WESTEC Services, Inc.

VOLUME II

SALTON SEA ANOMALY
MASTER ENVIRONMENTAL IMPACT REPORT
AND
MAGMA POWER PLANT #3 (49 MW)
ENVIRONMENTAL IMPACT REPORT
APPENDICES

Prepared For

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VOLUME II

TABLE OF CONTENTS

APPENDIX 2.3

HISTORY OF LOCAL DEVELOPMENT

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The history of geothermal development in Imperial County has been well documented in several publications (Palmer, 1975; Imperial County, 1977 and 1980; SDG&E, 1980). This historical data is summarized below.

1927 to 1954

The earliest known wells were drilled on Mullet Island by Pioneer Development Company during 1927-1928 and were designated as Pioneer 1, 2 and 3. Subsequently, several wells were drilled to the east of these three Pioneers within the Imperial Carbon Dioxide Field. This field, which contained 55 shallow wells, produced carbon dioxide (CO_2) between 1933 and 1954 for two dry ice manufacturing plants. The combined effects of the rising surface level of the Salton Sea and alternatives to the ice-making process eventually resulted in the cessation of CO_2 production in the Niland area by 1954.

1955 to 1971

No known drilling activity occurred between 1955 and 1957; however, during 1957-58 Kent Imperial Corporation drilled an exploratory well hoping to find oil. They encountered hot brine and steam instead. This well, designated as Sinclair 1, is considered to be the discovery well for the Salton Sea Anomaly, and stimulated other developers to undertake drilling. P.H. O'Neill of Texas drilled the first two wells, followed by Union Oil Company with two wells, Shell Oil Company with two wells, and Natomas Company with three wells farther to the south, thus greatly expanding the proven area of the reservoir (McCabe, 1980).

Other companies playing a major role in these early exploratory and experimental efforts included Union Oil Company; Imperial Thermal Products, Inc.; Geothermal Energy and Mineral Corporation; Magma Power Company; and Morton Salt Company. At about the same time, in 1961, exploratory well drilling began at Cerro Prieto, south of Mexicali, Baja California, Mexico. These successful wells more fully demonstrated the potential for geothermal power development within the Salton Trough, which includes the Salton Sea Anomaly.

The thrust of the activities within the Salton Sea Anomaly was aimed at determining the commercial potential for chemical extraction, mineral and salt recovery from the brines, and power production. In 1959, a small power plant was constructed at Sinclair 1, but was subsequently abandoned due to excessive scaling. These early efforts were eventually thwarted by brine handling problems and the availability of lower cost alternatives. To the best of our knowledge, no deep geothermal wells were drilled between 1965 and 1971.

1972 to 1980

Between 1972 and 1980, more wells were drilled in the Salton Sea KGRA by Magma Power Co. and Union Oil. Excerpts from McCabe (1980) describe the extent of some of these efforts:

> In 1972, recognizing the increasing energy shortage, Magma Power Company decided to approach the development of the resource with a new concept. The analysis of the brine of the Kent-Imperial #1 well indicated total salinity of only 33,921 ppm. In the light of subsequent knowledge, this analysis was fallacious and evidently was publicized to help promote the sale of stock to develop the leases owned by the oil and gas promotors.
>
> Studies confirmed our belief we could handle brines with a maximum salinity of 250,000 ppm. Magma Power Company drilled Magmamax #1 in 1972 to a depth of 2267 feet. The bottom hole temperature of the well was 510°F and the salinity content after flashing was 231,300 ppm. This discovery as to temperature and total salinity was indeed a surprise. We knew that we would not be cursed by sodium chloride precipitation which, of all the chlorides present, first precipitates out of the brine at reduction of temperatures, before the calcium chloride and potassium chloride content.
>
> Magmamax #1 was followed by the drilling of Woolsey #1 to a total depth of 2400 feet, temperature 460°F, total salinity 199,000 ppm. Woolsey #5 was drilled in 1979, total depth 1475 feet, temperature 404°F, salinity 170,550 ppm. The testing of Magmamax #1 indicated the CO_2 content of the flashed steam was 16 percent by volume which inhibited power generation in a conventional condensing steam turbine. As an alternate solution to this problem, it was decided to pass the steam through a heat exchanger and transfer the contained heat to isobutane using the binary principle of power generation.
>
> New Albion Resources Co. (NARCO), a wholly-owned subsidiary of San Diego Gas & Electric Co. and our equal partner in this area, entered into an agreement with the Department of Energy to jointly fund an experimental test plant to determine the

practicality of this concept. The operation was known as the GLEF plant and was operated intermittently for a period of four years from 1975 to mid-1980.

The results obtained from the drilling and testing activities by Magma, Union, Republic, NARCO and others are discussed in the text under Section 2.4, Reservoir Characteristics and Resource Capabilities, and in Appendix B. The most thorough data gathering and testing programs during this period were conducted by San Diego Gas and Electric Company (SDG&E) at the Geothermal Loop Experimental Facility (GLEF), which was constructed between May 1975 and June 1976.

The earliest tests during the 1972 to 1979 period were aimed at determining an appropriate energy conversion cycle for a power plant within the Salton Sea KGRA. Both flash and binary cycle systems were initially considered; however, the binary cycle was felt at that time (1972) to be preferable to the flash cycle because of the anticipated high noncondensable gas content of the geothermal brines.

In 1973, a series of tests was conducted on the binary conversion cycle; however, due to a rapid decline in heat exchange caused by scaling, a combined flash/binary process replaced the binary for further testing and evaluation. By 1974, the decision was reached to introduce a four-stage, flash/binary cycle into San Diego Gas & Electric's design of the GLEF. As noted earlier, this facility was dedicated in June 1976 and comprehensive testing began, using the wells Magmamax 1 and Woolsey 1 to produce the geothermal brine.

By 1977, test results and operational difficulties at the GLEF primarily related to heavy scaling, process oscillations, brine supply problems, and low noncondensable gas content led to a decision to initiate a major reevaluation of the GLEF project. The results of this reexamination indicated that a two-stage, flash cycle process was the most appropriate for commercial development within the Salton Sea KGRA. This 1978 recommendation was substantiated by further testing at the GLEF.

In September 1979, following several months of additional testing at the GLEF, the operation was terminated, and a final testing program involving an effluent brine treatment system was initiated. Following generally successful test results on this system, all but side stream testing and other minor activities were concluded. Detailed discussions of the GLEF operation, test procedures, final results and process recommendations were then documented and published in spring 1980 (SDG&E, 1980).

Commercial development of the resource continued with applications for two power plants. Magma Power has received a permit to build and operate a 28 megawatt two-stage flash/binary power plant on the site of the GLEF (Imperial County, 1979; Magma, 1980) using some of the equipment that was tested. In addition, Southern California Edison has received a permit for a 10 MW power plant in the Salton Sea KGRA with Union Oil supplying the steam. Both of these facilities, which will represent the first commercial power plants in the Salton Sea KGRA, are currently under construction.

Other major producers are also continuing their well drilling and evaluation efforts throughout the KGRA, including Republic Geothermal, which is conducting tests on several wells within its 3900-acre leasehold areas farther east within the KGRA, in the vicinity of Niland. As of this writing, the major geothermal developers in the Salton Sea Anomaly study area include the following:

Producer	Salton Sea KGRA Geothermal Leaseholds - 1981	
Union Oil Company	30,000 ac	(12,146 ha)
Magma Power	7,500 ac	(3,036 ha)
Republic Geothermal	3,900 ac	(1,579 ha)
New Albion Resources Company (NARCO)	0	0
TOTAL	41,400 ac	(16,761 ha)

REFERENCES

Imperial, County of, 1979, Final Environmental Impact Report for Forty-nine Megawatt Geothermal Power Plant and Facilities Niland Area KGRA, #211-78, (data submitted by Magma Power Company, et al.); Supplement to Environmental Impact Report, SCH 79072515 Amending Forty-Nine Megawatt to a Twenty-Eight Megawatt Geothermal Power Plant and Facilities, Niland Area, Salton Sea KGRA.

Imperial, County of, 1977, "Geothermal Element," Imperial County General Plan, Imperial County, El Centro, California.

Magma Power Company, 1979, "Final Environmental Impact Report #211-78 for Forty-nine Megawatt Geothermal Power Plant and Facilities, Niland Area Salton Sea KGRA."

McCabe, B.C., 1980, "A Chronological History of the Technology Developments for Reliable Electric Power Generation at the Niland Geothermal Area, Imperial County, California," Magma Power Company, December 28.

Palmer, T.D., 1975, Charactristics of Geothermal Wells Located in the Salton Sea Geothermal Field, Imperial Valley, California, Lawrence Livermore Laboratory, Livermore, California, UCEL-51976, December 15.

San Diego Gas & Electric (SDG&E), 1980, Final Report, Geothermal Loop Experimental Facility, April.

APPENDIX 2.4

WELL DATA

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WELL DATA

This appendix provides an overview of the data obtained from the host of drilling and testing activities that have taken place within the Salton Sea Anomaly. Table 2.4-1, included at the end of this appendix, provides an inventory of the wells within the Anomaly along with information on each well as to its current status (active, abandoned, etc.) and any test results obtained. It represents the best data currently available to WESTEC Services but is admittedly incomplete. Our intention in providing it as an appendix to the MEIR is to publish, in one location, an up to date summary of wells and well test results which can be used not only as a reference source but also as a base upon which the County and others can accumulate, record and analyze new data.

Generally speaking, the geothermal resource at the Salton Sea Anomaly contains brine which increases in temperature and salinity as one proceeds downward from a depth of about 1200 feet (366 m) to 8100 feet (2470 m). At a depth of roughly 3500 feet (1067 m) the salinity is approximately 300,000 parts per million (ppm), increasing to roughly 350,000 ppm at 8100 feet (2470 m) (McCabe, 1980). Table 2.4-2 provides a summary of the general characteristics of the geothermal resource found at the Salton Sea Anomaly.

From the surface to about 5000 feet down (1524 m), thick and recurrent sand bodies exist. Below that depth, a schist is penetrated and the brine is produced from features in the formation (McCabe, 1980).

The following paragraphs provide a brief summary of various characteristics of the wells drilled to date within the Salton Sea Anomaly.

A. Well Depth

Part of the exploratory well drilling process was aimed at identifying an optimal and cost-effective well depth for whatever resource was being sought. The three earliest wells (Pioneer 1, 2 and 3 in 1927-28) were relatively shallow, ranging in depth from 727 feet (222 m) for Pioneer 1 to 1473 feet (449 m) for Pioneer 3. Likewise, the 55 wells which comprised the Imperial Carbon Dioxide Field and produced CO_2 from 1933 to 1954 were also known to be relatively shallow.

The wells drilled between 1958 and 1965 were considerably deeper. Most ranged in depth from 5000 to 8000 feet (1524 to 2439 m), although the last well drilled during this period (IID 3 in 1965) only reached 1696 feet (517 m). The deepest well drilled during this phase of exploration was River Ranch 1 in 1964, which reached 8098 feet (2469 m).

Table 2.4-2

SALTON SEA ANOMALY
GENERAL RESOURCE CHARACTERISTICS AND RELATED DATA

Resource Characteristic	Average	Range
Depth to Reservoir Basement:	6000 ft (1829 m)[3]	N/A
Well Depth:		
1972 to 1980	3108 ft (948 m)[1,6]	2400 to 4368 ft (732-1332 m)[1,6]
Temperature:		
Downhole	500°F (260°C)[8]	370°F to 680°F ($188-360^\circ$C)[7]
Wellhead	375°F (191°C)[5]	370°F to 406°F (188°C to 208°C)[6]
Salinity (TDS in ppm):	225,000[5]	200,000 to 350,000[2,3]
Flow Rate (Mass Flow):	400,000 lb/hr[5] (181,000 kg/hr)	100,000 to 625,500 lb/hr[3] (45,000 to 283,000 kg/hr)
Pressure (psi at wellhead):	150[5]	18 to 585[3] 120 to 285[5]
Steam Content (percent by weight):	15[8]	N/A
Noncondensable Gases (percent by weight):	<1[5]	0.12 to 3[4,5,6]
Fluid Enthalpy (cal/g):	243[2]	210 to 285[2]

N/A = Not Available

Sources:

1. Palmer, 1975
2. Division of Oil and Gas, 1975
3. Imperial County, 1977
4. Ermak, 1977
5. SDG&E, 1980
6. Well Data (see Table B-2)
7. Based on 14 wells drilled to depths of 1600 to 8000 feet (480-2400 m) (Palmer 1975)
8. Geothermal developers' consensus

The last series of exploratory and production wells that was drilled (1972 to the present) was directed at determining the best method of extracting heat from the geothermal reservoir. These later wells, and those being drilled today, tend to range from about 2000 feet to as much as 6000 feet in depth (608 to 1829 m). For example, as shown in Table 2.4-1, the two wells used for production purposes at the GLEF, Magmamax 1 and Woolsey 1, were 2267 feet and 2401 feet, respectively (691 m and 732 m), although Woolsey 1 was later extended to 3490 feet (1064 m).

B. Downhole Temperature

As would be expected, the downhole temperatures encountered tend to vary with depth and with distance from the center of the Anomaly. (This can be better understood from the depth versus temperature tables contained in Palmer, 1975.) The earliest (and shallowest) wells encountered geothermal brine temperatures of roughly 244°F (118°C). In terms of a temperature gradient, this equates to roughly 31°F (16°C) per 100 feet of depth. Wells drilled during the middle exploratory period (1958-1965) obtained downhole temperatures of 398°F to 680°F (203°C to 360°C). The maximum temperature encountered was 680°F (360°C) at Elmore 1, which was drilled to a depth of 7118 feet (2170 m). The deepest well (8090 feet; 2466 m) obtained a downhole temperature of 653°F (345°C). Temperature gradients for these wells were about 41°F (21°C) per 100 feet of depth. The shallowest well drilled during this period encountered a downhole temperature of 362°F (183°C) at 1696 feet (517 m).

The more recent series of wells which were drilled between 1972 and 1979 recorded temperatures generally in the 460°F to 540°F range (238°C to 282°C), although Magmamax 3 drilled in 1972 recorded a downhole temperature of 580°F (304°C) at 4002 feet (1220 m). Temperature gradients for these wells averaged just under 48°F (27°C) per 100 feet of depth.

Without developing a three-dimensional model (temperature versus depth versus distance from the center of the anomaly), it is possible to draw some general conclusions regarding temperature versus location by holding well depth constant or by examining Palmer's depth versus temperature charts (1975). Figure 2.4-1 of the MEIR indicated that the center of the Niland Anomaly was in the vicinity of the Salton Buttes. Wells nearest the Buttes of which we are currently aware are those drilled in the early sixties. Of these, three were drilled to roughly 5000 feet (1524 m): Sportsman 1 (4723 feet; 1440 m); IID 1 (5232 feet; 1595 m); and State of California 1 (4838 feet; 1475 m). The average downhole temperature encountered at these three wells was 600°F (316°C). Roughly four miles south-southeast of these wells, two other wells were drilled to roughly the same depth during the same period: Sinclair 1 (3800 feet; 1159 m) and Sinclair 4 (5304 feet; 1617 m). The average temperature obtained at these wells was 495°F (257°C) which is considerably cooler than those drilled nearer the indicated center of the Anomaly.

The wells drilled in recent years (1972-1979) are located roughly three miles southeast of the earlier, hotter wells. However, except for Magmamax 2 at 4303 feet (1312 m) and Magmamax 3 (4002 feet; 1220 m), they are all considerably shallower than the series drilled during the 1960s, thus limiting their use for comparative purposes. Temperatures obtained at Magmamax 2 were roughly 532°F (278°C), which is generally comparable to the results discussed above. On the other hand, the downhole temperature of 580°F (304°C) obtained at Magmamax 3 at 4002 feet (1220 m) would seem somewhat inconsistent with the pattern of lower temperatures at greater distance from the center of the anomaly.

One final note regarding the downhole temperatures shown in Table 2.4-1 should be made. The average temperature of 640°F (340°C) was obtained from the County's Geothermal Element (Imperial County, 1977). Based on an examination of available test results, this figure seems somewhat high. The only temperatures recorded from existing wells that met or exceeded 640°F (340°C) were encountered at River Ranch 1 (653°F; 345°C) and Elmore 1 (680°F; 360°C). Both of these wells were drilled to depths beyond 7000 feet (2134 m), which is considerably greater than the wells that will probably be used for the production of power within the Salton Sea KGRA. A more reasonable figure, based on an average production well depth of about 2600 feet (793 m), would be about 500°F (260°C). This figure has been used throughout the MEIR as a representative downhole temperature within the Anomaly.

C. Salinity

The County's Geothermal Element indicated a total dissolved solids (TDS) range of 250,000 to 350,000 parts per million (ppm) within the Salton Sea Anomaly. Ermak (1977), on the other hand, produced an estimate of 200,000 ppm. Actual test results obtained at the GLEF recorded a salinity range for the geothermal brine of 200,000 to 245,000 ppm, and 40,000 to 80,000 ppm for the steam portion of the resource. Sodium, calcium and potassium salts were the major constituents.

Limited TDS data obtained from the exploratory wells drilled during the early sixties ranged from a low of 183,700 ppm at Sinclair 3 to a high of 387,500 ppm at Sinclair 4, roughly one-half mile distant. No discernible patterns related to salinity versus well depth or salinity versus location within the Anomaly were apparent from these data.

D. Flow Rates

The only well-documented information on flow rates is contained in Palmer, 1975 and in the final report on the GLEF (SDG&E, 1980), although Imperial County's Geothermal Element indicates a probable range of 100,000 to 625,500 pounds per hour (45,000-283,000 kg/hr). Initial flow rates obtained from the test wells at the GLEF site in 1972 averaged roughly 400,000 pounds per hour total mass flow (181,000 kg/hr). Those documented in Palmer (1975) for ten selected wells range from a low of 172,000 lb/hr (78,000 kg/hr) at IID 1 in 1965 to a high of 625,500 at the same well three years earlier. Design criteria for the 10 MW power plant proposed by Union Oil/SCE utilize a flow figure of 400,000 lbs/hr, which is expected to decline to approximately 300,000 lb/hr over a 30-year period (Imperial County, 1980).

E. Wellhead Pressure

Again, the only well-documented data regarding wellhead pressure test results were those contained in Palmer (1975) and those drilled at the GLEF site. Early tests at the GLEF (1972 to 1974) showed the "wellhead temperature and pressure remaining stable at 375^{o}F (190^{o}C) and 150 psig" (SDG&E, 1980). A five-day test at Woolsey 1 in 1976 produced a wellhead pressure of 120 psi. During 1977 pressure from the same well was recorded at 200 psi and in 1979 at 150 psi. A 350-hour test at Magmamax 2 produced a wellhead pressure of 280 psi in 1979. Also, based on tests conducted during 1979, pressure at Magmamax 1 was found to vary between 250 and 285 psi. Those documented in Palmer (1975) were 96 to 585 psi. A range of 18 to 585 psi was indicated in the County's Geothermal Element; however, for production purposes, it is probably more realistic to assume a range of 120 to 285 psi at the wellhead.

F. Noncondensable Gases

A ten-day flow test by Magma/NARCO in 1972 at one of the production wells on the GLEF site produced a brine mixture which contained three percent noncondensable gases by weight. Of the total noncondensable gases, carbon dioxide was found to be the major component by far (98 percent), with hydrogen sulfide (H_2S) constituting only 0.25 percent of the noncondensable gases. Further testing at the GLEF wells produced considerably lower percentages for noncondensable gases. The final report (SDG&E, 1980) estimated that much less than one percent (0.12 percent) of the geothermal brine consisted of noncondensable gases. This range of expectation is also reflected in the Union Oil/SCE EIR for the 10 MW plant, which states that "the total noncondensable gases could constitute as much as two percent by weight of steam, but is likely to be much less." Regarding the composition of the noncondensable gases themselves, it goes on to state that they "will consist primarily of carbon dioxide (CO_2) with small concentrations of nitrogen (N_2), methane (CH_4), and hydrogen sulfide (H_2S)" (Imperial County, 1980).

G. Other Test Results

The following excerpts from McCabe (1980) provide some insight into the problems associated with developing the geothermal resource at the Salton Sea KGRA and some of the solutions that have been developed as a result of years of testing:

> Two important dividends of knowledge resulting from the GLEF operation are that the CO_2 content of the brine through field operation is rapidly exhausted to about the same amount of incondensable gases found in the steam of the Big Geysers Project, and it has proven that the steam produced could be cleaned of any contaminants to about 5 ppm, a fine quality for steam turbine generation.
>
> Other interesting facets of technical information were studied and ascertained. The most difficult problem to resolve was the deposition of silica which continued to deposit in proportion to reduction of temperatures. This not only caused plugging and clogging of all the piping in the plant that was in contact with the brine, but of a more serious nature was the plugging of the injection wells. Magma realized that unless this was corrected, all hope of successful and reliable power generation would have to be abandoned.
>
> It is interesting to note the sequential factors of the evolution of this achievement and how this important problem has been solved. Magma's field operators observed that the brine residing in the Baker tanks for several months had not caused any corrosion. This was an empirical observation of great signficance, because we had constantly heard from all the experts we had contacted that discharged brine would absorb oxygen through contact with air and the corrosion therefrom would be so intense that the piping in our injection wells would rapidly disintegrate.
>
> Upon observing the results of what occurred when the brine was exposed to air, we vigorously proceeded to ascertain from qualified people the fact that at a total chloride content of 250,000 ppm oxygen absorption was nil. The Saturation Tables indicate oxygen absorption in a saline solution rapidly increases from distilled water to 35,000 ppm then decreases as the chlorides increase. The salinity of

the ocean has 35,000 ppm. This phenomenon of nature seems to be divinely designed in order to maintain life in the ocean and to dissolve adverse contaminants.

Magma observed that silica grew very rapidly on crystals previously precipitated and, therefore, experimented with a filter filled with steel filings. Upon testing, this filter promptly clogged with precipitated silica. Mr. John Featherstone, a competent chemist in the joint employ of NARCO and Magma Power, then conceived the use of a rotary clarifier whereby the silica in solution had the opportunity to contact silica crystals previously precipitated. A clarifier was bought and thoroughly tested, and it confirmed the practicality of this conception. The effluent was reduced to the order of 10 ppm which would cause no clogging of the injection wells. The GLEF operation then proceeded to install a larger clarifier where the results of the smaller unit were consistently confirmed.

There was yet another problem existing, and that was the precipitation of silica in the piping and steam separators. Mr. John Featherstone then conceived the utilization of a combination separator and crystallizer being constantly charged and seeded with silica obtained from the clarifier. Extensive experiments through a pilot crystallizer have proven the practicality and adaptability of this conception. The conception has eliminated the problem of deposition of silica in the crystallizer-steam separator and through the piping of the plant to the point of discharge into the clarifier.

In order to utilize the heat energy of the resource below 3000 feet, it was imperative that a method be conceived that would reduce the chloride content of the brine to less than 250,000 ppm. The temperature of the brine in the lower section ranges from 550°F to 625°F. The concept was developed of diluting this brine with a fluid of very low chloride content so as to reduce total saline solids to less than 250,000 ppm. Fortunately, at the resource there are three potential sources of such diluent, namely: Salton Sea water which has a salinity of 35,000 ppm, ditch or Alamo River water of approximately 3000 ppm, or condensate produced by the condensation of the steam produced by plant operation. The condensates are very valuable cooling waters so, therefore, it has been determined that to use ditch or Alamo River water is the preferable source of the supply of diluent.

The mixing of the diluent with the hot brine can be accomplished either subsurfacely or at the surface. We are convinced that the ideal place of mixing would be directly into the crystallizer because at that point any sulfates present would be associated with the silica seed and, therefore, would not precipitate. This phenomenon was determined by mixing Salton Sea water, which is heavy in sulfates, with saline brines directly into the clarifier where it was determined that the sufates precipitated out of the solution. The diluent water can easily be deoxygenated by raising the temperature to boiling prior to introduction into the crystallizer.

Table 2.4-1

SALTON SEA ANOMALY WELL INVENTORY AND CURRENT STATUS

WELL CHARACTERISTICS	Pioneer 1	Pioneer 2	Pioneer 3	Salton Sea Chemical Products 1	Salton Sea Chemical Products 5
Location (Sec, T&R)	10,11S,13E	10,11S,13E	10,11S,13E	28,11S,13E	25,11S,13E
Status[1]	ADN	ADN	ADN	ADN	ADN
Current Operator (previous operator if inactive well)	Pioneer Dvlpt.	Pioneer Dvlpt.	Pioneer Dvlpt.	Salton Sea Chemical Corp.	Salton Sea Chemical Corp.
Year Completed	1927	1927	1928	1932	1933
Map Reference No.	1	2	3	10	11
Depth - ft (m)	727 (222)	1263 (385)	1473 (449)	1054 (321)	960 (293)
Temperature: Downhole - °F(°C) Wellhead	244 (118)	180 (82)	154 (68)		
Salinity (TDS in ppm)			110,000		
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH			6.5		
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

Status:

P	-	Proposed but not yet approved.
A	-	Approved but not yet drilled.
ADA	-	Approved and drilled; currently in active use.
ADN	-	Approved and drilled; abandoned or not currently in active use.
ADR	-	Approved and drilled; currently used for reinjection

WELL CHARACTERISTICS	Pioneer 1	Pioneer 2	Pioneer 3	Salton Sea Chemical Products 1	Salton Sea Chemical Products 5
Chemical Analysis of Brine (ppm)					
Aluminum (Al)					
Ammonia (NH_4)					
Antimony (Sb)					
Arsenic (As)					
Barium (Ba)					
Boron (B)					
Bromine (Br)					
Calcium (Ca)			16,000		
Cesium (Cs)					
Chlorine (Cl)			68,000		
Chromium (Cr)					
Cobalt (Co)					
Copper (Cu)					
Florine (F)					
Iodine (I)					
Iron (Fe)					
Lead (Pb)					
Lithium (Li)					
Magnesium (Mg)					
Manganese (Mn)			4,000		
Nickel (Ni)					
Nitrate (NO_3)			1,050		
Potassium (K)					
Radon (Rn) 222					
Rubidium (Rb)					
Silica (SiO_2)					
Silver (Ag)					
Sodium (Na)			20,400		
Strontium (Sr)					
Sulfate (SO_4)			200		
Sulfur (S)					
Tin (Sn)					
Zinc (Zn)					

WELL CHARACTERISTICS	Imperial CO_2 Field (55 Wells)	Chandler/ Staton 1	Sinclair 1	Sportsman 1	IID 1
Location (Sec, T&R)		19,11S,14E	10,12S,13E	23,11S,13E	23,11S,13E
Status[1]	ADN	ADN	ADN	ADN	ADN
Current Operator (previous operator if inactive well)		Chandler & Staton	Kent Imperial	J.P. O'Neill	Imperial Magma
Year Completed	1933-54	1935	1958	1961	1962
Map Reference No.	12	8	4	81	33
Depth - ft (m)	Shallow	590 (180)	4725 (1441)	4729 (1442)	5232 (1595
Temperature: Downhole - °F(°C) Wellhead			561 (294)	590 (310)	622 (328)
Salinity (TDS in ppm)				334,987	278,000
Average Flow Rate (lb/hr)				315,000	445,000
Average Flow Rate (gpm)					
Pressure (psi at wellhead)				218	385
Steam Content (% by Weight)				16	14
Fluid Enthalpy (cal/g)				220	235
CO_2 as HCO_3					>150
pH				4.82-6.10	4.5
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

Status:

P - Proposed but not yet approved.
A - Approved but not yet drilled.
ADA - Approved and drilled; currently in active use.
ADN - Approved and drilled; abandoned or not currently in active use.
ADR - Approved and drilled; currently used for reinjection

WELL CHARACTERISTICS	Imperial CO_2 Field (55 Wells)	Chandler/ Staton 1	Sinclair 1	Sportsman 1	IID 1
Chemical Analysis of Brine (ppm)					
Aluminum (Al)					450
Ammonia (NH_4)					446
Antimony (Sb)					<1
Arsenic (As)					13
Barium (Ba)				149	218
Boron (B)					522
Bromine (Br)					133
Calcium (Ca)				34,470	30,500
Cesium (Cs)					19
Chlorine (Cl)				201,707	168,000
Chromium (Cr)					
Cobalt (Co)					
Copper (Cu)					9
Florine (F)					17
Iodine (I)					20
Iron (Fe)				4,200	2,677
Lead (Pb)					94
Lithium (Li)				150	258
Magnesium (Mg)				18	192
Manganese (Mn)					1,223
Nickel (Ni)					
Nitrate (NO_3)					35
Potassium (K)				24,000	18,200
Radon (Rn) 222					
Rubidium (Rb)					153
Silica (SiO_2)				5	137
Silver (Ag)					1
Sodium (Na)				70,000	55,500
Strontium (Sr)					675
Sulfate (SO_4)				34	30
Sulfur (S)					16
Tin (Sn)					
Zinc (Zn)					880

WELL CHARACTERISTICS	Sinclair 3	IID 2	River Ranch 1	State of California 1	Elmore 1
Location (Sec, T&R)	10,12S,13E	22,11S,13E	24,11S,13E	23,11S,13E	27,11S,13E
Status[1]	ADN	ADN	ADN	ADN	ADA
Current Operator (previous operator if inactive well)	Kent Imperial Corp.	Imperial Thermal Prod.	Imperial Magma	Imperial Thermal Prod.	
Year Completed	1963	1963	1964	1964	1964
Map Reference No.	8	34	45	46	47
Depth - ft (m)	6922 (2110)	5826 (1776)	8098 (2469)	4848 (1478)	7118 (2170)
Temperature: Downhole - °F(°C) Wellhead	536 (280)	626 (330)	653 (345)	590 (310)	680 (360)
Salinity (TDS in ppm)	183,700	258,765	245,000	219,500	
Average Flow Rate (lb/hr)	593,000	377,000		358,000	316,000
Average Flow Rate (gpm)					
Pressure (psi at wellhead)	185	228		404	
Steam Content (% by Weight)	12	16	20	18	35
Fluid Enthalpy (cal/g)	240	235	250	280	285
CO_2 as HCO_3	60			6,900	129
pH	4.8				5.2
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Sinclair 3	IID 2	River Ranch 1	State of California 1	Elmore 1
Chemical Analysis of Brine (ppm)					
Aluminum (Al)					0.7
Ammonia (NH_4)	455				
Antimony (Sb)					
Arsenic (As)	10				
Barium (Ba)	555	250		90	68
Boron (B)	210	390		290	
Bromine (Br)					
Calcium (Ca)	18,775	28,800		21,200	16,980
Cesium (Cs)		20		17	
Chlorine (Cl)	117,575	155,000		127,000	106,600
Chromium (Cr)					0.8
Cobalt (Co)					2.4
Copper (Cu)	1	3		2	0.7
Florine (F)	3.5				
Iodine (I)					
Iron (Fe)		2,000		1,200	127
Lead (Pb)	140	80		80	28
Lithium (Li)	65	210		80	125
Magnesium (Mg)	1,360	10		27	53
Manganese (Mn)	705	1,370		950	256
Nickel (Ni)					2.5
Nitrate (NO_3)					
Potassium (K)	10,510	16,500		14,000	4,231
Radon (Rn) 222					
Rubidium (Rb)				65	
Silica (SiO_2)					208
Silver (Ag)					
Sodium (Na)	43,470	53,000		47,800	40,400
Strontium (Sr)	435	440			350
Sulfate (SO_4)	58				35
Sulfur (S)		30		30	
Tin (Sn)					69
Zinc (Zn)		500		500	143

WELL CHARACTERISTICS	Sinclair 4	Hudson 1	IID 3	Magmamax 1	Woolsey 1
Location (Sec, T&R)	4,12S,13E	13,11S,13E	23,11S,13E	33,11S,13E	33,11S,13E
Status[1]	ADN	ADN	ADN	ADA	ADA
Current Operator (previous operator if inactive well)	Kent Imperial Corp.	Imperial Magma	Imperial Thermal Prod.	Imperial Magma	Magma Power Co.
Year Completed	1964	1964	1965	1972	1972
Map Reference No.	7	48	35	49	53
Depth - ft (m)	5304 (1617)	6141 (1872)	1696 (517)	2805 (855)	2401 (732)
Temperature: Downhole - °F(°C) Wellhead	500 (260)	500 (260)	392 (200)	510 (266) 370 (188)	460 (238) 384 (196)
Salinity (TDS in ppm)	327,030		35,600	231,300	199,000
Average Flow Rate (lb/hr)	450,000	432,000		410,000	298,000
Average Flow Rate (gpm)				550	400
Pressure (psi at wellhead)	250			150	120
Steam Content (% by Weight)	20	22		13	
Fluid Enthalpy (cal/g)	210	225	250		N/A
CO_2 as HCO_3			1,880		
pH	5.2		7.5	6.65	6.3
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Sinclair 4	Hudson 1	IID 3	Magmamax 1	Woolsey 1
Chemical Analysis of Brine (ppm)					
Aluminum (Al)	<100		2		
Ammonia (NH_4)			321		
Antimony (Sb)					
Arsenic (As)	10		<1		
Barium (Ba)	1,100		3		
Boron (B)	332		100	500	
Bromine (Br)	25		15		
Calcium (Ca)	26,138		1,130	25,000	9,500
Cesium (Cs)					
Chlorine (Cl)	182,645		19,700	20,548	64,000
Chromium (Cr)					
Cobalt (Co)					
Copper (Cu)	3				
Florine (F)	14		1		
Iodine (I)	13		5		
Iron (Fe)	1,224		<1	93	156
Lead (Pb)	60				
Lithium (Li)	344		40	28	73
Magnesium (Mg)	1,363		74	46	300
Manganese (Mn)			6	200	253
Nickel (Ni)					
Nitrate (NO_3)	5		9		
Potassium (K)	15,500		1,250	5,000	4,149
Radon (Rn) 222					
Rubidium (Rb)					
Silica (SiO_2)	358		120	500	145
Silver (Ag)	<1				
Sodium (Na)	56,891		10,600	52,500	42,394
Strontium (Sr)	445		85		
Sulfate (SO_4)	47		621		
Sulfur (S)					
Tin (Sn)					
Zinc (Zn)	600				

WELL CHARACTERISTICS	Magmamax 3	Magmamax 2	Magmamax 4	Elmore 3	Landers 1
Location (Sec, T&R)	33,11S,13E	33,11S,13E	33,11S,13E	27,11S,13E	20,12S,13E
Status[1]	ADR	ADR	ADA	ADA	ADA
Current Operator (previous operator if inactive well)	Imperial Magma	Imperial Magma	Imperial Magma	Imperial Magma	Mapco Geothermal
Year Completed	1972	1972	1972	1974	
Map Reference No.	51	50	52	71	76
Depth - ft (m)	4002 (1220)	4368(1332)	2567 (783)	2510 (765)	
Temperature: Downhole - °F(°C) Wellhead	580 (304)	532 (278) 407 (208)	464 (240)		
Salinity (TDS in ppm)				196,860	
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)		900			
Pressure (psi at wellhead)		280			
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)	N/A	N/A	N/A		
CO_2 as HCO_3				114	
pH				5.67	
Non-Condensable Gases (% by Weight) total of well fluid:				0.15	
Nitrogen				2.25	
Methane				0.77	
Carbon Dioxide				96.98	
Hydrogen Sulfide (H_2S)				nd	
H_2S as a % of noncondensable gas				nd	

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WELL CHARACTERISTICS	Magmamax 3	Magmamax 2	Magmamax 4	Elmore 3	Landers 1
Chemical Analysis of Brine (ppm)					
Aluminum (Al)				0.2	
Ammonia (NH_4)				414	
Antimony (Sb)					
Arsenic (As)					
Barium (Ba)				66	
Boron (B)					
Bromine (Br)					
Calcium (Ca)				18,914	
Cesium (Cs)					
Chlorine (Cl)				106,729	
Chromium (Cr)				0.9	
Cobalt (Co)				2.5	
Copper (Cu)				0.6	
Florine (F)					
Iodine (I)					
Iron (Fe)				127	
Lead (Pb)				29	
Lithium (Li)				125	
Magnesium (Mg)				439	
Manganese (Mn)				334	
Nickel (Ni)				2.5	
Nitrate (NO_3)					
Potassium (K)				4,504	
Radon (Rn) 222					
Rubidium (Rb)					
Silica (SiO_2)				152	
Silver (Ag)					
Sodium (Na)				37,346	
Strontium (Sr)				382	
Sulfate (SO_4)					
Sulfur (S)					
Tin (Sn)				76	
Zinc (Zn)				246	

WELL CHARACTERISTICS	Landers 2	Landers 3	Sardi 1	Biff 1	Woolsey 5
Location (Sec, T&R)	20,12S,13E	20,12S,13E	24,12S,13E	24,12S,13E	
Status[1]	ADA	ADR	ADN	ADN	
Current Operator (previous operator if inactive well)	Mapco Geothermal	Mapco Geotherma	Sardi Oil Co.	Sardi Oil Co.	
Year Completed					1979
Map Reference No.	77	78	79	80	
Depth - ft (m)					1475 (450)
Temperature: Downhole - °F(°C) Wellhead					404 (207)
Salinity (TDS in ppm)					170,550
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Sinclair 13	Sinclair 15	IID 5	IID 6	Fee 1
Location (Sec, T&R)	5,12S,13E	5,12S,13E	5,12S,13E	5,12S,13E	17,11S,14E
Status[1]	ADA	ADA	ADA	ADA	ADA
Current Operator (previous operator if inactive well)	Union Oil	Union Oil	Union Oil	Union Oil	Republic Geothermal
Year Completed	1980	1979-80	1979-80	1979-80	1979-80
Map Reference No.	16	18	37	38	56
Depth - ft (m)					
Temperature: Downhole - $^oF(^oC)$ Wellhead					
Salinity (TDS in ppm)					
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Britz 3	Sinclair 10	Sinclair 11	Sinclair 12	Sinclair 14
Location (Sec, T&R)	20,11S,14E	4,12S,13E	4,12S,13E	5,12S,13E	8,12S,13E
Status[1]	ADA	A	A	A	A
Current Operator (previous operator if inactive well)	Republic Geotherm-al	Union Oil	Union Oil	Union Oil	Union Oil
Year Completed	1979-80	Proposed	Proposed	Proposed	Proposed
Map Reference No.	66	13	14	15	17
Depth - ft (m)					
Temperature: Downhole - $^{o}F(^{o}C)$ Wellhead					
Salinity (TDS in ppm)					
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Sinclair 16	Sinclair 17	Sinclair 18	Sinclair 19	Sinclair 20
Location (Sec, T&R)	5,12S,13E	5,12S,13E	5,12S,13E	5,12S,13E	5,12S,13E
Status[1]	A	A	A	A	A
Current Operator (previous operator if inactive well)	Union Oil	Union Oil	Union Oil	Union Oil	Union Oil
Year Completed	Proposed	Proposed	Proposed	Proposed	Proposed
Map Reference No.	19	20	21	22	23
Depth - ft (m)					
Temperature: Downhole - °F(°C) Wellhead					
Salinity (TDS in ppm)					
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Sinclair 21	Sinclair 22	Sinclair 23	Sinclair 24	Sinclair 25
Location (Sec, T&R)	4,12S,13E	4,12S,13E	4,12S,13E	8,12S,13E	5,12S,13E
Status[1]	A	A	A	A	A
Current Operator (previous operator if inactive well)	Union Oil	Union Oil	Union Oil	Union Oil	Union Oil
Year Completed	Proposed	Proposed	Proposed	Proposed	Proposed
Map Reference No.	24	25	26	27	28
Depth - ft (m)					
Temperature: Downhole - °F(°C) Wellhead					
Salinity (TDS in ppm)					
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Sinclair 26	Sinclair 27	Sinclair 28	Sinclair 29	IID 7
Location (Sec, T&R)	9,12S,13E	8,12S,13E	8,12S,13E	9,12S,13E	32,11S,13E
Status[1]	A	A	A	A	A
Current Operator (previous operator if inactive well)	Union Oil	Union Oil	Union Oil	Union Oil	Union Oil
Year Completed	Proposed	Proposed	Proposed	Proposed	Proposed
Map Reference No.	29	30	31	32	39
Depth - ft (m)					
Temperature: Downhole - °F(°C) Wellhead					
Salinity (TDS in ppm)					
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	IID 8	IID 9	IID 10	IID 11	IID 12
Location (Sec, T&R)	33,11S,13E	5,12S,13E	5,12S,13E	5,12S,13E	5,12S,13E
Status[1]	A	A	A	A	A
Current Operator (previous operator if inactive well)	Union Oil	Union Oil	Union Oil	Union Oil	Union Oil
Year Completed	Proposed	Proposed	Proposed	Proposed	Proposed
Map Reference No.	40	41	42	43	44
Depth - ft (m)					
Temperature: Downhole - $^oF(^oC)$ Wellhead					
Salinity (TDS in ppm)					
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Fee 2	Fee 3	Fee 4	Fee 5	Fee 6
Location (Sec, T&R)	17,11S,14E	17,11S,14E	17,11S,14E	17,11S,14E	17,11S,14E
Status[1]	ADA	A	A	A	A
Current Operator (previous operator if inactive well)	Republic Geo-thermal	Republic Geo-thermal	Republic Geo-thermal	Republic Geo-thermal	Republic Geo-thermal
Year Completed	1980				
Map Reference No.	57	58	59	60	61
Depth - ft (m)					
Temperature: Downhole - °F(°C) Wellhead					
Salinity (TDS in ppm)					
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Fee 7	Fee 8	Britz 1	Britz 2	Britz 4
Location (Sec, T&R)	17,11S,14E	17,11S,14E	0,11S,14E	0,11S,14E	0,11S,14E
Status[1]	A	A	A	A	A
Current Operator (previous operator if inactive well)	Republic Geo-thermal	Republic Geo-thermal	Republic Geo-thermal	Republic Geo-thermal	Republic Geo-thermal
Year Completed					
Map Reference No.	62	63	64	65	67
Depth - ft (m)					
Temperature: Downhole - °F(°C) Wellhead					
Salinity (TDS in ppm)					
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Britz 5	Britz 6	Elmore 2	Elmore 4	Elmore 5
Location (Sec, T&R)	0,11S,14E	0,11S,14E	27,11S,13E	26,11S,13E	27,11S,13E
Status[1]	A	A	A	A	A
Current Operator (previous operator if inactive well)	Republic Geo-thermal	Republic Geo-thermal	Imperial Magma	Imperial Magma	Imperial Magma
Year Completed					
Map Reference No.	68	69	70	82	83
Depth - ft (m)					
Temperature: Downhole - °F(°C) Wellhead					
Salinity (TDS in ppm)					
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Elmore 6	Elmore 7	Elmore 8	Wiest 1	Wiest 2
Location (Sec, T&R)				26,11S,13E	26,11S,13E
Status[1]	Never Processed	Never Processed	Never Processed	A	A
Current Operator (previous operator if inactive well)	Imperial Magma	Imperial Magma	Imperial Magma	Imperial Magma	Imperial Magma
Year Completed					
Map Reference No.	84	85	86	87	88
Depth - ft (m)					
Temperature: Downhole - °F(°C) Wellhead					
Salinity (TDS in ppm)					
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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WELL CHARACTERISTICS	Wiest 3	Baretta 1	River Ranch 2	Sinclair 2	
Location (Sec, T&R)	26,11S,13E	27,11S,13E	25,11S,13E	10,12S,13E	
Status[1]	A	A	A	ADN	
Current Operator (previous operator if inactive well)	Imperial Magma	Imperial Magma	Imperial Magma	Kent Imperial Corp.	
Year Completed				1961	
Map Reference No.	89	90	91	5	
Depth - ft (m)				2363 (720)	
Temperature: Downhole - °F(°C) Wellhead					
Salinity (TDS in ppm)					
Average Flow Rate (lb/hr)					
Average Flow Rate (gpm)					
Pressure (psi at wellhead)					
Steam Content (% by Weight)					
Fluid Enthalpy (cal/g)					
CO_2 as HCO_3					
pH					
Non-Condensable Gases (% by Weight)					
Nitrogen					
Methane					
Carbon Dioxide					
Hydrogen Sulfide (H_2S)					
H_2S as a % of noncondensable gas					

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APPENDIX 2.6-1

WELL DRILLING PROCEDURES

APPENDIX 2.6-1
WELL DRILLING PROCEDURES

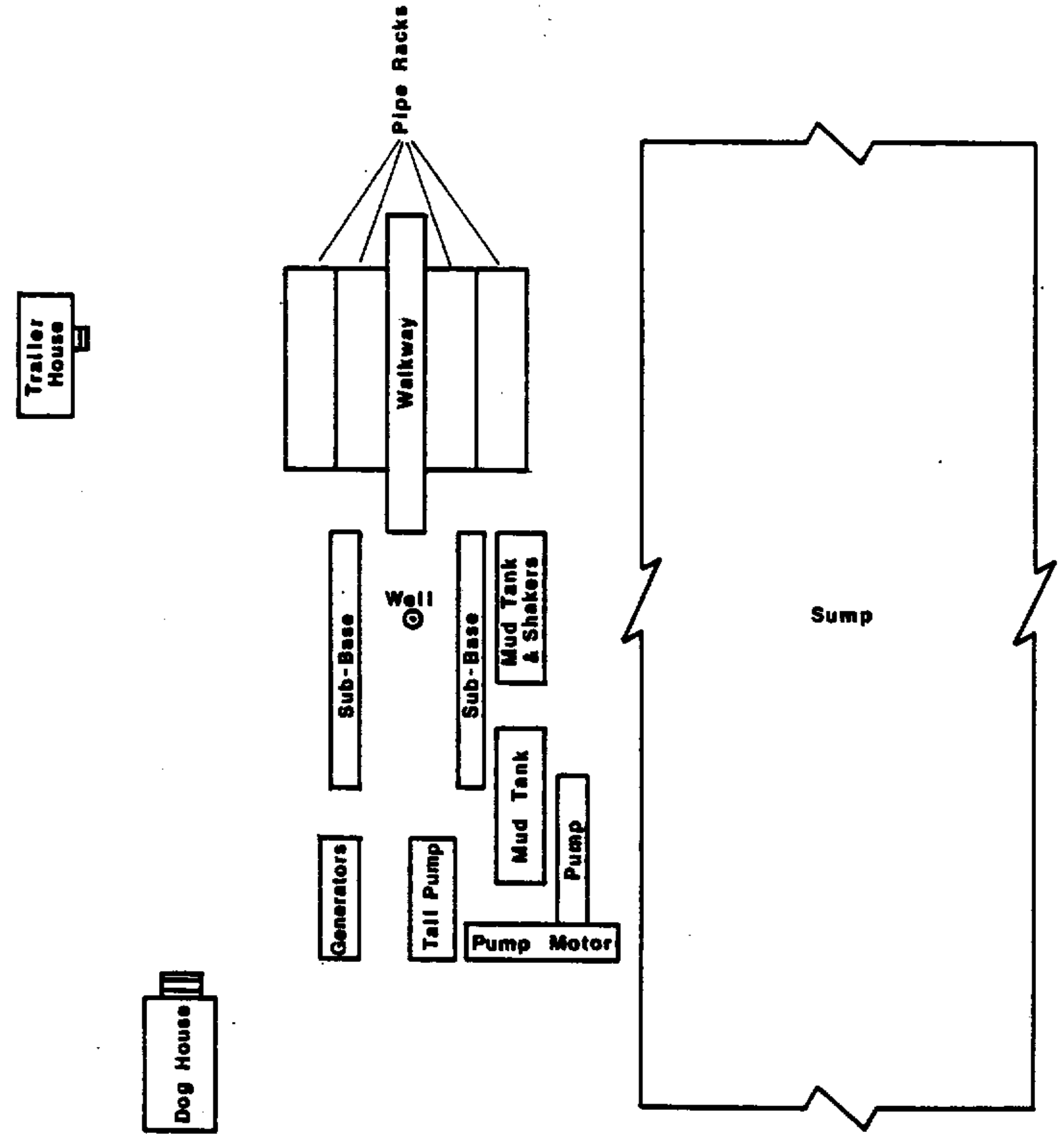
A topview of a typical drillsite layout during drilling operations is shown on Figure 2.6-1-1. The relative locations of the wellhead, drilling equipment, drilling sump, and ancillary features are illustrated. Figure 2.6-1-2 depicts a side view of a typical drilling rig and pad. Drilling operations are carried on 24 hours a day, 7 days a week until the total depth is reached. An estimated 3 to 5 weeks will be required to drill each well and approximately 12 to 15 persons will be working at each site at any one time. Well drilling operations are regulated by the California Division of Oil and Gas (CDOG). CDOG regulations cover the drilling program, the casing program and the provision of blowout protection equipment (BOPE).

The proposed wells will be drilled with a rotary drilling rig. Though exact conditions may vary somewhat from those mentioned below due to drilling rig availability, it is anticipated that the rotary drilling rig used will have a capability of drilling to at least 10,000 feet (3047 m). Such a drilling rig is normally equipped with a 300 horsepower (hp) drawworks. An independently-powered 500 hp mud pump will supply the hydraulics needed to drill efficiently. The mast and substructure are typically rated at 125 tons to provide a good margin of safety.

An example of well construction within the Salton Sea Anomaly is shown in Figure 2.6-1-3, although subsurface conditions and depths will of course vary from site to site. A recent exploratory well program within the Salton Sea KGRA called for the following casing program (WESTEC, 1980b), which is felt to be generally representative of that which would occur throughout the Salton Sea Anomaly.

- 20 inch (51 cm) diameter conductor casing to a depth of 100 feet (30.5 m) which would be cemented to the surface;
- 13-3/8 inch (34 cm) K-55 casing cemented at ±1200 feet (365.8 m);
- 9-5/8 (24 cm) K-55 casing cemented at ±2000 feet (610 m);
- 7 inch (18 cm) K-55 slotted liner hung to a depth of ±3500 feet (3048 m).

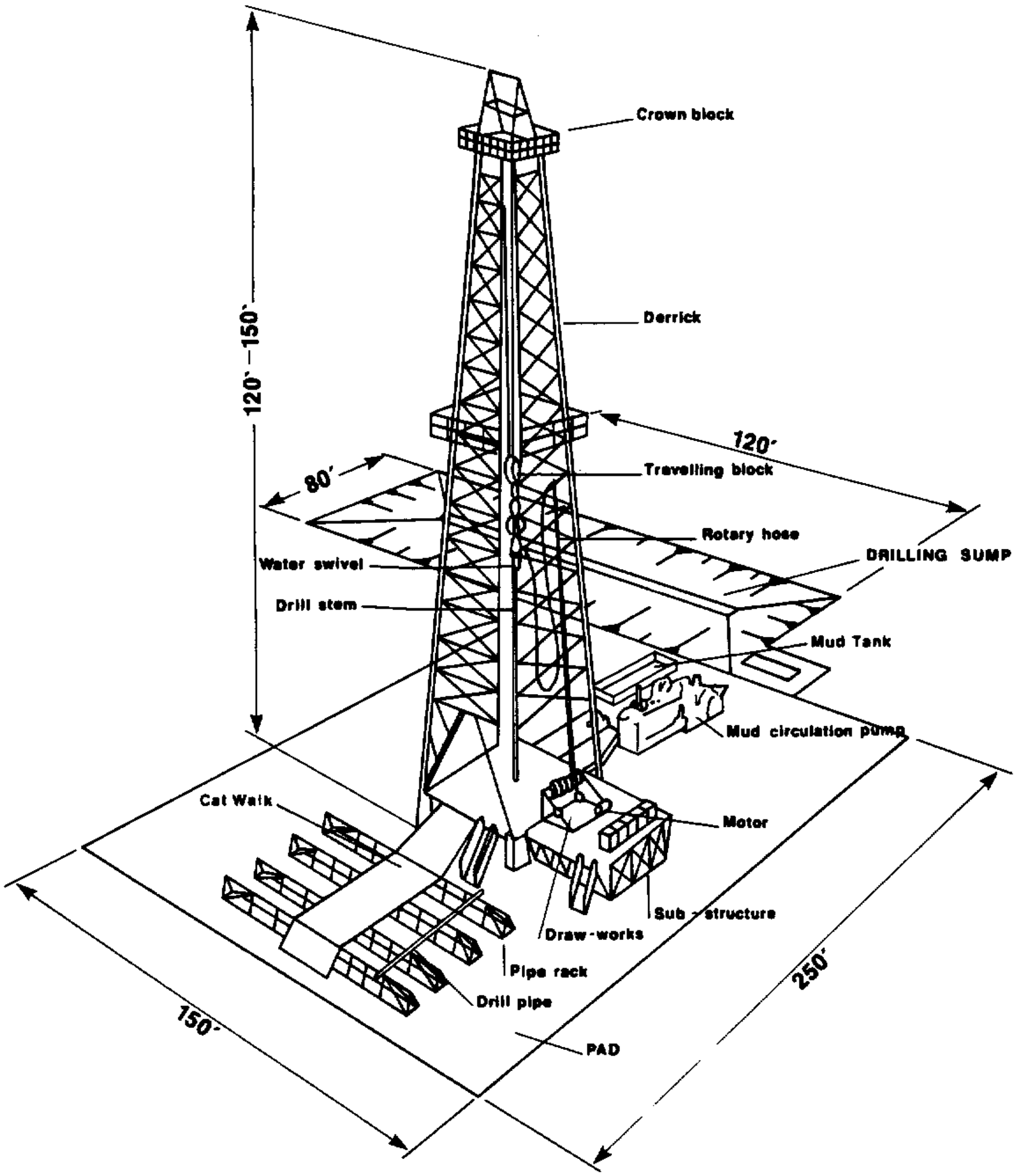
A typical drilling procedure would be initiated by using a rathole digger to drill a 26 inch hole to approximately 100 feet (30.5 m) and setting a 20 inch (51 cm) O.D. conductor pipe and ready-mix concrete to protect against washouts and shallow lost circulation zones. At that point, the rotary drilling rig and cooling tower would be installed. A 17-1/2 inch (44.5 cm) hole would then be drilled to approximately 1200 feet and the flow line temperature monitored every 30 minutes.



Source: WESTEC Services, Inc., 1980b

Layout of Typical Drillsite

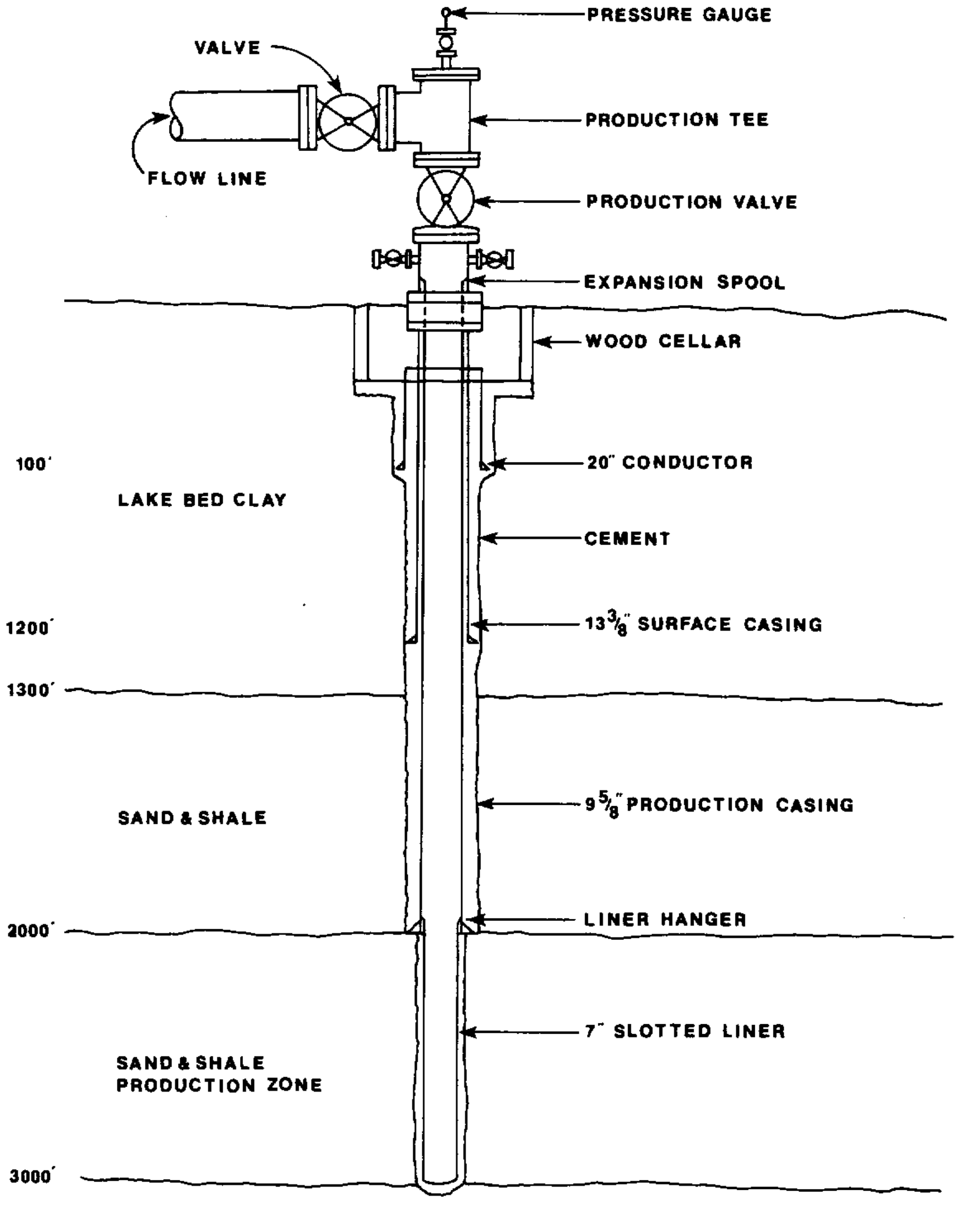
FIGURE A2.6-1-1



Source: WESTEC Services Inc., 1980b

Typical Drilling Rig and Pad

FIGURE A2.6-1-2



Source: WESTEC Services Inc., 1980a

Completion Profile of Exploratory Well (Example)

FIGURE A2.6-1-3

A viscous fluid termed "mud," which is primarily a mixture of clay and water, is used in well drilling. It serves the following functions:

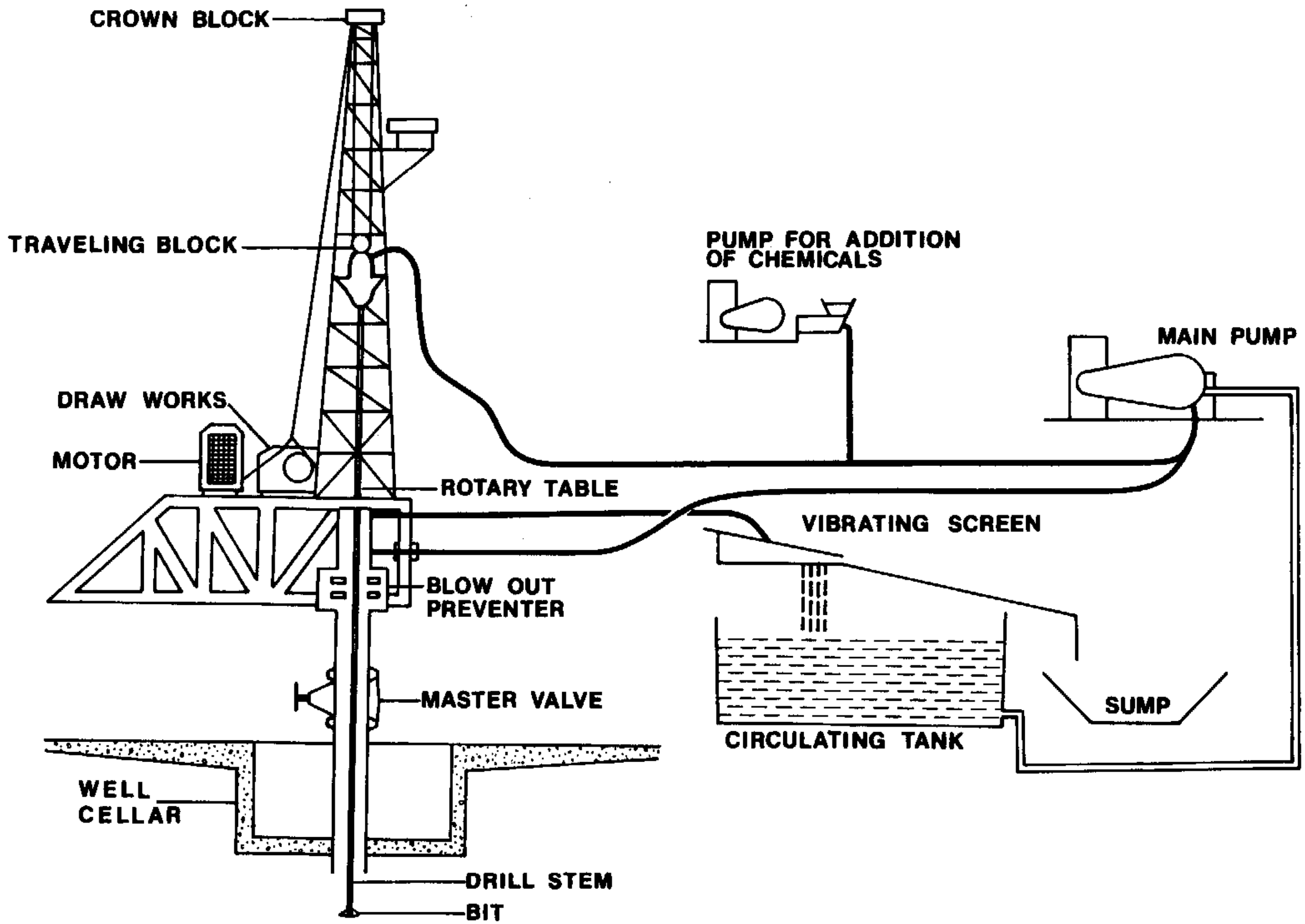
1) Remove cuttings from the hole.
2) Control subsurface pressure.
3) Cool and lubricate drill bit and pipe.
4) Prevent borehold walls from caving.
5) Prevent formation damage.
6) Provide maximum information from formations penetrated.
7) Suspend cuttings when circulation stops.
8) Suspend weight of drill string and casing.

The mud is circulated through a closed loop system. After coming out of the drillhole, the mud passes through a desilter and across a fine screen shale shaker, separating cuttings from the mud. The mud then passes through a cooling tower (dependent on bottom hole temperature), which reduces the temperature by about 40°F (22°C), and is returned to the drillhole via mud pumps. The cuttings are stored in the reserve pit (sump) until they are transported to an approved sanitary landfill, or neutralized and made arable. A typical drilling mud cycle is shown in Figure 2.6-1-4.

The sump is used to contain the drilling mud and cuttings. Materials that accumulate in the drilling sump will be periodically removed and trucked to an approved disposal site. The geothermal fluids will be concentrated by evaporation, then taken to a Class I or Class II-1 disposal site approved by the Regional Water Quality Control Board (RWQCB). A Class II-1 disposal site was recently approved and is now operating about five miles west of Westmorland. Drilling muds with extractable water containing a total dissolved solids concentration which is less than 6000 mg/l, and not containing hazardous wastes, may be disposed of at a Class II-2 disposal site approved by the Regional Board to receive said waste. An applicant would normally be required to submit to the Regional Board the results of analyses for the concentration of total dissolved solids contained in the extractable water of any drilling muds discharged at a Class II-2 disposal site, as well as the results of analyses for the following hazardous materials in drilling muds proposed for discharge at a Class II-2 disposal site:

1) Arsenic and arsenic compounds
2) Barium (excluding barite) and barium compounds
3) Inorganic lead compounds
4) Organic lead compounds
5) Manganese compounds
6) Zinc compounds

WESTEC Services, Inc.



Source: WESTEC Services Inc., 1980b

Typical Drilling Mud Cycle

FIGURE A2.6-1-4

The discharger will have to obtain a permit from the State of California Solid Waste Management Board unless all of the below listed conditions are met:

1) The wastes are disposed in sumps that have a total volume of two acre-feet or less,
2) The sumps receive wastes for one year or less, and
3) The disposal into the sump is controlled by waste discharge requirements issued by the Regional Board after consultation with the State Solid Waste Management Board.

Drilling muds and drill cuttings would not normally be discharged at the drill site unless the discharger receives specific waste discharge requirements from the Regional Board and a permit from the State Solid Waste Management Board.

Drilling fluid would primarily be a mixture of water and clay (sepliolite), containing varying quantities of additives, or gel-water and gel-lignite, depending on the particular drilling conditions and the company doing the drilling.

The well cleanout and actual testing program for each well would be dependent on local conditions and the objectives and desires of the developer. Specific test procedures for current testing programs within the Valley are described in detail by WESTEC (1980a, b and c) for those desiring more information.

During the performance of a typical well testing program several chemical agents would be on the site. These include: acids and complexing agents for scale control and equipment cleaning; flocculant and possibly high molecular weight polymers for suspended solids control; oxygen scavenging chemicals (primarily sodium bisulfite) and reaction inhibitors for corrosion control; and assorted laboratory reagents used in field analysis. In addition, several kinds of fuels, lubricants, sealers, and packing compounds will be located on each well site.

REFERENCES

WESTEC Services, Inc., 1980a, Superstition Hills Class II-1 Disposal Site, Final Environmental Impact Report, Volume I, San Diego, California.

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APPENDIX 2.6-2

POWER PLANT DESIGN CRITERIA

APPENDIX 2.6-2

POWER PLANT DESIGN CRITERIA

The following paragraphs describe the design criteria for four different situations within the Salton Sea KGRA: 1) the Geothermal Loop Experimental Facility (GLEF) (SDG&E, 1980); 2) Union Oil/SCE's recently approved 10 MW power plant (Imperial County, 1980); 3) Magma's approved 28 MW power plant (Imperial County, 1979; Magma, 1980); and 4) Magma's proposed 49 MW power plant (see Section 8.1 of MEIR text).

1. Geothermal Loop Experimental Facility (GLEF)

The following excerpts from SDG&E (1980) describe the recommended technology for power conversion based on extensive test results at the site:

> The primary objective of the feasibility and risk study was to define the most technically feasible and lowest cost near-term energy conversion process for a commercial-scale demonstration power plant at the Salton Sea Known Geothermal Resource Area (KGRA). The study incorporated the GLEF data while operating as a four-stage flash/binary loop. The purpose of the Geothermal Loop Experimental Facility (GLEF) at the Salton Sea KGRA was to obtain data for a commercial power plant. As originally constructed, it utilized the four-stage flash binary energy conversion process. However, the GLEF design was based on certain conditions and assumptions that subsequent data showed to be no longer valid. Therefore, this study was initiated to determine the most appropriate energy conversion process for the demonstration power plant based on current information and to define the future, if any, that GLEF testing needed to obtain critical design information for the type of plant selected.
>
> In order to ensure that the conceptual designs reflected the best data and that the results for the various designs would be comparable, a set of interface and design parameters was developed for use as the power plant and well field design criteria. Additionally, a standard cost estimating methodology was devised to assure compatibility between the various cost estimates.
>
> The most important design parameters considered were as follows:

- Net plant output is 50 MW.

- The plant is located within the Salton Sea KGRA, approximately 2500 feet west of Gentry Road and 2000 feet south of Sinclair Road.

- Steam condensate is used as cooling tower makeup, and injection flow is decreased by this amount.

- A Stretford unit is provided for removal of H_2S from noncondensable gas discharge.

- Brine effluent treatment to remove suspended solids from the brine prior to injection or elevated effluent brine temperatures are required to prevent injection well failures.

- Wellbottom temperature is 500°F (260°C) initially and declines linearly to 482°F (250°C) in 30 years. The process designs are based on 482°F (250°C) brine wellbottom conditions.

- Total dissolved solids content of the brine is 20 percent, and noncondensable gas content is 0.5 percent by weight of the total brine flow.

- Total production flow rate per well is 400,000 lb/hr, declining linearly to 300,000 lb/hr in 30 years. Injection flow rate per well is 600,000 lb/hr and remains constant.

- The production wells are slant drilled from an island located adjacent to the power plant. Injection wells are slant drilled from an island approximately 3000 feet from the production well island.

- Brine scaling rates, scale removal techniques and costs, and materials for use in brine service are based on GLEF or best data available.

- General operating parameters and costs are based on Geysers or worldwide geothermal plant experience.

The results of this study indicated that the most appropriate energy conversion process for the

50 MW (net) demonstration power plant was the two-stage flashed steam process using unmodified brine and three 50 percent trains of flash equipment. This option was the lowest in busbar cost, low in capital cost, and used proven and available equipment to achieve low risk. In addition, since existing geothermal flashed steam power plants have demonstrated that electrical power can be produced commercially, investor confidence is expected to be higher for this process than for the commercially untried flashed binary process.

The study went on to state the following conclusions (SDG&E, 1980):

> The most appropriate energy conversion process for a commercial scale, 50 MW demonstration power plant is the two-stage flashed steam process using unmodified brine and three 50 percent capacity trains of flash vessels. This is based on an analysis that incorporates the latest GLEF and related data and information.
>
> The capital cost for the two-stage flashed steam plant using unmodified brine and standby flash equipment was estimated to be $38.4 million. The capital cost for the corresponding well field was $9.83 million. The busbar energy production cost was 37.6 mills/kWh. These costs include escalation to first quarter 1982 prices.
>
> The option of using modified brine should be kept and developed.
>
> Plant capital costs are lower for plants incorporating the flashed steam process than for those incorporating the binary process. However, brine requirements and, therefore, well field capital costs are lower for binary plants. The result is that the energy production costs for the flashed steam and binary plants studied are the same to within the accuracy of the estimates.
>
> The lowest energy production cost of the alternatives studied for the binary process was 38.7 mills/kWh. Two alternatives, one utilizing the four-stage flash binary process with acidified brine and the other, a liquid/liquid binary process with acidified brine, had this same energy production cost. Future reductions in capital costs (in R&D) may result in an attractive alternative.
>
> No insurmountable risks were identified. The most important risks are those associated with brine

handling. If satisfactory means can be found for producing the brine, carrying it through the power plant, and injecting it into the subsurface formation, the project will have a reasonable probability of success.

The technical, economic, and risk analyses conducted during this study indicate that development should be carried forward.

The GLEF should be modified to simulate the two-stage flashed steam process. The test program described in this report should be supported by related studies that were also described.

And finally, the following recommendations were made (SDG&E, 1980):

The 50 MW (net) demonstration power plant at the Salton Sea KGRA should be based on the two-stage flashed steam energy conversion process using unmodified brine and redundant flash equipment. The GLEF should be modified and operated to reduce critical risk areas.

The overall feasibility study should go forward, at least through Phase II, to improve performance and cost data for the power plant and the well field and to define the best means for overcoming the important risks.

The option to use modified brine should be kept open. A small-scale loop, simulating the two-stage flashed steam process with modified brine, should be constructed and operated under the Department of Energy, Industrial Support Program, at the small test facility currently located next to the GLEF.

2. Union Oil/SCE 10 MW Plant

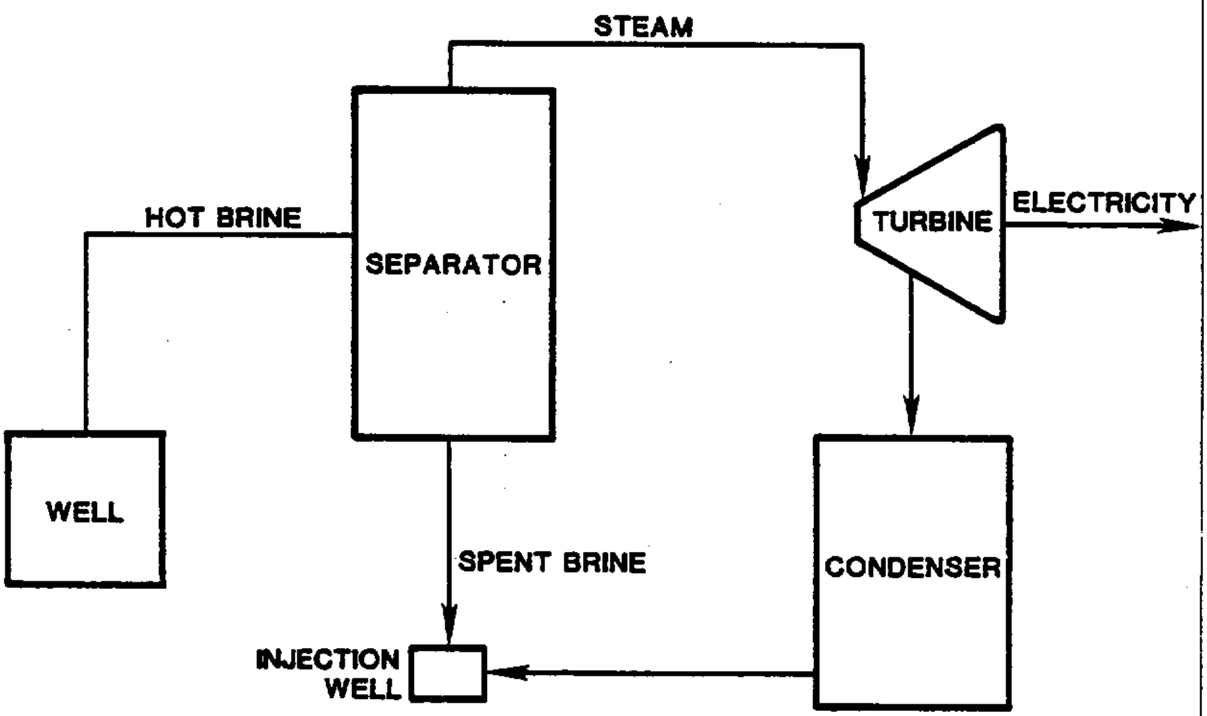
This plant was proposed as a demonstration project to show that the production of electricity from the geothermal resources within the Niland Anomaly is both technically and economically feasible. It was recently approved by the County. Although the requisite technology does exist and has been tested, the project proponents feel that "the unique fluid characteristics of the Salton Sea Anomaly require that it be demonstrated on the scale of a 10 MW project in this KGRA" (Imperial County, 1980). The plant will utilize a two-stage flash process, with excess brine being reinjected into the reservoir at approximately the same depth from which it was produced (2000 to 6000 feet). Following its passage through the generating turbine, the steam will be condensed back into liquid and either used for cooling tower makeup or reinjected with the brine. A brief description of the process (depicted in Figure 2.6-2-1) follows (Imperial County, 1980):

> As a result of a pressure drop as the fluid flows to the separators, the steam phase of the fluid will be flashed or separated from the liquid phase. The steam will then be washed and scrubbed to remove any remaining free water and particulates, and piped to the turbine generator.
>
> Under normal operating conditions, the remaining liquid brine may be pumped from the separators either through the sludge clarifier (which removes some solids which might plug injection facilities) and/or directly to the injection system, where it will be introduced into the geothermal reservoir at approximately the same depth from which it was produced. A 0.7 ac (0.3 ha) elevated brine pond is also located on the site for temporary storage of brine during startup, shutdown or emergency operations. Brine accumulated in the pond will be disposed of by reinjection.

3. Magma Power 28 MW Power Plant

The following excerpts from Imperial County (1979) are offered to describe the power conversion technology and system operation that will be utilized by Magma Power in their recently approved 28 MW power plant which will be located on the site of the GLEF (which was recently dismantled, except for a reactor/clarifier and other equipment which will be revised in this plant by Magma):

> A dual steam flash process will be used to produce electric power from the geothermal resource. A dual flash system was selected over a binary closed cycle process as Magma Power does not believe that a downhole pump capable of handling 500°F fluid has been successfully demonstrated. In addition, temperature reduction of the fluid would result in silica precipitation causing fouling of heat exchangers and components. For this highly saline geothermal brine (250,000 ppm) a closed binary system is not applicable. In the dual steam flash process, geothermal brine from the deeper (1800'-3000') of the two geothermal zones will be supplied by self-flowing wells.
>
> The brine is flashed to produce high pressure steam and the remaining brine is again flashed to produce low pressure steam. The steam is passed through a double entry steam turbine-generator to produce electric power, and the steam is then condensed by



Source: Department of Energy, 1980

Simplified Flashed –Steam Conversion Cycle

FIGURE A2.6-2-1

cooling water using surface condensers. The small amount of noncondensable gases produced with the brine is removed from the condensing system to prevent a buildup of pressure in the condenser. The only potential problem expected from noncondensable gas emissions is an occasional nuisance odor. If these noncondensable gases do prove to be a problem, they will be reacted and injected into wells with the brine. Residual brine from the second stage flash is treated in a clarifier to remove suspended solids and is then injected into injection wells.

Water for the cooling tower is supplied by using the steam condensate from the process. Although this practice reduces the volume of reinjected brine, about 80 percent of the brine is still available for reinjection. The Geothermal Element of the General Plan of Imperial County requires 100 percent reinjection unless approval for a lower percentage of injection is obtained from the Division of Oil & Gas (DOG), State of California. Permission to reinject 80 percent of total fluids instead of 100 percent has been granted by DOG with conditions.

4. Magma 49 MW Power Plant

A full description of this project is included within Section 8.1 of the MEIR. Basically, the plant will utilize a two-stage flash conversion cycle to generate electricity.

REFERENCES

Imperial, County of, 1980, Planning Department, Salton Sea Ten Megawatt Geothermal Demonstration Facility, Final Environmental Impact Report, December.

Imperial, County of, 1979, Final Environmental Impact Report for Forty-nine Megawatt Geothermal Power Plant and Facilities Niland Area KGRA, #211-78, (data submitted by Magma Power Company, et al.); Supplement to Environmental Impact Report, SCH 79072515 Amending Forty-nine Megawatt to a Twenty-eight Megawatt Geothermal Power Plant and Facilities, Niland Area, Salton Sea KGRA.

Magma Power Company, 1979, "Final Environmental Impact Report #211-78 for Forty-nine Megawatt Geothermal Power Plant and Facilities, Niland Area Salton Sea KGRA."

San Diego Gas & Electric (SDG&E), 1980, Final Report, Geothermal Loop Experimental Facility, April.

APPENDIX 3.1

GEOLOGY

APPENDIX 3.1

CALIFORNIA DIVISION OF MINES AND GEOLOGY, REPORT 122, SEISMIC MONITORING PROGRAM

Temporary Seismic Instrumentation

Geothermal seismicity could be monitored prior to any development of a geothermal site regardless of the nature of the well (exploratory or development). A minimum of four months of continuous seismic recording at some selected typical well sites could be considered. Upon beginning drilling procedures, seismic observations could be continued but at some distance, perhaps several kilometers from the drill site. An observed increase or decrease in the seismicity could be interpreted as an anomalous condition indicating the need of additional geophysical investigations. Upon completion of drilling operations, seismic monitoring could again be instituted at the initial observation site (if possible). The collection of geothermal seismicity data could continue for at least a period of four months after drilling had ceased. If seismicity were recorded, efforts should be made to correlate the seismicity with the various pertinent well parameters, such as temperature, pressure, and production rates. These parameters could be recorded continuously even during the final stage of seismic monitoring.

Seismic monitoring of geothermal areas could be accomplished with a single component seismograph system capable of a magnification of at least 10^6 in the frequency range of 10-30 hz (cycles); recordings should be on a time base permitting a reading accuracy of 0.2 second. Because single station observations would be made, no elaborate timing system is required. Single observational sites within a proposed geothermal development area should not be considered as adequate; the effect of numerous wells upon the geothermal seismicity is unknown and anomalous conditions which may be unique to wells should be identified.

Permanent Seismic Instrumentation

The instrumentation described under Temporary Seismic Instrumentation is applicable to the initial development of a particular geothermal field. After an area had been developed as a geothermal resource area, monitoring of the seismic field should be continued. Similar equipment could be installed near the producing field to monitor the effect of earthquakes and ground shaking on the power facilities. A desirable modification to the recorder unit would be the ability to record a standard radio time signal such as WWV. On the basis of the fact that the maximum distance from the producing well to the power station is about 2000 feet, it is estimated that one permanent seismic station may be needed per square mile of geothermal development.

Systems, Science and Software

SSS-R-81-4880

NILAND ANOMALY MEIR: INDUCED SUBSIDENCE AND INDUCED SEISMICITY

FINAL REPORT

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TABLE OF CONTENTS

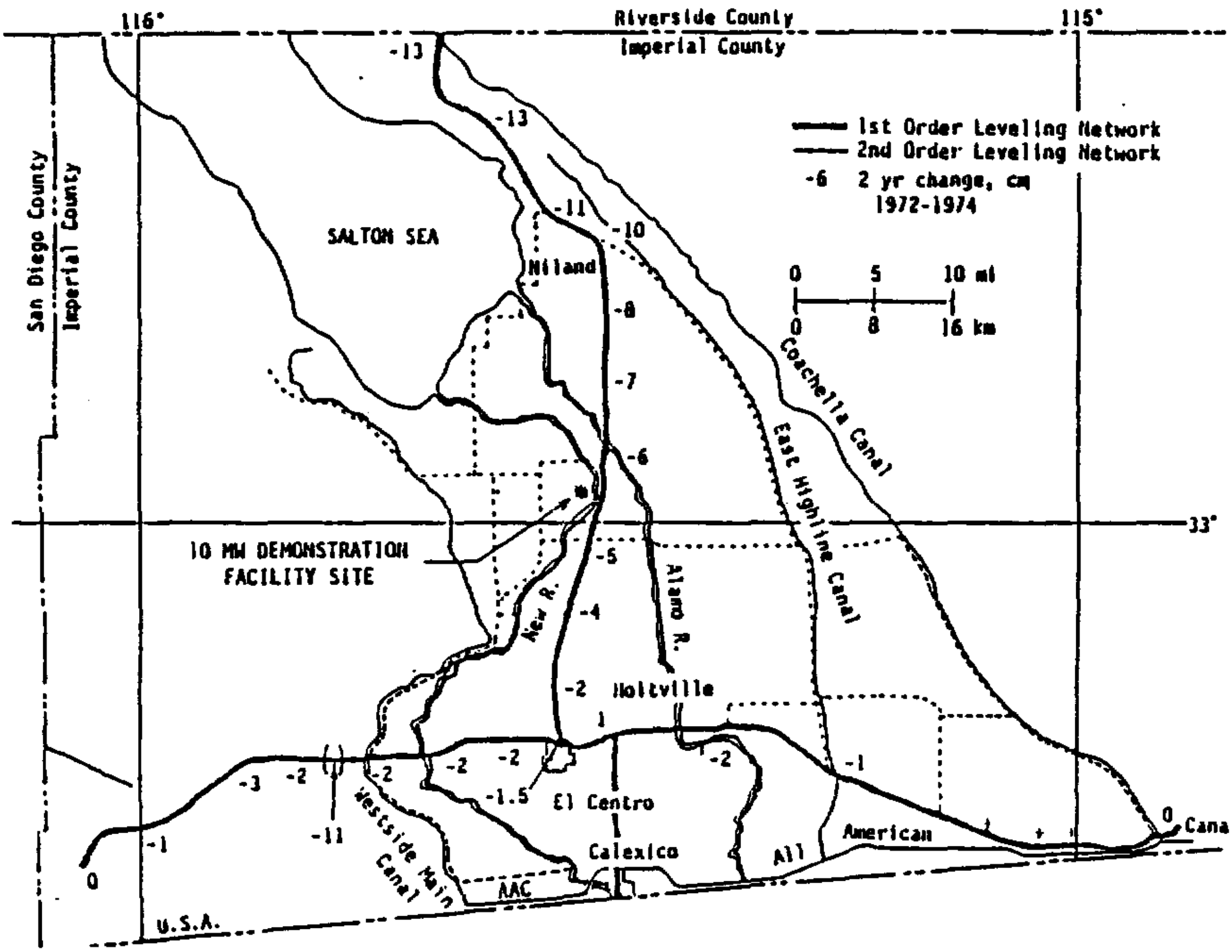
I. INDUCED SUBSIDENCE

1.1 EXISTING CONDITIONS

Subsidence of the ground surface due to natural causes in the Imperial Valley has been a concern to the agricultural industry for many years. Proper operation of the gravity-flow irrigation system in the valley is dependent on the maintenance of existing ground surface elevations. As these elevations have subsided to varying degrees across the valley, farmers have had to re-level their lands to keep the irrigation system functioning.

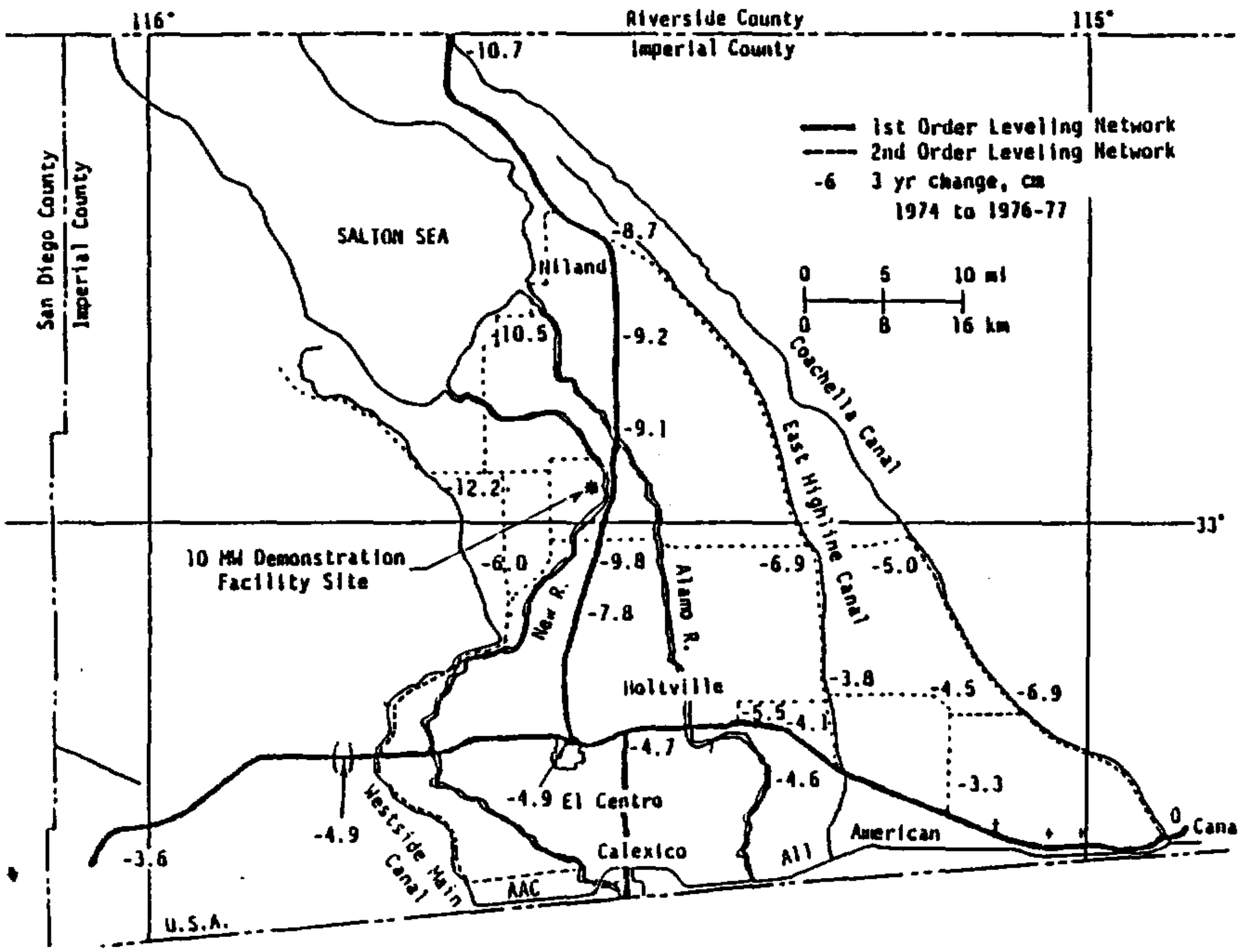
As the possibility of geothermal development in the Imperial Valley has increased, government agencies and private industry have initiated monitoring programs to gather baseline data on natural subsidence. Figure 1 shows the results of a leveling survey sponsored by the Imperial Valley Subsidence Detection Committee (Crow [1976]). Over the two-year period from 1972 to 1974, natural subsidence appears to be relatively large in the area of the Salton Sea and nearly non-existent near the International Border (Lofgren [1974]).

According to a survey completed by the National Geodetic Survey (NGS) in 1976-77, natural subsidence in the Imperial Valley is increasing (Reese [1977]). This is shown in Figure 2 using NGS data for the 1974 to 1976-77 period. As evident in Figure 2, the northern part of the valley is not subsiding as fast as in the previous two-year period, but the central portion of the valley south of Niland is experiencing an increasing subsidence rate (the actual subsidence, however, is still greater in the north).



SOURCE: Lofgren (1974), as presented in Crow (1976, pg. 87)

Figure 1. Imperial Valley Subsidence Detection Network and Measured Differences in Elevation over Two-Year Period from 1972 to 1974 (movement in centimeters).



SOURCE: REESE (1977)

Figure 2. Vertical Movement in the Imperial Valley Over Three-Year Period from 1974 to 1976-77 (movement in centimeters).

From the results of the above surveys, it is apparent that natural subsidence does occur over a widespread area in the Imperial Valley. Natural subsidence is, however, not expected to cause damage to lands in the valley since it (subsidence) is regionally distributed. The average slope of the valley from the International Border to the Salton Sea is approximately 1 m/km (grade ~ 0.001). As pointed out by Layton et al. [1980], even a continuation of more rapid rates of subsidence in the northern end of the valley over the next forty years would not cause any substantial change in the valley's slope.

Production (and reinjection) of geothermal fluids can also lead to subsidence. Extraction of geothermal fluids will cause a decline in reservoir pore pressures, and may result in formation compaction. Injection of colder waste fluids can be expected to cause local cooling of the reservoir and possible formation contraction (and hence compaction). Some or all of the formation compaction caused by extraction/injection of geothermal brines could be mainifested as land surface subsidence. Significant land surface subsidence could interfere with present gravity-type irrigation methods, and also subsurface drains that underlie the majority of valley's irrigation fields (Layton, et al. [1980]). It is, therefore, important to estimate the possible surface movement resulting from geothermal operations.

1.2 POTENTIAL FOR INDUCED SUBSIDENCE

1.2.1 Introduction and Background

Land subsidence is often caused by the compaction of the semi-consolidated strata of the reservoir as the effective overburden stress (defined as lithostatic stress minus fluid pressure) is increased due to geofluid (oil, groundwater, geothermal fluids) withdrawal. Areas of land subsidence associated with production of geothermal fluids include Wairakei, N.Z., and Cerro Prieto, Mexico. The most damaging and dramatic effects of subsidence within the Continental United States occurred at the Wilmington oil field (Long Beach, California). At Wilmington, sinking over an area of 50 square kilometers resulted in a subsidence bowl up to nine meters deep. The subsurface stresses caused by compaction and horizontal movement were releaved by several shallow earthquakes. To alleviate subsidence, a massive water reinjection program was begun in 1958. The repressurization program has been a success in so far as the vertical ground movement and earthquake activity have essentially stopped.

Fluid reinjection, while undoubtedly useful, is not a universal remedy to subsidence, for several reasons. First, while some of the compaction is elastic and may be recovered, it is well known that irreversible pore collapse (permanent deformation) also accompanies fluid withdrawal. Second, when geothermal fluid is used for electric power generation, only a fraction of the produced fluid may be available for reinjection. Third, reinjection (especially of concentrated brines characteristic of the Niland Anomaly) may not always be practical at (or near) the same horizontal and vertical location as production. Reinjection at a sufficient lateral distance from the production region may result in uneven surface displacement.

As a hydrothermal reservoir is depleted, its pore fluid pressure will decline. One of the principal effects of a reduction in pore pressure is a corresponding reduction in porosity. Injection of colder waste fluids may cause localized thermal contraction, and thus also contribute to reservoir compaction.

A general approach to modeling pore collapse/crack closure within the reservoir formation (and associated surface deformation) consists of solving the governing system of fluid flow and stress-deformation equations in a coupled manner (Brownell, et al. [1977]). The stress-deformation field is, in general, three-dimensional. Such sophisticated modeling techniques do exist at S^3 and have been applied to estimate the potential subsidence that might accompany production of geopressured fluid from the Austin Bayou Prospect in Brazoria County, Texas. Since the data on subsidence and material properties for the Niland Anomaly are very limited at the present time this sophisticated (and costly) approach is unwarranted at this time. We will instead utilize the simpler one-dimensional consolidation theory to study reservoir compaction at Niland.

One-dimensional consolidation theory can be obtained as a special case from the general three-dimensional coupled stress-deformation/fluid flow equations (Brownell, et al. [1977]) by invoking the following assumptions:

1. The reservoir undergoes primarily vertical compaction, and horizontal deformations are negligible. (This assumption should present no problem at Niland since the lateral extent of the reservoir vastly exceeds the reservoir thickness.)

2. The mass of fluid withdrawn is small relative to the total overburden so that the overburden remains essentially constant.

3. The rock grain is much stiffer than the porous rock.

Assumptions (1) and (2) imply that stress equilibrium is satisfied trivally. In this case, it is not necessary to explicitly solve the coupled stress-fluid flow equations; the vertical strain-rate is given by the relations:

$$\frac{\partial \varepsilon_z}{\partial t} \approx \frac{1}{h}\frac{\partial h}{\partial t} = C_m \frac{\partial p_f}{\partial t} ,$$

where

h = Formation Thickness

C_m = $1/(K+4/3\mu)$ = Uniaxial Formation Compressibility

K = Bulk Modulus of Porous Rock

μ = Shear Modulus of Porous Rock

ε_z = Vertical Strain:

To utilize the above strain-rate expression to predict reservoir compaction, we require (1) compressibility data for the various reservoir formations, and (2) the spatial and temporal pressure drop rate for the reservoir.

There exists little or no data in the open literature on the coefficient C_m for the Niland Anomaly formations. Limited amounts of compressibility data, are, however, available from other geothermal fields in the Imperial Valley. In their subsidence analysis for the proposed 10 MW North Brawley geothermal demonstration facility, Union Oil Company assumed that C_m is approximately 2×10^{-7} psi^{-1}; the latter value for C_m is based on sonic logs run in geothermal wells. As pointed out by Gray, et al. [1979], the use of log data generally yields too low a value for C_m (sometimes by as much as a factor of 4 or 5 compared to the "static laboratory measurements"). Some "static laboratory measurements" of compressibility from several Imperial Valley geothermal fields are also available. Schatz, et al. [1979] tested cores obtained from East Mesa (2200 m depth) and Cerro Prieto (1700 m depth) in the laboratory; the measured value of C_m is approximately 10^{-6} psi^{-1}. Chevron Oil Co. cites a value of the uniaxial compaction coefficient (based on laboratory testing on core samples taken from depths between 6027 feet and 6045 feet at Heber anomaly) of 0.4×10^{-6} psi^{-1}. Based on the above discussed measurements, an estimate of C_m for the Niland Anomaly formations would be of the order of 10^{-6} psi^{-1}.

The use of "laboratory data" to predict reservoir compaction poses two problems. Firstly, the compressibilities measured on small samples in the laboratory may not be representative of in situ rock aggregates. The reservoir behavior is often profoundly governed by formation heterogeneities, fractures, and other large scale features such as faults. For such a system, compaction (subsidence) behavior could be quite different from that predicted on the basis of laboratory measurements of C_m. (See Pritchett, et al. [1980] for a discussion of this question relative to the Wairakei geothermal field.) Secondly, the long term response of reservoir rocks (i.e., under production conditions) may be substantially different from that measured at the usual laboratory strain rates. (Recent long-term laboratory tests on cores obtained from various hydrothermal and geopressured systems (Schatz, et al. [1979]; Thompson, et al. [1979]) suggest that rocks may undergo creep compaction when subjected to long-term loads at elevated temperatures.) In general, the use of laboratory values of compressibility will always lead to too low an estimate for reservoir compaction and hence subsidence.

In their study of potential subsidence in Salton Sea KGRA, Layton, et al. [1980] placed C_m to be 10^{-4} psi^{-1} for the upper producing zone and 0.5×10^{-4} psi^{-1} for the lower producing zone. Although we do agree that the laboratory values of C_m will be generally too low, we find it rather difficult to visualize compressibilities of the order of 10^{-4} psi^{-1}. Such large compressibilities have neither been measured in the laboratory nor observed in the field. In the absence of other data, we will assume that an upper limit for C_m is 10^{-5} psi^{-1} (i.e., an order of magnitude larger than the laboratory value, but an order of magnitude smaller than the one assumed by Layton, et al.).

1.2.2 Reservoir Compaction

In the case of hydrothermal systems, the geothermal resource is a flowing convective fluid heated at depth and rising towards the surface as a result of the reduced density. The system is not only non-isothermal but also a dynamic system, as a consequence of buoyant flow. During the exploration and initial development stage, the natural pre-production flow of the fluid within the system will be dominant, except in the immediate vicinity of any exploratory wells. As the development of the resources takes place, the effect of the natural flow will likely be swamped by the pertubations induced by production and injection wells. The Lawrence Livermore Laboratory has correlated the data available from surface measurements and logs from various wells in the Niland Anomaly area. Riney et al. [1977] at S^3 used this data base and a computer based reservoir simulator (MUSHRM) to synthesize a preproduction model for a portion of the Anomaly. This preproduction model was also used to examine the pressure and temperature response of the reservoir for a variety of production/injection strategies.

Although a reservoir model of the type developed by Riney, et al. is highly desirable for detailed reservoir engineering studies, we feel that a simpler approach would suffice for purposes of estimating subsidence potential due to fluid production/injection. We consider a bounded reservoir (no heat or mass flux across the boundaries) with a uniform (or estimated average) temperature. The assumption of closed reservoir boundary is tantamount to ignoring any natural (or induced by production) mass or energy flux into the reservoir, and will in general lead to a conservative estimate (i.e., larger) for the pressure drop. We will examine the pressure response of the reservoir under two alternate production/injection strategies:

(i) Production with 80 percent reinjection into the producing horizon.

(ii) Production with 100 percent reinjection into the producing horizon.

These two production strategies represent probable extremes for the operational conditions that are likely to be permitted, and should define the maximum and the minimum expected pressure drop-rates (and reservoir compaction).

Figure 3 shows an areal view of the Salton Sea KGRA together with the projected locations of the various power plants expected to come on line during the period 1980-2010. Table 1 lists the rated capacities as well as the expected starting dates for these power plants. For our present purposes, it is assumed that a 50 MW would require 16 wells each producing 400,000 lb/hr; this implies that we will need to produce 128,000 lb/hr of brine for each MW of electric generating capacity. We will also assume that the geothermal reservoir lies approximately 2000 ft. below the surface, and that the depth to basement is 6000 ft. (net reservoir thickness = 4000 ft.). Layton, et al. [1980] assume that the upper production zone (thickness ~610 m) has a permeability of 150 md, while the lower zone (thickness ~610 m) has a permeability of 50 md; thus, the geothermal aquifer is estimated to have an average permeability of 100 md. Following Riney, et al. [1977], we will take the average formation porosity to be 0.2. The reservoir rocks are assumed to have the following thermodynamic properties:

Grain specific heat = 10^3 J/kg°K
Grain density = 2.65 10^3 kg/m^3
Grain thermal conductivity = 5.25 W/m °K

The relative permeabilities to liquid and vapor will be approximated by the usual Corey relation with the following residual saturations:

Liquid residual saturation = 0.3
Vapor residual saturation = 0.05

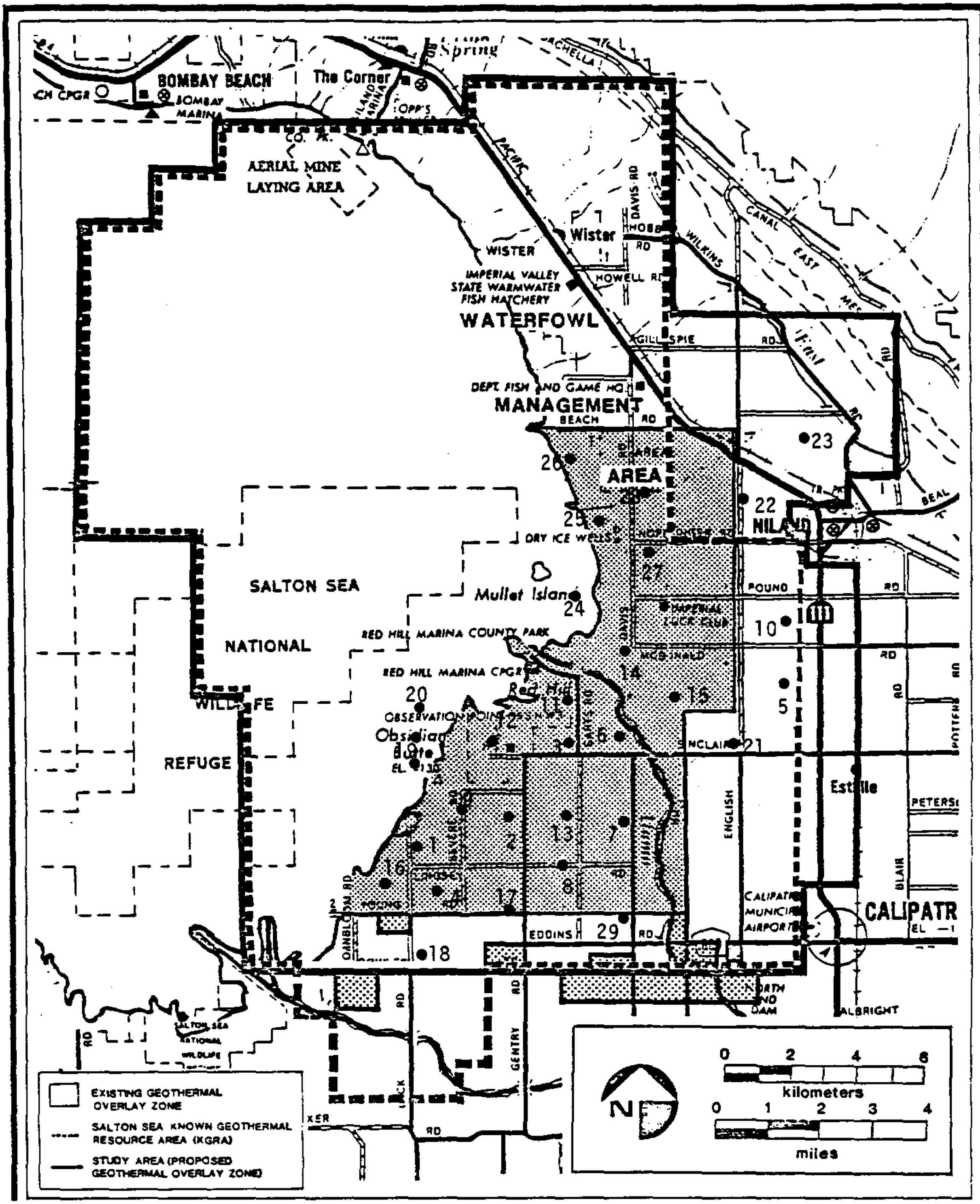


Figure 3. Proposed Study Area together with the Approximate Location of Various Power Plants (denoted by solid circles).

Table 1

MOST PROBABLE POWER PLANT DEVELOPMENT SCENARIO*

Year In Service	Applicant	Estimated Gross Generating Capacity (MW)	Cumulative Gross Generating Capacity Within the Salton Sea KGRA (MW)
1982	Union Oil/SCE[1]	10	10
	Magma[1]	28	38
1984	Magma[1,2]	49	87
1985	Republic	50	137
	Union Oil/SCE	50	187
1986	Magma	100 [3]	287
	Union Oil	100 [3]	387
1987	Republic	50	437
	Magma	100 [3]	537
	Union Oil	100 [3]	637
1988	Magma	100 [3]	737
	Union Oil	100 [3]	837
1989	Magma	50	887
	Union Oil	100 [3]	987
1992	Republic	50	1037
1995	Republic	50	1087
1996	Unknown	100 [3]	1187
1997	Unknown	100 [3]	1287
1998-2010	New capacity is expected to come on line at an approximate rate of 50 megwatts every two years until the "most probable" growth estimate of 1400 MW is achieved within the KGRA.		

* Based on geothermal developers' estimate of their future plans
1 Application for CUP received by County
2 Discussed as part of this MEIR
3 Two power plants of 50 MW each

Figure 4 shows the assumed initial distribution of temperature with depth in the Niland area. We will assume that the initial pressure distribution in the geothermal reservoir is nearly hydrostatic (see Figure 4). The hydrostatic pressure distribution is significantly removed from the saturation pressure at all depths in the reservoir (by approximately 78 bars at 2250 ft. depth, 98 bars at 4000 ft. depth, see Figure 4 for other depths). This suggests that for pressure drops less than 78 bars, an areal treatment should be adequate for assessing the impact of fluid production/injection at Niland. The areal treatment would naturally break down were the pressure drop to exceed 78 bars (in the simulations presented below, this occurred in only one case), and the areal calculation would lead to too high an estimate of pressure drop (and hence reservoir compaction).

The areal grid employed to model the study area is shown in Figure 5. Projected power plant locations are indicated by Arabic Numerals (1-29). For purposes of simulation, entire fluid production for a particular power plant was assigned to the grid block containing the power plant. The reinjection fluid was evenly distributed (based on the lengths of the block sides containing the power plant) among the 4 (3 where two power plants are in adjoining blocks) blocks adjoining the grid block containing the power plant; the reinjection blocks are indicated by x in Figure 5. In the simulations reported herein, fluid production/reinjection is represented by areally distributed mass sinks/sources; no attempt was made to resolve the flow around individual wells. This approach should be entirely adequate for investigating the gross compaction response of the geothermal reservoir due to brine production/injection. The reservoir brine is initially assumed to be at a P = 135.7 bars, T = 260°C and S (salinity by mass) = 0.25. The injected fluid is assumed to be at a temperature of approximately 100°C and a salinity of 0.25.

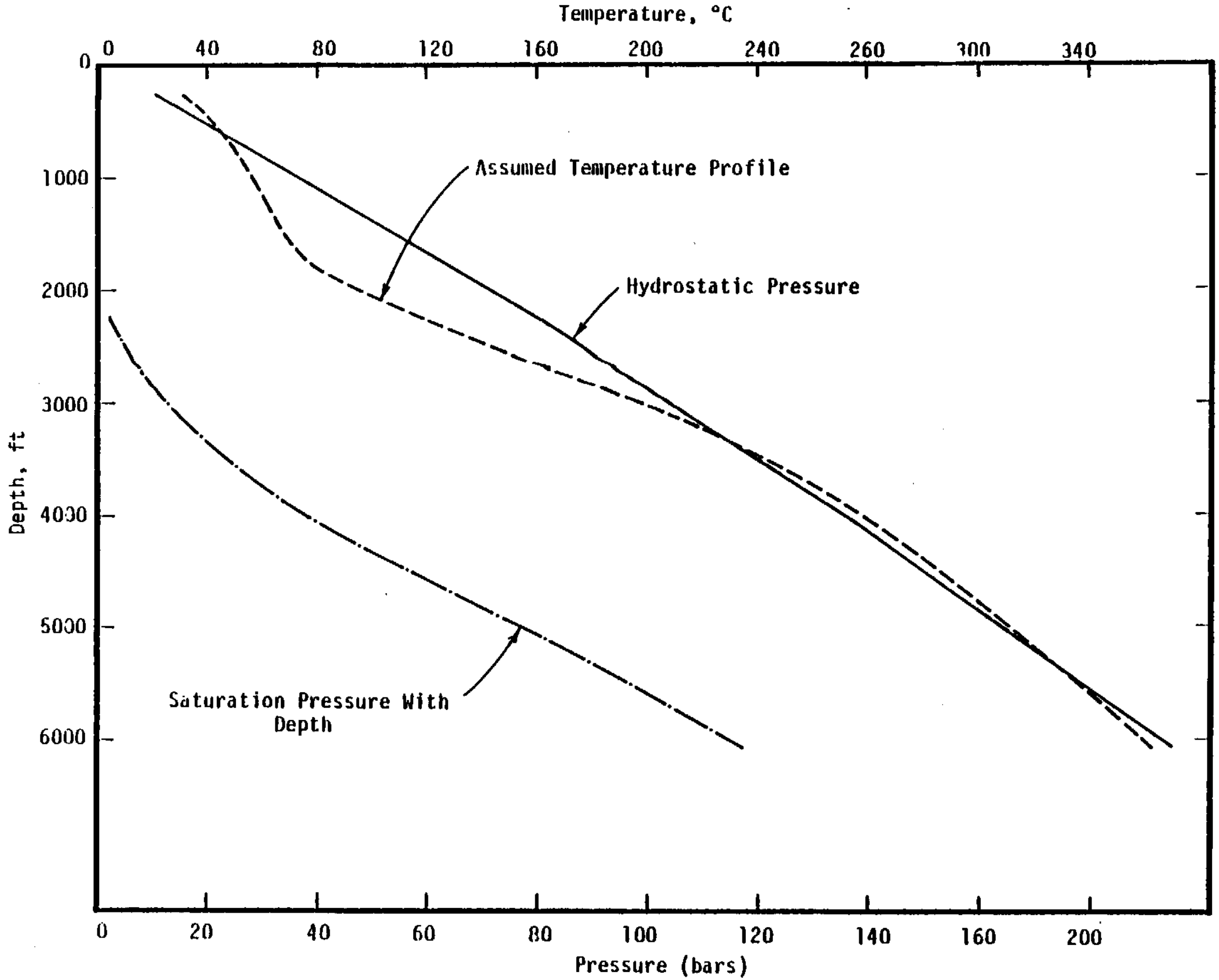


Figure 4. Initial Temperature, Pressure, and Saturation Pressure Distribution with Depth. Geothermal Fluids are Assumed to have a Salinity of 0.25 (per unit mass).

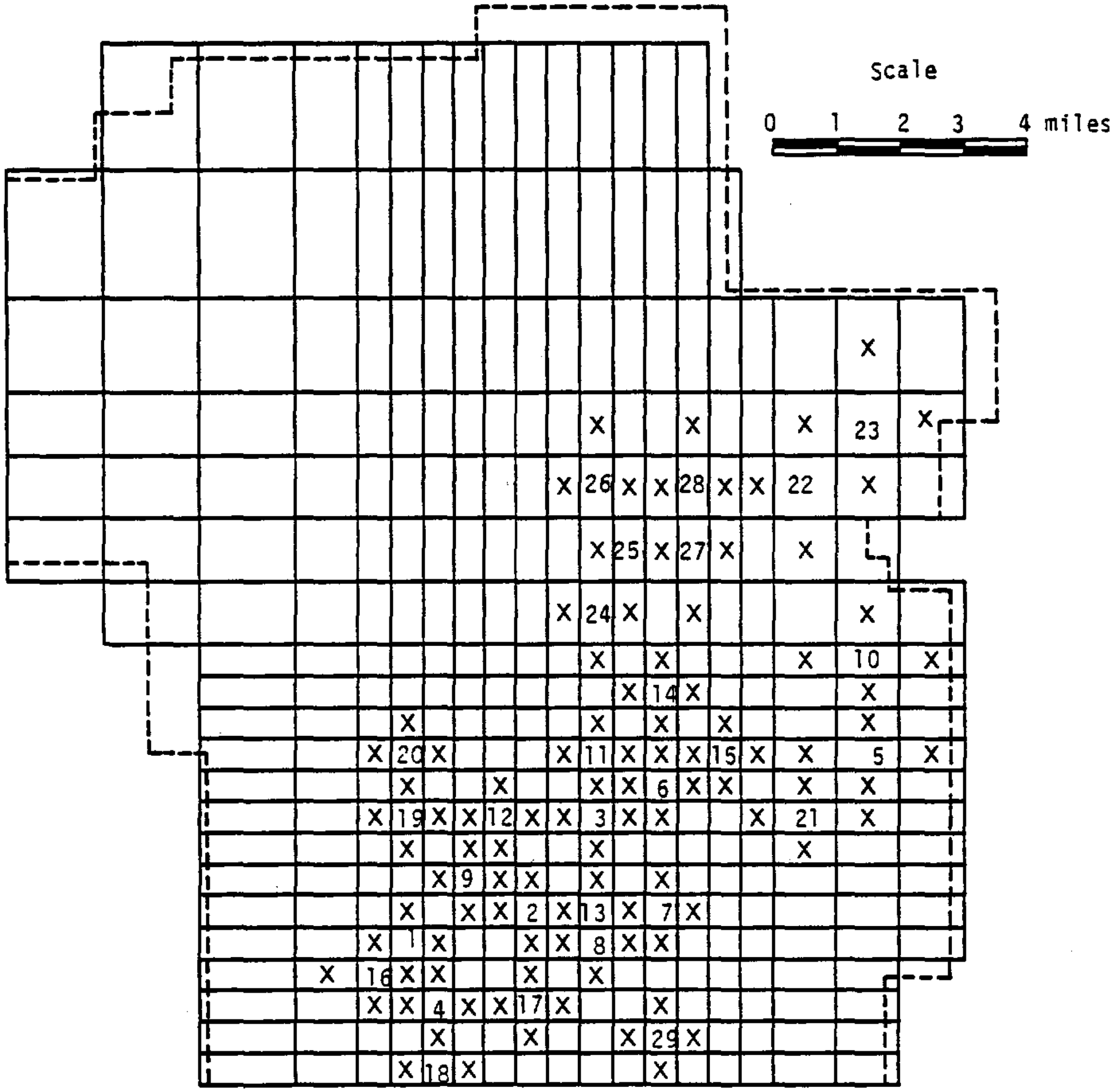


Figure 5. Numerical Grid Employed to Simulate the Project Area . The Project Area Boundaries, where they differ from the Grid Boundaries are indicated by a dashed Line. Power Plant Locations are De-noted by Arabic Numerals. Reinjection Blocks are Shown by X.

The S^3 geothermal reservoir simulator (CHARGR) was employed to simulate the reservoir response over the 30 year period (1981 - 2010) for the 4 cases listed in Table 2. For all the cases, an uplift compressibility factor of 10 was employed to reduce the amount of aquifer expansion where injection produced pressure increases (see e.g., Layton, et al. [1980]). The cases investigated cover the ranges of expected compaction coefficients and reinjection rates.

Table 2

COMPACTION COEFFICIENTS AND REINJECTION PERCENTAGES

	Compressibility	Uplift Compressibility	Reinjection Percentage
Case 1	10^{-6} psi^{-1}	10^{-7} psi^{-1}	80
Case 2	10^{-5} psi^{-1}	10^{-6} psi^{-1}	80
Case 3	10^{-6} psi^{-1}	10^{-7} psi^{-1}	100
Case 4	10^{-5} psi^{-1}	10^{-6} psi^{-1}	100

The simulator turns on different mass sinks/sources at various times corresponding to the projected startup of some 29 power plants (see Table 1). For the various cases listed in Table 1, the simulator yields pressure and temperature drops, and reservoir compaction as a function of time. Figures 6-9 show the computed compaction contours at t = 5, 10, 20, and 30 years for the four cases of Table 2. As may be expected, the compaction is greatest for the high compressibility partial injection case (Case 2, maximum compaction at 30 years - is over 35 ft.) and is lowest for the low compressbility full injection case (Case 3, maximum compaction at 30 years is somewhat over 4 ft.).

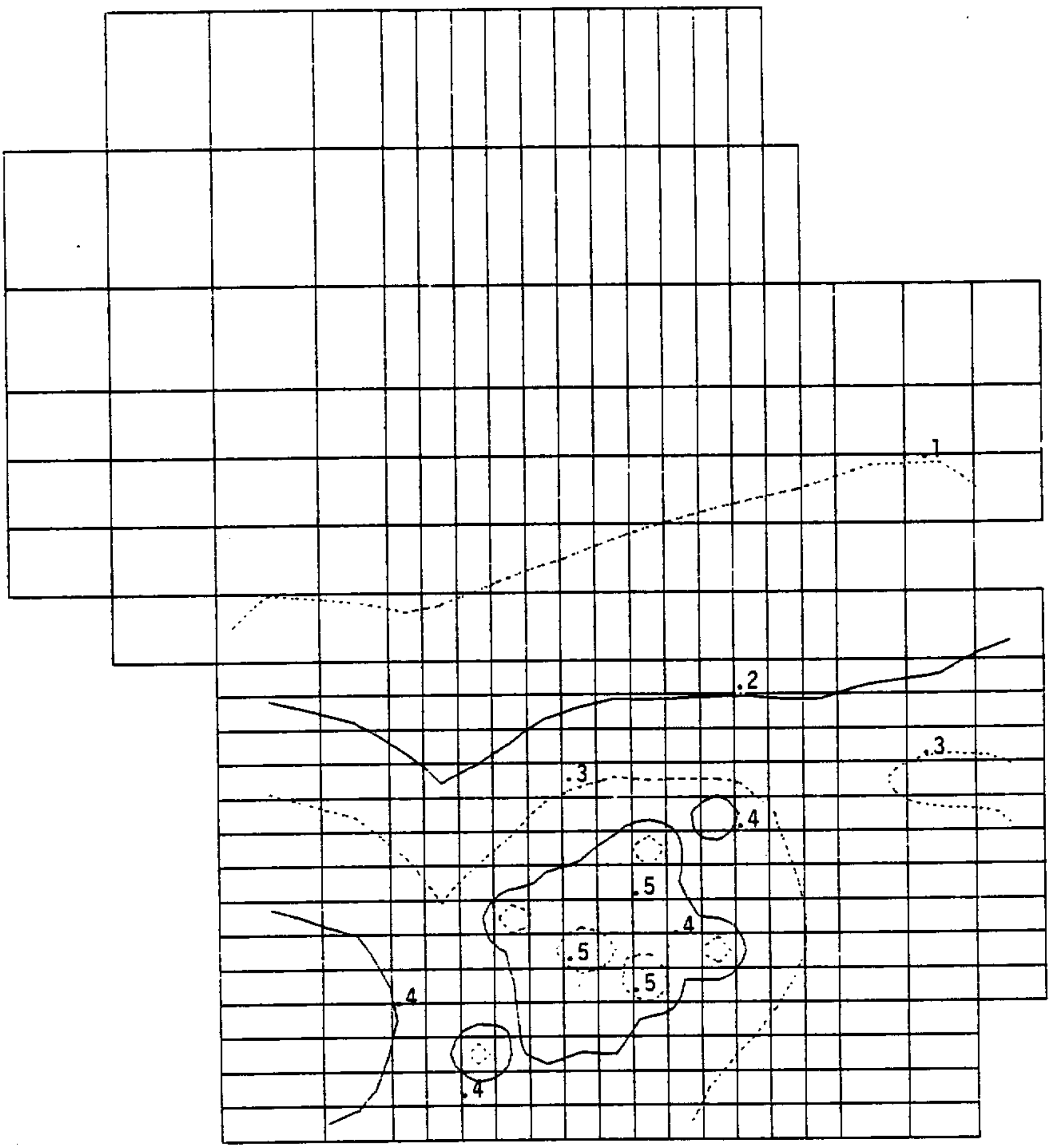


Figure 6a. Compaction Contours (feet) at t = 5 Years for Case 1.

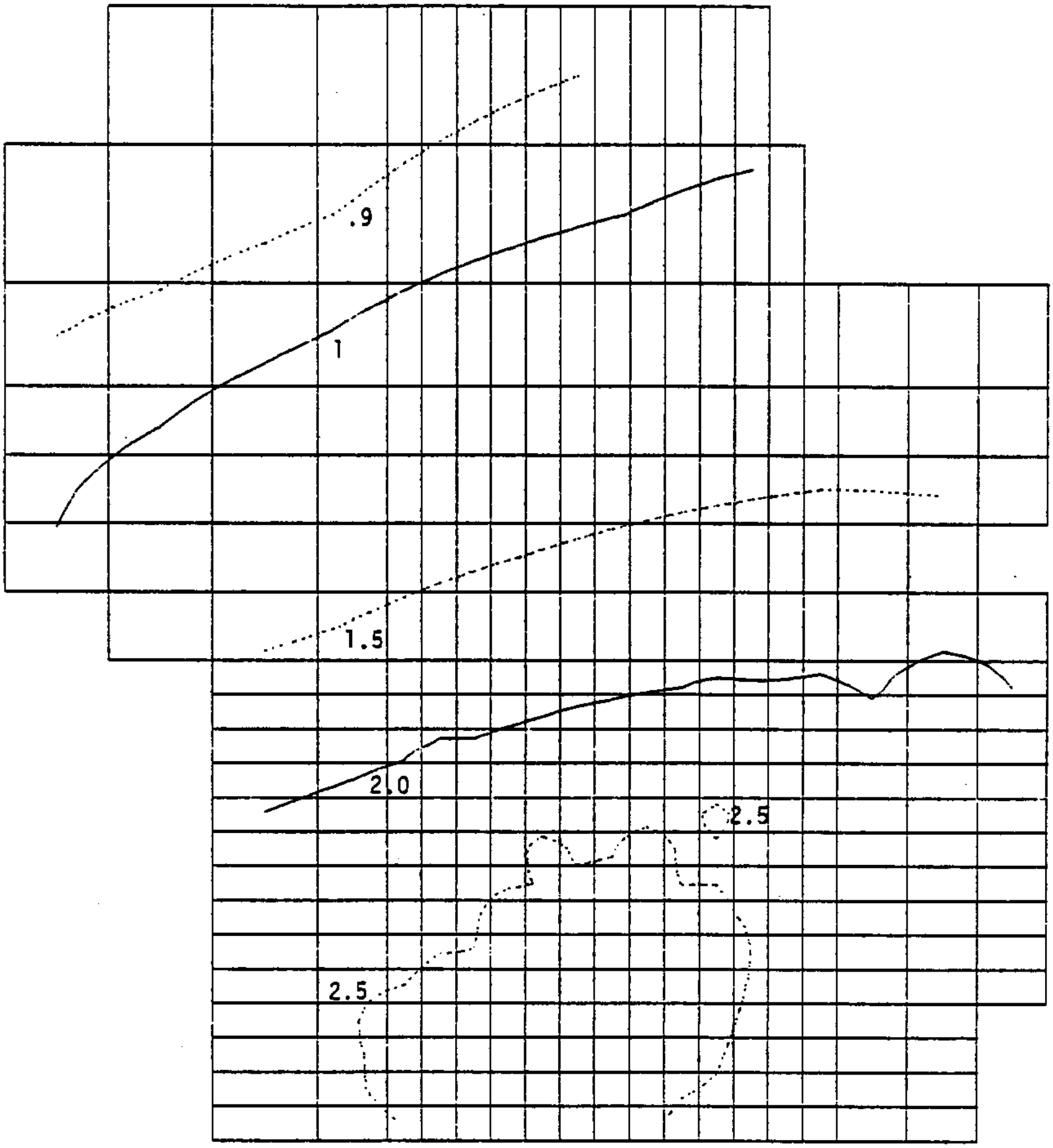


Figure 6b. Compaction Contours (feet) at t = 10 Years for Case 1.

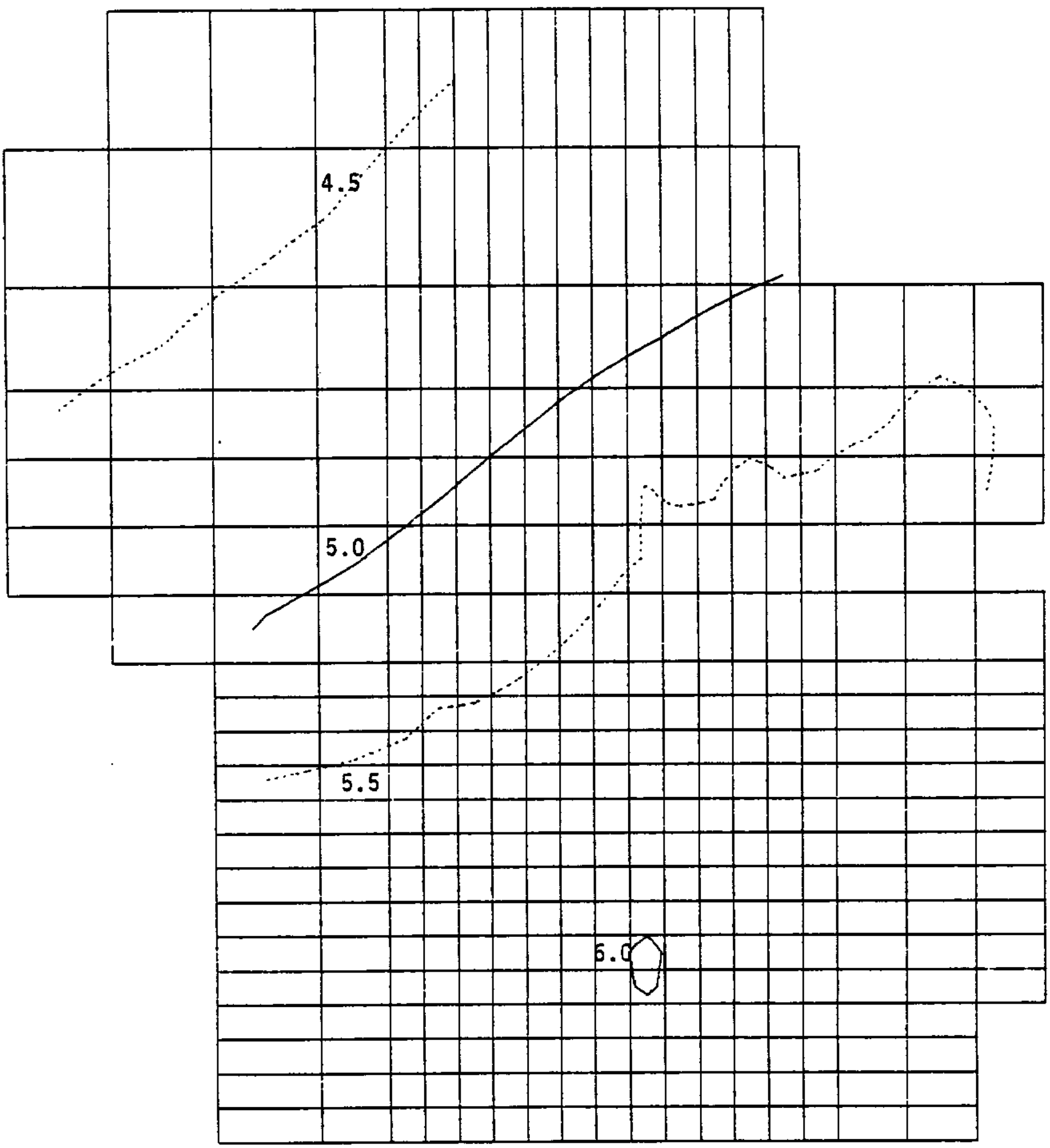


Figure 6c. Compaction Contours (feet) at t = 20 Years for Case 1.

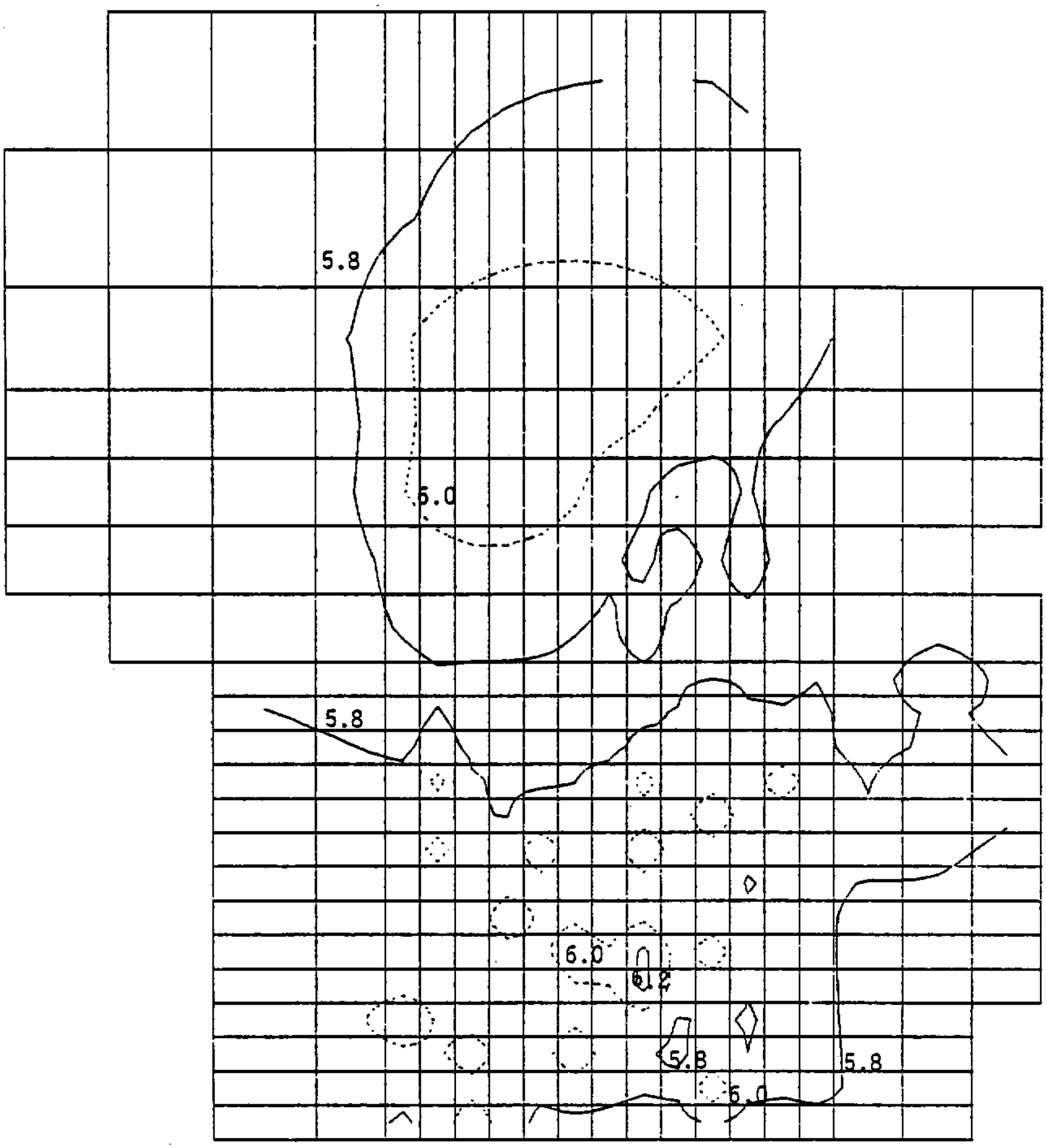


Figure 6d. Compaction Contours (feet) at t = 30 Years for Case 1.

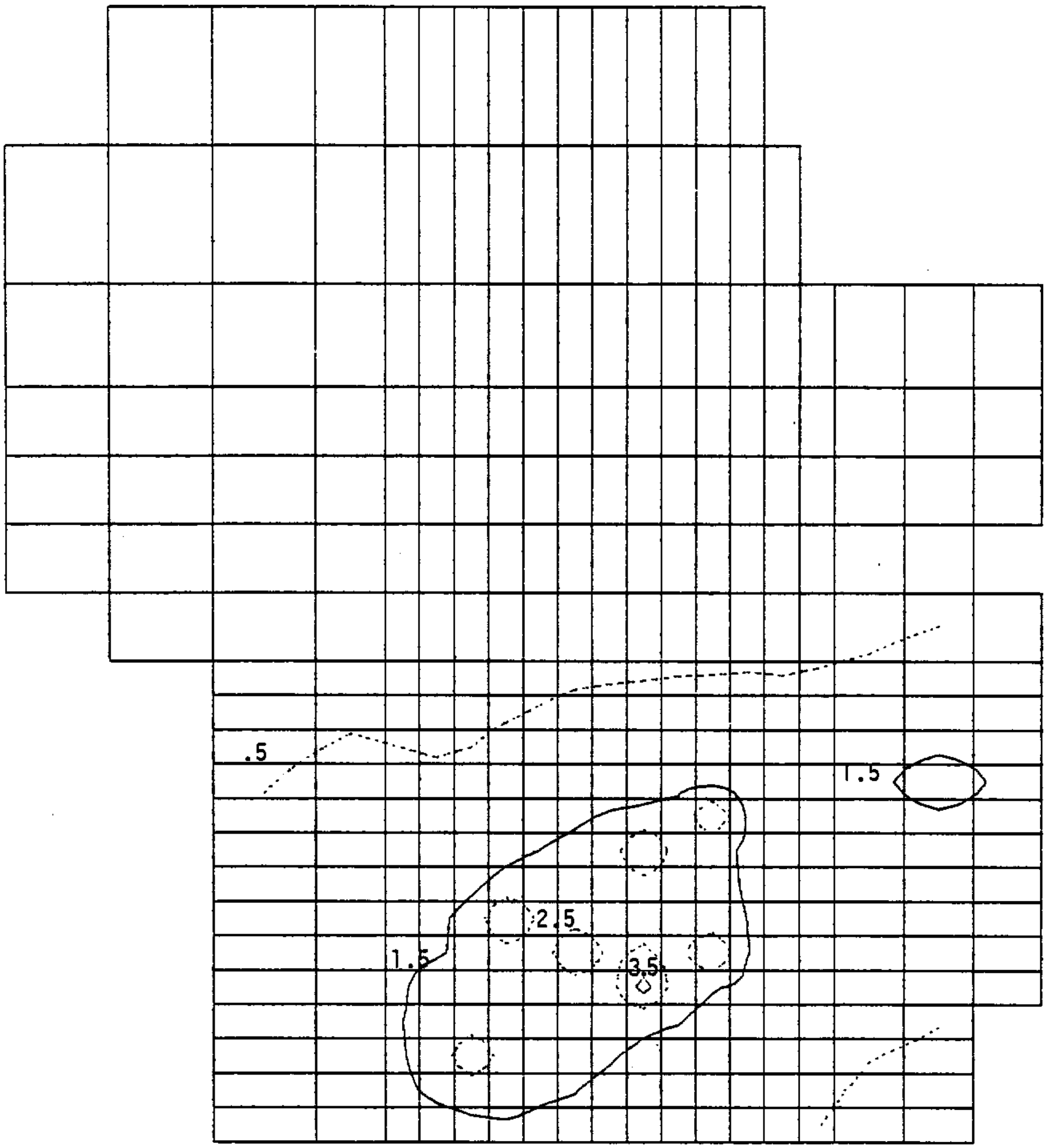


Figure 7a. Compaction Contours (feet) at t = 5 Years for Case 2.

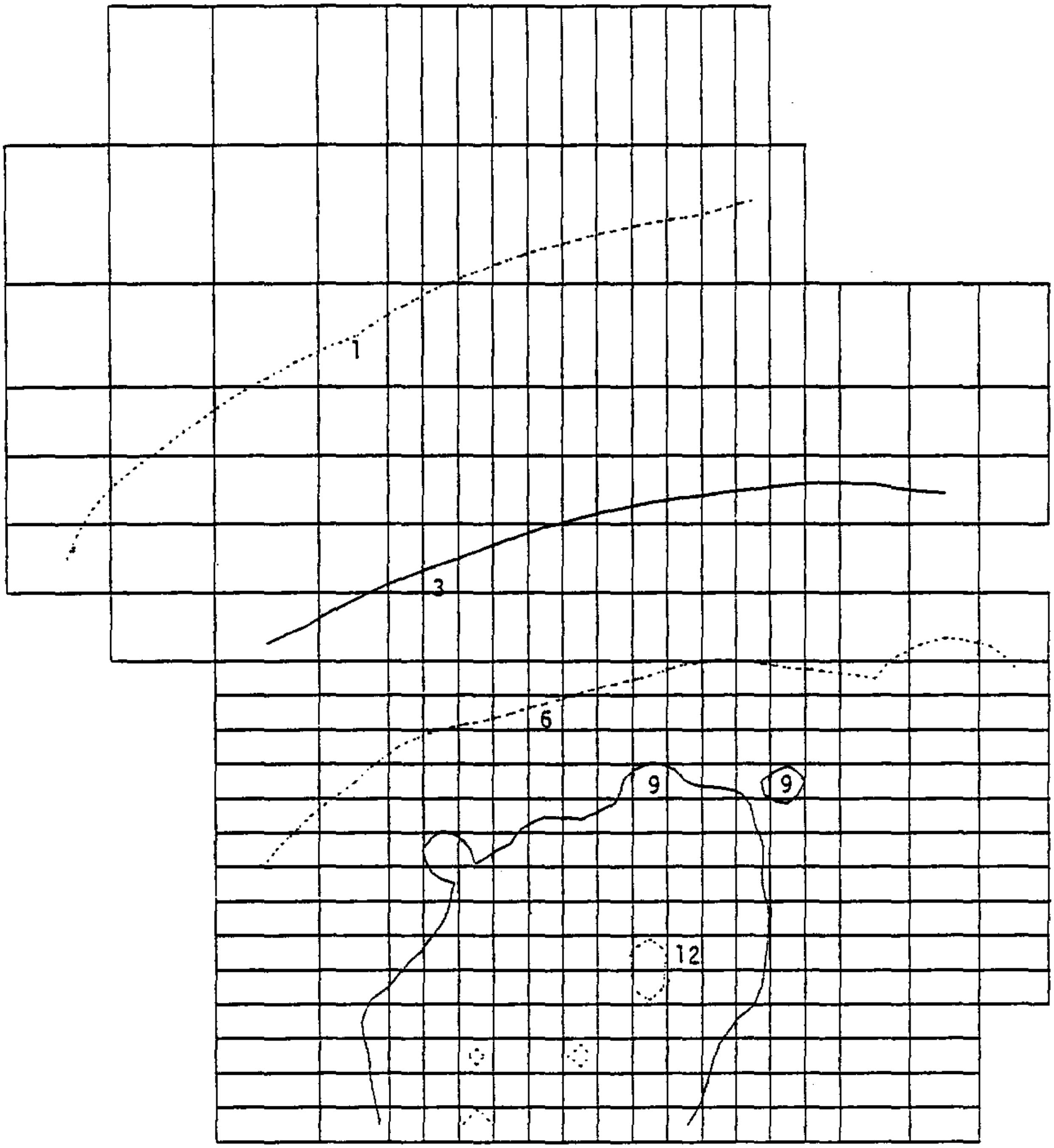


Figure 7b. Compaction Contours (feet) at t = 10 Years for Case 2.

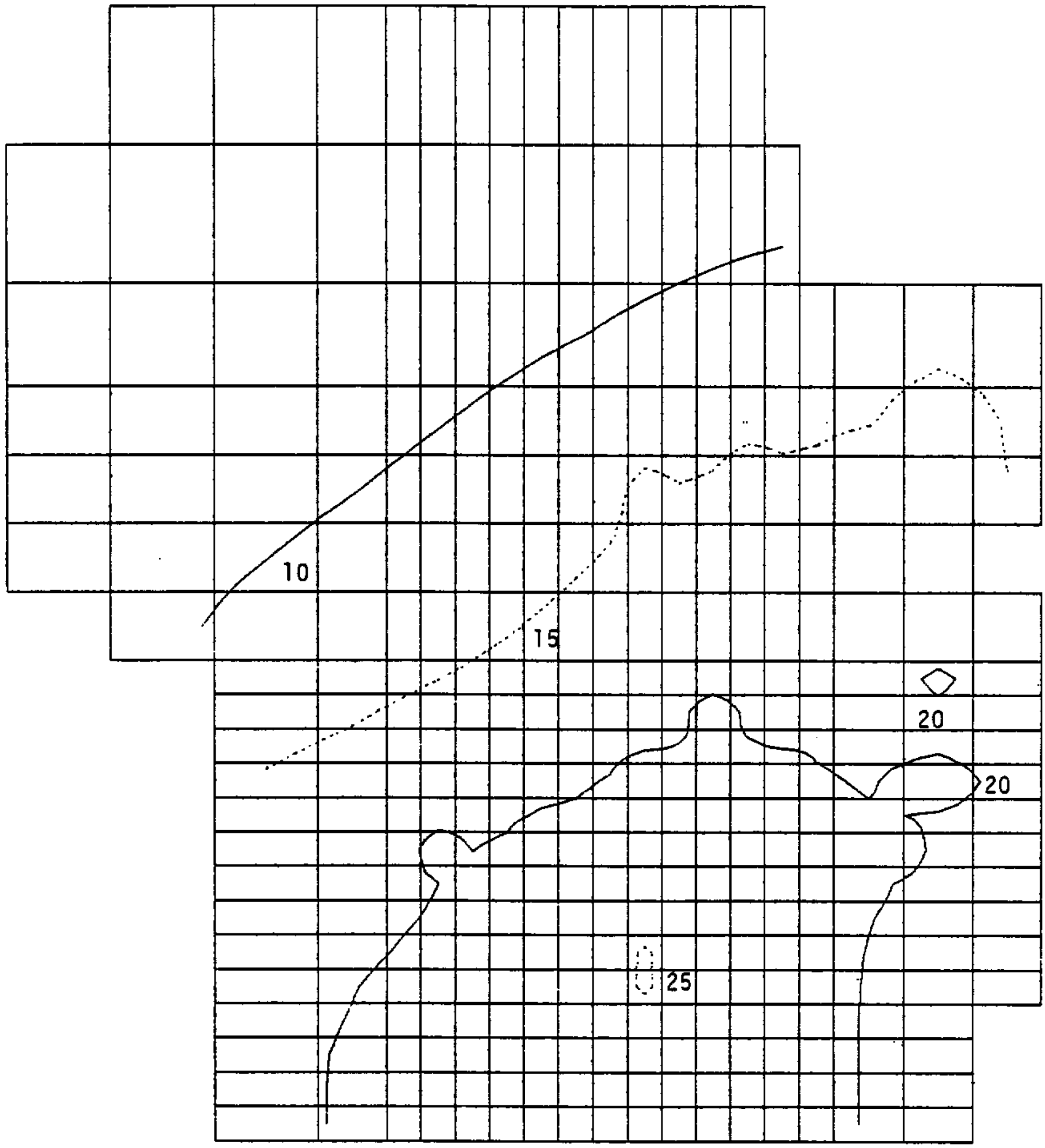


Figure 7c. Compaction Contours (feet) at t = 20 Years for Case 2.

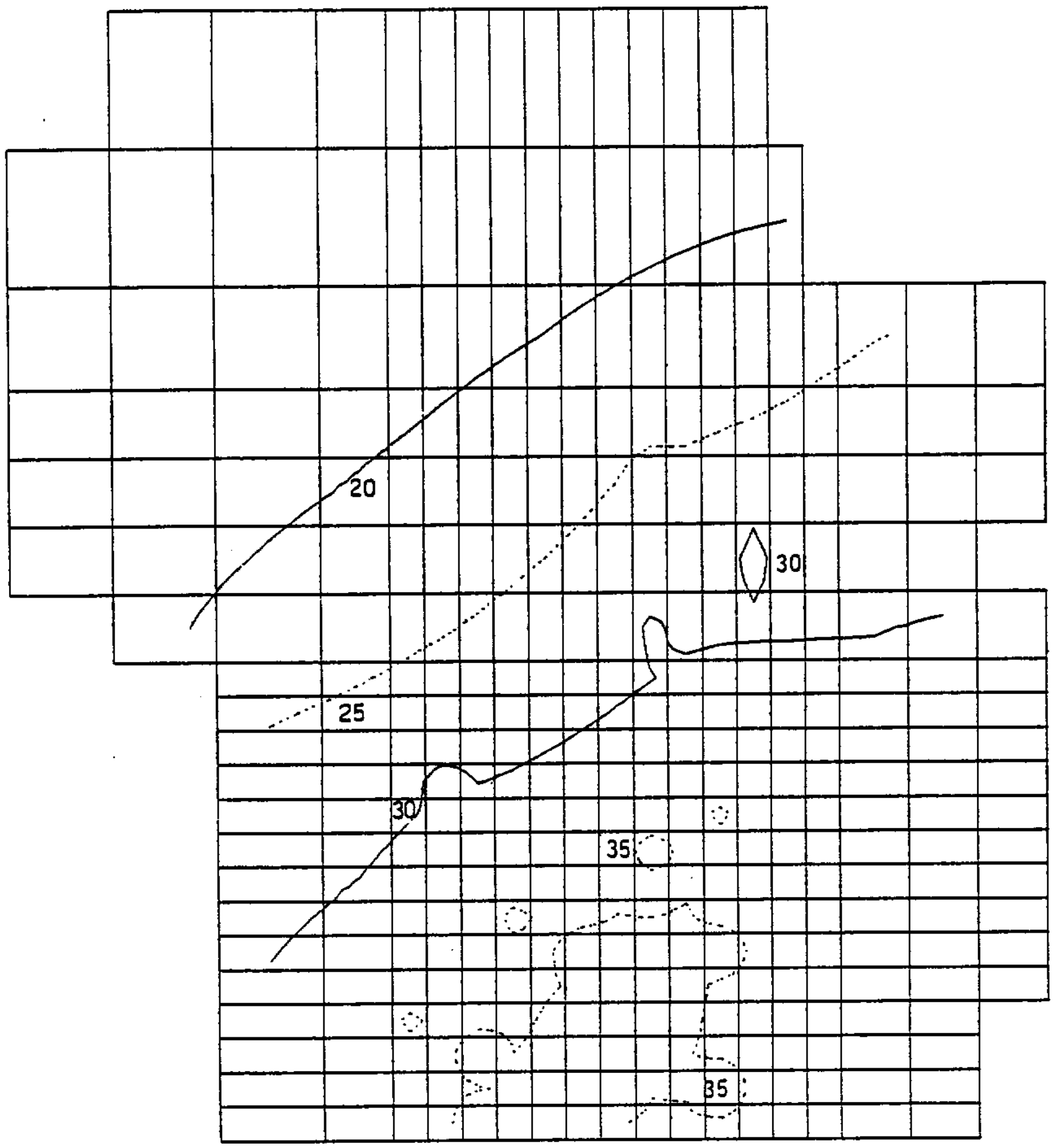


Figure 7d. Compaction Contours (feet) at t = 30 Years for Case 2.

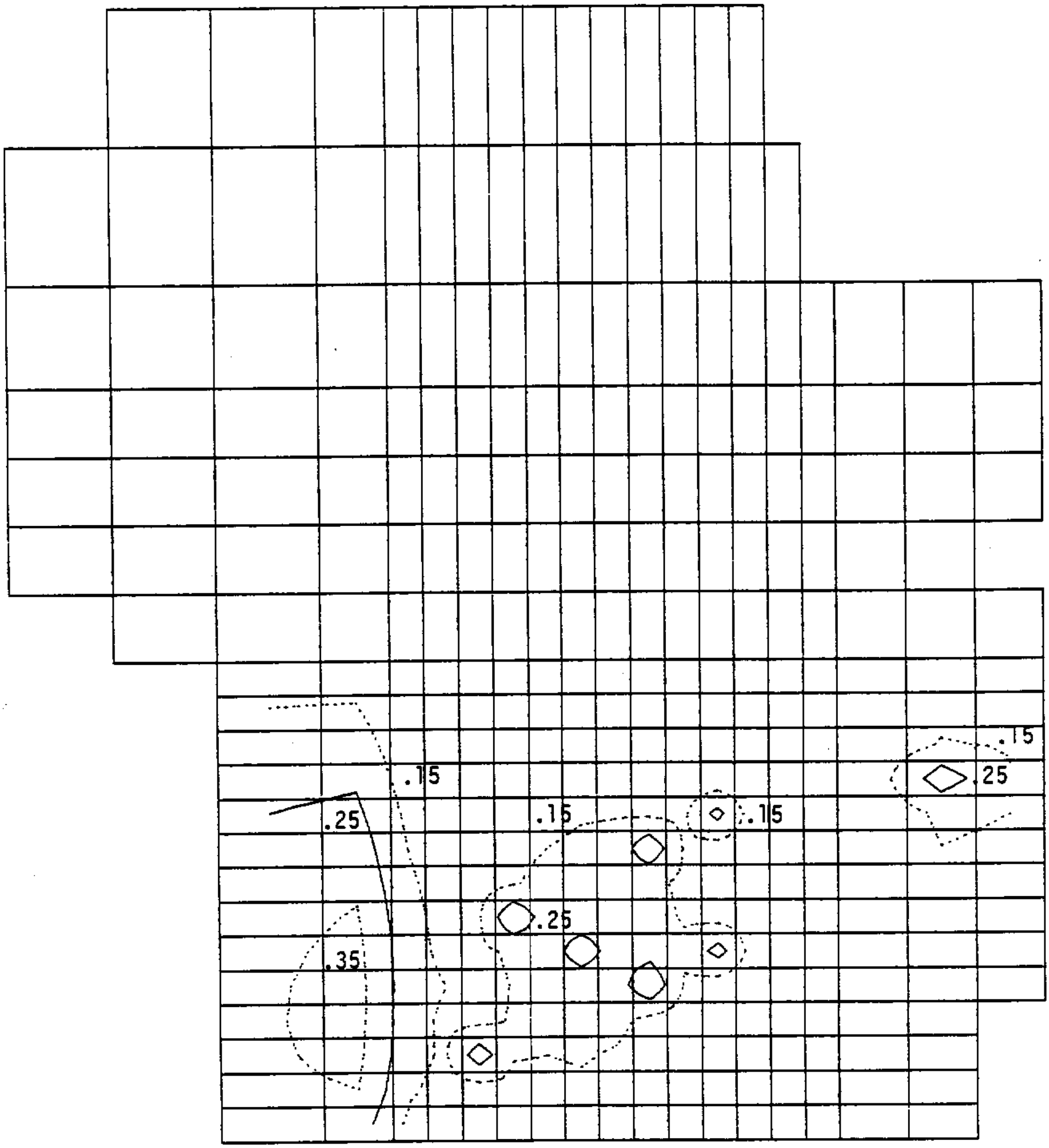


Figure 8a. Compaction Contours (feet) at t = 5 Years for Case 3.

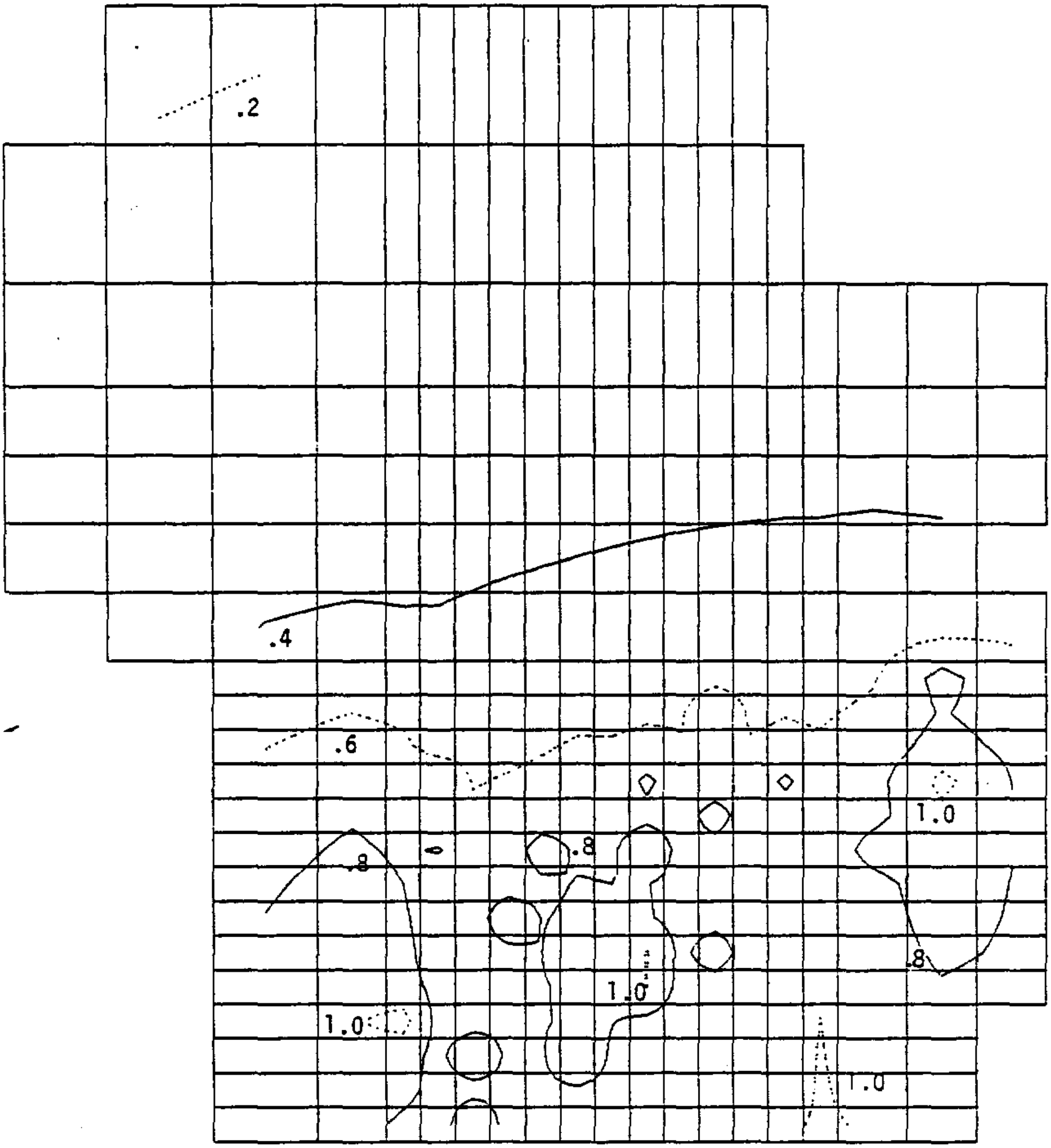


Figure 8b. Compaction Contours (feet) at t = 10 Years for Case 3.

Figure 8c. Compaction Contours (feet) at t = 20 Years for Case 3.

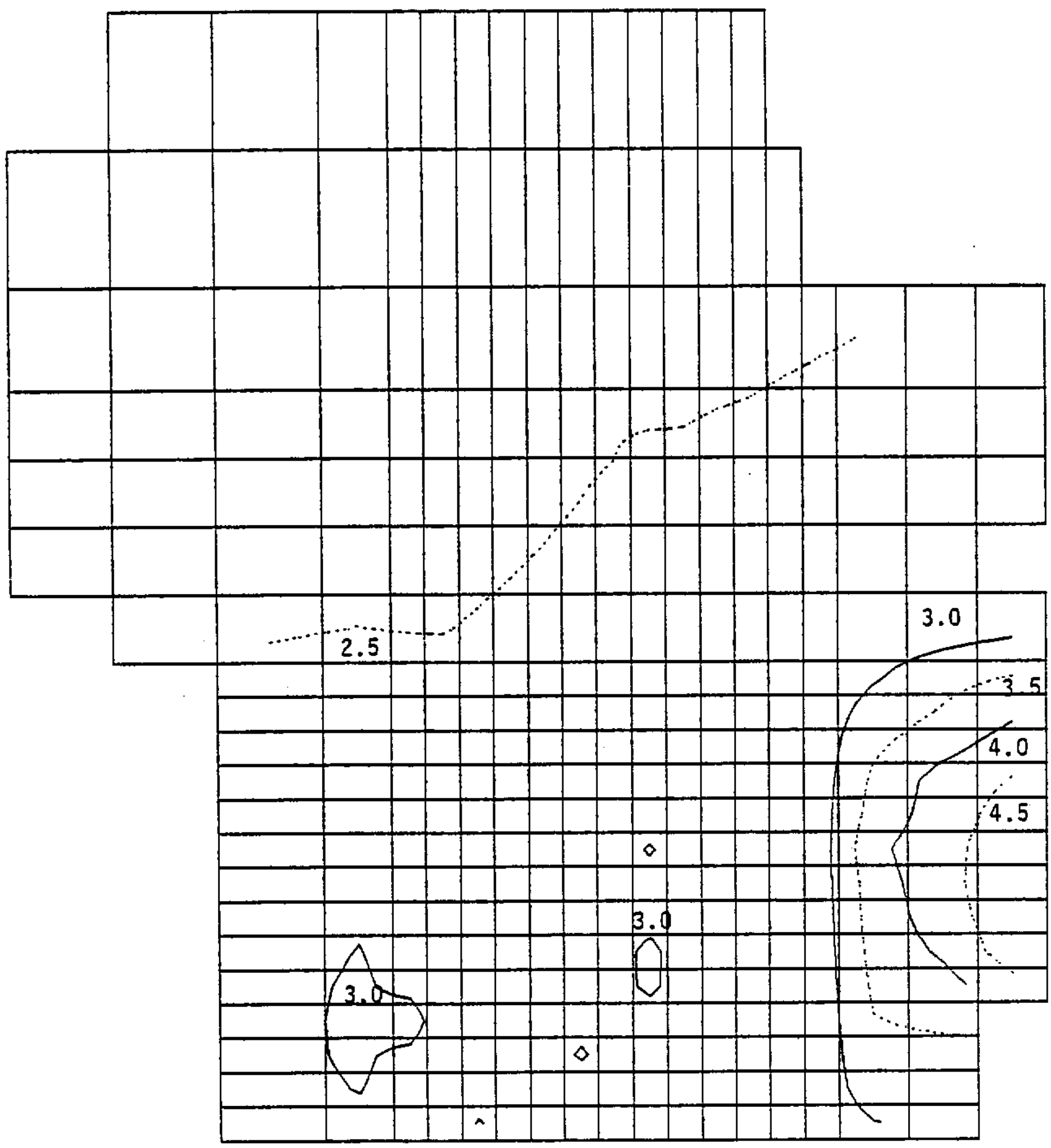


Figure 8d. Compaction Contours (feet) at t = 30 Years for Case 3.

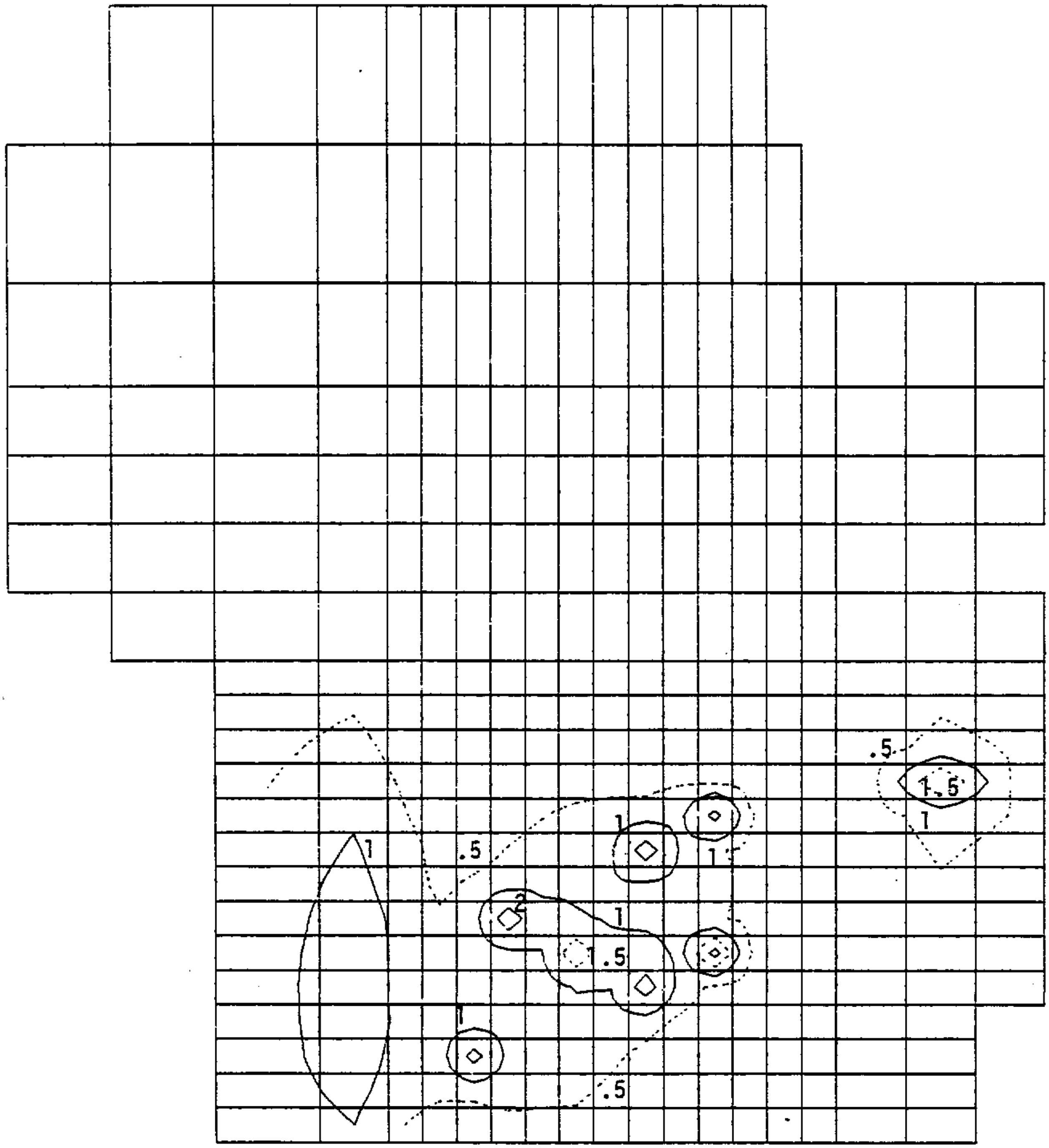


Figure 9a. Compaction Contours (feet) at t = 5 Years for Case 4.

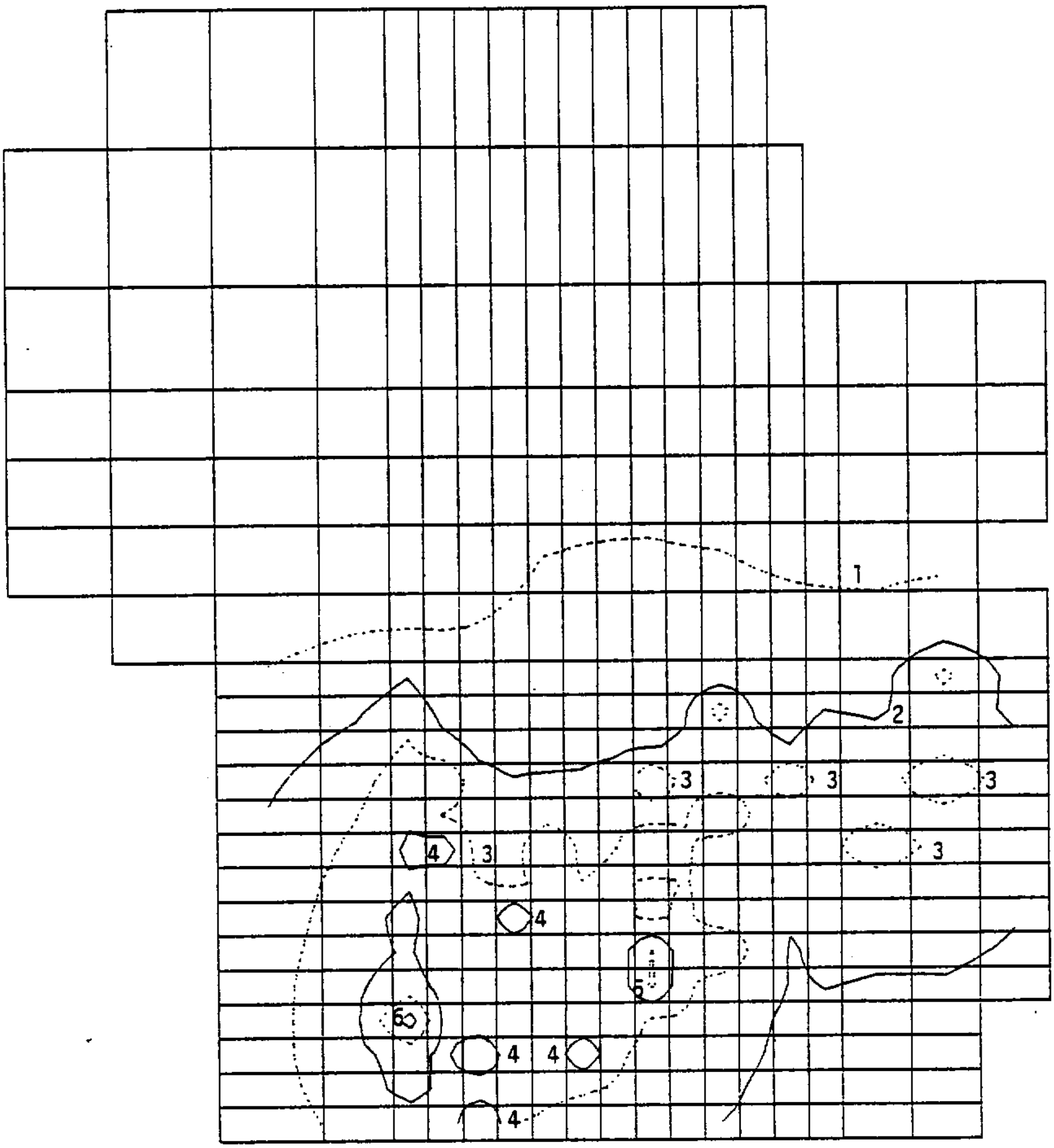


Figure 9b. Compaction Contours (feet) at t = 10 Years for Case 4.

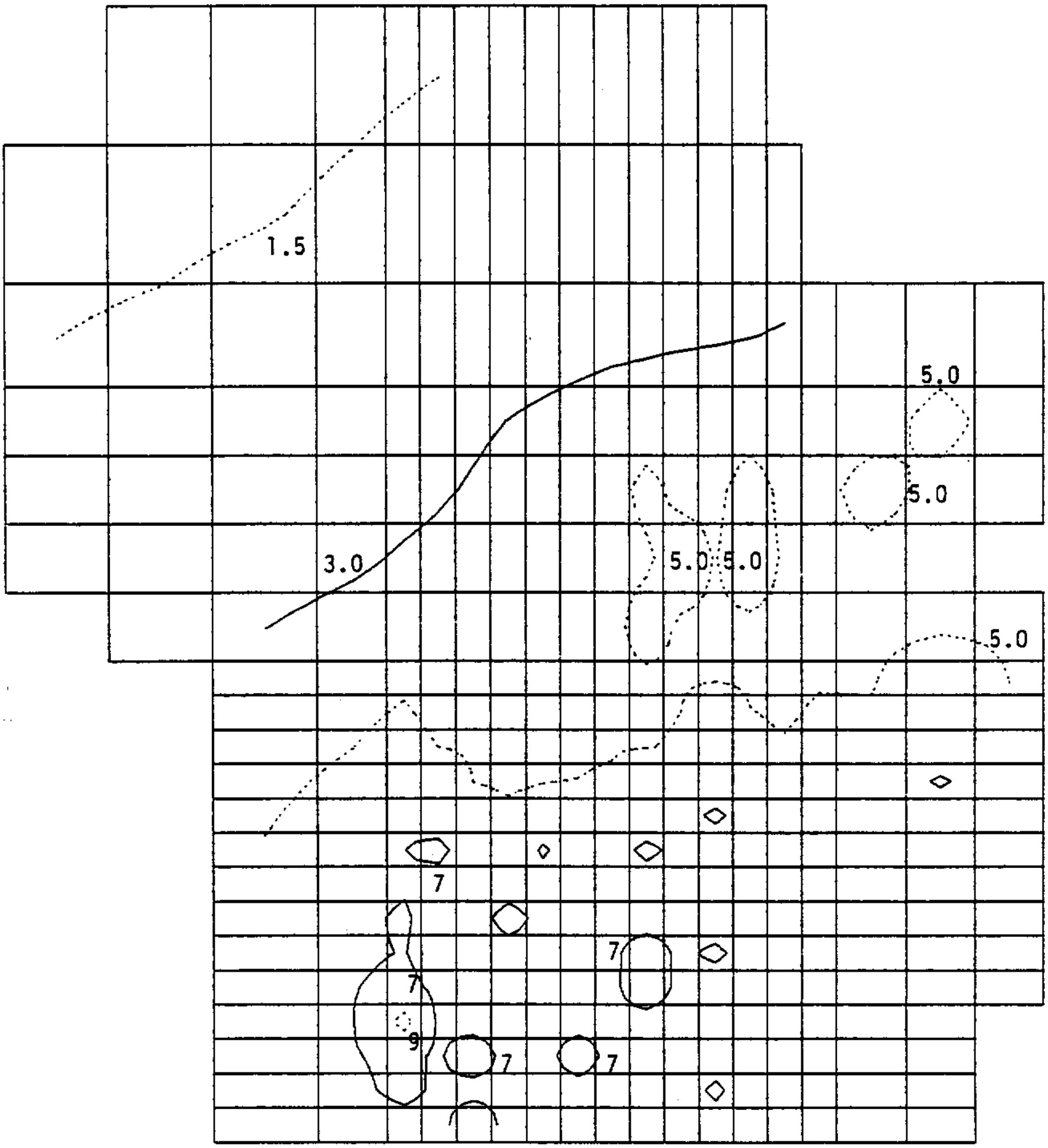


Figure 9c. Compaction Contours (feet) at t = 20 Years for Case 4.

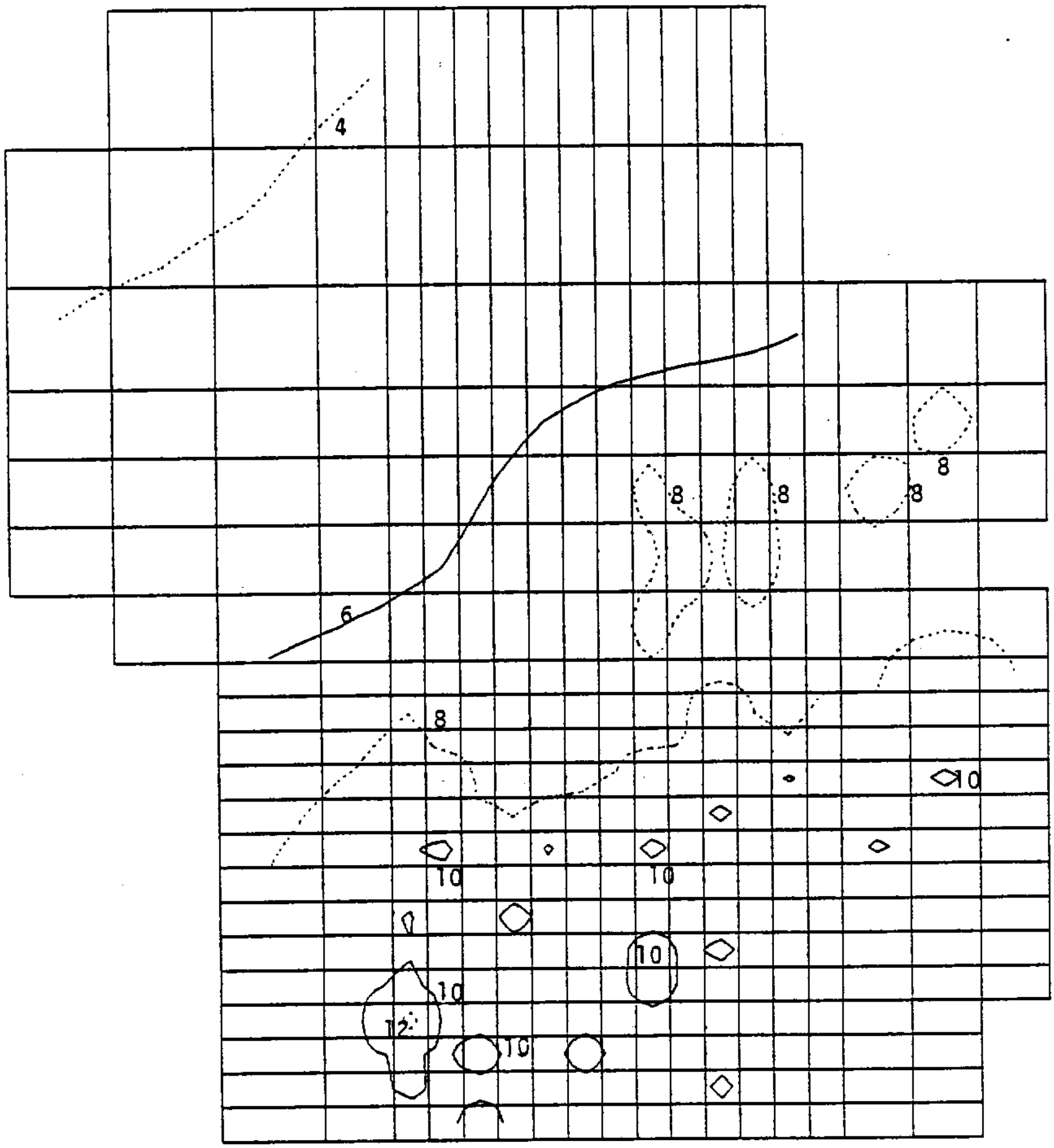


Figure 9d. Compaction Contours (feet) at t = 30 Years for Case 4.

The maximum pressure drop in Cases 2-4 was substantially less than 78 bars; for these cases no flashing should occur anywhere (a possible exception may be the region immediately surrounding a wellbore) in the reservoir and consequently the areal simulation should not break down. A different situation occurs in Case 1. Figure 10 shows the computed pressure drops for this case at t = 5, 10, 15 and 20 years. It is clear from Figure 10c that substantial portions of the reservoir are close to flashing at t = 15 years. Note that the computed pressure continues to drop even after t = 15 years (Figure 10d) since the reservoir pressure at 4000 ft. depth is some 98 bars over the saturation pressure at this depth. In any event, we do not expect the areal model to give accurate results after t = 15 years. For t > 15 years, the areal model will tend to somewhat overestimate pressure drops and thus, give a conservative estimate (ie. an over-estimate) of reservoir compaction.

For ready reference, the maximum compaction for the 4 cases as a function of time is summarized in Table 3. The maximum compaction at t = 30 years varies from a low of 4.5 ft. (Case 3) to a high of 35 ft. (Case 2). The effect of partial reinjection is to substantially (up to a factor of 3) increase reservoir compaction. The reservoir compaction does not linearly increase with formation compressibility (e.g., compare cases 3 and 4); this is explained by the fact that increasing formation compressibility tends to maintain reservoir pressures.

Table 3

RESERVOIR COMPACTION (FEET) AS A FUNCTION OF TIME

Time (Years)	Case 1	Case 2	Case 3	Case 4
5	0.5	3.5	0.35	2
10	2.5	12	1.0	6
20	6.0	25	2.7	9
30	6.2	35	4.5	12

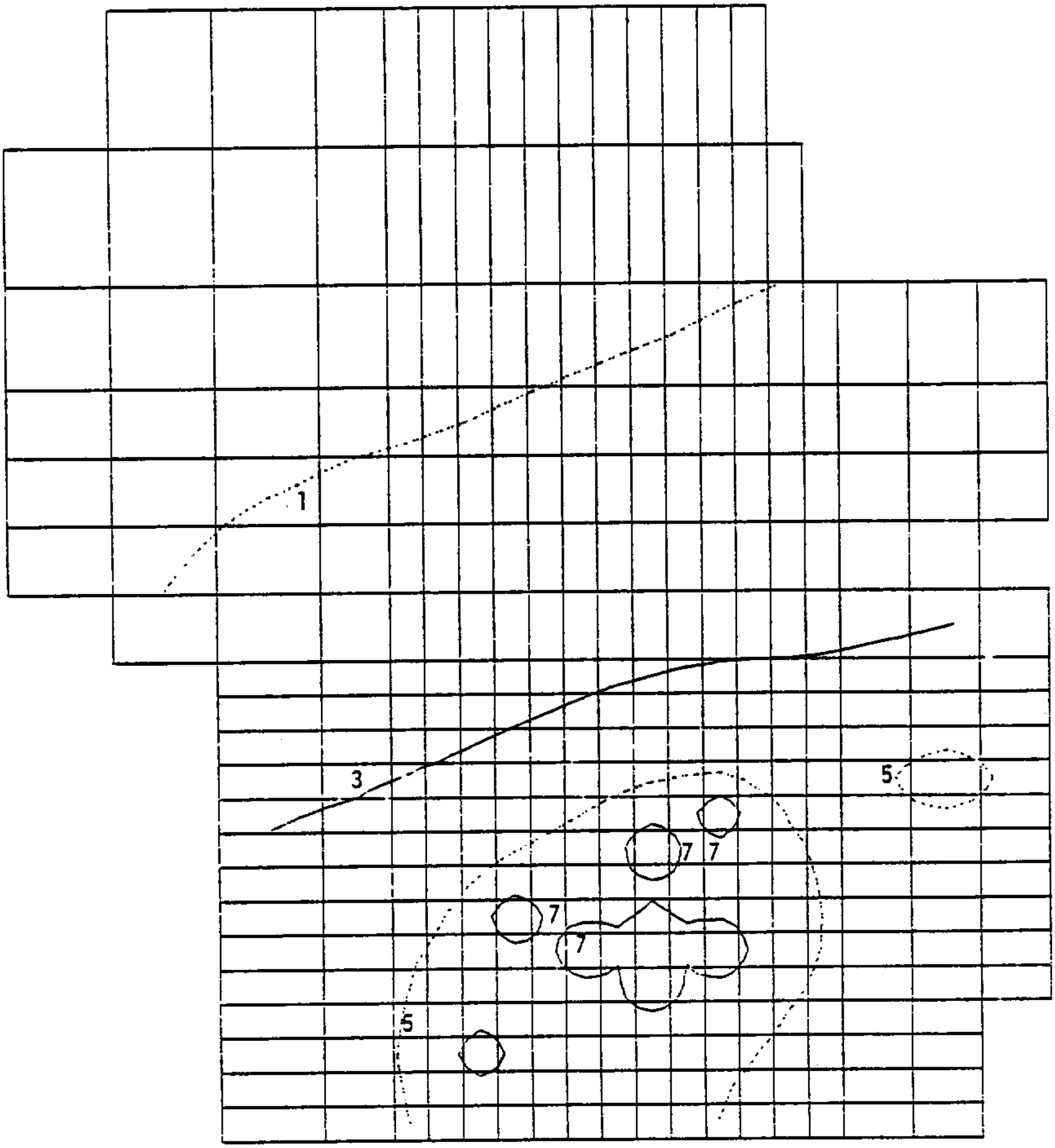


Figure 10a. Pressure Drop (bars) for Case 1 at t = 5 Years.

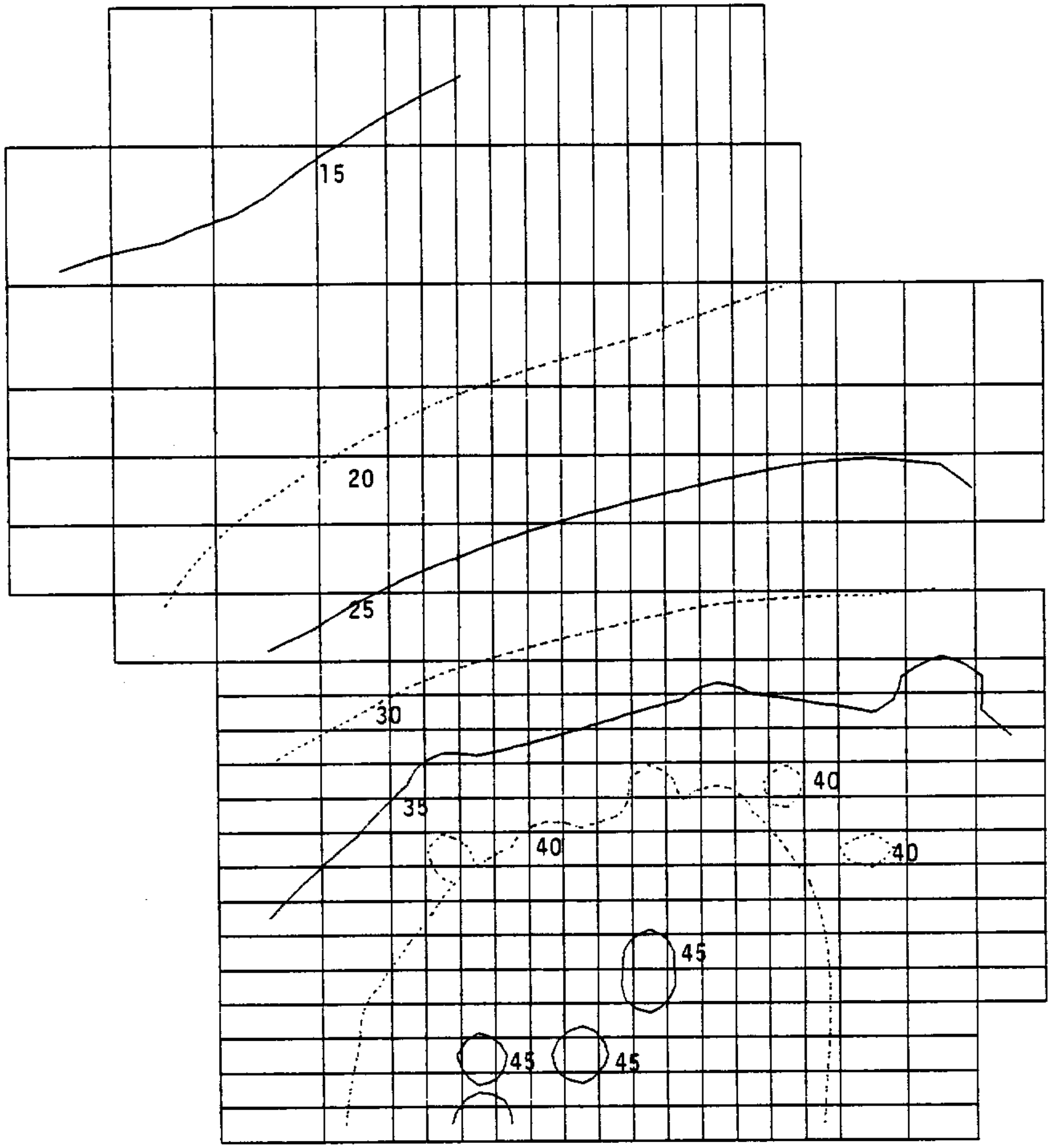


Figure 10b. Pressure Drop (bars) for Case 1 at t = 10 Years.

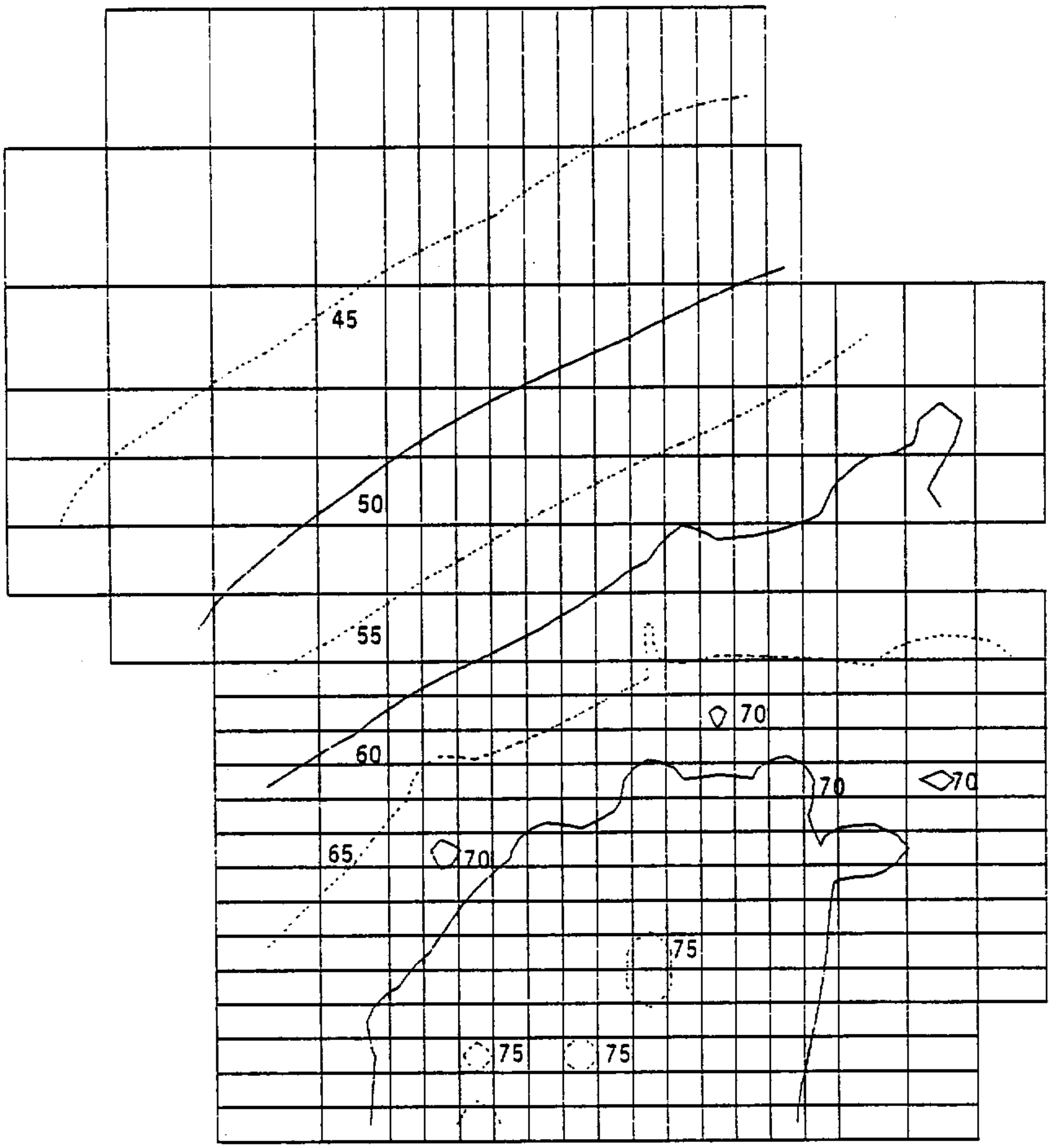


Figure 10c. Pressure Drop (bars) at t = 15 Years for Case 1.

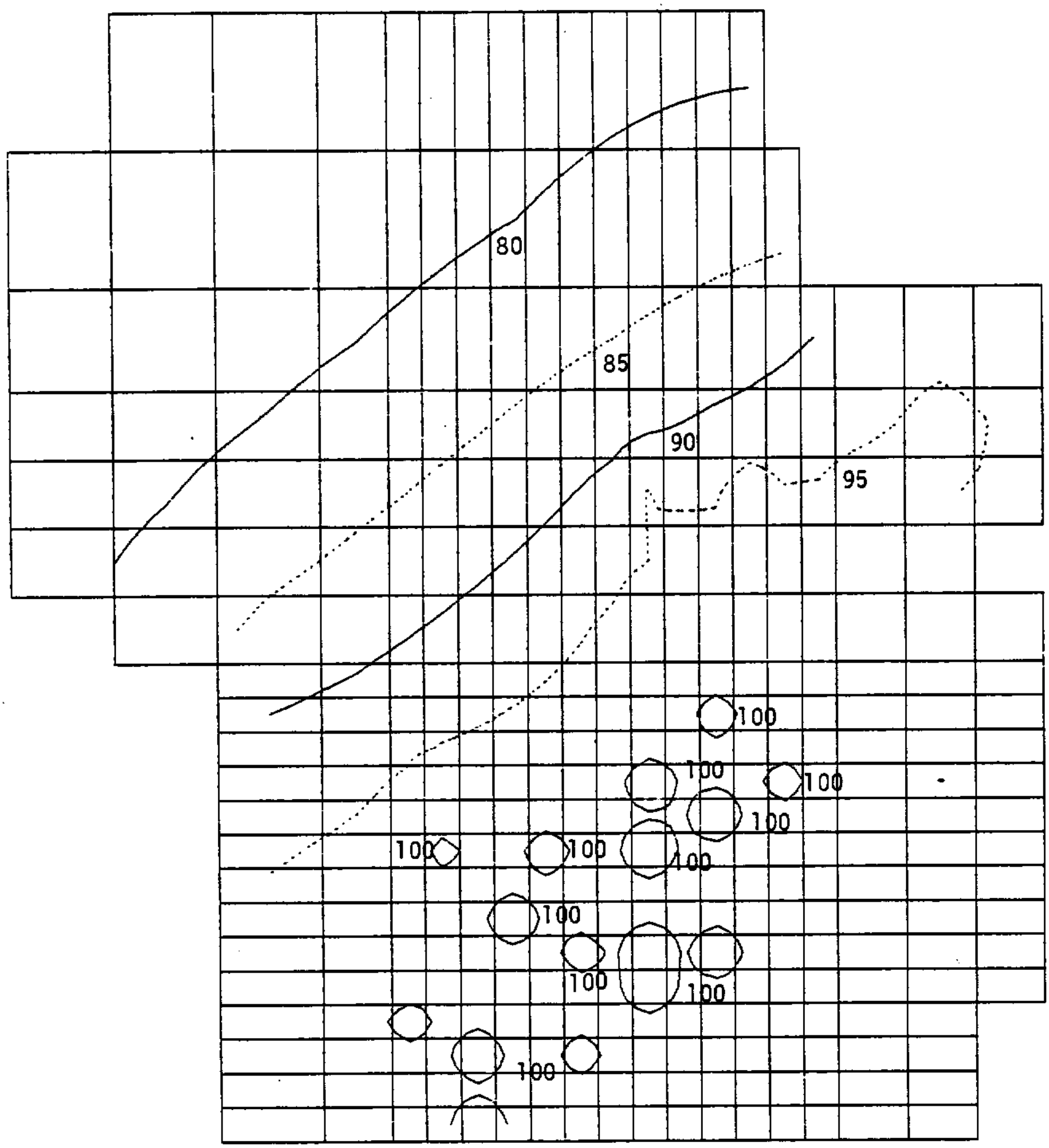


Figure 10d. Pressure Drop (in bars) at t = 20 Years for Case 1.

1.2.3 Thermal Contraction

Reinjection of colder waste fluids will lower temperatures in the vicinity of the reinjection wells. Figure 11 depicts the temperature drop contours for Case 3 at t=10, 20 and 30 years. Significant cooling occurs in the neighborhood of reinjection zones. Formation compaction due to thermal cooling is approximately given by (Garg, et al. [1977]):

$$\Delta h_{thermal} = h\beta \frac{1+\nu}{3(1-\nu)} \Delta T,$$

where

β = coefficient of volumetric thermal expansion

ν = Poisson's ratio

ΔT = Temperature drop

With $\nu = 0.2$, and $\beta = 5 \times 10^{-5}/°C$, we obtain

$$\Delta h_{thermal} = 0.1 \, \Delta T \text{ ft} \quad ,$$

where ΔT is in °C. Thus a drop of 10°C in temperature will result in one foot of reservoir compaction. Clearly, thermal compaction can be quite significant in the vicinity of reinjection wells. A compaction of the order of several feet can have serious consequences for the integrity of reinjection wells.

1.2.4 Surface Subsidence

In the preceding sections, we presented predictions of reservoir compaction accompanying drops in reservoir pressure/temperature. The formation compaction due to pressure drop (mechanical compaction) is spread over the entire area of the reservoir; the mechanical compaction is maximum in the area of power

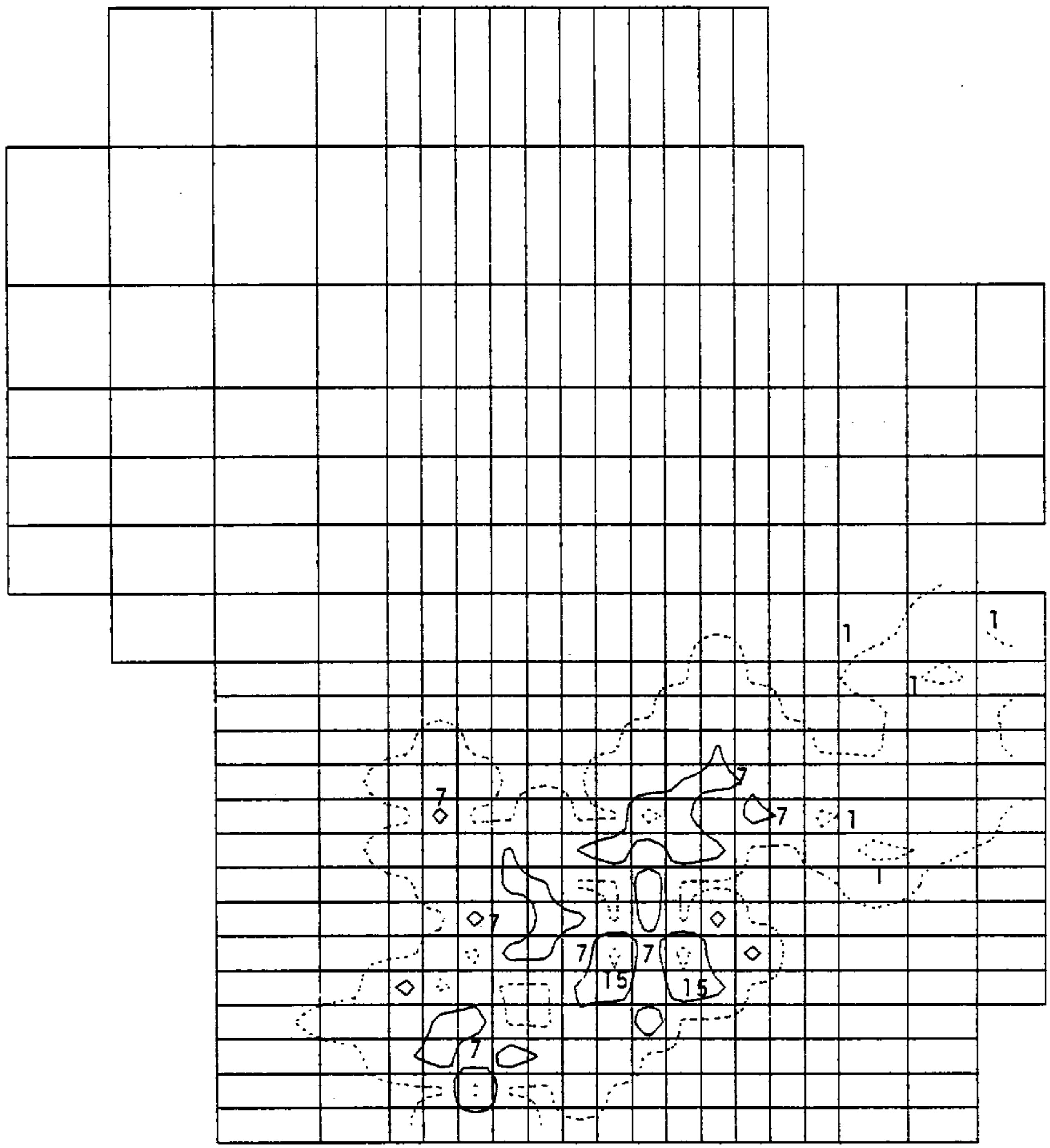


Figure 11a. Temperature Drop (°C) Contours at t = 10 Years for Case 3.

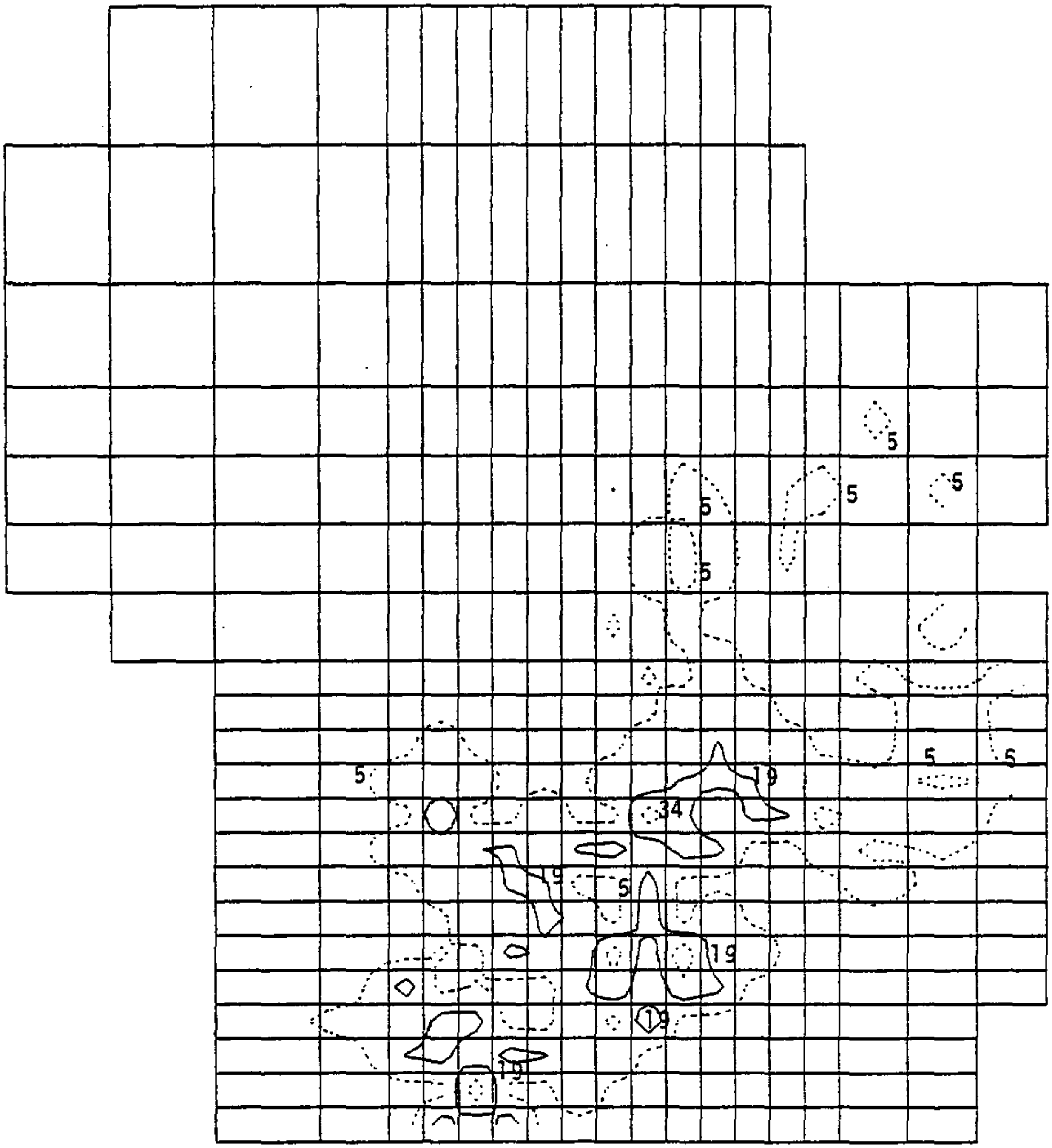


Figure 11b. Temperature Drop (°C) Contours at t = 20 Years for Case 3.

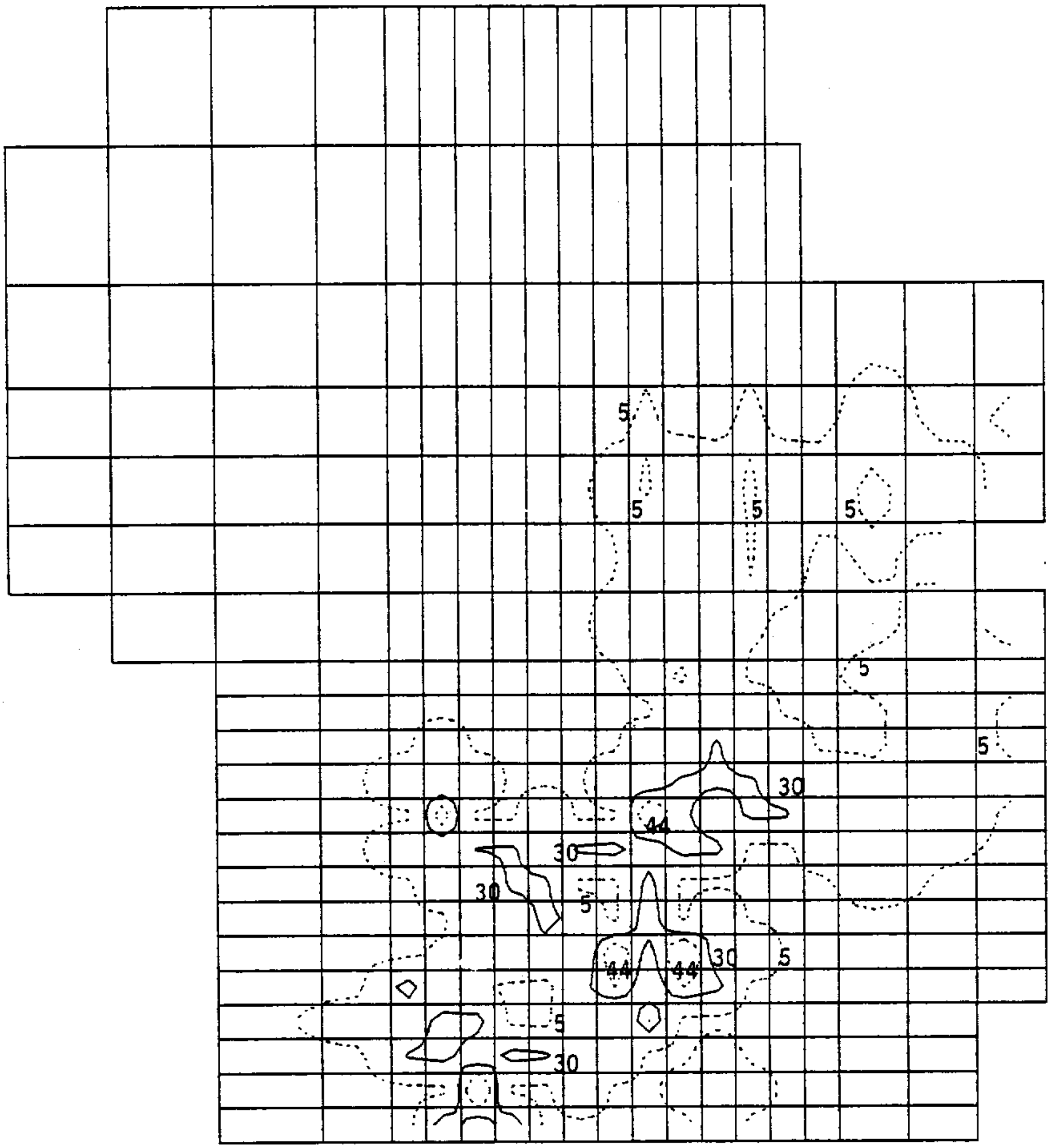


Figure 11c. Temperature Drop (°C) Contours at t = 30 Years for Case 3.

plants and declines somewhat as one moves to the north and northwest. The thermal compaction is, however, localized in the vicinity of reinjection zones. The predictions of mechanical compaction are perhaps somewhat pessimistic in view of the fact that we assumed the reservoir to have a closed boundary and to receive no recharge. Any recharge will naturally tend to reduce the calculated mechanical compaction.

The question now arises as to how much of the compaction will propagate upwards to the surface. An accurate analysis of subsidence requires a consideration of the structure, thickness and composition of the overburden. Assuming the overburden to be elastic, an estimate of surface motion can be obtained by employing Geertsma's [1973] "nucleus of strain" model. An application of Geertsma's method yields the following results:

(i) Practically none of the thermal compaction will appear at the surface;

(ii) Essentially all of the mechanical compaction will appear as surface subsidence;

(iii) Surface subsidence, albeit less than the reservoir compaction, will also occur over an area which is much greater than the geothermal overlay zone.

Imperial Valley is a complexely faulted region. It is entirely possible that differential movement will occur along some of these faults. Differential movement of this sort has been observed along the Texas Gulf Coast (see e.g., Gustavson and Kreitler [1976]). Practical effects of differential surface movement along the faults would be to (1) produce uneven surface subsidence, and (2) limit the surface area (beyond the project area) affected by subsidence. No precise estimates of differential fault movement are, however, possible at this stage; such estimates must await the actual experience with geothermal operations in the Imperial Valley.

Despite the uncertainties involved in our predictions of reservoir compaction and land subsidence, it is clear that geothermal operations at the scale envisaged in this MEIR have a potential for producing significant changes in the Niland area topography. Any substantial changes in topography would seriously impact surface structures and irrigation lands.

1.3 MITIGATION MEASURES (Subsidence)

It is estimated that maximum potential subsidence at Niland is in the range of 4 feet to 35 feet over a 30 year period. (We would like to stress here that the latter estimates for potential subsidence are subject to large errors in so far as at present there exists either only limited or no data on the overburden structure and material properties, formation compaction coefficient, and the distribution of pressure and temperature in the thermal reservoir. The predictions of subsidence are most likely pessimistic in view of the fact that we assumed the reservoir to have closed boundary and to receive no recharge. Any recharge will tend to reduce the calculated subsidence.) Additionally, there exists definite potential for differential fault movement, and land fissuring. The natural land subsidence at Niland due to regional tectonism is of the order of 1-4 cm/year. For the 30 year period, regional tectonic subsidence in the project area can be in the range of (2.5-6.0) ft. Thus there exists a possbility that geothermal related subsidence will greatly exceed the natural subsidence, and may damage the present canal and drain operations.

We would like to sound a note of caution here. Geothermally related subsidence would not appear uniformly over the 30 year period. In the early years when only a few of the plants would be operational, subsidence due to geothermal operations would be relatively small. The subsidence would, however, accelerate in later years as more and more geothermal plants come on line. This should provide sufficient time for mitigation measures to take place.

In accordance with the Imperial County Geothermal Element, production permits issued by the County will require operators to (1) reinject 100 percent of the produced fluids and (2) monitor subsidence detection networks. California State Division of Oil and Gas (DOG), in conjunction with the County's land use authority, may, however, relax the 100 percent reinjection requirement.* If detrimental subsidence is detected attributable to geothermal production, DOG would need to approve the operator's amelioration program.

In recent years, government and private agencies and private industry have initiated montioring programs to gather data on natural subsidence. These baseline data together with future regional leveling surveys and the subsidence monitoring by geothermal operators should be sufficient to differentiate regional subsidence/uplift caused by tectonic forces from geothermal development activities.

If damaging geothermal related subsidence is detected, one or more of the following mitigation measures may be taken:

1. Requiring over 100 percent reinjection to compensate for thermal contraction of reinjected fluids,

2. Stopping further geothermal activities,

3. Maintaining canal and drain gradients periodically.

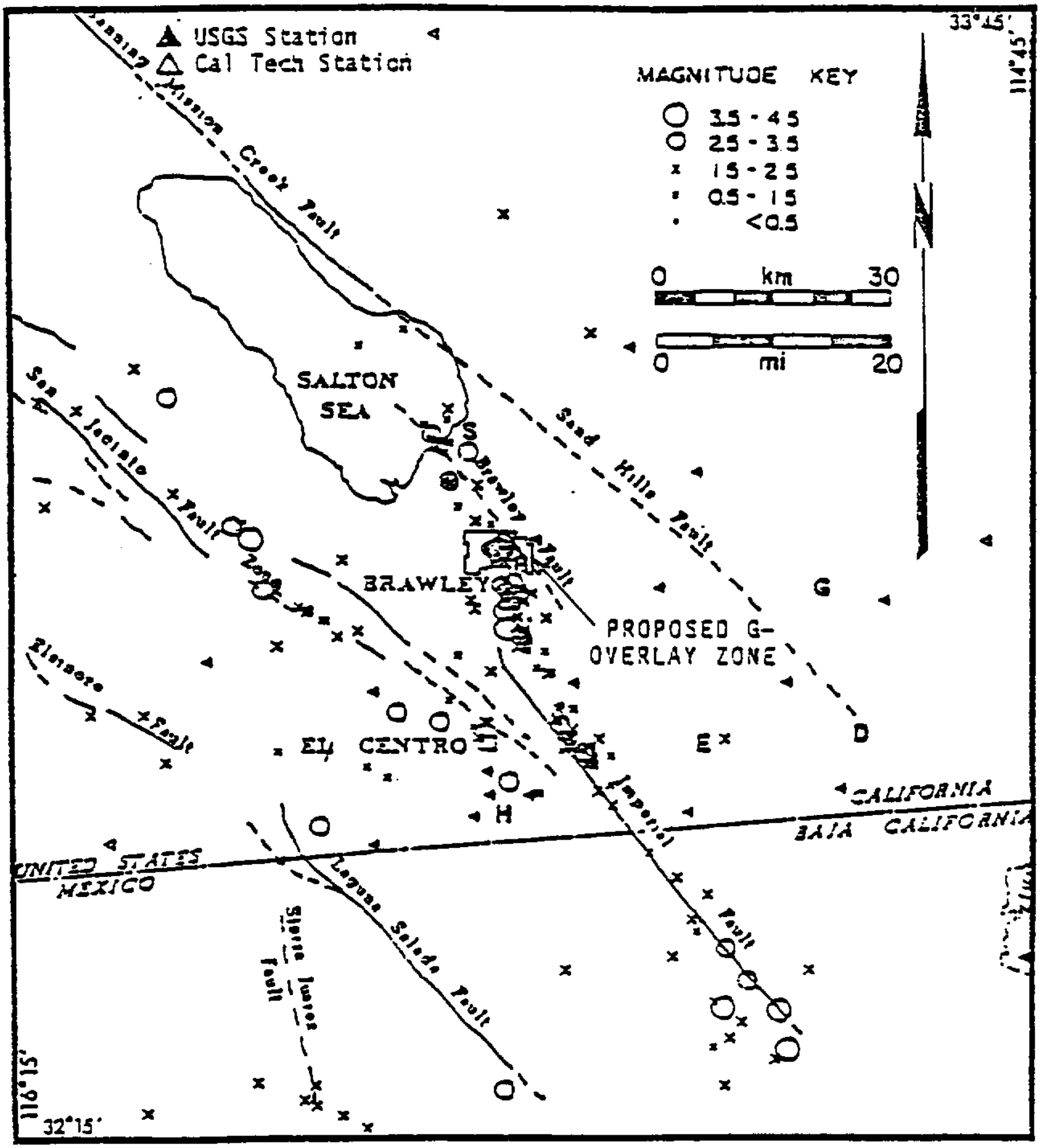
*This county procedure may be more completely stated by noting that applications for less than 100 percent reinjection are submitted to DOG. If DOG approves less than a 100 percent reinjection requirement, the County, in accordance with its land use authority may allow its permit to reflect this condition.

II. INDUCED SEISMICITY

2.1 REGIONAL SEISMICITY

The Salton Sea/Imperial Valley/Mexicali Valley geothermal basin is a sediment-filled rift valley which is, in effect, the northerly landward extension of the Gulf of California. The region is heavily faulted in a roughly NW-SE direction (Figure 12). Several of these faults have been the source of intense seismic activity during the last few decades. The East Pacific Rise (a seafloor spreading center) is believed to underlie both the Gulf of California and the geothermal rift zone, and is responsible for the abnormally high heat fluxes found throughout the area. The basement rock in most of the region is well over 4 kilometers below the present land surface. A recent S^3 analysis of the seismic and gravity data from the Imperial Valley shows the geothermal hot spots to be associated with locations where the basement rises to a much smaller distance from the surface (Savino, et al. [1979]). Several regions of potential interest for geothermal extraction have been identified, including the Cerro Prieto field in Mexico, the Niland, Dunes and East Mesa anomalies.

Expansion of the U. S. Geological Survey-California Institute of Technology seismic monitoring network early in 1973 has led to an accumulation of data concerning small magnitude earthquakes, earthquake swarms and microearthquake activity in the Imperial Valley. Information from this monitoring network resulted in the addition of the Brawley and Calipatria Faults to the list of known Faults in the Imperial Valley, just as the El Centro earthquake of 1940 added the Imperial fault.



Source: Hill *et al.*, 1975.

Figure 12. Earthquake Epicenters in the Imperial Valley, June 1, 1973 to May 31, 1974.

Results of seismic monitoring from June 1, 1973 to May 31, 1974 are shown in Figure 12 (Hill, et al. [1975]). Epicenters are concentrated primarily along the previously unknown Brawley Fault and along the Imperial Fault. Many of these epicenters were in the area of the proposed G-Overlay Zone at depths of between 16,500 and 40,000 ft. (5 to 12 km) (Table 4).

The statistical seismic data for the Imperial Valley has been analyzed by several investigators (see e.g., Evernden [1970], Hileman, et al. [1973]). The available statistical seismic data are, however, such that any conclusions about future seismicity and the present state of stress in the relatively small area of the Niland Anomaly are liable to be uncertain.

The Niland Anomaly lies in the high strain release zone. If we take 10 km x 10 km as a typical area of a geothermal operations we can combine the total strain release with the observed frequency N and magnitude M relation, to estimate the likelihood of occurrence of earthquakes in the area:

$$\log N = a - bM$$

where a and b are constants. For M = 0, the number of events N over 30 years is approximately 10,000 - 50,000; per year we get 300 - 1500 events (of M = 0), and thus $a \approx 2 - 3$. Also b = 0.85 for the Imperial Valley (Hileman, et al. [1973]).

In other words, for undisturbed conditions we expect each year to have, in an 10 x 10 km^2 area, 300 - 1500 events of M = 0; 50 - 200 events of M = 1; 15 - 30 events of M = 2; 2 - 10 events of M = 3; 0.1 - 1 events of M = 4; and 0.1 events of M = 5.

Table 4

DEPTH DISTRIBUTION OF HYPOCENTERS OF EARTHQUAKES OCCURRING WITHIN THE BRAWLEY AND IMPERIAL FAULT ZONES, JUNE 1, 1973 TO MAY 31, 1974

		Depth of Hypocenters (ft/m)	
Geothermal Field	Intergeothermal Areas	Minimum	Maximum
Niland		4,000/1,200	16,000/4,880
	Niland-Brawley (Brawley Fault)	12,000/3,660	28,500/8,690
Brawley		16,500/5,030	40,000/12,200
	Area between Brawley Fault and Imperial Fault	16,500/5,030	42,500/12,950
	Imperial Fault	17,000/5,180	48,000/14,630

Note: Gravity and seismic models of the Imperial Valley show the following significant features at the following depths (in feet and meters):

a. Top of basement at Niland Field = 18,000/5,500

b. Top of basement at Brawley Field = 22,000/5,700

c. Top of basement at Heber Field = 23,000/7,000

d. Base of crust in Imperial Valley = 46,000/14,000

Source: Hill, *et al.* [1975].

2.2 POTENTIAL FOR INDUCED SEISMICITY

Fluid injection in the presence of large tectonic stresses can lead to shear failure and fault slippage. As examples, we cite the experience at Rocky Mountain Arsenal near Denver, Colorado and Rangely field, Colorado. In both of these cases as the water was driven into the faulted region, small earthquakes began to occur. When the pumping was stopped, the occurrence of earthquakes persisted for a period, then as the fluid pressure declined by continued diffusion, the earthquake activity also diminished. Both locations exhibit very different regional and local geologic conditions from those at Niland. Table 5 identifies the critical data for these examples of injection-induced earthquakes. In the case of the Rocky Mountain Arsenal, high injection pressure was used because of the volume of toxic wastes being injected; at Rangely, the low porosity and permeability of the Weber sandstone reservoir encouraged high pressure injection for secondary recovery purposes. It should be noted that pore pressures were not only sufficient to reduce the normal stress across fracture surfaces, but were so high that they exceeded the least stress pressure for initiating fractures.

Macroearthquake activity (earthquakes greater than magnitude 3.0) has apparently never been attributed to the production of geothermal fluid, despite the fact that geothermal fluids (e.g., at Niland) tend to inhabit areas having high levels of seismicity. The effects of the production of large volumes of fluid on the accumulation of strain within a finite geothermal anomaly is unknown. The effects of the removal of large volumes of geothermal fluid from the center of the geothermal anomaly and the injection of equal volumes of lower temperature spent fluid near the periphery of the anomaly are also unknown. Only detailed seismic monitoring accompanying production will be able to contribute definitive data regarding this potential hazard. Relative to experience in

Table 5

CRITICAL DATA FOR EARTHQUAKES INDUCED BY INJECTION

Data	Rangely	Denver
Reservoir formation	Sandstone	Granite
Depth to injection zone	6,200 ft (1,884 m)	12,000 ft (3,648 m)
Average porosity of reservoir	12 percent	(Fractured)
Average permeability of reservoir	1 millidarcy	(Fractured)
Original reservoir pressure	2,465 psi	2,900 psi
Maximum pore pressure due to injection	4,205 psi	5,640 psi
Least stress for initiating fractures	3,725 psi	5,200 psi
Maximum magnitude of earthquakes	3.1	5.3
Focal depth of earthquakes	6,550 to 11,500 ft (1,991 to 3,496 m)	14,750 to 18,000 ft (4,484 to 5,472 m)

Sources: Healy, et al. [1968], Raleigh, et al. [1976].

producing liquid phase geothermal fields in Mexico, El Salvador, New Zealand and Japan, this factor is believed to be of minimum environmental significance.

In order to make a good estimate of seismic risk in any given geothermal area, we must know (1) the state of tectonic stress, (2) the rate at which it is accumulating, (3) the mechanics of faulting, and in particular the role of fluid pressure and the relation between injection and induced earthquake magnitudes, and (4) pore pressure and flow associated with the geothermal operation. Each one of these four items requires a model due to our limited knowledge in most practical situations.

If we assume that local injection and pumping operations cause only local deformation and do not trigger earthquakes which are substantially larger than the affected injection volume, we can estimate the tectonic state from past seismicity. The question then is how will this natural seismicity be modified by injection and pumping, etc. To answer this we must make further assumptions. Two possibilities follow:

1. In the frequency-magnitude relation, $\log N = a - bM$, assume that a and b are physical parameters which depend on pore pressure. The parameter a is a measure of the overall seismic activity and would increase with injection. The parameter b is a measure of the number of large events relative to small events; preliminary results (laboratory and theory) exist which suggest that the value of b increases with pore pressure. Thus, there is more seismic activity and relatively more small events than large ones at high pore pressure.

2. We can try a more mechanical rather than statistical model, in which one actually computes the distribution of pore pressure and finds its effects on triggering of slippage on a hypothetical fault plane.

The major difficulty in utilizing the first approach is the present lack of a theoretical and/or empirical relationship between the parameters a and b, and the pore pressure. The second approach is clouded by uncertainities regarding the fault strength. Although it is relatively straightforward to compute pore pressure changes (see Section I on Subsidence), there exists at present no method to utilize this information to make a quantitative estimate of induced seismicity. All that one can state with confidence at this time is that increases in pore pressure will lead to increased seismicity.

As part of reservoir compaction predictions presented in Section I, we calculated pore pressure changes that would accompany geothermal fluid extraction/reinjection operations. For the cases considered, even 100 percent reinjection did not lead to any buildup of pore pressures. The high porosity and permeability of the reservoir formation precludes the development of high pore pressures. In the above referred to calculations, no attempt was made to resolve the individual reinjection wells, and it is entirely possible that pore pressures in the immediate vicinity (few hundred feet at the most) do indeed experience a modest increase over the initial formation pressures. Increases in pore pressure in a small region surrounding the wellbore will not, however, significantly alter the seismic activity. We would also like to point out that the maximum allowable injection pressures are limited by the Division of Oil and Gas per the following formula:

$$P_i = 0.85D - P_h$$

where, P_i is the injection pressure, D equals depth, and P_h is the hydrostatic gradient which, at Niland, equals 0.47 psi per foot of depth. The reservoir basement at Niland lies at a depth of approximately 6000 ft.; this is the minimum hypocenter depth for microearthquakes in geothermal anomalies in the deepest portion of the Salton Trough basin. In view of the unlikelihood of significant pressure increases accompanying fluid injection and the relatively shallow depth of reservoir, we conclude that at present there exists little reason to expect that fluid injection will cause significant expansion of seismic activity at Niland.

In addition to seismicity induced by injection, concern has also been expressed that production-level withdrawal of fluids and heat from a geothermal reservoir may alter the seismic activity. Tien Lee recently theoretically calculated increases in frequency and magnitude of earthquakes within geothermal anomalies accompanying a release of thermal strain due to large scale production of geothermal fluid. Production equivalent to 100 MW for one year was estimated to have the potential to double the earthquake frequency and increase the maximum magnitude from 3.0 to 4.1 (Biehler and Tien Lee [1977]). Seismicity induced by the extraction of heat is, however, conjectural and can only be resolved by long-term seismic monitoring.

2.3 MITIGATION MEASURES - INDUCED SEISMICITY

The seismic characteristics of the Niland Anomaly lead to the conclusion that there are minimal enivronmental concerns related to potential earthquakes induced by geothermal production and injection practices on a commercial scale. The Niland Anomaly is characterized by high frequency, low magnitude (<3), shallow hypocenter earthquakes and literally continuous microseismic activity.

Detailed seismic and microseismic data for Imperial Valley KGRAs are currently being accumulated by the Lawrence Livermore Laboratory (Fuis [1977]). As geothermal development proceeds, the LLL seismic data will serve as a baseline against which induced seismicity due to fluid withdrawal or reinjection can be measured. Any statistically significant changes in the baseline seismic regime (an increase in seismic event frequency, magnitude or depth, for example) should be apparent.

If during the period of geothermal operations any statistically significant changes in the seismic activity do occur, then mitigation programs such as those utilized at the Rocky Mountain Arsenal and the Rangely Oil Field may be considered. These programs consisted of alternate periods of shutdown and full operation until a statistical relationship between earthquake activity and production-injection was obtained. In practice, these extreme measures will probably never be required because the volume of engineering data for the Niland Anomaly will have expanded to the point where computer modeling will very likely be able to account for any pressure or thermal factors responsible for increased seismic activity.

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APPENDIX 3.2

HYDROLOGY

Table A3.2-1

AVERAGE CHEMICAL QUALITY
OF NEW RIVER WATER (1962-1966)

Constituent (mg/l)	International Boundary	Upstream of Salton Sea
Calcium	242	233
Magnesium	123	117
Sodium	1,209	890
Potassium	---	---
Bicarbonate	291	288
Sulfate	732	797
Chloride	2,001	1,400
Nitrate	14	25
Fluoride	1.03	0.87
Boron	1.79	1.30
pH	7.3	7.5
Total Hardness	1,111	1,061
Electrical Conductivity (micromhos/cm @ 25°C)	7,354	5,828
Total Dissolved Solids	4,865	3,900
Dissolved Oxygen	6.3	7.9
Temperature (°F)	71	70
Flow (cfs)	144	507

Data from San Diego Gas & Electric Company (1976).

Table A3.2-2

AVERAGE CHEMICAL QUALITY
OF ALAMO RIVER WATER (1966)

Constituent (mg/1)	International Boundary	Upstream of Salton Sea
Calcium	182	199
Magnesium	97	112
Sodium and Potassium	627	525
Bicarbonate	289	247
Sulfate	815	872
Chloride	803	699
pH	7.9	7.5
Electrical Conductivity (micromhos/cm @ 25°C)	3,888	3,695
Total Dissolved Solids	2,838	2,703
Flow (cfs)	2	853

Data from VTN Consolidated, Inc. (1978).

Table A3.2-3

CHEMICAL QUALITY OF THE NEW RIVER NEAR THE OUTLET
(T12S/R13E-29E)

Constituent (mg/l)	Maximum	Minimum	Trimmed Mean
Calcium	290	80	221
Magnesium	141	25	116
Sodium	1,385	150	932
Potassium	50	16	28
Sulfate	893	831	881
Chloride	1,580	1,183	1,333
Boron	2.60	0.20	1.80
Fluoride	2.76	0.52	1.27
pH	8.0	6.5	7.6
Electrical Conductivity (micromhos/cm @ 25°C)	6,450	4,400	5,408
Total Dissolved Solids	4,430	3,384	3,790
Barium	0.41	0.13	0.19
Lithium	0.79	0.42	0.57
Manganese	0.26	0.06	0.16
Strontium	5.10	2.00	3.87
Zinc	0.05	0.00	0.01
Temperature (°C)	30.0	12.9	21.5

Data for 1976-77 from Lawrence Livermore Laboratory computer printout.

Table A3.2-4

CHEMICAL QUALITY OF THE ALAMO RIVER NEAR THE OUTLET
(T11S/R13E-23E)

Constituent (mg/l)	Maximum	Minimum	Trimmed Mean
Calcium	291	80	198
Magnesium	143	30	115
Sodium	817	150	596
Potassium	16	9	13
Sulfate	1,068	804	967
Chloride	840	590	741
Boron	1.33	0.10	0.93
Fluoride	2.69	0.64	1.43
pH	8.1	7.1	7.7
Electrical Conductivity (micromhos/cm @ 25°C)	4,900	3,400	3,848
Total Dissolved Solids	3,320	2,290	3,056
Barium	0.28	0.00	0.11
Lithium	0.24	0.16	0.20
Manganese	0.07	0.01	0.02
Strontium	5.00	2.00	3.24
Zinc	0.03	0.00	0.01
Temperature (°C)	30.8	10.4	20.7

Data for 1976-77 from Lawrence Livermore Laboratory computer printout.

Table A3.2-5

NUTRIENT CONCENTRATIONS IN THE NEW AND ALAMO RIVERS

Constituent (mg/l)	New River 4/18/72	New River 1968-69	Alamo River 4/18/72	Alamo River 1968-69
Organic Nitrogen	0.40	0.97	0.71	1.23
Ammonia-Nitrogen	1.10	0.47	0.29	0.58
Nitrite-nitrogen	0.22	0.22	0.32	0.32
Nitrate-Nitrogen	4.30	4.48	5.10	6.00
Orthophosphate-Phosphorous	0.27	0.29	0.25	0.20
Total Phosphorous	1.10	0.60	0.94	0.33
Total Nitrogen	6.02	6.14	6.42	8.13

Data from U.S. Department of the Interior and Resources Agency of California (1974).

Table A3.2-6

CHEMICAL QUALITY OF COLORADO RIVER WATER
AT IMPERIAL DAM (1972-1973)

Constituent (mg/l)	Maximum	Average
Calcium	95	88
Magnesium	36	34
Sodium	173	145
Potassium	5	5
Carbonate	0	0
Bicarbonate	188	174
Sulfate	370	336
Chloride	152	128
Nitrate	2.2	1.6
Fluoride	0.7	0.5
Boron	0.21	0.18
pH	8.1	8.0
Electrical Conductivity (micromhos/cm @ 25°C))	1,403	1,306
Total Dissolved Solids	962	856
Total Hardness	385	360

Data from San Diego Gas & Electric Company (1976).

Table A3.2-7

CHEMICAL QUALITY OF WATER IN THE VAIL 4 CANAL
(T12S/R13E-9R)

Constituent (mg/l)	Maximum	Minimum	Trimmed Mean
Calcium	202	20	100
Magnesium	79	15	35
Sodium	431	25	169
Potassium	14	4	6
Carbonate	29	0	9
Bicarbonate	312	145	198
Sulfate	1,120	322	456
Chloride	589	119	215
Boron	0.72	0.05	0.30
Fluoride	1.50	0.49	0.85
pH	—	7.5	8.2
Electrical Conductivity (microhmos/cm @ 25°C)	3,500	1,100	1,359
Total Dissolved Solids	3,212	772	1,149
Barium	—	0.00	0.12
Lithium	0.10	0.06	0.07
Manganese	0.22	0.05	0.08
Strontium	3.20	0.40	1.41
Zinc	1.15	0.00	0.01
Temperature (°C)	29.5	11.4	21.1

Data for 1976-77 from Lawrence Livermore Laboratory computer printout.

Table A3.2-8

CHEMICAL QUALITY OF WATER IN THE VAIL 4 CANAL
(T11S/R13E-33H)

Constituent (mg/l)	Maximum	Minimum	Trimmed Mean
Calcium	200	30	93
Magnesium	61	15	34
Sodium	410	50	159
Potassium	13	4	6
Carbonate	24	0	7
Bicarbonate	301	100	163
Sulfate	634	340	361
Chloride	577	120	154
Boron	1.15	0.09	0.30
Fluoride	1.63	0.46	0.82
pH	—	6.7	8.1
Electrical Conductivity (micromhos/cm @ 25°C)	3,160	1,040	1,299
Total Dissolved Solids	3,278	798	945
Barium	0.12	0.00	0.09
Lithium	0.10	0.06	0.07
Manganese	0.10	0.00	0.01
Strontium	1.60	0.60	1.36
Zinc	0.39	0.00	0.01
Temperature (°C)	32.1	8.8	21.6

Data from 1976-77 from Lawrence Livermore Laboratory computer printout.

Table A3.2-9

CHEMICAL QUALITY OF WATER IN THE VAIL 4A CANAL
(T11S/R13E-33L)

Constituent (mg/l)	Maximum	Minimum	Trimmed Mean
Calcium	138	73	93
Magnesium	68	24	35
Sodium	420	102	156
Potassium	13	4	6
Carbonate	26	0	8
Bicarbonate	179	135	156
Sulfate	731	332	379
Chloride	639	120	172
Boron	0.43	0.19	0.30
Fluoride	1.60	0.40	0.63
pH	—	6.5	8.1
Electrical Conductivity (micromhos/cm @ 25°C)	3,210	1,100	1,305
Total Dissolved Solids	3,158	796	999
Barium	0.17	0.00	0.10
Lithium	0.26	0.05	0.08
Manganese	0.08	0.00	0.01
Strontium	2.00	1.19	1.37
Zinc	0.53	0.00	0.02
Temperature (°C)	31.9	7.9	22.2

Data for 1976-77 from Lawrence Livermore Laboratory computer printout.

Table A3.2-10

CHEMICAL QUALITY OF WATER IN THE VAIL 4 DRAIN
(T12S/R13E-10N)

Constituent (mg/l)	Maximum	Minimum	Trimmed Mean
Calcium	456	68	247
Magnesium	335	30	133
Sodium	1,680	80	703
Potassium	20	8	12
Carbonate	0	0	0
Bicarbonate	300	250	275
Sulfate	2,693	365	1,039
Chloride	1,972	200	889
Boron	2.44	0.20	0.92
Fluroide	0.67	0.30	0.43
pH	8.6	6.7	7.9
Electrical Conductivity (micromhos/cm @ 25°C)	8,950	1,530	5,052
Total Dissolved Solids	7,640	1,010	2,805
Barium	0.19	0.00	0.09
Lithium	0.54	0.09	0.23
Manganese	0.79	0.06	0.30
Strontium	8.30	1.60	3.76
Zinc	0.27	0.00	0.02
Temperature (°C)	39.1	14.4	24.3

Data for 1976-77 from Lawrence Livermore Laboratory computer printout.

Table A3.2-11

CHEMICAL QUALITY OF WATER IN THE VAIL 4 DRAIN
(T11S/R13E-34E)

Constituent (mg/l)	Maximum	Minimum	Trimmed Mean
Calcium	587	150	286
Magnesium	273	50	143
Sodium	1,487	150	765
Potassium	26	8	13
Carbonate	0	0	0
Bicarbonate	245	195	220
Sulfate	2,519	706	1,437
Chloride	2,474	415	974
Boron	2.00	0.20	1.04
Fluoride	3.76	0.03	0.98
pH	8.5	6.8	7.2
Electrical Conductivity (micromhos/cm @ 25°C)	12,000	2,400	5,157
Total Dissolved Solids	7,100	1,888	3,869
Barium	0.32	0.00	0.14
Lithium	0.43	0.09	0.24
Manganese	2.27	0.07	0.55
Strontium	7.92	2.00	4.03
Zinc	0.08	0.00	0.02
Temperature (°C)	32.9	12.4	23.6

Data for 1976-77 from Lawrence Livermore Laboratory computer printout.

Table A3.2-12

CHEMICAL QUALITY OF WATER IN THE VAIL 4A DRAIN
(T11S/R13E-33Q)

Constituent (mg/l)	Maximum	Minimum	Trimmed Mean
Calcium	723	223	456
Magnesium	269	86	163
Sodium	1,680	480	1,081
Potassium	163	21	54
Carbonate	0	0	0
Bicarbonate	345	260	303
Sulfate	2,692	921	1,621
Chloride	2,645	590	1,558
Boron	4.43	0.71	1.83
Fluoride	0.82	0.48	0.65
pH	8.9	6.9	7.4
Electrical Conductivity (microhmos/cm @ 25°C)	11,000	3,500	7,641
Total Dissolved Solids	9,280	2,610	5,469
Barium	0.26	0.00	0.10
Lithium	2.72	0.41	1.12
Manganese	5.08	0.42	1.75
Strontium	9.60	3.90	5.89
Zinc	0.49	0.04	0.15
Temperature (°C)	29.5	15.0	23.2

Data for 1976-77 from Lawrence Livermore Laboratory computer printout.

Table A3.2-13

CHEMICAL QUALITY OF WATER IN THE VAIL 4A DRAIN
(T11S/R13E-33G)

Constituent (mg/l)	Maximum	Minimum	Trimmed Mean
Calcium	834	150	457
Magnesium	401	50	182
Sodium	2,256	317	1,104
Potassium	159	12	41
Carbonate	0	0	0
Bicarbonate	—	—	—
Sulfate	2,199	1,005	1,455
Chloride	3,560	620	1,803
Boron	6.77	0.61	2.19
Fluoride	1.29	0.03	0.59
pH	8.4	6.3	7.7
Electrical Conductivity (micromhos/cm @ 25°C)	15,000	1,900	7,038
Total Dissolved Solids	10,660	2,720	5,789
Barium	0.24	0.05	0.12
Lithium	2.65	0.10	0.90
Manganese	5.00	0.02	1.25
Strontium	12.22	2.01	6.57
Zinc	0.41	0.00	0.08
Temperature (°C)	36.0	11.1	24.6

Data for 1976-77 from Lawrence Livermore Laboratory computer printout.

Table A3.2-14

CHEMICAL QUALITY OF WATER IN THE PUMICE DRAIN
(T11S/R13E-33B)

Constituent (mg/l)	Maximum	Minimum	Trimmed Mean
Calcium	391	185	291
Magnesium	209	60	145
Sodium	998	450	744
Potassium	23	14	16
Carbonate	0	0	0
Bicarbonate	215	195	205
Sulfate	2,011	786	1,400
Chloride	1,060	490	864
Boron	1.09	0.56	0.90
Fluoride	1.40	0.65	1.03
pH	8.0	7.2	7.7
Electrical Conductivity (micromhos/cm @ 25°C)	6,000	3,000	4,471
Total Dissolved Solids	7,830	2,054	4,417
Barium	0.20	0.00	0.08
Lithium	0.36	0.18	0.27
Manganese	0.55	0.08	0.28
Strontium	9.20	2.30	4.25
Zinc	0.04	0.01	0.02
Temperature (°C)	33.7	7.8	20.3

Data for 1976-77 from Lawrence Livermore Laboratory computer printout.

Table A3.2-15

CHEMICAL ANALYSES OF SALTON SEA WATER

Constituent (mg/l)	5/1/79	10/30/79
Calcium	1,029	955
Magnesium	1,107	1,001
Sodium & Potassium	10,876	9,897
Bicarbonate	142	218
Sulfate	7,592	7,523
Chloride	16,128	14,188
pH	8.2	7.2
Electrical Conductivity (micromhos/cm @ 25°C)	50,520	49,380
Total Dissolved Solids	35,040	33,812

Data from Imperial Irrigation District (1979). Surface samples taken between Alamo and New River outlets.

Table A3.2-16

CHEMICAL QUALITY OF WATER IN THE SALTON SEA

Constituent (mg/l)	Maximum	Minimum	Trimmed Mean
Calcium	3,401	626	877
Magnesium	4,954	871	1,159
Sodium	36,041	7,726	9,632
Potassium	697	116	169
Sulfate	28,980	6,663	13,717
Chloride	50,801	12,125	16,880
Boron	26.01	1.20	11.77
Fluoride	34.00	0.83	12.66
pH	9.0	6.3	8.4
Electrical Conductivity (micromhos/cm @ 25°C)	65,400	38,000	41,455
Total Dissolved Solids	—	—	—
Barium	1.27	0.00	0.32
Lithium	33.80	1.00	3.04
Manganese	1.07	0.02	0.16
Strontium	40.50	8.90	14.03
Zinc	1.16	0.00	0.11
Temperature (°C)	32.0	17.2	22.8

Data for 1976-77 from Lawrence Livermore Laboratory computer printout.

Table A3.2-17

SALTON SEA NUTRIENT WATER QUALITY (1972)

Constitituent (mg/l)	Summer	Autumn	Winter	Spring
Nitrate Nitrogen	0.10	0.16	0.14	0.19
Nitrite Nitrogen	0.01	0.06	0.02	0.30
Ammonia Nitrogen	0.22	0.36	0.25	0.27
Organic Nitrogen	2.80	2.90	1.20	4.20
Total Nitrogen	3.13	3.48	1.61	4.96
Orthophosphate Phosphorous	0.04	0.02	0.03	0.06
Total Phosphorous	0.06	0.05	0.07	0.20
pH	7.8	7.6	8.6	8.4
Temperature (^{o}C)	29.5	23.1	15.2	23.3

Data from U.S. Department of Interior and Resources Agency of California (1974).

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APPENDIX 3.4

AIR QUALITY

APPENDIX 3.4

POTENTIAL HEALTH EFFECTS OF GEOTHERMAL POLLUTANTS*

Geothermal steam contains several contaminants which when inhaled or ingested in sufficient quantities can adversely impact human health. They are hydrogen sulfide (H_2S), radon-222 (^{222}Rn), ammonia (NH_3), and trace elements, in particular, mercury (Hg), arsenic (As), and boron (B). When geothermal steam is used to produce electrical energy, varying quantities of these contaminants are emitted by the goethermal wells and power plant cooling towers. The potential for adverse impacts to public health depends on: 1) the toxicity of the contaminants; 2) the concentration or quantity to which the public is exposed; and 3) the duration of exposure. Exposure to these contaminants can occur from inhalation of air, or ingestion of drinking water or food. The following discussion addresses potential adverse human health impacts associated with these contaminants.

Hydrogen Sulfide - Hydrogen sulfide is a toxic gas which can be fatal to humans when inhaled in concentrations of 1000 parts per million (ppm) and above for several minutes (NIOSH, 1977). Longer exposure to lower concentrations can also be fatal. In concentrations above the state occupational standard of 10 ppm (8-hour average) H_2S can cause irritation of the eyes and respiratory tract, damage to the lungs, and a loss of consciousness. Hydrogen sulfide at levels below 10 ppm may induce decreased corneal reflex, nausea, insomnia, headaches, loss of sleep, and other symptoms (Table 1) (Walton, A.H. and W.S. Simmons, 1978).

There have been relatively few studies of adverse health effects from exposure to H_2S at low concentrations (less than 0.1 ppm) (Ibid.). Because of the lack of studies and questions concerning the validity of results from some of the studies done, there appears to be controversy as to the potential for adverse effects from H_2S at low concentrations. Since long term exposure to low levels of H_2S have not been adequately studied, it is uncertain if such exposures adversely affect public health.

Some experts do not believe that exposure to concentrations below 1 ppm adversely affects human health (Simmons, 1979). The lowest concentration accepted by other experts as inducing adverse health effects is 0.08 ppm (Illinois Institute for Environmental Quality, 1974), almost three times greater than the California ambient air quality standard for H_2S. Nausea, fatigue, loss of appetite, dizziness, blurred vision and

---

*Adapted from Pacific Gas and Electric Co., 1979, Geysers 17 Geothermal Power Plant, Final EIR, Appendix B, August.

TABLE 1

HUMAN HEALTH EFFECTS OF HYDROGEN SULFIDE

ppm*	Health Effects	Reference
0.00047-0.0045	Odor threshold	Leonardos, 1969 Wilby, 1969
0.007-0.03	Slight odor	Gurinov, 1952
0.03	California ambient air quality standard for one-hour average (concentration based on the odor threshold)	ARB, 1970
0.04-0.13	Clear definite odor	Gurinov, 1952
0.08	Increased incidence of mental depression, dizziness and blurred vision	State of Illinois, 1974
0.30	Increased incidence of nausea, insomnia, shortness of breath and headaches with chronic exposure	Indiana APCD, 1964
0.7-7	Incidence of decreased corneal reflex with chronic exposure	State of Illinois, 1974 Rubin, 1975
4.6	Readily apparent, offensive odor	Simson, 1971 Yant, 1930
10	Threshold limit value for 8-hour exposure at the work place	American Conference of Governmental Industrial Hygienists, 1977
10-50	Threshold for irritative action with prolonged exposure: eye irritation such as conjunctivitis and at the higher concentrations dry throat. Fatigue, loss of appetite and insomnia with chronic exposure	Ahlborg, 1951 Gurinov, 1952 NIH, 1941
20-30	Very strong, but not intolerable odor	State of Illinois, 1971 Yant, 1930
70-150	Eye irritation after several hours of exposure; conjunctivitis, keratitis and photophobia. Threshold for olfactory paralysis occurring within minutes	Devege, 1956 Evans, 1967 Mitchell, 1925 AIHA, 1963
200-300	Serious local irritation to eyes and respiratory tract caused upon inhalation for one hour, with possible subsequent pulmonary edema. This is the maximum concentration which can be inhaled for one hour without serious consequences.	Mitchell, 1925 Haggard, 1925

Adapted from Walton, A.H. and W.S. Simmons, 1978 increased incidence of mental depression have been reported to result from chronic exposure to this concentration (Ibid.).

There have been studies which report adverse health effects at levels below 0.08 ppm. The validity of these low level studies, however, has been questioned (Lawrence Berkeley Lab, 1977a, Walton, 1978). Yet, the possibility that these low levels can induce adverse health effects cannot be dismissed without further evidence.

Exposure to H_2S may be more harmful to certain groups of individuals than to the general population. These H_2S sensitive groups include infants, individuals with anemia, eye or respiratory problems, schizoid or paranoid tendencies, and those who have recently consumed alcohol (Institute for Environmental Quality, 1974 and Walton, 1978).

The California ambient air quality standard for H_2S is 0.03 ppm (1-hour average) (see Table 2). Although public health protection was considered, this value was based on H_2S odor threshold. More recent studies have determined the odor threshod for H_2S to be substantially lower than that determined by the Department of Public Health panel. A report prepared by Lawrence Berkeley Laboratory (LBL) states that if the standard is to be based on known odor threshold, "then the standard should be lowered by a factor of 3 to 5 to the more recently accepted value for the odor preception threshold." (Case, 1977).

Radon-222 - The noncondensable gas fraction of steam originating from natural fumaroles and developed geothermal wells contains the radioactive gas, radon-222 (^{222}Rn). When the steam is used to produce electrical energy, ^{222}Rn and its daughter products are found in the cooling tower sludge, in the steam condensate released to the atmosphere from the cooling tower, and at various locations with the workings of the plant itself (i.e., the steam exhaust ducts and condensers).

The primary hazard associated with ^{222}Rn and its short-lived daughter products is inhalation and possible deposition in the lung. ^{222}Rn itself is usually inhaled and exhaled without deposition on lung tissues. However, the short-lived daughter products of ^{222}Rn (especially those which emit alpha particles), have a high probability for deposition. Deposition of an alpha-emitting substance on the lungs provides a greater potential for temporary or permanent tissue damage through the natural destructive action of the alpha energy.

Standards for radon-^{222} set by the Department of Health Services (DOHS), Section 30355 of Title 17 of the California Administrative Code, are 100 pCi/1 in air for a controlled area of 3 pCi/1 in air for an uncontrolled radiation area. These standards are for concentrations in air above natural background radiation. A controlled radiation area is interpreted as being an occupational area and an uncontrolled area is interpreted as being any area to which the general public would have access.

Ammonia - Ammonia is primarily an irritant to eyes, mucous membranes, and the upper respiratory tract. The lowest concentration reported to cause irritation to humans via inhalation is 20 parts per million (ppm) (EPA, 1977) and barely noticeable eye irritation has been reported at 5 ppm (NIOSH, 1974). Low level exposure has not been observed to cause chronic effects (EPA, 1977). The odor threshold has been reported to range between approximately 0.7 ppm and 50 ppm (National Academy of Science, 1977). Standards and suggested safe levels for exposure to ammonia are listed in Table 2).

Mercury - Inhalation of mercury compounds can induce cough, fever, bronchitis and pulmonary edema. Chronic poisoning results from the accumulation of mercury in the brain, kidney, and hair, and causes symptons such as headaches, dizziness and fever. Children are especially susceptible to mercury poisoning (Britt, 1976). Certain mercury compounds have been shown to have a potential to cause both cancer and birth defects (EPA, 1977).

Organisms, particularly those in aquatic environments, can absorb, concentrate, and transform trace elements. Mercury may be transformed to more toxic forms (such as methyl mercury), and accumulate in various links in food chains, particularly in higher trophic levels. Fish can absorb high mercury levels since they take up mercury compounds both through consumption of food and through their gills (Britt, 1976). Ingestion of mercury by humans can result in adverse health effects such as headaches, blurred vision, loss of muscular coordination and death (Waldbott, 1973). To protect public health from hazards of mercury ingestion, the Federal Food and Drug Administration recommends 1.0 ppm mercury in fish as a maximum safe level for human consumption. High concentrations of mercury have been measured in fish at Clear Lake, not far from The Geysers KGRA (Week, 1978). Although the mercury content in most fish tested was below the recommended safe level of 1.0 ppm in edible fish, a small number of the fish sampled exceeded this value. Such high levels are believed to be caused by sources other than mercury emissions from The Geysers power plant. Consequently, ongoing monitoring of mercury levels in fish in the Salton Sea should accompany geothermal development in the area.

Boron - compared with other atmospheric pollutants, the medical literature on boron and its compounds is sparce (Waldbott, 1973). Boron and most boron compounds are not highly toxic (Waldbott, 1973; Durocher, 1969), although boron hydrides have been rated as highly toxic (Durocher, 1969).

Chronic exposure to boron and boron compounds can result in reduced appetite, nausea, weight loss, increased risk of lung infection, central nervous system depression and kidney injury (Britt and Hushon, 1976).

Inhalation of boric acid and boron oxide in the form of dust can cause respiratory irritation, but is not likely to induce permanent damage (Waldbott, 1973).

Inhalation of boron hydrides (boranes) can result in severe central nervous system damage with symptoms including headache, dizziness, drowsiness, convulsions, fever, cough and pneumonia (Wilcox, 1973; Waldbott, 1973). Death or permanent damage may result (Durocher, 1969).

Arsenic - Geothermal power plant emissions will often contain arsenic, possibly in the form of suspended particulates, arsenic trioxide vapor, or arsine (Walton, 1978). Chronic exposure to arsenic trioxide may cause irritation to nose and throat, hair loss, tremors, anemia, and cancer of skin, lung, or liver (Britt, 1976).

Trace Elements - Geothermal steam contains trace elements, including mercury, arsenic, and boron, which potentially could affect public health. Suggested standards and safe levels for these pollutants in air are listed in Table 2.

TABLE 2

AIR QUALITY STANDARDS OR SUGGESTED SAFE LEVELS FOR SELECTED GEOTHERMAL POLLUTANTS USED TO DETERMINE PUBLIC HEALTH PROTECTION

POLLUTANT	TYPE OF STANDARD	AGENCY	STANDARD OR CONCENTRATION	AVERAGING TIME
Hydrogen Sulfide	California Ambient Air Quality Standard *	California Air Resources Board	0.03 ppm	1 hour
Sulfur Dioxide	California Ambient Air Quality Standard *	California Air Resources Board	0.50 ppm 0.05 ppm	1 hour 24 hours
Sulfate	California Ambient Air Quality Standard *	California Air Resources Board	25 ug/m^3	24 hours
Total Suspended Particulate	California Ambient Air Quality Standard *	California Air Resources Board	60 ug/m^3	Annual Geo-Metric Mean
			100 ug/m^3	24 hours
Radon - 222	California Ambient Air Quality Standard *, **	California Department of Health	3 pCi/l	Annual
Ammonia	California Occupational Standard	Calif. Occupational Safety & Health	25 ppm	8 hours
	Suggested Ambient Level Goal ***	U.S. Environmental Protection Agency	0.06 ppm	****
	Foreign Ambient Air Quality Standard	Russia & East European Countries	0.14-0.71 ppm	24 hours
Mercury	Suggested Ambient Standard	World Health Organization	0.8 ug/m^3	24 hours
	Suggested Ambient Level Goal *** (based on toxicity)	U.S. Environmental Protection Agency	0.1 ug/m^3	****
	Suggested Ambient Level Goal *** (based on carcinogenic potential)	U.S. Environmental Protection Agency	0.01 ug/m^3	****
	Maximum Recommended Concentration	U.S. Environmental Protection Agency	1 ug/m^3	24 hours
Arsenic	Suggested Occupational Standard	Nat. Inst. for Occup. Safety & Health	2.0 ug/m^3	15 minutes
	Suggested Threshold Limit Value	Amer. Conf. of Gov. & Ind. Hygienists	50 ug/m^3	8 hours
	Suggested Ambient Level Goal ***	U.S. Environmental Protection Agency	0.005 ug/m^3	****
	Suggested Ambient Standard	World Health Organization	[illegible].9 ug/m^3	24 hours
Boron	Suggested Ambient Standard	World Health Organization	50 ug/m^3	24 hours
	Suggested Ambient Level Goal ***	U.S. Environmental Protection Agency	7.4 ug/m^3	****

* The California ambient air quality standards for hydrogen sulfide, sulfur dioxide, sulfates, and total suspended particulates, and the Department of Health standard for radon-222 are established standards with which the project must comply. The values listed for ammonia, mercury, arsenic, and boron are not legally enforceable standards for public exposure, rather they are suggested guidelines for safe levels of these pollutants.

** This radon-222 standard is for concentrations in air above natural background, in uncontrolled radiation areas. An uncontrolled area is interpreted as any area to which the general public would have access. The standard for controlled (occupational) areas is 100 pCi/l.

*** The EPA Multimedia Environmental Goals are levels of significant contaminants or degradents that are judged to be (1) appropriate for preventing certain negative effects in the surrounding populations or ecosystems, or (2) representative of the control limits achievable through technology (EPA-600/7-77-136 Multimedia Environmental Goals for Environmental Assessment). These suggested environmental goals are used here as guidelines for evaluating the potential human health risks of ambient concentrations of unregulated pollutants.

**** Based on annual exposure

Compiled by California Energy Commission Staff

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APPENDIX 3.5

ACOUSTICAL ENVIRONMENT

APPENDIX 3.5
ACOUSTICAL ENVIRONMENT

A. Community Noise Survey Data

During a seven day period between January 2, 1981 and January 9, 1981, a community noise survey was performed in the study area. Some 26 sites as shown in Figure A3.5-1 were visited during representative segments of the 24-hour day. Each site was visited at least three times during the seven day period. Typical noise sources were determined, measured individually and catalogued. The overall noise environment was also measured, recorded and computer analyzed.

Survey Methods

The results of these measurements and analysis are presented in the following pages. The proposed geothermal development of the area would be operative on a 24-hour, seven day per week basis in construction, start-up, operations, and maintenance phases. Therefore, community noise was monitored during day, evening, and night periods (7:00 a.m. to 7:00 p.m., 7:00 p.m. to 10:00 p.m., and 10:00 p.m. to 7:00 a.m.) of the day for a seven day period from January 2, 1981 through January 9, 1981. Each site was monitored using a Bruel and Kjaer Type I Sound Level Meter, equipped with a condenser microphone which was field calibrated by means of a Bruel and Kjaer Acoustic Calibrator. Both pieces of equipment were checked and calibrated for response and sensitivity by means of instruments whose calibration is traceable to the National Bureau of Standards. Data were also recorded and subsequently computer analyzed to determine the statistical variation of the environmental noise. See Table A3.5-1 for statistical noise data, a site location description, and a list of specific noise sources and their sound pressure levels.

Table A3.5-2 presents a summary of the measured data, statistical descriptors, and the calculated sample community noise indices L_{dn} (day-night average sound level) and CNEL (Community Noise Equivalent Level) for the 26 sites shown on Figure A3.5-1. The maximum recorded level is indicated as L_{max}. The hourly average (equivalent continuous) A-weighted sound level for the period measured is presented as L_{eq}. All statistical measures L_x are A-weighted sound pressure levels with the subscript x denoting the percentage of time during the measurement period that the level presented was exceeded. The L_{dn} and CNEL systems are used to subjectively rate community noise on a 24-hour basis, weighting the noise occurring during the nighttime

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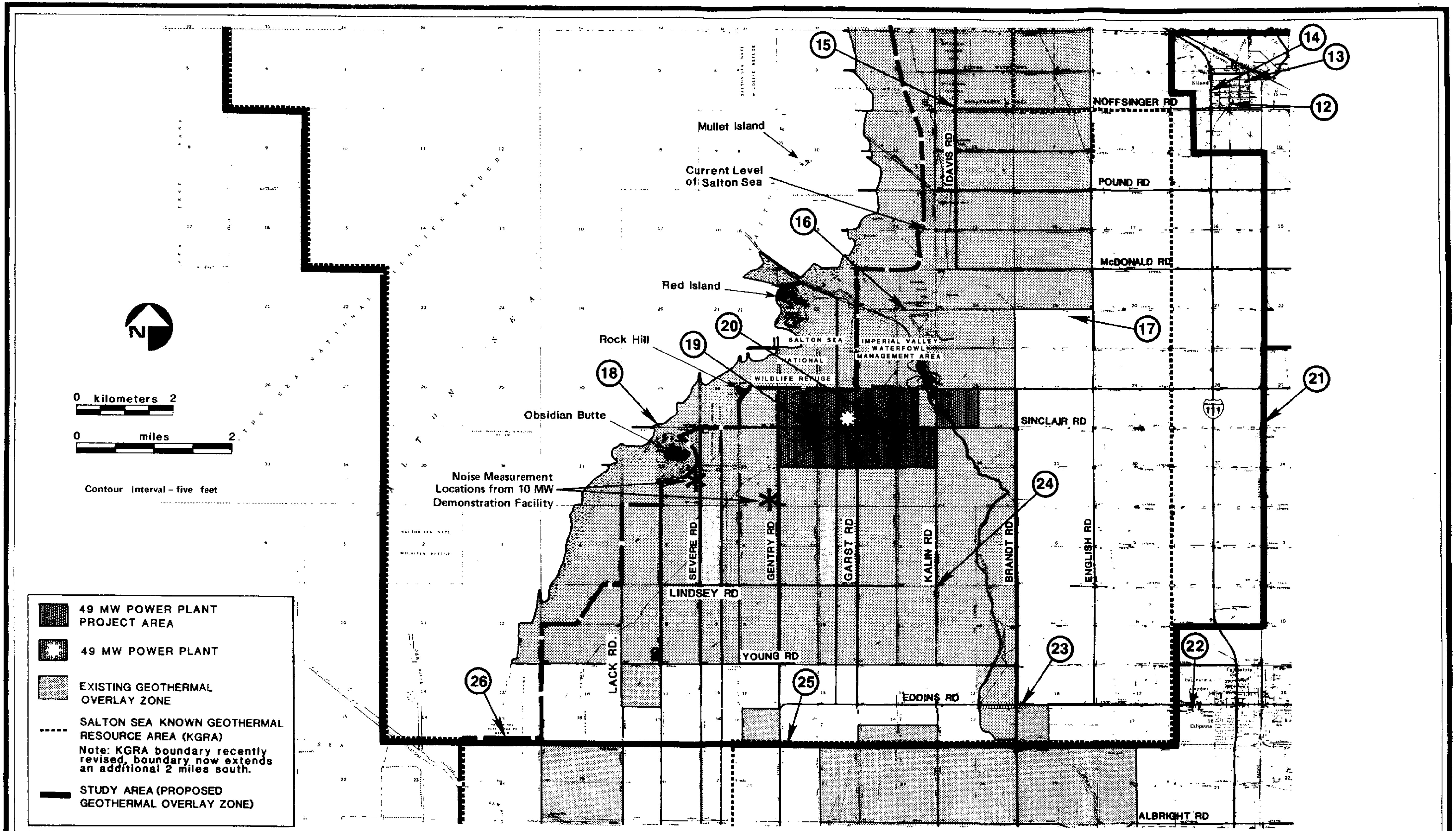
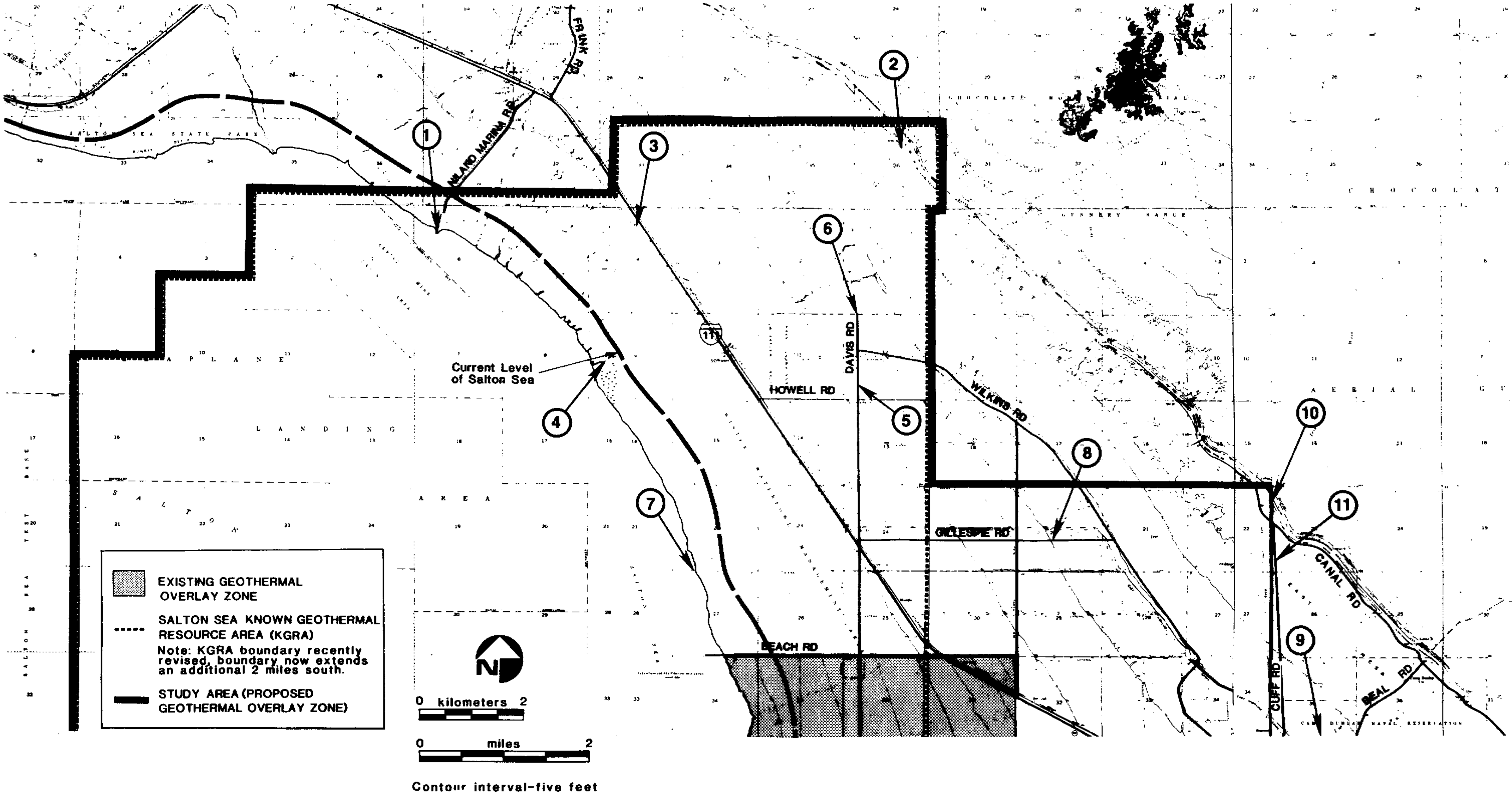


Community Noise Survey Locations - Part 1

FIGURE A3.5-1



Community Noise Survey Locations - Part 2

FIGURE A3.5-1

Table A3.5-1

EXISTING COMMUNITY NOISE CONDITIONS FOR PROPOSED NILAND ANOMALY GEOTHERMAL OVERLAY ZONE

Site Number: 1

Site Description: End of Niland Marina Road at waters edge in public recreation area designated as "Salton Sea-Niland Public Fishing Access."

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time, in Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	52	50	50	49	48	45	41	47
Evening 7 pm-10 pm	30	28	27	26	26	25	24	26
Night 10 pm-7 am	38	36	35	35	35	34	33	35

CNEL = 46 dB L_{dn} = 45 dB

Cataloged Noise Sources - by time period

Day: Light aircraft: 46-50 dBA
Train - 106 cars, 4 engines: 45-50 dBA
Hwy. 111: 38-40 dBA

Evening: Light aircraft: 42-47 dBA
General Background: 22-25 dBA

Night: Power line noise all along the Marina Road at 22-35 dBA. Very strange sounding low frequency.

Table A3.5-1 (Continued)

Site Number: 2

Site Description: Coachella Canal Road, four miles south from end of pavement below intersection at Frink Road. Fifty feet from roadway centerline. Location is open desert.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time, in Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	65	64	61	59	54	47	46	54
Evening 7 pm-10 pm	29	27	25	25	25	24	23	25
Night 10 pm-7 am	34	32	31	30	28	24	22	28

CNEL = 51 dB L_{dn} = 50 dB

Cataloged Noise Sources - by time period

Day: Motorcycles on road: 62 dBA peak and 54-56 dBA

Evening: No significant sources indentifiable. Breeze through brush: 21-22 dBA

Night: Background: 24-28 dBA
Distant aircraft: 25 dBA
Coyote pack: 34 dBA

Table A3.5-1 (Continued)

Site Number: 3

Site Description: Highway 111, two miles south of intersection with Frink Road. One hundred feet from centerline of roadway on old mud flats desert area.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time, in Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	80	76	68	65	61	45	40	63
Evening 7 pm-10 pm	79	77	73	69	64	54	49	67
Night 10 pm-7 am	74	71	65	61	53	42	37	59

CNEL = 68 dB L_{dn} = 66 dB

Cataloged Noise Sources - by time period

Day: Trucks: 74-80 dBA
All traffic noise

Evening: Train: 80- 84 dBA
Traffic noise

Night: Traffic noise

Table A3.5-1 (Continued)

Site Number: 4

Site Description: California Department of Fish and Game Imperial Wildlife Area Hunting Site 515-2 off Mallard Road.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time, in Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	46	43	42	41	41	40	39	41
Evening 7 pm-10 pm	33	31	30	30	29	28	27	30
Night 10 pm-7 am	44	43	41	41	40	36	33	39

CNEL = 46 dB L_{dn} = 45 dB

Cataloged Noise Sources - by time period

Day: Distant traffic

Evening: Waterfowl: 32 dBA max

Night: Distant traffic: peaking at 43 dBA

Table A3.5-1 (Continued)

Site Number: 5

Site Description: John Deere 8640 tractor with harrow: field west side of Davis Road between Howell and Hobbs Roads.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time, in Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am–7 pm	73	72	71	70	70	64	54	68
Evening 7 pm–10 pm	29	27	26	26	25	24	24	26
Night 10 pm–7 am	31	29	28	28	27	25	23	26

CNEL = 65 dB L_{dn} = 64 dB

Cataloged Noise Sources – by time period

Day: Tractor harrowing field

Evening:

Night:

Table A3.5-1 (Continued)

Site Number: 6

Site Description: Open field at end of Davis Road 3/4 mile north of Hobbs Road.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time, in Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	35	32	32	32	32	32	32	33
Evening 7 pm-10 pm	29	27	26	26	25	24	24	26
Night 10 pm-7 am	31	29	28	28	27	25	23	26

CNEL = 34 dB L_{dn} = 34 dB

Cataloged Noise Sources - by time period

Day: Distant traffic

Evening: Distant traffic

Night: Distant traffic
Dog: 25 dBA

Table A3.5-1 (Continued)

Site Number: 7

Site Description: Imperial Wildlife Area - California Department of Fish and Game edge of Salton Sea on first access road south of Wister Unit Headquarters.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	43	42	41	41	40	38	34	39
Evening 7 pm-10 pm	40	39	38	38	37	36	35	38
Night 10 pm-7 am	41	39	37	37	35	33	31	36

CNEL = 43 dB L_{dn} = 43 dB

Cataloged Noise Sources - by time period

Day: Gunshots: 40- 42 dBA
Light aircraft: 32- 36 dBA

Evening: Waves on sea: 37 dBA
Bird calls: 41 dBA
Distant traffic: 28- 30 dBA

Night: Train: 38 dBA
Birds: 30-34 dBA
Distant traffic: 33 dBA

Table A3.5-1 (Continued)

Site Number: 8

Site Description: Open field under Rainbird irrigation. South side of Gillespie Road 100 yards east of English Road.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time, in Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	52	52	52	52	52	52	52	52
Evening 7 pm-10 pm	52	52	52	52	52	52	52	52
Night 10 pm-7 am	52	52	52	52	52	52	52	52

CNEL = 59 dB L_{dn} = 58 dB

Cataloged Noise Sources - by time period

Day: Caterpillar 190 hp pump at 730 ft with sprinklers: 52 dBA

Evening: Caterpillar 190 hp pump at 730 ft with sprinklers: 52 dBA

Night: Caterpillar 190 hp pump at 730 ft with sprinklers: 52 dBA

Table A3.5-1 (Continued)

Site Number: 9

Site Description: 200 feet from Imperial Irrigation District Power Substation 50 MW peak rating, Beal Road 1/4 mile east of Wilkins.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am–7 pm	62	51	51	51	51	51	51	51
Evening 7 pm–10 pm	64	51	51	51	51	51	51	51
Night 10 pm–7 am	60	51	51	51	51	51	51	51

CNEL = 58 dB L_{dn} = 57 dB

Cataloged Noise Sources - by time period

Day: Dune buggy: 62 dBA
Transformer noise: 51 dBA

Evening: Traffic
Transformer noise: 51 dBA

Night: Traffic
Transformer noise: 51 dBA

Table A3.5-1 (Continued)

Site Number: 10

Site Description: Edge of Coachella Canal at intersection with Cliff Road.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	41	39	38	38	37	36	36	37
Evening 7 pm-10 pm	39	36	35	35	34	34	34	35
Night 10 pm-7 am	32	31	30	28	27	24	23	26

CNEL = 37 dB L_{dn} = 36 dB

Cataloged Noise Sources - by time period

Day: Generator running at encampment: 35-36 dBA

Evening: Generator: 33-35 dBA

Night: Quiet, no specific sources

Table A3.5-1 (Continued)

Site Number: 11

Site Description: Cuff Road 1/2 mile south of Coachella Canal Road. Open desert, dirt road.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	31	25	25	25	25	24	24	26
Evening 7 pm-10 pm	30	28	27	26	26	24	23	26
Night 10 pm-7 am	32	31	30	28	27	24	23	26

CNEL = 33 dB L_{dn} = 32 dB

Cataloged Noise Sources - by time period

Day: Jet aircraft: 30- 31 dBA
Non-specific background: 24 dBA

Evening: Traffic on distant road: 25 dBA

Night: No specific sources

Table A3.5-1 (Continued)

Site Number: 12

Site Description: Northeast corner of intersection of Niland and Noffsinger Roads in Niland in front of Highline Produce Company.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	64	61	59	58	57	57	56	58
Evening 7 pm-10 pm	65	62	58	57	57	48	41	55
Night 10 pm-7 am	53	52	52	52	52	52	51	53

CNEL = 61 dB L_{dn} = 60 dB

Cataloged Noise Sources - by time period

Day: Refrigeration equipment at Highline Produce: 51 dBA
Dogs: 64 dBA

Evening: Refrigeration equipment at Highline Produce: 51 dBA

Night: Refrigeration equipment: 51 dBA
Train: 48 dBA
Trucks on Hwy. 111: 33 dBA

Table A3.5-1 (Continued)

Site Number: 13

Site Description: Downtown Niland at the intersection of Niland, Main Street, and Memphis Avenue.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	73	68	64	61	58	53	49	58
Evening 7 pm-10 pm	72	71	68	66	65	55	45	63
Night 10 pm-7 am	47	45	45	45	45	45	43	45

CNEL = 61 dB L_{dn} = 58 dB

Cataloged Noise Sources - by time period

Day: Traffic, music, air conditioning, children playing

Evening: Train: 70-75 dBA
Dogs: 55 dBA
Cars: 64 dBA

Night: Train on siding: 46 dBA

Table A3.5-1 (Continued)

Site Number: 14

Site Description: 84 feet from centerline of Highway 111 south of intersection with N Street in Niland. In dirt parking area south of and adjacent to L&G Sporting Goods.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	75	73	71	68	65	59	50	65
Evening 7 pm-10 pm	66	65	63	62	60	55	51	59
Night 10 pm-7 am	74	72	68	65	59	52	49	61

CNEL = 68 dB L_{dn} = 68 dB

Cataloged Noise Sources - by time period

Day: Diesel trucks: 74-80 dBA

Evening: Diesel trucks: 65-66 dBA

Night: Idling truck at cafe across Highway: 45 dBA
Diesel trucks: 73 dBA

Table A3.5-1 (Continued)

Site Number: 15

Site Description: Intersection of Davis and Noffsinger Roads. Both are dirt. Near Dry Ice Wells, west of Niland.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	34	32	31	31	31	31	30	32
Evening 7 pm-10 pm	41	38	37	36	36	31	31	34
Night 10 pm-7 am	36	35	34	34	33	33	31	33

CNEL = 40 dB L_{dn} = 39 dB

Cataloged Noise Sources - by time period

Day: Distant traffic

Evening: Distant traffic
Aircraft flyover: 38 dBA

Night: Distant traffic
Train: 30 dBA
Intermittent powerline buzz: 30-34 dBA
Running water: 26-28 dBA

Table A3.5-1 (Continued)

Site Number: 16

Site Description: Salton Sea National Wildlife Refuge, end of Schrimpl Road adjacent to Blind Site 10.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	41	39	38	37	37	35	33	37
Evening 7 pm-10 pm	35	33	32	31	31	30	28	31
Night 10 pm-7 am	36	35	34	33	28	26	25	30

CNEL = 38 dB L_{dn} = 38 dB

Cataloged Noise Sources - by time period

Day: Wind in marsh grass

Evening: Insects: 31 dBA
Dog barks

Night: Insects: 25 dBA
Birds: 25 dBA
Dog: 28 dBA

Table A3.5-1 (Continued)

Site Number: 17

Site Description: 100 feet from tractor harvesting Bermuda grass for feed lot use along Schrimpl Road.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	71	70	68	67	65	58	42	63
Evening 7 pm-10 pm	35	33	32	31	31	30	28	31
Night 10 pm-7 am	36	35	34	33	28	26	25	30

CNEL = 60 dB L_{dn} = 59 dB

Cataloged Noise Sources - by time period

Day: John Deere Tractor Model 2640 towing a diesel 3 cylinder mini mower and bailer

Evening: Not measured
Use data from Site 16

Night: Not measured
Use data from Site 16

Table A3.5-1 (Continued)

Site Number: 18

Site Description: Salton Sea National Wildlife Refuge, end of dirt road termination of Sinclair Road past refuge headquarters.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	46	43	41	40	39	35	32	38
Evening 7 pm-10 pm	40	38	37	37	36	35	33	36
Night 10 pm-7 am	45	27	25	25	24	23	23	25

CNEL = 38 dB

L_{dn} = 36 dB

Cataloged Noise Sources - by time period

Day: Truck-mounted crane at refuge quarry: 35 dBA
Ducks: 35-38 dBA
Power line buzz: 35 dBA
Geese at 400 yards: 44 dBA

Evening: Waves on Salton Sea: 35-40 dBA

Night: Birds: 45 dBA

Table A3.5-1 (Continued)

Site Number: 19

Site Description: Proposed 49 MW power plant. Sinclair Road between Gentry and Garst Roads.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am–7 pm	65	59	58	57	56	52	48	55
Evening 7 pm–10 pm	30	28	28	27	27	26	25	27
Night 10 pm–7 am	30	28	28	27	26	25	23	26

CNEL = 52 dB L_{dn} = 51 dB

Cataloged Noise Sources - by time period

Day: Massey Furgeson Tractor Model 4900 with disc harrows

Evening: Distant geese: 26-28 dBA
Dogs: 30 dBA

Night: Geese in adjacent fields: 26-28 dBA

Table A3.5-1 (Continued)

Site Number: 20

Site Description: Proposed 49 MW power plant site residence at corner of Sinclair and Hatfield Roads.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	70	66	54	40	38	33	31	38
Evening 7 pm-10 pm	27	25	24	24	24	23	23	25
Night 10 pm-7 am	30	28	28	27	26	25	23	26

CNEL = 37 dB L_{dn} = 36 dB

Cataloged Noise Sources - by time period

Day: Car passby: 70 dBA
Packing cotton into large bales with stationary machines: 45- 46 dBA
Distant machinery at feed lot: 31 dBA

Evening: Crickets: 23 dBA
Distant traffic: 22 dBA

Night: Geese in adjacent fields: 26-28 dBA set levels

Table A3.5-1 (Continued)

Site Number: 21

Site Description: Sinclair Road just west of farm buildings on west side of Southern Pacific Railroad tracks.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	45	44	41	39	38	37	34	38
Evening 7 pm-10 pm	50	48	44	44	43	42	38	43
Night 10 pm-7 am	50	48	43	35	34	34	33	35

CNEL = 44 dB L_{dn} = 42 dB

Cataloged Noise Sources - by time period

Day: Pickup truck: 80 dBA not recorded
Crop duster: 40 dBA
Traffic on Highway 111: 45 dBA

Evening: Traffic

Night: Traffic

Table A3.5-1 (Continued)

Site Number: 22

Site Description: Front steps of Calipatria High School.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am–7 pm	80	76	72	68	63	57	50	65
Evening 7 pm–10 pm	65	63	61	56	48	41	37	53
Night 10 pm–7 am	42	41	40	38	37	35	35	36

CNEL = 62 dB L_{dn} = 61 dB

Cataloged Noise Sources - by time period

Day: Traffic
Helicopter: 68 dBA
Truck: 78 dBA
Girls screaming: 74 dBA

Evening: Dogs: 40 dBA
Tennis ball on fence: 42 dBA
Trucks on Highway 111: 44 dBA

Night: Dogs: 40 dBA
Trucks on Highway 111: 42 dBA

Table A3.5-1 (Continued)

Site Number: 23

Site Description: Brandt Road 100 yards south of Eddins Road behind Alamo Chemical Plant next to residential use.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	74	72	70	67	64	62	60	65
Evening 7 pm-10 pm	65	65	65	65	65	65	65	65
Night 10 pm-7 am	65	65	65	65	65	65	65	65

CNEL = 72 dB L_{dn} = 71 dB

Cataloged Noise Sources - by time period

Day: Cotton processing: 60 dBA
Tractor with cotton wagons: 75 dBA
Car passby: 74 dBA

Evening: Cotton processing: 65 dBA

Night: Cotton processing: 65 dBA

Table A3.5-1 (Continued)

Site Number: 24

Site Description: Northeast corner of intersection of Kalin and Lindsey Roads. Open fields.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	40	39	39	39	39	39	39	39
Evening 7 pm-10 pm	37	36	36	35	35	34	33	35
Night 10 pm-7 am	35	34	33	33	33	33	33	33

CNEL = 41 dB L_{dn} = 40 dB

Cataloged Noise Sources - by time period

Day: Crickets, distant traffic, distant industrial sounds

Evening: Crickets, distant traffic, distant industrial sounds

Night: Crickets, distant traffic, distant industrial sounds

Table A3.5-1 (Continued)

Site Number: 25

Site Description: Edge of Salton Sea National Wildlife Refuge at the end of Bowles Road.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	44	42	42	41	40	39	38	41
Evening 7 pm-10 pm	36	34	32	31	31	29	29	31
Night 10 pm-7 am	35	33	31	30	30	28	28	30

CNEL = 40 dB L_{dn} = 39 dB

Cataloged Noise Sources - by time period

Day: Dog: 38 dBA
Tractor: 38-40 dBA
Shots: 40-42 dBA
Bird calls: 39-44 dBA

Evening: Shots: 34 dBA
Bird calls: 38 dBA

Night: Birds: 34-38 dBA
Distant non-specific sources

Table A3.5-1 (Continued)

Site Number: 26

Site Description: 400 feet east of intersection of Bowles and Gentry Roads.

Time Period (Range of Hours)	Measured A-Weighted Sound Pressure Level, L, in dB. Subscript Indicates Time In Percent, Level is Exceeded							L_{eq} dB
	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	
Day 7 am-7 pm	42	41	40	40	39	36	34	38
Evening 7 pm-10 pm	58	36	33	32	31	30	28	33
Night 10 pm-7 am		32	30	30	29	28	26	29

CNEL = 38 dB L_{dn} = 38 dB

Cataloged Noise Sources - by time period

Day: Traffic: 36- 42 dBA
Light aircraft: 35 dBA

Evening: Dogs: 34 dBA
Cars on Gentry Road: 58 dBA
Crickets: 28 dBA
Distant gunfire

Night: Distant traffic

Table A3.5-2

NOISE MEASUREMENT SURVEY SUMMARY OF SAMPLED DATA
A-WEIGHTED SOUND PRESSURE LEVEL, dB

Site	Time	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	L_{eq}	CNEL	L_{dn}
1	day	52	50	50	49	48	45	41	47		
	evening	30	28	27	26	26	25	24	26		
	night	38	36	35	35	35	34	33	35		
	Daily Weighted Average									46	45
2	day	65	64	61	59	54	47	46	54		
	evening	29	27	25	25	25	24	23	25		
	night	34	32	31	30	28	24	22	28		
	Daily Weighted Average									51	50
3	day	80	76	68	65	61	45	40	63		
	evening	79	77	73	69	64	54	49	67		
	night	74	71	65	61	53	42	37	59		
	Daily Weighted Average									68	66
4	day	46	43	42	41	41	40	39	41		
	evening	33	31	30	30	29	28	27	30		
	night	44	43	41	41	40	36	33	39		
	Daily Weighted Average									46	45

Table A3.5-2 (continued)

Site	Time	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	L_{eq}	CNEL	L_{dn}
5	day	73	72	71	70	70	64	54	68		
	evening	29	27	26	26	25	24	24	26		
	night	31	29	28	28	27	25	23	26		
	Daily Weighted Average									65	64
6	day	35	32	32	32	32	32	32	33		
	evening	29	27	26	26	25	24	24	26		
	night	31	29	28	28	27	25	23	26		
	Daily Weighted Average									34	34
7	day	43	42	41	41	40	38	34	39		
	evening	40	39	38	38	37	36	35	38		
	night	41	39	37	37	35	33	31	36		
	Daily Weighted Average									43	43
8	day	52	52	52	52	52	52	52	52		
	evening	52	52	52	52	52	52	52	52		
	night	52	52	52	52	52	52	52	52		
	Daily Weighted Average									59	58
9	day	62	51	51	51	51	51	51	51		
	evening	64	51	51	51	51	51	51	51		
	night	60	51	51	51	51	51	51	51		
	Daily Weighted Average									58	57

Table A3.5-2 (continued)

Site	Time	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	L_{eq}	CNEL	L_{dn}
10	day	41	39	38	38	37	36	36	37		
	evening	39	36	35	35	34	34	34	35		
	night	32	31	30	28	27	24	23	26		
	Daily Weighted Average									37	36
11	day	31	25	25	25	25	24	24	26		
	evening	30	28	27	26	26	24	23	26		
	night	32	31	30	28	27	24	23	26		
	Daily Weighted Average									33	32
12	day	64	61	59	58	57	57	56	58		
	evening	65	62	58	57	57	48	41	55		
	night	53	52	52	52	52	52	51	53		
	Daily Weighted Average									61	60
13	day	73	68	64	61	58	53	49	58		
	evening	72	71	68	66	65	55	45	63		
	night	47	45	45	45	45	45	43	45		
	Daily Weighted Average									61	58
14	day	75	73	71	68	65	59	50	65		
	evening	66	65	63	62	60	55	51	59		
	night	74	72	68	65	59	52	49	61		
	Daily Weighted Average									68	68

Table A3.5-2 (continued)

Site	Time	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	L_{eq}	CNEL	L_{dn}
15	day	34	32	31	31	31	31	30	32		
	evening	41	38	37	36	36	31	31	34		
	night	36	35	34	34	33	33	31	33		
	Daily Weighted Average									40	39
16	day	41	39	38	37	37	35	33	37		
	evening	35	33	32	31	31	30	28	31		
	night	36	35	34	33	28	26	25	30		
	Daily Weighted Average									38	38
17	day	71	70	68	67	65	58	42	63		
	evening	35	33	32	31	31	30	28	31		
	night	36	35	34	33	28	26	25	30		
	Daily Weighted Average									60	59
18	day	46	43	41	40	39	35	32	38		
	evening	40	38	37	37	36	35	33	36		
	night	45	27	25	25	24	23	23	25		
	Daily Weighted Average									38	36
19	day	65	59	58	57	56	52	48	55		
	evening	30	28	28	27	27	26	25	27		
	night	30	28	28	27	26	25	23	26		
	Daily Weighted Average									52	51

Table A3.5-2 (continued)

Site	Time	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	L_{eq}	CNEL	L_{dn}
20	day	70	66	54	40	38	33	31	38		
	evening	27	25	24	24	24	23	23	25		
	night	30	28	28	27	26	25	23	26		
	Daily Weighted Average									37	36
21	day	45	44	41	39	38	37	34	38		
	evening	50	48	44	44	43	42	38	43		
	night	50	48	43	35	34	34	33	35		
	Daily Weighted Average									44	42
22	day	80	76	72	68	63	57	50	65		
	evening	65	63	61	56	48	41	37	53		
	night	42	41	40	38	37	35	35	36		
	Daily Weighted Average									62	61
23	day	74	72	70	67	64	62	60	65		
	evening	65	65	65	65	65	65	65	65		
	night	65	65	65	65	65	65	65	65		
	Daily Weighted Average									72	71
24	day	40	39	39	39	39	39	39	39		
	evening	37	36	36	35	35	34	33	35		
	night	35	34	33	33	33	33	33	33		
	Daily Weighted Average									41	40

Table A3.5-2 (continued)

Site	Time	L_{max}	L_1	L_5	L_{10}	L_{20}	L_{50}	L_{90}	L_{eq}	CNEL	L_{dn}
25	day	44	42	42	41	40	39	38	41		
	evening	36	34	32	31	31	29	29	31		
	night	35	33	31	30	30	28	28	30		
	Daily Weighted Average									40	39
26	day	42	41	40	40	39	36	34	38		
	evening	58	36	33	32	31	30	28	33		
	night	-	32	30	30	29	28	26	29		
	Daily Weighted Average									38	38

hours with a 10 decibel (dB) penalty to account for increased human annoyance to noise disturbance during sleeping time. The CNEL index also singles out the evening hours as an important time period and weights noise occurring during this time by an additional 5 dB. In practice, there is little difference between the L_{dn} and CNEL noise rating systems. However, both are shown since the State of California, The Environmental Protection Agency, and U.S. Department of Housing and Urban Development use these indices in their regulations.

B. Calculated Noise Levels

Two sets of calculated noise levels are presented. The first set of calculated levels are the L_{dn} and DNEL levels presented in Table A3.5-2 which were determined from sample noise measurements taken during representative portions of the day, evening, and night periods (7:00 a.m. to 7:00 p.m. to 10:00 p.m., and 10:30 p.m. to 7:00 a.m.) using the following equations:

$$CNEL = 10 \operatorname{Log}_{10} \frac{\sum_{i=1}^{24} W_i 10^{HNLi/10}}{24}$$

Where:

HNL = hourly equivalent continuous A-weighted sound pressure level (L_{eq}) for each hour in the day.

W_i = the time of day weighting factor from below:

W_i	Time
1	0700-1900
3.16	1900-2200
10	2200-0700

$$L_{dn} = 10 \operatorname{Log}_{10} \frac{\sum_{i=1}^{24} W_i 10^{L_{eq}/10}}{24}$$

Where:

L_{eq} = average A-weighted sound pressure level for each hour of the day.

W_i = the time of day weighting factor from below:

W_i	Time
1	0700-2200
10	2200-0700

The second set of calculated noise levels are associated with the two major transportation arterials that traverse the study area in a generally north-south direction. These are the Southern Pacific Transportation Company's (SPT) railroad tracks and State Highway 111. Both of these noise sources lend themselves to calculation of noise impacts. The most recent traffic information from the California Department of Transportation (Caltrans, 1980b) is shown in Table A3.5-3 for Highway 111 north of Niland and Table A3.5-4 for Highway 111 south of Niland.

Table A3.5-3

HIGHWAY 111 TRAFFIC NORTH OF NILAND
24-hour two-way counts

Vehicles (Trucks)	Count
5-axle	661
4-axle	27
3-axle	166
2-axle	285
Total Trucks	1,139
Total Vehicles	3,400

Table A3.5-4

HIGHWAY 111 TRAFFIC SOUTH OF NILAND
24-hour two-way counts

Vehicles (Trucks)	Count
5-axle	816
4-axle	37
3-axle	219
2-axle	272
Total Trucks	1,348
Total Vehicles	4,150

Railroad traffic is also split at Niland into north and south counts. Above Niland, the SPT Company's main east-west line from the Colton switchyards typically carries some eleven (11) freights each way on an average day (reference SPT Company's main Los Angeles Office). The tracks below Niland are used typically for one round trip per day for local use, being loaded and unloaded on the siding at Niland.

Community noise levels using the Federal Highway Administrations Traffic Noise Prediction Model FHWA-RD-77-108 were generated and used to calculate noise contours of equal loudness. Because of the relatively low level of background noise, and the generally flat terrain, the traffic noise is audible in many locations for more than a mile from the roadway. Using measured data and a methodology developed by the California State Office of Noise Control (Swing, 1975), railroad noise contours were developed for the study area. Because of the proximity of the railroad tracks and State Highway 111, the noise contours for each are combined. Generalized noise contours in the L_{dn}/CNEL noise indices are plotted for the composite of the railroad and highway noise (Figure A3.5-2). The effects of terrain shielding and atmospheric absorbtion were not included due to their variability over the complete study area.

C. Noise Standards

1. Federal Regulations and Guidelines

The standards and guidelines that are considered in this report that are federally based were issued by the Department of Housing and Urban Development (HUD), the United States Environmental Protection Agency (EPA), and the United States Geological Survey (USGS).

a. HUD - In 1979 HUD implemented Part 51, Environmental Criteria and Standards, to Title 25 of the CFR to: encourage the control of noise at its source and to promote land use patterns for housing and other noise sensitive urban needs that will provide a suitable separation between them and major noise sources.

This standard, shown in Table A3.5-5, requires that the magnitude of the external noise environment at a site be determined by the value of the day-night average sound level produced as the result of the accumulation of noise from all sources contributing to the external noise environment at the site. Day-night average sound level, abbreviated as DNL and symbolized as L_{dn}, is the 24-hour average sound level, in decibels, obtained after the addition of 10 decibels to sounds levels in the night from 10 pm to 7 am, as described in the previous section.

On an interim basis, when loud impulsive sounds, such as explosions or sonic booms, are experienced at a site, the day-night average sound level produced by the loud impulsive sounds alone is corrected by adding 8 decibels to it in assessing the acceptability of the site. Alternatively, the C-weighted day-night average sound level (L_{cdn}) may be used without the 8 decibel addition.

Table A3.5-5*

SITE ACCEPTABILITY STANDARDS

	Day-night average sound level (in decibels)	Special approvals and requirements
Acceptable	Not exceeding 65 dB (1)	None
Normally Unacceptable	Above 65 dB but not exceeding 75 dB	Special Approvals (2) Environmental Review (3) Attenuation (4)
Unacceptable	Above 75 dB	Special Approvals (2) Environmental Review (3) Attenuation (5)

NOTES:

(1) Acceptable threshold may be shifted to 70 dB in special circumstnaces pursuant to Section 51.105(a).

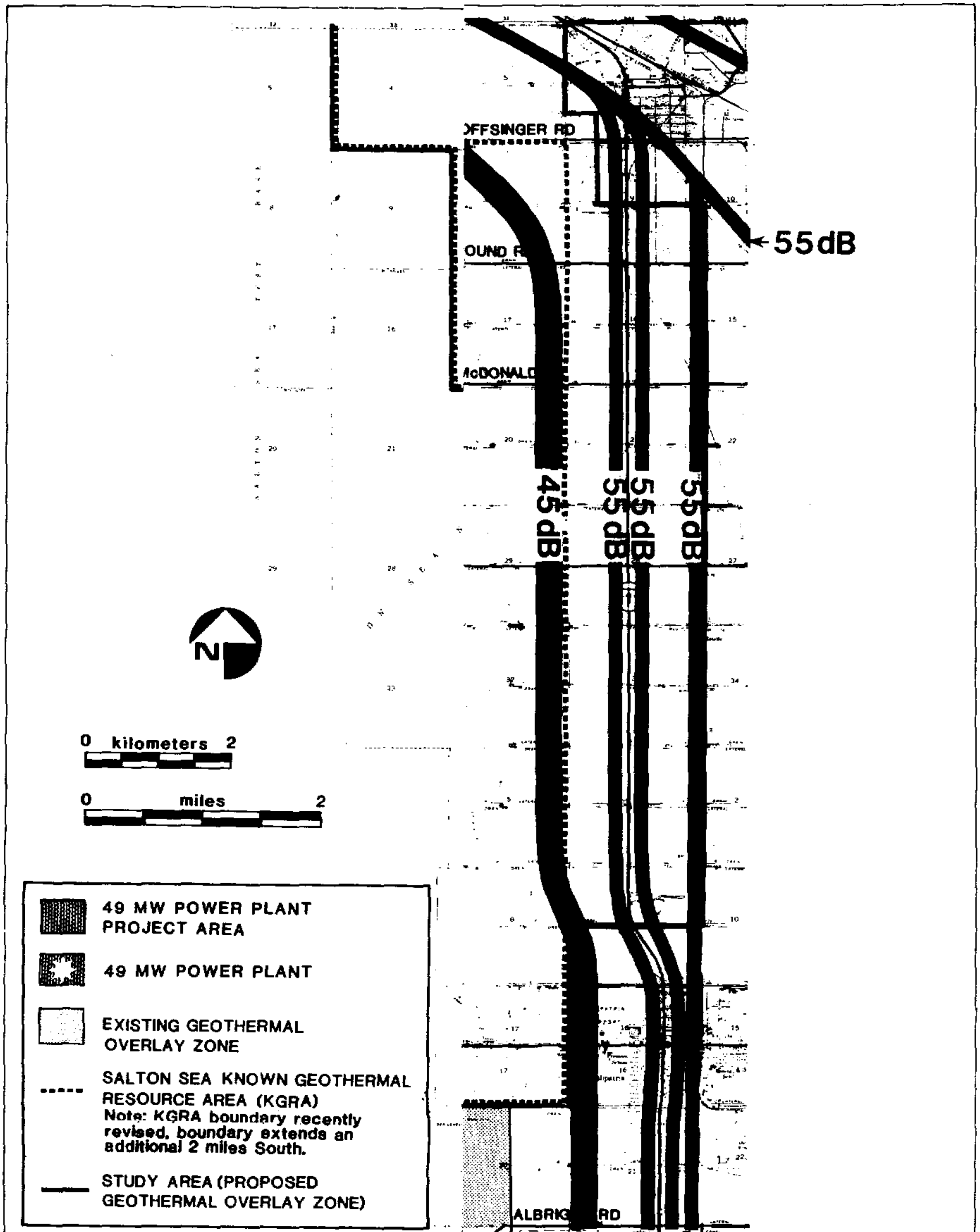
(2) See Section 51.104(b) for requirements.

(3) See Section 51.104(b) for requirements.

(4) 5 dB additional attenuation required for sites above 65 dB but not exceeding 70 dB and 10 dB additional attenuation required for sites above 70 dB but not exceeding 75 dB. (See Section 51.104(a).)

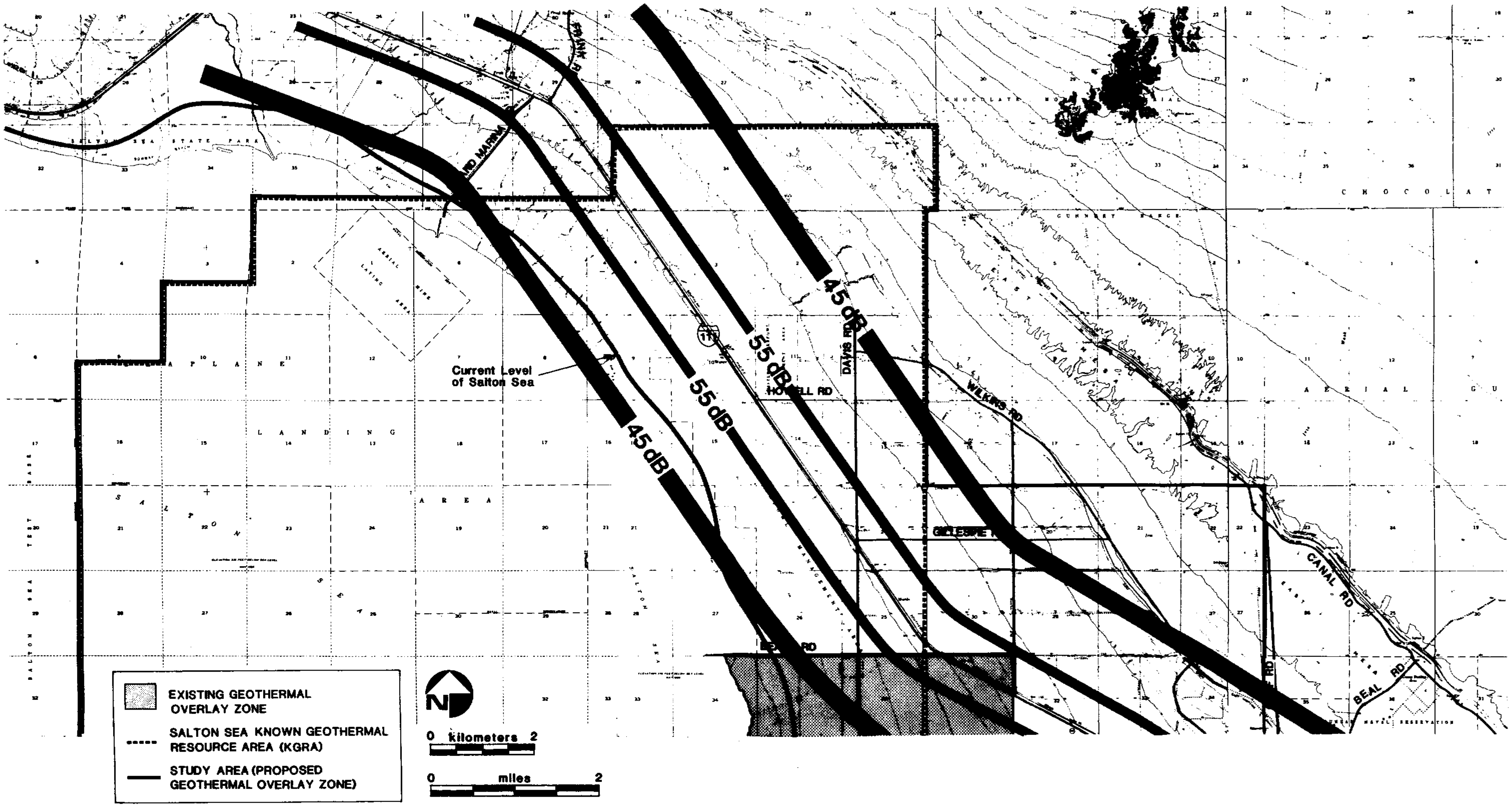
(5) Attenuation measures to be submitted to the Assistant Secretary for CPD for approval on a case-by-case basis.

* The noise environment inside a building is considered acceptable if (a) the noise environment external to the building complies with these standards, and (b) the building is constructed in a manner common to the area or, if of uncommon construction, has at least the equivalent noise attenuation characteristics.



*Topographic Effects Not Included

FIGURE A3.5-2



Combined Railroad and Highway Noise Contours* of Project Area in dB CNEL/Ldn Part II

*Topographic Effects Not Included

FIGURE A3.5-2

The degree of acceptability of the noise environment at a site is determined by the sound levels external to buildings or other facilities containing noise sensitive uses. The standards usually apply at a location 2 m (6.5 ft) from the building housing noise sensitive activities in the direction of the predominant noise source. For planning purposes where the building location is yet to be determined, the standards apply 2 m (6.5 ft) from the building setback line nearest to the predominant noise source. The standards also apply at other locations where it is determined that quiet outdoor space is required in an area ancillary to the principal use on the site.

b. EPA - In 1974 the U.S. EPA identified community noise levels, both exterior and intrusive to indoor spaces, that are requisite to protect public health and welfare with an adequate margin of safety for activity interference and hearing loss. Table A3.5-6 presents these levels, but, as will be shown in the following paragraphs, annoyance and dissatisfaction may be caused if previous levels were significantly below these levels, and were increased to them because of the proposed development. This is of particular importance in the study area where many areas currently have low noise levels. The following is a brief explanation of the sensitive areas defined in Table A3.5-6.

(1) Residential areas are areas where human beings live, including apartments, seasonal residences, and mobile homes, as well as year-round residents. A quiet environment is necessary in both urban and rural residential areas in order to prevent activity interference and annoyance, and to permit the hearing mechanism to recuperate if it is exposed to higher levels of noise during the other periods of the day. Although there is a separate category for commercial areas, commercial living accomodations such as hotels, motels, cottages, and inns should be included in the residential category since these are places where people sleep and sometimes spend extended periods of time.

(2) Commercial areas include retail and financial service facilities, offices, and miscellaneous commercial services. They do not include warehouses, manufacturing plants, and other industrial facilities, which are

Table A3.5-6

YEARLY AVERAGE* EQUIVALENT SOUND LEVELS IDENTIFIED AS REQUISITE TO PROTECT THE PUBLIC HEALTH AND WELFARE WITH AN ADEQUATE MARGIN OF SAFETY

		Indoor			Outdoor		
	Measure	Activity Interference	Hearing Loss Consideration	To Protect Against Both Effects(b)	Activity Interference	Hearing Loss Consideration	To Protect Against Both Effects (b)
Residential with Outside	L_{dn}	45		45	55		55
Space and Farm Residences	$L_{eq(24)}$		70			70	
Residential with No Outside Space	L_{dn} $L_{eq(24)}$	45	 70	45			
Commercial	$L_{eq(24)}$	(a)	70	70(c)	(a)	70	70(c)
Inside Transportation	$L_{eq(24)}$	(a)	70(a)				
Industrial	$L_{eq(24)(d)}$	(a)	70	70(c)	(a)	70	70(c)
Hospitals	L_{dn} $L_{eq(24)}$	45	 70	45	55	 70	55
Educational	$L_{eq(24)}$ $L_{eq(24)(d)}$	45	 70	45	55	 70	55
Recreational Areas	$L_{eq(24)}$	(a)	70	70(c)	(a)	70	70(c)
Farm Land and General Unpopulated Land	$L_{eq(24)}$				(a)	70	70(c)

Code:

a. Since different types of activities appear to be associated with different levels, identification of a maximum level for activity interference may be difficult except in those circumstances where speech communication is a critical activity.

b. Based on lowest level.

c. Based only on hearing loss.

d. An $L_{eq(8)}$ of 75 dB may be identified in these situations so long as the exposure over the remaining 16 hours per day is low enough to result in a negligible contribution to the 24-hour average, i.e., no greater than an L_{eq} of 60 dB.

Note: Explanation of identified level for hearing loss: the exposure period which results in hearing loss at the identified level is a period of 40 years.

* Refers to energy rather than arithmetic average.

Source: U.S. Environmental Protection Agency "Information on Levels of Environmental Noise Results Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," March 1974, 550/9-74-004.

included in the industrial classification. On the other hand, a level of $L_{eq}(24)$ of 70 dB has been identified to protect against hearing loss.

(3) Transportation facilities are included so as to protect individuals using public and private transportation.

(4) Industrial areas include such facilities as manufacturing plants, warehouses, storage areas, distribution facilties, and mining operations. Only a level for hearing loss is identified due to the lack of data with respect to annoyance and activity interference.

(5) Hospital areas include the immediate neighborhood of the hospital as well as its interior. A quiet environment is required in hospital areas because of the importance of sleep and adequate rest to recovery of patients.

(6) Educational areas include classrooms, auditoriums, schools in general, and those grounds not used for athletics. The principal consideration in the education environment is the prevention of interference with activities, particularly speech communication. An indoor noise level not exceeding $L_{eq}(24)$ of 45 dB is identified as adequate to facilitate thought and communication. Since teaching is occasionally conducted outside the classroom, an outdoor $L_{eq}(24)$ of 55 dB is identified as the maximum level to prevent activity interference.

(7) Recreational areas include facilities where noise exposure is voluntary. Included with this classification are nightclubs, theaters, stadiums, racetracks, beaches, amusement parks, and atheletic fields. Since some exposure in such areas is usually voluntary, there is seldom any interference with the desired activity.

(8) Farm and general unpopulated land primarily includes agricultural property used for the production of crops

or livestock. For such areas, the primary considerations are the protection of human hearing and the prevention of adverse effects on domestic and wild animals. Protection of hearing requires that an individual's exposure to intermittent noise does not exceed $L_{eq}(24)$ of 70 dB. A separate level for the exposure of animals is not identified due to the lack of data indicating that hearing damage risk for animals is substantially different from that of humans. The unpopulated areas include wilderness areas, parks, game refuges, and other areas that are set aside to provide enjoyment of the outdoors. Although quiet is not always of paramount importance in such areas, many individuals enjoy the special qualities of serenity and tranquility found in natural areas.

The EPA has generalized to any intruding noise a model first published by the Air Force relating aircraft noise and its effect on people. This model modifying the guidelines specified in Table A3.5-6 to include corrections for the predevelopment conditions, accounts for seven factors:

(1) Magnitude of the noise with a frequency weighting relating to human response.

(2) Duration of the intruding noise.

(3) Time of year (windows open or closed).

(4) Time of day noise occurs.

(5) Outdoor noise level in community when the intruding noise is not present.

(6) History of prior exposure to the noise source and attitude toward its owner.

(7) Existence of pure-tone or impulsive character in the noise.

Table A3.5-7 presents the corrections to be added to the predicted or measured noise levels for a new proposed intruding community noise source so that the source levels may be evaluated in terms of the guideline levels of Table A3.5-6. The "no reaction" response in Table A3.5-7 corresponds to a normalized

Table A3.5-7

CORRECTIONS TO BE ADDED TO THE MEASURED DAY-NIGHT SOUND LEVEL (Ldn) OF INTRUDING NOISE TO OBTAIN NORMALIZED Ldn(D-3)

Type of Correction	Description	Amount of Correction to be Added to Measured Ldn in dB
Seasonal Correction	Summer (or year-round operation)	0
	Winter only (or windows always closed)	-5
Correction for Outdoor Noise Level Measured in Absence of Intruding Noise	Quiet suburban or rural community (remote from large cities and from industrial activity and trucking).	+10
	Normal suburban community (not located near industrial activity).	+5
	Urban residential community (not immediately adjacent to heavily traveled roads and industrial areas).	0
	Noisy urban residential community (near relatively busy roads or industrial areas).	-5
	Very noisy urban residential community.	-10
Correction for Previous Exposure & Community Attitudes	No prior experience with the intruding noise	+5
	Community has had some previous exposure to intruding noise but little effort is being made to control the noise. This correction may also be applied in a situation where the community has not been exposed to the noise previously, but the people are aware that bona fide effort are being made to control the noise.	0
	Community has had considerable previous exposure to the intruding noise and the noise maker's relations with the community are good.	-5
	Community aware that operation causing noise is very necessary and it will not continue indefinitely. This correction can be applied for an operation of limited duration and under emergency circumstances.	-10
Pure Tone or Impulse	No pure tone or impulsive character	0
	Pure tone or impulsive character present	+5

outdoor day-night sound level which ranges between 50 and 61 dB with a mean of 55 dB. This mean value is 5 dB below the value that was utilized for categorizing the day-night sound level for a "residential urban community," which is the baseline category for the data in the table.

c. USGS - The U.S. Geological Survey in 1975 set a standard of 65 dB(A) at .8 km (0.5 mi) (applicable to geothermal operations on federal lands on East Mesa).[1]

2. State

The State of California has identified noise pollution as a major source of environmental impacts and has established standards in two specific areas that regulate and give guidance for community levels that are acceptable for residential uses. In 1970 the California Department of Aeronautics issued "Noise Standards," in the California Administrative Code, Chapter 9, Title 4 which established that outdoor noise levels of 65 dB CNEL were not to be exceeded in residential areas impacted by aircraft noise. In 1967 the state issued a set of Noise Insulation Standards in Title 25, Subchapter 10 of the California Administrative Code. These standards limit the noise level intrusive to residential buildings to 45 dB CNEL. Examination of typical building practices and the likelihood of doors and windows being left open for cooling and ventilation (based on an interior level of 45 dB CNEL) suggests that typical exterior noise levels in residential areas, including hotels and motels, shall not exceed 57 dB CNEL.

3. Local - Imperial County

When California State law was amended in 1972 to require a noise element for all city and county general plans, Imperial County adopted its own set of guidelines on October 1, 1974. The Imperial County Noise Element addresses such sources as airports, state highways, and freeways, railroads, county roads, water vehicles, and other noise emitters. Standards and limits are given in terms of the Composite Noise Rating (CNR), Noise Exposure Forecast (NEF) and HUD criteria. A summary of these noise categories is given in Table A3.5-8. Noise criteria specifically for geothermal development were established by Imperial County in 1971. The noise element standards and geothermal development standards are in conflict with each other and also do not agree with federal recommendations. A uniform, non-conflicting set of

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[1] U.S. Department of Energy, An Assessment of Geothermal Development in the Imperial Valley of California, DOE/EV-0092, Volume 1, July 1980.

Table A3.5-8

IMPERIAL COUNTY NOISE ELEMENT STANDARDS AND LIMITS

Critical

HUD - Clearly Unacceptable; Exceeds 80 dB(A) for 60 minutes per 24-hour period, or exceeds 75 dB(A) for 8 hours per 24-hour period.
NEF - Zone C, NEF greater than 40.
CNR - Zone E, CNR greater than 115.

Concern

HUD - Normally Unacceptable; Exceeds 65 dB(A) for 8 hours per 24-hour period, or loud repetitive sounds on-site.
NEF - Zone B, NEF greater than 30 and less than 40.
CNR - Zone 2, CNR greater than 100 and less than 115.

Caution

HUD - Normally Acceptable; Exceeds 65 dB(A) for 8 hours per 24-hour period.
NEF - Zone Upper A, NEF greater than 20 and less than 30.
CNR - Zone Upper 1, CNR 100+ 1/2 the distance between CNR 100 and CNR 115.

Allowable

HUD - Clearly Acceptable; does not exceed 45 dB(A) more than 30 minutes per 24 hours.
NEF - Zone A, NEF less than 20.
CNR - Zone 1, CNR less than 100.

Source: Imperial County Planning Department (1974).

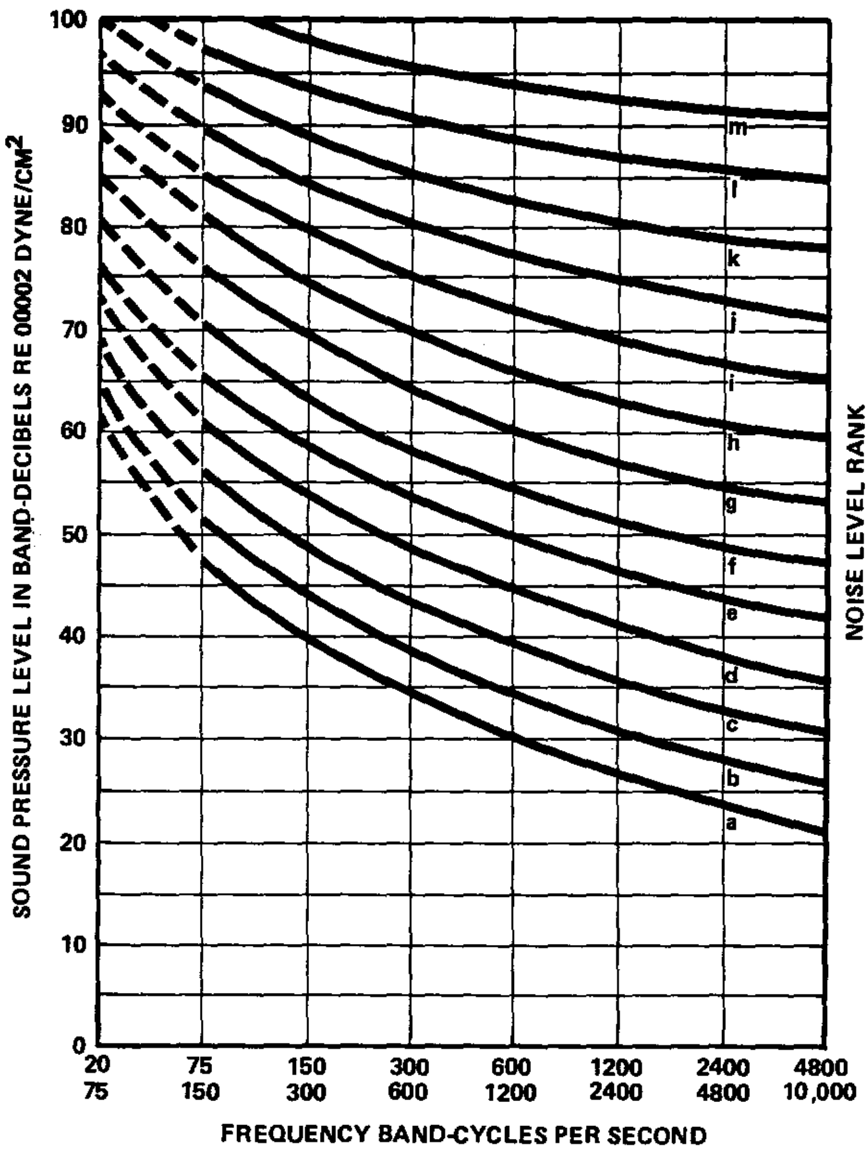
standards to meet the community (county) needs is required to adequately assess the impact of proposed development in terms of Imperial County requirements. The following paragraphs examine the various noise standards used by the County of Imperial.

a. HUD - As was documented in the paragraphs describing Federal requirements, the old HUD regulations as described in Circular 1390.2 were replaced in 1979 with a new set of standards that are written in a language and noise index that is more compatible with other standards and contemporary community noise evaluation and control procedures. This occurred after the Imperial County Noise Element was written, adopting the old HUD criteria. For the purposes of this EIR, the new HUD standards will be used as reflecting the "state-of-the-art" in Federal Criteria. It is recommended that the Imperial County Noise Element be updated to reflect these changes in Federal criteria, taking advantage of the simplification and increased utility now available in these standards.

b. NEF - The NEF, Noise Exposure Forecast, methodology was developed to evaluate the impact of aircraft operations on airport communities and as such is not strictly applicable to geothermal development.

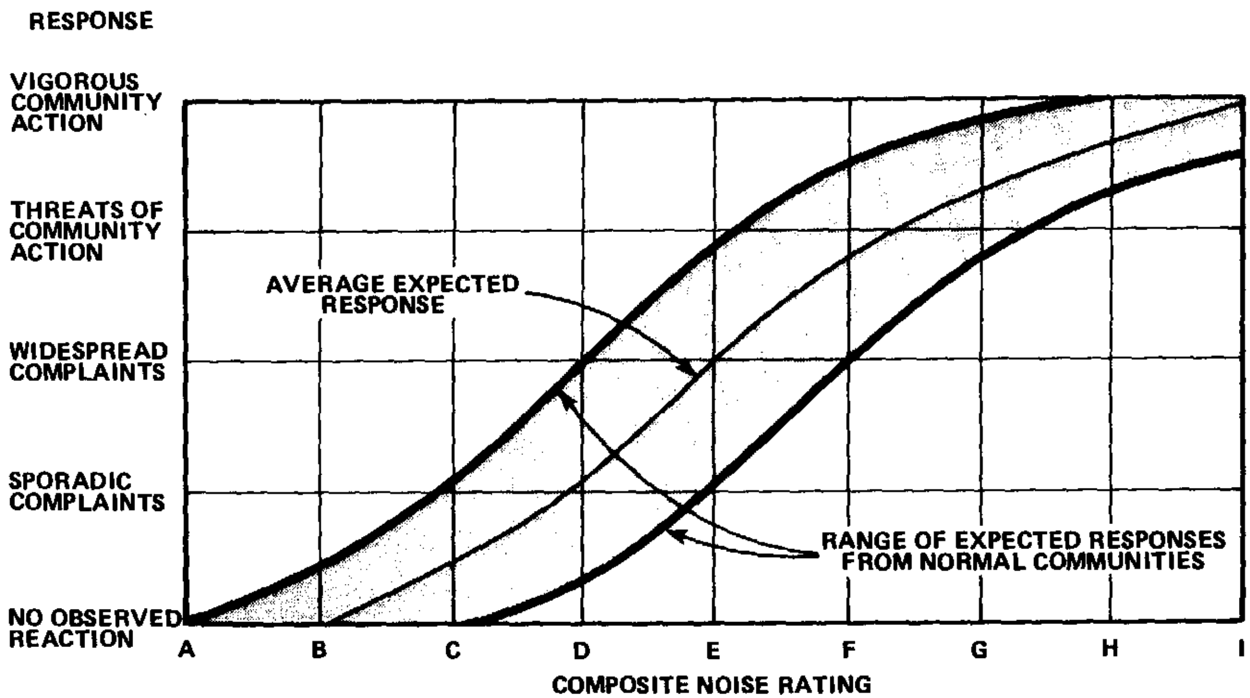
c. CNR - The Composite Nose Rating (CNR) is a measure which uses octave band sound pressure level data with appropriate corrections for special characteristics, background noise interference and time of day to assess the influence of various noise sources such as traffic and industrial noise, as well as aircraft noise on the community. The original version of CNR was developed in 1955 to cover all community noise sources and is now designated CNR_C. In 1964, another CNR now designated CNR_A was developed to evaluate the effects of aircraft flyovers on communities. For the purposes of this EIR, CNR_C will be used. Without going into all the available correction factors, the fundamentals of the CNR system are expressed in two sets of graphs. The first is a way of ranking a community noise source in terms of its spectral characteristics by plotting it on a rating curve as shown in Figure A3.5-3. The letter designations are then used to determine the typical community response to the proposed noise source from Figure A3.5-4. This provides for an evaluation of the level's acceptability to the surrounding community due to an increase in the noise environment from a proposed development.

d. County Geothermal Standards - Noise criteria specifically for geothermal development has been established in the "Terms, Conditions, Standards and



Rating Curve to Determine Noise Level Rank

FIGURE A3.5-3



Typical Community Response

FIGURE A3.5-4

Application Procedures for Initial Geothermal Development in Imperial County" (Imperial County, 1971). These criteria establish two classes, Class I and Class II, of drilling and production noise standards (see Figure A3.5-5). As shown, the Class II standard is subdivided to take various land use categories (i.e., industrial, commercial, dense residential, normal residential, and open space) into account. The category which would apply to any particular geothermal development project is determined by the County Planning Commission.

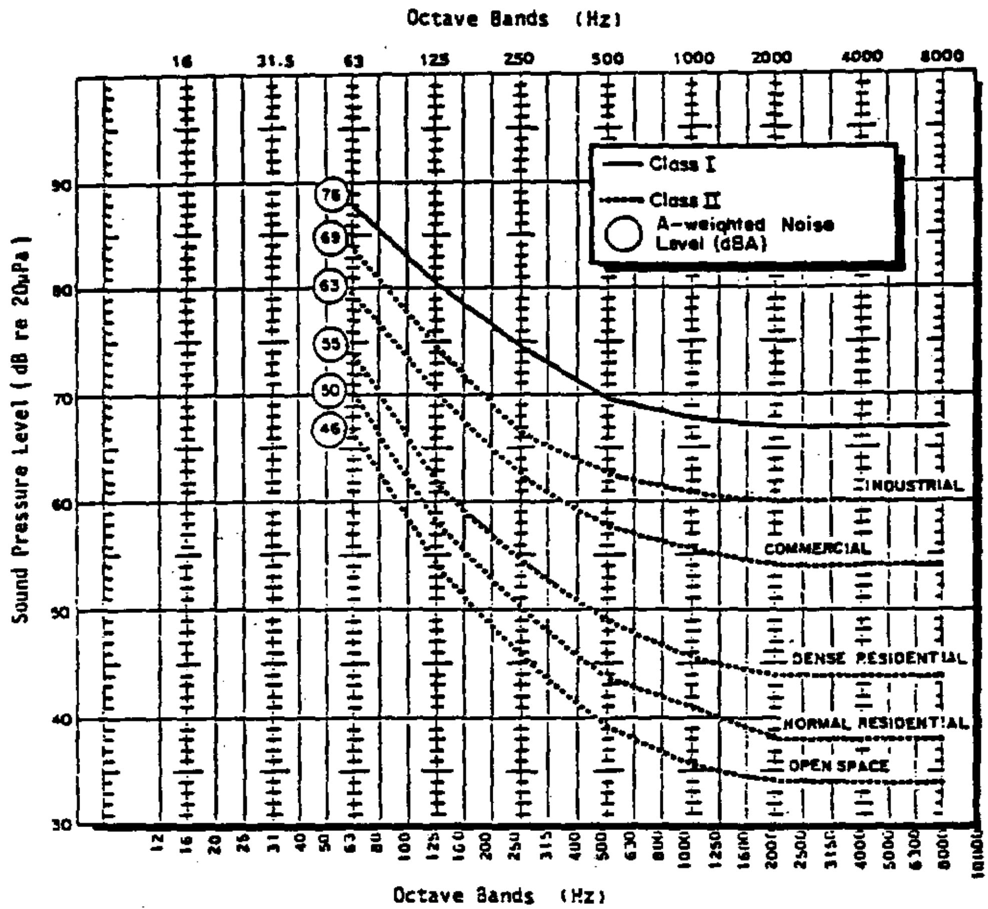
To be in compliance with these criteria, continuous generation of wide-band noise must be limited to the levels shown in Figure A3.5-5. Noise levels are determined by measurements taken at the boundary of the development parcel, which is defined to be at least 100 feet from any well. The prescribed levels may be exceeded by 10 percent if the noise is intermittent and occurs during daylight hours. Most other noise criteria recognize intermittent noise to be more annoying and therefore limit it more severely.

These noise standards for geothermal development have been evaluated in terms of noise element critera and are found to be in substantial conflict with their underlying federal criteria basis and those of the EPA. Table A3.5-9 translates the geothermal noise standards into the L_{dn} and CNEL indices.

Table A3.5-9

IMPERIAL COUNTY GEOTHERMAL NOISE STANDARDS IN TERMS OF THE L_{dn} and CNEL NOISE RATINGS IN DECIBELS

Standard and Land Use Rating	CNEL, dB	L_{dn}g dB
Class I		
(Land Use Rating as Applied)	82.7	82.3
Class II		
Industrial	75.7	75.3
Commercial	69.7	69.3
Dense Residential	61.7	61.3
Normal Residential	56.7	56.3
Open Space	52.7	52.3



County of Imperial Initial Geothermal Development
Class I and Class II Noise Standards (Based on preferred octave bands as defined by ANSI)

FIGURE A3.5-5

All but the Class II Open Space criteria violate EPA standards given in the L_{dn} index for open space and residential uses outdoors. The HUD criteria only concerns itself with outdoor levels as related to indoor levels attainable through typical construction techniques and, as such, show that reasonable interior housing levels could be obtained, but say nothing about the outdoor environment for human habitation. The Class II industrial and Class I standards also exceed the EPA standards for hearing protection. In terms of the CNR standards of the Noise Element, Table A3.5-10 shows the response that residents of a community would be expected to have to the levels allowed by the geothermal standards.

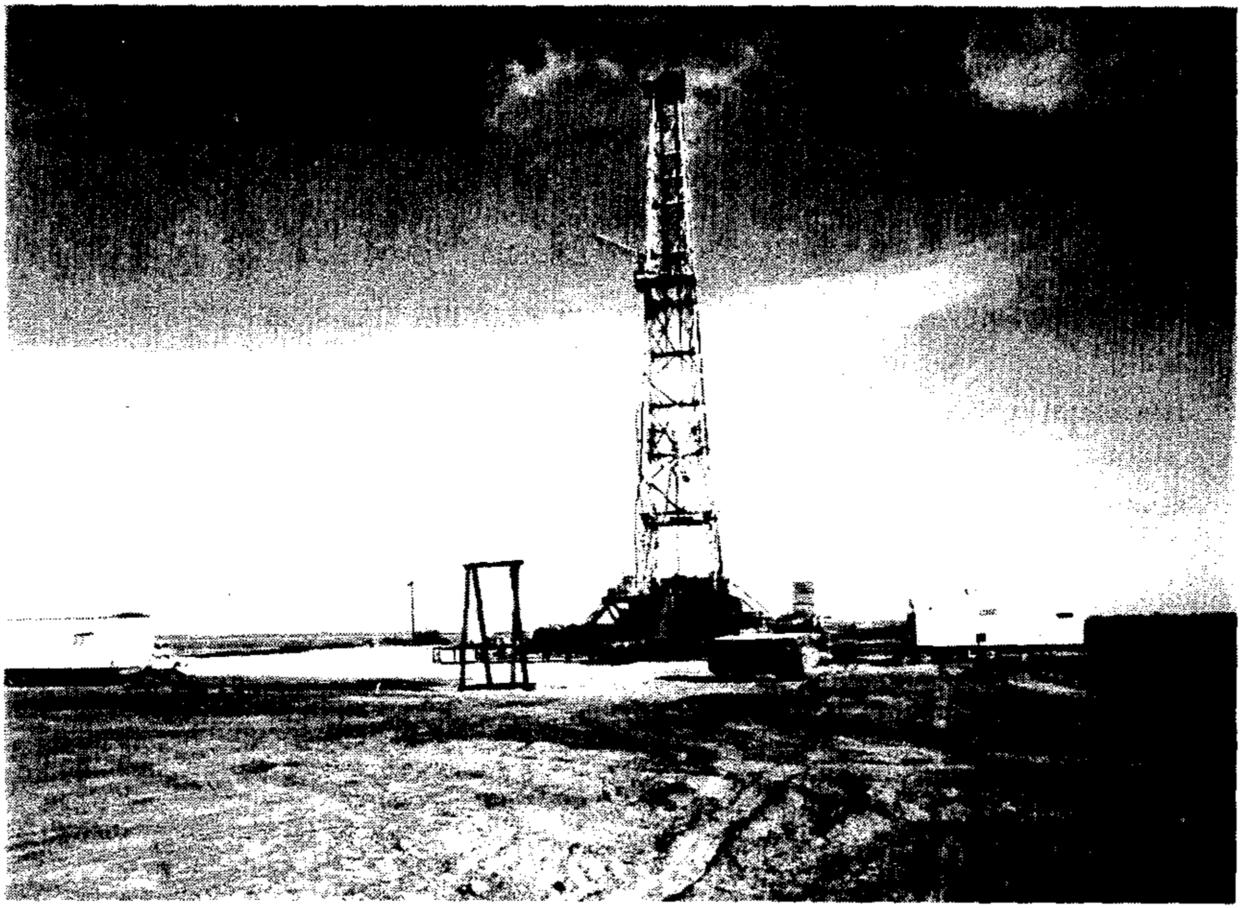
Table A3.5-10

CNR RATING OF IMPERIAL COUNTY GEOTHERMAL NOISE STANDARD

Development Class and Land Use Rating	Response
Class I	
(Land Use Rating as Applied)	Vigorous Community Action Against
Class II	
Industrial	Vigorous Community Action Against
Commercial	Vigorous Community Action Against
Dense Residential	Threats of Community Action
Normal Residential	Widespread Complaints
Open Space	Sporadic Complaints

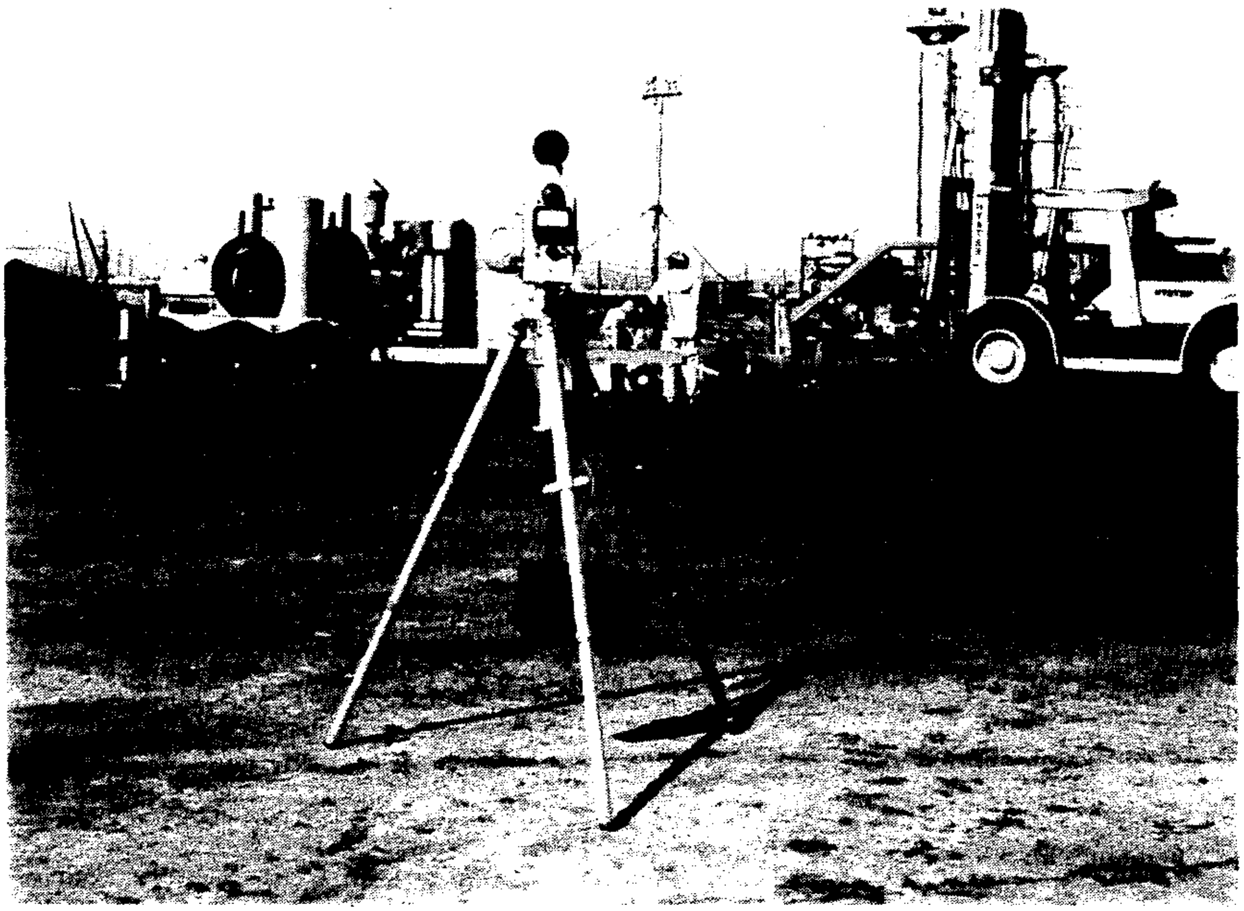
D. <u>Supporting Figures</u>

The following Figures A3.5-6 through A3.5-15 graphically describe noise-related geothermal facilities and equipment. These figures are referred to in the text.



Geothermal Well Drill Site, in Southcentral Imperial County, January 1981

FIGURE A3.5-6



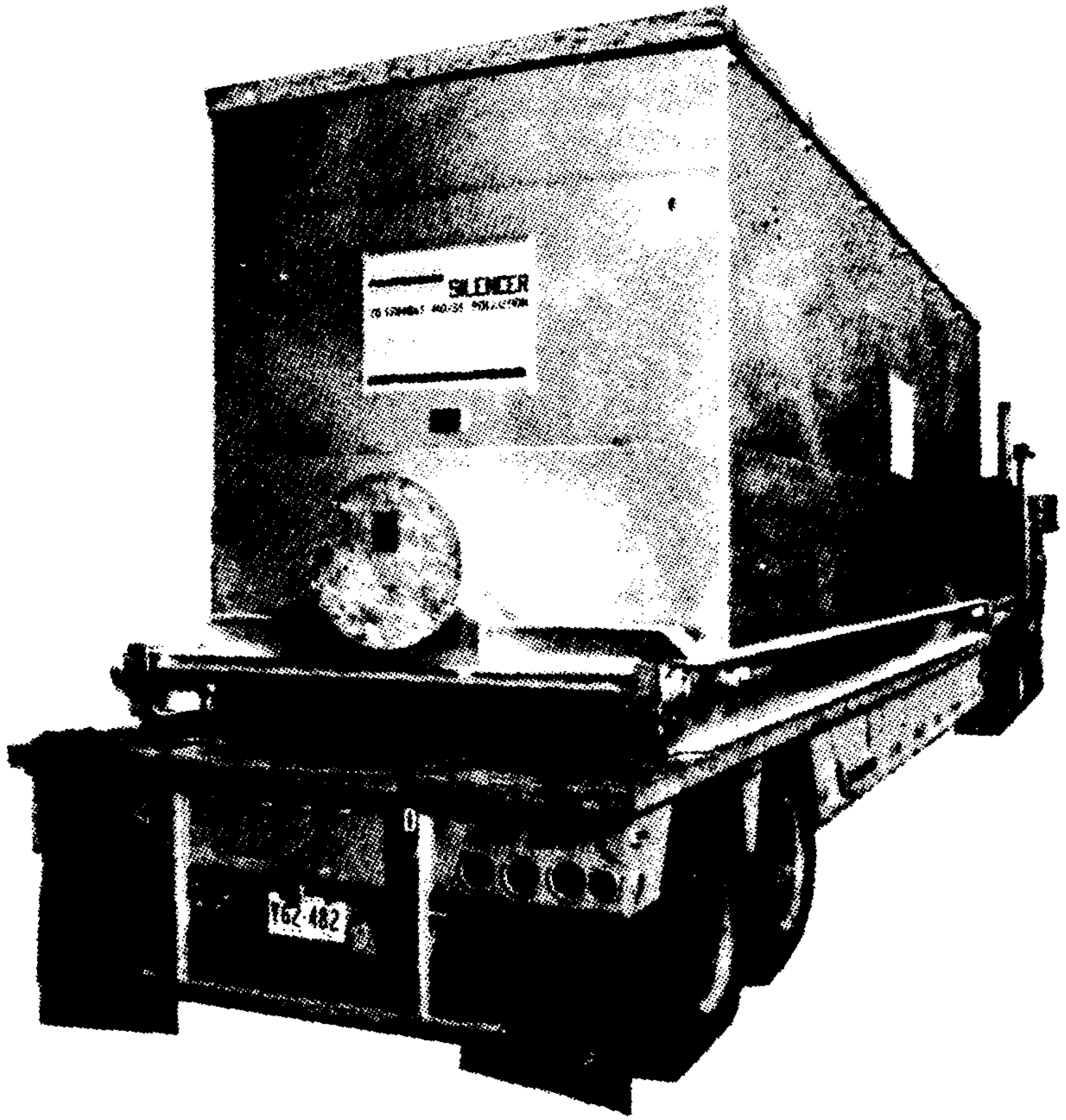
Hydro Blaster* Used for Descaling Operations
in Geothermal Pipes, Vessels and Valves

*Aqua Dyne 12,000 psi Pump Driven by a Detroit Diesel

FIGURE A3.5-7

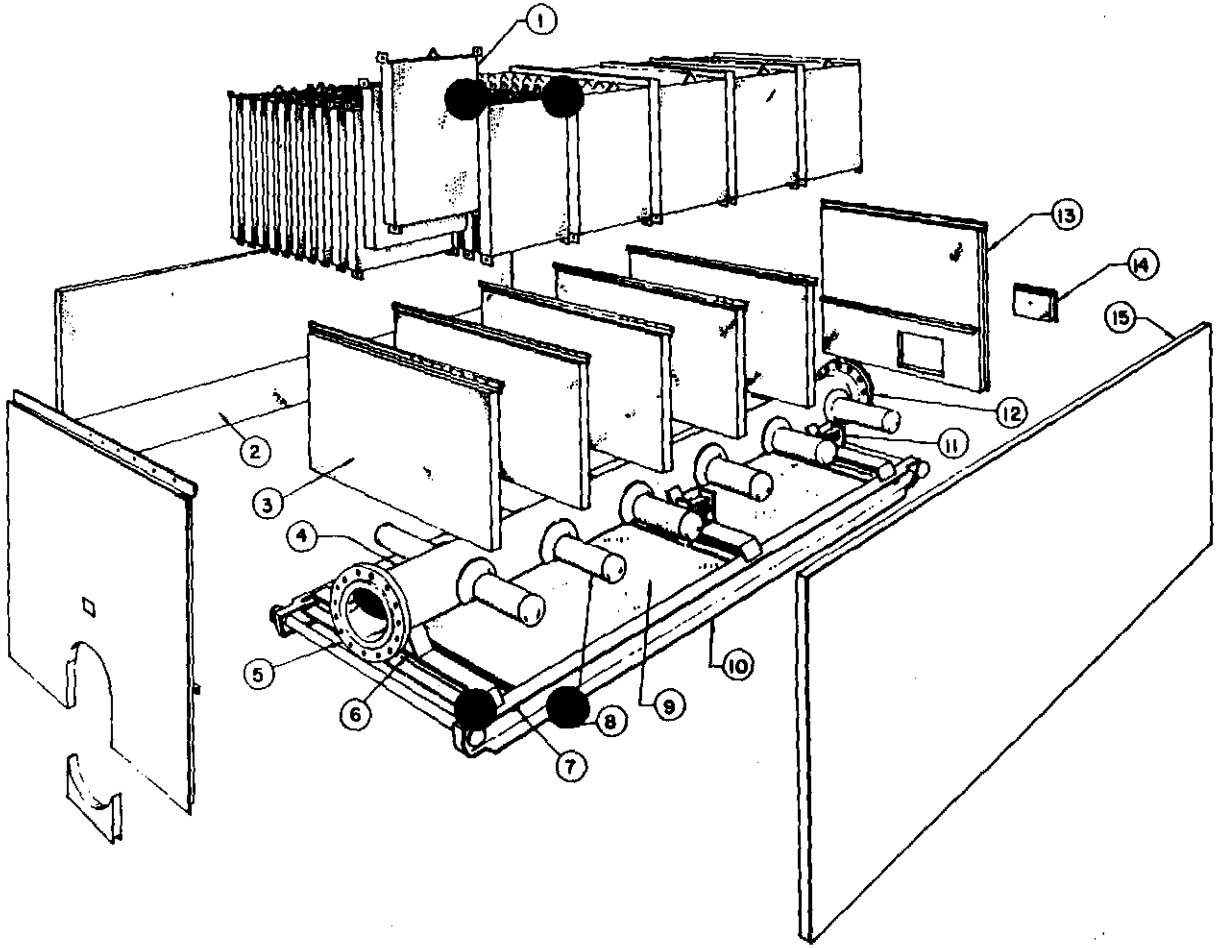
Typical 2-Cell Cooling Tower
(North Brawley Geothermal Demonstration Power Plant)

FIGURE
A3.5-8



Steam Blow Off Silencer (on Trailer)

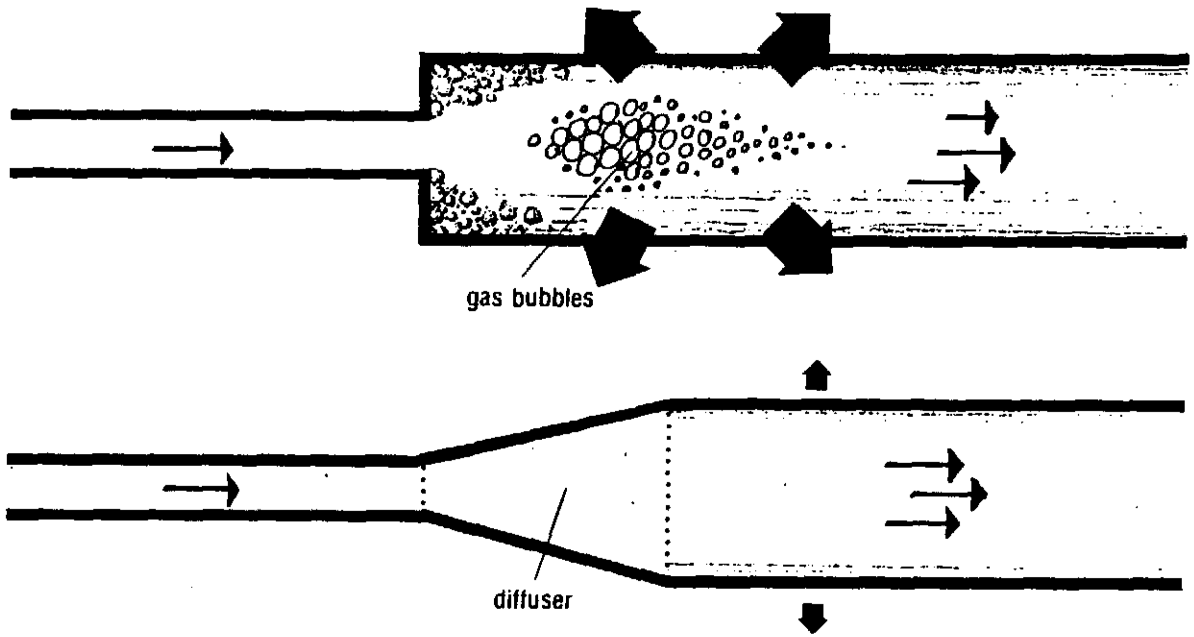
FIGURE A3.5-9



1. REMOVABLE ACOUSTIC PANEL
2. SCORIA PACKED BOTTOM CHAMBER
3. FIXED ACOUSTIC PARTITION
4. MULTI-BRANCH DIFFUSER MANIFOLD
5. INLET FLANGE
6. MANIFOLD FIXED SUPPORT ASSEMBLY
7. DRAIN
8. DIFFUSER
9. SCORIA PACKED ACOUSTIC FLOOR
10. SKID ASSEMBLY
11. MANIFOLD GUIDED SUPPORT ASSEMBLY
12. REMOVABLE DEBRIS IMPACT PLATE
13. ACOUSTIC END ENCLOSURE
14. MANWAY CLOSURE
15. ACOUSTIC SIDE ENCLOSURE

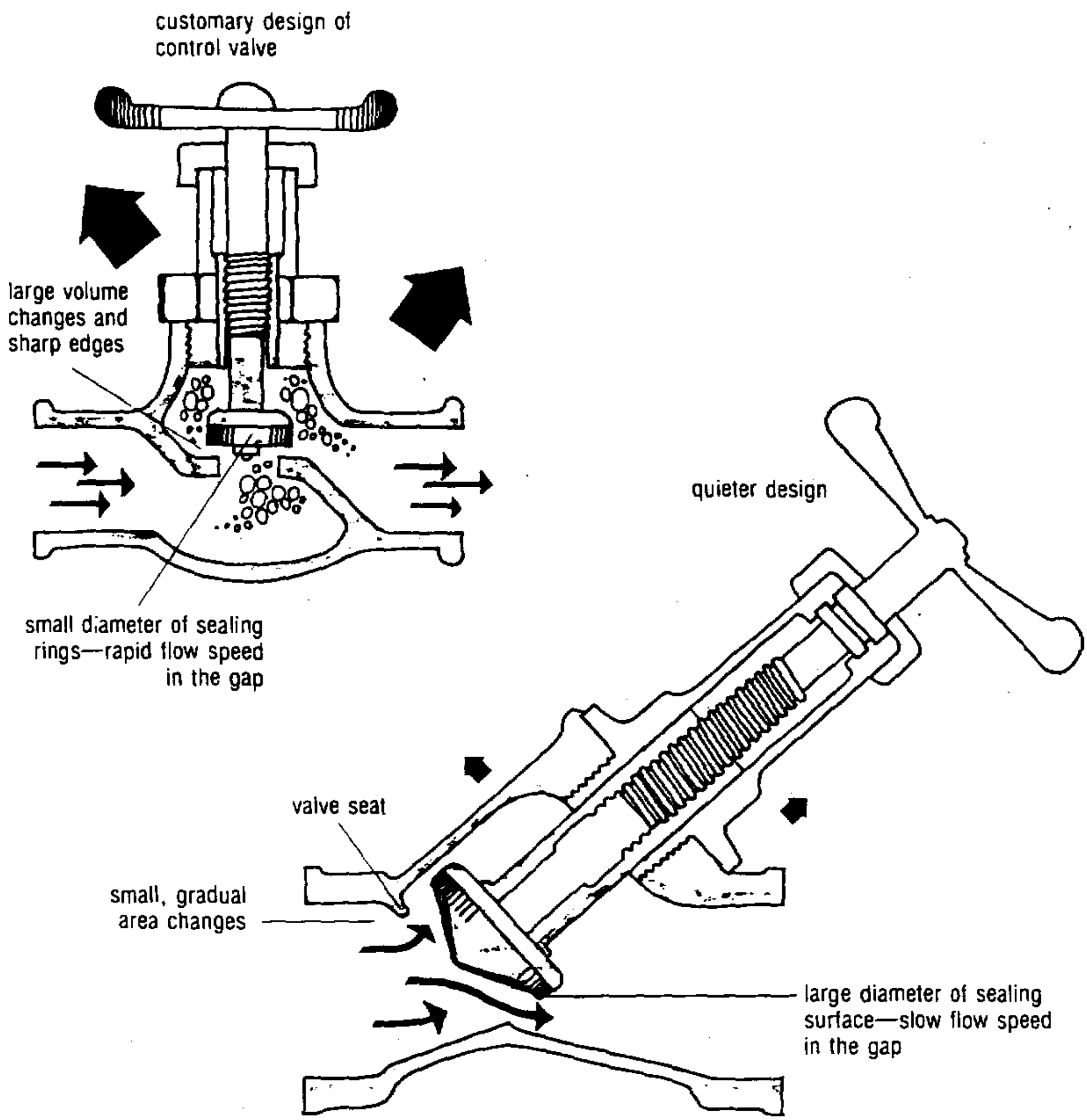
Exploded View of Portable Steam Blow Off Silencer for Geothermal Field Use

FIGURE A3.5-10



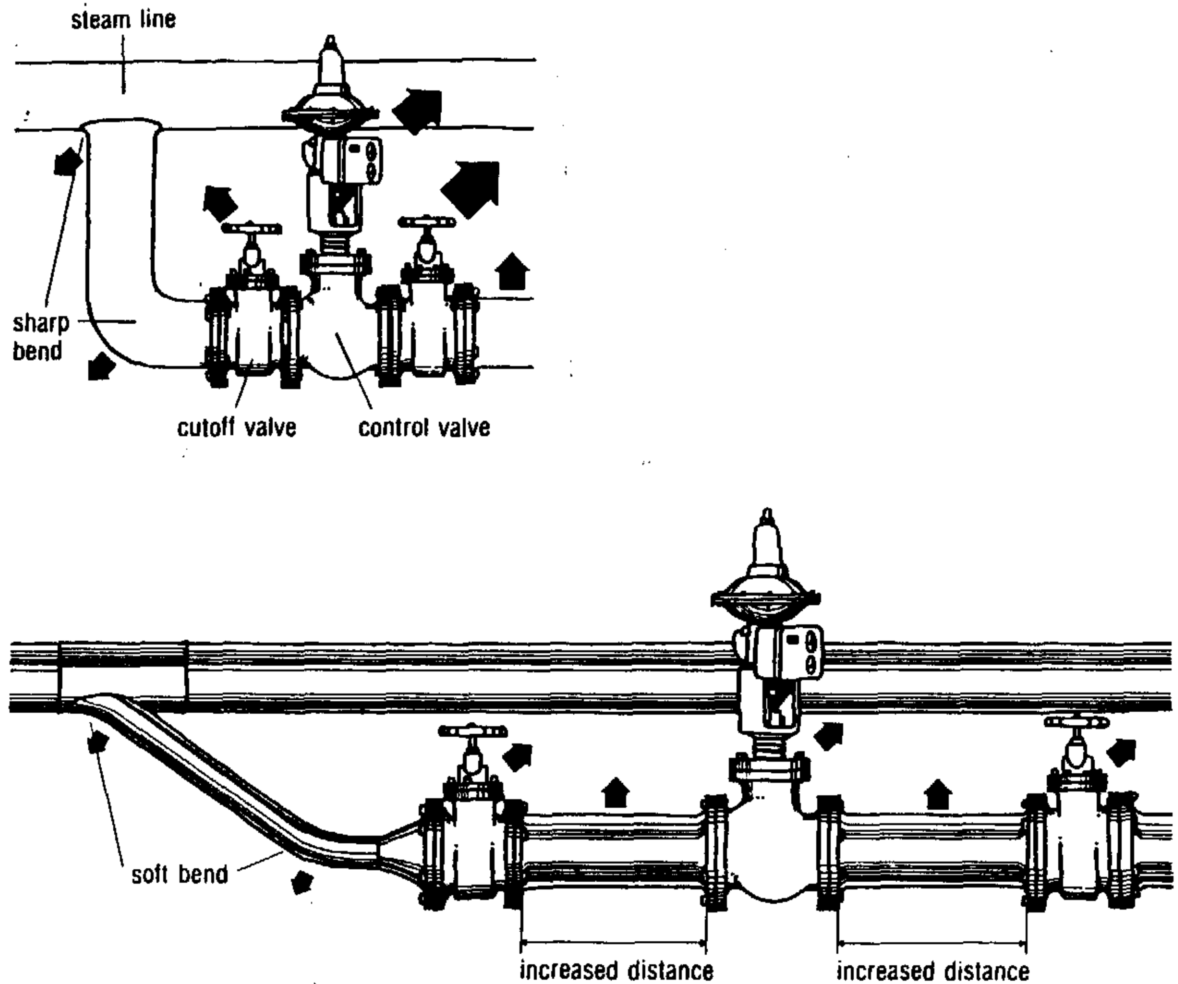
Method of Producing Pressure Drop in a Fluid Pipe System.

FIGURE A3.5-11



**Control Valves Contrasted for Noise Reduction Purposes.
(Upper Valve causes much Turbulence and Noise Radiation
Lower Valve is quieter because of Improved Flow Path)**

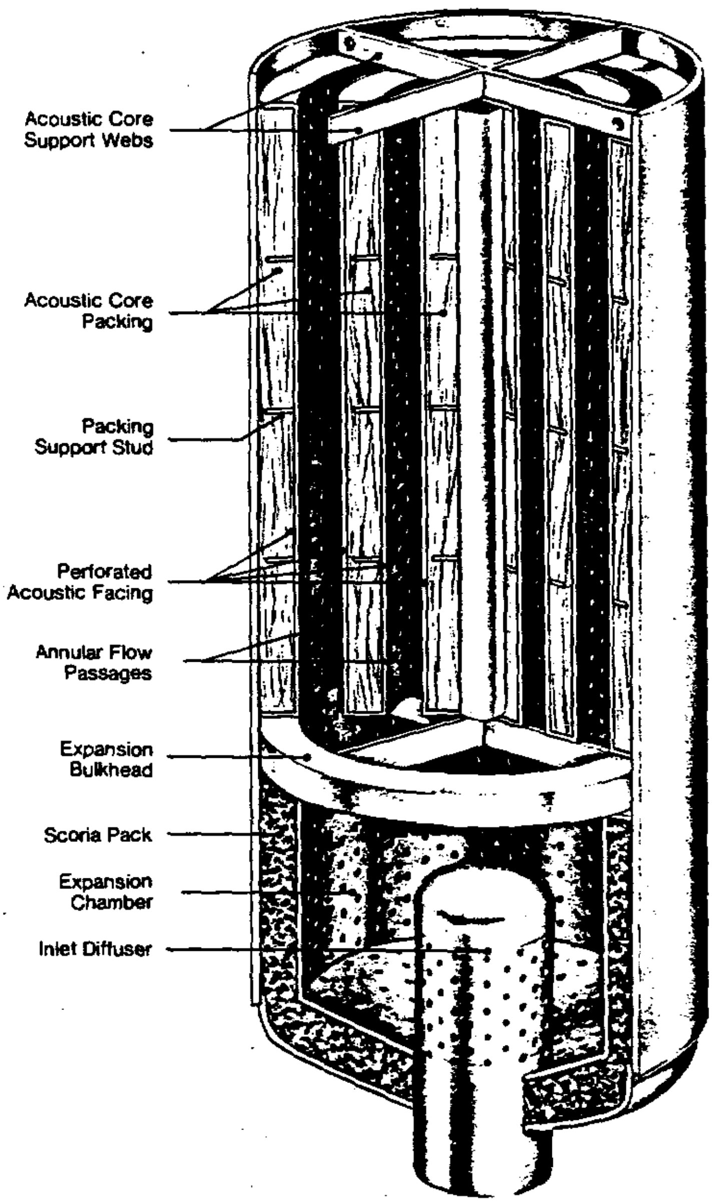
FIGURE A3.5-12



Steam Pipe Plumbing Alternative to Reduce Noise Generation and Radiation

(The Upper Configuration Emits The Greatest Amount Of Noise)

FIGURE A3.5-13



Diffuser-Built like a Pressure Vessel:

The inlet of a blow-off silencer receives the full impact of incoming flow. Strength at the inlet is important to prevent disintegration under the cyclic loading received in normal service. The diffuser, made from heavy perforated plate in larger models is constructed like a pressure vessel.

AcousticFacing-Heavy Gauge Sheet:

The acoustic facing is constructed of heavy gauge perforated sheet and serves to retain and provide acoustic access to the pack material so that noise can be absorbed. Hole size and spacing are selected to hold the pack in place and provide the required acoustic performance.

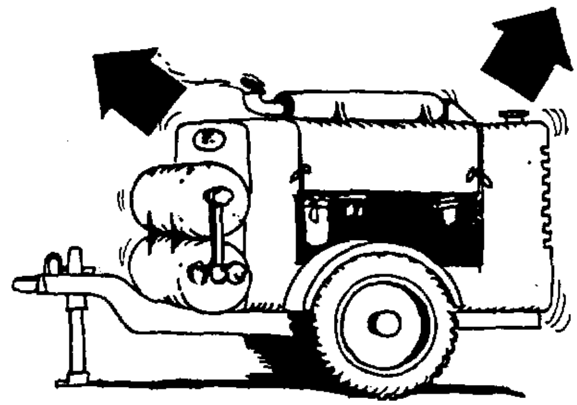
Acoustic Pack-Glass Fiber or Scoria:

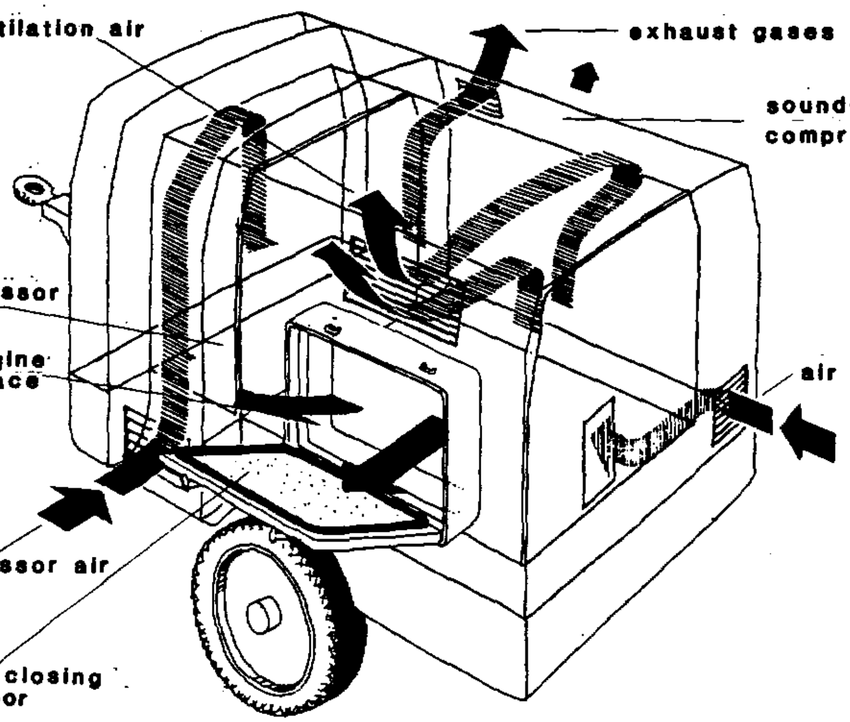
Long loomed glass fiber is used for operating temperatures up to 800 degrees F. This premium material is selected for its superior acoustic absorptivity and ability to withstand moderate grazing velocity without pulling through the acoustic facing.

For higher temperature or higher velocity application, scoria pack is used. Scoria is a porous, lightweight, rock-like material, unaffected by either temperature or high grazing velocity.

Typical Blow off Silencer for Use on Non-condensable Vent Stack.

FIGURE A3.5-14





SOUND CONTROLLED SYSTEM

Illustration of Unmitigated and Mitigated Portable Descaling Equipment Showing Differences

FIGURE A3.5-15

REFERENCES

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APPENDIX 3.6

BIOLOGY

Table A3.6-1

BIRDS OF THE SALTON SEA NATIONAL WILDLIFE REFUGE - REGULAR SIGHTINGS

Species	Season of Occurrence			
	Sp	Su	F	W
Common Loon	r	-	-	-
Horned Grebe	r	-	-	-
Western Grebe*	u	o	u	u
Pied-billed Grebe*	u	u	u	u
White Pelican*	-	o	o	-
Brown Pelican	-	o	o	-
Blue-footed Booby	-	r	r	-
Double-crested Cormorant*	u	u	u	u
Magnificent Frigatebird	-	o	-	-
Great Blue Heron*	c	c	c	c
Little Blue Heron	-	r	-	-
Green Heron*	u	u	u	u
Cattle Egret*	u	o	u	u
Common Egret*	c	u	u	c
Snowy Egret*	c	c	c	c
Louisiana Heron	r	-	-	r
Black-crowned Night Heron*	u	u	u	u
Least Bittern*	u	u	u	u
American Bittern	o	r	o	u
Wood Ibis	-	c	o	-
White-faced Ibis*	u	o	c	c
Roseate Spoonbill	-	r	r	-
Whistling Swan	-	-	-	r
Canada Goose	u	r	c	a
Black Brant	o	r	r	r
White-fronted Goose	u	r	u	u
Snow Geese	u	r	c	a
Blue Goose	-	-	-	o
Ross' Goose	-	-	-	u
Fulvous Tree Duck*	u	c	o	r
Mallard*	u	r	u	u
Gadwall	u	r	u	u

Key:

Sp = March - May
Su - June - August
F = September - November
W = December - February
* = Nests locally

a = abundant
c = common
u = uncommon
o = occasional
r = rare

Source: U.S. Fish and Wildlife Service, 1970.

Table A3.6-1 (Continued)

Species	Season of Occurrence			
	Sp	Su	F	W
Pintail*	a	o	a	a
Green-winged Teal	a	o	c	a
Blue-winged Teal	o	-	r	r
Cinnamon Teal*	c	u	c	u
European Widgeon	-	-	-	r
American Widgeon	c	r	a	a
Shoveler	c	o	c	a
Wood Duck	-	-	-	r
Redhead*	u	u	u	u
Ring-necked Duck	o	-	o	o
Canvasback	u	r	u	c
Greater Scaup	-	-	-	o
Lesser Scaup	c	o	c	c
Common Goldeneye	u	r	u	u
Bufflehead	u	r	u	u
Oldsquaw	-	-	r	r
White-winged Scoter	r	-	r	r
Surf Scoter	r	-	r	r
Ruddy Duck*	a	u	c	a
Hooded Merganser	-	-	-	r
Common Merganser	o	r	o	o
Red-breasted Merganser	u	r	o	r
Turkey Vulture	c	c	c	c
Sharp-shinned Hawk	c	c	c	c
Cooper's Hawk	o	-	o	u
Red-tailed Hawk	u	o	u	u
Swainson's Hawk	o	-	r	-
Ferruginous Hawk	-	-	r	r
Golden Eagle	-	-	r	r
Bald Eagle	-	-	r	r
Marsh Hawk	u	r	u	u
Osprey	r	r	r	r
Peregrine Falcon	r	r	r	r
Prairie Falcon	r	-	u	u
Pigeon Hawk, Merlin	r	-	o	o
American Kestrel	c	o	c	c
Gambel's Quail*	u	u	u	u
Ring-necked Pheasant*	u	u	u	u
Sandhill Crane	-	-	-	r
Clapper Rail*	r	r	r	r
Virginia Rail	u	o	u	u
Sora	u	o	u	u
Black Rail*	o	o	o	o

Table A3.6-1 (Continued)

Species	Season of Occurrence			
	Sp	Su	F	W
Common Gallinule*	u	u	u	u
American Coot*	a	c	a	a
Semipalmated Plover	c	-	u	o
Wilson's Plover*	-	r	-	-
Snowy Plover*	u	u	u	u
Killdeer	c	c	c	c
American Golden Plover	r	-	r	r
Black-bellied Plover	c	r	c	c
Mountain Plover	o	r	c	c
Ruddy Turnstone	r	-	r	-
Common Snipe	-	-	u	u
Long-billed Curlew	c	o	a	c
Whimbrel	a	o	c	c
Spotted Sandpiper	u	-	u	u
Solitary Sandpiper	r	-	o	-
Willet	a	o	a	c
Greater Yellowlegs	c	r	c	c
Lesser Yellowlegs	u	-	u	u
Knot	o	-	r	-
Pectoral Sandpiper	r	-	r	-
Baird's Sandpiper	r	-	o	-
Least Sandpiper	a	r	a	c
Durlin	c	r	c	c
Short-billed Dowitcher	u	-	o	o
Long-billed Dowitcher	a	r	a	a
Stilt Sandpiper	o	-	u	o
Semipalmated Sandpiper	r	-	-	-
Western Sandpiper	a	r	a	a
Marbled Godwit	c	o	c	c
Sanderling	o	-	o	-
American Avocet*	a	a	a	c
Black-necked Stilt*	a	a	o	r
Red Phalarope	r	-	r	-
Wilson's Phalarope	a	-	r	-
Northern Phalarope	c	-	a	r
Parasitic Jaeger	-	-	r	-
Mew Gull	-	r	-	r
Glaucus-winged Gull	r	-	r	r
Western Gull	r	o	r	r
Herring Gull	u	r	u	u
California Gull	c	o	c	u
Little Gull				
Ring-billed Gull	a	u	a	a

Table A3.6-1 (Continued)

Species	Season of Occurrence			
	Sp	Su	F	W
Laughing Gull*	r	u	o	-
Franklin's Gull	r	r	o	-
Bonaparte's Gull	u	r	u	o
Heerman's Gull	-	r	r	-
Gull-billed Tern*	r	u	-	-
Forester's Tern*	u	o	u	u
Common Tern	-	r	o	-
Caspian Tern*	c	u	c	o
Black Tern	a	c	a	-
Black Skimmer*	c	c	o	r
Rock Dove*	u	u	u	u
White-winged Dove*	o	u	-	-
Mourning Dove*	a	c	a	a
Ground Dove*	u	u	u	u
Yellow-billed Cuckoo	-	r	-	-
Roadrunner*	c	c	c	c
Barn Owl*	u	u	u	u
Screech Owl	r	r	r	r
Great Horned Owl*	o	o	o	o
Burrowing Owl*	c	c	c	c
Short-eared Owl	-	-	o	o
Long-eared Owl				
Poor-will	r	r	r	-
Lesser Nighthawk*	c	c	o	-
Vaux's Swift	u	-	u	-
White-throated Swift	o	-	o	u
Black-chinned Hummingbird	u	o	o	-
Costa's Hummingbird	o	o	-	-
Rufous Hummingbird	u	-	o	-
Calliope Hummingbird	o	-	-	-
Belted Kingfisher	u	-	u	u
Gila Woodpecker	r	r	r	r
Yellow-shafted Flicker	-	-	r	r
Red-shafted Flicker	c	-	c	c
Lewis' Woodpecker*	u	u	u	u
Western Kingbird*	a	c	-	-
Ash-throated Flycatcher*	u	o	u	-
Black Phoebe*	c	u	c	c
Say's Phoebe	c	-	c	c
Trail's Flycatcher	u	-	u	-
Hammond's Flycatcher	u	-	o	-
Dusky Flycatcher	o	-	o	-
Gray Flycatcher	o	-	o	r

Table A3.6-1 (Continued)

Species	Season of Occurrence			
	Sp	Su	F	W
Western Flycatcher	c	-	u	-
Western Wood Pewee	c	-	u	-
Olive-sided Flycatcher	u	-	o	-
Vermilion Flycatcher*	r	r	r	r
Horned Lark*	u	u	a	a
Violet-green Swallow	o	-	u	r
Tree Swallow	a	-	a	a
Bank Swallow	u	-	u	-
Rough-winged Swallow	c	u	c	r
Barn Swallow	c	-	a	r
Cliff Swallow	c	c	c	-
Purple Martin	o	-	-	-
Scrub Jay	-	-	r	r
Common Raven	o	o	o	o
Common Crow	-	-	r	r
Verdin*	c	c	c	c
Red-breasted Nuthatch	-	-	o	o
Brown Creeper	-	-	r	r
House Wren	u	-	u	u
Bewick's Wren	u	-	u	u
Cactus Wren*	u	u	u	u
Long-billed Marsh Wren*	c	c	c	c
Rock Wren	u	-	u	u
Mockingbird*	c	c	c	c
Crissal Thrasher*	u	u	u	u
LeConte's Thrasher*	r	r	r	r
Sage Thrasher	o	-	o	o
Robin	u	-	u	u
Varied Thrush				
Hermit Thrush	u	-	u	u
Swainson's Thrush	u	-	o	-
Western Bluebird	-	-	o	o
Mountain Bluebird	u	-	u	c
Townsend's Solitaire	-	-	r	r
Blue-gray Gnatcatcher	u	-	u	u
Black-tailed Gnatcatcher	r	r	r	r
Ruby-crowned Kinglet	c	-	c	c
Golden-crowned Kinglet*	-	-	-	r
Water Pipit	c	-	c	c
Cedar Waxwing	o	-	o	o
Phainopepla	o	-	o	o
Loggerhead Shrike*	c	c	c	c
Starling*	a	c	a	a

Table A3.6-1 (Continued)

Species	Season of Occurrence			
	Sp	Su	F	W
Bell's Vireo	o	-	-	r
Solitary Vireo	u	-	o	-
Warbling Vireo	c	-	u	-
Orange-crowned Warbler	a	-	a	a
Nashville Warbler	u	-	o	r
Virginia's Warbler	r	-	r	-
Lucy's Warbler	r	-	-	-
Yellow Warbler	c	-	u	r
Myrtle Warbler	o	-	o	o
Audubon's Warbler	a	-	a	a
Black-throated Grey Warbler	u	-	o	r
Townsend's Warbler	u	-	o	r
Hermit Warbler	u	-	o	r
Palm Warbler	-	-	-	r
MacGillivray's Warbler	u	-	o	-
Yellowthroat*	c	c	c	c
Yellow-breasted Chat*	u	u	-	-
Wilson's Warbler	c	-	c	r
American Redstart	r	-	o	o
House Sparrow*	c	c	c	c
Western Meadowlark*	c	c	c	c
Yellow-headed Blackbird*	a	a	u	c
Red-winged Blackbird*	a	a	a	a
Hooded Oriole	o	o	-	-
Bullock's Oriole*	c	c	-	-
Brewer's Blackbird	c	-	c	c
Great-tailed Grackle*	u	u	u	u
Brown-headed Cowbird*	c	u	c	c
Western Tanager	c	-	u	-
Summer Tanager	r	-	-	r
Black-headed Grosbeak	u	-	o	-
Blue Grosbeak*	u	u	-	-
Lazuli Bunting	u	-	o	-
House Finch*	c	c	c	c
Purple Finch	-	-	-	r
Pine Siskin	-	-	o	r
American Goldfinch	u	-	u	u
Lesser Goldfinch	u	-	u	u
Lawrence's Goldfinch	o	-	r	r
Green-tailed Towhee	o	-	o	o
Rufous-sided Towhee	o	-	o	o
Albert's Towhee*	u	u	u	u
Lark Bunting	-	-	r	r

Table A3.6-1 (Continued)

Species	Season of Occurrence			
	Sp	Su	F	W
Savannah Sparrow	c	o	c	a
Grasshopper Sparrow	-	-	r	-
Vesper Sparrow	u	-	u	u
Lark Sparrow	u	-	u	u
Sage Sparrow	-	-	o	o
Slate-colored Junco	-	-	r	r
Oregon Junco	u	-	u	u
Grey-headed Junco	-	-	r	r
Chipping Sparrow	u	-	u	u
Brewer's Sparrow	o	-	u	u
White-crowned Sparrow	c	-	a	a
Golden-crowned Sparrow	r	-	o	o
White-throated Sparrow	-	-	r	r
Fox Sparrow	r	-	o	o
Lincoln's Sparrow	u	-	c	c
Swamp Sparrow	r	-	o	o
Song Sparrow*	c	u	c	c
McCown's Longspur	-	-	o	o
Lapland Longspur	-	-	o	o
Chestnut-collared Longspur	-	-	r	r
Black-throated Sparrow	-	-	r	-
Black-chinned Sparrow	-	-	r	-

Table A3.6-2

IRREGULAR BIRDS OF THE SALTON SEA NATIONAL WILDLIFE REFUGE

These additional 44 species are of casual or accidental occurrence, in most instances substantiated by only one or two records. Most are well outside their normal range or habitat, but two, indicated with an *, formerly nested in the area, and now appear to be gone.

Arctic Loon
Brown Booby
New Zealand Shearwater
Sooty Shearwater
Leach's Storm-Petrel
Least Storm-Petrel
Reddish Egret
Black-bellied Tree Duck*
Black Duck
Baikal Teal
Barrow's Goldeneye
Black Scoter
Broad-winged Hawk
Rough-legged Hawk
Harris' Hawk*
American Oystercatcher
Wandering Tattler
Red-necked Stint
White-rumped Sandpiper
Ruff
Glaucous Gull
Black-legged Kittiwake
Sabine's Gull

Arctic Tern
Red-headed Woodpecker
Brown Thrasher
Northern Shrike
Least Tern
Band-tailed Pigeon
Flammulated Owl
Saw-whet Owl
Whip-Poor-Will
Black Swift
Gilded Flicker
Acorn Woodpecker
Nuttall's Woodpecker
Eastern Kingbird
Cassin's Kingbird
Tropical Kingbird
Eastern Phoebe
Coues' Flycatcher
Mountain Chickadee
White-breasted Nuthatch
Winter Wren
Bendire's Thrasher
Curve-billed Thrasher

Varied Thrush
Black-and-white Warbler
Tennessee Warbler
Parula Warbler
Black-throated Blue Warbler
Cerulean Warbler
Chestnut-sided Warbler
Blackpoll Warbler
Prairie Warbler
Ovenbird
Northern Waterthrush
Bobolink
Orchard Oriole
Scott's Oriole
Baltimore Oriole
Bronzed Cowbird
Dickcissel
Red Crossbill
Tree Sparrow
Harris' Sparrow
Red-eyed Vireo
Phyrrhuloxia
Rose-breasted Grosbeak

INDIVIDUAL EFFECTS OF VARIOUS COMPONENTS OF GEOTHERMAL BRINE

Salinity: The average salinity of brine from this resource area is 225,000 parts per million (SDG&E, 1980). This level of salinity would be highly toxic to both freshwater and saltwater organisms. The toxic reaction in fish would be due to the excessive withdrawal of water from the bloodstream, resulting in arrest of the circulatory system. This would occur most rapidly in freshwater fishes, but would be quite fast in marine fish as well. The localized effect of a hypersaline brine spill would dissipate with distance from the site, creating a zonal effect with decreasing toxicity as distance from the spill increases.

Temperature: The typical well-head temperature of a well in this KGRA would average 500°F (260°C) (Developer Concensus, 1981). The toxic effects of excess heat in aquatic systems is well-documented (Vernberg et al., 1977; Jones, 1964; Warren, 1971). The effects of elevated temperature on poikilothermic (cold-blooded) animals is profound. The metabolic rate in these animals is totally dependent upon external temperatures and increases quickly as water temperature increases. Rapid immersion in hot water causes degeneration of proteins and heat death follows quickly (Jones, 1964).

The high temperatures generated by a geothermal spill would create zonal effects similar to that shown for salinity, with localized high mortality and a decreasing effect as the heat dissipates into the water or atmosphere.

An added effect of high temperature would be the resulting condition of low oxygen levels or even anoxic conditions. The synergistic effects of salinity, temperature and low oxygen levels would create substantial impacts on the aquatic system. Most of the impacts from a spill would be for the duration of the spill and a short period afterwards, the possible exceptions being the potential of heavy metal bioaccumulation.

Carbon Dioxide: Extremely high levels of CO_2 would be released in a brine spill (1400 to 9800 pm; Table 2.4-3). Much of the gas would be vented and released to the atmosphere; but levels remaining in solution could cause respiratory distress and possible failure in fish and invertebrates. Levels as low as 5-10 ppm can cause death in fishes. (Jones, 1964). It is unknown how much CO_2 would remain in the spilled brine, but it would probably be sufficient to cause problems.

Ammonia: Ammonia is a major component of the toxic products in geothermal brine. Levels should average between 280 and 450 ppm in wells in this resource area (Table 2.4-3). These levels would be immediately toxic to fishes and invertebrates in the area of the spill. There would be a reduction in toxicity as the NH_3 is released as a gas into the atomosphere or picked up chemically in the aquatic system. If the NH_3 could be immediately converted to NH_4Cl (ammonium chloride) the toxicity would be reduced significantly (Jones, 1964). The high levels of discharged NH_3 would still have a significant negative impact on the aquatic system, even though the impact would be fairly short.

Hydrogen Sulfide: The average level of hydrogen sulfide (H_2S) in the brine of this resource area would be from 7.4 to 22.3 ppm (Table 2.4-3). Hydrogen sulfide acts as a respiratory depressant and is extremely toxic to fish at levels below 2 ppm (Jones, 1964). As for all of the other chemical components, H_2S would have a decreasing effect away from the spill site, evolving off as a gas or being diluted. The impact of this chemical would be significant but short-lived.

Lead, Zinc, and Copper: The expected brine levels for these metals would be: Lead (16-91 ppm), Zinc (102-500 pm), Copper (1.4-3.0 ppm). This data is from Table 2.4-3. Lead and zinc are both highly toxic, particularly at the expected concentrations. The metal ions react with the mucus film on the fish and it suffocates (Jones, 1964). Copper is also toxic, but expected values are not of particular significance. The high levels of calcium in the brine could counteract the acute toxicity of these heavy metals (Jones, 1964). Long term effects of added metals to the aquatic system could include effects on algal production and sublethal effects caused by the bioaccumulation of these metals, particularly lead into food chains. It would be necessary to sample fish and invertebrates to determine if a spill has created heavy metal levels in excess of FDA guidelines.

Arsenic: Arsenic, though known as a toxin to most forms of life, does not appear to be especially toxic to fish. The expected levels in the wells of resource area are 2.2 to 7.4 ppm (Table 2.4-3). These levels appear to be within tolerable limits according to Jones (1964). No significant impact is expected to result from arsenical compounds compared to effects already demonstrated for other components of the brine.

Synergistic effects: A brine spill of large magnitude could create substantial negative impacts on the aquatic system, whether fresh or salt water. The major synergist would be the elevated temperatures found within the area of the spill. This will tend to accelerate and intensify the toxic effects of the other chemicals as already noted. The major impact will be upon sessile or sedentray organisms, though fishes trapped within the spill zone would also be affected.

The effects of the brine spill will diminish with distance and time from the site of the spill. Each individual component will carry its own toxicity/distance relationship, and the synergistic relationships will very likely be significantly wider than the individual impacts.

Long term effects: The long term effects at the present are hard to identify. Bioaccumulation of heavy metals could pose significant problems to the aquatic food system and to humans as consumers. The fate of geothermal brine components in the environment needs to be established.

SENSITIVE AVIAN SPECIES

Common Loon: This species is on the California Department of Fish and Game's list of Species of Special Concern and the Audubon Blue List, based on a decline in nesting success. The Common Loon is a rare, spring migrant at the Salton Sea.

American White Pelican: This species is given highest priority on the California Department of Fish and Game's special concern list as well as the Audubon Blue List. The decline of this species is attributable to loss of breeding habitat and has been extirpated as a breeding species in southern California. White Pelicans formerly bred at the Salton Sea and are now primarily spring and fall migrants, with small numbers wintering and over-summering. Concentrations of White Pelicans can be found at the mouth of the New River, around Red Hill and at the Wister Unit.

Double-crested Cormorant: Both the Audubon Blue List and the California Department of Fish and Game's special concern list include this species because of a decline in breeding success attributable primarily to a loss of habitat. Double-crested Cormorants breed at the Salton Sea, nesting in dead trees along the shoreline of the sea, with particular concentrations found at the mouth of the New River, near Red Hill and at the Wister Unit.

White-faced Ibis: This species is on the California Department of Fish and Game's special concern list and on the marginal Audubon Blue List. Loss of nesting habitat accounts for the decline of this species which formerly bred commonly at the Salton Sea. In recent years there have been few nesting efforts. This is a marsh species, most often found at the mouth of the New River, near Red Hill and on the Wister Unit.

Great Blue Heron: This species is a common year-round resident at the Salton Sea and also breeds there. The species is on the Audubon Blue List, primarily based on its status in other parts of the country. Loss of habitat is the reason for this species' decline.

Black-crowned Night-heron: This species is also on the Audubon list and is an uncommon resident at the Salton Sea. Both roosts and nesting of this species are somewhat concentrated. Marshes are the preferred habitat.

Least Bittern: This species is on both Audubon's and the California Department of Fish and Game's special concern list and has declined because of loss of habitat. This is another marsh species which can be found year-round in the area, particularly along the New and Alamo Rivers.

American Bittern: Loss of habitat and pesticides account for the inclusion of this species on the Audubon Blue List. Though recorded year-round, this species is primarily a winter visitor to the Salton Sea. It is found in marsh habitat.

Fulvous Whistling Duck: This species has exhibited a serious decline in its population in California and is on the California Department of Fish and Game's special concern list. Fulvous Whistling Duck, which formerly was found along the southern California coast, in the San Joaquin Valley and at the south end of San Francisco Bay, is now found only in the Imperial Valley. Populations at the Salton Sea vary from year to year with marshes being the requisite habitat.

Canvasback: This species is on the Audubon list and is a regular winter visitor to the Salton Sea. Concentrations of Canvasback can be found particularly near the mouth of the Alamo and New Rivers and at the Wister Unit.

Wood Stork: This species, which is on the Audubon list, summers at the Salton Sea with concentrations found at the New River, the vicinity of Red Hill and at Wister.

Turkey Vulture: This species is on the Audubon list, primarily on the basis of its status elsewhere in the country. This species is recorded year-round at the Salton Sea.

Cooper's Hawk: This species is present in small numbers for most months of the year, primarily in areas with trees, i.e., along rivers and in residential areas. The species is on both the Audubon list and the California Department of Fish and Game's special concern list.

Sharp-shinned Hawk: Declining in other parts of the country, this species appears to be relatively stable in California and is primarily a fall and witer visitor to the Salton Sea. The species is on the Audubon list.

Swainson's Hawk: This species migrates in small numbers through the area. Development is not likely to affect this species. The species is on the Audubon list as well as the California Department of Fish and Game's special concern list.

Ferruginous Hawk: Loss of nesting habitat is one of the major reasons for the decline of this species which is a rare fall winter visitor to the area and is not likely to be affected by proposed development. The species is on the Audubon list.

Golden Eagle: The Golden Eagle is an exceedingly rare visitor in fall and winter to the area. It is on the Audubon list as well as the California Department of Fish and Game's special concern list.

Northern Harrier: This species forages over marsh and grassland and is not known to nest in the Imperial Valley. It is on the Audubon list as well as the California Department of Fish and Game's special concern list.

Osprey: This species is a fish-eater and can be found along the shoreline of the Salton Sea during all months of the year. The species is on both the Audubon list and the California Department of Fish and Game's special concern list.

Prairie Falcon: This species is recorded as a migrant and winter visitor in small numbers. Its decline appears to be due primarily to pesticides. It is on the Audubon list and is on the California Department of Fish and Game's special concern list.

Merlin: This species is a particularly rare migrant and winter visitor. It is on the Audubon list.

American Kestrel: This species, on the Audubon list, is common most of the year.

Sandhill Crane: This species, on the California Department of Fish and Game's special concern list, is a rare winter visitor to the area, though a small population winters south of Brawley.

Snowy Plover: This is a beach-nesting species which has declined significantly in California. It is found primarily along open mudflats and barnacle beaches on the Salton Sea's shoreline, with particular concentrations found between Red Hill and the Wister Unit. It is on the Audubon list as well as the California Department of Fish and Game's special concern list.

Common Tern: This species is primarily a summer and fall non-breeding visitor to the Salton Sea. Loss of nesting habitat has been the major reason for the decline of this species. It is on the Audubon list.

Gull-billed Tern: This is the only area in California where this species has been known to nest. Rising water levels have inundated many of the nesting areas. Should nesting areas potentially be affected by development plans, creation of aditional nesting habitat (islands?) should be required.

Black Tern: A large, non-breeding population of this species is present here from spring through fall. Numbers vary somewhat from year to year, with 1980 showing lower than usual numbers. Loss of nesting habitat in northern California may render this species greater significance in the future. It is on the Audubon list.

Black Skimmer: This species was first recorded in California in 1968 and has since established nesting colonies at the Salton Sea and in San Diego County. Rising water levels threaten the continued nesting of this species at the Salton Sea as does disturbance of nesting habitat (shell beaches and islands). It is on the California Department of Fish and Game's special concern list.

Yellow-billed Cuckoo: This species is a rare summer visitor and is on the Audubon list as well as the California Department of Fish and Game's special concern list.

Burrowing Owl: This species has taken up residence in the banks and in the canals in agricultural areas. Loss of habitat has contributed significantly to the decline of this species. It is on the Audubon list as well as the California Department of Fish and Game's special concern list.

Short-eared Owl: This is a marsh species which winters in small numbers in the area, particularly in the Wister Unit. The species is on the Audubon list and the California Department of Fish and Game's special concern list.

Gila Woodpecker: This species has nested in the Imperial Valley in wooded areas. It is on the California Department of Fish and Game's special concern list.

Vermilion Flycatcher: Loss of riparian habitat has led to the decline of this species in the Imperial Valley. It is on the California Department of Fish and Game's special concern list.

Willow Flycatcher: This species is a rare migrant in the area. It is on the Audubon list as well as the California Department of Fish and Game's special concern list.

Bank Swallow: The Bank Swallow suffers from disturbance on its nesting ground and is an uncommon migrant at the Salton Sea. It is on the California Department of Fish and Game's special concern list.

Purple Martin: This species is an occasional migrant in the area. It is on the Audubon list as well as the California Department of Fish and Game's special concern list.

Bewick's Wren: This species appears to be stable in California though declining in other parts of the country. It is on the Audubon list.

Western Bluebird: Small numbers of this species winter sporadically in this area. It is on the Audubon list.

Black-tailed Gnatcatcher: There are two distinct races of this species in California, both of which are declining because of habitat loss. One of the races is found in mesquite-creosote scrub in the Imperial Valley. It is on the Audubon list and the California Department of fish and Games special concern list.

Ruby-crowned Kinglet: This species appears to be stable in California. It is on the Audubon list.

Bell's Vireo: This species is considered endangered. It is a rare migrant and winter visitor in this area.

Warbling Vireo: This species is declining rapidly throughout the country. It is on the Audubon list.

Virginia's Warbler: The concern for this species is its nesting habitat, and development here will have no effect on this rare migrant. It is on the California Department of Fish and Game's special concern list.

Yellow Warbler: The decline of this species is attributable to loss of nesting habitat and cowbird parasitism and proposed geothermal development. It is on the Audubon list and the California Department of Fish and Game's special concern list.

Common Yellowthroat: This is a marsh species which is apparently declining because of loss of habitat. The species is on both the Audubon list and the California Department of Fish and Game's special concern list. It is common in appropriate habitat around the Salton Sea.

Yellow-breasted Chat: This is a riparian nester which also has suffered from loss of habitat. It is an uncommon breeding species at the Salton Sea and is on the Audubon list.

Summer Tanager: Loss of nesting habitat accounts for the decline of this riparian species. It is a rare migrant to the area and is on the California Department of Fish and Game list of special concern.

Gray-headed Junco: This species is a rare winter visitor to the Imperial Valley and is on the California Department of Fish and Game's list of special concern.

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APPENDIX 3.7

CULTURAL RESOURCE OVERVIEW OF THE SALTON SEA ANOMALY AREA

CULTURAL RESOURCE OVERVIEW OF

THE SALTON SEA ANOMALY AREA

IMPERIAL COUNTY, CALIFORNIA

Prepared For:

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January 1981

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

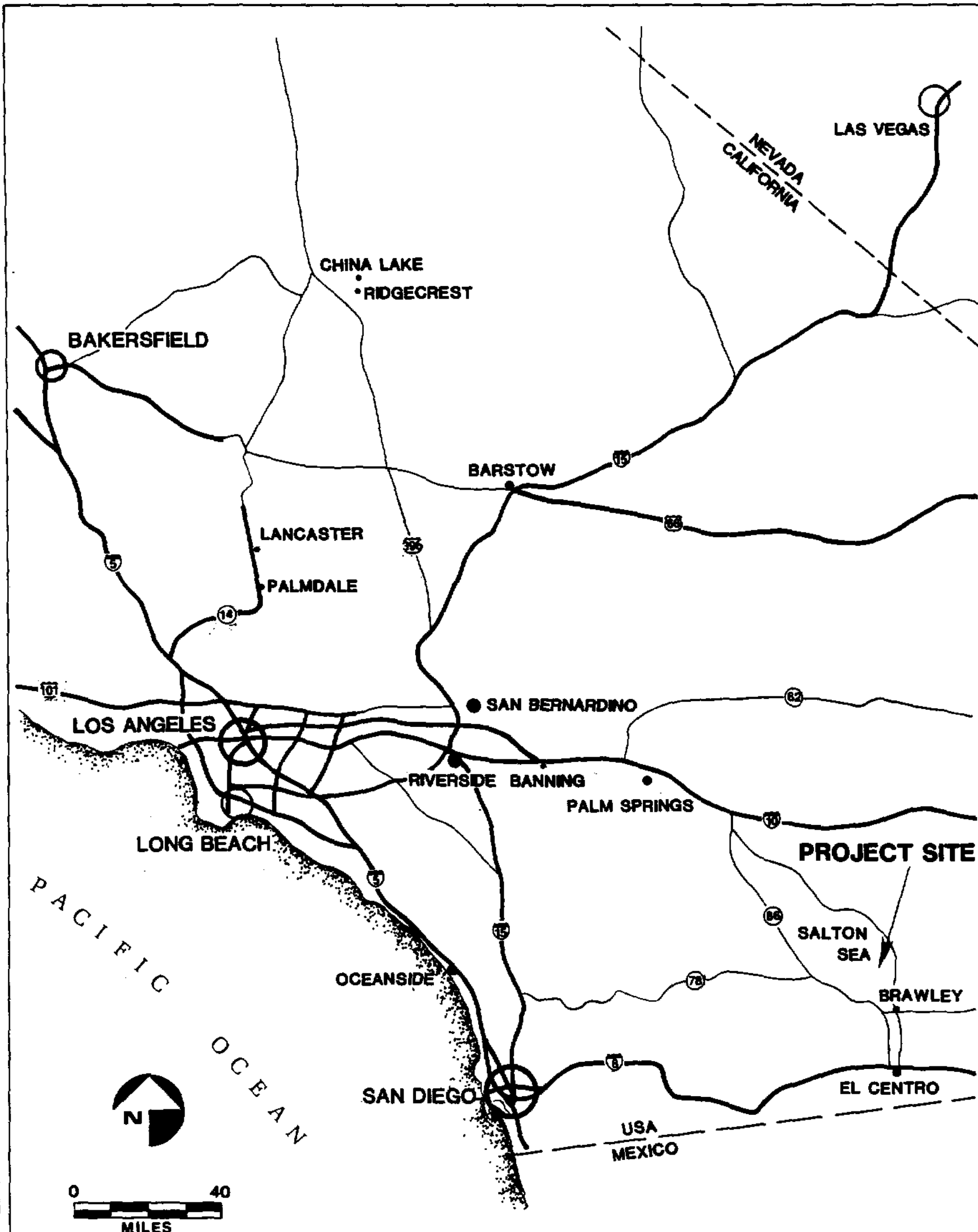
SECTION I

INTRODUCTION

The objective of this cultural resource overview is to provide the sponsoring agency (Imperial County) a regional archaeological/historical data base wherein sensitive areas have been clearly defined. Proposed geothermal development on and near sensitive cultural resource areas could conceivably result in irreversible impact to archaeological or historic sites. Information for this study was obtained from extant literature, personal communications, and consultations with institutions containing relevant data. Much of the background data provided in this report was extracted from the Bureau of Land Management sponsored Class II study of the East and West Mesa regions conducted by WESTEC Services, Inc. (Gallegos 1980).

The study region encompasses approximately 106,000 acres in the southeastern area of the Salton Sea. Roughly 54 percent of the project area lies within the Salton Sea (Figure 1). The cultural resource overview incorporates available site(s) data within the delineated Salton Sea Anomaly area and including a one-mile buffer zone immediately surrounding the project (Figure 2).

In past times, the study area was covered by a large intermittent body of water. The lake(s) which covered this area were entitled Lake LeConte, Lake Cahuilla, Blake Sea and Lake Brawley. For simplicity, the lakes at the approximately 40-foot above mean sea level (AMSL) elevation and earlier stands above 40 feet AMSL will be referred to as Lake Cahuilla. Lake Cahuilla created a rich environment for fish, shellfish, birds, mammals and man during the past 2000 years, as evidenced in the archaeological record and from coprolite remains studied by Wilke (1978).



Project Area in Relationship to Southern California

FIGURE 1

Figure 2

Project Area and Recorded Cultural Resources

(This figure is on file with Imperial County.)

1.1 GEOLOGY/GEOMORPHOLOGY

The region encompassing the current project area has been described by numerous investigators, beginning with William P. Blake's Report of a geologic reconnaissance in California (1858). Subsequent studies (D. T. MacDougal 1914; J. S. Brown 1920, 1923; U.S. Department of the Interior 1971; Morton 1977) have expanded the data base with regard to water resources, floral and faunal characteristics, geothermal fluids, soils and minerals. Thorough and concise discussions of geologic data pertinent to understanding prehistoric culture patterns for this region have been presented by Dr. D. L. Weide (1976) and Dr. Philip J. Wilke (1978).

Imperial County can be generally divided into three geomorphic provinces: the Peninsular Range, the Salton Trough, and the Mojave Desert (Morton 1977:13). Of specific interest to this report is the Salton Trough province, variously described as Salton Sink (MacDougal 1914), Cahuilla Basin, or Salton Basin (Wilke 1978). Basically a northwestern landward continuation of the Gulf of California rift, this structural trough was formed by gradual settling in association with uplift of the surrounding mountains during the Miocene, Pliocene, and Pleistocene epochs (Hamilton 1961; Morton 1977).

The Salton Trough province extends eastward from its western boundary adjacent to the Peninsular Range to the edges of the Chocolate and Cargo Muchacho Mountains. The region encompasses the structural trough of the Imperial and Coachella Valleys and the Salton Sea. This broad basin has a total area of approximately 8000 square miles, of which some 2000 square miles lie below sea level (MacDougal 1914:17).

A conspicuous ancient shoreline nearly surrounds the Salton Trough. The shoreline has a major break at the southeast end which is roughly 14 miles wide. This breach has been the entrance point for immense amounts of Colorado River water and for upstream sedimentary materials that are occasionally diverted from their historically normal channel (flowing south) into the Gulf of California. The diversion of these waters has been brought about by extreme build-up of deltaic sediments presenting an alluvial barrier between Colorado River waters and the Gulf of California (Blake 1858; MacDougal 1914; Brown 1920; Morton 1977). This phenomenon is documented to have occurred in major proportion (e.g., Lake Cahuilla) at least once in late prehistoric times (Blake 1858; D. Weide 1976; Morton 1977), but researchers have not as yet thoroughly determined the chronology or total number of prehistoric lakestands -- particularly for the culturally sensitive Late Pleistocene period (MacDougal 1914:25-29).

In addition to major lakestands brought about by ingressing water from the Colorado River, numerous temporary (or ephemeral) stands have come alive only to evaporate after a short span due to the shifting of the Colorado River. Based on the research of H. T. Cory, Chief Engineer for Imperial Valley canals, it is suggested that some floodwater found its way toward the Salton Trough province every year between the inundation of 1891 (Cory 1915; MacDougal 1914:19) and the flooding of 1905-1907, which inundated some 350,000 acres to a maximum depth of 83 feet (Morton 1977).

An unexposed succession of Tertiary and Quaternary sedimentary rocks with basement depths ranging from 15,400 to 11,000 feet at the east and west margins to over 20,000 feet in the central portions of the Imperial Valley (Morton 1977) lies below the alluvial and lake bottom sediment.

On the surface, the Salton Trough province exhibits at least three geomorphic areas: ancient lakebed sediments, alluvial channels and dune sands. The central portion (Imperial and Coachella Valleys, Salton Sink) is covered by clay and silt deposits from prehistoric lakestands. Shoreline deposits circumscribe the central lakebed deposits and consist predominantly of unconsolidated sand and gravel, grading into the previously mentioned silts and clays. Lake Cahuilla beds are generally believed to be less than

100 feet thick (Morton 1977:19), and may have received their heaviest rate of deposition during the Wisconsin or early postglacial age (Hubbs and Miller 1948). Dissected flat-lying alluvium is present on both mesa-like areas east and west of the central portion previously described. Consisting of poorly consolidated silts, sands and gravels, these newer alluviums typically form thin veneers of desert pavement (plains and terraces) between dry washes. An extensive, thick accumulation of dune sand comprising the Sand Hills occupies a northwest-trending area over the previously described alluvial surface in the East Mesa region. These dunes cover an approximate 160 square mile area and attain a thickness of at least 200 feet in their central parts (Morton 1977:22). Additionally, dune sands of Holocene age are common in Imperial Valley ranging from thin veneers to broad dunes at least 20 feet thick.

1.2 WATER RESOURCES

The importance of water to all living organisms throughout the world is most evident in those regions typically known as arid lands or deserts. In the Salton Trough province, water resources come from rainfall, the Colorado River and springs. The controlling factor for water is topography, and the presence or absence of water for any portion of the Salton Trough province is inexorably tied to the total geomorphic framework for the region. The intricacies of this relationship, thoroughly discussed by Brown (1920), MacDougal (1914), Morton (1977), and Wilke (1978), are briefly noted below.

Rainfall in the Salton Trough province is scant and varies widely from place to place. Along the western boundary, moisture-bearing coastal winds sweeping inland release most of their water as rain or snow on the higher summits of the Peninsular Mountains. The majority of this discharge occurs along the western slopes, as opposed to the eastern, primarily due to physical topography and prevailing winds. Resultant drainage patterns mimic the meteorological ones; most of these waters drain westward to the Pacific. Considerable amounts of water enter the northwest sector of the Salton Trough province by Whitewater River, San Gorgonio River, and Mission and Morongo Creeks from areas in San Gorgonio Pass and the San Bernardino Mountains (outside the Salton Trough proper). Rainfall for the remainder of the Salton Trough province area is meager at best.

The influence of Lake Cahuilla full to the 40 foot above mean sea level would have extended groundwater landward from the shoreline at up to several feet above this elevation, particularly in the sandy streambeds. Such would have been the case in Pinto Wash (Winter 1976). Groundwater was probably available within the access limits of mesquite roots for more than one mile from the shoreline (Went 1955). A backup of groundwater migrating down gradients within the alluvium of Pinto Wash would have extended this availability even further away from the lake shore. A very rapid demise of phreatophytic species (e.g. mesquite) would follow the even more rapid desiccation of the lake waters. The coarse alluvium of the wash would quickly drain off shallow groundwater following a lowering of the lake level and root growth would probably not be able to keep pace. The arid environment and inaccessible groundwater would prevent phreatophyte seedling establishment.

Meteorological records employed by Brown (1920:64) indicate an annual average rainfall of less than five inches and less than three inches in most places. The recently computed average annual rainfall for the Imperial Valley is 2.81 inches (Imperial Irrigation District 1977).

For the period from 1902 to 1906, the Colorado River and its tributaries at Yuma averaged an annual discharge of some 16,730,000 acre-feet, as shown by records of the United States Reclamation Service (Hely 1969). This disclosure represents the single most important water source for the entire Salton Trough province. Colorado

River water is currently diverted for the irrigation of Imperial and Coachella Valleys and has always supplied seepage to broad areas along its course, maintaining bodies of groundwater pumped for domestic uses in the Palo Verde and Yuma Valleys.

Climatic conditions throughout the Salton Trough are generally temperate during the winter months, unusually dry with regard to rainfall and humidity, and extremely warm throughout the summer.

1.3 PRESENT VEGETATION

The flora of southern California is generally characterized by many large plant genera such as *Eriogonum*, *Lupinus*, *Astragalus*, *Penstemon*, *Trifolium*, *Cryptantha*, *Phacelia*, *Mimulus*, *Lotus*, and *Gilia* (Munz 1974). Within the Salton Basin, the extreme variance of altitude (200 feet below to 10,000 feet AMSL) and annual precipitation (1 to 50 inches) have resulted in a diverse body of vegetation. These genera and species have been modified by hybridization and adaptation as climatic changes occurred throughout the area's long history. Interestingly, many of these are generally found in the Imperial Valley portion of the Colorado Desert, though not all species are represented within the study area.

Little paleobotanical literature relating specifically to this area is available. The most informative publication is that of Wilke (1978), which deals with prehistoric populations occupying areas around the northwestern shore of Lake Cahuilla.

During times when Lake Cahuilla was filled, there was probably a cooler, more humid environment with less fluctuation of temperatures between day and night. Assuming a full lakestand, there would have been a freshwater marsh biome at the lake's edge with Alkali Sink Scrub and Creosote Bush Scrub communities probably existing at greater distances from the shore (Hubbs 1959).

The Freshwater Marsh community is characterized by plants such as Typha latifolia, Typha angustifolia, Typha domingensis, Scirpus olneyi, Scirpus validus, Scirpus acutus, Eleocharis palustris, Carex senta, Carex obnupta, and Phagmites communis.

An Alkali Sink Scrub community usually has individuals of the following species: Atriplex polycarpa, A. lentiformis, A. breweri, A. spinifera, A. parryi; Sarcobatus vermiculatus, Allenrolfea occidentalis, Suaeda torreyana var. ramosissima, Salicornia virginica and Frankenia grandiflora var. campestris.

Characteristic members of the Creosote Bush Scrub Community are Ambrosia dumosa, Larrea tridentata, Fouquieria splendens, Dalea californica, Dalea schottii, Dalea spinosa, Encelia farinosa, Lycium brevipes, Lycium andersonii, Hymenoclea salsola, Encelia fructescens, Sphaeralcea ambigua, Baccharis sergiloides, Echinocereus engelmanii, Opuntia bigelovii, Opuntia echninocarpa, Opuntia basilaris, with Prosopis glandulosa var. torreyana, Olneya tesota, Pluchea sericea and Chilopsis linearis along the watercourses (Munz and Keck 1968). These plant communities do not exist as separate entities; elements of two or more plant communities can and quite often are mixed on any given tract of land.

A major portion of the study area is in proximity to modern farming areas and homes. In these areas there are many introduced species (i.e., ornamentals, fieldcrop plants and various "weeds") which flourish along roadsides due to water run-off and near canals where underground seepage affords extra moisture. For example, Tamarix pentandra, a common plant wherever sufficient water is available, is an ornamental and not a native species.

During the past five years, the southern California desert has experienced extreme precipitation, with accompanying temperature fluctuations. Flooding has transported plants and seeds great distances. The hot, strong winds combined with water and sand abrasion have scarified long dormant seeds, enabling seed germination. Combined, these factors have affected the growing, blooming and fruiting seasons for annuals, perennials, shrubs and trees beyond those previously recorded.

SECTION II

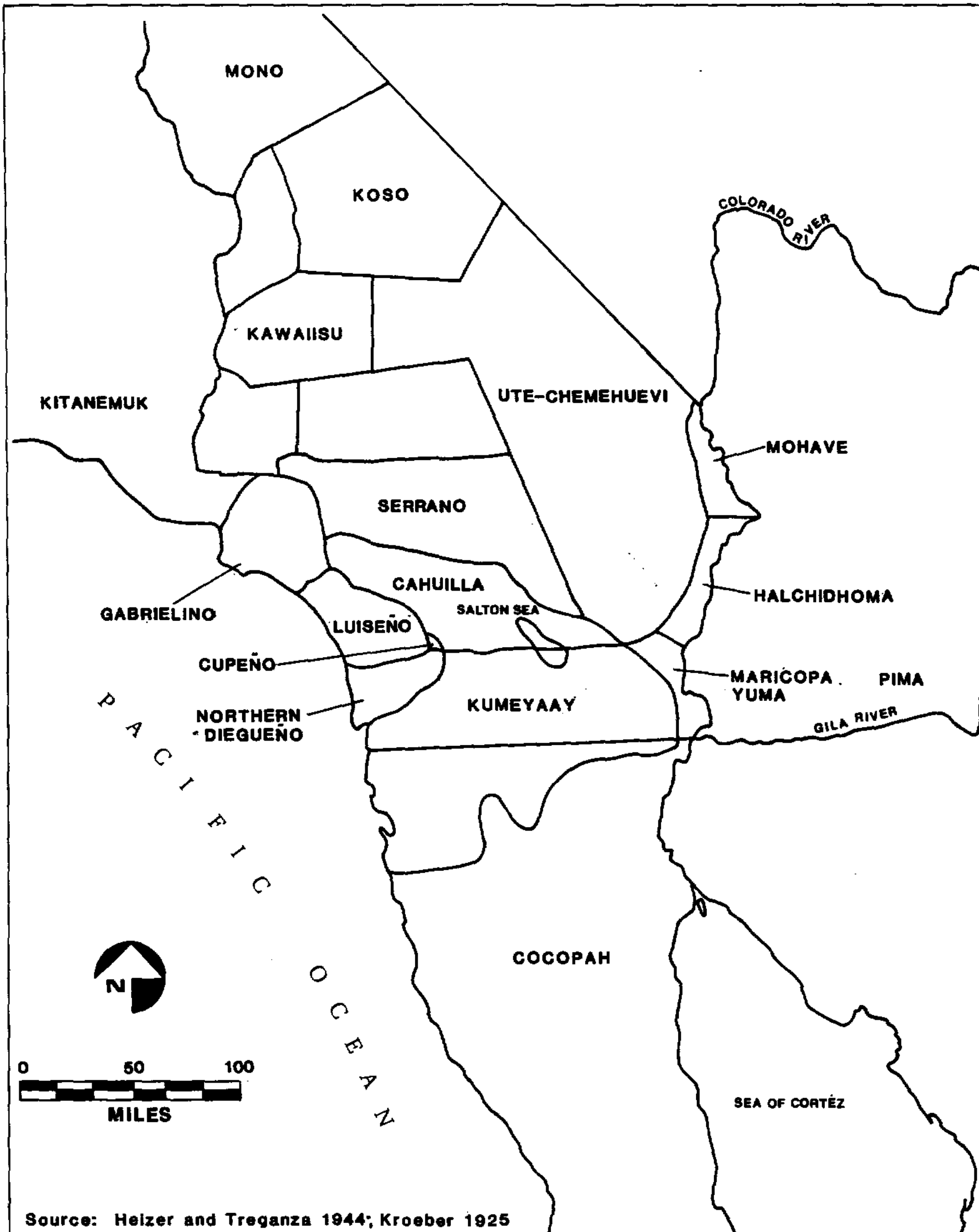
CULTURAL SEQUENCE

The following discussion presents a cultural sequence based on different levels of investigation and following several avenues of research. The earliest segment of the cultural sequence, the Pre-Projectile Point culture is the least well-defined and presents the greatest problems in interpretation. The Paleo-Indian Horizon/San Dieguito Complex is a generally accepted cultural sequence, although our discussion of these early hunters and gatherers is necessarily focused on manufacture of stone tools and inferred use. The Early Milling Horizon/Amargosan-La Jolla Complex is also weighted toward defining a culture by stone tools and their inferred function but our knowledge of Amargosan-La Jolla behavior and settlement patterns is better developed than for their predecessors.

The Late Milling Horizon/Yuman-Hakatayan Complex offers an almost overwhelming quantity of data. Information on these peoples can be drawn not only from archaeological sources but also from historic sources and ethnographic research. Yet no comprehensive Late Milling Horizon analysis has been produced for the study areas. Researchers are forced to rely on a generalized pattern rather than an outlined understanding of the late prehistoric cultural record. The transition from the hazy obscurity of the hypothetical early Pre-Projectile Point culture to the more defined later cultures is presented in both content and mood within the following discussion. In contrast, the student of the later peoples must become a master of focus and clarity. The approximate boundaries for the Late Milling cultures throughout the southwest desert region are shown in Figure 3.

2.1 PRE-PROJECTILE POINT/EARLY MAN CULTURES

Recent research along both coastal and inland southern California has seriously raised the possibility of a Pre-Projectile Point, Pre-Paleo-Indian (San Dieguito)



Cultural Zones of the Far Southwest
at the Time of European Contact (1769 AD)

FIGURE 3

culture. Unfortunately much of the data remains ambiguous and often suspect. The equivocal nature of the evidence for "Early Man" or Pre-Projectile Point cultures is due partially to the random methods of collection and biased analyses often employed by its advocates and partially to the probability that remnants of such an ancient culture will be sporadic and not easily recognized. Much of the early documentation of pre-San Dieguito cultures has been broadly conceived and short on substantiation (Carter 1957; Clements and Clements 1953).

Among the discordant promotions and hypotheses supporting Early Man, an increasingly harmonious and balanced theme is beginning to be heard. The research of Dr. Emma Lou Davis (1970:117, 1978) has been noteworthy for its well-reasoned documentation of an apparent Pre-Projectile Point stone tool tradition. Of even less quality and general acceptance, the Calico sites and supposedly contemporaneous lithic traditions, as defined by Ruth D. Simpson, may provide verification of a pre-San Dieguito desert complex (Simpson 1960:25-35). Several years of field research and analysis by Morlin Childers and Robert Begole may someday lend credence to the concept of Early Man in the Imperial and lower Colorado deserts (Childers 1974a; Bischoff, Childers and Shlemon 1976:129-130; Begole 1973).

A major stumbling block must be surmounted before most of the research cited above is accepted and Early Man becomes a valid, recognized tradition. The stumbling block is comprised of irregularly shaped, often jagged and always ancient appearing pieces of stone. True believers of Early Man see patterns in these lumps of quartzite, rhyolite and chert. They see stone tools fashioned and used by human foragers. To disbelievers the jagged edges are a typical products of natural forces such as thermal fracturing, exfoliation, stream tumbling and myriad other non-human acts of nature.

The stalemate between the believers and disbelievers is not apt to be easily or rapidly resolved. The general sparseness of datable material at, or associated with, hypothetical Early Man sites makes absolute dating difficult at best. Although dates between 8000 and 9000 years ago are generally accepted (Berger 1971; Warren 1967, 1966; Moriarty 1966; Carrico and Ezell 1978), dates beyond 10,000 years ago are as suspect as they are elusive. Human remains from Laguna Beach and the Los Angeles area have been dated at 17,000 years for "Laguna Woman" and over 23,600 years ago for "Los Angeles Man" (Berger 1971). A cairn burial in the Yuha Desert produced caliche covered human skeletal material, dubbed Yuha Man, dated at between almost 22,000 and 32,000 years ago (Childers 1974a, 1974b; Bischoff, Childers and Shlemon 1976:129-130, 1978:747-749; Bischoff, Meniam, Childers and Protsch 1976:128-129), although these dates have been questioned (Payen et al. 1978:448-452).

Physical characteristics of the Yuha Man were found similar to those of the La Jolla peoples of circa 7000 to 4000 years ago (Rogers 1963, 1977) and apparently different from the Del Mar Man remains (Rogers 1974) dated as the earliest (48,000 years ago) evidence of human occupation in North America. While the possibilities of the peopling of the Americas almost 50,000 years ago are tantalizing and stir the imagination, years of research and review will be required to validly assess the growing body of potentially supportive data.

Many archaeologists can accept the 9000 to 21,000-years-old dates and have little trouble agreeing that the rock cairns or stone tools are of human manufacture. It is beyond the 21,000-year-old barrier that only the true believers have dared to tread. Aided by amino acid racemization dating, several researchers (Bada, Schroeder, and Carter 1974; Bada and Helfman 1975; Minshall 1976) continue their claim for Early Man in southern California.

For the current research project we shall assume that the cultures or traditions postulated as occurring before 21,000 years ago are still hypothetical and that those better-dated yet ill-defined cultures between 10,000 and 20,000 years ago are tenuously accepted. It is hoped that projects such as the current one and other serious research programs will shed new light on the more than 20-year-old controversy of Early Man in southern California.

2.2 PALEO-INDIAN/SAN DIEGUITO (10,000-7500 BP)

The oldest well-documented inhabitants of the region were apparently the Paleo-Indian San Dieguito people. Based on tool typologies, environmental setting for known sites and assumed cultural distribution, the San Dieguito complex most probably represents a regional manifestation of the larger Western Lithic Co-Tradition (Davis et al. 1969). Another localized variation of this widespread tradition is the Lake Mojave complex (Warren, True and Eudey 1961; Bettinger and Taylor 1974). Claude Warren provides a fine overview and discussion of similarities among western Paleo-Indian tool assemblages (1967:168-185) while explaining his hypothesis that Paleo-Indian peoples moved out of the nondesert northern forests and into our now arid desert lands.

These people are believed to have occupied the mesas, mountains and deserts in and around the study area between 10,000 and 6000 years ago (Warren 1961:252-253; Rogers 1966:140-148; Ezell 1974:personal communication). The culture of the San Dieguito people has been divided into three relatively distinct phases representing assumed variations in time and space. Absolute dating of stratigraphic evidence for Rogers' phases is still a major research goal. Within these three phases there exist various "industries" which are geographically and ecologically based.

In general, the groups of the San Dieguito I phase apparently left only a sporadic permanent record on the land except for their scattered lithic tools and waste stone debris (Rogers 1939:25-31; Wallace 1955:214-230; Ezell 1974:personal communication). More specifically, San Dieguito I tool assemblages are characterized by ovate bifaces, spokeshaves, bilateral notched pebbles, scraper planes and chopping tools (Rogers 1939).

Many investigators, including Rogers (1966), thought that so-called sleeping circles and geometric stone alignments (intaglios) were of San Dieguito origin, but most scholars realize that there is no way to date most rock rings or to assign them a function. San Dieguito I sites are frequently located high above existing water sources and in settings suggestive of occupation contemporaneous with a much wetter, more lush environment. Apparently San Dieguito I peoples thrived in desert regions of southeast California but do not seem to have occupied the coastal plain of California or the Peninsular Ranges.

San Dieguito II is found in portions of the general study area. Lithic artifacts represented by this phase include more finely worked blades, somewhat smaller and lighter points, and a larger variety of scrapers and choppers. In general, however, the same morphological types remain basically unchanged from the earlier phase. Like their predecessors, these people were medium to large game hunters, and vegetal gatherers (Warren 1961:262; Moriarty 1969:1-18). It is also probable that people of the San Dieguito phases exploited lacustrine and riverine resources in these inland locations. Work by Kaldenberg and Ezell (1974) in San Diego County reveals that the San Dieguito harvested substantial marine resources. Other recent ethnographic work with hunting and gathering groups of southern California and Baja California illustrates the importance of the gathering portion of their subsistence (Bean and Saubel 1972; Aschmann 1959) with the observation that wooden vegetal preparation implements were used to some extent. This infers that early cultures such as San Dieguito phases may have used such perishable implements.

The terminal San Dieguito phase, San Dieguito III, represents a morphological and typological change as indicated by an altered technology. The tool types become far more varied both in style and in functional design. Such alteration in technological form can be attributed to environmental adaptation and/or to a technological "snowball" effect, wherein technological advances and changes thrive and feed on themselves and progressively create a new technological mode.

As a result of such technological changes, the tools of the San Dieguito III phase exhibit not only a wider variety of tool types, but also a fundamental refinement in tool manufacture. A primary difference in tool technology is represented by the introduction of pressure flaked blades and points. Unlike simple percussion flaking, pressure flaking requires a more delicate and finely conceived touch. The resulting tools exhibit form, complexity and balance not found in the early phases of the San Dieguito people.

Other diagnostic traits associated with San Dieguito III include scraper planes, choppers, plano-convex scrapers, crescentic stones, elongated bifacial knives, and intricate leaf-shaped projectile points (Rogers 1939:28-31, 1966). Beyond specific tool types and the introduction of pressure flaking, there exists no absolute method of discerning between San Dieguito II and III. Patination, a weathering process involving chemical change on the surface of stones, is a relative guide to antiquity and may provide gross distinctions between the San Dieguito phases; however, its use is limited by the many variables which are involved in its application (Arnold 1971; Alsoszatai-Petheo 1975; Bard et al. 1976; Laudermilk 1931).

2.3 DESERT CULTURES (7000-1000 BP)

Following the relative uniformity of the Paleo-Indian/Western Lithic Co-Tradition, the archaeological record becomes less clear and probably more specialized within particular regions. Inland peoples and lake terrace dwellers developed hunting and foraging tools as varied as the natural resources they exploited. In addition to environmental variations that may have given rise to artifact diversity, cultural isolation and/or successive migrations of new peoples could have led to apparent diversity in technology.

As discussed in detail below, the most basic or fundamentally defined complexes or periods are the desert-based Pinto Period circa 7000 to 4000 years ago and the Amargosa Period circa 4000 to 1500 years ago. Slightly better defined but far from well understood, the La Jolla/Oak Grove/Topanga/Pauma cultures existed roughly contemporaneously with the Pinto/Amargosa peoples circa 8000 to 1500 years ago.

2.3.1 Pinto/Amargosa Period (6000-1500 BP)

Based largely on projectile point types and a scatter of stone tools across the California/Arizona deserts, various authors have recently documented human occupation in these areas 8000 to 1500 years ago (Wilke 1976; E.L. Davis 1963, 1974, 1978). The work of these researchers has complimented earlier work by Rogers (1939, 1966) and Campbell and Campbell (1935). Large-scale surveys and continued comparison of tool types has led the later researchers to reject or at least seriously modify the "vacated desert" concept postulated earlier by Rogers and the Campbells. Although settlement was certainly sparse as a result of small population and nomadism, generalized cultural patterns were practiced by people sharing similar technology, environment and possibly ethnic backgrounds.

The Pinto complex was centered around major water sources including lake shores. From these now arid areas, bands of people migrated across the land in pursuit of medium-sized game, seeds, nuts and berries (Wilke 1976; Meighan 1976; Bettinger and Taylor 1974). Although milling tools have been associated with Pinto camps, distinctive Pinto projectile points, flaked stone and infrequent hammer-pounders are more representative of the Pinto tool assemblage.

The Amargosa Period is well-defined throughout the Great Basin but becomes unclear as one moves south and west across California. Beginning approximately 4000 years ago, the Amargosa complex clearly differs from the earlier Pinto complex. Amargosan points are also known as Elko or Elko-earred points or in the later Amargosan period as Gypsum Cave points. Typically, these points are notched and large stemmed (Campbell and Campbell 1935:pl. 13; Wallace 1978:Fig. 11). Food processing tools included trapezoidal/triangular blades, shaped and unshaped manos, and scraper planes. According to Wallace (1978:31), campsites are generally devoid of hearths, food remains and architectural features.

Late Amargosan or Amargosan-like technology melds into Millingstone Horizon types along coastal and peninsular range California, as noted by Wallace (1978:32), and Kowta (1969:39-40). Whether Amargosan peoples gradually amalgamated with Hakataya-Patayan peoples from the southwest or blended into other, as yet undefined, cultures is not clear. Amargosan migration to present-day northern Baja California and the upper Sonoran Desert is also a strong possibility (Hayden 1967, 1976).

2.3.2 La Jolla-Pauma (7500-1000 BP)

By about 7000 years ago a new group of peoples had begun to inhabit and exploit the coastal and inland regions of San Diego County replacing or evolving from San Dieguito III (Moriarty 1969:12-13). Whether the people or the economic base shifted during this time is not clear. Moriarty (1967) states that the San Dieguito to La Jolla transition was an economic and technologic response to environmental change and not a result of migration.

The La Jolla were nomadic exploiters of maritime resources (Harding 1951; Moriarty et al. 1959:185-216; Wallace 1960:277-306) who also relied on seed gathering and vegetal processing. The La Jolla may have been entering into the mortar and pestle phase late in the terminal stage of the La Jolla-Pauma transitional period (Warren

1961). The tool types of the La Jolla indicate that these members of what Wallace (1955) terms Early Milling Horizon possessed a far greater reliance on the sea and on foraging than did their predecessors, the San Dieguito people. The variety and quality of lithic tool manufacture is much more basic and unrefined when compared with even the basal phase of the San Dieguito complex, and lacks the point/blade aspect noted for contemporaneous Pinto-Amargosa peoples.

Characteristic traits of the La Jolla complex include fire hearths, shell middens, flexed inhumation, grinding implements, and absence of ceramics. Archetype La Jolla sites are located along the coast near bay or lagoon areas. In recent years, inland La Jolla sites of a seemingly later period have been discovered in transverse valleys and sheltered canyons, including Valley Center (Meighan 1954:215-227; True 1959:225-263; Warren et al. 1961:1-108). These noncoastal sites have led to a new name for La Jolla-type sites with an inland location. Meighan (1954), True (1959), and Warren et al. (1961) have applied the term Pauma Complex to certain inland sites which possess a predominance of grinding implements (especially manos and metates), lack of shell, greater tool variety, more sedentary life patterns than expressed by San Dieguito sites, and an increased dependence upon gathering. However, it is more probable that these inland sites represent a noncoastal manifestation of Early Milling peoples who adopted or developed a hunting mode more so than their coastal brethren. Wallace (1955:214-230) denotes this late transitional phase as Intermediate, and establishes its position as between Early Milling Horizon and Late Milling Horizon.

2.4 LATE MILLING/LATE PREHISTORIC (1000 BP-1800s AD)

By 1000 years BC, or almost 3000 years ago, Yuman-speaking peoples who shared cultural elements had occupied the Gila/Colorado River drainage (Moriarty 1966) and portions of the study area. Through gradual westward migration the Yumans drifted into Imperial and San Diego Counties where they came into contact with, and apparently acculturated with, the remnants of the Early Milling La Jolla-Amargosa cultural tradition (Moriarty 1965, 1966). Because of basic similarities in the late La Jolla/early Yuman patterns it is difficult to clearly define the contact period or point between La Jolla-Amargosa.

Much controversy surrounds the identity of the late prehistoric peoples who used and occupied the Imperial Valley region. At the time of European contact (ca. 1769 AD), the hot, parched surface of this broad desert basin was believed to have been unoccupied. Later, ethnographic research conducted and/or reported by Bourke (1889), Henshaw and Hodge (1907), Harrington (1908), Waterman (1909), Gifford (1918, 1931), Kroeber (1925) and others presented a mass of conflicting data regarding the name of the prehistoric occupants, but all agreed that much of the valley region had been occupied and used by peoples of the Yuman stock. General agreement with regard to cultural patterns and behaviors also exists. Within the Imperial Valley region, these prehistoric/protohistoric peoples possessed ceramics and basketry, practiced an informal "flood plain" agriculture (corn, beans, squash and melons) supported by a generalized hunter-gatherer subsistence base, maintained a closely knit clan system, had elaborate and extremely complex kinship patterns, and carried on extensive trade and cultural interaction with surrounding groups (Gifford 1918, 1931; Spier 1923; Kroeber 1925, 1943; Rogers 1936; Drucker 1937). Whether called Kamia, Kumeyaay or otherwise, the people occupying the Imperial region were of Yuman stock, and exercised a cultural pattern befitting that cultural heritage (Langdon 1975; Hedges 1975).

Dr. James R. Moriarty has suggested (1965, 1966) that there existed a preceramic Yuman phase as evidenced from his work at the Spindrift Site in La Jolla. Based on a limited number of radiometric samples, Moriarty has concluded that a prepottery Yuman phase had occupied the San Diego coast 2000 years ago and that by 1200 years before present (BP) ceramics had diffused from the eastern deserts.

Although some researchers still follow Rogers' belief that Yuman ceramics first appeared in San Diego County only 1000 years ago (Rogers 1945) there is a growing body of data that supports Moriarty's hypothesis. A recent excavation of a La Jolla/ Kumeyaay site in Sorrento Valley (Carrico 1975) encountered a cultural stratification with a basal date of 3755 years ago and a terminal date of 2525 BP. It is worth noting that the upper stratum (0-10 centimeters) of the dated column contained ceramics and projectile points commonly considered time markers indicative of Late Milling Kumeyaay. Radiometric dating of a large shell sample from this stratum produced a date of 2525±70 years BP. The near absence of ceramics and total lack of projectile points below the 10 centimeter level within a series of strata which contained a variety of seemingly early cultural material dated at 2925±70 BP (30-40 centimeters) and 3755±75 BP (50-60 centimeters) may indicate that this is a multicomponent, culturally stratified site containing a transition between La Jolla and Yuman circa 2500 years ago.

Whether the Yuman peoples arrived on the coastline 2500 years ago, 2000 years ago or 1500 years ago, they brought with them a culture heavily influenced by their Yuman neighbors in the eastern desert region of California and along the Colorado River. These prehistoric/protohistoric peoples possessed ceramics, operated a closely knit clan system, utilized a highly developed grinding technology, had elaborate and extremely complex kinship patterns, created rock art, and carried on extensive trade with the surrounding cultural areas (Rogers 1945:167-198; Kroeber 1925:709-725; Strong 1929). It has also been postulated that the Kumeyaay (Diegueno, after San Diego) and their northern neighbors, the Cahuilla, may have been practicing a basic type of proto-agriculture prior to Hispanic contact (Lewis 1973; Shipek 1974:personal communication; Treganza 1947).

About 1000 to 1500 years ago a group of Shoshonean-speaking people migrated out of the Great Basin region and intruded like a wedge into southern California. This wedge separated the Yuman groups and was eventually to cause great cultural variations (Kroeber 1925:178; True 1966). In coastal San Diego County, this group of Shoshonean intruders has been labeled the San Luis Rey I and II Complex (Meighan 1954: 215-227). When the early Hispanic missionaries contacted these people they called them the Luisenos, after the Mission San Luis Rey de Francia which was founded in the heart of Luiseno (San Luis Rey II) territory. In the desert regions, the Cahuilla and Chemehuevi bands represent Shoshonean intrusion in southeastern California. These Late Milling peoples occupied portions of the Lake Cahuilla shoreline and the Colorado River region well north of the current study area.

Although of a different linguistic stock, the Cahuilla and the Kumeyaay-Yumas shared cultural traits. D.L. True (1966) has suggested that the basic similarities in ecological exploitation, environmental setting and temporal placement forced the late-coming and highly nomadic Shoshoneans to adapt to a life style and cultural pattern which was established and functioning upon their arrival.

2.5 PROTOHISTORIC PERIOD

The Hispanic intrusion, 1769-1822, into Native American southern California affected the coastal tribes and those people who lived in well-traveled river valleys. The Mexican Period, 1822-1848, saw continued displacement of the native population by the expansion of the land-grant program and the development of extensive ranchos. The gold rush and the concomitant granting of statehood combined with an influx of aggressive, land-hungry Anglos caused a rapid displacement of the natives, as well as deterioration of their culture and lifeways (Shipek 1974:personal communication; Bancroft 1886; Kroeber 1925). During this period, when native cultures of the Colorado Desert and lower Colorado River were in direct contact with the highly influential Western culture, aboriginal lifeways became jeopardized.

Cultural descriptions of Native American groups from the time of early European contact to the present have been preserved in the writings of explorers, soldiers, settlers, ethnographers, and Native Americans. Based upon these written works of the past two centuries, a rather complete picture of protohistoric native Colorado Desert people can be recreated. Literature concerning the Cahuilla, Yuma, and Kamia (Kumeyaay) groups include Barrows (1900), Gifford (1918, 1931 and 1934), Hooper (1920), Strong (1929), Heizer and Whipple (1957), Kroeber (1925), Cox (1961) and Phillips (1975).

2.5.1 Yuma and Kamia (Kumeyaay)

Closely related geographically, and by kinship, customs and language, the Kamia and Yuma peoples of the Colorado Desert and lower Colorado River both can be identified as of the Yuma stock of the Hokan family (Kroeber 1925). Based upon linguistic criteria, the Yuman stock can be further subdivided into three divisions, one of which (the Central division) contains both aforementioned groups (Kroeber 1925).

The agriculturally-oriented Yuma who call themselves Kwichyana or Kuchiana were first named Yuma by Friar Kino in the early 1700s (Bolton 1919; Kroeber 1925). Today, the Native Americans of this region identify themselves as Quechan, a derivation of the Kwichyana (or Kuchiana) name (Kroeber 1925).

Due to their location along the Colorado River, the Yuman people were one of the native groups that experienced the earliest and most intense European contact in southern California. When Alarcon sailed up the Rio de los Tizones (Colorado River) in 1540, he was the first European to encounter the Yuman people even though they were previously aware of the Spanish and their equipment due to stories of Spaniards in New Mexico only a few months prior (Kroeber 1925).

Following early explorers like Alarcon in 1540 and Onate in 1605, missionaries entered the Colorado River region. Establishment of missions in Yuman territory was not initially successful. Two missions were established in 1779 only to be destroyed within two years by the intolerant Yumans (Kroeber 1925; Cox 1961). A punitive force of Spanish soldiers under Pedro Fages was sent to the Yuma territory.

Between 1781 and 1849, when gold was discovered in California, there was apparently little interaction between the Yuma and the Anglos (Spicer 1962). After 1849, however, there was considerable Anglo-Indian interaction due to the number of settlers and miners passing through the Gila/Colorado River area along the southern immigrant trail (Cox 1961). Hostile confrontations during this period were numerous, resulting in the establishment of a United States military fortification at Fort Yuma. Captain Samuel Heintzelman established the fort with three companies of soldiers near the mouth of the Gila River (Phillips 1975).

Confrontations between rival native groups probably took place well before the presence of Anglo influence, as indicated by the mention of aboriginal warfare in the early writings of Alarcon (1904). Other recorded native conflicts are not uncommon (Cox 1961). Alliances and feuds were generally well established. Killing of warriors and taking of slaves commonly occurred during these raids and battles (Cox 1961; Phillips 1975). To the Yuma, their Mojave and Kamia neighbors were considered friends while the Pima, Maricopa and Cocopa were enemies (Kroeber 1925; Gifford 1934). One of the earliest confrontations recorded occurred in the late eighteenth century. A small group of people living in the southern portion of the Imperial Valley, the Kohuana, were apparently annihilated by a combined force of Yuma, Mojave, and Kamia after they had unfortunately allied themselves with the Cocopa (Gifford 1931). Pima and Yuma clashed in 1858 with an unfavorable outcome for the Yuma (Kroeber 1925). Chronic warfare between the Yuma and Cocopa was eventually halted by the American military at Fort Yuma during the last half of the nineteenth century, though occasional raids and killings persisted until about 1900 (Gifford 1931).

The Kamia (or Desert Kumeyaay) of Imperial Valley generally experienced contact with the Spaniards, Mexicans and Americans later in time and less frequently than the Yuma due to their inhospitable desert domain. Kamia were first encountered by the Spanish during the 1775 expedition of Anza, Garces and Font and later by Garces in 1781 (Bancroft 1886). Following this exploratory period by the Spanish, few interactions between native Kamia and Anglos occurred until gold rush immigrants traveled across the valley (Bancroft 1886).

Territory of the Kamia had somewhat unfixed boundaries centered around the New River and Alamo River sloughs. Kamia reportedly established camps along the Colorado River near Algodones to the east although these are generally considered Yuman holdings (Gifford 1931). Hostile Cocopa lived south of the Kamia, west of the Colorado River Delta, and Shoshonean Cahuilla inhabited Coachella Valley to the north. Kamia are often identified as desert-dwelling Kumeyaay with only slight dialectical variation from these western kin (Gifford 1931). Boundaries between the Kumeyaay groups were not clearly definable since transitional locations such as Jacumba and the Anza Borrego area were inhabited by clans of both affiliations (Gifford 1931).

Kamia rarely battled neighboring groups without the support of their Yuman or Mojave allies due to their few numbers (Gifford 1931). It was reported by Don Agustin Janssens (1953), however, that the Kamia of Jacumba were responsible for the raid upon Otay Rancho. In addition, Kamia, under the leadership of their chief, Geronimo, were responsible for resistance toward the Americans from 1850 until his execution in 1852 (Phillips 1975).

As Americans entered and settled the Imperial Valley and adjacent Kamia holdings, inevitable conflicts occurred due to the competition for the scarce water and arable land within the desert valley. Travelers from Imperial Valley to Jacumba were periodically attacked (Ford 1976). Ranchers occasionally discovered livestock either slain or stolen by local Kumeyaay and Kamia (Odens 1977; McCain 1977:personal communication). Trouble between settlers and Kamia came to a head in 1880 when a group of angry ranchers rode into a rancheria near Jacumba and killed 15 Indian men, women and children (Odens 1977).

2.5.2 Cahuilla

Desert Cahuilla inhabited the northern end of the Salton Trough in Coachella Valley substantially north of the current study area in protohistoric times (Kroeber 1925). Lines of trade and communication existed between the Shoshonean-speaking Cahuilla and their Yuman-speaking Kamia neighbors to the south, but were not as developed as those established between intralinguistic groups (Hooper 1920; Kroeber 1925). Cahuilla traded items including bulbs, roots, cat-tail sprouts, yucca leaves, mescal, pine nuts, manzanita berries, chokecherries and mesquite beans to the Kamia and received gourd rattles and perhaps obsidian in return (Phillips 1975; J.T. Davis 1974).

Aside from the trade that occurred between the Kamia and Cahuilla, little influence of the Cahuilla can be found in the study area. Aggressive interactions between Kamia and Cahuilla were rare. Most recorded Cahuilla hostilities do not relate to neighboring groups but were usually between Cahuilla clans (Hooper 1920).

2.6 ARCHAEOLOGICAL PERSPECTIVE

Lake Cahuilla once covered an area roughly 35 miles wide and 105 miles long extending from Indio south, past the U.S./Mexico border. The importance of this large body of water to the understanding of past lifeways cannot be underestimated. Lake Cahuilla would have covered one-fourth of the lower southern portion of California and was present as recently as 500 years ago. Oral tradition of the Cahuilla states that "The lake was filled with fish, and ducks and geese occurred in great numbers. The Cahuilla lived in the mountains and used to come down to the lake to fish and hunt. The water gradually subsided little by little and their villages were moved down from the mountains into the valley" (Blake 1858:98). According to Heizer, Treganza and Kroeber the Kumeyaay occupied the study area. The most encompassing archaeological studies conducted along the shoreline to date are those of Malcolm Rogers in the 1920s and Ben McCown in the 1950s.

2.7 RECORD SEARCH DATA

WESTEC Services, Inc. has completed a thorough review of pertinent site record data from those institutions and agencies possessing such data. San Diego Museum of Man, and Imperial Valley College Museum in El Centro were found to have site information for archaeological/historical locales within the Salton Sea Anomaly Area. This information is on file with Imperial County.

2.8 PREVIOUS FIELDWORK

2.8.1 Introduction

Cultural resources within the Salton Sea area have come under professional scrutiny beginning in the 1920s, although relatively little work has directly applied to the Salton Sea Anomaly Area. Between approximately 1920 and 1970 avocationalist/ professional archaeologists conducted sporadic surveys of the Imperial Valley, particularly along the relic Lake Cahuilla shoreline (40 feet above mean sea level) and at natural seeps, springs, and drainages. Pursuant to California Environmental Quality Act of 1970 (CEQA), endeavors to assess cultural resources were greatly accelerated in the Imperial Valley as in the rest of the state. In 1973, Imperial Valley College instituted an active archaeological program of classroom surveys and testing in addition to environmental assessment surveys and testing. Also since 1970, private archaeological consulting firms have been contracted by public agencies and private developers to conduct cultural resource assessments and mitigation programs.

Based upon past and current archaeological studies of the Salton Sea and to comparable environments elsewhere in the Salton Sink region, archaeological predictive projections can be made relative to the Salton Sea Anomaly area.

2.8.2 Existing Archaeological Site Record

WESTEC Services, Inc. has completed a record search of the study area by contacting all appropriate archaeological institutions and individuals. San Diego Museum of Man, Imperial Valley College Museum (IVCM; District 10 Clearinghouse of the Society for California Archaeology) and B.E. McCown were found to possess such records. Some records from IVCM are geological notes of H.S. Washburn who conducted a survey for United States General Land Office in 1856. Some of these geologic records directly or indirectly relate to archaeological resources.

2.8.3 Previous Surveys and Reports

The studies of Malcolm Rogers (n.d.) and B.E. McCown (1957) stand out as the most interesting in the amount and kinds of materials encountered. These encompassing studies revealed a wealth of data presently located in notes and boxes. To date, no reports have been completed for either of these Lake Cahuilla shoreline studies. Other major surveys include Bell's (1974) Coachella Canal survey; Ellis and Crabtree's (1974) surveys for Geothermal Resource Areas; Weaver's (1977) and White et al. (1978) sample inventories. Eckhardt's (1979) study includes both intensive survey and random sampling of Lake Cahuilla's 40-foot above mean sea level (AMSL) shoreline and non-shoreline areas.

Studies conducted under the auspices of Imperial Valley College began in 1973-74 under the guidance of Mike Barker. Work by Jay and Sherilee von Werlhof, in conjunction with Imperial Valley College, which began in 1974, is ongoing. Studies by the von Werlhofs (n.d.; 1975a, b, c; 1977a, b, c; 1978a, b; 1979) in Imperial Valley have helped to 1) recognize the collected data and artifacts at Imperial Valley College Museum; and 2) provide the continuity of archaeological research.

The remaining surveys (Barker and Burton 1970; USDI, BLM 1975; Maxon 1975; Brooks et al. 1977; Dewey 1978a, b) were small in area and scope and vary greatly in quality of work, methods and results.

Overall, the results of these studies show the primary archaeological areas to be the relict 40-foot AMSL Lake Cahuilla shoreline (sites C-49 and McCown #22). Radiocarbon dates identify these areas as post AD 1400. Sites ranged from containing midden, bone, shell, pottery, lithics, milling tools and charcoal, to simple pottery scatters. Non-shoreline sites, as a group, do not reflect the concentrated, prolonged human occupation of the Lake Cahuilla shoreline (circa AD 1400), but are indicative of several occupational periods and activities. Within the Salton Sea area, non-shoreline sites appear to be primarily a result of late prehistoric human activity such as aboriginal trails (Imp-900, 901, 902, 903 and 904) and a quarry (C-89).

The following are descriptions of the two major studies which encompassed the project as part of their study area:

- Rogers, Malcolm J. (n.d.)

The earliest serious inventory of cultural resources along relict Lake Cahuilla's shoreline is that of Malcolm J. Rogers, circa 1920-1930 (Rogers n.d.). While serving as curator and, at times, director of the Museum of Man in San Diego, California, Rogers visited numerous locales along the breadth of the eastern shoreline, inventorying archaeological sites, performing limited subsurface testing and making collections for curation at the Museum of Man. As a small part of a larger, region-wide inventory, Rogers recorded some 21 sites along the eastern relict shoreline. Site records and supporting comments from this early work attest to a broader cultural assemblage than that which greets the modern day researcher (Rogers n.d.).

A reading of the field notebook maintained by Rogers discloses an early attempt to date the various occupations relative to the recessions of the relict lake. In recording site C-49 (located near the northeast corner of the current study area, a major zone of occupation along the eastern relict shorelines, Rogers writes:

> Four miles of intensive occupation from the earliest time down to sea level occupation. Not many sherds were found on the sea level terrace as it is badly washed, but no difference could be seen between them and the upper gravel terrace except that daubed ware formed a higher percentage on the sea level. On this terrace were some five big gravel house pits with quantities of charcoal and fishbones in the walls. The houses on this level are the largest, thirteen feet from rim to rim being common. They are often grouped in communities with rim to rim. Some have double circles as if one were a vestibule. Sea level terrace is the eighth one down from the UGT (upper gravel terrace). No occupation was found between. The UGT is covered with hundreds of gravel house pits in this region. They average from 6 feet to 13 feet in diameter, have door openings to the east and are sometimes double. A few rectangular ones were seen but these may have been ramadas. Daub ware seems scarcer on this level and small shallow pieces more common than elsewhere. After the gravel terrace was built, silt filled in back of it to considerable depth. Occupation begins near the bottom and is stratified. One fire, fishbone and sherd lens was found 5'6" under modern surface of silt which has been eroded some. Silt level had the greatest occupation but as it is the most eroded little can be found except the buried strata. All metate evidence was seen on this formation or on the fine gravel lands in the rear of it, especially at the north end and toward C-21 (Rogers n.d.).

Although no serious chronology for lakeshore sites was ever refined, it is obvious that Rogers considered the requisite temporal attributes to be present and site integrity to be sufficient for an attempt to date the various occupations around the shoreline. During the past four decades, much has passed to change the character of cultural resources along the relict shoreline; natural agencies, gravel quarries, water conveyances and access roads, and recreational activities have all disturbed their share of archaeological sites.

- McCown, Benjamin E.

During the period between 1953 and 1957, limited site survey, collection and testing was undertaken along the relict Lake Cahuilla shoreline by Benjamin Ernest McCown in affiliation with both the Southwest Museum and Archaeological Survey Association of Southern California (B.H. McCown 1979:personal communication). Survey members included numerous interested professionals (i.e., Dr. Carl Hubbs), amateurs and avocationalists working on weekends, holidays and vacations. The entire shoreline along the relict lake was traversed by vehicle and numerous regions were surveyed on foot. Although most of the significant fieldwork took place outside the current study area, collected data from this early effort may shed light on the observed prehistoric patterns of the region.

Materials collected during the survey are currently housed at the Archaeological Survey Association's (ASA) research facility in La Verne, California. The assemblies include a broad spectrum of artifact types, for example: granite pestles and manos; sandstone, granite and pumice slab metates; a large hopper mortar; debitage, flakes, cores, flake stone tools, knives and projectile points; pottery sherds; shellfish, fishbone, shell beads and shell pendants; and fire cracked rock, natural cobbles and datable carbon materials.

Method of retrieval included surface collection and subsurface testing. Small regions were surveyed, and when archaeological locales were encountered, they were mapped on 15 minute USGS quadrangles. Sketch mapping and surface collection of located sites was usually undertaken, and occasionally (when the resource warranted), a terrace wall would be faced-down or several pits excavated to test subsurface deposits, retrieve datable carbon samples or investigate subsurface strata.

Circumstances did not permit B.E. McCown to complete the survey or prepare a written report. The last field effort of the survey was a short visit to

Travertine Point in early 1958. Soon thereafter, Benjamin E. McCown was bedridden with cancer, and died on February 22, 1959. Efforts are now underway to catalog, analyze and document the materials from the Lake Cahuilla region, with analysis and report preparation projected for the next two years by Benjamin H. and Lucille McCown with the assistance of Ruth DeEtte Simpson and ASA members.

SECTION III

RECOMMENDATIONS

3.1 CULTURAL RESOURCE SENSITIVITY

The entire project region contains recorded evidence of historic and prehistoric occupation/land use. Unfortunately, instances of cultural resource damage, and/or removal, have been reported (Eckhardt 1979; von Werlhof 1978). Site impacts were caused by weathering (floods), inundation (Salton Sea), and recent historic development (farming activity). Nonetheless, a cultural resource overview within the study area has documented a significant number of, albeit widely scattered, archaeological/ historical locales. Moreover, a definite lack of systematic archaeological investigations for the immediate study environs has been noted, Malcolm Rogers (circa 1920-30) and Benjamin McCown (1953-57) notwithstanding.

An expressed objective of an overview of this nature is to provide management planners a generalized cultural resource sensitivity map. A hierarchy of potential sensitive archaeological regions has been established (Figure 4). The current overview proposes the following classification:

- Major: This designation identifies regions as having known or probable archaeological resources of a highly sensitive nature. Assessment is based upon extant records, previous fieldwork, and personal communications. As pertains to the current project, this region is best exemplified along the relict 40-foot shoreline of former Lake Cahuilla. Recorded locales generally reflect material remains indicative of a substantial cultural occupation, i.e., house pits, hearths, food remains, cremations, and assorted tools. In addition, sites regarded as being highly sensitive would also include areas of religious significance to native Americans, i.e., rock art, cremations, and rock alignments.

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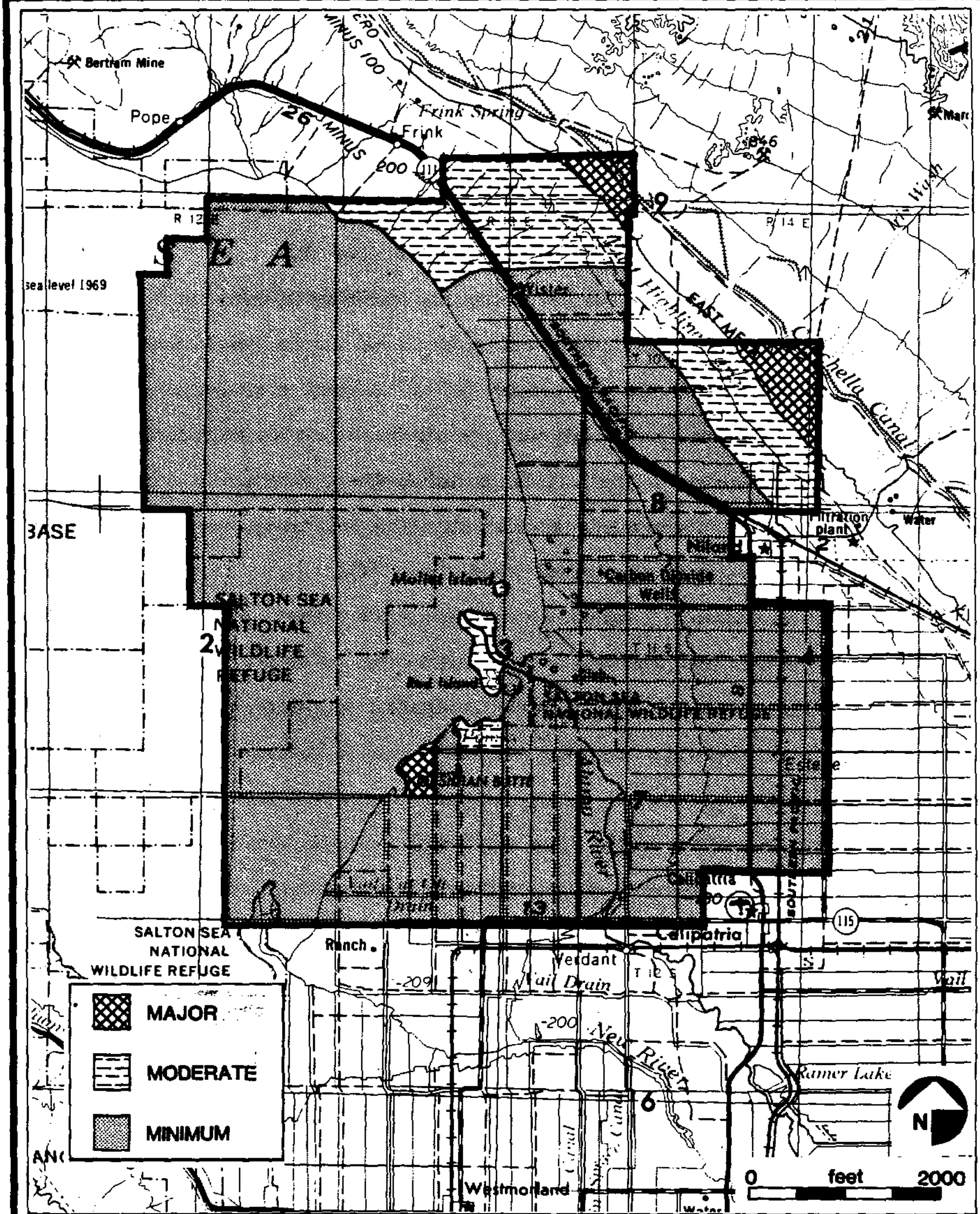

Cultural Resource Sensitivity Regions

FIGURE 4

- Moderate: This designation is based upon the likelihood of encountering archaeological remains in areas not previously surveyed, but in proximity to recorded site locales. Within the study, this region refers to "undisturbed" land below the relict shoreline (40-foot) to the present day Salton Sea shoreline. Also incorporated within this category would be Red Island, Mullet Island, and Rock Hill.

- Minimum: The low designation encompasses areas which have been irreversibly altered by land development in the recent historic period; specifically, all cultivated lands within the entire study region. Acreage considered as also having minimum archaeological sensitivity would include the Salton Sea and marshlands. Record search data indicates farmlands did contain evidence of native American land use (Washburn 1856). Unfortunately, the aboriginal trails, mesquite groves, and fresh water sources have been reported destroyed (von Werlhof 1978).

Major sensitivity regions are depicted on the Wister 7.5-minute USGS quadrangle. The Iris Wash quadrangle also contains zones of major archaeological sensitivity. Obsidian Butte, despite impacts, is regarded as a highly sensitive area. This resource is situated within the Obsidian Butte 7.5-minute quadrangle.

Moderately sensitive cultural resource areas are located within the Wister quadrangle, in addition to the Niland quadrangle, including Red Island, Mullet Island, and Rock Hill. These relict volcanic features are regarded by investigators as having potential sensitivity based upon their geologic uniqueness as possible lithic source material (Gallegos 1981: personal communication).

All remaining portions of the study region have been assigned minimum archaeological sensitivity, and consist generally of reclaimed lake bed lands, the Salton Sea, and wildlife habitat areas.

Classification of cultural resources within a hierarchy of major to minimum sensitivity zones is structured around existing records and does not reflect actual in-field examination by current investigators. Therefore, any information contained in the overview is subject to revisions pending input from ongoing archaeological research efforts.

3.2 POTENTIAL ARCHAEOLOGICAL FIELDWORK SCENARIOS

The approximately 106,000 acre study area includes: privately owned lands (developed and undeveloped), federal parcels, towns, highways, a railroad line, improved and unimproved dirt roads, irrigation canals, etc. Archaeological investigation in conjunction with geothermal development would be required to address studies under guidelines established by appropriate governing agencies, e.g., federal, state, or local.

Federal lands would require direct involvement with the Department of the Interior under the auspices of the Bureau of Land Management.

Today more cultural resource laws exist than ever before, mandating penalties for offenders. These laws begin with the Antiquities Act of 1906 (Public Law 59-209) which sets forth the basic principle that the Federal government, acting for all the people, should work toward the protection, preservation, and public availability of the nation's historic and prehistoric resources. The 1906 Antiquities Act has been greatly enhanced through the recent passage of Public Law 96-95 which acts to identify and clarify certain portions of the 1906 Act.

Other Federal mandates which are directly or indirectly applicable include: the National Historic Preservation Act of 1966 (Public Law 89-665; 80 Stat 915, 16 USC 470), Executive Order No. 11593 of 1971 (36 FR 8921, 16 USC 4321-4327), Federal Land Policy and Management Act of 1976 (Public Law 94-579, 90 Stat 2743, 43 USC 1701), Historic Sites Act of 1935 (Public Law 74-292, 49 Stat 666, 16 USC 461, et seq.), Council on Environmental Quality Guidelines (40 CFR Part 1500) and Procedures of the Advisory Council on Historic Preservation (36 CFR Part 800).

Archaeological studies conducted on private and state owned lands come under the regulations specified within the California Environmental Quality Act of 1970 (CEQA).

Management policy for the protection and preservation of cultural resources should be one of site avoidance whenever possible. The relict Lake Cahuilla 40-foot eastern shoreline should be seriously considered a major sensitive archaeological area to be avoided.

If in fact conflicts with cultural resources cannot be avoided, then mitigating programs should be developed and outlined to conform to professionally acceptable procedures. These procedures, based upon field reconnaissance of specific project areas, should be directed at resource management by surface collection and excavation as necessary. Data should statistically verify archaeological potential of each site (e.g., types of artifacts, amount of artifacts, and size of site). Research orientation for each site mitigated should be directed at regional research questions developed from studies conducted throughout Imperial County (Wilke 1978; Eckhardt 1979; Gallegos 1980). In some cases, a complete inventory (100 percent survey, collection and/or excavation) may be necessary in attempts to answer research problems. Select resource areas, due to size and complexity or lack thereof, may require a sampling program.

Through planning, geothermal land use can and should avoid sensitive archaeological areas.

Environmental planners should be aware of the fact that Lake Cahuilla's relict (40-foot) shoreline transcends the delineated study area. Anthropological implications concerning Lake Cahuilla are that, when full, this lake would have been 35 miles wide and 105 miles long, encompassing the Coachella Valley, Imperial Valley and parts of Mexico. The entire 40-foot shoreline is of National Register Significance and should be protected, where shoreline areas have not undergone serious impact. Lake Cahuilla shoreline site(s) contain the potential for answering many questions concerning native American adaptation, exploitation, and settlement for the late (AD 900-1500) period and possible earlier cultural manifestation (Gallegos 1980:182).

Obsidian Butte, C-89/Imp-452, is another area of significance to the archaeological community. Material from this geologic formation is encountered throughout coastal San Diego County. As a lithic source, Obsidian Butte represents the only known natural deposit in southern California south of Coso in Inyo County. Obsidian from the site was available after AD 1600; up until that time the deposit was submerged by Lake Cahuilla. An extensive obsidian trade network evolved from native American quarrying activity. It is believed that obsidian trade ended in the middle 1800s.

Despite inclusion as a region of moderate archaeological sensitivity, undeveloped lands situated in the northeast sector of the geothermal resource area may have excellent potential for containing sensitive cultural remains. A recent study (Phillips and Carrico 1981) documents recessional shoreline native American occupation at contour elevations minus 37 to minus 137 feet below sea level. Previous fieldwork in the Salton Sea basin has not systematically addressed this phenomenon. Record search data indicates a similar lack of fieldwork in the northeast sector of the project area. Concurrent lacustrine fluctuations could result in spatial distributions of cultural material reported by Phillips and Carrico. Hypotheses regarding likelihood of encountering cultural material dispersed along relict shorelines of Lake Cahuilla, within the current study, below the 40-foot contour must be approached with caution pending in-field examinations.

Reclaimed lands currently being used for agricultural endeavor are considered as having minimum potential for containing archaeological remains. Regardless, onfoot reconnaissances of specific project areas are required by law (CEQA 1970).

SECTION IV

CONCLUSIONS

A cultural resource overview for the Salton Sea Anomaly Area has documented through extant literature, record searches, and personal communication a region containing known and potential archaeological significance. Proposed geothermal developments within the study area may result in adverse impact to resource deposits. The overview is to be used as a planning document which will make available to the sponsoring agency (Imperial County) all extant knowledge concerning site locations, summary of previous fieldwork, cultural resource significance, and potential significance of unsurveyed territory. A hierarchy of sensitive archaeological zones has been developed. This arbitrary classification includes cultural resource areas, or suspected areas, of major, moderate, and minimum sensitivity. Assumptions regarding archaeological significance developed in the overview are tentative, often based upon incomplete site records, etc. Ongoing research within the study area may reveal new information which may either be disparate or highlight this current overview.

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RECORD SEARCH RESPONSE

NOTE

Site information provided separately as a data-support package is on file with Imperial County Planning Department.

WESTEC Services, Inc.
3211 Fifth Avenue
San Diego, CA 92103
(714) 294-9770

January 2, 1981

Mr. Russell Kaldenberg
District Archaeologist
Bureau of Land Management
Riverside District Office
1695 Spruce Street
Riverside, CA 92507

Subject: Cultural Resource Study for the Proposed Niland Anomaly MEIR Project

Dear Mr. Kaldenberg:

WESTEC Services, Inc. is currently engaged in a cultural resource study in the Salton Sea Known Geothermal Resource Area (KGRA) Imperial County, California.

The approximate 20,000 acre study region is an irregularly shaped area situated at the southeastern edge of the Salton Sea. Roughly 30 to 35 percent of the geothermal resource area lies within the Salton Sea itself, (map is included). WESTEC Services, Inc. has contacted the San Diego Museum of Man, and Imperial Valley College concerning their knowledge of existing cultural resources in the project region.

In order to achieve a thorough understanding of cultural resource potential within the immediate project boundaries we are requesting your assistance on this matter. We are seeking the following information; past and on-going historical/anthropological research, synopsis of your knowledge regarding cultural resource deposits, potential for existence of underwater sites, etc.

Any data that you can provide will be appreciated. Please feel free to contact the undersigned at your earliest convenience.

Sincerely,

Richard

Richard L. Carrico
Manager, Cultural Resources Group

RLC/cc
Enclosure

WESTEC Services, Inc.
3211 Fifth Avenue
San Diego, CA 92103
(714) 294-9770

January 2, 1981

Mr. Alex Kirkish
Bureau of Land Management
833 S. Waterman Avenue
El Centro, CA 92243

Subject: Cultural Resource Study for the Proposed Niland Anomaly MEIR Project

Dear Mr. Kirkish:

WESTEC Services, Inc. is currently engaged in a cultural resource study in the Salton Sea Known Geothermal Resource Area (KGRA) Imperial County, California.

The approximate 20,000 acre study region is an irregularly shaped area situated at the southeastern edge of the Salton Sea. Roughly 30 to 35 percent of the geothermal resource area lies within the Salton Sea itself, (map is included). WESTEC Services, Inc. has contacted the San Diego Museum of Man, and Imperial Valley College concerning their knowledge of existing cultural resources in the project region.

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Sincerely,

Richard

Richard L. Carrico
Manager, Cultural Resources Group

RLC/cc
Enclosure

WESTEC Services, Inc.
3211 Fifth Avenue
San Diego, CA 92103
(714) 294-9770

January 2, 1981

Dr. Knox Mellon
State Historic Preservation Officer
Office of Historic Preservation
California Department of Parks
and Recreation
The Resources Agency
1416 Ninth Street
Sacramento, CA 95814

Subject: Cultural Resource Study for the Proposed Niland Anomaly MEIR Project

Dear Dr. Mellon:

WESTEC Services, Inc. is currently engaged in a cultural resource study in the Salton Sea Known Geothermal Resource Area (KGRA) Imperial County, California.

The approximate 20,000 acre study region is an irregularly shaped area situated at the southeastern edge of the Salton Sea. Roughly 30 to 35 percent of the geothermal resource area lies within the Salton Sea itself, (map is included).

In order to achieve a thorough understanding of cultural resource potential within the immediate project boundaries we are requesting your assistance on this matter. We would like to obtain a list of all properties that (1) have been nominated to the National Register of Historic Places, or (2) are currently under consideration for such nomination. If, in addition, your office oversees a state-operated program of historic landmarks or other official site designation, we would appreciate receiving a list of such landmarks located within the aforesaid study area. Thank you for your help.

Sincerely,

Richard L. Carrico

Richard L. Carrico
Manager, Cultural Resources Group

RLC/cc
Enclosure

APPENDIX 3.8

LAND USE

APPENDIX 3.8

LAND USE

A. Imperial County General Plan

Geothermal Energy Development

- Encourage the exploration for and development of new sources of geothermal energy (Open Space Element).

- Provide for the maximum feasible development of geothermal energy, water, and minerals while assuring the maintenance of environmental quality (Conservation Element).

- Each geothermal anomaly shall be developed with due consideration for the optimum recovery of the resource (Geothermal Element).

- Participate in and promote a program to develop and centralize data relevant to the geothermal resource for the purpose of providing long-range direction based on reliable technical information (Conservation Element).

In addition to the foregoing, the document, "Imperial County Goals", published February 1975, contains additional goals which relate to the Geothermal Resource. While not part of the General Plan, the following goal also guides development of this resource:

- To increase the store of knowledge of geothermal resources, to encourage age and promote the beneficial development of geothermal resources for multiple use, including power, water, minerals and other uses, and to assure that the development is compatible with agriculture and our environment.

Agricultural Preservation

- Agriculture is the current mainstay of Imperial County's economy. Therefore, in order to achieve the General Plan goals it is imperative that the agricultural land be guarded against noncompatible land uses (Ultimate Land Use Plan).

- Preserve the majority of productive agricultural lands for the purpose of providing food and fiber to local, state, and national markets (Conservation Element).

- Production facilities must be sited in a manner designed to lessen impact on agriculture. Slant drilling may be required in irrigated areas when appropriate. Liquid transmission lines shall utilize existing easements or rights-of-way whenever possible (Geothermal Element).

- Geothermal resources, while potentially of considerable importance, will not be permitted to degrade the natural environment or threaten the continued viability of irrigated agriculture (Conservation Element).

- Preserve and enhance the agricultural base of Imperial County (Conservation Element).

- Retain the major portion of agricultural acreage currently in production. Also preserve major areas of Class II and III soils which are currently unirrigated but which offer significant potential when water is made available (Conservation Element).

Preservation and Utilization of Natural Resources

- Encourage only those uses and activities that are compatible with the fragile desert, aquatic and marshland environment (Open Space Element).

- Protect areas of significant mineral resource value, including available sand and gravel sources from unplanned urbanization (Conservation Element).

- Encourage the maximum utilization of available mineral resources consistent with the protection of the natural environment (Conservation Element).

- Encourage and provide for the management and wise use of water resources for contact and non-contact recreation, groundwater recharge, hydroelectric energy production, and wildlife habitat as well as for domestic and irrigation use (Conservation Element).

Environmental Protection

- Encourage development of geothermal energy and water desalinization consistent with environmental protection and the preservation of productive agricultural lands (Open Space Element).

- Encourage the exploration and development of geothermal resources by public and private organizations consistent with protection of environmental values (Conservation Element).

- In order to avoid hazards from accidential brine spills, each producer shall design all production and reinjection transmission lines to minimize such hazards (Geothermal Element).

- Production of geothermal resources requires use of water for both cooling and reinjection. Since agricultural production is likewise dependent upon water sources, it is the County's intention to require the efficient utilization of water in geothermal operations and to encourage and foster the use of other than irrigation water. However, the County will authorize the use of fresh water for demonstration or experimental power plants to a maximum of 75 megawatts net electric in each economic anomaly for the initial five years of operation (Geothermal Element).

- County standards will require reinjection of all geothermal fluids extracted from irrigated areas of the County or from any area that could directly impact those irrigated lands. Applications for deviation from the above policy will be submitted to the Division of Oil and Gas for review and findings prior to County consideration (Geothermal Element).

Land Use

- Geothermal Overlay Zoning and use of Conditional Use Permits are the most appropriate land use control devices to accomplish the County's desire of maximizing resource development while preserving land for agricultural uses. The area to be zoned should be large enough to encompass the area anticipated for ultimate development (Geothermal Element).

- Power transmission lines and corridors must be designed to minimize the impact on agricultural operations, urban areas and recreational activities (Geothermal Element).

Recreation

The following excerpts were all extracted from the Recreation Element.

- The Salton Sea National Wildlife Refuge provides habitat for waterfowl and opportunity for passive non-consumptive recreational uses. The Federal government should be encouraged to extend its land holdings to permanently preserve and protect these natural resources.

- Water bodies or streams are usually important recreational and aesthetic resources in the arid lands of Imperial County, and the Salton Sea is a water resource of regional importance. The Sea possesses productive fisheries and other water oriented opportunities, both active and passive. However, the salinity of the Salton Sea has risen significantly in recent years, and now threatens the continued existence of the fishery. If adequate measures are not taken to halt or reverse this process, it will disappear by the mid-1970s. Measures considered for the protection and enhancement of the Sea are discussed in the Conservation Element.

- Recognize the regional significance of the development and conservation of recreational opportunities in Imperial County.

- Provide a broad range of recreation facilities for all ages and economic groups, emphasizing family oriented opportunities.

- Encourage the acquisition and development of additional County, State, and Federal recreational facilities.

- Encourage State and Federal agencies to develop and operate recreational facilities which are determined by the County to possess more than local significance.

- Provide County input into State and Federal recreation and wildlife planning programs.

- Permit recreation uses primarily in areas adjacent to thoroughfares or bodies of water.

- Off-road vehicle use is recognized as a popular recreational pursuit in the Imperial Valley. Areas which are not severely affected by ORV use should be set aside for this purpose.

- Encourage the recreational use of lands located in hazardous areas such as flood plains.
- With the Imperial Irrigation District, explore the possibility of utilizing and improving certain portions of the canal system for picnic and fishing sites.
- Encourage the use of inobtrusive materials, structures, and color in power line transmission corridors. Vegetative screening is encouraged wherever possible.

The Recreation Element does not state any specific goals, objectives or policies. Instead, it summarizes the facilities which existed at the time it was written and recommends future expansion in some areas. It notes that the potential for campers along the eastern shore of the Salton Sea is enormous and that, in order to meet the recreational needs for the influx of visitors, additional facilities will be needed. The Element specifies that both the resident and the visitor should have better and more recreational facilities.

B. California Desert Conservation Area Final Environmental Impact Statement and Proposed Plan

Recreation Element

The BLM administers a small portion of the land within the study area. The vacant BLM lands that are open to the public include portions of seven one-square mile sections onshore and portions of 12 sections offshore. The total acreage of onshore lands is 2 to 3 square miles; offshore acreage is about 11.5 square miles. In general, the BLM has overlooked the lands they are responsible for in the study area; there have been no planning efforts for these lands (Schneider, 1980).

Some off-road vehicle use is currently evident in the northeastern portion of the study area. However, the California Desert Conservation Area Plan does not designate any of the study area for recreation opportunities (U.S. Department of the Interior, BLM, 1980b). That plan includes the following goals within the Recreation Element, most of which are oriented to land-based recreation:

- Provide a wide range of opportunities within resource capabilities for engaging in recreational activities for all Desert users, particularly those seeking release from adjacent urban environments.

- Provide recreational management and facilities consistent with sound visitor and resource protection practices, with emphasis on conserving desert resources that have special, scenic, historic, scientific, or recreation values.

- Protect Desert land users and minimize conflicts among recreationists and between recreationists and other users of desert resources.

- Enhance the enjoyment of the recreation experience, promote resource opportunities, and aid resource protection by increasing understanding of the California Desert's resources uses through public involvement in volunteer efforts, interpretation and environmental education programs, community outreach efforts, and other recreational resource programs.

- Monitor and evaluate visitor-use preferences and adjust Bureau programs to meet these changing needs.

- Provide for off-road vehicle use where appropriate in conformance with FLPMA, Section 601, and Executive Orders 11644 and 11989.

G-E-M Resources Element

The general goals of the G-E-M Resources Element are to:

- Actively develop and enhance the productive potential of G-E-M resources and the quality of the environment.

- Provide access to and availability of as much public land as possible for mineral exploration and development.

- Provide ways of access and opportunities for exploration and development on public lands which are assessed to have a potential for energy mineral resources (geothermal, oil, gas, uranium, thorium) considered to be paramount priorities nationally and statewide and mineral resources of local and state importance (sand and gravel, limestone, gypsum, iron, specialty clays and zeolites).

This Element makes special provisions for the Salton Sea which has been excluded from the multiple-use classification. Due to its sensitive nature as potential habitat for some federally listed rare and endangered wildlife species, the guidelines for Class L, described below, apply to all mineral leasing activities (oil, gas, geothermal, sodium and potash) on public land in and under the Salton Sea. Multiple use Class L is a limited use class; its purpose is to protect sensitive natural, scenic, ecological, and cultural resource values. Public lands designated as Class L are managed to provide for generally low-intensity, carefully controlled multiple use and development of resources while ensuring that sensitive natural areas are not diminished. In addition to parcels (both on land and underwater) under direct management of BLM, mineral rights on patented lands (private, state or other federally managed lands) in some cases may have been retained.

Designated economic resources include Locatable and Leaseable geothermal resources in the Salton Sea KGRA. Sand and gravel resources are shown along a belt on the eastern boundary and at one location now underwater in the Salton Sea.

Areas designated as having a Potential for Saleable Minerals include the volcanic domes with pumice, cinders and sand and gravel resources. Scattered areas along the eastern boundary appear to be designated as Past or Present Production (includes Caltrans materials sites and Caltrans sites in reserve). Other areas in this location are designated as having Favorable Lithology (sand and gravel).

The Salton Sea KGRA is designated as an area with a Potential for Energy Georesources. Exploratory drilling sites are classified as being "known valuable" for geothermal resources. The remainder of the study area outside of the KGRA are designated as "potentially valuable," for oil and gas.

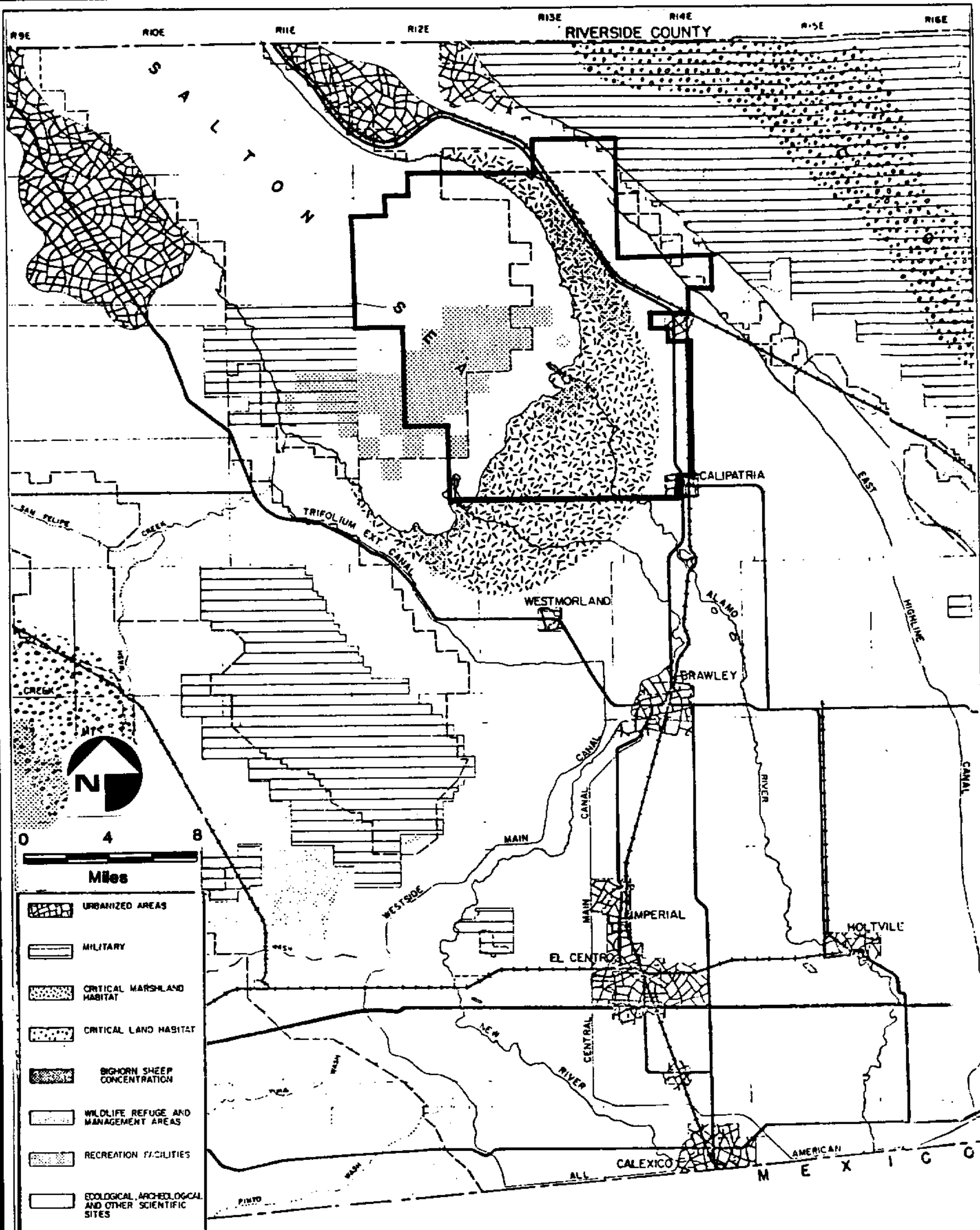
Energy Production and Utility Corridors Elements

Relevant goals of this Element are to:

- Identify locations for potential geothermal and wind power facilities.
- Establish a network of joint-use planning corridors capable of meeting projected power needs to the year 2000.

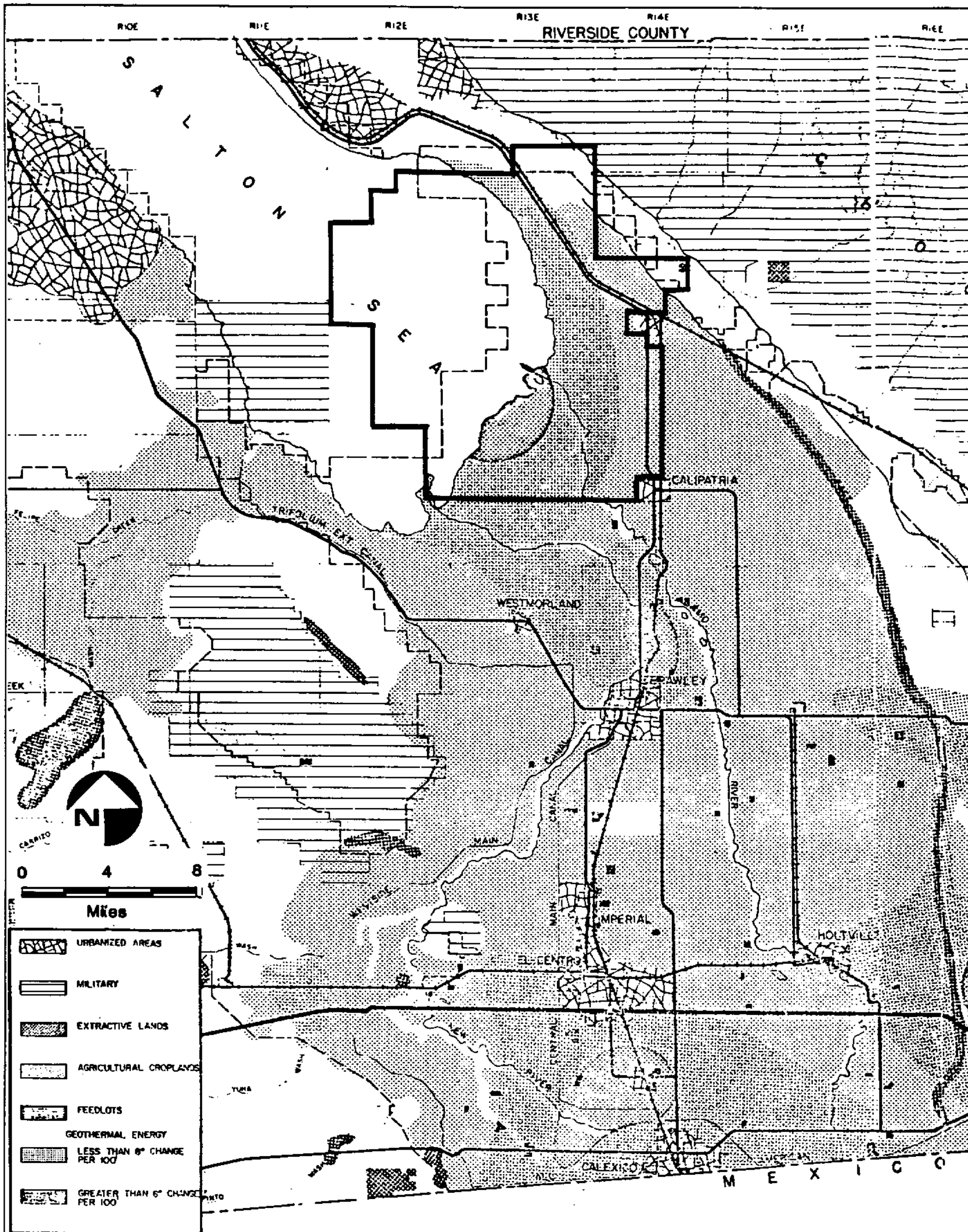
The Magma power plant site is designated on the Energy Production and Utility corridor map as well as the existing East Highline and Coachella Canal Systems. A corridor of joint responsibility of BLM and local government is proposed for an area just east of the study area.

WESTEC Services, Inc.



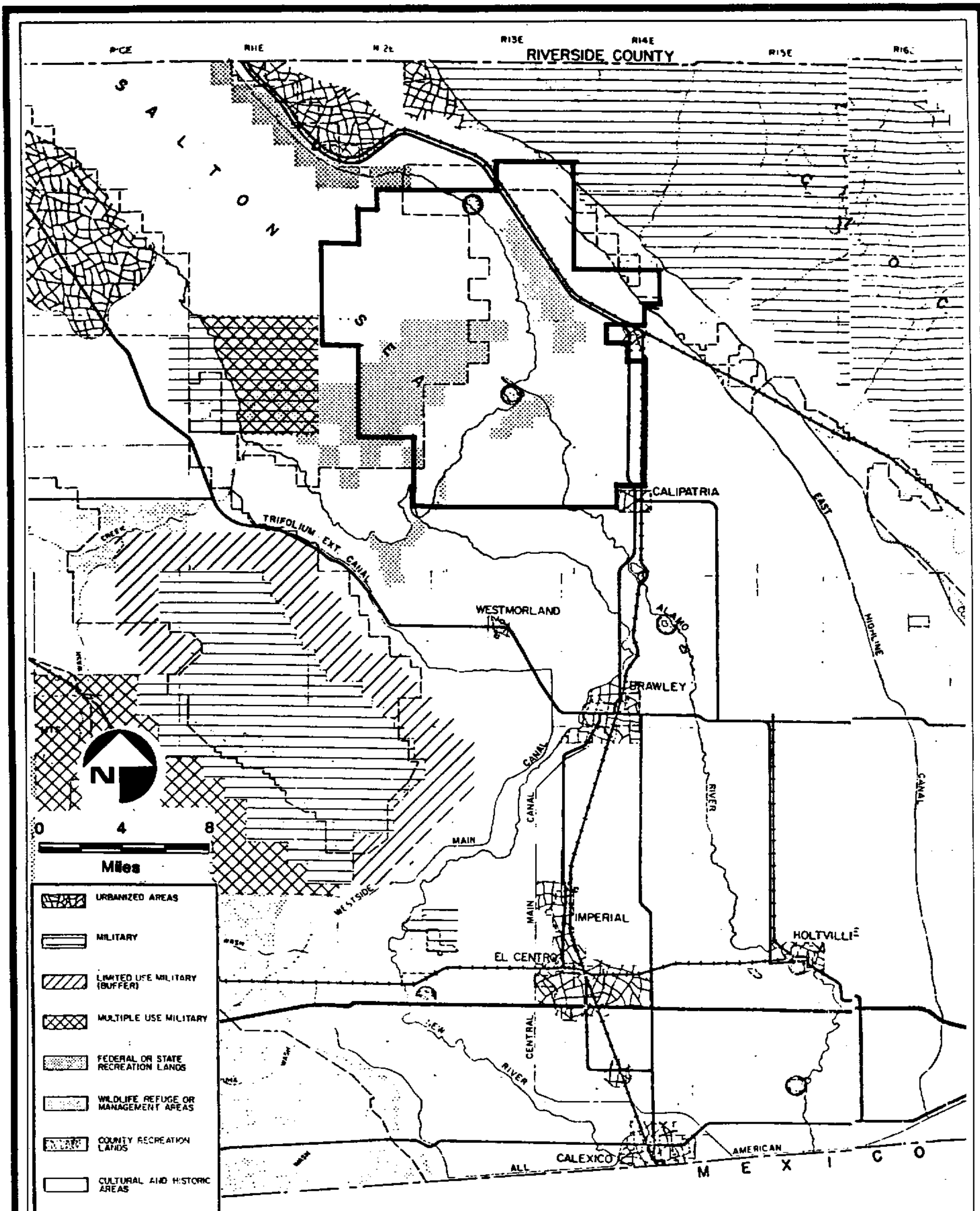
Open Space for the Preservation of Natural Resources
(Open Space Element)

FIGURE A3.8-1



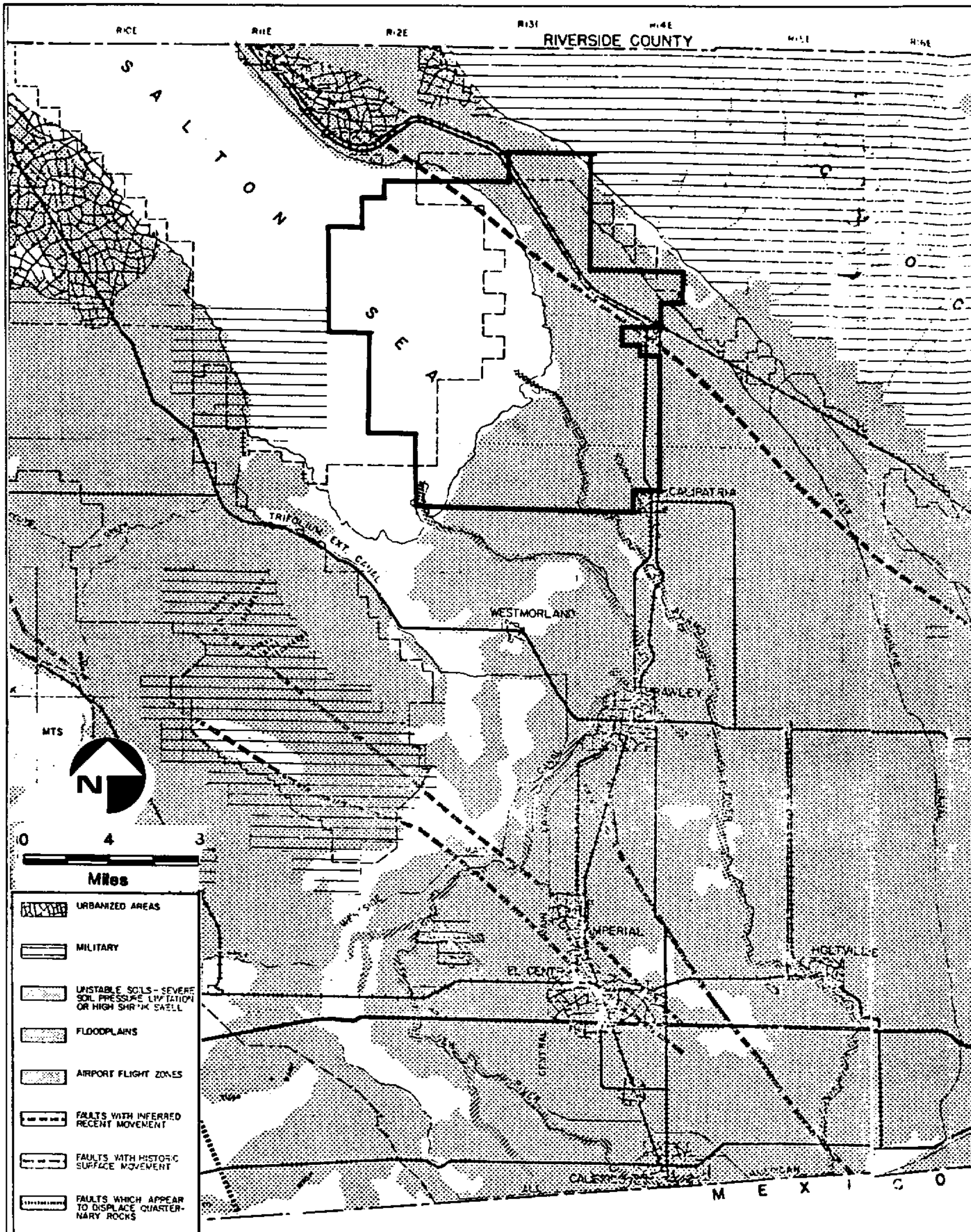
Open Space for the Managed Production of Resources
(Open Space Element)

FIGURE A3.8-2



Open Space for Outdoor Recreation
(Open Space Element)

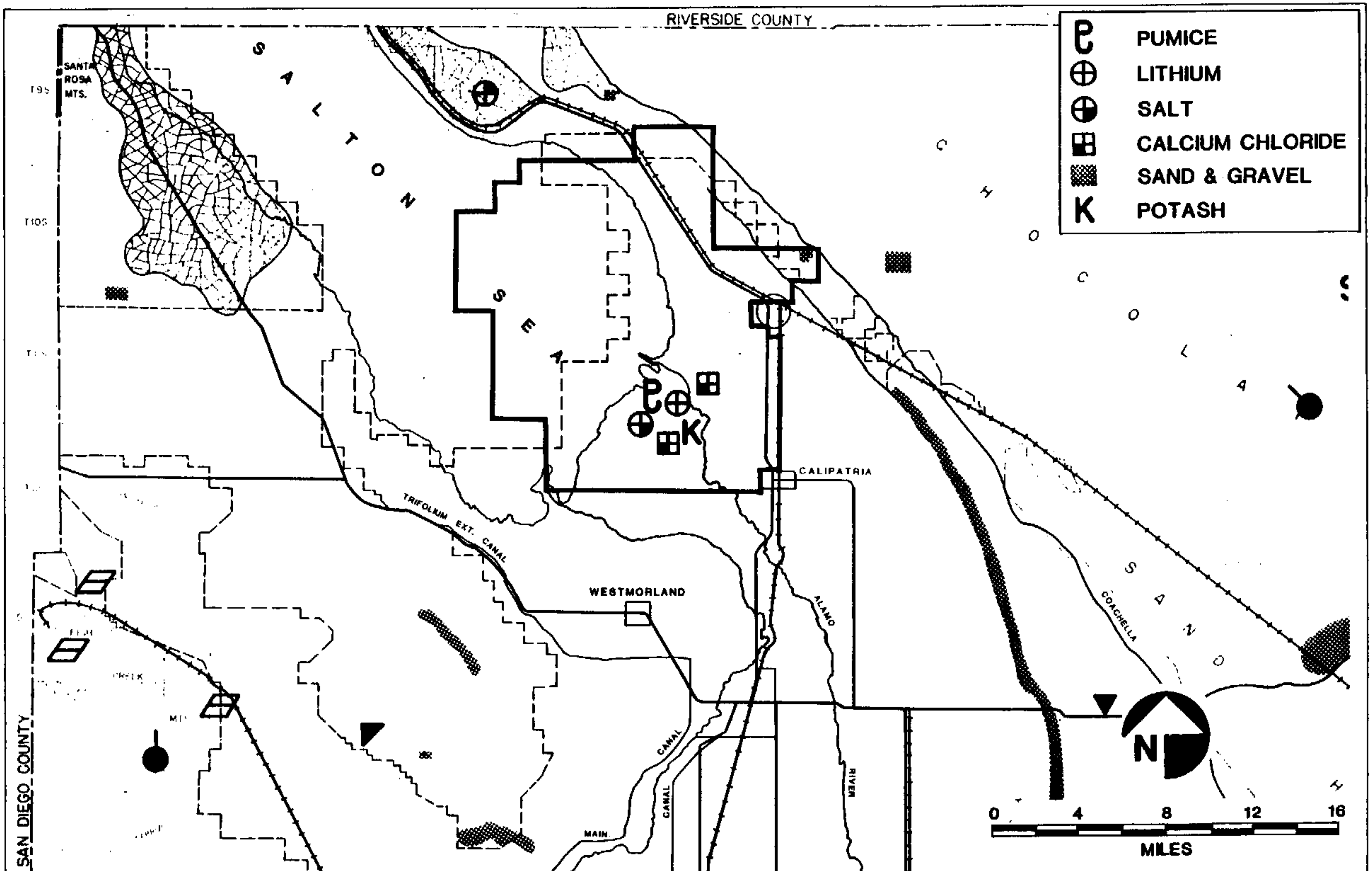
FIGURE A3.8-3



Open Space for the Protection of Public Health and Safety
(Open Space Element)

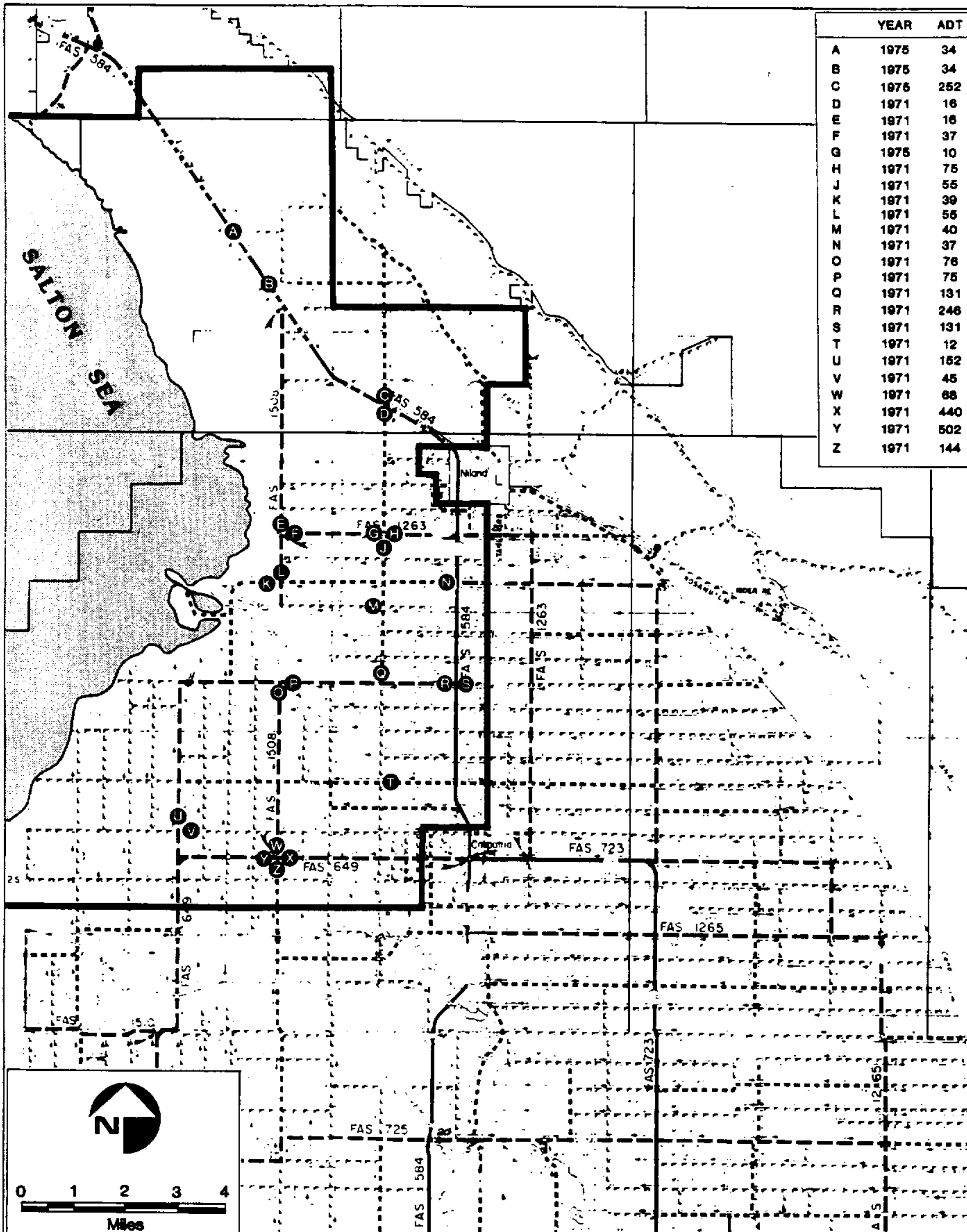
FIGURE A3.8-4

WESTEC Services, Inc.



Mineral Resources in Study Area (Conservation Element)

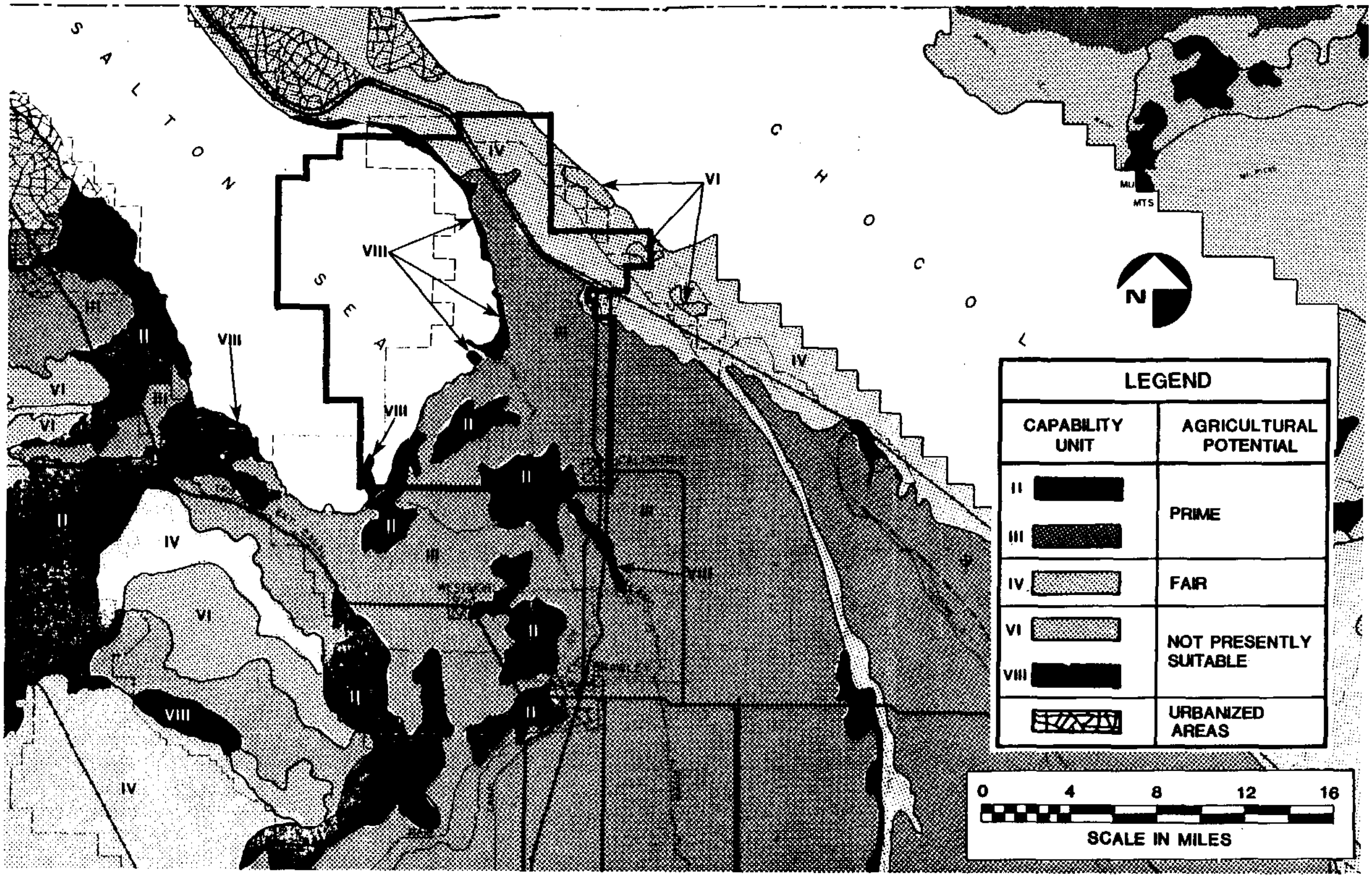
FIGURE A3.8-5



	YEAR	ADT
A	1975	34
B	1975	34
C	1975	252
D	1971	16
E	1971	16
F	1971	37
G	1975	10
H	1971	75
J	1971	55
K	1971	39
L	1971	55
M	1971	40
N	1971	37
O	1971	76
P	1971	75
Q	1971	131
R	1971	246
S	1971	131
T	1971	12
U	1971	152
V	1971	45
W	1971	68
X	1971	440
Y	1971	502
Z	1971	144

Imperial County Traffic Counts (1971–1975)

FIGURE A3.8-7



Agricultural Land Resources in Study Area (Conservation Element)

FIGURE A3.8-6

LAND USE

CORRESPONDENCE

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Conservation Division
345 Middlefield Road, MS 80
Menlo park, CA 94025

September 5, 1980

Memorandum

To: State Director, Bureau of Land Management, Sacramento, California

From: Conservation Manager, Western Region
U.S. Geological Survey

Subject: Additions to the Salton Sea KGRA, California

In accordance with Section 2(e) of the Geothermal Steam Act of 1970 (Public Law 91-581) and 43 CFR 3200.0-5, the following described lands have been defined as additions to the Salton Sea Known Geothermal Resources Area, effective September 5, 1980:

San Bernardino Meridian, California

T. 12 S., R. 12 E.,
Sec. 24.

T. 12 S., R. 13 E.,
Secs. 19 and 20;
Sec. 21, W½;
Sec. 28, W½;
Secs. 29, 30, 31, and 32.

T. 11 S., R. 14 E.,
Secs. 8, 17, and 20.

The area described aggreagates 7,085.40 acres, more or less.

We will publish notice of the action in the Federal Register as appropriate.

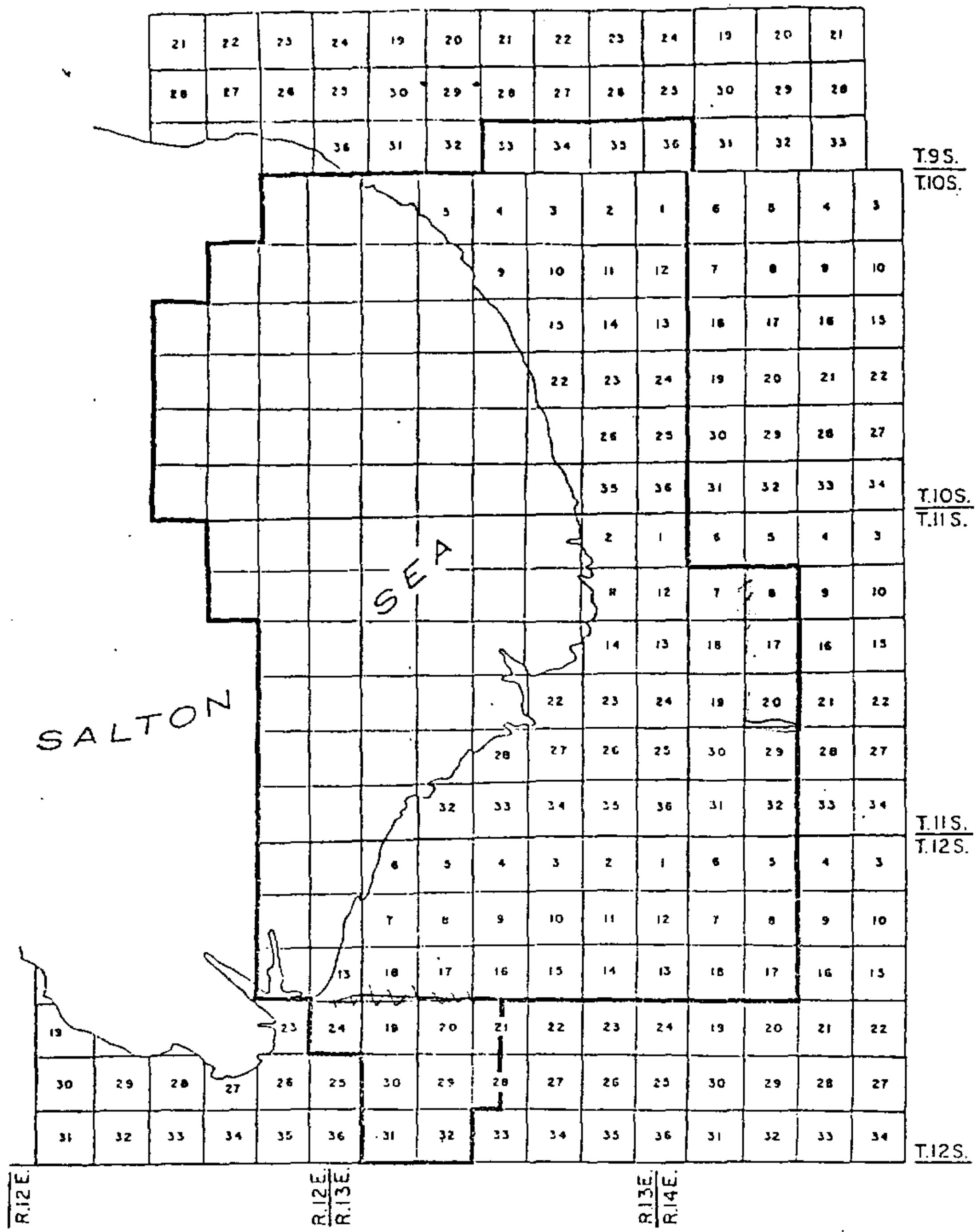
Conservation Manager
Western Region

Enclosure: KGRA Plat

cc: Conservation Manager, Western Region
Chief, Branch of Fluid Minerals Management
DCM, Geothermal
DCM Resource Evaluation, Western Region
District Geologist, L.A.
Coordinator, Geothermal Research Program

SALTON SEA K.G.R.A.

T.9-12S., R.12-14E., San Bernardino Meridian, California



Pursuant to the authority vested in the Secretary of the Interior by Sec. 21(a) of the Geothermal Steam Act of 1970 (84 Stat. 1566, 1572; 30 U.S.C. 1020), and delegations of authority in 220 Departmental Manual 4.1H, Geological Survey Manual 220.2.3, and Conservation Division Supplement (Geological Survey Manual) 220.2.1G, I redefine the

SALTON SEA

known geothermal resources area as indicated hereon, effective September 5, 1980

Henry L. Cullins
Acting Conservation Manager

(solid outline)	Previously defined	95,802.0
(dashed outline)	Defined this action	7,085.4
	Total acres	102,887.4

REFERENCES

Imperial, County of, 1977, "Geothermal Element," Imperial County General Plan, Imperial County, El Centro, California.

Imperial, County of, 1973, "Conservation Element," Imperial County General Plan, Imperial County, El Centro, California.

Imperial, County of, 1973, "Open Space Element," Imperial County General Plan, Imperial County, El Centro, California.

Imperial, County of, 1973, "Recreation Element," Imperial County General Plan, Imperial County, El Centro, California.

Imperial, County of, 1973, "Ultimate Land Use Plan," Imperial County General Plan, Imperial County, El Centro, California.

Imperial, County of, 1975, "Imperial County Goals," Imperial County, El Centro, California, February.

Schneider, Robert, 1980, Outdoor Recreation Planner, Bureau of Land Management, personal conversation, December 17.

U.S. Department of the Interior, Bureau of Land Management (BLM), 1980, The California Desert Conservation Area, Final Environmental Impact Statement, and Proposed Plan.

APPENDIX 3.9

SOCIOECONOMICS

APPENDIX 3.9
SOCIOECONOMICS

Tables A3.9-1 through A3.9-6 presented in this appendix provide fiscal information on a Tax Rate Area basis by in-service year for all geothermal facilities with presently determined sites. Tables A3.9-1, A3.9-2 and A3.9-3 provide the increases to market value, assessed value, and property tax revenue within the Tax Rate Area as a whole. Tables A3.9-4, A3.9-5 and A3.9-6 present the increases in property tax revenue accruing to taxing jurisdictions from new geothermal development by the in-service year. The total cumulative column is the total property tax revenue accruing to the Tax Rate Area and affected jurisdictions after all proposed development (with presently determined sites) has occurred.

Table A3.9-1

PROJECTED ADDITIONS TO MARKET VALUE BY TAX RATE AREA SELECTED GEOTHERMAL FACILITIES[1]
SALTON SEA KGRA, IMPERIAL COUNTY
(in Millions)

Tax Rate Area	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total Cumulative
58-000	$ 91.0		$ 84.0	$ 84.0											$ 259.0
58-003				$ 84.0		$ 84.0					$ 84.0			$ 84.0	$ 336.0
90-002					$340.0	$340.0	$340.0	$254.0							$1,274.0

[1] Only those facilities with presently determined sites have been included.

Source: WESTEC Services, Inc.; Williams-Kuebelbeck and Associates, Inc.

Table A3.9-2

PROJECTED ADDITIONS TO ASSESSED VALUE BY TAX RATE AREA SELECTED GEOTHERMAL FACILITIES[1]
SALTON SEA KGRA, IMPERIAL COUNTY
(in Millions)

Tax Rate Area	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total Cumulative
58-000	$22.8		$21.0	$21.0											$ 64.8
58-003				$21.0		$21.0					$21.0			$21.0	$ 84.0
90-002					$85.0	85.0	$85.0	$63.5							$318.5

[1] Only those facilities with presently determined sites have been included.

Source: Williams-Kuebelbeck and Associates, Inc.

Table A3.9-3

PROJECTED ADDITIONS TO PROPERTY TAX REVENUE BY TAX RATE AREA SELECTED GEOTHERMAL FACILITIES[1]
(in Thousands)

Tax Rate Area	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total Cumulative
58-000	$910.0		$840.0	$840.0											$ 2,590.0
58-003				$840.0		$ 840.0					$840.0			$840.0	$ 3,360.0
90-002					$3,400	$3,400.0									$12,740.0

[1]Only those facilities with presently determined sites have been included.

Source: Williams-Kuebelbeck and Associates, Inc.

Table A3.9-4

PROJECTED ADDITIONS TO
ANNUAL PROPERTY TAX REVENUE ACCURING TO TAXING JURISDICTIONS[1]
WITHIN TAX RATE AREA 58-000
(in Thousands of Constant 1981 Dollars)

Taxing Jurisdictions	Annual Tax Increment Factor	1982	1984	1985	Total
General Rund	.349	$317.6	$293.2	$293.2	$ 904.0
County School Service Fund	.004	3.6	3.4	3.4	10.4
Child Institutional Tuition	.001	0.9	0.8	0.8	2.5
Juvenile Hall	.004	3.6	3.4	3.4	10.4
Imperial Community College	.087	79.2	73.1	73.0	225.4
Physically Handicapped	.006	5.5	5.0	5.0	15.5
Trainable Severely Mentally Retarded	.002	1.8	1.7	1.7	5.2
Development Center	.002	1.8	1.7	1.7	5.2
Aurally Handicapped	.003	2.7	2.5	2.5	7.7
County Library	.012	10.9	10.0	10.0	30.9
Fire Protection	.055	50.1	46.2	46.2	142.5
Pioneers Memorial Hospital	.036	32.8	30.2	30.2	93.2
Calipatria Unified	.439	399.5	368.8	368.8	1,137.1
Total	1.000	$910.0	$840.0	$840.0	$2,590.0

[1]Property tax revenues have only been calculated for those facilities with presently determined sites.

Source: Williams-Kuebelbeck and Associates, Inc.

Table A3.9-5

PROJECTED ADDITIONS TO
ANNUAL PROPERTY TAX REVENUE ACCRUING TO TAXING JURISDICTIONS[1]
WITHIN TAX RATE AREA 58-003
(in Thousands of 1981 Dollars)

Taxing Jurisdictions	Annual Tax Increment Factor	1985	1987	1992	1995	Total
General Fund	.325	$273.0	$273.0	$273.0	$273.0	$1,092.0
School Service Fund	.004	3.4	3.4	3.4	3.4	13.6
Children's Institutional Tuition	.001	.9	.9	.9	.9	3.6
Juvenile Hall	.000	—	—	—	—	—
Imperial Community College	.081	68.0	68.0	68.0	68.0	272.0
Physically Handicapped	.006	5.0	5.0	5.0	5.0	20.0
Trainable Severely Mentally Retarded	.002	1.7	1.7	1.7	1.7	6.8
Development Center	.003	2.5	2.5	2.5	2.5	10.0
Aurally Handicapped	.003	2.5	2.5	2.5	2.5	10.0
County Library	.012	10.0	10.0	10.0	10.0	40.4
Fire Protection	.053	43.7	43.7	43.7	43.7	174.8
Pioneers Memorial Hospital	.033	27.7	27.7	27.7	27.7	110.8
Niland Fire District	.068	57.1	57.1	57.1	57.1	228.4
Calipatria Unified	.410	344.4	344.4	344.4	344.4	1,377.6
Total	100.000	$840.0	$840.0	$840.0	$840.0	$3,360.0

[1]Property tax revenues have only been calculated for those facilities with presently determined sites.

Source: Williams-Kuebelbeck and Associates, Inc.

Table A3.9-6

PROJECTED ADDITIONS TO
ANNUAL PROPERTY TAX REVENUE ACCRUING TO TAXING JURISDICTIONS[1]
WITHIN TAX RATE AREA 90002
(in Thousands of 1981 Dollars)

Taxing Jurisdictions	Annual Tax Increment Factor	1986	1987	1988	1989	Total
General Fund	.349	$1,186.6	$1,186.6	$1,186.6	$ 886.5	$ 4,446.3
County School Service Fund	.005	17.0	17.0	17.0	12.7	63.7
Children's Institutional Tuition	.001	3.4	3.4	3.4	2.5	12.7
Juvenile Hall	.000	—	—	—	—	—
Imperial Community College	.087	295.8	295.8	295.8	221.0	1,108.4
Physically Handicapped	.007	23.8	23.8	23.8	17.8	89.2
Trainable Severely Mentally Retarded	.002	6.8	6.8	6.8	5.1	25.5
Development Center	.003	10.2	10.2	10.2	7.6	38.2
Curably Handicapped	.003	10.2	10.2	10.2	7.6	38.2
County Library	.013	44.2	44.2	44.2	33.0	165.6
Fire Protection	.055	187.0	187.0	187.0	139.7	700.7
Pioneers Memorial Hospital	.036	122.4	122.4	122.4	91.4	458.6
Brawley Union High	.199	676.6	676.6	676.6	505.5	2,535.3
Westmoreland Elementary	.240	816.0	816.0	816.0	609.6	3,057.6
Total	1.000	$3,400.00	$3,400.0	$3,400.0	$2,540.0	$12,740.0

[1] Property tax revenues have only been calculated for those facilities with presently determined sites.

Source: Williams-Kuebelbeck and Associates, Inc.

REFERENCES

WESTEC Services, Inc., 1981, personal communication, January, 1981.

Williams-Kuebelbeck and Associates, Inc., 1981, Data generated for Niland Master Environmental Impact Report.

APPENDIX 3.10

VISUAL RESOURCES AND SCENIC QUALITY

TABLE OF CONTENTS

LIST OF FIGURES

TABLE OF CONTENTS (Continued

LIST OF FIGURES (Continued)

LIST OF TABLES

SECTION I
INTRODUCTION

The following study was conducted as part of a Master Environmental Impact Report for the Salton Sea Anomaly KGRA and Geothermal Overlay Expansion project for the County of Imperial. This report examines the existing visual resources within the study area and how they would be affected by the project. The study has been conducted according to the Bureau of Land Management (BLM) Visual Resource Management Procedure.

1.1 PURPOSE

The purpose of this study is to prepare a baseline inventory of the visual resources of the project area in Imperial County, California. The inventory consists of an evaluation of general landscape characteristics, scenic quality, the visibility of the landscape, and the visual sensitivity of the landscape and observers. The evaluation is intended to provide information necessary to assess the impact of potential geothermal development in the study area. The analysis was conducted in December 1980 and January 1981.

1.2 STUDY AREA

The project area is located on the eastern side of the Imperial Valley, as shown on Figure A3.10-1, and covers approximately 160 square miles, including a portion of the Salton Sea. Imperial Valley occupies a portion of a larger, northwest trending basin in the Basin and Range Province, known as the Salton Trough. The Salton Trough extends from San Gorgonio Pass on the north to the Gulf of California on the south. It is bounded on the west by the Peninsular Range of southern and Baja California and on the east by the Orocopia, Chocolate and Cargo Muchacho Mountains. The vast majority of the Trough is below sea level and very flat, consisting of wide stretches of desert, broken by agricultural lands, rural residences and small towns and cities. The surrounding mountains tend to emphasize the low elevation and extreme flatness of the terrain.

1.3 METHODOLOGY

The BLM's established method for visual resources inventory as contained in Manual 8400, Visual Resources Management, was utilized for this project. This method involves three separate components:

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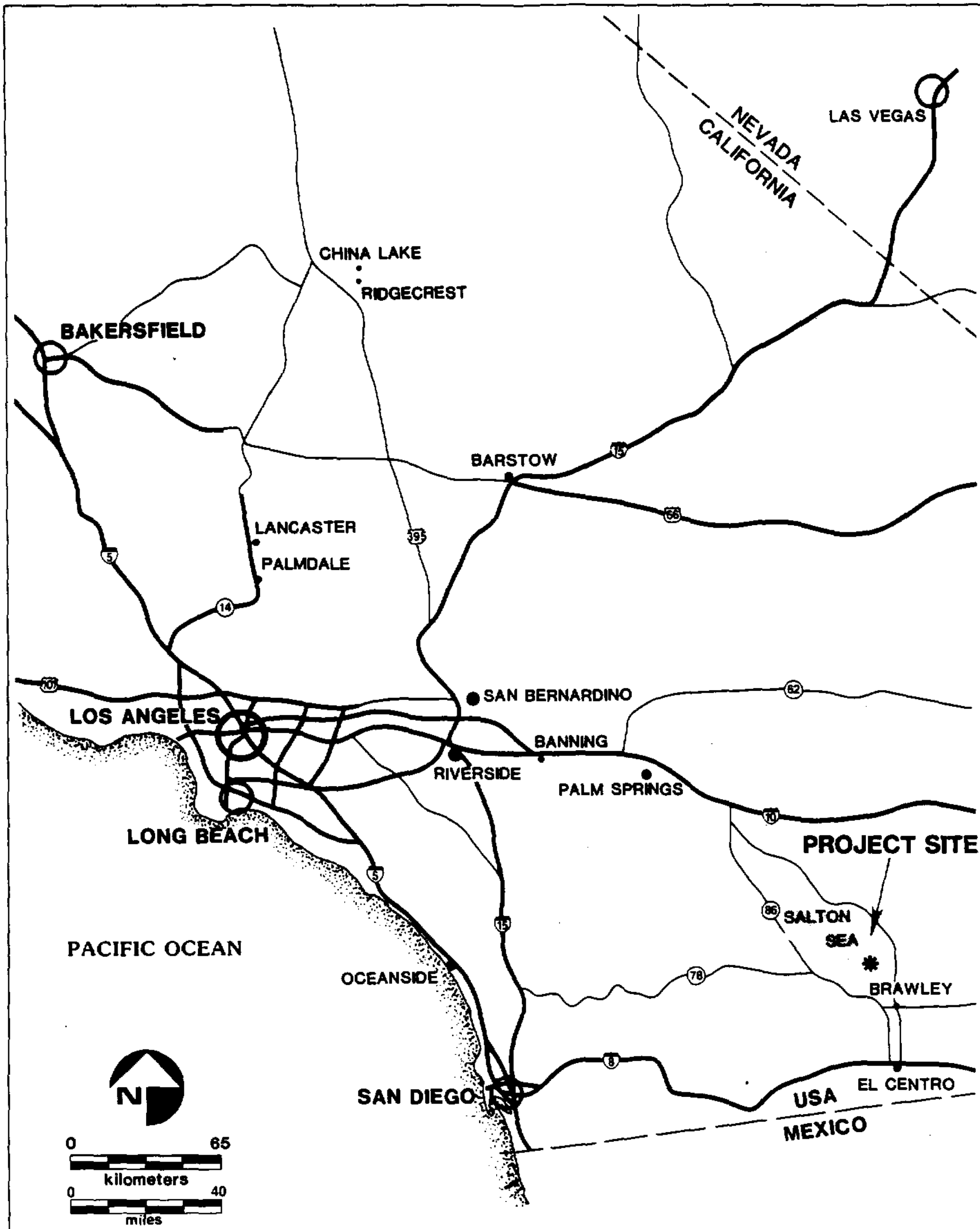


Regional Map

FIGURE A3.10-1

- Scenic Quality: the relative scenic value of a landscape.
- Visual Sensitivity: the number of observers of a landscape and their attitude towards visual change.
- Distance Zones: the viewer/landscape distance relationship.

The combination of these components identifies the overall value of visual resources and is used to determine an acceptable degree of alteration within each landscape.

Scenic quality analysis begins with an inventory of the elements contained within the landscape. Key factors are landform, topography, color, water availability, vegetation, uniqueness, cultural modifications, and the influence of adjacent scenery. Landscape character types are identified and mapped. Scenic quality is then rated on the basis of these key factors. Criteria used for this study were developed by the BLM during the California Desert Conservation Area survey, and are similar to those contained in Manual 8411, Upland Visual Resource Inventory and Evaluation. Criteria are explained in more detail in Section II, Scenic Quality.

Visual sensivity consists of both user volume and user attitudes. (In the BLM system, "user" is defined as an observer of the landscape, including both on- and offsite viewers.) User volume data was garnered from roadway traffic volume and from estimates of site users. User attitudes toward possible visual change were identified by BLM and Imperial County Planning Department staff who are familiar with the study area and local feelings. This is evaluated in Section III, Sensivitiy Analysis.

Distance zones are established to quantify the observer/landscape distance relationship. This entails locating users and viewers of the study area and determining the distance zone classification (such as foreground, middleground, background). See Section III for a more detailed discussion.

The BLM procedure combines scenic quality rating, landscape sensitivity and distance zones to designate visual resource management classes. There are five categories of VRM class, from Class I, which permits only ecological change, to Class V, which allows substantial visual modification. Section III contains an analysis of the visual resource classes in the study area.

The area has been surveyed for two major visual studies for SDG&E, the Arizona Public Service/SDG&E Interconnection Project (1980) and the Sundesert Nuclear Project Transmission System (1976). These documents were used extensively as a data base. In addition to a comprehensive search of existing data, the visual resources inventory utilized ground and air photos and field reconnaissance. BLM and Imperial County Planning Department personnel were also consulted.

SECTION II
SCENIC QUALITY

2.1 VISUAL RESOURCES INVENTORY

2.1.1 Topography

The study area is located on the eastern side of the Imperial Valley and is typical of the Imperial Valley: generally flat with little relative relief. The majority of the study area is located on an ancient lake bed, which is the reason for its extreme flatness. Elevations are low throughout this area, and the lowest elevation on the study area, the level of the Salton Sea, which is about 225 feet below mean sea level (MSL). The Salton Sea makes up approximately half the study area.

Two areas differ from the flat terrain of most of the site: the Chocolate Mountain foothills in the northeast; and the extinct volcanic domes in the center. The Chocolate Mountains lie to the east and northeast of the study area, and form the eastern boundary of the Imperial Valley. The foothills rise steadily and gradually from the level of the Salton Sea to a ridge about 1200 feet above MSL, with several peaks up to 2100 feet. The highest elevations on the study area (150 feet above MSL) are located in these foothills.

The extinct volcanic domes are located about seven miles northwest of Calipatria. These five domes are known as Mullet Island, Obsidian Butte, Rock Hill and Red Hill, which contains two domes. Elevations range from 190 to 127 feet below MSL, which indicates a relative relief of 35 to 100 feet above the level of the Salton Sea. Mullet Island, the lowest of the five, lies about 1½ miles from shoreline in the Salton Sea. The remaining four domes are close to the edge of the Salton Sea, and have recently been made islands by the continuing rise of water level. Because of the overall flatness of the study area, these low domes are visible for up to 12 miles on a clear day.

The study area is crossed by the northwest trending Alamo River. This river and the New River, to the south of the study area, have formed bird's foot deltas as they drain into the Salton Sea. Both deltas are included in the study area, and each extends approximately 2.5 miles into the Sea.

The northern portion of the study area is crossed by numerous small westward draining streams. Most of these are intermittent, but the southernmost, by Wister, is perennial, emptying into a marsh area by the Sea.

2.1.2 Vegetation

The study area is primarily used for agriculture. The northern portion of the area, however, is undisturbed. This area is very sparsely vegetated with desert scrub. Some marsh type vegetation occurs along the edge of the Salton Sea, and there is some riparian vegetation along the Alamo River and irrigation canals.

2.1.3 Land Use

The majority of the land in the study area is used for agriculture. The Salton Sea Wildlife Refuge and the Wister Waterfowl Management Area are located in and along the Salton Sea. The sea-land interface is used extensively for recreation, primarily for camping, hunting and fishing.

The study area is crossed by numerous two-lane roads, all of which follow field lines. State Highway 111 traverses the eastern and northern parts of the area. The Southern Pacific Railroad parallels SH 111 and forms a portion of the eastern study area boundary.

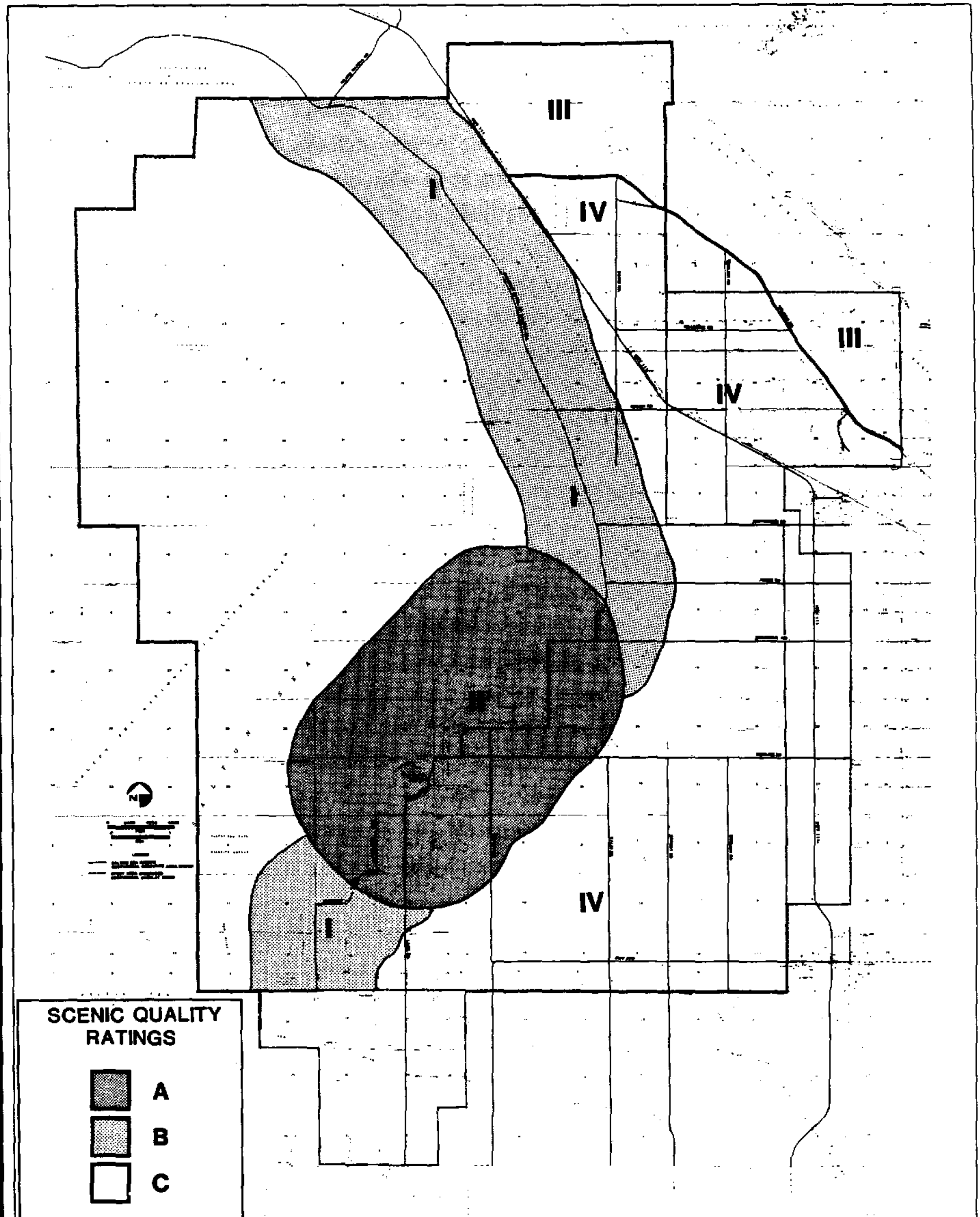
2.1.4 Cultural Modifications

Cultural modifications in the study area include agriculture, irrigation canals and drains, transmission lines, roadways, geothermal wells and several relatively isolated structures. The primary and most visible modification is the extensive agricultural land use throughout the study area. For the purpose of this study, this is considered to be a visual improvement rather than an intrusion, due to the increase in amount and variety of vegetation added to the landscape. Agriculture adds a pastoral appearance, which the VRM system finds to be an improvement. Some structures, particularly residences, are also determined to be visual improvements. In the study area, these residences generally cluster around the offsite communities of Niland and Calipatria.

Visual intrusions are those cultural modifications which have a "significantly depreciative effect" on scenic quality according to the BLM system. On the project site, these include geothermal wells, transmission lines and roadways.

2.2 SCENIC QUALITY RATING UNITS

To aid in the inventory of scenic quality, the study area was divided into rating units, shown on Figure A3.10-2. Landforms were used as the key indicator for the delineation of units, though other factors were also considered, including vegetation, cultural modification, color, uniqueness, presence of water and influence of adjacent scenery. Characteristics within each unit are similar; thus, scenic quality within each unit is fairly uniform.



Scenic Quality Rating Units

FIGURE A3.10-2

Scenic quality was rated for each unit following the criteria specified in the BLM's 8411 and VRM manuals. These criteria were adapted by the BLM specifically for use with desert landscapes during the preparation of the California Desert Conservation Area Plan (BLM, 1980). Criteria are given in Table A3.10-1. Each unit was rated according to the degree in which criteria were present. Units were given a numerical score, shown in Table A3.10-2, and assigned one of three levels of scenic quality. Rating scores and levels developed by the BLM were utilized, and are shown in Table A3.10-3.

Unit I is comprised of the land-sea interface. It is about 2.0 miles wide and runs the length of the project area along the present shoreline of the Salton Sea. The primary reason for the delineation of this unit was the presence of the Salton Sea, a dominant foreground feature throughout the unit. It should be noted that though foreground distance can extend up to 3 miles, in this case foreground views of the Sea generally are not possible from beyond 1.0 mile. This is due to the extreme flatness of the topography. In some places in the study area, dikes preclude views of the Sea from adjacent fields.

Both the land and sea areas of this unit appear as flat, horizontal lines. Waves are rarely present on the Salton Sea: noticeable waves occur less than three percent of the time; white caps occur less than one percent (Giroux, 1981). Vegetation is sparse, with some marsh type vegetation located near perennial streams. Colors in Unit I include shades of tan and light browns for land surfaces and blue to gray for water surfaces. Unit I was found to have a scenic quality rating of "average" according to the VRM system, primarily due to the presence of the Salton Sea.

Unit II is centered on the volcanic domes. The five rounded domes are visually dominant within a radius of approximately two miles. Beyond this distance, the domes are visible but not dominant in the landscape. Colors of the domes vary from red to gray to white, depending on sun angle and atmospheric haze. Vegetation includes agricultural crops, some riparian along the Alamo River, and some marsh-type plants along the shoreline. The shoreline is used extensively by bird watchers and for other recreational uses, since it is adjacent to the Salton Sea National Wildlife Refuge and the Wister Waterfowl Management Area. A scenic viewpoint located at the top of Obsidian Butte has been designated by the Automobile Club of Southern California (1978). Unit II has been given a scenic quality rating of "high," as Table A3.10-2 shows based on the combination of the relative uniqueness of the volcanic domes and the presence of the Salton Sea.

Table A3.10-1

SCENIC QUALITY - EXPLANATION OF RATING CRITERIA

LANDFORM

Topography becomes more interesting as it gets steeper or more massive, or more severely or universally sculptured. Outstanding landforms may be monumental, as the Grand Canyon, the Sawtooth Mountain Range in Idaho, the Wrangell Mountain Range in Alaska, or they may be exceedingly artistic and subtle as certain badlands, pinnacles, arches and other extraordinary formations.

VEGETATION

Primary consideration is given to the variety of patterns, forms, and textures created by plant life. Short-lived displays are important when they are known to be recurring or spectacular. Smaller scale vegetational features which add striking and intriguing detail elements to the landscape; e.g., gnarled or windbeaten trees, joshua trees, add interest to the landscape.

WATER

The presence of water adds movement or serenity to a scene. The degree to which water dominates the scene is the primary consideration.

COLOR

The overall color(s) of the basic components of the landscape (i.e., soil, rock, vegetation, etc.) are considered as they appear during seasons or periods of high use. Key factors to use when in rating "color" are variety, contrast and harmony.

ADJACENT SCENERY

This is the degree to which scenery outside the scenery unit being rated enhances the overall impression of the scenery within the rating unit. The distance which adjacent scenery will influence scenery within the rating unit will normally range from 0-5 miles, depending upon verticality of topography, vegetative cover and other such factors. This factor is generally applied to units which would normally rate very low in score, but the influence of the adjacent unit would enhance the visual quality and raise the score.

Table A3.10-1 (Continued)

SCENIC QUALITY - EXPLANATION OF RATING CRITERIA

UNIQUENESS

This factor provides an opportunity to give added importance to one or all of the scenic features that appear to be relatively unique or rare within one physiographic region. There may also be cases where a separate evaluation of each of the key factors does not give a true picture of the overall scenic quality of an area. Often it is a number of not so spectacular elements in the proper combination that produces the most pleasing and memorable scenery -- the scarcity factor can be used to recognize this type of area and give it the added emphasis it needs.

CULTURAL MODIFICATIONS

Cultural modifications in the landform/water, vegetation and addition of structures should be considered and may detract from the scenery in the form of a negative intrusion or actually complement or improve the scenic quality of a unit. Interest should not be confused with scenic quality.

Source: BLM, 1978.

Table A3.10-2

SCENIC QUALITY RATING OF THE STUDY AREA

Key Factors	Scenic Quality Rating Units I	II	III	IV
Landform	1	3	1	1
Color	1	2	1	2
Water	3	3	1	1
Vegetation	2	2	1	2
Uniqueness	2	4	1	1
Cultural Modification	1	1	1	-1
Influence of Adjacent Scenery	2	2	2	1
TOTAL:	12	17	8	7

High	14	-	21
Average	9	-	13
Poor	1	-	8

Table A3.9-2

PROJECTED ADDITIONS TO ASSESSED VALUE BY TAX RATE AREA SELECTED GEOTHERMAL FACILITIES[1]
SALTON SEA KGRA, IMPERIAL COUNTY
(In Millions)

Tax Rate Area	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total Cumulative
58-000	$22.8		$21.0	$21.0											$ 64.8
58-003				$21.0		$21.0					$21.0			$21.0	$ 84.0
90-002					$85.0	85.0	$85.0	$63.5							$318.5

[1] Only those facilities with presently determined sites have been included.

Source: Williams-Kuebelbeck and Associates, Inc.

Table A3.10-3 (Continued)

SCENERY QUALITY EVALUATION CHART
CALIFORNIA DESERT CONSERVATION AREA CRITERIA

KEY FACTORS	RATING CRITERIA AND SCORE		
WATER (BONUS)	Water a dominant or substantial element in the landscape.	Water present and in view but not a dominant or significant landscape element.	No water or seldom seen if present.
	3	2	1
VEGETATION	A variety of vegetation types as expressed in interesting forms, colors, and textures; OR extensive stands or picturesque distributions of striking plants either as dominant or important detail elements in the landscape.	Some variety of vegetation, but only one or two major types; OR presence of some plants which act as interesting detail elements in the landscape.	Little or no variety or contrast in vegetation. Few or no plants of notable detail interest.
	4	2	1
UNIQUENESS	Scenery one of a kind or rare within the region.	Scenery distinctive though somewhat similar to other places in the region.	Scenery common: much like other places in the region.
	6	2	1

Table A3.10-3 (Continued)

SCENERY QUALITY EVALUATION CHART
CALIFORNIA DESERT CONSERVATION AREA CRITERIA

KEY FACTORS	RATING CRITERIA AND SCORE		
CULTURAL MODIFICATION	Free from aesthetically undesirable or discordant sights and influences.	Scenic quality is somewhat depreciated by inharmonious intrusions but not so extensive that the scenic qualities are entirely negated.	Intrusions are so extensive that scenic qualities are for the most part nullified.
	2	1	4
INFLUENCE OF ADJACENT SCENERY	Adjacent scenery greatly enhances overall visual quality.	Adjacent scenery moderately enhances overall visual quality.	Adjacent scenery has little or no influence on overall visual quality.
	4	2-3	0-1

A = 14-21
B = 9-13
C = 1-2

Source: BLM, VRM: A Guide for Environmental Design Analysis (n.d.).

Unit III consists of the northernmost land in the study area. It is fairly flat with low rolling hills, and is cut by several intermittent and perennial streams which have formed shallow washes. The area is very sparsely vegetated with desert shrub and contains no notable viewpoints or prominent landmarks. The scenic quality of this unit is slightly enhanced by the adjacent Chocolate Mountains to the east. However, it has received a scenic quality rating of poor, as illustrated in Table A3.10-2.

The fourth scenic rating unit contains most of the agricultural land in the study area. Unit IV is very flat and is currently planted in agricultural crops, including cotton and hay. The Alamo River crosses this part of the study area, and the associated riparian vegetation is one of the few naturally occurring areas of vegetation in the unit. This unit is crossed extensively by paved and unpaved roads which serve to connect the agricultural land with the regional transportation network. The area has received a scenic quality rating of poor; the rating score is given in Table A3.10-2.

The remainder of the study area consists of the Salton Sea. This area has not been rated since the BLM desert criteria do not cover large water bodies. However, the Salton Sea is a unique inland desert sea which adds substantially to the scenic quality of the surrounding area. The combination of the sea and the mountains of the Imperial Valley provide unique desert views. Thus, the Salton Sea is considered to have Class B, or average scenic quality.

SECTION III
VISUAL SENSITIVITY

Visual sensitivity levels were determined for the entire study area. Sensitivity levels indicate the relative degree of user interest in visual resources and concern for changes in the existing landscape character. Criteria for determining sensitivity levels are user volume and user attitude toward change.

3.1 USER VOLUME

Three major types of outdoor recreational user groups can be identified in the study area: hunters and fishermen, boaters and waterskiiers, and retired persons. Hunters and fishermen are the most significant non-desert-oriented group. Conservative annual estimates of the numbers of people who enjoy these resources in the study area are given in Table A3.10-4. Boaters and waterskiiers comprise about 9 percent of total boat launchings. These are located at private marinas as well as Imperial County parks. Retired persons come to the Imperial Valley for open land and warm winter climate. Hot springs east of the Salton Sea both on and offsite have generated campgrounds with spaces for over 1000 campers and trailers (Twiss, et al., 1980).

User volume was mapped and is included as Figure A3.10-3. Highway use volume and area use volumes were used. Where two factors overlap, the highest value of the two, or the "worst-case" value, was utilized. Roadway use volume was measured in Average Daily Traffic (ADT); roads within the project site are shown in Table A3.10-5. Area use volumes were recorded in terms of visitor days and are given in Table A3.10-4. User volumes were classified as high, medium and low, as follows:

- Low: Less than 2000 visitor use days per year; or, less than 100 vehicles per day.
- Medium: 2000-20,000 visitor use days per year; or, 100-1000 vehicles per day.
- High: More than 20,000 visitor use days per year; or, more than 1000 vehicles per day.

These classifications throughout the project area were mapped and are given in Figure A3.10-3.

3.2 USER ATTITUDE

User attitude to visual change in the study area should ideally be measured by a public survey. The selection of public participants should include a statistically valid

Table A3.10-4

VISITOR USE DAYS IN THE PROJECT AREA

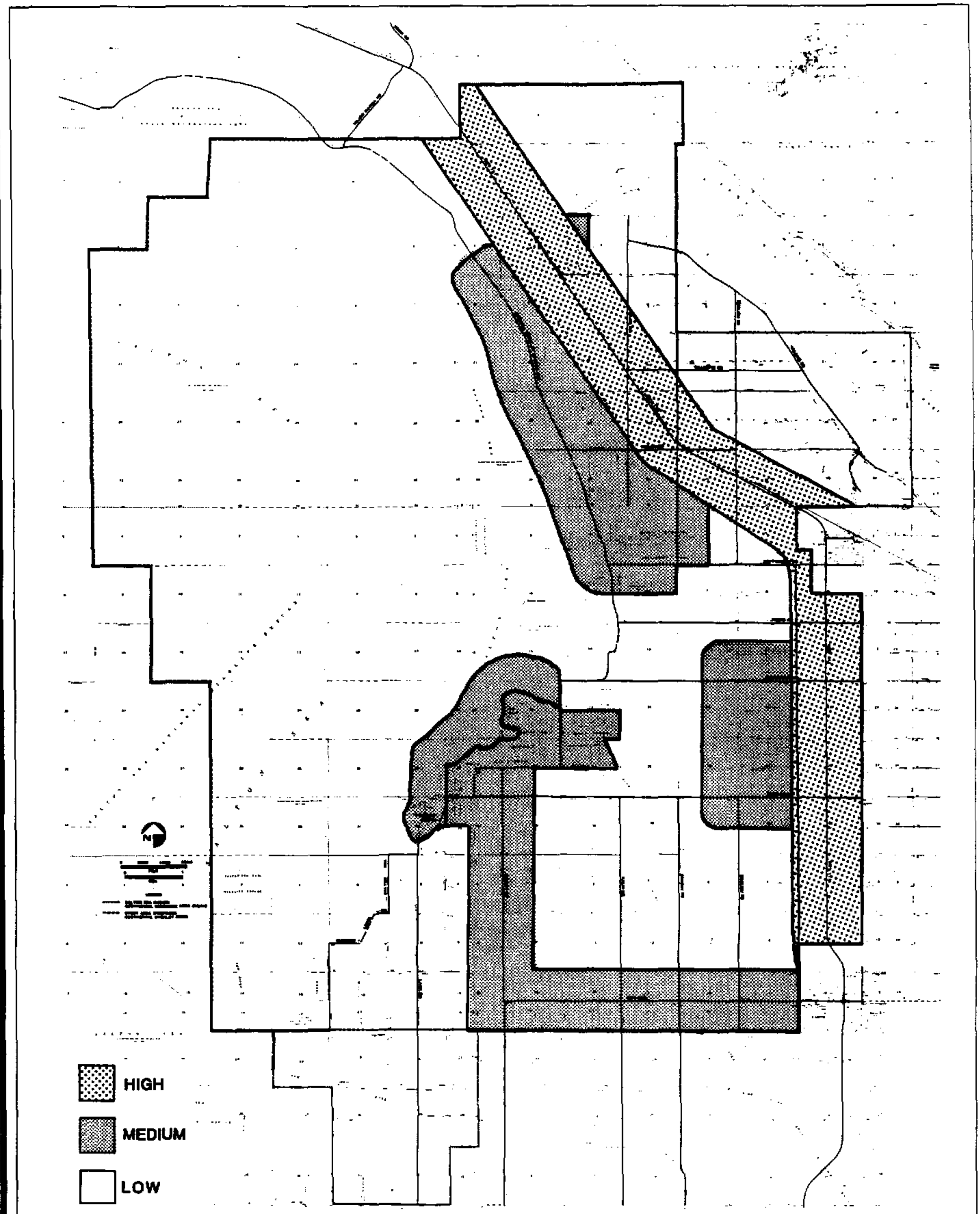
Use Area	Visitor Use Days
Boaters and Skiers	
Red Hill Marina[1]	11,134
Niland Marina[1]	111
Hunting and Fishing	
Wister and Hazard Waterfowl Management Areas[2]	11,494
Salton Sea National Wildlife Refuge[2]	6,992[3]
Private marinas (estimate)[4]	5,000[3]

1

2 California Department of Fish and Game, 1973.

3 Includes offsite areas.

4 Twiss et al., 1980.



User Volumes Of The Study Area

FIGURE A3.10-3

Table A3.10-5

AVERAGE DAILY TRAFFIC VOLUMES IN THE STUDY AREA

Roadway	Average Daily Traffic
State Route 111	2400-5300
Wilkins Road	90
English Road	20-255
Davis Road	40-55
Pound Road	10-75
McDonald Road	40-120
Sinclair Road	75-260
Highway S 30	440-505
Gentry Road	155
Kalin Road	70-145
Winslow Road	35
Howell Road	35

Source: Imperial County, Department of Public Works, Machine Traffic Counts, 1971, 1974, 1975; Caltrans, Traffic Volumes, 1979.

representation of local residents, area users, highway travelers and government agencies. For the purposes of this study, BLM and Imperial County Planning Department staff were interviewed. Staff members are familiar with the study area and resident and other user attitudes toward visual change (Schneider, 1980; Hinds, 1981). A survey of existing literature concerning visual sensivity was also made.

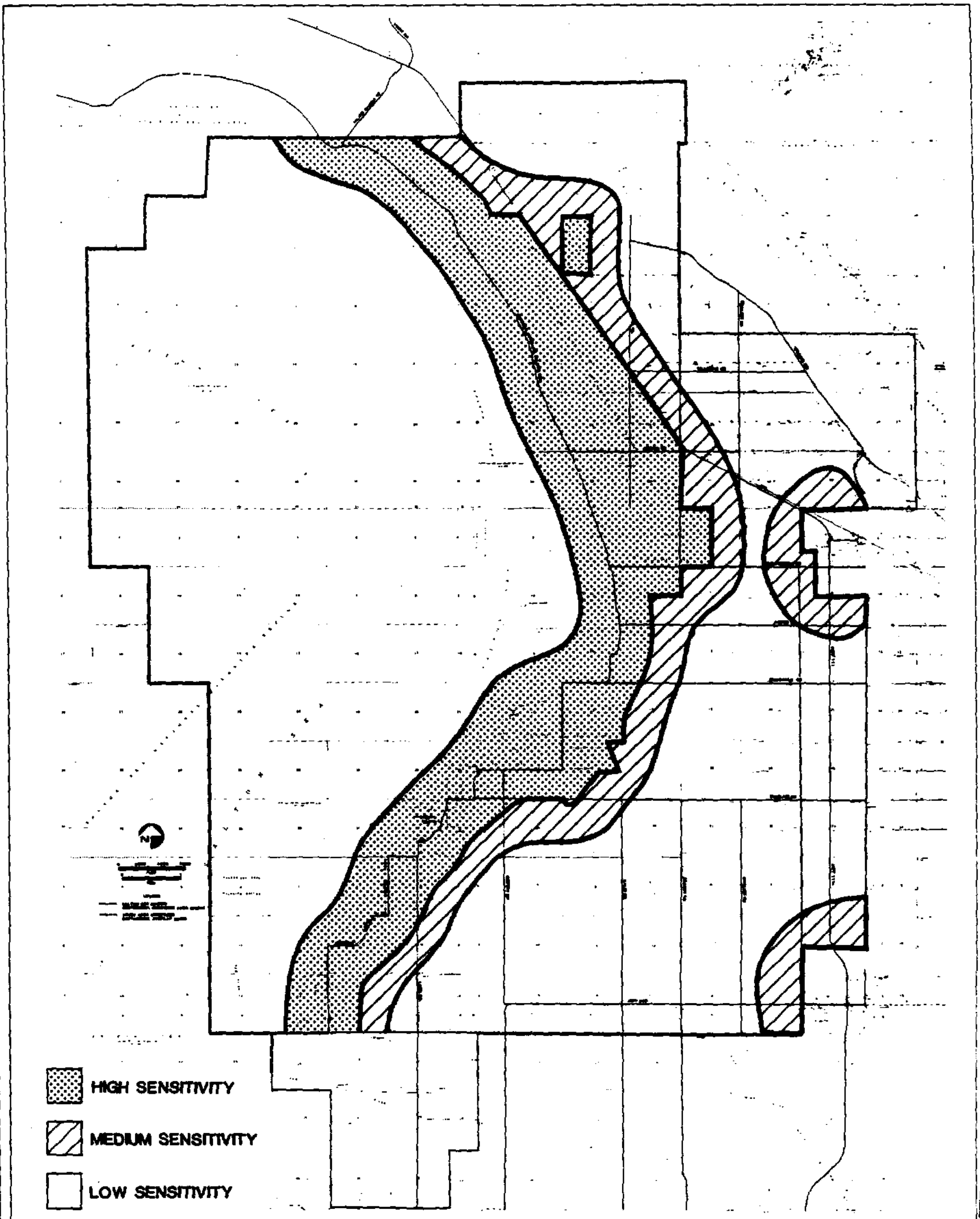
Areas of high concern include the waterfowl management and wildlife refuge areas. These areas are used for recreational purposes; users generally exhibit high levels of concern for recreational areas (Hinds, 1981). The volcanic domes are another area of high sensitivity due to their relative uniqueness within the region (Twiss, 1980). Areas of moderate concern include a zone paralleling the shoreline and buffer zones surrounding the communities of Niland and Calipatria. Low levels of concern are felt to occur in the remainder of the study area. Figure A3.10-4 shows the areas of high, medium and low concern.

3.3 FINAL SENSITIVITY LEVELS

User volume and user attitude are combined to determine final sensitivity ratings, shown in Figure A3.10-5. These ratings are calculated according to the following matrix. It should be noted that user attitude takes precedence over quantity of use.

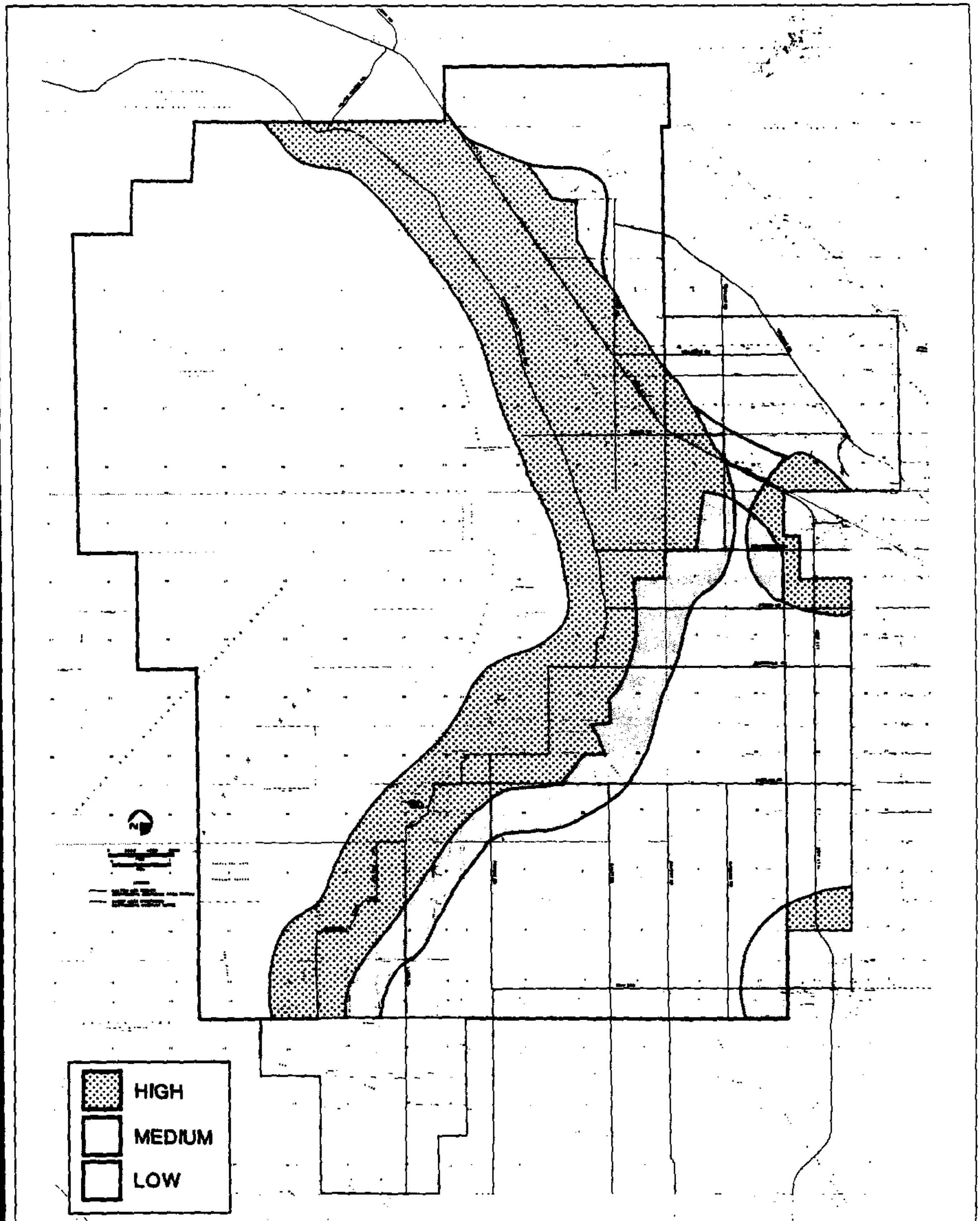
User Attitude	Quantity of Use	Sensitivity Rating
High	High	High
High	Medium	
Medium	High	
High	Low	
Low	High	
Medium	Medium	Medium
Medium	Low	
Low	Medium	
Low	Low	Low

High sensitivity ratings combine high and medium user volume with high and medium levels of concern. These areas are found along the shoreline and include the Waterfowl Management Area and the National Wildlife Refuge. Additional areas are located around Niland and Calipatria, where Highway 111 (which has a relatively high volume of use) enters the sensitive buffer zones which surround the communities.



Attitudes Toward Visual Change

FIGURE A3.10-4



Final Sensitivity Ratings

FIGURE A3.10-5

Areas of moderate sensitivity ratings provide an intermediate zone between the high level along the shoreline and the low level of the agricultural and undeveloped desert areas. Moderate sensitivity levels complete the buffer zones around communities, where traffic volumes are low. Areas with low sensitivity levels consist generally of agricultural and desert areas.

3.4 DISTANCE ZONES

Distance from the observer to the landscape being viewed is important in the visual resource analysis. The longer the distance from the observer to the scene, the less detailed the landscape appears. Objects located in the foreground (up to 1.5 miles) and the middleground (up to 5.0 miles) are close enough to the viewer to be observed in detail. The outer boundary of this zone is defined as the point where the texture and form of individual plants is no longer apparent in the landscape.

The background is the remaining area which can be seen, to approximately 15 miles. Vegetation must be visible at least as patterns of light and dark. Beyond this distance the only thing discernable is form or outline. Lands which cannot be seen or are seen from a distance of more than approximately 15 miles are classified as Seldom-Seen by the BLM system.

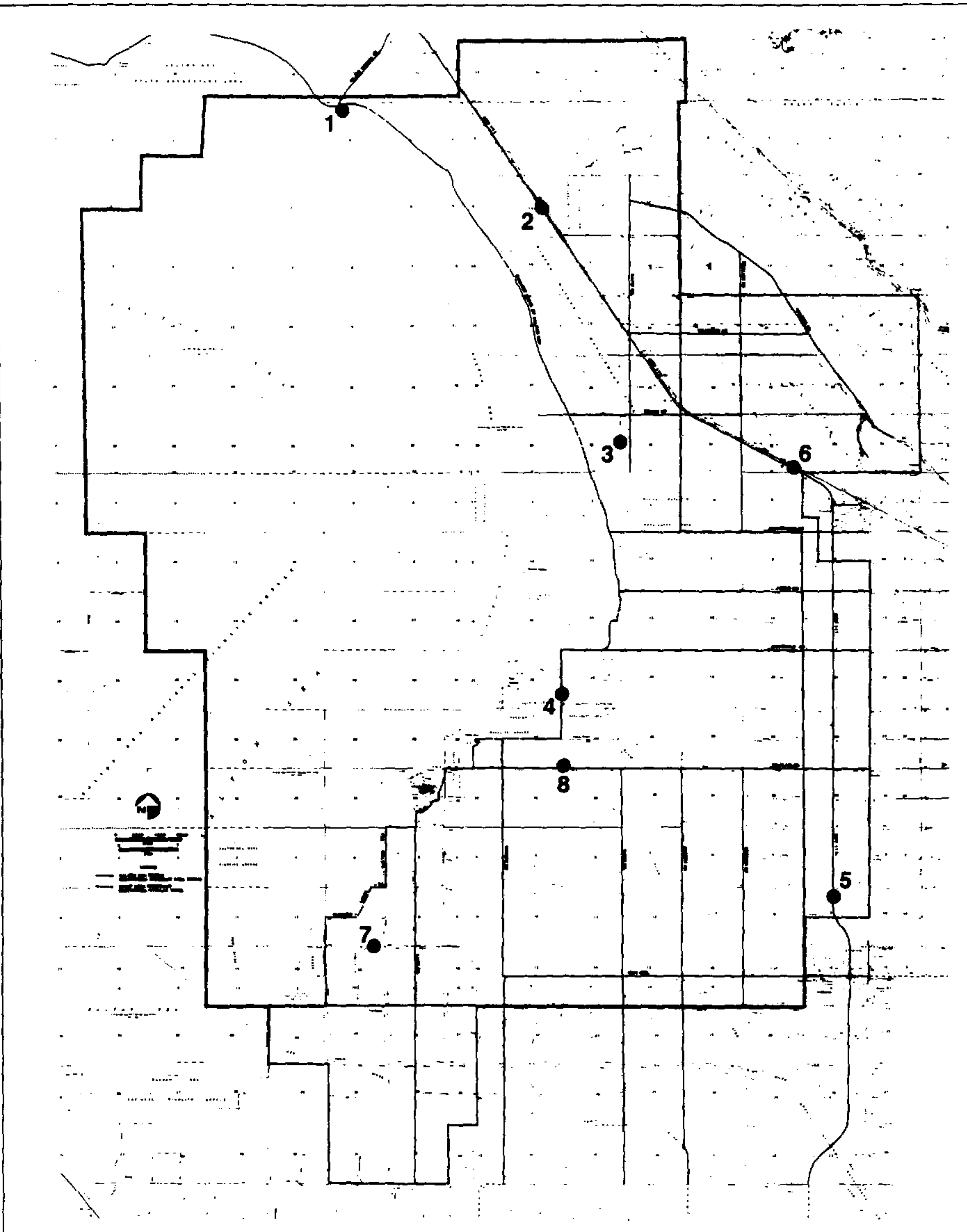
Distances are measured from Key Observation Points (KOPs). KOPs are located within areas of high or moderate sensitivity and are chosen to have a representative view of the area. KOPs in the study area are shown on Figure A3.10-6 and are listed below.

KEY OBSERVATION POINTS

Point No.	Location
1	Southern terminus of Niland Marina Road
2	Highway 111 at Wister Waterfowl Management Area Headquarters
3	Wister Road south of Beach Road.
4	Garst Road at Red Hill Marina Road.
5	Highway 111 north of Calipatria.
6	Highway 111 north of Niland.
7	Young Road west of Lack Road.
8	Sinclair Road at Garst Road.

All of the project area is included within the foreground-middleground zone of at least one of the KOPs.

WESTEC Services, Inc.



Key Observation Points

FIGURE A3.10-6

SECTION IV
VISUAL RESOURCE MANAGEMENT CLASSES

Tentative visual resource management (VRM) classes are used by the BLM to specify the amount of visual change permitted in the landscape. Each class describes a different degree of modification allowed in the basic elements of the landscape. The BLM system provides five classes which vary in the acceptable degree of visual change, as described in Table A3.10-6. They are particularly useful to the project because they can be used as a basis for constraint levels. Generally, Class I lands would be of such high scenic quality that any man-made intrusion would have an unacceptable level of impact. Class II areas would be affected to a high degree, but the impacts can usually be reduced to an acceptable level with appropriate mitigation measures. Class III lands would be affected to a moderate degree and mitigation can often reduce impacts to insignificance. Class IV areas would be affected by development to a low degree of significance. Mitigation measures would usually reduce the impact to insignificance. Class V areas would not be affected adversely by development.

VRM categories are determined by combining scenic quality classes, sensitivity levels and distance zones, according to Table A3.10-7. Class I applies only to classified special areas, such as designated Wilderness or Natural areas. Class V applies to areas identified in the scenic evaluation as having an unacceptable level of cultural modification which has substantially reduced the scenic quality.

Tentative VRM classes in the study area range from II to IV (see Figure A3.10-7). Class II areas include the land-sea interface and the area around the relatively unusual volcanic domes. This rating is due mostly to the high number of recreational users and the high sensitivity towards change of the land-sea interface, as previously discussed. Class III areas form partial buffer zones around the communities of Niland and Calipatria, where the high traffic use of Highway 111 combines with the high sensitivity of the area close to the communities. In addition, Class III areas are located between the Class II areas and the remainder of the study area, surrounding the land-sea interface, widening slightly to include portions of Highway 111 north of Niland. The remainder of the study area is designated Class IV, and consists of agricultural land and undeveloped desert.

Table A3.10-6

VISUAL RESOURCE MANAGEMENT CLASSES

CLASS I

This class provides primarily for only natural ecological changes. It is applied to wilderness areas, some natural areas, wild portions of the wild and scenic rivers, and other similar situations where development activities are to be very restricted.

CLASS II*

Changes in any of the basic elements (form, line, color, texture) caused by potential development should not be evident in the characteristic landscape. A contrast may be seen but should not attract attention.

CLASS III*

Contrasts to the basic elements (form, line, color, texture) caused by potential development may be evident and begin to attract attention in the characteristic landscape. However, the changes should remain subordinate to the existing characteristic landscape.

CLASS IV*

Contrasts may attract attention and be a dominant feature of the landscape in terms of scale; however, the change should repeat the basic elements (form, line, color, texture) inherent in the characteristic landscape.

---

*Structures located in the foreground distance zone (0-1/2 mile) often create a contrast that exceeds the VRM class, even when designed to harmonize and blend with the characteristic landscape. This may be especially true when a distinctive architectural motif or style is designed.

Table A3.10-6 (Continued)

VISUAL RESOURCE MANAGEMENT CLASSES

CLASS V

Change is needed or change may add acceptable visual variety to an area. This class applies to areas where the naturalistic character has been disturbed to a point where rehabilitation is needed to bring it back into character with the surrounding landscape. This class would apply to areas identified in the scenic evaluation where the quality class has been reduced because of unacceptable cultural modification. The contrast is inharmonious with the characteristic landscape. It may also be applied to areas that have the potential for enhancement, i.e., add acceptable visual variety to an area/site. It should be considered an interim or short-term classification until one of the other VRM class objectives can be reached through rehabilitation or enhancement. The desired visual resource management class should be identified.

Source: BLM, 1978.

Table A3.10-7

MATRIX FOR DETERMINING VISUAL RESOURCE MANAGEMENT CLASSES[1]

Scenic Quality Category	Sensitivity Level						
	High			Medium			Low
A	II	II	II	II	II	II	II
B	II	III	III/IV[3]	III	IV	IV	IV
C	III	IV	IV	IV	IV	IV	IV
Distance Zones[2]	F	B	S	F	B	S	All zones

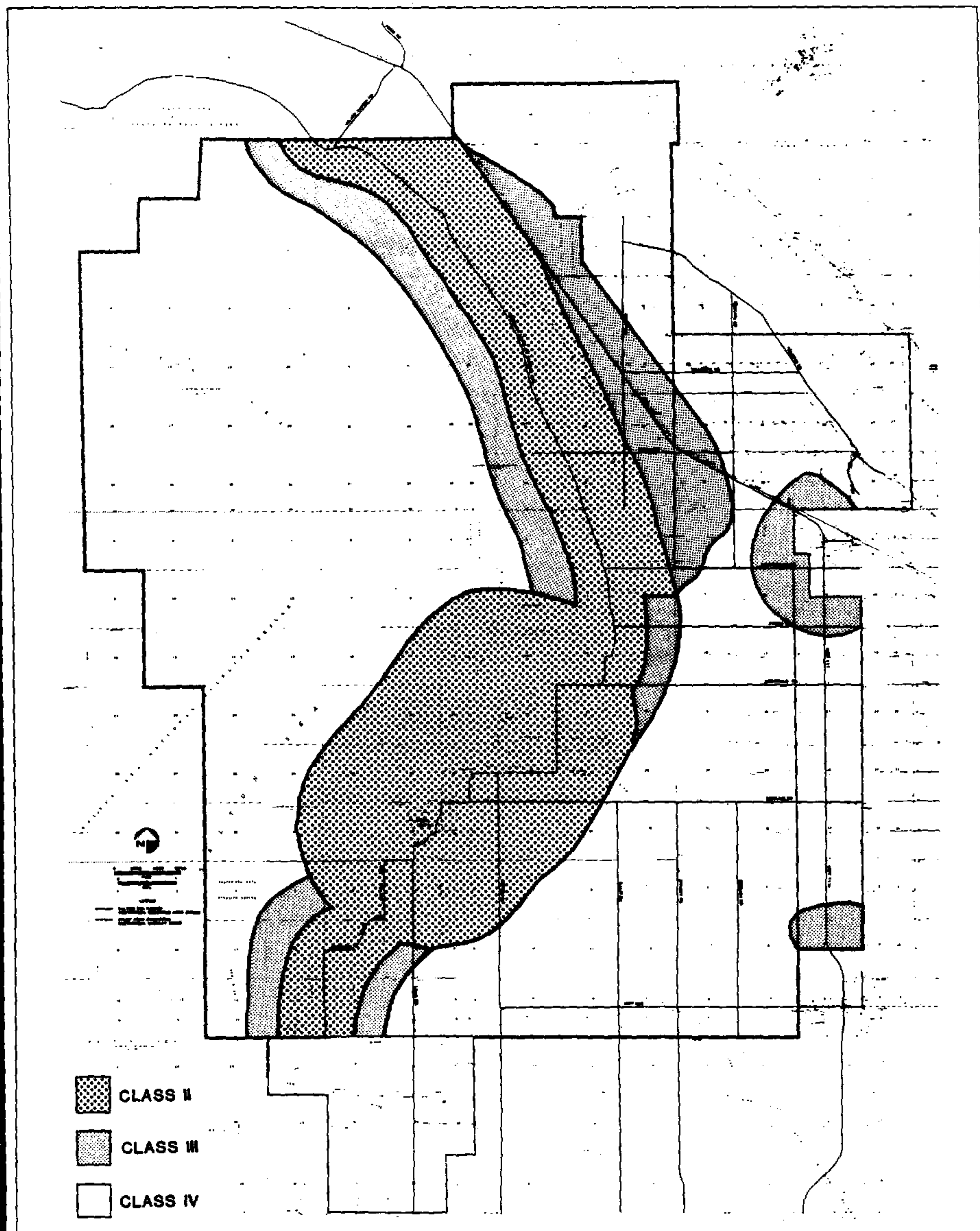
[1]Class I applies only to classified special areas, e.g., Wilderness, Natural areas, etc. Class V applies to areas identified in scenic quality inventory where quality class has been reduced because of unacceptable cultural modifications or areas that have a potential for enhancement.

[2]Distance zones

- F Foreground/middleground
- B Background
- S Seldom-Seen

[3]If the area being evaluated is adjacent to any VRM Class IV or higher, select Class III; if lower, select Class IV.

Source: BLM, 1978.



Visual Resource Class

FIGURE A3.10-7

SECTION V

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APPENDIX 3.11

COMMENTS ON THE NOTICE OF PREPARATION

CLAUDE M. FINNELL
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IMPERIAL COUNTY

OFFICE OF
AGRICULTURAL COMMISSIONER
DIRECTOR OF WEIGHTS AND MEASURES
AIR POLLUTION CONTROL OFFICER

November 6, 1980

RE: Niland Anomaly Master Environmental Impact Report (MEIR)

Mr. Alex Hinds, Geothermal Planner
Planning Department
Courthouse
El Centro, CA 92243

Dear Mr. Hinds:

Preliminary review of the document and past experience the following are our main concerns:

1. Continuous monitoring of H_2S will be required.
2. The salinity content of the brine and subsequent steam will generate particulate matter in an amount which may be deleterious to the surroundings.

Further clarification will be provided at your convenience.

Sincerely,

CLAUDE M. FINNELL
Air Pollution Control Officer

Carlos Villalon

Carlos Villalon
Air Pollution Control Engineer I

CV/ni

RECEIVED
NOV 10 1980
IMPERIAL COUNTY
PLANNING DEPARTMENT

Niland Chamber of Commerce

Post Office Box 97, Niland, California 92257

November 17, 1980

Mr. Alex Hinds, Geothermal Planner,
Planning Department,
County of Imperial,
El Centro, Ca. 92243

Sub: Proposed geothermal field
Boundary extension & development

Dear Mr. Hinds:

The subject rezoning of the Niland KGRA appears to have the potential of serious effects on the town of Niland.

By the proposed extension of the former perimeters right up to the town limits all manner of problems are projected for our people.

We have been told that leases for drilling are already being processed. Unless we are wrong on the legality of that action it would seem premature to do so, We are not aware that approval for extending the boundaries has been established. We know that many of our citizens are not aware of the situation and we assume that prior to any concrete action the subject will be completely explained to them and opportunity given to voice their opinion.

At this point the Chamber and many of our citizens directly oppose any such boundary extension. The possibilities for bad effects being generated by this proposal are almost unlimited as viewed at the moment. For just one: the whole question of routing connecting transmission lines is back to square one.

We urge you to make a substantial effort to inform our community as to the complete project prior to any action, including leasing, which will affect the town proper. This action might be well taken to occur prior to in depth EIR work.

Thank you for the opportunity to comment on the subject proposal.

Sincerely,

NILAND CHAMBER OF COMMERCE.

C. C. Irwin,
Public Relations,
P.O. Box 955,
Niland, Ca. 92257

TELEPHONE 714-355-1112

IMPERIAL IRRIGATION DISTRICT

OPERATING HEADQUARTERS • IMPERIAL, CALIFORNIA 92251

November 17, 1980

Mr. Alex Hinds, Geothermal Planner
County Planning Department
939 Main Street
El Centro, CA 92243

Dear Mr. Hinds:

Please refer to Niland Anomaly Master Environmental Impact Report (MEIR), I.S. No. 1103-80. We offer the following comments:

WATER: This project will have no apparent impact on the Water Department.

POWER: The project description states the MEIR "will address the anticipated full field and geothermal plant development up to a level capable of producing 1,400-MW of electricity", and "will examine impacts related to: ...3.) site specific development of 40-MW power plant."

The impacts created by a 49-MW power plant will be relatively minor, insofar as the District's electrical system is concerned. The actual route of the transmission line from the proposed plant site to the Niland Substation is, as yet, undetermined as is the voltage.

On the other hand, the impacts created by 1,400-MW of generation would be major. Before the available generation at any one anomaly exceeds 200-MW, the District's entire transmission system will require a major upgrading.

Very truly yours,

D. A. Twogood

D. A. TWOGOOD
General Manager

PARKS & RECREATION DEPARTMENT

RICHARD E. POLLOCK
DIRECTOR

COUNTY OF IMPERIAL

836 MAIN STREET
EL CENTRO, CALIFORNIA 92243
TELEPHONE 353-4266
AREA CODE 714

November 19, 1980

RECEIVED
NOV 19 1980
IMPERIAL COUNTY
PLANNING DEPARTMENT

Mr. Alex Hinds
Geothermal Planner
Imperial County Planning Dept.
1097 Airport Road
Imperial, Ca. 92251

SUBJECT: Draft E.I.R. Niland Anomoly - Master E.I.R.

The impact on land recreation, I believe, will be minimal. The impact of the off-shore development could have major impacts with regards to fish and waterfowl and boating navigation.

Spills or blow-outs off-shore of waste or non-compatable materials mixing with existing chemicals and bacteria could possibly be a danger to both fish and waterfowl in or on the south Salton Sea waters. Certain environmental changes occurring annually affect both fish and waterfowl now. The proposed off-shore development might increase the duration or intensity of bacteria growth and thereby increase waterfowl hazard. The annual fish kill period might be increased or more drastic.

There are many boating hazards in the Salton Sea. The off-shore development will add additional obstacles; however, with proper lighting it could become an excellent landmark for boaters safety.

Sincerely yours,

Richard E. Pollock
Director, Parks and Recreation Department

REP:sj

STATE OF CALIFORNIA – RESOURCES AGENCY EDMUND G. BROWN JR., Gov

STATE WATER RESOURCES CONTROL BOARD
DIVISION OF WATER RIGHTS
77 Cadillac Drive, Sacramento, CA 95825
(916) 924-2420

In Reply Refer
to: 334:TMc

NOVEMBER 28 1980

RECEIVED
DEC 1 1980
IMPERIAL COUNTY
PLANNING DEPARTMENT

Richard D. Mitchell
Planning Director
Imperial County Planning
Department
Courthouse
El Centro, CA 92243

Dear Mr. Mitchell:

INITIAL STUDY AND NOTICE OF DETERMINATION OF IMPERIAL COUNTY TO PREPARE A MASTER ENVIRONMENTAL IMPACT REPORT OF THE NILAND ANOMALY

Introduction

The project involves the full field development of the geothermal resource in and around the Salton Sea resource area. The Salton Sea Known Geothermal Area (KGRA) is capable of producing 1,400 MW of electricity for 30 years.

The County requires geothermal production and power plant activities to be confined within given geothermal overlay zones. Since the proposed project involves land outside the Salton Sea KGRA, the project area will have to be rezoned in order to incorporate the proposed project. The proposed Master Environmental Impact Report (MEIR) will consider rezoning of the area and will include a description of the probable geothermal technologies and development scenarios for the study area.

General Comment

Magma Power Company and New Albion Resources Company (MPC & NARC) have filed water rights Application 26462 for 50,000 afa to be diverted from the Salton Sea to be used in conjunction with the development of 500 MW of electricity. Since a water right permit will be required for this proposed project and probably future projects within the overlay zone, this Board will be a Responsible Agency and all future environmental documents should be circulated through the State Clearinghouse for our review.

Specific Comments

1. The MEIR should discuss the water rights that are necessary to implement MPC and NARC's proposed project as well as the water rights required for the development of the entire 1,400 MW.

2. The hydrology section should cover the amount of water required for full field development.

3. The MEIR should discuss power transmission line routes and their associated environmental impacts.

4. The MEIR should discuss in detail all water conservation measures which could be implemented under partial and full field development.

5. The alternative section of MEIR should include discussions in the following areas:

    a. Alternative sources of water

    b. Alternative sources of energy

    c. Energy conservation measures as an alternative to the proposed project.

Sincerely,

D W Sabiston

D. W. Sabiston
Program Manager

cc: Magma Power Company and
New Albion Resources Company
c/o John M. Burns
P. O. Box 168
San Diego, CA 92112

State of California THE RESOURCES AGENCY OF CALIFORNI

Memorandum

JAN 2 3 19[illegible]

To : Jim Burns
Assistant Secretary
Resources Agency

Alex Hinds, Geothermal Planner
Imperial County Courthouse
El Centro, CA 92243

Date : January 14, 1981

Subject: NOP for Draft EIR
Niland Anomaly, Geother
Development
Imperial County
SCH #80102409

From : **Department of Conservation—Office of the Director**

We recommend that the draft EIR for the proposed geothermal development in Imperial County contain the following:

1. A discussion of the regional geology, including structure and stratigraphy (map).
2. A detailed geologic map of project area.
3. A discussion of the local occurrence of geothermal water and potential target areas within the project.
4. A description of the regional and local seismicity (map).
5. A regional fault activity map and a discussion of the risks from surface fault rupture.
6. The potential impacts of the project on the geologic stability of the area (e.g. subsidence from groundwater withdrawal and the effects on aquifers from geothermal wastewater injection).
7. Reclamation plans.

We also recommend that CDMG Special Report #122, Engineering Geology of The Geysers Geothermal Resources Area, be a reference in the preparation of the EIR and, specifically, for the identification of seismic hazards.

Contributing to the preparation of this memo was Charles F. Armstrong (E.G. 976) of the Department's Division of Mines and Geology. For questions regarding these comments, contact me at (916) 322-5873.

Patrick G. Nevis
Environmental Program Coordinator

cc: C. Armstrong
P. Amimoto

CALIPATRIA UNIFIED SCHOOL DISTRICT

P O. Bin "G", Calipatria. Calif. 92233

Calipatria High School
Gary L. Smith
348-2254

Fremont School
Clayton R. Erickson
348-2842

Niland School
Jimmie C. Hughes
348-0636

District Superintendent
Eddie Ikard, Ph.D.
(714) 348-2892

RECEIVED
OCT 23 1980
IMPERIAL COUNTY
PLANNING DEPARTMENT

October 20, 1980

Mr. Richard D. Mitchell, Director
Planning Department
County of Imperial - Courthouse
El Centro, California 92243

Dear Mr. Mitchell:

RE: I.S.N. - 1103/80
Niland Anomaly

The trustees of the Calipatria Unified School District are acquainted with the proposed project as mentioned above. They urge your support and cooperation in finalizing details for implementation.

Every effort you may provide to the general public of this area in speaking at public hearings regarding the placement of power transmission lines will be appreciated.

Very truly yours,

Eddie Ikard

Eddie Ikard,
District Superintendent

EI:pd

APPENDIX 8.2

ARCHAEOLOGICAL SURVEY OF A PROPOSED 49 MW GEOTHERMAL PLANT SITE AND GEOTHERMAL WELLS

ARCHAEOLOGICAL SURVEY OF A PROPOSED 49 MW GEOTHERMAL PLANT SITE AND GEOTHERMAL WELLS LOCATIONS IN IMPERIAL COUNTY, CALIFORNIA

Prepared For:

Magma Geothermal Company
631 South Witmer Street
Los Angeles, California 90017

Prepared By:

WESTEC Services, Inc.
3211 Fifth Avenue
San Diego, California 92103

Randy L. Franklin
Associate Archaeologist

Richard L. Carrico
Manager,
Cultural Resources Group

January 1981

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

ATTACHMENTS

SECTION I

INTRODUCTION

WESTEC Services, Inc. of San Diego has recently completed an archaeological and historical reconnaissance of selected portions of a 1360-acre parcel near the southeastern edge of the Salton Sea. Magma Geothermal Company proposes construction of a 49 MW geothermal plant and excavation of twenty-seven well sites within the areas surveyed.

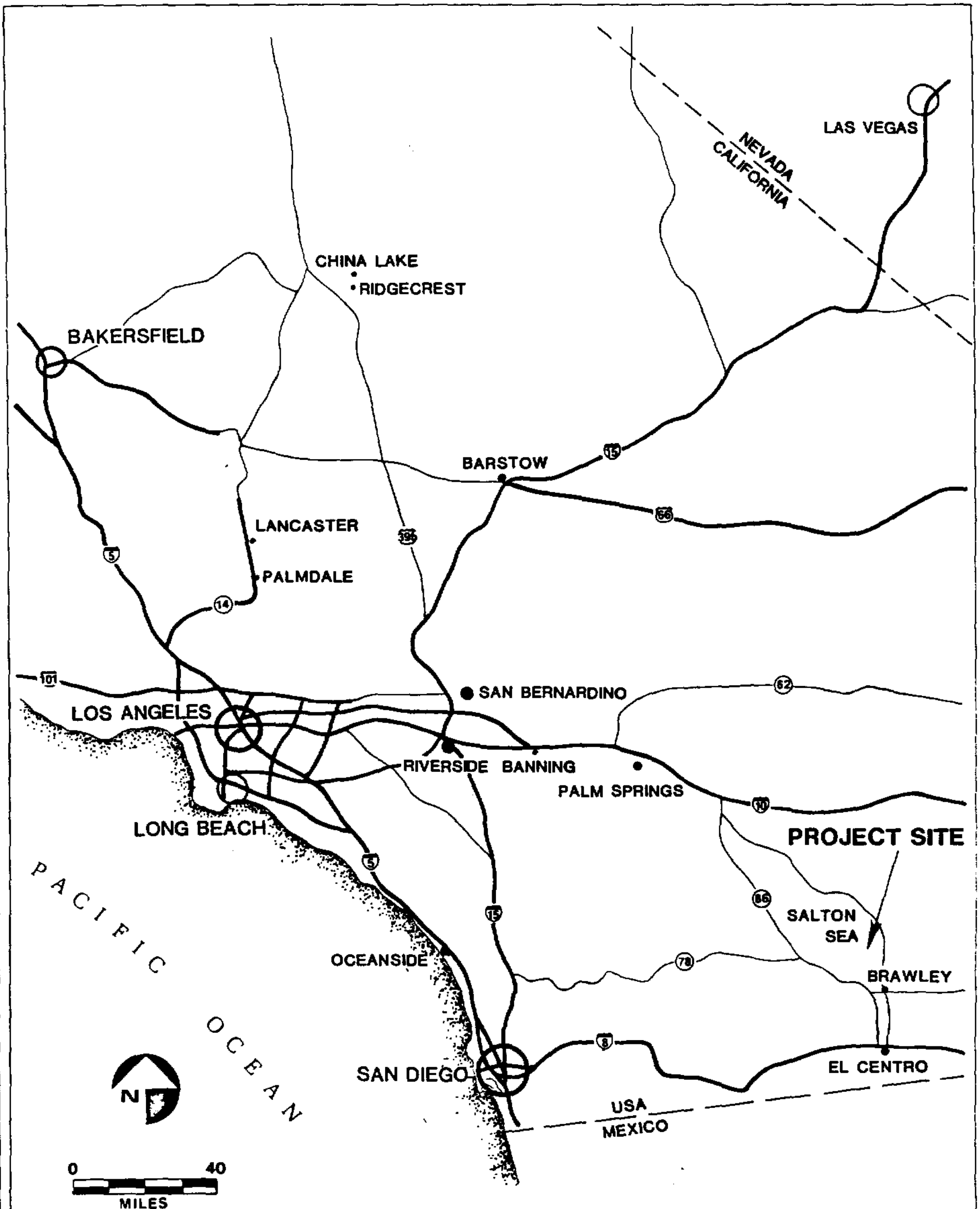
Field investigations were conducted on January 9, 1981. The survey consisted of an intensive on-foot examination of the proposed geothermal plant and seventeen of the projected well locales. A total of 34 hours was expended during the course of study. Overall project management was provided by Richard L. Carrico, Manager of the Cultural Resources Group. In-field supervision was assigned to Randy L. Franklin, Associate Archaeologist. Other project personnel included Jay Thesken and Robert Nagle.

1.1 PROJECT LOCATION

The subject property represents a small parcel within the larger Salton Sea Anomaly Area, Figure 1. As depicted on the USGS 7.5 minute Niland quadrangle map, the 49 MW geothermal plant and well sites are situated within Township 11 South, Range 13 East, Sections 25, 26, 27, 34 and 35. The approximately 1,360 acres extend roughly one-half mile north and south of Sinclair Road with Gentry Road forming the western boundary and Kalin Road the eastern limit (Figure 2).

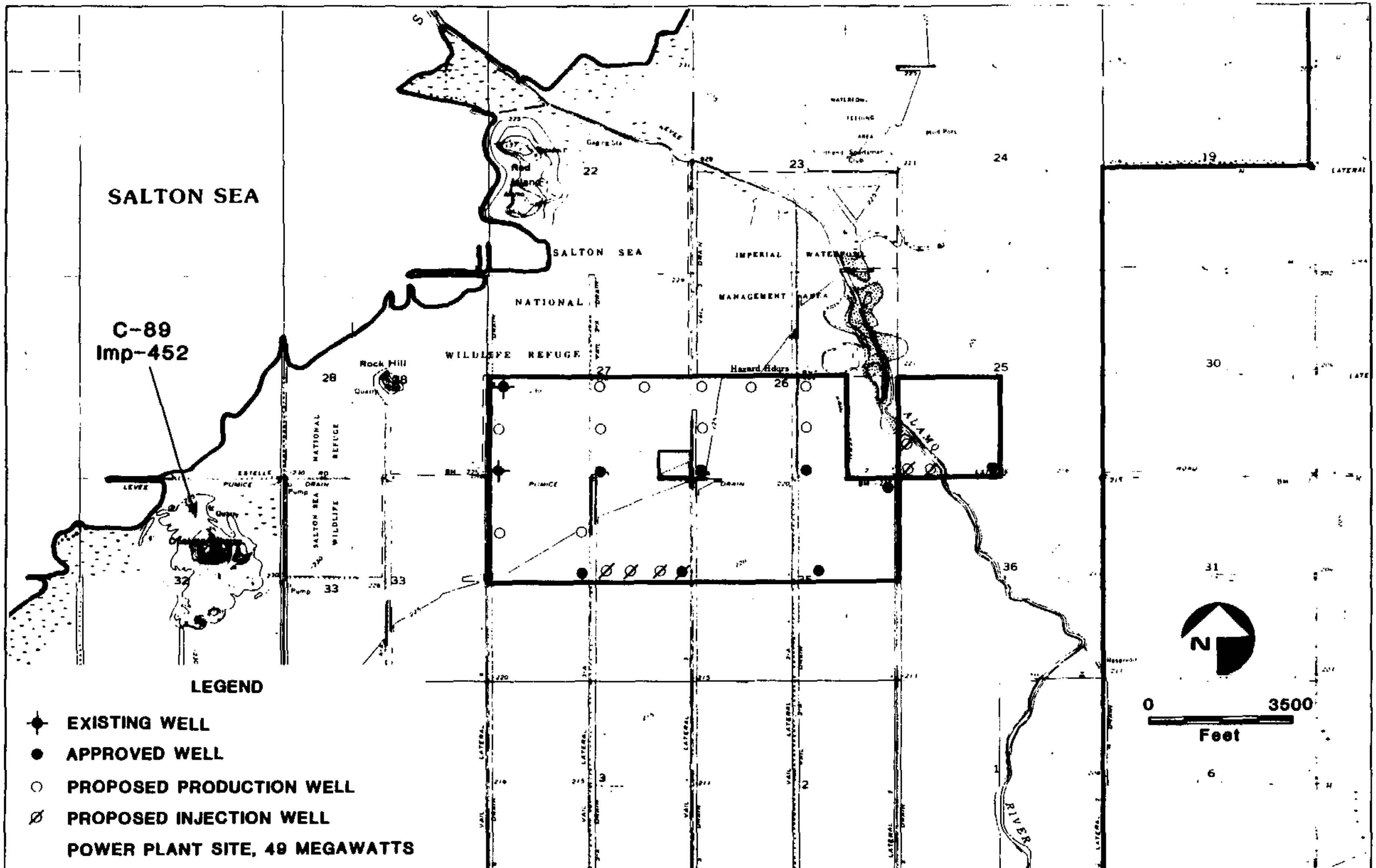
1.2 ENVIRONMENTAL SETTING

The subject property occupies the bottom of former Lake Cahuilla at a contour elevation of minus 225 mean sea level (MSL). The surrounding territory is comprised of reclaimed lake bed presently cultivated in cotton and alfalfa.



Project Area in Relationship to Southern California	FIGURE 1

WESTEC Services, Inc.



Specific Project Area as Depicted on Niland and Obsidian Butte 7.5 Minute USGS Quadrangles

FIGURE 2

A relatively undisturbed ±30 acre section of property is situated adjacent to Sinclair Road and abutting the west side of the Alamo River. Saltbush (Atriplex canescens), arrowweed (Pluchea sericea), pickleweed (Allenrolfea occidentalis), and tamarisk (Tamarix pentandra) were observed within this particular area. The Salton Sea National Wildlife Refuge constitutes the project's northern perimeter. The refuge area encompasses an extensive marshland biologic habitat.

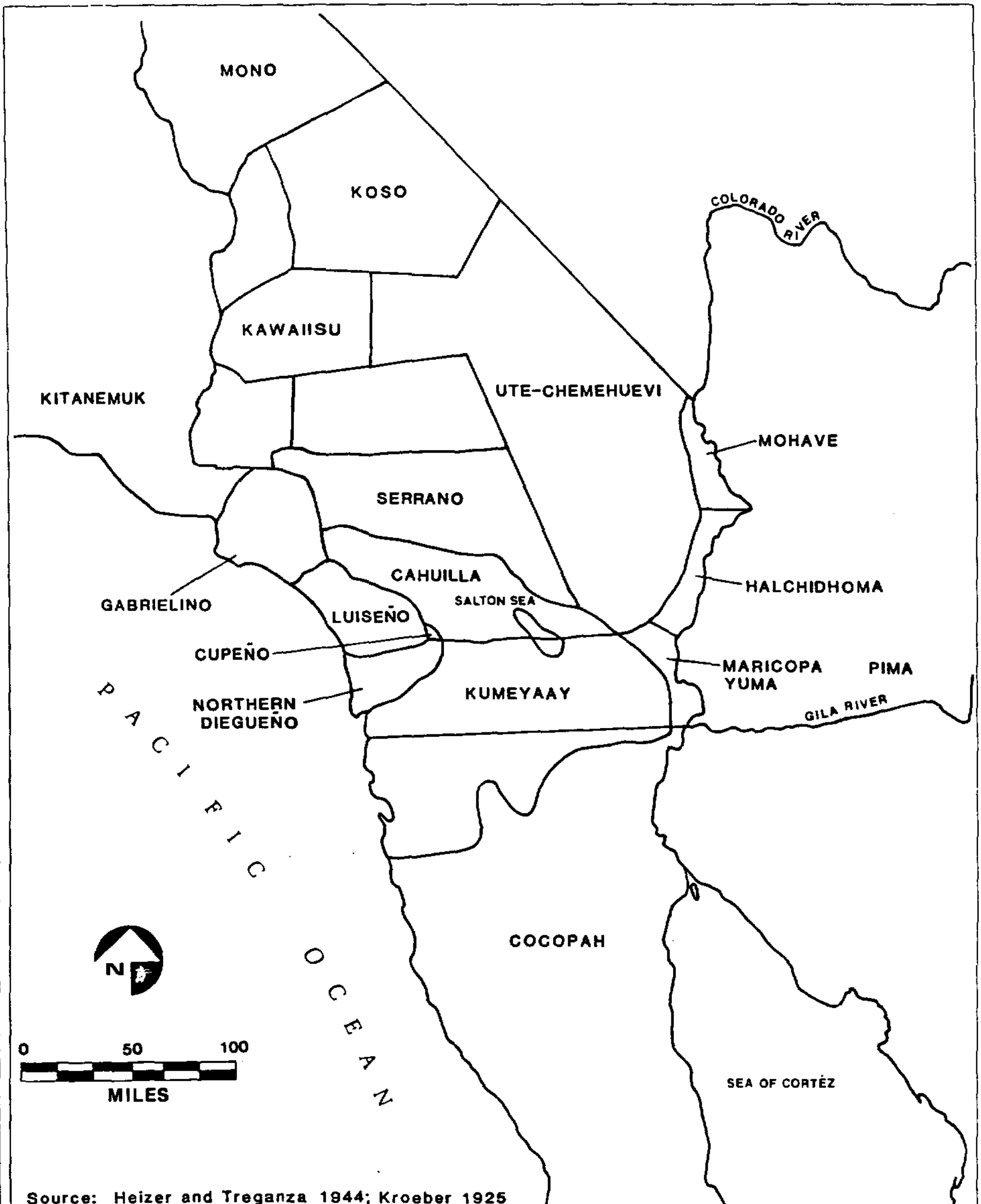
Geologically, the study area lies within what is referred to as the Salton Trough (Morton 1977:13). Basically a northwestern landward continuation of the Gulf of California rift, this structural trough was formed by gradual settling in association with uplift of the surrounding mountains during the Miocene, Pliocene, and Pleistocene (Hamilton 1961; Morton 1977). On the surface, the Salton Trough province exhibits at least three geomorphic environs: ancient lake bed sediments, alluvial channels and dune sands. The proposed geothermal project is characterized by clay and silt deposits from prehistoric lakes.

SECTION II

CULTURAL SEQUENCE (BACKGROUND DATA)

The following discussion presents a cultural sequence based on different levels of investigation and following several avenues of research. The earliest segment of the cultural sequence, the Pre-Projectile Point culture is the least well-defined and presents the greatest problems in interpretation. The Paleo-Indian Horizon/San Dieguito Complex is a generally accepted cultural sequence, although our discussion of these early hunters and gatherers is necessarily focused on manufacture of stone tools and inferred use. The Early Milling Horizon/Amargosan-La Jolla Complex is also weighted toward defining a culture by stone tools and their inferred function but our knowledge of Amargosan-La Jolla behavior and settlement patterns is better developed than for their predecessors.

The Late Milling Horizon/Yuman-Hakatayan Complex offers an almost overwhelming quantity of data. Information on these peoples can be drawn not only from archaeological sources but also from historic sources and ethnographic research. Yet no comprehensive Late Milling Horizon analysis has been produced for the study areas. Researchers are forced to rely on a generalized pattern rather than an outlined understanding of the late prehistoric cultural record. The transition from the hazy obscurity of the hypothetical early Pre-Projectile Point culture to the more defined later cultures is presented in both content and mood within the following discussion. In contrast, the student of the later peoples must become a master of focus and clarity. The approximate boundaries for the Late Milling cultures throughout the southwest desert region are shown in Figure 3.



Source: Heizer and Treganza 1944; Kroeber 1925

Cultural Zones of the Far Southwest at the Time of European Contact (1769 AD)

FIGURE 3

2.1 PRE-PROJECTILE POINT/EARLY MAN CULTURES

Recent research along both coastal and inland southern California has seriously raised the possibility of a Pre-Projectile Point, Pre-Paleo-Indian (San Dieguito) culture. Unfortunately much of the data remains ambiguous and often suspect. The equivocal nature of the evidence for "Early Man" or Pre-Projectile Point cultures is due partially to the random methods of collection and biased analyses often employed by its advocates and partially to the probability that remnants of such an ancient culture will be sporadic and not easily recognized. Much of the early documentation of pre-San Dieguito cultures has been broadly conceived and short on substantiation (Carter 1957; Clements and Clements 1953).

Among the discordant promotions and hypotheses supporting Early Man, an increasingly harmonious and balanced theme is beginning to be heard. The research of Dr. Emma Lou Davis (1970:117, 1978) has been noteworthy for its well-reasoned documentation of an apparent Pre-Projectile Point stone tool tradition. Of less even quality and general acceptance, the Calico sites and supposedly contemporaneous lithic traditions, as defined by Ruth D. Simpson, may provide verification of a pre-San Dieguito desert complex (Simpson 1960:25-35). Several years of field research and analysis by Morlin Childers and Robert Begole may someday lend credence to the concept of Early Man in the Imperial and lower Colorado deserts (Childers 1974b; Bischoff, Childers and Shlemon 1976:129-130; Begole 1973).

A major stumbling block must be surmounted before most of the research cited above is accepted and Early Man becomes a valid, recognized tradition. The stumbling block is comprised of irregularly shaped, often jagged and always ancient appearing pieces of stone. True believers of Early Man see patterns in these lumps of quartzite, rhyolite and chert. They see stone tools fashioned and used by human foragers. To disbelievers the jagged edges are atypical products of natural forces such as thermal fracturing, exfoliation, stream tumbling and myriad other non-human acts of nature.

The stalemate between the believers and disbelievers is not apt to be easily or rapidly resolved. The general sparseness of datable material, at or associated with, hypothetical Early Man sites makes absolute dating difficult at best. Although dates between 8000 and 9000 years ago are generally accepted (Berger 1971; Warren 1967, 1966; Moriarty 1966; Carrico and Ezell 1978), dates beyond 10,000 years ago are as suspect as they are elusive. Human remains from Laguna Beach and the Los Angeles area have been dated at 17,000 years for "Laguna Woman" and over 23,600 years ago for "Los Angeles Man" (Berger 1971). A cairn burial in the Yuha Desert produced caliche covered human skeletal material, dubbed Yuha Man, dated at between almost 22,000 and 32,000 years ago (Childers 1974b; Bischoff, Childers and Shlemon, 1976:129-130, 1978:747-749), although these dates have been questioned (Payen et al., 1978:448-452).

Physical characteristics of the Yuha Man were found similar to those of the La Jolla peoples of circa 7000 to 4000 years ago (Rogers 1963, 1977) and apparently different from the Del Mar Man remains (Rogers 1974) dated as the earliest (48,000 years ago) evidence of human occupation in North America. While the possibilities of the peopling of the Americas almost 50,000 years ago are tantalizing and stir the imagination, years of research and review will be required to validly assess the growing body of potentially supportive data.

Many archaeologists can accept the 9000 to 21,000-years-old dates and have little trouble agreeing that the rock cairns or stone tools are of human manufacture. It is beyond the 21,000-year-old barrier that only the true believers have dared to tread. Aided by amino acid racemization dating, several researchers (Bada, Schroeder, and Carter 1974; Bada and Helfman 1975; Minshall 1976) continue their claim for Early Man in southern California.

For the current research project we shall assume that the cultures or traditions postulated as occurring before 21,000 years ago are still hypothetical and that those better-dated yet ill-defined cultures between 10,000 and 20,000 years ago are tenuously accepted. It is hoped that projects such as the current one and other serious research programs will shed new light on the more than 20-year-old controversy of Early Man in southern California.

2.2 PALEO-INDIAN/SAN DIEGUITO (10,000-7500 BP)

The oldest well-documented inhabitants of the region were apparently the Paleo-Indian San Dieguito people. Based on tool typologies, environmental setting for known sites and assumed cultural distribution, the San Dieguito complex most probably represents a regional manifestation of the larger Western Lithic Co-Tradition (Davis et al., 1969). Another localized variation of this widespread tradition is the Lake Mojave complex (Warren, True and Eudey 1961, Bettinger and Taylor 1974). Claude Warren provides a fine overview and discussion of similarities among western Paleo-Indian tool assemblages (1967:168-185) while explaining his hypothesis that Paleo-Indian peoples moved out of the nondesert northern forests and into our now arid desert lands.

These people are believed to have occupied the mesas, mountains and deserts in and around the study area between 10,000 and 6000 years ago (Warren 1961:252-253; Rogers 1966:140-148; Ezell 1974:personal communication). The culture of the San Dieguito people has been divided into three relatively distinct phases representing assumed variations in time and space. Absolute dating of stratigraphic evidence for Rogers' phases is still a major research goal. Within these three phases there exist various "industries" which are geographically and ecologically based.

In general, the groups of the San Dieguito I phase apparently left only a sporadic permanent record on the land except for their scattered lithic tools and waste stone debris (Rogers 1939:25-31; Wallace 1955:189-191; Ezell 1974:personal communication). More specifically, San Dieguito I tool assemblages are characterized by ovate bifaces, spokeshaves, bilateral notched pebbles, scraper planes and chopping tools (Rogers 1939).

Many investigators, including Rogers (1966), thought that so-called sleeping circles and geometric stone alignments (intaglios) were of San Dieguito origin, but most scholars realize that there is no way to date most rock rings or to assign them a function. San Dieguito I sites are frequently located high above existing water sources and in settings suggestive of occupation contemporaneous with a much wetter, more lush environment. Apparently San Dieguito I peoples thrived in desert regions of southeast California but do not seem to have occupied the coastal plain of California or the Peninsular Ranges.

San Dieguito II is found in portions of the general study area. Lithic artifacts represented by this phase include more finely worked blades, somewhat smaller and lighter points, and a larger variety of scrapers and choppers. In general, however, the same morphological types remain basically unchanged from the earlier phase. Like their predecessors, these people were medium to large game hunters, and vegetal gatherers (Warren 1961:262; Moriarty 1969:1-18). It is also probable that people of the San Dieguito phases exploited lacustrine and riverine resources in these inland locations. Work by Kaldenberg and Ezell (1974) in San Diego County reveals that the San Dieguito harvested substantial marine resources. Other recent ethnographic work with hunting and gathering groups of southern California and Baja California illustrates the importance of the gathering portion of their subsistence (Bean and Saubel 1972; Aschmann 1959) with the observation that wooden vegetal preparation implements were used to some extent. This infers that early cultures such as San Dieguito phases may have used such perishable implements.

The terminal San Dieguito phase, San Dieguito III, represents a morphological and typological change as indicated by an altered technology. The tool types become far more varied both in style and in functional design. Such alteration in technological form can be attributed to environmental adaptation and/or to a technological "snowball" effect, wherein technological advances and changes thrive and feed on themselves and progressively create a new technological mode.

As a result of such technological changes, the tools of the San Dieguito III phase exhibit not only a wider variety of tool types, but also a fundamental refinement in tool manufacture. A primary difference in tool technology is represented by the introduction of pressure flaked blades and points. Unlike simple percussion flaking, pressure flaking requires a more delicate and finely conceived touch. The resulting tools exhibit form, complexity and balance not found in the early phases of the San Dieguito people.

Other diagnostic traits associated with San Dieguito III include scraper planes, choppers, plano-convex scrapers, crescentic stones, elongated bifacial knives, and intricate leaf-shaped projectile points (Rogers 1939:28-31, 1966). Beyond specific tool types and the introduction of pressure flaking, there exists no absolute method of discerning between San Dieguito II and III. Patination, a weathering process involving chemical change on the surface of stones, is a relative guide to antiquity and may provide gross distinctions between the San Dieguito phases; however, its use is limited by the many variables which are involved in its application (Arnold 1971; Alsoszatai-Petheo 1975; Bard et al., 1976; Laudermilk 1931).

2.3 DESERT CULTURES (7000-1000 BP)

Following the relative uniformity of the Paleo-Indian/Western Lithic Co-Tradition, the archaeological record becomes less clear and probably more specialized within particular regions. Inland peoples and lake terrace dwellers developed hunting and foraging tools as varied as the natural resources they exploited. In addition to environmental variations that may have given rise to artifact diversity, cultural isolation and/or successive migrations of new peoples could have led to apparent diversity in technology.

As discussed in detail below, the most basic or fundamentally defined complexes or periods are the desert-based Pinto Period circa 7000 to 4000 years ago and the Amargosa Period circa 4000 to 1500 years ago. Slightly better defined but far from well understood, the La Jolla/Oak Grove/Topanga/Pauma cultures existed roughly contemporaneously with the Pinto/Amargosa peoples circa 8000 to 1500 years ago.

2.3.1 Pinto/Amargosa Period (6000–1500 BP)

Based largely on projectile point types and a scatter of stone tools across the California/Arizona deserts, various authors have recently documented human occupation in these areas 8000 to 1500 years ago (Wilke 1976; E.L. Davis 1963, 1974, 1978). The work of these researchers has complimented earlier work by Rogers (1939, 1966) and Campbell and Campbell (1935). Large-scale surveys and continued comparison of tool types has led the later researchers to reject or at least seriously modify the "vacated desert" concept postulated earlier by Rogers and the Campbells. Although settlement was certainly sparse as a result of small population and nomadism, generalized cultural patterns were practiced by people sharing similar technology, environment and possibly ethnic backgrounds.

The Pinto complex was centered around major water sources including lake shores. From these now arid areas, bands of people migrated across the land in pursuit of medium-sized game, seeds, nuts and berries (Wilke 1976; Meighan 1976; Bettinger and Taylor 1974). Although milling tools have been associated with Pinto camps, distinctive Pinto projectile points, flaked stone and infrequent hammer-pounders are more representative of the Pinto tool assemblage.

The Amargosa Period is well-defined throughout the Great Basin but becomes unclear as one moves south and west across California. Beginning approximately 4000 years ago, the Amargosa complex clearly differs from the earlier Pinto complex. Amargosan points are also known as Elko or Elko-earred points or in the later Amargosan period as Gypsum Cave points. Typically, these points are notched and large stemmed (Campbell and Campbell 1935:pl. 13; Wallace 1978:Fig. 11). Food processing tools included trapezoidal/triangular blades, shaped and unshaped manos, and scraper planes. According to Wallace (1978:31), campsites are generally devoid of hearths, food remains and architectural features.

Late Amargosan or Amargosan-like technology melds into Millingstone Horizon types along coastal and peninsular range California, as noted by Wallace (1978:32), and Kowta (1969:39-40). Whether Amargosan peoples gradually amalgamated with Hakataya-Patayan peoples from the southwest or blended into other, as yet undefined, cultures is not clear. Amargosan migration to present-day northern Baja California and the upper Sonoran Desert is also a strong possibility (Hayden 1967, 1976).

2.3.2 La Jolla-Pauma (7500-1000 BP)

By about 7000 years ago a new group of peoples had begun to inhabit and exploit the coastal and inland regions of San Diego County replacing or evolving from San Dieguito III (Moriarty 1969:12-13). Whether the people, or the economic base shifted during this time is not clear. Moriarty (1967) states that the San Dieguito to La Jolla transition was an economic and technologic response to environmental change and not a result of migration.

The La Jolla were nomadic exploiters of maritime resources (Harding 1951; Moriarty et al., 1959:185-216; Wallace 1960:277-306) who also relied on seed gathering and vegetal processing. The La Jolla may have been entering into the mortar and pestle phase late in the terminal stage of the La Jolla-Pauma transitional period (Warren 1961). The tool types of the La Jolla indicate that these members of what Wallace (1955) terms Early Milling Horizon possessed a far greater reliance on the sea and on foraging than did their predecessors, the San Dieguito people. The variety and quality of lithic tool manufacture is much more basic and unrefined when compared with even the basal phase of the San Dieguito complex, and lacks the point/blade aspect noted for contemporaneous Pinto-Amargosa peoples.

Characteristic traits of the La Jolla complex include fire hearths, shell middens, flexed inhumation, grinding implements, and absence of ceramics. Archetype La Jolla sites are located along the coast near bay or lagoon areas. In recent years, inland La Jolla sites of a seemingly later period have been discovered in transverse valleys and sheltered canyons, including Valley Center (Meighan 1954:215-227; True 1959:225-263; Warren et al. 1961:1-108). These noncoastal sites have led to a new name for La Jolla-type sites with an inland location. Meighan (1954), True (1959), and Warren et al. (1961) have applied the term Pauma Complex to certain inland sites which possess a predominance of grinding implements (especially manos and metates), lack of shell, greater tool variety, more sedentary life patterns than expressed by San Dieguito sites, and an increased dependence upon gathering. However, it is more probable that these inland sites represent a noncoastal manifestation of Early Milling peoples who adopted or developed a hunting mode more so than their coastal brethren. Wallace (1955:214-230) denotes this late transitional phase as Intermediate, and establishes its position as between Early Milling Horizon and Late Milling Horizon.

2.4 LATE MILLING/LATE PREHISTORIC (1000 BP-1800s AD)

By 1000 years BC or almost 3000 years ago Yuman-speaking peoples who shared cultural elements had occupied the Gila/Colorado River drainage (Moriarty 1966) and portions of the study area. Through gradual westward migration the Yumans drifted into Imperial and San Diego Counties where they came into contact with, and apparently acculturated with, the remnants of the Early Milling La Jolla-Amargosa cultural tradition (Moriarty 1965, 1966). Because of basic similarities in the late La Jolla/early Yuman patterns it is difficult to clearly define the contact period or point between La Jolla-Amargosa.

Much controversy surrounds the identity of the late prehistoric peoples who used and occupied the Imperial Valley region. At the time of European contact (ca. 1769 AD), the hot, parched surface of this broad desert basin was believed to have been unoccupied. Later, ethnographic research conducted and/or reported by Bourke (1889), Henshaw and Hodge (1907), Harrington (1908), Waterman (1909), Gifford (1918, 1931), Kroeber (1925) and others presented a mass of conflicting data regarding the name of the prehistoric occupants, but all agreed that much of the valley region had been occupied and used by peoples of the Yuman stock. General agreement with regard to cultural patterns and behaviors also exists. Within the Imperial Valley region, these prehistoric/protohistoric peoples possessed ceramics and basketry, practiced an informal "flood plain" agriculture (corn, beans, squash and melons) supported by a generalized hunter-gatherer subsistence base, maintained a closely knit clan system, had elaborate and extremely complex kinship patterns, and carried on extensive trade and cultural interaction with surrounding groups (Gifford 1918, 1931; Spier 1923; Kroeber 1925, 1943; Rogers 1936; Drucker 1937). Whether called Kamia, Kumeyaay, or otherwise the people occupying the Imperial region were of Yuman stock, and exercised a cultural pattern befitting that cultural heritage (Langdon 1975; Hedges 1975).

Dr. James R. Moriarty has suggested (1965, 1966) that there existed a pre-ceramic Yuman phase as evidenced from his work at the Spindrift Site in La Jolla. Based on a limited number of radiometric samples, Moriarty has concluded that a pre-pottery Yuman phase had occupied the San Diego coast 2000 years ago and that by 1200 years before present (BP) ceramics had diffused from the eastern deserts.

Although some researchers still follow Rogers' belief that Yuman ceramics first appeared in San Diego County only 1000 years ago (Rogers 1945) there is a growing body of data that supports Moriarty's hypothesis. A recent excavation of a La Jolla/Kumeyaay site in Sorrento Valley (Carrico 1975) encountered a cultural stratification with a basal date of 3755 years ago and a terminal date of 2525 BP. It is worth noting that the upper stratum (0-10 centimeters) of the dated column contained ceramics and projectile points commonly considered time markers indicative of Late Milling Kumeyaay. Radiometric dating of a large shell sample from this stratum produced a date of 2525±70 years BP. The near absence of ceramics and total lack of projectile points below the 10 centimeter level within a series of strata which contained a variety of seemingly early cultural material dated at 2925±70 BP (30-40 centimeters) and 3755±75 BP (50-60 centimeters) may indicate that this is a multicomponent, culturally stratified site containing a transition between La Jolla and Yuman circa 2500 years ago.

Whether the Yuman peoples arrived on the coastline 2500 years ago, 2000 years ago or 1500 years ago, they brought with them a culture heavily influenced by their Yuman neighbors in the eastern desert region of California and along the Colorado River. These prehistoric/protohistoric peoples possessed ceramics, operated a closely knit clan system, utilized a highly developed grinding technology, had elaborate and extremely complex kinship patterns, created rock art, and carried on extensive trade with the surrounding cultural areas (Rogers 1945:167-198; Kroeber 1925:709-725; Strong 1929). It has also been postulated that the Kumeyaay (Diegueno, after San Diego) and their northern neighbors, the Cahuilla, may have been practicing a basic type of proto-agriculture prior to Hispanic contact (Lewis 1973; Shipek 1974:personal communication; Treganza 1947).

About 1000 to 1500 years ago a group of Shoshonean-speaking people migrated out of the Great Basin region and intruded like a wedge into southern California. This wedge separated the Yuman groups and was eventually to cause great cultural variations (Kroeber 1925:178; True 1966). In coastal San Diego County, this group of Shoshonean intruders has been labeled the San Luis Rey I and II Complex (Meighan 1954:215-227). When the early Hispanic missionaries contacted these people they called them the Luisenos, after the Mission San Luis Rey de Francia which was founded in the heart of Luiseno (San Luis Rey II) territory. In the desert regions, the Cahuilla and Chemehuevi bands represent Shoshonean intrusion in southeastern California. These Late Milling peoples occupied portions of the Lake Cahuilla shoreline and the Colorado River region well north of the current study area.

Although of a different linguistic stock, the Cahuilla and the Kumeyaay-Yumas shared cultural traits. D.L. True (1966) has suggested that the basic similarities in ecological exploitation, environmental setting and temporal placement forced the late-coming and highly nomadic Shoshoneans to adapt to a life style and cultural pattern which was established and functioning upon their arrival.

2.5 PROTOHISTORIC PERIOD

The Hispanic intrusion, 1769-1822, into Native American southern California affected the coastal tribes and those people who lived in well-traveled river valleys. The Mexican Period, 1822-1848, saw continued displacement of the native population by the expansion of the land-grant program and the development of extensive ranchos. The gold rush and the concomitant granting of statehood combined with an influx of aggressive, land-hungry Anglos caused a rapid displacement of the natives, as well as deterioration of their culture and lifeways (Shipek 1974:personal communication; Bancroft 1886; Kroeber 1925). During this period, when native cultures of the Colorado Desert and lower Colorado River were in direct contact with the highly influential Western culture, aboriginal lifeways became jeopardized.

Cultural descriptions of Native American groups from the time of early European contact to the present have been preserved in the writing of explorers, soldiers, settlers, ethnographers, and Native Americans. Based upon these written works of the past two centuries, a rather complete picture of protohistoric native Colorado Desert people can be recreated. Literature concerning the Cahuilla, Yuma, and Kamia (Kumeyaay) groups include Barrows (1900), Gifford (1918, 1931 and 1934), Hooper (1920), Strong (1929), Heizer and Whipple (1957), Kroeber (1925), Cox (1961) and Phillips (1975).

2.5.1 Yuma and Kamia (Kumeyaay)

Closely related geographically, and by kinship, customs and language, the Kamia and Yuma peoples of the Colorado Desert and lower Colorado River both can be identified as of the Yuma stock of the Hokan family (Kroeber 1925). Based upon linguistic criteria, the Yuman stock can be further subdivided into three divisions, one of which (the Central division) contains both aforementioned groups (Kroeber 1925).

The agriculturally-oriented Yuma who call themselves Kwichyana or Kuchiana were first named Yuma by Friar Kino in the early 1700s (Bolton 1919, Kroeber 1925). Today, the Native Americans of this region identify themselves as Quechan, a derivation of the Kwichyana (or Kuchiana) name (Kroeber 1925).

Due to their location along the Colorado River, the Yuman people were one of the native groups that experienced the earliest and most intense European contact in southern California. When Alarcon sailed up the Rio de los Tizones (Colorado River) in 1540, he was the first European to encounter the Yuman people even though they were previously aware of the Spanish and their equipment due to stories of Spaniards in New Mexico only a few months prior (Kroeber 1925).

Following early explorers like Alarcon in 1540 and Onate in 1605, missionaries entered the Colorado River region. Establishment of missions in Yuman territory was not initially successful. Two missions were established in 1779 only to be destroyed within two years by the intolerant Yumans (Kroeber 1925; Cox 1961). A punitive force of Spanish soldiers under Pedro Fages was sent to the Yuma territory.

Between 1781 and 1849, when gold was discovered in California, there was apparently little interaction between the Yuma and the Anglos (Spicer 1962). After 1849 however there was considerable Anglo-Indian interaction due to the number of settlers and miners passing through the Gila/Colorado River area along the southern immigrant trail (Cox 1961). Hostile confrontations during this period were numerous resulting in the establishment of a United States military fortification at Fort Yuma. Captain Samuel Heintzelman established the fort with three companies of soldiers near the mouth of the Gila River (Phillips 1975).

Confrontations between rival native groups probably took place well before the presence of Anglo influence as indicated by the mention of aboriginal warfare in the early writings of Alarcon (1904). Other recorded native conflicts are not uncommon (Cox 1961). Alliances and feuds were generally well established. Killing of warriors and taking of slaves commonly occurred during these raids and battles (Cox 1961; Phillips 1975). To the Yuma, their Mojave and Kamia neighbors were considered friends while the Pima, Maricopa and Cocopa were enemies (Kroeber 1925; Gifford 1934). One of the earliest confrontations recorded occurred in the late eighteenth century. A small group of people living in the southern portion of the Imperial Valley, the Kohuana, were apparently annihilated by a combined force of Yuma, Mojave, and Kamia after they had unfortunately allied themselves with the Cocopa (Gifford 1931). Pima and Yuma clashed in 1858 with an unfavorable outcome for the Yuma (Kroeber 1925). Chronic warfare between the Yuma and Cocopa was eventually halted by the American military at Fort Yuma during the last half of the nineteenth century even though occasional raids and killings persisted until about 1900 (Gifford 1931).

The Kamia (or Desert Kumeyaay) of Imperial Valley generally experienced contact with the Spaniards, Mexicans and Americans later in time and less frequently than the Yuma due to their inhospitable desert domain. Kamia were first encountered by the Spanish during the 1775 expedition of Anza, Garces and Font and later by Garces in 1781 (Bancroft 1886). Following this exploratory period by the Spanish, few interactions between native Kamia and Anglos occurred until gold rush immigrants traveled across the valley (Bancroft 1886).

Territory of the Kamia had somewhat unfixed boundaries centered around the New River and Alamo River sloughs. Kamia reportedly established camps along the Colorado River near Algodones to the east although this is generally considered Yuman holdings (Gifford 1931). Hostile Cocopa lived south of the Kamia west of the Colorado River Delta and Shoshonean Cahuilla inhabited Coachella Valley to the north. Kamia are often identified as desert-dwelling Kumeyaay with only slight dialectical variation from these western kin (Gifford 1931). Boundaries between the Kumeyaay groups were not clearly definable since transitional locations such as Jacumba and the Anza Borrego area were inhabited by clans of both affiliations (Gifford 1931).

Kamia rarely battled neighboring groups without the support of their Yuman or Mojave allies due to their few numbers (Gifford 1931). It was reported by Don Agustin Janssens (1953) however that the Kamia of Jacumba were responsible for the raid upon Otay Rancho. In addition, Kamia under the leadership of their chief, Geronimo, were responsible for resistance toward the Americans from 1850 until his execution in 1852 (Phillips 1975).

As Americans entered and settled the Imperial Valley and adjacent Kamia holdings, inevitable conflicts occurred due to the competition for the scarce water and arable land within the desert valley. Travelers from Imperial Valley to Jacumba were periodically attacked (Ford 1976). Ranchers occasionally discovered livestock either slain or stolen by local Kumeyaay and Kamia (Odens 1977; McCain 1977:personal communication). Trouble between settlers and Kamia came to a head in 1880 when a group of angry ranchers rode into a rancheria near Jacumba and killed 15 Indian men, women and children (Odens 1977).

2.5.2 Cahuilla

Desert Cahuilla inhabited the northern end of the Salton Trough in Coachella Valley substantially north of the current study area in protohistoric times (Kroeber 1925). Lines of trade and communication existed between the Shoshonean-speaking Cahuilla and their Yuman-speaking Kamia neighbors to the south, but were not as developed as those established between intralinguistic groups (Hooper 1920; Kroeber 1925). Cahuilla traded items including bulbs, roots, cat-tail sprouts, yucca leaves, mescal, pine nuts, manzanita berries, chokecherries and mesquite beans to the Kamia and received gourd rattles and perhaps obsidian in return (Phillips 1975; J.T. Davis 1974).

Aside from the trade that occurred between the Kamia and Cahuilla, little influence of the Cahuilla can be found in the study area. Aggressive interactions between Kamia and Cahuilla were rare. Most recorded Cahuilla hostilities do not relate to neighboring groups but were usually between Cahuilla clans (Hooper 1920).

2.6 ARCHAEOLOGICAL PERSPECTIVE

Lake Cahuilla once covered an area roughly 35 miles wide and 105 miles long extending from Indio south, past the U.S./Mexico border. The importance of this large body of water to the understanding of past lifeways cannot be underestimated. Lake Cahuilla would have covered one-fourth of the lower southern portion of California and was present as recently as 500 years ago. Oral tradition of the Cahuilla states that, "The lake was filled with fish, and that ducks and geese occurred in great numbers. The Cahuilla lived in the mountains and used to come down to the lake to fish and hunt. The water gradually subsided little by little and their villages were moved down from the mountains into the valley" (Blake 1856:98). According to Heizer, Treganza and Kroeber the Kumeyaau occupied the study area. The most encompassing archaeological studies conducted along the shoreline to date are those of Malcolm Rogers in the 1920s and Ben McCown in the 1950s.

2.7 RECORD SEARCH DATA

WESTEC Services, inc. has completed a thorough review of pertinent site record data from those institutions and agencies possessing such data. San Diego Museum of Man, and Imperial Valley College Museum in El Centro were found to have site information for archaeological/historical locales within the study area. Record search data has been provided within a support package to the client and is not contained in this report.

2.8 PREVIOUS FIELDWORK

The Salton Sea region has been the subject of numerous archaeological investigations. Unfortunately, the majority of these studies were conducted in areas far removed from the immediate project environs. In brief, the following individuals have provided survey/excavation manuscripts or field notes concerning native American settlement in Imperial County: Rogers (n.d.); McCown (1955, 1957); Barker and Burton (1970); Bell (1974); Ellis and Crabtree (1974); Maxon (1975); U.S. Department of Interior (USDI), Bureau of Land Management (1975); von Werlhof and von Werlhof (1975a, b, c; 1977a, b, c; 1978a, b; 1979, 1980); Brooks, et al. (1977); Weaver (1977); Dewey (1978a, b); White et al. (1978); Eckhardt (1979); Gallegos (1980); and Wilke (1978). These studies with the exception of Wilke (1978) were conducted in the East Mesa region, a study area most applicable to the current project.

In February 1980, an intensive examination of ten exploratory geothermal wells on the subject property was carried out by Jay von Werlhof from Imperial Valley College Museum. The Elmore series of wells (numbers 2, 4, 5, 6, and 8); Weist 1, 2, 3; Baretta 1; and R.R. 2 were found to be "devoid of historic or prehistoric cultural resources" (von Werlhof 1980).

Malcolm Rogers' (n.d.) work in the vicinity resulted in the recordation of a locale numbered C-89 (obsidian butte). This well-known resource is situated off the project to the southwest at 1¼ miles.

Rogers reported an obsidian quarry site affiliated with Yuman III (Kumeyaay) culture group. Rogers documented plentiful amounts of obsidian cobbles along terraces of the former Blake Sea. Thin seams were also noted within a shale formation. The cobbles had been extensively used as prehistoric source material. According to Rogers, C-89 represents the only known occurrence of obsidian in southern California. This lithic material was noted during the course of the current investigation. Appearance of this rock type did not result from prehistoric depositional processes, but rather from use of obsidian as rip-rap in road construction. Imperial Valley College Museum also has Obsidian Butte recorded as Imp-452 (Romandia n.d.). In proximity to the project are site areas numbered Imp-900 through 904. These locales were recorded as aboriginal trails (Washburn 1856). Specifically, the recorded areas were reported within Sections 6, 7, 8, 17, and 18 on the Obsidian Butte USGS 7.5 minute quadrangle. Past and on-going agriculture development has eliminated evidence for any trail system.

A more thorough synthesis of archaeological/historic sensitivity is presented within an overview for the entire Salton Sea Anomaly Area. Institutional response is provided as Attachment A in this report.

SECTION III

SURVEY TECHNIQUES AND RESULTS

3.1 FIELD SURVEY METHODS

The survey techniques employed in this study conform to the guidelines and requirements of the Society for California Archaeology (King et al. 1973), and with those set forth by the National Park Service in their "Guidelines for the Preparation of Statements on Environmental Impact on Archaeological Resources" (Scovill et al. 1972).

Basically, the survey method employed was an on-foot reconnaissance of those portions of the project to be impacted by future development as defined in the Niland Anomaly Master Environmental Impact Report (WESTEC 1980).

Certain survey limitations confronted the field crew in project assessment. Specifically, these limitations included: 1) intensive land utilization for agricultural endeavors, which in turn disrupt/remove possible resource deposits; and 2) project location (adjoining the Salton Sea) precludes expectations for encountering cultural resources in this area. With the exception of a ±30 acre parcel adjacent to Alamo River, remaining sections were being cultivated in either cotton or alfalfa. Nonetheless, a systematic approach was used in an attempt to locate any evidence for native American occupation/use within the confines of the 49 MW geothermal project. Briefly, the project entails construction of a 49 MW geothermal power plant on approximately 10.6 acres of land on the northwest corner of Sinclair and Garst Roads (Figure 2). In addition, 20 production, 7 injection, and 24 replacement wells have been proposed in association with the geothermal plant development. Each well has been determined to occupy 1.5 acres.

3.2 RECONNAISSANCE OF THE 49 MW PLANT SITE

The on-foot reconnaissance of the proposed 49 MW geothermal plant site was negative; no evidence for native American residence/use could be detected. This particular area, as of this writing, was planted in alfalfa, rendering ground visibility less than ideal. The three-person crew lined up along Garst Road with a 5 meter interval being maintained between each crew member. From this point a series of west/east transects were carried out on the 10.6 acre site until the entire parcel was covered. Despite luxuriant crop growth, intensive examination of exposed ground surfaces proved negative. Photographs were obtained during the course of this survey and are on file with WESTEC Services, Inc. in San Diego.

3.3 RECONNAISSANCE OF GEOTHERMAL WELL SITES

The proposed well sites were investigated in the following manner: each well has been tentatively assigned a precise location along USGS depicted landmarks, i.e., at regular intervals along existing roads. By using the Niland USGS 7.5 minute quadrangle and the transport vehicle odometer, the crew located each well site and proceeded to conduct transects of the 1.5 acre parcels with survey techniques applied at the proposed 49 MW plant locale. In total, seventeen wells were subject to examination by the WESTEC survey team. Results were negative; no areas exhibited any material trace of prehistoric occupation/use. Photographs were taken at each proposed well location. Ten wells (refer to Section 2.8) were not surveyed because they had been surveyed previously and were devoid of cultural resources. As in the case of the 10.6 acre 49 MW geothermal area, extensive agricultural practices have created measurable negative effect. Specifically, individual well sites were either being presently cultivated or the crops had recently been plowed under.

SECTION IV

ADVERSE EFFECTS

As currently proposed, the construction of the Magma Geothermal Company's 49 MW geothermal plant and well facilities will not cause adverse effects to cultural resources. The absence of cultural resources (archaeological and historical) within or near the proposed project precludes the possibility of impact or impairment to such resources.

This finding of no adverse effect is based on careful consideration of 36 CFR 800.2 and 36 CFR 800.3 (Federal Register, January 30, 1979).

SECTION V

RECOMMENDED MITIGATION

The results of an intensive on-foot reconnaissance of the proposed 49 MW geothermal plant and associated well sites were negative; no cultural resources, either historic or prehistoric, were encountered. No further action beyond information provided in this report is required by the investigators. The absence of cultural resources within the project area precludes the necessity for any mitigation based on the finding of no adverse effect.

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Attachment A

RECORD SEARCH RESPONSE

NOTE

Data support package filed with client, not included within this report.

California Archaeological Site Survey

Regional Office

Desert County of Imperial
Imperial Valley College and
I.V.C. Museum
442 Main Street
El Centro, CA. 92243
(714) 352-1667

January 7, 1981

Mr. Randy Franklin
WESTEC Services, Inc.
3211 Fifth Avenue
San Diego, CA 92103

Dear Randy:

Enclosed please find copies of 4-IMP sites within the area marked for your project NILAND MEIR on Quadrangle maps: Frink, Calipatria, Obsidian Butte, Wister, Niland, Westmorland, and Iris Wash.

You will note that a few of the sites are from an old 1854 USGLO survey and have a possibility of being totally destroyed through agriculture.

All sites have been mapped on your maps. Included with each map is a listing of sites.

Best regards,

Treola Ross
Executive Secretary
IVCEM

Enclosures

INVOICE ATTACHED

WESTEC Services, Inc.
SAN DIEGO, CALIFORNIA
Albuquerque, New Mexico
Brawley, California
Las Vegas, Nevada
Philadelphia, Pennsylvania
Sacramento, California
Santa Ana, California