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FINAL REPORT

STUDY OF POTENTIAL RECHARGE SITES IN THE ANTELOPE VALLEY

Prepared for

Antelope Valley State Water Contractors Association

Antelope Valley State Water Contractors Association

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September 2002

TABLE OF CONTENTS

Page No.

TABLE OF CONTENTS (continued)

Page No.

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I. Introduction

A goal of the Antelope Valley State Water Contractors Association (AVSWCA); a Joint Powers Authority composed of the Antelope Valley - East Kern Water Agency (AVEK), Littlerock Creek Irrigation (Littlerock) and Palmdale Water District (Palmdale), is to make optimum use of available water resources and supplies to meet Antelope Valley water needs. Water supplies available in the Antelope Valley include local surface water originating as rainfall runoff in the surrounding mountains, State Water Project (SWP) water through the SWP contracts held by the AVSWCA members, groundwater from the Antelope Valley Groundwater Basin, and potentially, recycled water from Water Reclamation Plants located in the Antelope Valley.

A proven method of optimizing surface water supplies is through conjunctive use of surface water with groundwater storage. Conjunctive use utilizes groundwater recharge facilities to store surface water that is seasonally available in excess of direct demands in available groundwater storage capacity. The recharged water can then be recovered at a later time when demands exceed surface water supply. AVSWCA retained Stetson Engineers Inc. (Stetson) to identify and evaluate an initial groundwater recharge project.

The groundwater recharge project evaluation includes the following tasks: description of background information including geography, hydrology and hydrogeology, a brief summary of relevant previous studies, a brief discussion of recharge by injection verses surface spreading, identification of potential recharge sites, development of evaluation criteria, ranking and selection of sites, description of an implementation plan and presentation of conclusions reached.

II. Background

A. Geography

1. The Antelope Valley is an enclosed drainage basin with no surface water outlet. The Antelope Valley is located in the extreme southwestern part of the Mojave Desert. The Los Angeles-Kern County Line bifurcates the valley in an east-west direction, with a small portion of the valley lying just east of the San Bernardino County Line. The Valley is bordered on the northwest by the Tehachapi Mountains and on the southwest by the San Gabriel Mountains, as shown on Plate I. The many streams that originate in the steep surrounding mountains often meander in ill-defined paths across the gently sloping valley floor. Storm water runoff that does not percolate in the groundwater basin eventually ponds in dry lakes at low points in the valley floor.

B. Geology

1. Geologic Formations

Geologic formations of the Antelope Valley may be broadly divided into two classifications: nonwater-bearing, consolidated rocks and water-bearing, unconsolidated deposits (Johnson, H.R. 1911). These geologic formations are summarized below. A geologic cross section in the area, which was generalized by the United States Geological Survey (USGS), is shown on Plate II.

The nonwater-bearing, consolidated rocks in the area consist of granatic and metamorphic rocks of the Tehachapi and Sierra Madre ranges, which constitute the basement complex of pre-Tertiary age, and sedimentary and volcanic rocks of Tertiary age. These rocks surround the Antelope Valley and form the sides and bottom of the groundwater basin (Lowel F.W. Duell, Jr. 1987). Some sedimentary rocks are of marine origin, but most of the volcanic rocks are interbedded with sedimentary rocks of continental origin. In some areas, the thickness of the consolidated rocks may exceed 1,500 feet. In other areas of the valley, these rocks are absent, and the unconsolidated deposits rest directly on the basement complex (Bloyd, R.M., Jr. August 28, 1967).

The water-bearing, unconsolidated deposits consist of the older alluvium, the fan deposits, the younger alluvium and dune sand, and the playa deposits. The unconsolidated deposits range in thickness from 0 to more than 1,900 feet (Bloyd, R.M., Jr. August 28, 1967). "The well records for the valley region indicate that the deeper deposits do not differ greatly from the gravels, sands, and clays of the surface" (Johnson, H.R. 1911).

The older alluvium of Pliocene and Pleistocene age underlies most of the valley floor at depth and consists of compact gravel, sand, silt, and clay. These deposits are weathered, and locally the feldspar has been altered to clay. Gravel is predominant near the mountains, but finer grained and better-sorted materials are found beneath the valley area.

The older fan deposits of Pliocene and Pleistocene occur as isolated erosional remnants and consist of slightly consolidated fanglomerate or unsorted boulder gravel, cobble-pebble gravel, and sand mainly from a granatic source. The younger fan deposits of Holocene age consist of unconsolidated angular boulders, cobbles, and gravel with small amount of sand, silt, and clay. These younger fan deposits are formed by intermittent streams originating from nearby hills and mountains and transporting the materials only a short distance (Lowel F.W. Duell, Jr. 1987).

The younger alluvium of Recent age consists unconsolidated sand and angular boulders, cobbles, and gravel with small quantities of silt, clay, and fine to medium windblown sand. These materials are common in the valley areas, but are generally less than 150 feet thick (Bloyd, R.M., Jr. August 28, 1967). Dune sand of Holocene age is partly composed of actively drifting fine to medium sand. The dunes have not been stabilized by vegetation and still drift during windy periods (Lowel F.W. Duell, Jr. 1987).

Playa or lacustrine deposits of Pleistocene through Holocene are composed of siltstone, clay, and marl. Individual clay beds are locally as much as 400 feet thick. These beds are interdbedded with lenses of coarser material as much as 20 feet thick. Playa deposits of Holocene age are composed of silt, clay, sandy clay, and small amounts of soluble salts. They occur mostly along faults in structural depressions or sagponds (Lowel F.W. Duell, Jr. 1987).

2. Geologic Features

The Mojave Desert region, including the Antelope Valley, is characterized by fault-block mountains and by fault-block basins, as shown on Plate III. The Tehachapi and San Gabriel Mountains, the major elevated fault blocks, were formed by uplifts along the Garlock and the San Andreas faults, respectively. Smaller displacements have occurred along other faults in the Antelope Valley. Some of the faults have been named, such as the Cottonwood, Rosamond, Randsburg-Mojave, Neenach, and Muroc. However, numerous smaller or less well-known faults remain nameless. The locations of these faults are shown on Plate 1 of the Water-Resources Investigations Report 84-4081 (the attached map).

The presence of these faults is important because they may form barriers that can influence the occurrence and movement of groundwater. Cementation and frictional heat and pressure, caused by faulting, can make unconsolidated materials along the fault plane less permeable.

In fact, many faults in the Antelope Valley have been considered barriers to groundwater movement and used to delineate the groundwater sub basins in the Antelope Valley by the Los Angeles County Flood Control District (LACFCD), as shown on Plate I. Where the faults are not visible at the surface of the ground, their presence may be indicated by difference in groundwater levels on adjacent sides of the fault. Therefore, where reliable data on water levels in wells are available, fault traces often can be mapped. "For example, the Neenach fault, the Randsburg-Mojave fault, and a part of the Muroc fault were postulated to exist after analyzing groundwater levels;" however, "some faults do not now seem to be barriers to ground-water movement" (Bloyd, R.M., Jr. August 28, 1967). The LACFCD subdivision of the groundwater sub basins in the Antelope Valley has also been used by the USGS, including its most recent investigation for the Antelope Valley (Sneed, Michelle and D.L. Galloway. 2000).

C. Hydrology

The average annual precipitation in the Antelope Valley drainage basin generally varies from 5 inches on the valley floor to more than 15 inches along the Tehachapi and San Gabriel Mountains. In a small area in the San Gabriel Mountains, the average annual precipitation exceeds 40 inches, as shown on Plate V. The Antelope Valley is drained by numerous small and short creeks originating from the San Gabriel Mountains and the Tehachapi Mountains, as shown on Plate V. The most significant creeks include Big Rock Creek, Littlerock Creek, and Amargosa Creek on the northern slope of the San Gabriel Mountains and Little Cottonwood Creek, Cottonwood Creek, and Oak Creek. All surface runoff and water discharged from springs along the mountain slopes flow toward the valley floor where there are alluvial deposit and gentle slopes. As the runoff flows further downstream, infiltration into permeable deposits increases (Bloyd, R.M., Jr. August 28, 1967). Perennial streams seldom extend beyond the foot of the mountains (Lowel F.W. Duell, Jr. 1987).

According to a study by the USGS, the major part of the streamflow entering the Antelope Valley is contributed by Big Rock Creek and Littlerock Creek from the San Gabriel Mountains and the Oak Creek from the Tehachapi Mountains. Based on available hydrologic data from the gaging stations shown on Plate IV, the average annual runoff is estimated at approximately 4.5 inches (21 percent of the average annual precipitation of 21.2 inches) for the Littlerock Creek basin, 9.0 inches (32 percent of the average annual precipitation of 28.1 inches) for the Big Rock Creek basin, and 1.2 inches (10 percent of the average annual precipitation of 12 inches) for the Oak Creek basin. The total average annual runoff from these watersheds was estimated to be 28,000 acre-feet (Bloyd, R.M., Jr. August 28, 1967).

In addition to natural creeks, an important water feature in the Antelope Valley is the presence of two major aqueducts: The California State Water Project (SWP) aqueduct and the City of Los Angeles, Department of Water and Power (DWP), aqueduct, shown on Plate IV.

The SWP aqueduct emerges from a tunnel through the Tehachapi Mountains in the western end of the Antelope Valley. The SWP aqueduct bifurcates shortly after emerging from the Tehachapi Tunnel. The west leg of the aqueduct extends southwest for a short distance before leaving the Antelope Valley. The east leg of the aqueduct extends southeast along the foot of the San Gabriel Mountains near the southern boundary of the Antelope Valley. Water from the SWP aqueduct has historically been accessed in the Antelope Valley by the members of the AVSWCA; the Antelope Valley-East Kern Water Agency, Littlerock Creek Irrigation District, and the Palmdale Water District, for agricultural, municipal and industrial use.

The DWP aqueduct enters the Antelope Valley at its northern boundary and travels southwest along the foot of the Tehachapi Mountains. In the vicinity of the Kern County/Los Angeles County line in the western Antelope Valley the aqueduct crosses the Antelope Valley in a north south direction until it reaches the foot of the San Gabriel Mountains. The DWP aqueduct follows the foot of the San Gabriel Mountains southeast to Fairmont Reservoir before leaving the Antelope Valley. Water from the DWP aqueduct has not historically been used in the Antelope Valley, other than for a brief period for groundwater recharge, discussed further below. Although water from the DWP aqueduct has not played a significant role in water management in the Antelope Valley, it should be noted that when a major supplemental surface water supply is available near a major groundwater basin, opportunities exist for mutually beneficial conjunctive use and water banking programs.

D. Hydrogeology

The hydrogeology of the Antelope Valley Groundwater Basin has been discussed in numerous the USGS studies and investigations. "Conceptually, the ground-water basin has been subdivided into 12 sub basins" (Sneed, Michelle and D.L. Galloway. 2000) by faults, bodies of consolidated rocks, groundwater divides, and in some areas, by arbitrary boundaries, as shown on Plate I. "Conceptually, the ground-water flow system in the Antelope Valley was divided into three aquifers - a shallow unconfined aquifer (the upper aquifer), which is thin and generally unproductive; a deeper and thicker confined aquifer (the middle aquifer), which is where most of the ground water is produced; and the deepest confined aquifer (the lower aquifer), which is thinner and produces less water than the middle aquifer" (Sneed, Michelle and D.L. Galloway. 2000). A generalized geologic section showing the upper, middle, and lower aquifers is shown on Plate VI.

Existence and Effectiveness of Groundwater Barriers

Hydrogeologic interpretations of the Antelope Valley Groundwater Basin similar to the following description by Weir, Crippen, and Dutcher have been common for many years. "Many faults border the area and several transect the ground-water basins and form barriers to ground-water flow between several of the ground-water basins or units of the area... Many of these features are not visible at the surface, but they are indicated by disparities in the water levels on opposite sides of the fault... The Randsburg-Mojave fault is concealed (Fig. 10) throughout most of its length, but the disparity of water levels in several places shows the approximate position of its trace. The Neenach fault, shown on Figure 10 trending west southwesterly through the west-central part of Antelope Valley, is postulated to exist solely on the basis of water-level disparities. A part of the trace of the Muroc fault was delineated by a large water-level disparity along its northwestern extent. Several other less prominent barriers, presumed to be faults, exist in the area" (Weir, J.E., Jr., J.R. Crippen, and L.C. Dutcher. March 1, 1965). The faults referenced above, shown on Figure 10 of Weir, Crippen and Dutcher's report, are shown on Plate I of this report.

Evaluating the effectiveness of each of the faults and sub-basin boundaries is beyond the scope of this study. However, due to the availability of the results of a USGS investigative effort regarding the Randsburg-Mojave and Neenach faults, the following discussion is presented as a case study of the possible influence of faults.

Because the positions and effectiveness of these features are of critical importance, the USGS proposed a program of test-well drilling and test pumping to obtain additional data to delineate these features, i.e. the Randsburg-Mojave and Neenach faults. The proposed test wells are shown on Plate VII. According to the USGS, the purpose of the test wells is to provide (a) additional control points for obtaining water level measurements; (b) hydrologic information relative to the position and extent of two possible faults which may act as ground-water barriers; (c) geologic information relative to thickness, character, extent, and correlation of the various subsurface deposits; (d) additional data for making aquifer rating tests to determine transmissivity and coefficient of storage; and (e) additional data to determine the effectiveness of proposed water-spreading tests in the western part of the Antelope Valley (Weir, J.E., Jr., J.R. Crippen, and L.C. Dutcher. March 1, 1965).

Eight wells were drilled for the USGS test-well drilling program. The well casing was 1½-inch galvanized pipe, except for Well 09N/15W-20F01 with a combination of 2 and 2½-inch galvanized pipe. Approximately 10 feet of perforated 2-inch tubing was installed at the bottom of the pipe in all wells. Characteristics and water levels in these wells are shown on Plate VIII. The USGS also made studies to obtain additional data in the area of the Randsburg-Mojave fault in the western part of the Antelope Valley. These studies were conducted in 1965 to obtain the resistivity of soil and deposits in selected areas, the earth's gravity along five cross sections, and water levels in five wells. The water level measurements in these wells are shown on Plate IX. The locations of the wells and gravity cross sections are shown on Plate X.

According to the report for this test-well drilling program, "one of the main purposes of drilling test wells 1 through 6 was to augment existing data in the area of the Randsburg-Mojave fault. On the basis of data from the completed test wells, the Randsburg-Mojave fault crosses the valley about as shown by Weir and others (1965, Fig. 10); however, the trace of the fault south of the Los Angeles County line curves in a more westerly direction than shown by Weir and others (1965, Fig. 10). Test wells 7 and 8 were drilled to augment data in the area of the Neenach fault. On the basis of data from the completed test wells, the Neenach fault extends westward across the southwestern part of the valley and terminates near State Highway 138, about 3 miles west of the Los Angeles aqueduct... The position of the Randsburg-Mojave Faults (Fig. 2) is in accord with both the gravity data and the water levels in wells" (Bloyd, R.M., Jr. March 1, 1966).

Water level measurements from the USGS test-well drilling program do not appear to be adequate to verify that "...the trace of the [Randsburg-Mojave] fault south of the Los Angeles County line curves in a more westerly direction than shown by Weir and others..." and that "...the Neenach fault extends westward across the southwestern part of the valley and terminates near State Highway 138, about 3 miles west of the Los Angeles aqueduct." Because the gravity data was not provided in the USGS report, it is not known if the gravity data is adequate to verify the position of the Randsburg-Mojave fault.

The 1965 USGS investigation does not appear to provide adequate supporting data to change the description of the "water-bearing rocks" of the Antelope Valley as described in the previous study. "Broadly considered, the great alluvial filling of the structural depression of the Antelope Valley is composed of lenticular and irregular beds which dip at low angles away from the bounding ranges and buttes. The gravels, sands, and clays show no evidence of deformation except at some points along the valley margins..., which have been flexed by the dislocations accompanying the uplift of the mountains" (Johnson, Harry H. 1911). A diagram of the "water-bearing rocks" of the Antelope Valley is shown on Plate XI. The distribution of interbedded layers of permeable materials (gravel and sand) and clay in this diagram is consistent with geologic formations prepared from drillers logs for wells along an east-west cross section across postulated fault lines, as shown on Plate XII.

Based on water levels measured by the USGS in 1962-1965 and 1996, groundwater barriers in the western part of the Antelope Valley, especially the Randsburg-Mojave and Neenach faults, do not appear to exist. In fact, if groundwater elevation contours are prepared without considering the faults' effects, as shown on Plates XIII and XIV, they are perfectly consistent with the area's hydrology and topography. Based on these groundwater contours, groundwater in the western part of the Antelope Valley appears to follow the general direction of surface waters, i.e. southeasterly down the slope of the Tehachapi Mountains and northerly down the San Gabriel Mountains, then turn easterly, as shown on Plates XIII and XIV.

Wells and Groundwater Production

Groundwater has been produced from wells throughout the Antelope Valley. In the early 1880, it was discovered that many of the wells in the lower parts of the valley were artesian and water from these wells flowed freely onto the ground surface for use. Pumping water from wells for irrigation was not initiated on a large scale until about 1900, when the use of turbine pumps was common. The number of wells in the Antelope Valley has not been determined accurately. In 1919, an estimated 500 wells had been drilled, and approximately 250 wells were equipped with turbine pumps (Weir, J.E., Jr., J.R. Crippen, and L.C. Dutcher. March 1, 1965). The USGS Ground Water Site Inventory database indicates there have been at least 3,723 different wells in the Antelope Valley at some point in time; however, the number of wells that were active in any given years is not known. Annual groundwater production has been reported to the California State Water Resources Control Board for only 906 wells from 1947 through 1991. The total estimated groundwater production increased from approximately 83,000 af/yr in 1947 to approximately 268,000 af/yr in 1956 then decreased to approximately 199,000 af/yr in 1964 and approximately 68,000 af/yr in 1991 (Templin, William E., et al. 1995). Since 1991, groundwater production appears to have increased due to increased agricultural activity. An updated estimate of groundwater production through 1995 is anticipated to be provided by the USGS in 2003.

E. Existing Recharge Facilities

As discussed above, surface water naturally percolates into the Antelope Valley groundwater basin as runoff flows across alluvial deposits, primarily near the foothills. The only known existing artificial recharge facility is the DWP's Kings Canyon Percolation Basin, shown on Plate XV. The Kings Canyon facility contains approximately 45 acres of recharge area, not including access roads, berms, and other features. Available records indicate that the Kings Canyon facilities were only operated during 1946 and 1947, recharging a total of 7,250 acre-feet of water from the DWP Aqueduct.

III. Previous Studies

The Antelope Valley and its groundwater has been the subject of many studies throughout the years. As part of the document search, documents were obtained from Stetson's in-house library, local university libraries, AVEK, City of Palmdale, the USGS, California Department of Water Resources (DWR), the LACDWP, and various consulting companies, which have performed studies in the Antelope Valley. A complete list of the documents, which were obtained, is shown in Section VIII – References.

Those selected reference documents, which discuss the groundwater basin and, more specifically, groundwater recharge, are described below and are listed in chronological order from most recent to oldest documents.

1. <u>*Palmdale Water Reclamation Concept Study (Kennedy/Jenks, 2000)*</u>
   The purpose of this study was to evaluate conceptual uses of reclaimed water produced by the Palmdale Water Reclamation Facility Plant (WRP), owned and operated by County Sanitation Districts of Los Angeles County (Sanitation Districts). One of the concepts included recharging local groundwater with highly treated effluent. The study refers to various studies by others and suggests two possible locations for surface spreading along Littlerock Creek in the Pearland sub-basin and downstream in the Buttes and Lancaster sub-basins. These sub-basins have been considered to be bounded by fault lines that serve as possible barriers to groundwater movement. Palmdale Water District has various wells in the Pearland and Lancaster sub-basins while the Buttes sub-basin is not currently used by municipal water agencies serving city residents.

   Since the study is related to reclaimed water, a lengthy discussion was presented on water quality regulations for recharging groundwater with reclaimed water. California Administrative Code Title 22 regulates groundwater recharge and the recharge must also comply with the Water Quality Control Plan for the Lahontan Region.

The study also discusses an extensive sand and gravel resource area between the communities of Palmdale and Littlerock, extending along Littlerock Creek. Surface mines are generally excavated to a depth of approximately 70 to 80 feet.

The upper portion of Amargosa Creek, considered by Los Angeles County, is not considered in this study due to the distance from the Palmdale WRP.

2. *Summary Report, Primary Zone of Surface Water Percolation, Amargosa Creek from 27th Street West to Hansa Street, Palmdale, Los Angeles County, California. (Earth Systems Consultants, 1994)*

   The purpose of this study was to determine the areas most suitable for surface recharge within the Amargosa Creek channel between approximately 27th Street West and Hansa Street in the city of Palmdale. The study area is shown on Plate XVI. Amargosa Creek is reported to be the third largest source of surface discharge in the southern Antelope Valley (Big Rock Creek and Littlerock Creek being the two largest contributors). This section of Amargosa Creek was earmarked for flood control facilities by the city of Palmdale and water purveyors were concerned that this may interfere with groundwater recharge if the channel is made relatively impermeable.

   Six boreholes were drilled, ranging from 60 to 100 feet deep. Borings were logged and evaluated. Based on the boring logs, the most suitable recharge point was shown to be at 25th Street West, while the most suitable recharge area extends from 15th to 25th Street West.

3. *Antelope Valley Groundwater Recharge Concept Plan, Air Force Site Along Amargosa Creek (Wilkins, et al, 1992)*
   Los Angeles County conducted a series of studies to determine where and how groundwater recharge could be achieved most effectively in the eastern Antelope Valley. In this most recent study, LA County concluded that the "Best Management Practice" (BMP) is to use Aquifer Storage and Recovery (ASR) wells to recharge groundwater. It was also recommended that if spreading basins are planned in the future, percolation tests should first be conducted and spreading basins should not be located near the air force base runways since the ponding water may attract migratory birds and cause interference with airplanes.

4. *Antelope Valley Groundwater Recharge Study, Phase 2, Air Force Site Along Amargosa Creek (Los Angeles County, 1991)*
   Los Angeles County conducted a study at an Air Force site along Amargosa Creek to determine the feasibility of recharging groundwater. The study showed that the vertical hydraulic conductivity of the soils is low while the horizontal conductivity is much higher. This translates into very slow vertical percolation from the surface to the groundwater table. It was estimated that it would take from 5 to 50 years for water to percolate down to the groundwater table. The study also concluded that, if spreading basins are selected as the method of recharging the groundwater, the spreading basins should be located in the eastern portion of the study site.

5. *Antelope Valley Spreading Grounds Study, Phase 1 – Preliminary Report (Los Angeles County, 1989)*
   Los Angeles County conducted a review of existing studies and reports related to groundwater recharge in the Antelope Valley. From their review they identified prospective areas where spreading grounds could be located. These locations included areas near the southern foothills along Littlerock Creek, Big Rock Creek, and Amargosa Creek. Each of these areas contain alluvial fan deposits. These three creeks are the most productive in the valley in terms of the amount of runoff they provide. Estimated runoffs for these creeks were 14,800 ac-ft/year (Littlerock), 13,200 ac-ft/year (Big Rock), and 9,000 ac-ft/yr (Amargosa).

6. *A Preliminary Evaluation of Geologic Bases for the Selection of Spreading Grounds in the Antelope Valley Study Area (Burkhalter, 1976)*
   Burkhalter discusses the rational behind percolation of water through existing geologic formations. Potential recharge areas are typically found adjacent to rocky hills, adjacent to faults, and within streambed channel deposits. Maps are provided with the report and they show potential spreading grounds. Among those identified are areas along Big Rock Creek and Littlerock Creek, as shown on Plate XVII.

IV. Injection Versus Surface Spreading

There are two common methods of recharging groundwater. These methods are by well injection and by surface spreading. These two methods are discussed in the following sections.

A. Injection

Injection wells may be a feasible method to recharge groundwater when sufficient land is unavailable for surface spreading or when layers of low permeability soil overlie the aquifer to be recharged.

Recharge through injection wells is typically more expensive than recharge by surface spreading due to the cost of the injection wells and the high water quality levels required for injection.

Typically water, which is recharged using wells, must be treated to potable standards. This reduces the potential for plugging the wells and depending on the circumstances, may also be a requirement of the California Department of Health Services.

B. Surface Spreading

The surface recharge method is well suited for locations that have readily available land on which to "spread" the water and where soils are permeable enough to allow percolation from the surface into the underground aquifer. As water percolates through the soils a certain level of water treatment can be achieved. This is typically referred to as Soil Aquifer Treatment (SAT). With surface recharge, clogging can also be a concern, however, with proper operating procedures and minimal maintenance clogging can be reduced.

In order to develop the most cost-effective recharge project possible, this study is limited to recharge by surface spreading.

V. Potential Sites for Surface Spreading

A. Evaluation Criteria

A set of general selection criteria was developed to be used as a guide in the exploration and selection of potential sites for surface spreading. Using these criteria, staff engineers were able to identify potential sites. These same criteria were then used to rank and better quantify the feasibility of each potential site.

The preliminary selection criteria are as follows:

1. *Are there direct benefits to AVSWCA groundwater producers?*
   It is AVSWCA's desire to be able to store surplus water as recharged groundwater in order to later recover the stored water when water supplies are scarcer. In the absence of significant barriers to groundwater movement, as indicated by the case study on faults in the western Antelope Valley, presented above, any recharge that reaches the usable aquifer adds to the water supply available to the AVSWCA groundwater producers throughout the Antelope Valley. In order to differentiate between the potential recharge sites, it has been assumed that the closer the location of the groundwater recharge to the Lancaster, Palmdale, Littlerock area, which includes groundwater production by Palmdale and by groundwater producers within AVEK and Littlerock, the greater the benefits that will be experienced.

2. *Is existing infrastructure sufficient?*
   Typically, the infrastructure that spreading grounds require include a water conveyance system from the source to the spreading grounds as well as small berms which allow the water to pond and percolate into the ground. At the source, modifications to canals or reservoirs are typically necessary to include new or modified outlet structures to divert flows to the spreading grounds. Where flows must be diverted upgradient from the source, depending on the available pressure head, pumps may also be added to the project.

3. *Are the environmental issues less than typical?*
   Environmental issues can vary greatly from site to site. Typically, however, sites, which are located in or near areas of existing habitat or wildlife, would require further studies and permits to allow the site to be altered. In general, if instream improvements were required, sites located in or along stream channels would require more studies and

efforts to deal with environmental issues than those sites, which are located away from stream channels.

4. *Will spreading grounds provide added benefits to others?*
   The presence of spreading grounds at some potential sites may provide an added benefit to others. Some additional benefits that spreading grounds could provide include landscape and habitat enhancement (i.e. ponds and increased vegetation); recreational benefits if spreading grounds are combined with parks or lakes; or point of discharge for recycled water, just to name a few.

   In contrast, the spreading grounds could also pose some problems. For example, where spreading grounds are near quarries, ponded water may percolate into adjacent quarries and cause quarry operations to be more difficult or to be halted. If located near the local airports, spreading grounds could increase the hazard of migrating birds interfering with air traffic. The spreading grounds may also present an attractive nuisance liability that must be addressed.

5. *Are the sources of recharge water close by?*
   In general, if the source of recharge water is close to the recharge site, the costs and efforts to implement the project diminish. Potential sites that are close to the water source or downstream along an existing water conveyance system are generally more advantageous since little is needed in the way of a water conveyance system. Conversely, if water must be conveyed over a long distance or even pumped upgradient of the water source, it becomes more costly to build and/or operate.

6. *Is the geology of the site conducive for percolation?*
   One of the most fundamental questions is whether or not percolation to the groundwater aquifer can actually occur. This is governed by the geology of the sites. Throughout much of the Antelope Valley well boring logs show that layers of clay and silt are very intermingled with permeable layers. This makes percolation more difficult. Geological formations near the base of the mountains and along stream channels tend to be more permeable and more conducive to percolation. Therefore, the closer one is to base of the mountains and along stream channels the more likely percolation will occur down to the groundwater aquifer.

7. *Are the spreading grounds recharge capacity high?*

   The overall objective of constructing spreading grounds is to recharge as much water as needed, or possible, in a desired location. A site with a high capacity for recharge, based on percolation capacity of the soils and the area of the spreading grounds, provides more significant recharge potential.

B. Description of Potential Sites

Several potential sites for surface spreading were investigated. Stetson conducted two extensive field trips to visit potential sites. Each potential site considered is described below. Table 1 summarizes estimated spreading capacities at potential sites. Actual sizes of the spreading basins can be varied to meet specific design criteria. For purposes of this study, however, the spreading basins were limited to between 10 to 50 acres. Plate XV shows the locations of the potential sites. Preliminary site maps and photographs of the vicinity of each site are shown on Plates XVIII through XXXVII.

1. Mescal Creek

   Mescal Creek is the eastern most site considered as part of this study. The potential spreading area on this creek is located between Highway 18 and Highway 138, just west of 243rd Street East. The Creek crosses over the California Aqueduct in a concrete flume and is then contained within berms on both sides of the channel as it travels north from the California Aqueduct. This area is also known as the Mescal Wildlife Sanctuary. A spreading basin at this site would be contained within the channel banks.

2. Big Rock Creek
   a. Channel Upstream of Siphon. The California Aqueduct crosses Big Rock Creek through a siphon about two miles upstream from Highway 138. Surface flows are commonly seen in this reach upstream of the siphon, even in the driest months of summer. Several shallow wells exist in this reach as well as some small recharge ponds. Historical stream flow measurements taken along the reach from Pallett Creek to the siphon show that surface flows are diminishing and percolating into the groundwater table. During a field trip in August 2001, the depth to the groundwater was measured at approximately 7 feet below ground surface (bgs) at an existing well a few hundred feet upstream from the siphon.

   b. Channel Downstream of Siphon. Downstream of where the California Aqueduct crosses Big Rock Creek; surface flows typically disappear in the dry summer months. It is reported that the siphon acts as a subsurface dam, blocking subsurface flows from passing downstream (LADPW, 1989).

   c. Gravel Pits. Approximately three miles downstream from the siphon, which crosses Big Rock Creek, an old gravel pit exists. This pit, owned by Vulcan Materials, was excavated to approximately 50 feet deep. During a field trip in August 2001, the depth to groundwater was measured to be approximately 242 ft bgs, using an existing well.

3. Littlerock Creek

A number of gravel pits exist along Avenue T where it crosses Littlerock Creek. Some old gravel pits exist just south of Avenue T and other operating gravel pits exist on the north side of Avenue T. During a recent recharge test performed by the AVSWCA, water was released from the California Aqueduct and spread in the channel. As the water percolated into the soils, it also moved laterally and into some of the gravel pits adjacent to the creek, causing quarry operations to be disrupted. At the bottom of some of the old gravel pits fine soils (clay and silt) exist and cause ponding of the mining wash water used in nearby quarry operations.

4. Amargosa Creek

Amargosa Creek runs along Elizabeth Lake Road, crosses the California Aqueduct, turns northeast and then north and passes through west Palmdale and into Lancaster. Just past the California Aqueduct the creek passes through residential developments. Geologic investigations conducted in the area (Earth Systems Consultants, 1994) concluded that the best segment of the creek to use for recharging the groundwater was between 15^{th} and 25^{th} Streets West.

5. Kings Canyon Percolation Basin

Kings Canyon Percolation Basin is located adjacent to the Los Angeles Aqueduct and 210^{th} Street West. This basin was operated in 1946 and 1947 by the Soil Conservation Service. In these two years a total of 7,250 acre feet of water from the DWP aqueduct were spread for recharge into the aquifer. The percolation basin has been abandoned. A well log of a well located adjacent to the percolation basin is shown in Plate XXXVIII. The location of the well is shown on Plate XXX. No further information was available on the construction or operations of this percolation basin. A proposed Kings Canyon site north of the California Aqueduct at 195^{th} Street West is shown on Plate XXX. The discussion and characteristics presented later in this report for the Kings Canyon Percolation Basin generally apply to a larger area adjacent to the California Aqueduct reaching to and including the Myrick Canyon area.

6. Tehachapi Afterbay/Alamos Creek

The California Aqueduct tunnels through the Tehachapi Mountains in the northwestern boundary of the Antelope Valley. Adjacent to where the aqueduct daylights into the valley a small concrete-faced earth embankment dam has been constructed across a small basin. This basin lies just east of the Tehachapi Afterbay and north of the canal bifurcation. The basin appears to not be in use and there is no water upstream of the dam. The USGS topography maps show a couple of springs upstream of the dam. This basin may be a potential spreading basin and is conveniently located adjacent to the California Aqueduct, which could supply water for spreading operations.

C. Project Ranking and Selection

A matrix of potential sites versus evaluation criteria was developed in order to rank and select the most favorable project sites at which to implement spreading grounds in the Antelope Valley. Table 2 presents this matrix. The following weighted scoring system was developed for the evaluation criteria.

	Criteria	Maximum Possible Score
1.	Direct Benefits to AVSWCA Members	25
2.	Existing Infrastructure	15
3.	Lack of Environmental Issues	20
4.	Added Benefits to Others	10
5.	Access to Recharge Water	15
6.	Geology Conducive for Percolation	25
7.	Recharge Capacity	20
	Total Maximum Possible Score	**130**

The weighted scoring system allows the more important criteria to have a greater influence on the selection of a site and helps to provide segregation in the site rankings.

A brief discussion of the most significant ranking criteria for each site is presented below.

1. Mescal Creek – Score 66

The Mescal Creek site is the lowest ranking site. The Mescal Creek site, which is relatively far from the majority of the AVSWCA groundwater producers, would not provide a significant benefit to other groundwater users, and most significantly, is located within a potentially environmentally sensitive area, the Mescal Wildlife Sanctuary.

2. Big Rock Creek

a. Channel Upstream of Siphon – Score 80

Although the geology at Big Rock Creek upstream of the siphon is conducive for percolation of groundwater, the thickness of the underlying aquifer appears to be relatively thin. Groundwater appears to rise to the ground surface in the vicinity of the siphon and recharge downstream of the siphon, limiting its potential benefit to AVSWCA groundwater producers. The possible barrier to groundwater movement presented by the siphon may contribute to the rising water. Its location upstream of the SWP aqueduct may require infrastructure to deliver SWP water.

b. Channel Downstream of Siphon – Score 98

Big Rock Creek downstream of the SWP siphon, had the highest score. The recharged groundwater should travel towards the Lancaster and Palmdale areas and would be available to other groundwater producers in AVSWCA. Recharge water is available from the adjacent SWP aqueduct and would require relatively little infrastructure to deliver.

c. Gravel Pits – Score 78

The Gravel Pits site along Big Rock Creek, downstream of the siphon, recorded a lower score due to the reduced percolation capacity of the relatively lower permeability of the soils at the bottom level of the pit. The gravel pit sites do have the potential for recharged groundwater to reach AVSWCA groundwater producers; a potential environmental benefit of modifying an unused gravel pit into a groundwater recharge facility, and the environmental issues may be minimal since the site has already been disrupted by mining operations.

3. Littlerock Creek – Score 91

The Littlerock Creek site would require little infrastructure due to its location immediately downstream of the SWP Aqueduct. Moderate environmental concerns may be encountered if the streambed and adjacent areas needed to be modified.

4. Amargosa Creek – Score 83

The Amargosa Creek site offers a favorable location to replenish pumping by major AVSWCA groundwater producers. However, the relatively lower permeability of soils in this area reduces the capacity of percolation.

5. Kings Canyon/Myrick Canyon Percolation Basin – Score 87

Although the Kings Canyon/Myrick Canyon Percolation Basin has the advantage of having had an existing facility with a short history of operation, its relative distance from most of the AVSWCA groundwater producers reduces its relative total score.

6. Tehachapi Afterbay/Alamos Creek – Score 77

Similar to the Kings Canyon Percolation Basin, the benefits of the Tehachapi Afterbay/Alamos Creek's existing infrastructure are reduced by its distance from most AVSWCA groundwater producers.

The highest-ranking site is Big Rock Creek, downstream of the SWP siphon, followed closely by the site on Littlerock Creek. The Big Rock Creek site, downstream of the SWP siphon would require relatively little new infrastructure to deliver or recharge water, appears to have favorable hydrogeologic conditions, and would have relatively few environmental issues if no major instream modifications are needed. Although located slightly further from some of the major groundwater producers within AVSWCA than Littlerock Creek and Amargosa Creek, the recharged groundwater should travel towards the Lancaster and Palmdale areas.

The Big Rock Creek site at the gravel pits ranks lower than the Big Rock Creek site downstream of the siphon due to the layer of low permeability soil at the bottom of the pits.

The Big Rock Creek site, downstream of the SWP siphon, ranks higher than the Littlerock Creek site, primarily due to the potentially higher total spreading capacity at Big Rock Creek. The spreading area at Littlerock Creek may be limited by potential interference with nearby quarry operations, and by underlying clay layers downstream of the quarries. However, this interference may be avoided by locating the spreading grounds a sufficient distance upstream from the quarries to minimize impacts the percolating groundwater would have on the quarries. Spreading grounds south of Highway 138 on Littlerock Creek would be about a mile upstream from the nearest quarry located along Avenue T.

Both Amargosa and Littlerock Creeks are very close to the pumping areas of influence of the three AVSWCA member agencies. Each location is also ideally located just downstream of the California Aqueduct where only minimal infrastructure would be necessary to convey the water from the aqueduct to the spreading grounds.

The Kings Canyon/Myrick Canyon percolation basin can also be located downstream of the California Aqueduct to minimize infrastructure requirements. Since the Kings Canyon/Myrick Canyon percolation basin is proposed to be an off creek facility, it can be sized to provide a relatively high total spreading capacity.

VI. Project Implementation

The discussion below is provided as a preliminary plan for implementation of a groundwater recharge project.

1. Project Implementation Agreement

   Based on the relative benefits discussed above, an agreement for establishing the source, quantities, and availability of the water to be recharged, and for funding the implementation items discussed below, and for operation and maintenance of the project can be developed.

2. Field Verification and Demonstration Project Plan

   A field verification and demonstration plan consisting of soil borings, construction of monitoring wells, a percolation test, and identifying the location, duration, water quantities to be used and infrastructure needed to conduct a demonstrative project, similar to the recent Littlerock Creek Demonstration Project, should be developed. Similar to the Littlerock Creek Demonstration project, a demonstration for instream recharge, such as Big Rock Creek and Amargosa Creek can be initiated without significant infrastructure. It is suggested that a more focused monitoring program, including the construction of new monitoring wells, be developed, if needed, to document the results of the demonstration project, and to verify suitable groundwater quality in the potential recharge area.

3. Land Ownership Resolution

   It should be determined which AVSWCA entity will hold title for ownership for property that may be required for the project. Land ownership can probably be resolved as part of the development of the project funding agreement.

4. Environmental Evaluation

   A more site-specific environmental evaluation should be performed after the field verification and demonstration project is complete, assuming the demonstration project does not require new construction, other than monitoring wells. Environmentally sensitive plants and animals have generally been identified in the Antelope Valley. Biological and cultural surveys should be conducted for the selected project site to determine potential specific sensitive issues and allow consideration of potential mitigation measures, if needed.

5. California Environmental Quality Act (CEQA) Compliance

   An Initial Environmental Study, utilizing information from the biological and cultural surveys discussed above, should be prepared and publicly circulated. The Initial Environmental Study will identify any potential environmental impacts. Following the Initial Environmental Study, a determination of the appropriate CEQA documents, Negative Declaration, Mitigated Negative Declaration, or an Environmental Impact Report, to be prepared can be made.

6. Regulatory Permits

   The planned use of treated municipal wastewater for groundwater recharge must meet stringent regulatory requirements from the California Regional Water Quality Control Board and the California Department of Health Services.

   The percolation of surface waters (local and imported) for groundwater recharge is not typically subject to permitting requirements from the California Regional Water Quality Control Board or the California Department of Health Services.

   AVSWCA staff has reported that the RWQCB-Lahontan Region has previously indicated some concern with utilizing SWP water for groundwater recharge in some groundwater basins for water quality reasons. Prior to preparation of the Initial Environmental Study, this issue should be resolved with the RWQCB.

   Construction in creek beds may require a permit from the U.S. Army Corps of Engineers.

7. Design and Construction Cost Estimate

   Presented below is a reconnaissance level cost estimate for implementation, design, and construction of a typical in-stream groundwater recharge project, excluding water transmission and delivery facilities. A more detailed cost estimate should be prepared following the verification and demonstration project.

Field Verification and Demonstration Project[1]	$615,000
Environmental Evaluation/CEQA[2]	$45,000
Design and Construction[3]	$100,000
	$760,000

8. Implementation Schedule

   A conceptual implementation schedule is presented in Table 3. The schedule assumes an instream recharge project.

9. Recovery of Recharged Water/Water Rights

   The project selection criteria favored a project that would allow use of recharged water by AVSWCA groundwater producers. The projects that ranked highest in the evaluation have the greatest likelihood of recharging water for later recovery

[1] Assumes three soil borings to a depth of 150 feet below ground surface complete as monitoring wells, preparation of a written monitoring and demonstration plan, supervision of demonstration, and 3,000 ac-ft of imported water for recharge at $180/ac-ft.

[2] Assumes one biological and one cultural survey, and preparation of an Initial Environmental Study, leading to a Mitigated Negative Declaration.

[3] Assumes instream recharge project with existing SWP turnout, design and installation of delivery pipeline and outlet, and no instream modifications.

by AVSWCA groundwater producers. The courts have established that parties recharging imported water into a groundwater basin have a right to recover the stored water. However, anyone with a well may pump as much water as can be put to beneficial use, until that use is challenged or adjudicated. It must be recognized that the intent of the proposed project is to benefit AVSWCA groundwater producers, but until a groundwater management structure is in place in the Antelope Valley, any recharge water is subject to use by anyone with a well that can extract it.

VII. Conclusions and Recommendations

A. Conclusions

Several viable recharge sites have been identified that could recharge surplus SWP water for later use, thereby increasing the water supply for the Antelope Valley. In cases where data was found on the geologic faults that are identified on recent maps, the faults do not appear to be a significant barrier to groundwater movement. Groundwater recharge from many of the sites identified would ultimately contribute to the regional water supply.

In order to identify an initial recharge site for the AVSWCA, several selection criteria were developed and applied to the sites identified. Sites on Amargosa Creek, Littlerock Creek, Big Rock Creek, and in the Kings Canyon/Myrick Canyon area were all ranked high in the evaluation process. The Big Rock Creek site, downstream of the siphon, ranks highest.

B. Recommendations

The Big Rock Creek site, downstream of the siphon site, is recommended as the initial project due to its high spreading capacity and its location relative to major groundwater production.

The implementation plan describes the steps to develop the project. Particular attention should be paid to soils and percolation capacity during the field verification process to verify that acceptable recharge capacity is possible.

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TABLES

TABLE 1

ESTIMATED SPREADING CAPACITIES OF POTENTIAL SPREADING SITES

LOCATION OF POTENTIAL SPREADING GROUNDS	WET AREA (ACRES)	PERCOLATION RATE (FEET/DAY)	CAPACITY (ACRE-FEET/YEAR)		REMARKS
			MAXIMUM	OPERATING	
CALIFORNIA AQUEDUCT DEBRIS BASIN	10	1	3,650	1,825	EXISTING
OSO CANYON SPREADING GROUNDS	50	1	18,250	9,125	
KINGS CANYON PERCOLATION BASIN	45	2	32,850	16,425	EXISTING
KINGS CANYON/MYRICK CANYON SPREADING GROUNDS	20	1	7,300	3,650	
AMARGOSA CREEK SPREADING GROUNDS	10	0.5	1,825	913	
LITTLEROCK CREEK SPREADING GROUNDS	10	1	3,650	1,825	CHANNEL
BIG ROCK CREEK SPREADING GROUNDS	40	1	14,600	7,300	
MESCAL CREEK SPREADING GROUNDS	15	1	5,475	2,738	CHANNEL
TOTAL	**200**		**87,600**	**43,800**	

NOTES

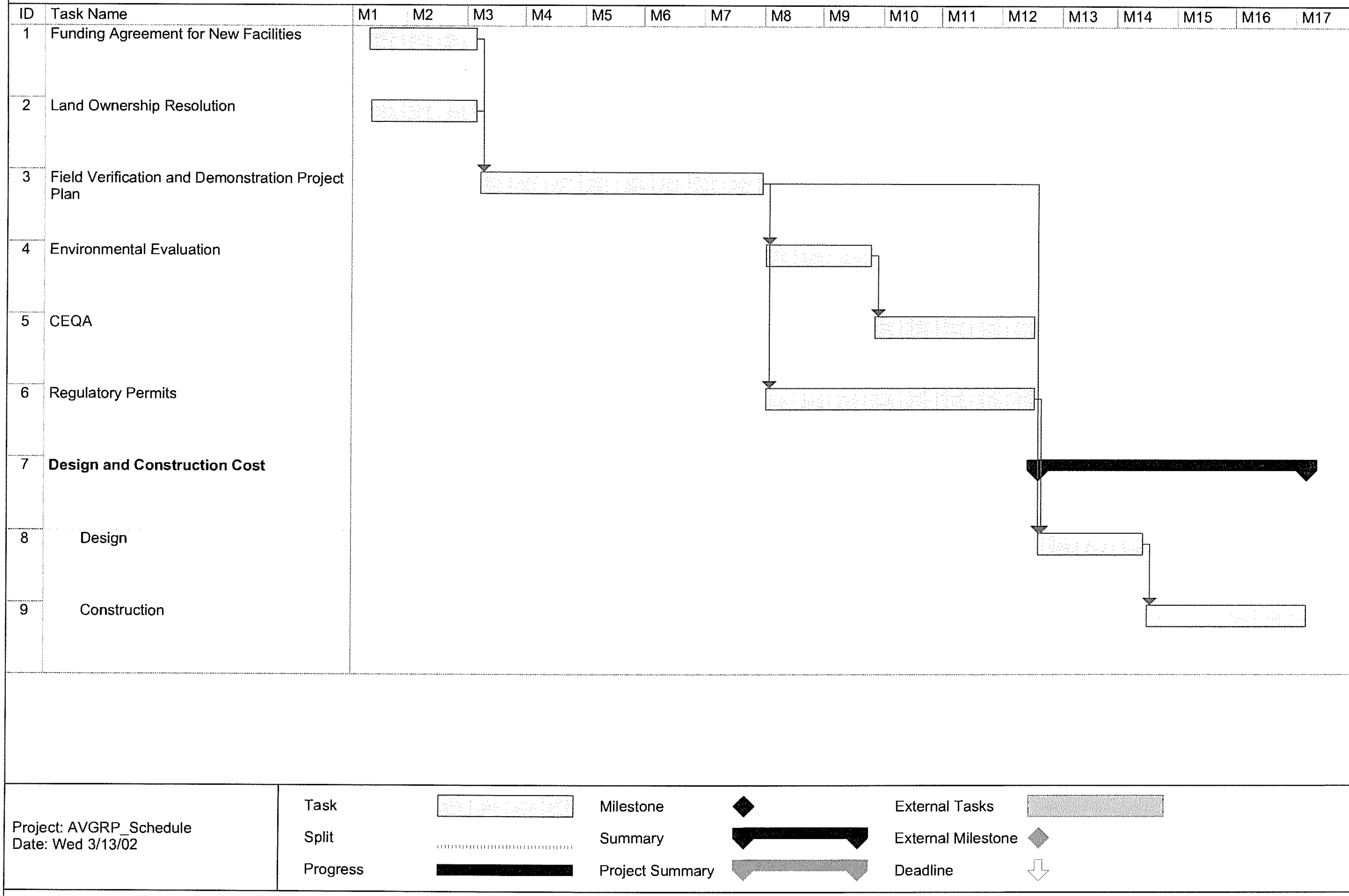
1. PERCOLATION RATE WAS ASSUMED AT 1.0 FEET PER DAY EXCEPT FOR AMARGOSA CREEK (0.5 FEET PER DAY)
2. PERCOLATION RATE FOR KINGS CANYON PERCOLATION BASIN WAS CALCULATED FROM ITS CAPACITY (45 CFS)
3. SPREADING GROUNDS WERE ASSUMED SHALLOW (LESS THAN 3 FEET DEEP) EXCEPT MESCAL AND LITTLE CREEKS
4. MAXIMUM CAPACITY - BASED ON CONTINUOUS OPERATION OF SPREADING GROUNDS
5. OPERATING CAPACITY - SPREADING GROUNDS WERE ASSUMED TO BE OPERATED 50 PERCENT OF TIME

TABLE 2

PROJECT MATRIX FOR POTENTIAL SPREADING GROUNDS IN THE ANTELOPE VALLEY

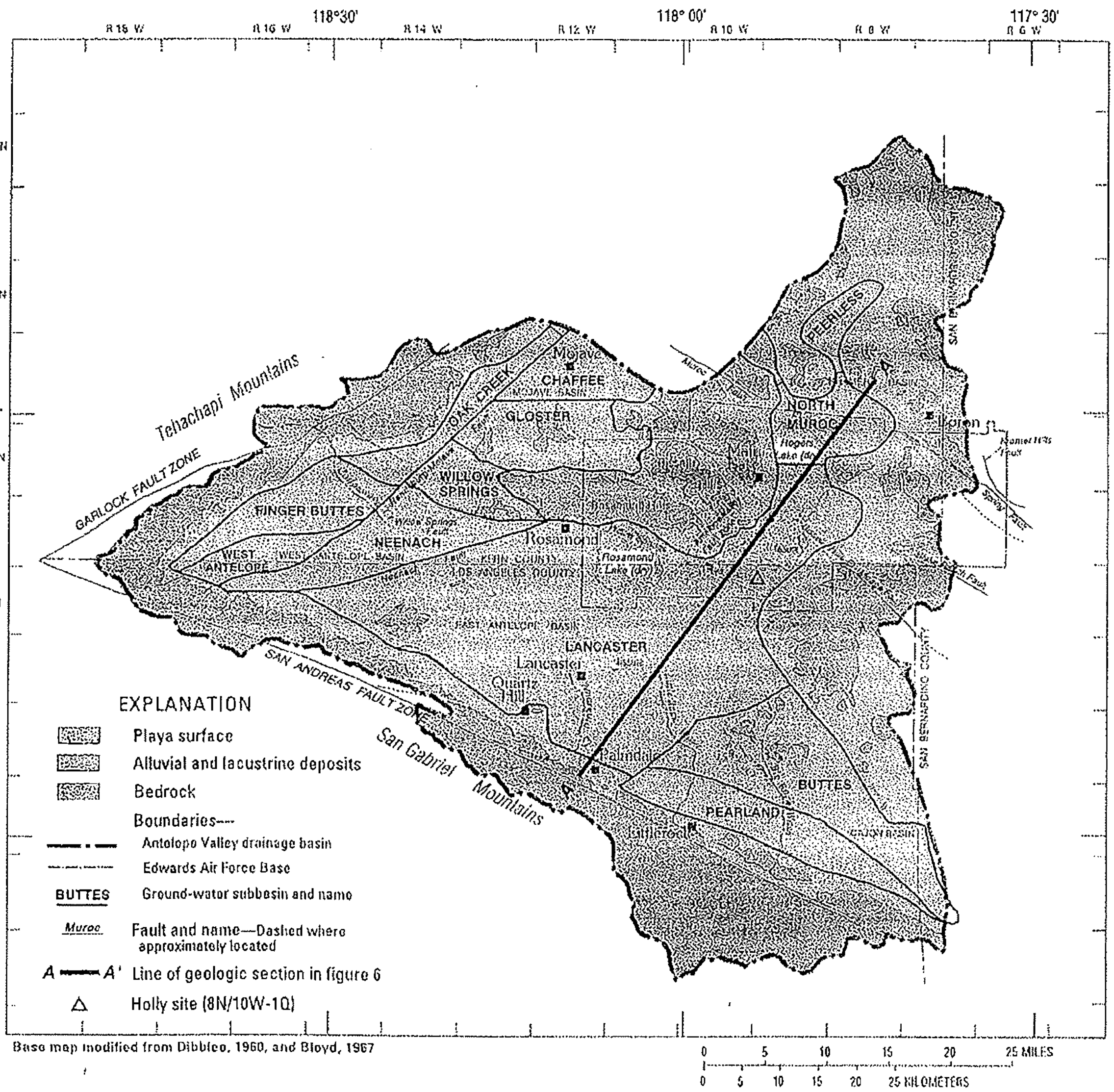
		POTENTIAL SITES							
Criteria	Max. Possible Score	Mescal Creek	Big Rock Creek Upstream of Siphon	Big Rock Creek Downstream of Siphon	Big Rock Creek at Gravel Pits	Littlerock Creek	Amargosa Creek	Kings Canyon/Myrick Canyon Percolation Basin	Tehachapi Afterbay/Alamos Creek
1. Are there direct benefits to AVSWCA groundwater producers?	25	5	10	20	20	20	25	10	10
2. Is existing infrastructure sufficient?	15	10	5	10	5	10	10	5	10
3. Are the environmental issues less than typical?	20	0	12	12	20	12	12	16	16
4. Will spreading ground provide added benefits to others?	10	6	8	6	8	4	6	6	6
5. Are the sources of recharge water close?	15	15	10	15	5	15	15	10	10
6. Is the geology of the site conducive for percolation?	25	20	25	20	15	20	15	20	15
7. Are the spreading grounds capacity high?	20	10	10	15	5	10	0	20	10
Matrix Total		**66.0**	**80.0**	**98.0**	**78.0**	**91.0**	**83.0**	**87.0**	**77.0**

TABLE 3
ANTELOPE VALLEY GROUNDWATER RECHARGE PROJECT
IMPLEMENTATION SCHEDULE



Project: AVGRP_Schedule
Date: Wed 3/13/02

PLATES



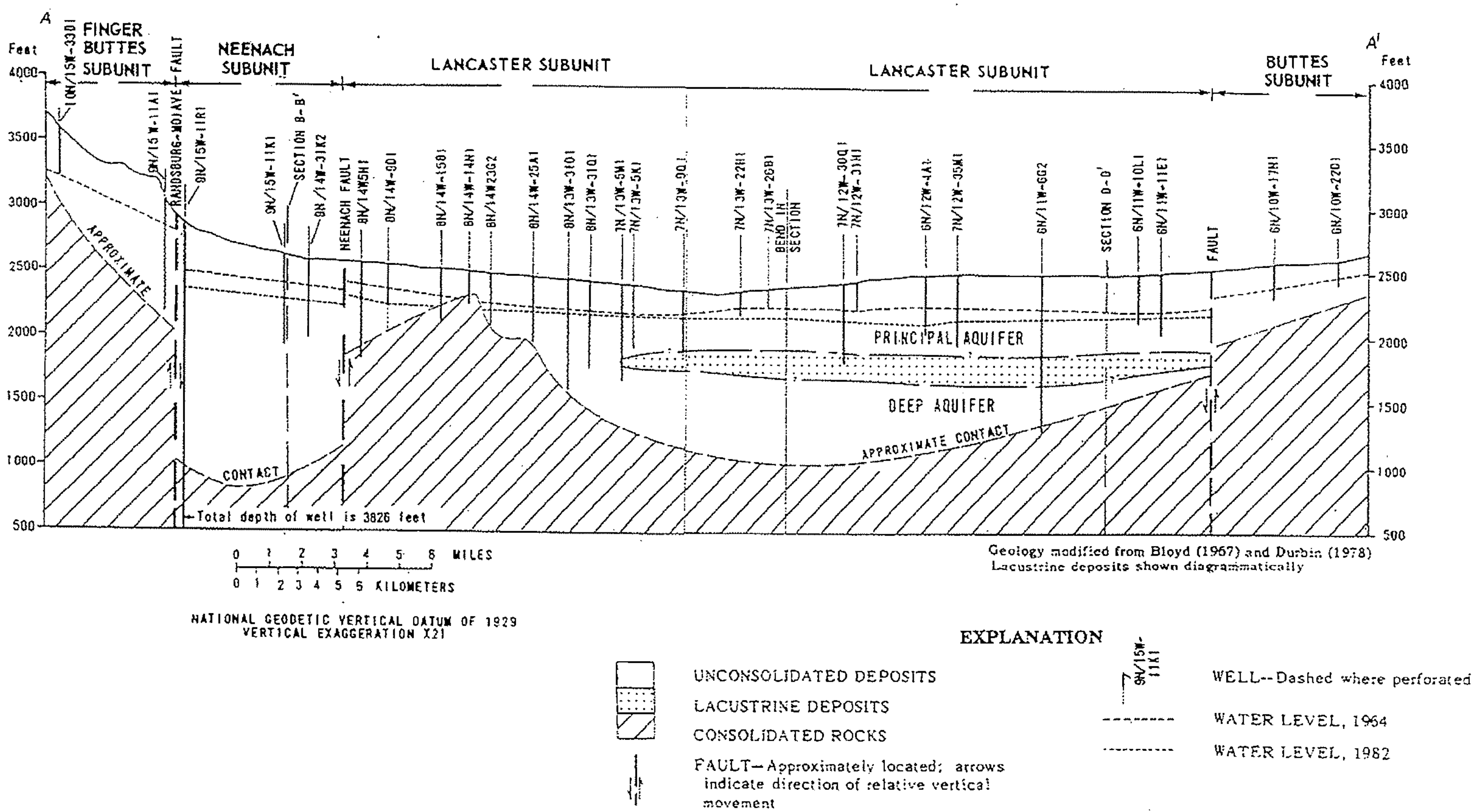
SOURCE : AQUIFER-SYSTEM COMPACTION AND LAND SUBSIDENCE: MEASUREMENTS, ANALYSES, AND SIMULATIONS - THE HOLLY SITE, EDWARDS AIR FORCE BASE, ANTELOPE VALLEY, CALIFORNIA
U.S. GEOLOGICAL SURVEY WATER-RESOURCES INVESTIGATIONS REPORT 00-4015, SNEED, MICHELLE AND D.L. GALLOWAY 2000

STETSON ENGINEERS INC.
West Covina San Rafael Mesa, Arizona
WATER RESOURCE ENGINEERS

ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

LOCATION MAP
ANTELOPE VALLEY, CALIFORNIA

02/19/02



SOURCE : WATER RESOURCES OF THE ANTELOPE VALLEY-EAST KERN WATER AGENCY AREA, CALIFORNIA. R.R. BLOYD, JR. AUGUST 28, 1967.
LOCATION OF CROSS SECTION IS SHOWN ON PLATE 1

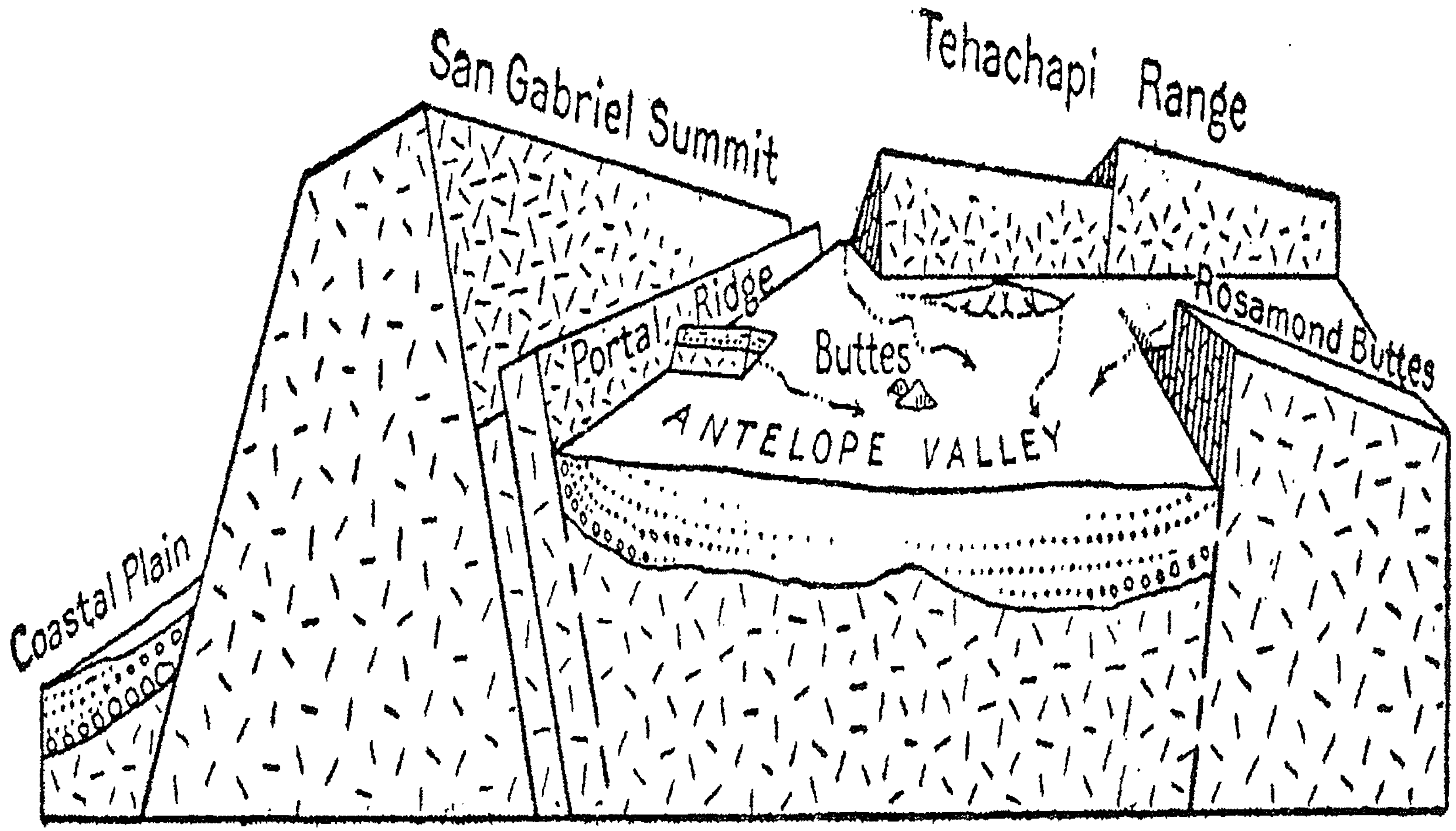
STETSON ENGINEERS INC.
West Covina San Rafael Mesa, Arizona
WATER RESOURCE ENGINEERS

ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

GENERALIZED CROSS SECTION AA'
ANTELOPE VALLEY, CALIFORNIA

02/22/02

PLATE II



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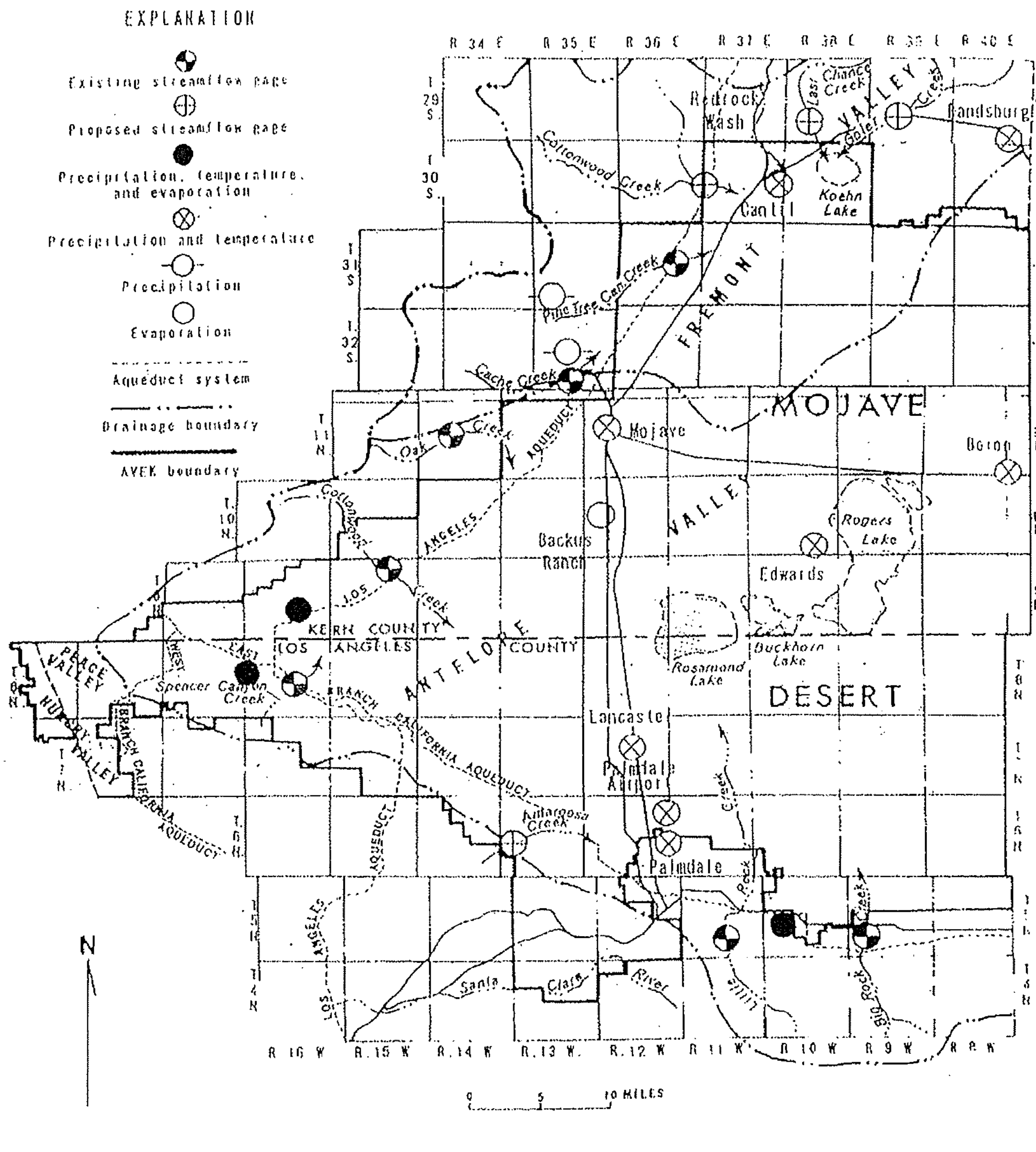
STETSON ENGINEERS INC.
West Covina San Rafael Mesa, Arizona
WATER RESOURCE ENGINEERS

ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

DIAGRAM SHOWING GEOLOGIC FEATURES
ANTELOPE VALLEY, CALIFORNIA

02/19/02

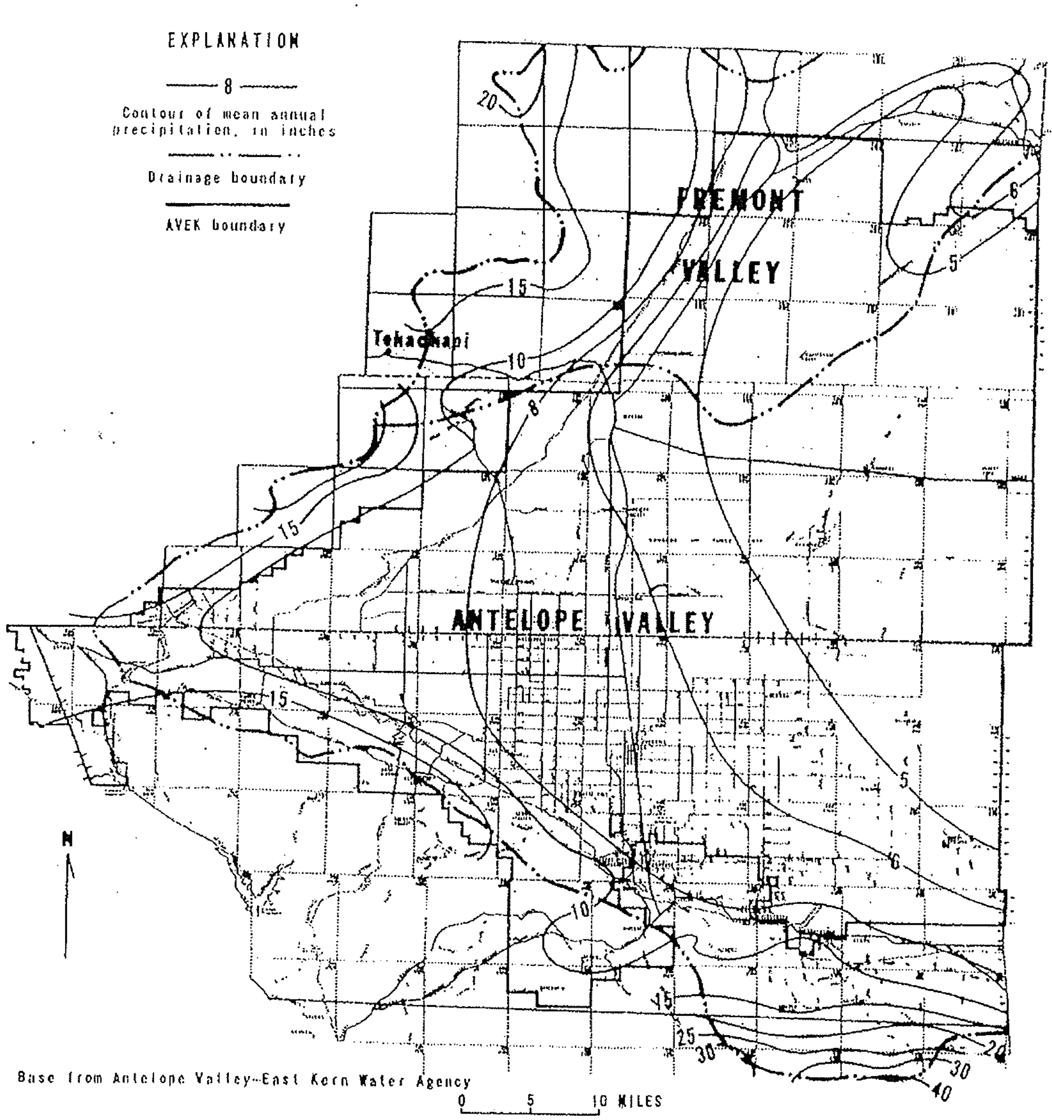


MAP OF THE AVEK AREA SHOWING LOCATION OF
STREAMFLOW GAGES AND WEATHER GAGES

SOURCE: WATER RESOURCES OF THE ANTELOPE VALLEY-EAST KERN WATER AGENCY AREA, CALIFORNIA. R.R. BLOYD, JR. AUGUST 28, 1967.
UPDATED AS OF MAY 31,2002 FOR PEARBLOSSOM AND CHECK 43

STETSON ENGINEERS INC. West Covina San Rafael Mesa, Arizona WATER RESOURCE ENGINEERS	ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION MAJOR CREEKS AND GAGING STATIONS ANTELOPE VALLEY, CALIFORNIA

02/21/02



MAP OF THE AVEK AREA SHOWING MEAN ANNUAL PRECIPITATION AND DRAINAGE BOUNDARIES

SOURCE : WATER RESOURCES OF THE ANTELOPE VALLEY-EAST KERN WATER AGENCY AREA, CALIFORNIA. R.R. BLOYD, JR. AUGUST 28, 1967.

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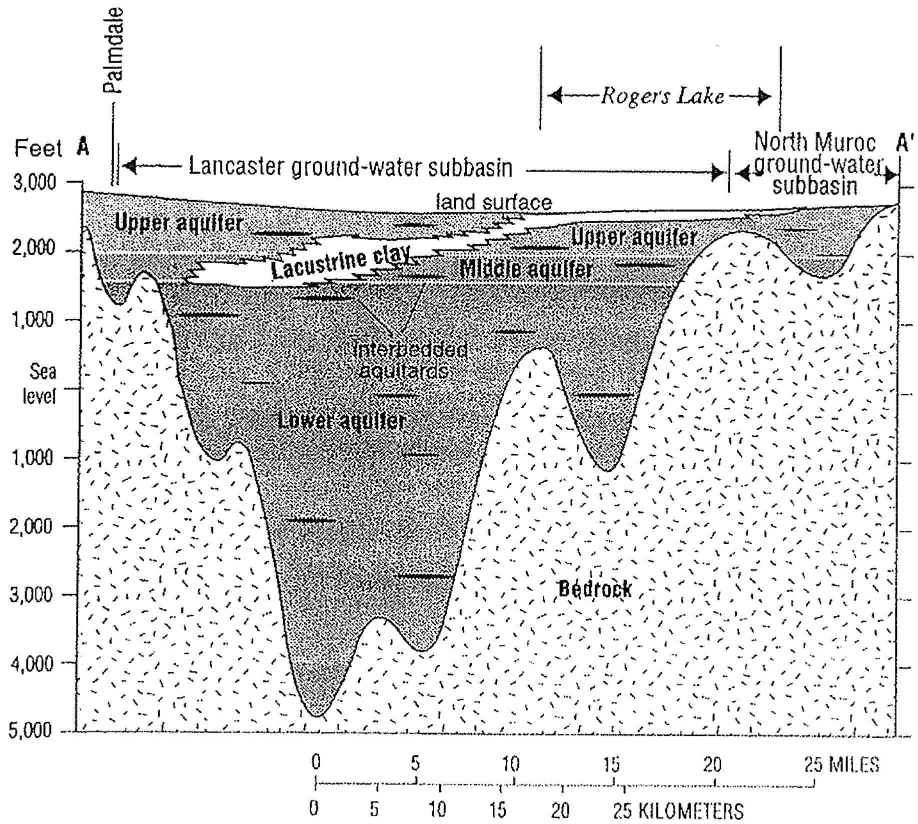
ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

AVERAGE ANNUAL PRECIPITATION
ANTELOPE VALLEY, CALIFORNIA

02/21/02



EXPLANATION

- Younger alluvium
- Older alluvium
- Continental deposits
- Lacustrine clay deposits
- Bedrock

SOURCE : AQUIFER-SYSTEM COMPACTION AND LAND SUBSIDENCE: MEASUREMENTS, ANALYSES, AND SIMULATIONS - THE HOLLY SITE, EDWARDS AIR FORCE BASE, ANTELOPE VALLEY, CALIFORNIA
U.S. GEOLOGICAL SURVEY WATER-RESOURCES INVESTIGATIONS REPORT 00-4015. SNEED, MICHELLE AND D.L. GALLOWAY. 2000

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	GENERALIZED GEOLOGIC SECTION IN LANCASTER AND NORTH MUROC SUB-BASINS

02/19/02

Table 4.--Proposed test wells in the western part of Antelope Valley, Calif.

Test-well number	Location	Depth (feet)	Approximate depth to water (ft)	Purpose
1	8N/16W-16A1	300	250(?)	Fault-barrier delineation.
2	8N/16W-11C1	230	180	Do.
3	9N/16W-34Q1	250	200	Do.
4	9N/15W-32C1	300	250	Do.
5	9N/15W-22G1	400	350	Do.
6	9N/15W-16F1	350	300(?)	Do.
7	9N/16W-28R1	400	325(?)	Do.
8	8N/15W- 9D1	200	150	Do.
9	8N/15W-17M1	200	200	Do.
10	9N/17W-25J1	400	350(?)	Do.
11	8N/16W- 9C1	300	230	Observing head change from infiltration.
12	8N/16W- 4N2[1/]	800	230	Aquifer test and observing head change from well injection.

1. Well should be 8 inches in diameter, whereas all other test wells should be 3 inches in diameter.

SOURCE : A PROGRESS REPORT AND PROPOSED TEST-WELL DRILLING PROGRAM FOR THE WATER-RESOURCES INVESTIGATION OF THE ANTELOPE VALLEY-EAST KERN WATER AGENCY AREA, CALIFORNIA - U.S. GEOLOGICAL SURVEY OPEN FILE REPORT 1965

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TEST WELLS FOR THE 1965 TEST-WELL DRILLING PROGRAM PROPOSED BY U.S. GEOLOGICAL SURVEY

02/22/02

PLATE VII

Data for test wells drilled in the western Antelope Valley area, California

U.S.G.S. well number	Test-well number	Depth (feet)	Altitude 1/	Depth to water (feet)	Date of measurement	Altitude of water surface 2/
9N/15W-20F1	1	420	3130	292.73	4- 6-65	2835
9N/15W-32B1	2	408	2825	310.64	4- 6-65	2515
8N/16W- 3F1	3	326	2860	193.14	4-13-65	2665
9N/15W-30Q1	4	413	2880	337.89	4-13-65	2540
8N/16W- 2R1	5	343	2795	165.53	4- 6-65	2630
8N/16W- 2F1	6	303	2800	169.46	4-12-65	2630
8N/15W-18H1	7	295	2790	202.28	4-14-65	2590
8N/16W-16A1	8	315	2925	292.88	4-21-65	2630

1. The altitude given is the altitude of the reference point above mean sea level. Altitudes were estimated from a topographic map.

2. The altitude given is the altitude, in whole feet, of the water surface above mean sea level. Values are rounded to nearest 5 feet.

SOURCE : A PROGRESS REPORT ON THE TEST-WELL DRILLING PROGRAM IN THE WESTERN PART OF ANTELOPE VALLEY, CALIFORNIA. U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT. MARCH 1, 1966.

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DATA FOR TEST WELLS INSTALLED DURING THE 1965 TEST-WELL DRILLING PROGRAM PROPOSED BY U.S. GEOLOGICAL SURVEY

02/22/02

PLATE VIII

Data for five wells in the western Antelope Valley area, California

U.S.G.S. well number	Depth (feet)	Altitude 1/	Depth to water (feet)	Date of measure-ment	Altitude of water surface 2/
8N/16W- 9G1	--	2895	278.59	3-23-65	2616
8N/16W- 9G2	a 300	2890	245.50	3-23-65	2644
9N/16W-31H1	a 360	3020	319.90	3-25-65	2700
9N/16W-30M1	422	3145	Dry	4- 8-65	--
9N/16W-27B1	350.4	3130	Dry	4-13-65	--

1. The altitude given is the altitude of the reference point above mean sea level. Altitudes were estimated from a topographic map.

2. The altitude given is the altitude, in whole feet, of the water surface above mean sea level.

a. Reported depth.

SOURCE: A PROGRESS REPORT ON THE TEST-WELL DRILLING PROGRAM IN THE WESTERN PART OF ANTELOPE VALLEY, CALIFORNIA
U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT, MARCH 1, 1966

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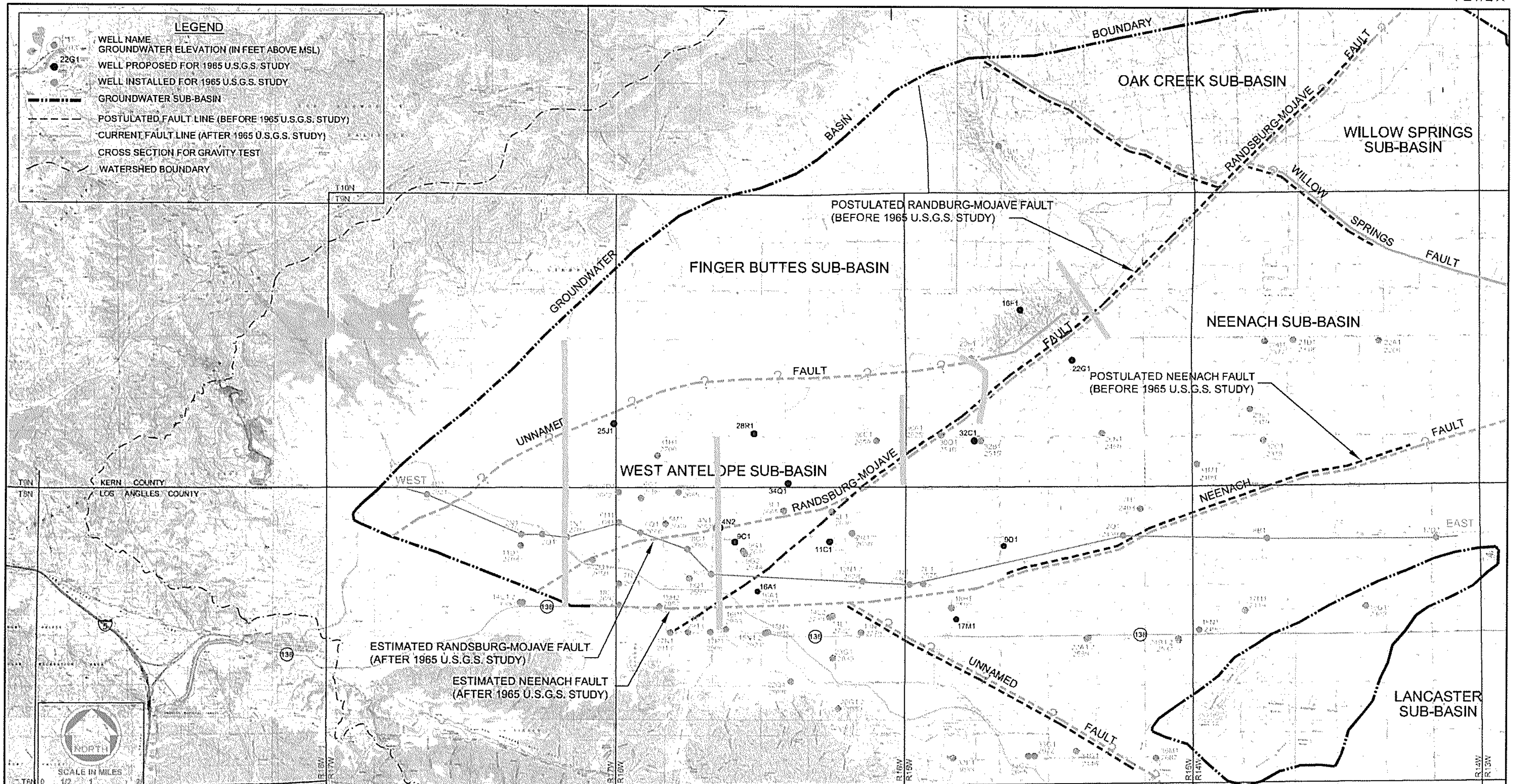
ADDITIONAL WATER LEVELS MEASURED DURING THE 1965 TEST-WELL DRILLING PROGRAM PROPOSED BY U.S. GEOLOGICAL SURVEY

02/22/02

PLATE IX



SOURCES:

1.- A Progress Report and Proposed Test-Well Drilling Program for the Water-Resources Investigation of The Antelope Valley-East Kern Water Agency Area, California. U.S. Geological Survey Open File Report 1965.

2.- A Progress Report on the Test-Well Drilling Program in the Western Part of Antelope Valley, California. U.S. Geological Survey Open File Report March, 1966.

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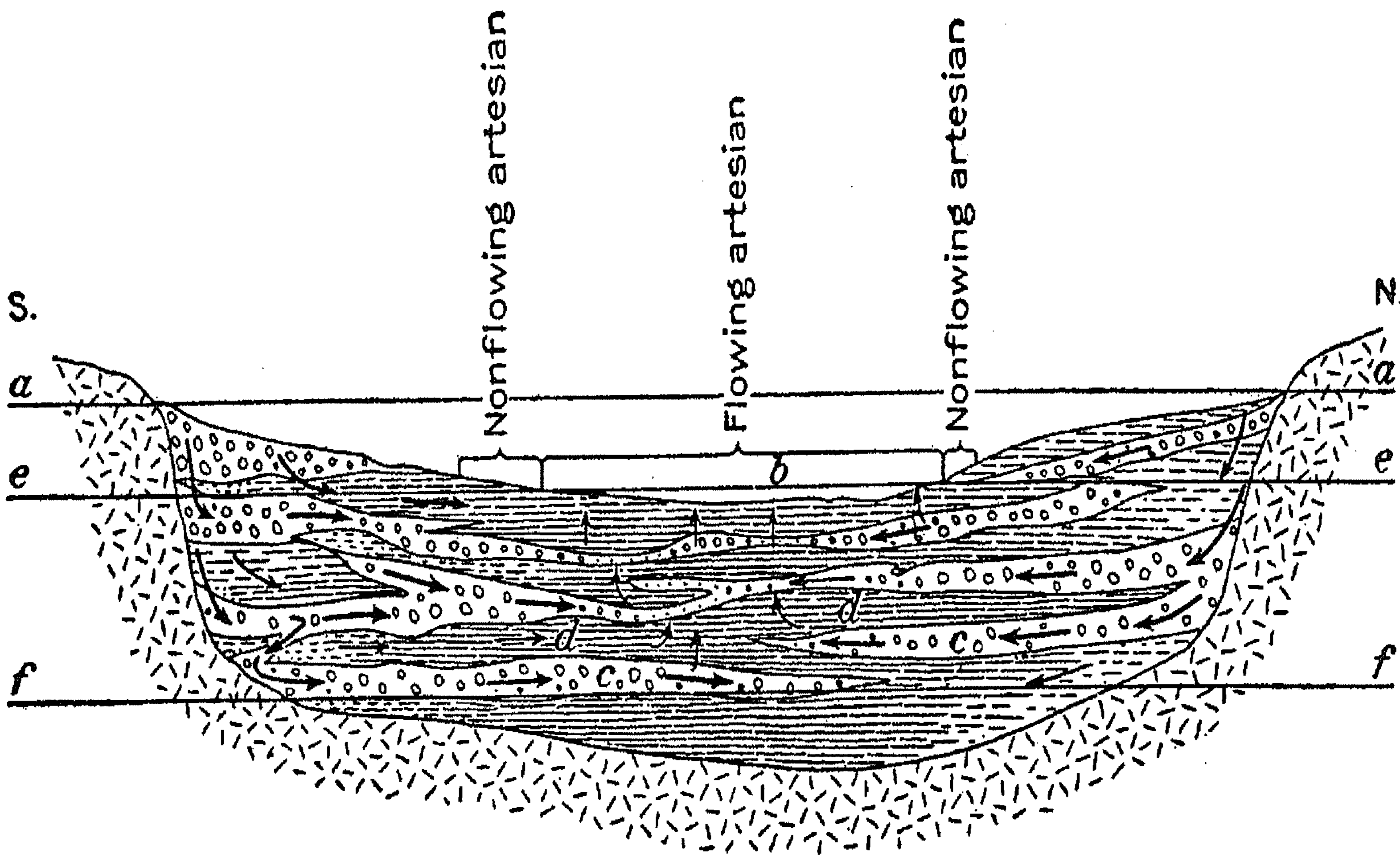
RESULTS OF THE 1965 U.S. GEOLOGICAL TEST-WELL DRILLING PROGRAM

F:\JOBS\1853\01\PLATE X.DWG
F:\JOBS\1853\01\PLATE X.PC2



SOURCE : WATER RESOURCES OF ANTELOPE VALLEY, CALIFORNIA. U.S. GEOLOGICAL SURVEY WATER-SUPPLY PAPER 278. HARRY R. JOHNSON. 1911.

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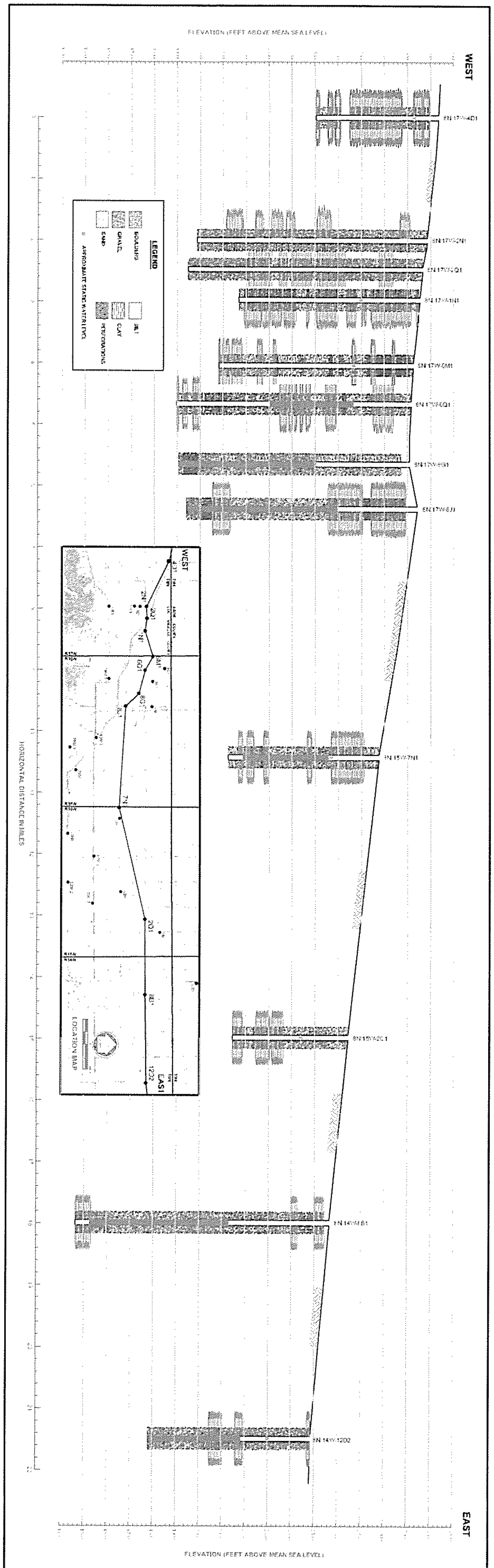
DIAGRAM OF GROUNDWATER BASIN
ANTELOPE VALLEY, CALIFORNIA

07/10/02

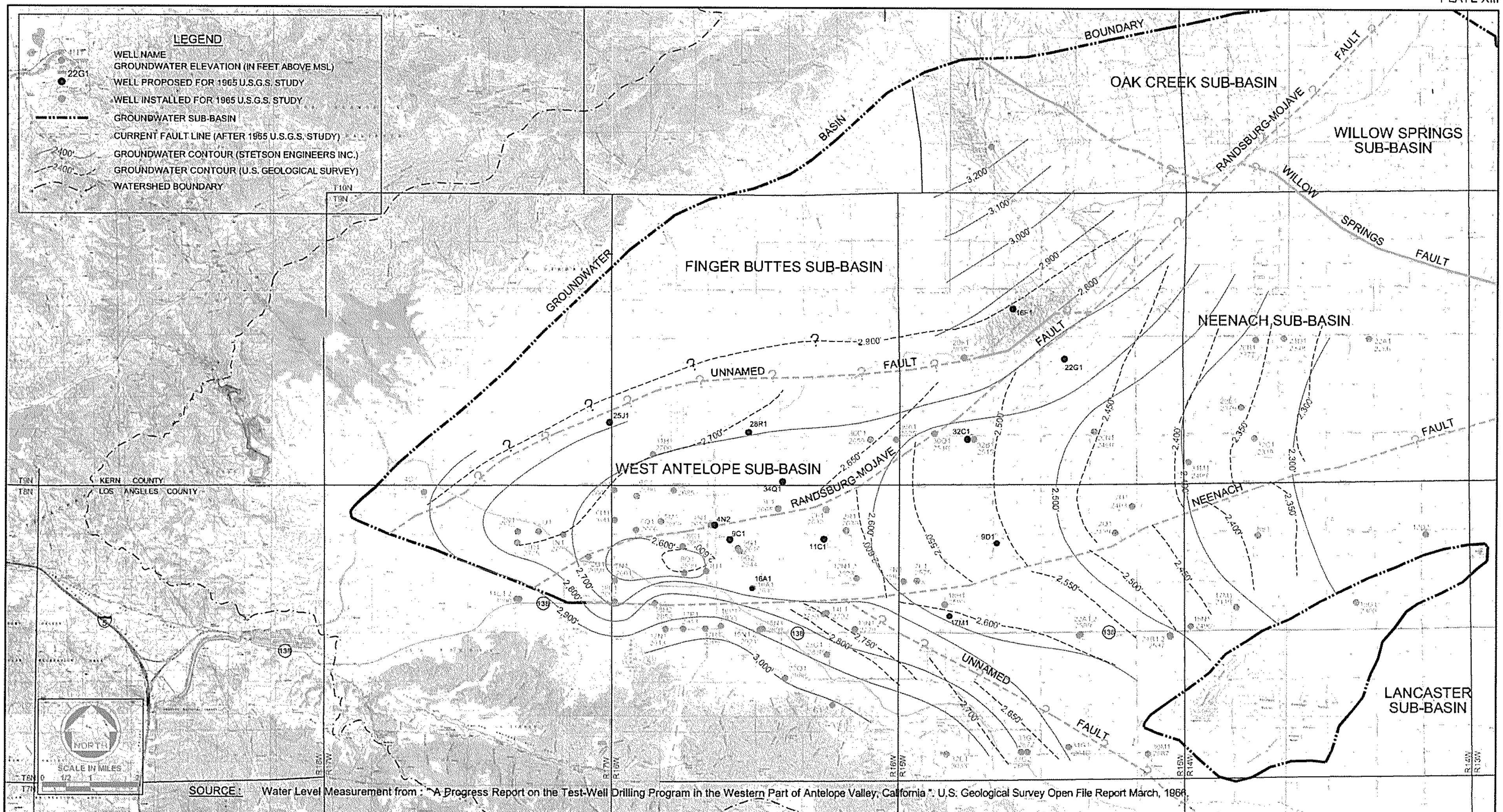
PLATE XI



ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

GEOLOGIC CROSS-SECTION IN WESTERN ANTELOPE VALLEY

PLATE XII



SOURCE: Water Level Measurement from : "A Progress Report on the Test-Well Drilling Program in the Western Part of Antelope Valley, California". U.S. Geological Survey Open File Report March, 1966.

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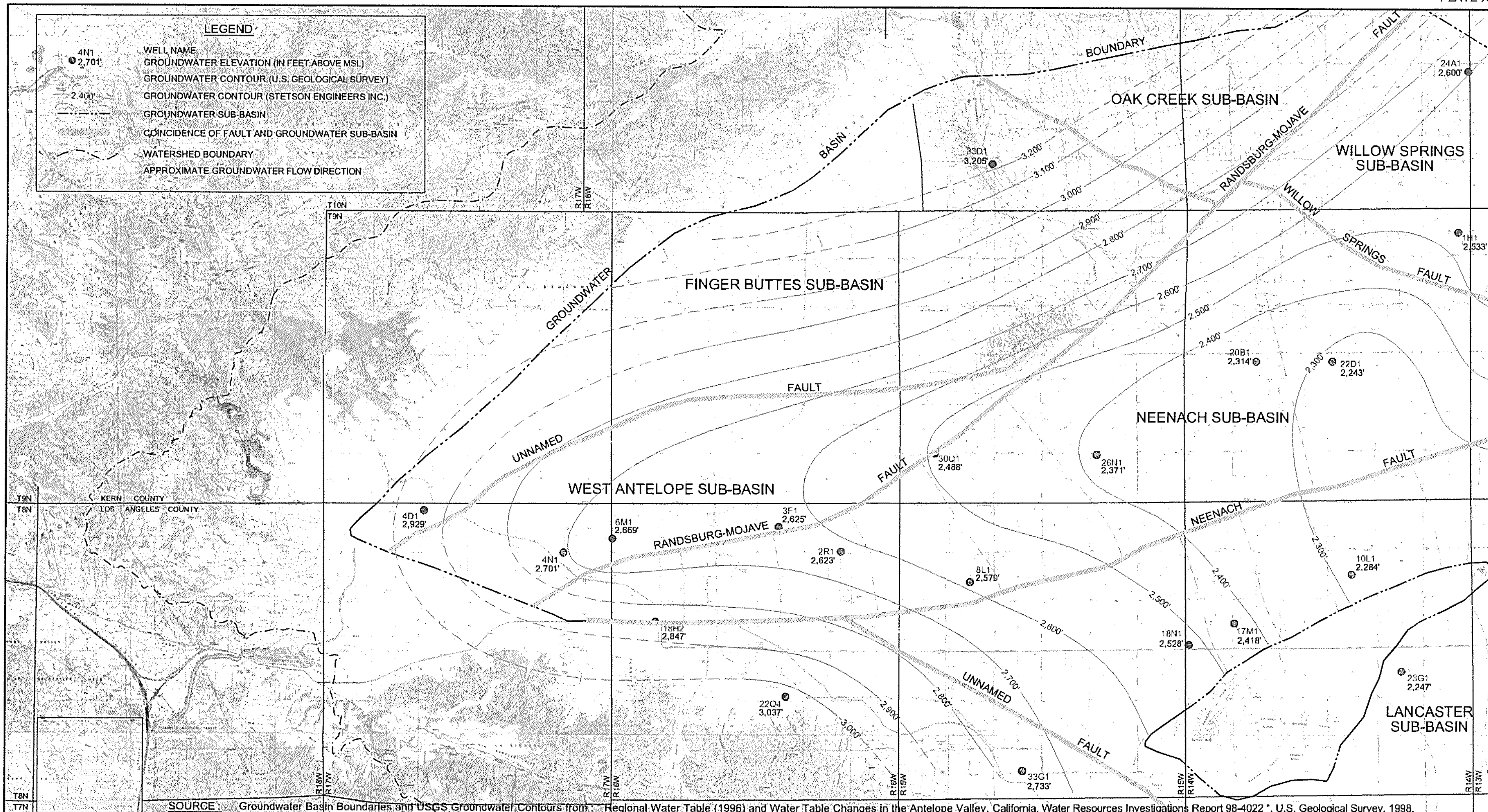
1962-1965 GROUNDWATER CONTOUR MAP IN THE WESTERN PART OF THE ANTELOPE VALLEY

F:\JOBS\1853\01\PLATE XIII.DWG
F:\JOBS\1853\01\PLATE XIII.PC2



SOURCE: Groundwater Basin Boundaries and USGS Groundwater Contours from: "Regional Water Table (1996) and Water Table Changes in the Antelope Valley, California. Water Resources Investigations Report 98-4022". U.S. Geological Survey. 1998.

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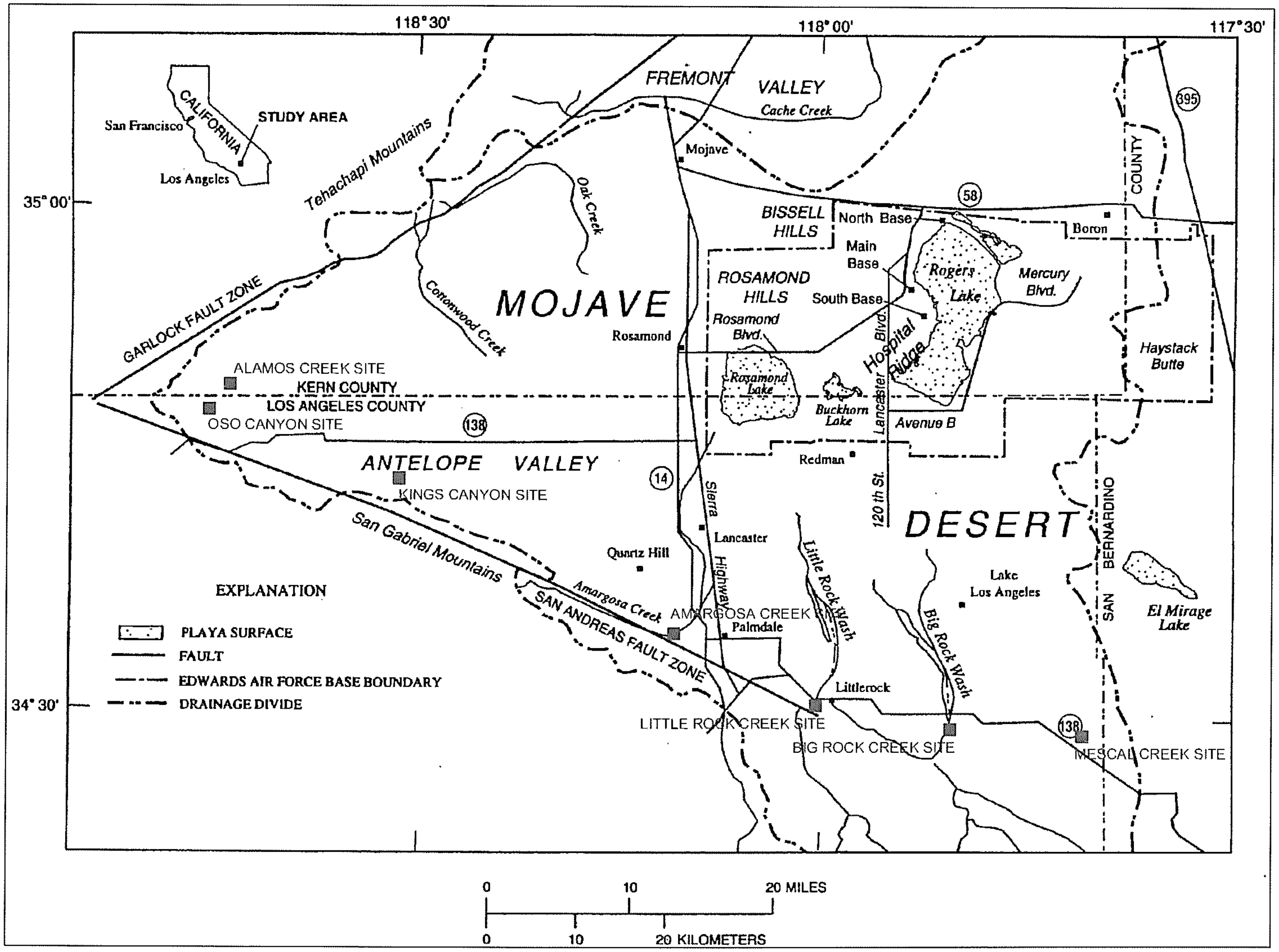
1996 GROUNDWATER CONTOUR MAP IN THE WESTERN PART OF THE ANTELOPE VALLEY

F:\JOBS\1853\01\PLATE XIV.DWG
F:\JOBS\1853\01\PLATE XIV.PC2



BASE MAP ADOPTED FROM U.S. GEOLOGICAL SURVEY WATER-RESOURCES INVESTIGATIONS REPORT 93-4114 (1993).

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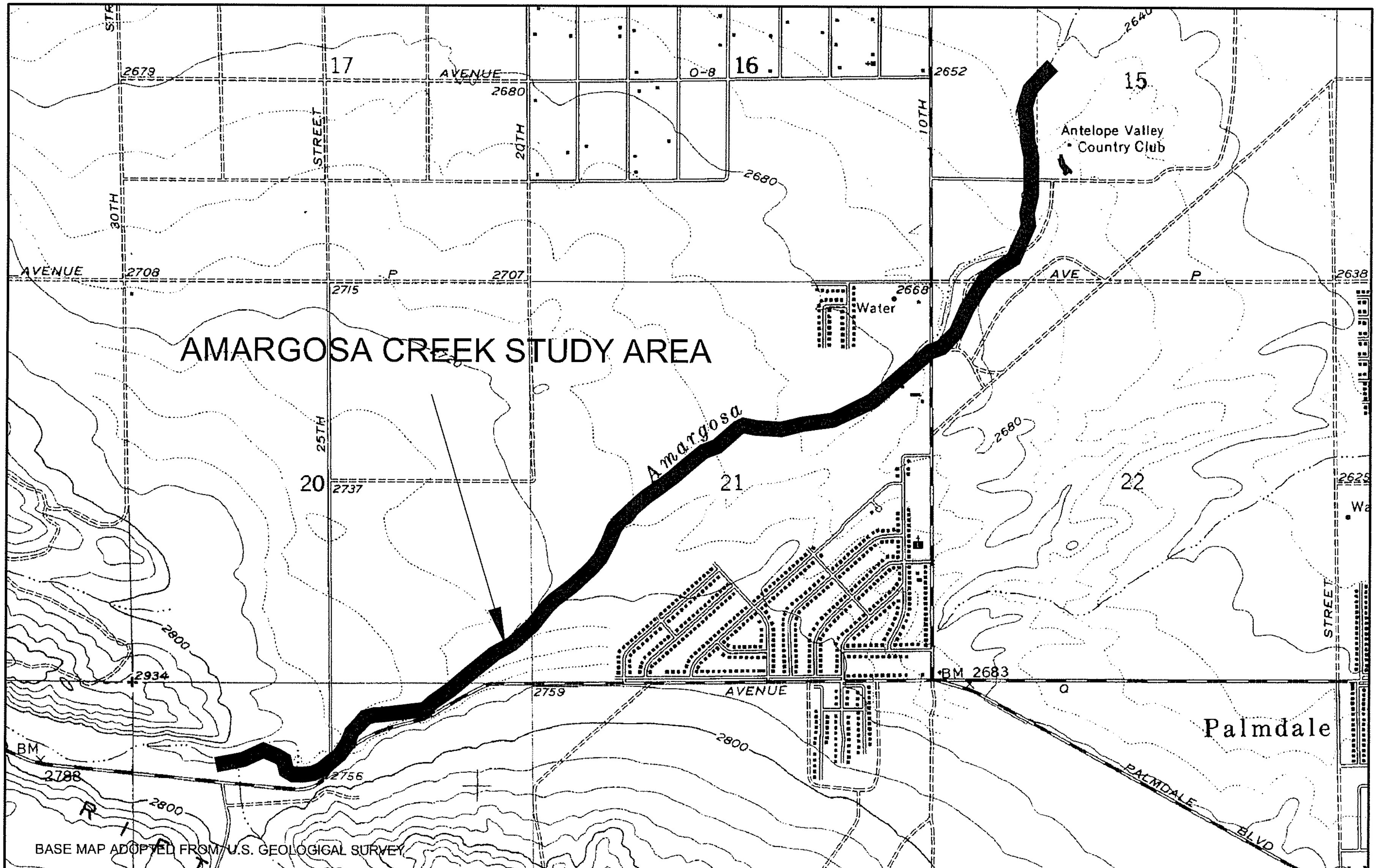
APPROXIMATE LOCATION OF POTENTIAL SURFACE SPREADING SITES

JOBS:\1853\01\PLATE_XV.DWG
JOBS:\1853\01\PLATE_1.PC2

PLATE XV



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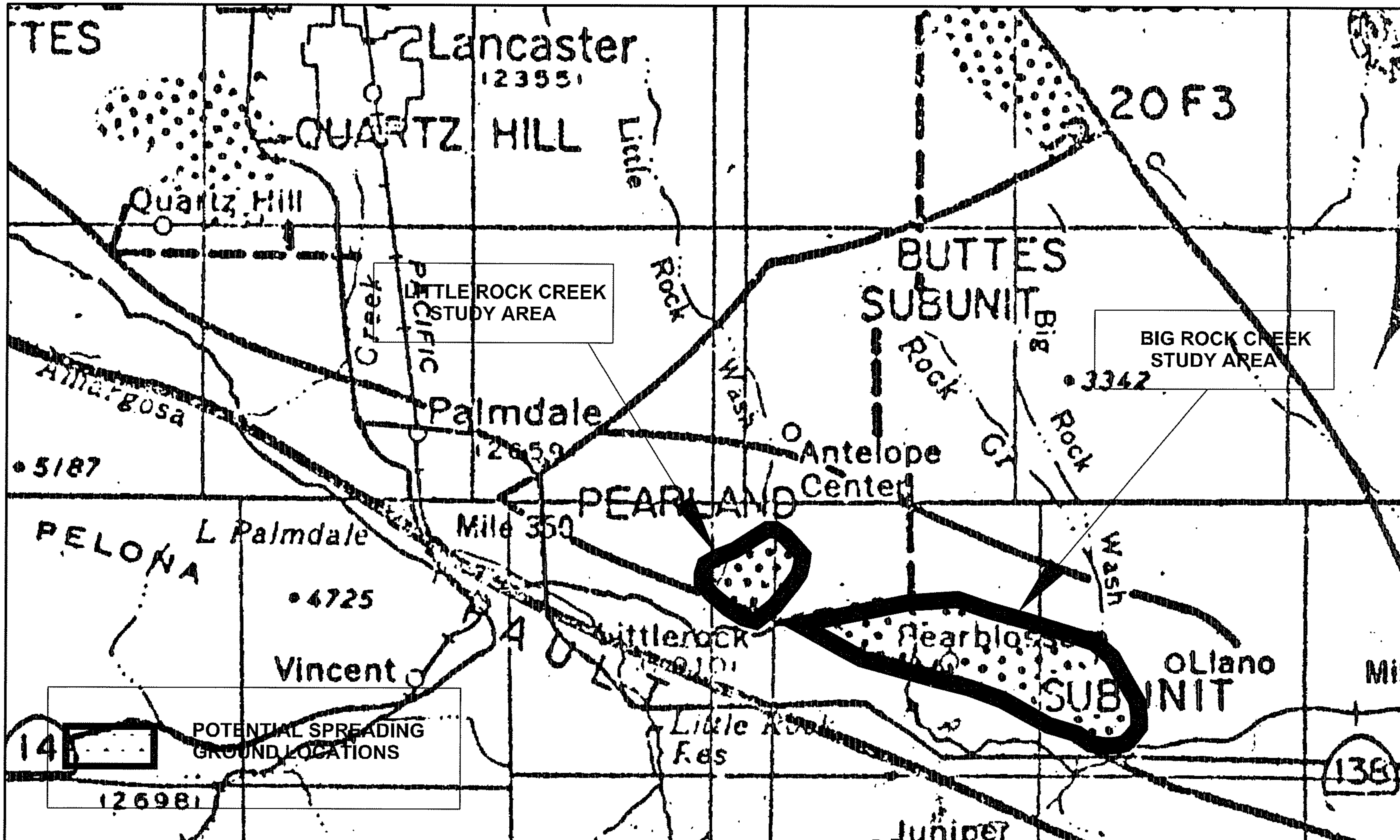
AMARGOSA CREEK STUDY AREA
FOR EARTH SYSTEMS CONSULTANTS' SUMMARY REPORT, 1994

JOBS:\1853\01\PLATE_XV.DWG
JOBS:\1853\01\PLATE_1.PC2

PLATE XVI



SOURCE: "A PRELIMINARY EVALUATION OF GEOLOGIC BASES FOR THE SELECTION OF SPREADING GROUNDS IN THE ANTELOPE VALLEY STUDY AREA"
GEORGE C. BURCKHALTER, STATE OF CALIFORNIA DEPARTMENT OF WATER RESOURCES, AUGUST 1976

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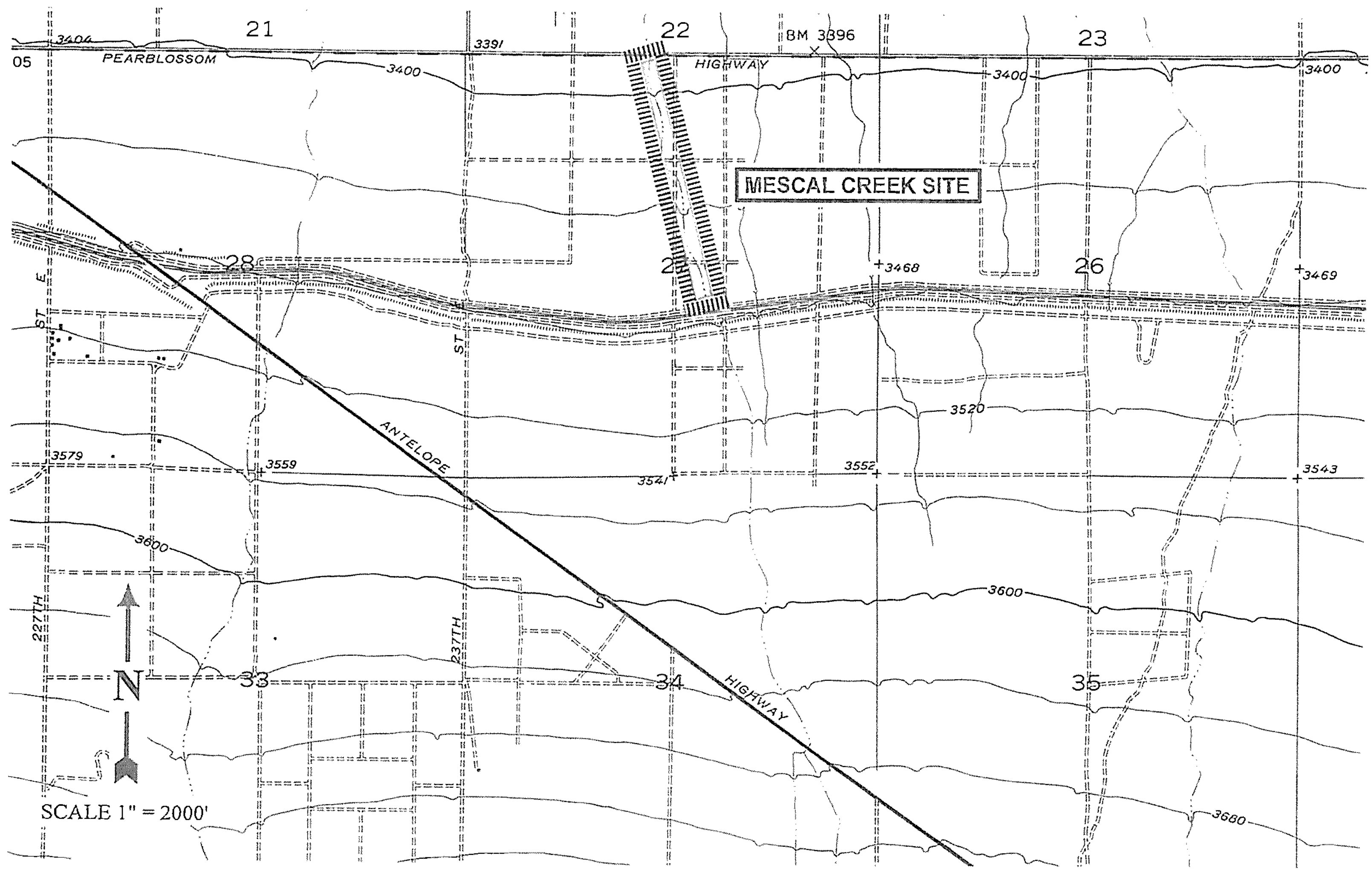
BIG ROCK CREEK AND LITTLE ROCK CREEK STUDY AREA
FOR DEPARTMENT OF WATER RESOURCES SPREADING GROUND STUDY, 1976

JOBS:\1853\01\PLATE_XV.DWG
JOBS:\1853\01\PLATE_1.PC2

PLATE XVII



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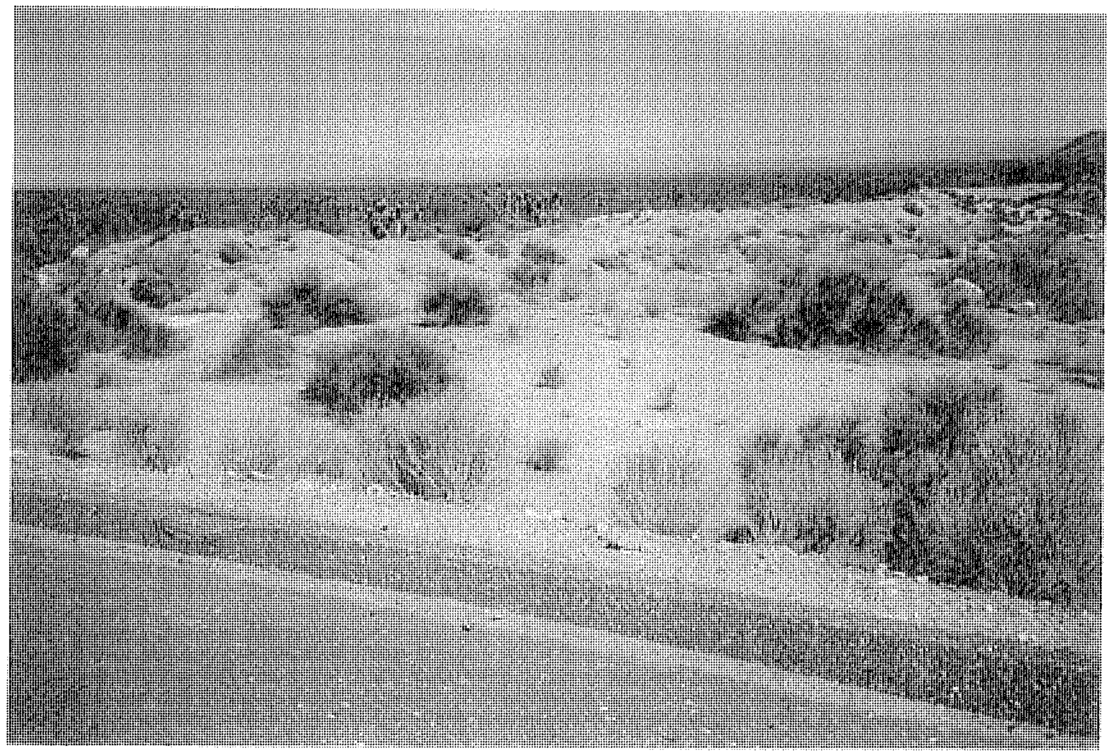
POTENTIAL SITES FOR SURFACE SPREADING
MESCAL CREEK SITE

09/06/2001

PLATE XVIII



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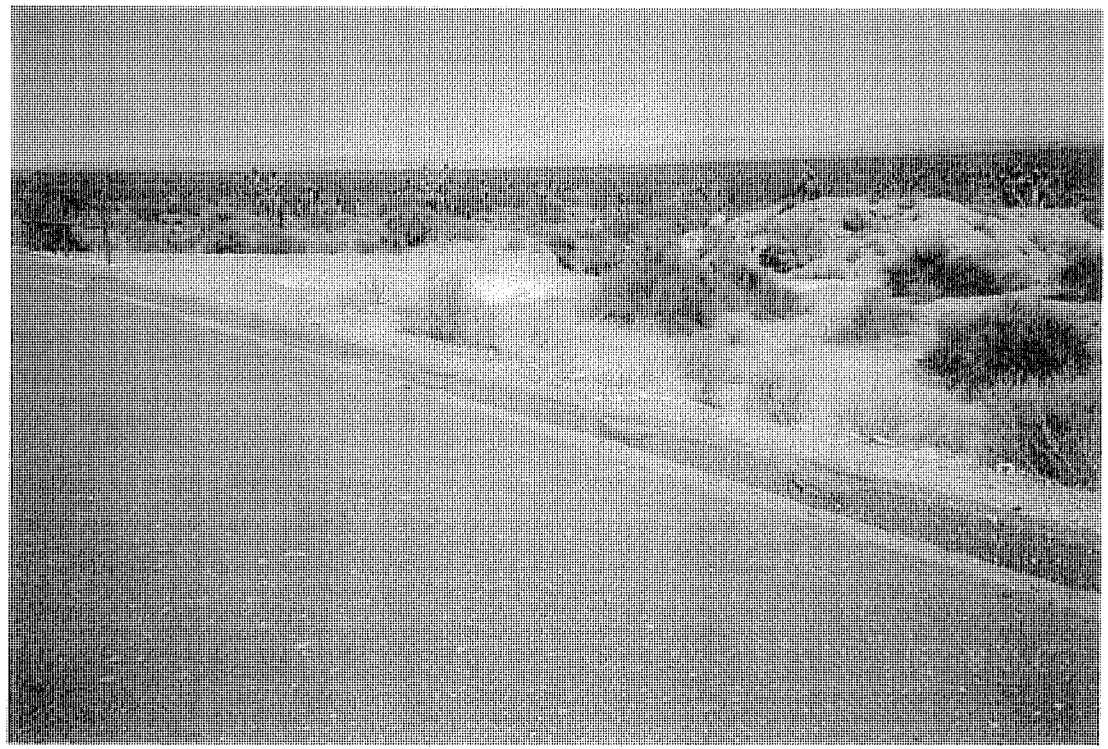
ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
MESCAL CREEK SITE (POTENTIAL SITE FOR SPREADING BASIN)

09/06/2001

PLATE XIX



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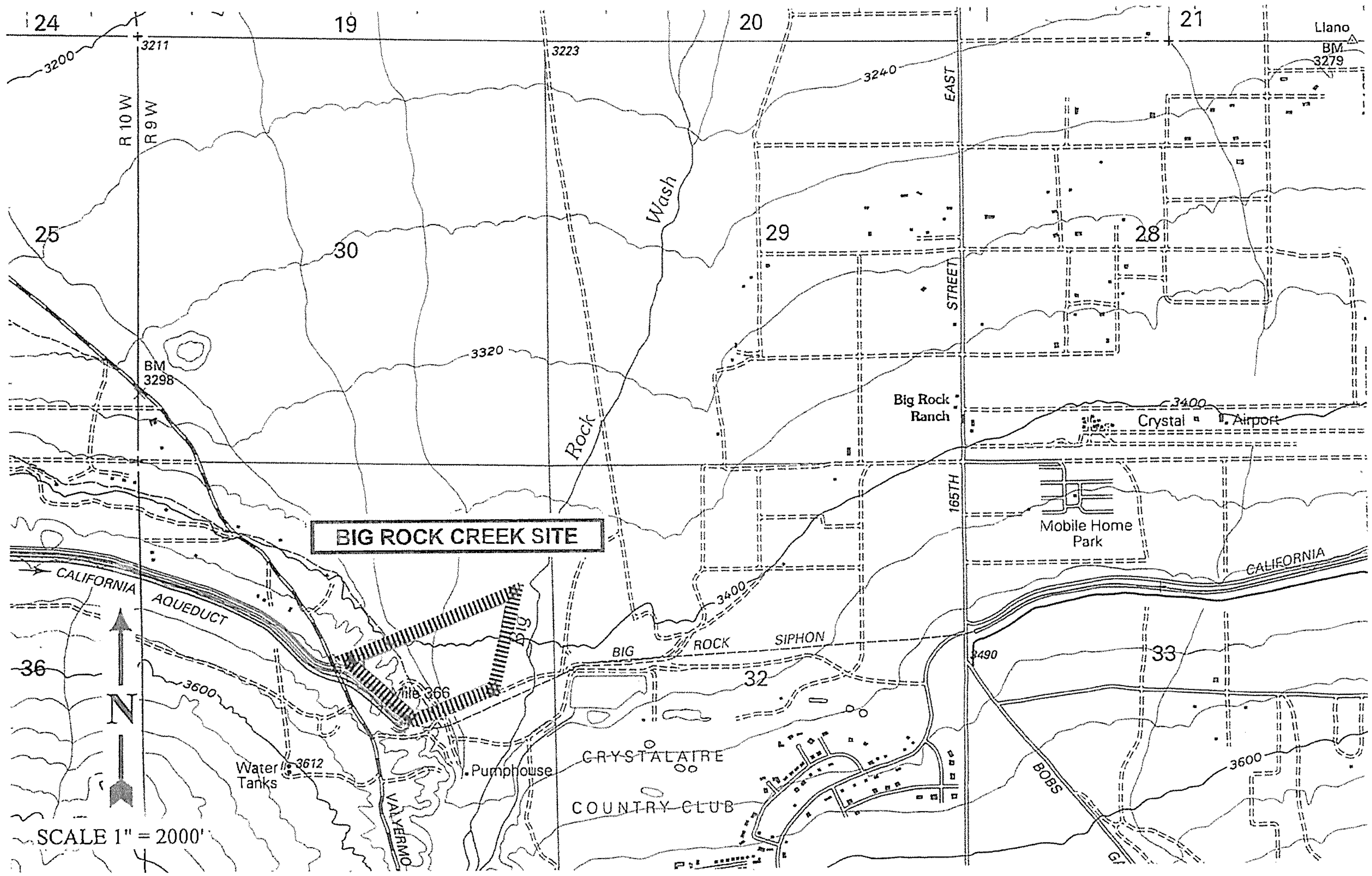
POTENTIAL SITES FOR SURFACE SPREADING
MESCAL CREEK SITE (MESCAL CREEK AT CALIFORNIA AQUEDUCT))

09/06/2001

PLATE XX



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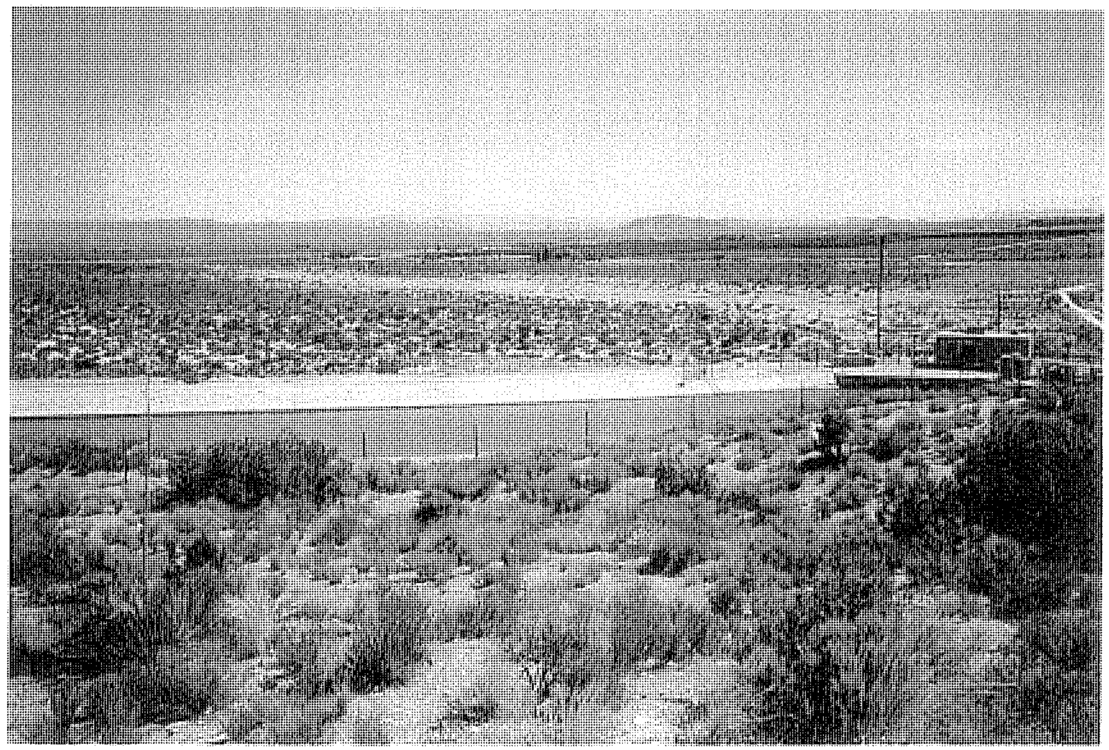
POTENTIAL SITES FOR SURFACE SPREADING
BIG ROCK CREEK SITE

09/06/2001

PLATE XXI



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POTENTIAL SITES FOR SURFACE SPREADING
BIG ROCK CREEK SITE (BIG ROCK CREEK AT CALIFORNIA AQUEDUCT)

09/06/2001

PLATE XXII

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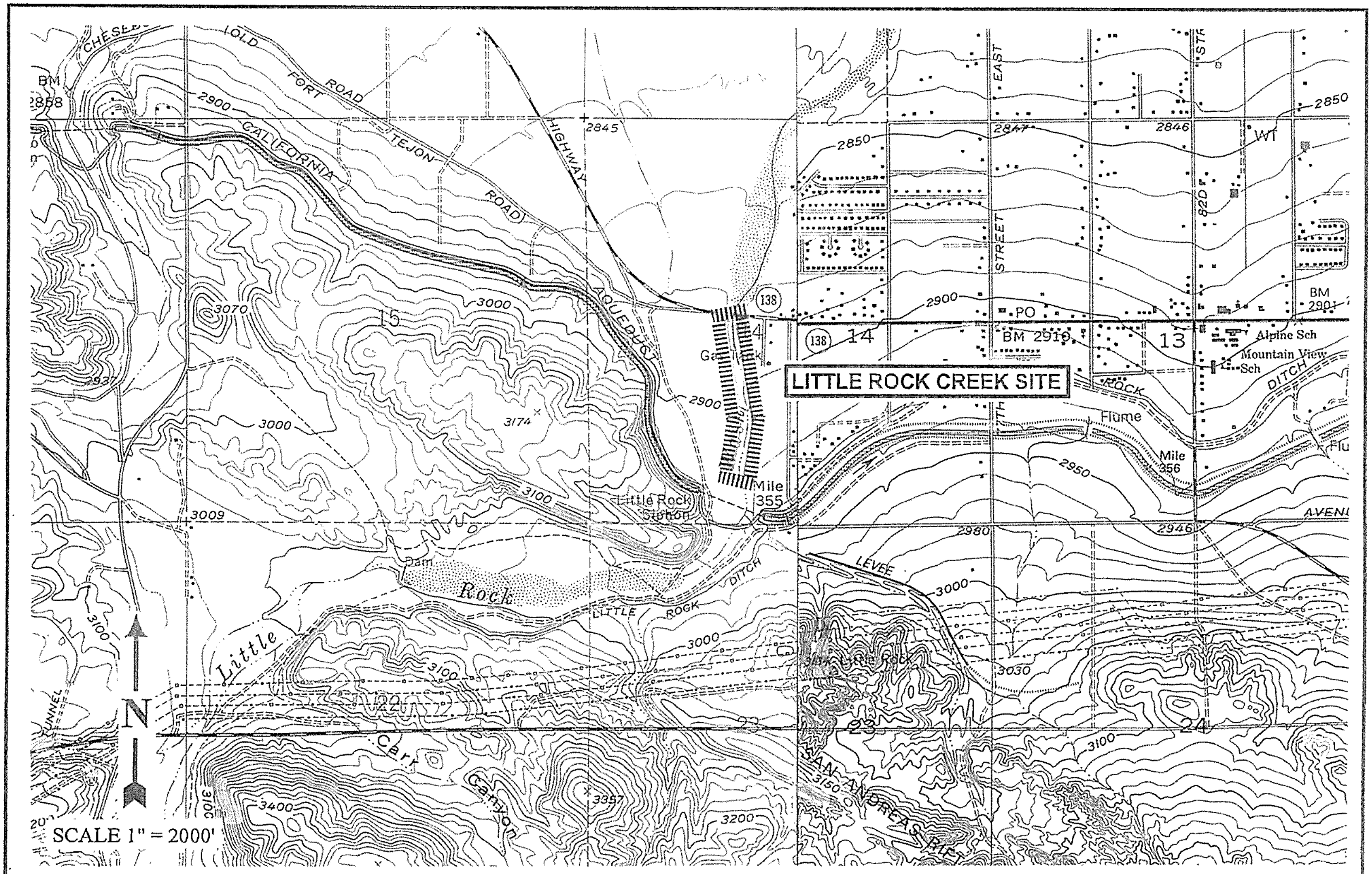
WATER RESOURCE ENGINEERS

ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
BIG ROCK CREEK SITE (POTENTIAL SITE FOR SPREADING BASIN)

09/06/2001

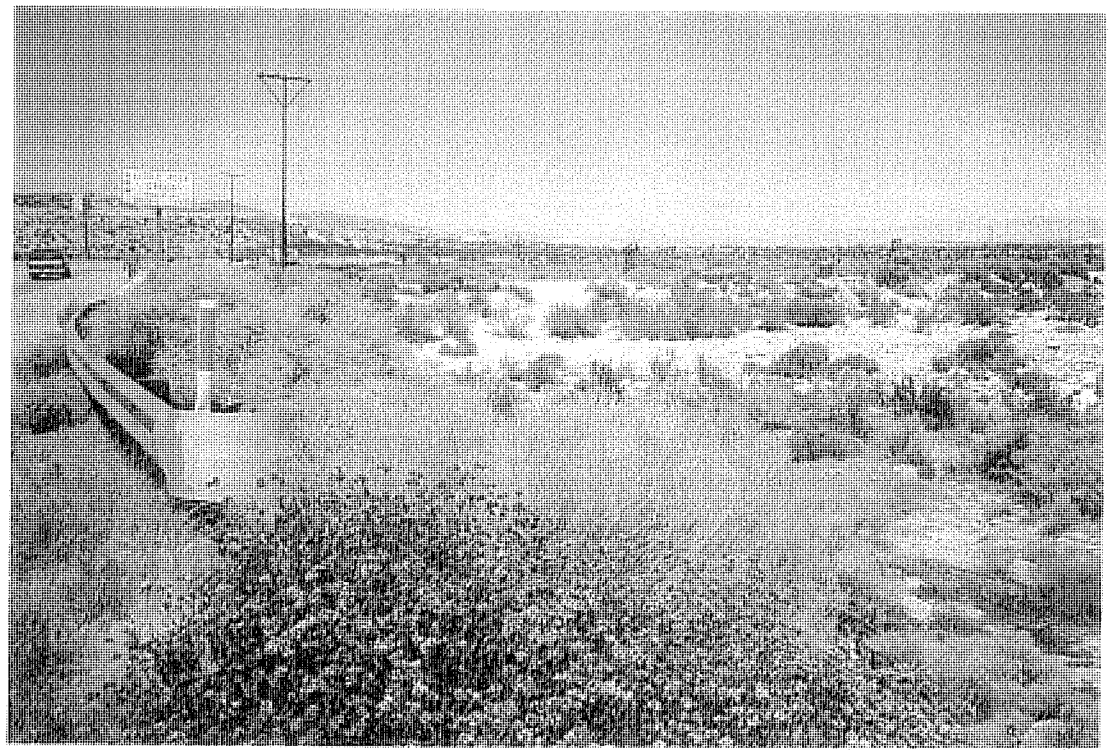
PLATE XXIII



STETSON ENGINEERS INC. West Covina San Rafael Mesa, Arizona WATER RESOURCE ENGINEERS	ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION POTENTIAL SITES FOR SURFACE SPREADING LITTLE ROCK CREEK SITE

09/06/2001

PLATE XXIV



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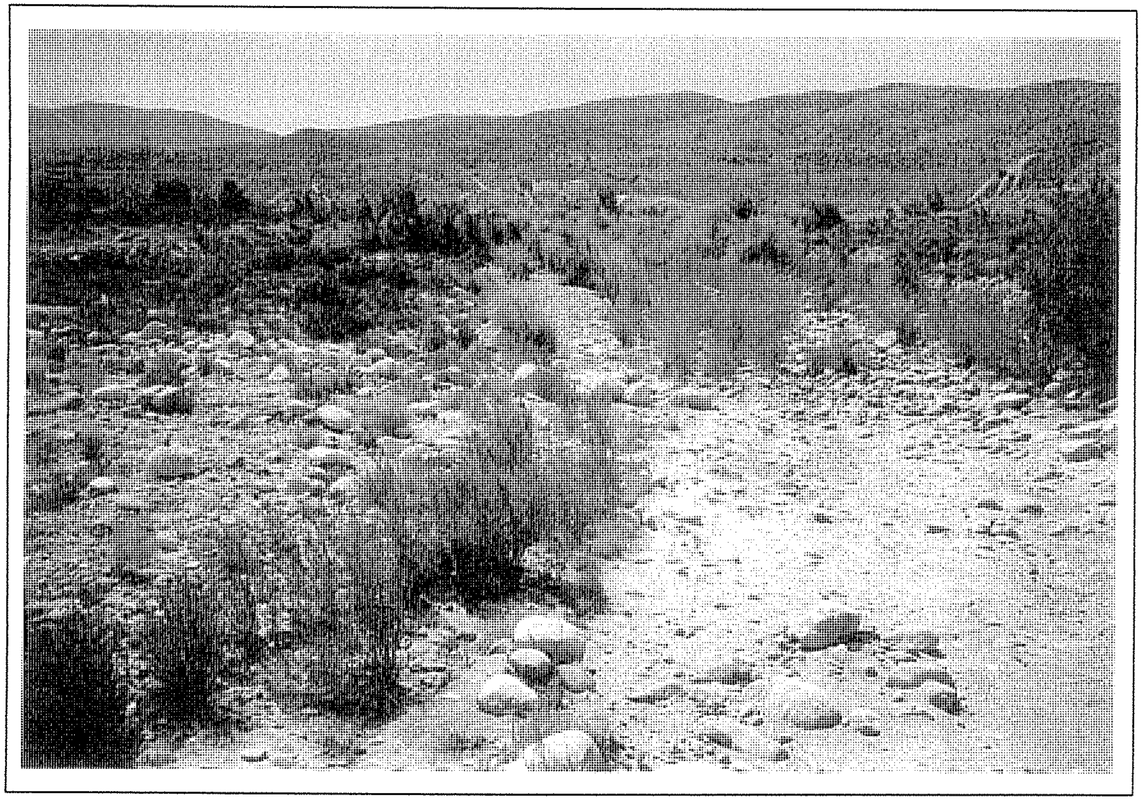
WATER RESOURCE ENGINEERS

ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
LITTLE ROCK CREEK SITE (LITTLE ROCK CREEK DOWNSTREAM OF HIGHWAY 138)

09/06/2001

PLATE XXV



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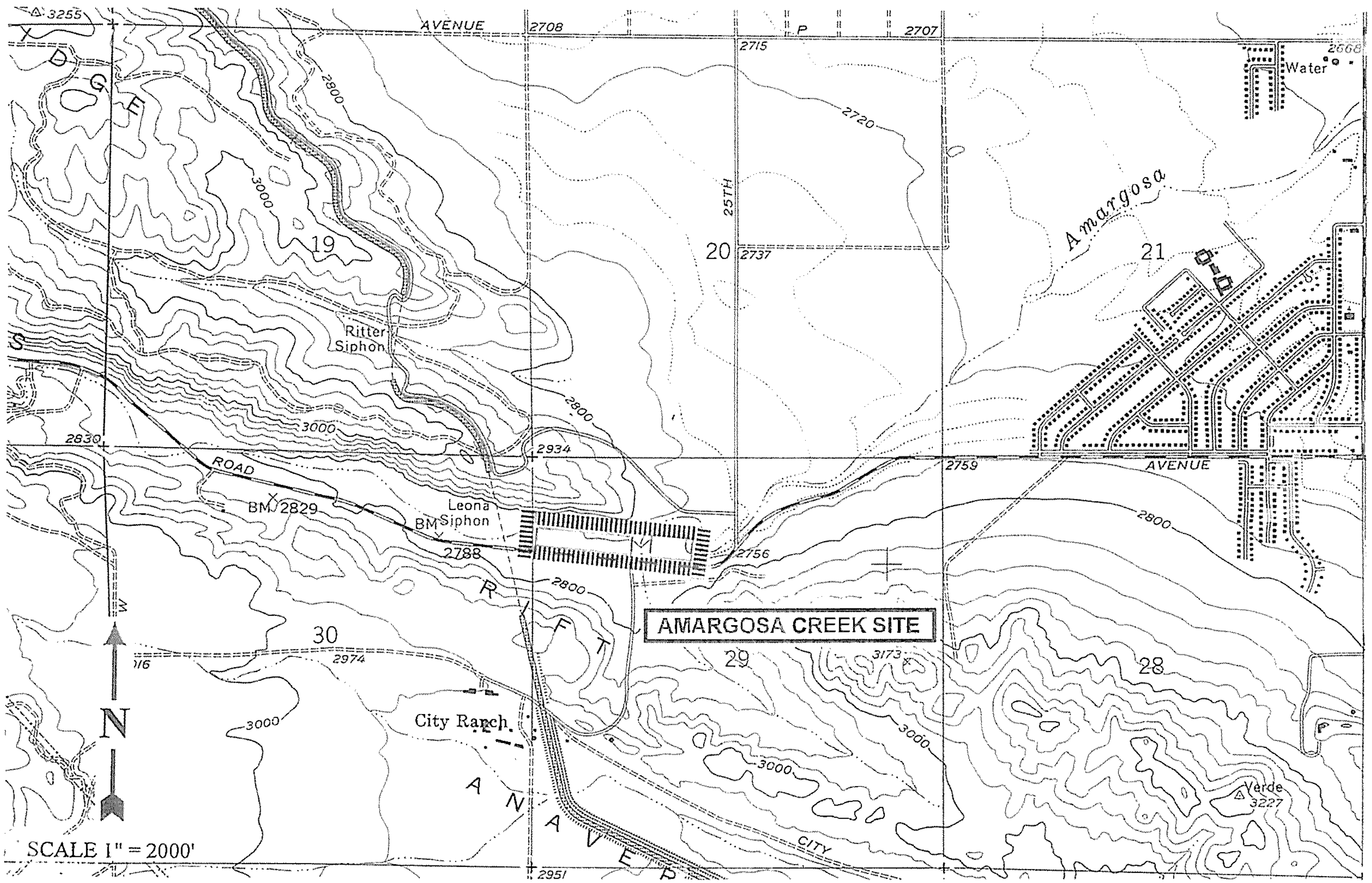
POTENTIAL SITES FOR SURFACE SPREADING
LITTLE ROCK CREEK SITE (LITTLE ROCK CREEK UPSTREAM OF HIGHWAY 138)

09/06/2001

PLATE XXVI



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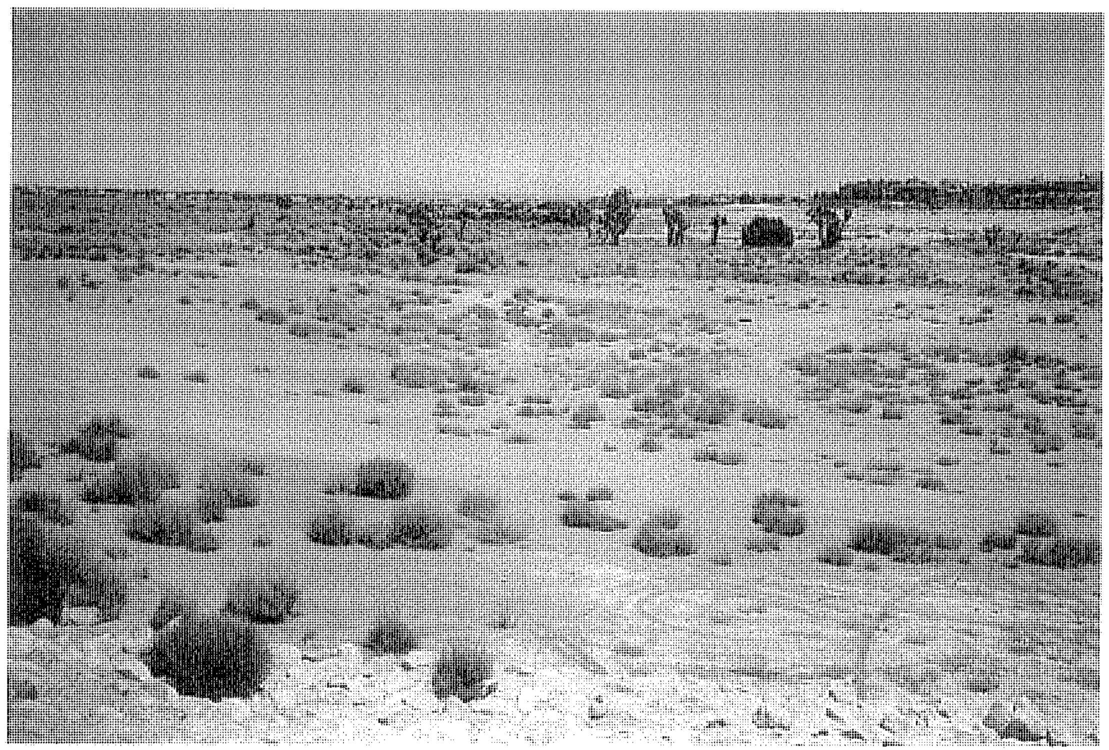
ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
AMARGOSA CREEK SITE

09/06/2001

PLATE XXVII



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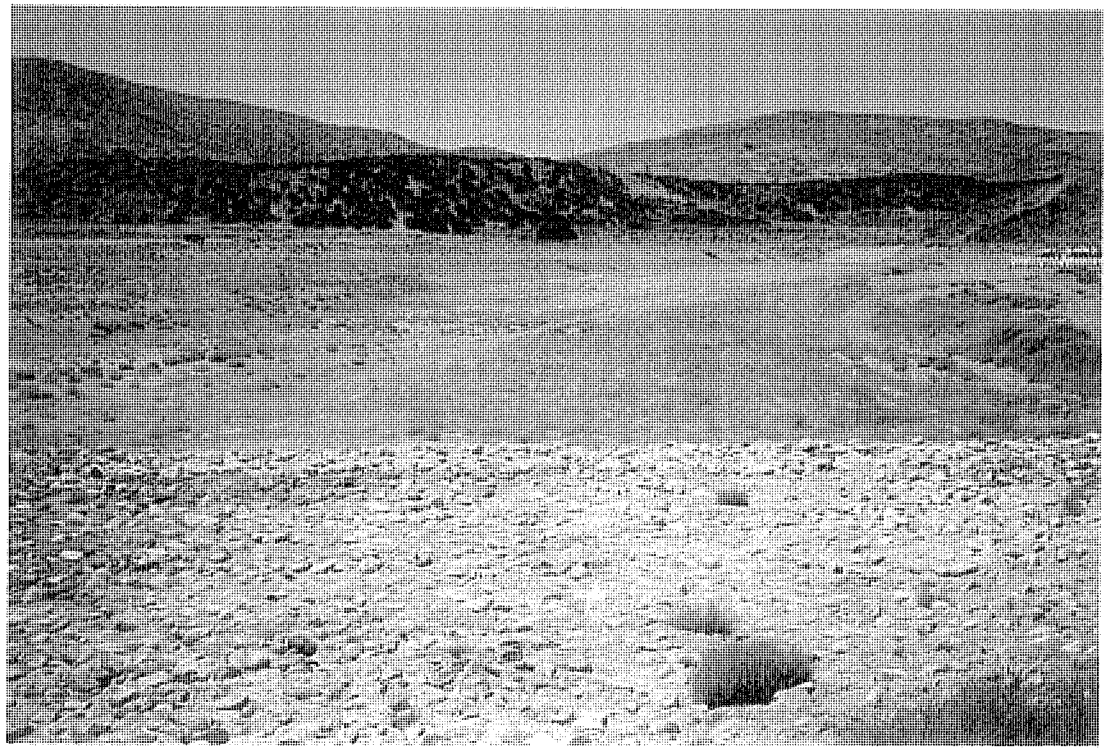
POTENTIAL SITES FOR SURFACE SPREADING
AMARGOSA CREEK SITE (AMARGOSA CREEK DOWNSTREAM OF 25TH STREET)

09/06/2001

PLATE XXVIII



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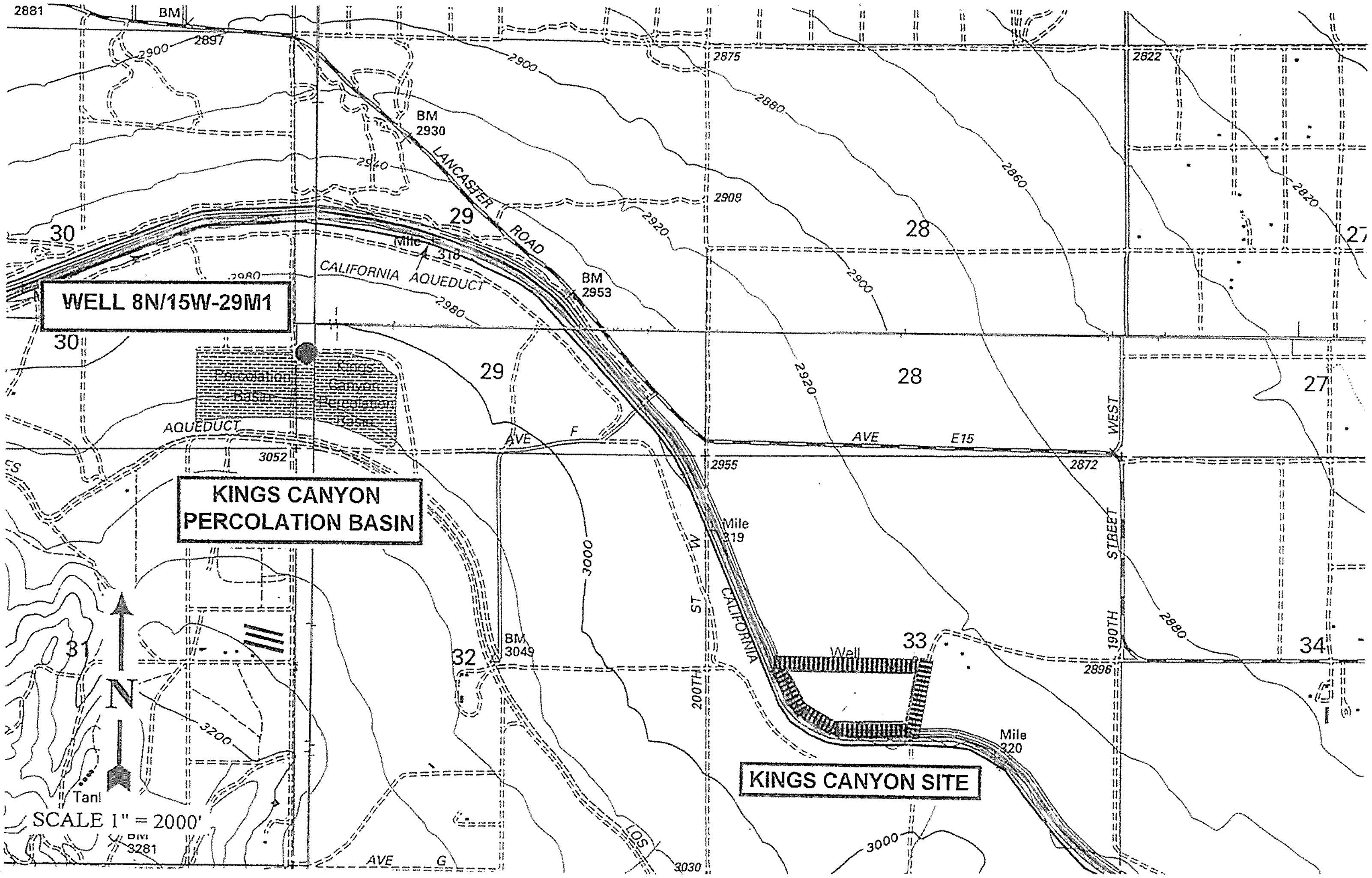
POTENTIAL SITES FOR SURFACE SPREADING
AMARGOSA CREEK SITE (AMARGOSA CREEK UPSTREAM OF 25TH STREET)

09/06/2001

PLATE XXIX



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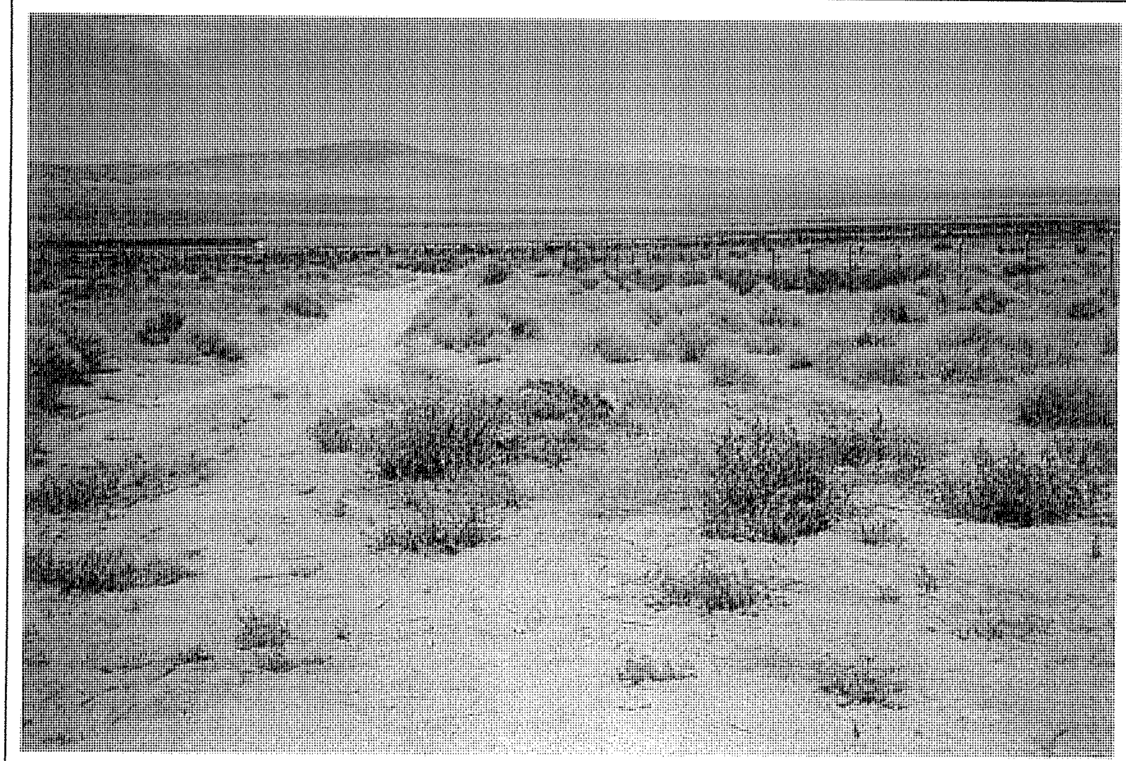
WATER RESOURCE ENGINEERS

ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
KINGS CANYON PERCOLATION BASIN SITE

09/06/2001

PLATE XXX



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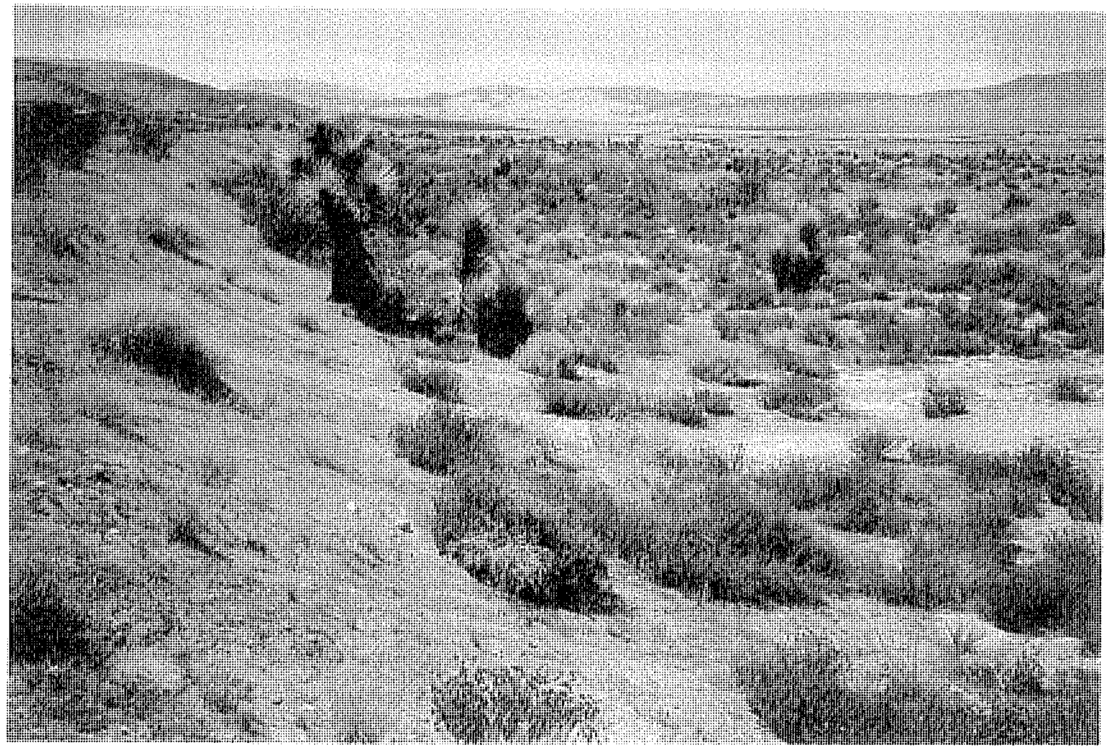
ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
KINGS CANYON SITE (LOOKING NORTH FROM LA AQUEDUCT AT SECTION LINE)

09/06/2001

PLATE XXXI



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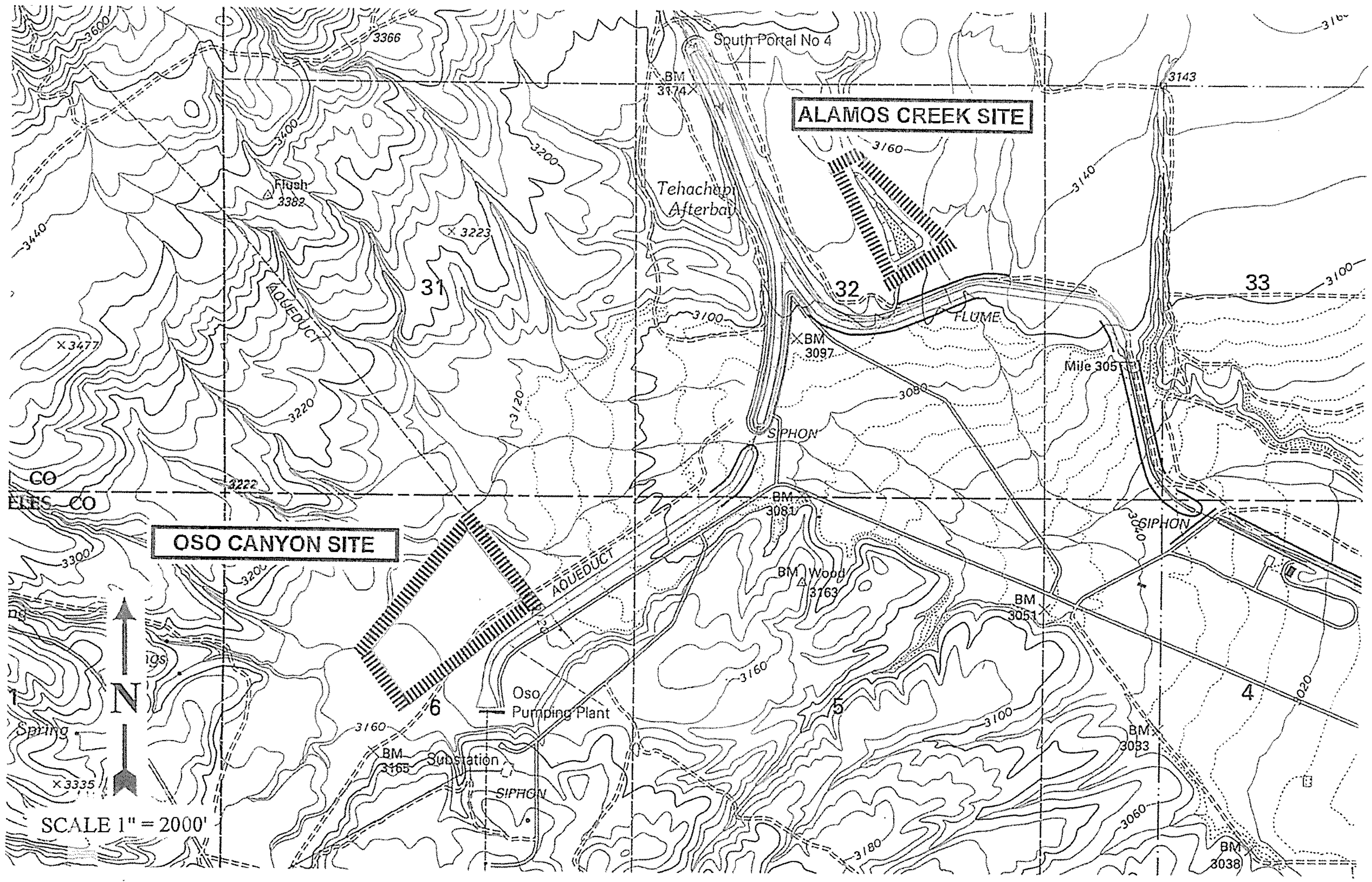
ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
KINGS CANYON SITE (KINGS CANYON PERCOLATION BASIN)

09/06/2001

PLATE XXXII



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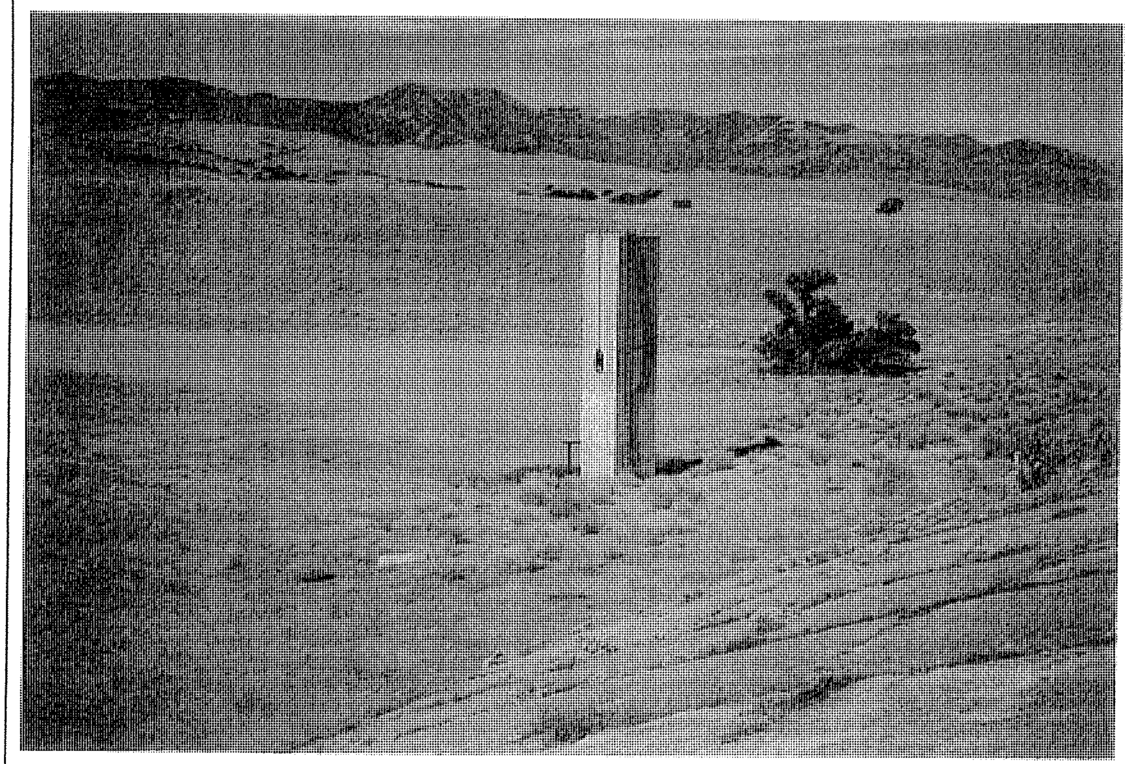
ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
ALAMOS CREEK AND OSO CANYON SITES

09/06/2001

PLATE XXXIII



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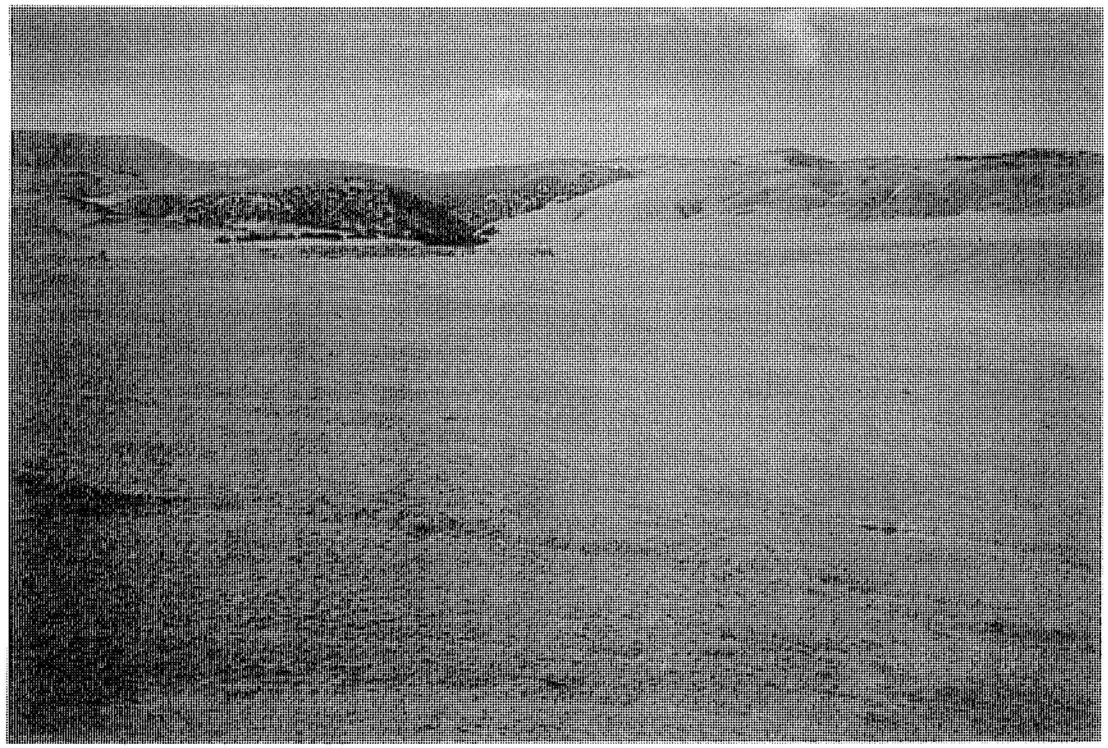
ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
ALAMOS CREEK SITE (CALIFORNIA AQUEDUCT DEBRIS BASIN)

09/06/2001

PLATE XXXIV



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WATER RESOURCE ENGINEERS

ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
ALAMOS CREEK SITE (LOOKING TO SOUTH PORTAL NO. 4)

09/06/2001

PLATE XXXV

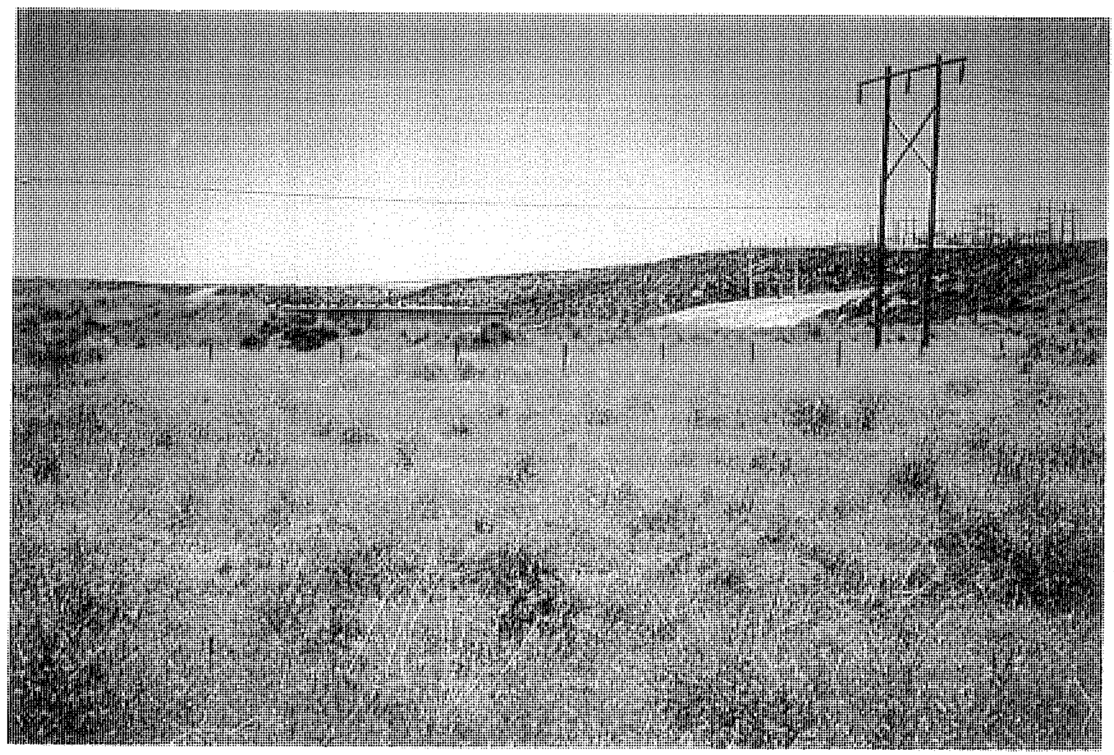
STETSON ENGINEERS INC.
West Covina San Rafael Mesa, Arizona
WATER RESOURCE ENGINEERS

ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
OSO CANYON SITE (LOOKING TO OSO CANYON)

09/06/2001

PLATE XXXVI



STETSON ENGINEERS INC.
West Covina San Rafael Mesa, Arizona
WATER RESOURCE ENGINEERS

ANTELOPE VALLEY STATE WATER CONTRACTORS ASSOCIATION

POTENTIAL SITES FOR SURFACE SPREADING
OSO CANYON SITE (LOOKING TO OSO PUMPING PLANT)

09/06/2001

PLATE XXXVII

8N/15W-29M1. Altitude about 3,017 ft. 6-inch casing.

	Thickness (feet)	Depth (feet)
No record	10	10
Sand and gravel	2	12
No record	8	20
Sand and gravel	4	24
No record	12	36
Sand, fine; silt	1	37
No record	9	46
Sand, fine; gravel	1	47
No record	18	65
Sand, coarse; gravel	2	67
No record	5	72
Sand and silt	1	73
No record	6	79
Clay and sand	1	80
No record	2	82
Silt and coarse gravel	3	85
No record	9	94
Clay and sand	1	95
No record	6	101
Sand and silt	3	104
No record	6	110
Sand and gravel	2	112
No record	1	113
Sand and silt	1	114
No record	5	119
Sand and gravel	1	120
No record	6	126
Sand; gravel; clay	1	127
No record	6	133
Sand and gravel	1	134
No record	7	141
Silt and gravel	1	142
No record	1	143
Silt; sand; gravel	1	144
No record	3	147
Clay and gravel	1	148
No record	3	151
Clay and gravel	10	161
No record	10	171
Sand and gravel	2	173
No record	13	186

SOURCE: WATER WELLS IN THE WESTERN PART OF THE ANTELOPE AREA, LOS ANGLES AND KERN COUNTIES, CALIFORNIA, DEPARTMENT OF WATER RESOURCES, MAY 1965

5 CONCLUSION

The Antelope Valley Groundwater Basin is comprised of two aquifers, the unconfined "principal aquifer" and the confined "deep" aquifer (section 2.4). Recent groundwater contours express a local gradient and flow path from the UAP to the north and east towards the City of Lancaster and Plant 42 (section 3.3).

Amargosa Creek is tributary to Lake Lancaster (detention basin north of Avenue H), Piute Ponds, and then Rosamond Dry Lake. The Amargosa Creek watershed area upstream of the POD is 29 square miles, which is approximately 20 percent of the watershed area of Lake Lancaster (160 square miles) and approximately 2 percent of the watershed area of Rosamond Dry Lake (1,200 square miles). Engineered storm drain systems convey water from the urban landscape to the channel at discrete points along the Amargosa Creek downstream from the UAP. Channel bed seepage occurs along the length of the Amargosa Creek down-stream from the UAP for approximately ten miles to north of Avenue J where finer silt and clay playa deposits impede seepage and recharge to the principal aquifer (section 2.4). Channel seepage results in recharge to the groundwater.

The recharge capacity of the proposed spreading basins is approximately 100 AF per day, and therefore the daily diversion capacity is limited to 100 AF. The discharge from Amargosa Creek watershed is flashy and will likely occur over periods of hours, rather than days. An instantaneous diversion rate of 100 cfs is recommended in order to capture up to 100 AFD.

Rainfall less evapotranspiration occurring in the Sierra Pelona Mountains results in runoff collected in the Amargosa Creek with little storage locally in the Natural Watershed (section 2.2). For the Amargosa Creek watershed, daily rainfall on average exceeds 1 inch on six days each year in the mountains and 2 days each year in the valley. In the mountains rainfall is expected to exceed 0.2 inches each hour 23 hours each year and 0.5 inches per hour 2 hours each year (section 3.1).

The average annual Amargosa Creek streamflow at the POD is estimated to be 2,600 AFY (section 4.2.2). Downstream of POD to Avenue J, urban runoff contributes an estimated 1,100 AFY on average to Amargosa Creek streamflow (section 4.3.2). Of the combined flows (3,700 AFY), 2,200 AFY is estimated to seep into the channel bed between the POD and Avenue J and provides recharge to the aquifer (section 4.3.3), and 1,500 AFY is estimated to flow past Avenue J and eventually flow into Lake Lancaster at Avenue H, Piute Ponds or Rosamond Dry Lake where recharge is limited due to the finer sediments of the historical and existing lakebeds (section 4.3.4).

The diversion potential, which is the maximum diversion that is possible from the streamflow at the POD, is 1,100 AFY on average (section 4.2.5). The diversion at POD based on streamflow at Avenue J is the volume that could be diverted without reducing the existing channel seepage between the POD and Avenue J. and is estimated to be 400 AFY (section 4.3.5). Total runoff at Avenue J after the proposed diversion is 1,100 AF on average (section 4.3.5).

The effect the diversion would have on the seasonally flooded areas downstream of Lake Lancaster and the seasonal flooding of Rosamond Dry Lake is minimal. The Amargosa Creek watershed above the POD is approximately 2% of the contributing watershed area of Rosamond Dry Lake. Due to the limited recharge capacity at the UAP of 100 AFD and to maintain the existing channel seepage, approximately 80% of the all the streamflow would pass by the point of diversion. Therefore the reduction in volume of seasonal flooding at Rosamond Dry Lake due to the diversion at the POD is approximately 1 percent.

Table 5-1: Summary of Results (all values in Acre-feet per Year)

Year		Volumes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Water Year
Average	Current	Streamflow at POD	446	543	293	221	17	0	3	0	17	0	505	655	**2,616**
		Urban runoff POD to Ave J	213	189	110	90	26	0	2	0	30	13	265	211	**1,116**
		Channel Seepage POD to Ave J	352	403	355	281	34	0	5	0	34	10	412	396	**2,227**
		Total Streamflow at Ave J	307	329	48	30	10	0	0	0	13	3	359	470	**1,506**
	Proposed	Diversion Potential at POD	135	208	252	193	17	0	3	0	15	0	162	185	**1,147**
		Diversion based on Streamflow at Ave J	70	86	39	29	5	0	0	0	2	0	104	83	**405**
		Streamflow after Diversion at Ave J	237	243	9	2	4	0	0	0	11	3	256	387	**1,101**
Maximum (WY 1969)	Current	Streamflow at POD	4,979	3,877	347	736	0	0	40	0	0	0	64	0	**10,004**
		Urban runoff POD to Ave J	687	878	11	137	0	0	27	0	0	0	128	0	**1,847**
		Channel Seepage POD to Ave J	2,343	2,107	347	758	0	0	66	0	0	0	163	0	**5,734**
		Total Streamflow at Ave J	3,323	2,649	10	114	0	0	2	0	0	0	30	0	**6,117**
	Proposed	Diversion Potential at POD	930	987	284	495	0	0	40	0	0	0	64	0	**2,762**
		Diversion based on Streamflow at Ave J	706	593	10	114	0	0	2	0	0	0	30	0	**1,433**
		Streamflow after Diversion at Ave J	2,617	2,056	0	0	0	0	0	0	0	0	0	0	**4,684**

Estimated Volume	Table
Streamflow at POD	4-2
Urban runoff POD to Ave J	4-5
Channel Seepage POD to Ave J	4-6
Total Streamflow at Ave J	4-7
Diversion Potential at POD	4-3
Diversion based on Streamflow at Ave J	4-8
Streamflow after Diversion at Ave J	4-9

The recharge operations will create a groundwater mound below the recharge basins that will dissipate and move down gradient from the basins to the north and east toward the City of Lancaster and Plant 42 (section 4.4).

The following limitations to the findings are due to lack of data or limited access to data.

- Amargosa Creek streamflow is not gaged and in this report is estimated using the best available data. Gaging stations in Amargosa Creek would provide more accurate estimates of flow.
- The channel seepage estimates are based on reported values not measured values.
- The amount of Amargosa Creek water which is retained in, flows through, evaporates, and percolates to recharge the groundwater at Lake Lancaster was not available. Based on the available boring and geologic mapping, and the persistent ponding of water in Lake Lancaster through the summer in wet years, the percolation is probably negligible.
- Limited data was available for the storm drainage system for most of the City of Lancaster; therefore the urban runoff from most of the City of Lancaster (north of Ave J) into Lake Lancaster was not estimated.
- The sediment flux from the Amargosa Creek watershed upstream of the POD to Rosamond Dry Lake is not known.

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