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POTENTIAL EFFECTS OF INCREASED GROUND-WATER PUMPAGE ON BARKA SL--ETC(U)
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LEVEL II

POTENTIAL EFFECTS OF INCREASED GROUND-WATER PUMPAGE ON BARKA SLOUGH, SAN ANTONIO CREEK VALLEY, SANTA BARBARA COUNTY, CALIFORNIA

Prepared in cooperation with the U.S. AIR FORCE

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations 80-95

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Ground-water use in San Antonio Creek valley, California, is expected to increase significantly as a result of a planned extensive agricultural development in the basin. This additional pumpage may cause significant stress on the ground-water system, particularly on the environmentally sensitive Barka Slough. Expectations of the developer are that about 6,640 acre-feet per year of consumptive ground-water use will be required to irrigate 2,500 acres of vineyards and 1,200 acres of truck-farmed vegetables. This represents an increase in net basin pumpage of about 60 percent. The developer plans to obtain this water from 12 large-diameter irrigation wells in the Harris Canyon area. Analysis of the potential drawdowns in the vicinity of Barka Slough, by using the Theis nonequilibrium formula, indicates that drawdowns would average 6 feet after 10 years of pumping and would eventually exceed 10 feet. Because the artesian head in the aquifer that supplies the slough is generally less than 3 feet above land surface, these declines would probably mean that the wetlands of Barka Slough would disappear. The effects of this particular agricultural development would be in addition to any decline caused by other increases in pumpage in the basin.

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UNITED STATES DEPARTMENT OF THE INTERIOR

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ILLUSTRATIONS

CONVERSION FACTORS

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

Multiply	By	To obtain
acre	0.004047	km^2 (square kilometer)
acre-ft/yr (acre-foot per year)	1,233	m^3/yr (cubic meter per year)
ft (foot)	0.3048	m (meter)
ft^2/d (foot squared per day)	0.0929	m^2/d (meter squared per day)
mi (mile)	1.609	km (kilometer)
mi^2 (square mile)	2.589	km^2 (square kilometer)

POTENTIAL EFFECTS OF INCREASED GROUND-WATER PUMPAGE ON

BARKA SLOUGH, SAN ANTONIO CREEK VALLEY, SANTA BARBARA COUNTY, CALIFORNIA

By Michael J. Mallory

ABSTRACT

Ground-water use in San Antonio Creek valley is expected to increase significantly as a result of planned extensive agricultural development in the basin. The effects of this additional stress on the ground-water system, particularly on the environmentally sensitive Barka Slough, are of concern in the basin.

Expectations of the developer are that about 6,640 acre-feet per year of additional consumptive ground-water use will be required to irrigate an agricultural development of 2,500 acres of vineyards and 1,200 acres of truck-farmed vegetables. This represents an increase in net basin pumpage of about 60 percent. The developer plans to obtain this water from 12 large-diameter irrigation wells in the Harris Canyon area.

Analysis of the potential drawdowns in the vicinity of Barka Slough, by using the Theis nonequilibrium formula, indicates that drawdowns would average 6 feet after 10 years of pumping and would eventually exceed 10 feet. Because the artesian head in the aquifer that supplies the slough is generally less than 3 feet above land surface, these declines would probably mean that the wetlands of Barka Slough would disappear.

An empirical relation, based on historical records of base flow in San Antonio Creek and net pumpage in the basin, also indicates that the additional irrigation withdrawals would cause base flow in San Antonio Creek to cease.

Both of these analyses consider the effects of only this particular agricultural development, which would be in addition to any decline caused by other increases in pumpage in the basin.

INTRODUCTION

Ground-water use in the San Antonio Creek valley (fig. 1), is expected to increase significantly with the establishment of an agricultural development in the Harris Canyon area. The development will consist of extensive irrigated vineyards on formerly unirrigated pastureland and a significant increase in acreage for truck-farmed vegetables. Because previous studies (Hutchinson, 1980) have indicated that withdrawals are already greater than the perennial yield of the ground-water basin, the effects of this additional stress are of concern, particularly with respect to the environmentally sensitive Barka Slough.

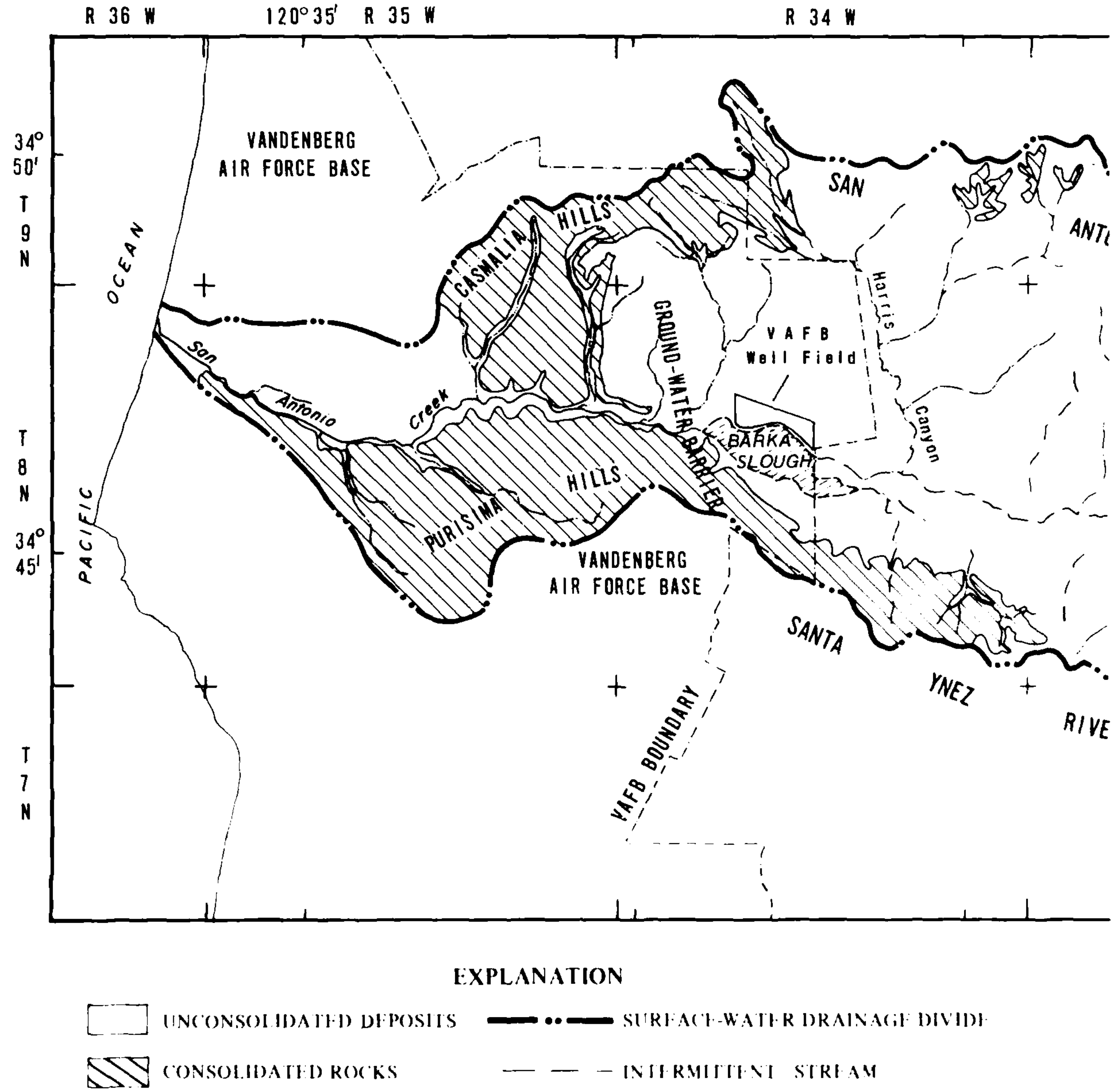
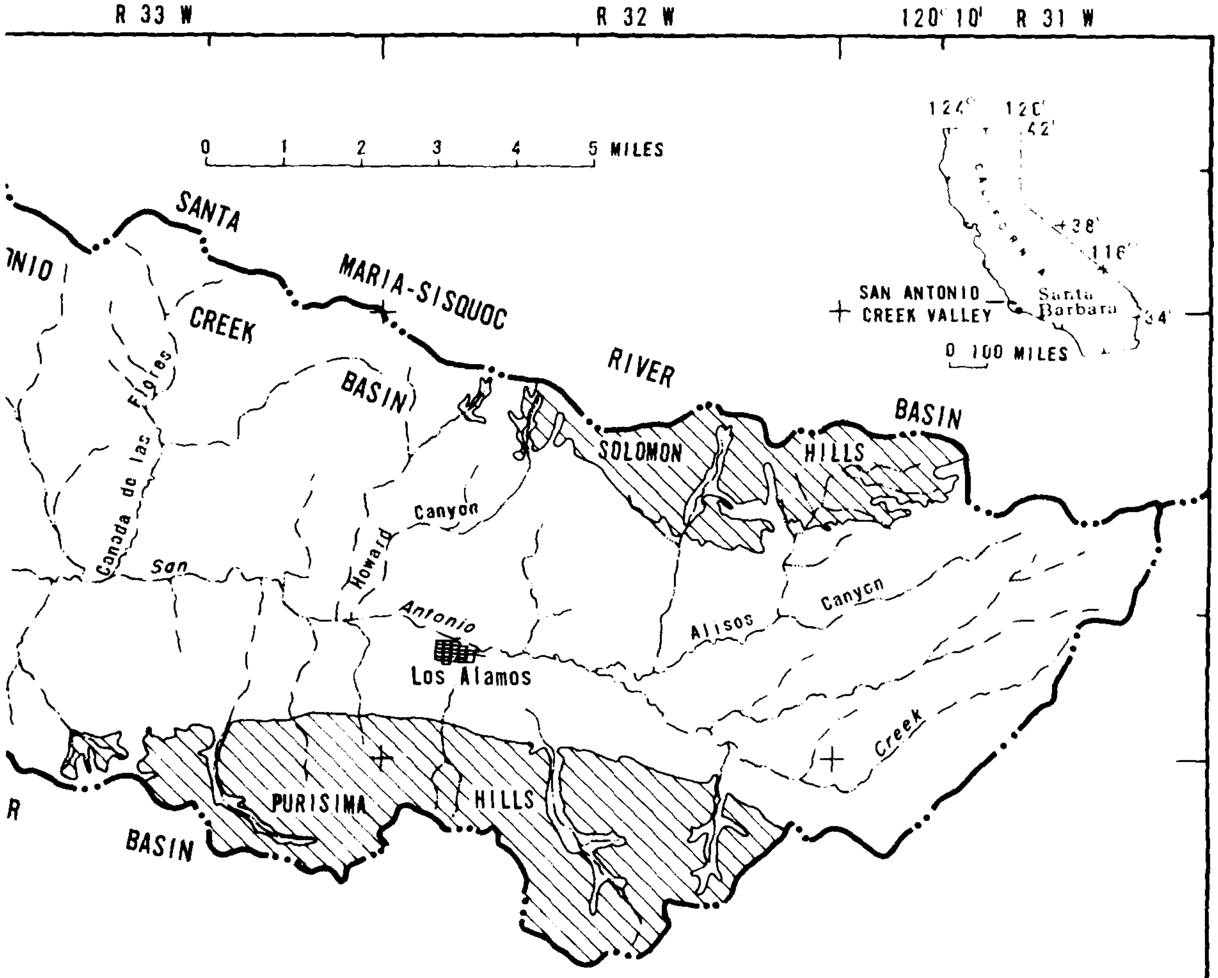


FIGURE 1.—Location and general features of San Antonio Creek valley.

Because the Barka Slough lies within the boundaries of Vandenberg Air Force Base (VAFB), the U.S. Air Force requested the cooperation of the Geological Survey in a preliminary evaluation of the potential effects on the slough of additional ground-water withdrawals. An analytical estimate of the potential effects of the new agricultural development on ground-water levels in the vicinity of Barka Slough is based on existing data. No new data were collected, except for a canvass of new irrigation wells and an interview with the developer. The reduction in base flow in San Antonio Creek that would result from this additional pumpage is estimated from an empirical relation based on the historical regimen of the basin.

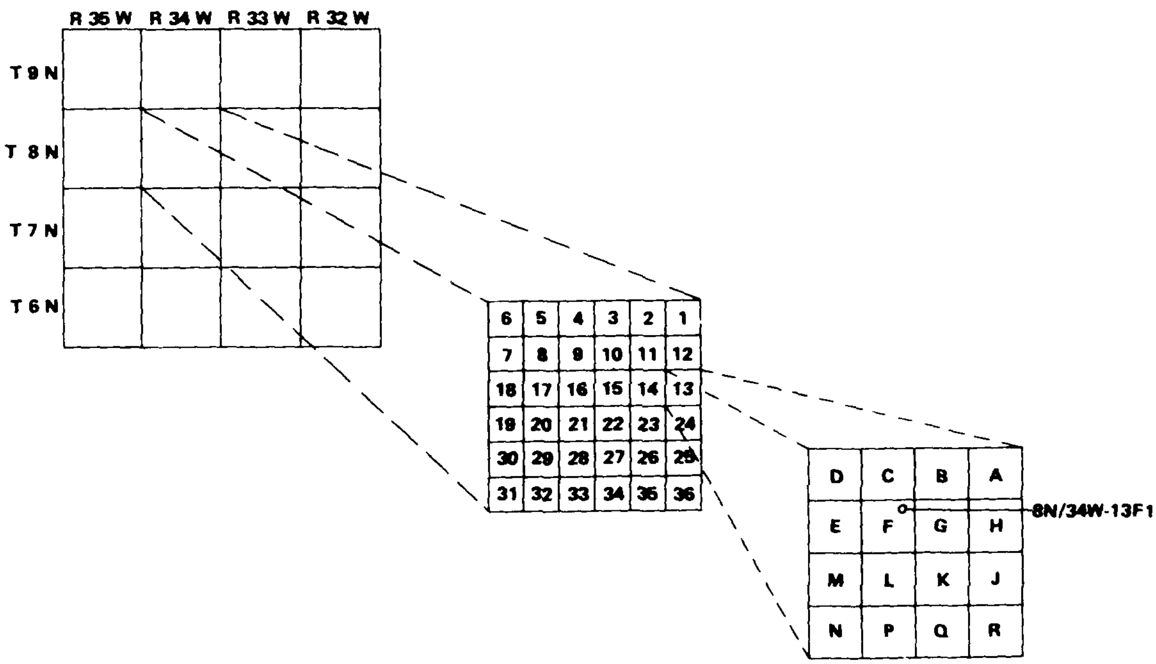


Consolidated-rock boundaries from K. S. Muir (1964)

FIGURE 1.--Continued.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for subdivision of public land. As shown by the diagram, that part of the number preceding the slash, as in 8N/34W-13F1, indicates the township (T. 8 N.); the number following the slash indicates the range (R. 34 W.); the number following the hyphen indicates the section (sec. 13); the letter following the section number indicates the 40-acre subdivision according to the lettered diagram below. The final digit is a serial number for wells in each 40-acre subdivision.



Description of the Area

The San Antonio Creek drainage basin consists of a 154 square-mile area in west-central Santa Barbara County, about 55 mi northwest of Santa Barbara (fig. 1). Because the topography, drainage, climate, land use, water use, and geohydrology of the area are discussed in detail in reports by Hutchinson (1980) and Muir (1964), only a brief summary of some of these features is included here. The reader is referred to the earlier reports for a more complete description.

The San Antonio Creek drainage basin is about 30 mi long and 7 mi wide. San Antonio Creek runs the length of the valley and is fed by tributaries that are slowly dissecting the surrounding hills. Altitudes in the area exceed 1,200 ft along the ridges that flank the valley. The valley floor ranges in altitude from 800 ft in the eastern part to sea level at the Pacific Ocean and is underlain by unconsolidated valley-fill deposits and a series of marine and continental sediments that make up the principal aquifer for ground-water supply. The ground-water basin underlies an area of about 110 mi^2. VAFB occupies the western quarter of the valley; the rest of the valley is primarily agricultural.

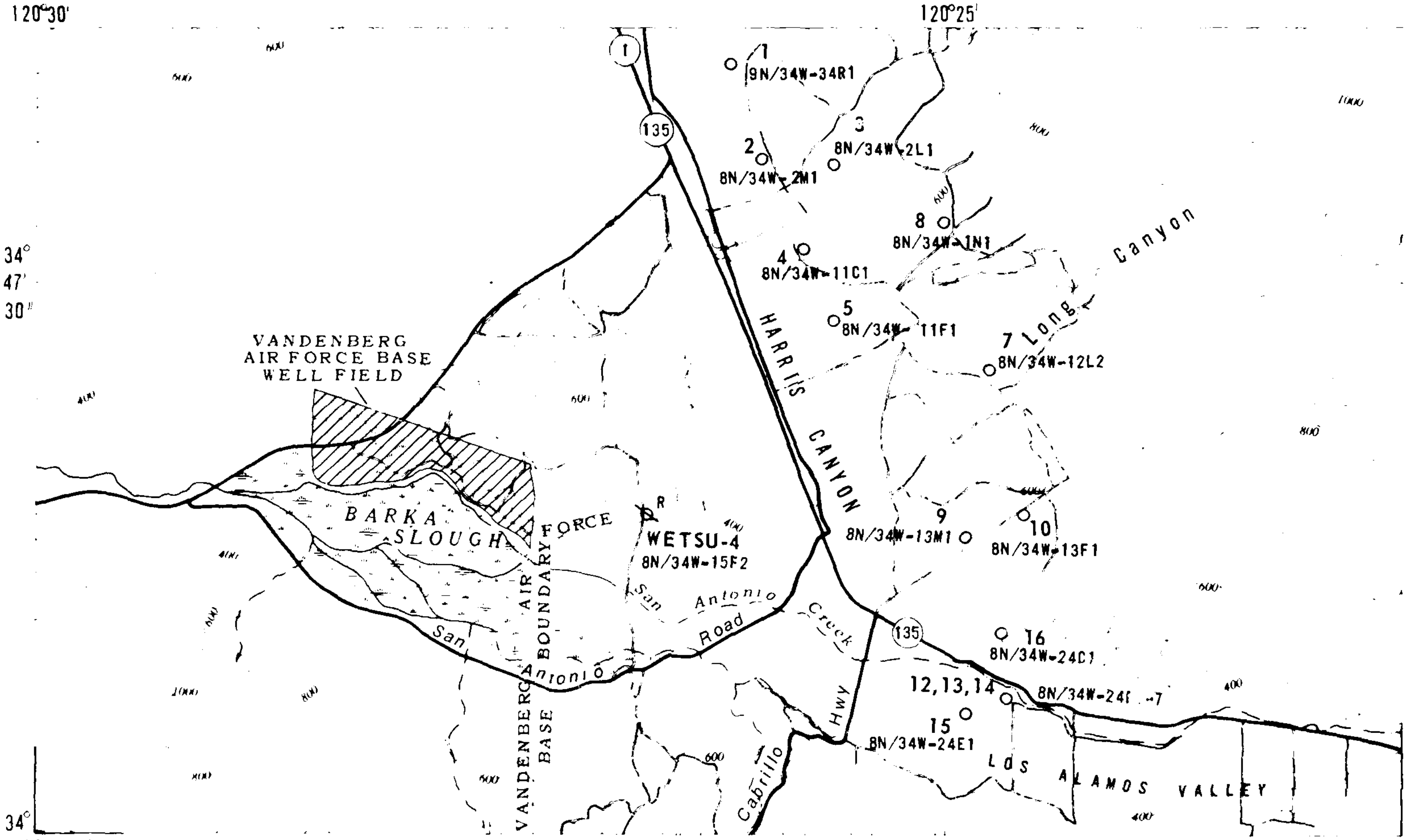
San Antonio Creek is intermittent east of Barka Slough, where its flow is derived mainly from seasonal surface runoff. West of the slough, flow is augmented by ground water discharged through the slough, and San Antonio Creek is perennial. A consolidated-rock barrier about 5 mi east of the Pacific coastline causes the upwelling of ground water to the land surface, a condition that results in the 550-acre Barka Slough. This slough is one of the few pristine marshlands in southern California and is known or believed to be inhabited by at least nine threatened or endangered species of wildlife (Descheneaux, 1975).

Hutchinson (1980) documented the dramatic increases in demand for municipal, irrigation, and military water supply in the valley and presented a comprehensive water budget for the period 1958-77. This water budget indicates a trend toward reduced base flow in San Antonio Creek in response to increased pumping and competition for ground water by phreatophytes.

POTENTIAL EFFECTS OF DEVELOPMENT

Scope of Planned Development

Approximately 2,500 acres of formerly unirrigated pastureland on the east slope of Harris Canyon are being converted to vineyards. In addition, there are plans to increase production of truck-farmed vegetables by growing multiple crops each year on 750 acres of land and to plant 450 additional acres of vegetable crops. Because vineyard irrigation is estimated by the developer to consume 1.5 ft of water per acre per year, this part of the development will represent a total consumptive draft on the ground-water system of 3,750 acre-ft/yr. The 450 acres of new vegetable crops are estimated by the developer to require a total consumptive use, for the multiple crops, of 3.5 ft of water per acre per year. The increase in the consumptive requirement of the 750 acres on which production is being accelerated is estimated to be 1.75 ft per acre per year. The vegetable crops, therefore, will require an additional 2,890 acre-ft/yr of irrigation water. Based on these figures, the total increase in consumptive water demand for this development is estimated to be 6,640 acre-ft/yr. This represents an increase of more than 60 percent over the net pumpage in the entire basin in 1977. Wells to supply this water were canvassed in January 1980. Because of the proximity of the wells (fig. 2) to Barka Slough and the VAFB well field, these areas may be significantly affected by the additional pumpage.



Base from U. S. Geological Survey Orcutt 1:24,000, 1959 Photorevised 1967 and 1974

CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

○ 15 8N/34W-24E1 IRRIGATION WELL– Upper number is local well number; lower number is tentative State well number

SWAMP

R WETSU-4 8N/34W-15F2 OBSERVATION WELL EQUIPPED WITH A CONTINUOUS RECORDER– Upper number is local well number; lower number is tentative State well number

FIGURE 2.–Location of irrigation wells, Vandenberg Air Force Base well field, and water-level monitoring well.

Aquifer Characteristics

In order to quantitatively evaluate the effects of the additional irrigation pumpage, the transmissivity and storage coefficient of the aquifer must be accurately defined. Pumping-test results reported by Hutchinson (1980) indicate that the aquifer transmissivity varies widely in the basin, possibly ranging from 2,600 to 34,000 ft^2/d.

Hutchinson's data for wells in the Harris Canyon area suggest a transmissivity of about 24,000 ft^2/d. This is the value that was used for computing projected drawdowns; however, a transmissivity of 24,000 ft^2/d is in the higher range for the San Antonio basin, and the drawdowns will be greater if the actual transmissivity is lower.

In the nearby Santa Ynez and Cuyama Valleys (off map), the specific yield of the Paso Robles Formation was estimated to be 15 percent (Miller, 1976, p. 37; Singer and Swarzenski, 1970, p. 19). On the basis of these estimates and assuming that the aquifer characteristics of Santa Barbara County's ground-water basins are similar, a storage coefficient of 0.15 was selected as representative of the unconfined areas of the aquifer, which include the part underlying the Harris Canyon area. As the drawdown effects of pumping in the Harris Canyon area reach the vicinity of Barka Slough, however, response of the aquifer system will in part reflect the much lower (approximately 0.0001) storage coefficient of the confined sediments underlying the slough. This lower storage coefficient will cause the actual drawdowns near the slough to be greater than those calculated for unconfined conditions. The drawdown for unconfined and confined conditions predicted in the following section indicates the minimum and maximum drawdown that might be expected from the proposed additional pumping.

Potential Drawdown

The Theis nonequilibrium formula (1935) provides a means of evaluating the effect on water levels in the vicinity of Barka Slough of each of the 12 irrigation wells shown in figure 2. Because the equations governing ground-water flow are linear operators mathematically, the total drawdown due to this development can be calculated at any point in the area of interest simply by summing the individual drawdowns due to each of the 12 irrigation wells.

Figures 3, 4, and 5 show the predicted additional drawdown in the Barka Slough area due to the proposed pumpage for irrigation after 1, 10, and 50 years, respectively, using this method. Figure 6 shows a hydrograph of the additional drawdown due to the proposed agricultural pumpage that might be expected to develop in the vicinity of well 8N/34W-15F2 (WETSU-4) on VAFB near the slough.

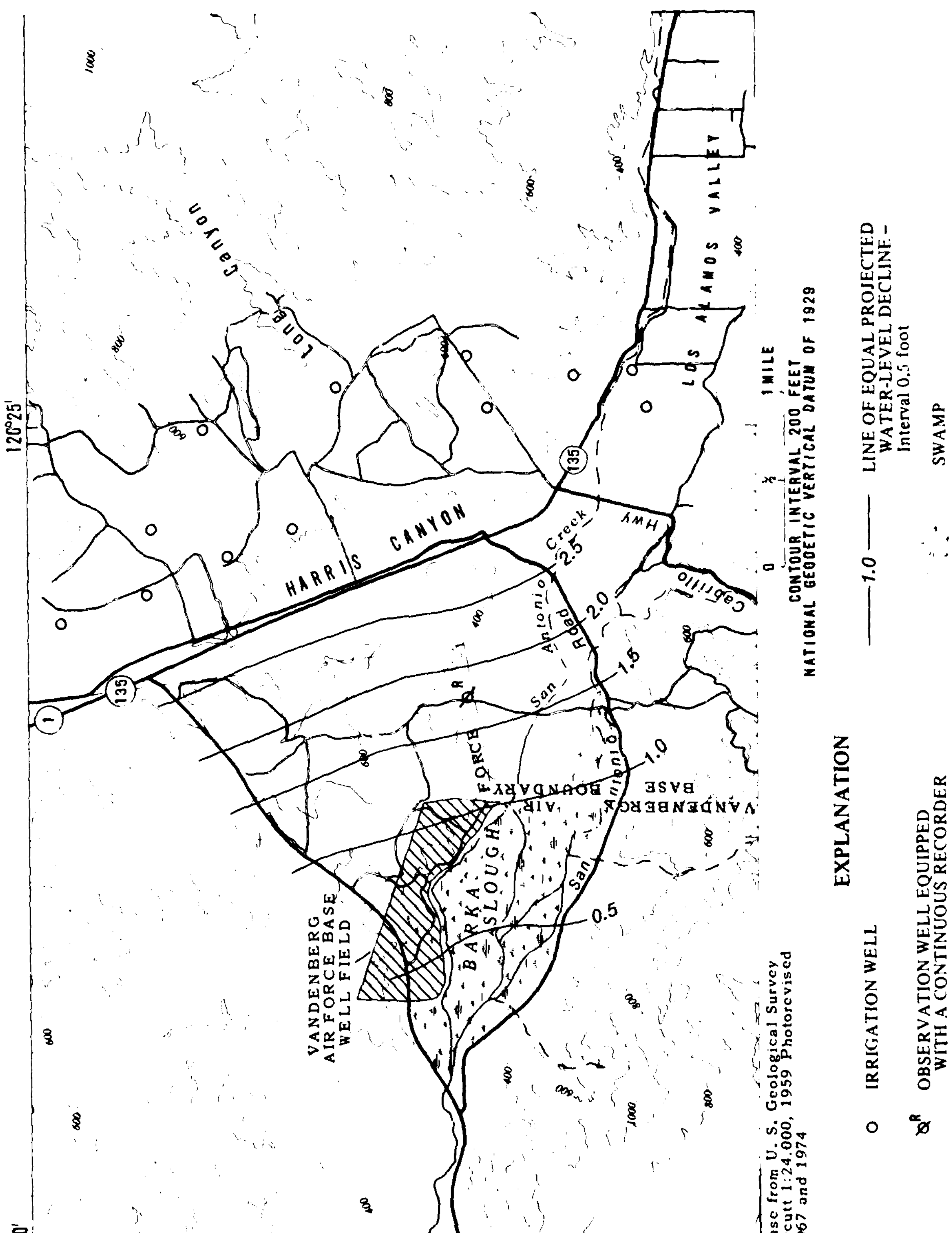
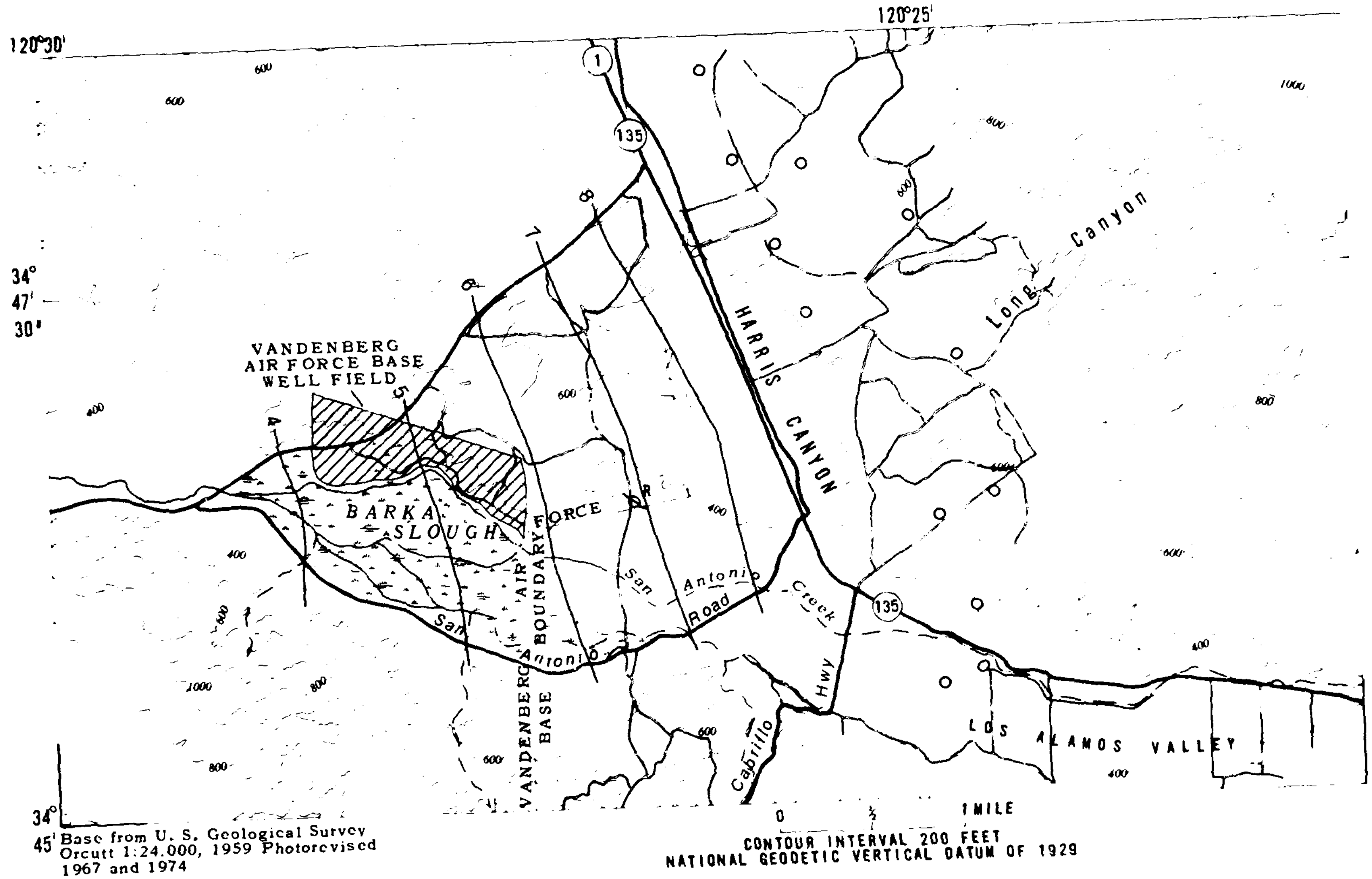


FIGURE 3.–Predicted additional drawdowns in the vicinity of Barka Slough after 1 year of proposed irrigation pumpage.



EXPLANATION

o IRRIGATION WELL

—— 4 —— LINE OF EQUAL PROJECTED WATER-LEVEL DECLINE–
Interval 1 foot

R OBSERVATION WELL EQUIPPED WITH A CONTINUOUS RECORDER

SWAMP

FIGURE 4.–Predicted additional drawdowns in the vicinity of Barka Slough after 10 years of proposed irrigation pumpage.

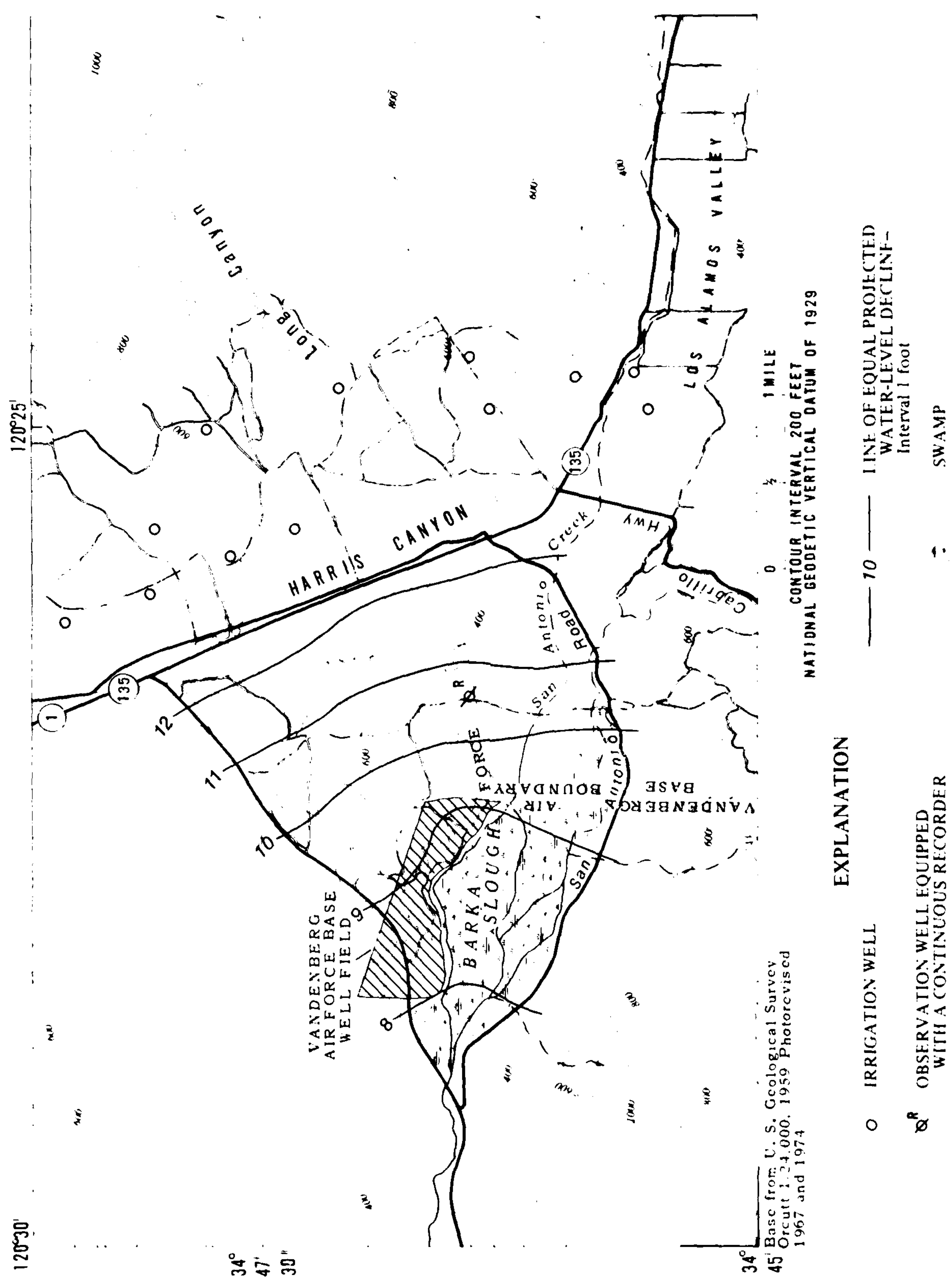


FIGURE 5.—Predicted additional drawdowns in the vicinity of Barka Slough after 50 years of proposed irrigation pumpage.

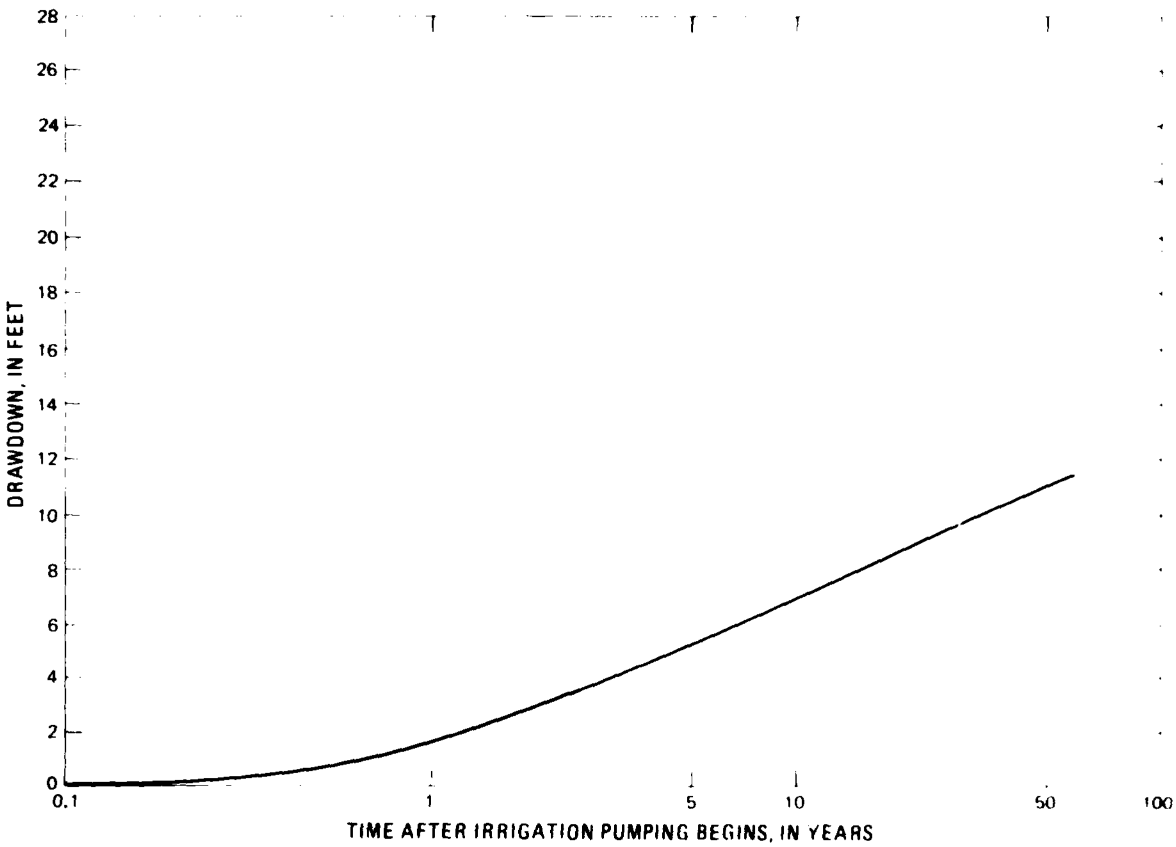


FIGURE 6.--Hydrograph of well 8N/34W-15F2, showing predicted additional drawdown due to proposed irrigation pumpage in the Harris Canyon area, assuming an unconfined aquifer.

The hydrographs indicate that, although it would take about a year after pumping begins for any noticeable drawdown to occur in the vicinity of Barka Slough, eventually, after about 50 years, the reduction of water levels in the area would be about 10 ft.

These predicted drawdowns represent the effect of only this instance of agricultural development. Increases in pumpage by municipal, military, or other agricultural users would cause drawdowns in addition to those calculated here. This development was unanticipated in the report of Hutchinson (1980), but these drawdowns superimposed on those calculated in Hutchinson's study indicate a total drawdown of 8 to 10 ft in the slough area after about 5 years of pumping.

Barka Slough is supplied with water by the upward leakage of ground water through clay confining beds that immediately underlie the slough. In 1976 several small-diameter holes were augered through the confining layer by the U.S. Geological Survey to monitor the head differential driving the upward leakage (J. A. Singer, U.S. Geological Survey, oral commun., 1980). At that time, about half the wells flowed over the top of their casings, which were finished about 3 ft above land surface. At present (1980) only one well continues to flow above its casing. This well has been shut in to measure the potentiometric head at land surface at this point. The head was determined in 1979 to be about 7 ft at land surface. A head reduction of 10 ft would therefore reverse the upward gradient which causes water to flow from the aquifer into Barka Slough. This reversal of gradient would mean that, instead of water flowing in from the aquifer, water would drain from Barka Slough into the aquifer. The drainage would continue until, eventually, the slough would be deprived of ground water.

The foregoing predicted drawdown assumes an unconfined storage coefficient; however, the aquifer directly beneath Barka Slough is confined, and examination of drill cuttings from wells in the western flank of Harris Canyon indicates significant amounts of clay (Peter Martin, U.S. Geological Survey, oral commun., 1980). The presence of extensive clay in the cuttings indicates that the aquifer may be subject to at least local intermittent confinement as far east as this area.

The effective storage coefficient of a confined aquifer is typically 100 to 1,000 times smaller than those typical of unconfined aquifers. This is due to the fact that in a confined aquifer the water discharged is derived from the expansion of the water and contraction of the aquifer skeleton as pressure in the aquifer is reduced; in an unconfined aquifer, however, water is derived from the physical drainage due to gravity from the pore space between the grains of the aquifer skeleton. Because both the compressibility of water and the modulus of elasticity of the material of the aquifer skeleton are small, the quantity of water that can be derived from storage in a confined aquifer is much smaller than if the same aquifer were unconfined.

No general analytical method is available to analyze the situation in which a pumping well affects an area that is partly confined and partly unconfined, as is the case in this example. An upper limit on the possible response of the aquifer, however, can be indicated by considering what the response would be if the entire system were confined. Although it is unlikely that the actual response of the aquifer to the increased development would be this great, it is likely that the response would lie somewhere between the more conservative values previously calculated and these values. Figure 7 shows a hydrograph of the response of a totally confined system in the vicinity of well 8N/34W-15F2 (WETSU-4). As can be seen by comparing figures 6 and 7, the response from a confined aquifer system to the proposed pumping would be seen much more quickly (more than 13 ft of drawdown at this location after 1 month) and would be much greater than for the unconfined system in which drawdown would be scarcely detectable after 1 month.

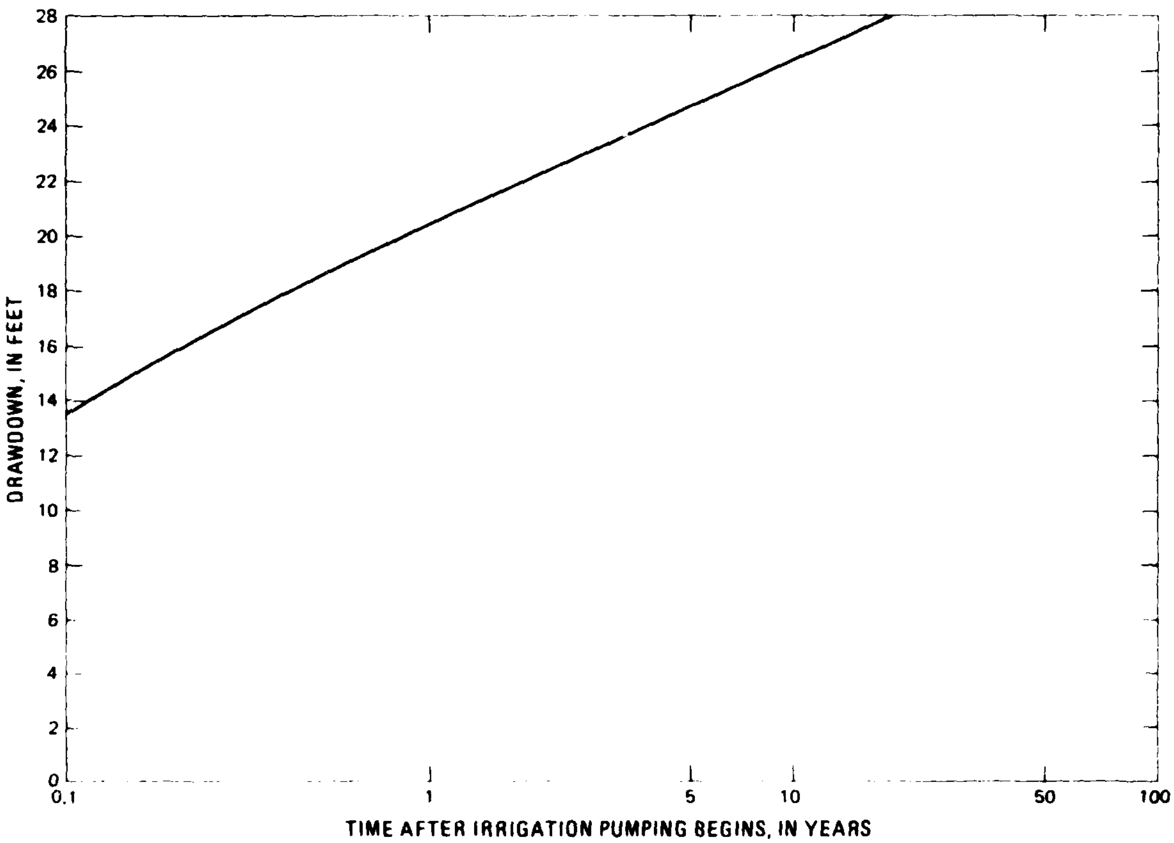


FIGURE 7.--Hydrograph of well 8N/34W-15F2, showing predicted additional drawdown due to proposed irrigation pumpage in the Harris Canyon area, assuming a confined aquifer.

Potential Reduction of Base Flow

Hutchinson (1980) presented graphic evidence, reproduced here as figure 8, of a strong empirical correlation between base flow in San Antonio Creek and net pumpage from the ground-water basin. For the period examined by Hutchinson, 1958-77, and considering only the years with precipitation within 25 percent of the long-term (1909-77) average, the relation between base flow and net pumpage has a correlation coefficient of 0.89. Even when all years are considered, the correlation coefficient of the relation (0.74) remains significant. The reduced correlation when years of exceptional precipitation are included should not be unexpected, because such conditions probably cause a significant variation in the percentages of the total precipitation that are lost to evapotranspiration and to overland flow.

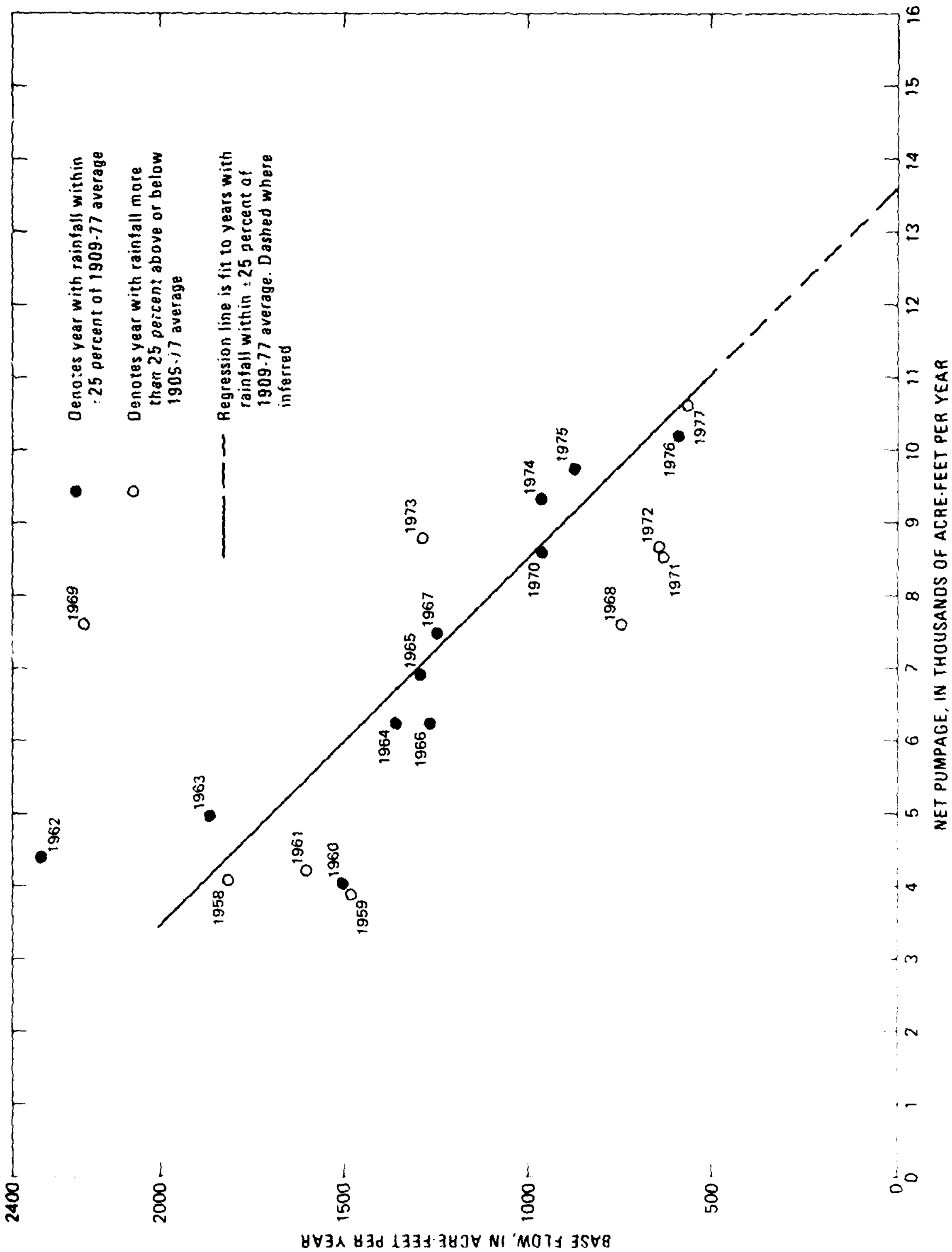


FIGURE [illegible].—Relation of net pumpage from the ground-water basin to base flow in San Antonio Creek for the period 1958-77 (from Hutchinson, 1980).

If we accept the validity of the regression developed by Hutchinson, it is possible to predict the potential reduction in base flow of San Antonio Creek at the mouth of Barka Slough. The slope of the regression line shown in figure 8 indicates that for every acre-foot per year increase in net pumpage there will be a decrease in base flow of approximately 0.2 acre-ft/yr. Therefore, additional pumpage of 6,640 acre-ft/yr would cause a reduction of base flow in San Antonio Creek of about 1,300 acre-ft/yr, more than twice the base flow which actually occurred in 1977 and greater than the base flow observed for any year since 1969. This evidence indicates that base flow in San Antonio Creek west of Barka Slough would cease and the wetlands of the slough would eventually disappear if the basin is subjected to increased pumpage of the magnitude considered here.

SUMMARY AND CONCLUSIONS

Two independent lines of evidence indicate that additional pumpage of 6,640 acre-ft/yr in San Antonio Creek basin would result in the eventual disappearance of the wetlands of Barka Slough.

An analysis, using the Theis formula, of the drawdown effects of 12 irrigation wells pumping this amount of water from the Harris Canyon area indicates that drawdown in the Barka Slough area would be about 6 ft after 10 years and would eventually exceed 10 ft. Because the artesian head in the aquifer underlying the slough is generally less than 3 ft above land surface and is not known to exceed 7 ft anywhere in the area, the expected drawdown would cause most recharge of water by upward leakage to the slough to cease in 10 years or less.

An empirical relation between base flow in San Antonio Creek west of Barka Slough and net ground-water pumpage in the basin indicates that an increase in ground-water pumpage of 6,640 acre-ft/yr would reduce base flow in the creek by 1,300 acre-ft/yr. Because this is more than twice the base flow of San Antonio Creek in recent years, this line of evidence also suggests that base flow in San Antonio Creek would cease and Barka Slough would begin to dry up.

The calculations presented here are conservative in that the aquifer transmissivity used is high in the range of transmissivities observed in the basin. Furthermore, the storage coefficient used in these calculations, 0.15, is characteristic of only the unconfined part of the basin. Although the part of the aquifer from which irrigation withdrawals will take place is probably unconfined, as drawdown effects due to the irrigation pumping spread westward, part of the water that will supply these withdrawals will be derived from the confined part of the aquifer system. Drawdowns in the confined part of the aquifer system can be expected to develop more rapidly than those calculated for a completely unconfined system.

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