PRELIMINARY EVALUATION OF THE POTENTIAL FOR ARTIFICIAL GROUND-WATER RECHARGE IN EASTERN SAN JOAQUIN COUNTY, CALIFORNIA

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CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

For readers who may prefer to use metric (International System or SI) units rather than inch-pound units, the conversion factors for the terms used in this report are listed below.

Multiply	By	To obtain
acre	4047	m^2 (square meters)
ft^3/s (cubic feet per second)	0.02832	m^3/s (cubic meters per second)
ft (feet)	.3048	m (meters)
$(gal/d)/ft^2$ (gallons per day per square foot)	.04047	m/d (meters per day)
in (inches)	25.4	mm (millimeters)
in/d (inches per day)	25.4	mm/d (millimeters per day)
in/h (inches per hour)	25.4	mm/h (millimeters per hour)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)

Temperature °F = temperature °C(1.8)+32.

GLOSSARY

This glossary presents simplified definitions of technical terms used in this report.

Alluvium: Clay, silt, sand, gravel, or similar detrital material deposited by running water.

Andesitic: Pertaining to a dark-colored, fine-grained, volcanic rock.

Aquifer: A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield water to wells and springs.

Aquifer system: A heterogeneous body of intercalated permeable and poorly permeable material that functions regionally as a water-yielding hydraulic unit.

Artificial recharge: Recharge at a rate greater than natural, resulting from man's activities.

Base line and meridian: A pair of coordinate axes, one east-west (base line) and the other north-south (meridian), from which township, range, section, and quarter-section corners are established in the U.S. Public Land Survey system. (There are three pairs of coordinates in California.)

Basement complex: The undifferentiated complex of rocks that underlies the rocks and unconsolidated deposits of interest in an area.

Basin spreading (artificial recharge): Impounding water in natural or manmade depressions behind levees, dikes, or dams.

Breccia: A coarse-grained rock, composed of angular broken rock fragments held together by a mineral cement or in a fine-grained matrix; the fragments have sharp edges and unworn corners.

Claypan: A dense, heavy, relatively impervious subsurface soil layer that owes its hardness to a relatively higher clay content than that of the overlying material. It is usually hard when dry and plastic when wet.

Confined aquifer: An aquifer containing confined ground water.

Confined ground water: Water under pressure significantly greater than atmospheric; its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the material in which the confined water occurs.

Conglomerate: A sedimentary rock, composed of rounded to subangular rock fragments set in a fine-grained matrix, and commonly cemented.

Cretaceous: A term used to denote the span of time between approximately 136 and 65 million years ago; also, the corresponding system of rocks.

Driller's log: The driller's report that describes the gross characteristics of the drill cuttings noted by the drilling crew as a well is drilled.

Eocene: A term used to denote the span of time between approximately 54 and 38 million years ago; also, the corresponding series of rocks.

Formation: A persistent body of rock or unconsolidated material having easily recognizable boundaries that can be traced in the field, and large enough to be represented on a geologic map as a practical unit for mapping and description.

Freshwater: In this report, water that has a concentration of dissolved solids less than about 2,000 milligrams per liter.

Geodetic: Pertaining to the determination of the size and shape of the Earth and the precise location of points on its surface.

Ground water: That part of the subsurface water that is in the zone of saturation.

Ground water divide: In this report, a ridge in the water table from which the ground water represented by the water table moves away in both directions.

Hardpan: A general term for a relatively hard, impervious and often clayey layer of soil lying at or just below land surface, produced as a result of cementation of soil particles. Its hardness does not change appreciably with changes in moisture content, and it does not slake or become plastic when mixed with water.

Head: The elevation relative to some datum (sea level) of the upper surface of water that occurs in a well that penetrates an aquifer. Static head.

Holocene: A term used to denote the span of time between approximately 10,000 years ago and the present; also, the corresponding series of rocks.

Hydraulic conductivity: The property or capacity of a porous rock, sediment, or soil for transmitting a fluid. It commonly is used interchangeably with coefficient of permeability.

Igneous: A rock or mineral that solidified from molten or partly molten material; also applied to processes leading to, related to, or resulting from the formation of such rocks.

Metamorphic rock: Any rock derived from pre-existing rocks by mineralogical, chemical, and/or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust.

Miocene: A term used to denote the span of time between approximately 24 and 5 million years ago; also, the corresponding series of rocks.

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of the coterminous United States, Alaska, and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

Phase (soil): A division of soil type.

Pleistocene: A term used to denote the span of time between approximately 1.8 million and 10,000 years ago; also, the corresponding series of rocks.

Pliocene: A term used to denote the span of time between approximately 5 and 1.8 million years ago; also, the corresponding series of rocks.

Quaternary: A term used to denote the span of time between approximately 1.8 million years ago and the present; also, the corresponding system of rocks.

Range: See township.

Recharge: The processes related in the absorption and addition of water to the zone of saturation.

Rhyolitic: A term pertaining to a group of extrusive igneous rocks (the volcanic equivalent of granite).

Section: One of 36 units of subdivision of a township, representing a piece of land normally 1 square mile in area.

Sedimentary: Pertaining to or containing solid fragmental material that originates from weathering of rocks and is transported or deposited by air, water, or ice, or that accumulates by other natural agents, and that forms on the Earth's surface at ordinary temperatures.

Series (geology): A division of rock formations smaller than a system.

Series (soils): A group of soils having the same genetic horizons, similar important characteristics and àrrangement in the profile, and underlain by similar parent material.

Specific yield: A term indicating potential capacity to store water in a material such as rock or soil. The ratio of (1) the volume of water which the material, after being saturated, will yield by gravity to (2) the volume of the material.

Subsoil: A soil of indefinite thickness below the topsoil.

Surface water: All waters on the surface of the earth, including fresh and salt water, ice, and snow.

System: A major division of rock formations.

Tertiary: A term used to denote the span of time between approximately 65 and 1.8 million years ago; also, the corresponding system of rocks.

Topsoil: The surface soil usually including the average plow depth.

Township: A unit of survey of the U.S. Public Land Survey system, representing a piece of land that normally is divided into 36 sections. Townships are used in conjunction with ranges. Townships are numbered consecutively north and south of a specified base line and ranges are numbered east and west of a principal meridian.

Tuff: A general term for all rocks resulting from consolidation of material from a volcanic eruption.

Type (soil): A division of soil series.

Unconfined aquifer: An aquifer in which the upper surface of the saturated zone, the water table, is at atmospheric pressure and is free to rise and fall.

Unconfined ground water: Water that is in an unconfined aquifer.

Water table: The upper surface of the zone of saturation in an unconfined aquifer.

Well canvass: A systematic field examination of wells.

Zone of saturation: A subsurface zone in which all the interstices are filled with water under pressure greater than that of the atmosphere.

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ABSTRACT

In response to increasing demand on water supplies and declining water levels in San Joaquin County, the U.S. Geological Survey, in cooperation with the San Joaquin County Flood Control and Water Conservation District, is evaluating the potential for artificially recharging the aquifer system in eastern San Joaquin County, California. This study (phase 1 of 3 phases) included a well inventory and analyses of existing data on geology, soils, and drillers' logs. Twenty sites were identified for exploratory test drilling in areas potentially favorable for artificial recharge. Of the sites, 10 are in areas adjacent to the Mokelumne River, 6 are in areas adjacent to the Calaveras River and Mormon Slough, and 4 are north of Littlejohns Creek.

INTRODUCTION

Problem

Lowering of the water table, which became noticeable between 1954 and 1964 in eastern San Joaquin County, and the eastward movement of poor quality water into the Stockton area (California Department of Water Resources, 1967), combined with projected increases in water needs, have been a cause of concern to officials of San Joaquin County. In an effort to resolve their ground-water problems, the U.S. Geological Survey, in cooperation with the San Joaquin County Flood Control and Water Conservation District, began a study to evaluate the potential for artificially recharging the aquifer system in the eastern part of the county with surplus surface water that is available during the winter and spring months.

Location and General Features

The project area (fig. 1) comprises about 250 mi^2 in the central part of California's Central Valley, east of the confluence of the San Joaquin and Sacramento Rivers, and west of the Sierra Nevada. Topography ranges from low hills in the east (western edge of the Sierra Nevada foothills) to gently rolling in the central areas, to nearly level in the west.

The project area consists of two parts. The northern part (about 50 mi^2) lies along the Mokelumne River and the southern part (about 200 mi^2) includes the Calaveras River, Mormon Slough, and Littlejohns Creek (fig. 2). Stockton (population 150,000, 1980 estimate) and Lodi (population 35,000), the largest cities in the county (population 347,000, U.S. Bureau of Census, 1981), are west of the project area.

July is the warmest month and averages about 76°F; January, the coolest month, averages about 45°F. Average annual precipitation is about 14 inches, occurring mostly between October and April (U.S. Department of Commerce, 1980, p. 4, 9). Precipitation increases at higher altitudes in the Sierra Nevada to the east.

Streamflows in the rivers flowing into the area depend on precipitation and melting snowpack in the Sierra Nevada. Flows in the Mokelumne and Calaveras Rivers are regulated by dams so that water is available for irrigation during the summer months. The average discharge in the Mokelumne River below Camanche Dam is 804 ft^3/s, based on 50 years of record, and in the Calaveras River below New Hogan Dam is 211 ft^3/s, based on 17 years of record (U.S. Geological Survey, 1979, p. 263, 382).

Purpose and Scope

The purpose of the project is to evaluate the potential for artificial recharge of surface water, using the basin-spreading method, to the unconfined aquifer system in the eastern part of San Joaquin County. The project is divided into three phases. Continuation of each successive phase depends on an evaluation of the results from the previous phase. This report summarizes the results of phase 1 in which areas that appear most suitable for artificial recharge and selected sites for more detailed study were identified. The scope of phase 1 consisted of a comprehensive well inventory during the summer of 1980 and an analysis of existing data. In phase 2, wells would be drilled at sites selected in phase 1 to define characteristics of the sediments above the water table. The sites would be evaluated for suitability for recharge and, if favorable, sites would be selected for recharge testing. In phase 3, tests would be conducted at a maximum of three sites where potential infiltration rates will be determined.

Approach

In this report, information on geology, soils, drillers' logs, and land use was used to generate a series of maps that define the more promising areas for artificial recharge. Hydraulic conductivity of geologic units and soils was estimated from various sources, most of which do not provide quantitative values or correlations. For example, the California Department of Water Resources (1967, p. 27) indicates that the Mehrten Formation has a low to high 'permeability' ranging from 0.1 to 501 $(gal/d)/ft^2$. The same source (1967, p. 44) indicates that infiltration rates for soils range from 0.6 to 2 in/h (about 14 to 48 in/d). In a supplementary plate, Retzer and Glassey (1951) indicate a low soil 'permeability' (infiltration rate) is less than 3 in/d and that a high 'permeability' is greater than 25 in/d. Therefore, no attempt was made to quantify hydraulic conductivity. Rather, hydraulic conductivity, as used in this report, is a relative term designated as very high, high, moderate, low, or very low. Data on soils were used to delineate areas of hardpan and claypan. Specific yields were estimated from drillers' logs to define the more promising areas with respect to deeper sediments. Finally, data on land use were used to define areas more readily available for potential recharge facilities.

Well-Numbering System

The well-numbering system used by the Geological Survey in California indicates the location of wells according to the rectangular system for the subdivision of public lands. For example, in the number 1N/8E-16K1, the part of the number preceding the slash indicates the township (T. 1 N.); the number after the slash the range (R. 8 E.); the digits after the hyphen the section (sec. 16); and the letter after the section number the 40-acre subdivision of the section as indicated in the diagram below. Within each 40-acre tract the wells are numbered serially as indicated by the final digit of the well number. Thus, well 1N/8E-16K1 was the first well to be listed in NW¼SE¼ sec. 16. For wells not located in the field by the Geological Survey, the final digit has been omitted. The entire study area is north and east of the Mount Diablo base line and meridian.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Acknowledgments

Data collection for this report was made possible by the cooperation of public agencies. Mr. Howard S. Hitchcock of the San Joaquin County Flood Control and Water Conservation District was especially helpful in supplying hydrologic data. Personnel of the California Department of Water Resources were helpful in providing specific yield information and crop-survey maps.

GEOLOGIC UNITS

The geologic units that are exposed at the land surface in the project area include unconsolidated deposits of Holocene, Pleistocene, and Pliocene age and consolidated rocks of Pliocene, Miocene and Oligocene age (fig. 2, table 1). Older rocks are exposed east of the project area and lie at depths greater than those of interest in the area of this project.

TABLE 1. - Generalized section of geologic units and hydraulic conductivities

[After California Department of Water Resources (1967, p. 13) and Piper and others (1939, pl. 1)]

System	Series	Geologic unit	Lithologic character	Maximum thickness (feet)	Hydraulic conductivity
		Unconsolidated deposits			
QUATERNARY	Holocene	Stream-channel deposits	Sand and gravel with lesser amounts of silt and clay.	50(?)	High
	Holocene and Pleistocene	Holocene alluvium and Pleistocene sediments formerly called the Victor Formation	Discontinuous lenses of gravel, sand, silt, and clay.	150	Moderate
TERTIARY	Pliocene	Laguna Formation	Poorly sorted sand, silt, clay, and gravel.	1,000	Moderate
		Consolidated rocks			
	Pliocene and Miocene	Mehrten Formation	Andesitic sandstone, siltstone, breccia, conglomerate, and tuff.	600	High to low
	Miocene and Oligocene	Valley Springs Formation	Rhyolitic ash, clay, and gravel.	500	Low

Unconsolidated Deposits

Stream-Channel Deposits

Stream-channel deposits are exposed along the major streams in the area and are especially extensive along the channel of the Mokelumne River (fig. 2). The deposits consist of sand and gravel with lesser amounts of silt and clay. Although the deposits are generally thin, they probably have high hydraulic conductivity and offer ready avenues for infiltration of water.

Holocene Alluvium and Pleistocene Sediments

Holocene alluvium and Pleistocene sediments formerly called the Victor Formation are exposed over the central and western parts of the area (fig. 2) and merge gradually with flood-basin deposits west of the project area. These sediments consist of sand, gravel, silt, and clay and generally are coarser grained than the underlying Laguna Formation. They are rather thin, and so most wells penetrate through them into the underlying formations.

Laguna Formation

The Laguna Formation of Pliocene age is exposed in a northwestward trending belt near the middle of the project area (fig. 2). It consists of stream-laid sand and clay. The unit dips gently westward and thickens to about 1,000 ft in the vicinity of Stockton. Because the lithology is similar to underlying and overlying units, it is difficult to distinguish below land surface.

Consolidated Rocks

Mehrten Formation

The Mehrten Formation of late Tertiary age is exposed along the eastern edge of the area (fig. 2). It consists of stream-laid deposits of sandstone, breccia, conglomerate, tuff, and siltstone (Piper and others, 1939, p. 61-67). The formation dips westward. In the Stockton area it lies 800 to 1,000 ft below land surface. The upper part of the formation is finer grained than the lower parts and some of the strata are discontinuous. Because of the varied lithology, the Mehrten Formation has hydraulic conductivity ranging from high to low (California Deptartment of Water Resources, 1967, p. 21-26).

Valley Springs Formation

The Valley Springs Formation of Middle Tertiary age is exposed in the eastern part of the area (fig. 2). It is a sequence of rhyolitic ash, clay, sand, and gravel. The California Department of Water Resources indicated that, although sand and clay layers within it are more continuous than similar types in overlying formations, the formation is generally too deep for economic productivity by wells in the main agricultural and urban areas. Furthermore, the formation probably has low hydraulic conductivity (California Department of Water Resources, 1967, p. 19-20).

SOILS

The character of a soil can affect the infiltration rate of water into that soil. The infiltration rate at a spreading basin is not constant, but is highest when water is first applied to the underlying soil. After a period of time, such as a few hours or days, the rate decreases until it becomes constant. Generally, the coarser the soil, the higher its constant infiltration rate will be (Bouwer, 1978, p. 4). However, the flow of water through the soil will be hindered if a barrier, such as hardpan, is present.

Soils in the Stockton and Lodi areas have been mapped in great detail by Retzer and Glassey (1951) and Cosby and Carpenter (1937). The soils are classified emphasizing those characteristics (including hydraulic conductivity and the presence of hardpan or claypan) that influence the adaptability of the land to the production of crops, plants, grasses, and trees. The sequential classification of soils is by series, type, and, if necessary, phase (table 2).

Hydraulic conductivities based on the classification of the mapped soils are shown in table 2 and figures 3 and 4. In addition, the classified soils are used to define areas of hardpan and claypan (fig. 5). Figures 3, 4, and 5 show that the largest areas of soils free of hardpan and claypan and having very high to moderate hydraulic conductivities are those that are crossed by the Mokelumne and Calaveras Rivers and Mormon Slough.

TABLE 2. - Classification and hydraulic conductivity of soils

[After Retzer and Glassey (1951), and Cosby and Carpenter (1937)]

Soil			Hydraulic conductivity[1]		
Series	Type	Phase	Topsoil	Subsoil	Notes
Bear Creek	Clay loam		Low	Low	
	Adobe clay		Low	Low	
	Clay		Low	Low	
	Cobbly clay loam		Moderate	Moderate	
	Gravelly sandy loam		High	High	
Columbia	Very fine sandy loam		Moderate	Moderate	
Cometa	Sandy loam		Moderate	Very low	Claypan
Greenfield	Sandy loam		High	High	
	Gravelly loam		Moderate	Moderate	
Hanford	Loamy sand		High	High	
	Sandy loam		Moderate	Moderate	
Honcut	Clay		Moderate	Moderate	
	Clay	Shallow	Low	Very low	
	Fine sandy loam		Moderate	Very low	
	Very fine sandy loam		Moderate	Moderate	
Landlow	Clay		Low	Very low	
	Clay adobe		Very low	Very low	
Madera-Almo			Variable	Very low	Hardpan
Pentz	Cobbly sandy loam		Moderate	Moderate	
	Sandy loam		Moderate	Moderate	
	Sandy loam	Undulating	Moderate	Moderate	
Pentz-Redding	Gravelly loam		Moderate	Moderate	
Peters	Clay adobe		Low	Low	
	Clay adobe	Level	Low	Low	
	Cobbly clay		Low	Low	
Romona	Sandy loam		Moderate	Moderate	
Redding	Gravelly loam		Moderate	Very low	Hardpan
Rocklin	Loam		Moderate	Very low	
	Loam	Deep	Moderate	Very low	
San Joaquin	Loam		Moderate	Very low	Hardpan
Stockton	Clay (adobe)		Very low	Very low	
Tuscan			Low	Very low	
Whitney	Fine sandy loam		Moderate	Moderate	
Wyman	Clay		Low	Low	
	Clay loam		Moderate	Low	
	Clay loam	Poorly drained	Low	Low	
	Clay loam	Shallow	Low	Low	
	Silt loam		Moderate	Moderate	

[1]See text page 3.

HYDROLOGY

Fresh ground water in the study area occurs in the Holocene alluvium and Pleistocene sediments formerly called the Victor Formation, Laguna Formation, Mehrten Formation, and in the upper part of the Valley Springs Formation (California Department of Water Resources, 1967, p. 17-35). Stream-channel deposits generally are above the water table and act only as avenues for infiltration of surface water to the underlying units. Because the sedimentary beds containing freshwater are gradational and occur as lenses, partial confinement probably occurs. The beds are interconnected, however, and the freshwater aquifer as a unit is considered to be unconfined for the purposes of this study.

A water-level map of the study area is shown in figure 6. Ground water moves from areas of high to low head, perpendicular to lines of equal head. Water levels for the autumn of 1979 show that ground water generally moved toward a depression in the water table in T. 1 N., R. 8 E. In addition, ground water from a mound near the town of Victor moved northward out of the study area.

Recharge to the aquifer occurs from streams, irrigation, and precipitation. The aquifer gained additional water by movement of ground water into the study area beneath the southern and eastern boundaries.

Ground-water discharge from the area is principally by pumping. However, water also leaves the area as ground-water outflow north of Victor.

Sufficient capacity exists in the sediments above the water table to store additional ground water. Depth to water in the eastern part of the area was not mapped, but elsewhere in the area, depth to the water table ranges from a minimum of about 50 ft near Victor to at least 140 ft in the southwestern part of the area (fig. 7).

SPECIFIC YIELD

The California Department of Water Resources has demonstrated that an increase in specific yield is related to an increase in hydraulic conductivity (California Department of Water Resources, 1974a, p. 135-138). On the basis of this relation, specific yield is used in this report as an additional guide to evaluate areas for potential artificial recharge. Thus, specific yield provides a relative index of potential for flow of water through sediments deeper than the soil zone and surficial geologic units.

Specific yield data were obtained by translating descriptions of materials on drillers' logs to values of specific yield using the method defined by Davis and others (1959, p. 202-206). Those values were processed by computer to calculate estimated average specific yield values for each section and for several depth intervals below land surface. The reliability of computed section averages depends on the availability and accuracy of well logs and, consequently, varies among the sections. Results from the 25- to 50-foot interval are the most reliable of several zones tested. The location of wells used to compute average values are shown in figure 8. Specific yield values of 0.10 or greater arbitrarily are considered as potentially better for artificial recharge than lower values (fig. 9).

AREAS POTENTIALLY SUITABLE FOR ARTIFICIAL RECHARGE

The infiltration rate will be controlled mostly by near surface conditions such as land surface topography and the presence of hardpan. The flow of water after it enters the ground will depend on the hydraulic characteristics of the aquifer.

The potential for artificial recharge is delineated into areas of high, medium, and low potential (fig. 10), which were determined by superimposing the maps of hydraulic conductivity with the map delineating hardpan and claypan described earlier. Although some of the results are based on geologic units that are exposed in the area, heaviest emphasis is based on the classification of soils. Areas of high recharge potential are mostly adjacent to the Mokelumne River, Calaveras River, and Mormon Slough. Additional areas of high recharge potential lie in the southeast part of the study area north of Littlejohns Creek. It should be noted that in the area of high potential near the town of Victor, the water table is 50 ft below land surface (fig. 7). Although 50 ft of sediments represent significant potential for storage of water, the thickness of sediments above the water table is much greater in the other areas. Also, the area of high recharge potential near Victor lies above the part of the aquifer where water is moving out of the project area. Therefore, the area near Victor is less desirable for artificial recharge than other areas of high potential.

The more promising parts within areas of high recharge potential are considered to be those where the computed average specific yields are largest. Figure 10 also shows the parts of high potential areas where average specific yield is 0.10 or greater.

LAND USE AND DRILL SITE SELECTION

Initial investigation of potential recharge sites should be limited to areas that are potentially least costly to acquire or modify. Delineation of land development was obtained from a 1976 California Department of Water Resources land use survey and field checked in 1980. Land use is grouped into classes and subclasses according to: (1) types of agricultural, urban, or recreational development, and kinds of native vegetation; (2) kinds of crop for a given year; (3) intercrop practices; and (4) source of water supply (California Department of Water Resources, written commun., 1978). Areas of high recharge potential where average specific yield is greater than or equal to 0.10 (fig. 10) are divided into two groups: a relatively high cost group and a relatively low cost group. The relatively low cost group includes natural vegetation, irrigated pasture, and field, grain, and truck crops. The relatively high cost group includes orchards and vineyards, areas incidental to agriculture (such as farmsteads), and free water surfaces (such as ponds). (See figs. 11-13.) An additional requirement is used for hilly areas in the southeast part of the project area north of Littlejohns Creek. Only relatively level sites are considered suitable for artificial recharge in the hilly areas.

Sites for further investigation (phase 2 of the study) are restricted to lands in the relatively low cost group that are most accessible. Drilling of twenty test holes is planned. Tentative locations of the drilling sites are shown in figures 11-13. Drilling of test holes 6 through 20 will be based on results from initial drilling of holes 1 through 5.

SUMMARY

In response to increasing demand on water supplies and declining water levels in San Joaquin County, the U.S. Geological Survey, in cooperation with the San Joaquin County Flood Control and Water Conservation District, is evaluating the potential for artificially recharging the aquifer system in eastern San Joaquin County, California.

The purpose of the project is to evaluate the potential for artificial recharge of surface water, using the basin-spreading method, to the unconfined aquifer system in the eastern part of San Joaquin County. In this report (phase 1 of 3 phases) information on geology, soils, drillers' logs, and land use, plus that gained from a well inventory, was used to indicate the more promising areas for artificial recharge.

Geologic units exposed at land surface in the project area include unconsolidated deposits overlying consolidated rocks. Hydraulic conductivity of those materials ranges from low to high. In addition, soils in the area have hydraulic conductivities ranging from very low to high.

Fresh ground water in the area occurs in the upper part of the consolidated rocks and in the unconsolidated deposits. Water levels for the autumn of 1979 show that ground water generally moved toward a depression in the water table in T. 1 N., R. 8 E. In addition, ground water from a mound near Victor moved northward out of the area. Depth to the water table ranges from a minimum of about 50 ft near Victor to at least 140 ft in the southwestern part of the area. Therefore, sufficient capacity exists in the sediments above the water table to store additional ground water.

Specific yield was used as a relative index of potential for flow of water through sediments deeper than the soil zone and surficial geologic units. Values of specific yield were obtained from drillers' logs for the 25-to 50-foot interval. Specific yields of 0.10 or greater arbitrarily were considered as potentially better for artificial recharge than lower values.

Initial investigation of potential recharge sites were limited to those areas of medium to high hydraulic conductivity of soils and surficial geologic units of specific yield values equal to or greater than 0.10. Within those areas, land development and topographic relief aided the selection of 20 drilling sites for further exploration. Ten of the sites are in areas adjacent to the Mokelumne River, six are in areas adjacent to the Calaveras River and Mormon Slough, and four are north of Littlejohns Creek.

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No page 14

ILLUSTRATIONS

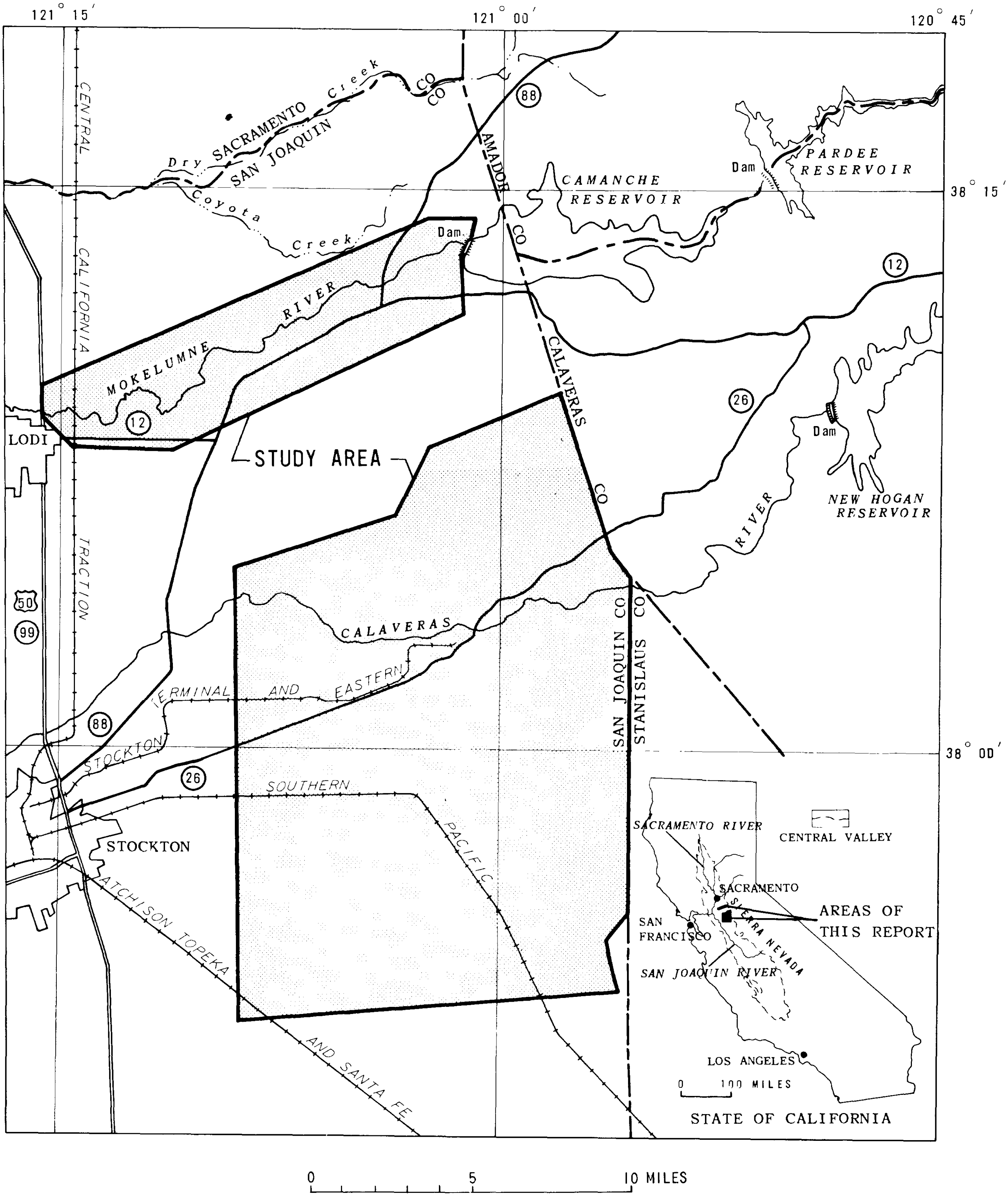
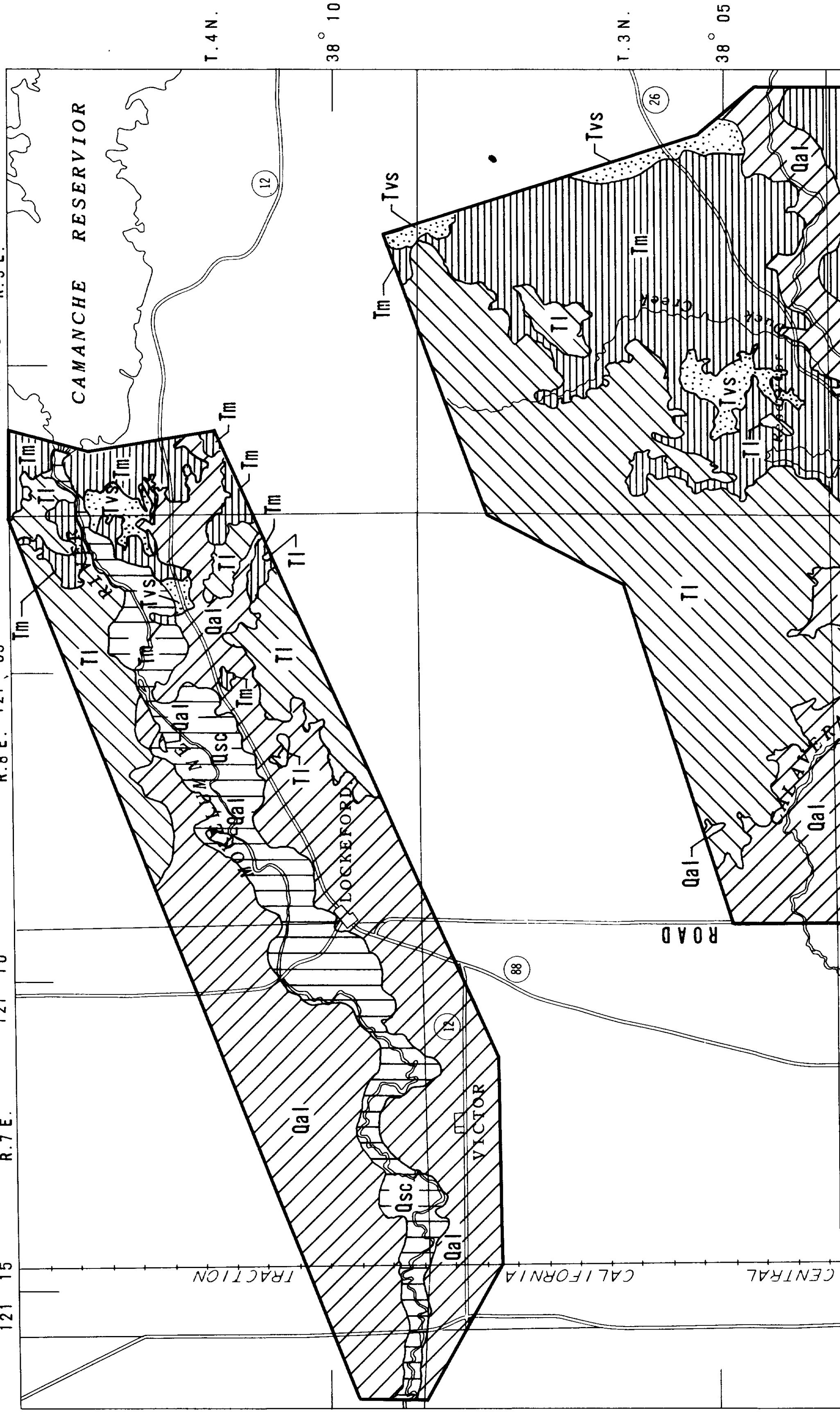


FIGURE 1.--Study areas.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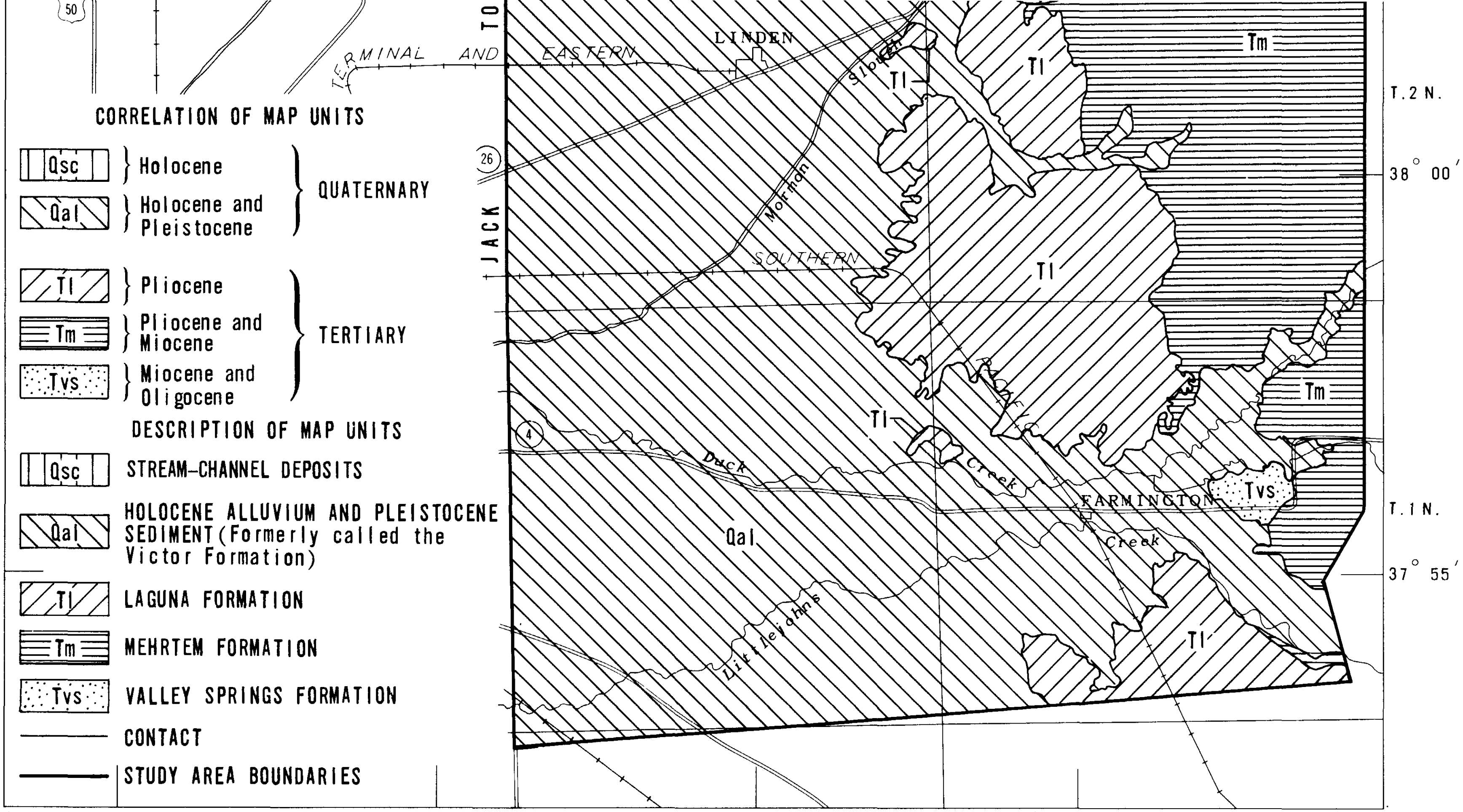

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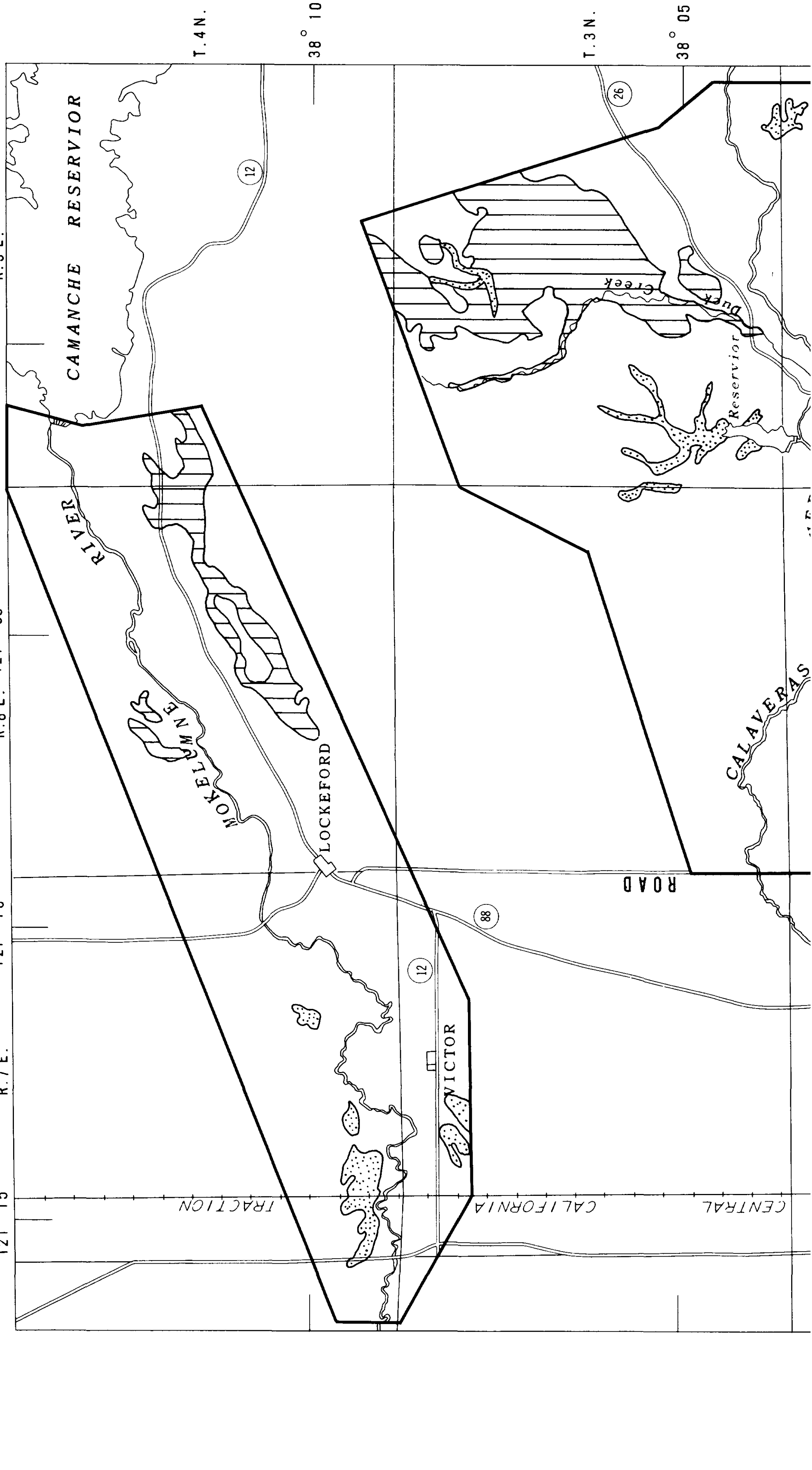
Geology from California Department of Water Resources, 1967

FIGURE 2.--Geologic map.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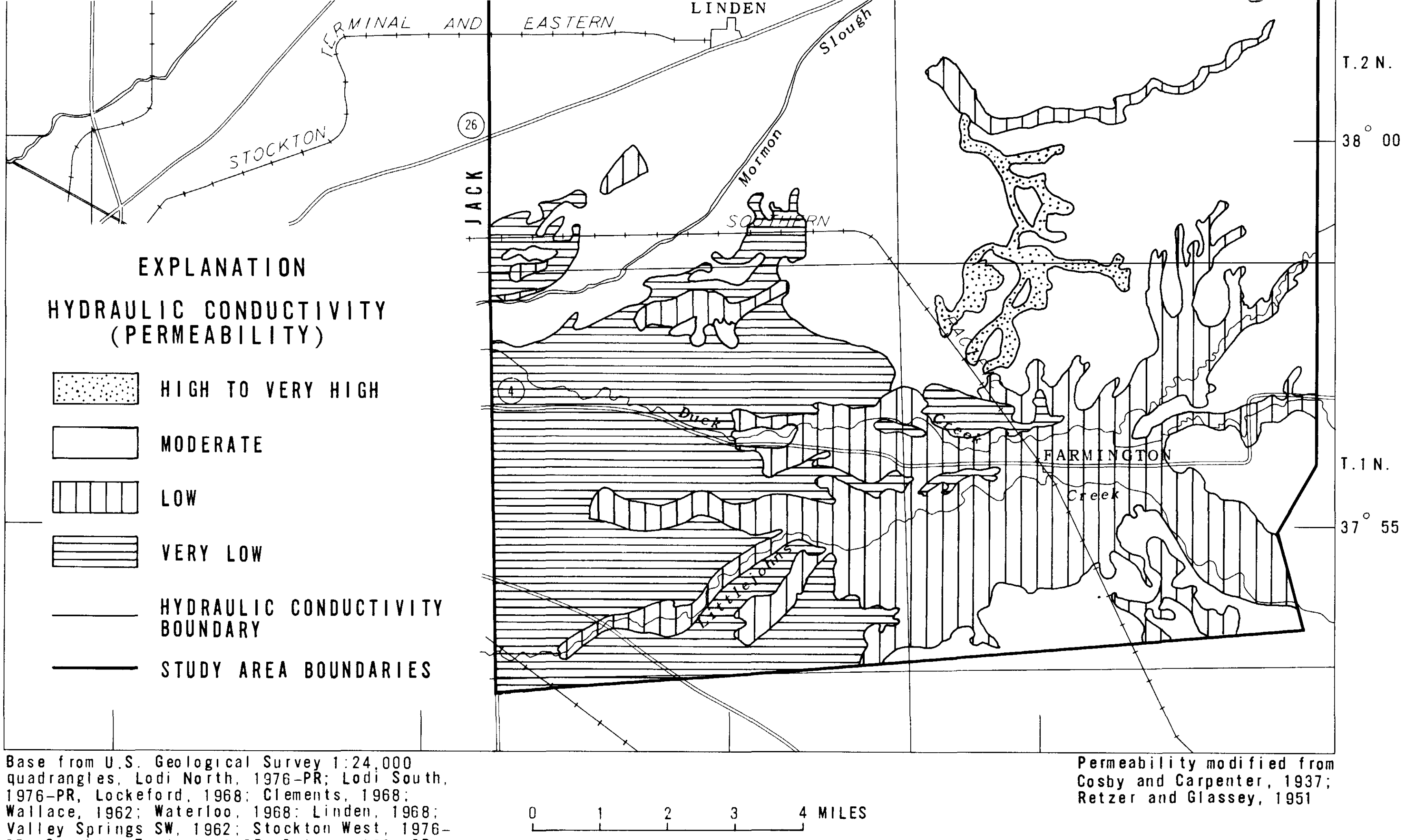
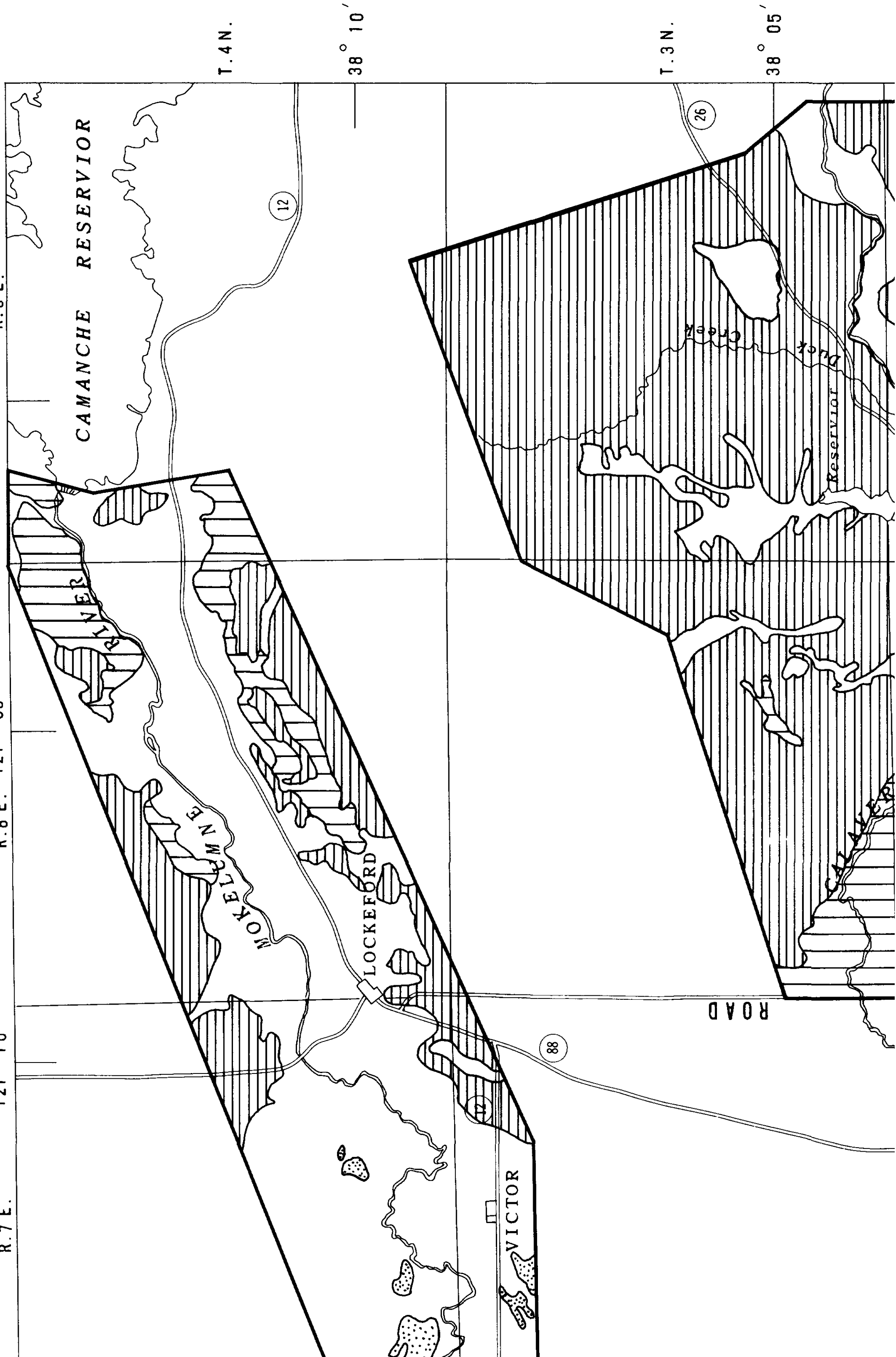


Base from U.S. Geological Survey 1:24,000 quadrangles, Lodi North, 1976-PR; Lodi South, 1976-PR, Lockeford, 1968; Clements, 1968; Wallace, 1962; Waterloo, 1968; Linden, 1968; Valley Springs SW, 1962; Stockton West, 1976-PR; Stockton East, 1976-PR; Peters, 1968-PR; Farmington, 1968.

Permeability modified from Cosby and Carpenter, 1937; Retzer and Glassey, 1951

FIGURE 3.--Hydraulic conductivity of topsoils.



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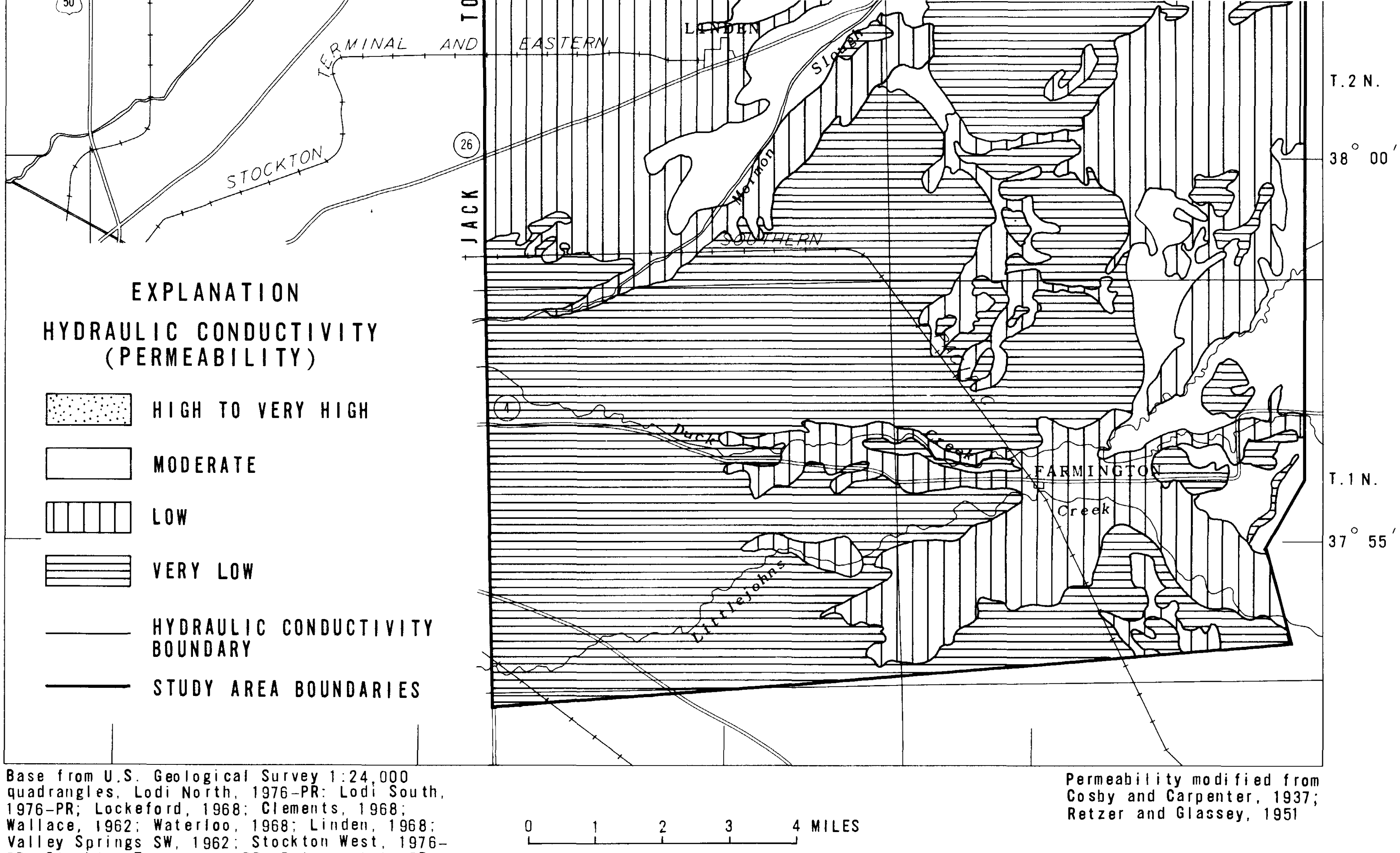

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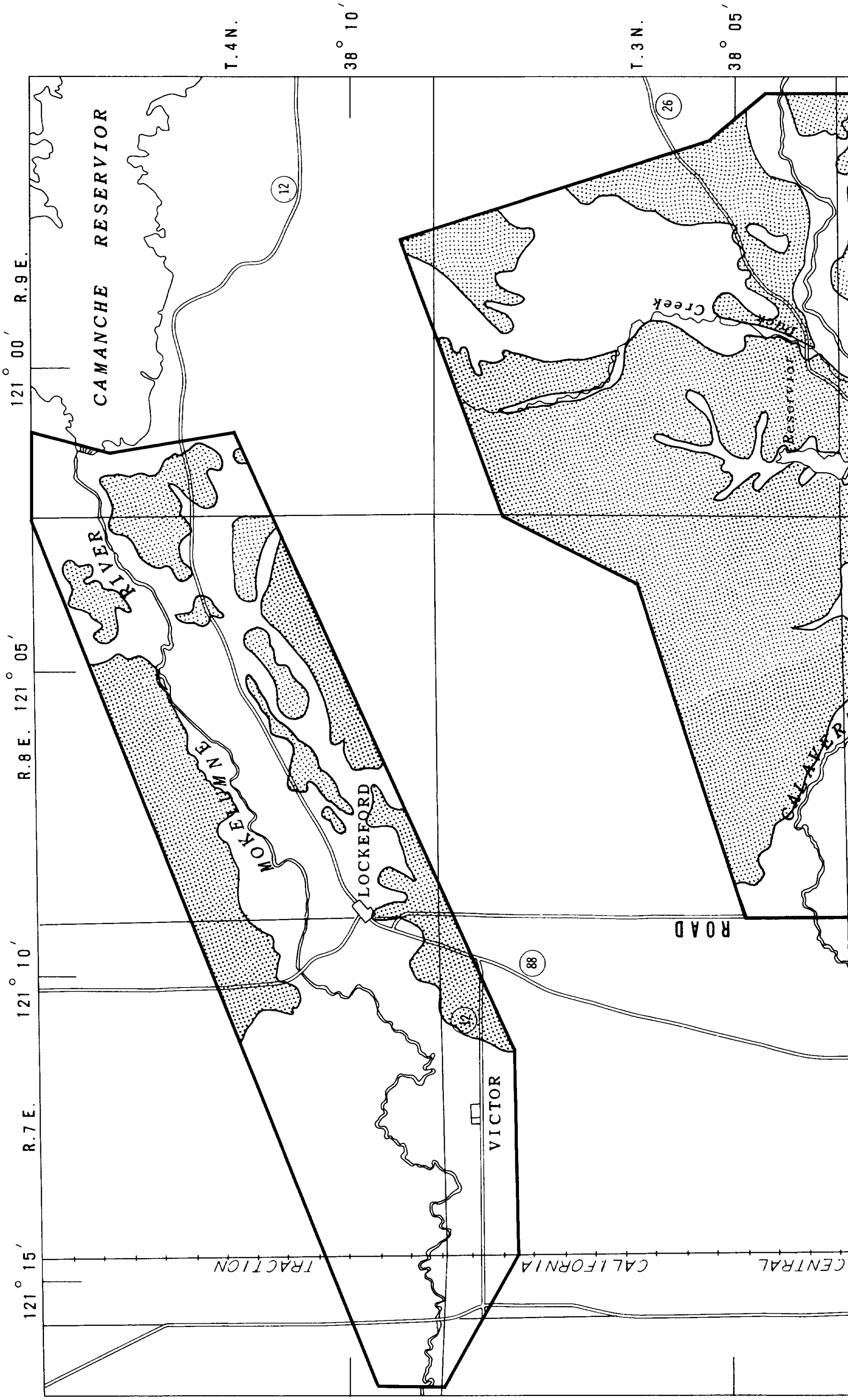
Permeability modified from Cosby and Carpenter, 1937; Retzer and Glassey, 1951

FIGURE 4.--Hydraulic conductivity of subsoils.



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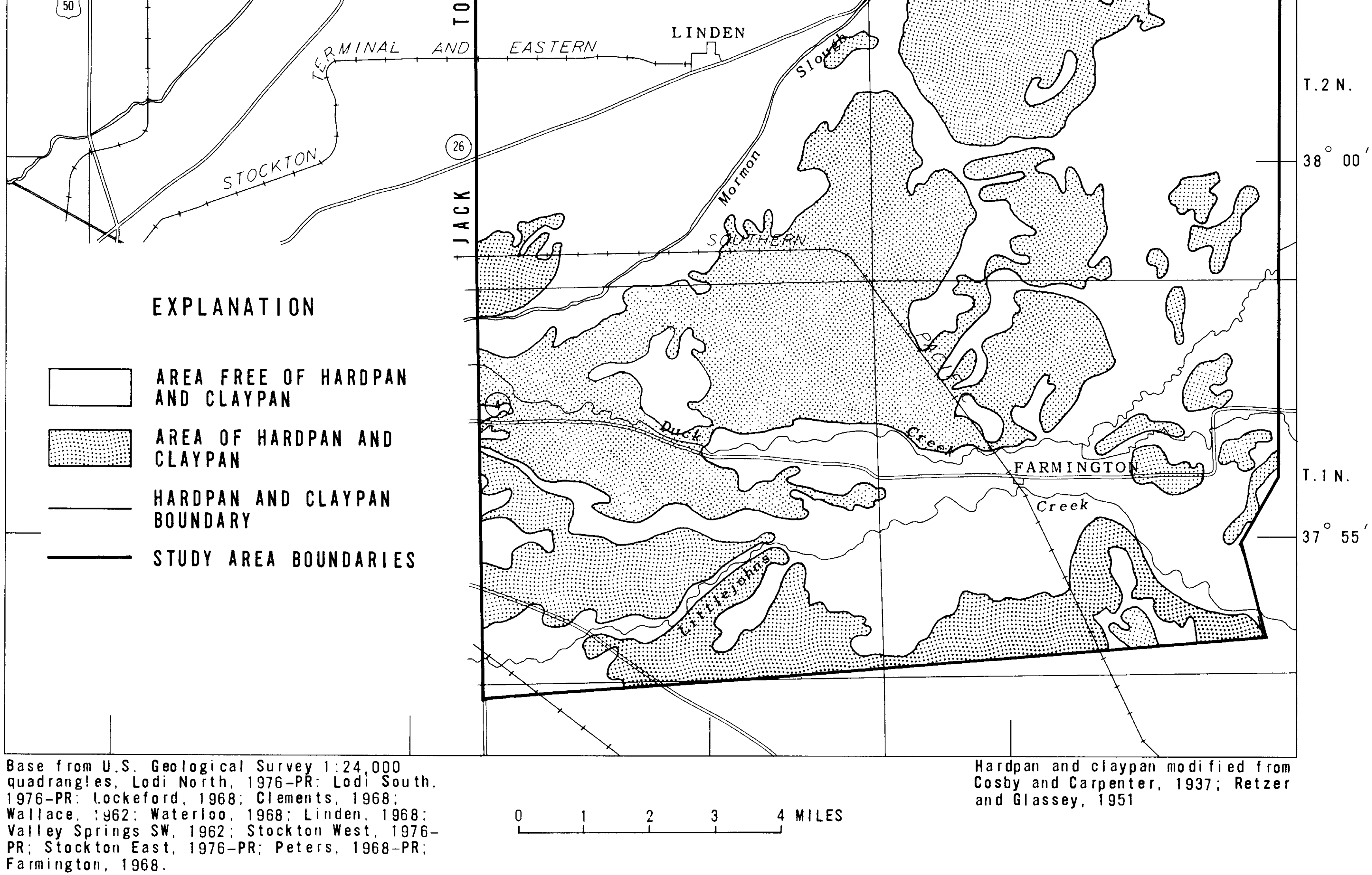
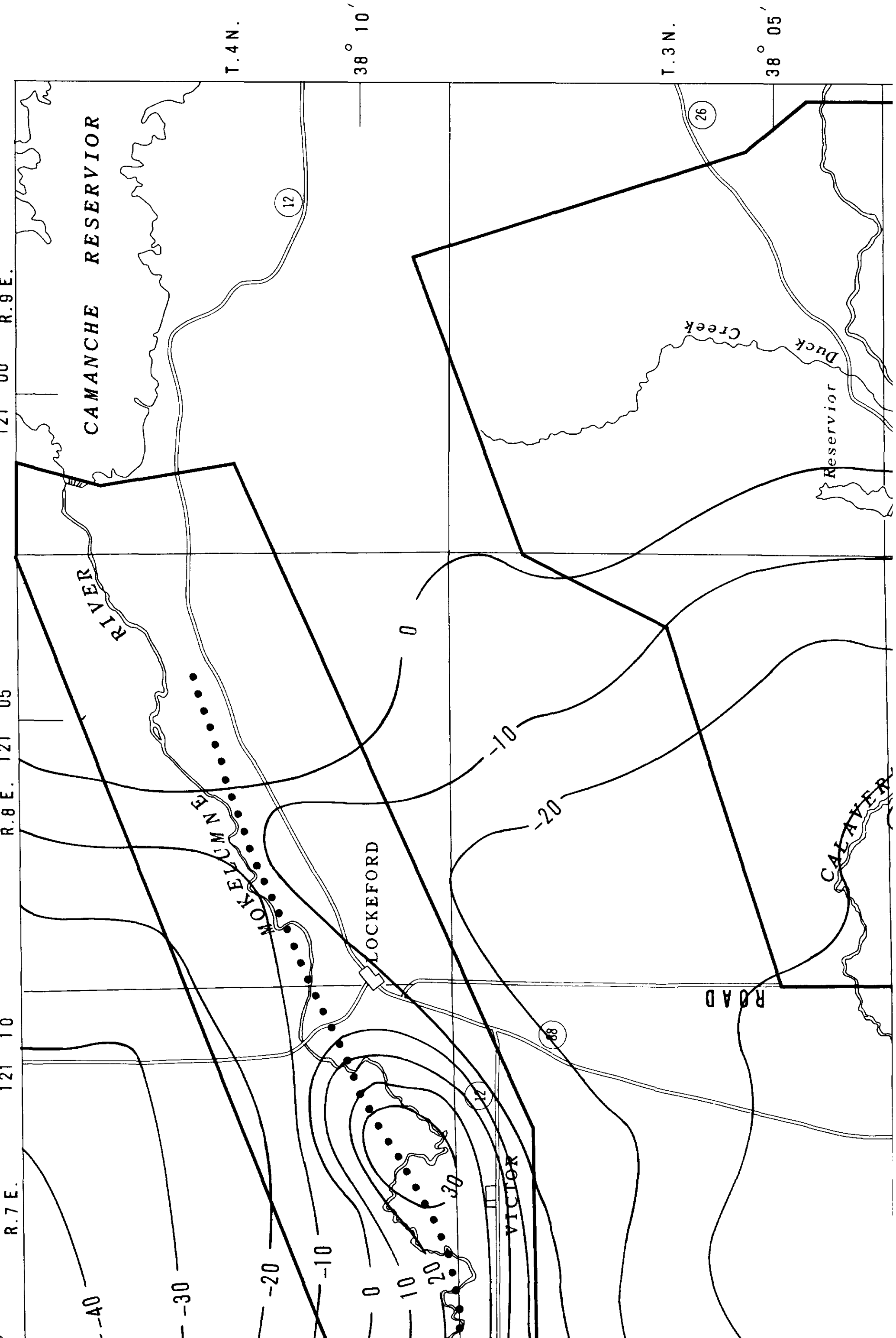


FIGURE 5.--Areas of hardpan and claypan.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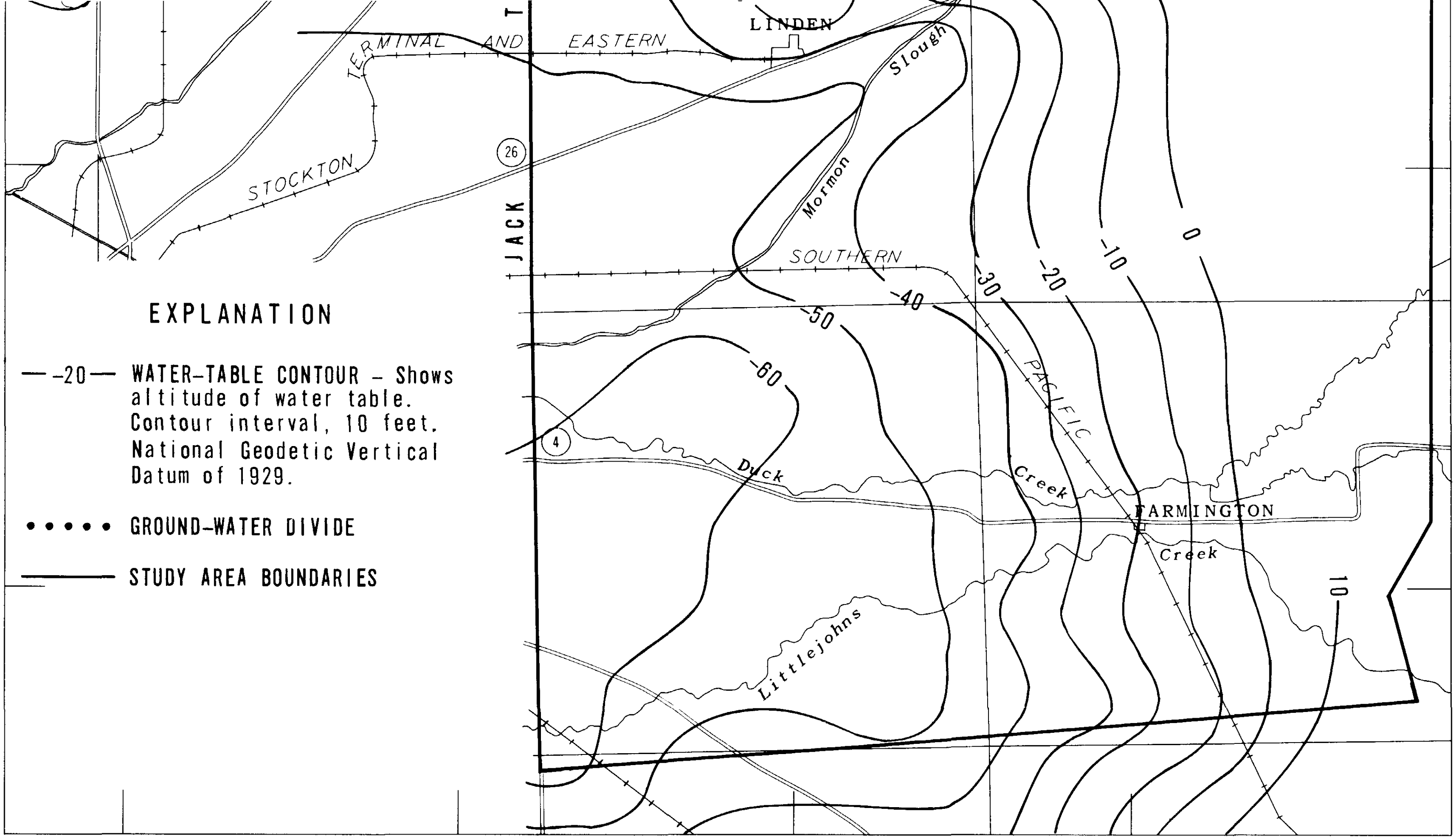

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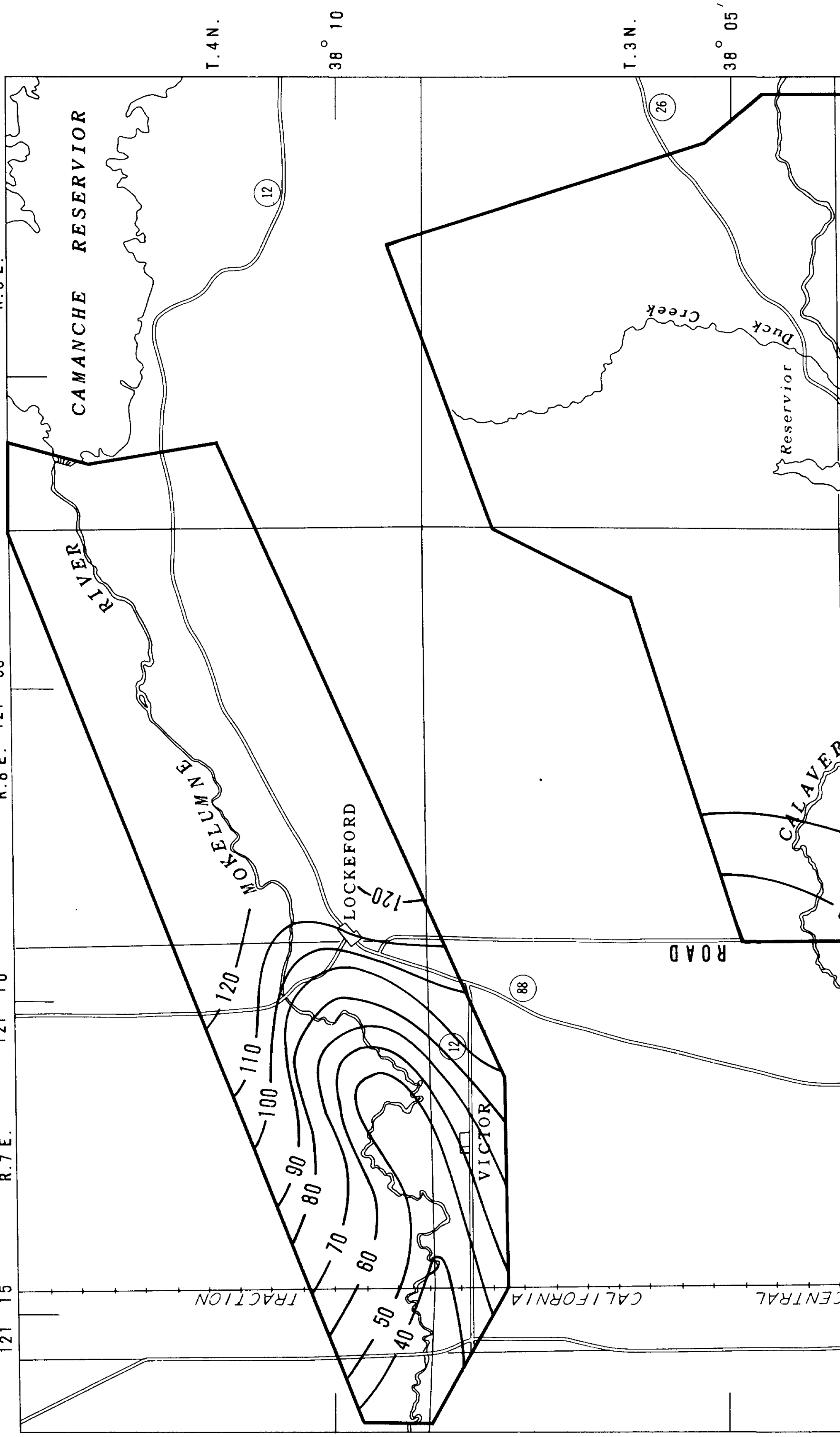
Altitude of water table from San Joaquin County Flood Control and Water Conservation District, 1979

FIGURE 6.--Altitude of water table, autumn 1979.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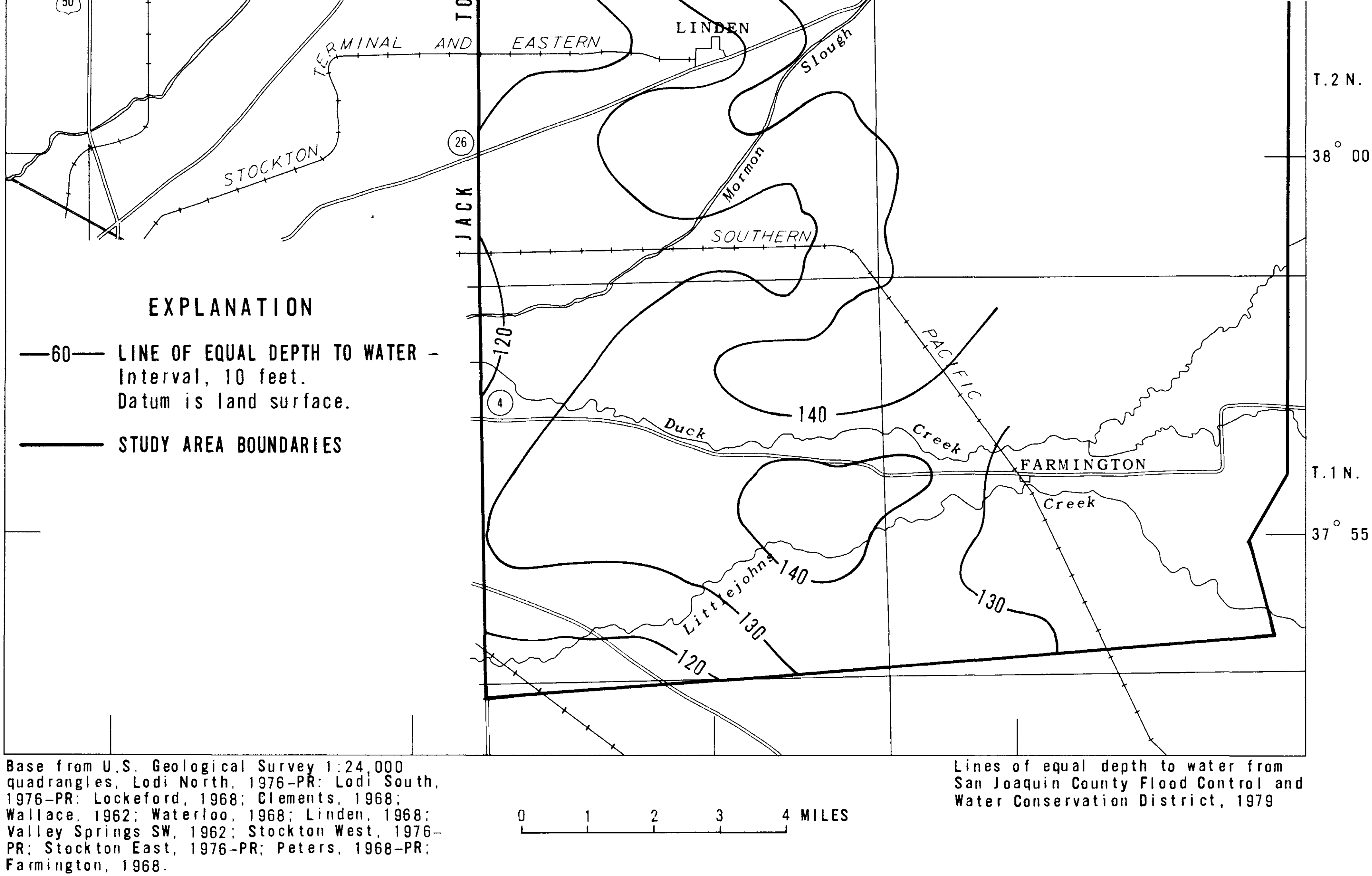
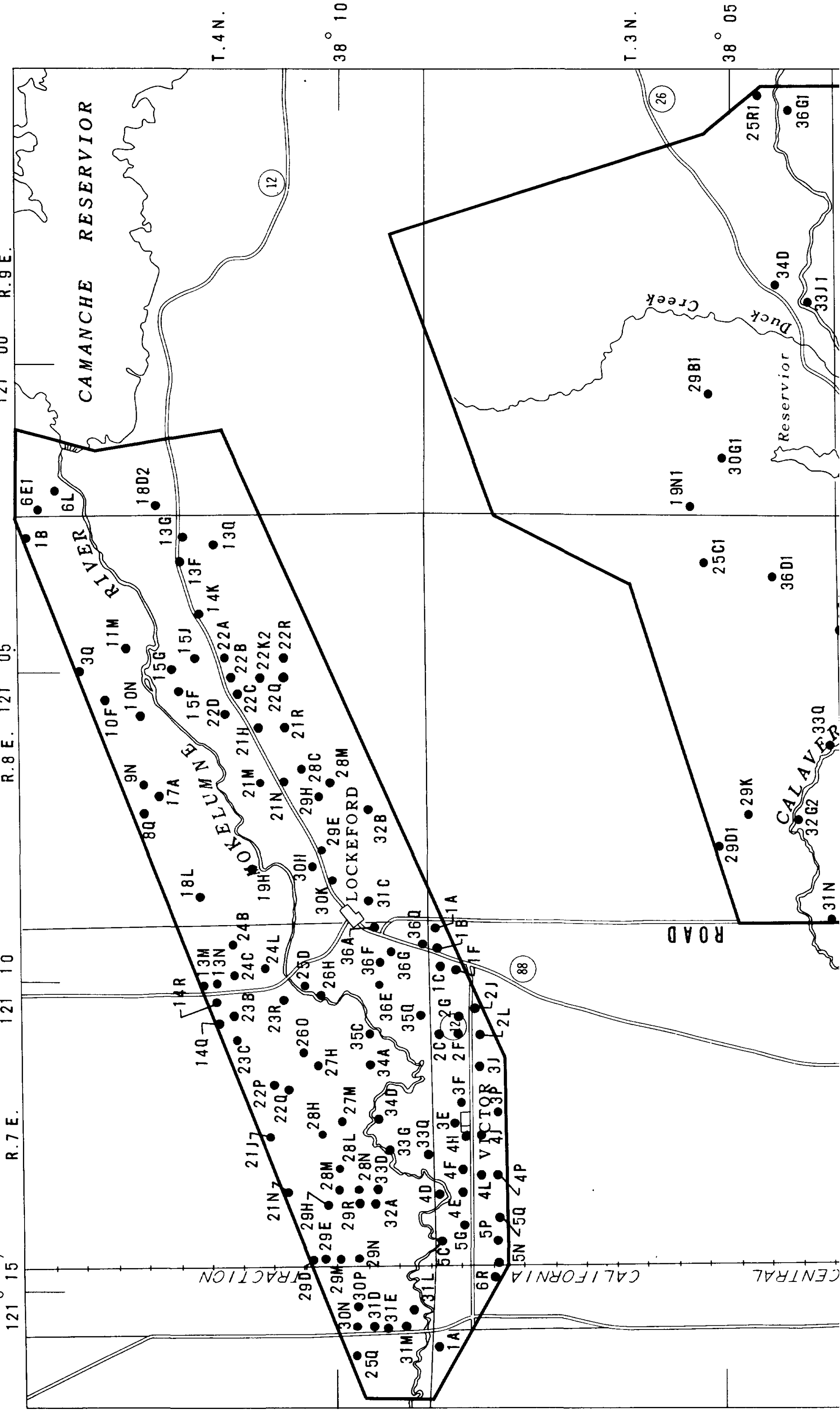


FIGURE 7.--Depth to water table, autumn 1979.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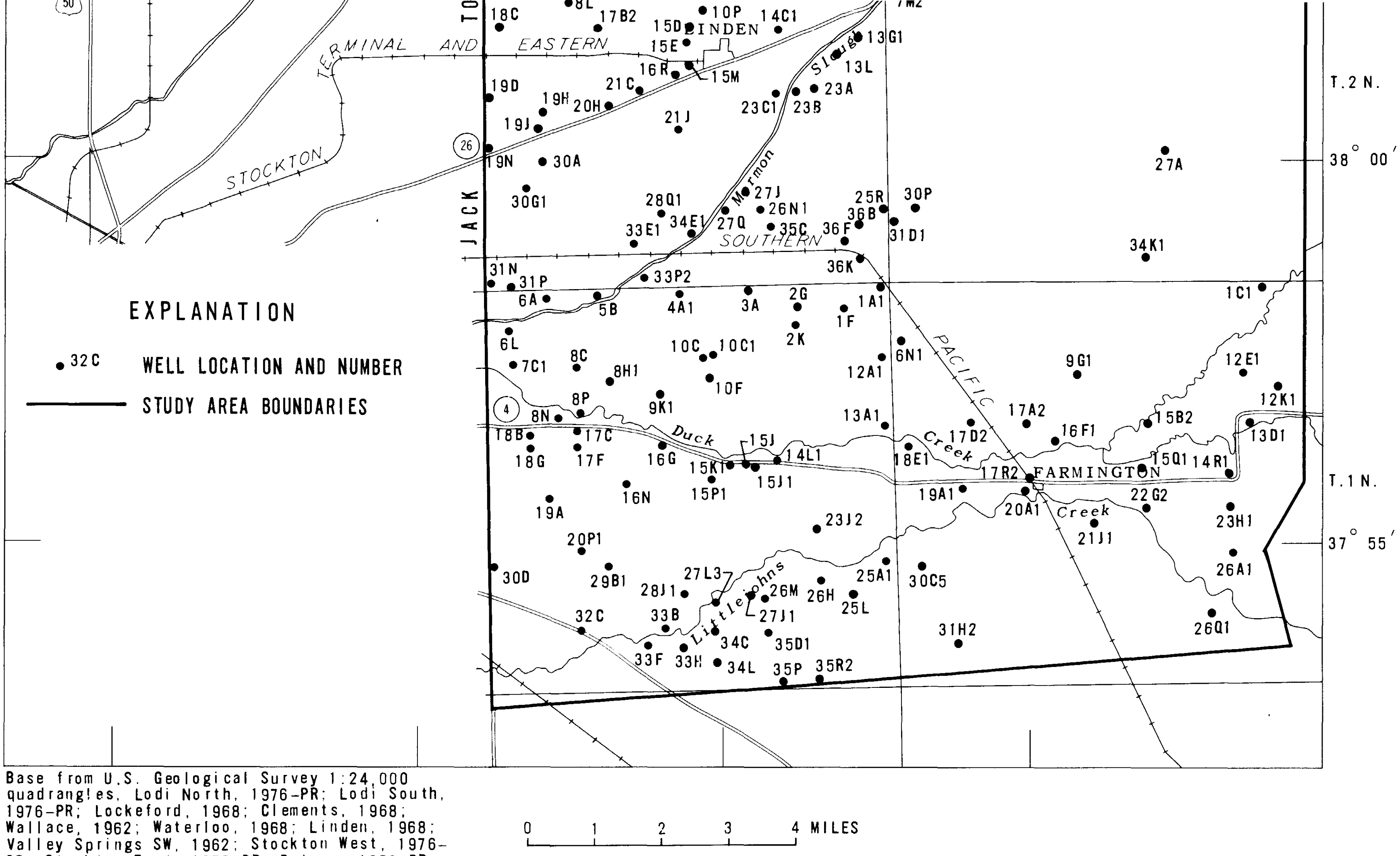

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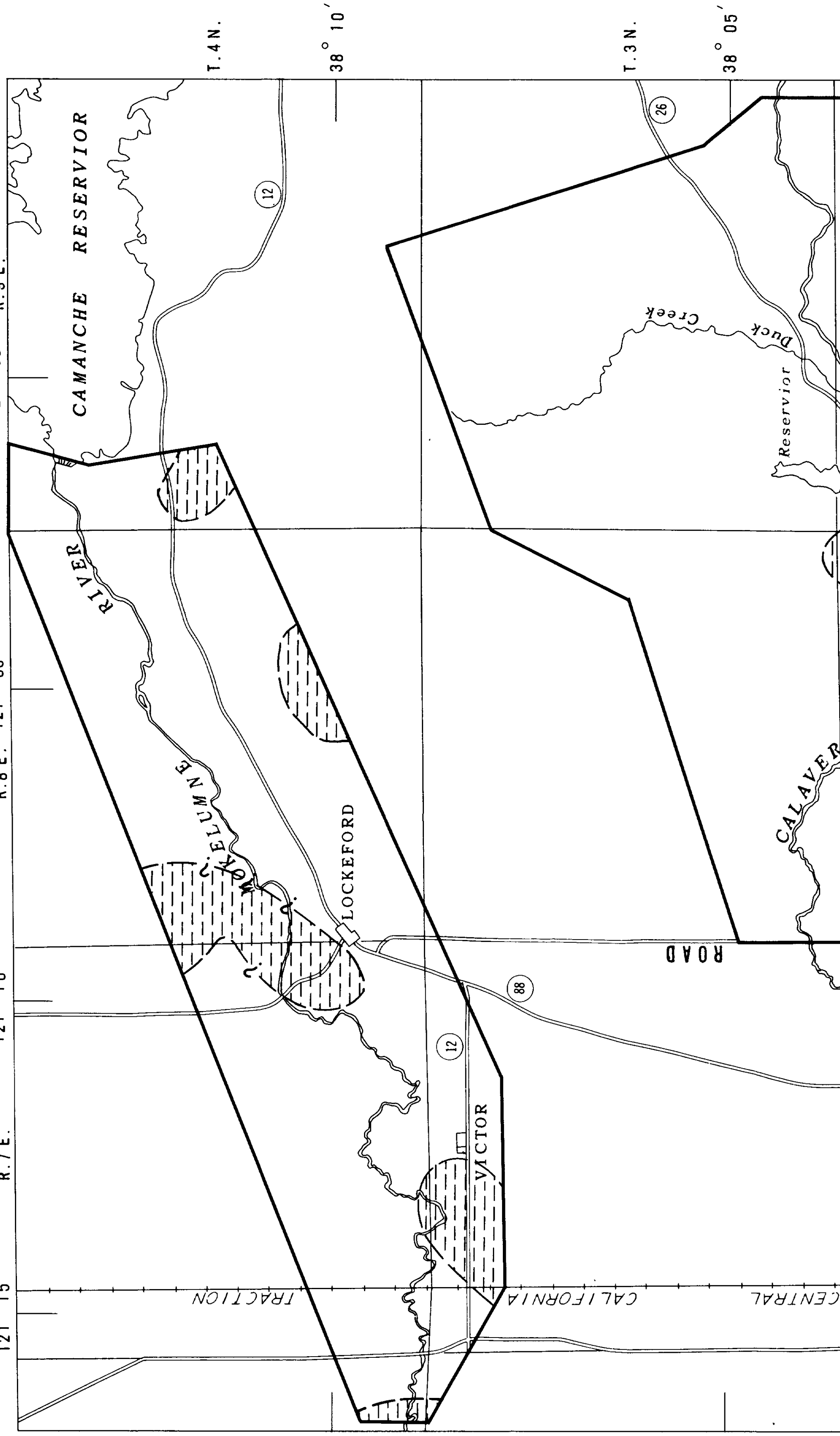
FIGURE 8.--Location of wells used to compute specific yield.



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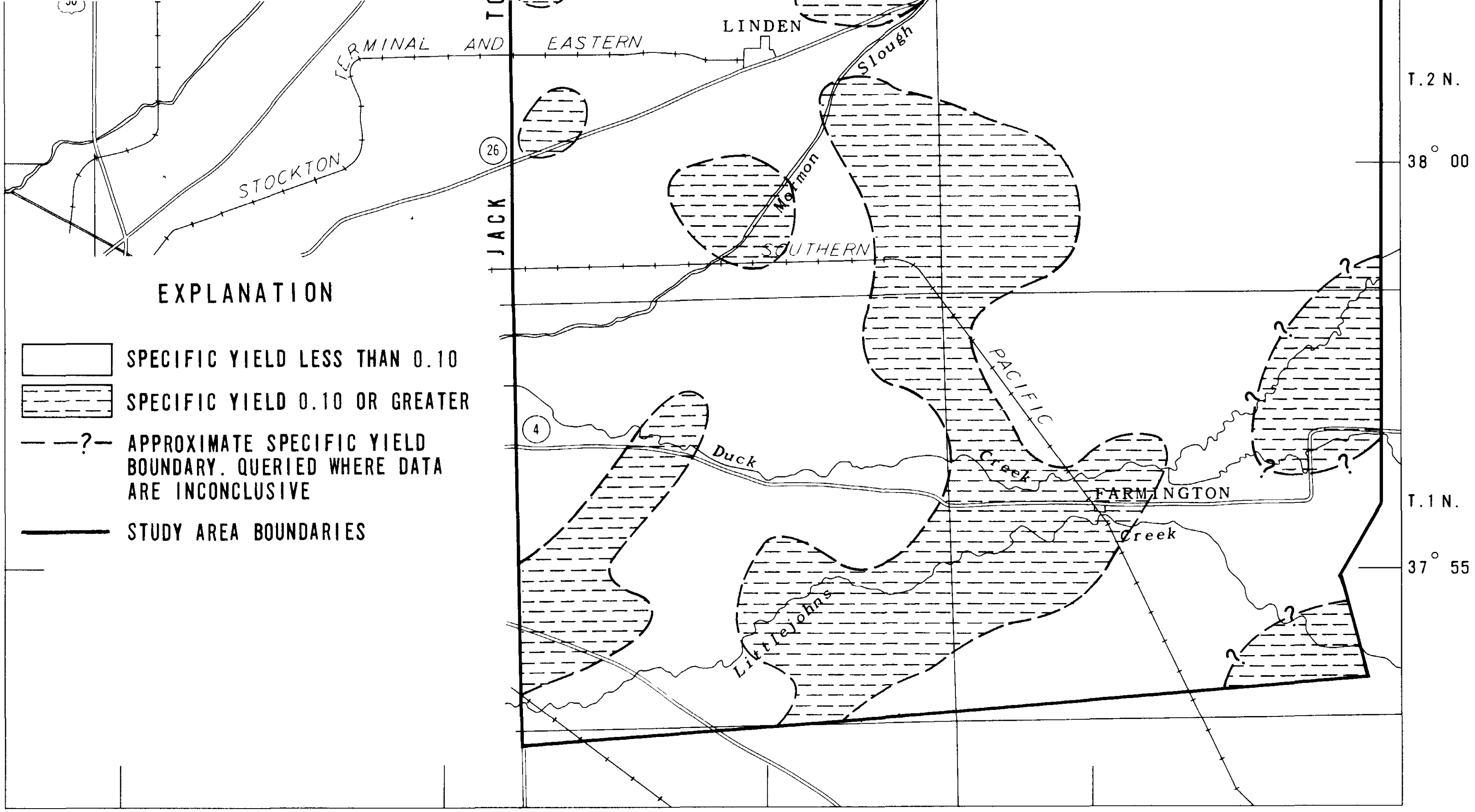

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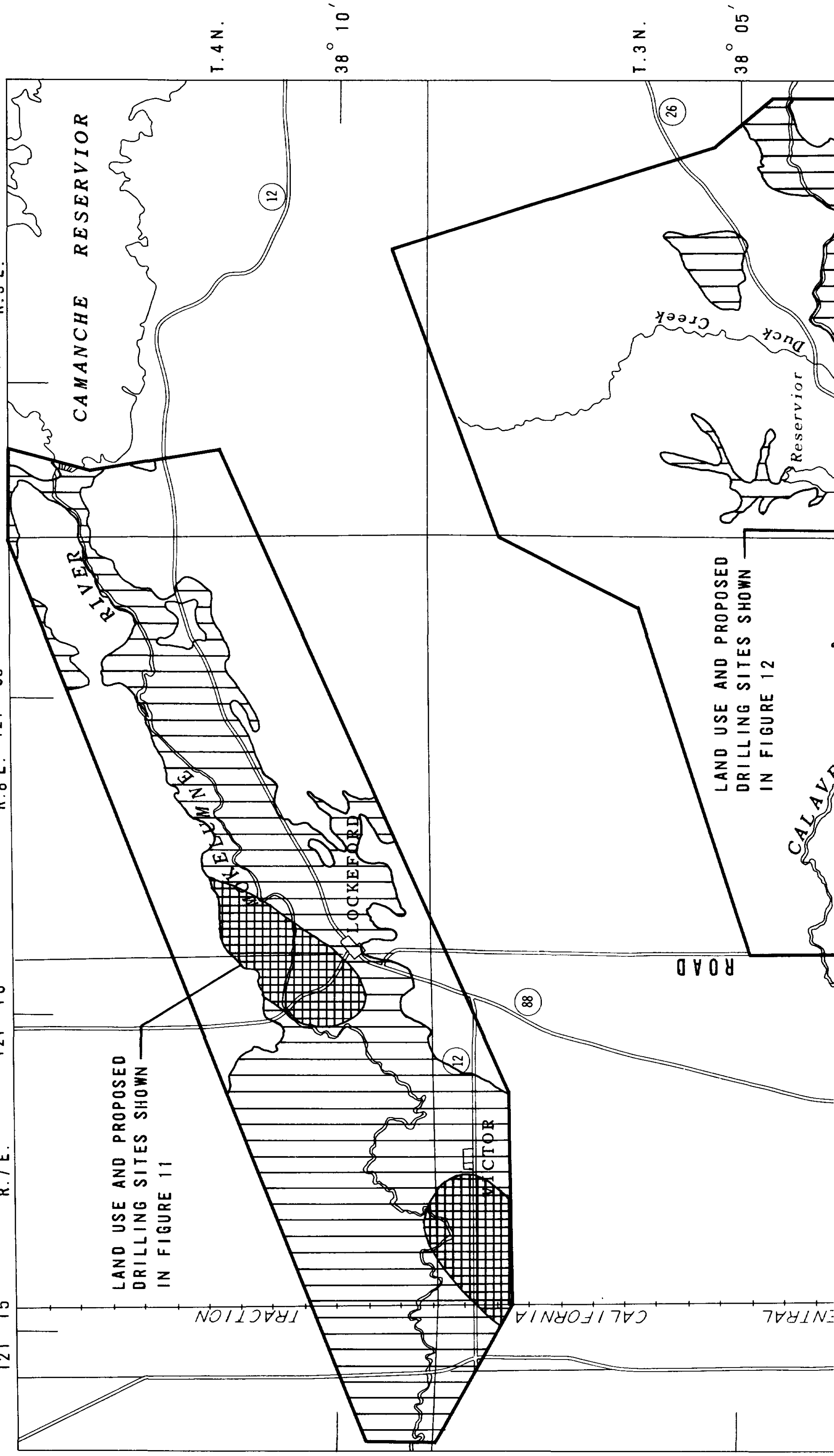
FIGURE 9.--Average specific yield in the depth interval from 25 to 50 feet below land surface.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LAND USE AND PROPOSED DRILLING SITES SHOWN IN FIGURE 11
LAND USE AND PROPOSED DRILLING SITES SHOWN IN FIGURE 12

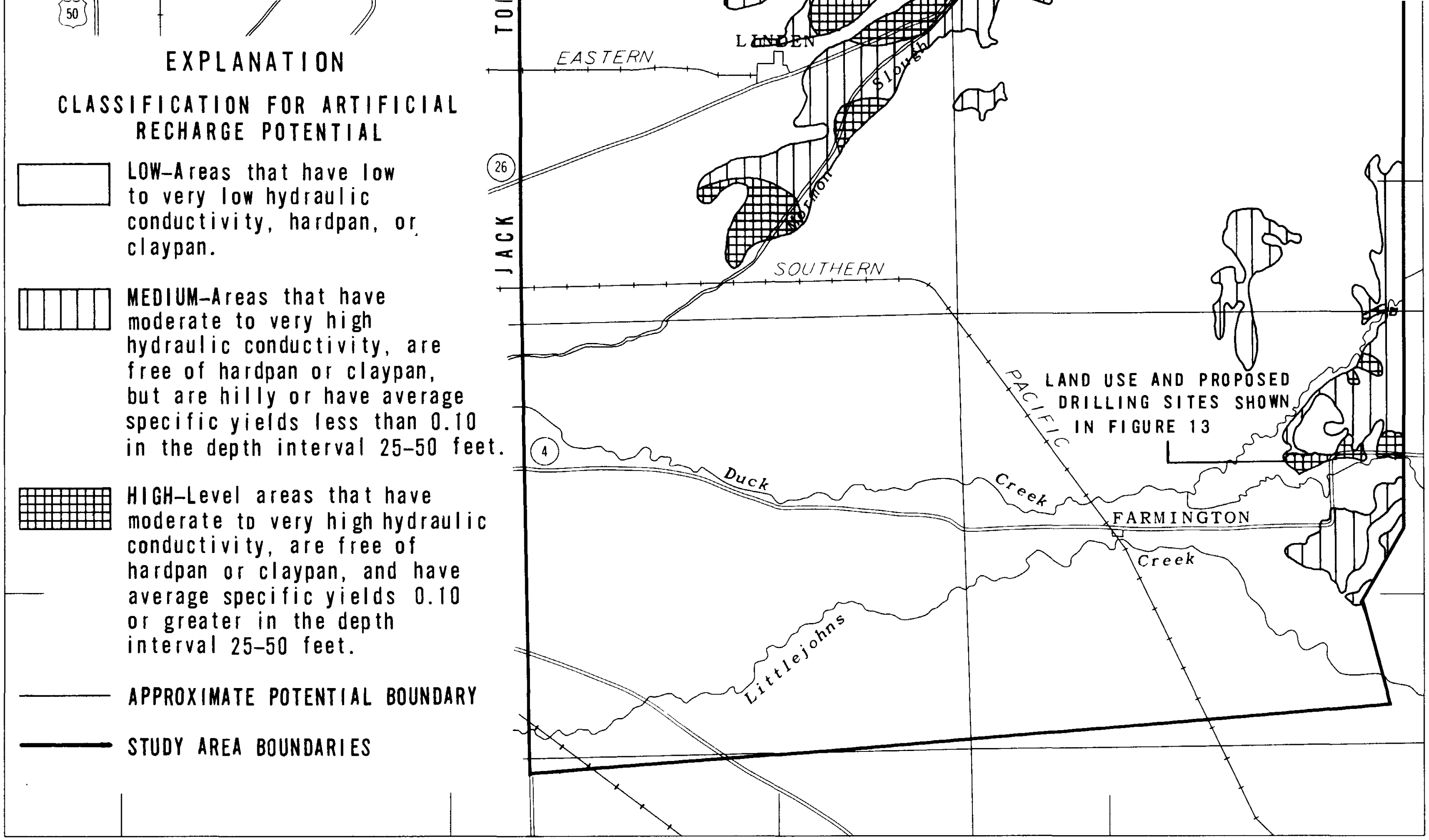

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FIGURE 10.--Areas of high, medium, and low artificial recharge potential.

EXPLANATION

LAND-USE CATEGORIES
(Land use after California Department of Water Resources, 1976)

NATIVE VEGETATION

IRRIGATED PASTURE

FIELD, GRAIN, OR TRUCK CROPS

ORCHARD OR VINEYARD

URBAN, FREE WATER SURFACE, OR INCIDENTAL TO AGRICULTURE (Such as farmsteads)

●4 PROPOSED DRILLING SITE

+ SECTION CORNER

— — — TOWNSHIP OR RANGE LINE

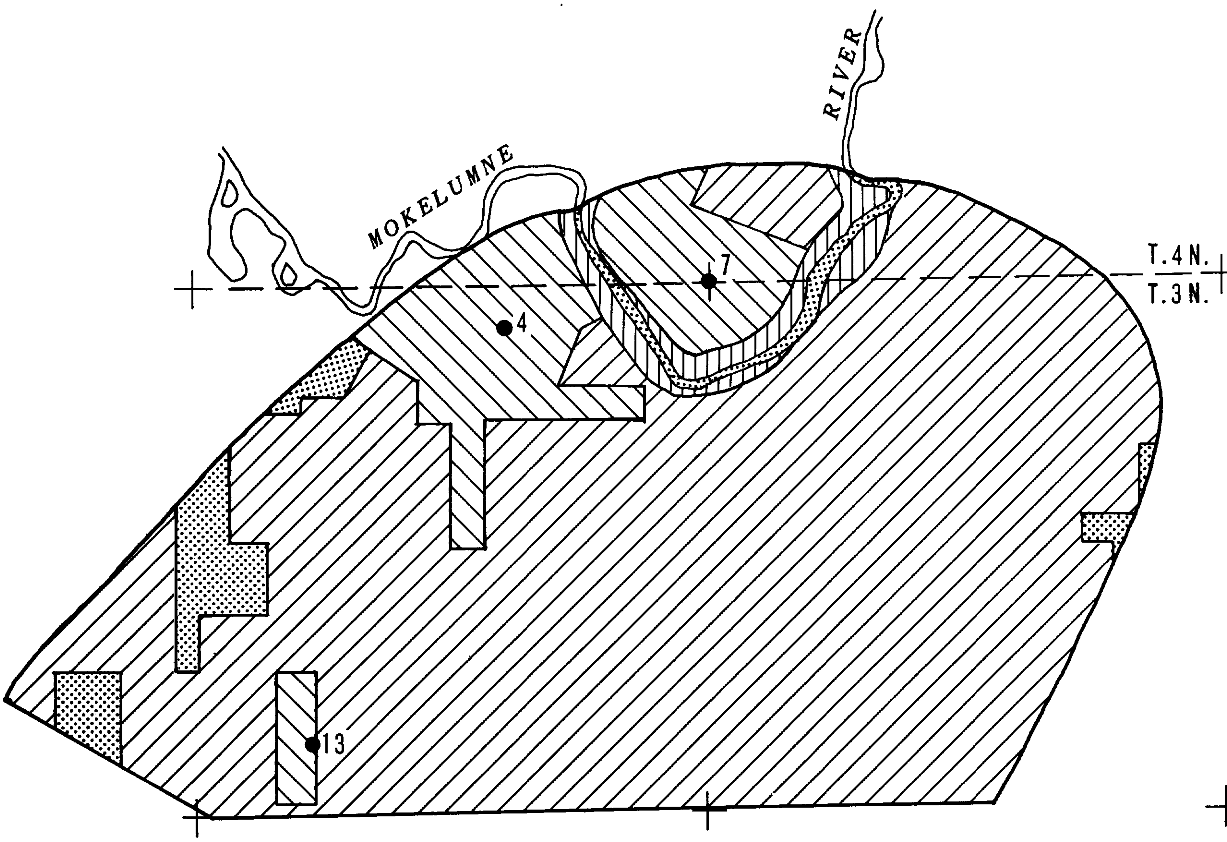
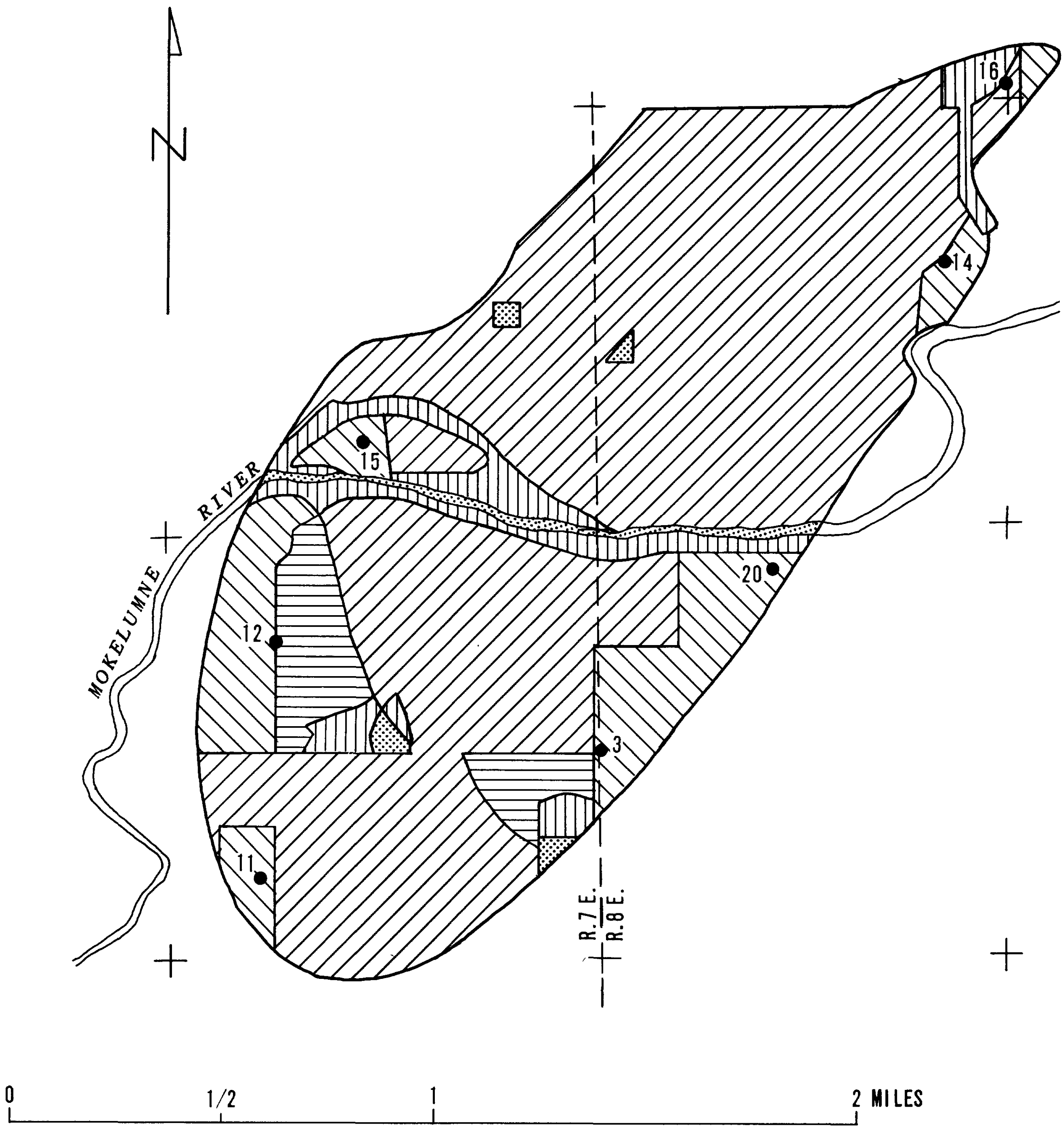


FIGURE 11.--Land use and proposed drilling sites in areas of



high artificial recharge potential near the Mokelumne River.

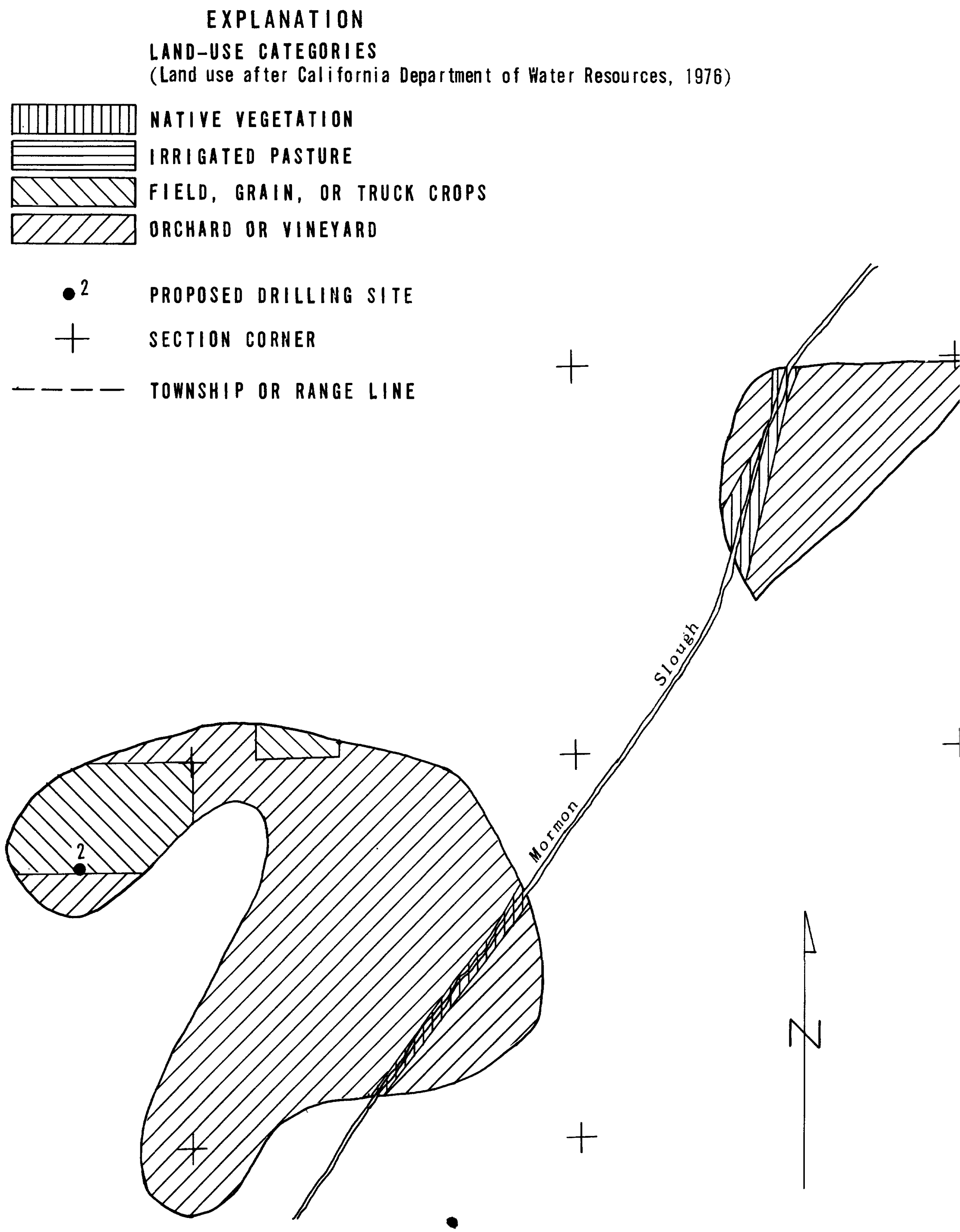
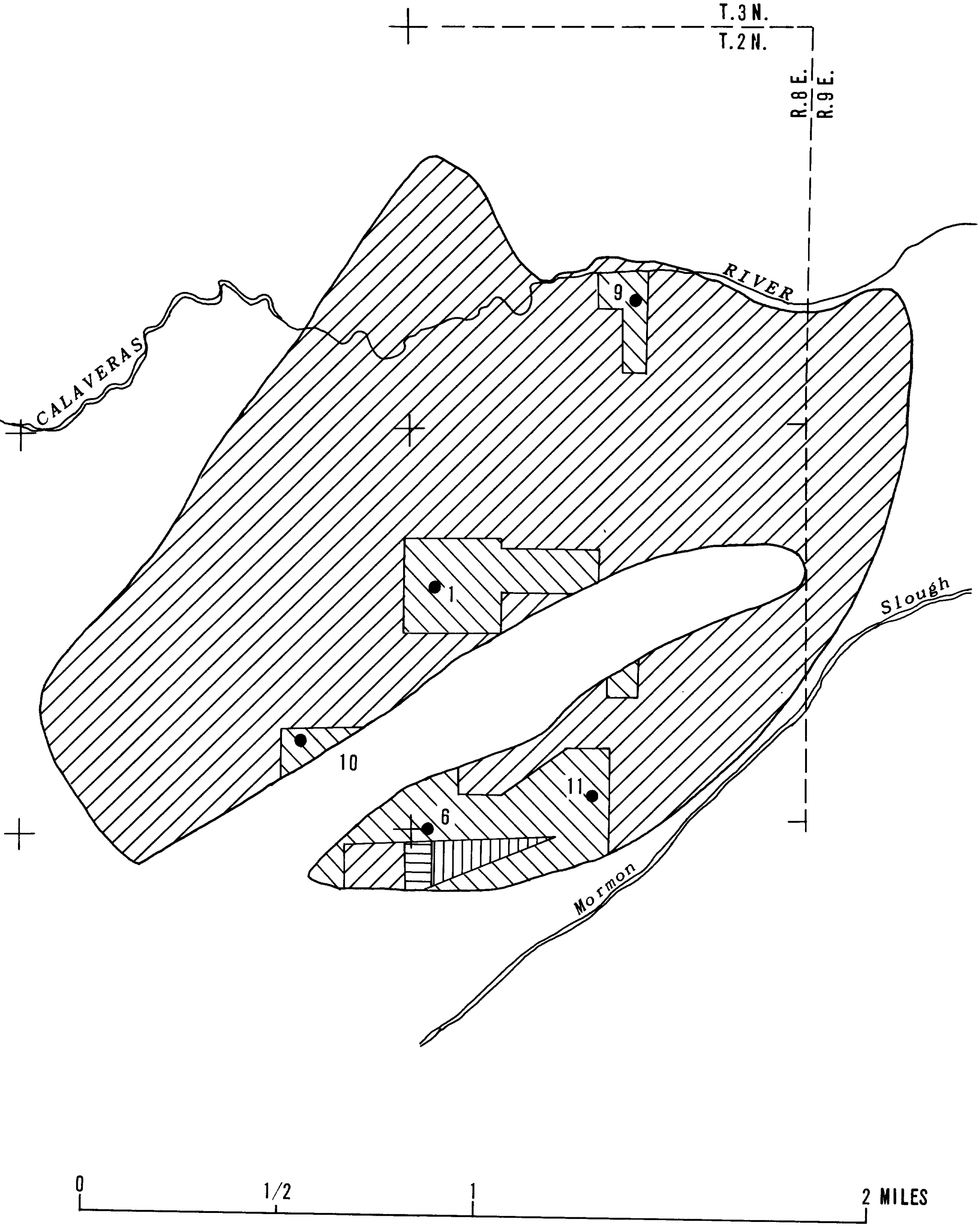


FIGURE 12.--Land use and proposed drilling sites in areas of



high artificial recharge potential near the Calaveras River.

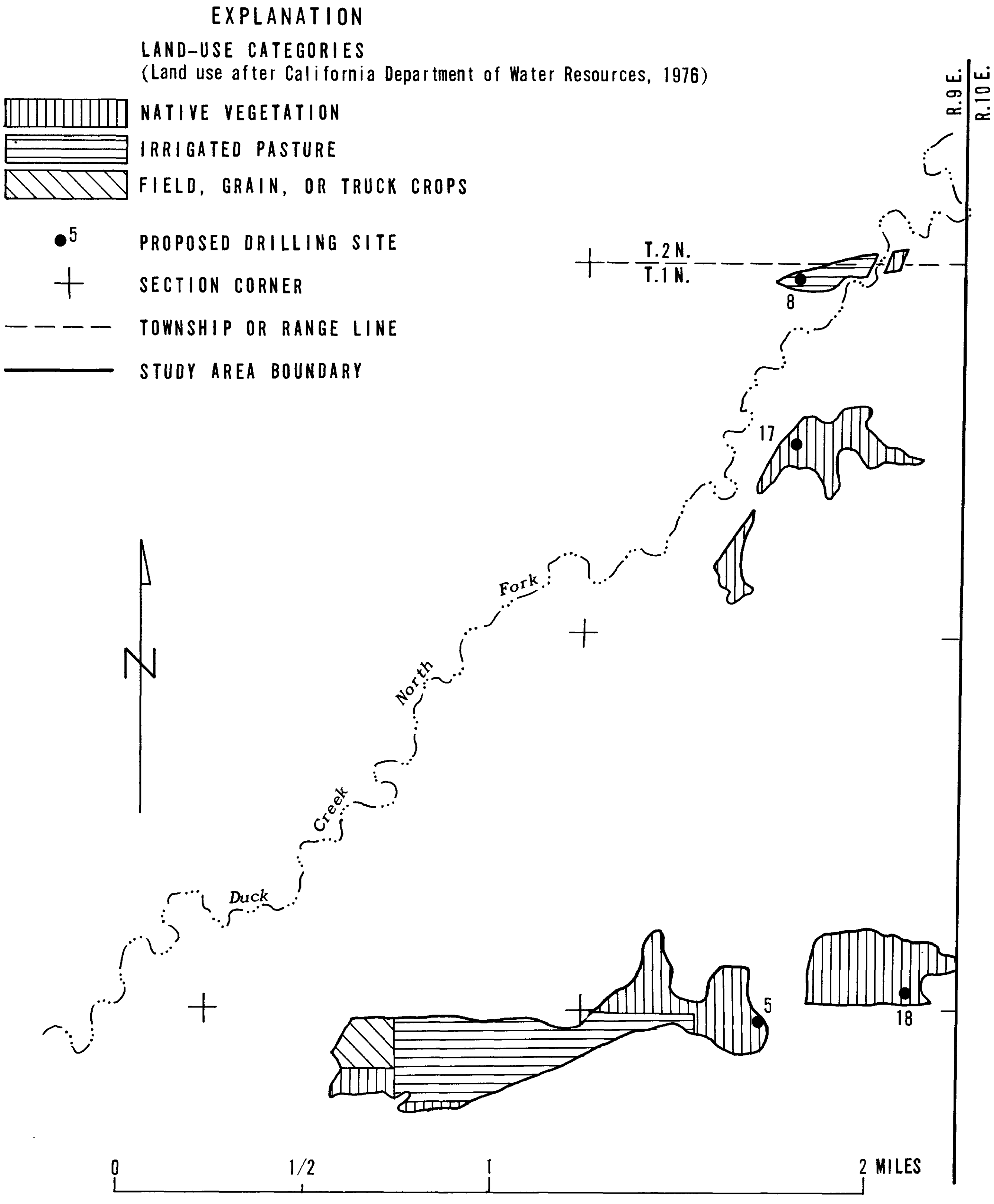


FIGURE 13.--Land use and proposed drilling sites in areas of high artificial recharge potential north of Littlejohns Creek.