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FINAL REPORT
HYDROGEOLOGIC ASSESSMENT REPORT
HARPER LAKE, CALIFORNIA
for
LUZ Development
and
Finance Corporation
88-03219.18
April 7, 1989

THE MARK GROUP
ENGINEERS & GEOLOGISTS, INC.

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LUZ Development and Finance Corporation
924 Westwood Blvd., Suite 1000
Los Angeles, California 90024

Attention: Ms. Necy Sumait

Subject: Final Report - Hydrogeologic Assessment Report, Harper Lake, California

Dear Ms. Sumait:

Enclosed are twelve (12) copies of the Hydrogeologic Assessment Report, Harper Lake, California. The report presents a review of geologic and hydrologic conditions at the subject site.

Should you have any questions, please feel free to contact us. In addition, any background information or reports will remain on file for future reference.

Sincerely,
The MARK Group,
Engineers & Geologists, Inc.

Stephen J. Turnbull
Senior Hydrogeologist

Raymond L. Moresco, C.E.G.
Director of Operations

RLM\SJT:nrc

88219-18.L1

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PROFESSIONAL CERTIFICATION
REPORT
for
LUZ Development and Finance Corporation
924 Westwood Blvd., Suite 1000
Los Angeles, California 90024

88-03219.18
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This report has been prepared by the staff of The MARK Group, Engineers & Geologists, Inc. under the professional supervision of the principal whose seal and signature appear hereon.

The findings, recommendations, specifications or professional opinions are presented, within the limits prescribed by the client, after being prepared in accordance with generally accepted professional engineering and geologic practice. There is no other warranty, either express or implied.

CERTIFIED ENGINEERING GEOLOGIST
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Raymond L. Moresco, C.E.G.
Director of Operations

88219-18.CRT

TABLE OF CONTENTS

<u>List of Tables</u>

<u>List of Drawings</u>

1.0 INTRODUCTION

This report presents an investigation of hydrogeologic conditions in the Harper Valley Groundwater Basin in San Bernardino County, California. LUZ Development and Finance Corporation (LUZ) contracted The MARK Group, Engineers & Geologists, Inc. (MARK) to evaluate the long-term feasibility of withdrawing approximately 4,750 acre-feet per year of groundwater from the Harper Valley Basin. LUZ plans to install five 80-megawatt Solar Electric Generating Systems that require the groundwater for cooling purposes. The facility will be located near Harper Lake in the region labeled "site vicinity map" on Drawing 1. After the water is used for cooling, it will be discharged into Harper Lake to maintain the wetlands for use by wildlife.

2.0 EXECUTIVE SUMMARY

The objective of this work is to estimate the feasibility of pumping 4,750 acre-feet/year of groundwater from the Harper Valley Groundwater Basin for a total of 40 years. A review of available information on groundwater conditions and geology indicates that LUZ will have sufficient water supply for the project. Based on groundwater recharge estimates calculated by The MARK Group Engineers and Geologists, Inc. (MARK) and the California Department of Water Resources (DWR), the total worst-case groundwater deficit for each year of pumping would be 3,200 acre-foot/year. This would indicate that the basin would continue to be in an overdraft situation; however, calculations by MARK indicate that groundwater recharge may be greater than calculated by the DWR, and pumping withdrawal may be partially offset by that additional recharge. These calculations presented in this report, indicate that a water balance deficit of from 0.0 to 1,500 acre-feet per year.

3.0 SCOPE OF WORK

The project objective has been met by completing the following scope of work:

1. Review the available literature pertaining to the geologic and hydrogeologic conditions in the vicinity of the project site.

2. Collect readily available information on groundwater use, groundwater levels, and groundwater quality from the California Department of Water Resources, San Bernardino County Environmental Health Division, Mojave Valley Water Agency, and U.S. Geological Survey.

3. Review information as available from test wells completed by LUZ.

4. Analyze the data collected and form a conceptual hydrogeologic model of the Harper Valley Groundwater Basin.

5. Prepare a report on groundwater conditions in the basin, including an analysis to predict the effects of groundwater pumping on the basin.

4.0 BACKGROUND

4.1 Previous Work

The foremost works concerning the geologic conditions of the area have been published by Dibblee (1968) for the California Division of Mines and Geology. Dibblee's works encompasses the portions of the basin within the Fremont Peak and Opal Mountain 15 minute quadrangles. Additional geologic information for the area is found in Dibblee, 1960.

Several water resource publications by the California Department of Water Resources (DWR) partially address the groundwater conditions of the Harper Valley Basin (DWR 1967, 1971, 1979). DWR (1967) is a hydrogeologic evaluation of the Mojave River Groundwater Basins that contains some information on the Harper Basin. DWR (1971) contains water well information for the Harper Basin and the Cuddleback and Superior basins to the north. DWR (1979) includes an analyses of potential groundwater use for power plant cooling water and contains a short summary of the Harper Valley Basin. Additional information on hydrologic conditions for the southern part of the Harper Basin is found in Mojave Water Agency (MWA), 1983.

Unpublished water level and water quality data were collected for selected wells in the Harper Valley area from the California Department of Water Resources (DWR) in Los Angeles. Drillers logs were collected from the San Bernardino County Department of Environmental Health for the Harper Valley.

Previous studies for LUZ on the groundwater conditions in Harper Valley have been completed by Leroy Crandall (1986) and Robert Fox (1988). Additional water level information is available in Leroy Crandall (1986), and Fox (1988) contains a review of the Leroy Crandall report.

4.2 Climatology

The Harper Valley Groundwater Basin is located in the west central Mojave Desert in northwestern San Bernardino County. In this portion of the desert the mean annual precipitation is approximately five inches (DWR 1967). The daily temperature ranges from 32°F to 61°F during the month of January. In the summer months however, the average diurnal temperatures range from 72°F to 104°F. Average pan evaporation rate for the basin is 90 inches annually, with a maximum monthly evaporation rate of approximately 12 inches in July, and a minimum monthly evaporation rate of 2.5 inches in January (National Oceanic and Atmospheric Administration, 1974).

4.3 Site Background

The Harper Valley Groundwater Basin is located in northwestern San Bernardino County, California with a small portion of the basin included in Kern County (Drawing 1). The basin encompasses approximately 510 square miles. The elevation of the basin floor ranges from approximately 2,000 feet above mean sea level (msl) at Harper Lake to about 2,900 feet in the far northwest portions of the basin. The basin is bordered on the northeast by Fremont Peak and the Gravel Hills, on the southeast by a series of northerly trending low hills and Iron Mountain, and on the west by a topographic divide that separates the basin from the Antelope Valley Groundwater Basin.

The current permanent resident population in the vicinity of the proposed site is estimated to be approximately 50 people. The primary land use in the vicinity of the proposed site is agricultural production, although this is gradually being reduced. Production in the vicinity of the site has been approximately 2,000 acres of alfalfa annually, with historic records indicating that as much as 3,000 acres of alfalfa has been in production at times in the past. An Edison power line, Santa Fe Railroad right-of-way, and Pacific Gas and Electric high pressure gas line traverse the central and southern portion of the basin. A wildlife (waterfowl) preserve, created and watered by irrigation runoff, is also located near the proposed site with the associated wetlands encompassing portions of T11N, R4W, Sections 20, 21, 27, and 28. Records from the Bureau of Land Management do not indicate the presence of Indian Reservations, springs, or state historic areas that would be impacted by pumping at the subject site.

Mean annual precipitation in the basin is 4 inches at the basin floor to 8 inches in the surrounding mountains. Rainfall occurs mostly in the winter months, with summer rainfall being rare.

5.0 GEOLOGY

The geologic studies have included a review of published papers and unpublished data relevant to the study area. The primary objective of this geologic investigation is to estimate the availability and movement of groundwater by developing and understanding the nature of the geologic materials found within the Harper Valley Groundwater Basin.

Rocks exposed within and adjacent to the basin include igneous, metamorphic and sedimentary rocks ranging in age from Precambrian to Recent (Holocene). For this study the approach will be to focus on rock units of hydrologic significance and briefly discuss their characteristics and define groundwater flow in the groundwater basin.

5.1 Regional Geology

The geologic units in the Harper, Superior, and Cuddleback Valley areas can be divided into two main groups, the consolidated rocks and the unconsolidated deposits. The formations within these groups have dissimilar water-bearing characteristics, but in general, the unconsolidated gravel, sand, and clay deposits of Quaternary age are more porous and permeable than the consolidated basalts, schists, and granites of pre-Tertiary, Tertiary, and Quaternary age. The consolidated rocks form the mountains and hills surrounding the valley. These consolidated rocks also underlie the sediments forming the "bottom" of the basin for production water wells. The consolidated rocks have generally low primary permeability, and unknown storage capacity in broken areas of secondary permeability. They receive a major part of the precipitation where exposed within the drainage area surrounding the basin. It is the runoff from these mountains and hills that contributes recharge to the aquifers contained in the unconsolidated deposits. The unconsolidated deposits occur in the valleys and contain most of the groundwater stored in the area (Drawing 2). The unconsolidated deposits are generally interbedded layers of gravel, sand, silt, and clay with sand being the most abundant constituent.

The oldest unit in the area is the basement complex, of pre-Tertiary age, which consists of undifferentiated igneous and metamorphic rocks (Drawing 3). This unit is commonly referred to as basement complex, or bedrock, in the well logs, and is mainly composed of quartz monzonite and gneiss. The basement complex, or bedrock, is generally low in permeability except in fractures and weathered zones that yield small quantities of water. Compared to the amount of water available in the unconsolidated formations, stored water available in the basement complex is small.

The sedimentary rocks (Drawing 3), of Tertiary age, overlying the basement complex consist of beds of sandstone and shale with some intrusive basalt flows. These rocks are generally located to the north of the proposed site. Rocks of this unit yield little water to wells and springs.

The basalt flows, called the Black Mountain Basalt, of Pleistocene age overlie the older unconsolidated alluvial deposits in parts of the areas, and in other parts rest directly on Tertiary Sandstone or pre-Tertiary bedrock units. The Black Mountain Basalt is not considered an aquifer. The location of the Black Mountain Basalt is discussed in more detail in the local geology section.

The older alluvium, of Pleistocene age, underlies most of the valley-floor areas and is commonly overlain by a layer of younger alluvium. It is deposited above the igneous, metamorphic, and consolidated sedimentary rocks previously explained, but is transected in places by basalt flows (Drawing 3). The older alluvium consists mainly of moderately sorted sand with gravel, silt, and clay.

It is generally unconsolidated, but in some places it is slightly cemented. This unit is porous and permeable, extends below the water table, yields water freely to wells, and is the principal water-bearing unit in the area. This unit is also shown as the principal aquifer material shown in the local geologic cross section as Qal in Drawings 5, 6, and 7. The Black Mountain Basalt formation is generally located somewhere within the older alluvium.

The older alluvial fan deposits, of Pleistocene age, are composed of gravel, boulders, and sand derived from the granitic and metamorphic rocks and, where saturated, yield water to wells. This formation is located principally near the mountain fronts, and provides for recharge to the basin from percolation of runoff from the mountains.

The younger alluvium of Holocene age, deposited above the older alluvium consists of sand with small quantities of gravel, silt, and clay. Deposition of this material is still taking place in the valley areas during infrequent time of streamflow (intermittent). This unit is permeable and, where saturated, will yield water to wells. It is generally thin and is not an important water-bearing unit, because it generally lies above the water table. However, it does transmit precipitation and water from the intermittent streams to the older alluvium's aquifer.

The windblown sand, of Holocene age, is composed of actively drifting fine to medium sand, ranging from a few feet to more than 25 feet in thickness. In parts of the area the sand may be saturated, but generally it is above the regional water table.

5.2 Regional Structure

There are three major northwest trending fault zones located within the Harper Valley Groundwater Basin: the Blackwater-Mud Hills Fault Zone, the Harper

Fault Zone, and the Lockhart Fault Zone. For the most part, these faults control the surface exposures of the bedrock materials adjacent to the basin and have resulted in the formation of the Harper Dry Lake.

The Lockhart group of faults includes the North Lockhart fault, the South Lockhart fault and the Lockhart Fault (Drawing 2). The Lockhart Fault is located three miles south of the Lockhart ranch. The fault trace is not exposed and is difficult to recognize on the ground, but it appears prominently on aerial photographs as a straight line running N50°W for about 10 miles. It has been known to be active in very late Quaternary time because it breaks the older alluvium, which indicates that the major aquifer (water-bearing zone) in the Harper Valley has been displaced by the fault, altering its water bearing characteristics.

The South Lockhart fault lies 2 to 3 miles southwest of the Lockhart fault. Northwest of the lake it approaches and probably joins the Lockhart fault. To the southeast it diverges from it and dies out in older alluvium. The fault is within the older alluvium and its position is marked by the surface expression of weak scarps which show on aerial photographs.

The Harper Valley Fault Zone and the Black Water Fault Zone are located to the northeast of Harper Lake. The Harper Valley Fault Zone is located principally within the bedrock units of the valley, and does not appear to influence groundwater flow in the site area. The Black Water Fault Zones is also located too far from Harper Lake to influence local groundwater flow.

5.3 Local Geology

The geology in the area of the LUZ development site is shown in three cross-sections. The locations of these cross-sections are shown in Drawing 4. The local geologic cross-sections are labeled A-A', A'-A", and B-B' and are presented in Drawings 5, 6, and 7. Many of the wells shown are projected to the cross-section line. The cross-sections are intended to depict the thickness of the major aquifer below the site. This representation can be useful in choosing locations and depths for additional wells at the site.

Cross section A-A' (Drawing 5) extends west to east showing the thickness of the main aquifer (water bearing zone) labeled Qal at approximately 300 feet. This main aquifer generally extends vertically from the basalt labeled Qb to the top of the water table. Most water supply wells are generally drilled to the top of this basalt layer. Below the basalt, additional alluvium provides a second water-bearing zone. The quality of water from this lower water-bearing zone is not known.

Cross section A'-A" (Drawing 6) extends further to the northwest beyond cross section A-A'. This cross section shows that the thickness of the main aquifer (labeled Qal) to the west is generally about 400 feet. Apparently, the alluvial water-bearing zone below the basalt layer is not present at the east end of Harper Lake as indicated by well 11N4W23C1. This indicates that any wells to be drilled through the basalt to pump from the lower water-bearing zone below the basalt should only originate in the site vicinity west of Harper Lake.

Cross section B-B' (Drawing 7) contains the most well data, and shows the shape of the main aquifer below the proposed site. This cross section can be used to estimate the depth of additional production wells in the site vicinity. It also confirms the general aquifer thickness below the site of approximately 300 to 400 feet. Well No. 11N5W29G2 also called test well #3, encountered the basalt layer from a depth of 490 to 530 feet below land surface. This test well then encountered gravel and clay from 530 feet to a total of 950 feet. At a depth of 950 feet the well encountered bedrock.

In summary, cross-sections A-A', A'-A", and B-B' show the presence of the main water supply aquifer, and a second water-bearing zone below where the basalt layer is present. Well production indicates that groundwater yield is higher from the main water supply aquifer than the lower water-bearing zone.

6.0 HYDROGEOLOGY

Groundwater for the proposed LUZ project is planned to be extracted from the Harper Valley Groundwater Basin (Drawing 1). The California Department of Water Resources defines the basin as within the Harper Hydrologic Subunit.

Hydrologic information on the basin has been obtained from the water wells and gas exploratory wells drilled over the years and has been presented in the cross-sections. Additional hydrogeology information available related to the basin includes groundwater elevations, groundwater recharge, aquifer characteristics, and groundwater use. The groundwater elevations were obtained mainly from the data collected by the California Department of Water Resources and Leroy Crandall, Inc. Information on aquifer characteristics, groundwater recharge, and groundwater use was collected mainly from the DWR.

6.1 Groundwater Elevations

Water levels within the vicinity of the Harper Valley Groundwater Basin vary from ground surface near Harper Lake (perched water) to nearly 300 feet below ground surface 10 miles west of the study area near Kramer Junction.

Elevations of groundwater vary from a high of approximately 2,500 feet msl in the northwest for well 31S/42E-23L1 to approximately 1,850 feet msl for well 11S/5W-24N2 at Harper Lake. Locations of select wells are shown in Drawing A-1. A comparison of elevations is required because groundwater flows from areas of higher groundwater elevation to areas of lower groundwater elevation. Drawing 8 documents that the levels are consistently lower at Harper Lake, allowing for groundwater to move from the perimeters of the basin to the central lake area.

There are approximately 30 irrigation wells in the vicinity of the site location area where LUZ plans to install the power plants. Many of these wells were required when agricultural production in the area was higher. Water levels recorded during 1986 through 1988 from 11 of these wells were used to create the contour map, as well as the historic water levels obtained from the DWR (Drawing 8). The wells in the vicinity of the site are generally perforated at depths of 200 to 500 feet below land surface for a total perforated interval of 300 feet. This includes well number 11N/5W-13H1, 11N/5W-24G1, and 11N/5W-24N1. Well yields, calculated by the Southern California Edison Company, for the 30 wells in the site vicinity wells vary from 371 gallons per minute (gpm) for well 11N/5W-24Q2 to 1,333 gpm for well 11N/4W-19D1 with an average yield of 885 gallons per minute. This indicates that LUZ Development should plan for an average well yield of 800 to 1,000 gpm from properly constructed production wells.

Values for specific capacity, a measure of well yield in gallons per minute per foot (gpm/ft) of drawdown, have been calculated by the Southern California Edison Company for production wells in the study area. The specific capacity of twelve (12) wells are available from wells in township 11N, range 4W, sections 19, 24, 29, 32, and 33. Specific capacities vary from 20 gallons per minute per foot (gpm/ft) for well 11N/4W-19F1 to 48 (gpm/ft) for well 11N/4W-29L1. The average specific capacity for wells in the vicinity of the site is 37 gpm/ft. Results from these specific capacity tests indicate that pumping water level drawdown within a production well during pumping will be in the range of 50 to 100 feet.

The regional groundwater elevations in Drawing 8 represent groundwater in first major water supply aquifer, generally occurring from a depth of 100 to 500 feet below ground surface. Groundwater elevations in the northeast portion of the basin, in the vicinity of Black's Ranch, vary from 1,998 feet msl for well 11N/3W-28R2 to 2,038 feet msl for well 11N/3W-15E1. Water level elevations in the Middle Mojave Groundwater Basin near Barstow, California (Drawing 8) vary from 2,113 feet msl for well 10N/4W-29M1 to 2,041, feet msl for well 10N/3W-27R1. These groundwater elevations are higher than groundwater elevations in the Harper Valley Groundwater Basin, indicating that the groundwater flow gradient is from the Middle Mojave Basin into the Harper Valley Basin. Records from wells and geologic maps from Mojave Water Agency (MWA) (1983) indicate that the thickness of the aquifer between the basins is approximately 75 feet, allowing for underflow between the basins. The past pumping at Hinkley in the Middle Mojave does not appear to have influenced water levels in the Harper Basin.

Groundwater elevations in the western portion of the Harper Valley near Kramer Junction vary from 2,243 feet msl for well 10N/6W-5E1 to 2,300 feet msl for 10N/6W-6L1. These water levels indicate groundwater flow from the west towards Harper Lake. Aquifer thickness from geologic maps and well logs indicate that the thickness of sediments in the area of Kramer Junction are 400 to 500 feet thick.

Shallow borings completed by Applied Geotechnical Engineering, Inc. (1987) for the site construction indicated that shallow (perched) groundwater is present west of Harper Lake. Beneath the proposed construction site, (Drawing 1) groundwater levels vary from 9 to 26 feet below ground surface. The groundwater elevations show that groundwater flow is toward the wetlands from the site area. The groundwater flow direction from the irrigated farmland towards the wetlands indicates that applied irrigation water is the source of this shallow perched water.

6.2 Groundwater Recharge

The amount of groundwater recharge to the Harper Valley Groundwater Basin is important in the overall water balance at the site. The estimated amount of recharge for the basin is taken from estimates compiled by the California Department of Water Resources (DWR) and calculations completed by MARK.

Recharge to the basin occurs by the following sources. 1) storm runoff from the highlands that enters the ephemeral streams and ultimately percolates into the basin's alluvial aquifer, 2) recharge on the basin floor from rainfall, 3) recharge on the surrounding mountain areas that percolates into the bedrock and flows into the basin, 4) and underflow from the Middle Mojave Basin (see Drawing B-1). The Department of Water Resources (1967) claims that precipitation less than eight inches annually is used to satisfy the growth and transpiration requirements of native vegetation, or is lost to evaporation allowing virtually no direct groundwater recharge; however, more recent work with stable isotope tests shows that recharge in desert environments varies from 0.34 to 0.51 percent of precipitation (Stone, 1986). For the 297,200 acre Harper Valley Basin Floor, calculations indicate that 420 acre-feet/year may be recharging (Appendix C). Percolation of rainwater into the 100,800 acres of hills surrounding the basin flowing into the basin aquifer may represent another 300 acre-feet/yr of recharge (Appendix C). Estimates in DWR (1967) lists the amount of recharge to Harper Valley Basin from storm surface runoff during storms from the highlands that recharges the alluvium at 550 acre-feet/year. This number represents approximately 1% of the 6 to 8 inches of annual precipitation that falls on the 100,800 acres of mountains and hills surrounding the basin that drains into Harper Valley. We question the earlier DWR (1967) recharge estimate as it appears, in our opinion, conservative. We believe that a significantly higher net recharge estimate is feasible based on the recent studies. However, the 550 acre-feet/year net recharge will be used in our calculations because it is consistent with estimates from other similar basins (DWR, 1967).

Underflow from basin to basin also provides additional recharge to the Harper Valley. The amount of groundwater from the adjacent Cuddleback Basin to the north has been estimated as negligible by the DWR. An analysis of 1955 water levels in the narrow pass between the basins indicates that the hydraulic gradient was nearly 0.0, which would indicate a subsurface drainage divide with little or no groundwater flow into the Harper Basin from Cuddleback Basin. However, there is surface water inflow from the Cuddleback Basin to Harper Valley in intermittent streams, and that volume has not been estimated.

The amount of basin underflow from the Middle Mojave Basin to the Harper Valley Basin is calculated in DWR (1967) to be 1,000 acre-feet/year. This value is probably a conservative estimate reflecting the estimated gradient and thickness of saturated sediments at the time. Calculations by MARK from data in MWA, 1983 indicate that the value for recharge from Middle Mojave Basin may be closer to 3,000 acre-feet/year (Appendix C). Groundwater contours as shown in Drawing 8 indicate that the natural basin groundwater flow direction is from the Middle Mojave Basin into the Harper Valley Basin. In addition, during periods of severe flooding the Mojave River overflows northward into Harper Lake (MWA, 1983).

The Lockhart fault, trending northwesterly, is located approximately in the center of the basin, to the west of the site. The Lockhart fault reduces the amount of groundwater flow in the Harper Valley Basin from the west/southwest to the northeast (CDWR, 1967). This is supported by the generally higher levels of the water table southwest of the faults (CDWR, 1967). The amount of groundwater flow reduced by the fault is not known.

6.3 Aquifer Characteristics

The parameters that define the groundwater flow to wells within Harper Valley Basin are transmissivity, aquifer thickness, and storage coefficient. The value for transmissivity represents an aquifer's ability to transfer water to wells and these values are often used in calculations of well spacing and groundwater flow rates. Reliable values for transmissivity in the basin are generally unavailable. Transmissivity has been roughly calculated for various wells in the vicinity of Harper Lake from specific capacity values. Specific capacity calculations, are usually provided by drillers testing a new well or electrical power companies as part of a service to identify pumping well efficiencies. These tests generally indicate that transmissivity values are sufficient for production rates of 800 to 1,000 gallons per minute. Estimated transmissivities range from 10,000 gpd/ft to nearly 100,000 gpd/ft in the Harper Valley area.

The value for storage coefficient is a unitless measure of the amount of water in storage available to withdraw by wells based on extended pumping versus drawdown correlations. The DWR has estimated a storage coefficient of 0.12 for the aquifer materials in the basin. This is within the commonly calculated storage coefficient values for basins like the Harper Valley. The estimated water table storage coefficient indicates that the total amount of water level decline can be reduced by spreading the production wells further apart in the site vicinity.

Total storage capacity in the Harper Valley groundwater basin, using 0.12 as the storage coefficient, is estimated at 2,497,000 acre-feet (DWR, 1979). This estimate includes water in the entire basin. Some of this water would not be available for pumping because the aquifer materials below the alluvium, such as the basalt layer has a low permeability, and groundwater barriers, such as the Lockhart Fault, may impede groundwater flow.

6.4 Groundwater Use

Groundwater use in the Harper Valley area has historically been for irrigated agriculture. This water has principally been withdrawn from the main water supply aquifer. Groundwater from shallow sources, such as the shallow groundwater zone recharged by irrigation water contribute moisture to the natural consumptive use of plants and general evaporation.

The estimated amount of consumptive groundwater use in the basin includes the agricultural areas near Harper Lake. Water use by the valley's scattered residents (domestic use) is negligible compared to irrigation usage at the Lockhart Ranch. References to the Lockhart Ranch includes the Most and Baker Ranches.

Historic water well pumping values could not be obtained from the State Division of Water Resources because no records were kept. Historic water use can best be estimated by assuming that approximately 5 acre-feet/acre was applied for agricultural production each year (MWA, 1983). Records of agricultural production were collected from the San Bernardino County Agricultural Commissioner for the Lockhart, Most, and Baker ranches. Annual agricultural production in the Harper Valley site location has generally varied from 1,800 acres in 1953, to 2,300 acres in 1955, and to 2,500 acres during 1968. Annual production varied from 2,000 to 2,500 acres from 1968 until 1983.

Annual production from 1984 until 1988 was approximately 1,500 acres. The reported value for acreage planted per year at the Lockhart Ranch is shown in Appendix A. Based on an average pumping value of 5 acre-feet/acre, this indicates that approximately 6,500 to 18,000 acre-feet annually of groundwater has been used for agricultural production in the vicinity of the site. Some of this water (drain waters) may have recharged the shallow, perched groundwater system near the wetlands area.

Water level declines due to agricultural pumping from 1953 through 1986 are documented in Drawing 9. Levels of drawdown vary from 80 feet at the center of the study area to 20 feet in the area of Black's Ranch. The drop in water levels of 10's of feet without recovery indicates that groundwater extraction in Harper Basin has historically exceeded recharge. Appendix A documents the total estimated pumping for the period 1953-1986 at 380,000 acre-feet from the Lockhart Ranch. Records from the San Bernardino County Agricultural Commissioner indicate that the Lockhart Ranch was the only farm in the Harper Valley. The pumping records consider acreage for the Most, Baker, and Lockhart ranches together. The Oasis Ranch, located east of the lake in the Black's Ranch area has been operating for approximately 5 years beginning in 1984.

The historic change in water levels (Drawing 9) documents a drawdown depression cone centered around the agricultural activities just west and south of Harper lake. The volume of un-watered sediments in the cone of depression, represents approximately 94,300 acre-feet depletion of groundwater storage, using the storage coefficient of 0.12 (Appendix B). These values will be used in the following water balance calculations.

6.5 Water Balance

Two separate water balances are completed for the Harper Valley. The first water balance is for the years 1953-1986 to evaluate overall long-term pumping discharge and recharge. The second water balance is for expected future withdrawals in the basin to estimate the effects of the 4,750 acre-feet of pumping by the LUZ project.

6.5.1 Long Term Water Balance

The 1953-1986 water balance for the Harper Valley groundwater basin assumes the following:

- Evaporation and consumptive use accounts for 80% groundwater pumped for irrigation. Therefore, once water is removed from the ground, 20% of it returns as recharge, with 80% being is used by agriculture, evaporation, or the wetlands area.
- Recharge to the basin occurs from storm runoff from the highlands that enters the ephemeral streams and ultimately percolates into the basin's alluvial aquifer, recharge on the basin floor from rainfall, recharge on the surrounding mountain areas that percolates into the bedrock and flows into the basin, and underflow from the Middle Mojave Basin (See Drawing B-1 of Appendix B).
- Sources of groundwater discharge are agricultural pumping at the Lockhart Ranch.

Appendix A outlines the pumping estimates for the Lockhart Ranch from 1953 through 1986. For this 34 year period the estimated pumping for the Lockhart Ranch is 380,000 acre-feet. Appendix B outlines the 1953-1986 water balance calculations. This 34 year period was selected since the data on pumping and the change in water levels was available for that period. The calculated loss in storage (Appendix B) for the period is 76,000 acre-feet of groundwater. The difference in these two numbers is shown below:

o Total Pumping (1953-1986)	380,000 acre-feet
o Loss in Storage (1953-1986)	- 76,000 acre-feet
o Recharge (1953-1986)	304,000 acre-feet

This indicates that approximately 304,000 acre-feet of water recharged the basin, based on the assumptions listed in Appendix B. Without this recharge the pumping depression would be much bigger than shown in Drawing 9. Assuming that approximately 20% of pumping withdrawals recharges the basin (76,000 acre-feet) this leaves a total of 228,000 acre-feet of recharge from outside sources to the basin over the 34 year period as shown below:

Estimated Total Recharge (1953-1986)	304,000 acre-feet
Irrigation Percolation Recharge	-76,000 acre-feet
Recharge to Basin (1953-1986)	228,000 acre-feet

This recharge value of 228,000 acre-feet represents an annual recharge of approximately 6,500 acre-feet/year.

A review of literature and calculations by MARK was completed to confirm this estimate of annual recharge. A detailed explanation of the recharge estimates shown below is contained in Appendix C. Listed below are the components of estimated recharge (Drawing B-1).

o Runoff from Mountains	550 acre-feet/year
o Recharge to Basin Floor	420 acre-feet/year
o Recharge to Mountain Areas	300 acre-feet/year
o Recharge from Mojave Basin	1,000-2,700 acre-feet/year
	approximately 2,300-4,000 acre-feet/year

The recharge from the Middle Mojave Basin is underflow calculated based on Darcy's Law through the sediments between the basins. This Middle Mojave recharge value of 2,700 acre-feet/year is calculated by MARK and the value of 1,000 acre-feet/year is reported in DWR (1967). Storm runoff from the highlands of 550 acre-feet that enters the ephemeral streams and recharges the basin is estimated from DWR (1973). Direct recharge to the basin floor is estimated from a recharge value to 0.34% of precipitation. Recharge to the mountain areas represent 0.51% of precipitation, and underflow from these highland areas will most likely recharge the basin sediments.

In summary, the Harper Valley recharge calculations and the separate long-term water balance indicate approximately 2,300 to 6,500 acre-feet/year of recharge per year to the Harper Valley Groundwater Basin. The 2,300 can be considered a conservative minimum with 6,500 being a realistic maximum.

6.5.2 Projected Water Balance

The projected water balance is used to estimate the impacts of future groundwater use. The projected water balance is based the following assumptions:

- o Groundwater pumping for the LUZ project will be 4,750 acre-feet/year.
- o Additional groundwater withdrawals in the basin are assumed to be for the Oasis Ranch totalling 675 acre-feet/yr.
- o Additional consumptive use for the valleys scattered residents is assumed negligible.
- o Recharge to the basin occurs from storm runoff from the highlands that enters the ephemeral streams and ultimately percolates into the basin's alluvial aquifer, recharge on the basin floor from rainfall, recharge on the surrounding mountain areas that percolates into the bedrock and flows into the basin, and underflow from the Middle Mojave Basin.

The estimate for total discharge is shown below:

Pumping for the LUZ Powerplants	4,750 acre-feet/year
Oasis Ranch	675 acre-feet/year
Total Discharge	5,425 acre-feet/year (assume 5,500)

The estimates for total recharge are shown below and explained in Appendix C.

Runoff from Mountains	550 acre-feet/year
Recharge to the Basin Floor	420 acre-feet/year
Recharge to the Mountain Areas	300 acre-feet/year
Underflow from Mojave Basin	1,000-2,700 acre-feet/year
Total Recharge	approximately 2,300-4,000 acre-feet/yr

Recharge estimates from both the long-term water balance (section 6.5.1) and the short term water balance above are used to calculate the groundwater overdraft or surplus. These values for recharge and discharge have been used to calculate the following annual change in storage:

- Recharge from long-term water balance (section 6.5.1) of 6,500 acre-feet/year 6500-5,500 = +1,000 acre-feet/year surplus
- Recharge from MARK calculations and DWR reported values presented above (High recharge) 4,000-5,500 = -1,500 acre-feet/year overdraft (Low recharge) 2,300-5,500 = -3,200 acre-feet/year overdraft

The long-term water balances' estimated recharge of 6,500 acre-feet per year indicates that the basin would not be in a condition of overdraft. The separate recharge estimates calculated by MARK and the DWR, with annual recharge varying from 4,000 to 2,300 acre-feet/year respectively, estimate annual overdraft of 1,500 to 3,200 acre-feet/year respectively. Selecting the 3,200 acre-feet/year as a worst case value for overdraft, over a 40 year period the total overdraft would be 128,000 acre-feet withdrawn from the basin. This amount of overdraft would represent roughly 5% of the total basin storage of 2,497,000 acre-feet. The amount of additional drawdown would be approximately twice the drawdown observed to date. Total drawdown would be approximately twice the present 80 feet. This estimate of drawdown is taken from a comparison of historic storage loss and resulting drawdown and estimated storage loss.

In summary, the expected recharge to the basin varies from 2,300 acre-feet/year to 6,500 acre-feet/year. The lowest value for recharge (2,300 acre-feet) uses the DWR (1967) estimate of recharge from the Middle Mojave Basin of 1,000 feet. This estimate was made in 1967 without the additional water well information outlined in the Mojave Water Agency Report 1983. Therefore, MARK's use of a refined estimate of 2,700 acre-feet/year of recharge from the Mojave Basin is based on considerably more data. Using this estimate combined with the long-term water balance, the recharge value would be 4,000 to 6,500 acre-feet year. This would result in a 40 year deficit of zero (0) to 60,000 acre-feet total. This is smaller than the 34 year, 1953-1986 deficit of 95,000 acre-feet per year.

7.0 WATER QUALITY

Water Quality, generally for Harper Valley, and particularly in the area of the LUZ Development (Lockhart Ranch), is of interest in relation to the projected groundwater use. The better the water quality, the less costs for processing LUZ will have to incur.

Water in the desert environment is usually higher in dissolved salts than typically found elsewhere. These dissolved salts are composed of minerals that are generally not hazardous, but create poor taste and residue problems such as pipe scaling and "bathtub stains". From cursory analysis, the irrigation wells in Harper Valley show values ranging from approximately 400 milligrams per litre (mg/l) total dissolved solids (TDS) to 2600 mg/l TDS (Drawing 10). This map shows TDS concentrations for the main water supply aquifer in the Harper Valley. The shallow "perched zone" water within some 20 feet of the surface, especially near the lake, is very high in salts due to concentration by irrigation runoff surface evaporation. This "perched" horizon is typically avoided in screening wells, but may be a source of poor quality recharge to the water table. Water quality appears to vary with depth in several water quality horizons found beneath the area. One of the test wells used for a current investigation, listed as 11N/5W-19G, with a screened interval of 544-670 feet below land surface had a TDS of only 455 mg/l. The well is located almost in the center of 11N/5W Section 19, and is within half a mile of the lake as well as existing irrigation wells with TDS values of 1,000 to 2,700 mg/l. Its yield was low, making water from this well useful for small volume domestic water purposes only. It represents a potential source of lower-demand, good-quality water in the LUZ energy development program.

A water sample from an additional test well located in the center of section 24 and labeled 11N/5W24L1 recorded a TDS value of 2140 mg/l at a depth of 280 to 320 feet. This well is further from the wetlands area, and has a lower TDS value than some wells adjacent to the wetlands. The TDS concentrations tend to be higher near the lake area as shown in Drawing 10.

One well, 11N/4S19H1, has a long history of sampling for water quality. This well is approximately 210 feet deep, drilled in 1936 for domestic and irrigation purposes with a driller reported low yield of less than 100 gpm in a variably reported 12-inch or 10-inch diameter casing.

The TDS for this well in a period of 25 years, extending up until 1978, varied from an initial 2,310 mg/l in 1953, to 2,806 mg/l in 1978. (Parts per million (ppm) and milligrams per litre (mg/l) values for TDS can be considered analogous.) There are a couple of anomalies of 981 mg/l and 990 mg/l in 1971 and 1972, that are thought to be ascribed to this well incorrectly.

The series of analyses indicated that TDS has increased by some 500 mg/l in the 25-year period from 1953 to 1978. Although the trend for this well is not alarming, it does appear to indicate that some increasing TDS concentration with time.

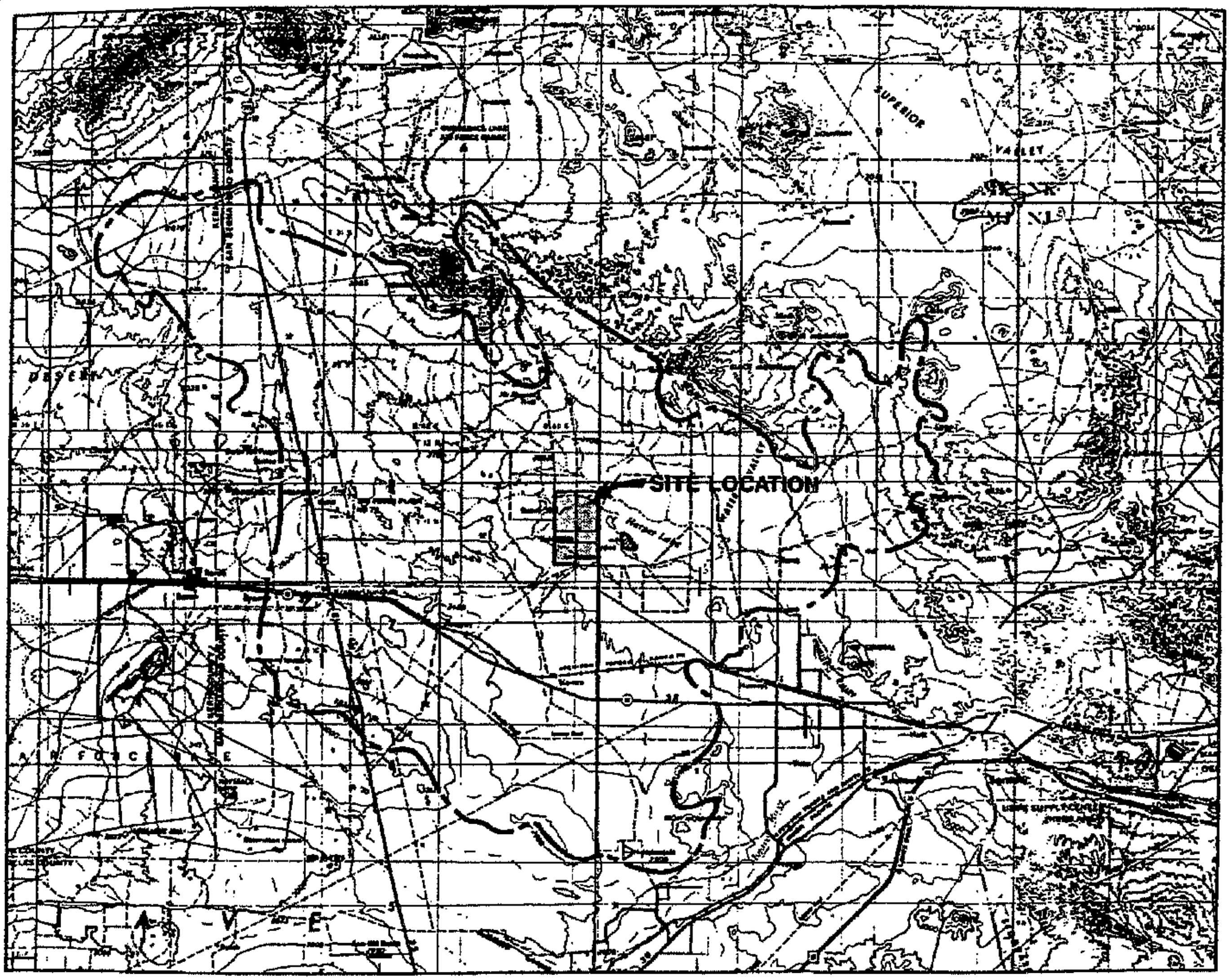
Another well, with more limited documentation, shows some increasing TDS concentration. This well, 11N/5W-24G1 was drilled in about 1938, producing 720 gpm from a depth of 250 feet. Water quality analyses from 1953, recorded 875 mg/l TDS. A water quality sample taken in 1968 was reported to have 1250 mg/l TDS, or an approximate increase of 300 mg/l in 15 years. Increases in TDS concentration over time are probably largely the result movement of higher TDS groundwater from the irrigated farmland westward toward the pumping depression created by pumping at the ranch wells. Irrigation in dry areas generally causes increases in shallow groundwater salinity. In general, wells located further from the dry lake, exhibit better water quality readings than those adjacent to the dry lake.

Drawing 9 presents a computer-generated water quality (TDS) map, using data points from samples collected during 1986 through 1988. The map shows improved water quality with distance from the Harper Dry Lake area. The water quality contours document that relatively better quality water is contributed from the Mojave River underflow area to the south and west and from the Harper Basin recharge areas to the north.

The water quality data generally indicates that the maximum TDS concentration from wells in the Harper Valley is 2,500 mg/l. Samples from some wells are higher, but many wells are also lower in TDS concentrations. To obtain the derived well yield and water quality of equal to or less than 2,500 mg/l it may be necessary to mix water from several wells. Water from wells with lower TDS concentrations would be mixed with water from wells with higher TDS concentration to maintain an overall TDS concentration below 2,500 mg/l. Using this method, LUZ should be able to maintain TDS concentration values in the 2,000 to 2,500 mg/l range.

TABLE 1
Total Dissolved Solids Concentrations Over Time for Well 11N/4W-19H1

DATE	ELECTRICAL CONDUCTIVITY IN MICROMOHS/CM	TOTAL DISSOLVED SOLIDS IN Mg/l
06/24/53	3584	2310
07/27/71	1587	981
08/22/72	1527	990
04/19/73	3817	2382
11/20/74	3861	2505
04/28/75	3956	2310
04/27/76	3861	2413
12/10/76	4043	2430
04/25/77	4124	2462
12/14/77	3400	2686
04/19/78	3944	2806



EXPLANATION

HARPER LAKE GROUNDWATER BASIN BOUNDARY

WETLANDS

NORTH

0 5 10 MILES

SCALE

SOURCES:

USGS SAN BERNARDINO AND TRONA 1:250,000 SHEETS.
DWR BULLETIN 84.
DWR BULLETIN 106-1.

THE MARK GROUP
ENGINEERS & GEOLOGISTS, INC.

SITE VICINITY MAP

HARPER VALLEY GROUNDWATER BASIN
LUZ DEVELOPMENT
HARPER VALLEY, CALIFORNIA

PROJECT NO. 8803219.18

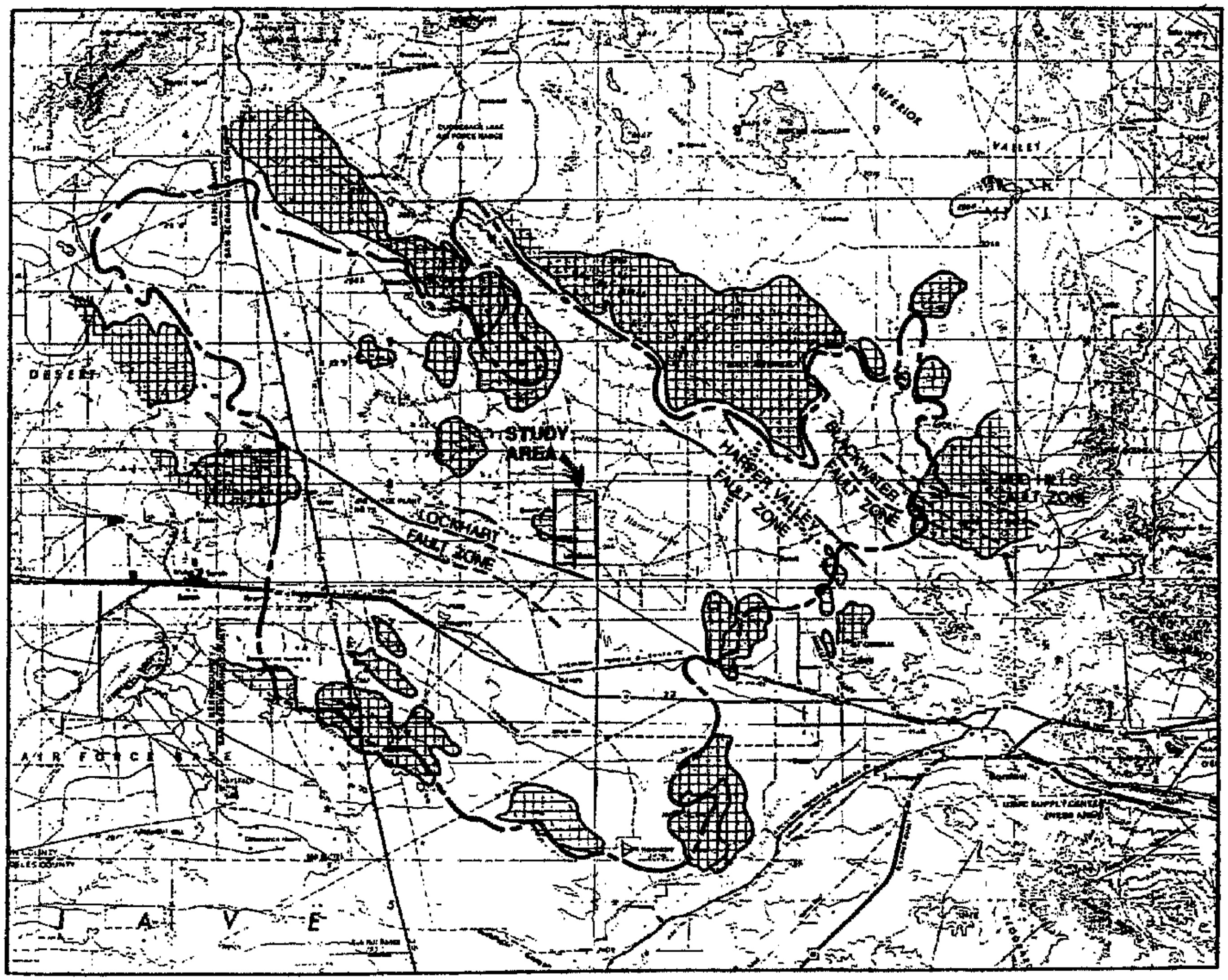
DRAWING NO. 1

Prepared By ____

Approved By ____

Date 3/11/89

project. Wells can be strategically pumped to maintain TDS concentrations lower, in the range of 2,000 mg/l.



EXPLANATION

HARPER LAKE GROUNDWATER BASIN BOUNDARY (UNCONSOLIDATED INSIDE BASIN BOUNDARY

CONSOLIDATED ROCK

FAULT

NORTH

0 5 10 MILES

SCALE

SOURCES:

USGS SAN BERNARDINO AND TRONA 1:250,000 SHEETS.

DWR BULLETIN 84

DWR BULLETIN 106-1

GENERAL GEOLOGIC MAP

HARPER VALLEY GROUNDWATER BASIN
LUZ DEVELOPMENT
HARPER VALLEY, CALIFORNIA

THE MARK GROUP
ENGINEERS & GEOLOGISTS, INC.

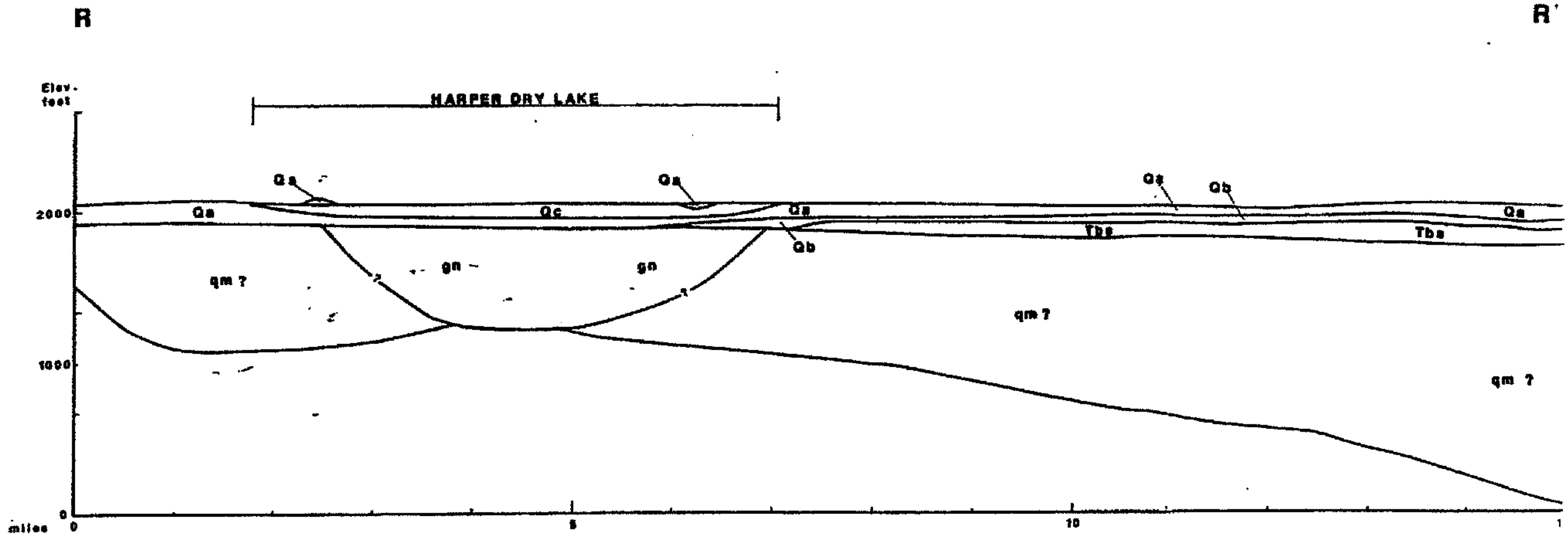
PROJECT NO. 8803219.18

DRAWING NO. 2

Prepared By SET

Approved By Ola

Date 2/11/87



GEOLOGIC UNITS

Sedimentary and Volcanic Rocks — UNCONSOLIDATED FORMATIONS

QUATERNARY:
- Qa — Alluvial Gravel and Sand (both Younger and Older)
- Qs — Wind Blow Sand
- Qc — Clay and Silt of Mud Flats
- Qb — Black Mountain Basalt

CONSOLIDATED FORMATIONS

TERTIARY:
- Tbs — Terrestial Sandstone

Igneous and Metamorphic Rocks

- JURA-CRETACEOUS: qm — Quartz Monzonite
- PRECAMBRIAN ?: gn — Quartz Diorite Gneiss

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IDEALIZED CROSS SECTION R-R'
Harper Valley Groundwater Basin
LUZ Development
Harper Valley, California

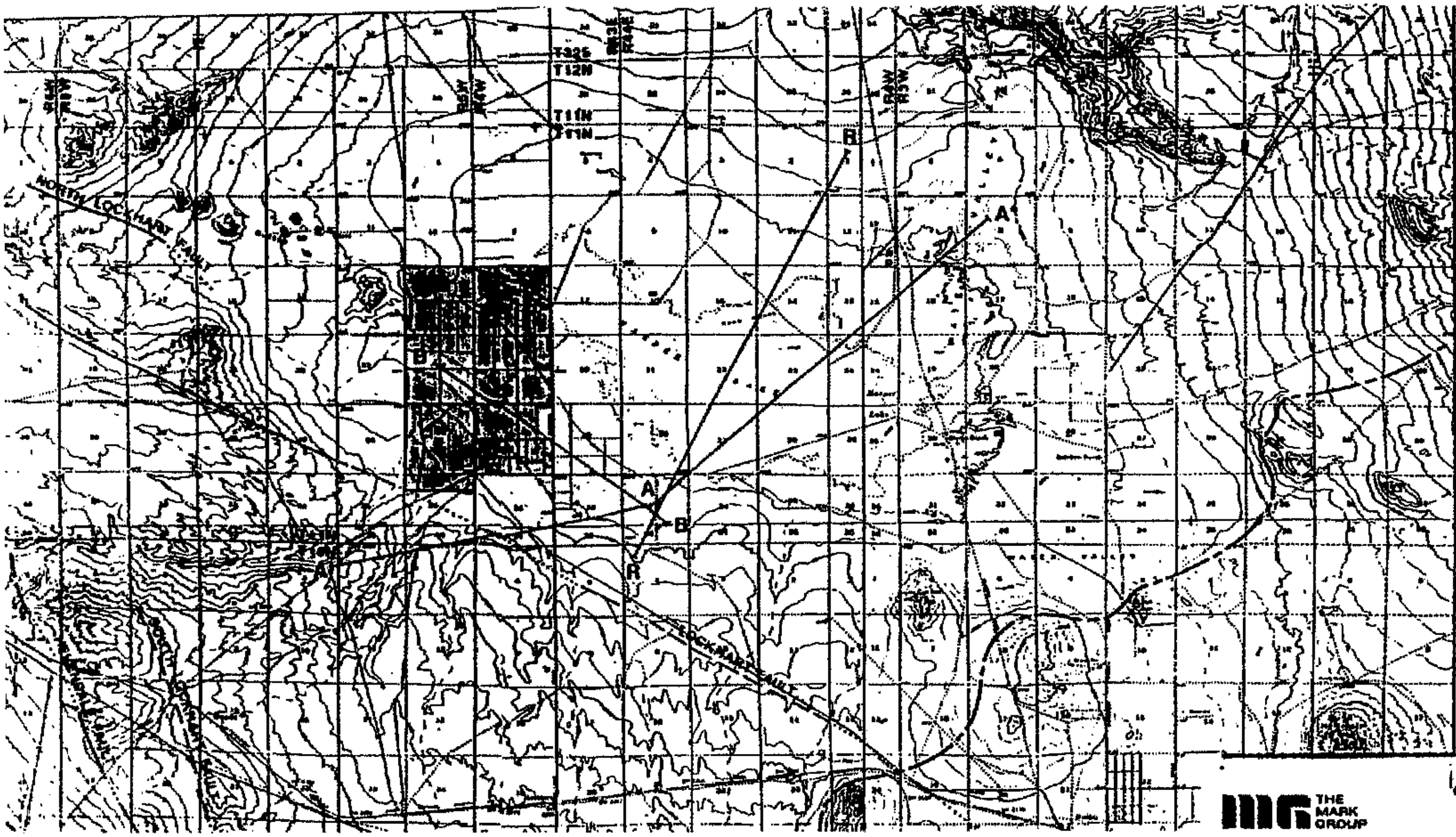
PROJECT NO. 88-03219.18

FIGURE 3

Prepared By ______

Approved By ______

Date 2/6/89



EXPLANATION

HARPER LAKE GROUNDWATER BASIN BOUNDARY

SITE LOCATION

R — R' LOCATION OF CROSS SECTION

NORTH

0 1 2 3 MILES

SCALE

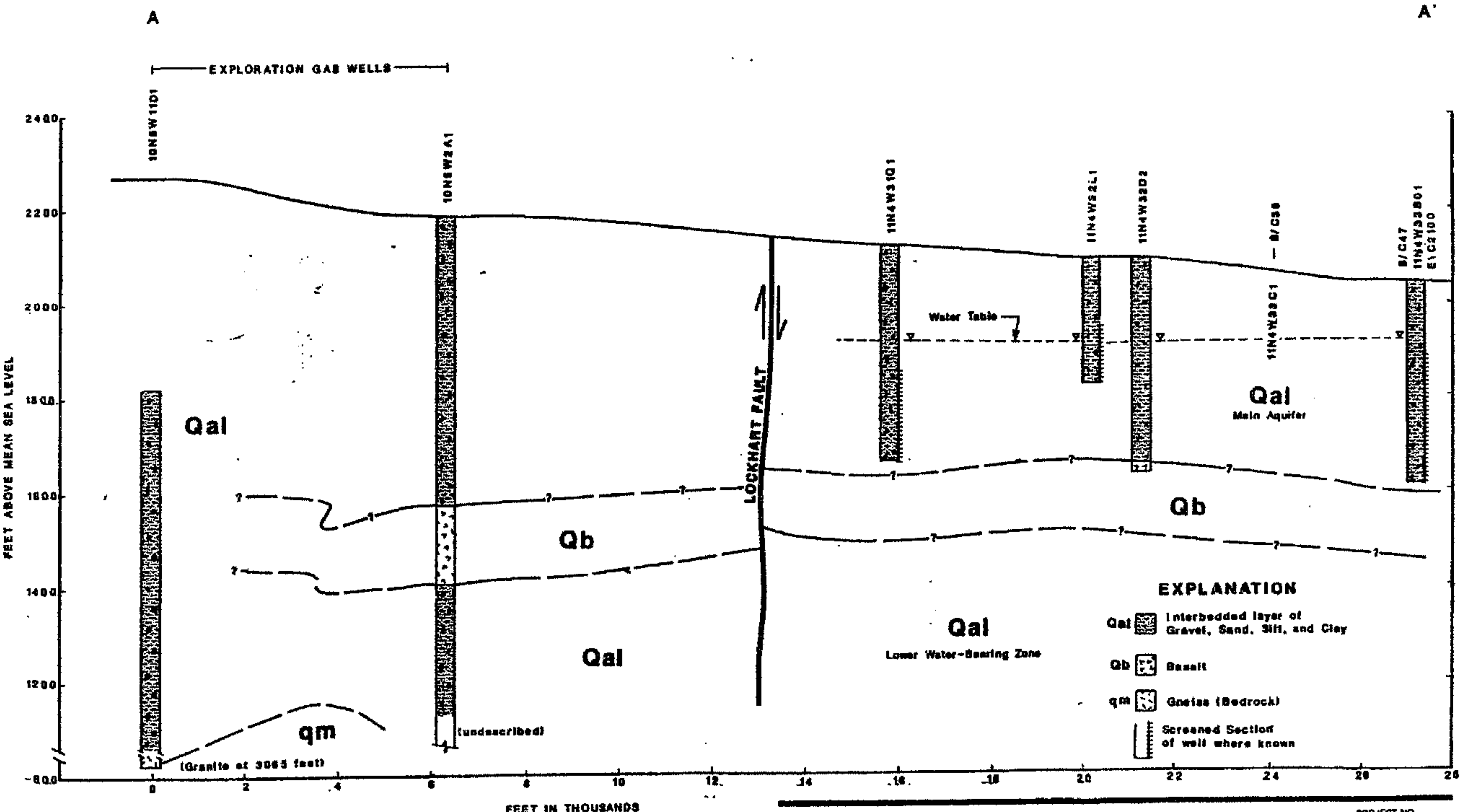
SOURCES:

LOCATION OF GEOLOGIC CROSS SECTIONS

HARPER VALLEY GROUNDWATER BASIN

THE MARK GROUP

4



Prepared By ________ Approved By ________ Date 9/11/89

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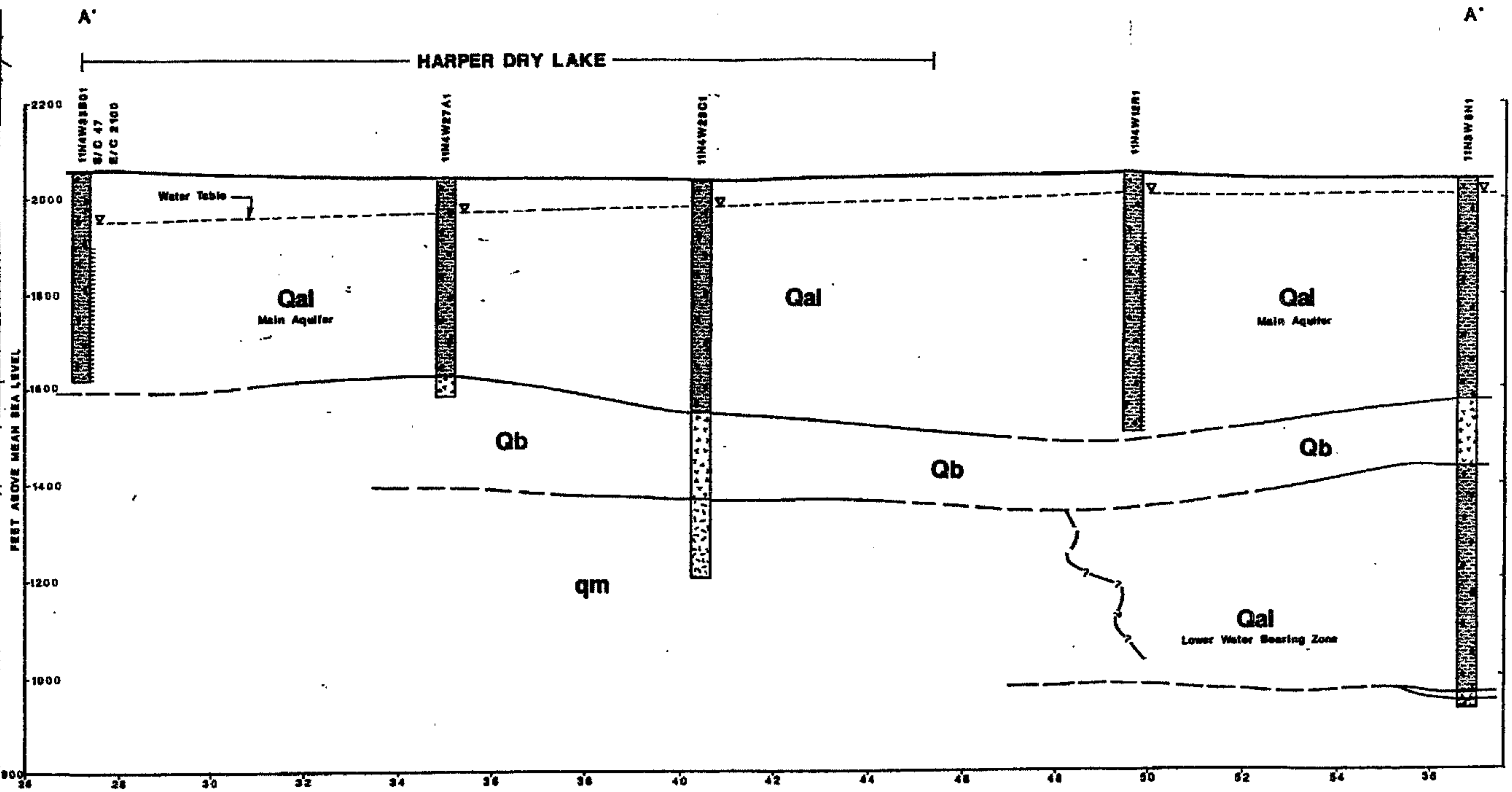
GEOLOGIC CROSS SECTION A-A'
Harper Valley Groundwater Basin
LUZ Development
Harper Valley, California

PROJECT NO.
88-03219.18

DRAWING NO.
5



EXPLANATION

Qal — Interbedded layer of Gravel, Sand, Silt, and Clay

Qb — Basalt

qm — Gneiss (Bedrock)

Screened Section of Well where known

THE MARK GROUP
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GEOLOGIC CROSS SECTION A'-A'
Harper Valley Groundwater Basin
LUZ Development
Harper Valley, California

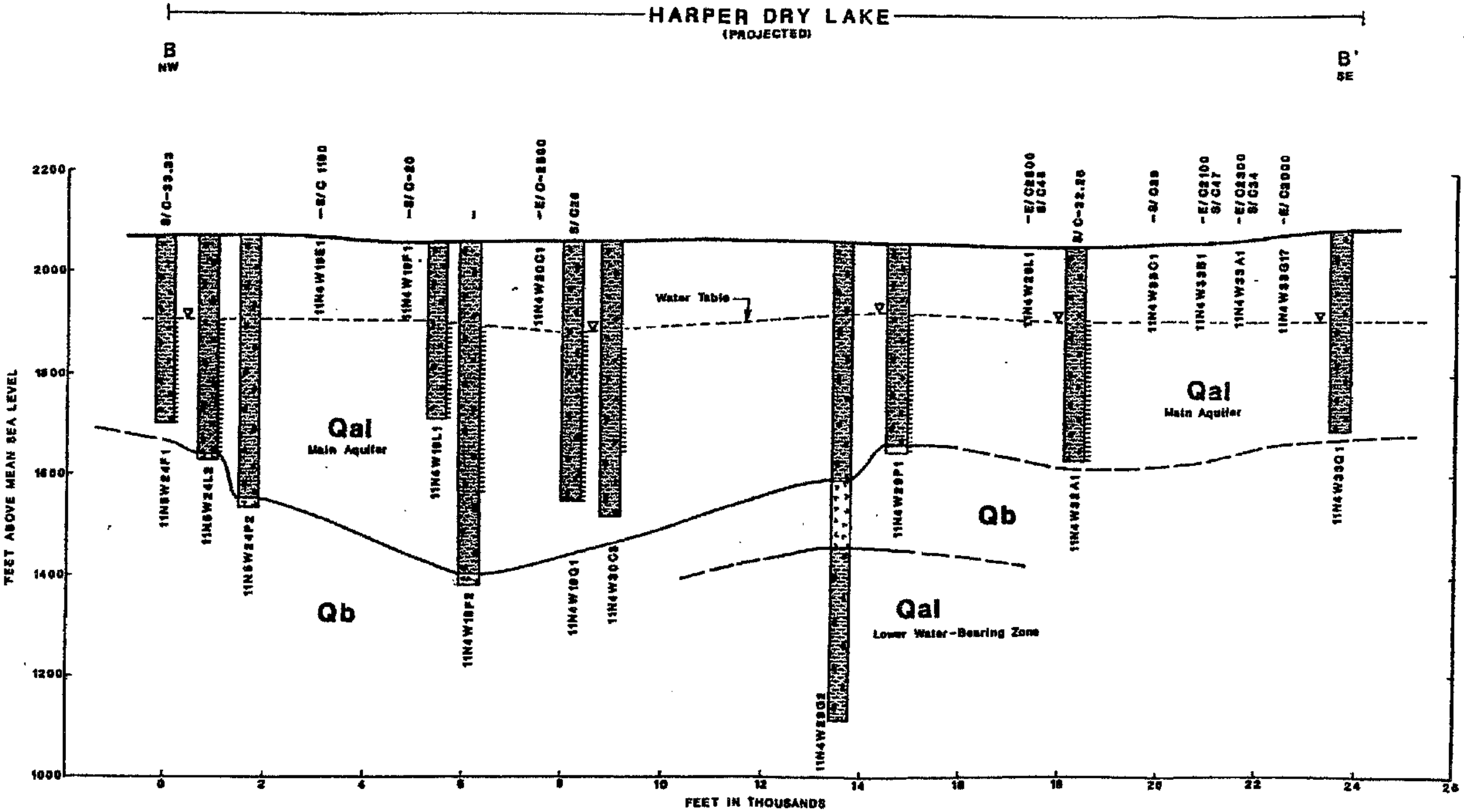
PROJECT NO.
88-03219.18

DRAWING NO.
6

Prepared By

Approved By

Date



EXPLANATION

Qal — Interbedded Gravel, Sand, Silt, and Clay

Qb — Basalt

S/C- Specific Capacity

Screened Section of Well where known

E/C- Specific Conductance in micromohs/cm

THE MARK GROUP
ENGINEERS & GEOLOGISTS, INC.

GEOLOGIC CROSS SECTION
Harper Valley Groundwater Basin
LUZ Development
Harper Valley, California

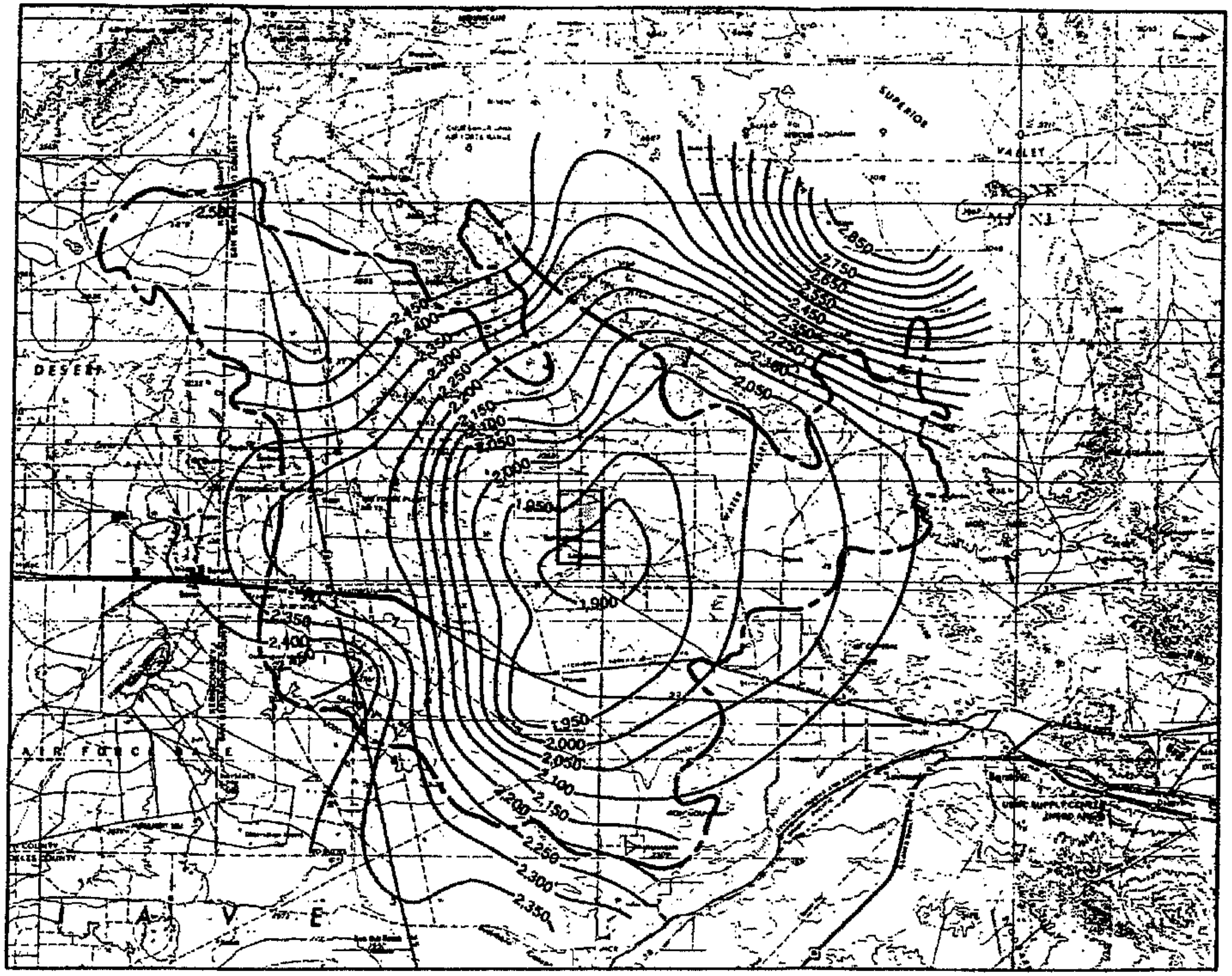
PROJECT NO. 88-03219.18

DRAWING NO. 7

Prepared By

Approved By

Date 2/11/89



EXPLANATION

2,800 — LINE OF EQUAL WATER LEVEL ABOVE MEAN SEA LEVEL

HARPER LAKE BASIN BOUNDARY

SITE LOCATION

NORTH

0 5 10 MILES

SCALE

SOURCES:

USGS SAN BERNARDINO AND TRONA 1:250,000 SHEETS.

DWR BULLETIN 84

DWR BULLETIN 106-1

UNPUBLISHED DWR DATA

THE MARK GROUP
ENGINEERS & GEOLOGISTS, INC.

WATER LEVELS IN THE HARPER GROUNDWATER BASIN

HARPER VALLEY GROUNDWATER BASIN
LUZ DEVELOPMENT
HARPER VALLEY, CALIFORNIA

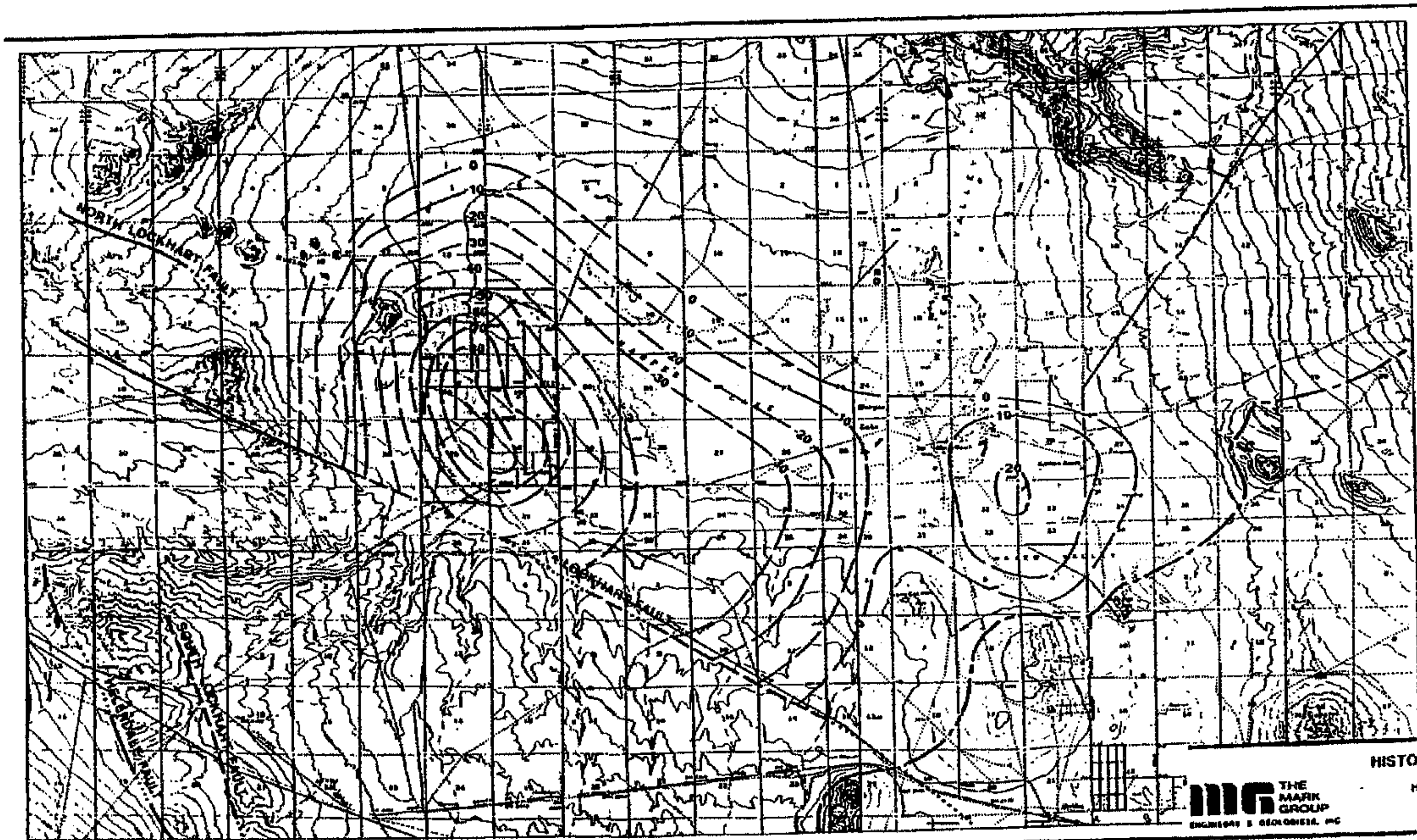
PROJECT NO. 8803219.18

DRAWING NO. 8

Prepared By ____

Approved By ____

Date 2/11/91



EXPLANATION

HARPER LAKE GROUNDWATER BASIN BOUNDARY

CHANGE IN GROUNDWATER LEVELS (FT) 1958-1986

SITE LOCATION

NORTH

SCALE

0 1 2 3 MILES

SOURCES

USGS FREMONT PEAK (1956), OWL MOUNTAIN (1955)
HAWES (1956) AND BARSTOW (1956) 1:62,500 SHEETS

DWR BULL 84

DWR BULL 91-1

DWR BULL 91-3

DWR BULL 106-1

MOJAVE VALLEY WATER AGENCY 1983

UNPUBLISHED DWR DATA

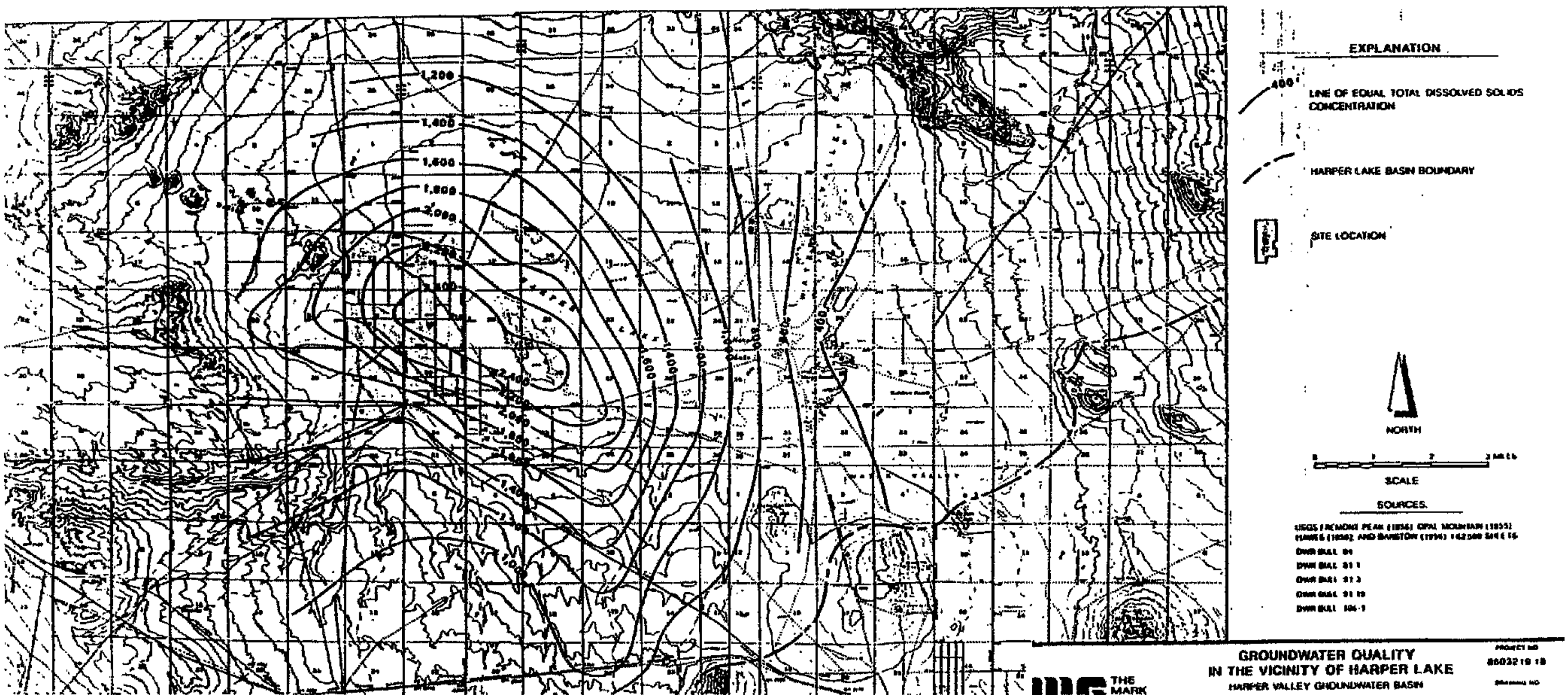
THE MARK GROUP
ENGINEERS & GEOLOGISTS, INC

HISTORIC CHANGE IN WATER LEVELS

HARPER VALLEY GROUNDWATER BASIN
LUZ DEVELOPMENT
HARPER VALLEY, CALIFORNIA

PROJECT NO. 8803219
DRAWING NO. 9

Prepared by: ______ Approved By: ______ Date 2/16/91



GROUNDWATER QUALITY IN THE VICINITY OF HARPER LAKE

HARPER VALLEY GROUNDWATER BASIN

8.0 CONCLUSIONS

Based on the worst case groundwater recharge and discharge estimates, the total worst case groundwater deficit for each year of pumping projected by LUZ would be 3,200 acre-feet/yr, making a total 40 year projected groundwater deficit of 128,000 acre-feet. Using the conservatively estimated total deficit of 128,000 acre-feet, this would represent a total of 5% of estimated storage in the Harper Valley Basin of 2,497,000 acre-feet. Even with this worse-case deficit, the LUZ project will have sufficient water for the power plant project at a withdrawal rate of 4,750 acre-feet/year, which is less than the prior 50 year average withdrawal.

Calculations by The MARK Group indicates that groundwater recharge may be greater than calculated by the DWR estimates, based on more recent data, and pumping withdrawal may be offset by recharge. For example, a long-term water balance and calculations by MARK indicate that annual basin recharge is 4,000 to 6,500 acre-feet/year. These higher recharge estimates should result in far smaller deficits, and may even result in a condition where groundwater pumping is offset by recharge.

The successful past operation of the ranch withdrawing 6,000 to 15,000 acre-feet/yr over a 50 year period also supports the continued reliable availability of groundwater. The LUZ project plan to withdraw approximately 4,750 acre-feet/year is less than the historic average annual amount of groundwater extraction by pumping for the Lockhart Ranch.

Groundwater Quality in the vicinity of the Harper Valley area indicates that the highest TDS concentrations are located in the area west of Harper Lake. TDS concentrations will generally be below the 2,500 requirements for the

9.0 REFERENCES

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Appendices

APPENDIX A

Pumping Estimates for the Lockhart/Most Ranch

To correspond with the map created from pumping withdrawal values from Figure 9 of the report, pumping values for the Lockhart and Most wells are estimated from 1953-1986. Based on unpublished records from the San Bernardino County Agricultural Commissioner, the Most/Lockhart/Baker Ranches were the only agricultural operations in the Harper Valley during that period. These three ranches are calculated as one total value of acreage by the County. In approximately 1984, an additional ranch, called the Oasis Ranch, was developed on the east end of Harper Lake. It contains approximately 4 irrigation pivots, each with 135 acres. Information on total acreage from 1953 through 1988 is obtained from the following sources:

Year	Source
1953-1970	DWR, 1973
1970-1988	San Bernardino County Agricultural Commissioner

Data previous to 1953 on agricultural production is too sparse for accurate calculations. The calculation of total pumpage is made by assuming that each planted acre requires 5 acre-feet of water per acre (MWA, 1982). Therefore, the total acreage per year is multiplied by 5 acre-feet/acre to obtain the value for pumpage (Table A-1).

TABLE 1: 1989 WELL INVENTORY

MARK	WELL NUMBER STATE	MOST	DATE MEASURED	DEPTH TO WATER (FT)	SURFACE ELEVATION (FT)	WATER ELEVATION (FT)	USE	REMARKS
1	11N/4W-30N	14	11/28/89	224.08	2104	1880	Irrigation	Not pumping 11-28-89
2	11N/4W-30N	28			2104		Irrigation	Cascading water falling into well. Unable to obtain measurement. Not pumping 11-28-89.
3	11N/4W-30N	21	11/28/89	207	2098	1891	Irrigation	No access port. Drillers moved pump to allow for later access. Not pumping 11-28-89.
4	11N/4W-30E	15	11/28/89	215	2087	1872	Irrigation	TD = 534 Drillers removed pump. Well no longer efficient for irrigation purposes.
5	11N/4W-30D	22	12/05/89	207.71	2082	1874	Irrigation	Drillers raised pump to allow measurement access. Not pumping 12-5-89.
6	11N/4W-19Q		12/04/89	185.75	2058	1872	Monitor	Casing covered with cap. Easy measuring access. No pump.
7	11N/4W-19Q	5			2058		Construction	Pumping well (Q = 700 gpm). Provides water for construction site.
8	11N/4W-30K	33	11/28/89	203.35	2080	1877	Irrigation	Not pumping 11-28-89
9	11N/4W-30P	6			2083		Irrigation	Unable to measure; Pump attatched; Not pumping 11-28-89.
10	11N/4W-19E	34			2058		Irrigation	Submersible pump. Pumping at 14:30 11-28-89 = 4,777,222 gallons.

TABLE 1: 1989 WELL INVENTORY

	WELL NUMBER							
MARK	STATE	MOST	DATE MEASURED	DEPTH TO WATER (FT)	SURFACE ELEVATION (FT)	WATER ELEVATION (FT)	USE	REMARKS
11	11N/4W-19E	16			2058		Irrigation	Has submersible pump. No access for measurement.
12	11N/4W-19K	8	12/04/89	180.79	2059	1878	Irrigation	Not pumping 12-04-89.
13	11N/4W-19F	17	11/29/89	172.36	2049	1877	Irrigation	Used for pumping test 12/06/89 - 12/09/89.
14	11N/4W-19G		11/29/89	161.37	2048	1887	Monitor	TD = 475' - Volcanics/Schist below middle aquifer. Perforated in lower aquifer - upward vertical gradient (FOX - 1989).
15	11N/4W-18H		11/28/89	137.75	2023	1885	Monitor	No pump, casing covered by railroad ties.
16	11N/4W-19A		11/28/89	151.24	2034	1883	Monitor	No pump.
17	11N/5W-24K		12/05/89	210.63	2085	1874	Irrigation	Located within LUZ Construction site. Submersible pump (FOX 1989) removed 12/05/89. TD = 430'.
18	11N/5W-24Q				2087		Irrigation	Well or booster station? No access for measurement.
19	11N/5W-24P				2098		Irrigation (Construction)	New pump. Not pumping as of 12/05/89. No access for measurement.
20	11N/4W-33Q		11/29/89	213.05	2095	1882	Domestic	Domestic well. No pump.
21	11N/4W-30H		11/29/89	170	2052	1882	Domestic	Domestic well. Not pumping.

TABLE 1: 1989 WELL INVENTORY

MARK	WELL NUMBER STATE	MOST	DATE MEASURED	DEPTH TO WATER (FT)	SURFACE ELEVATION (FT)	WATER ELEVATION (FT)	USE	REMARKS
22	11N/4W-29D				2050			
23	11N/4W-19R		11/29/89	11.43	2044	2033	Monitor	Shallow aquifer (perched) monitoring well.
24	11N/4W-19J		11/29/89	158.67	2039	1880	Monitor	No pump. 6' casing welded to bottom of cover.
25	11N/4W-19H		11/29/89	159.45	2040	1881	Monitor	No pump. Open hole in concrete pad.
26	11N/4W-19L		11/29/89		2056		Monitor	Dry to 128'.
27	11N/4W-19L		12/04/89	182.1	2056	1874	Monitor	Open casing, no pump.
28	11N/4W-19H		12/05/89	162.55	2045	1882	Monitor	Pump removed, 12/89.
29	11N/4W-33C	1			2040		Irrigation	Pumping 11/29/89, flow meter non-functioning.
30	11N/4W-33B	2			2040		Irrigation	Not pumping 11/29/89. Attempted measurement. Survey chain obstructed 100'.
31	11N/4W-33G	3			2060		Irrigation	Pumping 11/29/89. Q = 1000 gpm.
32	11N/4W-33H	4			2059		Irrigation	Not pumping 11/29/89. Has airline in access port. Survey chain obstructed 166'.
33	11N/4W-32D	11			2075		Irrigation	Not pumping 11/29/89. No access port.

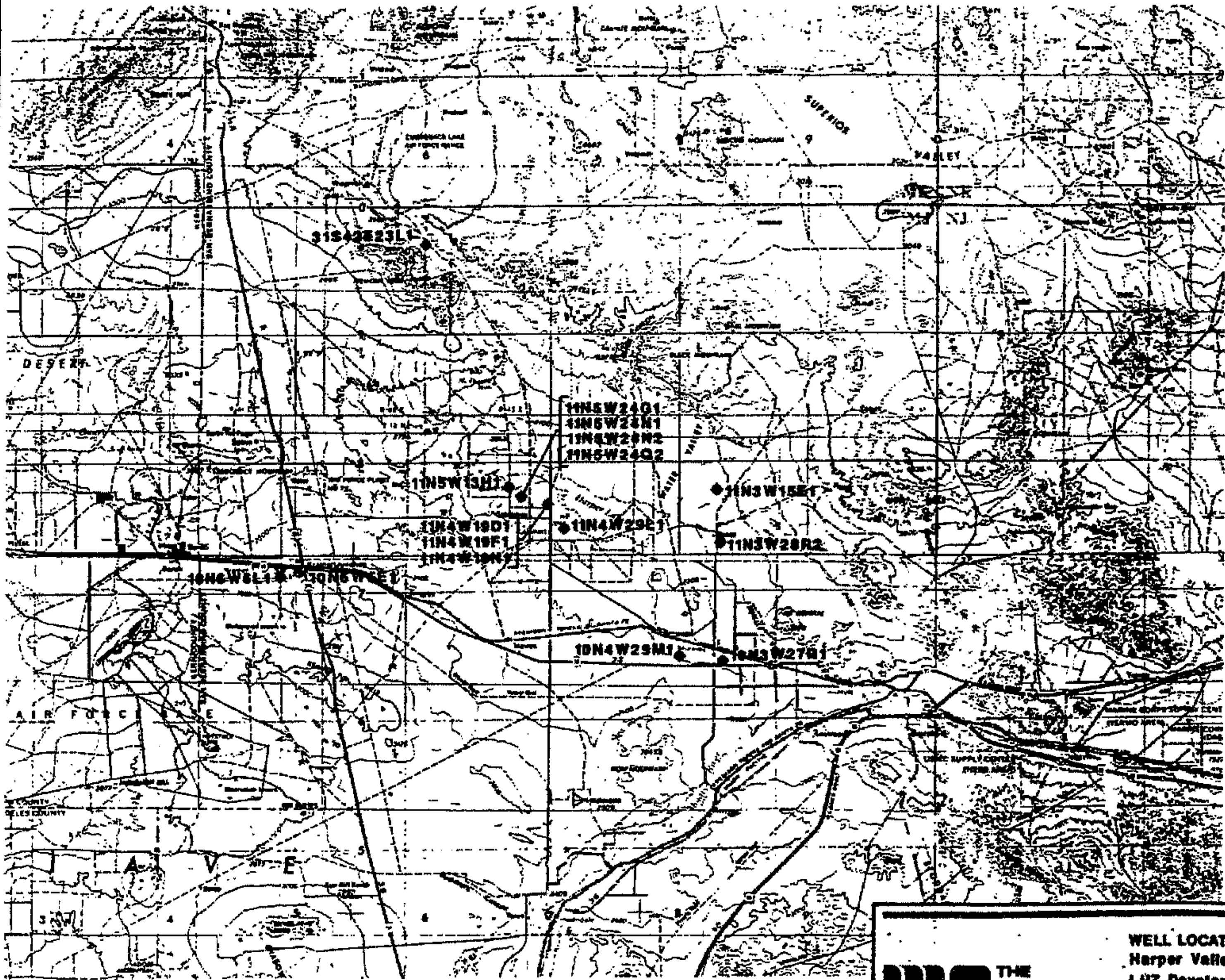
TABLE 1: 1989 WELL INVENTORY

MARK	WELL NUMBER STATE	MOST	DATE MEASURED	DEPTH TO WATER (FT)	SURFACE ELEVATION (FT)	WATER ELEVATION (FT)	USE	REMARKS
34	11N/4W-29Q	19			2050		Irrigation	Not pumping 11/29/89. No access port.
35	11N/4W-32A				2044		Irrigation	Pumping 11/29/89. USGS observation well. No flow meter.
36	11N/4W-29N		11/29/89	167	2067	1899	Monitor	TD = 698′ Screened to deep aquifer (FOX, 1989).
37	11N/4W-28N	29			2040		Irrigation	Pumping 11/29/89. Q = 1000 gpm.
38	11N/4W-30A	7	11/29/89		2045		Irrigation	Pumping 11/29/89. Q = 1000 gpm.

TABLE A-1 PUMPING ESTIMATES

PUMPING ESTIMATES FROM THE LOCKHART RANCH, HARPER VALLEY, CALIFORNIA

YEAR	ACRES OF CROPS	AC-FT/ AC/YR	AC-FT OF WATER
1953	1800	5	9000
1954	1800	5	9000
1955	2300	5	11500
1956	2300	5	11500
1957	2300	5	11500
1958	2300	5	11500
1959	2300	5	11500
1960	2300	5	11500
1961	2300	5	11500
1962	2300	5	11500
1963	2300	5	11500
1964	2300	5	11500
1965	2300	5	11500
1966	2300	5	11500
1967	2300	5	11500
1968	2520	5	12600
1969	2520	5	12600
1970	2520	5	12600
1971	2520	5	12600
1972	2165	5	10825
1973	2540	5	12700
1974	2140	5	10700
1975	2140	5	10700
1976	2140	5	10700
1977	2720	5	13600
1978	2990	5	14950
1979	2700	5	13500
1980	2230	5	11150
1981	1480	5	7400
1982	2500	5	12500
1983	2500	5	12500
1984	1300	5	6500
1985	1300	5	6500
1986	1300	5	6500
		TOTAL:	378625



EXPLANATION

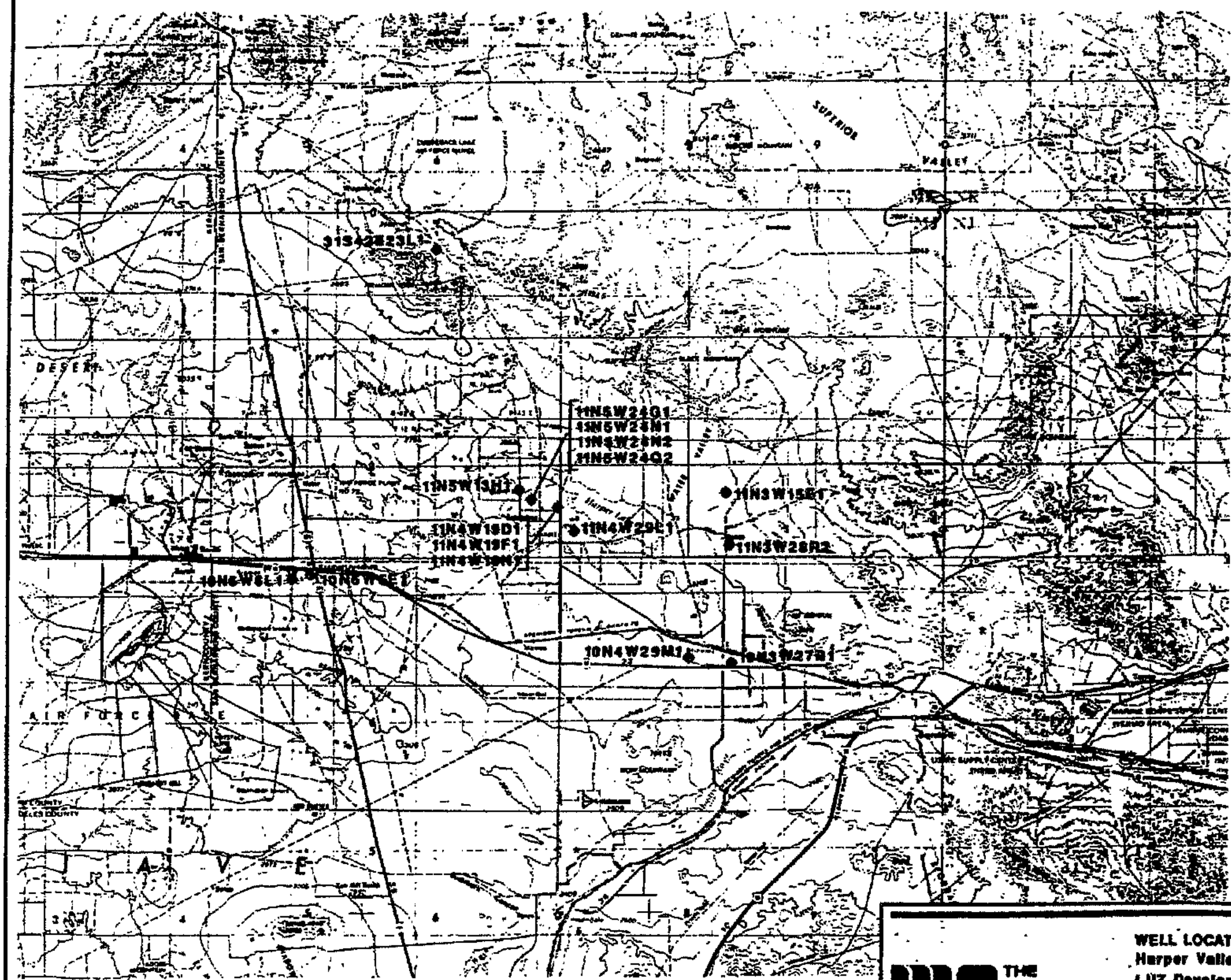
11N5W24Q2 ◆ LOCATION AND NUMBER OF WATER WELLS IN THE HARPER VALLEY

THE MARK GROUP
CONSTRUCTION ENGINEERS, INC.

WELL LOCATIONS
Harper Valley Groundwater Basin
LUZ Development
Harper Valley, California

PROJECT NO.
88-03219.18

FIGURE
A-1



EXPLANATION

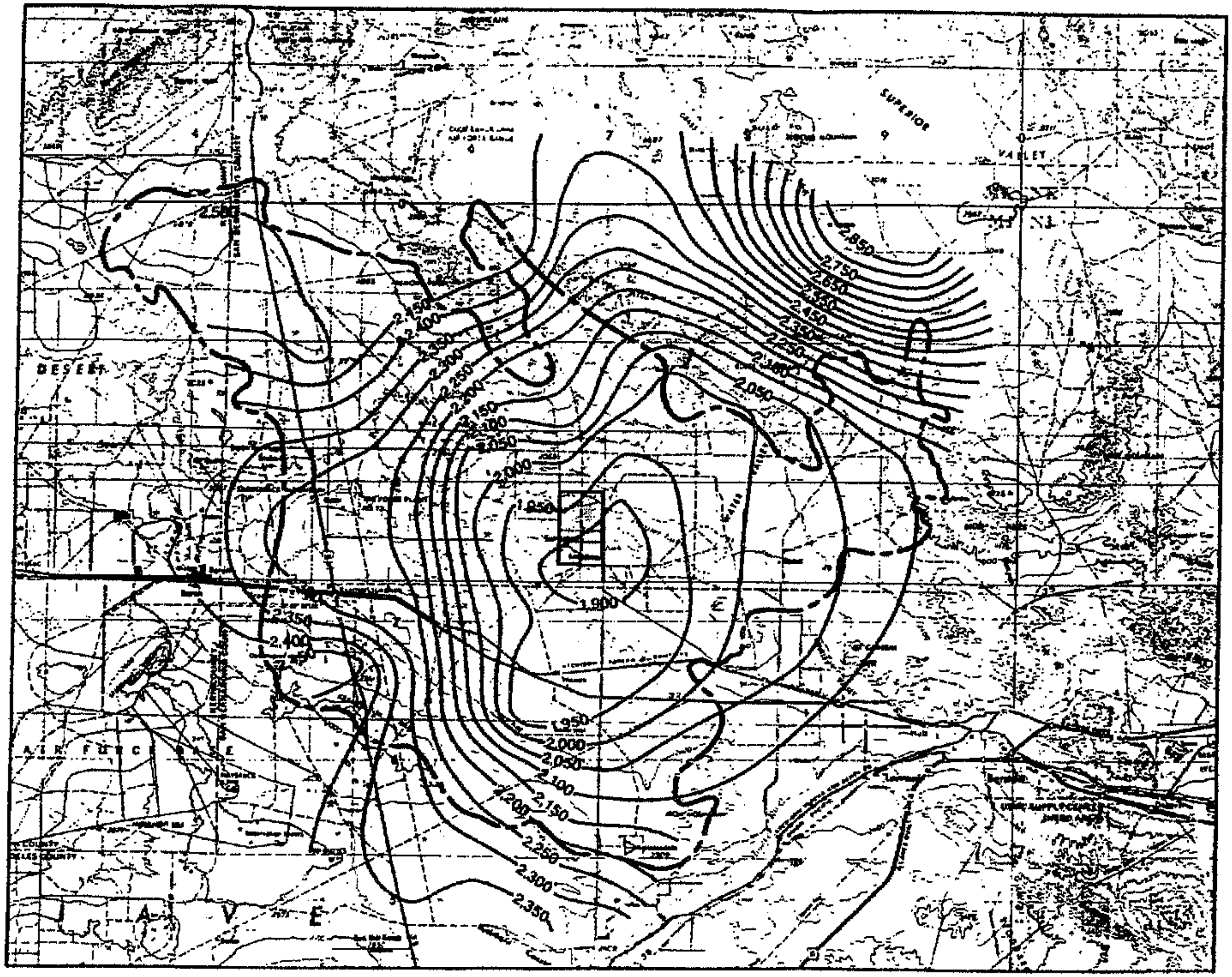
11NSW24Q2 ◆ LOCATION AND NUMBER OF WATER WELLS IN THE HARPER VALLEY

THE MARK GROUP
CONSTRUCTION ENGINEERS, INC.

WELL LOCATIONS
Harper Valley Groundwater Basin
LUZ Development
Harper Valley, California

PROJECT NO.
88-03219.18

FIGURE
A-1



EXPLANATION

2,800 — LINE OF EQUAL WATER LEVEL ABOVE MEAN SEA LEVEL

HARPER LAKE BASIN BOUNDARY

SITE LOCATION

NORTH

0 5 10 MILES

SCALE

SOURCES:

USGS SAN BERNARDINO AND TRONA 1:250,000 SHEETS.
DWR BULLETIN 84
DWR BULLETIN 106-1
UNPUBLISHED DWR DATA

THE MARK GROUP
ENGINEERS & GEOLOGISTS, INC.

WATER LEVELS IN THE HARPER GROUNDWATER BASIN
HARPER VALLEY GROUNDWATER BASIN
LUZ DEVELOPMENT
HARPER VALLEY, CALIFORNIA

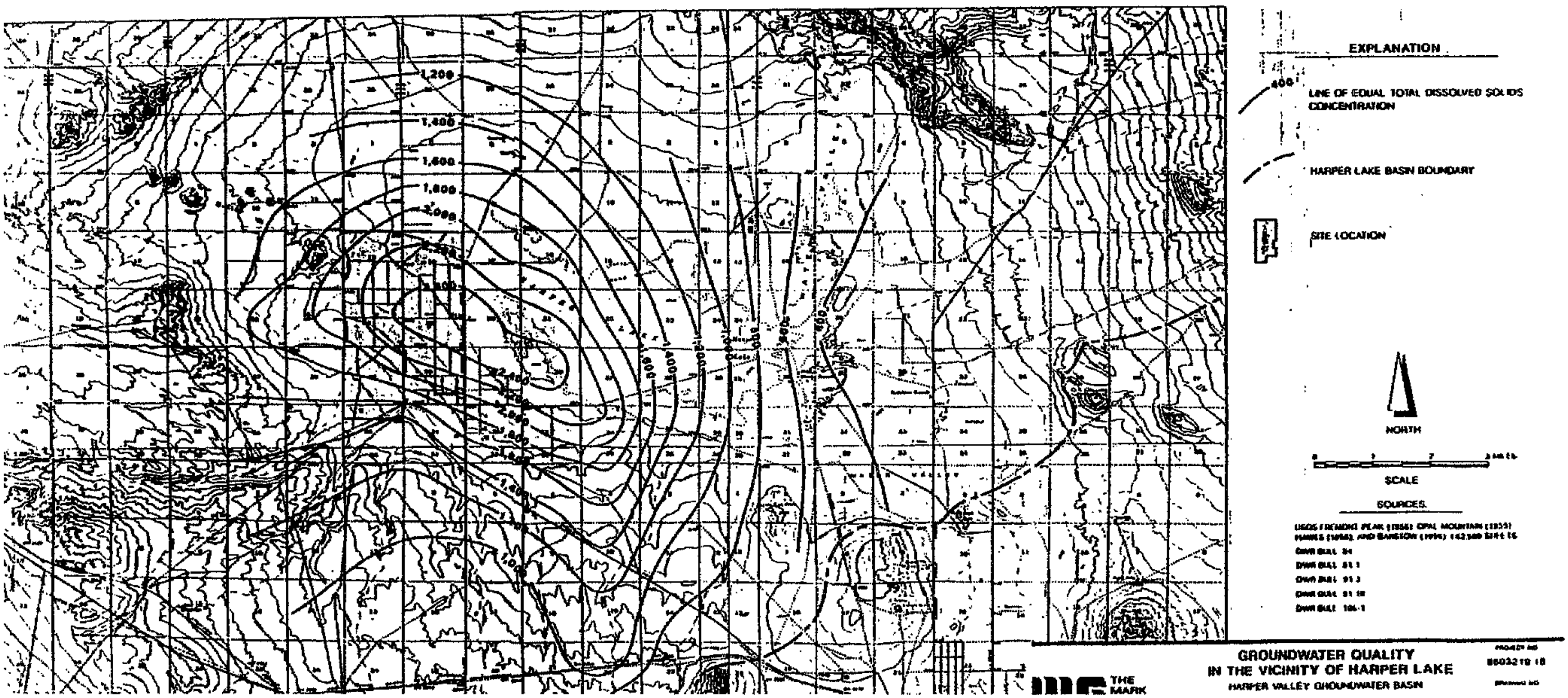
PROJECT NO. 8803219.18

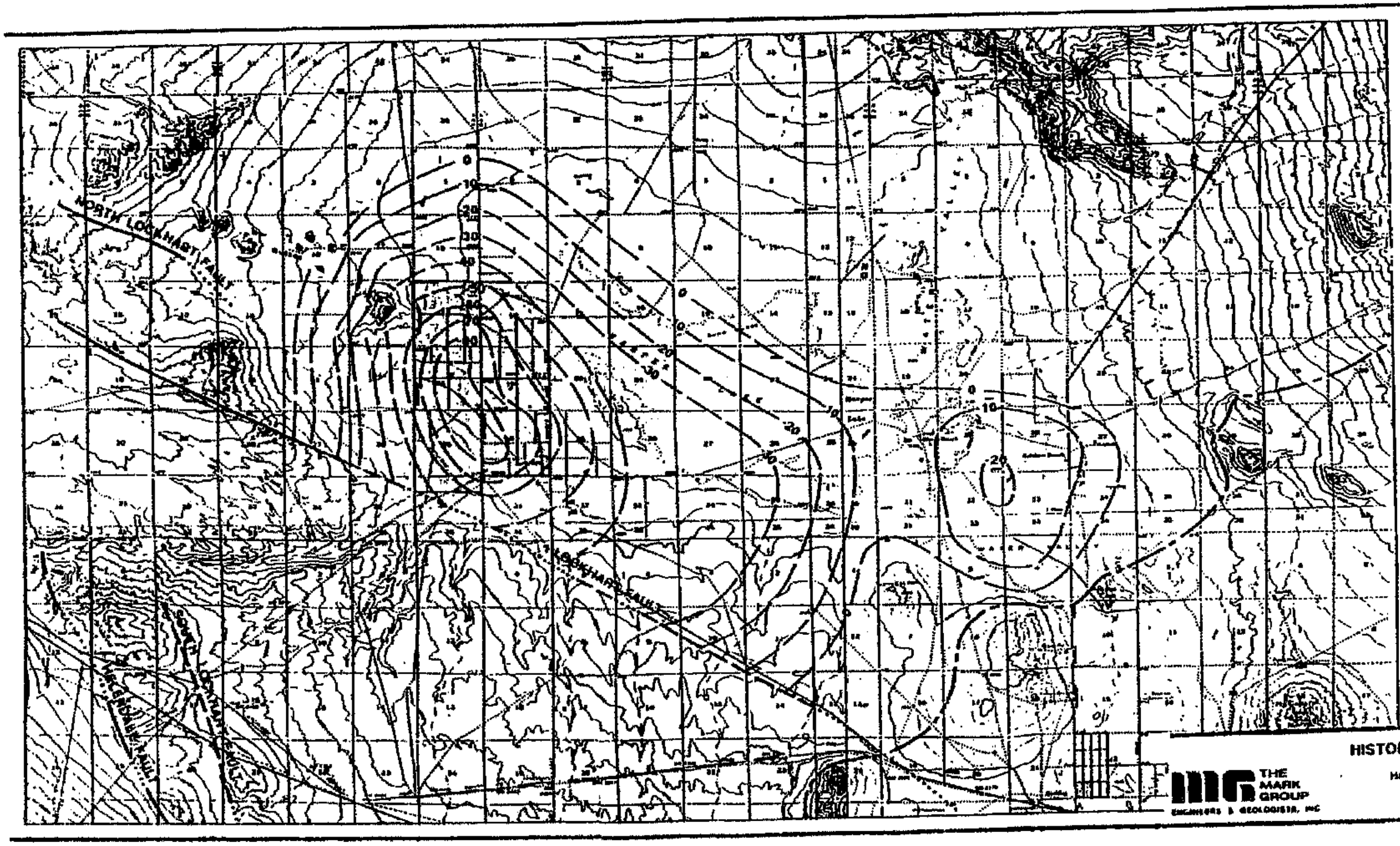
DRAWING NO. 8

Prepared By ________

Approved By ________

Date 2/11/91


1,200
1,400
1,600
1,800
2,000
EXPLANATION
400
LINE OF EQUAL TOTAL DISSOLVED SOLIDS CONCENTRATION
HARPER LAKE BASIN BOUNDARY
SITE LOCATION
NORTH
SCALE
SOURCES.
DWR BULL 106-1
GROUNDWATER QUALITY
IN THE VICINITY OF HARPER LAKE
HARPER VALLEY GROUNDWATER BASIN
THE MARK



EXPLANATION

HARPER LAKE GROUNDWATER BASIN BOUNDARY

CHANGE IN GROUNDWATER LEVELS (FT) 1958-1986

SITE LOCATION

NORTH

SCALE

SOURCES

USGS FREMONT PEAK (1956), OPAL MOUNTAIN (1955), HAWES (1956), AND BARSTOW (1956) 1:62,500 SERIES
DWR BULL 84
DWR BULL 91-1
DWR BULL 91-3
DWR BULL 106-1
MOJAVE VALLEY WATER AGENCY 1983
UNPUBLISHED DWR DATA

HISTORIC CHANGE IN WATER LEVELS

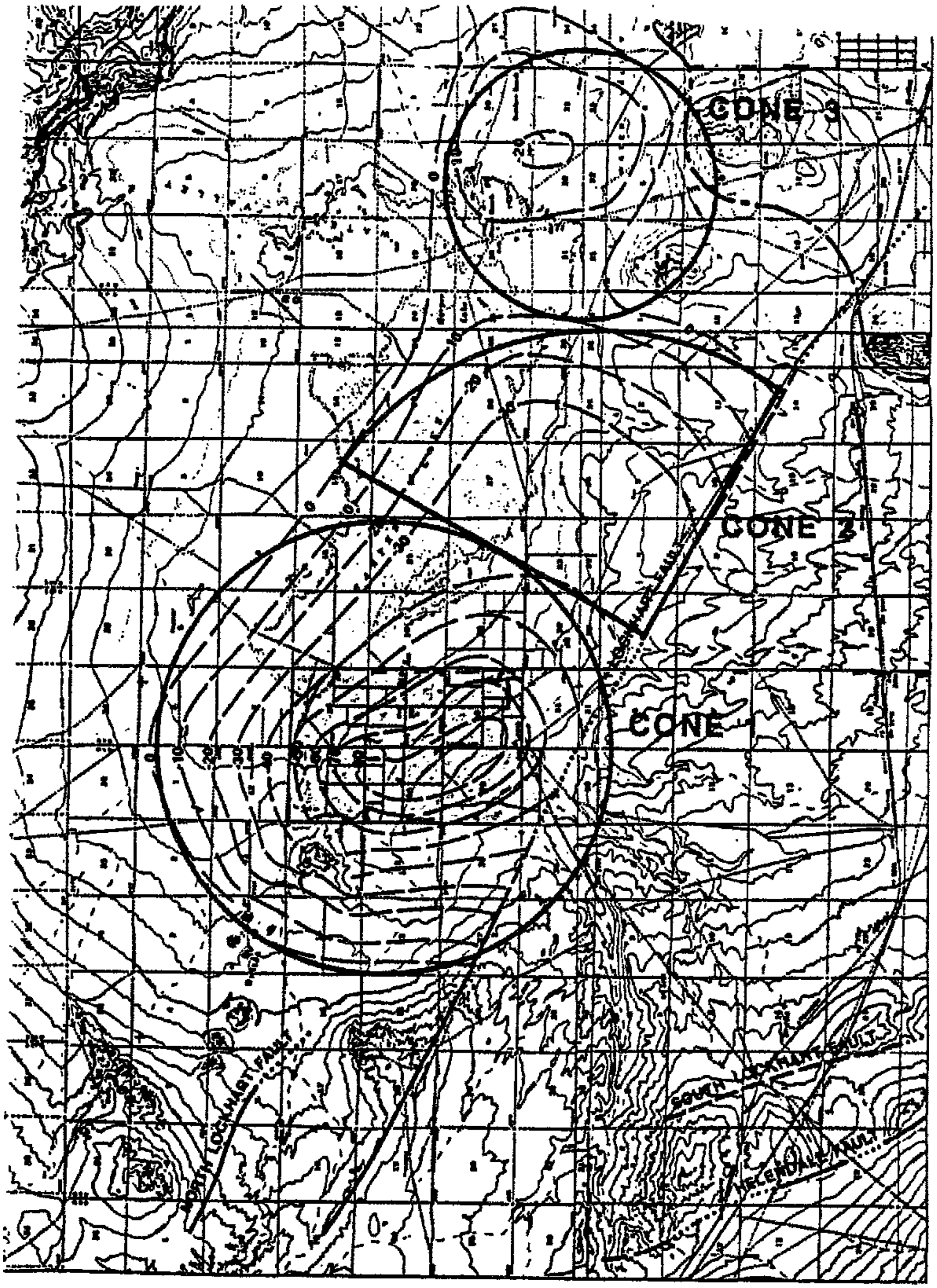
HARPER VALLEY GROUNDWATER BASIN
LUZ DEVELOPMENT
HARPER VALLEY CALIFORNIA

THE MARK GROUP
ENGINEERS & GEOLOGISTS, INC

PROJECT NO. 880321-01

DRAWING NO. 9

Prepared By: _______ Approved By: _______ Date: 2/16/87



Prepared By KJK Approved By [signature] Date 3/11/87

THE MARK GROUP
ENGINEERS & GEOLOGISTS, INC.

1953 - 1986 WATER BALANCE

HARPER VALLEY GROUNDWATER BASIN
LUZ DEVELOPMENT
HARPER VALLEY, CALIFORNIA

PROJECT NO. 88-03219.16

DRAWING NO. B-2