of oceanic crust trailing the accreted island arc was left to form a forearc basin. Onto this fragment of oceanic crust, vast volumes of sediment were carried from the uplifting volcanic mountains and eroding continental crust to the east. The sediments were deposited in deep marine conditions by submarine fans formed by turbidity currents. Some sediment was carried across the forearc basin and into the subduction zone. In the subduction zone, the sediments were deformed and mixed as the oceanic crust descended, resulting in extremely disrupted material. Fragments of oceanic crust were tectonically mixed into the sediments, along with oceanic sedimentary deposits scraped off the descending oceanic plate. High temperatures and pressures, and abundant fluids resulted in low grade metamorphism of the mixed sediments and rocks of this subduction complex.

This extremely disrupted mixture of deep-marine muds, sands, and gravels of continental origin, and fragments of oceanic mudstones, shales, cherts, limestones, and volcanic rocks which accumulated in the subduction complex represent the Franciscan Assemblage. As the subduction complex continued to thicken, portions of it were carried down the subduction zone, but because of low densities could not descend as the oceanic plate did. Buoyancy forces caused the complex to rise, causing a raised or shelfed margin of the outer edge of the oceanic crust beneath the forearc basin.

In the forearc basin, continued sediment sources from the Sierra Nevada caused a thick (10,000's of feet) sequence of deep marine mudstones and sandstones to accumulate. These deposits are, in contrast to the Franciscan, only slightly deformed, although coarser-grained units tend to be limited in lateral extent. These deposits underlie the Great Valley province to the east and are termed the Great Valley Sequence.

Towards the end of the Mesozoic (circa 75 to 65 m.y.) the rising subduction complex began to isolate the Great Valley from the subduction zone, and the forearc basin was filled with late Cretaceous shallow marine deltaic and shelfal deposits, although deep marine

conditions continued in the Southern San Joaquin Valley. By early Cenozoic time (circa 59 m.y.), the plate tectonic configuration had changed and the subduction zone - forearc basin was replaced.

In the San Benito County area, this long (208 to 65 m.y.) interval of time encompassing the Jurassic and Cretaceous periods of the Mesozoic era is recorded in the Franciscan Assemblage of the subduction complex, and the Great Valley Sequence in the core of the Diablo Range. The Franciscan Assemblage, as mentioned, is a highly structurally deformed and complex mixture of laterally restricted sandstone bodies contained in a matrix of disrupted shales and mudstones. Intermixed are cherts, bodies of siliceous shales, and fragments of oceanic volcanic or igneous rocks (ultrabasic rocks - ub). The sandstones are moderately to well lithified and generally contain abundant fine-grained material that has little porosity or void space for ground water. The finer-grained shales and mudstones are well lithified although so badly disrupted that porosity and permeability are very low. In general, the Franciscan Assemblage is considered a poor to non water bearing unit, although locally limited shallow ground water sufficient for low-yielding wells for domestic or stock watering uses are possible. Usually, the number of "dry" or low yield wells is very high, and poor water quality is often a problem.

The Great Valley Sequence within the County is less deformed and has greater stratigraphic continuity. The most widespread unit in the County is the Cretaceous Panoche Formation (Dibblee, 1979) consisting of marine-shales, sandstones and conglomerates. These units are moderately to well lithified and consolidated, and are believed to have little porosity and permeability. In general, like the Franciscan Assemblage, these rocks are considered a poor to non-water bearing unit, although locally limited supplies of domestic or stock water may be possible. Poor water quality, usually of high total dissolved solids and salinity because of remaining connate water, limits ground-water development.

By early Tertiary time (late Paleocene - circa 59 m.y.) the plate tectonic configuration had changed to a transform fault motion between the Pacific and North American plates, where

relative motion consisted of horizontal movement along a Proto-San Andreas Fault zone. Northward motion of the Pacific plate carried with it fragments of the Sierra Nevada granitic basement, which is termed the Salinian block, from southern California. Through most of the remainder of the Tertiary, marine conditions along the California continental borderland became more restricted as the transform fault plate boundary evolved. Deep marine basin conditions persisted into Pliocene time (3 to 4 m.y.) in the southern San Joaquin Valley, linked across the rising Coastal Ranges and the Salinian block by seaways of marine waters. At times, much of the Coastal borderland was covered by widespread marine conditions of continental shelf depths, while at others only one or two arms of marine conditions would extend into the San Joaquin Valley. In these later times, islands of uplifted blocks of Salinian rocks or Franciscan Assemblage and Great Valley sequence were raised and eroded.

In San Benito County, much of the Tertiary rock units are limited in extent having never been deposited or subsequently removed by erosion. These units are collectively shown on the geologic map as Tertiary marine sediments (T<sub>m</sub> - Plate 1), although some non-marine deposits may be present. The older Tertiary marine units of Eocene and Oligocene age (58 to 36.6 m.y. and 36.6 to 23.7 m.y.) are largely confined along the western margins of the San Joaquin Valley, and in the Vallecitos syncline across the Diablo Range. Other slivers of rocks exist along the San Andreas Fault zone preserved by down-dropped blocks between faults. West of the San Andreas fault, the older Tertiary units are largely not present due to the lack of deposition or subsequent erosion.

Younger Tertiary marine rocks are more extensive, probably representing periods when more widespread marine conditions existed. Miocene age (23.7 to 5.3 m.y.) rocks include Monterey shale dominated by siliceous shale and chert. Miocene volcanic fields are partially preserved in the Quien Sabe area and Pinnacles National Park area (T<sub>v</sub>, Plate 1). Pliocene marine rocks are the most widespread of the Tertiary units in the County, probably because of preservation of the last major marine interval covering the Coastal borderland. A thick sequence (Purisima Formation) of Pliocene marine grading to non-marine deposits

of several thousands of feet exist in the northern County between the San Andreas and Calaveras Faults (Plate 1). Similar rocks occur along the San Andreas Fault Zone and across the low relief area south of the Gabilan Range known as the Gabilan Mesa.

Most of the Tertiary marine sedimentary rocks appear to be moderately to well lithified and consolidated. Rock types are variable but include sandstones, shales, mudstones, siliceous shales, and cherts. A variety of formational names are used for these units (Dibblee, 1979, see references). The units are slightly to moderately deformed in some areas, to very strongly deformed by folding and faulting along the major fault zones in the County. Information on the ground-water potential of most of these units is very limited. Based on their marine origin, structural configurations, degree of consolidation, and lithology, they are believed to represent poor to non-water bearing rocks. However, some limited water production from the coarser-grained units (sandstones and conglomerates) may be locally possible. It is suspected that water yields may be low, and water quality of high salinity may pose problems due to connate waters. However, carefully located wells in geologically investigated areas could allow some water development at least for domestic or stock watering uses.

Tertiary non-marine units (Tn) are largely confined to the northern County and appear to represent the non-marine deposits overlying marines units which marked the closure of the last marine seaway into the San Joaquin Valley. These units are mostly known from surface exposures and limited oil and gas test holes associated with the Flint Hills and Hollister area (Wilkinson, 1967). The units appear to consist of thick interbedded sand and gravels and mudstones of probably fluvial and floodplain origin. A few oil and gas test holes indicate "fresh" water extending to depths of 1,200 to 1,800 feet, but most ground-water exploration has been only to depths of less than 1,000 feet. The ability to differentiate these units from younger overlying deposits may not be possible in the subsurface due to their similar lithologic nature.

It is suspected that some deep wells adjacent to the Losmerias Muertas Hills and in the San

Juan Valley may be producing from the Tertiary non-marine units. The unit in the northern basins should be considered a potential, but largely unexplored ground-water source. The unit may be capable of yielding modest to large amounts of ground water, but depths would tend to be great (1,000 to 1,800 feet). Aquifer characteristics may be poor due to age, compaction and lithology; and poor water quality, containing high total dissolved solids, high mineral concentrations, and methane or hydrogen sulfide gases, could occur.

Late in the Pliocene, the last marine seaway had closed and only non-marine sedimentary deposition would occur in the County area. By the end of the Pliocene (1.6 m.y.), the general major features of the County probably existed. The San Andreas and Calaveras Fault zones were active with horizontal motion. The deformation and uplift of the Diablo Range continued, and the Salinian block west of the San Andreas continued its northward movement.

The last major rock unit exposed in the County is the Mesozoic granitic rocks of the Gabilan range west of the San Andreas Fault zone. These intrusive igneous rocks of granitic composition are equivalent to those in the Sierra Nevada formed during the volcanic arc evolution, as mentioned previously. The rocks were originally located in Southern California and were transported by plate movements northward along the San Andreas transform faults. The rocks are mainly medium to coarse grained granitic rocks with small contained masses of older metamorphic sedimentary rocks. The rocks are generally massive, well lithified and lacking in porosity or permeability. Limited ground-water production may be possible from deep weathered zones, fractures, and fault zones.

In late Pliocene to Pleistocene (1.6 to 0.01 m.y.), non-marine alluvial fan, fluvial and floodplain Older Alluvium deposits (QTs - Plate 1) were deposited along the San Andreas Fault Zone and in the Santa Clara Valley fed by sediment eroded from the adjacent uplands. These units are less deformed and less consolidated than the Tertiary non-marine units. Some of the Older Alluvium may be in part time-equivalent to the Tertiary non-marine units, but age restraints for both units are lacking. The original extent and

configuration of these units is not clear, but most preserved sections are between or adjacent to the San Andreas Zone faults. A large area of exposure along Tres Pinos Creek is known as the San Benito Gravels and was studied in some detail by Griffin (1967), who attributed them to alluvial fans and fluvial deposition. Similar deposits in the northern Santa Clara Valley are known as the Santa Clara Formation. Probably an ancestral Santa Clara Valley existed in which these deposits were formed by a northward flowing stream system. Some deposits in the southern County may be related to similar deposits formed by streams draining through the Salinas Valley.

The Older Alluvium deposits are weakly consolidated interbedded gravel, sand, and mudstones formed by alluvial fans and fluvial systems. They are believed to underlie most of the southern Santa Clara valley, although they are difficult to differentiate from younger alluvium and slightly older (Tn) similar units in the subsurface. The coarser-grained units are probably sources of ground water in the main northern ground-water basins at depths of 300 to 1,000 feet. Well yields appear to be relatively high with good water quality.

Overlying the Older Alluvium deposits are Younger Alluvium (Qa) of probably Pleistocene to Recent Age. These units were deposited by fluvial systems draining northward probably across the San Andreas fault into the Monterey Bay area. The unit consists of unconsolidated gravel and sands interbedded with mudstones. Some speculation (Herd and Helley, 1977) of the existence of a large lake in the Santa Clara Valley has been made, but evidence is limited or unclear (McMasters and others, 1987). Most of the shallower wells at depths of less than 300 feet in the main northern basin are probably completed in the alluvium and some of the underlying QTs deposits. Water yields are generally high with good water quality.

West of the San Andreas Fault in the Monterey Bay area, thick (600 to 1,000 feet) aeolian and stream deposits of Pleistocene age (Qc - Plate 1) known as the Aromas Red Sands (Allen, 1946) exist. The sediments were apparently sourced from the Salinas River Valley and ancestral Pajaro/San Benito Rivers which crossed the San Andreas Fault Zone. These

deposits are probably in part equivalent to the Older Alluvium in San Benito County. The Aromas is an excellent, high yielding aquifer of generally good water quality. A small area of San Benito County, in the Aromas area, is underlain by the Aromas Red Sands.

In summary, most of the County lies outside of defined ground-water basins and is underlain by Mesozoic and Tertiary igneous and marine sedimentary rocks which have limited potential for ground-water development. Ground-water basins in the County are restricted to areas where largely Pleistocene non-marine, alluvium occurs. These basins are defined and examined in the following section.

### Ground-Water Basins

A ground-water basin, as used in this report, is taken to mean a definable area where sufficiently thick geologic materials are present which have adequate porosity and permeability to yield ground-water to wells in quantities necessary to meet agricultural, industrial, municipal, or domestic supply requirements. In general, these areas are underlain by unconsolidated young sedimentary deposits of interbedded gravel, sand and mudstones (silts and clays). In San Benito County, the California Department of Water Resources defined and summarized the ground-water basins as part of a state wide study (DWR, 1975 and 1980).

In this investigation, LSCE reviewed the available information concerning ground water in the County, and evaluated the various basins. As noted previously, the basins are divisible into two groups: the major ground-water basins in the northern portion of the County, and minor ground-water basins in the remainder of the County. The names of the basins were taken from DWR (1975 and 1980) with some modifications based on geologic maps or current findings. The ground-water basins are shown on Plate 1. Emphasis has been placed on the northern basins where information and utilization of the ground-water resource is concentrated. Information on the minor basins is relatively limited, but is summarized in a following section.

a simplified lithologic column for the well log drawn at a scale of one inch to 500 feet. Approximately 500 logs were treated this way while the remainder were redundant, unable to be adequately located, or had inadequate lithologic descriptions. Adequate coverage of the basins was achieved, although coverage of certain areas was relatively sparse. These latter areas included the northern portion of the Bolsa sub-basin, the northeastern and southeastern Hollister Valley sub-basin, the San Benito/Tres Pinos basin in general, the western Hollister subbasin, and the western San Juan Valley subbasin.

From the quadrangle overlays, representative geologic cross-sections were located and constructed to show subsurface relationships across the basins (Figure 3.1 and Plates 2 through 5). From review of the well logs, it was apparent that most wells were less than 400 feet deep with larger wells extending to 600 to 800 feet. Relatively few wells had been drilled or constructed to depths of 1,000 feet. Limited numbers of oil and gas test holes indicated that the base of fresh water, as indicated by electrical log characteristics, occurred at depths of 1,200 to 1,800 feet, potentially indicating that 600 to 1,000 feet of fresh groundwater strata remains largely unexplored. Attempts at deep stratigraphic correlation based on oil and gas logs were unsuccessful due to lack of adequate well control. Kilburn (1972) presented deep geologic cross-sections of the basins, but these should be used with caution as they lack indications of the base of fresh water; and correlations and relationships are based on limited information.

The geologic cross-sections prepared for this report should be considered partially schematic and a tentative representation of subsurface conditions. Correlation of subsurface units is difficult and units may not be as areally widespread or consistent as indicated on the cross-sections. Separation of Younger Alluvium (Qa) from Older Alluvium (QTs), Tertiary non-marine units (Tn) is virtually impossible in the subsurface because of their similar lithologic natures. The cross-sections in general show alluvium in the upper 200 feet, underlain by older units whose correlation is based on surface map relationships and are generally shown as questionable or queried. However, the cross-sections show some general patterns and relationships for the uppermost 800 feet on a basin-wide scale. No other detailed cross-



sections of the ground-water basins such as these have been found in any of the reviewed literature. These cross-sections may be used, with caution, to predict possible well depths and lithologies to be encountered around the basins during exploration. Obviously, more detailed hydrogeologic study and test hole drilling are prerequisites of site specific exploration for water wells.

### **San Benito River and Tres Pinos Creek Valley Basins**

The San Benito River and Tres Pinos Creek subbasin is similar to the minor ground-water basins in the County. The basin extends several miles up the valleys of the two streams until the valley sides narrow and just the stream channel remains. This area is extremely complex geologically due to the intensive faulting and deformation in the Calaveras and San Andreas fault zones. In addition, other faults which have been named include the Tres Pinos and Paicines faults.

Well control for the area is very poor, and because of the lithologic similarity between younger and older alluvium and Tertiary non-marine units, differentiation is virtually impossible. Combined with the intense deformation of all units older than the younger alluvium (Qa), subsurface geologic correlation was considered not possible.

Based on the detailed geologic maps of the area, and the limited well control, the geology is best summarized as thin, unconsolidated alluvium of stream channel origin overlying the deformed older alluvium and Tertiary non-marine units. The alluvium is considered to be less than 200 feet thick in the northern portion to less than 100 feet toward the south. Areas where broad valley floors are present may contain thicker deposits. Most wells and water yield is probably occurring from the alluvium. Deeper wells east of the Calaveras fault probably penetrate older alluvium (QTs), probably San Benito gravels which are extensively exposed in the area. These beds may contain large volumes of water probably recharged from the alluvium and the outcrop areas. Areas west of the Calaveras fault are underlain by Tertiary non-marine units, which because of greater age, consolidation, original

finer-grained nature, and higher degree of deformation may not yield as much water. Well yields and aquifer characteristics may be highly variable. Wells constructed in thick alluvium or which encountered older coarse-grained beds may yield large quantities of water. Other wells in fault zones or in highly deformed older sedimentary units may yield little water.

### Minor Ground Water Basins

Outside of the major ground water basins in the northern part of the County are a number of other stream valleys which contain unconsolidated alluvium. These valley basins are less well known, and information on them is largely lacking. Geologic map coverage exists for all of the areas, but subsurface information, especially well logs, is very limited. For this study, these areas were only briefly examined based on DWR (1975 and 1980) definition of basins, and included other topographic or geologic areas where evidence of unconsolidated alluvium deposits exist. A brief outline of each of these basins is found in the following section. Comparative data on the size and general ground-water factors for all the smaller basins are included in Table 3.1

#### Pacheco Creek Valley

Most of this stream valley lies outside San Benito County and the valley is recharge area of the Hollister Valley subbasin to the west. Some well logs were found in the area. Probably 100 to 200 feet of coarse alluvium underlies the valley and some high yielding wells are possible.

#### Santa Ana Valley

This small valley area west of the Hollister Valley subbasin was defined by DWR (1975). It appears that fault movement along the Quien Sabe Fault zone may have allowed deposition of alluvium from local streams and Santa Ana Creek to have accumulated. A few well logs

Table 3.1  
Ground-Water Basins

| Basin                     | Area<br>(sq. miles) | Well<br>Logs | Maximum Alluvium<br>Thickness (ft.) | Older Units                              | Ground-Water Resources                                                  | Comments                             |
|---------------------------|---------------------|--------------|-------------------------------------|------------------------------------------|-------------------------------------------------------------------------|--------------------------------------|
| Aromas Subbasin           | 10*                 | Some-Many    | 200+ Qc-600                         | Tertiary Marine                          | Adequate for domestic, stock,<br>and agriculture use                    | Part of larger Monterey<br>Bay area. |
| Santa Ana Valley          | 4                   | Some         | 0-50                                | Panoche<br>Formation                     | Limited, low yields, sufficient<br>for domestic and stock use           | May not be ground-water<br>basin     |
| Upper Santa Ana<br>Valley | 2                   | None         | 0-50                                | Panoche<br>Formation                     | Limited, low yields, sufficient<br>for domestic and stock use           | May not be ground-water<br>basin     |
| Quien Sabe Valley         | 8                   | None         | <200                                | Tertiary<br>Volcanic Rocks               | Limited, low yields, sufficient<br>for domestic and stock use           | Needs field survey for<br>wells      |
| Los Mueritos Valley       | 2                   | None         | <100                                | Franciscan<br>Assemblage                 | Limited, low yields, may be<br>sufficient for domestic and<br>stock use | May not be ground-water<br>basin     |
| Las Aguilas               | 6                   | None         | <100                                | Franciscan<br>Assemblage                 | Limited, low yields, may be<br>sufficient for domestic and<br>stock use | Needs field survey for<br>wells      |
| Antelope Valley           | 1                   | None         | <100                                | Franciscan<br>Assemblage                 | Limited, low yield, may be<br>sufficient for domestic and<br>stock use  | May not be ground-water<br>basin     |
| Upper Tres Pinos<br>Creek | 36                  | None         | <100                                | Older Alluvium/<br>San Benito<br>Gravels | Limited, low yield, may be<br>sufficient for domestic and<br>stock use  | Needs field survey for<br>wells      |

Table 3.1 (Continued)  
Ground-Water Basins

| Basin                     | Area<br>(sq. miles) | Well<br>Logs | Maximum Alluvium<br>Thickness (ft.) | Older Units                           | Ground-Water Resources                                                  | Comments                         |
|---------------------------|---------------------|--------------|-------------------------------------|---------------------------------------|-------------------------------------------------------------------------|----------------------------------|
| Cienaga Valley            | 3                   | None         | <100                                | Granite                               | Limited, may be low yield,<br>sufficient for domestic and<br>stock use  | Needs field survey for<br>wells  |
| Gloria Valley             | 2                   | None         | <100                                | Granite                               | Limited, low yields, may be<br>sufficient for domestic and<br>stock use | May not be ground-water<br>basin |
| Bear Valley               | 3                   | None         | <100                                | Tertiary Non-<br>Marine and<br>Marine | Limited, low yields, may be<br>sufficient for domestic and<br>stock use | May not be ground-water<br>basin |
| Dry Lake Valley           | 2                   | None         | <200                                | Tertiary Marine                       | Limited, low yields, may be<br>sufficient for domestic and<br>stock use | May not be ground-water<br>basin |
| San Benito Valley         | 2                   | None         | <200                                | Tertiary Non-<br>Marine and<br>Marine | Limited, low yield, may be<br>sufficient for domestic and<br>stock use  | May not be ground-water<br>basin |
| Little Panoche<br>Valley* | 5                   | None         | <100<br>QTs-200+                    | Tertiary Non-<br>Marine               | Limited, low yield, may be<br>sufficient for domestic and<br>stock use  | May not be ground-water<br>basin |
| Panoche Valley            | 51                  | Some         | 300+                                | Older Alluvium                        | May be sufficient for<br>agricultural use                               | Needs detailed study             |
| Topo Valley               | 5                   | None         | <200                                | Tertiary Marine                       | Limited, low yield, may be<br>sufficient for domestic and<br>stock use  | May not be ground-water<br>basin |

Table 3.1 (Continued)  
Ground-Water Basins

| Basin                      | Area<br>(sq. miles) | Well<br>Logs | Maximum Alluvium<br>Thickness (ft.) | Older Units                                   | Ground-Water Resources                                                 | Comments                         |
|----------------------------|---------------------|--------------|-------------------------------------|-----------------------------------------------|------------------------------------------------------------------------|----------------------------------|
| Vallecitos Creek<br>Valley | 23                  | None         | <200                                | Tertiary Non-<br>Marine and<br>Marine         | Limited, low yield, may be<br>sufficient for domestic and<br>stock use | Needs field survey for<br>wells  |
| Hernandez Valley           | 5                   | None         | <100                                | Franciscan<br>Assemblage &<br>Tertiary Marine | Limited, low yield, may be<br>sufficient for domestic and<br>stock use | May not be ground-water<br>basin |
| Bitterwater Valley         | 9                   | None         | 200                                 | Tertiary Non-<br>Marine                       | Limited, low yield, may be<br>sufficient for domestic and<br>stock use | Needs field survey for<br>wells  |
| Peachtree Valley           | 4                   | None         | <200                                | Granite &<br>Tertiary Non-<br>Marine          | Limited, low yield, may be<br>sufficient for domestic and<br>stock use | Needs field survey for<br>wells  |
| Priest Valley*             | 2                   | None         | <200                                | Tertiary Marine                               | Limited, low yield, may be<br>sufficient for domestic and<br>stock use | May not be ground-water<br>basin |

\*Part of Valley Outside of County

and geologic map relationships indicate that the alluvium is very thin and underlain by Panoche Formation. Well yields can be expected to be low, sufficient for domestic and stock use. Some slightly larger yields may be possible at the northern end of the valley in thicker alluvium, but no logs were found in this area. The area may in fact not represent a definable ground-water basin.

### **Upper Santa Ana Valley**

Defined by DWR (1975), this area is probably similar to the Santa Ana Valley. Thin alluvium overlies Panoche Formation. No well logs were found in the area. Well yields are probably low but may be sufficient for domestic or stock use. The area may not represent a definable ground-water basin.

### **Quien Sabe Valley**

This small alluvial valley lies in the Diablo Range and probably consists of thin (less than 200 feet) alluvium overlying Tertiary volcanic rocks. No well logs were found for the area, but it is suspected that some ground water may occur in the alluvium. Some ground water may also occur in the volcanic rocks, but this is unknown. It can be expected that some limited ground-water production may be achieved for domestic, stock, and possibly limited agricultural use.

### **Los Muertos Valley**

This small stream valley has probably thin (100 feet) alluvium deposits on the valley floor overlying Franciscan Assemblage. There are no available well logs, but some limited ground-water may exist, sufficient for domestic or stock use.

### Las Aguitas Valley

This is a small, multiple channel stream valley complex with thin (less than 100 feet) alluvium overlying Franciscan Assemblage. There are not available well logs, but some limited ground-water may exist at shallow depth, sufficient for domestic or stock use.

### Antelope Valley

This is a very small stream valley with thin alluvium (less than 100 feet) overlying Franciscan Assemblage and some San Benito gravel (QTs). There is probably very limited ground water present, possibly sufficient for limited domestic or stock use. The valley may not represent a ground-water basin because of its small size and limited ground-water availability.

### Upper Tres Pinos Creek

This large area is composed of extensive exposures of San Benito gravel (QTs) in steep bluffs and hills. The Tres Pinos Creek flow across the center of the area is deeply incised into the San Benito gravel. Thin Alluvium (less than 100 feet) occurs along the stream. No well logs were found, but some ground water may be present in the alluvium and in the underlying San Benito gravels, sufficient for stock and domestic uses. The area may not be a ground-water basin, but may be an important area of recharge to San Benito gravels downstream in the Tres Pinos Creek Valley area.

### Cienaga Valley

This is a small stream valley west of San Andreas fault zone, consisting of thin (less than 100 feet) alluvium overlying granitic rocks. Although no well logs were located, small quantities of ground-water may be present in the alluvium and possibly from fractured granitic rocks sufficient for domestic or stock uses. The valley may not represent a

definable ground-water basin if the alluvium does not contain ground water.

#### **Gloria Valley**

This is a very small stream valley containing thin (less than 100 feet) alluvium. No well logs were located; however, small quantities of ground water might be developed from the alluvium or possibly from fractured underlying granite, sufficient for domestic or stock uses. This valley may not be a definable ground water basin, if the alluvium does not contain ground water.

#### **Bear Valley**

Small, elongate stream valley consisting of thin (less than 100 feet) alluvium overlying Tertiary marine non-marine sedimentary rocks. No well logs were located; however, the alluvium may contain some ground water sufficient for domestic or stock uses. Tertiary marine units may not contain usable water. Tertiary non-marine units may contain ground water at sites where they occur beneath alluvium. This may not represent ground-water basin, if water is not present in the alluvium or non-marine units.

#### **Dry Lake Valley**

Defined by DWR, this small, possibly structurally controlled, basin with probably thin (less than 200 feet) alluvium is underlain by Tertiary non-marine units west of fault and by Tertiary marine sandstones. Some ground-water may be present in the alluvium and underlying units, sufficient for domestic and stock use, although no well logs were found. This may not represent ground-water basin if the alluvium is dry.

#### **San Benito Valley**

This is a small area of wide alluvium along the San Benito River with thin alluvium (less

than 200 feet) overlying deformed Tertiary marine to non-marine units. No well logs were found, but some ground water may be present sufficient for domestic or stock use. This may not represent definable ground-water basin, if the alluvium is dry.

### **Topo Valley**

This is a small stream valley overlying granite, Tertiary non-marine units. No well logs were found. The alluvium may be thin (less than 200 feet) and ground water may be present sufficient for domestic or stock use. May not represent definable ground-water basinal alluvium.

### **Bitterwater Valley**

Defined by DWR, this small stream valley has thin (less than 200 feet) alluvium overlying Tertiary non-marine units. Boundary placed at junction of stream at southern end, but valley continues into Peach Tree Valley. No well logs were found, but small quantities of shallow ground water may be present for domestic or stock uses.

### **Peachtree Valley**

A small portion of this valley lies within the County as a defined by DWR. Thin alluvium (less than 200 feet) overlies granite and possibly Tertiary non-marine units. No well logs were found. Some ground water may be present in the alluvium, sufficient for domestic and stock use.

### **Hernandez Valley**

This is a small valley defined by DWR along San Benito River. Thin alluvium (less than 100 feet) overlies Franciscan Assemblage and Tertiary marine units. Although no well logs were found, some ground-water may be present at shallow depth sufficient for domestic and

stock uses. This may not represent a definable ground water basin.

### **Priest Valley**

A small portion of this valley occurs in San Benito County along Lewis Creek. Thin alluvium (less than 200 feet) overlies Tertiary marine units. No well logs were found, although some limited ground water may be present for domestic and stock uses.

### **Little Panoche Valley**

This is a small portion of larger valley outside of County where there are thick exposures of older Alluvium deposits and small areas of younger alluvium. No well logs were found; however, some ground water may be sufficient for domestic and stock use.

### **Vallecitos Creek Valley**

This larger stream valley, defined by DWR, consists of thin (less than 200 feet) alluvium with adjacent Tertiary marine and non-marine units. No well logs were found. Some ground water may be present in the valley sufficient for domestic, stock and limited agricultural uses.

### **Panoche Valley**

Defined by DWR, this larger alluvial valley is probably the most significant ground-water basin outside of the northern major basins. The broad valley floor is underlain by several hundred feet of younger and older alluvium (Creegan and D'Angelo, 1959). Some well logs were found for the area; but more detailed study would be required to examine the basin, and such was not a priority of this investigation. It appears that some wells may have high yields, and sufficient water may be available for both domestic and agricultural uses.

## *IV. North County (Hollister, San Juan, Bolsa, Pacheco) Basins*

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### **Review of Previous Investigations**

A brief description of the three basins that were modeled by the U.S. Geological Survey (USGS), and a discussion of their model results is presented below in order to introduce the state of knowledge at the beginning of this investigation. The citations for each of these studies are Hollister (Kapple, 1979), San Juan (Faye, 1974), and Bolsa (Faye, 1976). These studies expanded on the work of Kilburn (1972).

#### **Hollister Basin**

The aquifers in the Hollister basin consist of clay, silt, sand, gravel, and poorly consolidated sandstone. Both unconfined and confined conditions exist, and faults in the area act as semipermeable barriers to ground-water flow. The basin is essentially closed with recharge provided by subsurface inflow and by stream and rainfall infiltration, and discharge through pumping and leakage from the confined aquifer upward to the unconfined aquifer. This leakage is eventually lost to evapotranspiration or drained from San Felipe Lake by surface diversion. The USGS estimated average total recharge to be approximately 16,500 acre-feet per year. Average discharge was approximately 19,400 acre-feet per year during the period from 1951 to 1968.

Between 1946 and 1968, ground-water flow patterns were altered by increased pumping near Hollister. Pre-development flow patterns were generally to the northwest, towards San Felipe Lake. By 1968, the direction of ground-water flow had reversed toward a cone of depression near Hollister.

The application of the model developed by the USGS was primarily associated with the prediction of ground-water level response under an increased pumping scenario. In addition, this scenario included recharge of 720 acre-feet per year of imported water that would be released down Pacheco Creek. The results of this scenario were dramatic declines in water levels, and retardation of the decline north of the County line due the imported water.

### San Juan Basin

Ground water in the San Juan Basin occurs in alluvium of Holocene age, and in the Purisima Formation of Pliocene age. Most of the San Juan Valley is formed by the alluvium which consists of lenticular beds of unconsolidated gravel, sand, silt, and clay. The alluvium is generally very permeable, and is the principally developed source of ground water in the basin.

Prior to development (1913), ground-water flowed toward the northwest portion of the basin, roughly along the course of the San Benito River. Development of ground water between 1913 and 1945 caused a change in flow pattern as a cone of depression formed in the area west of Morse, and flow to the northwest reversed into this area. Due to the generally unconfined nature of the basin, the magnitude of the change was not large, but storage losses were significant.

Based on the USGS model, pre-development recharge to the basin averaged approximately 6,700 acre-feet per year and occurred as subsurface flow into the eastern part of the basin and from infiltration of rain, direct runoff, and minor streamflow. Pre-development discharge was also approximately 6,700 acre-feet and occurred as discharge from the aquifer to the San Benito River. This pre-development recharge was termed "perennial recharge" by the USGS.

Large-scale ground-water development occurred in the area after 1945, and caused water

levels to decline throughout most of the basin. Progressive depletion of aquifer storage changed the San Benito River from a gaining stream to a losing stream. Based on the USGS model, the average discharge from the basin from 1945 to 1968 averaged approximately 13,100 acre-feet per year. Of this, approximately 12,900 acre-feet per year occurred as pumpage from wells, and approximately 200 acre-feet occurred as aquifer discharge to the San Benito River. Recharge during the same period averaged 9,800 acre-feet per year. Of this, 3,100 acre-feet per year occurred as infiltration from the San Benito River, and the remaining 6,700 acre-feet per year occurred as perennial recharge described above.

Based on model simulations, 3,000 acre-feet of additional recharge due to the introduction of imported water would cause significant recovery of water levels within nine years in the eastern portion of the basin. These same simulations showed that water levels in other portions of the basin would be generally unaffected; however, these simulations limited the area of the additional recharge to the eastern portion of the basin.

#### **Bolsa Basin**

Ground water in the Bolsa Basin occurs in the alluvium of Holocene age, older alluvium of Pleistocene and Pliocene age, and the Purisima Formation of Pliocene age. Saturated deposits of alluvium and upper Purisima are moderately to extremely permeable, and are the source of most of the ground water pumped in the basin.

Based on the ground-water flow model of the basin, pre-development recharge to the basin averaged approximately 8,400 acre-feet per year and occurred as subsurface inflow, infiltration of rainfall, and infiltration of minor streamflow. The pre-development discharge averaged approximately 8,400 acre-feet per year, and is considered to have occurred as leakage from the confined aquifer into the overlying unconfined aquifer and then ultimately discharged as evapotranspiration and as discharge to the Pajaro River.

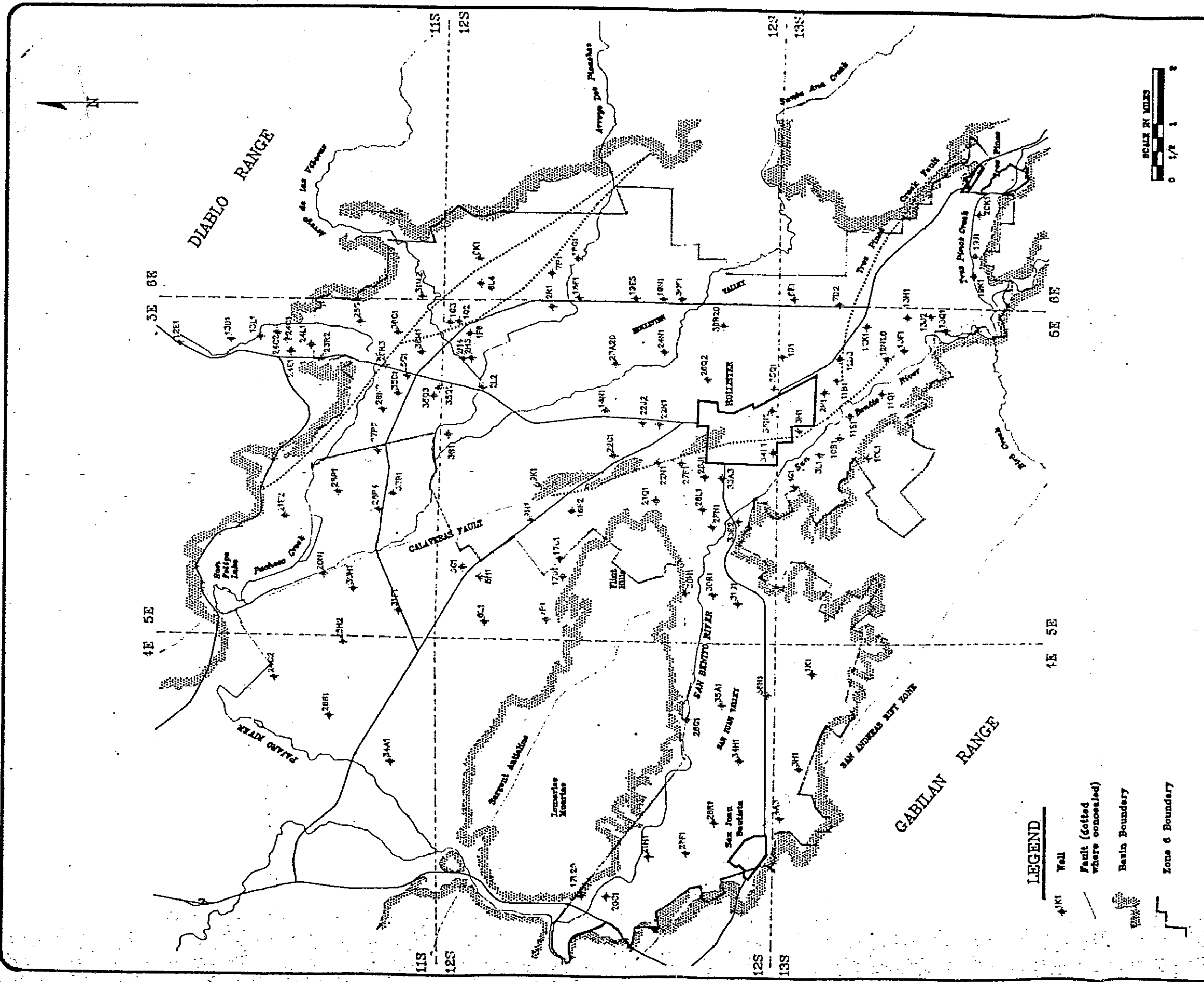
Ground-water flow conditions changed dramatically after 1945. Ground-water levels were lowered as a result of increased pumpage, and aquifer storage was reduced. Based on model simulations, recharge to the aquifer from 1945 to 1969 averaged 4,500 acre-feet per year, and discharge averaged 5,800 acre-feet per year.

The pattern of ground-water flow changed from northwesterly/westerly in 1945 to southeasterly in 1969 due to heavy and continuous pumping, especially in the southern portion of the basin (located just north of Hollister). The declines in ground-water levels in the southern portion of the basin approached and exceeded 80 feet in the southern end of the basin during this period, but were on the order of 20 feet in the northern portion.

The result of this change was that ground water ceased to flow out of the Basin in the area of the Pajaro River and Highway 101, and began to flow toward Hollister, where a large cone of depression had formed.

#### Review of Hydrologic Data

The objectives of reviewing hydrologic data in the northern basins were: 1) to develop an understanding of the ground-water flow system and the hydrologic boundaries of the flow system (most notably faults), 2) to develop an understanding of the recent trends in ground-water levels, and 3) to develop an understanding of the impact of San Felipe water on the ground-water system. The data that were used in this analysis were obtained from the San Benito County Water District (SBCWD), California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (USBR). Ground-water level data prior to 1977 were derived from DWR and USBR records. Ground-water level data since 1977 and imported water data since 1987 were obtained from SBCWD. The locations of 111 wells that were used in this review are presented in Figure 4.1.



Well Locations and Zone 6 Boundary,  
San Benito County

१३

FIGURE

#### 4.1

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## Ground-Water Flow System

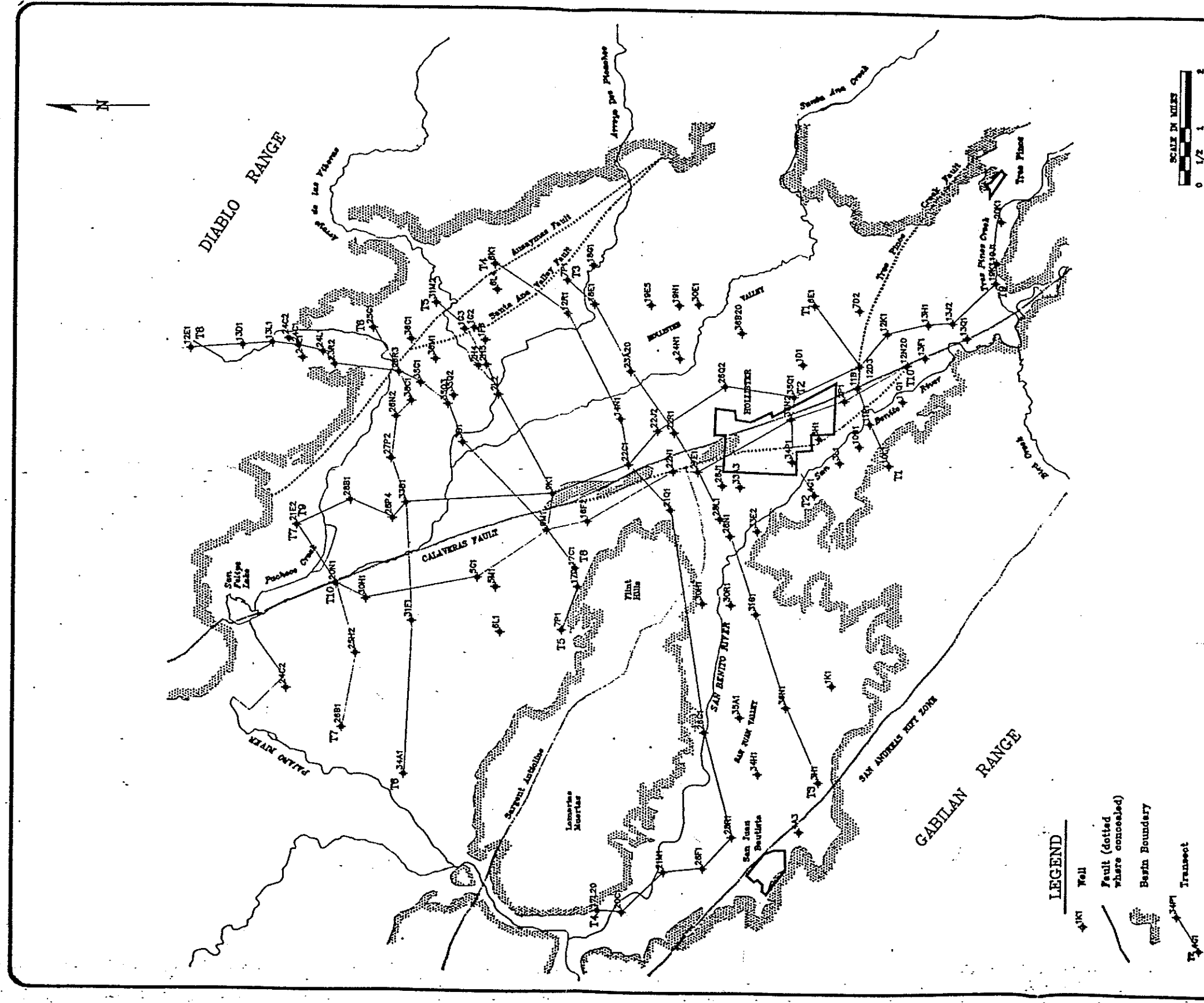
The north County area is geologically complex, largely due the presence of several faults, notably the Calaveras fault which the USGS had assumed to be a complete barrier to ground-water flow. Other faults present in the area are the Tres Pinos Creek, Ausaymas, Santa Ana Valley, and the Sargent faults. Historically, the Tres Pinos Creek fault was assumed to have little or no flow across it, and the Ausaymas and Santa Ana Valley faults were treated as partial barriers to flow by Kapple (1979). The San Andreas Fault Zone has been assumed to form the southwestern boundary to flow in the San Juan Valley, and the Sargent Anticline has been considered to divide the San Juan and Bolsa Basins.

The effect of these faults was reassessed in this investigation by analyzing historic ground-water levels throughout the study area. Ten water level transects across several of the faults and ground-water contour maps were constructed to identify any differences in ground-water elevation due to the faults. The location of the transects are depicted in Figure 4.2. Water level data from the 1970's and 1980's were plotted, including spring and fall measurements during drought and post-drought periods.

In the transects crossing the southwestern portion of the area, large differences in ground-water elevation exist across the Calaveras fault. Ground-water elevations differed by 120 to 150 feet across one mile in 1981 (Transects 2 and 3, Figures 4.3 and 4.4). The ground-water flow direction was to the east, which is a reversal of the pre-development condition as documented by the USGS.

Further north, little to no water level change exists across the Calaveras fault. The difference along Transect 4 is about 40 feet over a one and one-half mile section (Figure 4.5). Transects 5 and 6, further north, do not show any difference attributable to the fault (Figures 4.6 and 4.7).

The water level data indicate that ground-water flow directions have been significantly



Water-Level Transect Locations,  
San Benito County

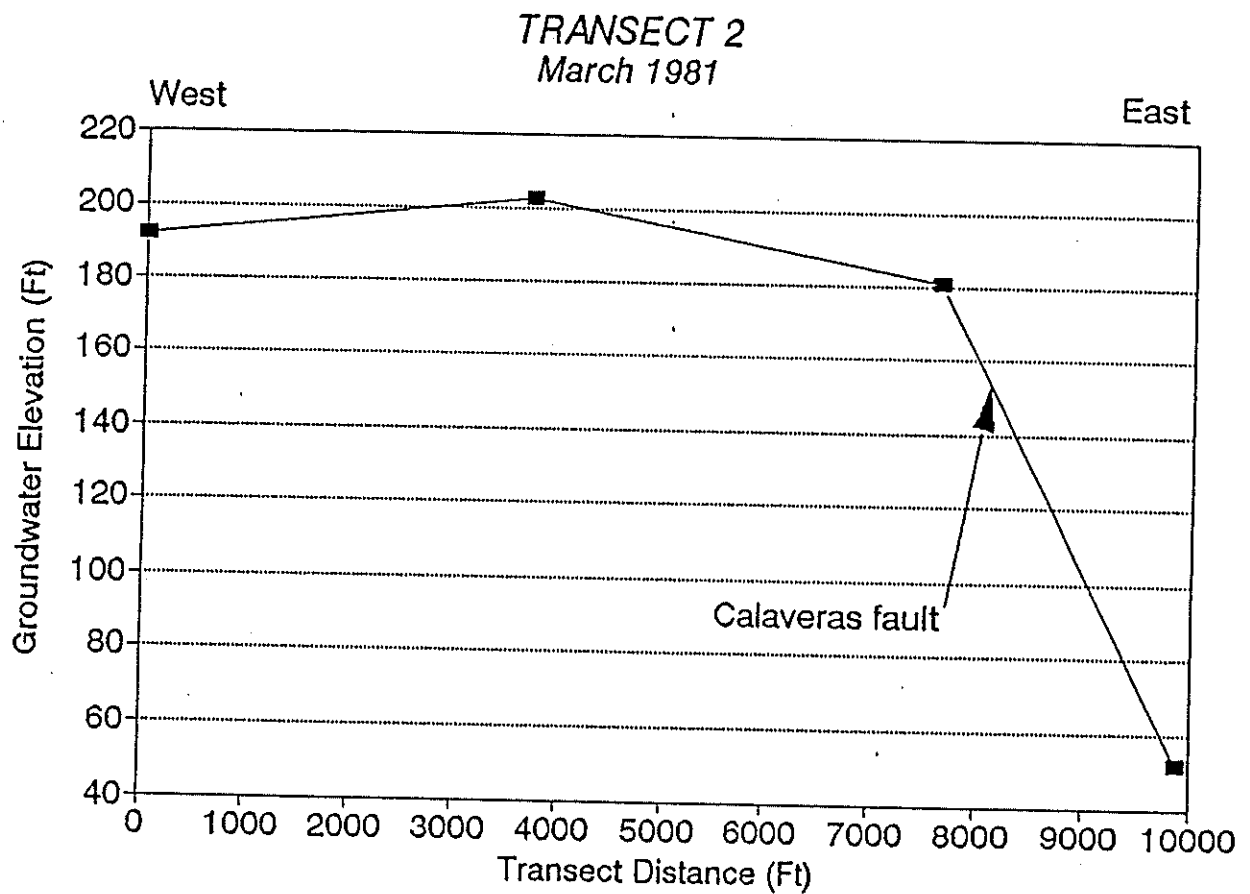
**FIGURE**

## 4.2

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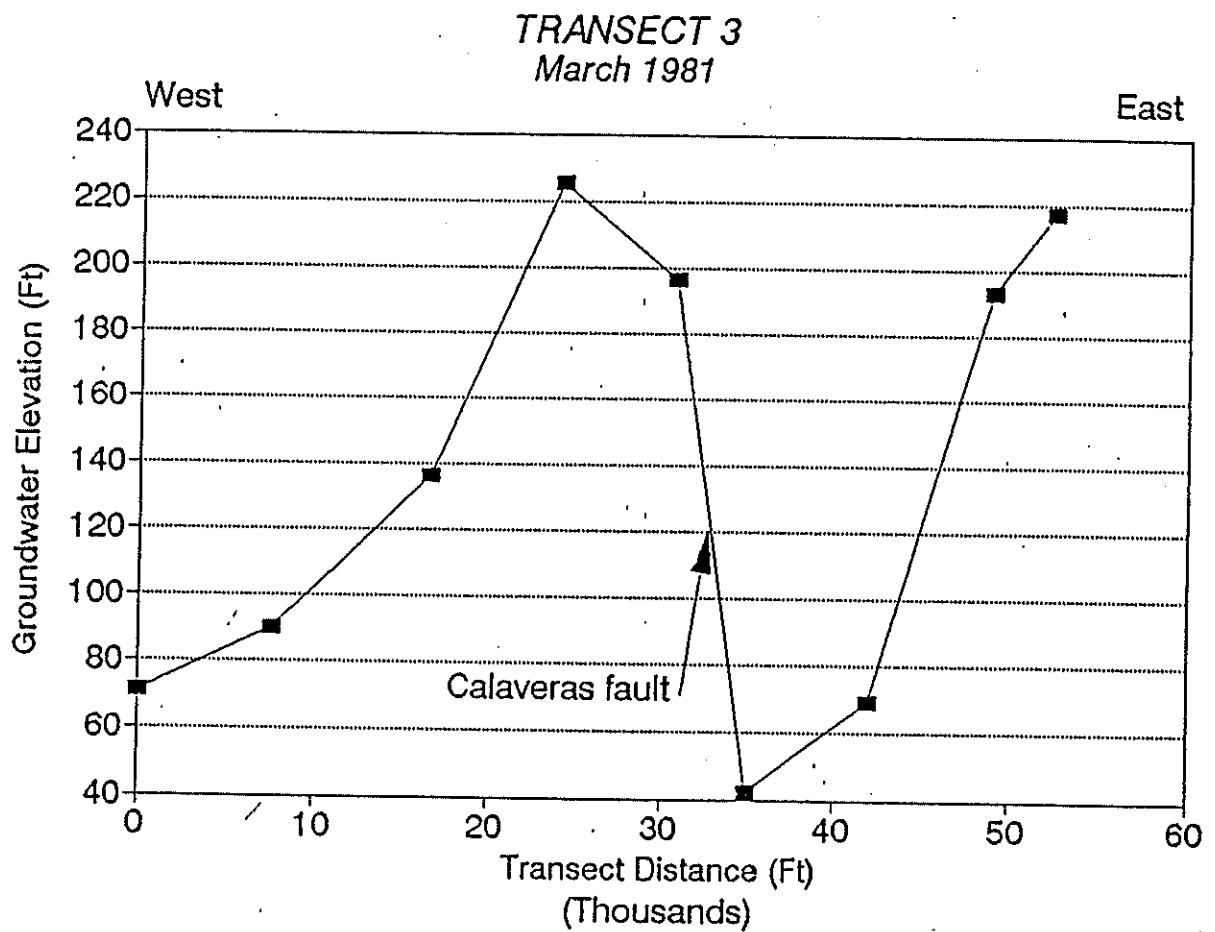
**FIGURE**  
**4.3**



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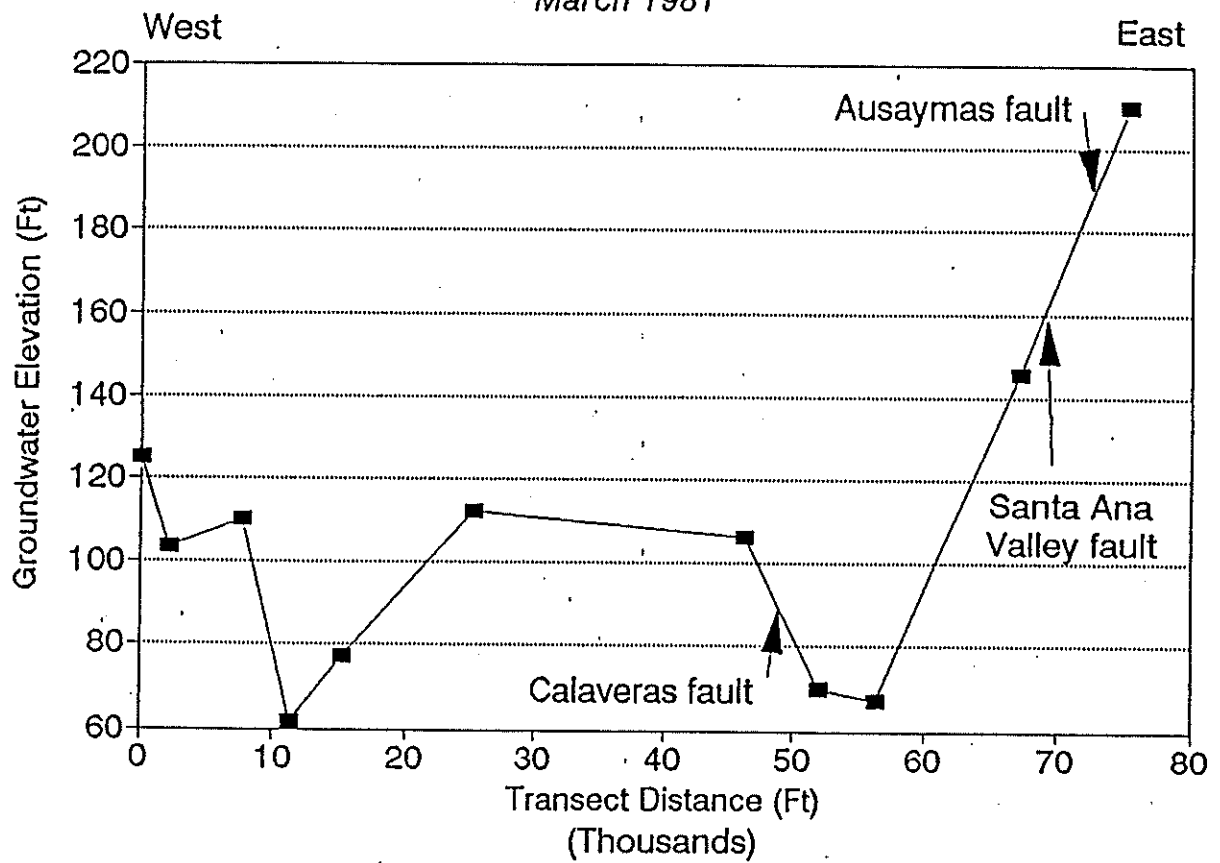
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FIGURE

4.4

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**TRANSECT 4**  
March 1981



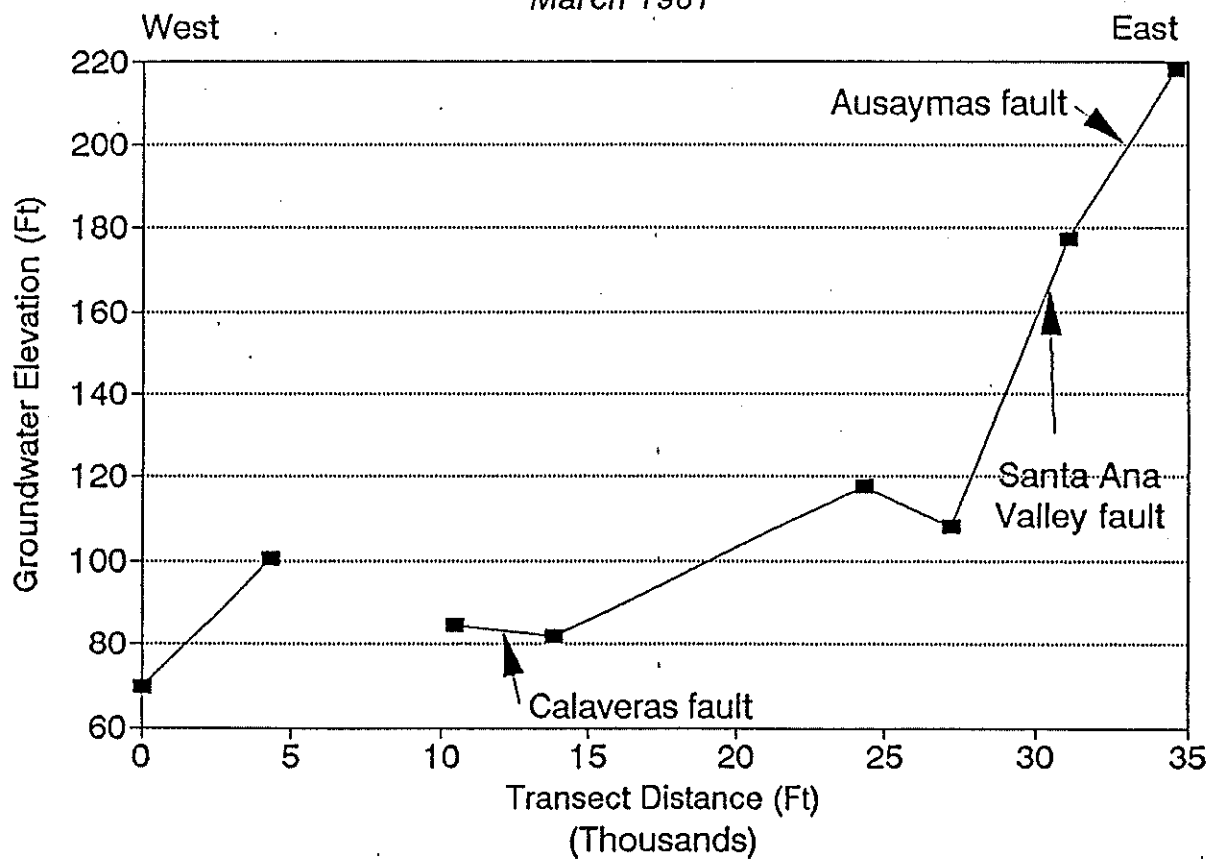
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**FIGURE**  
**4.5**

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**TRANSECT 5**  
March 1981



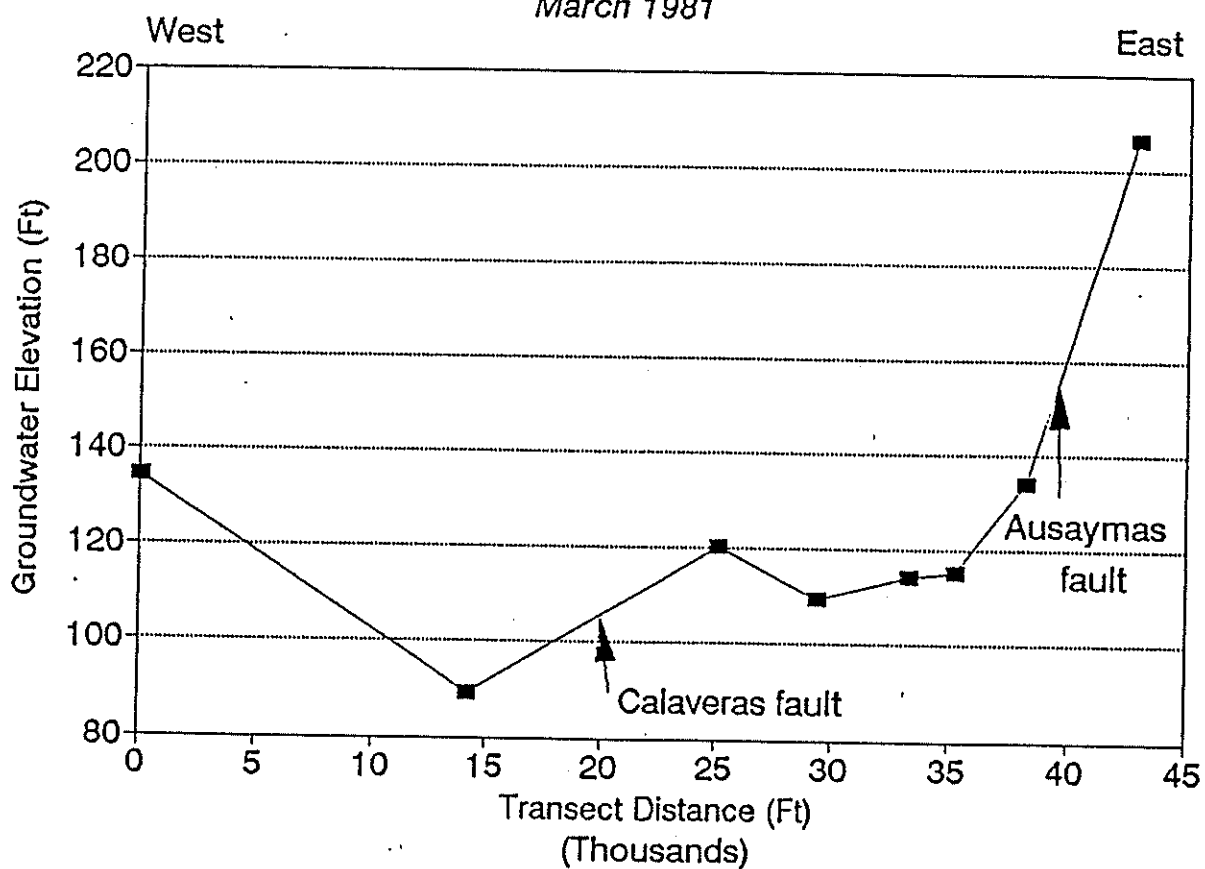
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**FIGURE**  
**4.6**

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TRANSECT 6  
March 1981



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FIGURE  
4.7

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reversed from pre-development conditions across the Calaveras fault in the southern portion of the study area. Further, the transects show that ground-water in the northern reach of the Calaveras fault flows across the Calaveras fault without significant restriction by the fault.

Transect 9 across the Tres Pinos Creek fault shows a difference in ground-water elevations of 300 feet in approximately one mile during 1980 (Figure 4.8). Thus, the fault appears to be a significant barrier to flow. Transect 10 runs parallel to and west of the Calaveras fault, crossing the Sargent fault. Ground-water elevations decreased 100 feet from south to north in one-half mile across the Sargent fault in 1980 (Figure 4.9). However, it is not clear whether this decrease is due to the fault or to a topographic restriction between the Flint Hills and a knoll associated with the Calaveras fault.

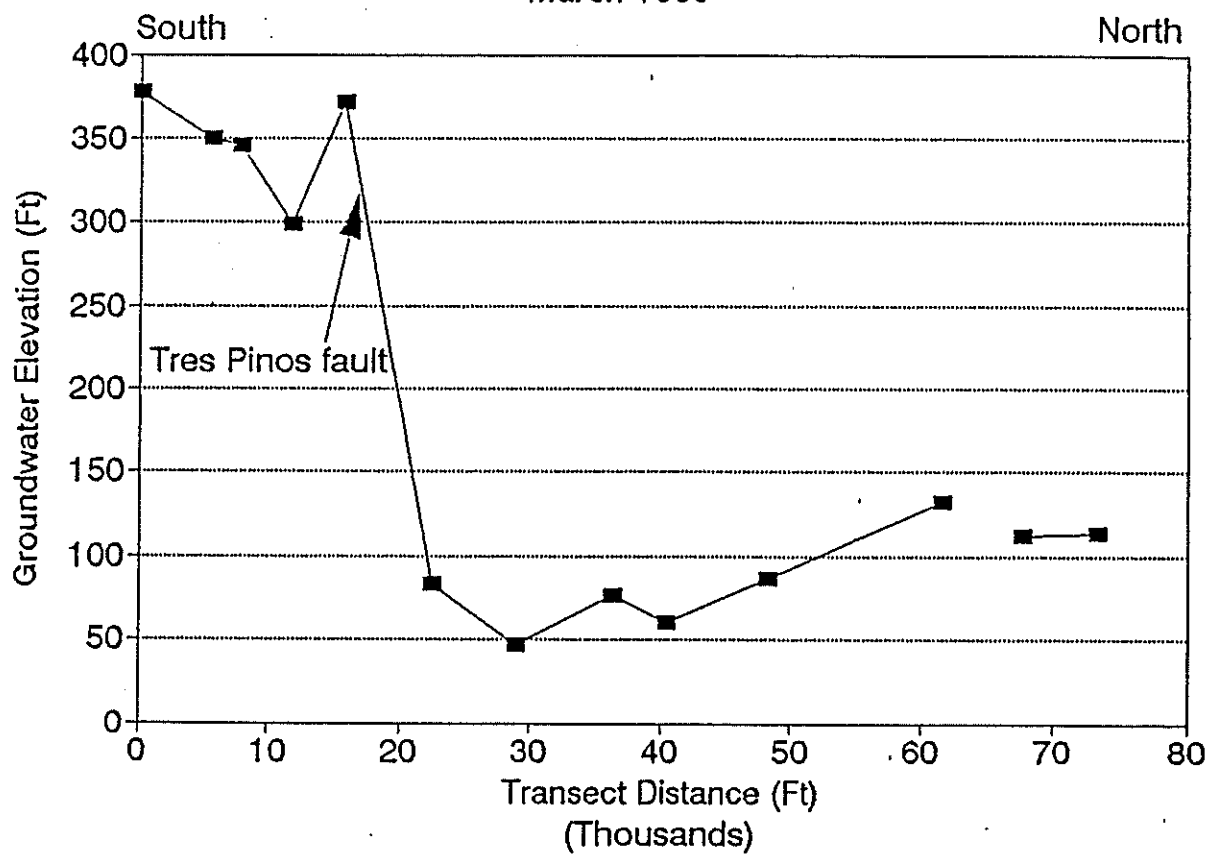
The Ausaymas and Santa Ana Valley faults do not appear to restrict ground-water flow as shown in Transects 4 and 5 (Figures 4.5 and 4.6).

Ground-water elevation contour maps were prepared for several periods from 1959 to 1990. Water level contour maps from October 1977 and October 1990 best illustrate the aquifer geometry and the effect of faults on ground-water flow (Figures 4.10 and 4.11). Both maps provide "worst-case" ground-water conditions since they represent the state of the basin after several years of drought and at the end of the growing season.

The contour maps confirm that the Calaveras fault, even at its southern end, is only a partial barrier to ground-water flow. The eastward flow of ground water from the San Juan Valley toward a cone of depression in the vicinity of Hollister is strong evidence of this statement. As reported by the USGS, ground-water flowed from the Hollister area toward the San Juan Valley prior to large scale development in the 1940's.

The Tres Pinos Creek fault appears to be an effective barrier to ground-water flow as evidenced by the sharp drop of ground-water elevation across the fault. The contour maps

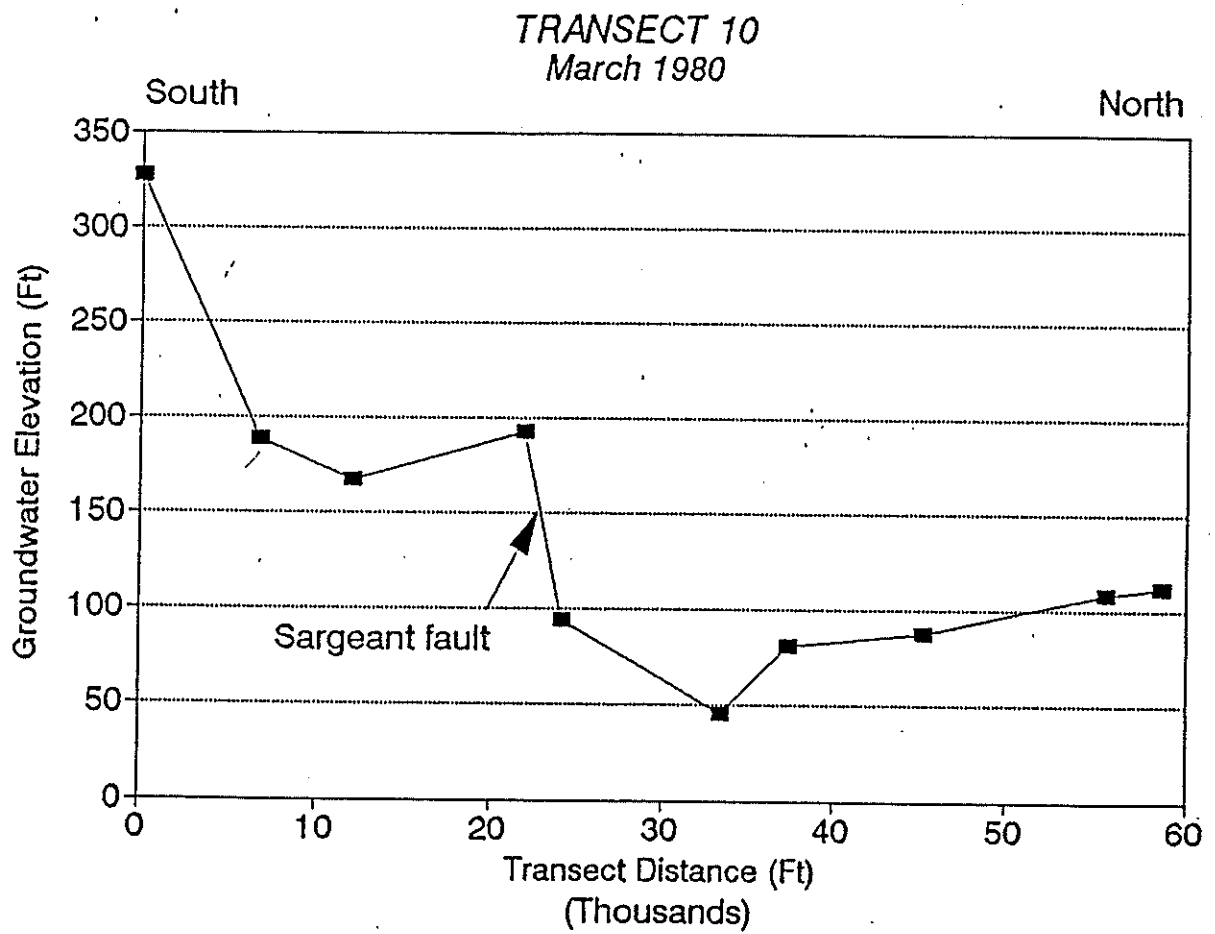
# TRANSECT 9 March 1980



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Ground-Water Investigation

FIGURE  
4.8  
90-1-084  
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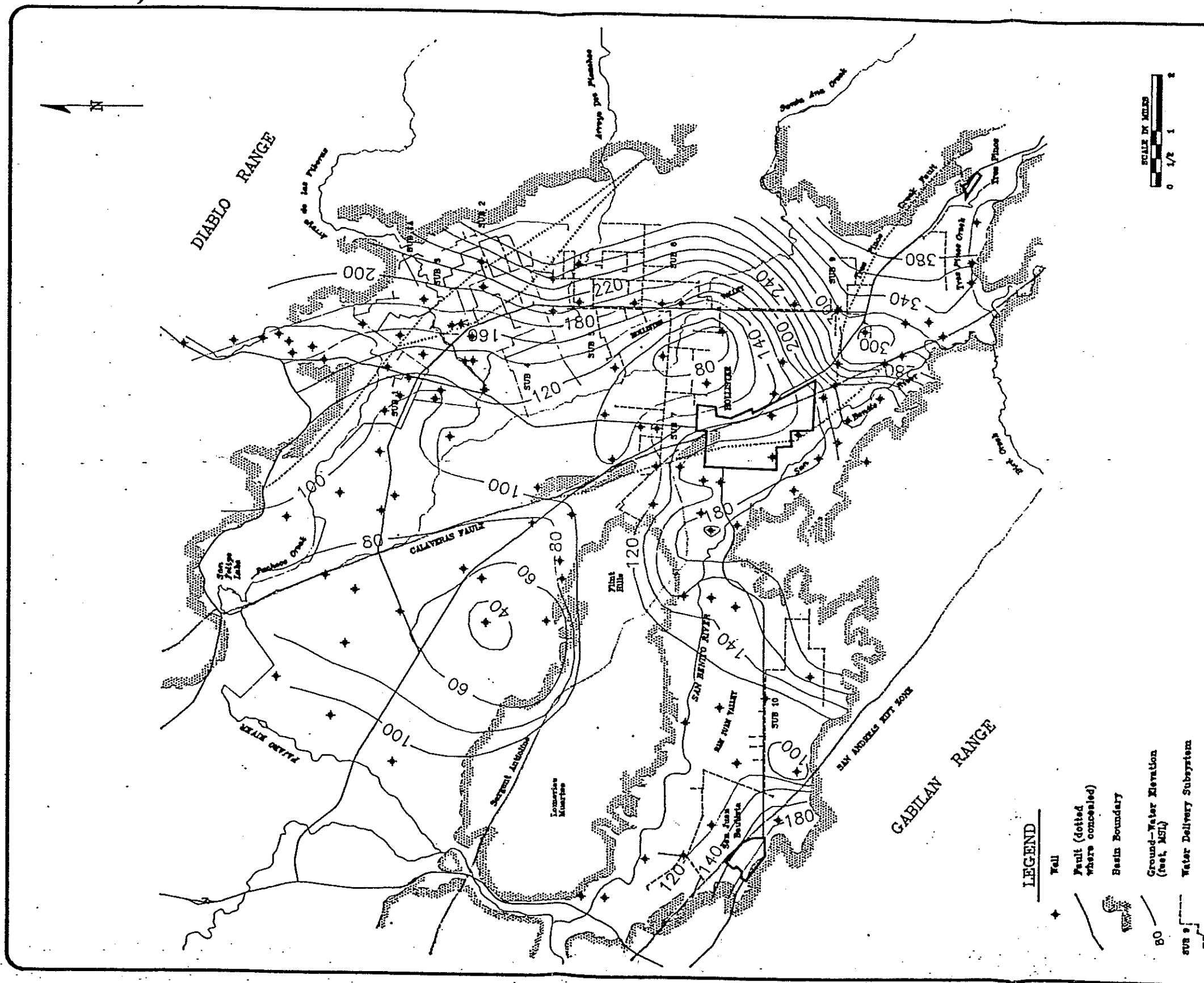


FIGURE 4.11

Contours of Equal Ground-Water Elevation, October 1990, San Benito County

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Ground-Water Investigation

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show no evidence of restricted ground-water flow across the Ausaymas and Santa Ana faults.

The contour maps also provide some insight into ground-water level trends. It can be seen that ground-water levels are generally higher in fall 1990 than in fall 1977. Although the large pumping cone of depression still exists east of Hollister, the ground-water elevation has risen between 1977 and 1990. The cone of depression in the northern portion of the study area just east of the Calaveras fault, evident in 1977, is not present in 1990. Ground-water elevations in the San Juan Valley have risen about 40 feet between 1977 and 1990. In contrast, the cone of depression in the northwestern portion of the study area (Bolsa Basin) has remained relatively constant.

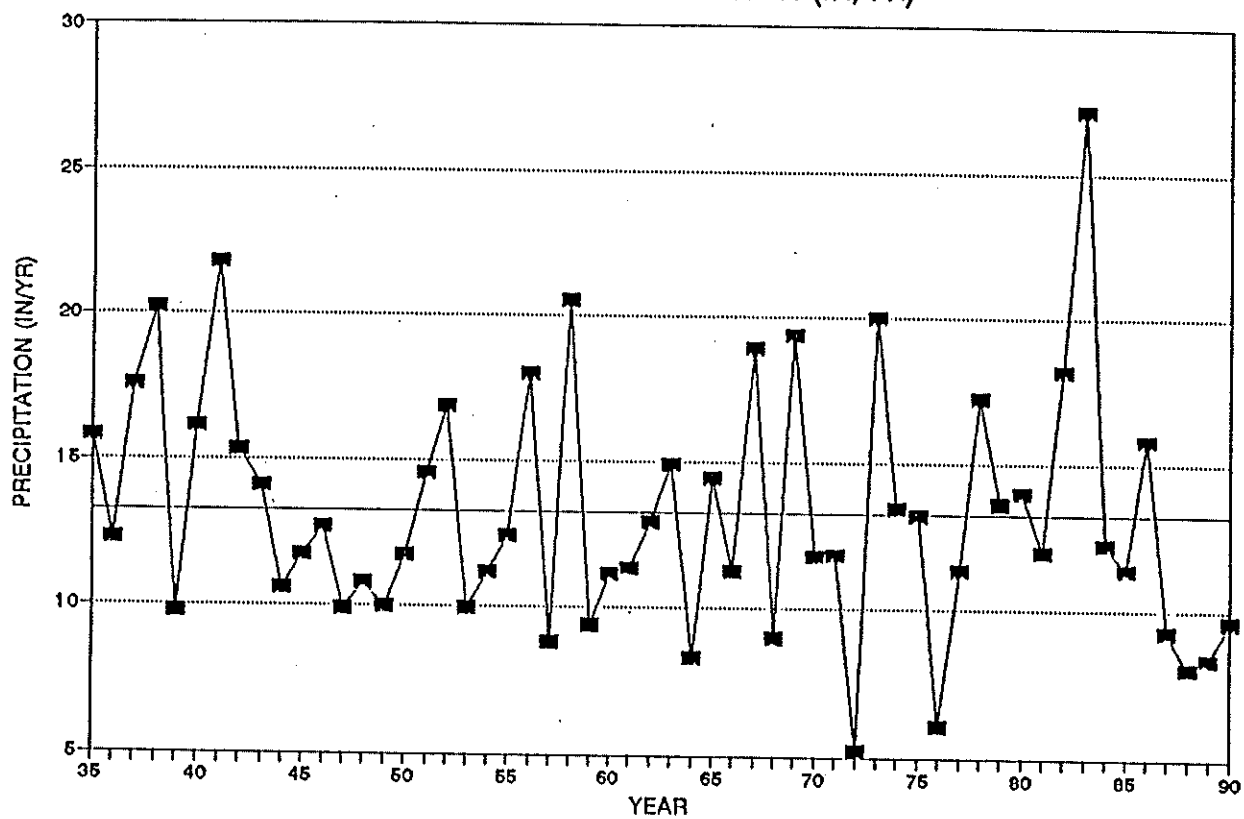
As more fully developed below, these observations are consistent with the conclusion that importation of San Felipe water has had a beneficial effect on ground-water levels.

### Ground-Water Level Trends

The discussion of ground-water level trends is based on the hydrographs of ground-water levels in selected wells shown on Figure 4.1, and is organized by groups of wells in the various identified basins: Pacheco, Hollister, Bolsa, and San Juan. In addition, hydrographs of wells in areas along the San Benito River, and in the areas where Tres Pinos Creek and the San Benito River flow into the Hollister Basin are discussed. All hydrographs discussed are presented in Appendix A.

Since precipitation is the primary source of ground water in the area up to 1987, and represents the most significant source of ground water since 1987, it follows that periods with higher than average precipitation will cause a general rise in ground-water levels and periods with less than average precipitation will cause a general decline in ground-water levels. Relatively wet and dry periods can be seen in Figure 4.12 which depicts the annual precipitation at Hollister from 1935 to 1990. Average precipitation during this period was 13.25 inches per year, and is shown as a horizontal line on the graph.

# HOLLISTER PRECIPITATION (IN/YR)



ACTUAL PRECIP     
 
 1935-1990 AVERAGE



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FIGURE

4.12

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**Pacheco Creek Area** - This area is outside of Zone 6 of the SBCWD (the area within which all San Felipe deliveries are made) and therefore receives no imported water. Hydrographs of wells (e.g. T11S/R5E-13D1) depict a slight downward trend since the late 1930's. Periodic declines in water levels correspond to periods with below average precipitation. Note that the lowest water levels on record have occurred during the current drought.

**Hollister Basin** - This "basin" can be further subdivided into areas with imported water and areas without imported water. The hydrographs of wells in areas without imported water (e.g. T11S/R5E-28B1, T11S/R5E-27P2, T11S/R5E-35C1, T11S/R5E-36M1, and T12S/R5E-3B1) all depict a general downward trend since the late 1930's and a strong response to the droughts of the late 1970's and late 1980's with a strong recovery in the early and mid 1980's. The hydrographs of wells in areas where imported water has been applied (e.g. T12S/R5E-24N1, T12S/R5E-36B20, T12S/R6E-6K1 and T12S/R6E-7P1) depict the same general downward trend since the late 1930's and response to the drought of the late 1970's as areas outside of imported water application. However, since the commencement of supplemental surface water importation in 1987, declines in water levels are either non-existent or the decline is not as dramatic.

**Tres Pinos/Hollister Boundary** - The ground-water conditions in the area where Tres Pinos Creek flows into the Hollister Basin is depicted by the hydrograph of Well T13S/R6E-20K1. The fluctuations of water levels correspond to wet and dry periods, and the lack of a long term trend since the early 1950's appears to indicate that the long term average inflow from the Tres Pinos area has not been affected by pumping in the Tres Pinos area. Annual inflow, however, is likely variable due to recharge and changes in pumping in the Tres Pinos area in wet and dry years.

**Paicines/Hollister Boundary** - The area where the San Benito River flows into the Hollister Basin represents the boundary between the Paicines area and the Hollister Basin. As in the Tres Pinos/Hollister boundary area, the hydrograph of Well T13S/R5E-13J2 indicates no long term trend, only fluctuations due to recharge/pumping conditions in the Paicines area.

Below the "boundary" area, the hydrograph of well T13S/R5E-11Q1 depicts conditions along the San Benito River south of Hollister. The slight downward trend, and fluctuations that correspond to wet and dry periods appear to be consistent with a well that receives recharge from a nearby river in an area where regional pumping exceeds regional recharge.

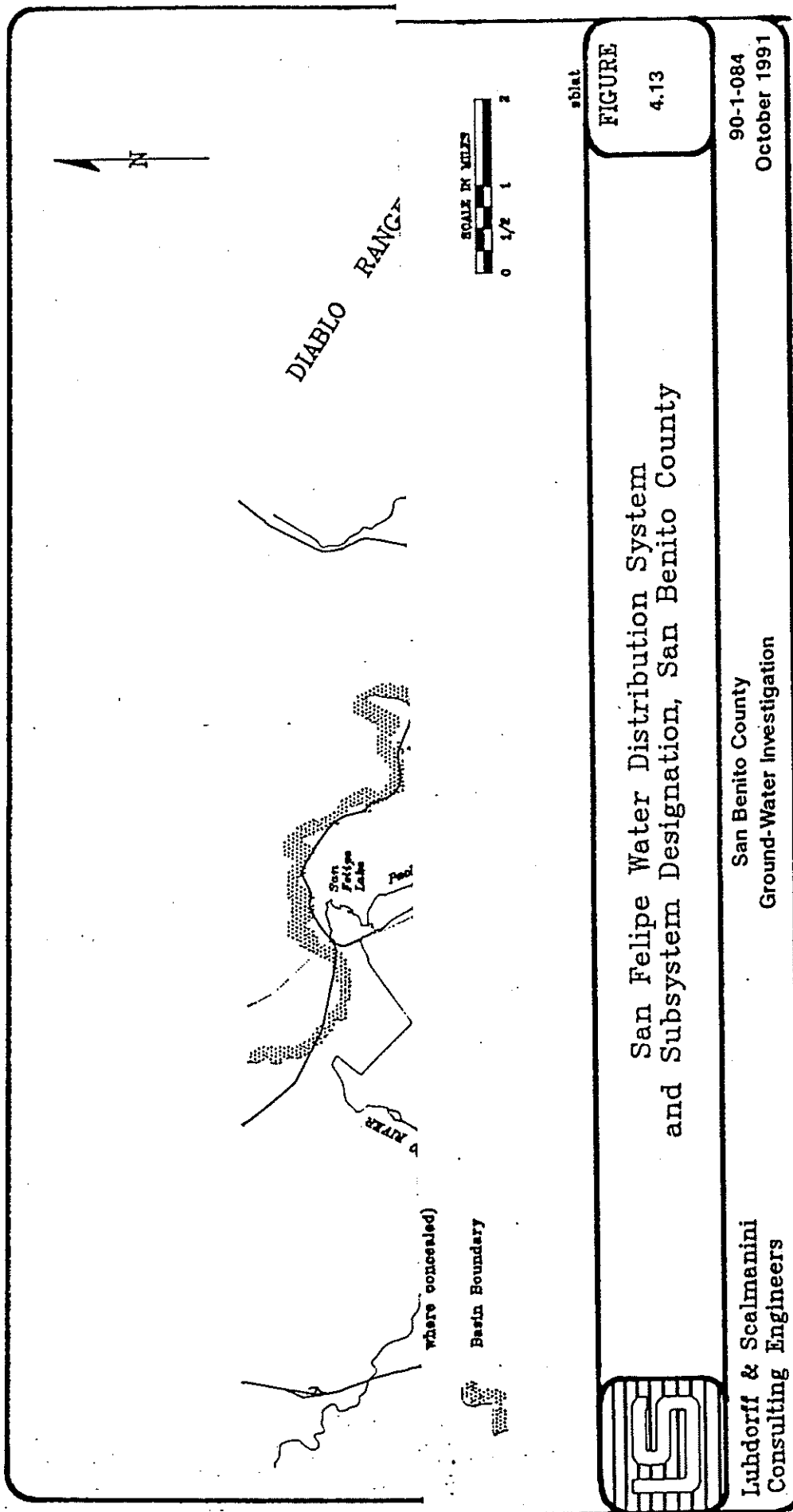
**Bolsa Basin** - This area is a significant distance from the area where imported water is applied. Hydrographs of wells in this area (e.g. T11S/R5E-31F1, T12S/R5E-17D1, and T12S/R5E-22N1) depict significant long term decline and fluctuations corresponding to the wet and dry periods. In some areas, the wet period of the early and mid-1980's did not cause any significant recovery, while in other areas, recovery has been followed by a steep drop in water level in the late 1980's.

**San Juan Basin** - In areas where no San Felipe water was delivered (e.g. T12S/R4E-20C1) water levels have declined since the 1950's. In areas where San Felipe water has been applied as irrigation water (e.g. T13S/R4E-1K1), water levels have recovered dramatically since the mid 1980's and have remained at a level that is relatively high even during the current drought. In areas adjacent to San Felipe deliveries (e.g. T13S/R4E-3H1), the long term decline has not been dramatically reversed, but water levels have stabilized somewhat, apparently due to the beneficial effects of recharge from irrigation water.

#### Effect of San Felipe Water on Ground-Water Levels

San Felipe deliveries began in September 1987. Since then, the San Benito County Water District has maintained records of deliveries on a monthly basis by individual meter. The distribution system has been subdivided by the district into various subsystems as depicted in Figure 4.13. These data were analyzed in conjunction with ground-water level data to evaluate the effects of this imported water on the ground-water flow system.

Figure 4.14 depicts the amount of total San Felipe deliveries from September 1987 to December 1990 in six month increments. Note that deliveries in the April 1987 to

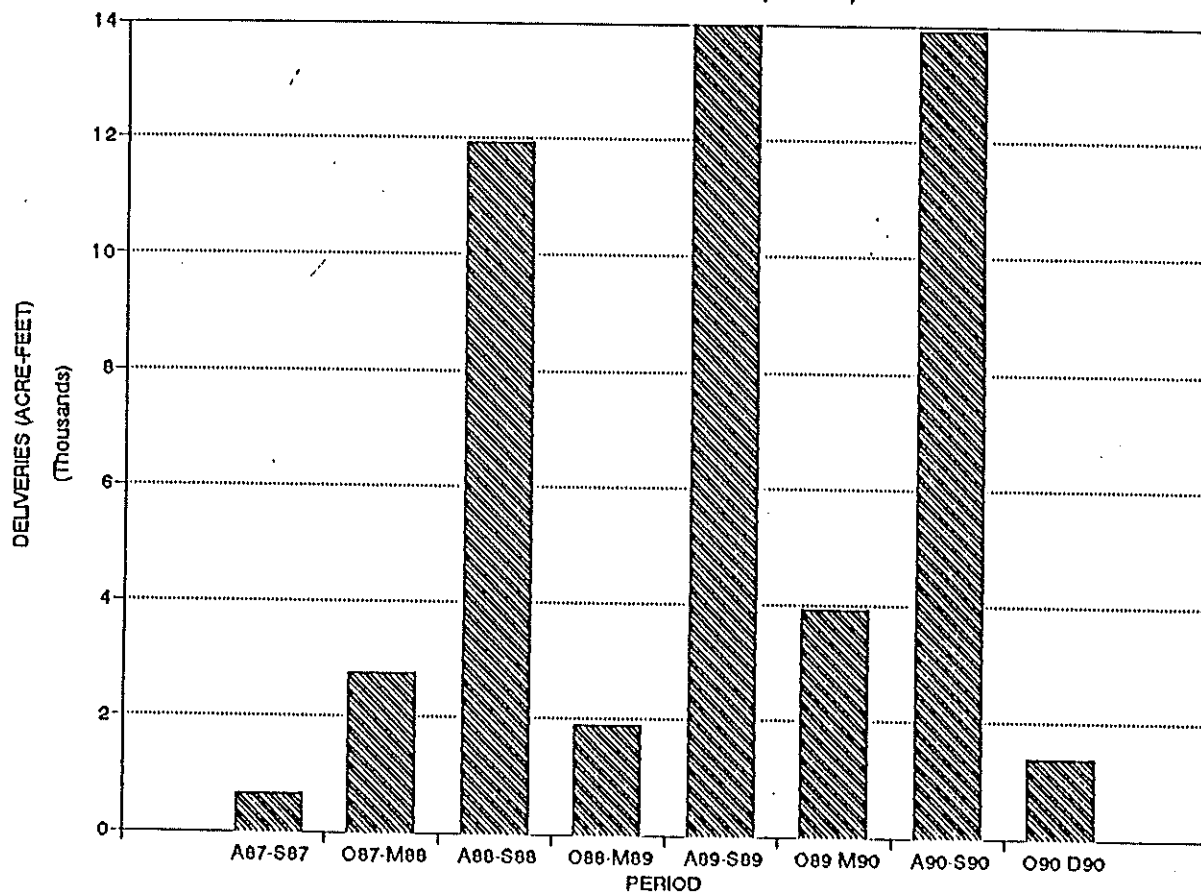


# San Felipe Water Distribution System and Subsystem Designation, San Benito County

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# SAN BENITO COUNTY WATER DISTRICT SAN FELIPE DELIVERIES (TOTAL)



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FIGURE  
4.14

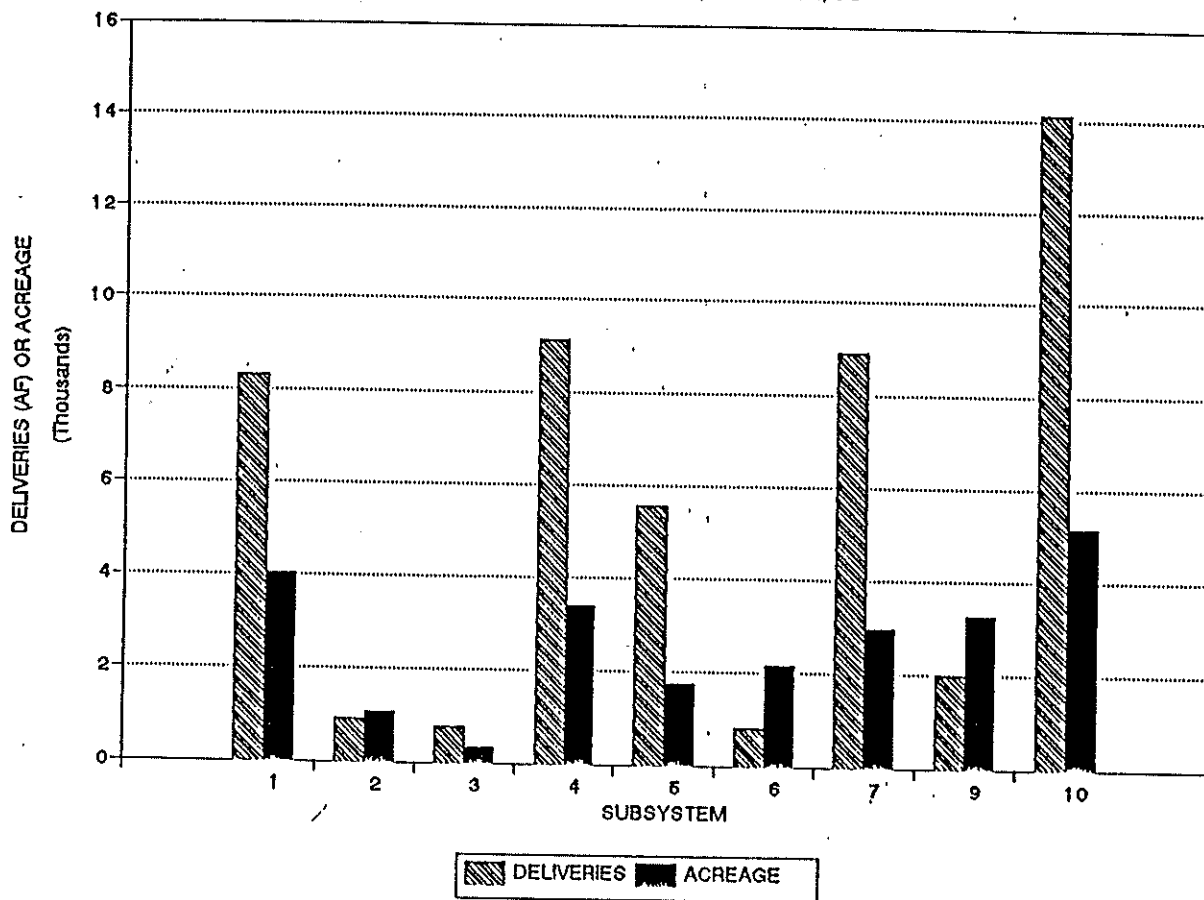
September 1987 period is extremely low due to the fact that deliveries only occurred in the last month of that period. Note also that deliveries in the April to September period, which corresponds to the irrigation season, are significantly higher than in the October to March period.

The total deliveries from September 1987 to December 1990 are broken down into subsystem deliveries in Figure 4.15. Total acreage in each subsystem is also presented in Figure 4.15. It can be seen that some subsystems have received substantially more water than others on a total volume (acre-foot) basis and on a unit (acre-foot per acre) basis. It follows that areas such as Subsystem 10 should realize more ground-water benefit from imported water delivery than areas such as Subsystem 9.

Figures 4.16 to 4.21 depict imported water deliveries by subsystem from September 1987 to October 1990 in six month increments along with a hydrograph of a well in that particular subsystem. For reference to ground-water trends, the hydrograph covers the period March 1980 to October 1990. It can be seen from these figures that, in general, the subsystems with the highest San Felipe water deliveries exhibit the most ground-water level recovery. Areas with relatively low imported water deliveries (Subsystems 6 and 9) exhibit only moderate levels of recovery. This phenomenon can be attributed to the fact that imported water causes two type of benefits: 1) reduction in pumping and 2) increase in ground-water recharge. It is generally accepted in San Benito County that when an individual farmer takes San Felipe water and uses the water for irrigation, ground-water pumping is reduced by an approximately equivalent amount. This is in contrast to a situation in other areas where the imported water is used to increase irrigated acreage.

Increased ground-water recharge is assumed to occur since the evapotranspiration demands are typically lower than the amount of applied water. Prior to the importation of supplemental water, some of the pumped ground water would deep percolate back into the ground-water basin. Since the introduction of imported water on an individual farm will still result in deep percolation of excess irrigation water, the deep percolation of this imported

# SAN BENITO COUNTY WATER DISTRICT TOTAL DELIVERIES 9/87 TO 12/90

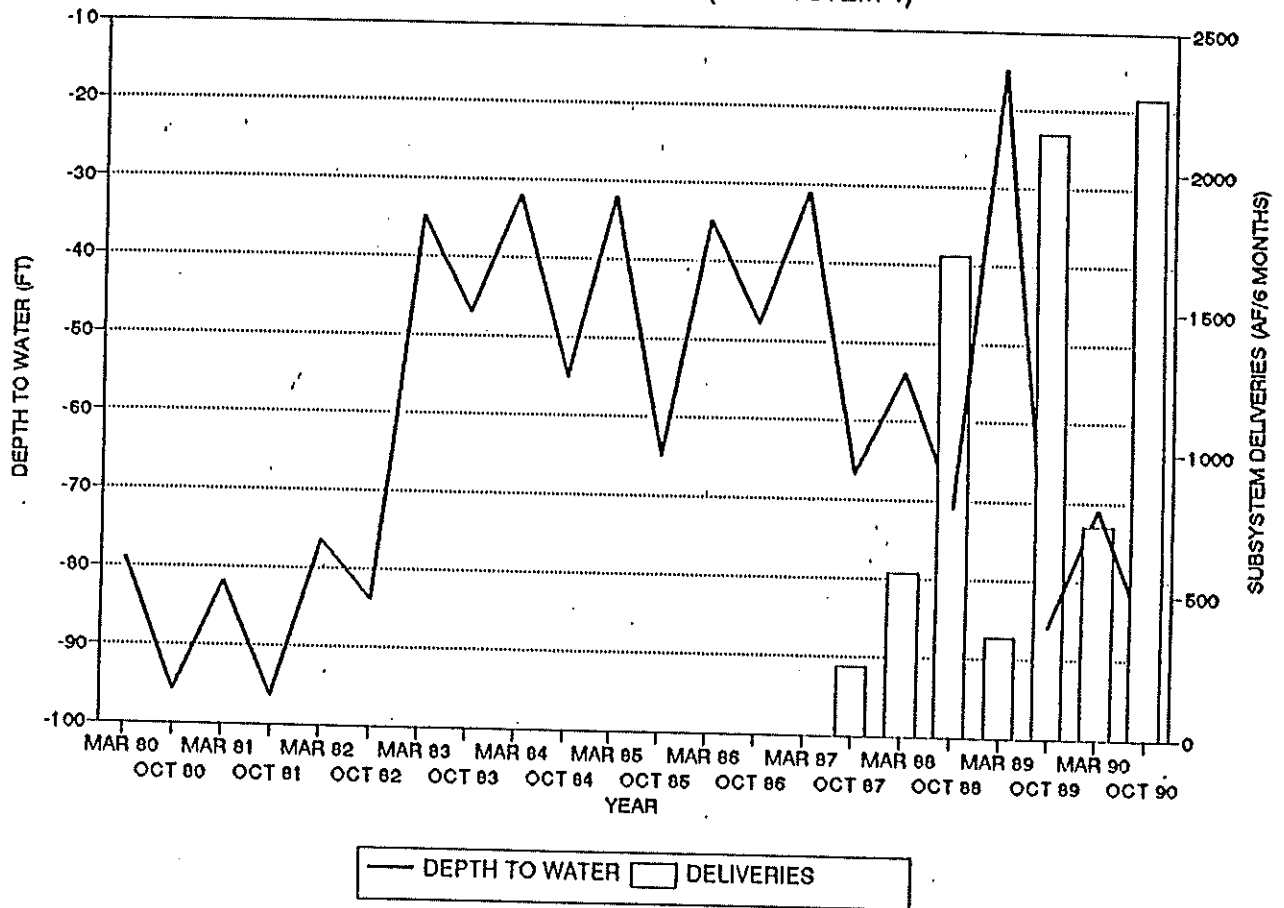


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FIGURE  
4.15  
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# WELL T11R5-35C1 HYDROGRAPH AND SAN FELIPE DELIVERIES (SUBSYSTEM 1)



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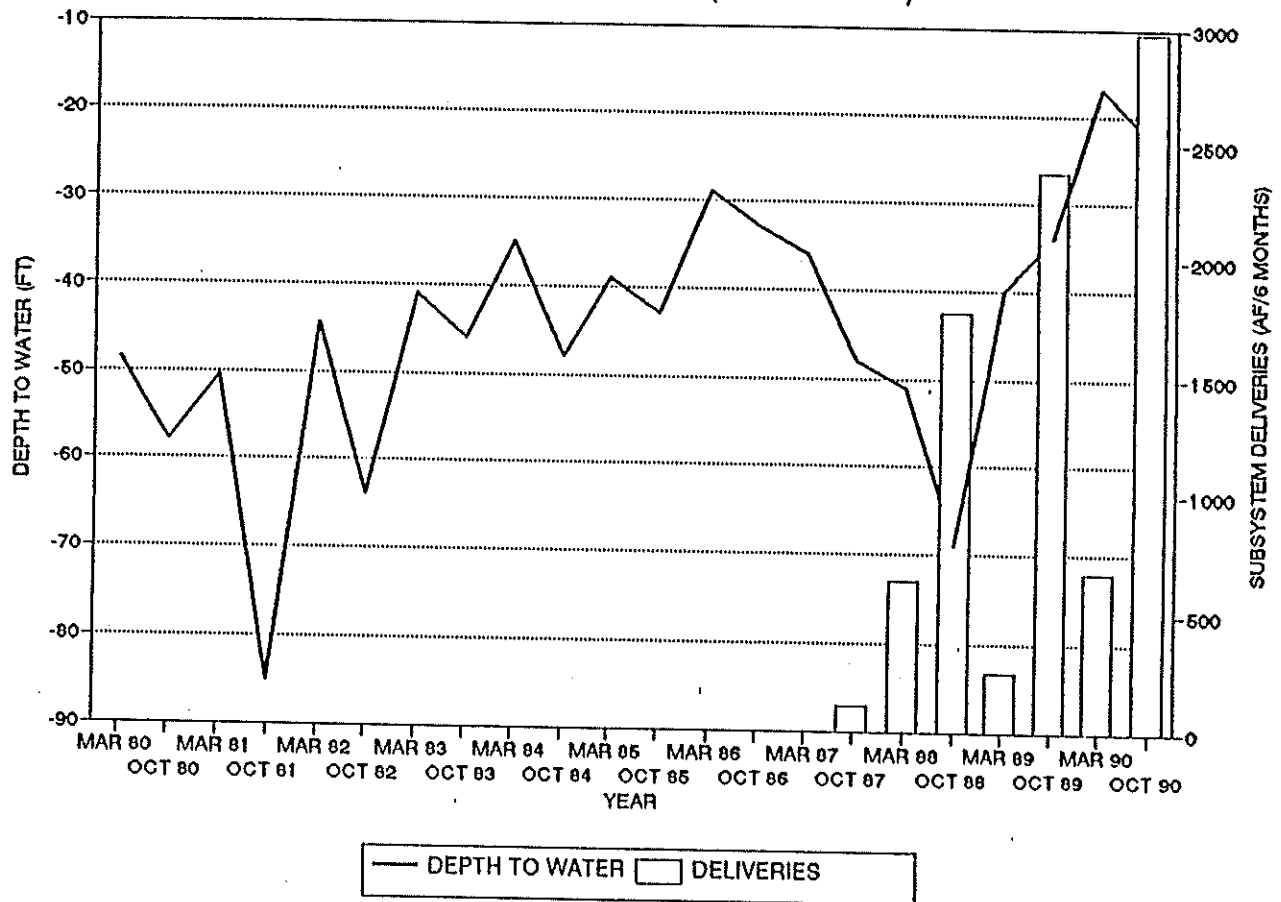
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FIGURE

4.16

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# WELL T12R6-6K1 HYDROGRAPH AND SAN FELIPE DELIVERIES (SUBSYSTEM 4)



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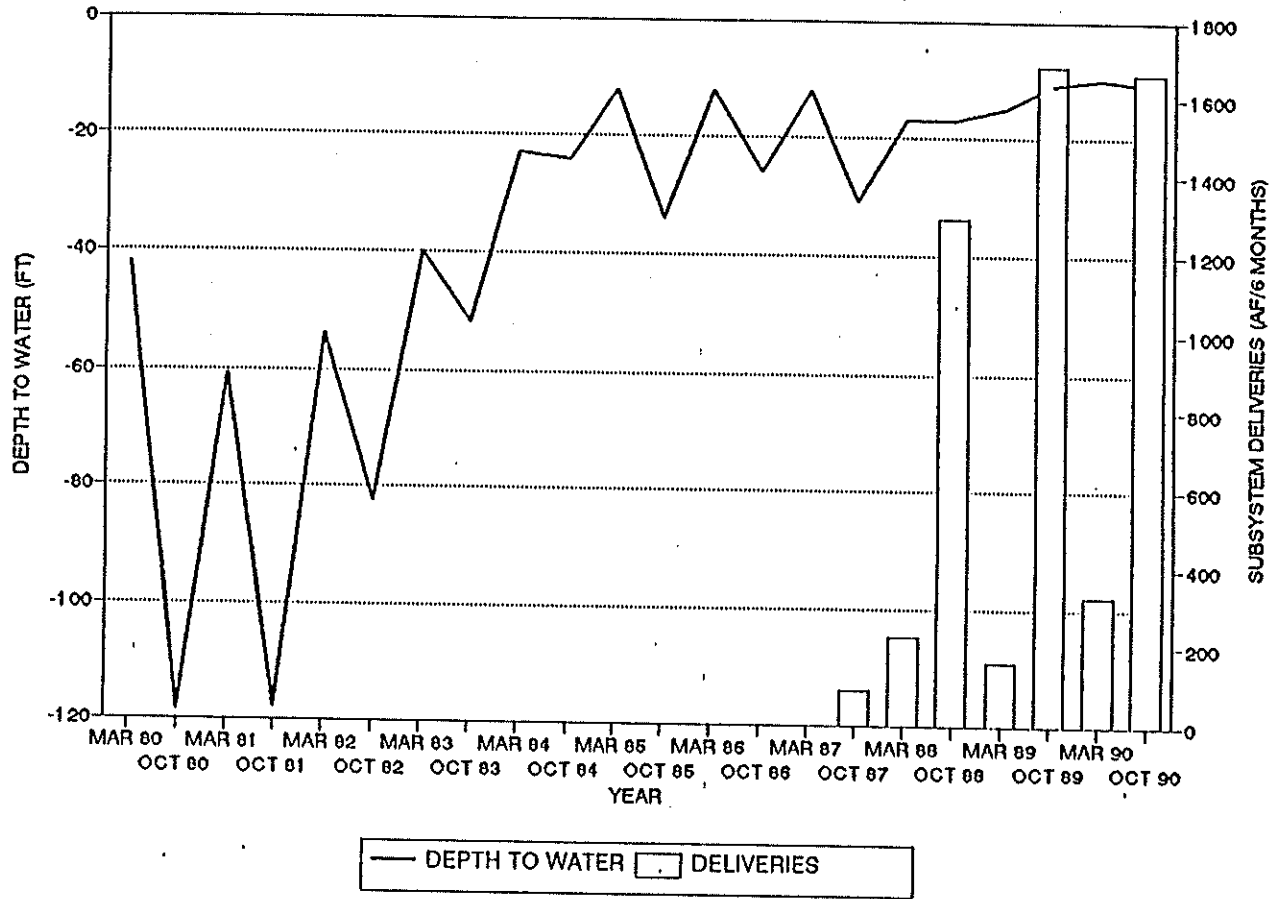
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FIGURE

4.17

# WELL T12R6-7P1 HYDROGRAPH AND SAN FELIPE DELIVERIES (SUBSYSTEM 5)



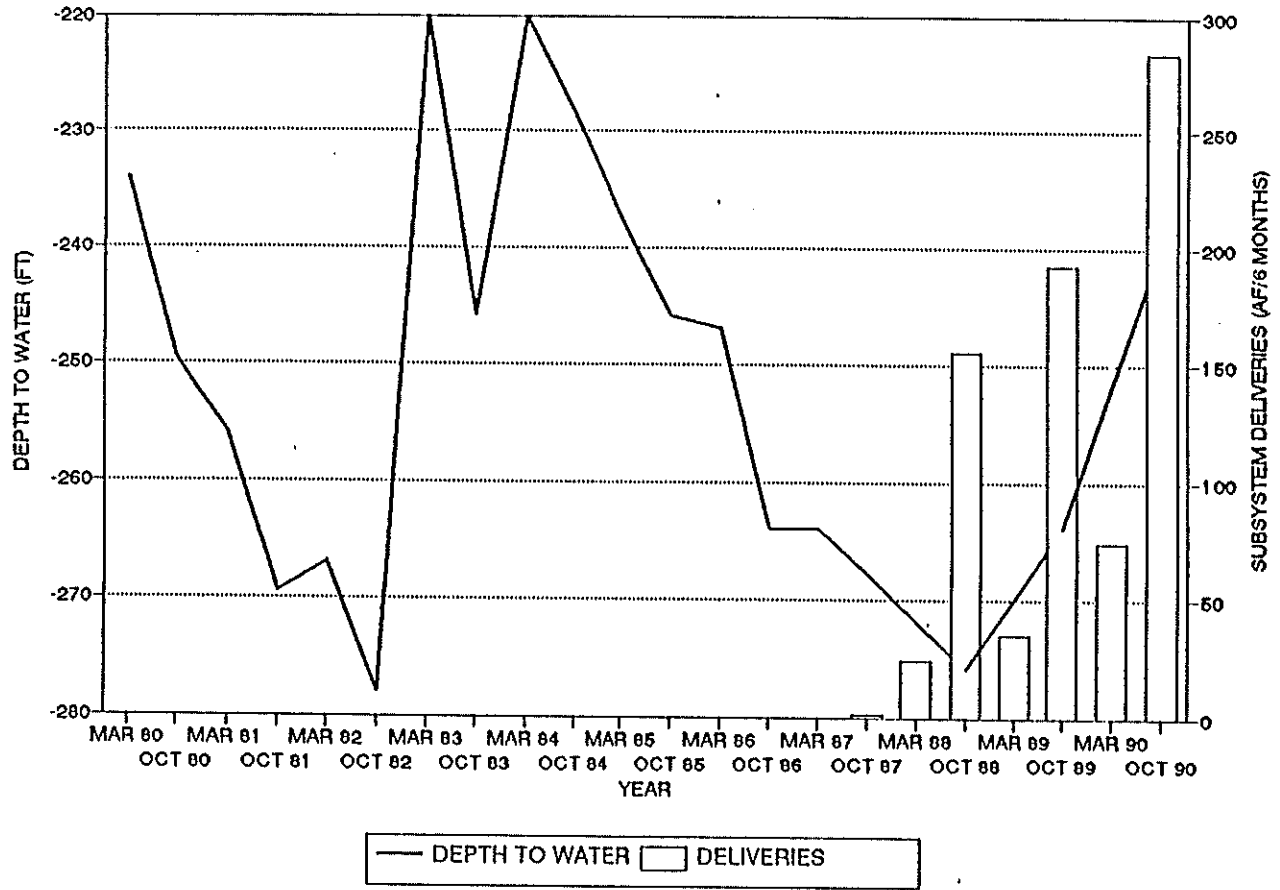
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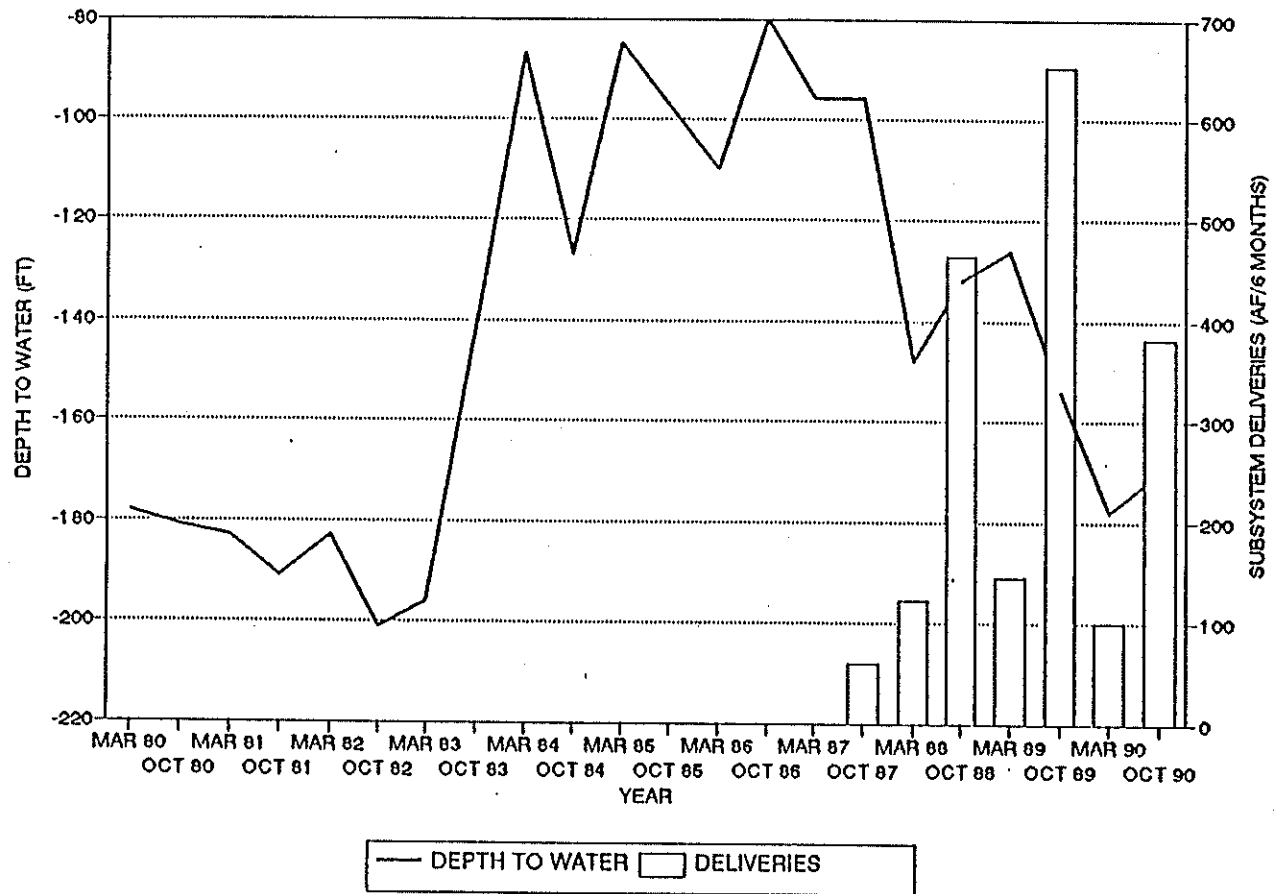
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FIGURE  
4.18

WELL T12R5-36B20 HYDROGRAPH AND  
SAN FELIPE DELIVERIES (SUBSYSTEM 6)



# WELL T13R6-07D2 HYDROGRAPH AND SAN FELIPE DELIVERIES (SUBSYSTEM 9)



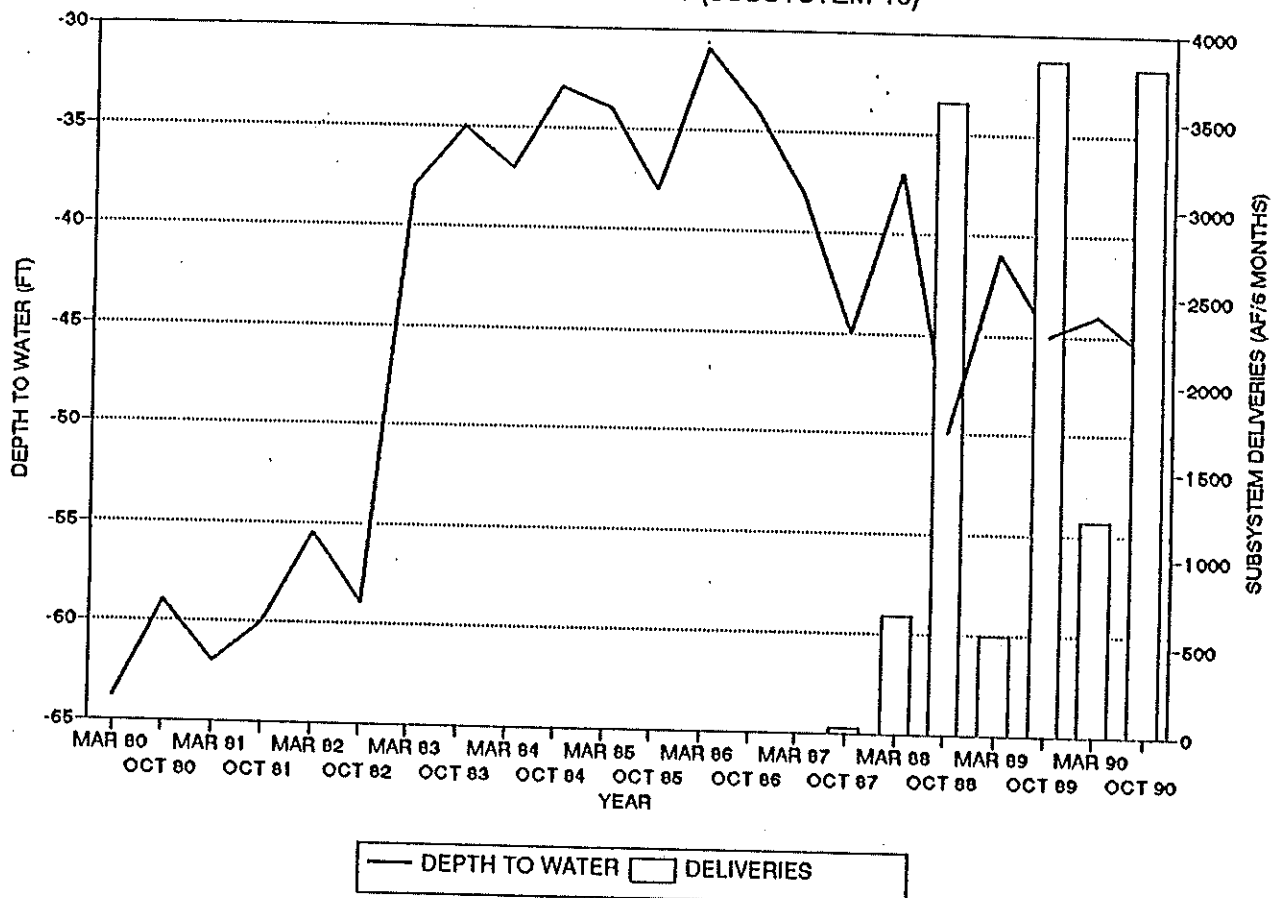
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FIGURE  
4.20

# WELL T13R4-01K1 HYDROGRAPH AND SAN FELIPE DELIVERIES (SUBSYSTEM 10)



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FIGURE  
4.21  
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water can be considered a "new" recharge source which will contribute to a rise in water levels.

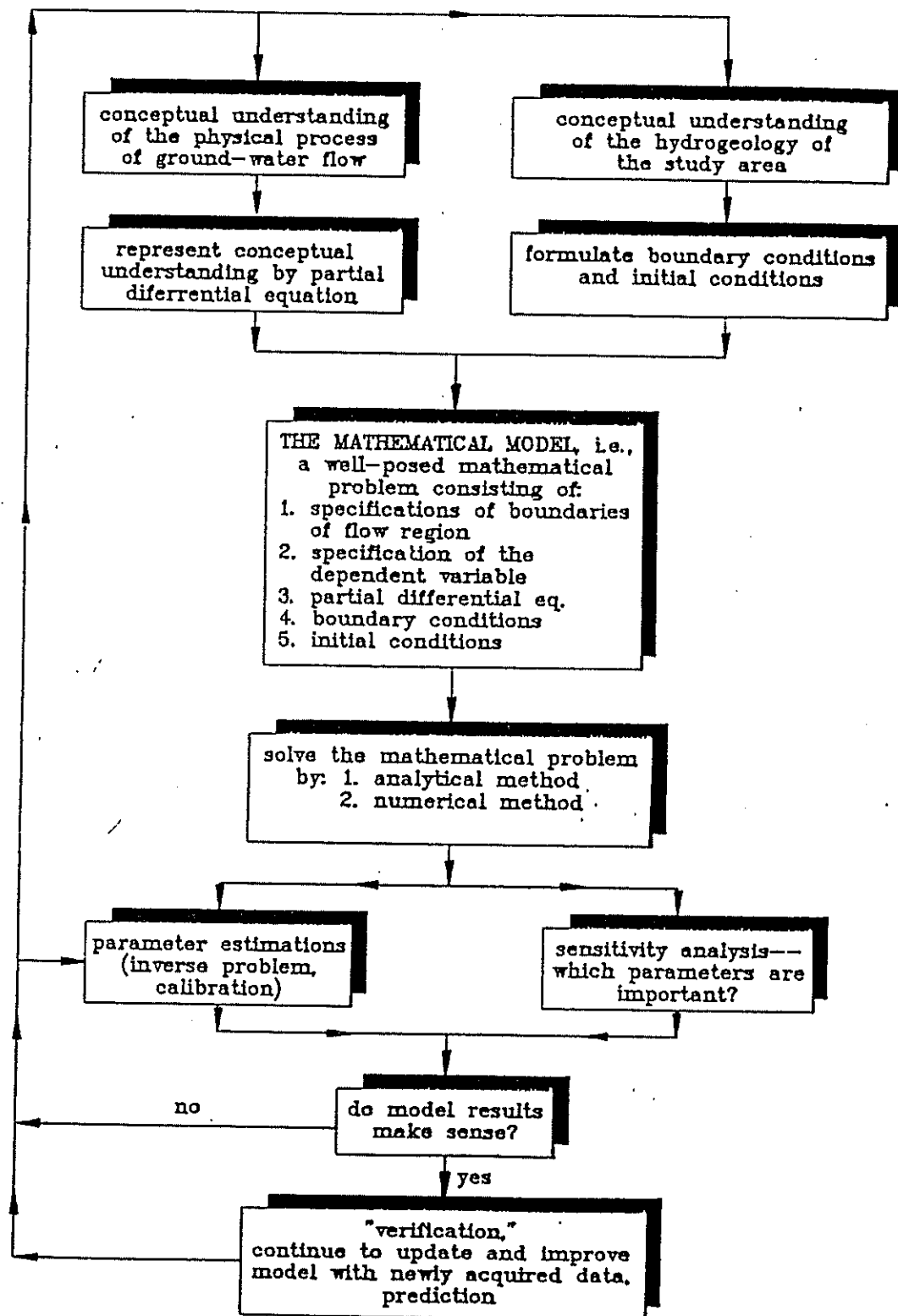
### Definition of a Ground-Water Model

The review of the geologic and hydrologic data allowed for the development of concepts and data that can be used to formulate a ground-water model of the area. Prior to a discussion of model development and the details of the model, the following description of a ground-water model is offered to place the objectives of this effort, and the methods that are being used, into perspective.

A ground-water model can be defined as a simplified version of a real ground-water system that approximately simulates the response of the system to identified stresses. The response of the system is usually "measured" in terms of hydraulic head (ground-water level) changes, and examples of identified stresses include pumping and recharge from excess irrigation water. Results of the model include the calculated ground-water levels throughout the model area and a summary of the inflows to and outflows from the modeled ground-water system, and the storage change in the area over a specified period of time. This calculated ground-water budget of the model area can be used in conjunction with other information to develop estimates of "safe yield" of the area under a given set of assumptions.

The process of developing a ground-water model is depicted in Figure 4.22, and begins with the development of a conceptual model of the ground-water system. This conceptual model is generally developed after a review of available reports on the geology and hydrology of the area, development of an understanding of how ground-water resources are developed and "managed", and a detailed analysis of ground-water level data.

The process continues by translating this conceptual model into a mathematical model and defining a "well-posed mathematical problem" that consists of the governing equations of flow and all pertinent boundary conditions. The mathematical problem is then solved by a



chosen method, in this case a numerical approach utilizing finite-differences through the use of a well documented FORTRAN program (MODFLOW) developed by the U.S. Geological Survey (McDonald and Harbaugh, 1988).

The process then enters an iterative stage (calibration) in which the model estimates of head and water budget are compared to historical data; and the estimates of parameters that define the ground-water flow system and the details of boundary condition specification are adjusted in order to cause the model estimated heads to agree, as closely as possible, with the historic data. The calibration period in this model is fall 1987 to fall 1990 in six month increments. Actual heads for fall 1987 were used to initialize the model, and heads in the spring and fall of each year were calculated and compared to historic data.

### Conceptual Model of Ground-Water System

The development of any ground-water model begins with the development of a conceptual model of the ground-water system of interest. This conceptual model consists of a set of assumptions that reduce the real system and its inherent complexities, all of which cannot be simulated, to a simplified version that is acceptable in view of the objectives of the investigation. Necessary components of the conceptual model include:

- Aquifer geometry
- Conceptualization of how ground-water flows into and out of the identified flow system
- Mode of flow (i.e. two or three dimensional)
- Conceptualization of how rivers interact with the ground-water flow system
- Location of recharge and discharge areas within the system
- Nature of the aquifer materials

The conceptual model of the ground-water system in the North County area including the basic components of inflow and outflows is shown diagrammatically on Figure 4.23.

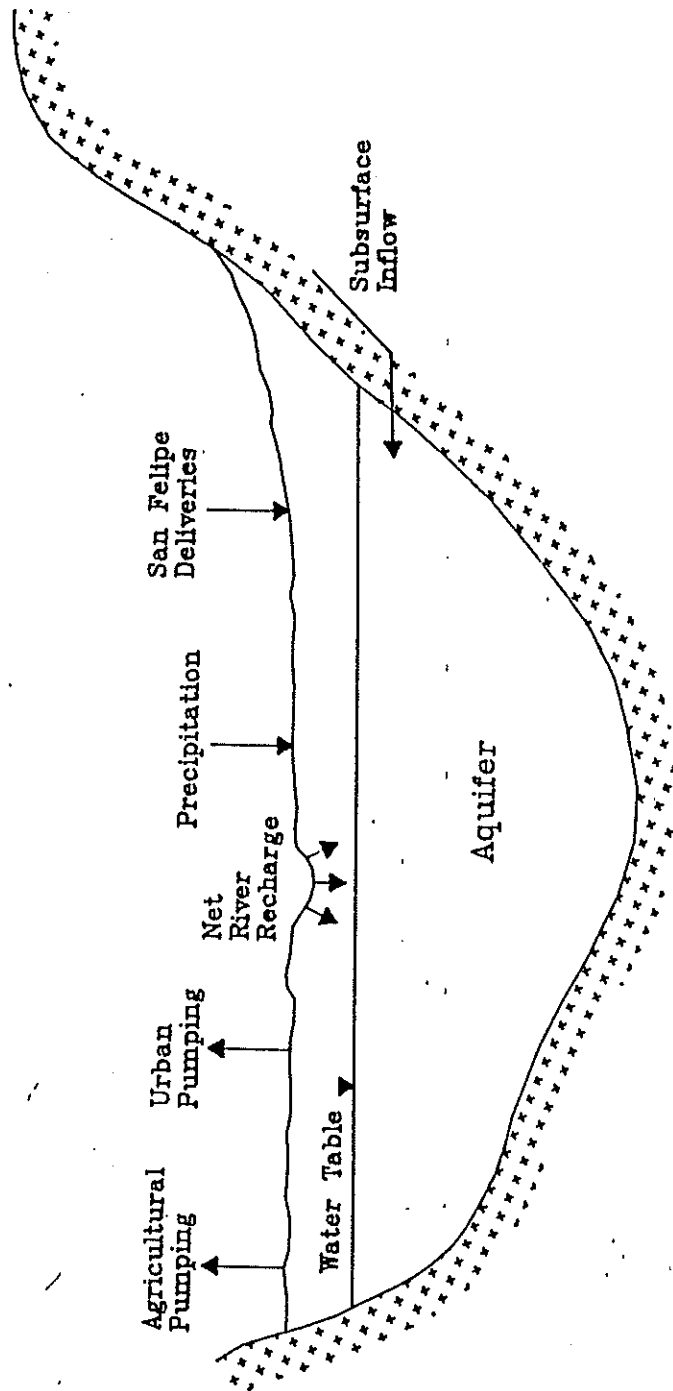
### **Aquifer Geometry**

The conceptualized flow system is bounded by the Pajaro River on the northwest, the Diablo Range on the northeast and east, the San Andreas Fault Zone on the southwest, and the Tres Pinos/Paicines area on the south. Implementation of this assumption connotes that no significant amount of ground water flows beneath across these boundaries, except where the Santa Ana River, Tres Pinos Creek and the San Benito River cross the model boundaries.

The aquifer system was conceptualized as a single layer, with no distinction between an unconfined upper aquifer and a lower system of confined aquifers which is generally expected in this type of area. Detailed geologic and hydrologic information that would be necessary to vertically subdivide the system vertically is not available, and an effort to vertically subdivide the flow system would likely introduce significant error and reduce the confidence of the results. This assumption does not materially affect the accuracy of the model in terms of a regional investigation. A more detailed investigation of a particular area would require that the vertical geometry of the aquifer system be defined more completely.

### **Conceptualization of Rivers**

The rivers that bound the flow system (San Benito and Pajaro) can either receive water from the ground-water system (gaining stream conditions) or discharge water to the ground-water system (losing stream condition). The details of this boundary condition are discussed below as part of the description of the implementation of the conceptual model into a mathematical model.



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# Illustration of Conceptual Ground-Water Model

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FIGURE

4.23

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### **Conceptualization of Flow Across Boundaries**

Flow across certain boundaries is assumed in this conceptualization due to the difficulty in choosing true physical boundaries of the flow system in some areas, and the probability that the locations of true boundaries are considerable distances from the major area of interest. It has been assumed that the flow across these boundaries of the model can be simulated by specifying a flow that represents either flow into or flow out of the model area. Details are presented below.

### **Conceptualization of Net Recharge/Discharge**

Due to a general lack of data and information on the spatial and temporal distribution of recharge from precipitation and irrigation return, and discharge from pumping and evapotranspiration, it has been assumed that all these sources can be treated as a single term of net recharge or discharge. While far from ideal, this assumption allows for the simulation of a system that approximates reality by including some basic concepts of the causes of ground-water level fluctuations. The details of the implementation of this approach are covered below.

### **Nature of Aquifer Materials**

The conceptual model is complete with the statement that the aquifer system is assumed to be heterogeneous (spatially varying aquifer properties), and horizontally isotropic (aquifer properties are the same in any horizontal direction).

Aquifer properties define the quantitative characteristics of the geologic materials of the flow system, and include transmissivity and storativity. Transmissivity is defined as the hydraulic conductivity of the aquifer (which is analogous to aquifer permeability) times the aquifer thickness, and storativity is an expression of how much water is released from storage given a unit change in head (water level), and can be defined as the specific storage

times the thickness of the aquifer.

### **Relation of Assumptions and Model Limitations**

Note that these assumptions greatly simplify the real system, but are necessary to simulate the ground-water response to various stresses. Some of these assumptions are necessary because the real system is too complex to simulate in its entirety (i.e. only regional flow is simulated while truly local conditions are not simulated), while other assumptions reflect the imperfect knowledge of the aquifer system, and limitations on information related to the spatial and temporal distributions of recharge and discharge. These assumptions need to be considered when identifying the limitations of the model, and when interpreting the results.

### **Model Development and Calibration**

#### **Discretization of the Flow System**

Numerical models require that the flow regime be discretized over space by dividing the continuous aquifer system into a set of discrete cells. Aquifer characteristics such as transmissivity and storativity are defined for each cell and assumed to be constant for the entire cell. The heterogeneity of the system is simulated by varying these properties from cell to cell.

Discretization over time is accomplished by dividing the period of interest into increments called stress periods (in this case six months). Parameters that vary with time such as recharge, pumpage, and river conductance are assumed to be constant for each cell during a single stress period but are allowed to change from one stress period to another.

Discretization of the flow system over space and time allows the governing equations of the mathematical model to be solved to yield values of head (water level) for each cell at the end of each stress period. Flow between adjacent cells is calculated based on the aquifer

properties of the cells and the head difference between the cells.

The discretization of the flow system into a uniform grid of cells is shown in Figure 4.24. There are 34 columns and 42 rows and each cell measures 2,000 feet by 2,000 feet. The grid is rotated 21.5 degrees from north for better alignment with geologic features such as the Calaveras fault and the hills east of the Hollister Valley. Because water level measurements were available only for wells in the valleys, most hilly areas were removed from the model's domain by designating them as inactive cells. The cells around the perimeter of the Flint Hills are exceptions to this and remain active to provide recharge to the Bolsa and San Juan Valleys. The model contains 884 active cells which encompass 81,175 total acres. All model boundaries were designated as no-flow boundaries, and flow into and out of the system was simulated as components of net recharge.

This is a single layer (two-dimensional) model because geologic and hydraulic head data were not available to discretize the flow system vertically. As with the three USGS models described earlier, the base of the flow system was considered to be the contact between the Purisima Formation and the bedrock, with a thickness of up to 4,000 feet in some areas. Confined, semi-confined, and unconfined aquifers are present in the model area; but for modeling purposes, the aquifer system is designated as a confined aquifer (which means that transmissivity and storativity remain constant).

### Aquifer Parameters

Initial estimates of transmissivity and storativity were derived from the original calibrated USGS models. When developing these models, the USGS researchers estimated transmissivity by first calculating hydraulic conductivity from well yield (specific capacity) data and then multiplying that hydraulic conductivity by the assumed saturated thickness of the aquifer. Estimates of storativity were obtained by assigning literature values to the lithologies reported on well logs. The initial transmissivity and storativity estimates, and the data used to determine them have apparently been lost. These parameters were modified



during calibration and only the calibrated values in the published reports were available for this investigation. The published values were checked and modified as appropriate on the basis of the geologic work previously described, and on the basis of site specific investigation obtained during this investigation.

As shown on Figure 4.25, the model was divided into twenty-seven "aquifer parameter" zones for calibration purposes. The cells in each zone were assigned equal values of transmissivity and storativity, and these values were modified during the calibration process. Initial and calibrated estimates of transmissivity and storativity are presented in Table 4.1.

### Simulation of Rivers

Two rivers, the Pajaro and the San Benito, are simulated as head-dependent boundaries in the model, meaning that flow between the river and the ground-water system is a function of the river stage (stream level) in a cell, the head (ground-water level) in the cell, and the hydraulic properties of the aquifer and the streambed. For this model, river bottom elevations were taken from topographic maps and the depth of water in the rivers was estimated based on the USGS Water-Data report for 1988. The initial value of streambed conductance (CRIV) was obtained using the following equation (McDonald and Harbaugh, 1988):

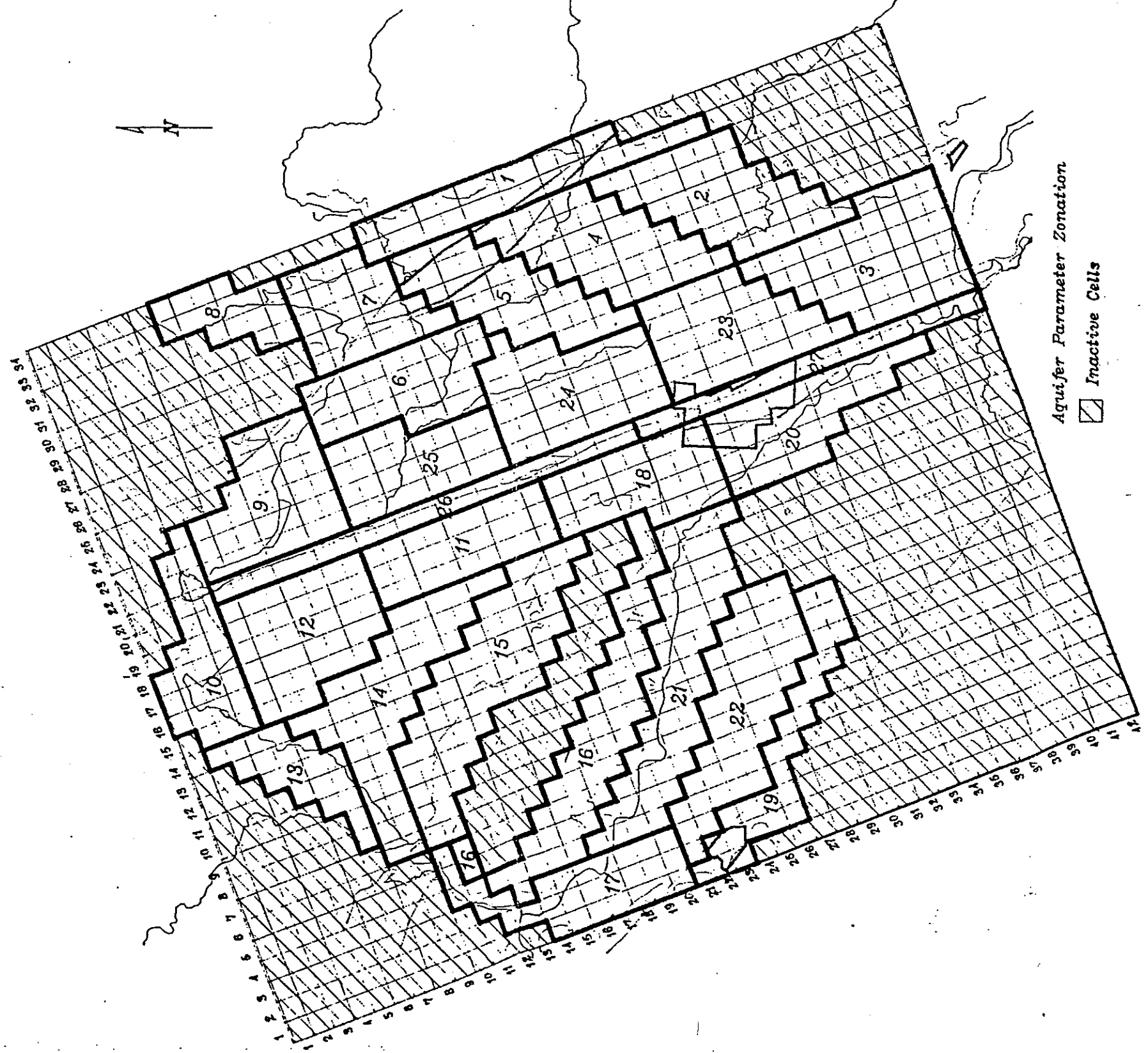
$$CRIV = L * W * K / B$$

where:

- L = length of river in cell (ft)
- W = width of river in cell (ft)
- K = hydraulic conductivity of streambed (ft/day)
- B = thickness of streambed (ft)

To obtain an initial estimate for streambed conductance, the length of the river reach in each cell was measured. Constant values of 100 feet for the width of the river, 10 feet for the streambed thickness, and 35 ft/day for hydraulic conductivity were assumed. The initial





Aquifer Parameter Zonation  
 [Hatched Box] Inactive Cells



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Aquifer Parameter Zonation for Ground-Water Model

FIGURE

4.25

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**TABLE 4.1**  
**TRANSMISSIVITY AND STORATIVITY:**  
**ORIGINAL ESTIMATES AND CALIBRATED VALUES**

| <u>ZONE</u> | <u>TRANSMISSIVITY</u><br>(ft <sup>2</sup> /day) |                   | <u>STORATIVITY</u><br>(dimensionless) |                   |
|-------------|-------------------------------------------------|-------------------|---------------------------------------|-------------------|
|             | <u>ORIGINAL</u>                                 | <u>CALIBRATED</u> | <u>ORIGINAL</u>                       | <u>CALIBRATED</u> |
| 1           | 1000                                            | 5000              | 1.00E-01                              | 3.00E-01          |
| 2           | 1000                                            | 1400              | 3.00E-02                              | 5.70E-02          |
| 3           | 2500                                            | 6000              | 2.00E-01                              | 5.00E-02          |
| 4           | 5000                                            | 2000              | 1.00E-02                              | 5.50E-02          |
| 5           | 10000                                           | 2000              | 1.00E-01                              | 1.10E-02          |
| 6           | 15000                                           | 13000             | 3.00E-02                              | 5.80E-02          |
| 7           | 20000                                           | 10000             | 1.00E-01                              | 7.00E-03          |
| 8           | 25000                                           | 25000             | 3.00E-02                              | 7.50E-02          |
| 9           | 20000                                           | 5000              | 3.00E-02                              | 5.00E-02          |
| 10          | 2500                                            | 2500              | 5.00E-04                              | 1.00E-01          |
| 11          | 10000                                           | 4000              | 1.00E-03                              | 4.00E-02          |
| 12          | 10000                                           | 7000              | 5.00E-04                              | 1.20E-02          |
| 13          | 20000                                           | 15000             | 5.00E-04                              | 1.00E-03          |
| 14          | 7500                                            | 15000             | 1.00E-01                              | 2.00E-02          |
| 15          | 5000                                            | 5000              | 1.00E-01                              | 2.00E-02          |
| 16          | 1000                                            | 1500              | 1.00E-01                              | 1.00E-03          |
| 17          | 5000                                            | 3000              | 1.00E-01                              | 2.00E-02          |
| 18          | 10000                                           | 8000              | 1.00E-01                              | 5.00E-02          |
| 19          | 1000                                            | 500               | 1.00E-01                              | 1.00E-01          |
| 20          | 10000                                           | 11000             | 1.00E-01                              | 2.00E-01          |
| 21          | 10000                                           | 7500              | 1.00E-01                              | 1.00E-01          |
| 22          | 5000                                            | 5000              | 1.00E-03                              | 5.00E-02          |
| 23          | 5000                                            | 5000              | 1.00E-02                              | 1.00E-01          |
| 24          | 15000                                           | 3000              | 1.00E-01                              | 8.00E-02          |
| 25          | 20000                                           | 20000             | 1.00E-01                              | 1.00E-03          |
| 26          | 2500                                            | 2500              | 1.00E-03                              | 5.00E-02          |
| 27          | 1000                                            | 300               | 1.00E-03                              | 1.00E-01          |

conductances calculated from these values ranged from 70,000 ft<sup>2</sup>/day to 1,260,000 ft<sup>2</sup>/day.

Both river stage and streambed conductivity were adjusted during calibration. Calibrated values of water depth in the rivers varied from 0 to 5 feet. In recent years, the San Benito River has generally been dry even in the winter, but hydrographs of wells near the river are relatively constant, indicating that recharge may still be occurring from short flow episodes. Initial values of streambed conductance for the San Benito River were reduced by at least one order of magnitude during calibration.

Confidence in conductance estimates is low because few wells are located within or adjacent to river cells to provide water level data, especially along the Pajaro River. Estimating flow to and from the Pajaro River was problematic because its proximity to the northeastern boundary of the model made it difficult to distinguish between leakage from the river and inflow from the Santa Clara Valley. Overall flow estimates to and from the general area, however, are considered good.

### Ground-Water Pumpage

Pumpage data for individual wells were available only from the City of Hollister, the Sunnyslope Water District, and canneries owned by Tri-Valley Growers and San Benito Foods. Table 4.2 presents the locations of the wells in terms of model row and column and the volume of water pumped for each stress period. These wells represent only a fraction of the total ground-water withdrawals within the model domain, but due to the lack of specific data, the remaining pumpage (generally agricultural) was included in the net recharge/discharge term discussed below.

### Net Recharge/Discharge

The model was divided into twenty-five "recharge" zones to facilitate calculation and modification of values used in MODFLOW's recharge package. Zones 1, 3, 4, 5, 6, 7, 9, and

TABLE 4.2  
PUMPAGE DATA BY STRESS PERIOD FOR INDIVIDUAL WELLS

|                               | Location: |        | Pumpage |
|-------------------------------|-----------|--------|---------|
|                               | Row       | Column | (ac-ft) |
| <u>Oct 1987 - Mar 1988</u>    |           |        |         |
| City of Hollister Well 2      | 31        | 21     | 298.6   |
| City of Hollister Well 3      | 23        | 24     | 0.0     |
| City of Hollister Well 4      | 29        | 19     | 579.3   |
| City of Hollister Well 5      | 30        | 19     | 0.4     |
| Cannery Wells                 | 30        | 22     | 321.5   |
| Sunnyslope Well 1             | 33        | 21     | 199.3   |
| Sunnyslope Wells 4 & 5        | 35        | 22     | 183.9   |
| Sunnyslope Wells 6 & 7        | 36        | 23     | 204.1   |
| <u>April 1988 - Sept 1988</u> |           |        |         |
| City of Hollister Well 2      | 31        | 21     | 589.0   |
| City of Hollister Well 3      | 23        | 24     | 0.0     |
| City of Hollister Well 4      | 29        | 19     | 578.1   |
| City of Hollister Well 5      | 30        | 19     | 331.8   |
| Cannery Wells                 | 30        | 22     | 597.1   |
| Sunnyslope Well 1             | 33        | 21     | 448.2   |
| Sunnyslope Wells 4 & 5        | 35        | 22     | 452.4   |
| Sunnyslope Wells 6 & 7        | 36        | 23     | 401.4   |
| <u>Oct 1988 - Mar 1989</u>    |           |        |         |
| City of Hollister Well 2      | 31        | 21     | 38.8    |
| City of Hollister Well 3      | 23        | 24     | 0.0     |
| City of Hollister Well 4      | 29        | 19     | 842.2   |
| City of Hollister Well 5      | 30        | 19     | 35.6    |
| Cannery Wells                 | 30        | 22     | 501.1   |
| Sunnyslope Well 1             | 33        | 21     | 366.1   |
| Sunnyslope Wells 4 & 5        | 35        | 22     | 103.1   |
| Sunnyslope Wells 6 & 7        | 36        | 23     | 98.2    |
| <u>April 1989 - Sept 1989</u> |           |        |         |
| City of Hollister Well 2      | 31        | 21     | 332.1   |
| City of Hollister Well 3      | 23        | 24     | 30.7    |
| City of Hollister Well 4      | 29        | 19     | 969.2   |
| City of Hollister Well 5      | 30        | 19     | 291.1   |
| Cannery Wells                 | 30        | 22     | 930.7   |
| Sunnyslope Well 1             | 33        | 21     | 546.5   |
| Sunnyslope Wells 4 & 5        | 35        | 22     | 444.5   |
| Sunnyslope Wells 6 & 7        | 36        | 23     | 210.1   |
| <u>Oct 1989 - Mar 1990</u>    |           |        |         |
| City of Hollister Well 2      | 31        | 21     | 166.3   |
| City of Hollister Well 3      | 23        | 24     | 8.3     |
| City of Hollister Well 4      | 29        | 19     | 319.3   |
| City of Hollister Well 5      | 30        | 19     | 518.4   |
| Cannery Wells                 | 30        | 22     | 414.9   |
| Sunnyslope Well 1             | 33        | 21     | 466.7   |
| Sunnyslope Wells 4 & 5        | 35        | 22     | 296.6   |
| Sunnyslope Wells 6 & 7        | 36        | 23     | 74.4    |
| <u>April 1990 - Sept 1990</u> |           |        |         |
| City of Hollister Well 2      | 31        | 21     | 134.3   |
| City of Hollister Well 3      | 23        | 24     | 53.6    |
| City of Hollister Well 4      | 29        | 19     | 535.7   |
| City of Hollister Well 5      | 30        | 19     | 662.8   |
| Cannery Wells                 | 30        | 22     | 770.5   |
| Sunnyslope Well 1             | 33        | 21     | 408.7   |
| Sunnyslope Wells 4 & 5        | 35        | 22     | 281.3   |
| Sunnyslope Wells 6 & 7        | 36        | 23     | 331.5   |

10 correspond to the San Felipe subsystem number. The location of the zones and the subsystem network are shown on Figure 4.26.

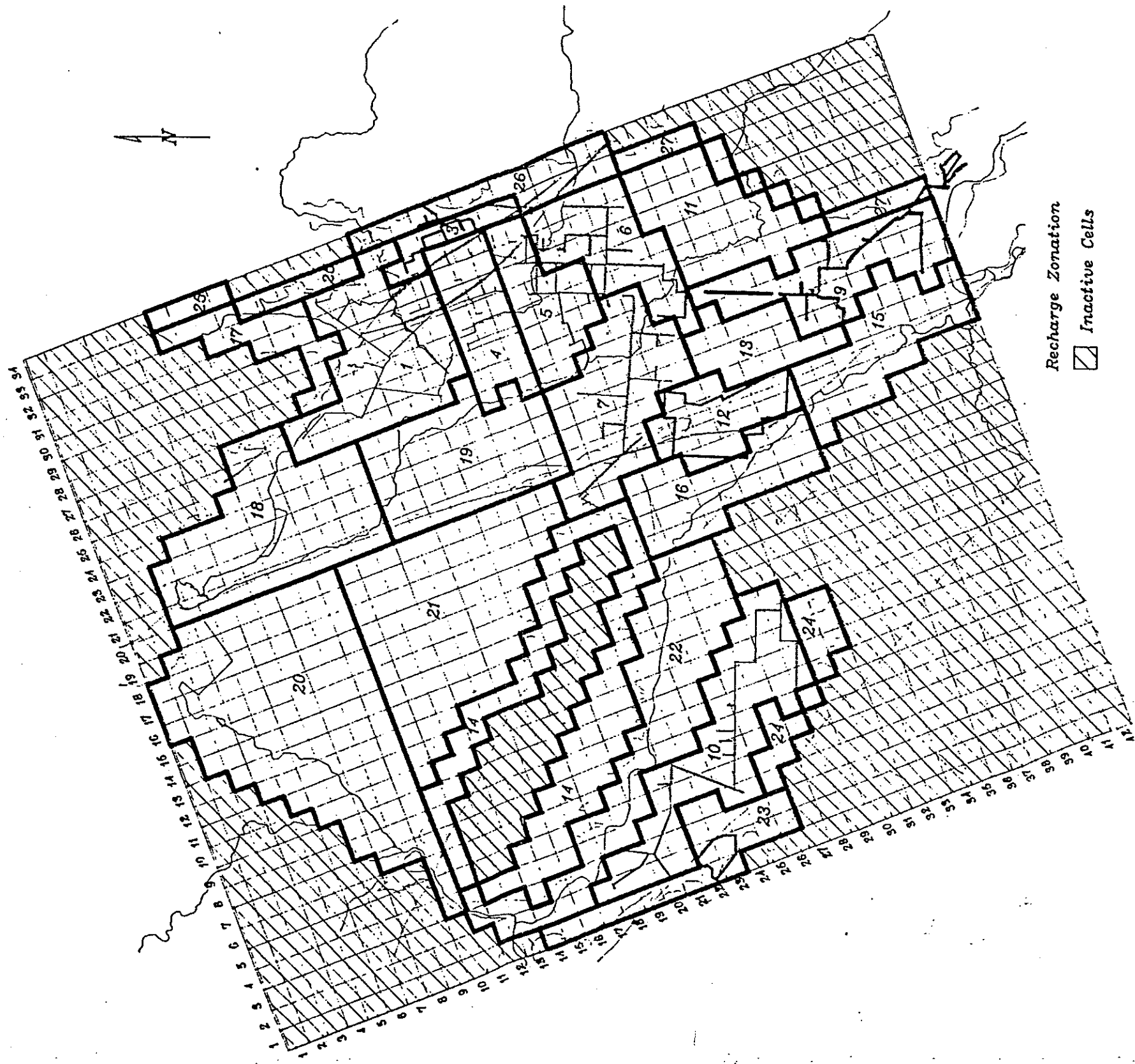
The components used to estimate the net recharge/discharge for each zone and each stress period were San Felipe deliveries, precipitation, inflow, and duty. A brief description of each component is given below:

**San Felipe Deliveries (SFD)** - When calculating recharge, 90 percent of the imported water distributed by the San Felipe subsystems was applied to duty and 10 percent was assumed lost to evaporation.

**Precipitation (PCP)** - Precipitation data for the city of Hollister was used for all zones of the model. It was assumed that only 50 percent of the measured precipitation would apply to duty and that the remainder would be lost to evaporation and runoff.

**Inflow (INF)** - To compensate for the use of a no-flow boundary condition for all model boundaries, additional recharge was simulated in areas where subsurface inflow was expected to occur based on water level contour maps. Zones 25, 26, and 27 were created to simulate flow into the Hollister Valley from the east and the southeast. Similarly additional recharge in zones 23 and 24 allowed flow into the San Juan Valley from the southwest and west. Due to the low permeability of the hills, these inflows were expected to be small and were adjusted as needed for calibration purposes. Inflow into the Bolsa basin from the southern portion of the Santa Clara Valley had been expected but may have been masked by simulated leakage from the Pajaro River.

**Duty (DUT)** - Duty is defined as the amount of irrigation water that must be applied to grow a particular crop. Cropping patterns in the basins were estimated from 1989 land use maps produced from aerial photographs by the California Department of Water Resources (DWR). Estimates of the duty required for specific crops were also obtained from DWR (1986) data. These values were used to estimate the duty requirements for each recharge



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Aquifer Recharge Zonation for Ground-Water Model

FIGURE

4.26

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zone. It was assumed that 90 percent of the annual duty was a demand during the April through September stress period and 10 percent occurred between October and March. It was further assumed that all duty not supplied by imported water or precipitation would be made up by ground-water pumping.

In summary, the net recharge or net discharge from an area was calculated by the following equation:

$$\text{Net Recharge/Discharge} = \text{DUT} - (\text{SFD} + \text{PCP}) + \text{INF}$$

If the result of the above equation was a negative number, a net discharge was assumed to occur from pumped ground water. If the result was a positive number, net recharge was assumed to occur in the form of deep percolation of precipitation and/or excess irrigation water and, in appropriate areas, subsurface inflow.

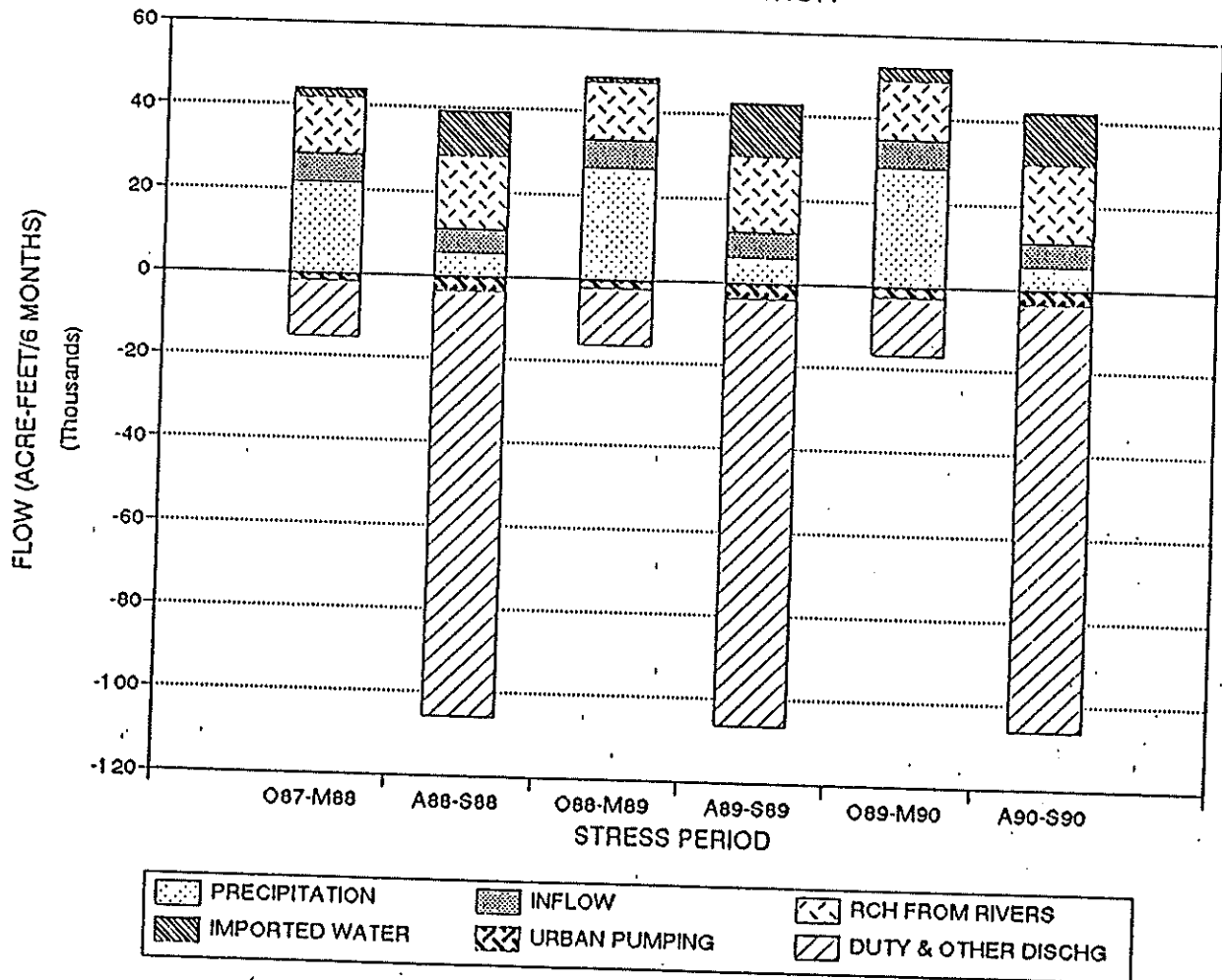
Table 4.3 and Figure 4.27 show these recharge/discharge components along with leakage from the rivers, and the pumpage by individual wells. The pumping is labeled "urban pumping" because pumpage by the City of Hollister and the canneries are the largest components.

The development of net recharge/discharge data is critical to proper application of the model in the future. Simulation of changed land use will have to include an analysis of the current use of the land in order to establish how the change should be modeled with this tool. If the changed land use involves a conversion from agricultural to urban or suburban, the net change in water use amount, timing, and fate must be added (or subtracted) to the net recharge/discharge to the area. Changes in San Felipe water deliveries must also be included in the calculation of net recharge/discharge.

TABLE 4.3  
RECHARGE/DISCHARGE COMPONENTS FOR 1987-1990 SIMULATION (ac-ft)

|                      | <u>O87-M88</u> | <u>A88-S88</u> | <u>O88-M89</u> | <u>A89-S89</u> | <u>O89-M90</u> | <u>A90-S90</u> |
|----------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| <u>INFLOW</u>        |                |                |                |                |                |                |
| RECHARGE FROM RIVERS | 13526          | 18029          | 14032          | 18474          | 14455          | 18805          |
| IMPORTED WATER       | 2511           | 10987          | 1714           | 12871          | 3582           | 12763          |
| PRECIPITATION        | 21891          | 5702           | 26478          | 6217           | 28367          | 5518           |
| INFLOW               | 6978           | 6016           | 6978           | 6016           | 6978           | 6016           |
| TOTAL                | 44906          | 40733          | 49202          | 43577          | 53382          | 43102          |
| <u>OUTFLOW</u>       |                |                |                |                |                |                |
| URBAN PUMPING        | 1782           | 3408           | 1980           | 3765           | 2259           | 3577           |
| DUTY                 | 8582           | 77658          | 8582           | 77658          | 8582           | 77658          |
| OTHER DISCHARGE      | 3785           | 21816          | 3906           | 22064          | 4091           | 22054          |
| TOTAL                | 14148          | 102882         | 14468          | 103487         | 14931          | 103289         |

# RECHARGE/DISCHARGE COMPONENTS 1987 - 1990 SIMULATION



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FIGURE  
4.27

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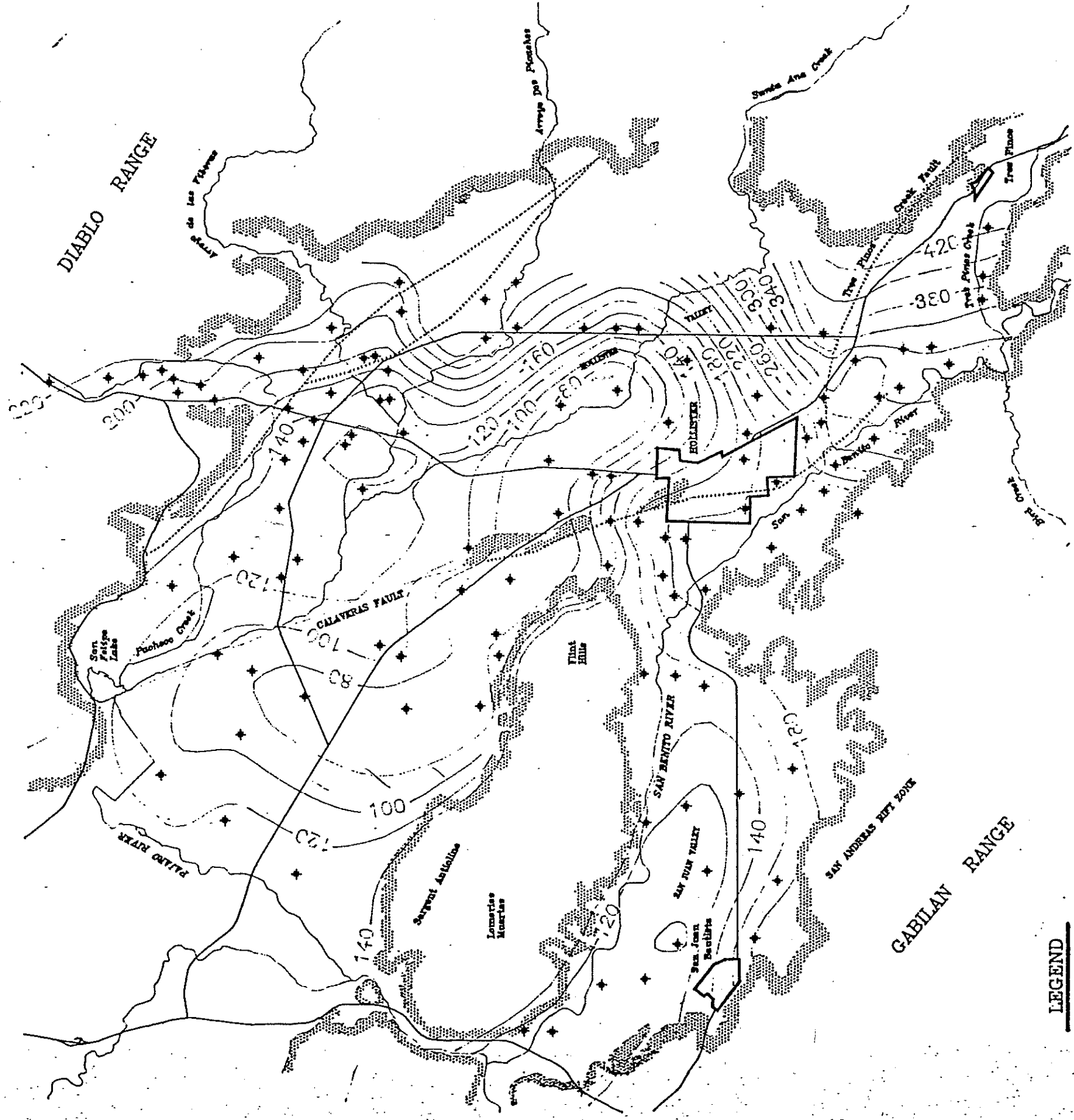
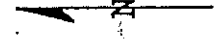
## Model Calibration and Results

The model was calibrated by simulating ground-water flow for the three year period from October 1987 to October 1990. This period was selected because San Felipe deliveries began in September 1987, and because October 1990 water level data were the most recent available when the model was being developed. Ground-water level measurements for October 1987 were contoured and used as the initial condition for the simulation. These ground-water level contours are shown on Figure 4.28 along with the locations of eighty-seven wells used to calibrate the model.

Stress periods six months long were used to approximately coincide with water level measurements which have historically been made in October and March. Simulated head at the end of each stress period was compared with the actual head measured in the wells, and model parameters were adjusted accordingly. Parameters modified for calibration purposes were transmissivity, storativity, river conductance, and recharge. Recharge was adjusted by adding inflow at the boundaries and by adding an additional discharge term for certain zones in the Hollister Valley where simulated heads were high.

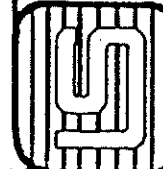
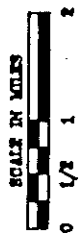
Three problems limited the accuracy of calibration: 1) many of the eighty-seven wells were clustered, leaving other areas without adequate well control for calibration purposes, 2) many well hydrographs exhibit unusual patterns which are often quite localized and which cannot be simulated with a this type of regional model, and 3) when contouring the starting heads, data were averaged and smoothed so that localized variations in head were ignored, especially in areas with clustered data. Therefore the initial head at individual wells was often too high or too low. In these cases, the calibration objective was to match the trend of the hydrographs rather than the individual measurements.

The hydrographs of the eighty-seven wells and the simulated water levels are presented in the Appendix B. Contour plots of simulated head for the last stress period are shown on Figure 4.29. The general pattern of these head contours approximates the actual water level



LEGEND

- Well
- Fault (dotted where concealed)
- Basin Boundary
- Ground-Water Elevation (feet, MSL)



Contours of Equal Ground-Water Elevation,  
October 1987, San Benito County

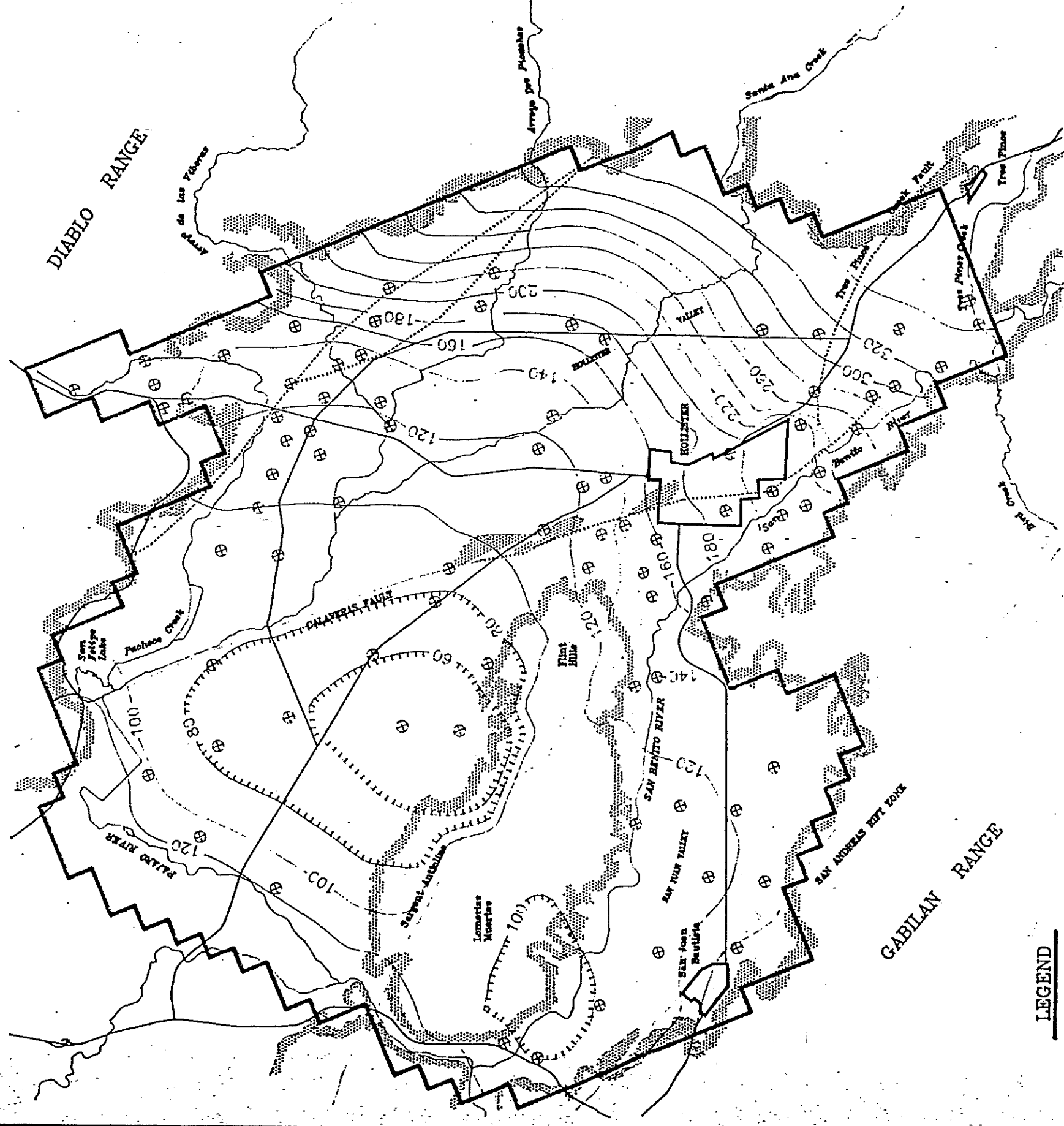
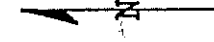
FIGURE

4.28

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Ground-Water Investigation

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**LEGEND**

- Well
- Fault (dotted where concealed)
- Basin Boundary
- Simulated Ground-Water Elevation (feet, MSL), Model Boundary Shown



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Simulated Contours of Ground-Water Elevation,  
October 1990, San Benito County

FIGURE  
4.29

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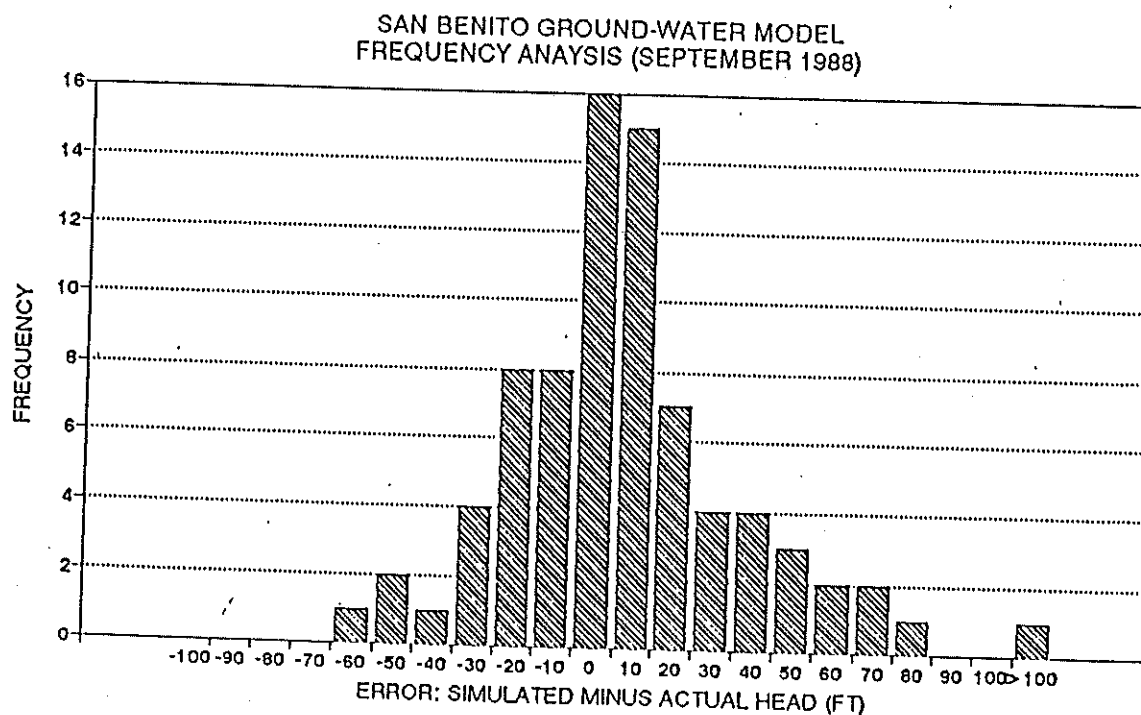
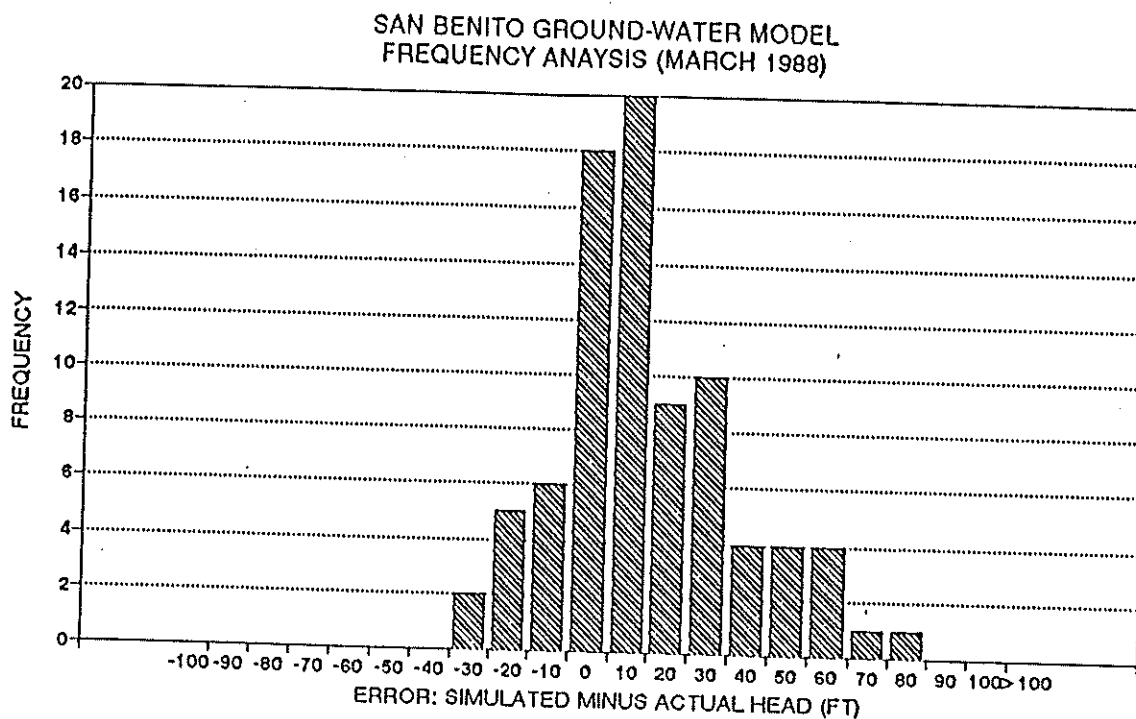
contours depicted on Figure 4.11 but with much less heterogeneity than the real data. Histograms of the difference between simulated and actual head for each well are presented in Figures 4.30 through 4.32 for each of the six stress periods.

The ground-water budget calculated by the model is presented on Table 4.4 and Figure 4.33. Note that, on the bar graph, storage depletion is positive because it represents water released from storage and entering the flow system, and storage gain is negative to indicate water leaving the flow system and entering storage. Total flow during the summer stress periods is considerably more than total flow during the winter due to irrigation pumping and the associated storage depletion. For each of these dry years, storage gain in the winter is less than storage depletion in the summer so that the net volume of water available in storage continued to decline during the calibration period over the entire model area.

During this period, average storage depletion over the entire area was approximately 27,000 acre-feet per year, recharge from the river was approximately 32,000 acre-feet per year; and agricultural pumpage was approximately 42,000 acre-feet per year.

### Additional Simulations

Since the model was calibrated by simulating three successive dry years, the response of the model to continued drought is largely predictable. Because model response to wet conditions was less certain, the calibrated model was used to simulate three wet years (referred to as October 1990 to September 1993 for convenience) in order to check model performance and to examine the rate of aquifer recovery once the drought ends. Heads generated by the model for October 1990 were used as the initial condition for this simulation. Precipitation data from 1981-1982, a year with 137 percent of average precipitation, was used to seed the net recharge/discharge calculations, and inflow to the system and river stage elevations were also increased. Values for urban pumping, surface deliveries, and duty were retained from the last two stress period of the calibration run (October 1989 to March 1990, and April 1990 to September 1990).

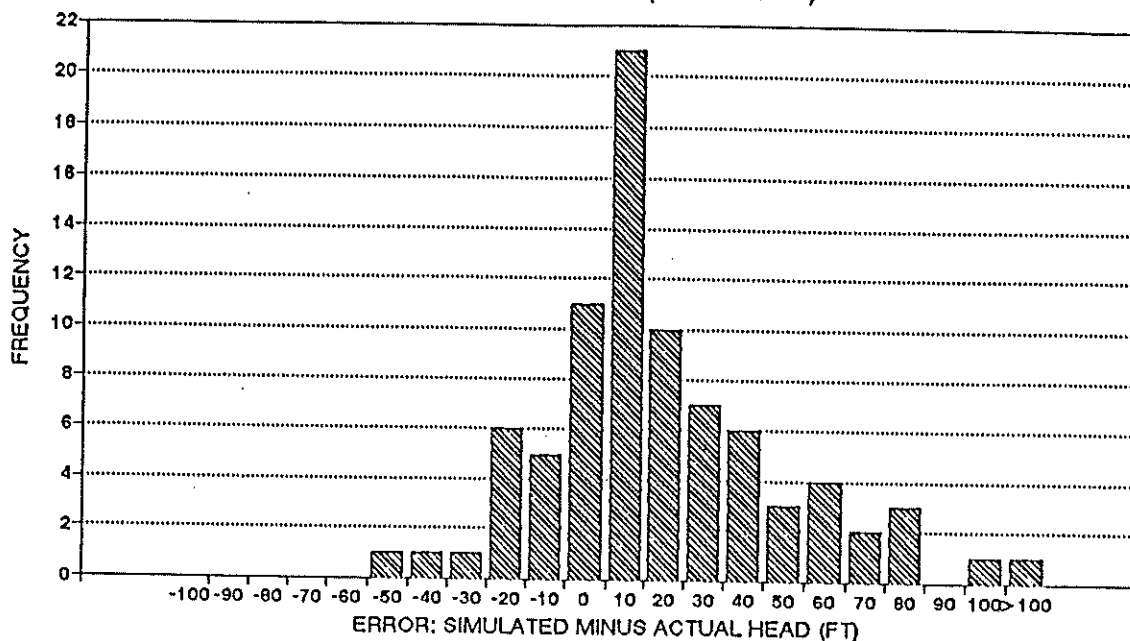


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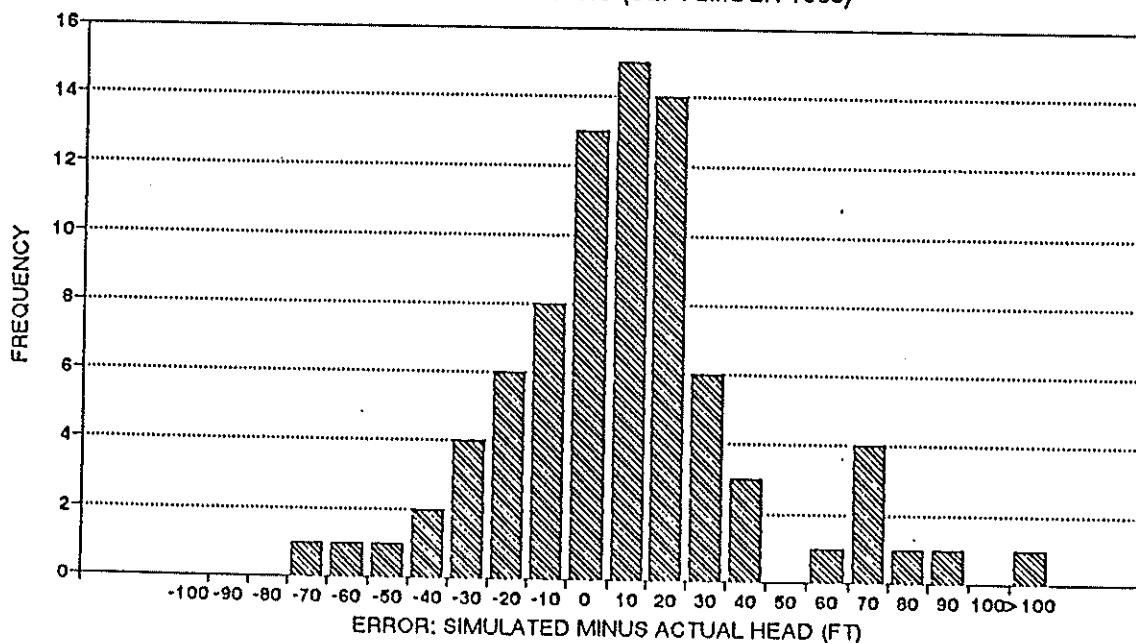
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**FIGURE  
4.30**  
  
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SAN BENITO GROUND-WATER MODEL  
FREQUENCY ANALYSIS (MARCH 1989)



SAN BENITO GROUND-WATER MODEL  
FREQUENCY ANALYSIS (SEPTEMBER 1989)



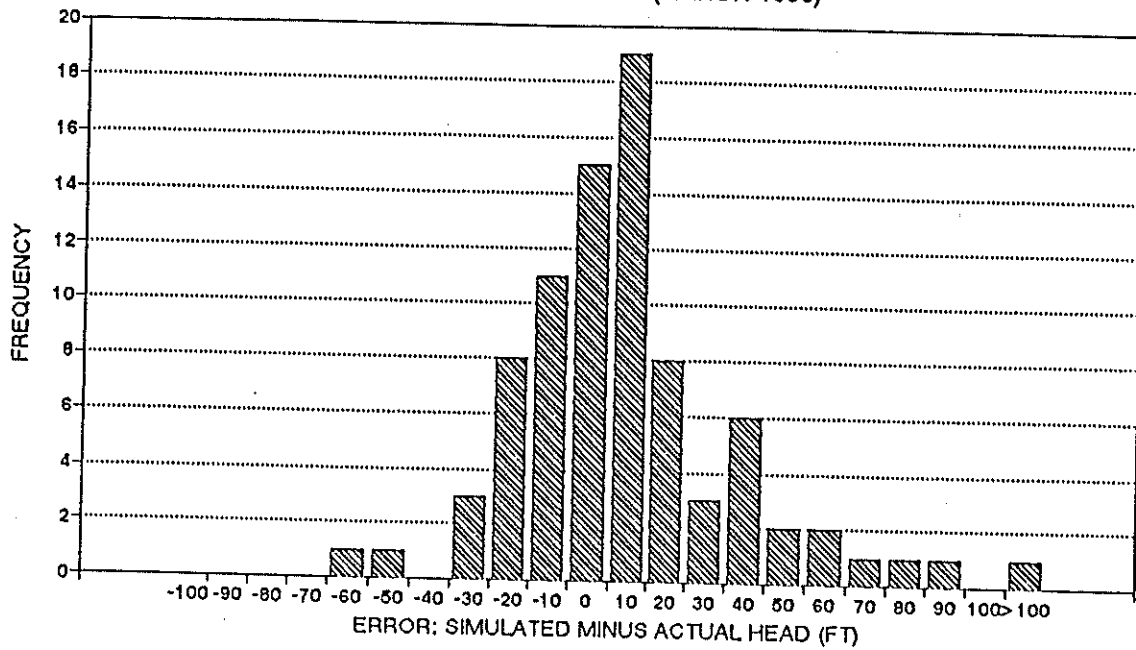
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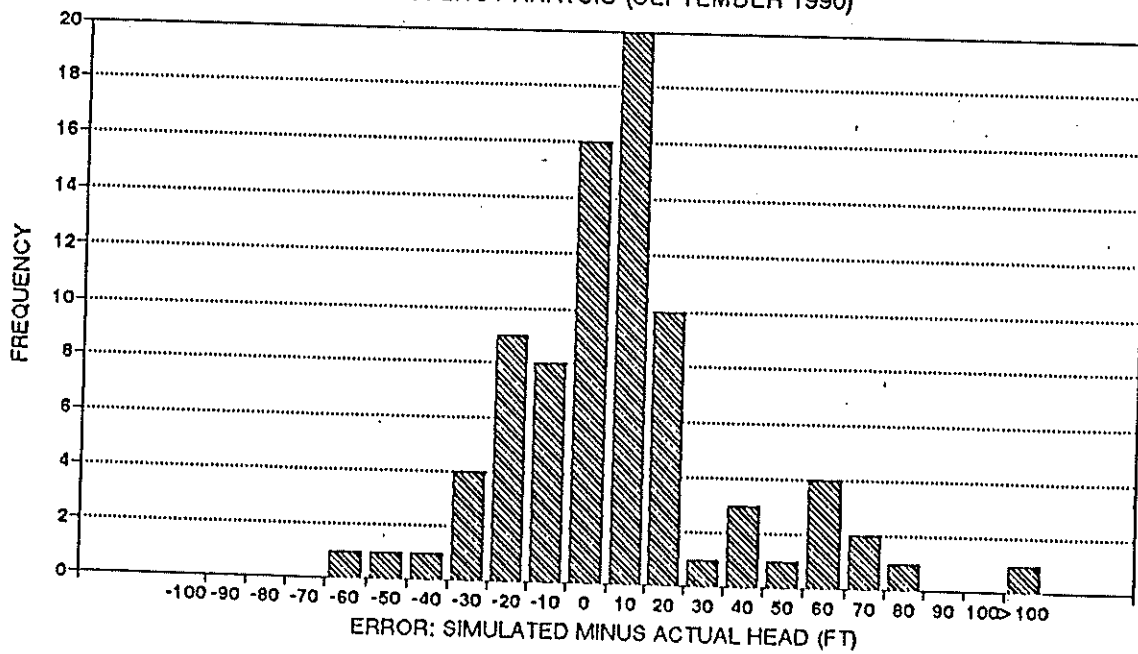
90-1-084  
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FIGURE  
4.31

SAN BENITO GROUND-WATER MODEL  
FREQUENCY ANALYSIS (MARCH 1990)



SAN BENITO GROUND-WATER MODEL  
FREQUENCY ANALYSIS (SEPTEMBER 1990)



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FIGURE  
4.32  
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TABLE 4.4

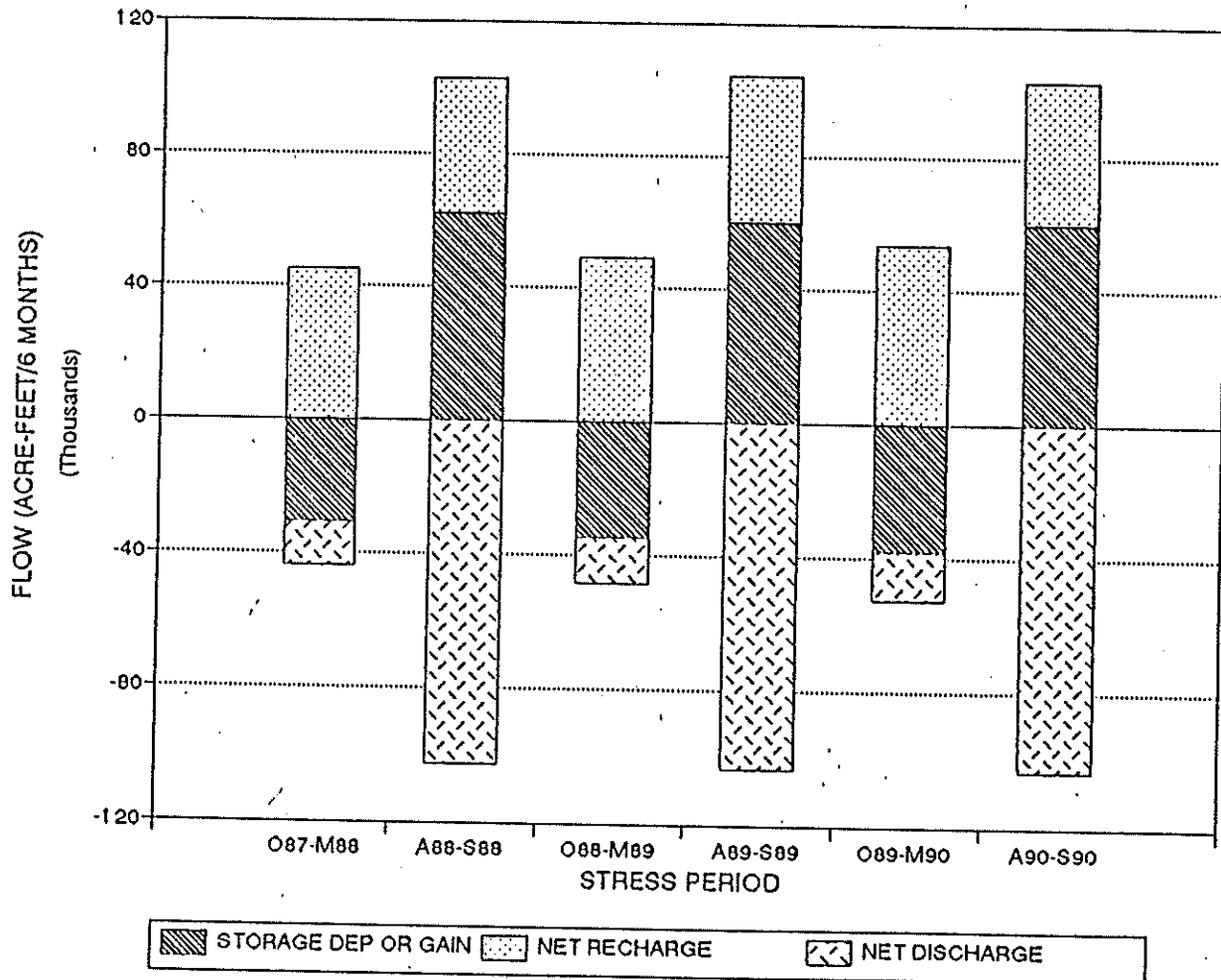
## RECHARGE/DISCHARGE COMPONENTS FOR 1987-1990 SIMULATION (ac-ft)

|                      | O87-M88 | A88-S88 | O88-M89 | A89-S89 | O89-M90 | A90-S90 |
|----------------------|---------|---------|---------|---------|---------|---------|
| <u>INFLOW</u>        |         |         |         |         |         |         |
| RECHARGE FROM RIVERS | 13526   | 18029   | 14032   | 18474   | 14455   | 18805   |
| IMPORTED WATER       | 2511    | 10987   | 1714    | 12871   | 3582    | 12763   |
| PRECIPITATION        | 21891   | 5702    | 26478   | 6217    | 28367   | 5518    |
| INFLOW               | 6978    | 6016    | 6978    | 6016    | 6978    | 6016    |
| TOTAL                | 44906   | 40733   | 49202   | 43577   | 53382   | 43102   |
| <u>OUTFLOW</u>       |         |         |         |         |         |         |
| URBAN PUMPING        | 1782    | 3408    | 1980    | 3765    | 2259    | 3577    |
| DUTY                 | 8582    | 77658   | 8582    | 77658   | 8582    | 77658   |
| OTHER DISCHARGE      | 3785    | 21816   | 3906    | 22064   | 4091    | 22054   |
| TOTAL                | 14148   | 102882  | 14468   | 103487  | 14931   | 103289  |

## MODEL CALCULATED WATER BUDGET FOR 1987-1990 SIMULATION (ac-ft)

|                      | O87-M88 | A88-S88 | O88-M89 | A89-S89 | O89-M90 | A90-S90 |
|----------------------|---------|---------|---------|---------|---------|---------|
| <u>INFLOW</u>        |         |         |         |         |         |         |
| STORAGE DEPLETION    | 6457    | 62987   | 2997    | 60009   | 2145    | 60273   |
| RECHARGE FROM RIVERS | 13612   | 18029   | 14136   | 18474   | 14577   | 18805   |
| OTHER RECHARGE       | 19013   | 2812    | 22682   | 3055    | 26254   | 2708    |
| TOTAL                | 39082   | 83828   | 39815   | 81538   | 42976   | 81786   |
| <u>OUTFLOW</u>       |         |         |         |         |         |         |
| STORAGE GAIN         | 37214   | 839     | 37731   | 100     | 40595   | 84      |
| DISCHARGE TO RIVERS  | 85      | 0       | 104     | 0       | 122     | 0       |
| URBAN PUMPING        | 1782    | 3408    | 1980    | 3765    | 2259    | 3577    |
| OTHER DISCHARGE      | 0       | 79581   | 0       | 77674   | 0       | 78124   |
| TOTAL                | 39082   | 83828   | 39814   | 81539   | 42976   | 81785   |

# CALCULATED WATER BUDGET 1987 - 1990 SIMULATION



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FIGURE  
4.33

Table 4.5 and Figure 4.34 depict the recharge/discharge components used in this simulation. The water budget calculated by the model is also shown in Table 4.5 and in Figure 4.35. Aquifer storage increases each year because storage gain in the winter is greater than storage depletion during the irrigation season. Hydrographs plotted on Figures 4.36 and 4.37 provide examples of the simulated response of selected wells to the wet conditions. In most cases water levels rise at a slower rate than they fell during the dry years. Based on this simulation, storage gain over the entire model area was 29,000 acre-feet per year, river recharge was approximately 44,000 acre-feet per year, and agricultural pumpage was approximately 19,000 acre-feet per year.

Another simulation was conducted to examine the effect of San Felipe deliveries of imported water on the flow system. This was done simply by rerunning the October 1987 through October 1990 simulation without any imported water. It was assumed that total duty would not change and the additional irrigation water required would be made up by increased pumpage. The recharge/discharge components and the water budget calculated for this simulation are presented in Table 4.6 and Figures 4.38 and 4.39. Hydrographs plotted on Figures 4.40 to 4.41 provide examples of the simulated response of selected wells without any imported water. Based on this simulation, storage depletion over the entire model area was approximately 41,000 acre-feet per year, river recharge was approximately 33,000 acre-feet per year; and agricultural pumpage was approximately 56,000 acre-feet per year.

Simulations of an alternative that assumed increasing San Felipe deliveries through time (a likely scenario since current deliveries are significantly below contract entitlements) were deferred since the distribution of increased deliveries into various subsystems is a critical assumption that would have significant implications on results. Once a distribution pattern is established, simulations of this type can be run, or alternative patterns of distribution can be run to investigate the benefits of different distribution patterns as part of a planning process.

TABLE 4.5

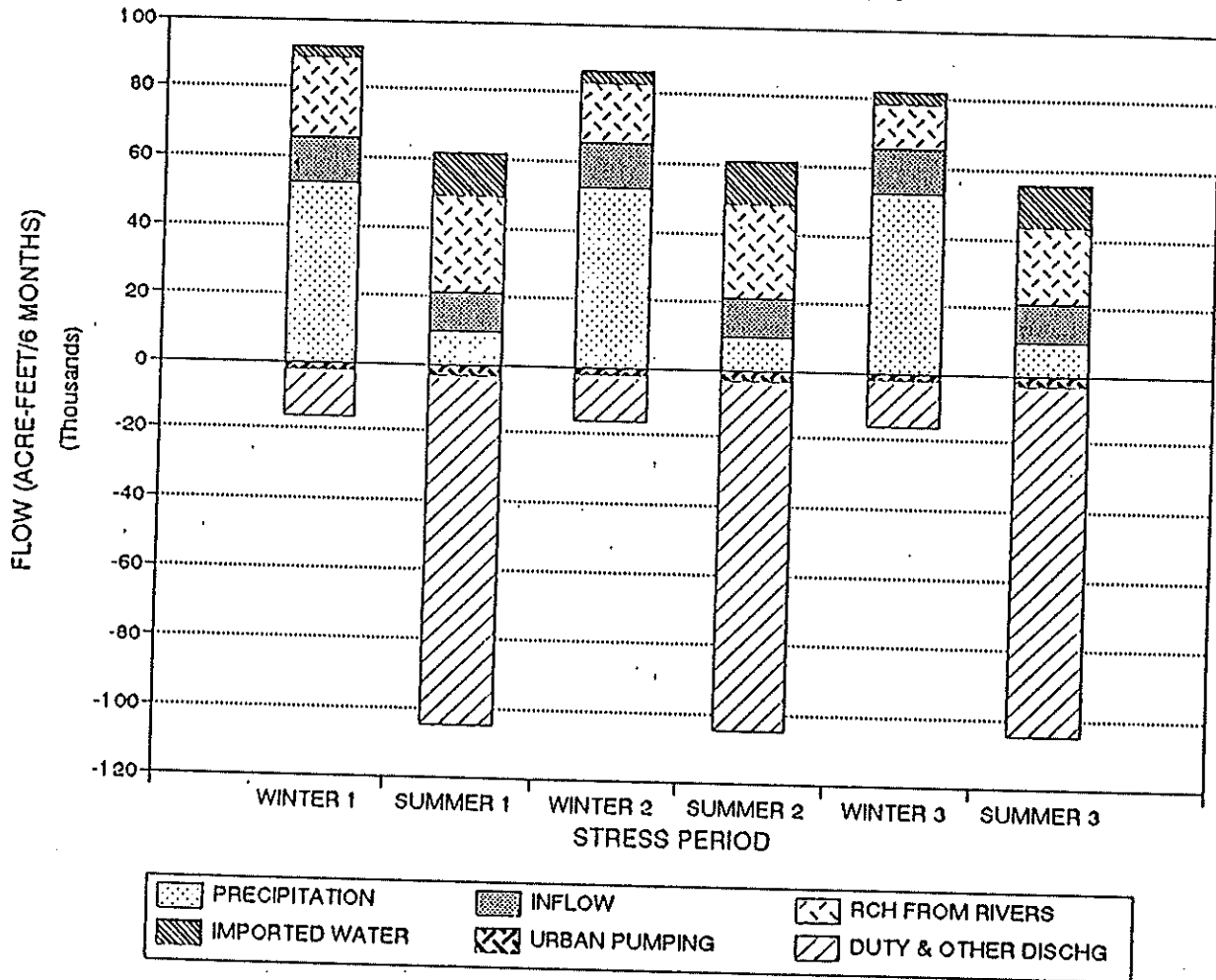
## RECHARGE/DISCHARGE COMPONENTS FOR SIMULATION OF WET YEARS (ac-ft)

|                      | YEAR 1<br>WINTER | YEAR 1<br>SUMMER | YEAR 2<br>WINTER | YEAR 2<br>SUMMER | YEAR 3<br>WINTER | YEAR 3<br>SUMMER |
|----------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| <u>INFLOW</u>        |                  |                  |                  |                  |                  |                  |
| RECHARGE FROM RIVERS | 23240            | 28378            | 17509            | 27579            | 13139            | 22474            |
| IMPORTED WATER       | 3582             | 12763            | 3582             | 12763            | 3582             | 12763            |
| PRECIPITATION        | 52282            | 9822             | 52282            | 9822             | 52282            | 9822             |
| INFLOW               | 13554            | 11629            | 13554            | 11629            | 13554            | 11629            |
| TOTAL                | 92658            | 62592            | 86927            | 61792            | 82557            | 56687            |
| <u>OUTFLOW</u>       |                  |                  |                  |                  |                  |                  |
| URBAN PUMPING        | 2259             | 3577             | 2259             | 3577             | 2259             | 3577             |
| DUTY                 | 8488             | 76809            | 8488             | 76809            | 8488             | 76809            |
| OTHER DISCHARGE      | 4260             | 21092            | 4260             | 21092            | 4260             | 21092            |
| TOTAL                | 15007            | 101478           | 15007            | 101478           | 15007            | 101478           |

## MODEL CALCULATED WATER BUDGET FOR SIMULATION OF WET YEARS (ac-ft)

|                      | YEAR 1<br>WINTER | YEAR 1<br>SUMMER | YEAR 2<br>WINTER | YEAR 2<br>SUMMER | YEAR 3<br>WINTER | YEAR 3<br>SUMMER |
|----------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| <u>INFLOW</u>        |                  |                  |                  |                  |                  |                  |
| STORAGE DEPLETION    | 93               | 41485            | 38               | 42208            | 41               | 47149            |
| RECHARGE FROM RIVERS | 24129            | 28378            | 18776            | 27579            | 14816            | 22474            |
| OTHER RECHARGE       | 56576            | 8151             | 56576            | 8151             | 56576            | 8151             |
| TOTAL                | 80799            | 78014            | 75390            | 77938            | 71433            | 77774            |
| <u>OUTFLOW</u>       |                  |                  |                  |                  |                  |                  |
| STORAGE GAIN         | 77651            | 1750             | 71864            | 1674             | 67498            | 1510             |
| DISCHARGE TO RIVERS  | 889              | 0                | 1266             | 0                | 1677             | 0                |
| URBAN PUMPING        | 2259             | 3577             | 2259             | 3577             | 2259             | 3577             |
| OTHER DISCHARGE      | 0                | 72687            | 0                | 72687            | 0                | 72687            |
| TOTAL                | 80799            | 78015            | 75389            | 77938            | 71433            | 77774            |

# RECHARGE/DISCHARGE COMPONENTS SIMULATION OF WET CONDITIONS

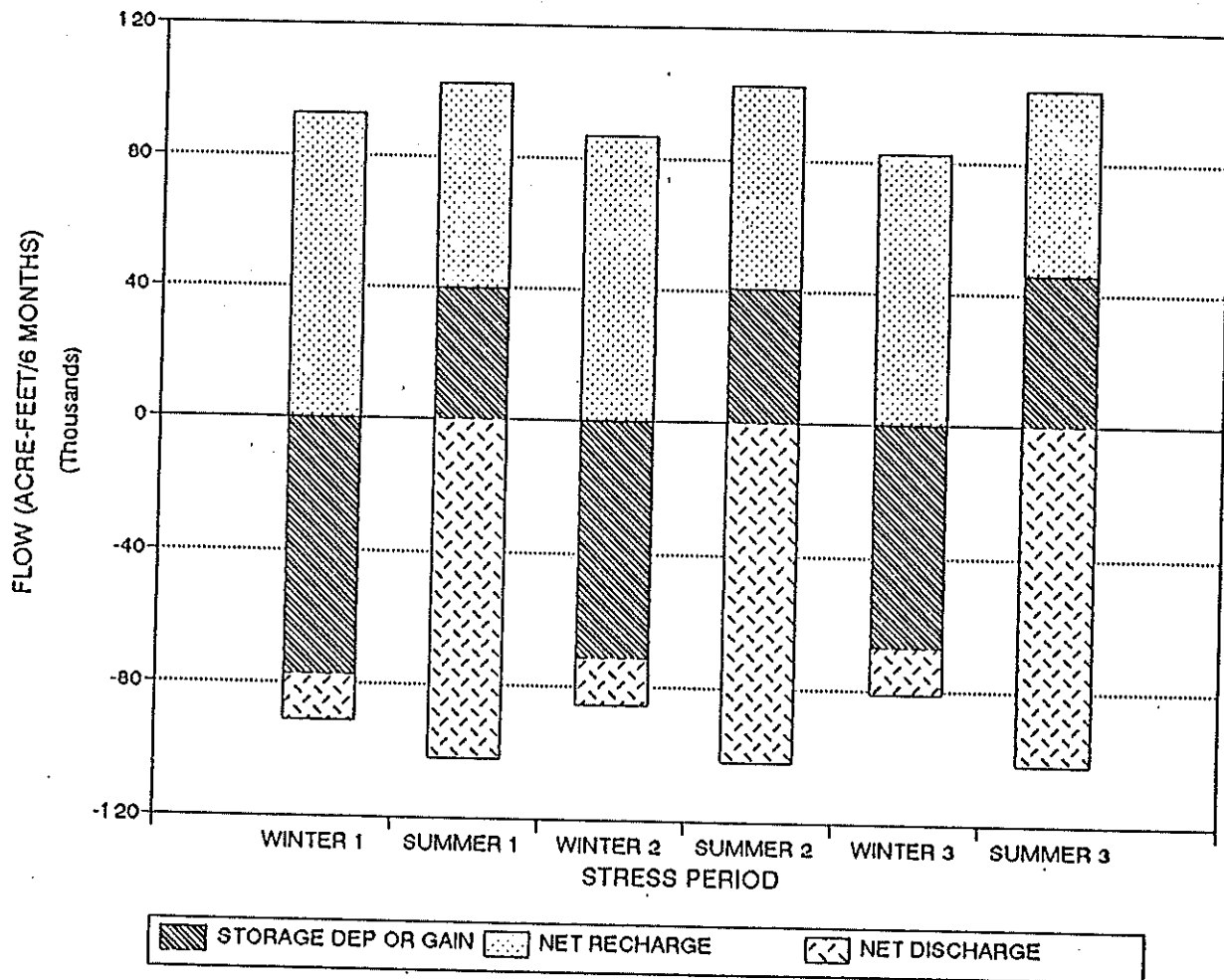


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FIGURE  
4.34  
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# CALCULATED WATER BUDGET SIMULATION OF WET CONDITIONS



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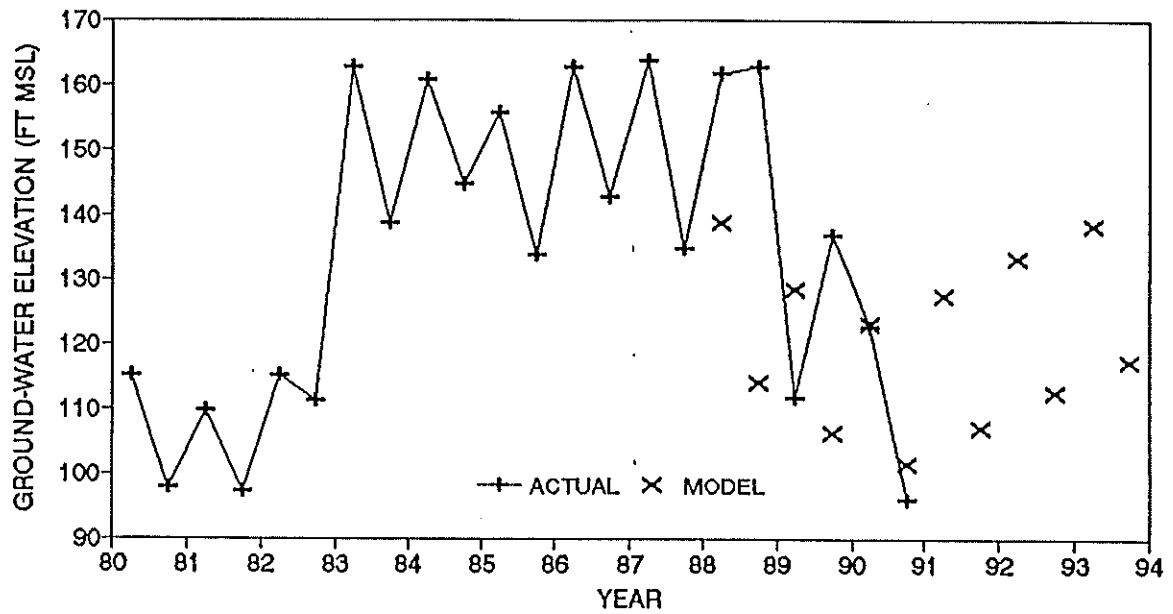
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Ground-Water Investigation

FIGURE

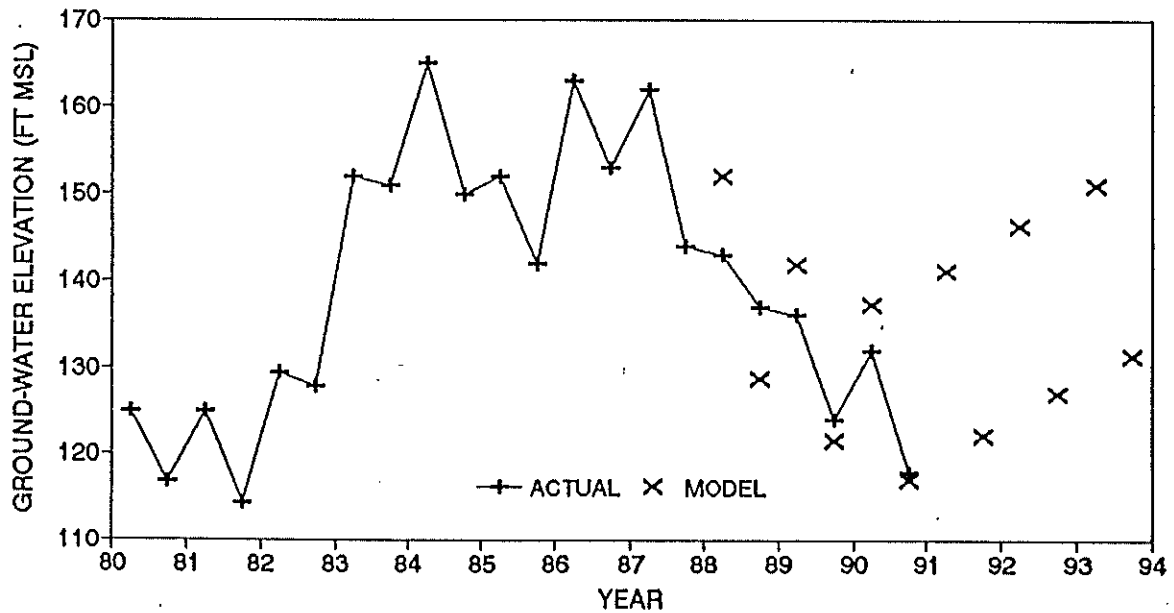
4.35

90-1-084  
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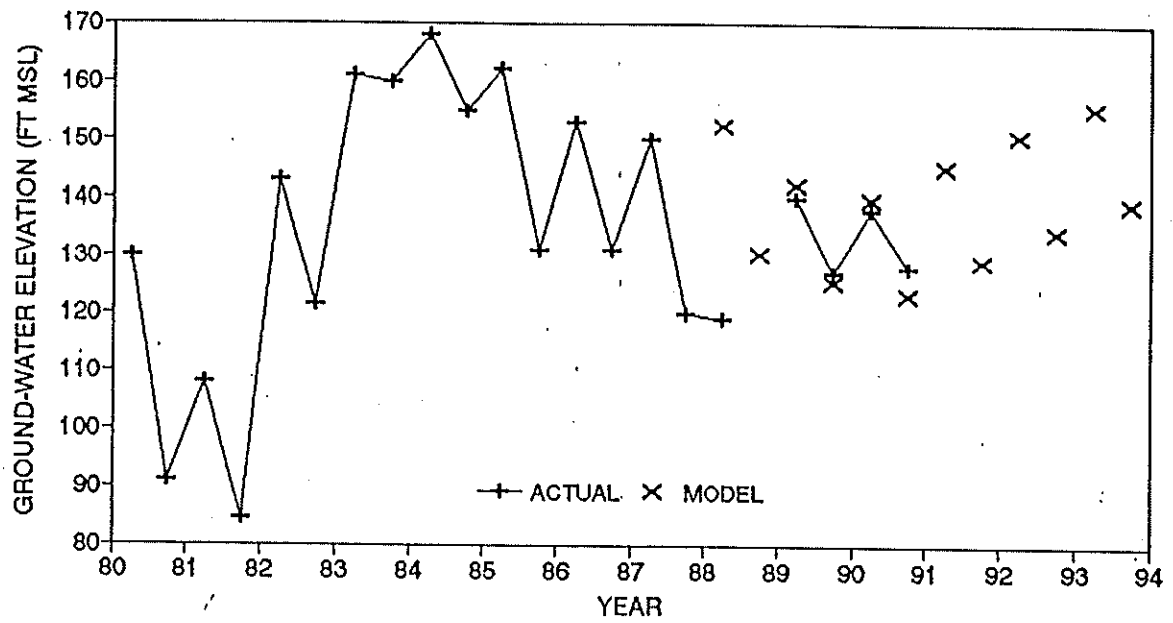
HYDROGRAPH COMPARISON: WELL 11-5-27P2  
SIMULATION OF 1987-90 PLUS 3 WET YEARS



HYDROGRAPH COMPARISON: WELL 11-5-35G1  
SIMULATION OF 1987-90 PLUS 3 WET YEARS



HYDROGRAPH COMPARISON: WELL 12-5-2H5  
SIMULATION OF 1987-90 PLUS 3 WET YEARS



HYDROGRAPH COMPARISON: WELL 12-4-36N1  
SIMULATION OF 1987-90 PLUS 3 WET YEARS

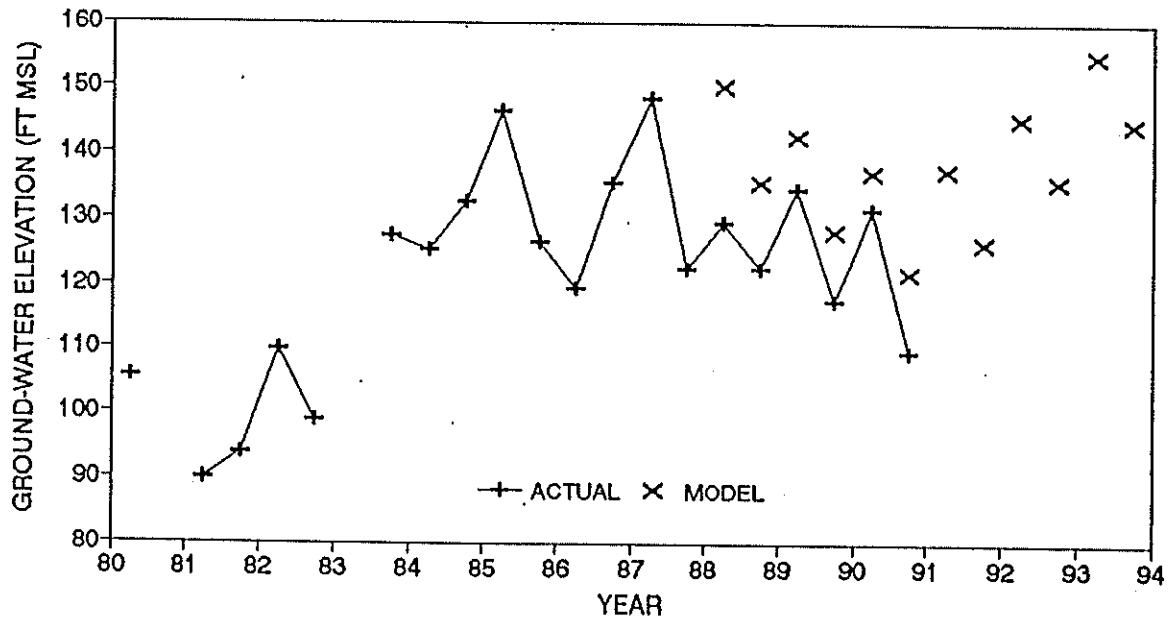


TABLE 4.6

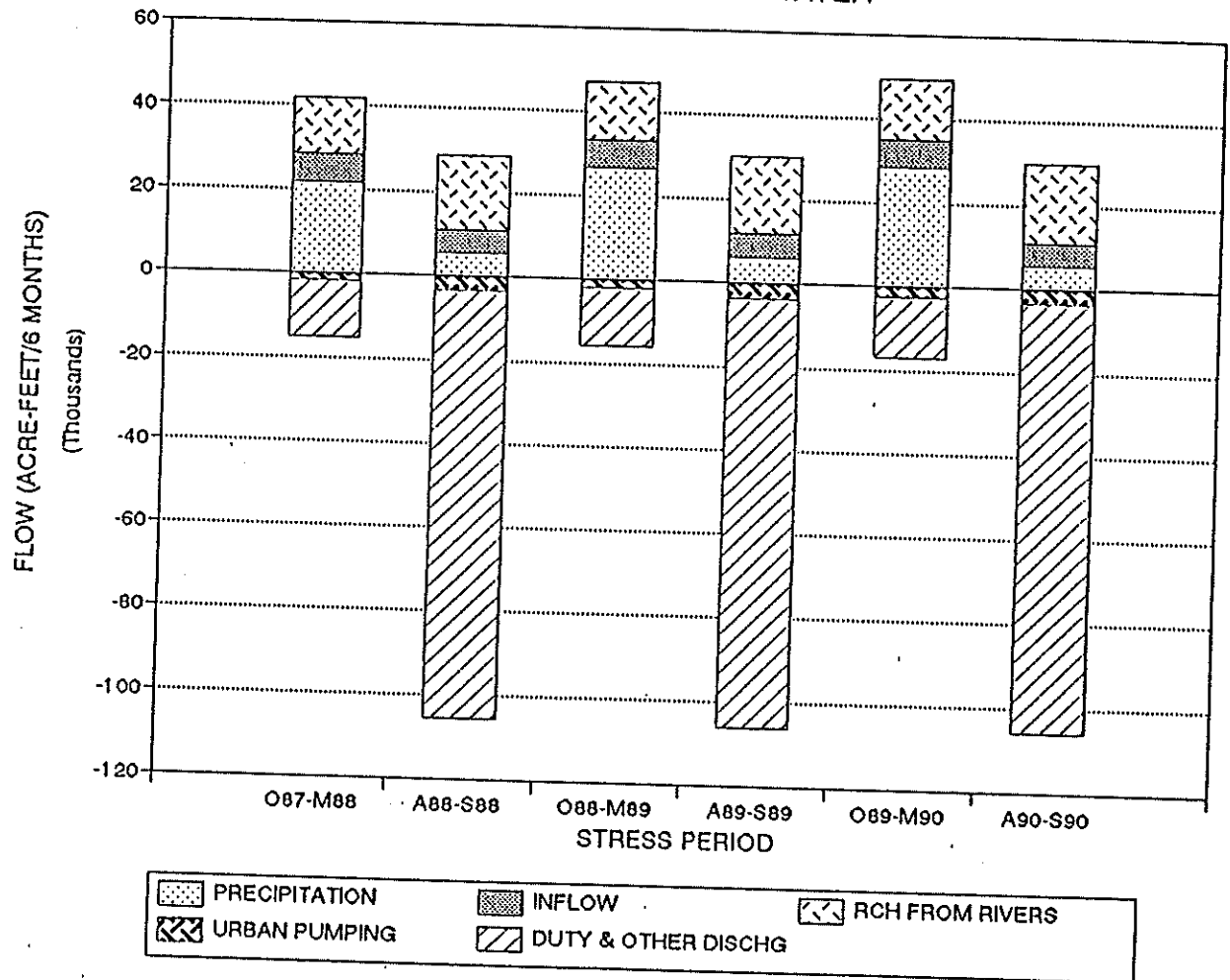
RECHARGE/DISCHARGE COMPONENTS FOR 1987-1990 SIMULATION  
WITHOUT SAN FELIPE WATER (ac-ft)

|                      | O87-M88 | A88-S88 | O88-M89 | A89-S89 | O89-M90 | A90-S90 |
|----------------------|---------|---------|---------|---------|---------|---------|
| <u>INFLOW</u>        |         |         |         |         |         |         |
| STORAGE DEPLETION    | 7181    | 73011   | 3640    | 72419   | 3211    | 72398   |
| RECHARGE FROM RIVERS | 13615   | 18054   | 14205   | 18590   | 14770   | 19059   |
| OTHER RECHARGE       | 17627   | 2418    | 21639   | 2512    | 23300   | 2386    |
| TOTAL                | 38423   | 93483   | 39484   | 93521   | 41281   | 93843   |
| <u>OUTFLOW</u>       |         |         |         |         |         |         |
| STORAGE GAIN         | 35513   | 153     | 36783   | 5       | 38388   | 33      |
| DISCHARGE TO RIVERS  | 85      | 0       | 102     | 0       | 117     | 0       |
| URBAN PUMPING        | 1782    | 3408    | 1980    | 3765    | 2259    | 3577    |
| OTHER DISCHARGE      | 1043    | 89925   | 620     | 89710   | 518     | 90231   |
| TOTAL                | 38423   | 93485   | 39484   | 93480   | 41281   | 93841   |

MODEL CALCULATED WATER BUDGET FOR 1987-1990 SIMULATION  
WITHOUT SAN FELIPE WATER (ac-ft)

|                      | O87-M88 | A88-S88 | O88-M89 | A89-S89 | O89-M90 | A90-S90 |
|----------------------|---------|---------|---------|---------|---------|---------|
| <u>INFLOW</u>        |         |         |         |         |         |         |
| RECHARGE FROM RIVERS | 13531   | 18054   | 14103   | 18590   | 14653   | 19059   |
| IMPORTED WATER       | 0       | 0       | 0       | 0       | 0       | 0       |
| PRECIPITATION        | 21891   | 5702    | 26478   | 6217    | 28367   | 5518    |
| INFLOW               | 6978    | 6016    | 6978    | 6016    | 6978    | 6016    |
| TOTAL                | 42399   | 29772   | 47559   | 30823   | 49998   | 30593   |
| <u>OUTFLOW</u>       |         |         |         |         |         |         |
| URBAN PUMPING        | 1782    | 3408    | 1980    | 3765    | 2259    | 3577    |
| DUTY                 | 8582    | 77658   | 8582    | 77658   | 8582    | 77658   |
| OTHER DISCHARGE      | 3704    | 21566   | 3854    | 21773   | 3981    | 21720   |
| TOTAL                | 14067   | 102632  | 14416   | 103196  | 14821   | 102956  |

# RECHARGE/DISCHARGE COMPONENTS WITHOUT IMPORTED WATER



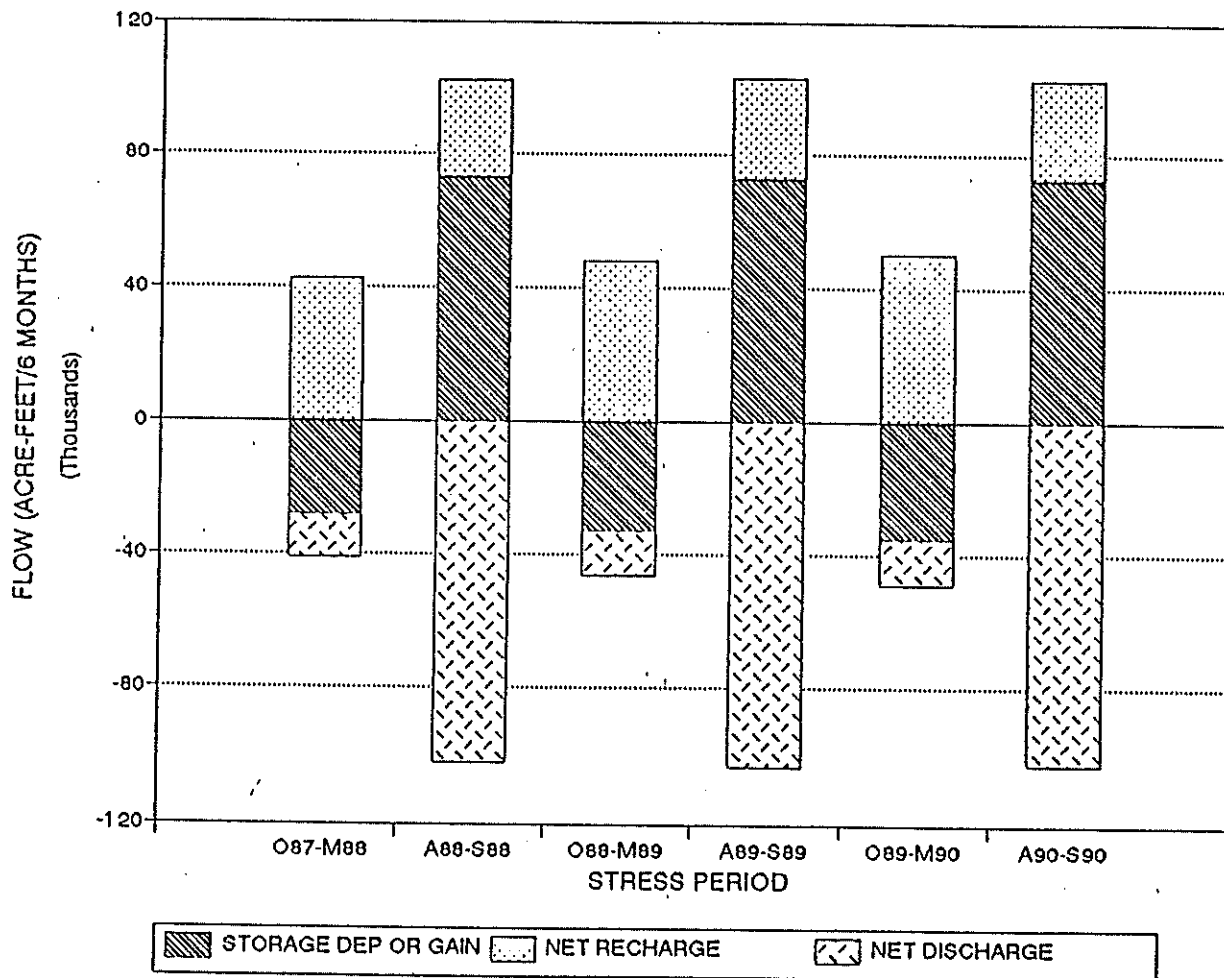
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Ground-Water Investigation

FIGURE  
4.38

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# CALCULATED WATER BUDGET WITHOUT IMPORTED WATER

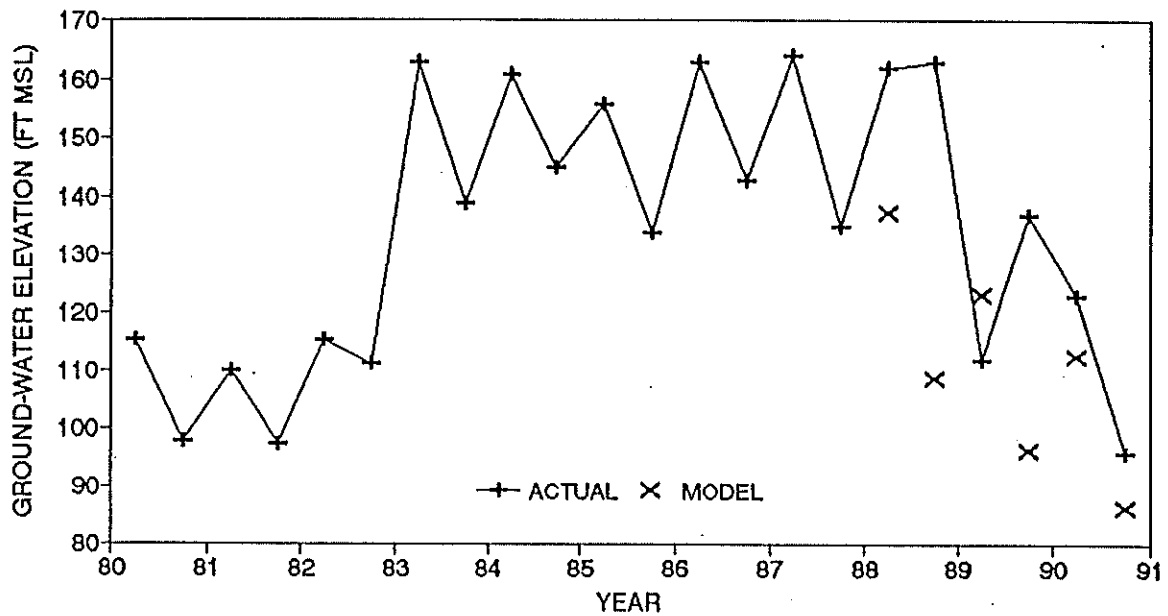


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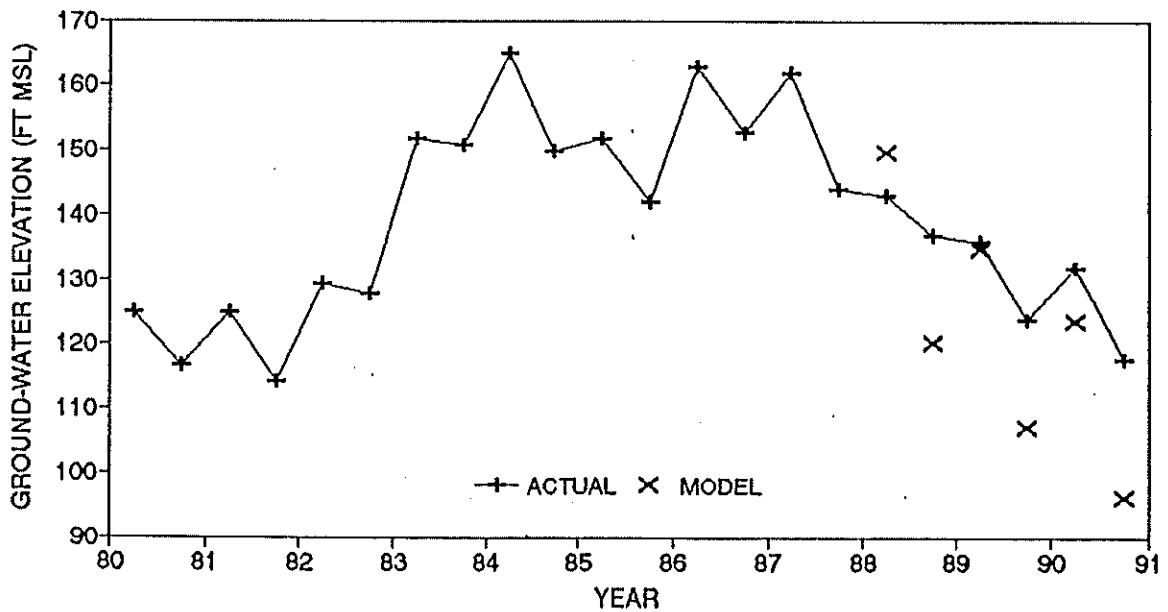
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FIGURE  
4.39  
90-1-084  
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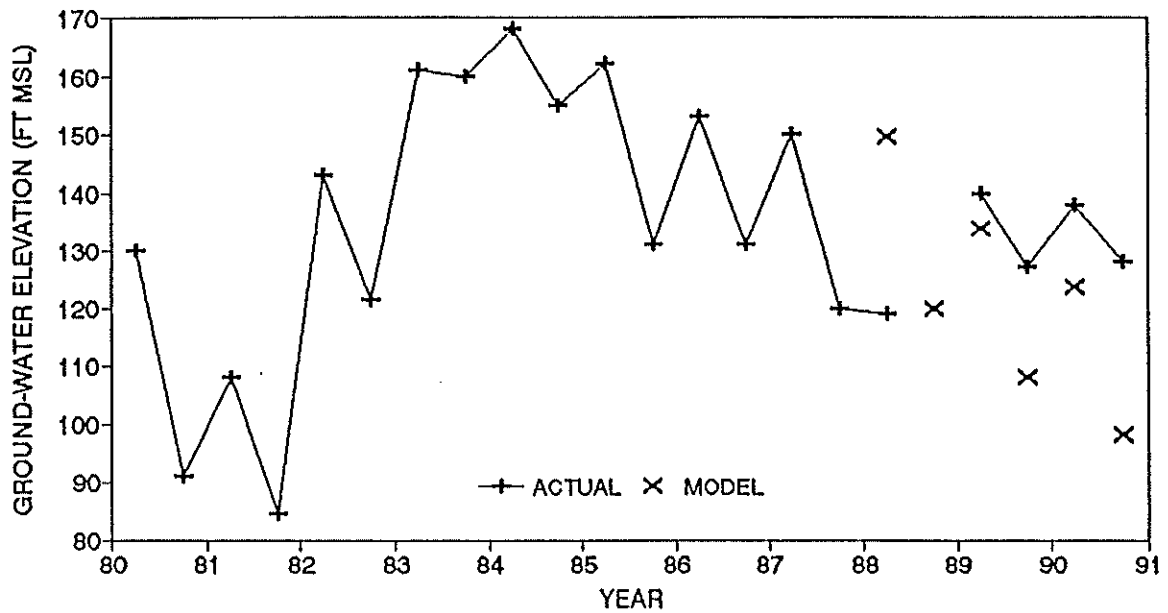
HYDROGRAPH COMPARISON: WELL 11-5-27P2  
SIMULATION WITHOUT SAN FELIPE WATER



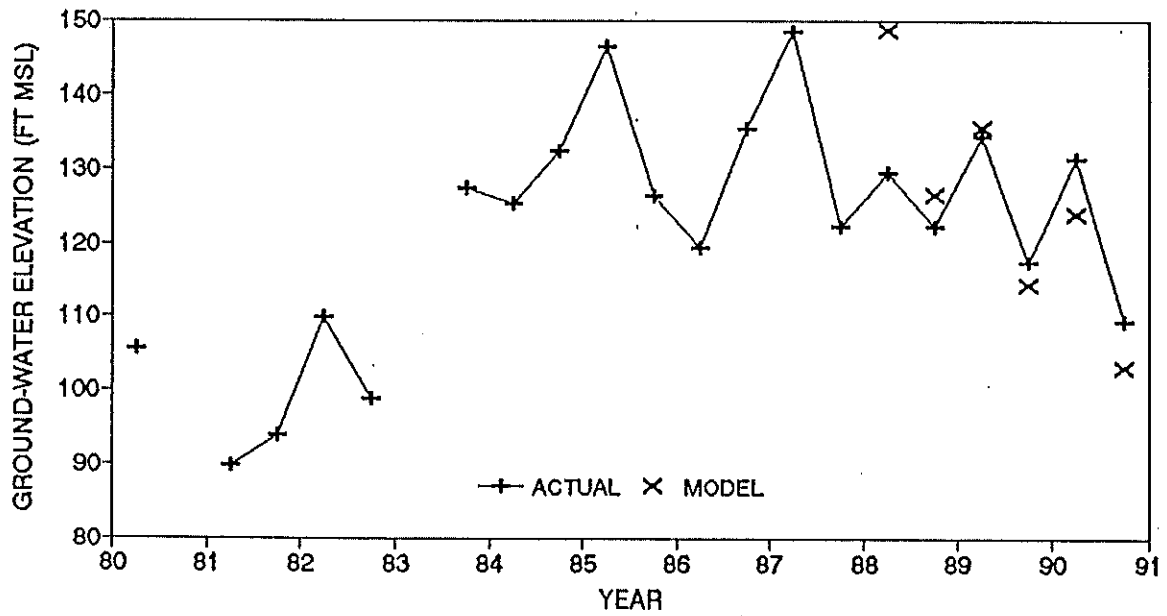
HYDROGRAPH COMPARISON: WELL 11-5-35G1  
SIMULATION WITHOUT SAN FELIPE WATER



HYDROGRAPH COMPARISON: WELL 12-5-2H5  
SIMULATION WITHOUT SAN FELIPE WATER



HYDROGRAPH COMPARISON: WELL 12-4-36N1  
SIMULATION WITHOUT SAN FELIPE WATER



## Synthesis of Results

As stated previously, most safe yield estimates begin with the objective of no long-term storage change, and define an average annual rate of pumping that will meet that objective. Implicit assumptions in this approach include a basic time frame reference, an assumption of a particular pattern of ground-water pumping, an assumption related to the continued importation of water, and an assumption related to the land use of the area. Specifically, if pumping patterns and importation amounts and patterns do not change, and land use remains constant, the average amount of pumping that will cause no net storage change over a specified period of time can be easily determined with the model. If land use, pumping patterns, and importation amounts and patterns change, the task becomes somewhat more difficult in that the estimate of safe yield can be rather sensitive to the particular set of changed conditions.

The selection of a particular time period on which to base a safe yield estimate is also an important consideration, and is one that does not generally lend itself to a purely objective choice. It is generally recognized that the period should be relatively long (approximately 20 to 30 years), begin and end at the end of a period dry years, contain a reasonable mix of wet and dry years, and, most importantly, should be a period of time when hydrologic practices (i.e. pumping patterns, land use, and amount and pattern of water importation) are reasonably static. In considering these criteria, it is clear that selection of a time period is difficult in this case, largely due to the recent importation of water. It should be noted that the calibration period for the model was chosen with these criteria in mind, and ultimately the decision to simulate a short time period with reasonably static hydrologic conditions was chosen.

Another criterion that needs to be considered in the selection of a time period relates to the policy issue of ground-water flow conditions and management. The recognition of declining ground-water levels (storage declines) and flow reversals was a major impetus to bring San Felipe water into the area. If the management objective is to rapidly return ground-water

levels and flow patterns to conditions that were present in the 1940's, "safe yield" pumping would be extremely small since the present level of pumping is not consistent with this objective, despite the availability of imported water. Consequently, achieving this objective would have severe economic effects in the region as agricultural pumping would have to be drastically curtailed.

On the other hand, if the management objective is to cause no further decline in ground-water storage and accept present conditions as a baseline, "safe yield" pumping will largely be a function of the amount of imported water since this is something that can be "managed". Operating under this assumption allows the results of the model to be analyzed to develop an estimate of safe yield.

As described earlier, the model results include a calculated ground-water budget, and the development of the net recharge/discharge data yields estimates of recharge and discharge components. The data from the calculated ground-water budget and the net recharge/discharge calculations are combined and summarized in Table 4.7 and Figure 4.42 for the three scenarios run with the model. Note that the values are expressed in terms of acre-feet per year, and that when the storage change value is negative, a storage decline was calculated.

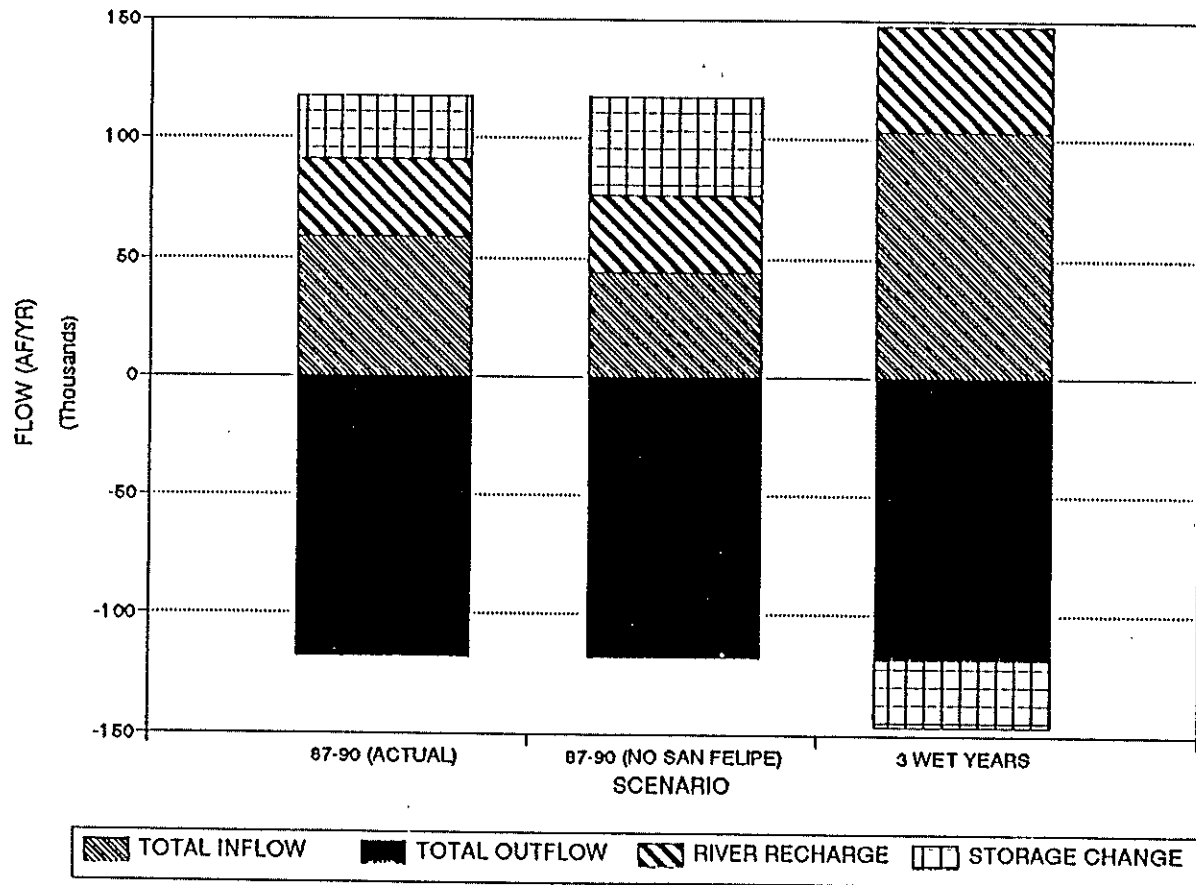
The sum of San Felipe deliveries (90 percent of actual deliveries) and precipitation (50 percent of actual) can be plotted with the calculated storage change in order to gain some perspective as to the role of the basic sources of recharge on storage change (Figure 4.43). It would be possible to plot total agricultural and urban pumpage with storage change (a method generally known as the Hill method), but from the County's and Water District's perspectives, these are less "manageable" quantities than imports. The inclusion of precipitation, while not a manageable source, is necessary to "correct" for the below average precipitation that has occurred observed over the past few years.

Note that the linear relationship between the sum of San Felipe deliveries and storage

TABLE 4.7  
WATER BUDGET SUMMARY FOR MODEL SIMULATIONS

|                      | 87-90  | 87-90<br>(NO<br>SAN FELIPE) | 3 WET<br>YEARS |
|----------------------|--------|-----------------------------|----------------|
| <u>INFLOW</u>        |        |                             |                |
| SAN FELIPE (90%)     | 14809  | 0                           | 16345          |
| PRECIPITATION (50%)  | 31391  | 31391                       | 62104          |
| GROUND-WATER INFLOW  | 12993  | 12993                       | 25183          |
| TOTAL                | 59193  | 44384                       | 103632         |
| <u>OUTFLOW</u>       |        |                             |                |
| URBAN PUMPING        | 5586   | 5586                        | 5833           |
| CROP DUTY            | 86240  | 86240                       | 86240          |
| "OTHER" DISCHARGE    | 26448  | 26448                       | 26448          |
| TOTAL                | 118274 | 118274                      | 118521         |
| INFLOW - OUTFLOW     | -59081 | -73890                      | -14889         |
| NET RIVER RECHARGE   | 32440  | 32663                       | 44106          |
| STORAGE CHANGE       | -26641 | -41227                      | 29217          |
| SAN FELIPE + PCP     | 46200  | 31391                       | 78449          |
| ESTIMATED AG PUMPAGE | 41642  | 56144                       | 19311          |

# GROUND-WATER MODEL AREA WATER BUDGETS

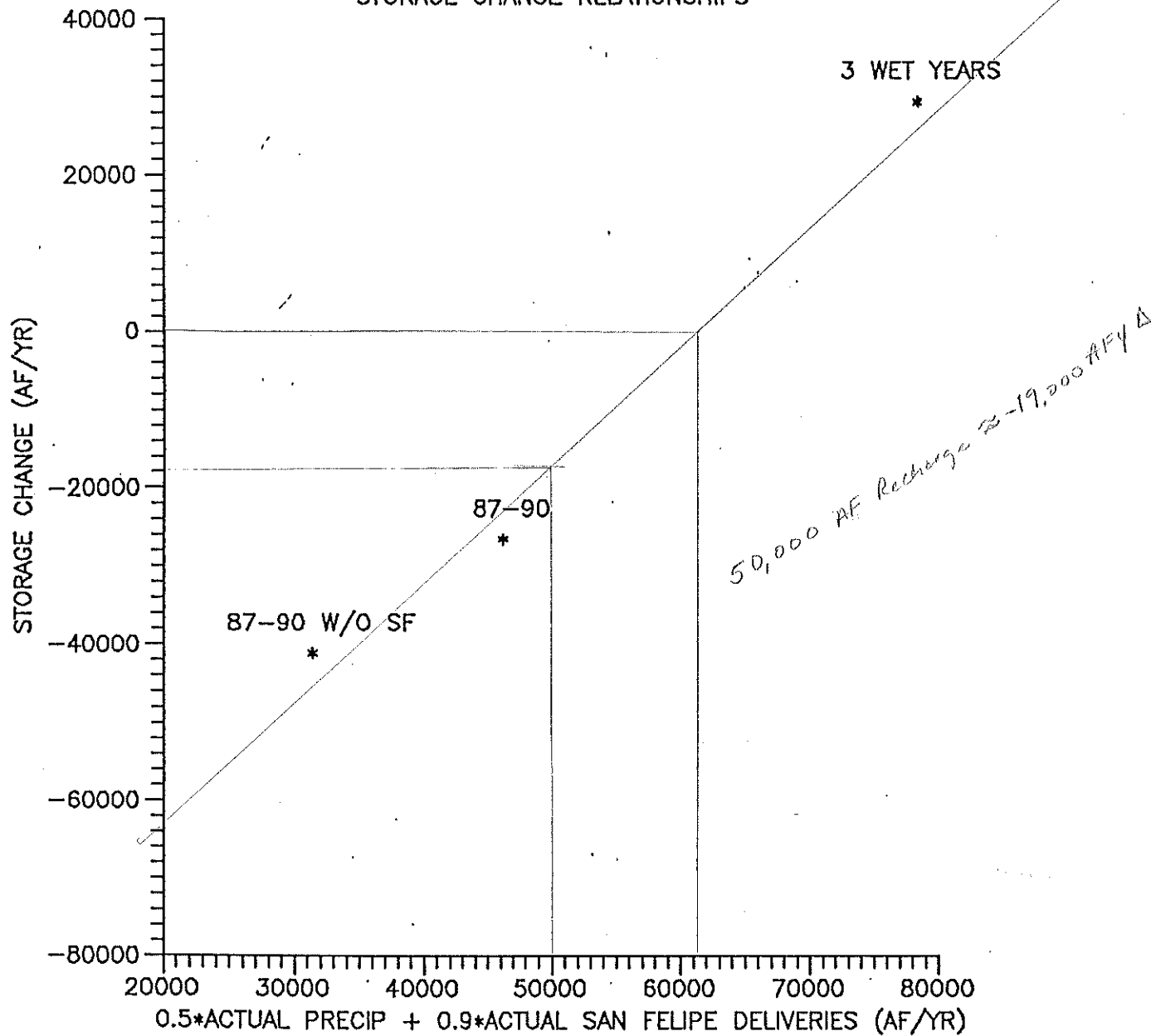


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FIGURE  
4.42  
90-1-084  
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# ESTIMATED MODEL AREA STORAGE CHANGE RELATIONSHIPS



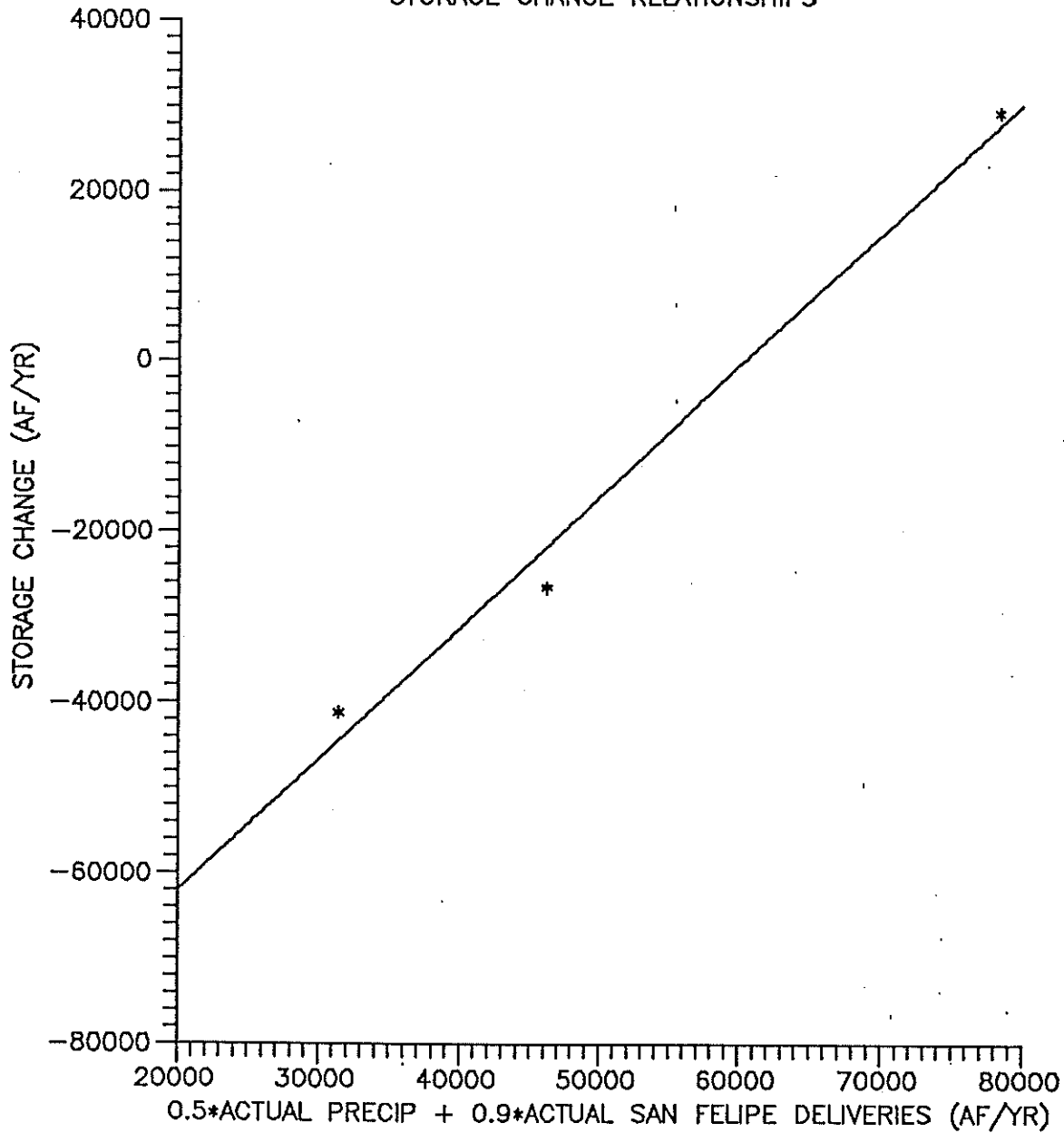
change (as depicted in Figure 4.44) allows for the evaluation of long term storage change under various assumptions of San Felipe deliveries and precipitation. Figure 4.45 depicts two such scenarios: 1) deliveries at current levels and average precipitation, which result in approximately no net storage change, and 2) no deliveries and average precipitation, which results in a storage decline of approximately 26,000 acre-feet per year. Implicit in the second scenario is that ground-water pumping would replace the imported water.

From this analysis, it can be concluded that the current rate and pattern of deliveries (approximately 16,000 acre-feet per year), and the current rate and pattern of average urban, suburban, and agricultural pumpage (approximately 38,000 acre-feet per year) will cause no further decline in ground-water storage over the entire model area over the long term. The concept of "long term" is critical to this analysis. Ground-water storage will continue to fluctuate in response to variations in precipitation and pumping, but long term storage should not significantly increase or decrease under current conditions. The long-term average values that correspond to this condition are presented diagrammatically in Figure 4.46.

It is reasonable to expect, however, that as San Felipe deliveries increase toward the contract entitlement and as pumping decreases in response to the use of the supplemental water, ground-water storage will increase and ground-water levels will recover. The location of this recovery will be largely dependent on the pattern of the increased deliveries, and on precipitation amounts during that period.

It must be emphasized that this conclusion is drawn for the entire area. The dynamics of ground water flow are such that as ground-water levels in areas with imported water begin to increase, ground-water will begin to flow into areas which have depressed ground-water levels and no imported water. Therefore, it is reasonable to conclude that, in time, ground-water flow directions will gradually change from current patterns to some other pattern that represents a new equilibrium condition. It is difficult to estimate how long it will take to reach this new equilibrium condition since it is largely dependent on the annual

# ESTIMATED MODEL AREA STORAGE CHANGE RELATIONSHIPS



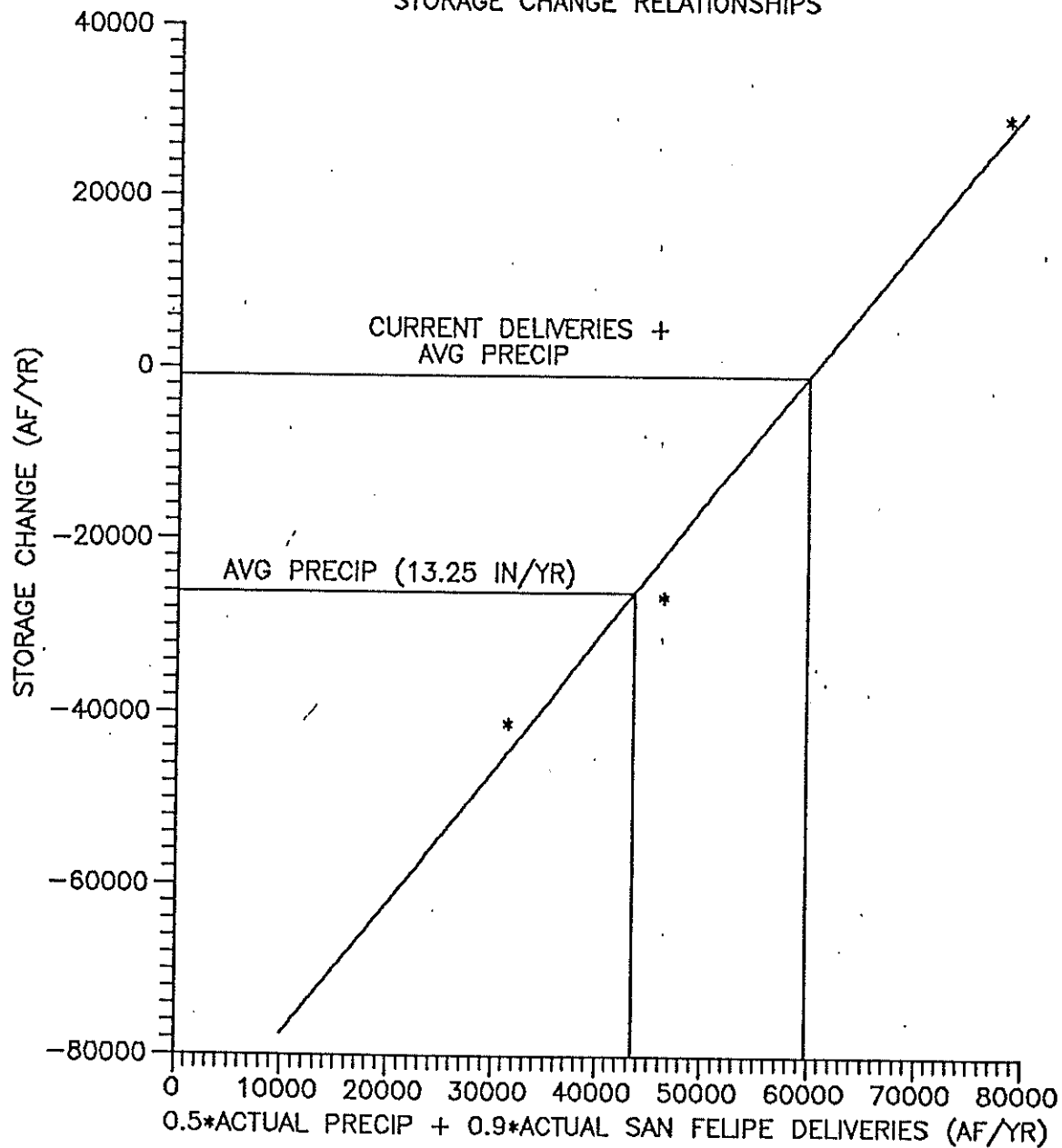
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FIGURE  
4.44

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# ESTIMATED MODEL AREA STORAGE CHANGE RELATIONSHIPS



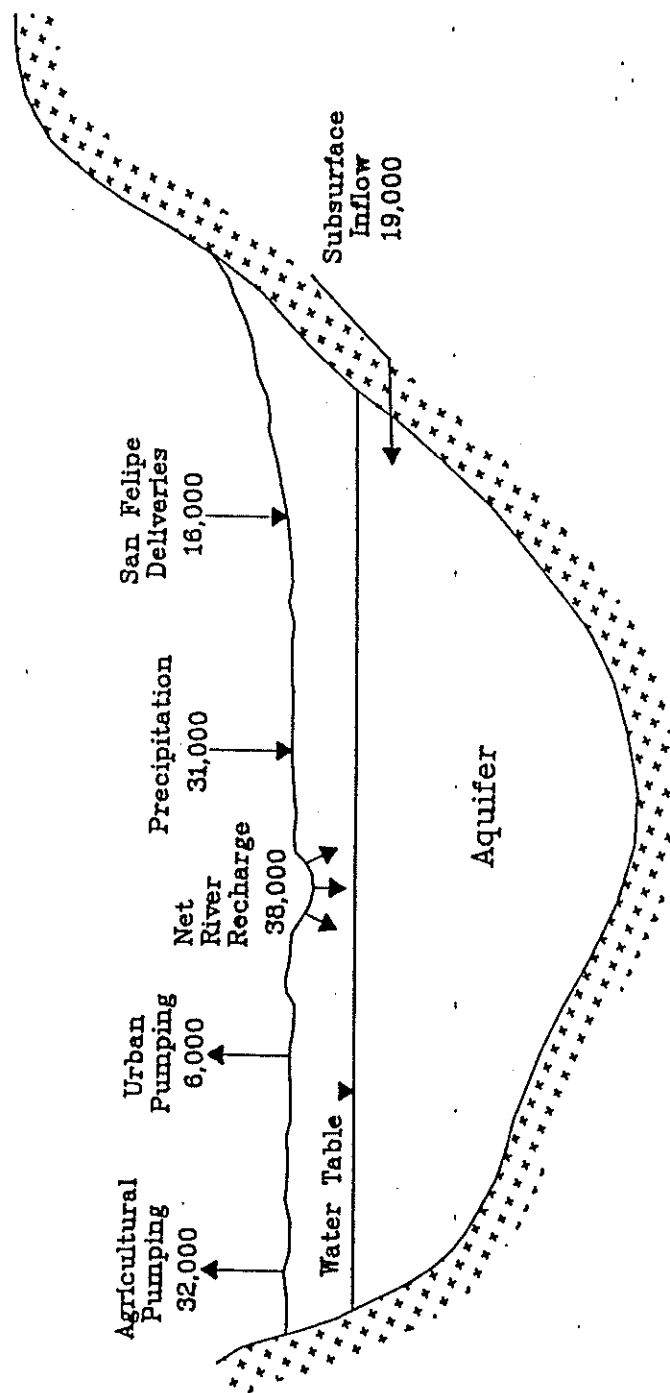
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FIGURE

4.45

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Conceptual Ground-Water Model with Safe-Yield Values  
(all values in acre-feet per year)

FIGURE  
4.46



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precipitation pattern in the future. If several wet years were to occur beginning next year, re-establishment of equilibrium conditions would be faster than if the drought were to continue.

In the future, the conclusions as to the regional changes of ground-water storage can be used in evaluating development projects by requiring a detailed, site-specific hydrologic investigation of the proposed project coupled with an evaluation of how the project would impact regional hydrology. The detailed investigation should include as a minimum the following: 1) geologic evaluation that is aimed at identifying aquifer geometry and characteristics, 2) aquifer testing of the area to determine the aquifer characteristics and well yields of the area, and 3) an analysis to compare and contrast current and proposed water use and fate (e.g. sewerage away from the area vs. on-site treatment and disposal/irrigation). This information would be needed to simulate the proposed project in the model and to develop conclusions as to the regional impacts of the project. This analysis should in no way be considered a substitute for a thorough site specific analysis of impacts since the model only simulates truly regional conditions.

## *V. Paicines and Tres Pinos Basins*

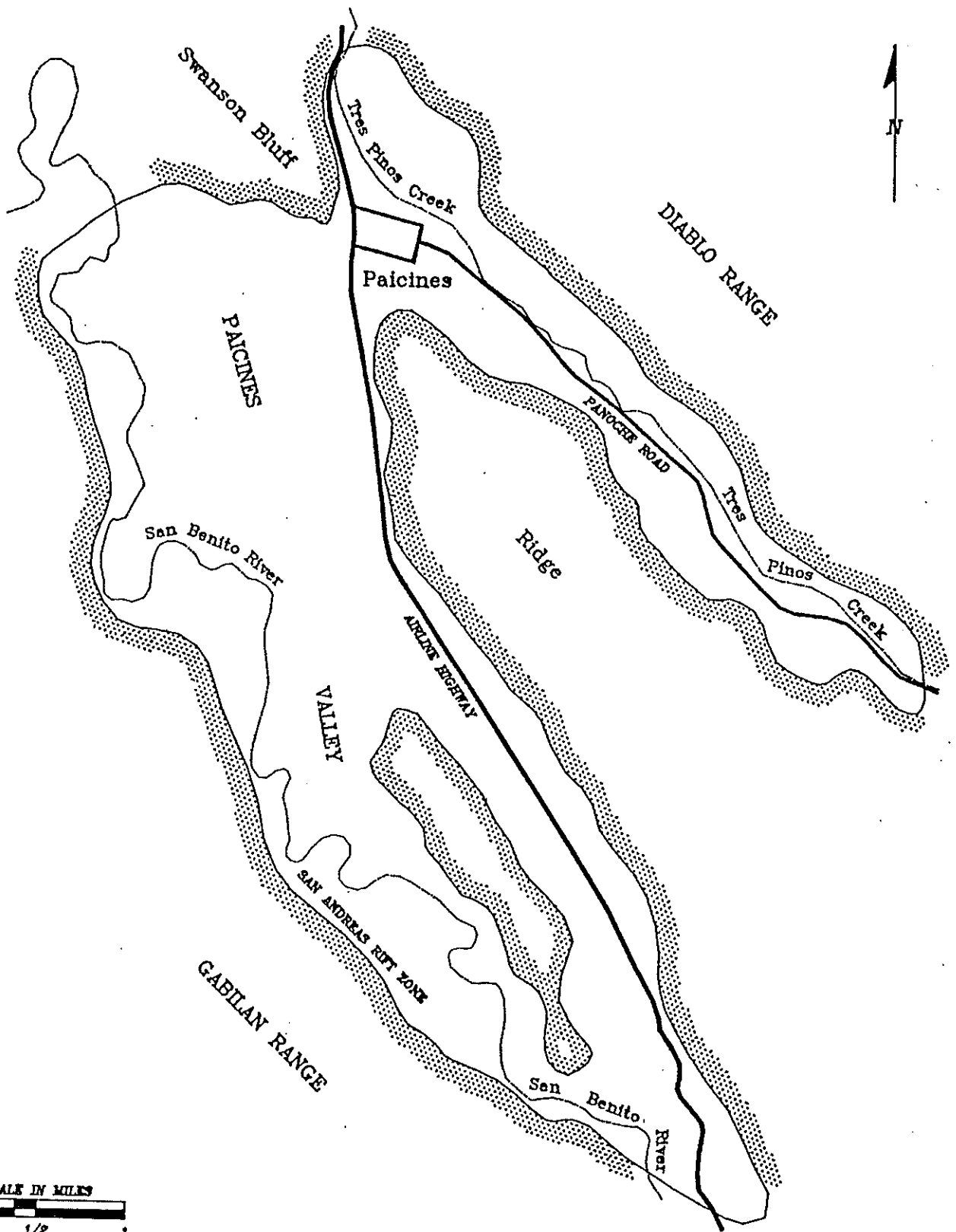
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The Paicines and Tres Pinos basins underlie two alluvial valleys that intersect beneath the town of Paicines (Figure 5.1), southeast of Hollister along Airline Highway. The larger of the two valleys, Paicines Valley, is drained by the San Benito River, and the smaller is drained by Tres Pinos Creek. The valleys have a combined basin area of approximately 8,800 acres. Historically, the basins have been developed by a relatively small number of wells, with generally good yields, for irrigation of row crops, vineyards, and orchards. However, as discussed in greater detail below, there has been essentially no organized collection of ground-water related data in either basin; and the initial assessment within this investigation was that the only product might consist of recommendations for specific data collection in order that the yield of the basin(s) could be analyzed at some future time. Ultimately, as also discussed below, it was possible to identify some ground-water related data which allowed an assessment of recent (15 to 20 years) ground-water conditions and the development of initial basin yield estimates on which current water supply and management decisions can be based, and which can be updated as appropriate after implementation of recommended ground-water monitoring.

### **Previous Investigations and Hydrologic Data**

There have been no published investigations of ground-water occurrence and yield in the Paicines or Tres Pinos basins. It is not known whether there have been any previous attempts; however, any such attempt would have faced similar constraints from the lack of hydrologic data, at least from the normal sources of such records, the State Department of Water Resources (DWR) and local agencies such as the County and water districts.

Initial inquiry to DWR as part of this investigation identified that ground-water level



From Paicines and Cherry Peak U.S.G.S. 7 1/2' Quadrangles

# Location Map, Paicines and Tres Pinos Valleys

FIGURE  
5.1



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measurements and water quality data are not maintained at DWR for any well in either basin. Other useful data such as pumped well test reports for aquifer characteristic determination and assessment of well yields are also not available. The most useful data in the public record for the analysis ultimately completed was a series of four land use surveys by DWR over the period 1968 to present (1991); these survey results were used to estimate historical water use in the basins. Also useful in the following analysis were a precipitation station record from 1948 to present at Paicines (on the Ohrwall Ranch), and stream pumping records on the San Benito River at the Willow Creek School pumping station and on the Tres Pinos Creek approximately two miles downstream from Paicines.

The limited data described above would be an inadequate basis for development of any assessment of basin yield. Further investigation into possible data sources resulted in acquisition of a number of well logs and records of utility company (PG&E) pump test reports which have been conducted over the past 15 to 20 years from the Ridgemark Corp., which has apparently acquired significant portions of both valleys from Almaden Vineyards, which had farmed grapes in the Paicines area for a number of years prior to the mid-1980's. Key items of ground-water related data on the PG&E pump test reports, in terms of this initial assessment of ground-water conditions and basin yield, included: static and pumping water levels on the dates of the tests, pumping capacities, well yield as measured by its specific capacity (gallons per minute per foot of water level drawdown during pumping), energy required per unit volume of water pumped, and total energy consumed for pumping in a given year. These latter data, combined with the DWR land use surveys, were the key components in developing the following initial assessment of basin yield on both the Paicines and Tres Pinos basins.

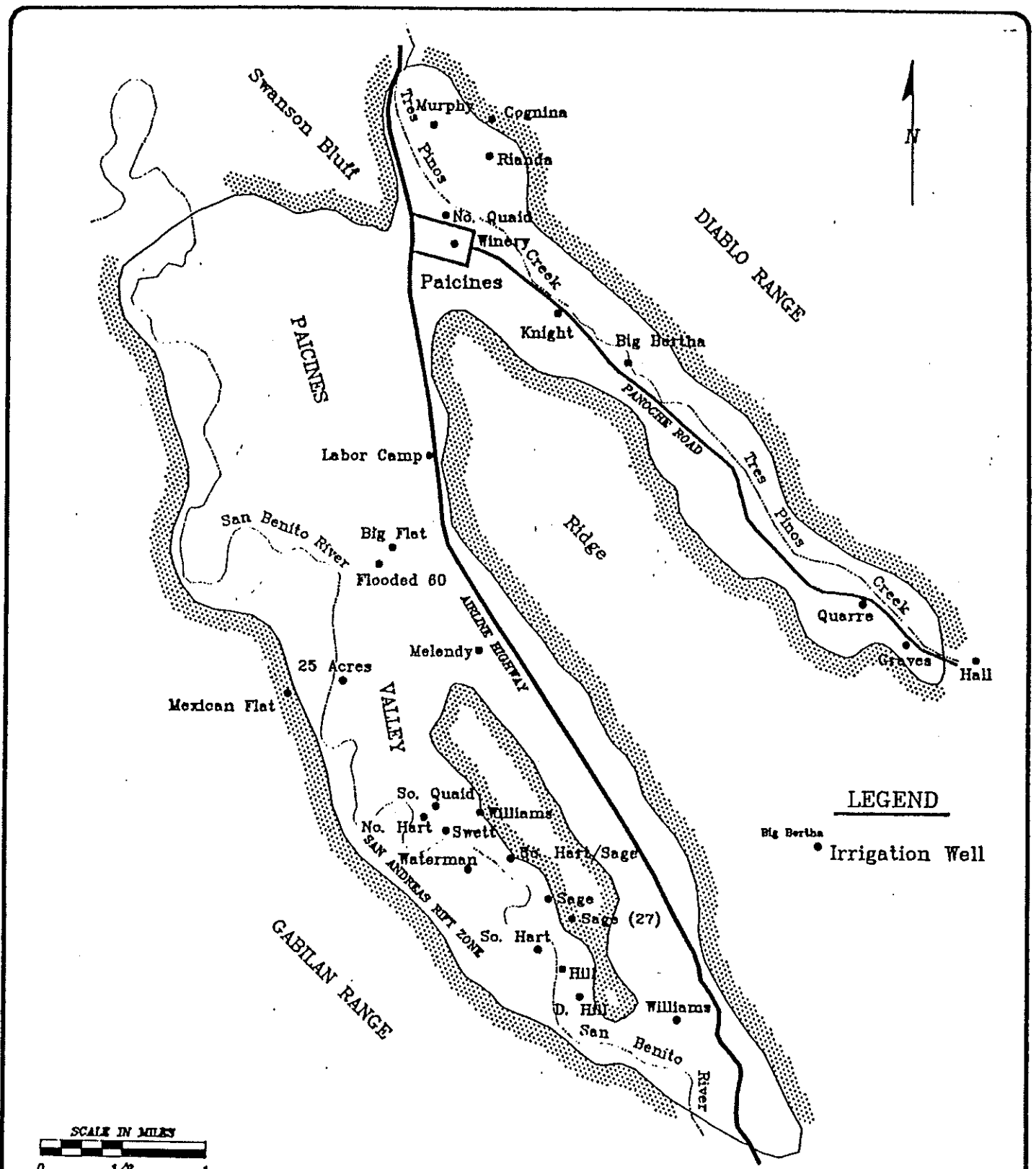
#### Geologic Setting and Occurrence of Ground Water

Both the Paicines and Tres Pinos valley areas are underlain by alluvial aquifers which are composed of interlayered sand, gravel, boulders, and clay. Several irrigation wells in the Paicines Valley penetrate alluvial deposits to depths ranging from less than 100 to below 500

feet. Wells in the Tres Pinos Creek valley penetrate alluvial deposits to depths ranging from 135 to 630 feet. There is insufficient control of both areal extent and aquifer thickness, and lack of any well test data from which to determine aquifer storage coefficients, on which to calculate a volume of ground water in storage. The combination of highly faulted geology and wide variation in well depths suggests that the areal extent of the aquifer system is limited to within the valleys and to 500 or 600 feet; however, the historic practice of completing wells only as deep as necessary, without any documented exploration to depth throughout the area, has resulted in a limit to define aquifer materials throughout the two valleys.

### Ground-Water Levels

Of the 29 wells for which some records (PG&E pump tests) could be obtained (Figure 5.2), the majority included static water measurements from the early to mid 1970's to the later 1980's; three wells had one or two measurements as early as the 1960's. It should be noted that most of the wells (18) had four or fewer static water level measurements over a typical period of 10 to 20 years, so exacting analysis of seasonal fluctuations could not be made. However, based on some of those measurements and on the balance of the wells for which there were a few more (as many as seven) measurements, hydrographs of depth to ground water were prepared to examine long term general trends. Illustrative examples of typical trends in both valleys are illustrated by water level fluctuations in four wells (Figures 5.3 and 5.4), two of which (Big Flat and South Quaid) are in the Paicines Valley and the other two of which (Knight and Big Bertha) are in the Tres Pinos Valley. The Paicines wells show long term relatively constant ground-water levels until the beginning of the current drought, with a notable decline detected at the time of the first measurements (1978) after the 1976-77 dry period. Although no measurements were made during that drought, it is reasonable to assume that ground-water levels were lower in that '76-'77 period and were recovering when the '78 measurements were made. More significant is the fact that ground-water levels ultimately recovered to essentially pre-drought conditions and remained there through the early 1980's. In the Tres Pinos basin, ground-water levels have also remained nearly



From Paicines and Cherry Peak U.S.G.S. 7 1/2' Quadrangles



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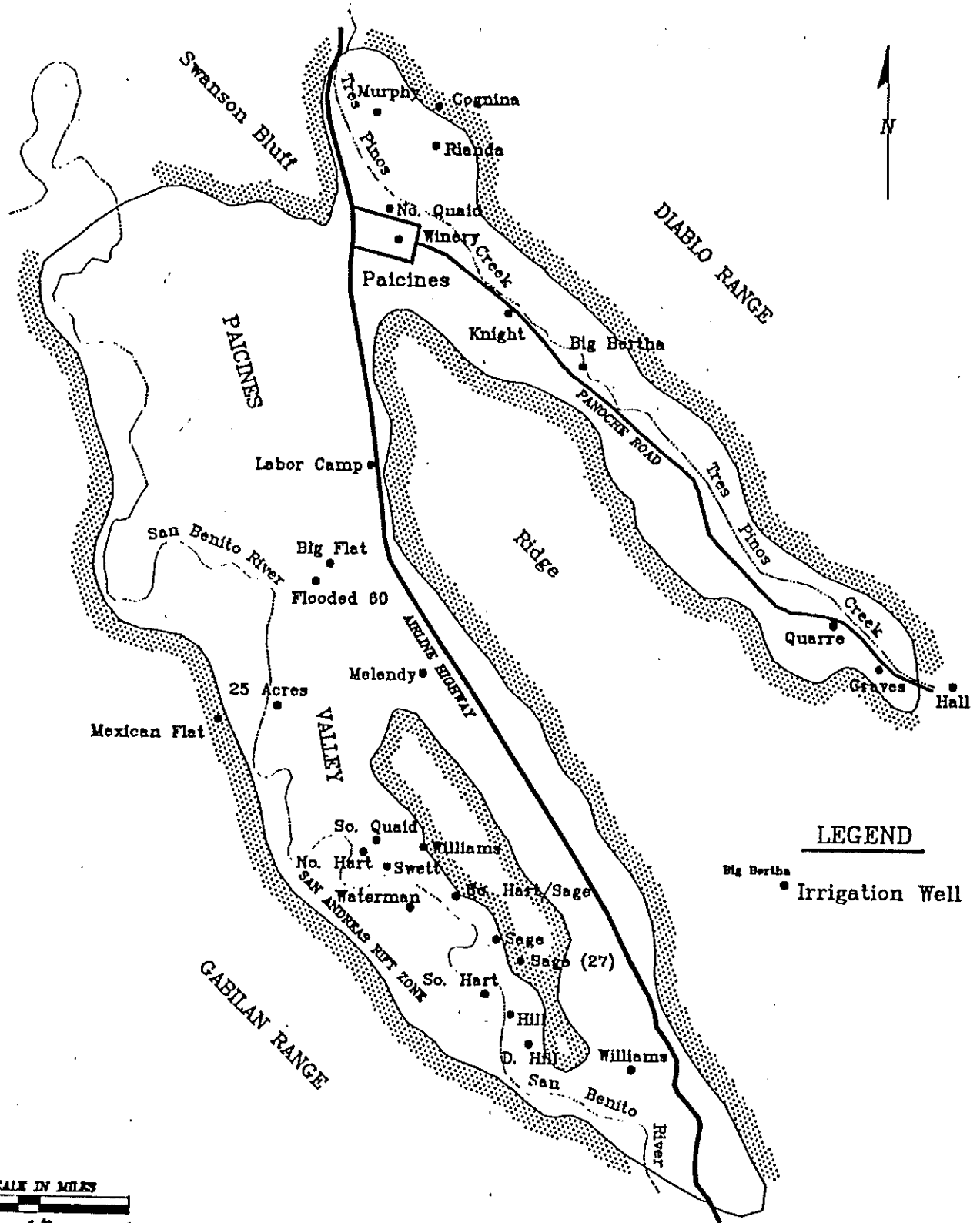
# Well Location Map, Paicines and Tres Pinos Valleys

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FIGURE

5.2

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From Paicines and Cherry Peak U.S.G.S. 7 1/2' Quadrangles

Well Location Map,  
Paicines and Tres Pinos Valleys

FIGURE

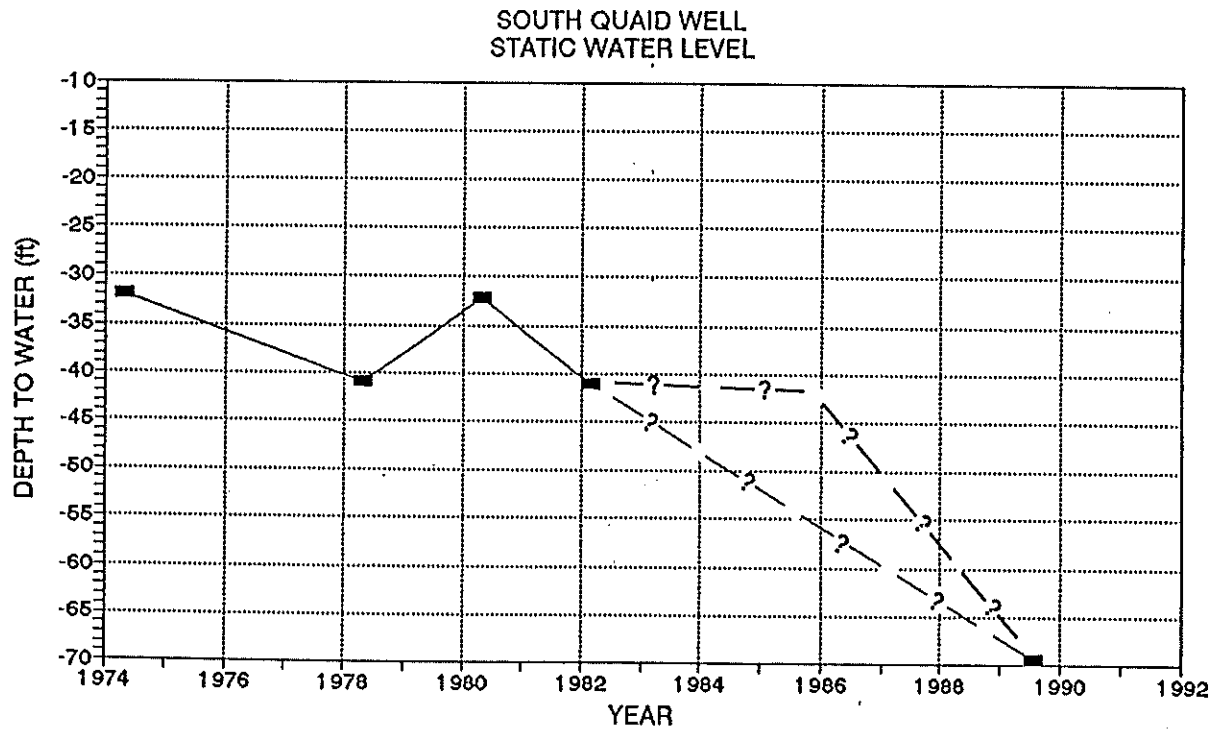
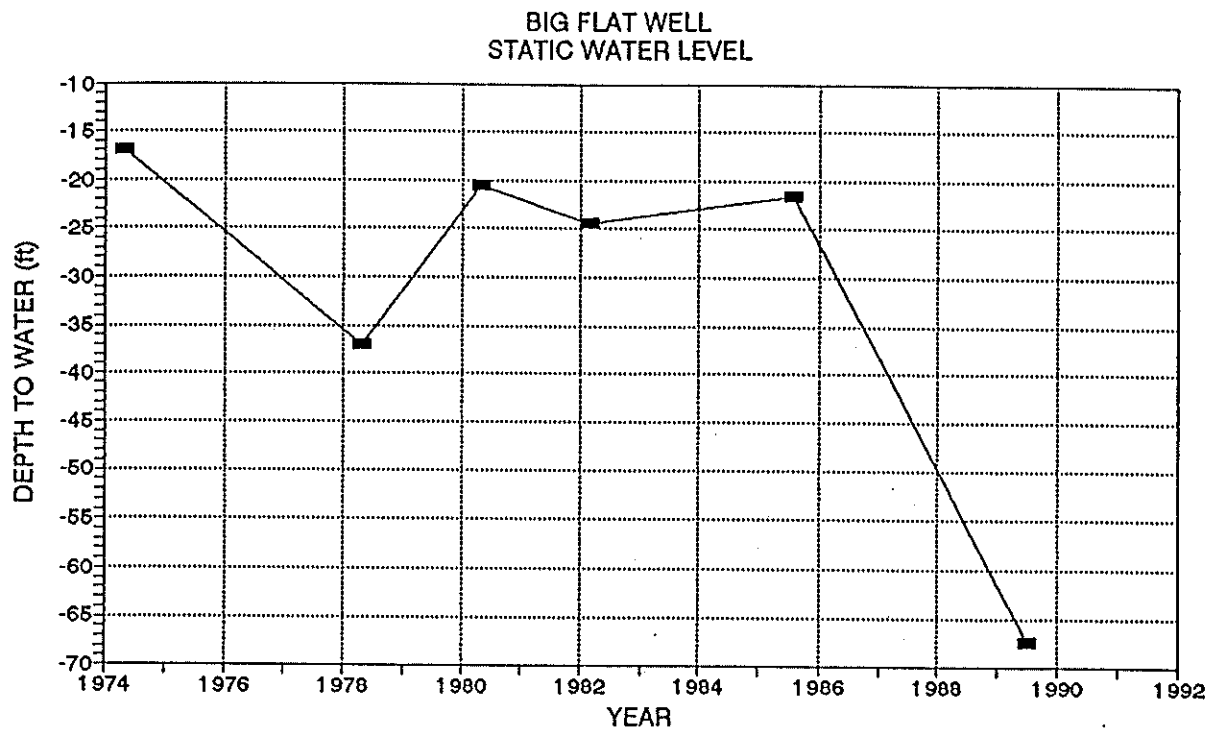
5.2



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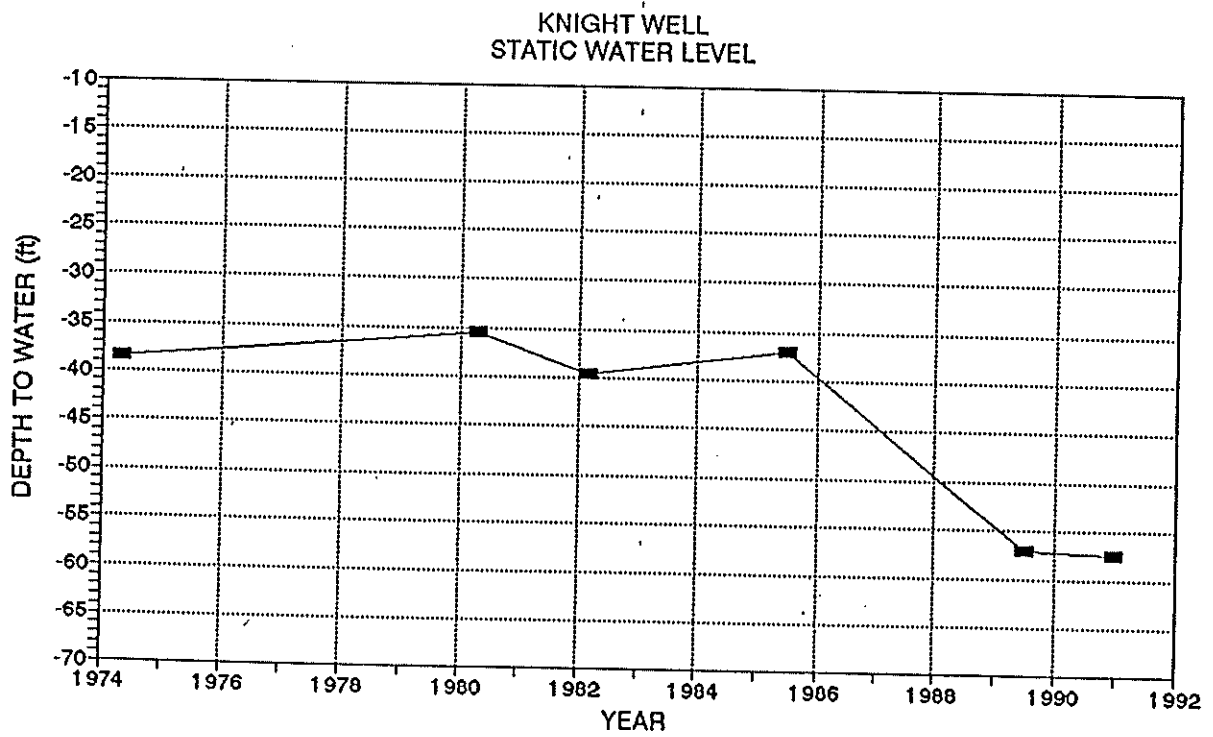
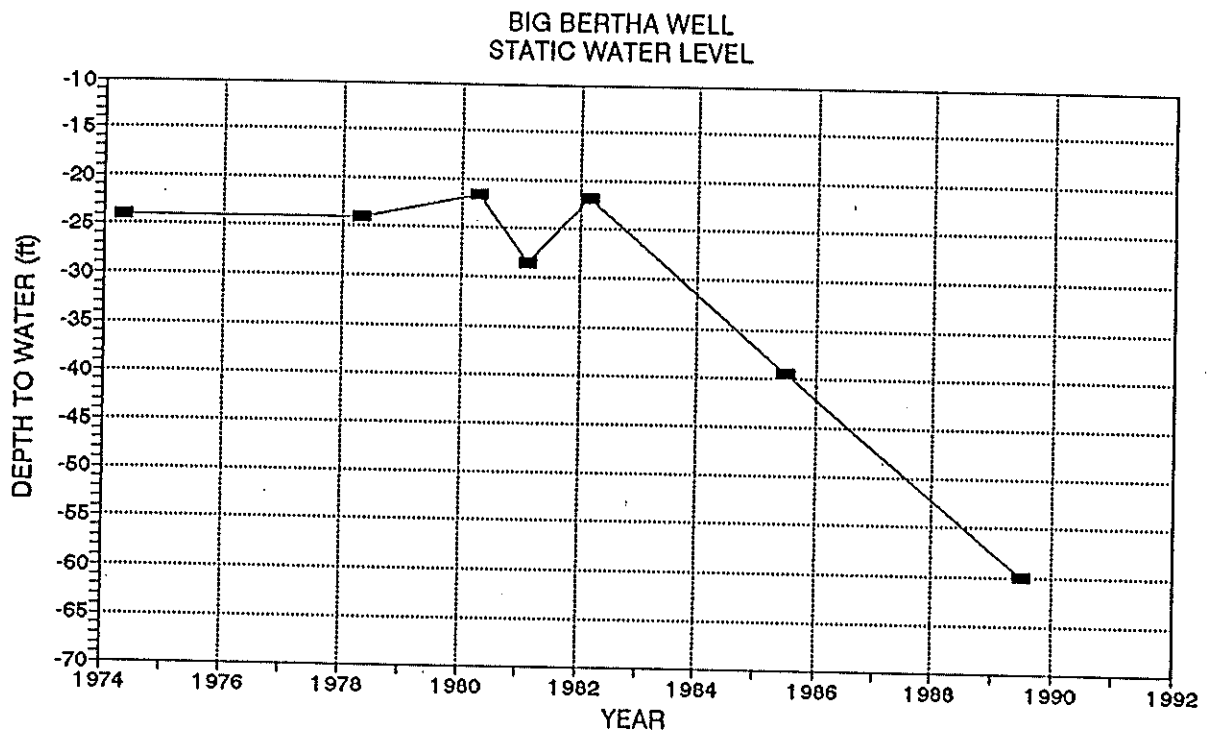
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### Hydrographs of Depth to Ground Water, Paicines Valley

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**FIGURE**  
**5.3**

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### Hydrographs of Depth to Ground Water, Tres Pinos Valley

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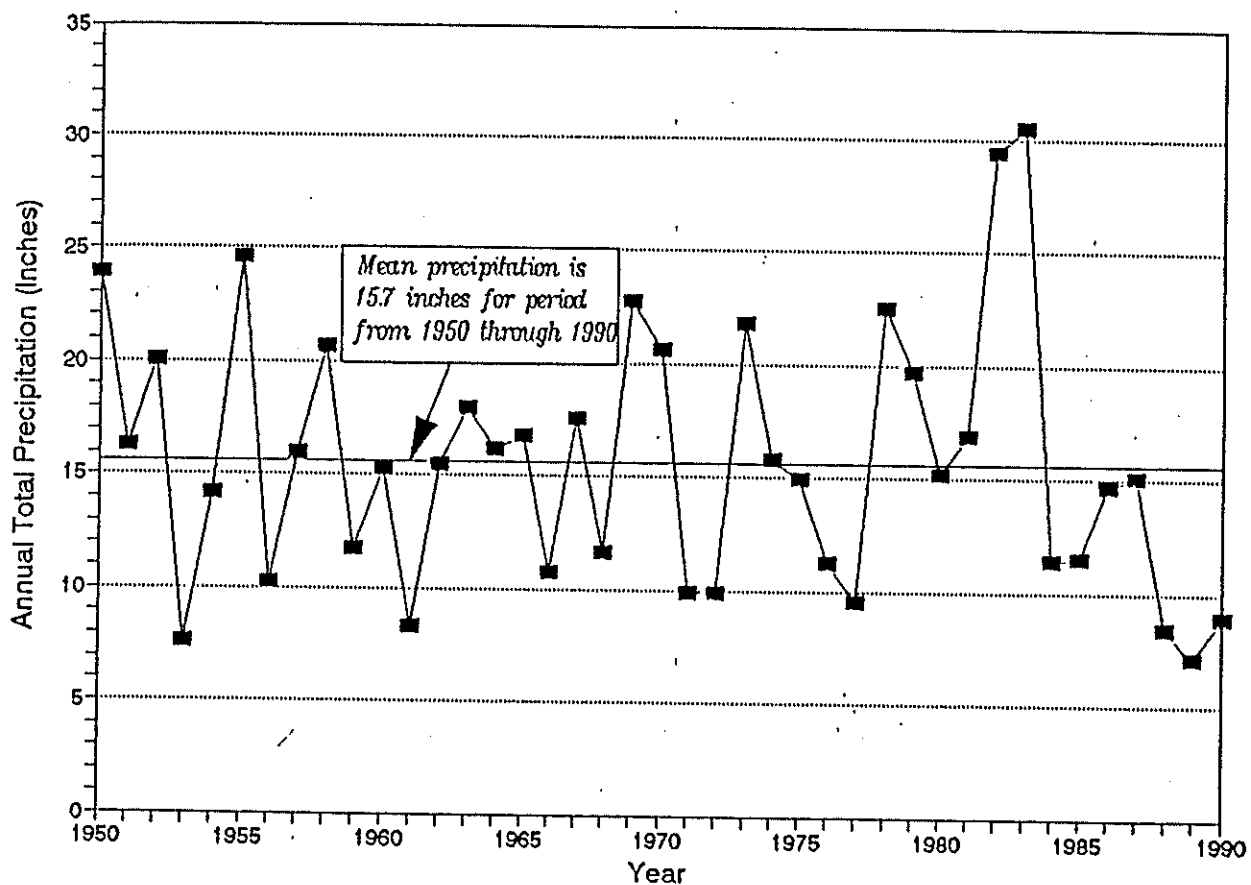
FIGURE  
5.4

90-1-084  
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constant from the early 1970's through the mid 1980's when the current dry conditions commenced. There is insufficient data to detect the impacts of the 1976-77 drought, but water levels before and after that event are essentially the same.

An examination of precipitation data from the Paicines area (Figure 5.5), in combination with the ground-water level hydrographs, suggests that the basins respond readily to precipitation in terms of recovery from drought-related water level and storage declines. However, it also appears that the near constant ground-water levels in the various wells through the early 1980's (Figures 5.3 and 5.5) represent effectively full basins; the high precipitation of 1982 and 1983 did not cause ground-water levels to increase above historical values. To further examine that concept, a contour map of equal ground-water elevations was prepared for the most recent pre-drought conditions, Spring 1985, which is also indicative of typical basin conditions over the preceding ten or more years. Those contours (Figure 5.6) suggest that ground water flow is parallel to the San Benito River and Tres Pinos Creek, respectively, and may be contributing some base flow to the streams. It should be noted that, to prepare the contour map of ground-water elevations, surface elevations were estimated from a topographic map, and the resultant ground-water contour elevation should not be considered exact. However, although the illustrated contours may be slightly in error due to a lack of surveyed wellhead elevations, they indicate a ground-water system in reasonable equilibrium with the streams over a long pre-drought period.

Further evidence of the basin's strong response to changes in precipitation is the significant decrease in ground-water elevations caused by the current drought. The basin is experiencing an unprecedented seventh continuous year of below-average precipitation. In 1989, the basin received the lowest amount of precipitation in the 40-year record of the Paicines area (45 percent of the 40-year mean value). The amounts received in 1988 and 1990 were the fourth and fifth lowest recordings.



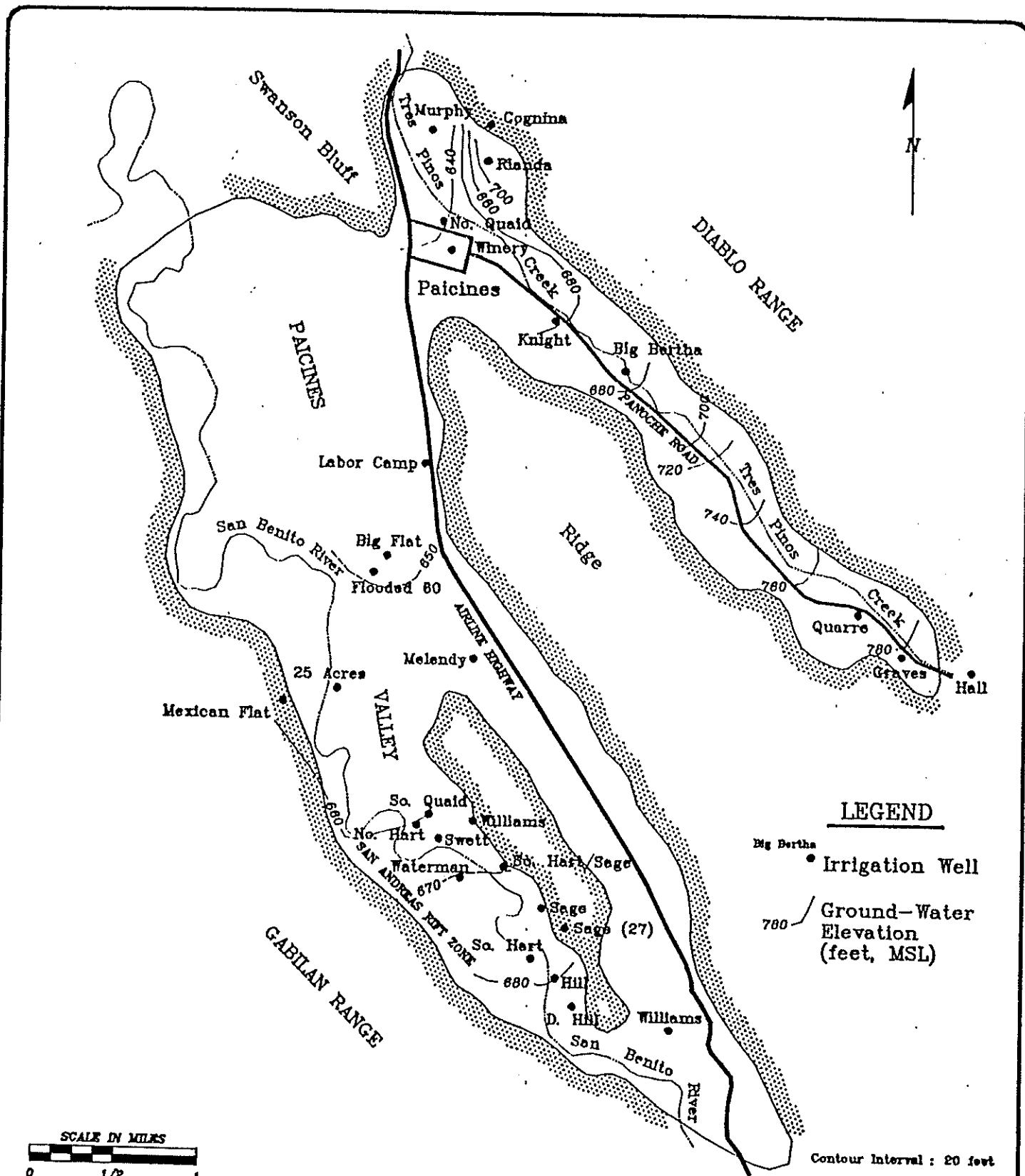
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Precipitation at Ohrwall Ranch Station from 1950 to 1990,  
Palcines Valley

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FIGURE  
5.5

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**LEGEND**

- Big Bertha Irrigation Well
- 780 Ground-Water Elevation (feet, MSL)

Contour Interval : 20 feet

From Paicines and Cherry Peak U.S.G.S. 7 1/2' Quadrangles

Contours of Equal Ground-Water Elevation, Spring 1985,  
Paicines and Tres Pinos Valleys

**FIGURE**  
5.6



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## Ground-Water Pumpage

Since the ultimate goal of the Paicines-Tres Pinos analysis was to estimate an initial value of safe yield for management and planning purposes, it was necessary to try to quantify pumpage which had resulted in the ground-water levels, and associated basin storage, described above. Since there are no meters or other direct records of pumpage, the approach to estimating pumpage was to first utilize land use data and crop water duties to determine an amount of water applied to the two valleys. Those results were then compared to data from PG&E on its pump test reports; for 30 wells in 1985, based on a combination of energy required to pump a certain volume of water and total energy consumed for pumping, the total volume of water pumped from those wells was computed. Ground-water pumpage from the Paicines and Tres Pinos basins was estimated during four separate periods from land-use survey information compiled by DWR for 1967, 1975, 1983, and 1989. Those surveyed periods cover a similar time span as the ground-water level hydrographs. The estimates were calculated assuming average duties for the crops identified in the surveys and an average irrigation efficiency of 80 percent; the results for both valleys are summarized in Table 5.1.

On an area-wide basis, the pumpage estimates are reasonably consistent over the surveyed periods. Estimated total pumpage from both basins ranged from about 6,500 to nearly 9,500 acre-feet per year, and averaged slightly more than 8,000 acre-feet per year. As introduced above, those figures can be compared to the energy-related pumpage calculation from thirty wells in 1985; total pumpage from those wells in that year was about 5,500 acre feet. The latter figure is concluded to support the range of pumpage which was indirectly estimated from land use as described above, given that PG&E energy consumption records were not available for all wells in the basins.

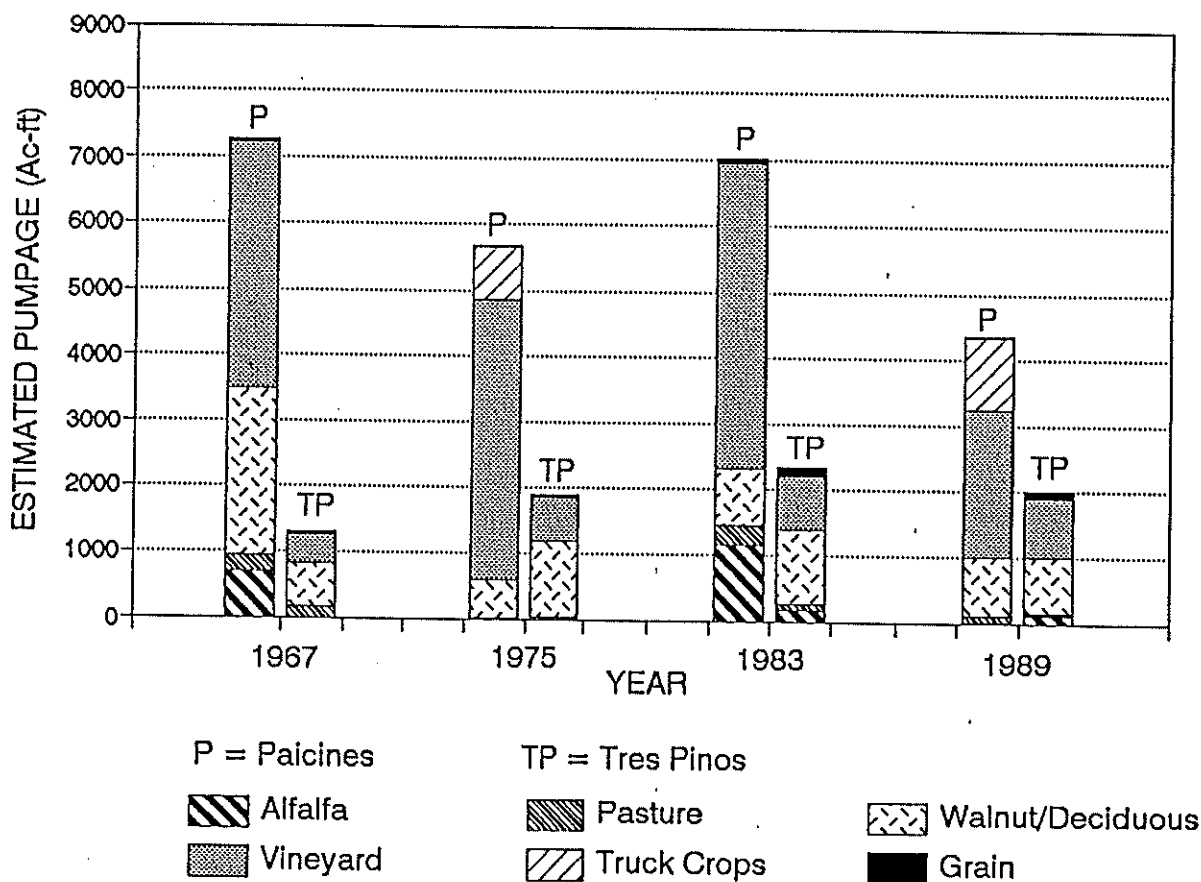
In light of the above, lacking any better data, it appears that average total ground-water pumpage in the Paicines and Tres Pinos basins since the late 1960's has been on the order of 8,000 acre-feet per year. As detailed in Table 5.1 and shown in Figure 5.7, that total has

TABLE 5.1  
ESTIMATED PUMPAGE BASED ON LAND-USE SURVEYS

| Crop          | ACREAGE  |       | Duty<br>(ac-ft/ac) | ESTIMATED PUMPAGE WITH<br>80% EFFICIENCY (ac-ft) |              |        |
|---------------|----------|-------|--------------------|--------------------------------------------------|--------------|--------|
|               | Paicines | Tres  |                    | Paicines                                         | Tres         | Total  |
|               |          | Pinos |                    |                                                  | Pinos        |        |
| <u>1967</u>   |          |       |                    |                                                  |              |        |
| Alfalfa       | 153      | 0     | 3.5                | 669.4                                            | 0.0          |        |
| Mixed Pasture | 65       | 43    | 3.2                | 260.0                                            | 172.0        |        |
| Walnut/Decid. | 826      | 206   | 2.5                | 2581.2                                           | 643.7        |        |
| Vineyard      | 2743     | 366   | 1.1                | <u>3771.6</u>                                    | <u>503.2</u> |        |
|               |          |       |                    | 7282.3                                           | 1319.1       | 8601.3 |
| <u>1975</u>   |          |       |                    |                                                  |              |        |
| Alfalfa       | 0        | 14    | 3.5                | 0.0                                              | 61.3         |        |
| Walnut/Decid. | 188      | 369   | 2.5                | 587.5                                            | 1153.1       |        |
| Vineyard      | 3110     | 523   | 1.1                | 4276.3                                           | 719.2        |        |
| Native Past.  | 5        | 0     | 3.2                | 20.0                                             | 0.0          |        |
| Melon/Tomato  | 86       | 0     | 2.2                | 236.5                                            | 0.0          |        |
| Misc. Truck   | 268      | 0     | 1.8                | <u>603.0</u>                                     | <u>0.0</u>   |        |
|               |          |       |                    | 5723.2                                           | 1933.6       | 7656.8 |
| <u>1983</u>   |          |       |                    |                                                  |              |        |
| Alfalfa       | 260      | 41    | 3.5                | 1137.5                                           | 179.4        |        |
| Mixed Pasture | 83       | 27    | 3.2                | 332.0                                            | 108.0        |        |
| Walnut/Decid. | 273      | 364   | 2.5                | 853.1                                            | 1137.5       |        |
| Vineyard      | 3377     | 603   | 1.1                | 4643.4                                           | 829.1        |        |
| Misc. Truck   | 3        | 0     | 1.8                | 6.8                                              | 0.0          |        |
| Grain         | 63       | 115   | 1.0                | <u>78.8</u>                                      | <u>143.8</u> |        |
|               |          |       |                    | 7051.6                                           | 2397.7       | 9449.3 |
| <u>1989</u>   |          |       |                    |                                                  |              |        |
| Alfalfa       | 5        | 24    | 3.5                | 21.9                                             | 105.0        |        |
| Mixed Pasture | 34       | 4     | 3.2                | 108.8                                            | 55.2         |        |
| Walnut/Decid. | 291      | 279   | 2.5                | 909.4                                            | 871.9        |        |
| Vineyard      | 2061     | 259   | 1.1                | 2267.1                                           | 922.9        |        |
| Melon/Tomato  | 386      | 0     | 2.2                | 1061.5                                           | 0.0          |        |
| Misc. Truck   | 16       | 0     | 1.8                | 36.0                                             | 0.0          |        |
| Grain         | 23       | 107   | 1.0                | <u>28.8</u>                                      | <u>133.8</u> |        |
|               |          |       |                    | 4433.5                                           | 2088.6       | 6522.1 |

Duty estimates for crops from DWR Bulletin 113-3

# ESTIMATED PUMPAGE BASED ON LAND-USE SURVEYS



Luhdorff & Scalmanini  
Consulting Engineers

Estimated Ground-Water Pumpage,  
Paicines and Tres Pinos Valleys

San Benito County  
Ground-Water Investigation

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FIGURE  
5.7

been divided among Paicines and Tres Pinos approximately as follows: Paicines pumpage has ranged from a recent low value of approximately 4,400 AF/yr., probably due to the large scale reduction in vineyard acreage since the early 1980's, to slightly over 7,000 AF/yr. in the late 1960's and early 1980's; Tres Pinos pumpage has increased from about 1,300 AF/yr. in the late 1960's to an average slightly above 2,000 AF/yr. over most of the last 15 years.

### Basin Yield

Lacking specific data on aquifer extent, characteristics, storage, and other pertinent parameters of a water budget for the two basins, it would be appropriate to initially address the yield of the basin by applying one concept or definition of safe yield in a general way; in this case, that definition would be that safe yield is approximately that value of pumpage or net draft on the basin which results in no change of ground-water levels and/or ground-water storage, as indicated by those levels.

In the Paicines Valley, ground-water levels and associated storage remained essentially constant over a 10 to 15 year period preceding the current drought. During that time, pumpage ranged between about 5,700 and nearly 7,300 AF/yr., suggesting that the basin, under a range of longer term average conditions, can support that amount of pumpage without adverse effect. Obviously, under recent extended dry conditions, ground-water levels have significantly declined despite an apparent recent decline in pumpage to about 4,400 AF/yr. There is a reasonable possibility that similar water level conditions occurred in 1976-77, but there are no data to confirm such to have been the case, except for slightly depressed water levels immediately after that drought. However, if such a decline did occur, post-drought recovery was apparently to pre-drought levels. At this point in time, it is hydrologically sound to initially estimate the safe yield of the Paicines basin to be in the 6,000 to 7,000 acre-feet per year range, to implement a ground-water monitoring program as recommended below, and to then update this initial estimate on the basis of more complete data and after a return to average conditions.

Ground-water levels and associated storage in the Tres Pinos basin remained essentially constant like the Paicines basin over the 10 to 15 years preceding the current drought. During most of that time, average pumpage was slightly more than 2,000 AF/yr., suggesting that the basin, under average conditions, can support about that level of pumpage without adverse effect. Under recent dry conditions, ground-water levels have significantly declined as in the Paicines basin; but, in Tres Pinos Valley, pumpage has not apparently changed much. Although there is no data to suggest that a similar decline has ever previously occurred, ground-water levels were essentially the same before and after the 1976-77 drought, and remained at those levels until the onset of current dry conditions. In that light, it is hydrologically sound to initially estimate the safe yield of the Tres Pinos basin to be about 2,000 acre-feet per year, to implement ground-water monitoring as recommended below, and to then update this initial estimate on the basis of that updated and more complete data after a return to average conditions.

## *VI. Future Ground-Water Monitoring*

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Historical ground-water monitoring has been extensive in the northern portion of San Benito County but has been virtually nonexistent in the balance of the County. In light of the analyses completed as part of this investigation, it is appropriate that the County and/or individual water purveyors or water management agencies consider the need for ongoing ground-water monitoring in order that the findings of this investigation can be updated and, in particular, that the North County model can be properly interpreted and applied as conditions (i.e. imported water deliveries, land use, etc.) change with time.

In the greater North County area, there is no apparent need to change the historic data collection efforts, particularly in Zone 6 of the County Water District. Within those boundaries, the frequency and number of ground-water level and quality observations, and the detailed metering of imported water deliveries and ground-water pumping are excellent and should be continued. Outside the Zone 6 boundaries, ground-water related data is not as extensive but is adequate. It would be ideal if that data, along with regular precipitation and stream gauging records, could be complemented with detailed pumpage data. However, it may be impractical to achieve such data and, in light of the use of net recharge for modeling purposes, it is consequently not critical that the cost of equipment and data collection to record pumpage be expended. In summary, throughout the North County area, it is recommended that the historic and current collection of data be continued on ground-water levels and quality, precipitation, streamflow and diversions, imported water deliveries, stream gauging, land use, and well yield (aquifer characteristics). With regard to the latter determination of aquifer characteristics, the County should require that, for newly constructed medium to high capacity wells (designed to produce more than 200 gpm), adequate testing be conducted to collect data which can be interpreted to estimate aquifer characteristics at the well site.

In the Paicines and Tres Pinos basins, data collection has been so non-existent that it did not initially appear that this investigation could produce even an estimate of safe yield. The identification and collection of very limited data from an uncommon source (PG&E pump test reports) allowed preliminary analyses of those basins to be completed. However, while the initial safe yield estimates provide points from which ground-water management can begin in those valleys, there is a significant need for some organized ground-water and related data collection. Based on the limited data available for the area and the analyses conducted as reported herein, the following data collection effort is recommended if the County wishes to be able to interpret the initial safe yield estimates and update them in light of basin response to future pumping and hydrologic conditions.

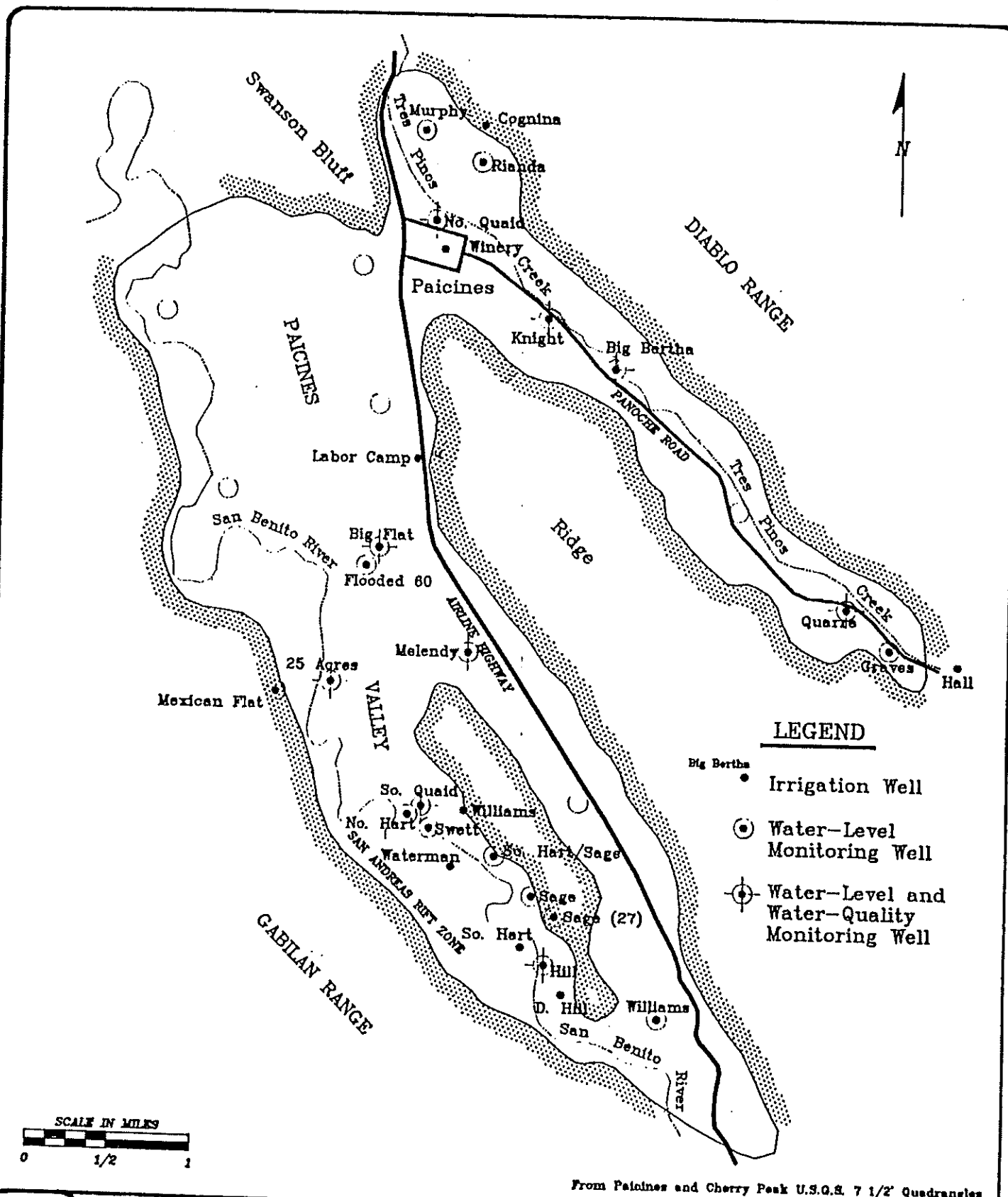
- **Precipitation** -- continuation of the Paicines (Ohrwall Ranch) gauge
- **Ground-Water Levels** -- initiation of a semi-annual (Spring and Fall) program of water level measurements in a network of approximately 25 wells, as illustrated in Figure 6-1. Where possible, the wells recommended for monitoring were selected over other nearby wells based on the availability of well logs such that any data from the wells can be "qualified" in terms of aquifer system, well completion, etc. In a few cases, wells were selected merely on the need to create a previously non-existent ground-water monitoring network and program, with recognition to the generally small number of existing wells with or without logs. Finally, where there are no known wells, locations have been identified where ground-water level data would be valuable; such locations can be added to the network when production well are constructed or when the County elects to install dedicated monitoring wells.
- **Ground-Water Quality** -- initiation of an annual program of ground-water quality sampling in a network of approximately ten wells, again chosen on the basis of available logs and the desire to provide some distribution of data in the two valleys.
- **Stream Flow and Diversions** -- maintenance of historic stream flow gauges on the San Benito River and Tres Pinos Creek, complemented by data collection on stream diversions, including the amount and use of the water.
- **Ground-Water Pumpage** -- if possible, obtain records of pumpage for various uses; if not possible, consider obtaining annual records of power consumption for pumping from all wells; continue receipt of land use mapping and

associated water use interpretation from DWR.

- **Well and Aquifer Characteristics** – when possible, require or participate in the testing of new wells (or existing wells) to identify the yields of wells and to allow calculation of the hydraulic characteristics of the aquifer system.

The recommended Paicines/Tres Pinos monitoring network is illustrated in Figure 6.1. Note that none of the existing wells has a common state well number (i.e. T12S/R5E-20M1) because none of the Paicines/Tres Pinos wells has been included in any state monitoring network. If the County implements these monitoring recommendations, such identification numbers can be assigned in cooperation with DWR.

Finally, as noted in the introduction to this report, there is a number of very small valleys in the County which overlie apparently small individual ground-water basins. Given their small size, and the lack of development or other pressure on them, the County may wish to not initiate any ground-water monitoring in them. However, if the County can envision the need to ultimately determine an aquifer yield value for any of these small basins, it should design a modified (i.e. smaller) version of the ground-water monitoring program recommended for the Paicines/Tres Pinos valleys above.



Recommended Ground-Water Monitoring Network,  
Paicines and Tres Pinos Valleys

FIGURE

6.1



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San Benito County  
Ground-Water Investigation

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