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DELANO NITRATE
INVESTIGATION

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NORMAN B. LIVERMORE, JR.
Administrator
The Resources Agency

RONALD REAGAN
Governor
State of California

WILLIAM R. GIANELLI
Director
Department of Water Resources

FOREWORD

This bulletin presents the findings and recommendations of the Department of Water Resources regarding the occurrence of excessive nitrate concentrations in ground water underlying the vicinity of Delano, Kern County.

This investigation was requested by Senator Walter W. Stiern of the Eighteenth Senatorial District, Kern and Kings Counties. Authorization for this investigation is contained in Section 229 of the California Water Code. This statute authorizes the Department to investigate conditions of the quality of all waters within the State as related to all sources of pollution. The Department may recommend any steps which might be taken to improve or protect the quality of such waters.

The findings of this investigation emphasize the need for the determination of the significance of nitrate levels in drinking water with respect to public health.

William R. Gianelli

William R. Gianelli, Director
Department of Water Resources
The Resources Agency
State of California

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

RONALD REAGAN, Governor
NORMAN B. LIVERMORE, JR., Administrator, The Resources Agency
WILLIAM R. GIANELLI, Director, Department of Water Resources
JOHN R. TEERINK, Deputy Director, Department of Water Resources

SAN JOAQUIN DISTRICT

Carl L. Stetson District Engineer
Richard W. Meffley Chief, Special Investigations Section

This report was prepared
under the supervision
of

Victor B. McIntyre Chief, Water Quality Unit

By

Benjamin D. Kor Associate Engineer, Water Resources
Robert A. Schneider Assistant Engineer, Water Resources

Assisted by

Lester S. Obata Engineering Aid II

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ABSTRACT

Nitrate concentrations in ground water used by the City of Delano, Kern County, are in excess of the limit of 45 milligrams per liter recommended by the U. S. Public Health Service Drinking Water Standards of 1962. / Methemoglobinemia in infants has been associated with the consumption of nitrate laden water. Continual irrigation with water containing high nitrate concentrations is in many cases detrimental to crops. / In the vicinity of Delano, nitrate of undetermined origin is being transported to ground water by water applied at the ground surface. As the water table underlying the Delano vicinity rises, nitrate concentrations increase. As a temporary solution, Delano pumps only wells which produce water containing lesser nitrate levels. / The need for action to effect a lasting solution is contingent upon the determination of the significance of nitrate levels in drinking water with respect to public health.

CHAPTER I. INTRODUCTION

In February 1967 the Department of Water Resources initiated a study of nitrate concentrations in ground waters underlying the vicinity of Delano, Kern County. This investigation was conducted under the Water Quality Investigations Program of the San Joaquin District. The investigation was coordinated with the University of California, the State Departments of Public Health and Agriculture, the Kern County Farm Advisor, Kern County Department of Public Health, the Cities of Delano and McFarland, Di Giorgio Corporation, and the local water purveyors.

The purpose of the study was to determine (1) the levels of nitrate concentrations in ground waters of the area with respect to the recommended limits for drinking water as set by the U. S. Public Health Service, and (2) if the concentration of nitrates could be reduced by modifying the supply wells.

Comments on the report by the State Department of Public Health are included in the Appendix.

Conclusions

1. Nitrate concentrations in ground waters underlying the vicinity of Delano are currently in excess of the limit of 45 milligrams per liter (mg/l) recommended by the U. S. Public Health Service Drinking Water Standards of 1962. High nitrate concentrations have been detected in municipal well water since July, 1964. A summary of nitrate concentrations in water from Delano's municipal wells is shown in Table 5^{1/}.

2. Nitrate concentrations detected within the area of investigation were the highest in areas:

- a. under which ground water has risen markedly over recent years;
- b. of high permeability requiring greater amounts of applied water for agricultural use;
- c. that have been irrigated for the longest period of time;
- d. which pump ground water from areas of greater transmissibility, and/or are down gradient (ground water gradient) from areas listed under conditions a. and b.

3. The source of excessive nitrate concentrations in ground waters lies above the water table. The nitrates are transported to ground water by water applied at the ground surface.

4. The amounts of nitrate occurring in ground water from specific sources was indeterminate. However, the majority of nitrate degradation appears to be the result of a combination of both natural and applied nitrate, excluding sewage.

5. Nitrate concentrations detected in ground water underlying the City of Delano and the study area vary with seasonal fluctuations of the water table. As the water table rises nitrate concentrations increase.

6. Rising water table conditions in the study area are attributed to the importation of new water into the area via the Friant-Kern Canal and the attendant reduction of ground water pumping.

7. All aquifer depth zones underlying the City are susceptible to possible degradation from excessive nitrate concentrations.

^{1/} All tables are bound at the end of the text.

8. It was not possible to determine whether nitrates in ground water within the study area would recur at the levels detected.

9. The most feasible method of controlling nitrate levels at present is being implemented by the City of Delano by the modification of its pumping schedule.

10. It is doubtful that modifications in the construction of City wells would yield a lasting solution to the problem of nitrate degradation.

11. If excessive nitrate levels and the hazard to public health become critical in the future it may be necessary for the City of Delano to provide an alternative source of water or to provide treatment for its present supplies.

12. The increase in nitrate concentrations in ground water under the conditions previously described may not be exclusive to the area of this investigation. Similar geologic and hydrologic conditions occur in other areas of the San Joaquin Valley and the State in general.

Recommendations

To alleviate the problems associated with excessive nitrate concentrations in ground waters underlying the vicinity of the City of Delano, it is recommended that:

1. The City of Delano continue to monitor nitrate levels in its municipal supply wells to:

a. operate that combination of supply wells yielding the lowest possible nitrate levels in supply reservoirs;

b. determine whether the recent and current occurrence of high nitrate concentrations in ground waters underlying the area is a short or long term condition;

c. justify possible future needs for imported or treated domestic water; and

d. aid the Department of Water Resources or other agencies in the event further studies are initiated.

2. The City of Delano evaluate possible sources of imported water and/or methods of treating water to reduce nitrate levels.

3. The commercial fertilizer industry recognize the potential magnitude of the problem of high nitrates in ground water from both public health and agricultural standpoints; that the industry continue to apprise consumers of economical and efficient use of fertilizers under varying conditions and of the potential hazards of over-fertilization, and; that the industry continue to conduct research toward the development of more efficient fertilizers.

CHAPTER II. THE NITRATE PROBLEM

The occurrence of excessive nitrate concentrations in ground water is not a condition limited to the Delano area. Data compiled since 1951 in the Department's ground water quality data program indicate excessive nitrate concentrations in several areas and an overall increase in nitrate concentration in ground waters of the San Joaquin Valley. In addition to the areal scope there are several problems associated with excessive nitrates that are of statewide concern.

Health Hazard

The problem most widely publicized is the potential hazard to public health created by the occurrence of high nitrate concentrations in drinking water. This condition has been associated with cyanosis in infants, medically termed methemoglobinemia. One theory for the etiology of this disease is the reduction of nitrate to nitrite in the upper intestinal tracts of infants. Upon entering the blood stream a reaction of nitrite with hemoglobin occurs forming methemoglobin. This substance, which cannot be oxygenated, reduces the capacity of the blood to transport oxygen through the circulatory system. Children over six months of age suppress the nitrite producing bacteria through greater gastric acidity.

The State of Minnesota reported 139 cases including 14 deaths from 1947 to 1950^{1/}. In an 18-state survey conducted in 1951 methemoglobinemia was reported in 278 cases of which 39 were fatal. In all of these cases the concentration of nitrates in water supplies was in excess of 45 mg/l.^{2/}

Effects on Agriculture

Nitrates may have an increasing impact on agriculture and the economy of the

State. Excessive nitrates in ground waters used for irrigation can cause a degradation in the quality of fruits and vegetables produced by creating an imbalance between nitrogen and sugar in the plant. In the early stages of crop production nitrogen is applied to the soil or plant to enhance growth. As the harvesting period approaches these applications are discontinued to retard growth and to allow the crop to mature. In areas where high nitrate ground water is the only source of irrigation water, harvested fruits such as grapes may be large but sugarless. Adverse effects of excessive nitrates on tomatoes include the production of large vines and late maturing fruit. In the case of citrus fruits typical effects of excessive nitrates are more green color on the surface of the fruit at harvest time, coarser textured peel, and a lower percentage of juice in the fruit. The sugar content of sugar beets is also reduced as a result of irrigating with water containing an overabundance of nitrates. Similar adverse effects occur in many other crops irrigated with excessive nitrate water only.

Livestock Hazard

Excess nitrates in livestock drinking water can cause a disease in cattle which is similar to infant cyanosis. Some effects are loss of appetite, reduced milk production, vitamin deficiency symptoms, abortion, and death.

Hazard to Industry

Nitrates are injurious to the dyeing of wool and silk fabrics. They are also harmful to fermentation processes and can cause disagreeable tastes in beer.

In summary, the potential threats to public health, agriculture, livestock, and industry are of statewide magnitude and should be of statewide concern.

^{1/} U. S. Public Health Service Drinking Water Standards 1962.

^{2/} Walton, Graham, Survey of Literature Relating to Infant Methemoglobinemia Due to Nitrate-Containing Water, 1951.

CHAPTER III. NITRATE SOURCES

Atmosphere

The initial and most abundant source of nitrogen is the earth's atmosphere. Its total content is slightly more than 4.5 quadrillion tons, or 1,600 pounds of elemental nitrogen per square foot of the earth's surface. The atmosphere supplies nitrogen to the outer crust of the earth through precipitation, impingement, and fixation of micro-organisms in soil and water.

Fixation

Nitrogen fixation by micro-organisms occurs in the root nodes of leguminous plants, by soil organisms, by aerobic and anerobic bacteria, and by some blue-green algae. In addition, the photosynthetic bacteria also have the capacity to fix nitrogen. Nitrogen contributed to the soil by these sources is oxidized to the stable and soluble nitrate radical (NO_3^{-1}). It has been reported that legumes commonly fix 40 to 200 pounds of nitrogen per acre per year^{1/}. Values of 20 to 40 pounds of nitrogen per acre per year have been reported as the work of certain aerobic and anerobic bacteria and blue-green algae.

Organic Decomposition

Any form of plant or animal life can ultimately be considered as a contributor of nitrate to the soil. Herbivorous animals convert plant proteins to animal proteins. The higher animals excrete waste nitrogen as urea which in turn is decomposed by bacteria to ammonia. During plant and animal decay, bacteria decompose organic compounds to form amino acids, then ammonia, then nitrites, and finally nitrates.

^{1/} Allison, F. E., "The Enigma of Soil Nitrogen Balance Sheets", 1955.

Subsurface Sources

If the above processes of nitrogen buildup are viewed over the aging process of the earth the total amount of nitrogen currently available on and below the earth's surface can be assumed to be of significant proportions. In his 1961 report on geochemistry, Frank Wlotzka reported an average ammonia-nitrogen content for clay and clay slate as 580 grams per ton^{1/}. He stated there were cases of complete absence of nitrate. However, in the presence of percolating waters some percentage of this ammonia-nitrogen could theoretically be oxidized to nitrate.

Sewage

Sewage wastes contain nitrogen in various forms. Microorganisms, either introduced during sewage treatment or naturally present in water or soils, convert all the forms to a more highly oxidized state (nitrate).

Applied Fertilizers

In addition to the sources previously mentioned a significant source of nitrogen in soils and water is fertilizers. It is difficult, if not impossible, to determine the amounts of nitrate contributed to ground water by commercial fertilizers. Some of the difficulties are inadequate information on the amounts and types of fertilizer actually applied to crops, limited knowledge of subsurface movement, and the indeterminate amounts of nitrate present in ground water through other sources. However, the potential of fertilizers as nitrate

^{1/} Feth, J. H., "Nitrogen Compounds in Natural Water-A Review", Water Resources Research, First Quarter 1966.

contributors to ground water can be illustrated in several ways. According to J. W. Biggar in a 1958 report on the subject, 1,050,918 tons of commercial fertilizer were sold in California in 1956. This amount represented a 60 percent increase over that sold in 1950 with no indication that the saturation point had been reached. When spread over the 6.9 million acres of irrigated land in California, this tonnage is equivalent to 300 pounds per acre^{1/}. In some areas the rate of application is actually much higher than this average figure. In the Delano area rates of fertilizer applications as high as 1,000 pounds per acre were reported to the Kern County Farm Advisor's office. Several types of fertilizers are commonly used in this area of the San Joaquin Valley. Among them are ammonium sulfate (21% nitrogen), ammonium nitrate (31% to 33% nitrogen), and anhydrous ammonia (81% nitrogen).

Although the ultimate effect of fertilizers on ground water is not known at present, previous and continuing studies by the Department indicate they will definitely be of significance in the future. Numerous samples of tile drain effluent collected over a widespread area of the western San Joaquin Valley have been analyzed for nitrate to identify the quality of agricultural waste waters that would be disposed in the proposed San Joaquin Drainage Facilities. The average nitrate concentration anticipated is over 90 mg/l. If water of this quality is allowed to continue to recharge Valley aquifers the concentration of nitrate in ground water pumped can be expected to approach this excessive level.

^{1/} J. W. Biggar, "The Relation of Fertilizers to Soil and Ground Water Salinity", Quality of Water for Irrigation Committee on Research in Water Resources, 1958.

27R1 STATE WELL NO.

AREA OF INVESTIGATION
AND WELLS SAMPLED



CHAPTER IV. THE STUDY AREA

The area of study for this investigation consists of approximately 130 square miles (Figure 1). This rectangular area extends approximately four miles to the north, four miles to the west, and approximately five miles to the east of the City of Delano. The southern boundary of the area is about two miles south of the City of McFarland.

Communities

The City of Delano has a population of approximately 15,000. It is situated about 145 miles north of Los Angeles and about 250 miles southeast of San Francisco. U. S. Highway 99 is the major artery through the City. The City's average elevation is 310 feet above mean sea level. Rainfall averages 6.44 inches per year and temperatures range from an average low of 38 degrees during the winter months to an average high of 90 degrees in the summer months.

McFarland's population is less than 5,000. This city is situated approximately six miles south of Delano along U. S. Highway 99.

McFarland's average elevation is about 350 feet above mean sea level. Precipitation and temperatures are approximately equal to those of Delano.

Agriculture

The economy of this area of the San Joaquin Valley is dependent on agriculture. Cotton, grapes, and field crops are the major products grown. In recent years increased citrus plantings have marked the foothills along the eastern boundary of the study area.

Industry

Industry is primarily directed to the packing, processing, and shipping of agricultural products. The area is served by four wineries and five cotton gins. There are several fruit and vegetable packing sheds located within the study area.

CHAPTER V. SOILS

The area of investigation includes five basic physiographic soil divisions (Figure 2) as classified by the United States Department of Agriculture in its soil survey of "The Wasco Area, California", 1942.

Basin Areas, Flat

These areas (1) located west and northwest of Delano were partly occupied by the former lake beds of Goose Lake and Tulare Lake, and by the old swamp-like channel connecting Tulare Lake with Buena Vista Lake west of Bakersfield. These soils were developed under poor drainage conditions and at present are poorly drained. The soils are underlain by extremely compact impermeable subsoils and as a result they contain injurious accumulations of alkali. They are low in agricultural value consequently much of the area is not beneficially used.

Basin Areas, Gentle Slope

These areas (2) located northwest of McFarland were developed under slightly less restricted drainage conditions. The soils in this division contain a slight to moderate amount of salts and are suitable for crops (cotton, alfalfa, or barley) that are fairly tolerant to salts. Surface drainage is poor but subsurface drainage in most places is adequate enough to allow soils to be reclaimed with the use of gypsum and by leaching.

Recent Alluvial Fans and Stream Bottoms

These soils (3) located in the northeast and southwest portion of the study area are the most agriculturally productive. A large part of this division is occupied by the fans formed from material washed from Rag Gulch and Poso Creek. These soils have an indefinite drainage system and are underlain by friable or fairly friable

subsoils. The soils are recent with little evidence of profile development and have been modified little since soil deposition. Soils in this division have been under agricultural production longer than all other soil types within the area of investigation. These soils are also the most permeable soils in the area. Because of the permeability the amounts of irrigation water and fertilizers added are greatest in this division.

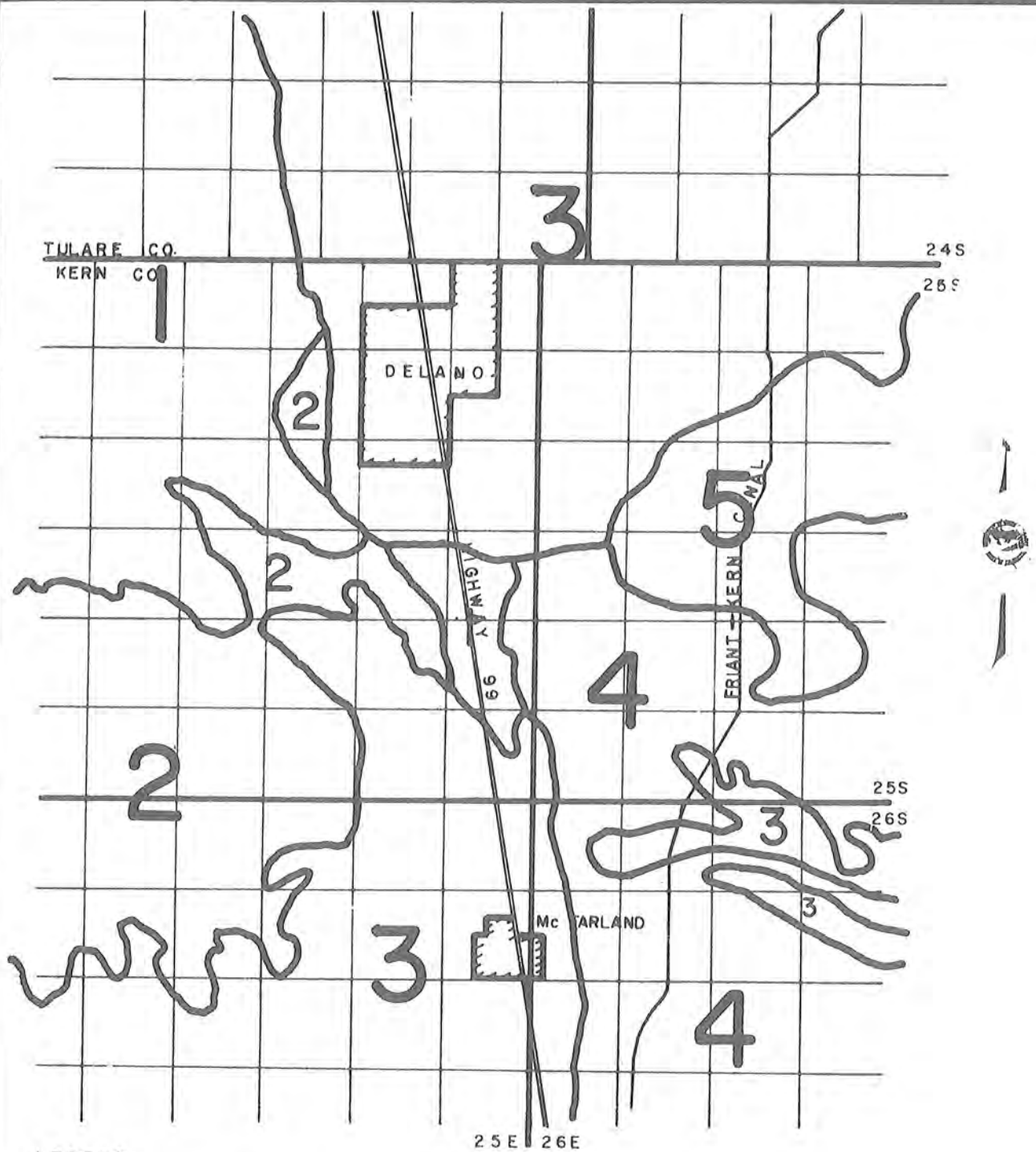
Old Alluvial Fans Having Smooth Microrelief

These soils (4) situated in the southeast corner of the study area have somewhat compact moderately developed subsoils. They have a well advanced profile development but drainage throughout them is adequate.

Old Alluvial Fans Having Hog Wallow Microrelief

These alluvial fans (5) found in the eastern portion of the study area are similar to the old alluvial fans with smooth microrelief with the exception that they are underlain by a rocklike hardpan. The hardpan is from one to two feet thick beginning at a depth ranging from two to four feet.

The semi-arid conditions have hindered the accumulation of organic material and most of the well-drained soils in the area have low organic content. The low organic content of the soils has necessitated the addition of fertilizers to add the needed nitrate to the soil. Permeability and the quantity of fertilizers and water applied are directly related. Nitrates do not accumulate in well-drained soils and greater amounts are required to maintain adequate nitrogen for plant utilization in such soils.

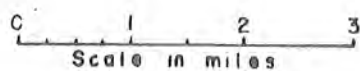


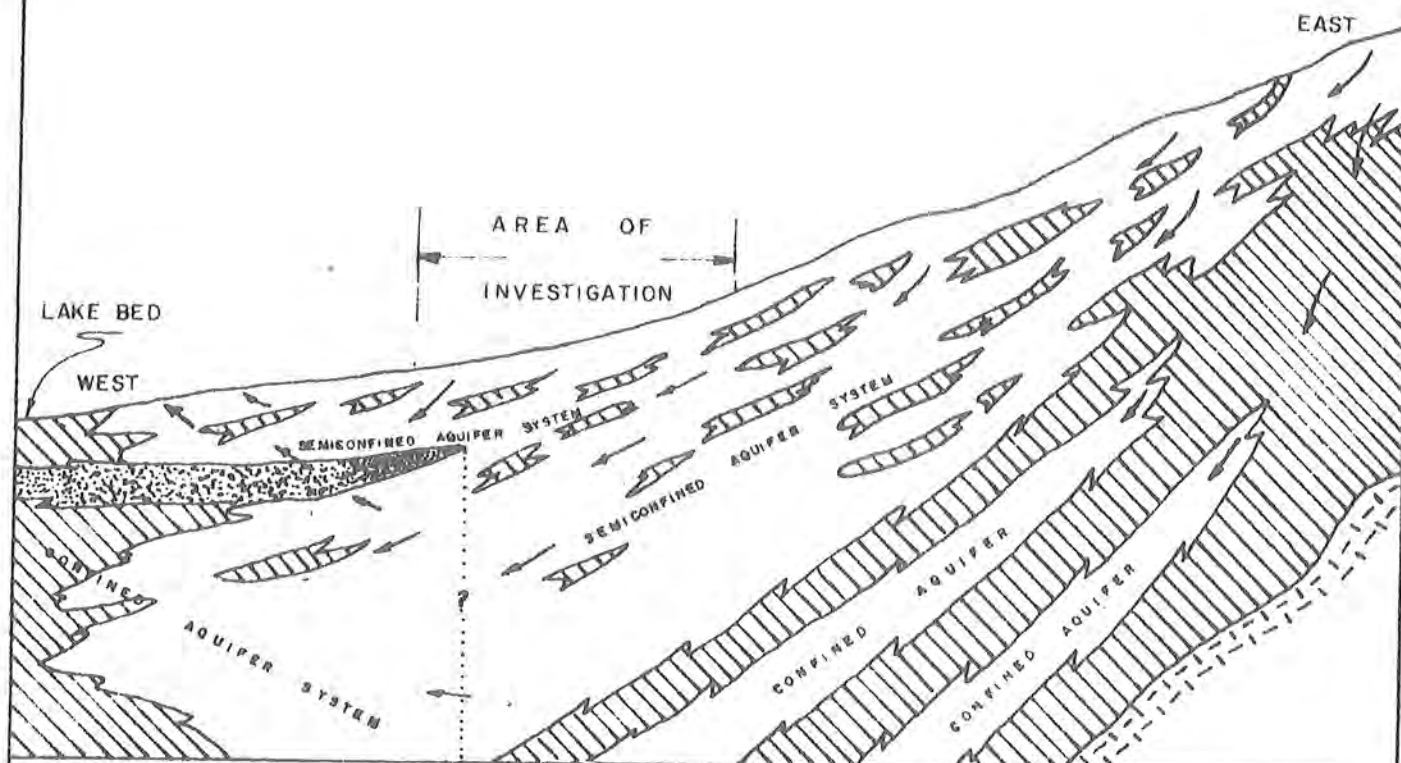
LEGEND

- 1 BASIN AREAS, FLAT
- 2 BASIN AREAS, GENTLE SLOPE
- 3 RECENT ALLUVIAL FANS & STREAM BOTTOMS
- 4 OLD ALLUVIAL FANS, SMOOTH MICRORELIEF
- 5 OLD ALLUVIAL FANS, HOG WALLOW MICRORELIEF

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SAN JOAQUIN DISTRICT
DELANO NITRATE INVESTIGATION

BASIC SOIL DIVISIONS





LEGEND

-  LOW PERMEABILITY DEPOSITS
-  WATER YIELDING DEPOSITS
-  CORCORAN CLAY MEMBER OF TULARE FORMATION
-  BASEMENT COMPLEX
-  DIRECTION OF GROUND WATER FLOW
-  BOUNDARY BETWEEN CONFINED AND SEMICONFINED AQUIFER SYSTEMS

STATE OF CALIFORNIA
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 DEPARTMENT OF WATER RESOURCES
 SAN JOAQUIN DISTRICT
 DELANO NITRATE INVESTIGATION

TYPICAL GEOLOGIC CROSS
 SECTION EAST-WEST
 THROUGH STUDY AREA

CHAPTER VI. GEOLOGY

Geologic information below the soil zone was taken from a report prepared by the United States Geological Survey^{1/}.

The area of investigation includes four main geologic units which are classified according to age.

Younger Alluvium

This unit is a heterogeneous complex of interstratified discontinuous beds of unsorted to fairly well sorted clay, silt, sand, and gravel. Areal, this unit corresponds to the recent alluvial fans and stream bottom soil areas and is highly permeable.

Older Alluvium

This unit consists of poorly sorted lenticular deposits of clay, silt, sand, and gravel, and may be loosely consolidated to cemented. It underlies the younger alluvium unit until it outcrops towards the eastern portion of the Valley. At the surface it forms the old alluvial fan soils in the easterly portion of the study area. It is moderately to highly permeable.

Tulare Formation

This unit consists of poorly sorted lenticular deposits of gypsiferous clay, silt, and gravel derived predominantly from the Coast Ranges. It contains the Corcoran Clay Member, an extensive stratum of diatomaceous silty clay. The Corcoran

Clay underlies the northwestern portion of the study area. Its boundary has not been well defined. With the exception of the Corcoran Clay, the Tulare Formation is moderately to highly permeable.

Continental Deposits, Undifferentiated

This unit consists of poorly sorted lenticular deposits of clay, silt, sand and gravel derived predominantly from the Sierra Nevada. It underlies the other three units and in combination with the Tulare Formation is the main source of ground water in the study area. The unit is moderately to highly permeable, and yields moderate to large quantities of water.

Of the four basic units the younger alluvium is the most permeable. The older alluvium is less permeable on the average than the younger alluvium owing to the presence of cemented zones, hardpan characteristics and a greater degree of consolidation.

A pictorial description of the geologic conditions in the study area is presented in Figure 3. The low permeability lenses situated at random throughout the water yielding deposits create semi-confined ground water conditions. The degree of confinement in the principal-pumped zone (depths below 300 feet) is not uniform. Some piezometric fluctuations correlate with water levels in the shallow zone whereas others show characteristics of a confined zone.

^{1/} "Geology, Hydrology, and Quality of Water in the Terra Bella-Lost Hills Area, San Joaquin Valley, California", April 30, 1963.

Historical Ground Water Conditions^{1/}

The earliest available ground water records for the study area were compiled in 1905. Data collected during the next two years showed that ground water under the study area was being overdrafted at a rapid rate as a result of increased irrigation. The lowering of the water table was fairly consistent over the entire area until about 1927. At that time a cone of depression began to form in ground water approximately three miles northeast of central Delano. In 1944 a secondary cone of depression was detected about three miles east of McFarland. The U. S. Bureau of Reclamation surmised that this secondary cone was the result of increased pumping for new development during World War II. By 1946 the mean water table within the study area had dropped approximately 130 feet. A maximum drop of 250 feet occurred in the cone of depression northeast of Delano. A drop of about 150 feet occurred in the cone of depression east of McFarland. The maximum overdraft of ground water within the area of study occurred in 1950. The mean lowering of the water table at that time was estimated to be in the order of 170 feet. In 1951 the use of ground water for irrigation began to decrease as the result of the availability of surface water imported via the Friant-Kern Canal. The reduction in ground water pumping along with the application of imported water resulted in the beginning of a gradual recovery of the mean water table throughout the study area.

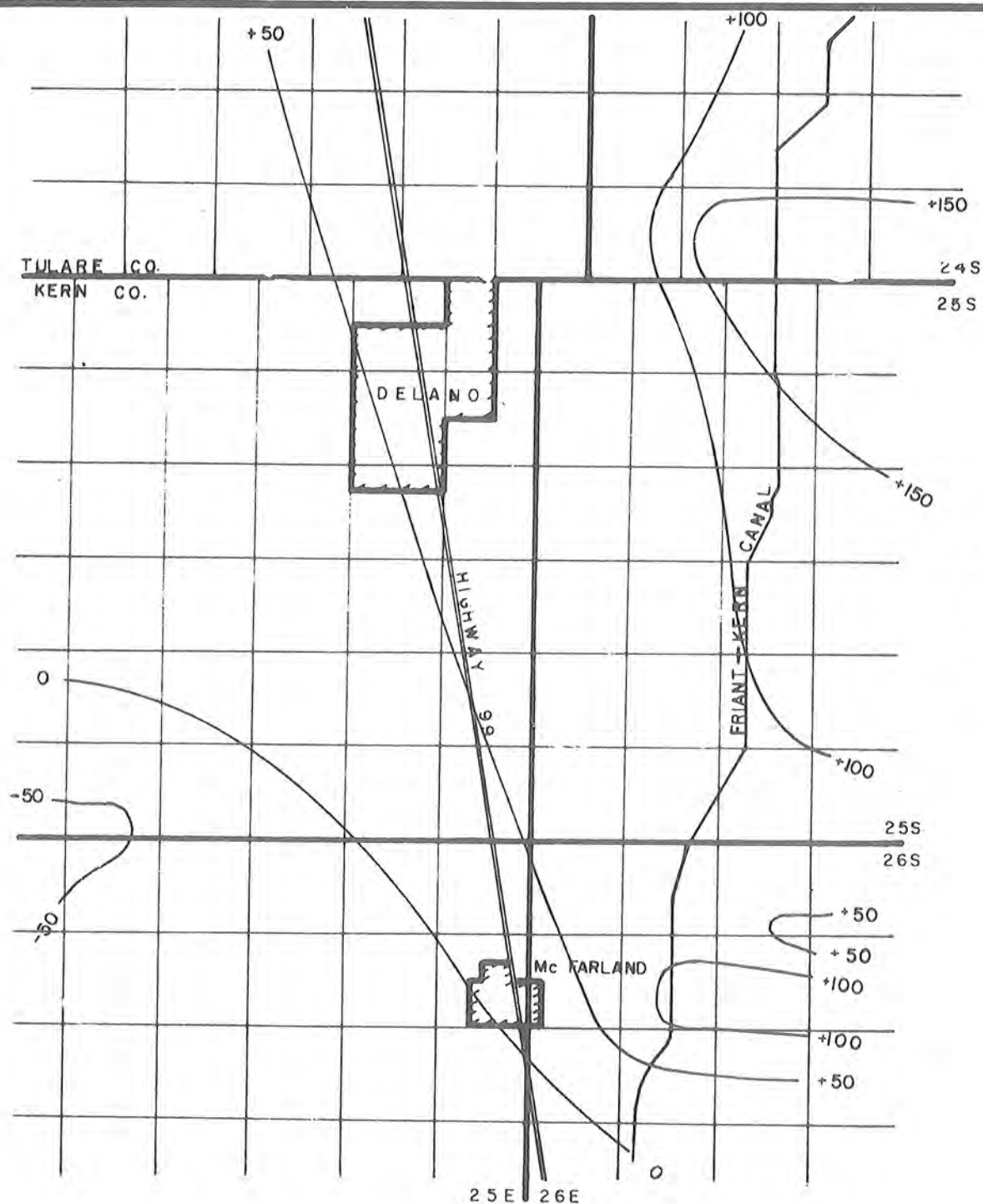
^{1/} "Water Supply Study of the Southern San Joaquin Municipal Utility District, California," 1948, U. S. Department of the Interior, Bureau of Reclamation, Region 2.

Present Ground Water Conditions

The continued and increased use of imported surface water and the corresponding reduction of ground water usage has resulted in a marked and extensive recovery of the mean water table in the study area. Some portions of the general area such as the former cones of depression northeast of Delano and east of McFarland have recovered as much as 150 feet (Figure 4). The non-uniform water table recovery has resulted in the formation of a ground water mound in the area northeast of Delano which was formerly the area of greatest depression. The former depressed area east of McFarland has recovered to the point that the water table gradient now slopes to the west (Figure 5).

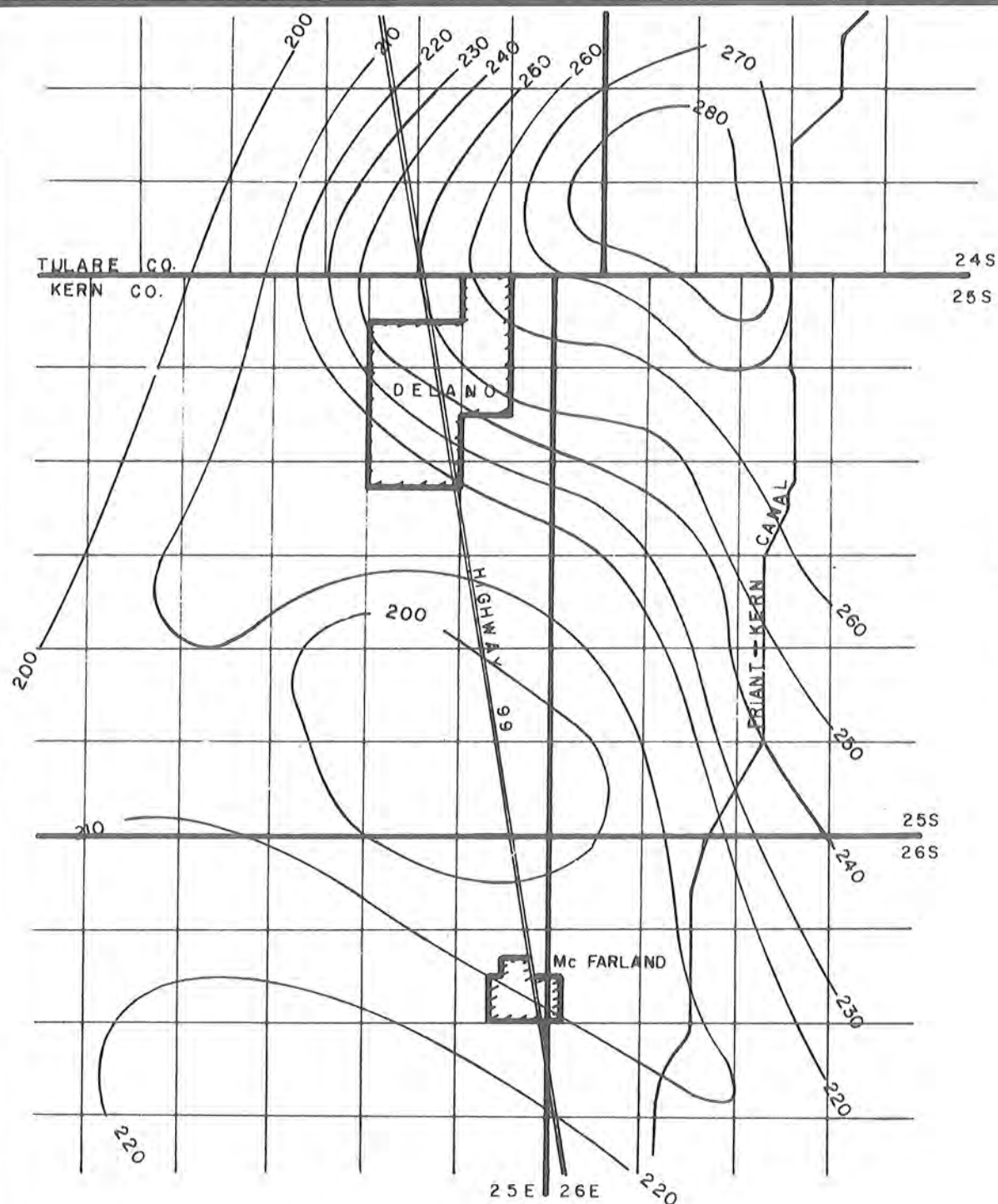
Effects of Pressure, Permeability, and Specific Yield

The movement and distribution of ground water within the study area is complex in nature. The irregularities of areal geologic formations have created a condition of semiconfinement in ground water throughout most of the study area. The exception is the confined aquifer system underlying the Corcoran Clay in the northwestern portion of the area of investigation. Water introduced to the more permeable intake areas east of the area of study migrates in a westerly direction as it percolates downward. It begins to accumulate pressure as it migrates under the series of impermeable, irregular lenses. This pressure is released in deeper wells in the study area which pierce the series of confining lenses west of the intake area. Ground water movement is apparently influenced further in specific portions of the



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SAN JOAQUIN DISTRICT
DELANO NITRATE INVESTIGATION
CHANGE IN GROUND WATER
LEVELS, 1951 - 67

0 1 2 3
Scale in miles



STATE OF CALIFORNIA
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 SAN JOAQUIN DISTRICT
 DELANO NITRATE INVESTIGATION
 GROUND WATER ELEVATIONS,
 SEMI-CONFINED AQUIFER,
 SPRING 1967

0 1 2 3
 Scale in miles

study area by variations in specific yield of the semiconfined aquifer system. Deeper wells in the vicinity of Delano appear to draw water more readily from the coarser deposits to the northeast than from the less permeable materials in their immediate area. In the past the resultant depletion was evidenced by the existence of the cone of depression in this area. More recently the greater permeability northeast of the City and the resultant need for larger amounts of applied irrigation water in combination with the reduction of pumping over the entire area have accounted for the creation of the ground water mound northeast of Delano.

Water Quality

In its report on the Terra Bella-Lost Hills area the U. S. Geological Survey described ground water quality in general across the entire area. Surface water from the eastside of the San Joaquin Valley is typically of a calcium bicarbonate character. As it percolates and

migrates westward cation exchange replaces the calcium with adsorbed sodium creating a sodium bicarbonate water in deeper zones of the semiconfined aquifer system. Sodium concentrations increase with distance from the recharge area and the depth of water below the land surface. Chloride and sulfate anions are predominant in the shallower zones toward the east side. Analyses of water from shallow wells (0-300 feet) show generally higher concentrations of total dissolved solids with calcium chloride-sulfate water as the predominant type. Sodium chloride-sulfate waters penetrate the deeper zones of the semiconfined aquifer system along the east boundary of the current area of study. The Delano study area in particular appears to be within a complex area of water quality transition. In March, 1967 nine different characters of water were identified in samples collected from City wells. This complexity of ground water quality was apparent throughout the study area. Mineral analyses indicating the heterogeneous nature of waters are shown in Table 1.

The determination of nitrate concentrations in the public water supply of the City of Delano is being accomplished by monitoring the quality of water pumped from the city's wells. The determination of possible methods of alleviating the problem, however, required identification of the sources and extent, both areally and with depth, of excessive nitrate concentrations. Accordingly, the area of investigation was expanded in all directions to provide for coverage of all areal conditions which could affect ground water quality in the City of Delano.

Compiled Data

In March, 1967 all the pertinent data previously compiled by the Department were evaluated. The data included ground water analyses, water levels, geology, and well logs. No patterns of nitrate concentrations were discernible from past water quality analyses. Although numerous analyses of water from the study area were available only a few included an analysis for nitrate. The limited number of nitrate analyses and the limited corresponding well water levels prevented an accurate correlation of concentration with depth to water. Examination of available drilling logs showed the irregularities of geologic formations in the study area. Water wells in the area vary in depth from approximately 200 to 1,200 feet. Most of these wells are perforated throughout a large percentage of their depths and are gravel packed.

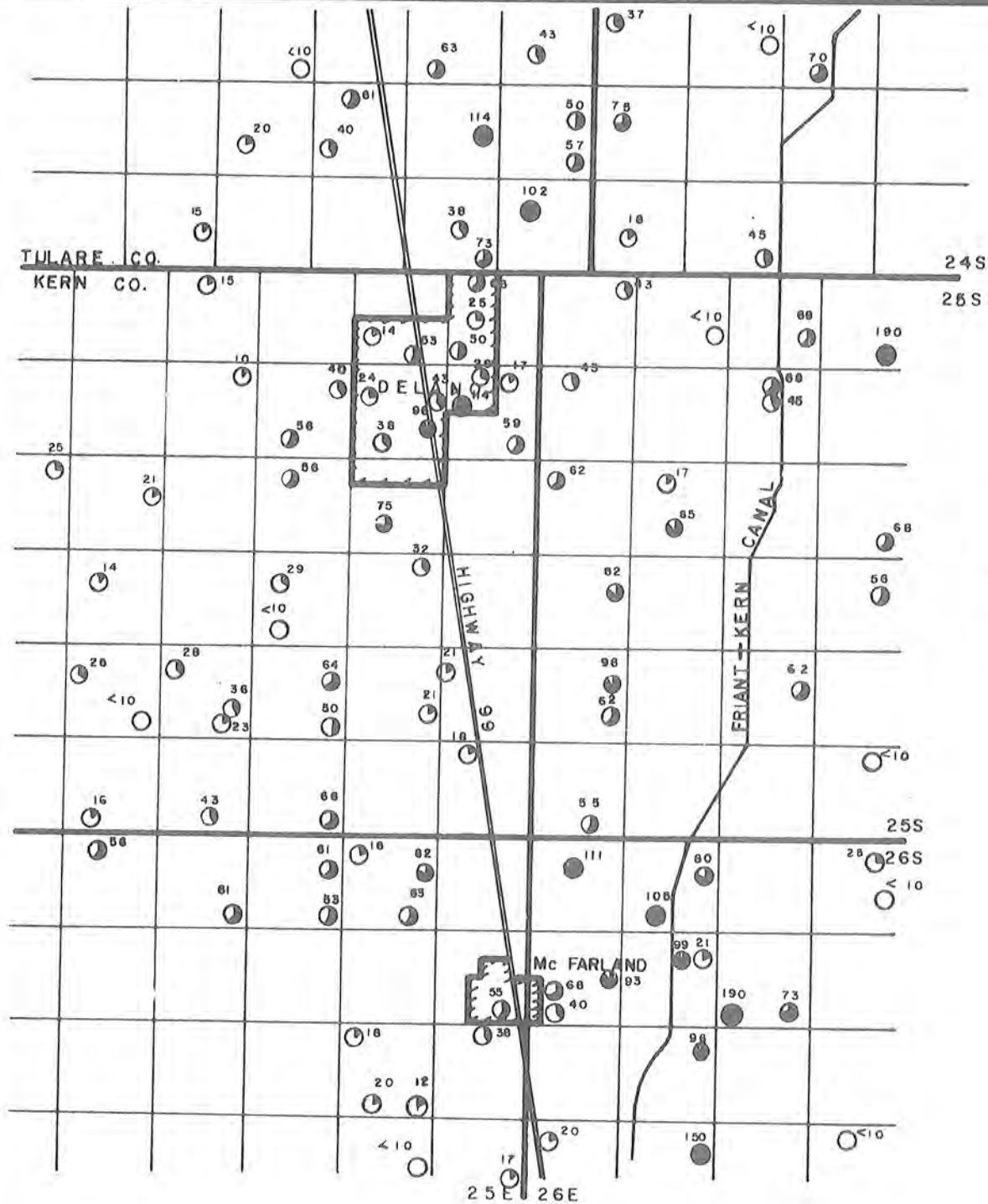
Initial Sampling Run

On March 23, 1967 water samples were collected from 105 wells throughout the 130 square mile study area. Water levels were measured where possible. Nitrate

concentrations^{1/} are included in Table 1. Analyses of the samples indicated three general areas of high nitrate concentrations over the entire study area as shown in Figure 6. The first area extends from about three miles east of Delano to three miles east of McFarland along the Friant-Kern Canal. The second area is centered approximately three miles northwest of McFarland and covers an area of approximately ten square miles. The third area extends from the City of Delano two miles in a northeasterly direction. The average nitrate concentration detected over the study area during this sampling run was approximately 50 mg/l. There was no apparent correlation between nitrates and water levels measured at the time or between nitrates and specific conductance (an indicator of total dissolved solids concentration). When compared to limited analyses dating back to 1942, the current analyses showed a general increase of nitrate concentration within the study area. This discovery indicated that the source of nitrates could be within the depth zone from the surface to the water table. A deep seated source would not show this wide fluctuation of concentrations, particularly over such a widespread area. The areal magnitude and the locations of the highest nitrate concentrations also indicated that the source was not centralized such as would be the case if sewage effluent were the primary source.

^{1/} The majority of nitrate analyses were determined with the use of Hach kits. Laboratory tests show this method to be accurate to within 15 percent of the standard method.

FIGURE 6



LEGEND

- 25 mg/l
- ◐ 50 mg/l
- ◑ 75 mg/l
- 100mg/l and greater

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
DELANO NITRATE INVESTIGATION

NITRATE CONCENTRATIONS DETECTED
IN MARCH 1967

0 1 2 3
Scale in miles

Evaluation of Compiled Data

During April of 1967 all of the compiled data were re-evaluated in an attempt to correlate nitrates with other variables. No standard terminology is used by well drillers in classifying excavated materials. It was difficult therefore, to identify and correlate geologic features. It was possible, however, to detect discontinuous impermeable zones and a diatomaceous clay layer similar to that reported by the U. S. Geological Survey^{1/}. It is possible that these discontinuities have contributed to the non-uniform occurrence of nitrate in ground water. This possibility is supported when comparison is made of nitrate concentrations in water pumped from two of Delano's municipal wells. The two wells (Nos. 6 and 7)^{2/} are situated approximately one-quarter mile apart. They are approximately equal in depth and diameter, perforated in the same depth intervals, and equal in horsepower. However, driller's logs show that the geology in the area of the two wells is dissimilar. The average nitrate concentration detected over a period of six years in water from well number 6 was about 90 mg/l as compared to about 53 mg/l for well number 7.

The comparison of nitrates with other mineral constituents detected in local ground water, including various trace elements, showed no definite correlation.

An attempt to formulate a nitrogen balance proved infeasible because of unknown factors such as rate, concentration, and period of fertilizer applications and the amount of native nitrogen in the

^{1/} "Geology, Hydrology, and Quality of Water in the Terra-Bella-Lost Hills Area, San Joaquin Valley, California", April 30, 1963.

^{2/} Delano City Well No. 6 is State Well No. 25/25-12El. Delano City Well No. 7 is State Well No. 25/25-11Hl.

subsurface profile prior to fertilizer application.

The fact that no definite correlations were discernible indicated that the effect of any single variable was being masked by the influence of other variables combined and/or that basic data over a longer time period were required.

Collection of Additional Data

In May 1967 representatives of the Sierra Vista Ranch, which is located about three miles northeast of Delano in the area of the former cone of ground water depression, released their agricultural records for examination in the interest of identifying the source of the nitrate problem. Pertinent information included the amounts of water used annually, average annual water level elevations, well logs, rates and types of fertilizer used, and ground water analyses. Examination of the records revealed problems of evaluation similar to those encountered in examining previous data. Although portions of the data, such as annual water levels and amounts of applied water, were relatively comprehensive, other information such as the amounts of applied fertilizers and ground water analyses were limited. However, a significant correlation was noted between annual water table levels and nitrate concentrations. Average depths to water at Sierra Vista Ranch are shown in Table 2. In 1927 the average standing level of water in wells of the Sierra Vista Ranch was at a depth of 144 feet. By 1951 this level had dropped to a depth of 304 feet. In 1952 the effects of utilizing Friant-Kern Canal water began to be reflected by rising water table elevations within the boundaries of the Ranch. By 1958 the average water level had risen 127 feet to a depth of 177 feet. This level represented a

short term peak in ground water underlying the Ranch. The succeeding three years were critically dry requiring a greater use of ground water and causing the average standing water table to drop to a depth of 201 feet in 1961. Table 3 shows historical nitrate analyses for five wells owned by Sierra Vista Ranch. With the exception of well number 24/26-20H1 all analyses show peak nitrate concentrations during 1958 or 1959 correlating with the water table high in that period. In addition they indicate a marked rise in nitrates during the interval prior to the water table peak. The apparent inconsistency indicated in analyses of water from well number 24/26-20H1 is related to the season during which the samples were collected. The 1959 samples were collected in April and August during and immediately after the season of heaviest pumping. The maximum average pumping level at Sierra Vista Ranch in 1959 was at a depth of 325 feet. The 1960 sample was collected in March, when little or no pumping occurs in this area. The average standing level at the Ranch in 1960 was at a depth of 199 feet. The fact that the correlation of nitrate concentrations and ground water levels is detectable supports the theory of nitrate sources being from the ground surface or in the zone between the surface and the water table. This detection also indicated that the concentration of nitrates at depths approaching the water table is of significant proportions.

Measurements of Nitrate Concentrations in Soil Profiles

The apparent buildup of nitrate concentrations with depth prompted a check of the frontal movement of nitrates through various soil profiles in the study area. Prior to field testing, available reports on the subject were reviewed to gain a better understanding of the phenomena associated with leaching. Two studies conducted in

1963 and 1964 by Dyer^{1/} best described nitrate leaching. For his first experiment Dyer packed a nitrate-rich soil of the Panoche Series into a column measuring 117 inches in height. The column was partially leached under unsaturated flow conditions with a saturated gypsum solution equivalent to a 12.5-inch irrigation applied at a rate of 0.34 inches per hour. He found that about one-half of the original soil moisture was not displaced downward with the leached nitrate. Nitrate concentrations remaining in the leached zone were negligible while those some distance below this zone were displaced into a front at a concentration about twice that found in the original soil solution. The second study, comparing irrigated and adjacent unirrigated soils, also indicated this frontal buildup of nitrates in irrigated soils beginning at depths up to 25 feet in concentrations in excess of those detected in adjacent unirrigated soil profiles. The irrigated soils had been used agriculturally for 11 to 14 years during which time each plot received an average of about 20 feet of applied irrigation water. On the average the upper limit of nitrate fronts occurred at a depth of about 20 feet.

In general, soils in the Delano area have been in agricultural use for longer periods than the irrigated Panoche soils used in Dyer's studies.

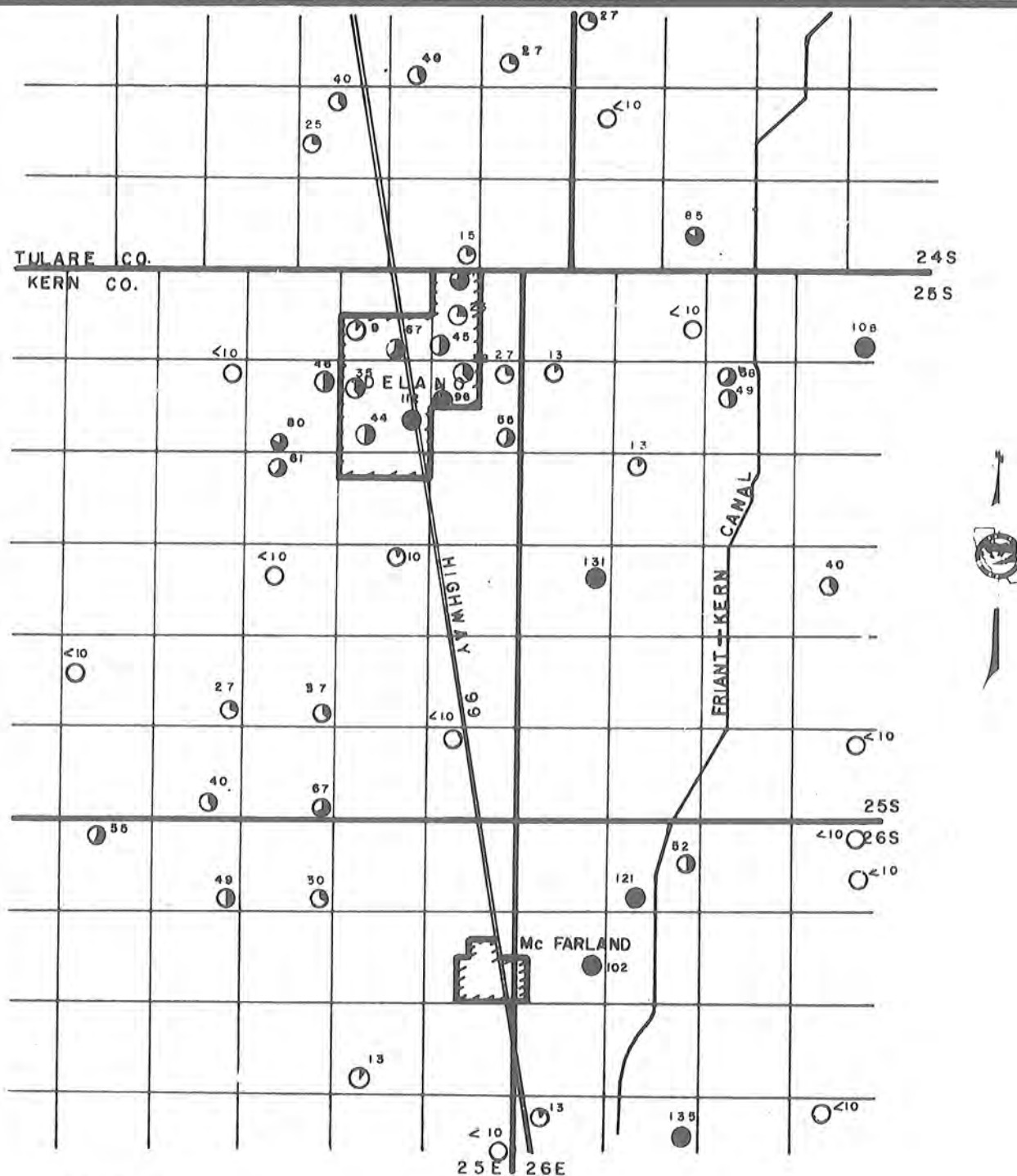
^{1/} "Unsaturated Flow Phenomena in Panoche Sandy Clay Loam as Indicated by Leaching of Chloride and Nitrate Ions", "Interpretation of Chloride and Nitrate Ion Distribution Patterns in Adjacent Irrigated and Nonirrigated Panoche Soils", Kenneth L. Dyer, Soil Scientist, Fresno Field Station, A. R. S., U. S. D. A.

Compilation of Supporting Evidence

In addition, greater amounts of water are applied to crops in the Delano area. A 36-year applied water average of over five acre-feet annually was recorded by the Sierra Vista Ranch. Most of the soils in the Delano area are as permeable as the Panoche Series. The smooth alluvial fans and basin areas are slightly less permeable. Consequently, a marked frontal buildup of nitrates in soils within the study area was not anticipated within the 19-foot depth limitation imposed by the use of a hand auger during this investigation. A frontal buildup would be expected at depths approaching the water table. However, recent frontal activity in these soils and a more pronounced front in recently developed agricultural areas was anticipated. The magnitude of nitrate concentrations in soils which had never been irrigated was also desired. Analyses of extracts taken from selected soils are shown in Table 4. With the exception of one hole all of the soil profiles showed only a slight frontal activity. An assumed recent frontal buildup is illustrated by the profile of hole number 25/26-5D. The profile of hole number 25/25-11R, an area which had no record of fertilization or irrigation, indicated a nitrate concentration at the surface greater than most found at any depth in any other profile. If this condition originally existed in areal soils prior to irrigation or fertilization the amounts and concentration of nitrates leached can be assumed to be of large proportions. The one exception mentioned previously was hole number 26/26-15C located in a grove of oranges planted in 1958. The nitrate concentration of 598 mg/l in the first foot of depth, after approximately nine years of irrigation, can only be attributed to the application of fertilizers.

A review of historical annual water table fluctuations as indicated by a limited number of monitoring wells in the study area showed that ground water levels in general ranged from highs during the winter months to lows during the summer due to irrigation practices. The Department conducted a sampling run in September 1967, to determine nitrate levels in ground water as compared to those detected in March. Analyses showed that nitrate concentrations had dropped from an average of about 50 mg/l in March to about 39 mg/l in September over the entire study area. Ground water levels in general also dropped. Nitrate concentrations are shown in Table 1. Figure 7 illustrates the distribution of nitrate concentrations detected in September. The areas of high concentrations are in the same general locations as those detected in the March sampling run.

By January, 1968 the City of Delano had compiled nitrate analyses for its water supply system by months for the entire previous year. Because of the construction of its wells, however, the City was unable to monitor ground water fluctuations within the same area. In an attempt to further correlate nitrate concentrations and water levels a plot was made of depths to water in the monitoring well nearest the city (State Well Number 25/26-16P1) and the monthly average of nitrate levels detected in the city water supply system (Figure 8). Although it is situated some three miles away, the



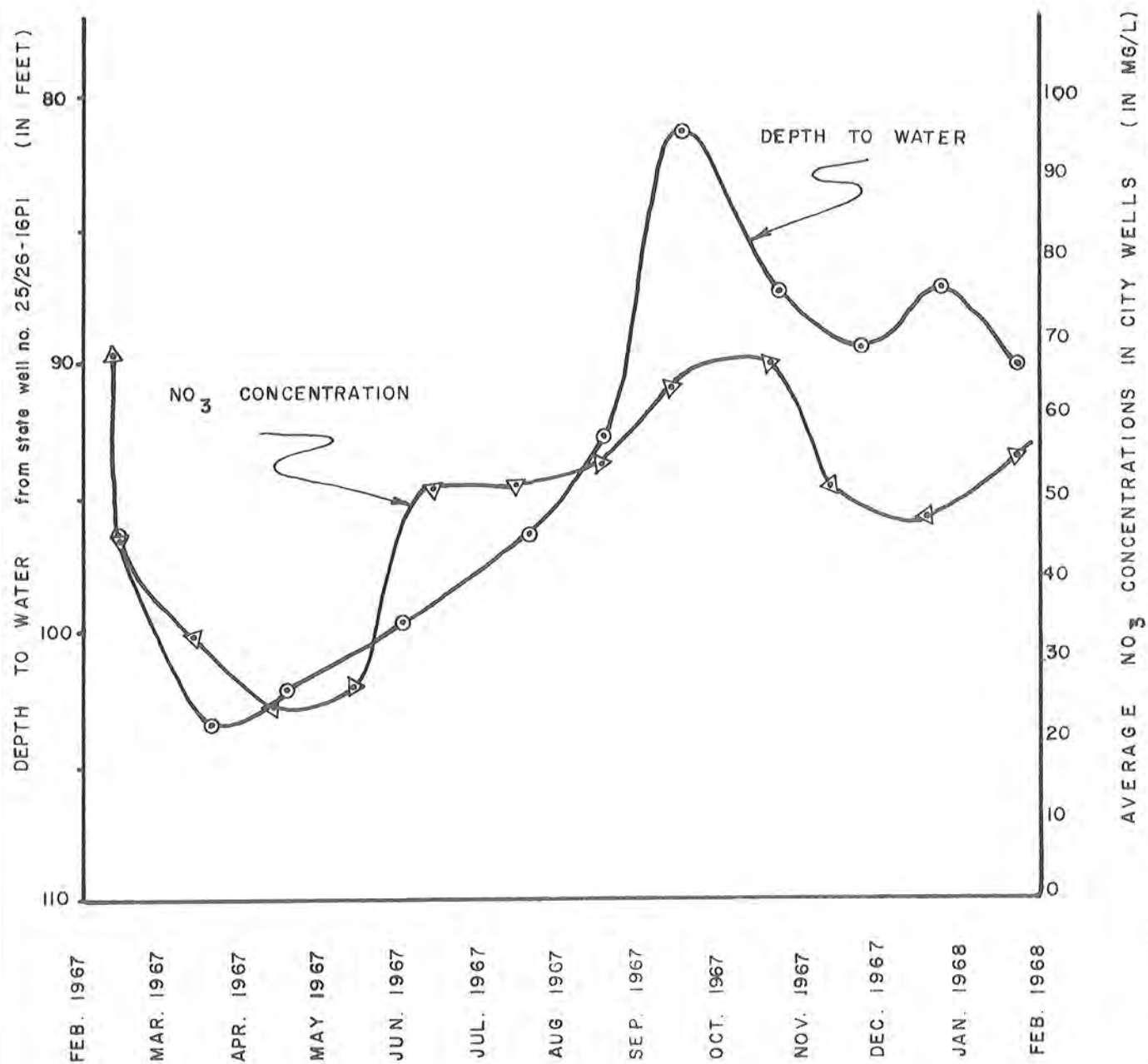
LEGEND

- 25 mg/l
- ⊙ 50 mg/l
- ⊗ 75 mg/l
- 100mg/l and greater

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
DELANO NITRATE INVESTIGATION

NITRATE CONCENTRATIONS DETECTED
IN SEPTEMBER 1967

0 1 2 3
Scale in miles



STATE OF CALIFORNIA
 THE RESOURCES AGENCY
 DEPARTMENT OF WATER RESOURCES
 SAN JOAQUIN DISTRICT
 DELANO NITRATE INVESTIGATION

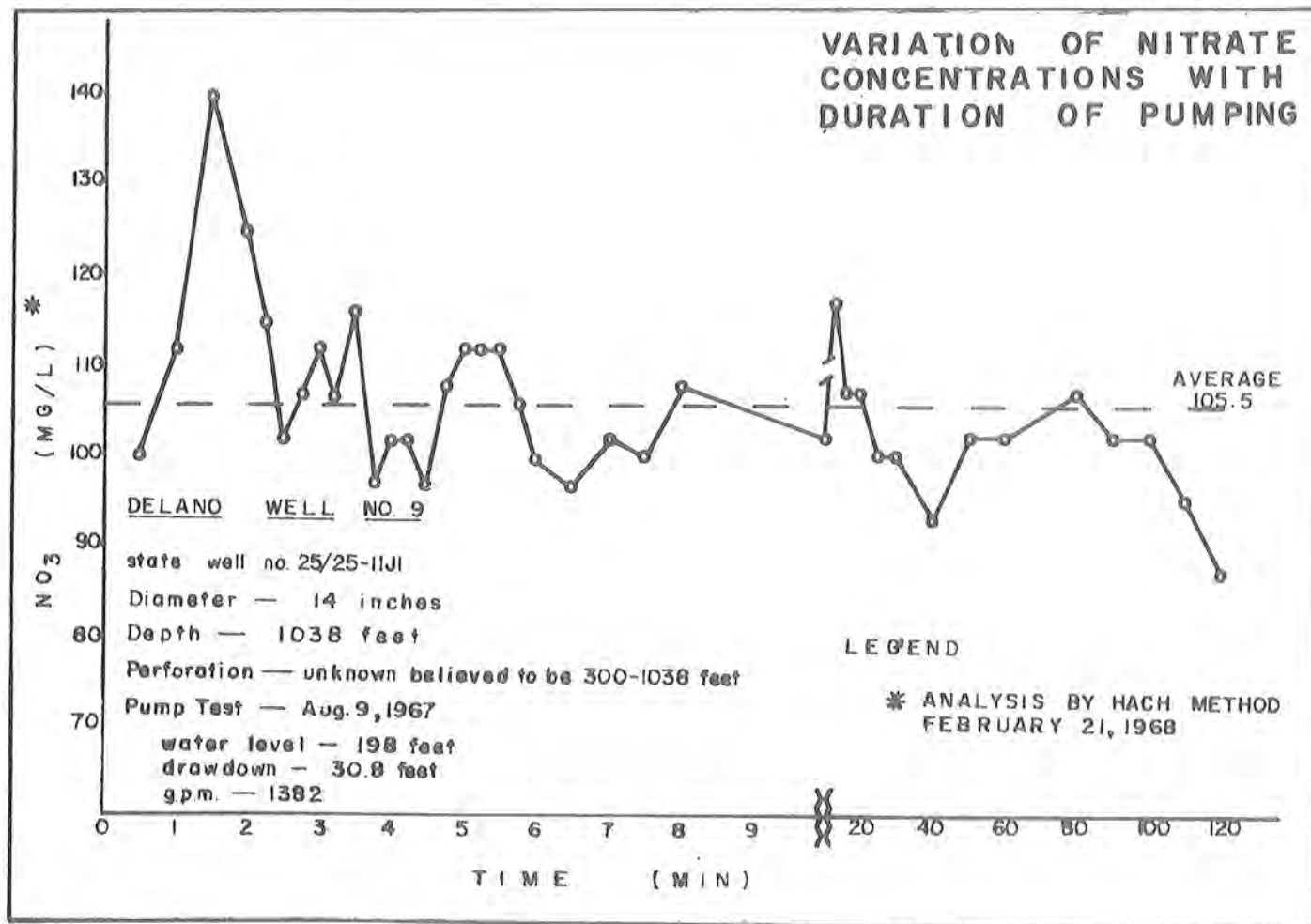
VARIATION OF NITRATE
 CONCENTRATIONS WITH
 DEPTH TO WATER

plot of water table fluctuations in the monitoring well shows a definite correlation with nitrate concentrations detected within the city limits. The most apparent but consistent deviation is the lag of approximately one month between nitrate high and lows and the corresponding highs and lows of the water table.

In February, 1968 one more test was conducted in the interest of supporting the theory that nitrate sources were above the water table. With the city's cooperation, one well (No. 9, State Well No. 25/25-11J1) was pumped and water samples were taken over a two hour period. Theoretically, if nitrate concentrations were highest at the water table they would be reflected in a peak soon after pumping began. Subsequently, they would taper off to a concentration

representative of pumping from a combination of the various depth zones. The results of the test are plotted on Figure 9. The quality of initial quantities of water pumped is representative of the water already inside the well above the perforated interval. Immediately after the exhaustion of this amount, water from between the top of perforations and the water table would be pumped. The plot indicates that nitrate concentrations are in fact higher at shallower zones of the aquifer (140 mg/l at peak as compared to 88 mg/l after two hours). However, the relatively small maximum variation (52 mg/l) indicates the possibility of nitrate degradation in more than just the shallow portion of the aquifer.

FIGURE 9



CHAPTER IX. EVALUATION

The various tests conducted and the conditions existing within the study area as determined during this investigation clearly indicate that the source of excessive nitrate concentrations lies above the water table. Prior and recent testing of nitrate leaching phenomena, and evidence of high nitrate concentration in the depth zones of the fluctuating water table indicate that nitrates are accumulating in greater concentrations with increasing depths as water is applied to the land surface. Although the amounts of nitrates in ground water attributable to specific sources were indeterminate it is concluded that the bulk of the degradation is not attributable to sewage wastes because of the areal magnitude of the problem and the limited number of sewage sources. The City of Delano's sewage treatment plant is located two miles west of the city in an area of low nitrate ground water.

Excessive nitrates in ground water along the north-south path in the eastern portion of the study area appear to be the result of a combination of conditions. Ground water elevations throughout this area have increased markedly since the construction of the Friant-Kern Canal. These rising water table conditions and the descending movement of nitrates have compounded degradation of ground water. Extensive agricultural development has occurred in this area in recent decades resulting in the application of significant amounts of water. Permeabilities along this path are in general good to excellent.

High nitrate concentrations in the northern portion of the study area

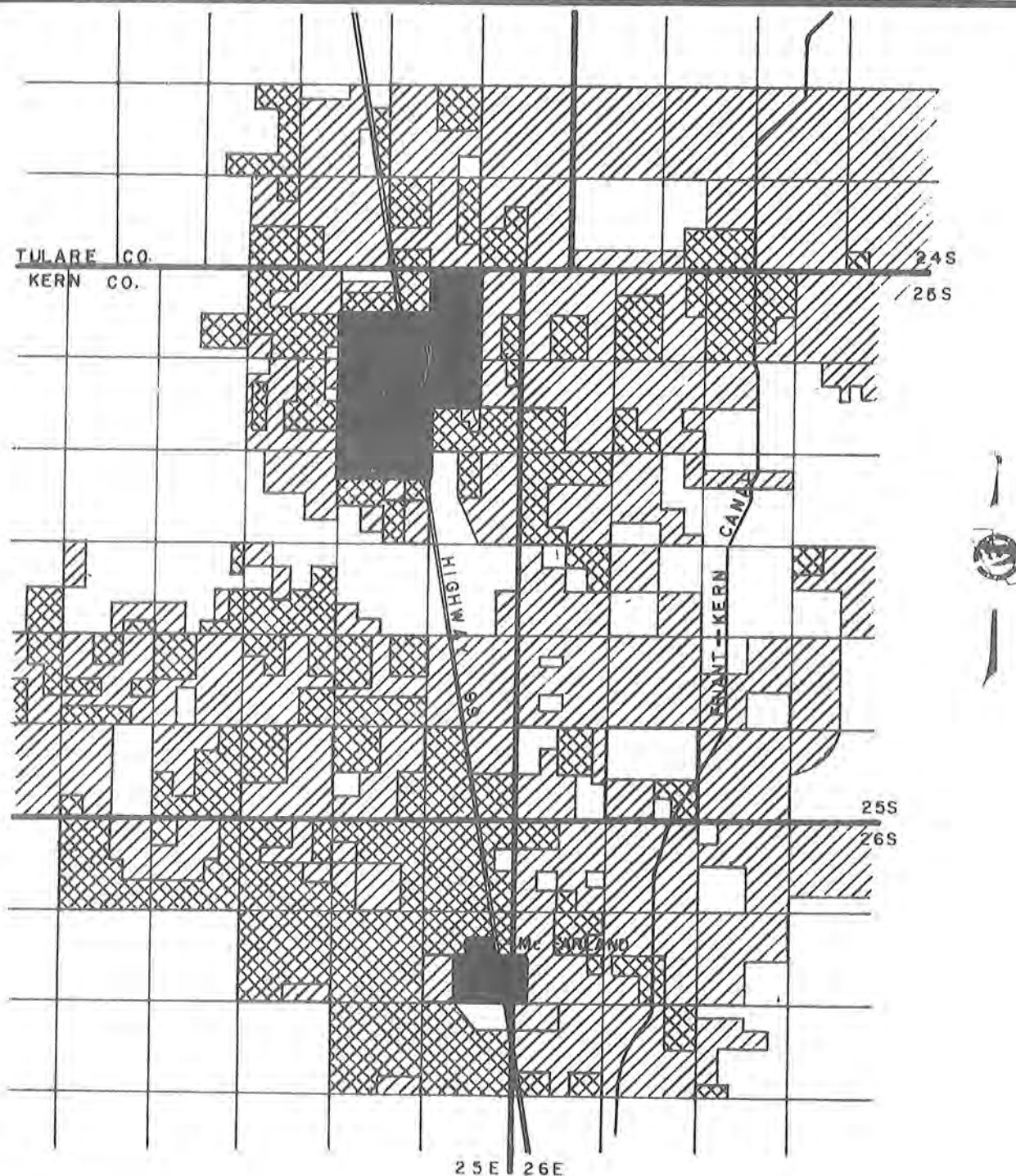
appear to be the result of the same combination of conditions listed above. Conditions indicate that the City of Delano is drawing its nitrate rich water from this area. The gravel packed deep wells of the City draw water from an extensive zone of the semiconfined aquifer. At greater depths water is drawn more readily from the shallower coarser deposits to the northeast. Water at lesser depths is also pumped from the northeast as the result of the downward water table gradient from that direction.

The City of McFarland is down gradient from the high nitrate areas north and east of it and apparently draws water from these areas.

The high nitrate area northwest of McFarland is apparently the result of long term applications of water to the land surface. Soils and subsurface deposits in this area are not as permeable as those to the north and east. The water table has not risen significantly in this area in recent decades. For the most part however, lands in this area have been irrigated since the early 1900's (Figure 10).

It was impossible to determine whether nitrate levels in the future would recur in similar or increased concentrations in the Delano area. However, nitrate concentrations in ground waters throughout the San Joaquin Valley and the State in general have been increasing steadily for a number of years. The most important task presently remaining is the determination of the significance of nitrate levels with respect to public health.

FIGURE 10



LEGEND

-  PRESENT URBAN AREAS
-  IRRIGATED AREA 1946
-  IRRIGATED AREA 1946 & 1920

STATE OF CALIFORNIA
 THE RESOURCES AGENCY
 DEPARTMENT OF WATER RESOURCES
 SAN JOAQUIN DISTRICT
 DELANO NITRATE INVESTIGATION

IRRIGATED LANDS

0 1 2 3
 Scale in miles

TABLE 1: MINERAL ANALYSES OF GROUND WATER - DELANO NITRATE INVESTIGATION

State Well Number	Depth in Feet	Perforated Interval	Mineral Constituents in Milligrams per Liter													B	TDS	Total Hardness	EC Micromhos	pH	Date
			Ca	Mg	Na	K	CO ₃	HCO ₃	SO ₄	Cl	NO ₃										
24S/25E-21L1	432	--	2.7	4.3	31.0	1.7	0	139	18	14	9.1	0.17	260	85	307	7.6	5-57				
24S/25E-21R1	700	--	--	--	--	--	--	--	--	--	--	--	--	--	240	--	3-67				
24S/25E-23P1	800	200-800	29.0	2.3	38.0	2.4	0	104	14	22	48.0	0.18	267	82	358	7.7	6-59				
24S/25E-24L2	600	--	--	--	--	--	--	--	--	--	40.0*	--	--	--	415	--	3-67				
24S/25E-24P1	1,002	300-1,002	17.0	1.3	38.0	1.8	0	90	12	23	43.0*	--	--	--	420	--	9-67				
24S/25E-25P1	1,206	330-1,204	11.2	3.3	41.2	--	4.8	99	6	18	27.0*	0.1	140	48	470	--	3-67				
			31.4	--	44.2	--	0	96	--	--	--	--	--	--	450	--	9-67				
			33.2	--	46.7	2.3	0	97	18	36	47.7	0.2	--	--	291	8.3	3-67				
			30.4	--	44.6	2.3	0	93	14	36	42.2	0.2	--	--	400	8.1	2-47				
			37.2	--	42.5	2.3	TR	109	29	36	49.6	0.3	--	--	390	7.7	5-59				
24S/25E-25P2	365	--	109.4	--	72.7	4.7	0	106	--	--	94.2	0.2	--	--	370	7.8	8-59				
24S/25E-25H1	1,200	--	--	--	--	--	--	--	--	--	--	--	--	--	420	8.1	2-60				
24S/25E-25R1	1,530	444-1,530	--	--	--	--	--	--	--	--	50*	--	--	--	960	8.0	5-59				
24S/25E-26J1	--	--	65	3.2	--	--	--	--	--	--	57*	--	--	--	697	--	3-67				
24S/25E-27C1	200	68-170	--	--	--	--	0	54	--	127	114*	--	--	--	454	--	3-67				
24S/25E-27M1	200	--	--	--	--	--	--	--	--	--	61*	--	--	175	854	7.9	3-67				
			--	--	--	--	--	--	--	--	40*	--	--	--	556	--	3-67				
24S/25E-28L1	450	100-450	--	--	--	--	--	--	--	--	40*	--	--	--	625	--	9-67				
24S/25E-32J1	600	150-600	--	--	--	--	--	--	--	--	25*	--	--	--	500	--	3-67				
24S/25E-35K2	--	--	--	--	--	--	--	--	--	--	20*	--	--	--	540	--	9-67				
24S/25E-35R1	--	--	--	--	--	--	--	--	--	--	15*	--	--	--	276	--	3-67				
			--	--	--	--	--	--	--	--	38*	--	--	--	296	--	3-67				
24S/25E-36P2	250	190-250	34	20	--	--	--	--	--	--	73*	--	--	--	446	--	3-67				
24S/25E-36J1	1,415	437-1,398	5	1	67	0.7	9	192	--	68	15*	--	--	--	540	--	3-67				
24S/26E-19D1	642	290-630	--	--	--	--	--	112	29	30	102*	--	--	166	841	8.4	3-67				
24S/26E-20H1	1,254	300-1,254	--	3.8	99.8	--	6	--	--	--	37*	--	--	17	334	8.1	10-58				
			7.8	2.2	62.7	--	12	--	--	--	27*	--	--	--	400	--	3-67				
			75.8	--	38.6	2.3	0	159	44	38	--	--	--	--	410	--	9-67				
			35.4	--	40.2	2.3	0	111	25	20	1.2	0.2	303	--	--	8.5	11-35				
			104.8	--	42.8	2.7	0	126	76	60	68.8	--	--	--	--	--	6-39				
			52.8	--	32.2	1.8	0	140	84	62	77.5	TR	--	--	570	7.6	5-59				
24S/26E-20M1	502	104-502	37	8.1	29	2.6	0	118	20	36	86.2	0.5	--	--	670	7.6	8-59				
24S/26E-20Q1	596	325-596	54.8	--	36.4	2.3	0	116	18	28	44.0	0.2	--	--	740	7.5	3-60				
			55.0	--	41.0	2.7	0	99	--	39	72.5	TR	251	126	450	7.9	9-62				
24S/26E-21A1	1,404	396-1,398	10.8	5.8	90.8	--	0	91	11	50	91.8	0.5	--	--	401	7.7	2-58				
			26.4	--	37.7	2.0	0	91	--	5	25	0.5	--	--	450	7.8	8-59				
			25.6	--	36.3	1.6	0	100	--	25	--	0.2	--	--	490	8.1	3-60				
			29.8	--	36.8	2.0	0	93	13	21	20.5	TR	--	--	--	--	8.0	12-47			
			35.0	--	34.5	1.8	TR	91	23	25	31.6	0.4	--	--	300	8.1	5-59				
24S/26E-21P1	--	--	--	--	--	--	--	104	5	31	22.9	0.5	--	--	320	8.0	2-60				
			--	--	--	--	--	5	--	--	40.9	0.2	--	--	330	7.5	3-60				
24S/26E-28D1	1,200	330-1,200	15	4.1	41.4	--	9	--	--	--	70*	--	--	--	360	8.0	9-62				
			91.6	--	55.2	2.3	0	110	6	23	--	--	--	--	502	--	3-67				
			52.6	--	50.6	2.3	0	--	--	--	41.5	0.1	--	56	--	--	8.6	3-47			
			49.0	--	46.0	2.3	0	110	--	40	49.0	0.1	--	--	720	7.5	5-59				
24S/26E-28H1	843	215-843	41.2	--	43.7	1.8	TR	115	--	38	51.5	0.2	--	--	510	7.6	8-59				
			--	2.3	58.2	--	3	123	17	36	37.8	0.2	--	--	480	7.2	3-60				
			86.8	--	63.5	2.7	0	109	24	18	--	--	--	--	430	7.8	9-62				
			81.6	--	56.6	3.1	0	173	--	--	85.6	--	207	18	--	--	8.4	11-35			
24S/26E-28P1	1,197	250-1,197	80.8	--	57.5	3.5	0	153	--	53	81.2	0.2	--	--	740	7.7	5-59				
			57.6	--	70.8	3.5	0	153	70	56	81.2	0.3	--	--	700	7.8	8-59				
			49.2	--	67.7	3.1	0	--	--	--	--	--	--	--	700	7.8	2-60				
			50.4	--	68.6	3.5	0	135	35	46	71.3	--	--	--	--	--	--	--			
24S/26E-29H2	1,201	330-1,201	50.6	--	47.8	2.3	0	139	46	47	63.9	0.3	--	--	610	--	5-59				
			53.0	--	49.8	2.3	0	--	--	--	--	0.3	--	--	560	7.8	8-59				
			53.0	--	48.8	2.7	0	104	--	46	68.8	--	--	--	590	--	2-60				
			51.4	--	46.0	2.1	TR	104	31	--	77.5	TR	--	--	480	7.9	5-59				
24S/26E-29P1	612	300-598	67.2	--	63.5	3.9	0	101	30	48	73.8	0.3	--	--	510	7.6	8-59				
			56.2	--	62.2	3.5	0	122	16	45	63.9	0.2	--	--	510	8.0	2-60				
24S/26E-29R1	1,300	288-1,245	14.6	2.7	65.8	--	2	162	--	50	88.0	0.1	--	--	490	7.9	9-62				
			60.8	--	64.4	3.5	0	144	39	52	75.6	0.3	--	--	620	7.8	5-59				
			38.4	--	53.8	2.3	0	--	--	--	--	--	--	--	610	8.0	2-60				
			44.8	--	55.2	2.7	0	161	98	25	--	0	264	48	--	--	8.3	7-44			
24S/26E-30P1	760	--	60.8	6.8	8.9	--	--	119	54	25	--	0.2	--	--	620	8.1	5-59				
			97.2	--	70.8	3.9	--	152	31	37	20.5	0.2	--	--	450	7.7	8-59				
			72.8	--	62.2	3.1	0	140	--	50	5.0	--	--	--	490	7.6	2-60				
			98.0	--	73.6	4.3	0	135	--	--	--	--	--	--	--	--	--	--			
			53.2	--	53.0	2.5	0	104	48	60	142.6	--	--	180	640	7.6	4-50				
			--	--	--	--	--	150	72	90	115.3	TR	--	--	830	7.8	5-59				
			--	--	--	--	--	119	21	48	130.8	0.1	--	--	670	7.7	8-59				
24S/26E-30K1	1,163	240-1,163	66.8	--	63.5	3.5	0	--	--	--	79.4	0.3	--	--	890	7.8	2-60				
			53.8	--	60.3	2.7	0	--	--	--	75*	--	--	--	560	7.9	9-62				
			66.0	--	62.0	3.5	0	--	--	--	10*	--	--	--	785	--	3-57				
24S/26E-30P1	1,240	112-1,240	104.4	--	81.0	5.5	0	106	--	--	114.1	--	--	--	450	--	9-67				
			113.2	--	79.5	4.7	0	99	40	48	97.3	--	--	--	640	7.6	5-59				
			--	--	--	--	--	107	53	58	109.1	0.3	--	--	570	8.0	8-59				
			--	--	--	--	--	244	--	--	109.7	--	--	--	680	8.0	2-60				
			--	--	--	--	--	198	82	92	105.4	0.2	--	--	930	7.8	5-59				
			--	--	--	--	--	--	--	--	--	--	--	--	950	7.6	8-59				

TABLE 1: MINERAL ANALYSES OF GROUND WATER - DELANO NITRATE INVESTIGATION (Continued)

State Well Number	Depth : in : Feet :	Perforated : Interval :	Mineral Constituents in Milligrams per Liter													EC : Micromhos :	pH :	Date :		
			Ca	Mg	Na	K	CO ₃	HCO ₃	SO ₄	Cl	NO ₃	B	TDS	Total Hardness						
24S/26E-31J1	1,224	215-1,224	4.1 31.6	1.1 ---	73.4 56.6	-- 2.7	3 ---	110 131	39 28	34 23.6	-- 0.4	218 ---	15 ---	-- 420	8.4 8.0	11-35 8-59				
24S/26E-31L2	1,778	365-1,600	7	1	116	1.9	0	231	19	42	6	0.6	401	24	533	8.1	9-58			
			7.6	1.2	111	2.1	0	288	22	34	2.5	0.6	314	24	513	7.9	4-61			
			7.2	0	55	0.8	0	104	20	20	2.9	0.1	168	18	270	8.1	9-62			
			11	1.1	90	1.8	0	192	23	31	18*	0.4	253	32	493	8.0	3-67			
24S/26E-32H1	485	183-465	4.0	0.5	24.8	--	0	26	9	26	0	0.1	--	--	273	6.8	7-54			
			58.0	--	100.2	4.7	0	--	--	--	71.3	--	--	--	720	7.7	5-59			
			58.2	--	86.6	3.9	--	197	24	57	94.2	0.6	--	--	720	7.5	8-59			
			59.0	--	96.6	4.3	0	201	41	61	86.8	0.3	--	--	700	7.8	2-60			
24S/26E-32L1	502	184-480	--	8	69	--	TR	156	35	43	--	--	--	--	--	--	--			
			28.0	4.9	43.7	--	0	140	10	38	76	0.1	375	149	--	--	8.3	11-35		
			53.4	--	83.8	2.3	0	175	--	--	--	--	--	--	670	8.0	7-52			
			48.4	--	80.6	3.5	0	171	30	50	73	0.2	--	--	620	7.7	4-59			
			49.8	--	77.3	4.3	0	162	25	58	72.0	0.2	--	--	630	7.4	8-59			
			55.8	--	84.0	4.1	TR	209	26	57	71.4	0.2	--	--	670	7.9	2-60			
			--	--	--	--	--	--	--	--	85*	--	--	--	700	7.8	9-62			
			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9-67		
			24S/26E-32P1	537	120-537	41.0	--	64.8	3.1	0	--	--	--	47.7	--	--	--	530	7.7	5-59
						38.8	--	61.6	3.5	0	153	--	35	45.9	0.2	--	--	480	7.7	8-59
24S/26E-32R1	1,204	252-1,201	48.2	--	64.8	3.5	0	137	44	48	52.1	0.4	--	--	510	7.8	2-60			
			6.0	1.7	56.8	--	7	144	9	40	--	0.2	232	--	--	--	8.2	2-47		
24S/26E-32R2	500	---	36.0	--	66.2	3.1	0	--	--	--	21.1	--	--	--	470	7.6	5-59			
			21.0	--	62.2	25.8	0	125	60	33	11.8	0.1	--	--	420	7.6	8-59			
			33.2	--	58.8	3.1	0	132	45	35	13.6	0.3	--	--	480	7.7	2-60			
			30.0	2.4	31.7	--	1	139	--	4	24	5.4	0.0	--	--	598	8.3	8-52		
24S/26E-33F1	950	0-950	53.4	--	82.4	6.6	0	181	--	--	--	--	--	--	630	7.8	5-59			
			55.0	--	83.7	3.9	0	194	34	50	74.4	0.2	--	--	640	7.8	8-59			
			54.6	--	82.4	4.7	0	182	48	52	62.0	0.4	--	--	640	7.8	2-60			
			59.4	--	87.5	3.5	TR	250	17	53	57	0.2	--	--	700	7.8	9-62			
			66.0	--	87.5	3.9	0	239	37	49	69.4	0.1	--	--	800	7.8	7-65			
			--	--	--	--	--	--	--	--	42*	--	--	--	695	--	3-67			
			39.6	--	77.3	2.7	0	--	--	--	--	--	--	--	520	7.8	5-59			
			43.6	--	75.7	2.7	0	172	39	37	52.7	0.3	--	--	530	7.6	8-59			
			38.0	--	77.3	2.7	0	165	43	39	40.3	TR	--	--	570	7.8	2-60			
			35.6	--	71.3	2.1	TR	171	18	38	42.8	0.2	--	--	500	7.8	9-62			
24S/26E-33F2	1,206	---	59.6	--	94.8	3.9	0	226	--	--	83.1	--	--	--	730	7.8	3-59			
			36.8	--	75.7	3.1	0	169	24	40	55.8	0.7	--	--	520	7.7	8-59			
			59.0	--	103.4	4.7	0	223	52	59	73.2	0.4	--	--	740	8.0	3-60			
24S/26E-33H1	977	189-977	14.6	2.7	65.8	--	2	119	54	25	--	264	--	--	--	8.3	7-44			
			62.2	--	94.7	4.3	0	230	88	55	11.8	0.5	--	--	720	8.1	7-59			
			52.6	--	68.0	3.5	0	188	--	45	44.0	0.7	--	--	630	7.5	8-59			
24S/26E-33M1	602	222-579	66.4	--	101.0	4.7	0	225	--	53	88	0.5	--	--	750	7.7	8-59			
			53.4	--	89.2	3.9	0	192	50	50	65.1	0.4	--	--	680	7.7	2-60			
24S/26E-33P1	741	270-741	24.4	--	60.7	2.7	0	134	24	30	26.7	0.5	--	--	400	8.0	8-59			
			29.0	--	70.2	3.1	0	148	26	41	27.9	0.4	--	--	460	7.6	2-60			
24S/26E-34F1	--	--	2.0	2.2	117	9.4	0	135	--	67	--	--	--	14	606	7.7	7-58			
24S/26E-34Q2	1,410	550-1,390	6	1	94	1.5	0	146	46	38	6	0.3	329	21	459	7.9	9-58			
25S/25E-1C1	547	---	36	6	42	3	0	98	25	25	13	--	273	115	--	--	8.3	4-61		
			48.4	5.9	41.2	--	0	132	20	43	56.0	--	281	145	556	7.9	2-67			
			30	5.4	--	--	0	88	--	35	66*	--	--	--	470	8.3	3-57			
			47	5.4	45.5	--	0	132	20	41	64	--	290	140	769	7.9	1-68			
25S/25E-1F1	1,002	342-1,002	22	0.2	--	--	9	95	--	17	25*	--	--	56	320	8.5	3-67			
			16.8	2.4	51.1	--	3.6	101	15	27	25	--	192	52	500	8.2	1-68			
25S/25E-2M1	1,012	310-1,012	36.8	0.8	104	1.6	--	44	112	101	7.5	--	444	96	--	8.1	5-58			
			30	3.6	--	--	9	108	--	14	14*	--	--	90	329	8.6	3-67			
			28.8	2.9	32.9	--	0	119	16	23	11	--	175	84	500	8.0	1-68			
25S/25E-2R2	1,002	348-1,002	21	2.9	38.5	2.2	0	75	38	28	0.3	--	222	64	--	7.9	10-55			
			39	6.0	--	--	10	104	--	37	53*	--	--	122	512	8.6	3-67			
			36.8	6.8	53.4	--	0	118	34	43	54	--	287	120	714	7.8	1-68			
25S/25E-3R1	428	74-418	49	6.8	43	3.1	0	136	45	45	--	--	150	515	8.2	5-54				
25S/25E-4C1	120	50-120	--	--	--	--	--	--	--	--	15*	--	--	--	258	--	3-67			
25S/25E-4Q1	--	--	32 32 31 34 -- -- --	2.4 3.6 5 5.8 -- -- --	30 28 32 32 31 36	2.2 2.1 1.9 2.2 2.3 --	0 0 0 0 -- 0	129 128 133 133 -- -- 119	24 20 25 26 -- -- --	14 16 19 24 13 31 30	10 12 11 12 -- -- --	0.1 0.1 0.1 0.1 0.1 0.0 --	250 246 244 286 88 127 108	90 95 99 109 88 -- --	279 343 354 381 323 442 419	7.5 7.9 7.9 8.3 -- -- 8.2	5-57 7-59 7-60 6-61 7-62 8-63 8-64			
25S/25E-7R1	430	--	30 33	1.5 0.9	62 64	0.8 1.0	0 0	76 74	68 84	49 49	13 13	0.1 0.0	320 345	81 86	464 474	7.8 7.8	8-56 7-58			
25S/25E-9A2	252	150-252	--	--	--	--	--	--	--	--	10* <10*	--	--	--	282 300	--	3-67 9-67			
25S/25E-10A1	1,000	400-1,000	45 43.6	2.2 3.7	-- 63.0	-- --	4 0	98 104	-- 53	51 55	40* 52	--	--	124	553 588	8.4 7.9	3-67 1-68			
25S/25E-10P1	431	120-431	75 -- --	10 -- --	66 -- --	3.6 -- --	0 -- --	118 -- --	175 -- --	39 -- --	38 56* 80	0.0 -- --	577 -- --	228 -- --	764 950 900	7.6 -- --	7-58 3-67 9-67			
25S/25E-11	125	--	42	6	49	--	0	120	51	29	--	--	354	--	--	--	1910			
25S/25E-11	220	--	39	5	50	--	0	92	66	48	--	--	364	--	--	--	7-1910			
25S/25E-11E1	1,002	300-1,002	43.0	2.7	50	2.6	--	78	55	55	7	--	331	119	--	--	8.0	5-58		
			41	3.2	--	--	4	93	--	49	24*	--	--	--	516	8.5	3-67			
			42.4	2.0	55.0	--	0	96	57	40	39.0	--	285	114	556	7.8	1-68			

TABLE 1: MINERAL ANALYSES OF GROUND WATER - DELANO NITRATE INVESTIGATION (Continued)

ANALYSES OF GROUND WATER - DELANO NITRATE INVESTIGATION (Continued)																				
State Well Number	Depth in Feet	Perforated Interval	Mineral Constituents in Milligrams per Liter													TDS	Total Hardness	EC Micromhos	pH	Date
			Ca	Mg	Na	K	CO ₃	HCO ₃	SO ₄	Cl	NO ₃	B								
25S/25E-11H1	1,008	300-1,002	21	1.9	55	2.2	0	64	40	49	0.4				248	60				
			38	2.9			0	84		52	43*				107					
25S/25E-11J1	592	--	36.8	3.7	75.2		0	87	62	61	60				343	107	563	7.5	10-5	
			48.4	2.2	83	3.2		72	79	65	18				450	130	623	8.3	3-67	
			53.6	2.4	66		0	78	38	88	74				361	144		7.9	1-68	
25S/25E-11P1	1,006	298-1,000	51	3.9	79	2.4	0	75	66	82	96*				471	143	833	8.3	6-58	
			53.6	2.9	90.2		0	78	79	87	90				443	146	755	8.0	2-67	
25S/25E-12A1	615	--	46.6	2.2	82	2.0		55	82	95	8				411	126	833	8.1	3-67	
			51	3.4			0	68	111	117	38*				472	141	772	8.2	5-58	
25S/25E-12B1	--	--	51.6	2.4	107.4			69		112	52.0					139	870	7.9	3-67	
25S/25E-12C1	1,002	504-1,002	--	--	--	--	--	--	--	--	27*						500	--	3-67	
			19	1.8	68	1.4	0	--	--	--	17*						430	--	9-67	
25S/25E-12E1	1,000	300-1,000	11	0.4	76	0.7	7	64	58	39	5.0				287	55	557	--	3-67	
			12	0.5	97	--	11	58	60	41	24*				300	32		--	2-55	
25S/25E-12J1	420	--	59	7.3	50.8	--	0	127	83	48	36				350	178	460	7.8	3-67	
			57.6	8.1	68	3.0	0	125	24	71	74				466	173	571	8.5	1-68	
25S/25E-12R1	--	--	38	18	66	5.1	0	131	62	72	88				431	177	800	7.9	2-67	
			--	--	--	--	--	126	97	57	34				444	169	735	7.8	3-67	
25S/25E-14L1	1,200	245-1,200	--	--	--	--	--	--	--	--	59*						833	7.8	1-68	
25S/25E-15b	350	--	45	2.8	52	2.1	0	--	--	--	55*						669	--	3-67	
25S/25E-15C1	300	--	--	--	--	--	--	--	--	--	75*						785	--	9-67	
25S/25E-17	170	--	--	--	--	--	--	110	67	55	15				380		1,170	--	3-67	
25S/25E-17H1	--	--	110	6.0	100	1.7	0	--	--	--	56*							--	4-45	
			--	--	--	--	--	--	--	--	61*							--		
25S/25E-18A1	93	--	--	--	--	--	--	89	180	170	13				790		1,160	--	3-67	
25S/25E-19R2	650	--	--	--	--	--	--	--	--	--	21						800	--	9-67	
25S/25E-20E1	900	--	8	0	50	0.3	7	--	--	--	25*							--	3-47	
25S/25E-21b	--	--	--	--	--	--	--	46	31	30	7						840	--	3-67	
			--	--	--	--	--	--	--	--	0.2				184	20	900	--	3-67	
25S/25E-22	--	--	73	6.3	97	2.5	0	--	--	--	14*						282	8.9	9-58	
25S/25E-22D1	840	460-840	110	10.0	110	3.6	0	140	170	86	11				640		438	--	3-67	
25S/25E-22D2	1,350	860-1,350	14	0.5	96	0.6	0	90	260	160	19				840			--	3-47	
25S/25E-22F1	197	--	4.5	0.7	69	0.4	0	31	92	86	7.8							--	9-46	
			--	--	--	--	--	49	49	49	1.2				681	37	615	7.4	5-64	
25S/25E-22F1	399	150-399	120	7	101	1.9	0	--	--	--	0.1				232	14	368	7.8	5-64	
			--	--	--	--	--	--	--	--	29*						1,250	--	3-67	
25S/25E-23B2	500	182-500	28	1.0	73	1.2	0	90	278	122	26						1,050	--	9-67	
			--	--	--	--	--	--	--	--	<10*				764	329		--		
25S/25E-24K1	1,000	300-1,000	30	5	75	--	0	97	69	44	17						1,127	8.3	9-58	
25S/25E-24R1	865	300-865	40	0	90	10		--	--	--	32*				369	74	950	--	3-67	
			55	7	110	0		--	--	--	10*						483	7.6	4-57	
25S/25E-25D1	666	350-666	42	1.5	86	1.9	0	75	80	55	--						545	--	3-67	
			--	--	--	--	--	80	105	80	--						540	--	9-67	
25S/25E-25Q1	765	300-765	35	0	95	--	0	74	150	112	21				584	168	500	8.2	4-51	
25S/25E-26b	812	--	71	6.2	92	2.2	1	67	116	74	9.8				438	111	680	7.8	4-51	
			19	1.5	75	3.3	0	--	--	--	21*						878	8.0	9-58	
			73	6.8	91	3.3	0	65	105	70	--						541	7.6	9-56	
			53	5.3	78	2.3	3.7	--	--	--	0.1						1,120	--	3-67	
25S/25E-26A1	1,008	300-1,008	30	0	80	--	5	87	88	140	44				580		600	8.1	4-51	
25S/25E-26J1	900	246-900	--	--	--	--	--	47	76	63	--				310			--	5-42	
25S/25E-27H	300	150-300	--	--	--	--	--	83	88	150	53				630			--	12-42	
25S/25E-27R1	550	--	--	--	--	--	--	52	78	117	35				480			--	10-44	
			--	--	--	--	--	--	--	--	0.1							--	11-44	
25S/25E-28E1	870	--	--	--	--	--	--	--	--	--	21*						510	--	4-51	
25S/25E-28R1	804	300-804	92	7.7	59	--	0	--	--	--	64*						610	--	3-67	
			--	--	--	--	--	--	--	--	50*						880	--	3-67	
25S/25E-28R2	--	--	31	1.3	67	2.0	0	--	--	--	37*						916	--	3-67	
			--	--	--	--	--	56	70	187	28*						740	--	9-67	
25S/25E-29E	--	--	--	--	--	--	--	--	--	--	23*						456	--	3-67	
			--	--	--	--	--	85	66	12	36*				312	83	790	--	3-67	
25S/25E-29R1	914	274-912	--	--	--	--	--	--	--	--	27*						900	--	1946	
25S/25E-31A1	400	--	--	--	--	--	--	--	--	--	21*						518	7.8	7-59	
25S/25E-31P1	--	--	4	0	30	0.3	4	--	--	--	<10*						1,260	--	3-67	
25S/25E-32P	--	--	7.8	0.6	33	0.3	0	--	--	--	<10*						1,100	--	9-67	
25S/25E-33Q1	350	120-350	--	--	--	--	--	17	13	7	0.1				114	12	646	--	3-67	
			--	--	--	--	--	20	14	5.0	0.0				143	22	675	--	9-67	
			--	--	--	--	--	--	--	--	16*						204	--	3-67	
			--	--	--	--	--	--	--	--	43*						183	8.7	9-58	
			--	--	--	--	--	--	--	--	40*						197	7.7	8-56	
			--	--	--	--	--	--	--	--	--						308	--	3-67	
			--	--	--	--	--	--	--	--	--						1,240	--	3-67	
			--	--	--	--	--	--	--	--	--						1,050	--	9-67	

TABLE 1: MINERAL ANALYSES OF GROUND WATER - DELANO NITRATE INVESTIGATION (Continued)

State Well Number	Depth in Feet	Perforated Interval	Mineral Constituents in Milligrams per Liter													EC Micromhos	pH	Date
			Ca	Mg	Na	K	CO ₃	HCO ₃	SO ₄	Cl	NO ₃	B	TDS	Total Hardness				
25S/25E-34R1	500	--	--	--	--	--	--	--	--	--	68*	--	--	--	1,500	--	3-67	
											67*	--	--	--	1,300	--	9-67	
25S/25E-36b	--	--	36	3.3	81	4.1	0	100	89	70	15	--	400	--	--	--	4-45	
25S/25E-36C1	752	300-752	15	0	85	--	5	45	65	40	--	0.0	--	--	380	--	4-51	
			--	--	--	--	--	--	--	--	18*	--	--	--	497	--	3-67	
			--	--	--	--	--	--	--	--	10*	--	--	--	500	--	9-67	
25S/26E-3D1	800	--	9	1.9	56	--	0	109	28	22	--	--	--	--	300	--	1946	
25S/26E-3R1	501	135-501	90	18	106	5.1	0	208	119	82	190*	0.0	690	297	1,130	7.6	3-67	
			--	--	--	--	--	--	--	--	108*	--	--	--	880	--	9-67	
25S/26E-4J1	1,170	--	--	--	--	--	--	--	--	--	68*	--	--	--	400	--	3-67	
25S/26E-5A1	1,201	252-1,201	51.4	--	80.0	4.7	0	170	--	--	57.7	--	--	--	600	7.4	5-59	
			44.4	--	80.5	3.9	0	167	49	41	55.8	TR	--	--	590	7.5	8-59	
			49.8	--	80.5	3.9	0	172	53	46	53.3	0.6	--	--	620	7.7	2-60	
25S/26E-5J1	1,015	--	--	--	--	--	--	--	--	--	<10*	--	--	--	560	--	3-67	
			--	--	--	--	--	--	--	--	<10*	--	--	--	480	--	9-67	
25S/26E-5L1	992	385-992	67.0	--	80.0	5.1	0	210	--	--	57.7	--	--	--	710	7.5	5-59	
			64.2	--	77.3	4.7	0	189	67	48	53.3	--	--	--	620	7.5	8-59	
			92.2	--	91.0	6.6	0	290	48	72	58.3	0.3	--	--	880	7.8	2-60	
25S/26E-6A1	1,304	240-1,304	31	4.2	56	3.5	0	141	34	29	33	0.0	305	95	465	8.1	7-58	
			--	--	--	--	--	--	--	--	43*	--	--	--	525	--	3-67	
			--	--	--	--	--	--	--	--	13*	--	--	--	825	--	3-67	
			--	--	--	--	--	--	--	--	--	--	--	--	690	--	9-67	
25S/26E-8F1	1,257	586-1,257	11.0	6.1	65.8	--	0	110	50	37	--	--	--	--	--	--	1939	
25S/26E-8H1	1,101	--	13	2.3	72	1.5	0	119	49	30	9.5	0.1	272	42	409	8.0	4-57	
25S/26E-9C1	1,000	200-1,000	--	--	--	--	--	--	--	--	68*	--	--	--	460	--	3-67	
			--	--	--	--	--	--	--	--	58*	--	--	--	450	--	9-67	
25S/26E-9D1	912	250-835	13	6	87	--	--	116	50	30	--	0.1	--	--	--	--	1939	
25S/26E-9F2	300	--	--	--	--	--	--	--	--	--	45*	--	--	--	880	--	3-67	
			--	--	--	--	--	--	--	--	49*	--	--	--	710	--	9-67	
25S/26E-15R1	453	200-444	--	--	--	--	--	--	--	--	68*	--	--	--	450	--	3-67	
25S/26E-16J1	684	290-639	15	1.1	53	2.3	0	108	40	20	8.4	0.1	240	42	325	7.9	7-57	
			21	3	53	2.8	0	113	37	23	23	0.1	264	66	369	8.2	8-58	
			18	2.2	51	2.1	0	108	36	20	14	0.1	249	54	363	7.9	6-59	
			17	1.6	53	2.2	0	107	36	21	14	0.1	252	49	357	8.1	6-61	
			19	3.5	54	2.2	0	114	36	21	18	0.1	267	62	360	8.2	6-62	
			--	--	52	--	--	--	--	22	--	0.0	--	63	389	--	8-63	
25S/26E-16J2	1,200	550-1,200	18	1.6	52	2.2	0	115	38	18	8.5	0.0	253	51	330	8.1	7-56	
25S/26E-16F1	860	0-860	27	7.2	50	1.8	0	137	82	7	6.5	0.1	269	97	428	7.8	5-64	
25S/26E-16F2	1,120	880-1,120	2.2	1.6	52	0.6	0	91	27	19	0.9	0.0	205	12	292	7.2	5-64	
25S/26E-17	780	--	28	3.8	49	2.1	1	110	46	28	16	--	300	--	--	--	5-42	
			38	3.5	69	4.9	0	88	85	70	--	--	390	--	--	--	12-42	
			23	4.0	45	4.2	0	120	38	18	11	--	280	--	--	--	8-44	
			25	3.9	48	1.3	0	110	42	24	8.8	--	300	--	--	--	9-44	
25S/26E-17C1	505	--	--	--	--	--	--	--	--	--	17*	--	--	--	325	--	3-67	
			--	--	--	--	--	--	--	--	13*	--	--	--	550	--	9-67	
25S/26E-17L1	527	--	52	9.1	--	--	9	102	--	71	85*	--	--	167	670	8.4	3-67	
25S/26E-18	700	--	76	15.0	66	6.2	0	200	65	80	60	--	580	--	--	--	4-45	
25S/26E-18D1	400	--	--	--	--	--	--	--	--	--	62*	--	--	--	890	--	3-67	
25S/26E-19H1	427	--	62	14	--	--	9	124	--	79	82*	--	--	213	777	8.4	3-67	
			--	--	--	--	--	--	--	--	131*	--	--	--	940	--	9-67	
25S/26E-22D2	--	--	21	4.0	48	2.1	0	118	22	23	24	0.1	271	69	356	8.0	8-56	
25S/26E-22D1	1,250	256-1,250	14	1.7	61	1.4	0	88	44	31	15	0.1	256	42	376	7.6	2-59	
			--	--	--	--	--	--	--	--	56*	--	--	--	545	--	3-67	
			--	--	--	--	--	--	--	--	40*	--	--	--	430	--	9-67	
25S/26E-28H1	882	250-840	--	--	--	--	--	--	--	--	62*	--	--	--	1,000	--	3-67	
25S/26E-29F1	741	--	27	2.1	82	1.4	0	90	76	68	9.4	0.3	350	76	560	7.5	6-59	
25S/26E-30H1	612	141-612	35	2.2	88	1.8	0	81	101	67	20	0.0	398	96	628	7.7	9-56	
			114	--	--	--	0	127	--	140	95*	--	--	400	1,300	--	3-67	
25S/26E-30J2	900	600-900	--	--	--	--	--	--	--	--	62*	--	--	--	864	--	3-67	
25S/26E-31Q1	1,008	--	15	5	95	--	15	35	75	70	10	0.0	--	--	510	8.9	5-51	
25S/26E-31P1	--	40	1.5	78	1.6	0	58	93	65	40	0.0	372	106	604	7.5	9-56		
25S/26E-31Q1	400	--	7.0	10.0	74	--	0	79	67	57	--	0.1	--	--	--	--	1939	
			--	--	--	--	--	--	--	--	55*	--	--	--	490	--	3-67	
25S/26E-33R1	1,000	352-1,000	72	13	145	4.2	0	67	213	173	37	0.3	1,094	233	1,235	8.2	9-58	
25S/26E-34B1	500	480-484	--	--	--	--	--	--	--	--	410*	--	--	--	1,390	--	3-67	
			--	--	--	--	--	--	--	--	410*	--	--	--	1,050	--	9-67	
26S/25E-1C1	275	--	--	--	--	--	0	80	60	67	--	--	--	102	--	--	6-44	
26S/25E-1N1	300	219-300	66	10	61	1.9	0	88	50	115	56	0	484	190	737	8.0	9-58	
26S/25E-2A1	--	--	50.2	6.1	62.1	--	0	140	43	50	--	0.1	--	--	560	--	12-42	
26S/25E-2D	--	--	--	--	--	--	--	--	--	--	18*	--	--	--	438	--	3-67	

TABLE 1: MINERAL ANALYSES OF GROUND WATER - DELANO NITRATE INVESTIGATION (Continued)

State Well Number	Depth : : in : : Feet :	Perforated Interval	Mineral Constituents in Milligrams per Liter													B	TDS	Total Hardness	EC Micromhos	pH	Date
			Ca	Mg	Na	K	CO ₃	HCO ₃	SO ₄	Cl	NO ₃										
26S/25E-2E1	717	--	12.0	10.0	31.0	--	--	79	27	32	--	0.0	--	--	--	--	--	--	--	--	1939
26S/25E-2H1	--	--	54 87	6.1 20	46	--	0 3	86 85	67	64	--	0.0	--	--	--	--	--	--	--	--	12-42
26S/25E-2Q1	500	--	--	--	--	--	--	--	--	137	82*	--	--	--	--	--	299	480 934	8.4	3-67	3-67
26S/25E-3H1	700	200-700	40	1	48	1.5	0	45	37	73	63*	--	--	--	--	--	--	675	--	3-67	3-67
26S/25E-3R1	450	100-450	50	8.2	56	1.7	0	103 96	85	52 47	39	0.1	360	158	139	--	--	486 500	8.3	9-58	3-67
26S/25E-4E2	--	--	2	1	36	0.3	8	42	15	13	5	0.3	140	8	--	--	--	555 564 510 500	8.0 8.2	8-63 8-64	3-67
26S/25E-4R1	--	--	--	--	--	--	--	--	--	--	62* 49*	--	--	--	--	--	--	218	8.9	9-58	9-58
26S/25E-5C1	365	50-365	90	4.2	68	1.0	0	58	105	137	56* 55*	0.0	490	242	--	--	--	950 800	--	3-67	9-67
26S/25E-5J1	500	48-500	13	0	30	0.7	0	57	19	19	11	0	150	33	--	--	--	884	7.4	3-67	9-67
26S/25E-9P1	725	262-716	5.2 10.4 4.0	2.8 5.9 3.7	24.0 21.6 21.6	-- 15 6	33 68 45	5 10 3	14 16 14	-- 12 0.1	0.4 0.0 0.0	103 158 81	24 50 25	191 257 229	9.0 8.3 8.8	4-49 11-51 8-52	--	--	--	--	--
26S/25E-9P1	725	263-720	9.2 28.0	3.7 7.3	20.7 11.3	-- 7 3	57 117	6 12	13 14	-- 10.0	0.0 0.0	134 213	38 100	210 344	8.3 8.3	3-49 11-51	--	--	--	--	--
26S/25E-9R1	812	298-802	5.2 11.2 4.0 9.0 5	3.3 5.4 2.4 0.8 0	24.2 13.4 25.5 23.0 30	-- 16 7 11 2 0	33 66 40 59 57	15 8 3 12 14	13 14 16 6 10	-- 9.2 0.1 14 5	0.0 0.0 0.0 0.1 0.1	128 142 81 144 122	26 50 20 26 13	216 229 208 176	8.3 8.3 8.5 8.2	3-49 11-51 9-56 9-58	--	--	--	--	--
26S/25E-10H1	1,000	--	--	--	--	--	0	84	19	18	--	0.4	--	--	--	--	--	236	--	1-52	1-52
26S/25E-11P1	816	450-816	18.1	6.1	23.0	--	0	61	32	25	--	0.1	--	--	--	--	--	--	--	--	1939
26S/25E-12Q1	1,002	348-1,002	16.4 54.4	0.0 3.7	30.4 24.8	1.2 0	59 87	22 33	18 63	1.2 64.0 46.8	-- -- --	165 290	41 145	500	8.2	10-55	--	--	--	--	--
26S/25E-13C1	802	500-802	29.6 44.4	32.7 0.5	75.4 31.0 20.7	-- 0 0	90 59 73	85 24 10	171 15 61	55* 2.4 53.0 51.0 73.0 92.5 38*	-- -- -- -- -- -- --	450 158 226	208 46 112	769 328	7.6	1-66 3-67	--	--	--	--	--
26S/25E-14D	400	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1939
26S/25E-14P1	468	100-468	21.1 25	5.0 3.4	5.1 30	-- 1.1 0	73 130	12 16	7 9	-- 9.5 20* 13*	0.0 0.0	181	76	277 300 400	8.0	9-56 3-67 9-67	--	--	--	--	--
26S/25E-14R1	--	--	30	2.9	29	1.5	0	135	11	10	12*	0.0	141	87	304	8.0	3-67	--	--	--	--
26S/25E-15F1	810	300-810	7.2 8.0 8.1	5.1 2.4 0.6	16.5 24.4 47.8	-- 12 3	43 43 198	7 10 11	11 13 10	-- 0.5 5.1	-- 0.1 --	124 119 117	39 30 23	190 224 129	8.4 8.5 8.9	3-49 11-51 7-55	--	--	--	--	--
26S/25E-15H1	810	300-805	13.6 12.8 21.0	8.9 6.8 2.0	3.5 28.1 28.0	-- 3 --	71 99 113	7 10 16	8 14 7	-- 8.6 13	0.1 0.1 --	161 191 172	71 60 61	237 296 312	8.0 8.3 8.4	3-49 11-51 9-56	--	--	--	--	--
26S/25E-15P1	927	282-913	4.8 10.8 8.0 13.6	7.0 5.6 2.4 0.0	36.1 19.8 25.8 30.8	-- 7 5 5	98 76 65 80	11 9 4 9	13 10 13 13	-- 10.2 0.1 5.8	0.5 0.1 0.0 0.0	126 155 92 117	41 50 30 34	212 239 229 168	8.3 8.3 8.7 8.3	10-50 11-51 8-52 6-55	--	--	--	--	--
26S/25E-15R1	810	300-805	11.6 10.4	7.8 5.9	12.0 23.0	-- 11	70 63	4 12	11 13	-- 8.8	0.4 0.0	118 156	61 50	160 190	8.4 8.3	2-49 11-51	--	--	--	--	--
26S/25E-16F1	932	280-922	16.4	2.1	16.7	--	11	56	3	13	2.8	0.4	91	50	220	8.5	10-50	--	--	--	--
26S/25E-16H1	806	300-806	8.4	2.7	21.9	--	8	57	3	12	--	0.2	118	32	204	8.3	3-49	--	--	--	--
26S/25E-16R1	930	279-896	20.4 16.0	7.3 7.3	98.7 31.7	-- 3	111 128	95 9	43 14	9.4 11.0	0.2 0.1	345 230	81 70	27 38	8.5 8.3	9-50 11-51	--	--	--	--	--
26S/25E-22H1	920	282-920	19.6 10.8	7.3 3.2	34.9 34.3	-- 16 3	74 101	40 9	18 13	8.6 12.2	0.6 0.0	173 196	79 50	237 275	8.3 8.3	9-50 11-51	--	--	--	--	--
26S/25E-23P1	812	300-791	15.2	1.0	30.1	--	2	87	14	12	--	0.4	171	42	210	8.4	12-48	--	--	--	--
26S/25E-23H1	810	300-804	12.4 10.0 15.7	2.1 3.7 0.7	24.2 25.8 25.2	-- 0 2	77 92 85	10 4 13	14 12 6	-- 0.1 11	0.6 0.0 0.0	126 101 162	41 40 41	237 261 244	8.0 8.0 8.6	1-49 8-52 8-56	--	--	--	--	--
26S/25E-23P1	810	300-804	12.2 16	2.2 1.0	29.4 25	-- 1.2 0	83 95	7 8	15 8	-- 2.7	0.0 0.0	140 128	40 44	248 199	7.6 7.8	1-49 8-56	--	--	--	--	--
26S/25E-24Q1	--	--	26	7	28	--	--	134	14	27	--	4.5*	159 150	59 83	264 327	8.2 8.0	2-49 3-67	--	--	--	--
26S/25E-24R1	422	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1937
26S/26E-3A1	720	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	380 350	--	3-67	9-67
			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1,340 1,100	--	3-67	9-67

TABLE 1: MINERAL ANALYSES OF GROUND WATER - DELANO NITRATE INVESTIGATION (Continued)

State Well Number	Depth : : in : : Feet :	Perforated : : Interval :	Mineral Constituents in Milligrams per Liter														EC : : Micromhos :	pH :	Date
			Ca	Mg	Na	K	CO ₃	HCO ₃	SO ₄	Cl	NO ₃	B	TDS	Total Hardness					
26S/26E-3J2	1,330	--	--	--	--	--	--	--	--	--	<10*	--	--	--	1,005	--	3-67		
			--	--	--	--	--	--	--	--	<10*	--	--	--	875	--	9-67		
26S/26E-5H1	700	--	42	3.6	--	--	0	46	--	106	80*	--	--	--	863	--	3-67		
			--	--	--	--	--	--	--	--	52*	--	--	--	710	--	9-67		
26S/26E-5P1	717	284-710	61	4.9	105	2.4	0	46	130	112	105*	0.0	542	172	860	7.5	3-67		
			--	--	--	--	--	--	--	--	121*	--	--	--	750	--	9-67		
26S/26E-6P2	400	--	129	18	--	--	0	71	--	123	111*	--	--	395	1,230	--	3-67		
26S/26E-7J1	420	--	62	4.8	--	--	0	64	--	109	93*	--	--	174	760	--	3-67		
			--	--	--	--	--	--	--	--	102*	--	--	--	650	--	9-67		
26S/26E-7M1	602	242-584	13.7	0.7	29.5	--	0	47	24	16	2.0	--	--	140	38	--	10-51		
			43.2	1.2	31.6	--	0	75	--	--	57.0	--	--	113	455	8.0	3-65		
			--	--	--	--	--	--	--	--	49.9	--	--	--	--	--	4-65		
			--	--	--	--	--	--	--	--	42.1	--	--	--	--	--	5-65		
			--	--	--	--	--	--	--	--	34.1	--	--	--	--	--	10-65		
			46.4	12.2	80.7	--	0	70	90	71	112.5	--	448	166	1,000	7.8	1-66		
			--	--	--	--	--	--	--	--	68*	--	--	--	620	--	3-67		
26S/26E-7M2	1,002	340-1,002	19	2.2	20	3.0	--	--	25	21	14.2	--	178	58	--	8.4	1-57		
			69	6.3	23.9	--	0	81	87	66	72.0	--	365	198	588	7.9	3-65		
			--	--	--	--	--	--	--	--	54.3	--	--	--	--	--	4-65		
			--	--	--	--	--	--	--	--	61.1	--	--	--	--	--	5-65		
			--	--	--	--	--	--	--	--	62.9	--	--	--	--	--	10-65		
			61.6	7.6	55.9	--	0	78	101	52	79.0	--	397	185	926	7.9	1-66		
			--	--	--	--	--	--	--	--	40*	--	--	--	560	--	3-67		
26S/26E-8F1	700	--	77	13	--	0	54	--	99	99*	--	--	--	244	942	8.2	3-67		
26S/26E-8H1	675	194-675	--	--	--	--	--	--	--	21*	--	--	--	--	320	--	3-67		
26S/26E-9H1	--	--	302	45	--	5	96	--	164	190*	--	--	--	939	2,570	--	3-67		
26S/26E-9R1	450	300-450	--	--	--	8	48	--	50	--	--	--	--	16	414	9.1	7-59		
			--	--	--	--	--	--	--	73*	--	--	--	--	750	--	3-67		
26S/26E-10R1	1,000	--	14	0.2	148	0.8	0	67	127	113	2.7	0.1	464	36	760	7.5	8-56		
26S/26E-16P1	500	--	--	--	--	--	12	44	20	14	--	--	--	13	--	--	6-44		
			--	--	--	--	7	64	5	14	--	--	106	16	--	8.3	5-47		
26S/26E-16Q1	798	--	6.2	1.2	57	0.6	0	55	44	27	11	0.0	184	20	283	8.1	8-63		
26S/26E-17H1	475	--	78	7.2	--	--	0	52	--	144	96	--	--	224	895	8.0	3-67		
26S/26E-19P2	501	212-480	--	--	--	--	--	--	--	--	20*	--	--	--	298	--	3-67		
			--	--	--	--	--	--	--	--	13*	--	--	--	380	--	9-67		
26S/26E-20J1	804	300-804	158	9.1	--	--	0	59	--	109	150*	--	--	432	1,330	8.0	3-67		
			--	--	--	--	--	--	--	--	135*	--	--	--	690	--	9-67		
26S/26E-21R1	1,008	358-1,008	8	0	74	1	0	61	66	45	4	0.0	274	21	411	7.7	9-58		
26S/26E-22C1	938	--	12	0.7	101	0.8	0	69	81	73	0.5	0.1	326	33	551	7.6	8-56		
			--	--	--	--	--	--	--	--	<10*	--	--	--	350	--	3-67		
			--	--	--	--	--	--	--	--	<10*	--	--	--	520	--	9-67		
26S/26E-22G1	--	--	--	--	--	--	--	--	--	--	35*	--	--	--	--	--	9-67		

*Analysis by Hach field kit.

TABLE 2

AVERAGE DEPTHS TO WATER AT SIERRA VISTA RANCH
DELANO NITRATE INVESTIGATION

<u>Year</u>	<u>Average Pumping Depth in feet</u>	<u>Average Standing Depth in feet</u>	<u>Year</u>	<u>Average Pumping Depth in feet</u>	<u>Average Standing Depth in feet</u>
1926	203	---	1945	328	247
1927	231	144	1946	370	275
1928	246	155	1947	379	289
1929	256	163	1948	398	292
1930	258	168	1949	410	307
1931	261	178	1950	431	300
1932	265	180	1951	440	304
1933	266	184	1952	358	286
1934	272	193	1953	355	271
1935	276	198	1954	340	248
1936	275	200	1955	307	228
1937	282	205	1956	292	208
1938	287	206	1957	302	192
1939	292	214	1958	281	177
1940	303	216	1959	325	197
1941	306	223	1960	357	199
1942	309	224	1961	368	201
1943	318	231	1962	307	195
1944	332	252			

TABLE 3

NITRATE ANALYSES SIERRA VISTA RANCH
DELANO NITRATE INVESTIGATION

<u>State Well No.:</u>	<u>: Depth (feet)</u>	<u>: Perforated Interval :</u>	<u>Nitrate mg/l (Month-Year)</u>					
24/26-20H1	1254	254-1254	1.2 6-39	68.8 5-59	77.5 8-59	86.2 3-60	44.0 9-62	
24/26-30F1	760	20-760	5.0 4-50	142.6 5-59	115.3 8-59	130.8 2-60	79.4 9-62	75.0 3-67
24/26-31L2	1778	355-1778	6.0 9-58	2.5 4-61	2.9 9-62	7.1 3-67		
24/26-32R1	1201	252-1201	21.1 5-59	11.8 8-59	13.8 2-60			
24/26-32R2	500	Unknown	5.4 8-52	74.4 8-59	62 2-60	57 9-62	69.4 7-65	45.0 3-67

TABLE 4

ANALYSES OF SOIL EXTRACTS
DELANO NITRATE INVESTIGATION

HOLE NO. 26/25 1P

Crop History: Near Producers Murrey Cotton Gin on hard packed ground with no vegetative cover.

Soil Type: Hesperia loam, Recent Alluvial Fans and Stream Bottoms

					<u>Saturation*</u> <u>Percentage</u>	<u>EC</u> <u>Micromhos</u> <u>@ 25° C</u>	<u>NO₃</u> <u>mg/l</u>
Depth to Sample in feet	1-0				31	6220	2.0
" " " " "	3-0				41	2360	6.5
" " " " "	5-0				46	673	76
" " " " "	7-0				42	529	53
" " " " "	10-0				25	622	31
" " " " "	15-0				28	599	38
" " " " "	16-1				26	494	28

HOLE NO. 25/26 5D

Crop History: In old vineyard near intersection of County Line Road and Driver Avenue. Irrigated since 1946.

Soil Type: Hanford Sandy Loam, Recent Alluvial Fans and Stream Bottoms.

					<u>Saturation</u> <u>Percentage</u>	<u>EC</u> <u>Micromhos</u> <u>@ 25° C</u>	<u>NO₃</u> <u>mg/l</u>
Depth to Sample in feet	1-0				35	508	0.9
" " " " "	3-0				22	856	5.3
" " " " "	5-0				23	1020	36
" " " " "	7-0				33	657	57
" " " " "	10-0				28	350	21
" " " " "	15-0				28	420	12
" " " " "	19-0				26	767	31

* 12-18% - Sand 50-150% - Clay

TABLE 4 (Cont.)

HOLE NO. 25/25 11R

Crop History: Delano City Yard by Well No. 10-No vegetative cover.
No record of irrigation
Soil Type: Hanford Sandy Loam, Recent Alluvial Fans and Stream
Bottoms.

Depth to Sample in feet					<u>Saturation Percentage</u>	<u>EC Micromhos @ 25°C</u>	<u>NO₃ mg/l</u>	
"	"	"	"	"	1-0	25	842	77
"	"	"	"	"	3-0	20	905	47
"	"	"	"	"	5-0	27	874	41
"	"	"	"	"	7-0	46	684	26
"	"	"	"	"	10-0	33	512	1.3
"	"	"	"	"	15-0	22	615	4.5
"	"	"	"	"	19-0	33	790	15

HOLE NO. 26/26 15C

Crop History: In an orange grove. Irrigated since 1958.
Soil Type: Delano Clay Loam, Smooth Old Alluvial Fans

Depth to Sample in feet					<u>Saturation Percentage</u>	<u>EC Micromhos @ 25°C</u>	<u>NO₃ mg/l</u>	
"	"	"	"	"	1-0	32	4650	598
"	"	"	"	"	3-0	56	1720	429
"	"	"	"	"	5-0	22	734	18
"	"	"	"	"	7-0	25	710	24
"	"	"	"	"	12-0	35	495	21

HOLE NO. 25/25 15H

Crop History: In a field of wheat 25' from edge of field. Irrigated
since 1946.
Soil Type: Hesperia fine sandy loam, Recent Alluvial Fans and
Stream Bottoms.

					<u>Saturation Percentage</u>	<u>EC Micromhos @ 25 C</u>	<u>NO₃ mg/l</u>
Depth to Sample in feet				1-0	26	935	8.4
"	"	"	"	3-0	26	675	17
"	"	"	"	5-0	52	562	56
"	"	"	"	7-0	53	506	35
"	"	"	"	10-0	47	2350	50
"	"	"	"	15-0	30	511	15
"	"	"	"	19-0	22	494	7.9

TABLE 4 (Cont.)

HOLE NO. 26/26 16R

Crop History: On the edge of a field of beets. Irrigated subsequent to 1946.

Soil Type: Delano Clay Loam, Smooth Old Alluvial Fans

					<u>Saturation Percentage</u>	<u>EC Micromhos @ 25°C</u>	<u>NO₃ mg/l</u>
Depth to Sample in feet	1-0				20	572	31
" " " " "	3-0				25	897	23
" " " " "	5-0				21	1020	16
" " " " "	7-0				25	1110	23
" " " " "	10-0				35	847	23
" " " " "	15-0				28	766	19
" " " " "	19-0				19	1120	17

HOLE NO. 26/26 17A

Crop History: In old almond orchard. Irrigated since 1920.

Soil Type: Delano Sandy Loam, Smooth Old Alluvial Fans

					<u>Saturation Percentage</u>	<u>EC Micromhos @ 25 C</u>	<u>NO₃ mg/l</u>
Depth to Sample in feet	1-0				50	435	37
" " " " "	3-0				52	664	14
" " " " "	5-0				23	488	3.9
" " " " "	7-0				24	353	5.4
" " " " "	10-0				32	316	6.6
" " " " "	15-0				28	286	5.8
" " " " "	19-0				30	284	5.6

HOLE NO. 25/25 20R

Crop History: In a four year old vineyard, previously cotton.

Soil Type: Traver Loam, Gentle Slope Basin Areas

					<u>Saturation Percentage</u>	<u>EC Micromhos @ 25°C</u>	<u>mg/l</u>
Depth to Sample in feet	1-0				51	839	7.1
" " " " "	3-0				44	716	9.4
" " " " "	5-0				53	2260	9.6
" " " " "	7-0				47	2260	15
" " " " "	10-0				22	1350	5.4
" " " " "	15-0				19	2130	4.7
" " " " "	19-0				35	4640	27

TABLE 4 (Cont.)

HOLE NO. 25/25 21N

Crop History: Alfalfa, cotton and potatoes rotated. Irrigated since 1946

Soil Type: Traver Sandy Loam, Gentle Slope Basin Areas

Depth to Sample in feet					<u>Saturation Percentage</u>	<u>EC Micromhos @ 25 °C</u>	<u>NO₃ mg/l</u>
"	"	"	"	"	1-0		
"	"	"	"	"	3-0	29	524
"	"	"	"	"	5-0	29	2410
"	"	"	"	"	7-0	28	479
"	"	"	"	"	10-0	26	2320
"	"	"	"	"	15-0	37	1900
"	"	"	"	"	19-0	46	1790
						29	2330
							26
							9.0
							10
							11
							25
							32
							19

HOLE NO. 24/26 29M

Crop History: 75 feet west of the Friant-Kern Canal in the canal right-of-way. Irrigated from 1946 to about 1950.

Soil Type: Hanford Sandy Loam, Recent Alluvial Fans and Stream Bottoms.

Depth to Sample in feet					<u>Saturation Percentage</u>	<u>EC Micromhos @ 25 °C</u>	<u>NO₃ mg/l</u>
"	"	"	"	"	1-0		
"	"	"	"	"	3-0	17	472
"	"	"	"	"	5-0	18	636
"	"	"	"	"	7-0	19	1400
"	"	"	"	"	10-0	19	1240
"	"	"	"	"	15-0	19	1360
"	"	"	"	"	19-0	33	681
						24	802
							12
							13
							43
							46
							78
							41
							26

TABLE 5
 DELANO NITRATE INVESTIGATION
 NITRATE ANALYSES OF WATER FROM
 MUNICIPAL SUPPLY SYSTEM
 CITY OF DELANO
 (milligrams per liter)

Date	State Well Number ^{1/}										
	1C1	1F1	2M1	2R2	12C1	12E1	11H1	11E1	11J1	11P1	10A
	City Well Number										
	1	2	3	4	5	6	7	8	9	11	12
Feb. 62	1	2	3	2	2	2	2	4	3	-	-
7/15/64	54	8	9	12	10	15	55	27	9	10	10
7/15/66	106	20	12	52	33	110	70	48	109	59	39
1/ 9/67	176	19	9	69	33	164	79	52	168	70	70
1/25/67	Cont. Run 185	-	-	-	-	280	-	-	220	-	-
2/15/67	56	-	-	-	-	74	-	-	74	-	-
2/19/67	44	-	-	-	-	-	-	-	-	-	-
3/15/67	46	10	6	31	26	62	36	20	65	30	27
4/14/67	34	8	5	20	14	50	25	14	53	20	18
5/15/67	44	8	8	20	16	58	20	14	60	20	19
6/15/67	74	14	12	53	25	94	65	24	104	54	50
7/10/67	44	16	24	35	104	60	54	50	106	62	60
7/16/67	46	11	9	62	40	94	72	33	91	62	49
8/16/67	46	11	9	62	40	94	72	33	91	62	49
9/19/67	77	23	9	45	38	96	67	35	112	44	46
10/16/67	74	22	10	54	29	93	50	36	127	69	53
11/16/67	65	20	7	50	35	97	52	40	100	48	48
12/16/67	60	14	8	44	33	88	60	30	94	48	42
1/20/68	74	25	10	58	38	82	64	44	99	60	44

^{1/} All wells are located in Township 25 South, Range 25 East.
 e.g. City Well Number 1 is State Well Number 25/25-1C1.

APPENDIX

C O P Y

State of California

Department of Public Health

MEMORANDUM

To : Mr. Carl L. Stetson, District Engineer
San Joaquin District
State Department of Water Resources
P. O. Box 2385
Fresno, California 93723

Date: June 14, 1968

Subject: Comments on
"Delano Nitrate
Investigation"

From: Bureau of Sanitary Engineering

This is in response to your request for comments on the "Delano Nitrate Investigation" report of the Department of Water Resources. This report points to the growing need for continued and increasingly closer surveillance of the nitrate content of ground water supplies in the Delano area in particular, and to the need for continued surveillance of nitrate content of ground water supplies in general.

The U. S. Public Health Service Drinking Water Standards of 1962 provide a general guide for nitrate levels in domestic water supply. A "recommended" limit for nitrates of 45 mg/l was set along with a statement that where the nitrate content exceeds 45 mg/l the public should be warned of the potential dangers of using the water for infant feeding. It is significant to note that the standard for nitrates is "recommended" rather than "mandatory". The "recommended" limits should not be exceeded whenever more suitable supplies are, or can be made, available at reasonable cost. The "mandatory" limits, if exceeded, shall be grounds for rejection of the supply. The primary reason for placing the nitrate limits in the "recommended" rather than in the "mandatory" category is because of the lack of evidence that community water supplies with high levels of nitrate have been the cause of infant illness.

Serious and occasionally fatal poisoning in infants has occurred following ingestion of well waters shown to contain nitrate. Almost without exception, cases of infant illness have been attributed to ingestion of water from farm well water supplies. When the 1962 standards were established, there were no reports of methemoglobinemia in infants fed water from public supplies in the United States, although levels of nitrate in some supplies may be routinely in excess of 45 mg/l. There is still considerable uncertainty as to the details of the mechanism by which high nitrate waters will cause infant illness. One hypothesis is that high levels of nitrate must be accompanied by bacterial contamination to cause disease.

In the absence of a better understanding of the problem, it is evident that efforts should be made to minimize use of high nitrate waters in domestic water systems. Second, it is most desirable that scientific investigation be made to better understand the phenomenon involved. It would be of particular interest to have information on the correlation between levels of methemoglobin in the blood of infants, and nitrate level of their drinking water supply. Delano might be a good location to carry out such an epidemiological study. Unfortunately, this department does not have the funds necessary to carry out this study. We have therefore attempted to stimulate the local health department and local physicians to carry out this work with such assistance as this Department can give. The results of your study may stimulate the local agencies as well as this Department to increased efforts in this regard.

For the record, we are attaching a copy of this Department's policy for Administrative procedures when nitrates in public water supplies exceed the Public Health Service Drinking Water Standards.

/s/ H. B. Foster, Jr.

H. B. Foster, Jr., Chief
Bureau of Sanitary Engineering

HBf:mjh

C O P Y

POLICY FOR ADMINISTRATIVE PROCEDURES
WHEN NITRATES IN PUBLIC WATER SUPPLIES
EXCEED USPHS DRINKING WATER STANDARDS

California State Department of Public Health
March 1967

The Public Health Service in its Drinking Water Standards set a recommended limit for nitrates of 45 mg/l with a statement to the effect that where the nitrate content exceeds 45 mg/l, the public should be warned of the potential dangers of using the water for infant feeding.

The widespread occurrence of well water with nitrate levels exceeding these standards has not been shown to produce methemoglobinemia in California residents. Recognizing the complexity of the process, the question was discussed as to who should be notified and in what manner. As a result of this discussion, and the review by an ad hoc advisory committee of pediatric hematologists which met on June 6, 1966, the following policy will be placed in effect:*

1. Where a source of domestic water exceeds 45 mg/l of nitrates,
 - a. the local health officer and the water utility are to be notified by the Bureau of Sanitary Engineering that the Public Health Service's recommended limits for nitrates have been exceeded, and
 - b. the water utility is to be encouraged to reduce the nitrates level in the water distribution system to meet the Drinking Water Standards and to report the results to the Bureau of Sanitary Engineering.
2. When the nitrate content of water, as delivered to the consumers of any significant portion of the community, exceeds 90 mg/l,
 - a. the local health officer will be requested by the Bureau of Sanitary Engineering to advise the physicians practicing in the community of the facts concerning the nitrate content of the water supply and the risks and hazards involved, and
 - b. the water purveyor will be required to develop a special sampling program to determine the extent and levels of nitrates in the distribution system.
 - c. When nitrate content of water continues to exceed 90 mg/l each case should be specifically investigated to determine an appropriate course of action.

*Epidemiological studies of the levels of methemoglobin in formula fed infants are needed for setting scientifically valid standards. Such studies should be made by the Department, the local health officer, and the water purveyor so that health problems of any consequence will not result to the population using the water supply.