12-1990

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Wild, Harry Stephen Jr., "Hydrogeology and Hydrogeochemistry of the Shallow Alluvial Aquifer Zone, Las Vegas Valley, Nevada" (1990). *UNLV Theses, Dissertations, Professional Papers, and Capstones*. 1114.
http://dx.doi.org/10.34917/2493756

HYDROGEOLOGY AND HYDROGEOCHEMISTRY OF THE SHALLOW ALLUVIAL AQUIFER ZONE, LAS VEGAS VALLEY, NEVADA

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of

Master of Science
in
Geoscience

Department of Geoscience
University of Nevada, Las Vegas
December, 1990

ABSTRACT

In Las Vegas Valley, Nevada, the shallow alluvial aquifer zone is a possible source of contamination to the principal alluvial aquifers that provide 30% of the public drinking water supply for the valley. Development of the principal aquifers has lowered pressure head in the principal aquifers and created the potential for downward seepage from the shallow aquifer zone. This study was undertaken to characterize the hydrogeology and hydrogeochemistry of the shallow alluvial aquifer zone and to compare the hydrogeochemistry of the shallow and principal alluvial aquifer zones

A 37 well shallow ground water monitoring network was established and water-level, water-quality, and isotopic data were collected between June, 1988 and December, 1989. Water levels fluctuate seasonally and are influenced by land use practices. Irrigation influenced water levels are higher in fall and lower in winter while the natural water level pattern has lows in the fall and highs in the winter. Water temperature, pH, and EC appear to be unaffected by local land use practices. Temperatures are high in fall and low in spring. pH remains fairly constant near neutrality throughout the year. EC appears to be controlled by alternating varible length cycles of concentration and dilution of saline water near the water table.

Water quality evolves along flow path from a fresh Ca^{2+}-Mg^{2+}-HCO_3^- type water with TDS around 300 mg/l in the north to a moderately saline Ca^{2+}-Mg^{2+}-SO_4^{2-} type water with TDS around 8000 mg/l in the southeast near Las Vegas Wash. TDS varies temporally but does not follow a seasonal pattern. Ion ratios remain constant throughout the year. Water samples are generally oversaturated with respect to calcite, dolomite, and quartz, but are undersaturated with respect to gysum and amorphous silica. Delta D and δ^{18} O indicate that the water in the shallow aquifer zone originated as principal aquifer zone water.

Comparison of shallow to principal aquifer zone data reveals that Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, TDS, SiO_2, TOC, PO_4^{3-}, B, Mn, Se, and tritium are all suitable for use as natural tracers for tracing the downward leakage of water from the shallow to the principal aquifer zone.

Comparison of historical shallow aquifer zone data to the data generated during this investigation reveals that water levels in the shallow aquifer zone rose by an average of about 0.5 meter from 1972 to 1989 and that TDS increased by around 570 mg/l between 1981 and 1989.

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LIST OF ABBREVIATIONS

Basic Magnesium, Incorporated	BMI
Colorado River Water	CRW
cubic meters	m^3
cubic meters per second	m^3/s
cubic meters per year	m^3/year
degrees Celsius	°C
degrees Fahrenheit	°F
delta deuterium	δD
delta oxygen-18	$\delta^{18}O$
Desert Research Institute Water Resources Center	DRIWRC
dissolved organic carbon	DOC
electrical conductivity	EC
hydrogen ion concentration	pH
kilograms per second	kg/s
kilograms per year	kg/yr
kilometers	km
kilometers per hour	km/hr
Las Vegas Valley Water District	LVVWD
maximum contaminant level	MCL
meters	m
meters per second	m/s
meters per year	m/yr
micromhos per centimeter	μmhos/cm
milliequivalents per liter	meq/l
milligrams per liter	mg/l

North Las Vegas Water District	NLVWD
partial pressure of dissolved carbon dioxide	P_{CO_2}
percent	%
per mil	°/oo
polyvinyl chloride	PVC
saturation index	SI
secondary maximum contaminant level	SMCL
Southern Nevada water system	SNWS
square kilometers	km^2
total organic carbon	TOC
total dissolved solids	TDS
tritium units	TU
U.S. Environmental Protection Agency	EPA
U.S. Geological Survey	USGS
University of Nevada, Las Vegas	UNLV

INTRODUCTION

Historical Background

Since its founding in 1855, Las Vegas, Nevada has grown from a population of 30 people to approximately 750,000 people in 1990. Las Vegas currently has the fastest growth rate of any city in the United States and is growing by 3,000 to 6,000 new residents per month (Las Vegas Review-Journal, September 07, 1990) The combination of a large population and an arid climate has lead to the importation of large quantities of Colorado River water to supplement the limited ground-water supply.

The large volume of water used for landscape irrigation in excess of consumptive use currently recharges the shallow alluvial aquifer zone. The generally poor quality of the shallow aquifer zone water has been further degraded by this secondary recharge which mobilizes soluble salts, fertilizers, organics, and other undesirable chemical constituents. This poor quality water in the shallow aquifer zone has the potential to percolate downward, through the underlying leaky confining beds, and contaminate the principal production aquifers in the valley.

Under predevelopment conditions, the alluvial aquifer system is assumed to have been in steady state equilibrium, with discharge equalling recharge. Recharge to the shallow aquifer zone occurred by upward movement of water under artesian pressure and by infiltration of spring and seep flows discharging from the principal aquifers along fault and fracture planes (Maxey and Jameson, 1948). Discharge from the shallow aquifer under these conditions was primarily from evaporation and transpiration from the water table (Dettinger, 1987).

Development of ground-water resources in Las Vegas Valley began with the completion of the first successful well in 1907. The majority of the early wells drilled in the valley were completed in the deep confined aquifers and were flowing artesian wells. Most of these wells were uncapped and allowed to flow continuously. By the early 1940's, the rate of ground-water withdrawal exceeded the rate of natural recharge (Maxey and Jameson, 1948; Brothers and Katzer, 1988).

Mining of water from the principal aquifer zone that began in the 1940's has continued to the present. As the population of Las Vegas Valley has grown from approximately 10,000 in 1940 to approximately 750,000 in 1990 (Figure 1), the rate of ground-water pumpage has increased from 37,000,000 m^3/yr to 85,000,000 m^3/yr (Figure 2). Average annual natural recharge is approximately 43,000,000 m^3 (Maxey and Jameson, 1948; Brothers and Katzer, 1988). The principal aquifer zone of the Las Vegas Valley alluvial aquifer system currently provides approximately 29% of the public water supply for the valley (Brothers and Katzer, 1988).

Overdrafting of the principal aquifers for nearly 50 years has resulted in the loss of natural artesian pressure from most of the valley and has caused a decline in the potentiometric surface of the confined principal aquifer zone, in excess of 100 meters, in the northwestern part of the valley (Brothers and Katzer, 1988). Loss of natural upward artesian pressure and potentiometric surface decline has reversed the vertical hydraulic gradient in the shallow aquifer zone. Reversal of the natural hydraulic gradient has created the potential for downward percolation of poor quality water from the shallow aquifer zone into the underlying zone of principal production aquifers.

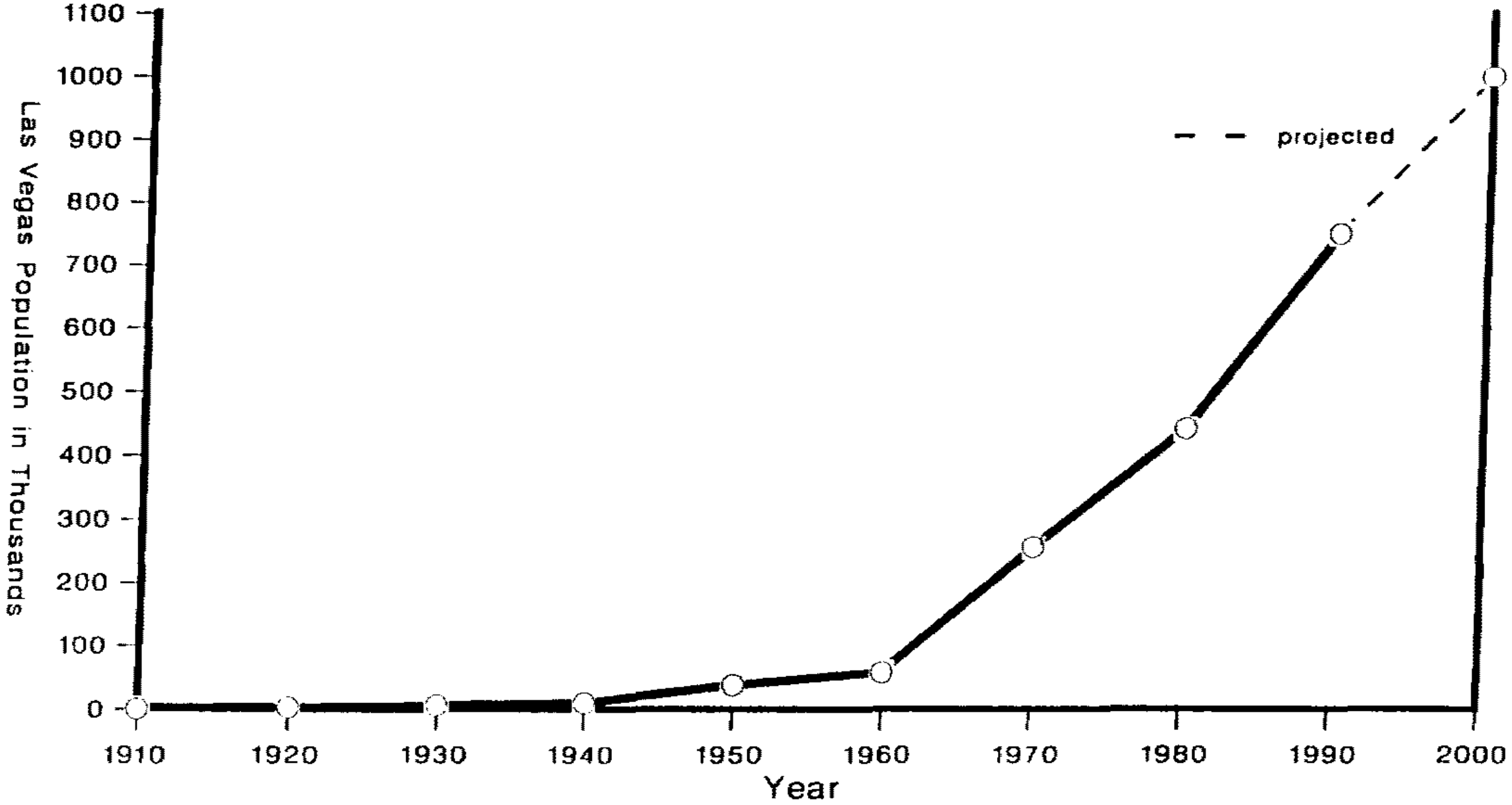


Figure 1. Graph of Las Vegas Valley, Nevada population from 1910 to 2000 (sources: Maxey and Jameson, 1948; Brothers and Katzer, 1988).

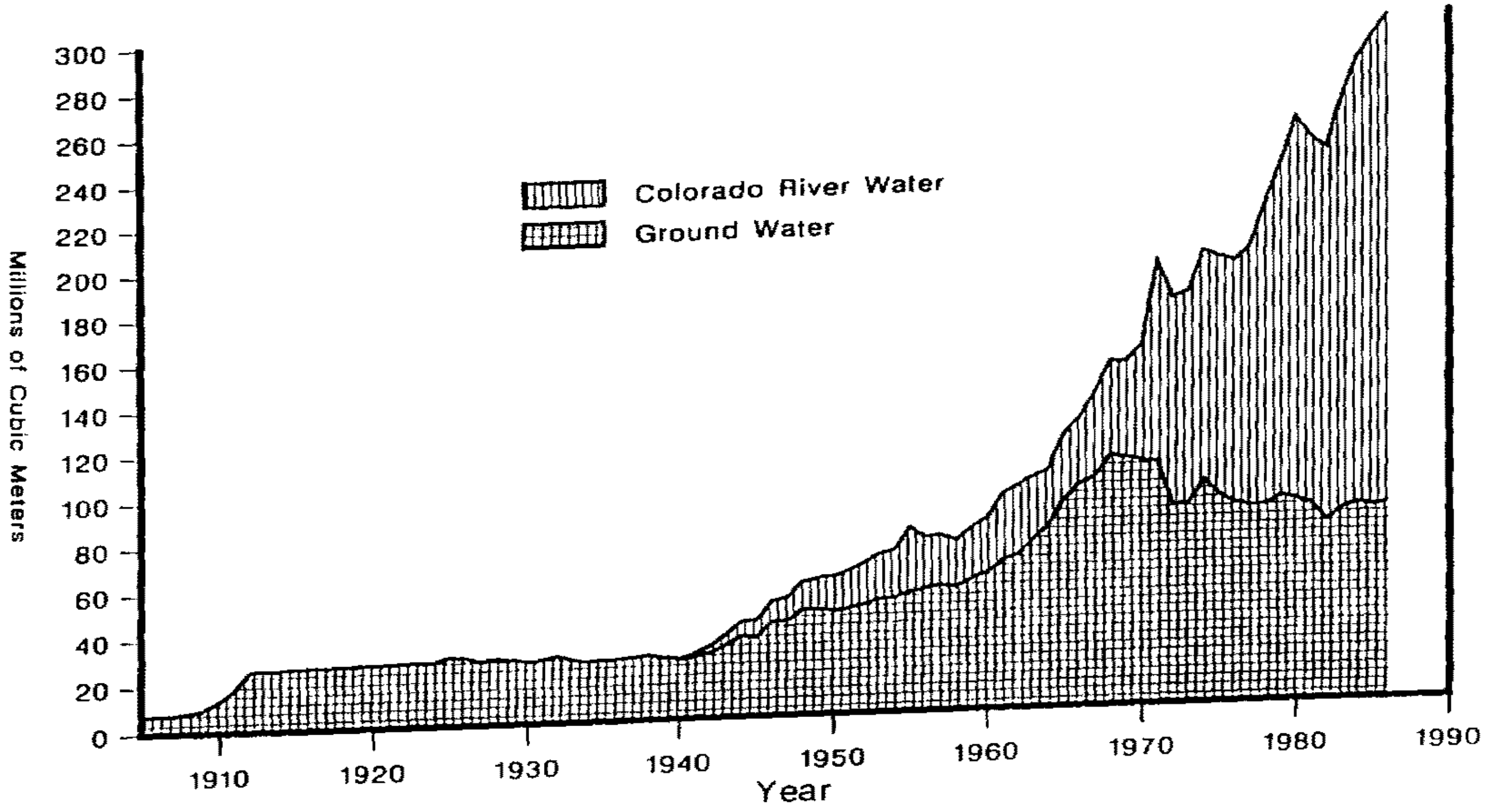


Figure 2. Graph of Las Vegas Valley, Nevada water use from 1900 to 1987 (sources: Maxey and Jameson, 1948; Malmberg, 1965; Harrill, 1976a; and Brothers and Katzer, 1988).

Beginning in 1942 with deliveries to the Basic Magnesium Incorporated (BMI) complex in Henderson, increasing amounts of Colorado River water have been imported into the valley to meet the water needs of the rapidly growing population. In 1964, the U.S. Supreme Court upheld the previously allocated 370,000,000 m^3/yr of Colorado River water for the State of Nevada. Delivery of Colorado River water has been made possible by the Southern Nevada Water System (SNWS), a series of pipelines and pumpstations between Lake Mead on the Colorado River and the Las Vegas Valley. The volume of Colorado River water delivered to Las Vegas Valley in 1986 was 207,000,000 m^3, approximately 71% of the public water supply (Brothers and Katzer, 1988).

Shallow aquifer zone water quality, which was generally poor under predevelopment conditions due to saline soils and high evapotranspiration rates, has been further degraded by the overapplication of landscape irrigation water to lawns and golfcourses in the valley. In 1986, secondary recharge to the shallow aquifer zone from over irrigation was estimated to be about 62,000,000 m^3 (Brothers and Katzer, 1988), 1.4 times the natural recharge rate for the entire Las Vegas Valley alluvial aquifer system. Since 1970, secondary recharge to the shallow aquifer zone has caused a water table rise of 1.5 to 4 m.

Purpose

In May, 1988, a comprehensive study of the Las Vegas Valley shallow alluvial aquifer zone was undertaken jointly by the Las Vegas Valley Water District's (LVVWD's) Department of Research, the Desert Research Institute Water Resources Center (DRIWRC), and the Geoscience Department of the University of Nevada, Las Vegas (UNLV). This research project was divided into five phases or stages with specific objectives for each stage. These five stages of the project are are: (1) the physical, hydrogeochemical, and isotopic characterization of the shallow aquifer zone, (2) the quantification of secondary recharge to the shallow zone from over irrigation, (3) the evaluation of the hydraulic properties of the shallow aquifer zone and any hydraulic connections between the shallow and deep aquifers, (4) the calculation of the volume of leakage from the shallow to the underlying principal aquifers, and (5) the evaluation of the impact of this leakage upon water quality in the principal aquifer zone. This document summarizes the results of work performed during Stage 1, the physical, chemical, and isotopic analysis of the shallow aquifer zone. This research will increase the understanding of both the hydrogeology of the Las Vegas Valley alluvial aquifer system and of other alluvial aquifer systems in the Basin and Range physiographic province.

Objectives

The specific objectives of Stage 1 of the research project were to:

1. **Assemble ground-water quality data and and relevant well data for the Las Vegas Valley alluvial aquifer system and compile a database for future reference,**

2. **Establish a monitoring well network for the Las Vegas Valley shallow alluvial aquifer zone,**

3. **Characterize the physical properties, ground-water chemistry, and isotopic composition of the Las Vegas Valley shallow alluvial aquifer zone both spatially and temporally,**

4. **Determine the effects of land use practices upon the physical properties, ground-water chemistry, and isotopic composition of the Las Vegas Valley shallow alluvial aquifer zone,**

5. **Identify possible natural tracers present in the ground water of the Las Vegas Valley shallow alluvial aquifer zone to be used for tracing the downward migration of water from the shallow to the principal aquifer zone,**

6. **Identify any historical trends in the water quality and water level data of the Las Vegas Valley shallow alluvial aquifer zone, and**

7. **Develop a conceptual model that explains the spatial and temporal variations in the physical properties, ground-water chemistry, and isotopic composition of the Las Vegas Valley shallow alluvial aquifer zone.**

Previous Investigations

The first investigation of the hydrogeology and geology of southern Nevada was performed by Gilbert in 1875. The earliest hydrologic studies in the valley were made by Mendenhall (1909), Carpenter (1915), Hardman and Miller (1934), and Miller and others (1953). All were water resources surveys concerned with determining the suitability of ground water for irrigation and domestic use.

The first in-depth hydrogeologic investigation of the study area was performed by Maxey and Jameson (1948). Malmberg (1965) modified some of the findings of Maxey and Jameson using data not available to them. Loeltz (1963) conducted an investigation of ground-water conditions in the Lake Mead Base area in the northeastern corner of the valley. Domenico and others (1964) used an electric analog model of the principal alluvial aquifers which was used to predict water level changes between 1963 and 1969. Orcutt and Cochran (1967) used a computer model of the principal aquifers to evaluate the feasibility of artificially injecting waste water.

Harrill (1976) modeled the responses of the principal aquifers to a variety of stress conditions. Cochran *et al.*, (1977) developed an interdisciplinary water resource management plan. Westphal (1977) attempted to model the near-surface zone with poor results due to lack of data. A detailed investigation of the relationship between surficial geology and shallow ground water quality was made by Dinger (1977). Kaufmann (1978) made an in depth study of the effects of land use practices upon water quality in the first 90 m of alluvial aquifers in the valley. A study by Patt (1978) evaluated the relationships between water distribution, uses, and recharge to the shallow ground water system. Woessner (1980b) evaluated the economic impacts of the rising water table in the shallow aquifer zone.

Weaver (1982) conducted a study to predict the effects of artificially recharging Colorado River water into the principal alluvial aquifer. In a pilot project designed to test Weaver's hypotheses, Brothers and Katzer (1987) artificially recharged the principal alluvial aquifers of the valley. Broadbent (1980) developed a numerical model of the principal aquifer zone to estimate the effects of artificial recharge. In 1982, Van Denburgh and others (1982) developed general design criteria for a water quality monitoring program and then defined a ground-water quality monitoring network for the valley. Dettinger (1987) developed the monitoring network described by Van Denburgh and others (1982).

In 1984, Converse Consultants performed an investigation of the shallow ground water system in a small area of the southeast portion of the valley (Converse Consultants, 1985). Noack (1988) conducted an investigation of the sources of water recharging the principal alluvial aquifer zone. Brothers and Katzer (1988) resampled the network established by Dettinger and defined ground water chemistry changes resulting from stressed aquifer conditions in Las Vegas valley.

The possible relationships between a large regional carbonate aquifer ground-water flow system and the Las Vegas Valley ground-water system have been investigated by Mifflin (1968), Naff *et al.*, (1974), Hess and Mifflin (1978), and Noack (1988).

The problems in the lower Las Vegas Wash, i.e., salinity loading of the Colorado River, headward erosion of Las Vegas Wash, and the large contaminant plume of highly saline ground-water and hazardous organic compounds between the BMI complex and the wash have been studied by the U.S. Federal Water Pollution Control Administration (1963), URS (1977a,b), Kaufmann (1978), Bierly and Associates (1980), Geraghty and Miller (1980), Woessner (1980a), JRB Associates (1981), French *et al.*, (1982), Stauffer Chemical Company (1982), Kleinfelder and Associates (1983), Technos, Inc. (1983), Desert Research Institute Water Resources Center (1984), Ecology and Environment, Inc. (1984), and Roline and Sartoris (1988).

The geology of the Las Vegas Valley area has been described by Longwell and others (1965), Price (1966), Haynes (1967), Tabor (1970), Dinger (1977), Bingler (1977), Bell and Smith (1980), Bell (1981), Bohannon (1984), and Quade (1986). Land subsidence in the valley has been investigated by Maxey and Jameson (1948), Malmberg (1964 and 1965), Domenico and others (1964), Mindling (1965, 1971), Harrill (1976), and Bell (1981).

Water level data for Las Vegas Valley have been published in Maxey and Jameson (1948), Harrill (1976a, 1976b, and 1977), Katzer (1977), Wood (1979, 1988a, and 1988b), and Maurer (1989).

ENVIRONMENTAL SETTING

Physiography

Las Vegas Valley is an alluvium filled intermontain topographic and structural basin in the Basin and Range physiographic province of the western United States. The valley lies between 35°30'00" and 37°15'00" north latitude and 115°00'00" and 116°00'00" west longitude, and is bordered on the west by the Spring Mountains, on the north by the Sheep and Las Vegas Ranges, on the east by Frenchman and Sunrise Mountains, and on the south by the McCullough Range and the River Mountains. Covering approximately 4100 km^2 of Clark County in southeastern Nevada, the urbanized areas of metropolitan Las Vegas, North Las Vegas, and Henderson and Nellis Air Force Base are the population centers of the valley.

Las Vegas Valley can be divided into three physiographic units: mountains, piedmont surfaces, and valley lowlands. Surrounding mountains are separated from valley lowlands by wide, gently sloping alluvial fans collectively referred to as piedmont surfaces. Valley lowlands slope gently to the east and southeast, except in the vicinity of fault scarps, where relief is locally as much as 30 meters or, at Whitney Mesa, approximately 60 meters. The valley floor ranges in altitude from 730 meters on the west side to 460 meters in the southeast corner at Las Vegas Wash (Figure 3).

Las Vegas Wash in the southeast corner of the valley carries urban surface runoff, sewage-treatment plant effluent, and ground water from the valley to Lake Mead on the Colorado River (Dettinger, 1987). The study area lies

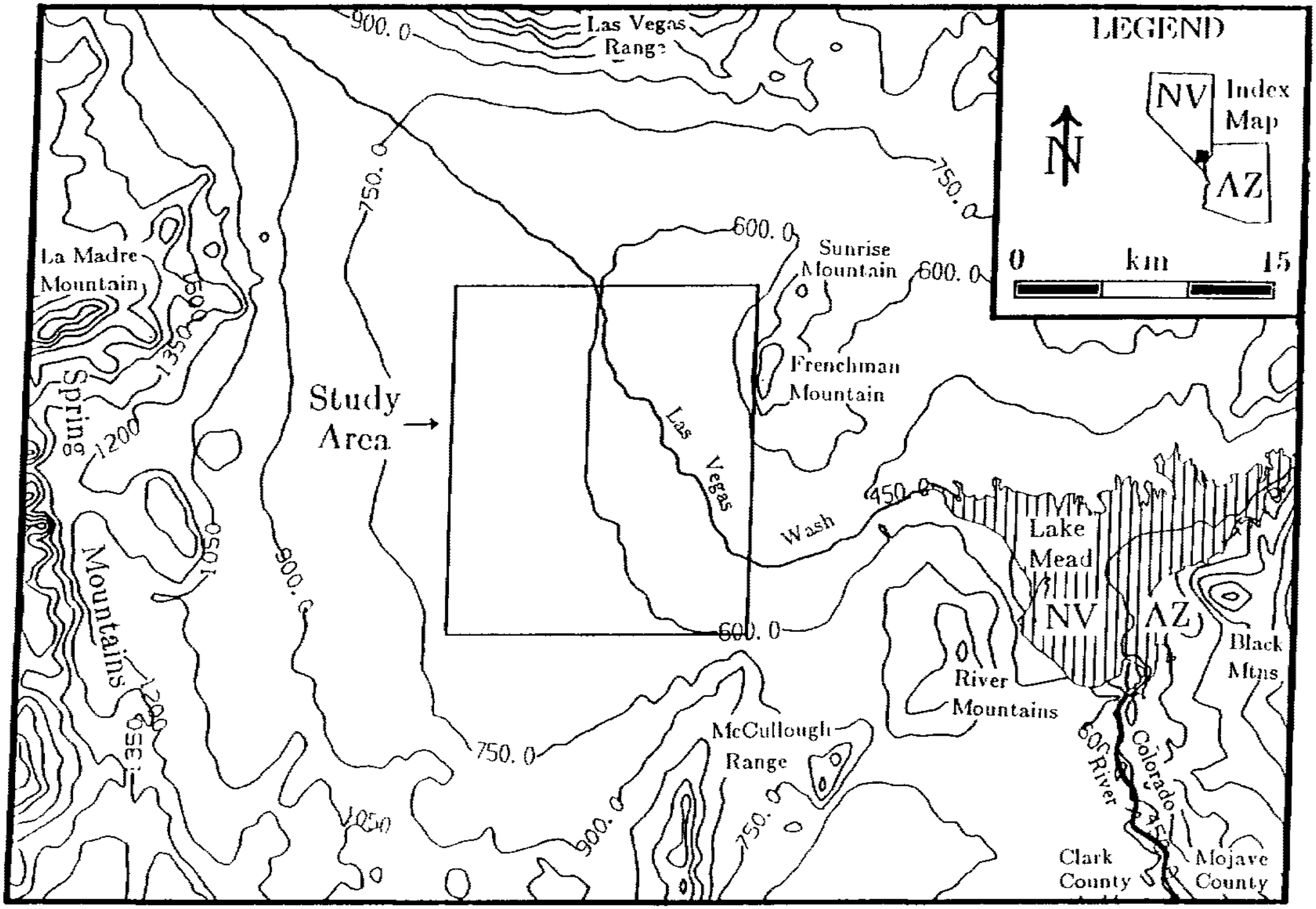


Figure 3. Topographic Map of southern Nevada and location of Las Vegas Valley study area. Contour interval = 150 meters.

predominantly within the urbanized areas in the central valley (Figure 4).

Climate

The climate of the Las Vegas Valley area ranges from arid in the valley lowlands to semi-arid on the piedmont surfaces to sub-humid at higher elevations in the mountains (Maxey and Jameson, 1948; Domenico and others, 1964). Low relative humidity, low rainfall, and a wide range of diurnal temperature fluctuations characterize the arid climate of the valley lowlands. Summers are long and hot with maximum temperatures in the 38-46 °C (100-115 °F) range and minimum temperatures usually falling between 21° and 24 °C (70° and 75 °F). Winters are generally short and mild with average daytime temperatures near 16 °C (60 °F) and minimum temperatures averaging about 2° C (35° F) (Houghton *et al.*, 1975). Strong winds are common, especially during the spring. Usually there is at least one wind storm per month with wind velocities in excess of 50 kilometers per hour and as high as 100 kilometers per hour.

Potential evaporation rate in the valley is extremely high, exceeding 2 meters per year. Average annual precipitation is less than 13 centimeters (Houghton *et al.*, 1975). Most rainfall occurs during the winter months and during July and August. Precipitation increases with elevation and approaches 80 centimeters per year in the Spring Mountains where storms are more frequent and of longer duration. Precipitation that occurs as rain and snowfall in the Spring Mountains represents the majority of water available for recharging the alluvial aquifer system of Las Vegas Valley.

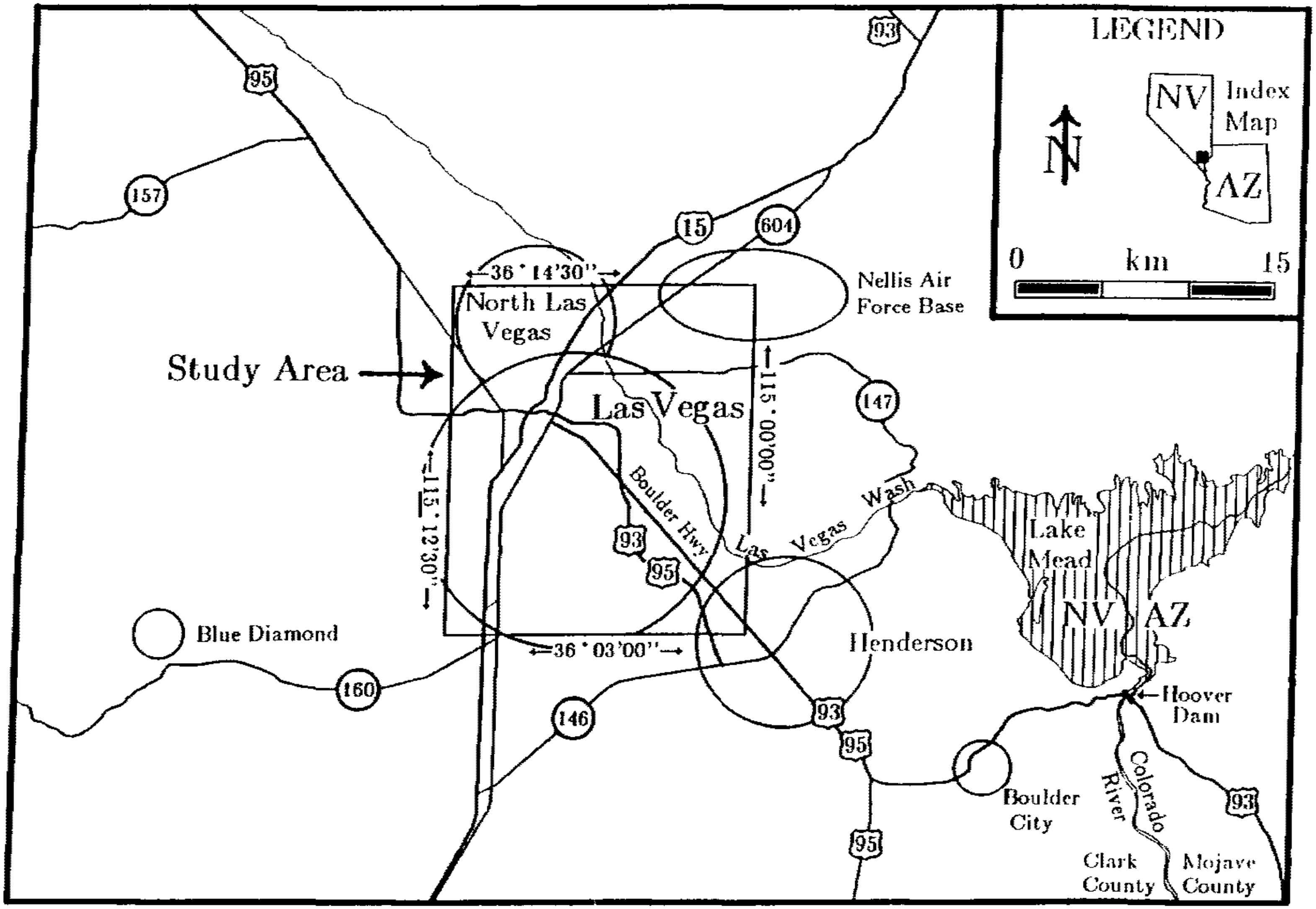


Figure 4. Map of major cultural features in southern Nevada and location of Las Vegas Valley study area.

Geology

Bedrock

The geologic units in the Las Vegas Valley are basal bedrock and alluvial valley-fill with alluvium predominating at the surface. Bedrock makes up the mountain areas surrounding the valley and the structural basin in which the alluvium was deposited. Bedrock ranges in age from Precambrian to Miocene and consists of carbonate and clastic sedimentary rocks, metamorphic rocks, and volcanic and intrusive sedimentary rocks (Plume, 1989).

The most common bedrock unit in the Las Vegas Valley area consists of Precambrian and Paleozoic carbonate rocks, but clastic rocks such as conglomerate, quartzite, sandstone, and shale are locally common. Carbonate rocks predominate in the Spring Mountains, Frenchman Mountain, and the Las Vegas and Sheep Ranges. Igneous rocks in the valley consist primarily of volcanic rocks in the McCullough Range and River Mountains, but also include scattered dikes in the River Mountains (Plume, 1989).

Valley-fill

The Las Vegas Valley structural basin has accumulated 900-1500 meters of alluvial and lacustrine sediments derived from the adjacent fault block mountain ranges (Dettinger, 1987). These valley-fill deposits consist of Miocene clastic deposits, the Miocene Muddy Creek Formation, and Tertiary and Quaternary sedimentary deposits (Plume, 1989). Coarse-grained deposits suggest proximity to source area, with progradation to finer sediments basinward. Because of the complex relationships between the alluvial, fluvial, and lacustrine deposition of the valley-fill deposits, beds are both laterally and vertically discontinuous.

Miocene clastic deposits occur on the lower slopes of Frenchman Mountain, the River Mountains, and the Las Vegas Range. This unit includes the Thumb Formation and unnamed clastic rocks in the Las Vegas Range. The Thumb Formation consists of interbedded siltstone, sandstone, conglomerate, claystone, freshwater limestone, gypsum beds, and lava flows (Bell and Smith, 1980; Plume, 1989). Miocene clastic rocks at the southern end of the Las Vegas Range consist of conglomerate interbedded with sandstone and tuffaceous sediments (Longwell and others, 1965). Thickness of Miocene clastic deposits is estimated to range from 1800 to 2100 meters east of the study area, and is more than 1500 meters north of the study area (Longwell and others, 1965; Plume, 1989).

The Muddy Creek Formation of Miocene and Pliocene age occurs as valley-fill deposits that are coarse-grained near mountains and progressively finer grained toward the center of the valley (Longwell and others, 1965; Plume, 1989). In the study area, the Muddy Creek Formation outcrops in several places as: (1) clayey silt and silty clay northwest of Whitney Mesa (Bingler, 1977); (2) weakly bedded silt on the face of Whitney Mesa (Bingler, 1977); (3) interbedded gravel, sand, silt, and clay south and west of Frenchman Mountain (Bingler, 1977; Bell and Smith, 1980;); (4) a fanglomerate east of Henderson (Bell and Smith, 1980); and (5) fine sandstone, siltstone, and clay north of Sunrise Mountain (Longwell and others, 1965; Plume, 1989). Exposures of the Muddy Creek Formation range from 12 meters northwest of Whitney Mesa to 100 meters north and east of Henderson (Bingler, 1977; Bell and Smith, 1980; Plume, 1989). Total thickness of the Muddy Creek Formation in the valley is uncertain due to the difficulty in distinguishing the formation from other Tertiary and Quaternary valley-fill deposits. Estimates of the thickness range from about 100 meters northeast of Henderson (Bell and Smith, 1980) to about 900 meters east of Whitney Mesa (Malmberg, 1965; Plume, 1989).

Quaternary deposits of gravel, sand, silt, clay, and Tertiary and Quaternary conglomerates overlie older valley-fill. These deposits are surficial and may represent only the upper 10-15 meters of the valley-fill (Plume, 1989). Dinger (1977) conducted a detailed investigation of grain size distributions and mineralogic compositions of surficial geological deposits in Las Vegas Valley. The surficial deposits identified in Plate 1 of Dinger's (1977) study were grouped on the basis of mineralogic composition to form Figure 5. As shown in Figure 5, the surficial deposits in the western, northern, and central valley are composed primarily of carbonate materials while the deposits in the southern and eastern valley contain carbonate materials, gypsum, and igneous clasts (Maxey and Jameson, 1948; Dinger, 1977).

Coarse grained deposits are found on alluvial fans and pediments along Las Vegas Wash in the southeast part of the study area. Most of the deposits are Quaternary age poorly sorted, unconsolidated to cemented gravel and sandy gravel on alluvial fans and pediments of fine sand. Tertiary and Quaternary conglomerates are also locally exposed along Las Vegas Wash (Haynes, 1967; Bingler, 1977; Bell and Smith, 1980; Matti and Bachhuber, 1982; Matti and Morton, 1982a,b; Plume, 1989).

Light colored, heterogeneous deposits occur in the valley lowlands from Corn Creek Springs southeast to the Paradise Valley area (Plume, 1989). They are a mixture of coarse- and fine-grained deposits south of Whitney Mesa (Bingler, 1977); interbedded silt, sand, and gravel from Paradise Valley to North Las Vegas (Matti and Bachhuber, 1982; Matti and Morton, 1982a,b); and silt, sand, and gravel in the north and northwest parts of Las Vegas Valley (Haynes, 1967; Plume, 1989).

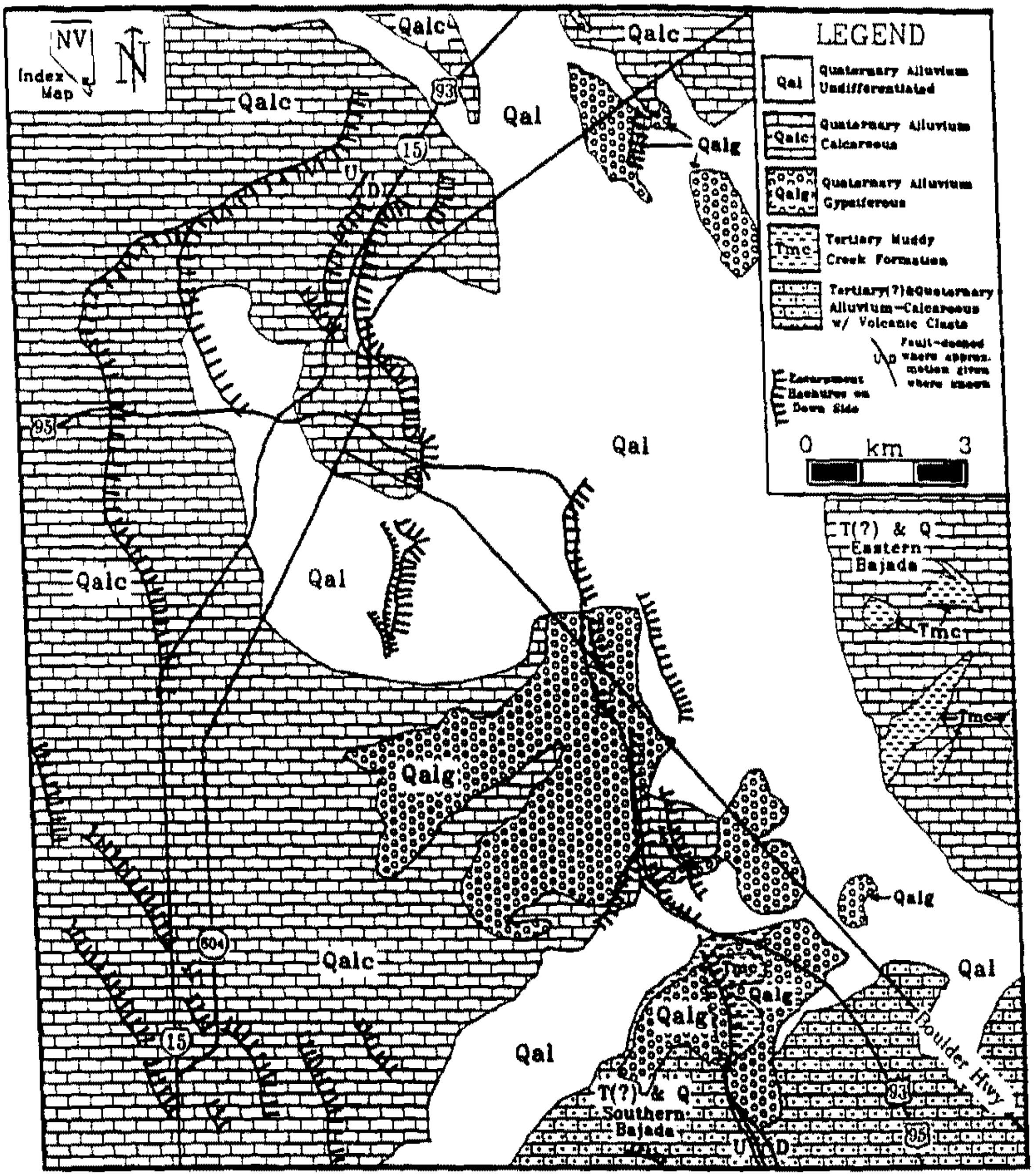


Figure 5. Generalized geologic map of surficial valley-fill deposits in Las Vegas Valley, Nevada (after Dinger, 1977).

In the northwest and north-central parts of the study area, the valley lowlands are underlain by fine-grained deposits of sandy silt and mudstone that range in age from 14,000 to 30,000 years (Haynes, 1967; Plume, 1989). Originally thought to be lacustrine deposits (Longwell and others, 1965; Haynes, 1967), these deposits were named the Las Vegas Formation (Longwell and others, 1965). More recent evidence suggests, however, that the formation was deposited within a playa (Mifflin and Wheat, 1979; Plume, 1989).

Since carbonate lithologies dominate in the mountains surrounding Las Vegas Valley, the clastic valley fill deposits are rich in carbonate clasts. The abundance of carbonate material, in combination with historical climatic and hydrologic conditions, has led to the widespread formation of caliche horizons in the valley-fill deposits (Orcutt and Cochran, 1967).

Structure

The Paleozoic carbonate rocks and the Permian, Triassic, and Jurassic clastic rocks were largely undisturbed prior to the late Mesozoic. These rocks were folded and offset by thrust faulting in late Mesozoic and by block and strike-slip faulting in the Miocene and Pliocene (Plume, 1989). The Las Vegas Valley structural basin was formed during the Pliocene by normal faults at the base of Frenchman Mountain. The structural basin beneath the valley consists of two parts: a deep (600 to 1500 meter) depression beneath most of the valley and a shallow bedrock surface on the west side that slopes gently toward the east (Plume, 1989).

Boundaries of the deep depression generally coincide with the margins of the valley on the north, south, and east sides. On the west side, the deep part of the basin terminates 11-13 kilometers east of the valley margin (Plume, 1989). Valley-fill deposits covering the eastern sloping shallow bedrock surface that underlies the western part of the valley from La Madre Mountain to the McCullough Range ranges in thickness from near zero at the valley margin to around 300 meters along the west side of the Las Vegas city limits (Plume, 1989).

The Las Vegas shear zone is a major structural feature in southern Nevada and may serve as a conduit for movement of water through a large regional carbonate aquifer flow system (Mifflin, 1968; Naff and others, 1974; Hess and Mifflin, 1978; Noack, 1988). The shear zone is a strike-slip fault along which right lateral movement of as much as 72 kilometers is thought to have occurred (Fleck, 1970; Plume, 1989). The zone trends northwest north of the study area from Sunrise Mountain past Corn Creek Springs and roughly coincides with the deepest part of the bedrock basin (Plume, 1989).

Fault scarps as high as 30 meters occur in the valley-fill deposits of Las Vegas Valley. The scarps are believed to be the result of normal faulting although some of the scarps may have receded due to erosion and no longer mark the fault lines (Bell, 1981; Plume, 1989). The scarps trend north to northwest in southern parts of the valley, but change trend toward the northeast in the northern parts of the valley (Plume, 1989). The most common explanation for the origin of these faults is differential compaction of valley-fill deposits (Maxey and Jameson, 1948; Domenico and others, 1964). This explanation was proposed because of the coincidence of scarps on the west side of the valley with abrupt lateral changes in grain sizes between interfingering coarse-grained alluvial fan deposits and fine-grained valley lowland deposits. Other investigators, however, believe that the presence of scarps on the east side of the valley that do not coincide with changes in grain-size distributions indicate that the scarps are controlled by the shape of the structural basin and are therefore of tectonic origin (Plume, 1989). Faults in the valley-fill are possibly related to both differential compaction and to structural displacement of bedrock (Bell, 1981;

Plume, 1989).

Hydrogeology

The ground-water system of Las Vegas Valley has been described as an alluvial reservoir, as much as 1500 meters thick, contained within a basin formed by surrounding and underlying consolidated rocks (Plume, 1984). One of the characteristics of the hydrogeologic units in the valley is that they vary in depth, thickness, and hydrologic impact. The valley-fill deposits occur in discontinuous, irregular, and lenticular beds typical of alluvial deposition in arid and semi-arid climates (Maxey and Jameson, 1948). Differentiation between units at any particular site is difficult. Therefore, a single range of depths that corresponds to these units cannot be defined.

The hydrogeology of Las Vegas Valley has, in the past, been discussed in terms of a shallow unconfined zone and deeper zones of alternating high permeability deposits of gravels, sands, and fractured cemented deposits interfingered with low permeability leaky confining beds of silts, clays, evaporites, and caliche. Summarizing from numerous previous investigators, the following hydrogeologic units have been defined in the valley: (1) a shallow unconfined zone that consists of the water table and the first 10 meters of saturated sediments (Brothers and Katzer, 1988); (2) an intermediate zone, or "near surface reservoir", composed of fine grained deposits that range from 10-60 meters below the water table (Malmberg, 1965; Brothers and Katzer, 1988); (3) the deep zone of production aquifers that are composed of thick beds of coarse- and intermediate-grained deposits that range from 60-300 meters below the water table (Dettinger, 1987; Brothers and Katzer, 1988); (4) the untapped deep zone of basin-fill sediments that is below most of the deepest production wells in the valley (Dettinger, 1987); and (5) the deep carbonate bedrock aquifer thought both to be part of a large regional ground-water flow system and to be separated from the deep zone of production aquifers by approximately 1000 meters of aquitards (Maxey and Jameson, 1948; Mifflin, 1968; Naff and others, 1974; Hess and Mifflin, 1978; Noack, 1988). The intermediate and deep zones of production aquifers are often collectively referred to as the "zone of principal production aquifers", the "principal aquifer zone", or simply the "principal aquifers". The range in depths presented above should only be considered as general guidelines due to the great lithologic variability in the valley-fill deposits.

Prior to development of ground-water resources in the early 1900's, the Las Vegas Valley ground-water system is assumed to have been in steady-state equilibrium, with discharge generally equaling recharge. Primary recharge areas for the alluvial aquifer system are the Spring Mountains to the west and, to a lessor degree, the Sheep Range to the north. Recharge to the deeper zones of the system occur primarily as bedrock transmits ground-water from the recharge areas to the valley-fill deposits (Plume, 1989). Water in the alluvial aquifer generally flows from west to east driven by higher hydraulic heads in the recharge areas. The average annual natural recharge rate to the alluvial aquifer is estimated to be between 37,000,000 and 43,000,000 m^3 (Maxey and Jameson, 1948).

Noack (1988) identified two, and perhaps three, water masses of separate origin in the principal aquifer zone. An isotopically heavier mass of calcium-sulfate type water in the alluvial fans of the relatively shallow western basin represents low altitude mountain front recharge that reaches the principal aquifers along short flow paths. An isotopically lighter mass of calcium-bicarbonate type water in the northern neck of the valley is thought to be a mixture of waters recharged to the Spring Mountains during the Pleistocene and waters discharged from a regional carbonate aquifer flow system along the Las

Vegas Shear Zone. Carbon isotope data indicated that ground-water discharge from a regional carbonate aquifer source may be occurring in the vicinity of the LVVWD's main well field. Noack (1988) also suggested that ground-water discharge from this regional source may be recharging the alluvial aquifer all along the axis of the valley.

Under natural conditions, discharge from the alluvial aquifer system occurred from springs and seeps fed by upward leakage of water from the deeper confined artesian zones through leaky confining layers and along fault planes. Large natural springs in the central valley sustained aboriginal peoples of the area for thousands of years and attracted the first white explorers and settlers to the valley (Maxey and Jameson, 1948).

Under predevelopment conditions, the shallow aquifer zone was recharged by the upward movement of water from the deeper confined zones and by the infiltration of artesian spring and seep flows. The primary means of discharge from the shallow zone was evapotranspiration (Maxey and Jameson, 1948). Las Vegas Wash, a tributary of the Colorado River, was an ephemeral stream with an estimated annual discharge of 300,000 m^3/yr (Kaufmann, 1978).

Development of ground-water resources in the valley began with the completion of the first successful well in 1907. Most of the early wells drilled in the valley were flowing artesian wells completed in the confined principal aquifer zone. The majority of these flowing wells were uncapped and were allowed to flow continuously. Large volumes of water were wasted due to residents' beliefs that the valley was underlain by an inexhaustible water supply and that restricting the flow from these flowing artesian wells was a needless and expensive chore (Maxey and Jameson, 1948).

Overdraft conditions were established by the early 1940's, when the rate of ground-water withdrawal first exceeded the rate of natural recharge (Maxey and Jameson, 1948). Figure 6 is a generalized cross section of the Las Vegas Valley alluvial aquifer system prior to establishment of overdraft conditions. Overdrafting of the principal aquifer zone at rates 2-3 times the natural recharge rate has continued from the 1940's to the present (1990). Mining of water from the principal aquifers for nearly fifty years has had a number of adverse effects upon the Las Vegas Valley ground-water system. These effects are: (1) the loss of natural artesian pressure from the principal aquifers in most of the valley; (2) potentiometric surface declines of around 90 meters in the principal aquifers near the LVVWD's main well field (Brothers and Katzer, 1988); (3) aquifer compaction resulting in both widespread land subsidence and loss of around 120,000,000,000 m^3 of ground-water storage capacity (Terry Katzer, LVVWD, personal communication, 1988); and (4) the reversal of the natural vertical hydraulic gradient for the shallow and intermediate aquifer zones resulting in the creation of a perched shallow zone in the northwest and central parts of valley (Brothers and Katzer, 1988). Reversal of the natural gradient for the shallow and intermediate zones has created the potential for the contamination of the public water supply by the downward percolation of extremely poor quality water from the perched shallow zone into the underlying principal production aquifers.

About the time that overdraft conditions were first established in the early 1940's, importation of Colorado River water from Lake Mead into the valley began with deliveries to the Basic Magnesium Incorporated (BMI) complex in Henderson in 1942. In 1964, the United States Supreme Court upheld the previously allocated 370,000,000 m^3/yr (300,000 acre-feet/yr) of Colorado River water for Southern Nevada. In 1971, Stage I of the Southern Nevada Water System (SNWS), a series of pipelines and pumpstations designed to supply this water

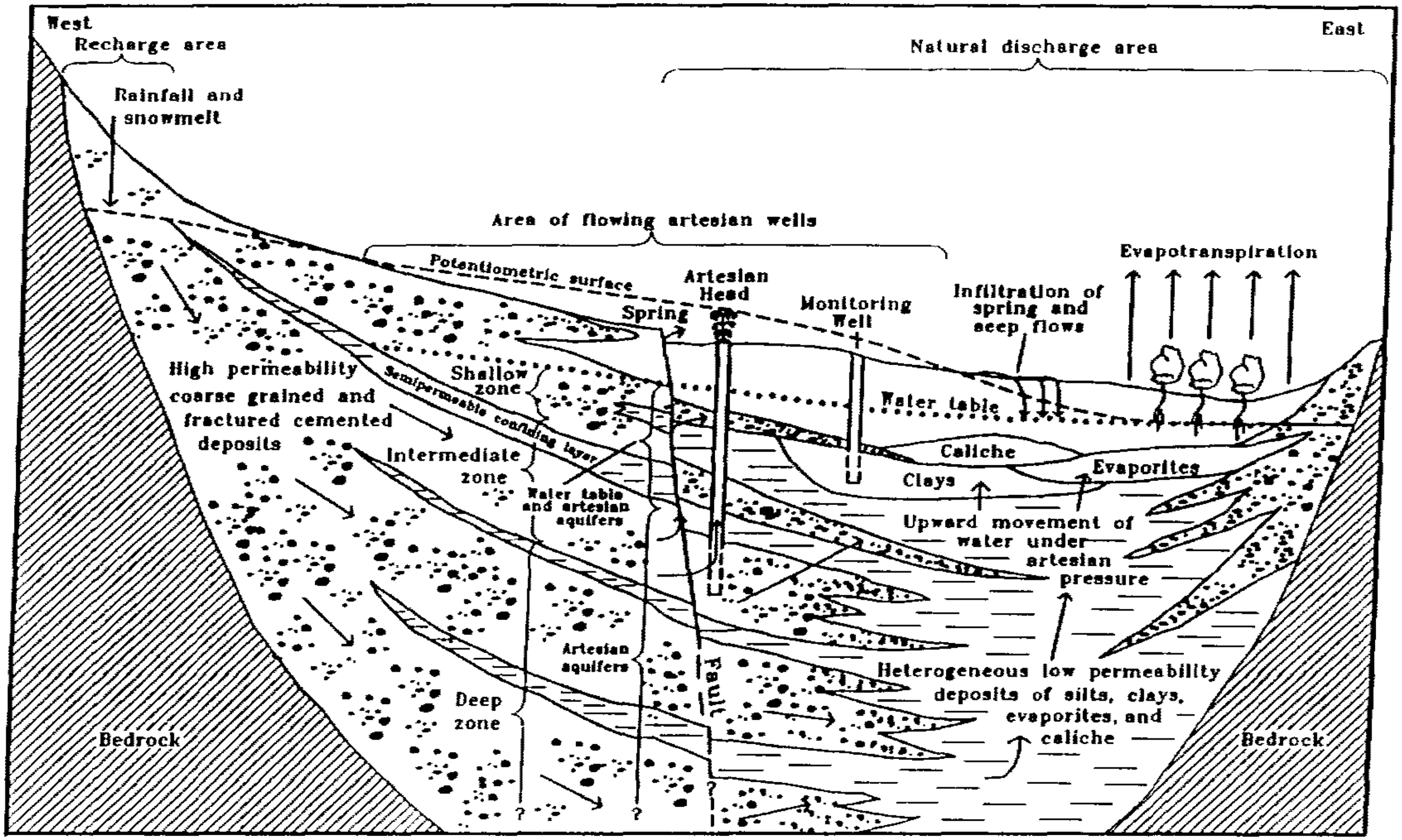


Figure 6. Generalized cross section of the Las Vegas Valley, Nevada alluvial aquifer system under steady-state conditions (after Malmberg, 1965).

from Lake Mead to Las Vegas Valley, came on-line. Stage II of the SNWS became operational in 1981, thereby providing the capacity for importation of the entire allocation. Since completion of the SNWS, ground-water pumpage has declined from a 1967-71 average rate of 99,000,000 m^3/yr to a 1986 rate of 85,000,000 m^3/yr (Harrill, 1976; Brothers and Katzer, 1988).

Currently, the principal aquifers of the valley are being recharged by the natural sources discussed above, by artificial recharge of Colorado River water, and presumably by secondary recharge from the downward leakage of water from the shallow aquifer zone (Brothers and Katzer, 1987). For the last three years, 1987-1990, the LVVWD has been artificially recharging Colorado River water into the principal aquifers in their main well field in the winter for withdrawal during the summer peak water demand season (Brothers and Katzer, 1987; Kay Brothers, LVVWD, personal communication, 1988).

Discharge from the principal aquifers today (1990) is primarily from ground-water pumpage. However, secondary recharge and artificial recharge have slowed the historical rate of declines in water levels in the principal aquifers. The 1987 rate of decline was about 60-90 centimeters per year (Brothers and Katzer, 1988). In 1986, 42,000,000 m^3 of the total 85,000,000 m^3 of ground water pumped from the principal zone originated from secondary recharge and storage (Brothers and Katzer, 1988).

While water levels have been declining in most of the principal aquifers in the valley, water levels in the shallow aquifer have been rising. The shallow aquifer zone is currently recharged by a combination of upward leakage from underlying confined aquifers and by secondary recharge from overirrigation and infiltration of urban surface runoff. The potentiometric surface of the principal aquifers beneath Henderson and south and east of Whitney Mesa is still above land surface, thus indicating that recharge to the shallow zone by upward leakage from the principal aquifers is still occurring in these areas (Kay Brothers, LVVWD, personal communication, 1988).

Application of landscape irrigation water in excess of the consumptive use rate caused a water table rise of 1.5 - 5 meters in the shallow aquifer zone between 1970 and 1985 (Converse Consultants, 1985). Patt (1976) estimated a consumptive use rate for Las Vegas Valley of approximately 1.7 m/yr. The average application rate of landscape irrigation water is estimated to be 3-4 m/yr (Terry Katzer, LVVWD, personal communication, 1988). This excess water infiltrates past the root zone into the shallow aquifer and causes a rise in the water table. Secondary recharge to the shallow zone from over irrigation was estimated at 62,000,000 m^3 in 1986, 1.4 times the natural recharge rate for the entire Las Vegas Valley alluvial aquifer system (Brothers and Katzer, 1988). Secondary recharge also degrades shallow ground-water quality by mobilizing soluble salts stored in the unsaturated zone as well as fertilizers, organics, and other undesirable chemical constituents.

Ground water is currently discharged from the shallow aquifer zone by evapotranspiration, ground-water inflow into Las Vegas Wash, and possibly by ground-water inflow into Tropicana and Flamingo Washes. Las Vegas Wash is now a perennial stream carrying both treated effluent from the Clark County and City of Las Vegas sewage treatment plants and ground-water from the valley into Lake Mead at the approximate rate of 3.4 m^3/s (107,000,000 m^3/yr) (Roline and Sartoris, 1988). Based upon projections in the work of Westphal and Nork (1972), Bateman (1976), and the U.S. Bureau of Reclamation (1982), the current rate of shallow ground-water inflow into Las Vegas Wash is estimated to be approximately 0.51 m^3/s (16,000,000 m^3/yr). With an average total dissolved solids (TDS) concentration of 6,600 mg/l (Bateman, 1976) the shallow ground-water discharging into Las Vegas Wash carries approximately 3.4 kg/s or 110,000,000 kg/yr of dissolved salts from Las Vegas Valley into the Colorado River. Thus, problems associated with Las Vegas Valley shallow alluvial aquifer zone not only have the potential to impact the lives of Southern Nevadans but also have the potential to impact the lives of the other water users in the lower Colorado River Basin in Arizona, California, and Mexico.

METHODOLOGY

Literature Review

A literature review was conducted for published water quality and relevant well location and construction data for the Las Vegas Valley alluvial aquifer system in order to satisfy Objective 1 of this investigation, the compilation of existing water quality and well data for Las Vegas Valley. The data was compiled into a computerized data base using the UNIFY® Relational Database Management System developed by the Unify Corporation for computers utilizing the UNIX® computer operating system. UNIFY® is a menu-driven program that was essential for the organization, storage, and retrieval of the large amount of data assembled.

Published water quality data was obtained from the following investigations: Dinger (1977), Kaufmann (1978), Weaver (1982), Dettinger (1987), and Brothers and Katzer (1988). Water level data was compiled both from the investigations listed above and from the following sources: Maurer (1989), unpublished data collected by the Las Vegas Valley Water District (LVVWD), and unpublished data collected by the Desert Research Institute Water Resources Center (DRIWRC). The data compiled in the database was supplemented by field and laboratory data collected for this investigation. The data assembled into the database is contained in Appendices A-F of this report.

Monitoring Network

Shallow well location and construction data compiled into the database was evaluated in order to judge the suitability of existing wells for inclusion in a monitoring network, thus adressing Objective 2 of this investigation, the establishment of a shallow aquifer zone ground-water monitoring network. Suitability for inclusion in the monitoring network was judged not only on the basis of spatial location and well construction, but also upon the surficial land use practices at each well site, this permitted Objective 4 of this investigation, the determination of the effects of land use practices upon ground-water parameters in the shallow aquifer zone, to be addressed. Wells were included in the monitoring network from each of the four land use categories in Las Vegas Valley: undeveloped, residential (single family dwellings and apartment complexes), commercial (businesses other than apartment complexes), and large turf areas (golfcourses, parks, and schools). Thirty-two wells were judged to be suitable for inclusion in the original network.

During the course of the investigation, 1 new well, NLVWD College Park #2b, was drilled and 4 existing wells were added to the monitoring network, bringing the total number of wells in the final monitoring network to 37. The location and construction data for the wells in the final monitoring network, cross referenced to earlier published investigations that utilized these same wells, is contained in Appendix A. Figure 7 is a map of the final monitoring well network.

Well Numbering System

The system of numbering wells in this report is based upon the cadastral land survey system of the U.S. Government referenced to the Mount Diablo

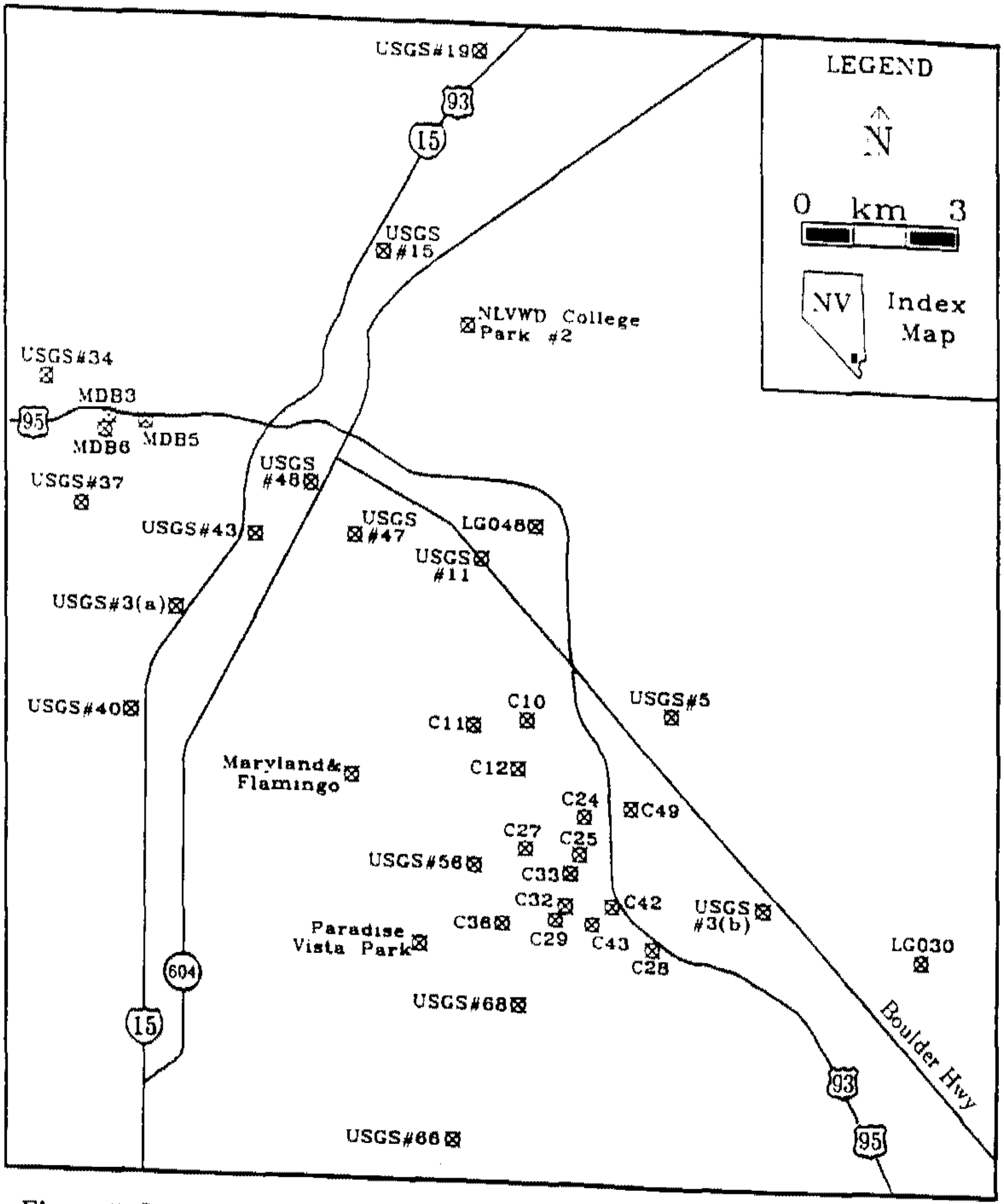


Figure 7. Location and identification of shallow monitoring wells used in this investigation.

baseline. Due to the lack of a consistent well numbering system in the previous investigations of water quality in Las Vegas Valley, each site in the database was assigned a site number. The site number, in addition to designating the well, describes its position in the land net. Each well's site number includes the township, range, section, subdivision of the section, and well sequence number.

For example, well site number 20613024301 designates the well in section 30 of township 20 south, range 61 east. Subsequent numbers indicate specifically where the well is in section 30. The northeast quarter section is represented by the number "1", and the other three quarter sections in a counter clockwise direction are designated "2", "3", and "4", respectively. Each quarter can be similarly subdivided; the usual limit is 4 letters, which define an area of 2.5 acres (approximately 1 hectare). The first number in the sequence indicates the largest subdivision in the section and the last number the smallest. A zero indicates that the precise position of the well in that subdivision is unknown. The last digit in the site number is a well sequence number, which is useful when two wells are so close together that they would otherwise have the same number. Thus, the well just discussed is the first well in the southwest quarter of the southeast quarter of the northwest quarter of section 30, township 20 south, range 61 east.

Sites are also identified in this report by a local name given to each site by the owner or original investigator. Two wells drilled by the U.S. Geological Survey (USGS) for which no local site name could be found, "Maryland & Flamingo" and "Paradise Vista Park", were named according to their geographic location. The one well drilled for this study next to the North Las Vegas Water District's "College Park #2" well was named "NLVWD College Park #2b".

Ground-water Sampling

A ground-water sampling program was designed and implemented, thus addressing Objective 3 of this investigation, the spatial and temporal characterization of the physical properties, chemical composition, and isotopic composition of ground-water in the shallow alluvial aquifer zone of Las Vegas Valley. Beginning in June, 1988, water levels were measured monthly in all wells in the monitoring network. Ground-water samples for water quality and environmental isotope analysis were collected quarterly from wells in the monitoring network in June, September, and December, 1988 and in March and June, 1989. Temperature, pH, and electrical conductivity data was collected from 12 wells on a monthly basis from June, 1988 to December, 1989 and from an additional 9 wells on a quarterly basis from June, 1988 to September, 1989. These field and laboratory data are contained in Appendices B through F.

Ground-water sampling protocol was based upon Wood (1976) and Claasen (1982). Prior to sampling, static water level in the well was measured with either a steel tape or an electric water level probe and the volume of water in the casing was calculated. All of the wells utilized in this investigation are used only for ground-water monitoring, it was therefore necessary to purge the stagnant water from the well bore prior to sampling.

Before submersing the pump in the well, the pump was cleaned by rinsing the exterior with deionized water and by pumping 4-8 liters of deionized water through the pump interior and discharge line. The decontamination procedure prior to sampling for pesticides and herbicides in September, 1988 was more thorough than the normal decontamination procedure. During this procedure, the exterior of the pump was cleaned by successive submersion in three 1.5 m long sections of PVC pipe capped on one end and filled respectively with: (1) a mixture of non-phosphate soap and deionized water, (2) a mixture of 10% acetone and deionized water, and (3) pure deionized water. The exterior of the pump was scrubbed while setting in each solution. The interior of the pump was cleaned by placing the discharge line of the pump into the solution in which the pump was submersed and allowing the solution to circulate for several minutes prior to immersion in the next solution. Deionized water was obtained from the Chemistry Department of the University of Nevada, Las Vegas (UNLV).

After decontamination, the pump was lowered to within the screened interval of the well and purging began. The wells were sampled using a nitrogen driven bladder pump, a submersible electric turbine pump, or a peristaltic pump. One sample, sample # 444, was collected with a bailer. Soon after pumping began, initial temperature, pH, and specific electrical conductivity (EC) measurements were recorded. Subsequent measurements were made at regular time intervals corresponding to the time required for the removal of one well volume of water. When these parameters were stable for two consecutive measurements, the sample was collected.

Two to ten well volumes were purged from each well prior to sample collection, with the exceptions of 6 wells that are completed in low hydraulic conductivity deposits. Due to the length of time required for full recovery after purging, it was not feasible to remove 2 or more well volumes of water from these wells prior to sampling. These 6 wells, C28, Maryland & Flamingo, Paradise Vista Park, USGS#15, USGS#34, and USGS#47, were purged dry, allowed to recover to the approximate pre-pumping static water level, and then sampled. Samples were collected directly from the pump discharge line to limit the amount of time available for degassing of $CO_{2(aq)}$.

Sample containers were prewashed in the laboratory with deionized water and were twice rinsed with filtered or unfiltered formation water, depending upon the sample being collected, prior to the introduction of the sample into the container. Sample containers for pesticide and herbicide samples were decontaminated by washing with non-phosphate soap and hot tap water and then rinsed with: tap water, (1:1) hydrochloric acid, tap water, and deionized water. The sample containers were then baked in an oven overnight at 110 ° C.

Samples for major ion, ortho phosphate (OPO_4^{3-}), dissolved organic carbon (DOC), pesticide, herbicide, and trace metals analyses were all pressure filtered with a nitrogen gas driven barrel filter unit fitted with a 0.45 μm membrane filter. Samples for total phosphate (TPO_4^{3-}), total organic carbon (TOC), and isotope analyses were unfiltered. All samples were sealed immediately after collection with Parafilm® paraffin film and electrical tape. All samples, except isotope samples, were then immediately packed in ice and were shipped cold to the Desert Research Institute's analytical laboratory in Reno, Nevada within 24 hours of collection.

Table 1 summarizes the sample types collected, sample volumes, filtered/unfiltered status, container types, preservatives, and preservative volumes for all samples collected for this study.

Quality assurance requirements were met during the sampling procedure by the collection of blanks and duplicates. To determine the precision of the laboratory analyses, 10% of all samples submitted to the laboratories for every type of analysis were blind duplicates. To check the pump decontamination procedure, equipment blanks of deionized water were collected from the pump discharge line after the last step of the decontamination process. To check the sample container decontamination and sample handling procedures, trip blanks of deionized water were prepared in the laboratory and then taken into the field and subjected to the same handling procedures as the other sample containers before submission to the laboratory. Both types of blanks were blind to the analytical

Table 1. Types, volumes, and treatment methods of ground-water samples collected from the Las Vegas Valley, Nevada shallow alluvial aquifer zone for this investigation.

Sample Type	Filtered?	Sample Volume	Container Type	Preservative	Preservative Volume
Major Cation	yes	500 ml	polyethylene		
Major Anion	yes	500 ml	polyethylene		
Ortho Phosphate	yes	250 ml	polyethylene	H_2SO_4(1:1)	0.5 ml
Total Phosphate	no	250 ml	polyethylene	H_2SO_4(1:1)	0.5 ml
DOC	yes	250 ml	glass		
TOC	no	250 ml	glass		
Trace Metals	yes	500 ml	polyethylene	HNO_3	10 drops
Pesticide	yes	1 *l*	tinted glass		
Herbicide	yes	1 *l*	tinted glass		
Stable Isotopes	no	12 ml	glass		
Tritium	no	1 *l*	glass		
Alkalinity	yes	250 ml	polyethylene		

Table ~~3~~ 2. Types and number of data collected from wells in the Las Vegas Valley, Nevada shallow alluvial aquifer zone monitoring well network.

Site Name	Water Level (# measurements)	Temp., pH, EC (# measurements)	Chemistry & Isotopes (# samples)
C10	16	1	
C11	18	16	5
C12	4	1	
C24	15	1	
C25	15	1	
C27	19	17	5
C28	16	4	4
C29	19	17	5
C32	18	5	5
C33	19	17	
C36	19	17	
C42	19	17	5
C43	16	1	
C49	17	5	5
LG030	15	5	5
LG048	17	5	5
M.Pkwy&Flam.	17	5	5
MDB3	1	1	1
MDB5	1	1	1
MDB6	1	1	1
NLV C. Park #2b	5	1	1
P.Vista Park	17	5	5
USGS #3a	16		
USGS #3b	16		
USGS #5	19	16	5
USGS #11	18	16	5
USGS #15	19	14	5
USGS #19	16	1	1
USGS #34	18	6	6
USGS #37	17	5	5
USGS #40	18	16	5
USGS #43	19	17	5
USGS #47	19	14	1
USGS #48	15		
USGS #56	16		
USGS #66	10		
USGS #68	15	1	

laboratory.

Several unstable chemical and physical parameters were measured in the field immediately after samples were withdrawn in order to minimize the effects of $CO_{2_{(aq)}}$ degassing and temperature changes. These parameters were temperature, pH, specific electrical conductivity, and alkalinity.

Sample temperatures were measured with one of the following pieces of equipment: (1) a Presto-Tek® Poly-Pram pH-EC-temperature meter (accuracy: ±0.15 ° C), (2) an Orion® SA230 pH-temperature meter (accuracy: ±0.1 ° C), or (3) a FisherScientific® 14-983-17M mercury thermometer (accuracy: ±0.1 ° C).

Sample pH was measured with one of the following pieces of equipment: (1) a Corning® 103 Hand Held pH Meter, (2) an Orion® model 211 digital pH meter, or (3) an Orion® model SA230 digital pH meter. All of the above pH meters were equipped with Orion® gel-filled combination pH electrodes and had an accuracy of ±0.01 pH units. Prior to measuring sample pH, the meter and probe were calibrated according to the manufacturer's instructions with laboratory prepared FisherScientific® Buffer Salt solutions (accuracy: ±0.02 pH at 25 ° C) of pH 4.01 and pH 7.41. Sample pH was then measured to the nearest 0.01 pH units. After measurement of sample pH, meter calibration was re-checked and was considered acceptable if buffer pH measured within ±0.05 pH units of the original calibration.

Measurements of specific electrical conductivity (EC) were made with either a Presto-Tek® Poly-Pram pH-EC-temperature meter or a Cole-Parmer® model 1481-60 EC meter. EC standards of 500, 1000, 5000, and 10000 μmhos/cm were prepared by dissolving 0.2620, 0.5265, 2.78, and 5.75 grams, respectively, of oven dried potassium chloride (KCl) in one liter of deionized water. Meter calibration and calculation of correction factors were performed in one of two possible manners. For the samples collected in June, September, and December, 1988, EC standards were allowed to thermally equilibrate to the formation temperature by being bathed with formation water in a flow-through box. After thermal equilibration, conductivity standards (500, 1000, 5000, and 10000 μmhos/cm) were measured for meter calibration. After March, 1989 meter calibration was performed in the laboratory at the beginning and checked at the end of each sampling day using the same conductivity standards listed above.

Alkalinity was measured by utilizing a Hach® Digital Titrator and one of the pH meters described above. Sulfuric acid (1.6N) was slowly titrated into a filtered 100 ml sample until a sample pH of less than 3.5 was obtained. Alkalinity was determined by plotting pH versus titrant volume and selecting an appropriate end point from the resulting curve. Bicarbonate was then determined with a simple calculation. Alkalinity was measured in the field for the samples collected between June 1-13, 1988. After June 13, 1988, samples were collected in 250 or 500 ml polyethylene bottles, sealed with Parafilm® paraffin film and electrical tape, and packed in ice. The alkalinity titration was then performed in the laboratory at the end of the day after each sample had been warmed to within 1 ° C of its temperature at the time of collection.

Chemical Analyses

Chemical analyses of water samples for major ions, phosphate, fluoride, organic carbon, total dissolved solids, and trace metals were conducted at the Desert Research Institute's analytical laboratory in Reno, Nevada. The samples were prepared in accordance with methodology described in "Methods for Chemical Analysis of Water and Wastes", EPA-600/4-79-020 (U.S. Environmental Monitoring and Support Laboratories, 1979). Analyses of water samples for pesticides and herbicides were performed by Alpha Analytical, Inc. in Sparks, Nevada. These samples were analyzed according to the methods found in "Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater", EPA-600/4-82-057 (U.S Environmental Monitoring and Support Laboratories, 1982). Appendix K lists the species analyzed, methods of analysis, equipment used, and appropriate references.

Isotopic Analyses

Isotopic analyses for oxygen-18 (^{18}O) and deuterium (^{2}H or D) were conducted at the Desert Research Institute's environmental isotope laboratory in Las Vegas, Nevada. Samples analyzed for deuterium were prepared by the uranium oxidation method described by Friedmund (1953). The resulting hydrogen gas was analyzed with a 3-60-HD Nuclide (Nier type) mass spectrometer for $^{2}H/^{1}H$ ratios. Samples were prepared for ^{18}O analysis following the guanidine hydrochloride extraction method described by Dugan *et al.*, (1985). The resulting carbon dioxide gas was analyzed for $^{18}O/^{16}O$ ratios with a Finnigan-Matt Delta E (Nier type) mass spectrometer.

Tritium analyses were performed at the Desert Research Institute's tritium laboratory in Reno, Nevada. Samples were prepared according to the method described by Johns (1975).

Land Use Practices

As stated above, in order to help achieve Objective 4 (the determination of the effects of land use practices upon the physical, chemical, and isotopic parameters of ground-water in the shallow aquifer zone), wells were selected for inclusion in the final monitoring network not only on the basis of construction and location, but also on the basis of the surficial land use at each site. A map showing the general spatial distribution of the four kinds of surficial land uses and the locations of the wells in the final monitoring network, Figure 8, was prepared in order to better evaluate the effects of land use upon shallow aquifer zone ground-water parameters.

Land use data used in preparing Figure 8 was obtained from the February, 1988 1:126,720 scale (1 inch:2 miles) large aerial photomozaic of Las Vegas Valley photographed and sold by Cooper Aerial of Nevada. The photomozaic was divided into 914.4 meter (3000 foot) grid squares that corresponded to the grid mesh of the Las Vegas Valley Water District's three dimensional finite difference computer model of the Las Vegas Valley alluvial aquifer system. Each grid square on the photograph was subdivided to the nearest 1% into the four different types of general land use categories in Las Vegas Valley: undeveloped, residential (single family dwellings and apartment complexes), commercial (businesses other than apartment complexes), and large turf areas (golfcourses, parks, and schools). This data was then randomly field checked for accuracy. The photomozaic and the data extracted from the photomozaic was then used in conjunction with the U.S. Geological Survey's four 1:24,000 7.5 minute quadrangle maps of Las Vegas Valley (Las Vegas NE, NW, SE, and SW) to prepare Figure 8.

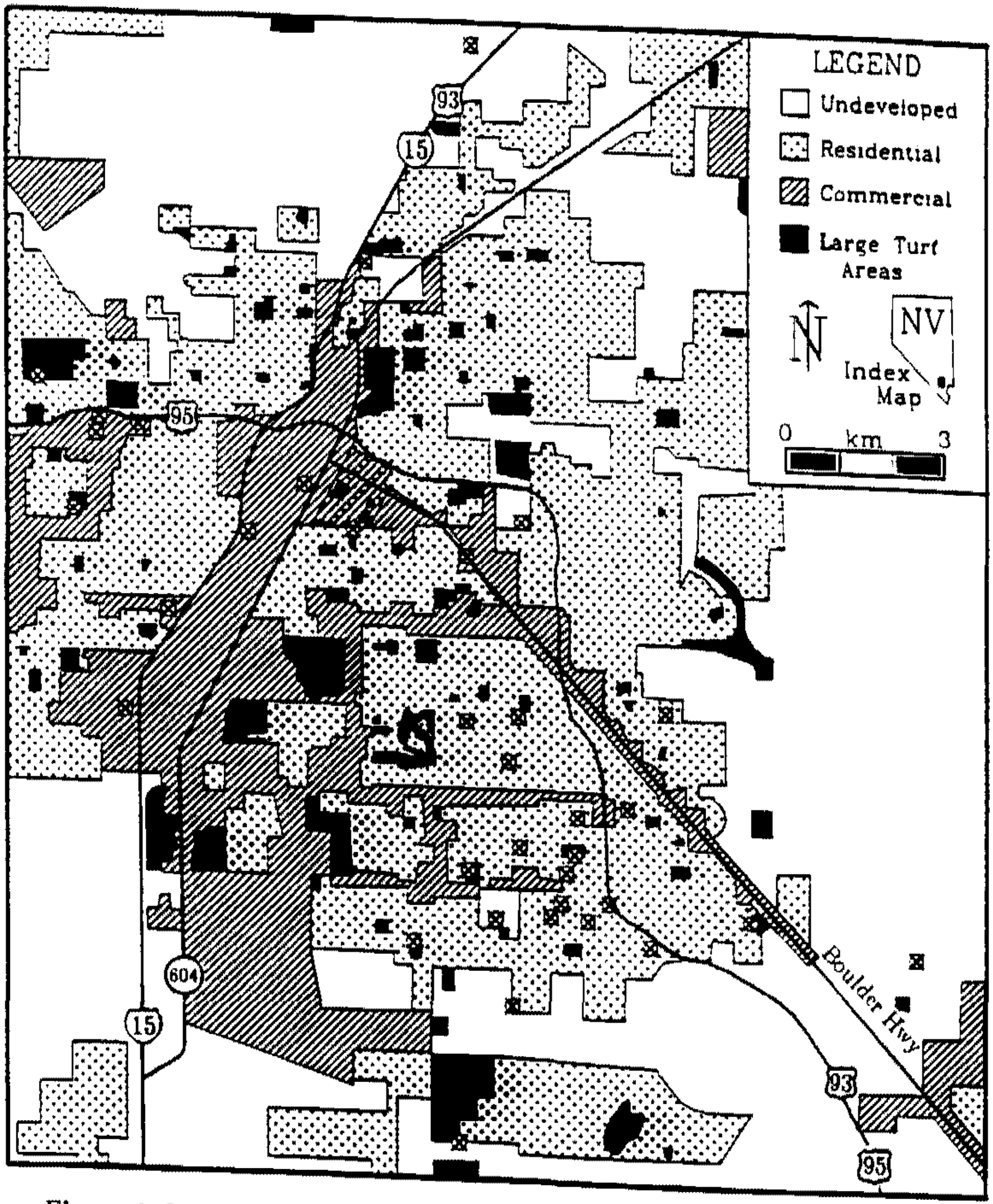


Figure 8. Map of surficial land use patterns in Las Vegas Valley, Nevada, February, 1988.

RESULTS AND DISCUSSION

Water Levels

Water levels were measured monthly in the wells and piezometers in the shallow aquifer zone monitoring network. These data are tabulated in Appendix B. A computer generated depth to water isobath map was prepared from these data (Figure 9). Depth to water is generally within 4 meters and locally within 2 meters of land surface in the central and southeastern portions of the study area. Depth to water increases progressively with increasing distance from the central and southeastern parts of the valley.

An equipotential contour map of the shallow aquifer zone water table (Figure 10) indicates that water generally flows from the higher elevation areas of the valley in the west and northwest toward the lower elevation areas in the east and southeast before discharging into Las Vegas Wash.

Water level hydrographs prepared from the water level data in Appendix B and grouped by land use category are contained in Appendix G. These hydrographs display two distinct patterns of cyclical annual water level fluctuations. Sites displaying Pattern 1 (Figure 11) generally have water table lows in the fall and highs in the late winter to spring. Pattern 1 is 180° out of phase with Pattern 2, which generally has annual water table highs in the fall and annual water table lows in the late winter to spring (Figure 12). There is a strong correlation between surficial land use practices and observed patterns of annual water table fluctuations.

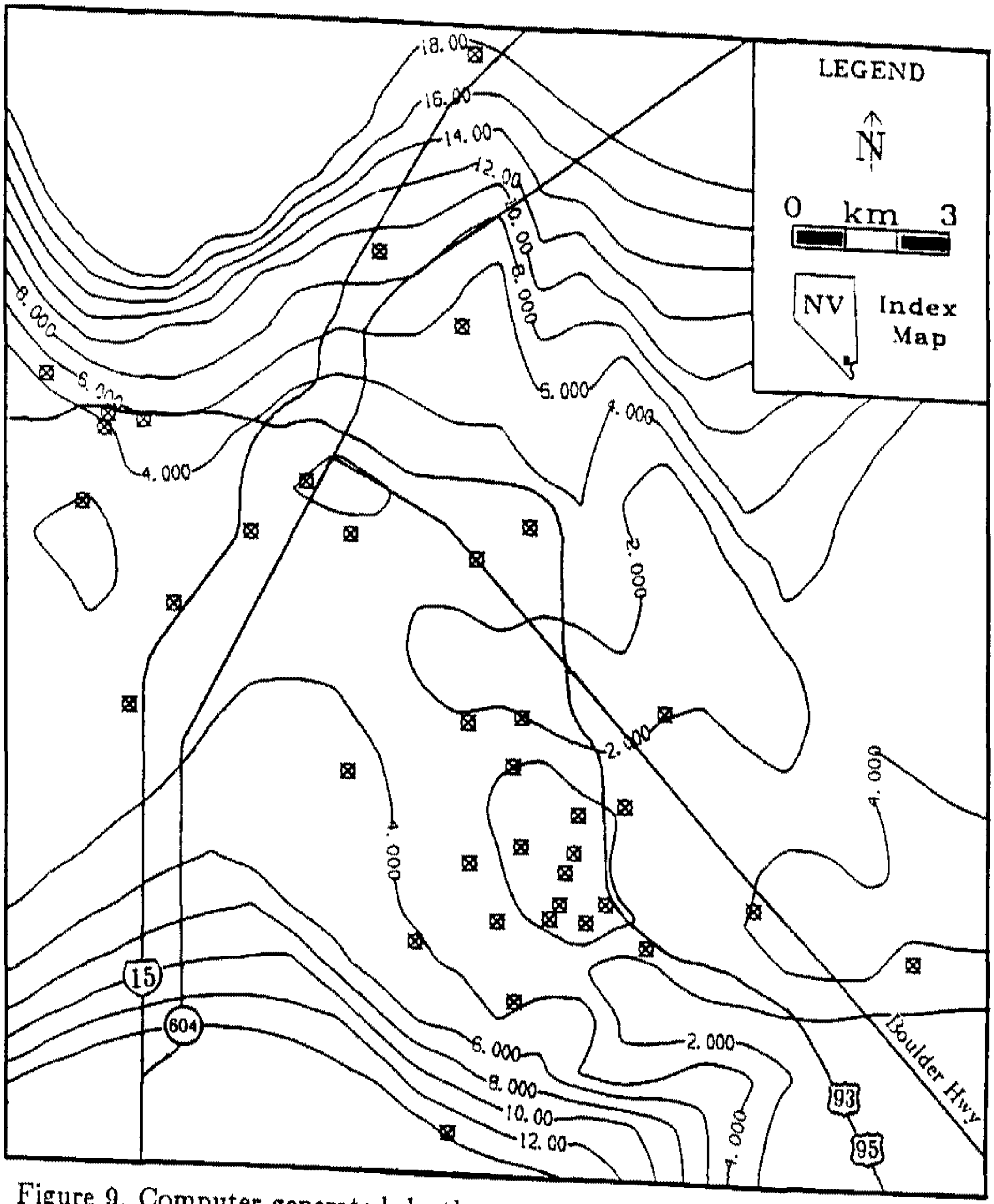


Figure 9. Computer generated depth to water isobath map of the Las Vegas Valley shallow alluvial aquifer zone, 1988-89. Contour interval = 2 meters.

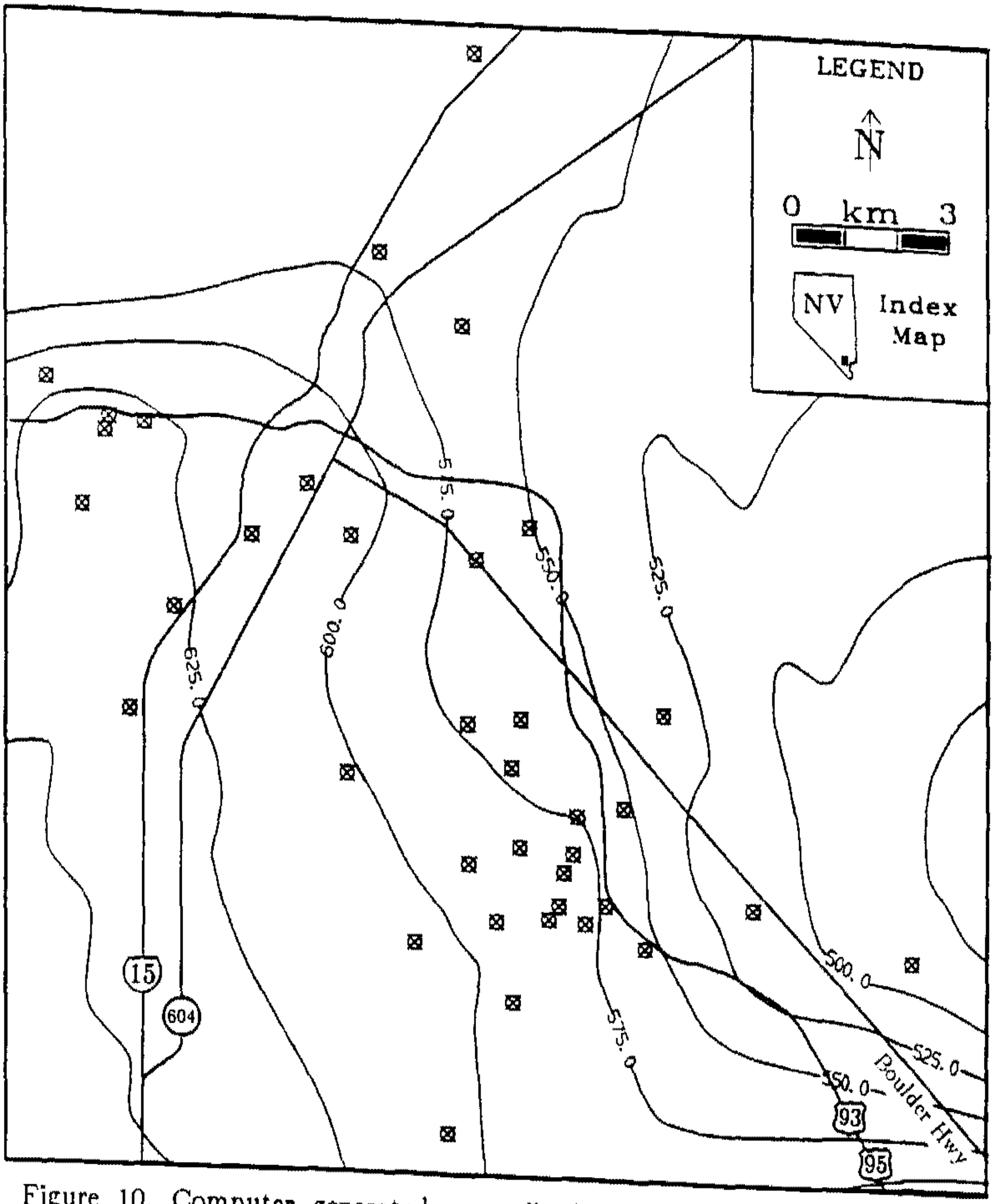


Figure 10. Computer generated generalized equipotential surface contour map of the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Contour interval = 25 meters.

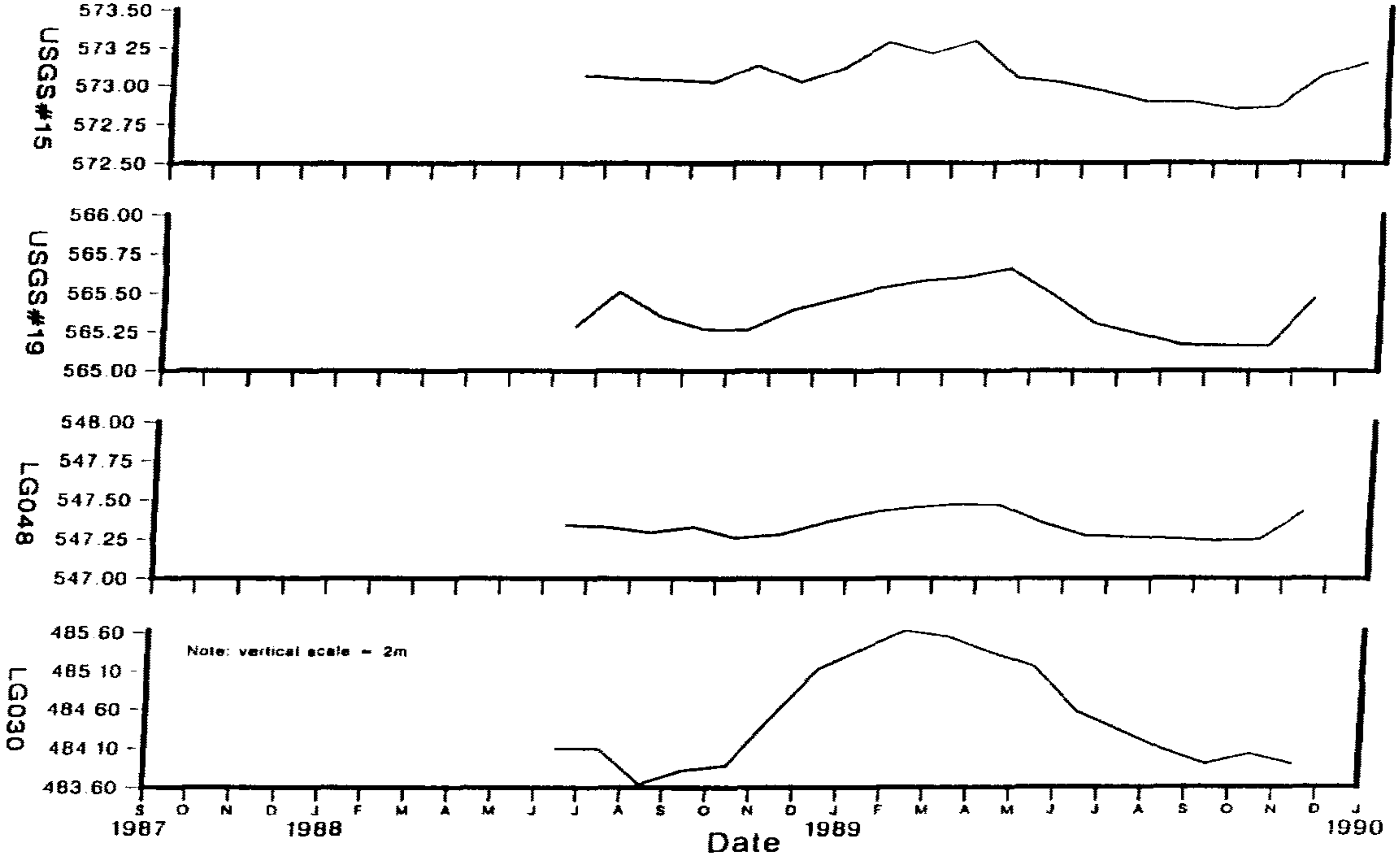


Figure 11. Example water level hydrographs of wells displaying Pattern 1 of seasonal water level fluctuations in the Las Vegas Valley shallow alluvial aquifer zone. All four plots are from wells in the "undeveloped" land use category.

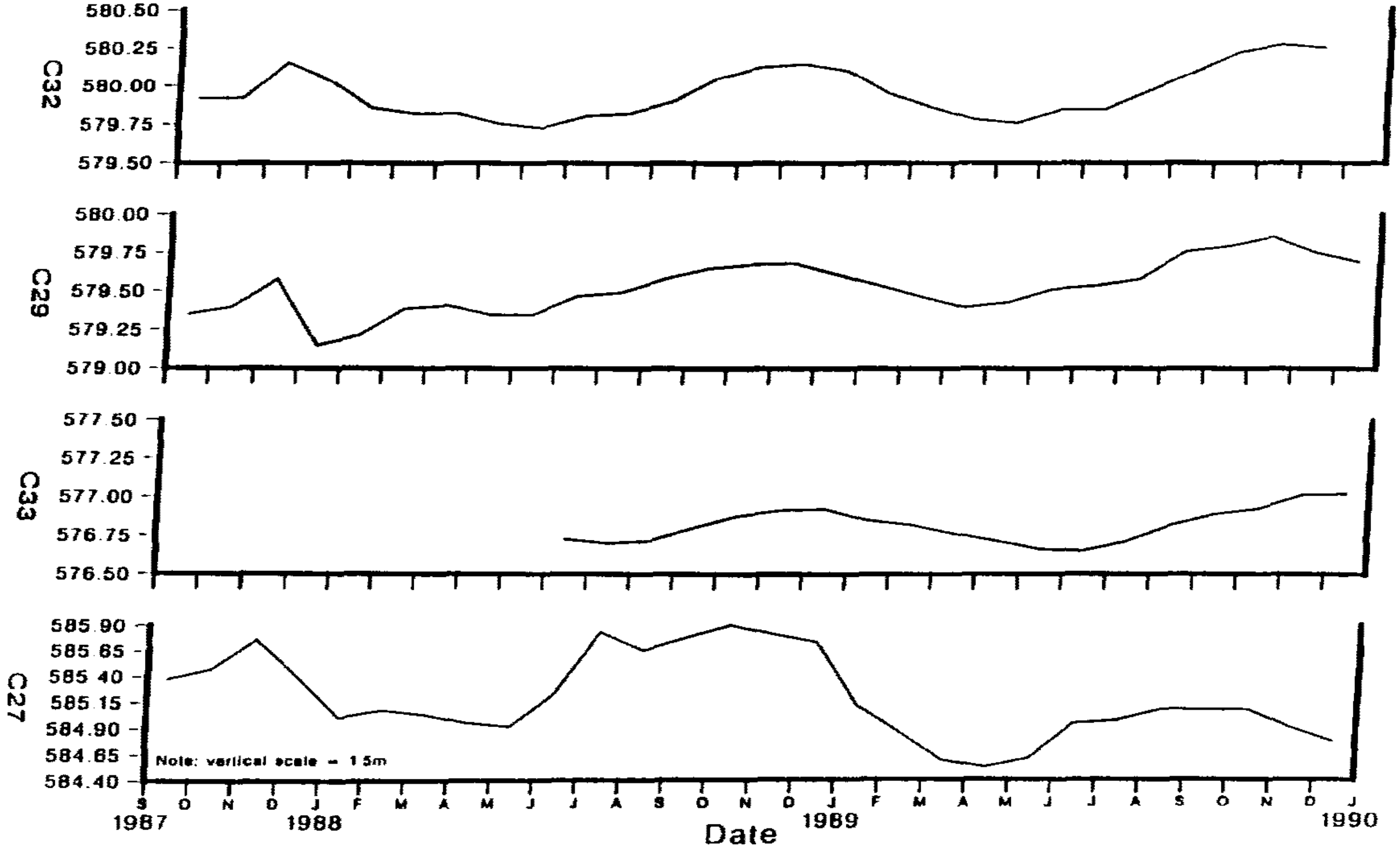


Figure 12. Example water level hydrographs of wells displaying Pattern 2 of seasonal water level fluctuations in the Las Vegas Valley shallow alluvial aquifer zone. All four plots are from wells in the "residential" land use category.

Table ~~2~~ 3. Water level flux pattern versus land use for shallow monitoring wells in the Las Vegas Valley, Nevada shallow alluvial aquifer zone.

Site	Pattern 1	Pattern 2	No Pattern
C10		residential	
C11		residential	
C24	residential		
C25	residential		
C27		residential	
C28		residential	
C29		residential	
C32		residential	
C33		residential	
C36		residential	
C42		residential	
C43		residential	
C49		residential	
LG030	undeveloped		
LG048	undeveloped		
M.Pkwy&Flam.		commercial	
P.Vista Park		turf areas	
USGS #3a		commercial	
USGS #3b			turf areas
USGS #5	residential		
USGS #11			commercial
USGS #15	undeveloped		
USGS #19	undeveloped		
USGS #34		turf areas	
USGS #37		turf areas	
USGS #40		commercial	
USGS #43	commercial		
USGS #47			undeveloped
USGS #56		turf areas	
USGS #68	undeveloped		

Sites displaying Pattern 1 appear to follow the intuitive cycle of water table fluctuations in the valley. Pattern 1 sites experience a declining water table during the summer due to the high summer evapotranspiration rate. The water table rise observed at these sites in the winter is due to either low winter evapotranspiration rates decreasing discharge, year round irrigation practices, increased upward leakage from the principal aquifers caused by lower pumpage rates in winter, or some combination of the three factors. Of the 10 sites exhibiting Pattern 1: 5 are from the "undeveloped" category, 3 are from the "residential" category, and 2 are from the "commercial" category.

Sites displaying Pattern 2 are strongly influenced by turf grass irrigation practices. Pattern 2 sites display a water table rise during the heavy summer turf irrigation season in spite of the extremely high summer evapotranspiration rates. Of the 17 sites exhibiting Pattern 2 behavior: 10 are from the "residential" category, 4 are from the "turf areas" category, and 3 are from the "commercial" category.

The effects of irrigation practices upon water levels in the Las Vegas Valley shallow alluvial aquifer zone are similar to the irrigation effects documented in other studies of shallow unconfined alluvial aquifers in the Basin and Range physiographic province conducted by Seiler and Waddell (1984), Peter (1987), Lico *et al.* (1987), and Garn (1988).

Temperature, pH, and Electrical Conductivity

Water temperature, pH and specific electrical conductivity (EC) data were collected monthly at 12 wells and quarterly at an additional 9 wells. These data are tabulated in Appendix B. The mean annual shallow ground water temperature is 21.6 ° C, which is elevated with respect to the mean annual air temperature of Las Vegas Valley of 18.6 ° C (Houghton *et al.*, 1975). The maximum range of water temperatures is 10.2 ° C, from a minimum of 15.7 ° C to a maximum of 25.9 ° C, while the average annual range of temperature fluctuations is 2.9 ° C. The average annual range of water temperatures is considerably less than the average annual range of air temperatures of 7.8 ° C (Houghton *et al.*, 1975).

Water temperature versus time plots grouped by land use category in Appendix H reveal that land use practices have little, if any, effect upon the annual cycle of temperature fluctuations. Twenty of the twenty-one sites at which time series data was collected display the same pattern of cyclical annual temperature variations. Water temperatures reach their annual low in late winter to spring, rise during the summer, and then reach their annual high in late summer to fall. There is a one to three month lag between the annual highs and lows in air temperature and the annual highs and lows in water temperatures.

This lag between annual air and water temperature highs and lows and the relatively lower range of water temperature fluctuations are as expected. The resistance of soil to heat conduction from the atmosphere tends to damp the amplitude of thermal waves propagated from air to soil. Because a temperature gradient must develop in the soil before heat begins to flow to depth and because of the relatively low thermal conductivity of water, there is a time lag between maximum and minimum air temperatures, soil temperatures, and shallow ground water temperatures. The decrease of amplitude and increase of phase lag are typical phenomena in the propagation of periodic temperature waves through soil and water (Hanks and Ashcroft, 1980; Hillel, 1980).

The pH of shallow aquifer zone waters sampled for this study are all near neutrality with a mean of 7.04 and range of 6.73-7.68. Time series plots of pH in Appendix I indicate that there is little seasonal variation in the pH of shallow zone waters at the majority of sites sampled. pH appears to remain relatively constant at most (15 of 21) sites with only minor monthly fluctuations. Of the 6 sites that display significant variations in pH, 4 of 6 have a pattern of high pH in the fall and spring and low pH's in summer and winter. The other 2 sites that display significant variations in pH exhibit random variations.

Specific electrical conductivity (EC) or specific conductance of shallow aquifer zone waters ranges from 544-9640 μmhos/cm (eqiuvalent to μSiemens/cm) and has a mean value and standard deviation of 4920 and 2120 μmhos/cm, respectively. EC is generally lowest in the north and northeast and increases along flow path toward the highest values in the southeast near Las Vegas Wash. The waters at site C36, several kilometers upgradient from Las Vegas Wash, had the highest recorded EC values, due to the possible presence of a local gypsum deposit.

Plots of EC versus time in Appendix J reveal that waters at 18 of 21 wells display similar patterns of temporal variations in EC. EC appears to follow a seasonal pattern of semi-annual highs in mid-summer and late fall to early winter for the first 6-7 months of the study. However, after approximately January, 1989, all 18 of these wells experienced a steady decline in EC values through the conclusion of the study in December, 1989. The steady decline in EC values from January to December, 1989 indicates that factors other than those with annual cycles such as water temperature or dilution/concentration from a rising and falling water table effect the EC value of shallow aquifer zone waters. One explanation for the observed pattern of EC variations is that there are alternating periods of dissolution of salts from the unsaturated zone and mixing of saline waters near the water table with less saline water at greater depths.

High secondary recharge rates from overirrigation and the associated rising water table result in the leaching of salts from the unsaturated zone into waters of the shallow aquifer zone. These two factors, in concert with the high rate of evapotranspiration in the valley, contribute to the formation of a zone of highly saline water near the water table. Dettinger (1987) noted that the poorest quality water everywhere in Las Vegas Valley was extracted from near the water table. This highly saline zone of water near the water table then becomes less saline due to mixing by diffusion and hydrodynamic dispersion effecting a more uniform distribution of salinity in the shallow aquifer zone. Thus the observed patterns of EC variations are the result of periods of dissolution and concentration alternating with periods of diffusion and dispersion. Data indicating that neither mineral precipitation nor ion exchange reactions are affecting EC variations are presented in the following section.

Ground-water ~~Major Ion~~ Geochemistry

Spatial Variations

Ground-water quality was evaluated spatially and temporally using analyses from 24 and 18 wells, respectively. Wells used in the temporal analysis of water quality were sampled 5 times, on a quarterly basis, between June, 1988 and June, 1989. Ninety-nine samples were collected and analyzed for major ions. Samples from the Meadows Detention Basin (MDB wells) were not included in the evaluation of ground-water chemistry because these wells were contaminated with drilling fluids. Figure 7 shows the sample points used.

Chemistry of ground waters in the study area is strongly influenced by lithology. A trilinear (Piper) diagram (Piper, 1944) (Figure 13) shows the majority of samples lying within the Ca^{2+}-Mg^{2+}-SO_4^{2-} hydrochemical facies as defined by Back (1966). This is the result of the large amounts of gypsum

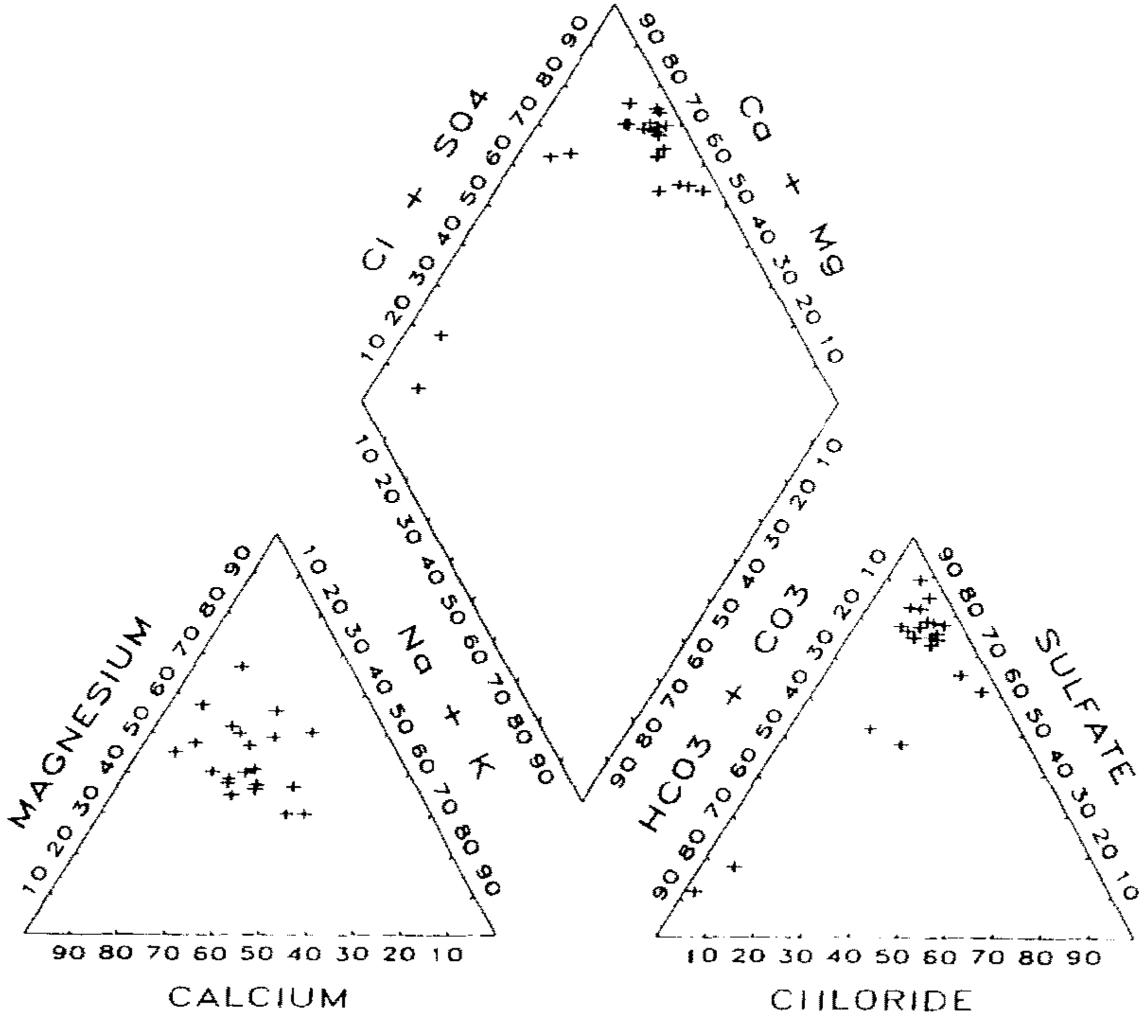


Figure 13. Trilinear diagram (% meq/l) of ground water from the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Plot symbols represent 1988-89 average for each site sampled.

($CaSO_4.2H_2O$),

calcite ($CaCO_3$), and dolomite ($(Ca,Mg)CO_3$) present in the surficial alluvial deposits in the study area.

Water quality in the study area is generally poor as indicated by TDS (Figure 14). TDS concentrations in the study area ranged from 319 milligrams per liter (mg/l) at site USGS#15 to 8680 mg/l at site C27 and had a mean value and standard deviation of 3760 mg/l and 1950 mg/l, respectively. Water-type and total dissolved solids (TDS) content are not only a function of the lithology of the study area, but are also a function of position along the ground-water flow path.

Figure 14 illustrates the increase in TDS content along the general northwest-southeast ground-water flow path in the study area. The highest TDS waters in the valley are generally found at the terminus of the ground-water flow path in the southeast near Las Vegas Wash. However, site C27, with the highest TDS content observed, is several kilometers (km) upgradient from Las Vegas Wash. This anomalously high value is most likely due to well completion in or near a gypsum deposit.

Water-types appear to evolve along flow path from a Ca^{2+}-Mg^{2+}-HCO_3^- type water in the north and northwest parts of the study area to a Ca^{2+}-Mg^{2+}-SO_4^{2-} type water in the rest of the study area. Ground-water moving along a flow path tends to evolve chemically from the composition of pure atmospheric precipitation to that of seawater (Chebotarev, 1955). The apparent evolution of water types in the Las Vegas Valley shallow aquifer zone is due to a number of factors besides natural evolution of waters along a flow path. These factors are: (1) the relative predominance of carbonate materials and lack of gypsum in the

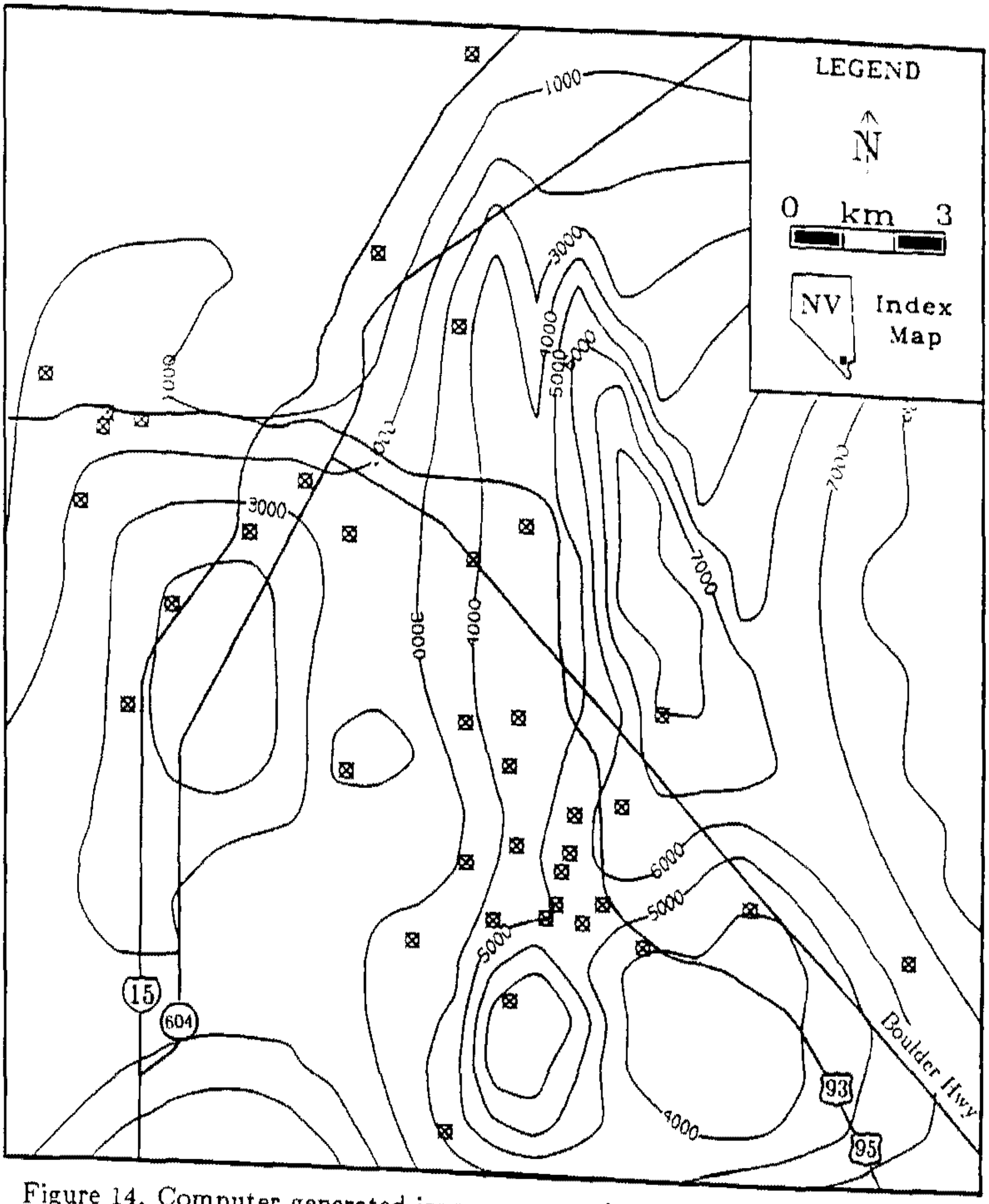


Figure 14. Computer generated isogram map of TDS of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Contour interval = 1000 mg/l.

valley-fill deposits of the northwest, (2) the greater solubility of the highly gypsiferous soils in the central and southeastern parts of the valley, (3) the increased residence time of the water in the soluble deposits of the central and southeastern valley due to the relatively finer-grained nature of the deposits in those areas, and (4) the progressive salt loading of shallow ground water as it moves along flow path due to the leaching of salts by overapplication of irrigation water (Dinger, 1977; Kaufmann, 1978).

Isogram concentration contour maps for individual major ions (Figures 15-21) are also useful for the evaluation of spatial changes in ground-water chemistry in the study area. Concentrations of all major cations (Na^+, K^+, Ca^{2+}, and Mg^{2+}) increase along flow path from northwest to southeast. Ca^{2+}/Mg^{2+} ratios generally decreased along flow path from around 1.7 to around 1.0 (Figure 22). Concentrations of Cl^- and SO_4^{2-} also increase along flow path, reflecting the dissolution of gypsum and halite (NaCl) due to the factors outlined above.

Bicarbonate (HCO_3^-) concentrations do not appear to follow a spatial trend across the study area. Bicarbonate concentrations range from a high of 584 mg/l at site USGS#37 to a low of 154 mg/l at site C32 in the southeast. Bicarbonate concentrations appear to be controlled more by the partial pressure of dissolved $CO_{2(aq)}$ (P_{CO_2}) than by lithology. All of the sites in the study area had P_{CO_2}s that were elevated relative to the atmospheric value of $10^{-3.5}$ atmospheres. Figure 23 is a contour map of log (to the base 10) P_{CO_2} in the shallow aquifer zone. Note the similarities between Figures 21 and 23, the contour maps of HCO_3^- and P_{CO_2} values, respectively. If HCO_3^- concentrations are controlled more by P_{CO_2} than lithology, then P_{CO_2} variations across the study area could help account for the apparent evolution of shallow zone waters from a Ca^{2+}-Mg^{2+}-HCO_3^- type water in the north to a Ca^{2+}-Mg^{2+}-SO_4^{2-} type water in the

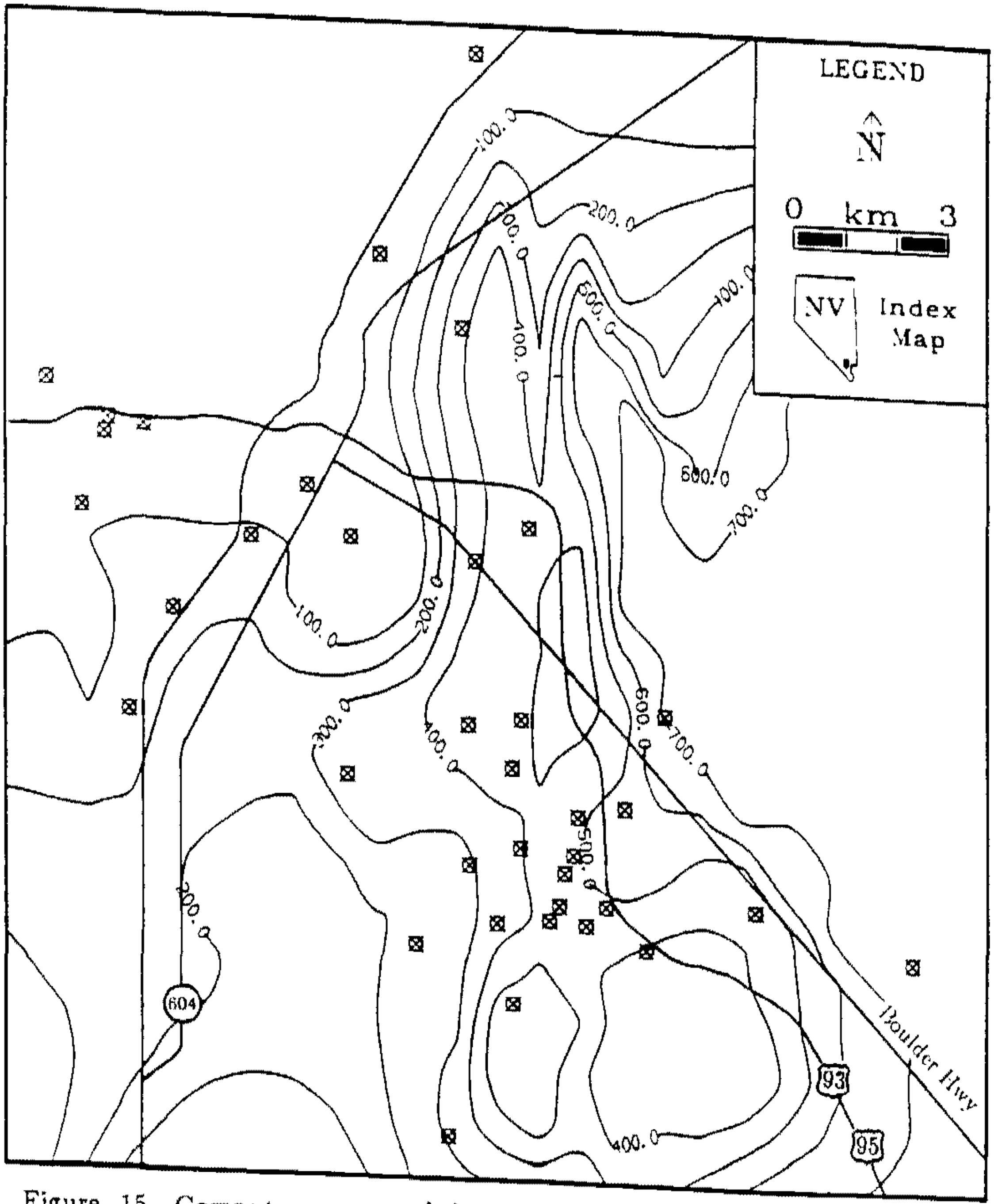


Figure 15. Computer generated isogram map of Na^+ concentrations of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Contour interval = 100 mg/l.

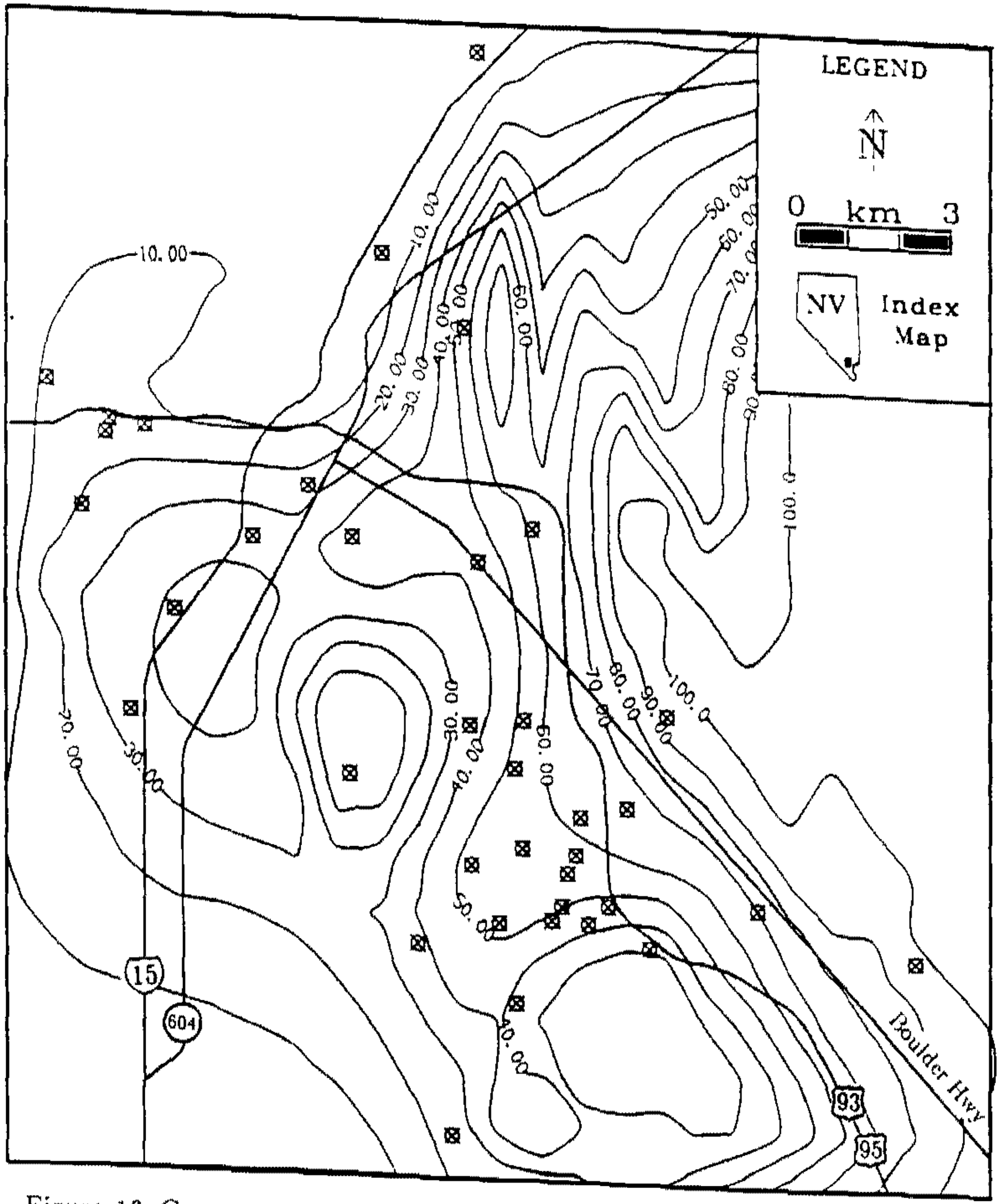


Figure 16. Computer generated isogram map of K^+ concentrations of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Contour interval = 10 mg/l.

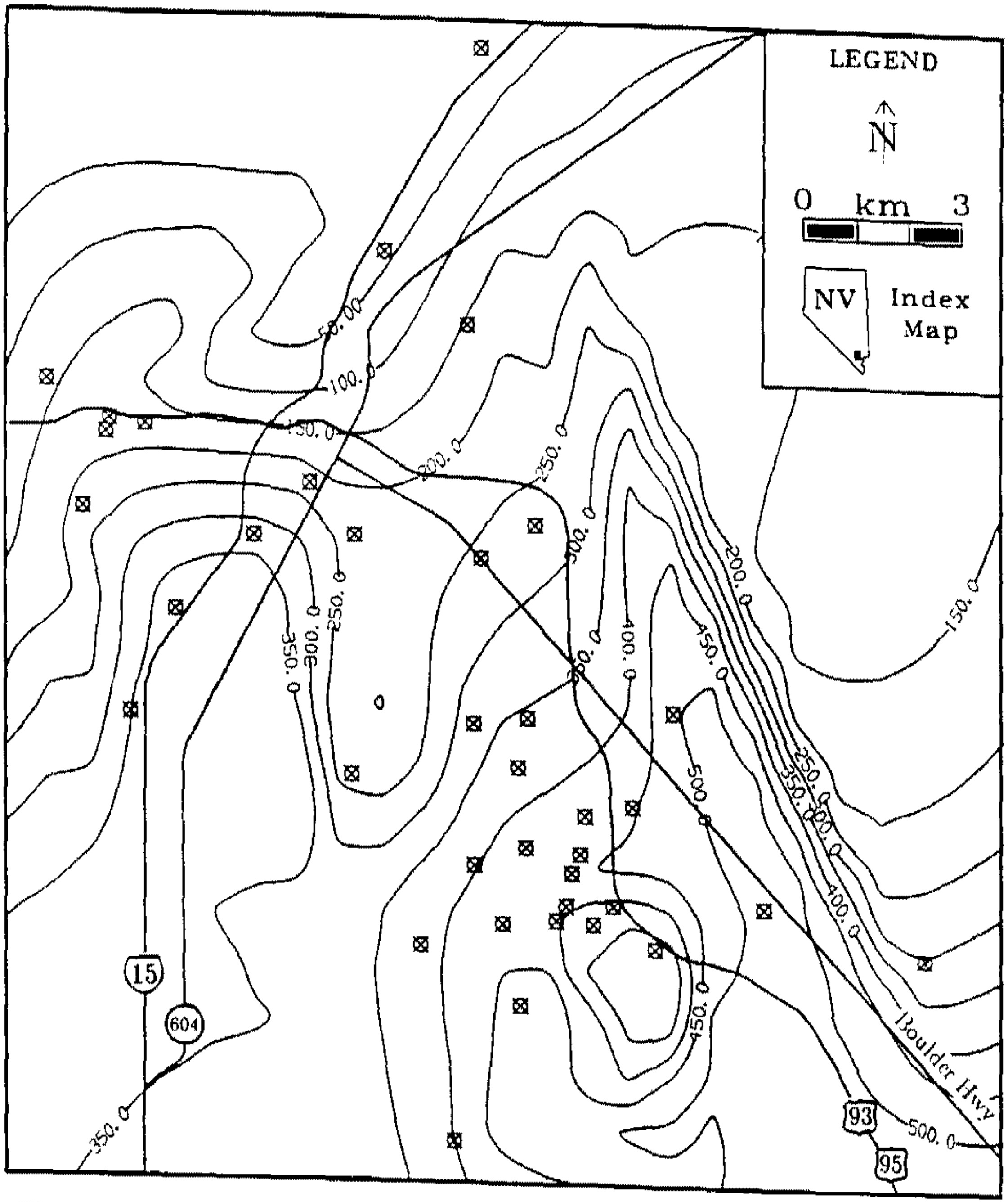


Figure 17. Computer generated isogram map of Ca^{2+} concentrations of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Contour interval = 50 mg/l.

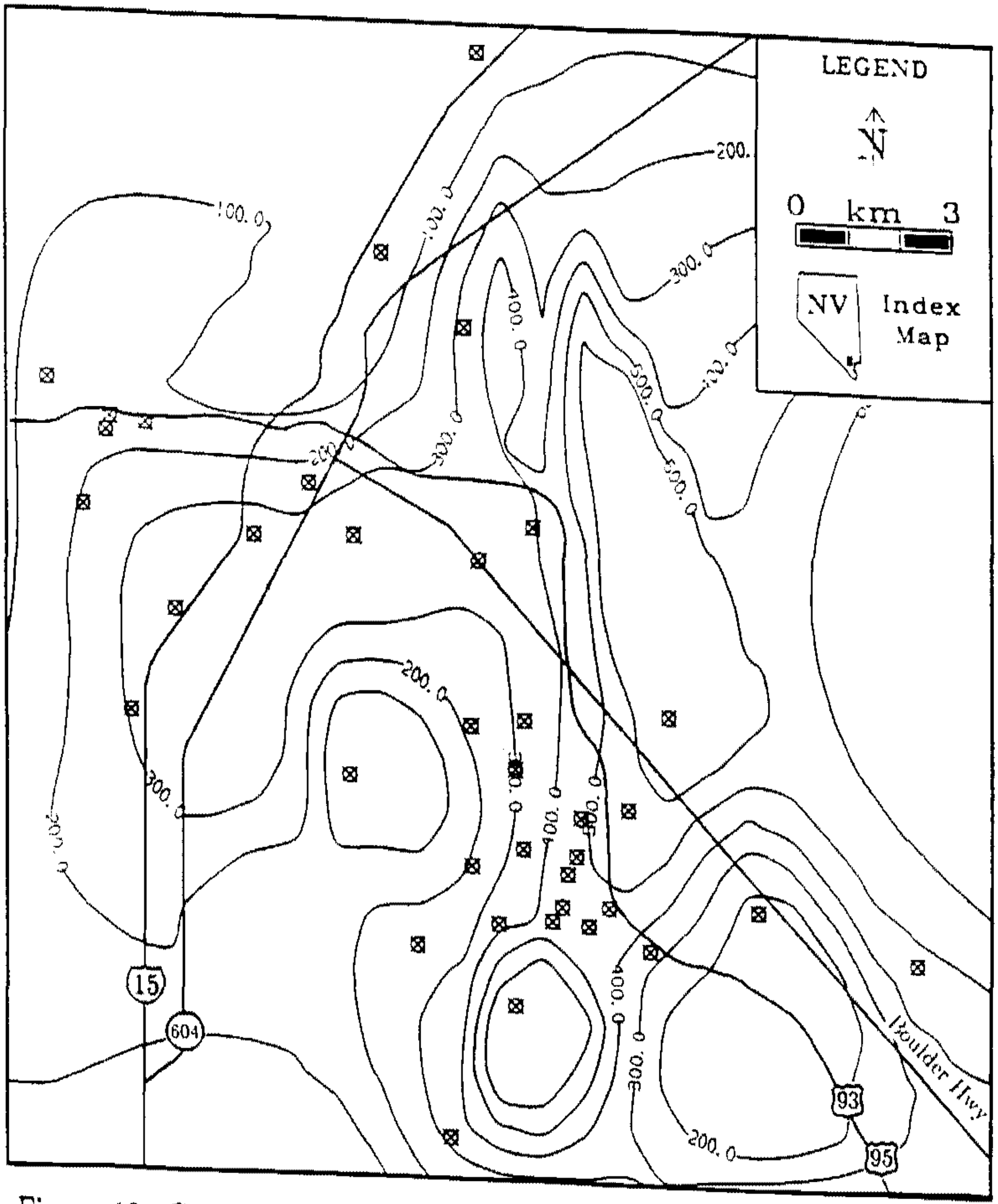


Figure 18. Computer generated isogram map of Mg^{2+} concentrations of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Contour interval = 100 mg/l.

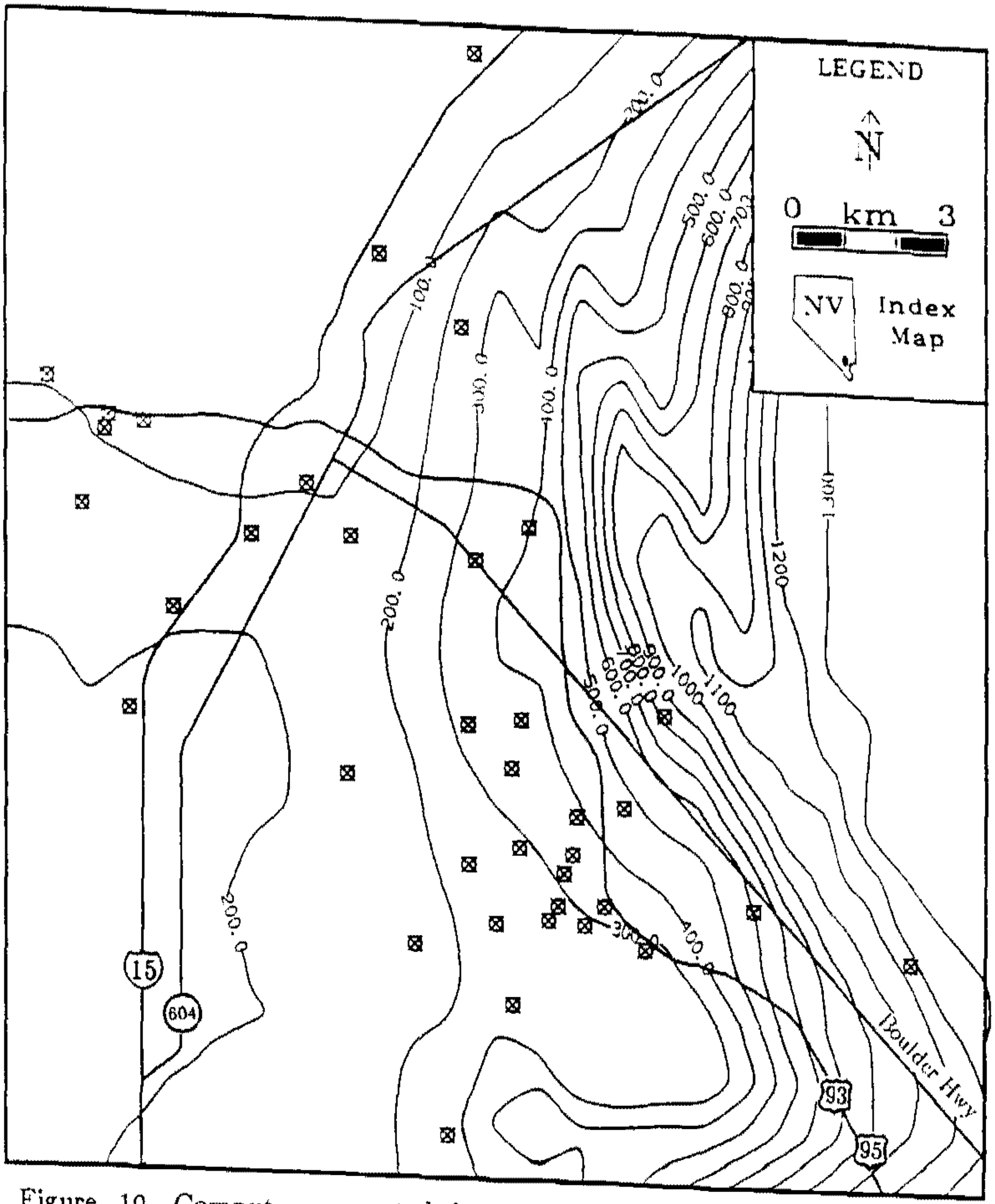


Figure 19. Computer generated isogram map of Cl⁻ concentrations of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Contour interval = 100 mg/l.

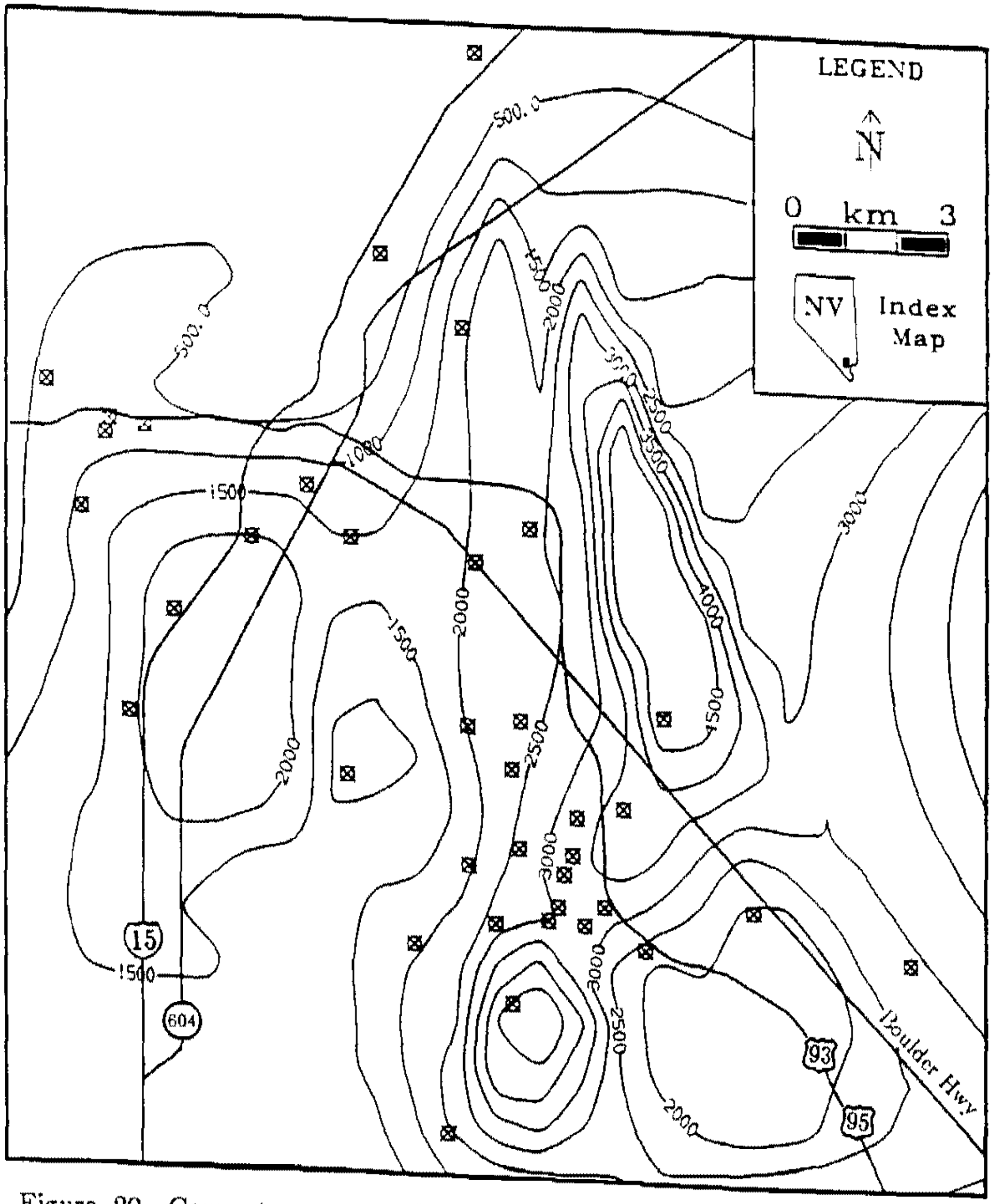


Figure 20. Computer generated isogram map of SO_4^{2-} concentrations of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Contour interval = 500 mg/l.

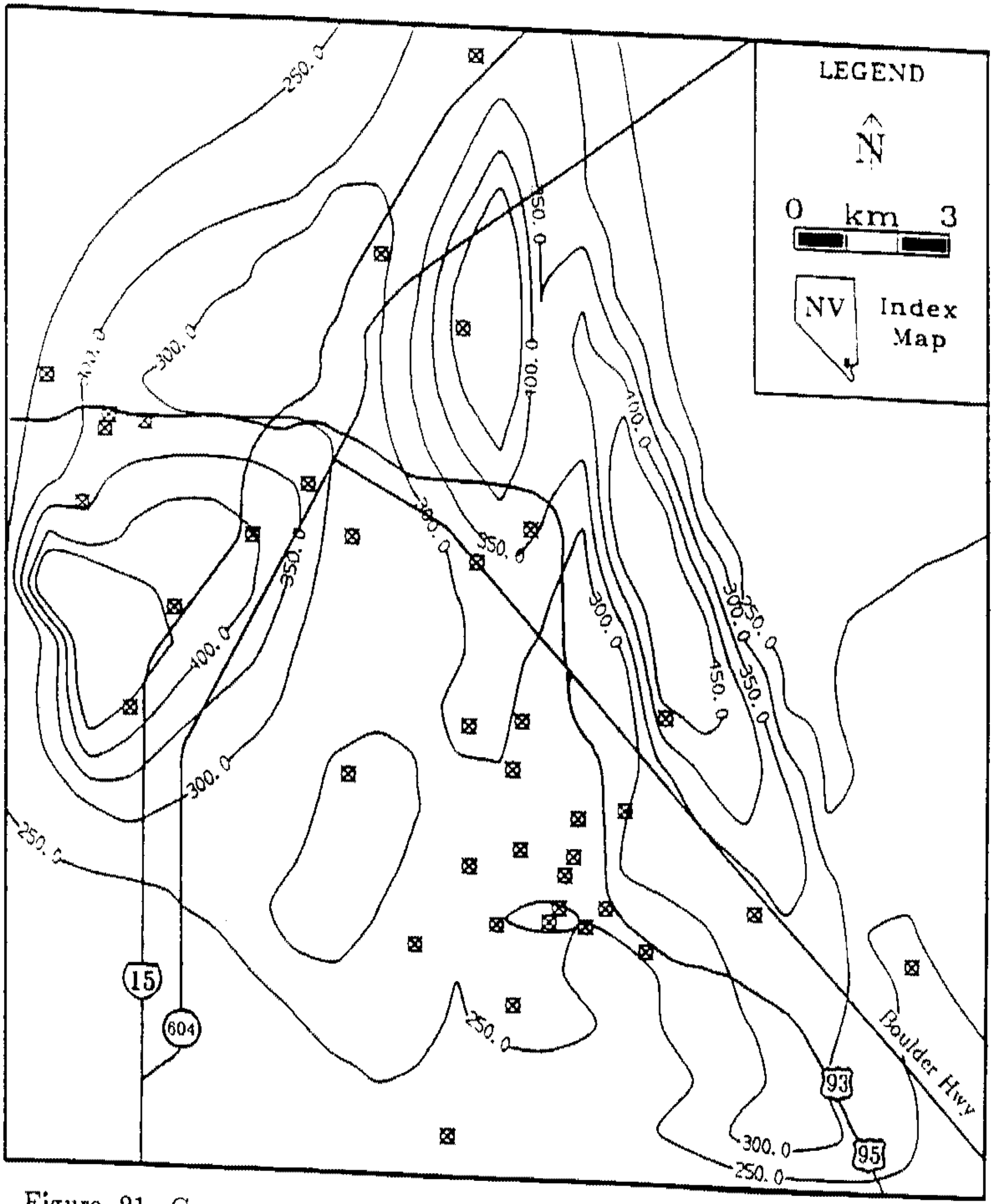


Figure 21. Computer generated isogram map of HCO_3^- concentrations of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone. 1988-89. Contour interval = 50 mg/l.

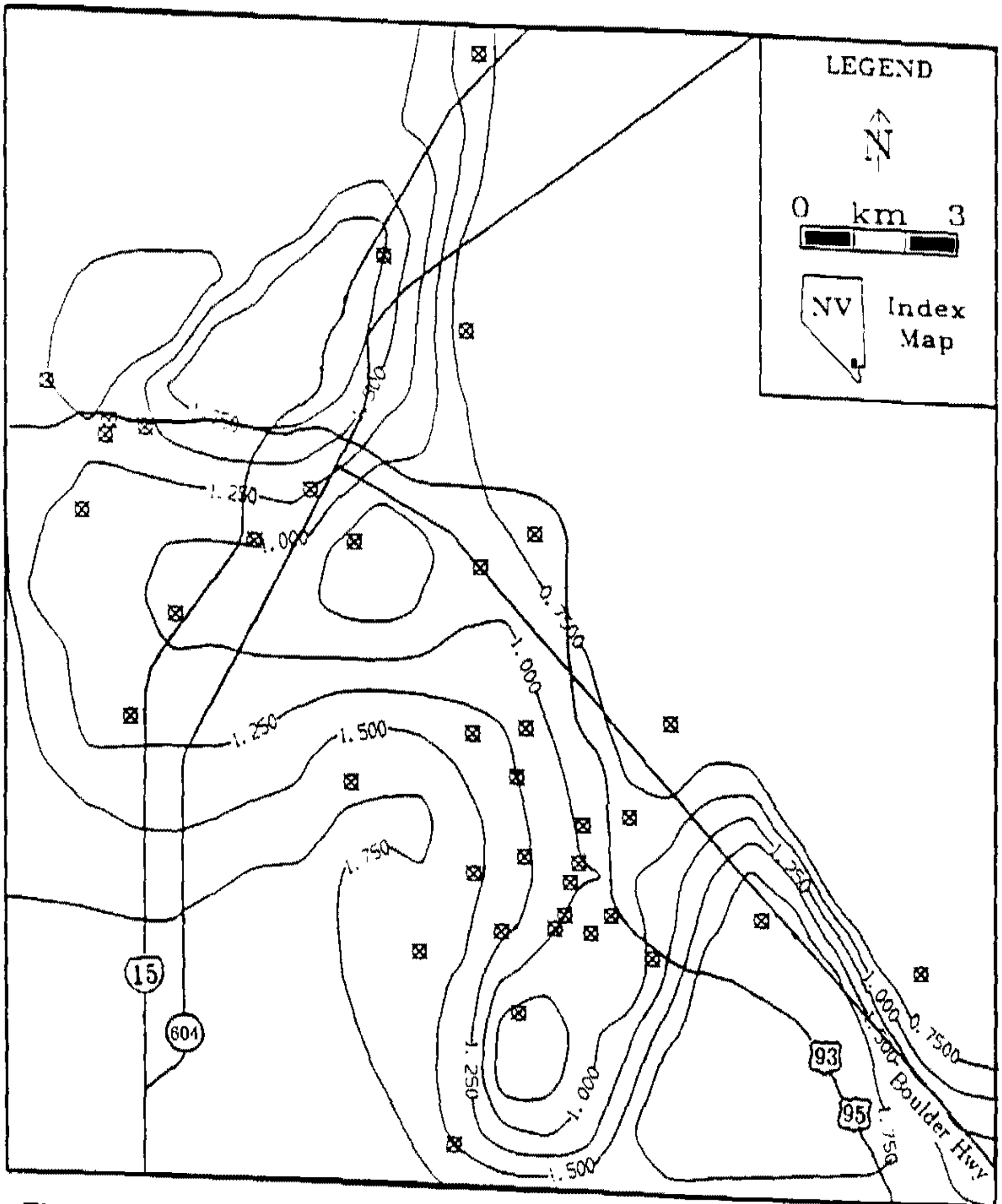


Figure 22. Computer generated contour map of Ca^{2+}/Mg^{2+} ratios of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Contour interval = 0.25.

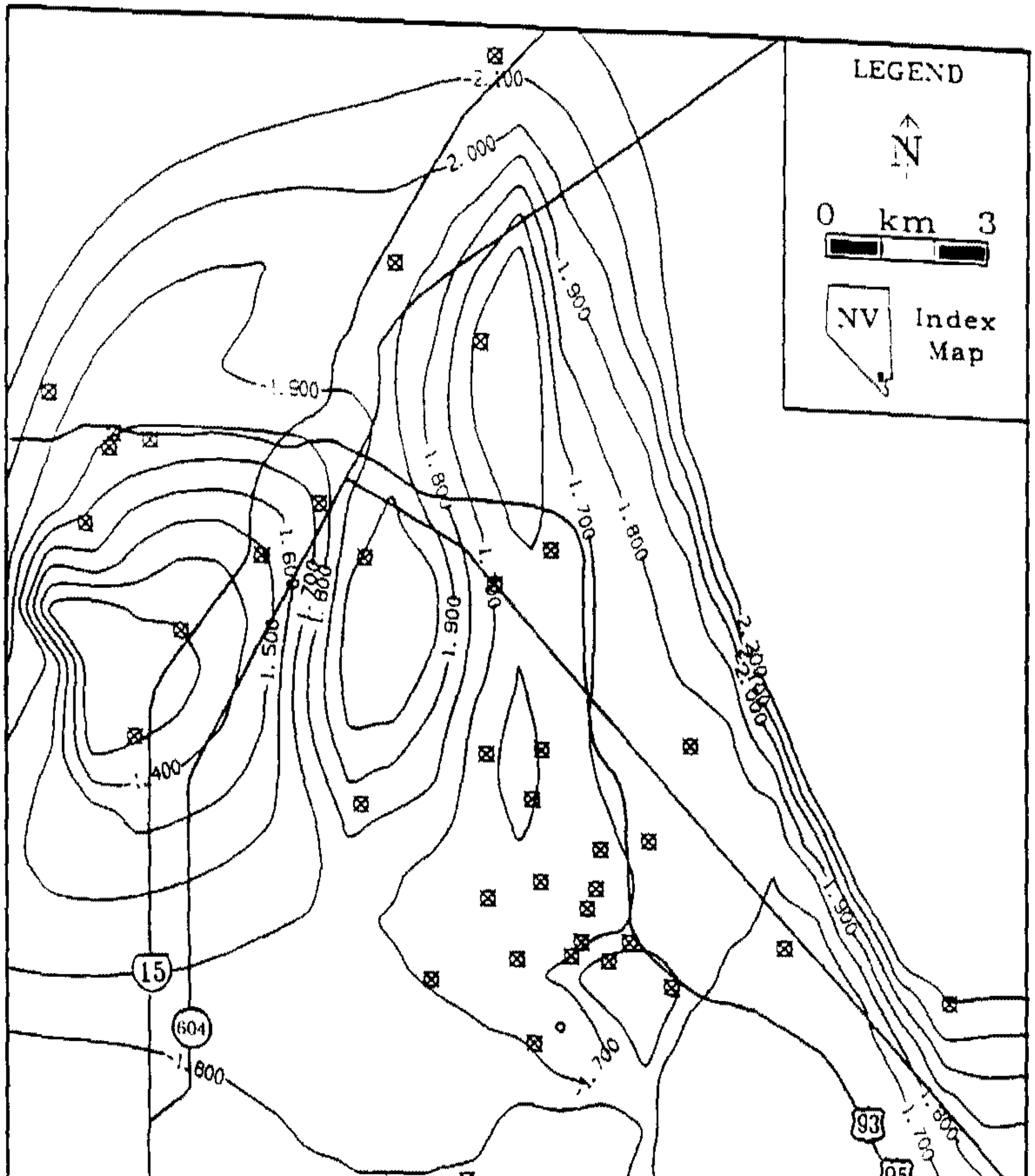


Figure 23. Computer generated contour map of log P_{CO_2} of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Contour interval = 0.1.

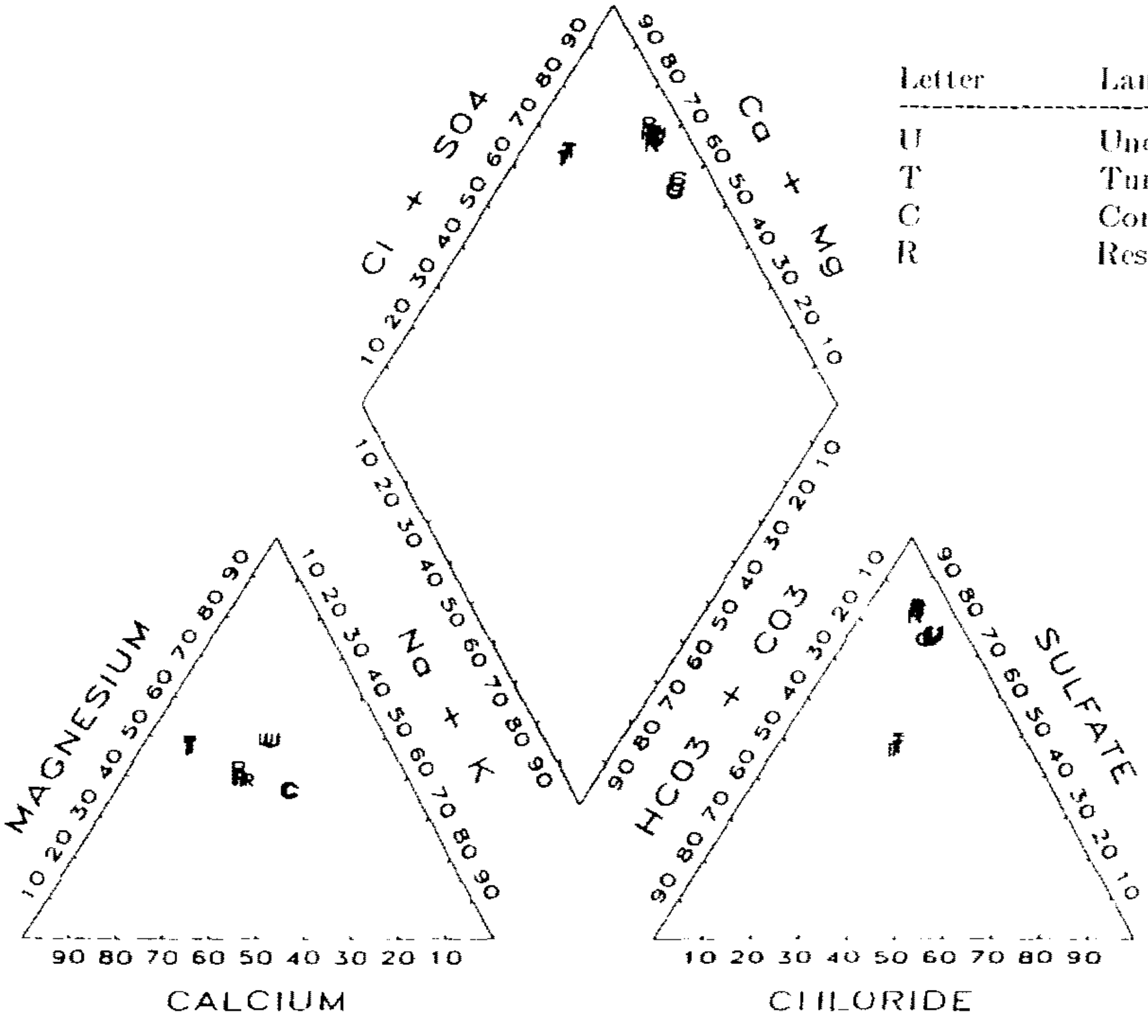
rest of the study area.

Temporal Variations

The difference between the maximum and minimum total dissolved solids (TDS) concentration observed at each site range from 39 mg/l at site USGS#15 to 1570 mg/l at site C27 and averages 400 mg/l valley-wide. Temporal variations in TDS as a percentage of average TDS concentrations at each site ranges from 3% at sites C42, C49, and USGS#43 to 20% at site C27 and averages 10% valley-wide. There is no discernable cyclical annual pattern of TDS fluctuations; TDS highs and lows are distributed fairly uniformly throughout the year. Neither is there any indication that land use practices are affecting short-term TDS variations.

Although TDS concentrations vary temporally at each site, ion ratios remain fairly constant throughout the year. Successive sample analyses from a single site plotted on a trilinear diagram almost invariably plot directly on top of each other. Figure 24, a trilinear diagram with 20 sample analyses plotted, 5 analyses from each of 4 sites, illustrates the lack of temporal variation in the ion ratios of shallow zone waters. This lack of temporal variation in ion ratios suggests that neither mineral phase precipitation nor ion-exchange processes are occurring or that they are relatively minor processes in the shallow aquifer zone.

The most likely explanation for the observed temporal variations in TDS concentrations is therefore one of alternating cycles of dissolution causing TDS rises and diffusion and dispersion causing TDS drops. Dissolution of aquifer material results from dissolution along flow path, secondary recharge, and water table rises. Secondary recharge and a rising water table, in concert with the high evapotranspiration rate in the valley, result in the formation of a zone of highly saline water near the water table. Dettinger (1987) noted that the worst quality



Letter	Land Use	Site
U	Undeveloped	LG018
T	Turf Areas	USGS#37
C	Commercial	USGS#11
R	Residential	C11

Figure 24. Trilinear diagram (% meq/l) of 5 quarterly samples from each of 4 shallow wells in the Las Vegas Valley, Nevada shallow alluvial aquifer zone.

water everywhere in the valley was near the water table. This zone of highly saline water then apparently becomes less concentrated in time as diffusion and hydrodynamic dispersion mix the less saline water at depth in with the saline zone.

Nutrients

NO_3^- concentrations in the study area ranged from 0.4 mg/l at site USGS#19 to 80.2 mg/l at site USGS#40 and averaged 22.2 mg/l valley-wide. Nitrate concentrations do not appear to be controlled by lithology, but rather by the presence of septic tanks in the valley, by the application of sewage effluent to golfcourses, and primarily by fertilization practices and overirrigation of turf grass (Hess and Patt, 1977; Kaufmann, 1978; Robert Morris, Nevada Cooperative Extension, personal communication, 1990). Overirrigation of turf grass in the valley increases nitrate transport to ground water six fold, independent of fertilization rates (Morton *et al.*, 1988).

Total organic carbon (TOC) concentrations (expressed as carbon) ranged from 0.50 to 9.4 mg/l and averaged 2.6 mg/l while dissolved organic carbon (DOC) concentrations ranged from 0.90 to 9.4 mg/l and averaged 2.6 mg/l. TOC data collected by Dettinger (1987) in 1981 and 1982 indicated that TOC values in shallow ground water ranged from <0.10 mg/l to 13.0 mg/l and had a mean concentration of 5.1 mg/l. The difference between the average TOC concentrations observed in this investigation and those observed by Dettinger (1987) suggests that TOC concentrations may be decreasing in the study area.

TOC content is a semi-quantitative measurement of organic water quality which can indicate the presence of a multitude of organic compounds from either natural or artificial sources. TOC concentrations have been used in Las Vegas Valley and elsewhere as a general indicator of more specific organic

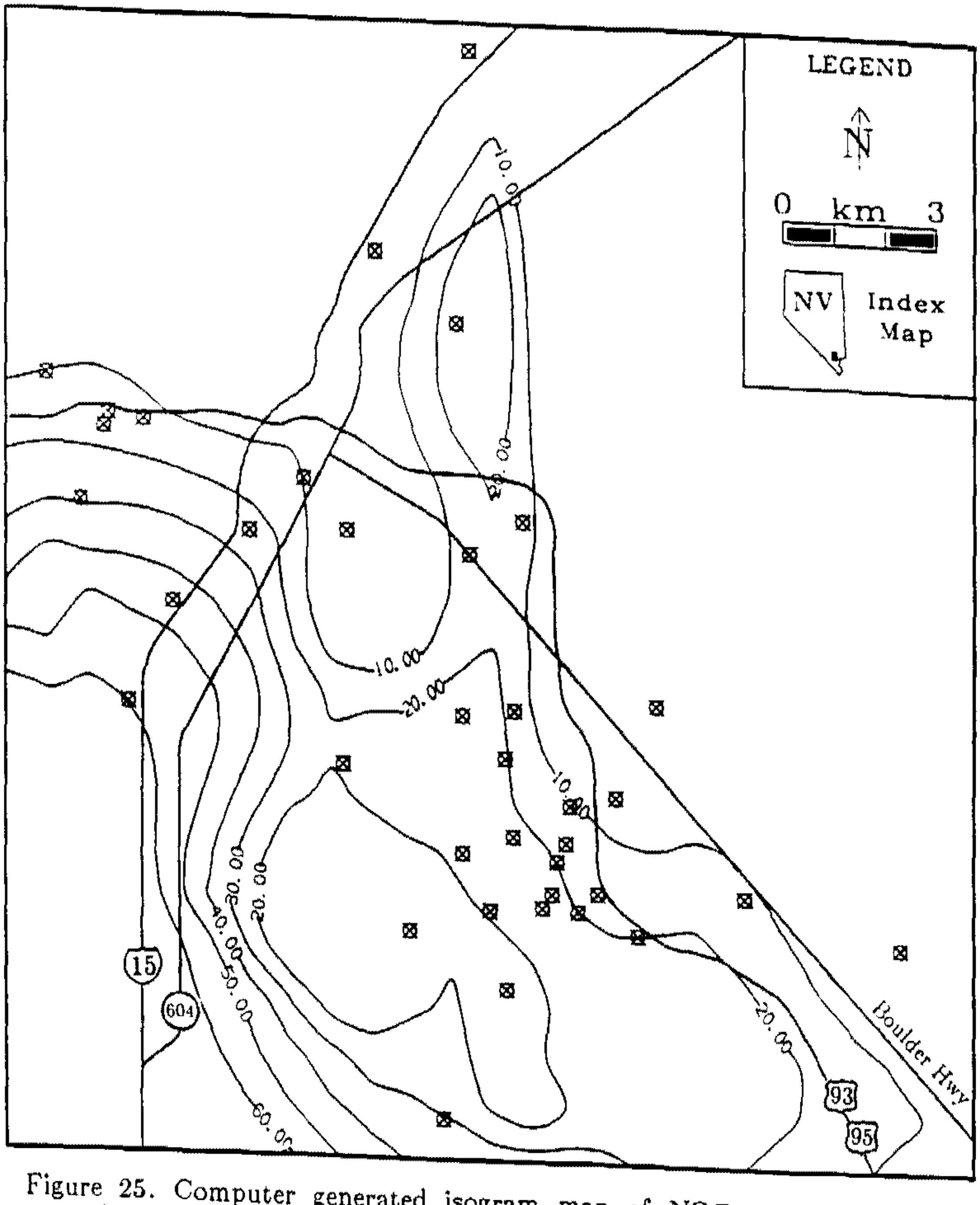


Figure 25. Computer generated isogram map of NO_3^- concentrations of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89. Contour interval = 10 mg/l.

contamination problems (Dettinger, 1987). Both the Nevada Division of Environmental Protection and the industries involved in the mitigation of the large contaminant plume between the BMI complex in Henderson and the Las Vegas Wash have used the 5 mg/l TOC contour as an informal indicator of the aereal extent of the contaminated ground-water (Dettinger, 1987). Using this method, only one site, USGS#37, located in Rotary Park near Charleston Boulevard and Valley View Boulevard, exceeded the 5 mg/l TOC concentration indicative of contamination. However, because this site is located in a large city park and depth to water is only 2-3 meters, the high 9.4 mg/l TOC and DOC concentrations are most likely due to the close connection of shallow ground water to the reservoir of organic matter in the unsaturated zone (Dettinger, 1987).

Thirty-six samples were analyzed for both total and dissolved concentrations of the orthophosphate ion (PO_4^{3-}). Total PO_4^{3-} concentrations ranged from <0.005 mg/l to 0.14 mg/l and averaged 0.026 mg/l while dissolved PO_4^{3-} concentrations ranged from <0.005 to 0.065 mg/l and averaged 0.029 mg/l. Dissolved PO_4^{3-} data was collected by both Kaufmann (1978) and Dettinger (1987) who reported average values of 0.79 and 0.09 mg/l, respectively. Based upon these two previous values and the current average value of 0.029 mg/l dissolved PO_4^{3-}, it appears that PO_4^{3-} concentrations have been decreasing over the last 16-18 years.

PO_4^{3-} in ground water can come from weathering of calcium phosphate (apatite), from calcium phosphate fertilizer, from human or animal wastes, and from household detergents (Hem, 1985). Septic tank leachate of human waste and household detergent is the source of most of the PO_4^{3-} in shallow aquifer zone waters. Fertilizers are only a minor source of PO_4^{3-} in Las Vegas Valley due to the extremely low mobility of PO_4^{3-} in soils and sediments (Hem, 1985).

Therefore, the decreasing concentrations of both total and dissolved PO_4^{3-} in shallow ground water is most likely due to the decreasing number of septic tanks in the valley. Based upon this hypothesis, it is expected that PO_4^{3-} concentrations in shallow ground water in Las Vegas Valley will continue to fall as more houses using septic tanks connect to the Clark County Sanitation District's water treatment system.

Geochemical Modeling

All ground-water samples with major ion, pH, and temperature data were analyzed using the geochemical computer model WATEQDR (Bohm and Jacobson, 1981). WATEQDR is an modified version of WATEQF, a FORTRAN IV program developed by Plummer *et al.* (1976) that models the thermodynamic speciation of inorganic ions and complex species for a given water sample. WATEQDR was used to calculate activity coefficients, ionic activity products, saturation indices of minerals, and partial pressures of gases. The saturation indices (SI's) of calcite, dolomite, gypsum, and quartz were examined because these minerals have all been indentified by numerous previous authors as major components of the surficial valley-fill deposits in the study area. P_{CO_2} and SI values are given as the common logarithm (log) in the following discussion and in Appendix L.

Log P_{CO_2} values ranged from -2.18 to -1.14 atmosphere (atm) in the study area with an average value of -1.74 atm. A contour map of the average log P_{CO_2} of the shallow aquifer zone (Figure 23) may be explained by plant respiration and aerobic decay resulting in localized areas of high CO_2 concentrations in the soil atmosphere, which in turn are causing localized areas of ground-water with elevated log P_{CO_2} values. P_{CO_2} values in the shallow aquifer zone are generally high in the summer and winter and low in the fall and spring.

Roughly two thirds of the samples collected were oversaturated with respect to calcite. This oversaturation indicates that ground waters in the west and north are dissolving calcite from the predominant carbonate valley-fill deposits in these areas while waters farther along the flow path are at equilibrium or are precipitating this mineral. The lack of seasonal variations in ion ratios of shallow zone waters noted in the previous section suggests that calcite precipitation is not occurring in the study area. However, it is possible that calcite is being dissolved from the unsaturated zone at the same rate that it is precipitating in the waters of the shallow zone. A dynamic equilibrium between dissolution and precipitation of calcite would then explain both the oversaturation of shallow zone waters with respect to calcite, which indicates mineral precipitation, and the constancy of ion ratios throughout the year, which contraindicates mineral precipitation.

Calcite SI's are 180° out of phase with P_{CO_2} variations with highs in the fall and spring and lows in winter and summer. The decrease of P_{CO_2} in fall and spring increase the state of saturation of this mineral. High summer CO_2 concentrations in the soil atmosphere from both evaporation and higher rates of plant root and microorganism respiration cause elevated P_{CO_2}s (Hillel, 1980), thus allowing more calcite to be dissolved. Since more calcite can be dissolved, an apparent drop occurs in the saturation index of calcite (Drever, 1982).

Seventy-nine out of 92 samples collected were undersaturated with gypsum, suggesting that this mineral is being dissolved in the study area. Three sites, C27, C29, and LG030, had waters that were at or near equilibrium with gypsum. Saturation of gypsum at site LG030 was expected since this site is at the terminus of the shallow ground-water flow path near Las Vegas Wash. Saturation of gypsum at sites C27 and C29 plus the high TDS and sulfate (SO_4^{2-})

concentrations at these two sites indicates that these wells are completed in gypsum deposits or in highly gypsiferous soils; the drilling logs in Converse Consultants (1985) report are unclear in regard to the lithology of the screened interval of these two sites.

SI values for gypsum are higher in summer and winter and lower in fall and spring. This pattern is in phase with P_{CO_2} variations and 180° out of phase with calcite SI variations. The P_{CO_2}-calcite-gypsum system in the shallow aquifer zone is driven by annual temperature variations and the common-ion effect. As stated above, high summer temperatures cause higher rates of evaporation and respiration, which increase the CO_2 content of the soil atmosphere and the P_{CO_2} in shallow ground water (Brook *et al.*, 1983). Higher P_{CO_2}s, in concert with the lower solubility of calcite at elevated temperatures (Stumm and Morgan, 1981), cause a drop in the saturation state of calcite in summer (Drever, 1982). Although the solubility of gypsum also decreases as a function of increasing temperature (Stumm and Morgan, 1981), as the saturation state of calcite drops in the summer, more gypsum is dissolved as a result of the common-ion effect. Therefore, the SI of gypsum rises in summer.

If water contains an ion which is also present in a salt, then the common-ion effect will lower the solubility of that salt in the water. In the current study, the solubility of calcite, in water at equilibrium or oversaturated with calcite, is reduced by the addition of Ca^{2+} ions, the common ion, from the dissolution of gypsum. Thus, dissolution of gypsum may cause calcite to precipitate out of solution due to the common-ion effect (Freeze and Cherry, 1979; Drever, 1982). Likewise, the solubility of gypsum will be lowered by the addition of Ca^{2+} ions to the solution from the dissolution of gypsum.

In the waters of the Las Vegas Valley shallow alluvial aquifer zone, high temperatures and P_{CO_2}'s in summer decrease the solubility and saturation state of calcite, allowing dissolution of gypsum and an increase in gypsum saturation due to the common-ion effect. In winter, lower temperatures increase gypsum solubility (Wigley, 1973; Stumm and Morgan, 1981) which results in dissolution of gypsum, a decrease in the saturation state of calcite (Wigley, 1973), and the production of $CO_{2(aq)}$ (Drever, 1982).

All samples collected were oversaturated with respect to quartz, but the majority were undersaturated with respect to amorphous silica. The amorphous silica equilibrium value ($SI = 0$), rather than the quartz equilibrium value, is considered to be the upper limit for silica solubility in natural waters (Stumm and Morgan, 1981; Hem, 1985). Therefore, with the exception of sites C28, C49, LG030, USGS#5, USGS#19, and USGS#43 all sites were undersaturated with respect to dissolved amorphous silica. Although unlikely due to the extremely low reaction kinetics (Stumm and Morgan, 1981; Hem, 1985), the waters at these 6 sites may be precipitating silica. In general, dissolved silica concentrations are higher in summer and lower in winter, most likely due to the effects of temperature on silica solubility (Hem, 1985) and possibly due to the effects of evapotranspiration.

As previously stated, the lack of temporal variations in the ion ratios of shallow zone waters suggests that precipitation of mineral phases, if occurring at all, is a relatively minor process.

Water Quality Standards

Water samples were evaluated for compliance with federal drinking water quality standards. Water quality regulations are enforced by the U.S.

Environmental Protection Agency (EPA) in accordance with the 1974 Safe Drinking Water Act. Drinking water regulations are defined in the National Interim Primary Drinking Water Regulations of 1975 and are published in the Code of Federal Regulations (CFR) title 40, parts 100 to 149.

Water samples were evaluated with respect to both maximum contaminant levels (MCL's) and secondary maximum contaminant levels (SMCL's). MCL's are enforceable regulations which stipulate water purity standards for human public water supplies (PWS's). A PWS has to have at least 15 service connections or serve 25 people on a daily basis at least 60 days per year (Dixon, 1990). None of the wells sampled for this investigation qualify as a PWS. However, studies are currently being performed to determine possible alternative uses for shallow aquifer zone waters, such as for irrigation of salt-tolerant plants (Dale Devott, University of Nevada, Las Vegas Environmental Research Center, personal communication, 1990).

MCL's were exceeded 22 times while SMCL's were exceeded 241 times. MCL's were exceeded twice for arsenic, 11 times for selenium, and 9 times for nitrate. SMCL's were exceeded twice for iron, 3 times for manganese, and twice for pH. Sites LG030 and LG048 exceeded the SMCL's for both iron and manganese; this is most likely due to the deterioration of the mild steel casing used at these two sites. The 2 excedences for pH were from sites MDB3 and MDB6, both of which were contaminated with drilling fluids. The majority of SMCL excedences were for chloride (58), sulfate (87), and total dissolved solids (89). These excedences are due to the highly soluble nature of the gypsum and halite that are present in the surficial valley-fill deposits of the study area and the extremely high evapotranspiration rate in the valley. Table 4 gives the summary statistics for major ions, nutrients and isotopes; Table 5 gives the summary statistics for trace metals. Tables 6 and 7 give the water quality standards and

Table 4. Summary statistics of major ions (mg/l), nutrients (mg/l), and isotopes of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone.

Analysis	Minimum	Maximum	**Mean**
pH	6.73	11.76	**7.09**
TDS	252	8680	**3780**
sodium	6.34	992	**328**
potassium	2.36	104	**35.3**
calcium	27	570	**354**
magnesium	0.24	831	**278**
bicarbonate	55	584	**281**
chloride	4.1	1370	**347**
sulfate	34.2	5250	**2015**
silica	13.1	71	**36.5**
nitrate (as N)	0.01	18.1	**5.1**
TOC	0.50	9.4	**2.6**
DOC	0.90	9.4	**2.6**
ortho phosphate	<0.005	0.065	**0.029**
total phosphate	<0.005	0.14	**0.026**
tritium	<5 TU	30 TU	**21.1 TU**
δD	-104 per mil	-89 per mil	**-97 per mil**
$\delta^{18}O$	-14.0 per mil	-11.2 per mil	**-12.6 per mil**

Table 5. Summary statistics of trace element concentrations (mg/l) for ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone.

Ion	Number of > Detection Samples Limit	Minimum	Maximum	**Mean**
arsenic	17/19	<0.002	0.060	**0.015**
barium	19/19	0.007	0.183	**0.026**
boron	19/19	0.05	5.00	**1.98**
cadmium	0/19	<0.005		
chromium	1/19	<0.02	0.04	**0.04**
copper	18/19	<0.005	0.062	**0.020**
fluoride	37/37	0.06	6.03	**0.57**
iron	4/19	<0.01	8.40	**2.33**
lead	0/19	<0.02		
manganese	5/19	<0.01	0.13	**0.08**
mercury	0/19	<0.0002		
nickel	0/19	<0.01		
selenium	17/19	<0.002	0.045	**0.019**
silver	0/19	<0.005		
zinc	6/19	<0.005	0.059	**0.019**

Table 6. Maximum contaminant levels (MCLs) and number of concentrations in ground-water samples from the Las Vegas Valley, Nevada shallow alluvial aquifer zone that exceeded the MCL for selected inorganic chemicals.

Contaminant	EPA MCL	# Samples	# Exceeding
arsenic	0.05 mg/l	19	0
barium	1 mg/l	19	0
cadmium	0.010 mg/l	19	0
chromium	0.05 mg/l	19	0
lead	0.05 mg/l	19	0
mercury	0.002 mg/l	19	0
nitrate (as N)	10 mg/l	95	9
selenium	0.01 mg/l	19	11
silver	0.05 mg/l	19	0

Table 7. Secondary maximum contaminant levels (SMCLs) and number of concentrations in ground-water samples from the Las Vegas Valley, Nevada shallow alluvial aquifer zone that exceeded the SMCL for selected inorganic chemicals.

Contaminant	EPA MCL	# Samples	# Exceeding
chloride	250 mg/l	95	58
copper	1 mg/l	19	0
fluoride	2.0 mg/l	37	0
iron	0.3 mg/l	19	2
manganese	0.05 mg/l	19	3
pH	6.5-8.5	251	2
sulfate	250 mg/l	95	87
TDS	500 mg/l	95	89
zinc	5 mg/l	19	0

number of excedences for constituents on the MCL and SMCL lists, respectively.

Environmental Isotopes

Environmental isotopes of hydrogen and oxygen were used to ascertain the source and relative age of water in the shallow aquifer zone. The radioactive isotope tritium (^{3}H) and the stable isotopes deuterium (^{2}H or D) and oxygen-18 (^{18}O) were used in this investigation.

Water (H_2O) molecules are composed of various combinations of hydrogen and oxygen isotopes and the physical behavior of these molecules is dependent upon the resulting molecular weights. During phase changes, heavier molecules tend to occupy the lower energy state while lighter molecules occupy the higher energy state. Fractionation of isotopes during phase changes is the basis for the use of stable isotope ratios as fingerprints of waters from different sources. Concentrations of the different isotopes are reported as the ratio of heavy to light isotopes relative to a standard. The resulting delta (δ) values are defined by:

$$\delta\,^{18}\mathrm{O} = \left[\frac{(^{18}\mathrm{O}\,/\,^{16}\mathrm{O})_{\mathrm{sample}}}{(^{18}\mathrm{O}\,/\,^{16}\mathrm{O})_{\mathrm{standard}}} - 1\right] \times 1000$$

$$\delta\,\mathrm{D} = \left[\frac{(^{2}\mathrm{H}\,/\,^{1}\mathrm{H})_{\mathrm{sample}}}{(^{2}\mathrm{H}\,/\,^{1}\mathrm{H})_{\mathrm{standard}}} - 1\right] \times 1000.$$

Delta values are reported in per mil ($^{o}/oo$) units. The V-SMOW (Vienna Standard Mean Ocean Water) standard was used to report δ values of oxygen-18 and deuterium. Tritium values are reported in tritium units (TU), which is defined as one tritium atom per 10^{18} hydrogen atoms, the equivalent of 7.2 decays/minute/liter of H_2O or 3.2 Picocuries per liter (pCi/l) (Fritz and Fontes, 1980).

Stable hydrogen and oxygen isotopes are regarded as conservative tracers since they are part of the water (H_2O) molecule and are therefore unaffected by chemical reactions. Once water has been recharged into an aquifer, there are only two means by which its δD or $\delta^{18}O$ content can be altered. Evaporation from the water table is the first way that the isotopic content of water may be altered as lighter isotopes are driven off and the water shifts toward a heavier isotopic composition. Mixing of two waters with different isotopic signatures is another means by which the δD or $\delta^{18}O$ value of water can be altered after recharge into an aquifer.

The presence of tritium in the hydrologic cycle is due to both natural and anthropogenic processes. Prior to the above-ground testing of thermonuclear hydrogen bombs, the natural level of tritium was estimated to be about 1-10 tritium units (TU) (Fritz and Fontes, 1980). Atmospheric testing of thermonuclear devices increased tritium levels in precipitation to as high as 9000 TU at Socorro, New Mexico (Rabinowitz *et al.*, 1977). Currently, tritium values in precipitation are usually below 100 TU (Drever, 1982). Tritium is used in groundwater studies today to distinguish between water that recharged an aquifer prior to the atmospheric detonation of nuclear devices (prior to 1952) and water that was recharged after 1952. Tritium follows the law of radioactive decay:

$$A_{\text{sample}} = A_{\text{initial}}\, e^{-\lambda T}$$

where

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

and

$t_{1/2} = \frac{1}{2}\text{life} = 12.35$ years.

This law indicates that given an initial tritium activity in water in a closed system, after time T, the tritium activity can be calculated by this equation.

Tritium Analyses

Analysis of 19 samples for tritium revealed the presence of tritium above the background level/detection limit of 5 TU in 16 samples (Figure 26). The mean tritium value, excluding those sites with less than 5 TU, is 21.1 TU. Kaufmann (1978) reported the 1971-73 average tritium value in the Las Vegas Valley shallow alluvial aquifer zone to be 50.1 TU, which was a composite value obtained both from wells purposely located in or near irrigated areas (average = 54.7 TU) and from springs, seeps, and underdrains (average = 45.4 TU). Working through the radioactive decay equation for tritium, an original activity of 50.1 TU will decay to 20.4 TU after 16 years' (1972 to 1988) decay. The projected value of 20.4 TU and the measured mean of 21.1 are essentially identical since the 0.6 TU difference is well within the measurement error of ±2-3 TU.

The match of projected and measured tritium values suggests that no tritium, and, therefore no modern water, has been added to the shallow aquifer zone since Kaufmann (1978) collected his samples in 1971-73. However, this is contrary to the known facts. Converse Consultants (1985) reported a 1.5-3 meter rise in the shallow aquifer zone water table between 1970 and 1985. This rise was due to the accumulation of secondary recharge waters in the shallow zone (Converse Consultants, 1985). The match of projected and measured tritium values could also be explained by the secondary recharge of non-tritiated water in the shallow aquifer zone. In view of the known facts regarding the rising shallow zone water table and the fact that tritiated Lake Mead water has only recently

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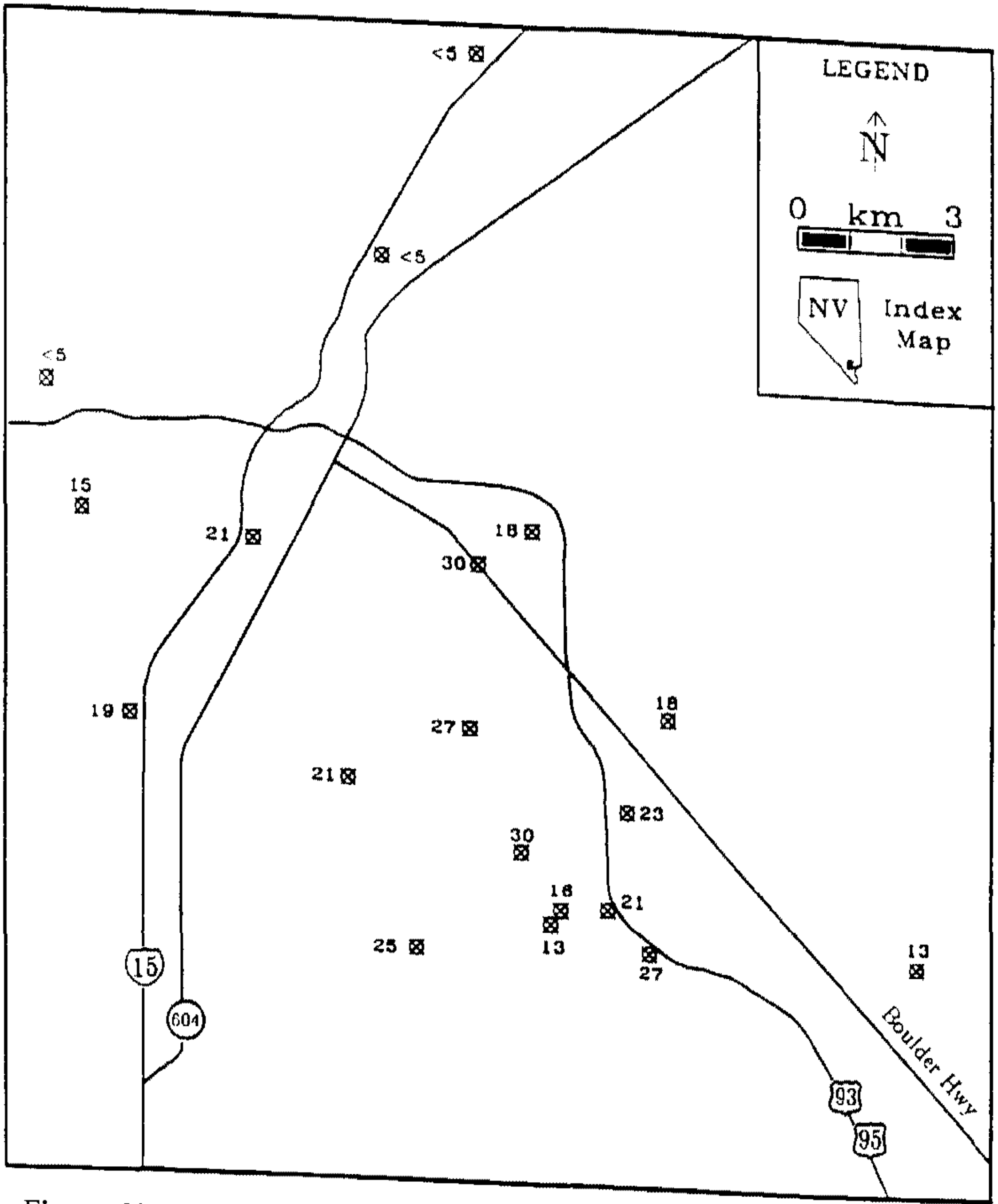

Figure 26. Sample locations and tritium activities (TU) of ground-water samples in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89.

been used on a widespread basis in the valley, the past use of principal aquifer water for landscape irrigation is the most plausible explanation for the match between projected and observed tritium values.

Similarly, the lack of tritium above background levels in the northern study area indicates that no modern recharge has occurred in this area. However, this area of the valley is still served primarily by ground water from the principal aquifers which was recharged in the Spring Mountains during the Pleistocene (Noack, 1988). Therefore, irrigation and secondary recharge waters in this area should contain only background levels of tritium.

Interpretation of tritium data in the shallow aquifer zone is complicated by a number of factors. These are: the unknown tritium activity of Colorado River water, the mixing of tritiated Colorado River water and untritiated ground water in the public water supply distribution system, and the lack of quantitative secondary recharge rates for the various parts of the valley. Both tritiated and untritiated water are mixed at different ratios in reservoirs in the valley before the water is distributed. Thus, the tritium activity of irrigation and associated secondary recharge waters varies both spatially and temporally in the valley. Even if the tritium content of Colorado River water and secondary recharge waters were known conclusively, without a quantitative evaluation of the spatial variations in secondary recharge rates, there is no way to determine the input of tritium into the ground water of the shallow aquifer zone. Therefore, waters of unknown tritium activity are being recharged into the shallow aquifer zone at unknown rates, making the interpretation of tritium data virtually impossible.

Stable Isotope Analyses

Ninety-nine ground-water samples were analyzed for stable isotope ratios of δ^{18} O and δD. The factors that complicated the interpretation of the tritium data, i.e., the spatial and temporal variations in the isotopic signatures of secondary recharge waters and the lack of quantitative secondary recharge data, also make the interpretation of the stable isotope data difficult, if not impossible.

Delta deuterium in the shallow zone ranges between -89 per mil (°/oo) and -104°/oo and has a mean value of -97°/oo. Delta oxygen-18 ranges from -11.2°/oo to -14.0°/oo and averages -12.6°/oo. Average values of δD and $\delta^{18} O$ plotted on the study area basemap (Figures 27 and 28) reveal that the isotopically lightest waters are generally found in the northern part of the study area while the isotopically heaviest water is found at the terminal end of the shallow groundwater flow path near Las Vegas Wash. This suggests that the water in the shallow zone is becoming progressively enriched in both D and $^{18} O$ along flow path due to the fractionation effects of evaporation. However, Figures 27 and 26 do not show a spatial trend toward progressive enrichment in either D of $^{18} O$ along flow path.

The observed pattern of the lightest water in the north and the heaviest water near Las Vegas Wash can be attributed to the widespread use of isotopically light principal aquifer zone water in the north and to the extremely high evaporation rate at Las Vegas Wash due to the shallow water table and low elevation in the vicinity of the wash. Summer water levels at site LG030, the site with the isotopically heaviest water in the shallow aquifer zone, are more than 3 meters lower than the winter water levels.

Evaluation of the temporal variations in δD and $\delta^{18} O$ indicated that although there are seasonal shifts in both isotope ratios, no consistent seasonal trend can be discerned. for example, of the 18 wells from which time series isotope data was collected, between June and September, 1988;

3 sites shifted toward heavier compositions of δD and $\delta^{18} O$,

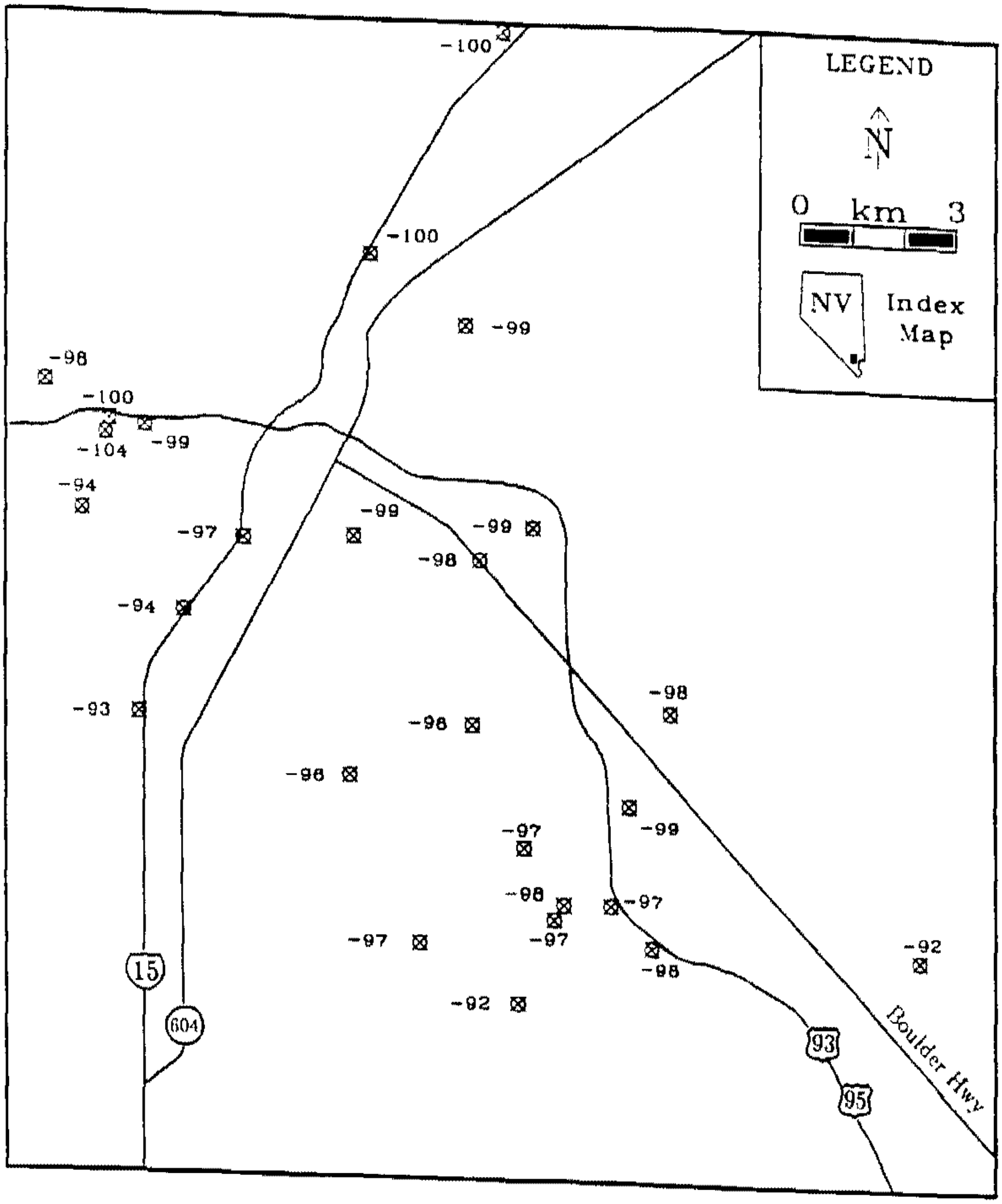

Figure 27. Sample locations and average δD of ground-water samples in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89.

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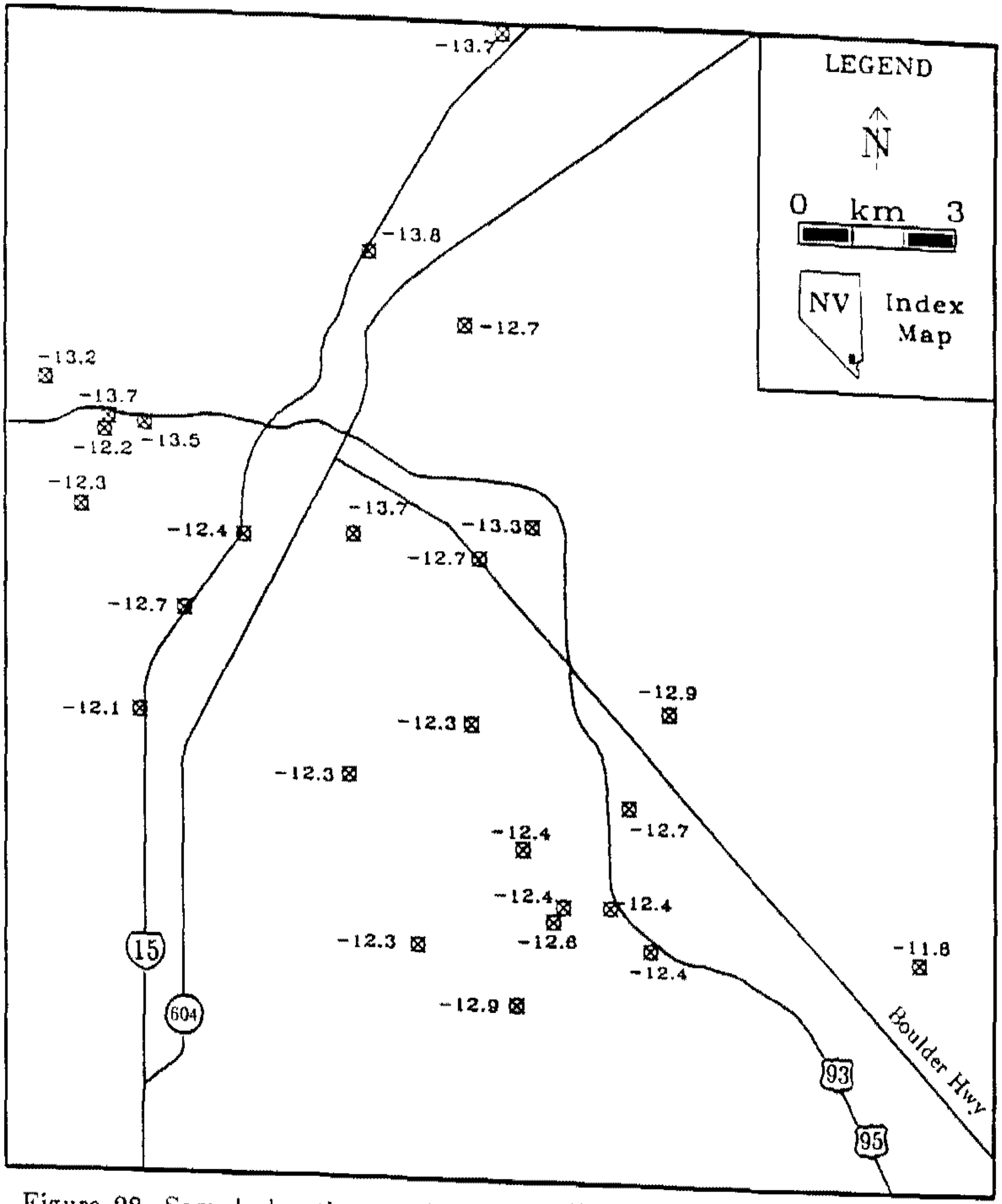

Figure 28. Sample locations and average δ^{18} O of ground-water samples in the Las Vegas Valley, Nevada shallow alluvial aquifer zone, 1988-89.

3 sites shifted toward lighter compositions of δD and δ^{18} O,

3 sites shifted toward a heavier composition of δD and a lighter composition of δ^{18} O,

4 sites shifted toward a heavier composition of δD and had no change in δ^{18} O,

4 sites had no change in δD and shifted toward a lighter composition of δ^{18} O, and

1 site had no change in either δD or δ^{18} O.

Thus, during any given time period, some sites are shifting toward heavier compositions, some sites are shifting toward lighter compositions, some sites have a shift in one ratio but not the other, and some sites do not change at all. The factors affecting this system are depth to water, evapotranspiration rates, secondary recharge rates, isotopic signature of source waters, and mixing of source waters before distribution. Without the knowledge of the spatial and temporal variations in the isotopic signature of secondary recharge waters and the rate of secondary recharge, it is impossible to quantify the individual effects of these factors.

Figure 29 is a scatter plot of waters from the shallow aquifer zone, the principal aquifer zone, and Lake Mead via the Southern Nevada Water System (SNWS). The ratio of $\delta D:\delta^{18}$ O ($\delta D = 8*\delta^{18}$ O + 10) for global ground water, surface water, and precipitation, defined by Craig (1961) and referred to as the Craig Meteoric Water Line (MWL) is also shown on Figure 29. Figure 29 reveals that shallow zone waters plot in a relatively tight cluster within a low humidity evaporation envelope of principal aquifer zone waters. The similarity between shallow zone waters and principal zone waters is not suprizing in light of the fact that the principal aquifer zone was the sole source of water in the valley, except in Henderson, until completion of Stage 1 of the SNWS in 1971. If current water use trends in the valley (Figure 2) continue, it is expected that the isotopic

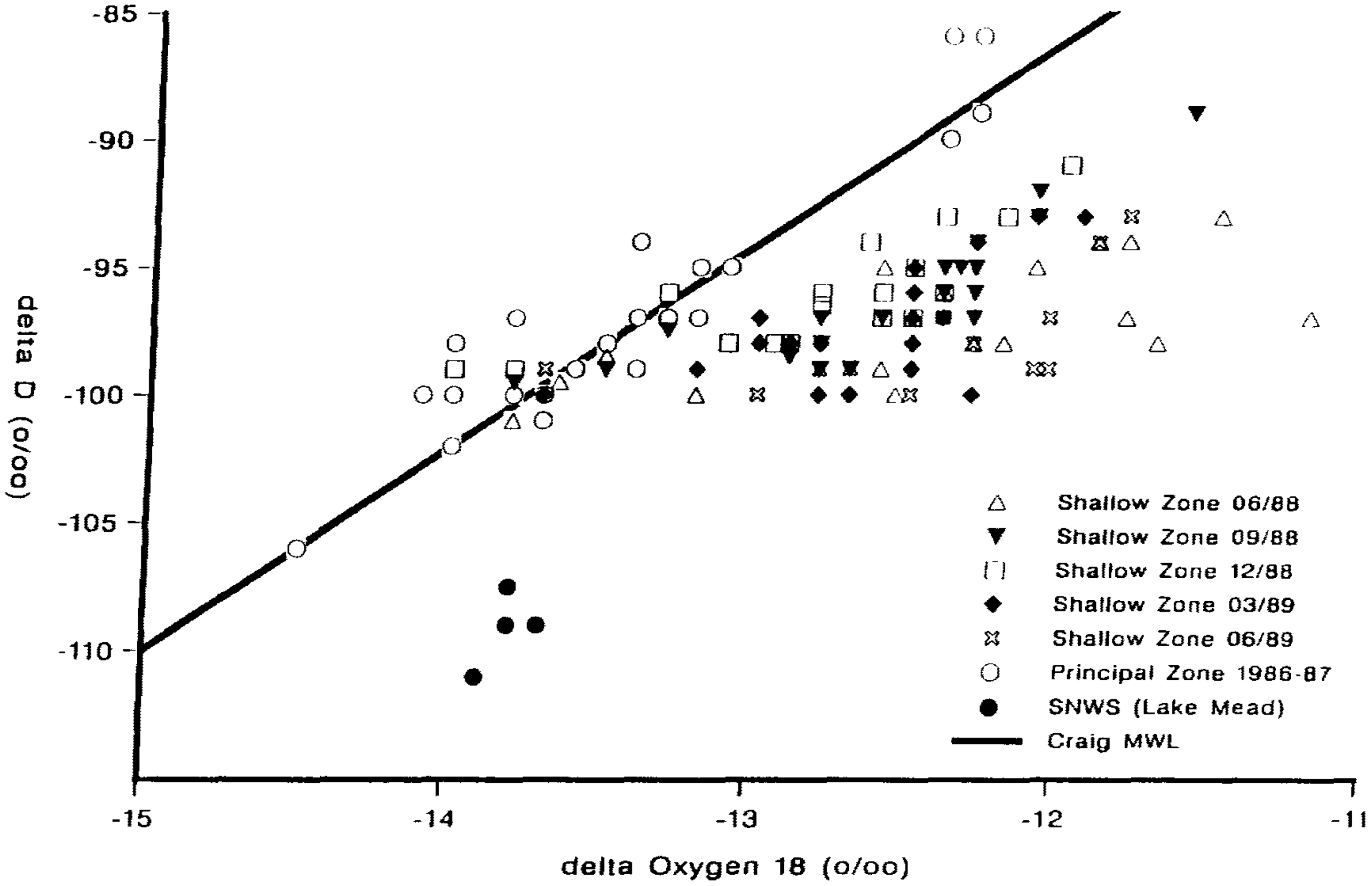

Figure 29. δD vs. $\delta^{18}O$ plot of ground-water samples from the Las Vegas Valley, Nevada shallow and principal aquifer zones and Colorado River water from the SNWS.

composition of the shallow aquifer zone will gradually shift toward the lighter composition of Lake Mead or evaporated Lake Mead water.

Natural Tracers

In order to meet Objective 5 of this investigation, the identification of possible natural tracers in the shallow aquifer zone, a comparison was made between the dissolved constituents and isotopes of the shallow zone and those in the principal aquifer zone. The shallow and principal zone data were treated as groups of samples from the population of Las Vegas Valley alluvial aquifer system water samples and were assumed to have normal distributions. Principal aquifer data from Kaufmann (1978), Weaver (1982), Dettinger (1987), Brothers and Katzer (1988), and Noack (1988) was compared both to shallow aquifer zone data from these same previous investigations, except Weaver (1982), and to the data gathered during this investigation. Student's t-test was used to determine whether there was a significant statistical difference between the two groups of samples. Tables 8 and 9 summarize the results of Student's t-test for chemical and isotopic variables between the shallow and principal alluvial aquifer zones.

The t-test results indicate that there is a significant difference between the shallow and principal zones for the majority of variables tested. There was no difference between the shallow and principal zone data for bicarbonate, phosphate, deuterium, arsenic, copper, and zinc. All other variables tested showed a significant difference between the shallow and principal zones.

Other varibles which were shown to differ significantly between the shallow and principal zones are: total dissolved solids (TDS), silica (sio2), fluoride (F^-), nitrate (NO_3^-), total organic carbon (TOC), tritium, δoxygen-18 (δ^{18} O), boron (B), barium (Ba), iron (Fe), manganese (Mn), and selenium (Se). From this list

Table 8. Results of Student's t-test for ions (mg/l) and stable isotopes $(^{o}/_{oo})$ from the Las Vegas Valley, Nevada shallow and principal alluvial aquifer zones.

Variable	Shallow Zone Mean (#Samples)	Shallow Zone σ	Principal Zone Mean (#Samples)	Principal Zone σ	Degrees of Freedom	t	Significant Difference?
Na^+	417 (285)	1100	27.5 (161)	47.8	444	4.49	yes
K^+	65.7 (286)	351	4.39 (161)	4.28	445	2.21	yes
Ca^{2+}	326 (288)	182	63.8 (161)	36.7	447	18.11	yes
Mg^{2+}	254 (286)	241	33.6 (161)	15.8	445	11.55	yes
HCO_3^-	251 (256)	106	244 (120)	292	374	0.32	no
Cl^-	479 (288)	1005	26.5 (161)	46.2	447	5.71	yes
SO_4^{2-}	1900 (287)	2580	143 (161)	164	446	8.61	yes
SiO_2	40.0 (158)	34.0	20.4 (127)	14.6	283	6.05	yes
TDS	3740 (285)	5310	470. (146)	294	429	7.42	yes
F^-	0.75 (183)	0.51	0.43 (157)	0.43	338	6.17	yes
NO_3^-	18.2 (242)	26.4	9.2 (107)	35.8	347	2.63	yes
TOC	3.70 (59)	2.94	0.54 (18)	0.30	75	4.51	yes
OPO_4	0.38 (38)	1.46	0.04 (60)	0.04	96	1.79	no
δD	-97 (109)	2.74	-97 (31)	4.21	138	0.16	no
$\delta^{18}O$	-12.6 (109)	0.58	-13.5 (31)	0.55	138	7.20	yes

Table 9. Results of Student's t-test for trace metals (mg/l) from the Las Vegas Valley, Nevada shallow and principal alluvial aquifer zones.

Variable	Shallow Zone		Principal Zone		Degrees of Freedom	t	Significant Difference?
	Mean (#Samples)	σ	Mean (#Samples)	σ			
As	0.012 (44)	0.016	0.043 (52)	0.162	94	1.26	no
B	1.31 (46)	1.22	0.25 (81)	0.24	125	7.54	yes
Ba	0.055 (29)	0.063	0.084 (71)	0.039	98	2.79	yes
Cu	0.022 (31)	0.019	0.014 (20)	0.022	49	1.48	no
Fe	0.691 (37)	1.609	0.056 (63)	0.168	98	3.11	yes
Mn	0.082 (36)	0.079	0.010 (45)	0.020	79	5.90	yes
Se	0.013 (30)	0.012	0.002 (12)	0.001	40	3.16	yes
Zn	0.061 (32)	0.082	0.111 (51)	0.174	81	1.54	no

only TDS, SiO_2, TOC, PO_4^{3-}, B, Mn, Se, and tritium are suitable for use as natural tracers. Fluoride, nitrate, δ^{18} O, barium, and iron are all unsuitable because of the large standard deviations of these variables in the principal aquifers. Barium was also excluded because it is more concentrated in the principal zone than in the shallow zone.

In summary the variables that are suitable for use as possible natural tracers are Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, TDS, SiO_2, TOC, PO_4^{3-}, B, Mn, Se, and tritium. Tritium is an ideal tracer because it is part of the water molecule and is therefore unaffected by chemical reactions. However, if no new tritium is added to the waters of the shallow aquifer zone in the future, the current average tritium content of 21 TU will decay to below background levels ($<$5 TU) within 25-30 years. The presence of one of the suitable tracers in water samples from the principal aquifers, in a concentration more than 1.96 standard deviations above the mean principal zone concentration for that constituent, should be considered indicative of contamination from the shallow aquifer zone, within a 95% confidence interval.

Historical Trends

Historical shallow aquifer zone water quality data from Kaufmann (1978) and Dettinger (1987) and historical water level data from Wood (1988b) were compared to the data generated during this investigation in order to identify historical trends in the data. The historical and current water quality data were treated as groups of samples from the population of Las Vegas Valley shallow alluvial aquifer zone waters. Student's t-test was used to determine if there were significant statistical differences between shallow zone water quality data collected by Kaufmann (1978) in the early 1970's and the data collected for this investigation in 1988 and 1989. Table 8 summarizes the results of Student's t-

Table 10. Results of Student's t-test for major ions and TDS of historical (1971-73) and current (1988-89) ground-water samples from the Las Vegas Valley, Nevada shallow alluvial aquifer zone.

Variable	Historical (1971-73) Mean (#Samples)	σ	Current (1988-89) Mean (#Samples)	σ	Degrees of Freedom	t	Significant Difference?
TDS	3380 (121)	2110	3950 (92)	1890	211	2.06	yes
Na^+	378 (121)	341	344 (92)	226	211	0.82	no
K^+	42.4 (121)	36.3	36.4 (92)	23.7	211	1.37	no
Ca^{2+}	318 (121)	168	366 (92)	142	211	2.21	yes
Mg^{2+}	240.(121)	129	293 (92)	157	211	2.69	yes
HCO_3^-	233 (121)	90.2	285 (92)	87.4	211	4.16	yes
Cl^-	442 (121)	432	357 (92)	278	211	1.64	no
SO_4^{2-}	1780 (121)	1110	2110 (92)	1090	211	2.19	yes
F^-	0.99 (77)	0.61	0.50 (37)	0.39	112	4.55	yes
NO_3^-	11.0 (121)	23.5	23.7 (92)	18.4	211	4.30	yes

test for major ions between the historical and current data.

Total dissolved solids (TDS) data generated by Dettinger (1987) in the early 1980's was compared to the 1988-89 data gathered from the same shallow wells that Dettinger (1987) used. Water level data collected from these same wells during the late 1970's and early 1980's in Wood (1988b) was compared to the 1989 water levels gathered from these wells for this investigation. Figures 30 and 31 are computer contoured maps which display the changes in TDS concentrations and water levels, respectively, between 1981 and 1989.

Student's t-test indicated that there were significant differences between the 1971-73 and 1988-89 concentrations of Ca^{2+}, Mg^{2+}, HCO_3^-, SO_4^{2-}, NO_3^-, F^-, and TDS. With the exception of fluoride, all of the varibles showed an increase during this time period. TDS concentrations have increased from a 1971-73 average of 3380 mg/l to a 1988-89 average of 3950 mg/l, an increase of 570 mg/l. Figure 30 indicates that the areas that have experienced the largest increases in TDS concentrations are the central and eastern parts of the valley. These results are not unexpected since the overapplication of irrigation waters and the rising shallow aquifer zone water table have long been qualitatively understood to leach salts from the unsaturated zone.

Net water level change in the Las Vegas Valley shallow alluvial aquifer zone between 1981 and 1989 is +0.5 meters. Water levels have risen by about 1 meter in the parts of the valley that have experienced a water table rise between 1981 and 1989. Figure 31 shows that the areas of the valley that have experienced the greatest water table rises are the southwest and southeast. Water levels in the northeastern, eastern, and south-central valley appear to have declined by about 1 meter between 1981 and 1989. Converse Consultants (1985) noted that the shallow zone water table was rising in the south-central valley between

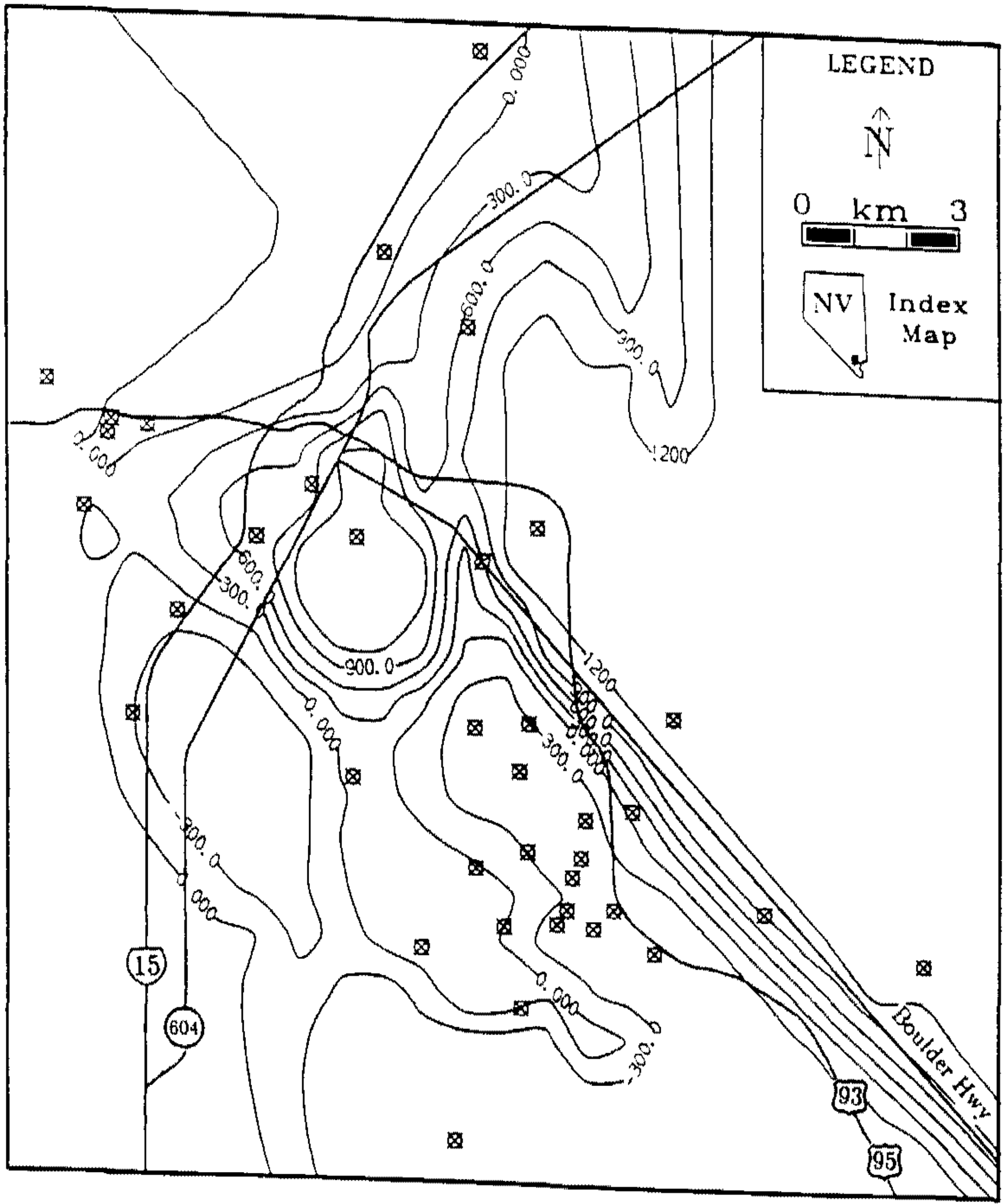

Figure 30. Computer generated contour map showing changes in the TDS concentration of ground water in the Las Vegas Valley, Nevada shallow alluvial aquifer zone between 1981 and 1989. Contour interval = 300 mg/l.

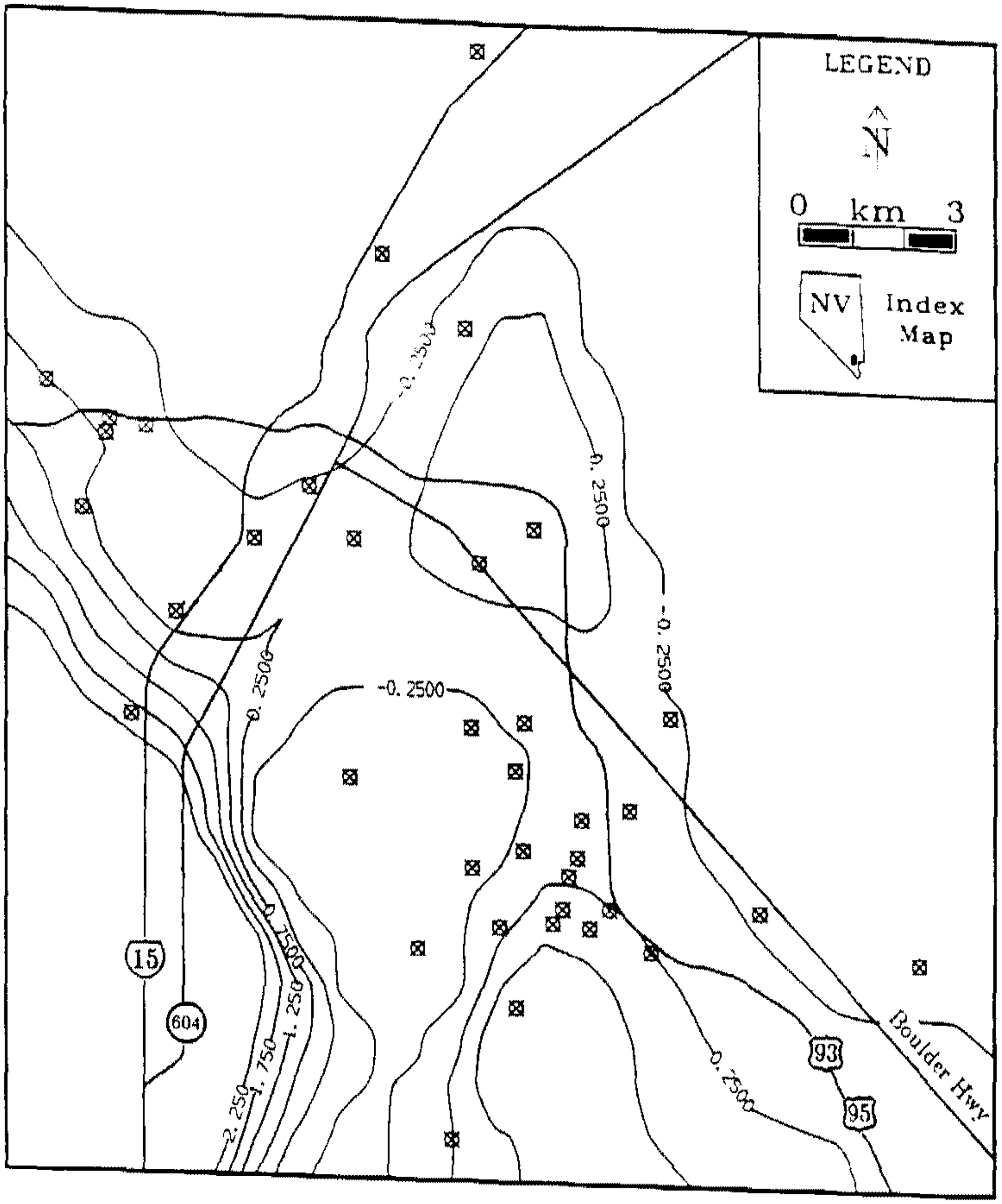

Figure 31. Computer generated contour map showing changes in water levels in the Las Vegas Valley, Nevada shallow alluvial aquifer zone between 1981 and 1989. Contour interval = 0.25 meters.

1970 and 1980 and stabilized after 1980. If current water use trends (Figure 2) and irrigation practices continue, it is expected that both the TDS concentration and the water table of the shallow aquifer zone will continue to rise.

SUMMARY AND CONCLUSIONS

The Las Vegas Valley shallow alluvial aquifer zone is a possible source of contamination to the public drinking water supply of the valley, a known source of contamination to the Colorado River, and a possible future resource to be exploited by the residents of the valley. Therefore, a thorough understanding of the recharge processes, hydraulics, and chemical nature of the shallow aquifer zone are essential to adequately plan for future water needs. This research indicates that shallow aquifer zone water quality is poor due to a combination of natural and anthropogenic causes and that water quality will further degrade if current water use trends in the valley continue. Figure 32 is a diagram of the conceptual model illustrating the hydrogeologic systems in the Las Vegas Valley, Nevada shallow alluvial aquifer zone.

Depth to water in the study area is generally less than 4 meters. A generalized equipotential water table map suggests that ground-water flow is from west to east toward the Las Vegas Wash. There are two distinct patterns of annual water level fluctuations in the valley, both of which are controlled by surficial land use practices. The natural pattern of seasonal fluctuations has water table lows in the fall and highs in the late winter to spring. The second pattern of annual water table fluctuations is influenced by irrigation practices in the valley and has water table highs in the fall and lows in the late winter to spring.

Water temperature is unaffected by land use practices and follows an annual cycle of highs in the fall and lows in the late winter to spring. The pH of shallow zone waters is near neutrality valley-wide and remains fairly constant throughout the year with only minor monthly variations. EC variations followed a similar pattern in the majority of wells sampled, experiencing semi-annual highs in mid-summer and late fall, 1988, followed by a steady decline through

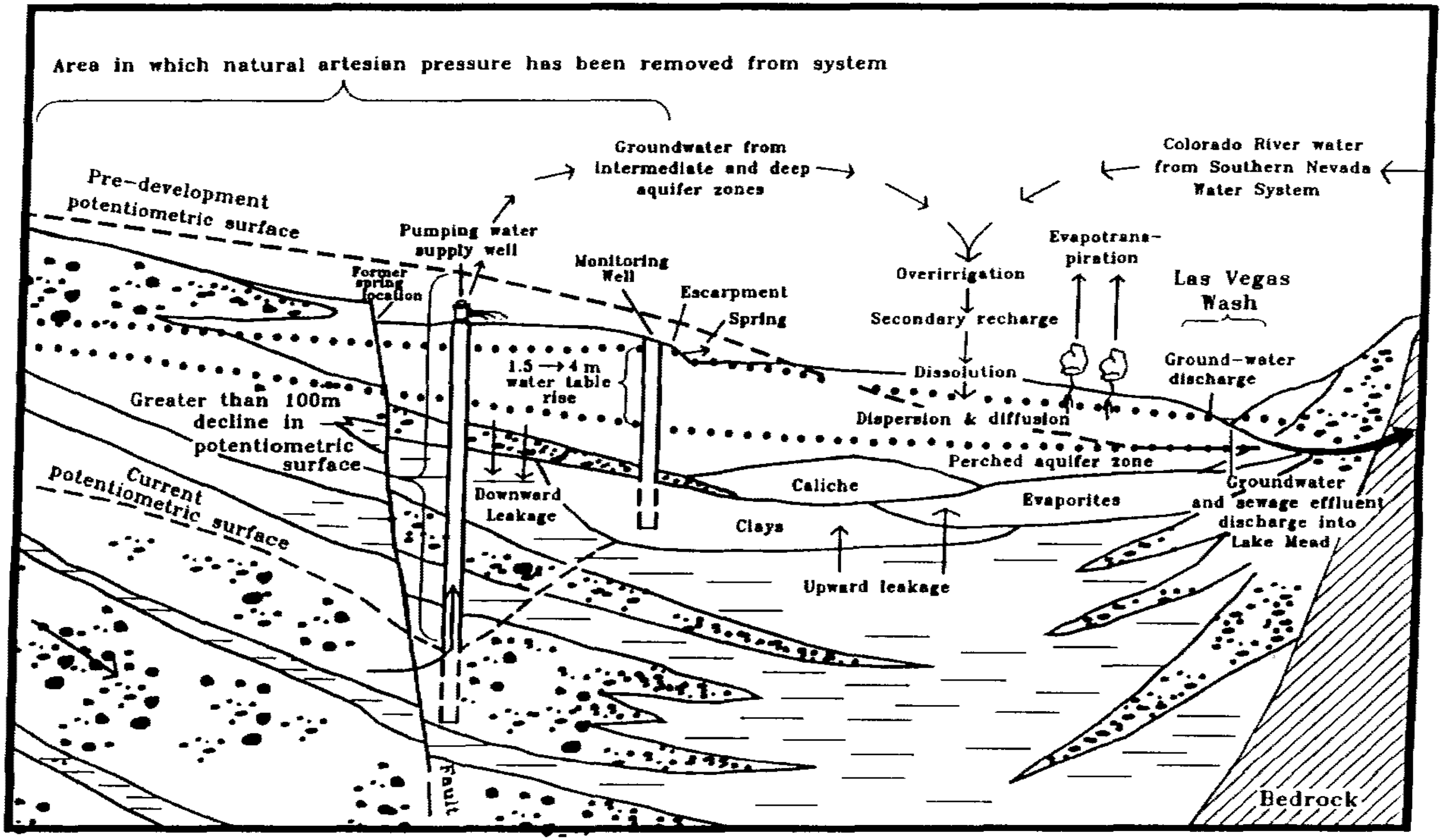

Figure 32. Generalized diagram of a conceptual model illustrating the current hydrogeologic systems of the Las Vegas Valley, Nevada shallow alluvial aquifer zone.

the end of 1989. This pattern may be explained by alternating periods of variable duration during which saline water is concentrated at the water table and diluted by diffusion and hydrodynamic dispersion.

Ground-water quality changes along flow path from a fresh Ca^{2+}-Mg^{2+}-HCO_3^- type water to a moderately saline Ca^{2+}-Mg^{2+}-SO_4^{2-} type water. This evolution along flow path is due to natural dissolution, evapotranspiration, greater solubility of the gypsiferous soils in the eastern valley, decreasing aquifer permeability from west to east, and addition of salts from secondary recharge. Concentrations of all major ions, except bicarbonate, increase along flow path. Bicarbonate concentrations appear to be controlled by P_{CO_2} rather than lithology.

TDS concentrations vary temporally but do not appear to follow an annual pattern. TDS highs and lows are distributed fairly uniformly throughout the year. There is no evidence indicating that surficial land use practices are affecting short term TDS fluctuations. Trilinear diagram plots indicate that as TDS concentrations fluctuate, ion ratios remain constant. This suggests that ion ratios, and therefore, water-types, are unaffected by the chemical composition of secondary recharge waters and are controlled by the mineralogy of the surficial valley-fill deposits.

Constancy of ion ratios also supports the model proposed to explain the observed temporal EC variations. According to the proposed model, the variations in EC/TDS are caused by a cycle of dissolution of aquifer material by secondary recharge, concentration of saline water near the water table from this dissolution and from evapotranspiration, and dilution of the saline zone from mixing due to diffusion and hydrodynamic dispersion. The lack of temporal variations in ion ratios supports the proposed model because it indicates that

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neither mineral precipitation or ion-exchange processes are occurring to a noticeable extent in the shallow aquifer zone, thereby eliminating these two processes from consideration as factors controlling temporal EC/TDS variations.

NO_3^- concentrations do not follow a spatial trend across the study area and appear to be strongly controlled by land use, *e.g.*, septic tank use, irrigation with treated sewage effluent, and primarily by fertilization practices and overirrigation of turf grass. PO_4^{3-} concentrations have been declining in shallow ground water over the last 16-18 years, most likely as a result of the decreasing use of septic tanks.

Geochemical modeling with WATEQDR indicates that most of the samples collected were oversaturated with respect to calcite and dolomite, undersaturated with respect to gypsum, and had elevated P_{CO_2} values relative to atmospheric P_{CO_2}. Temporal analysis of the P_{CO_2}-calcite-gypsum system indicates that the saturation index (SI) of calcite varies inversely with P_{CO_2} and gypsum SI variations. The SI of gypsum and P_{CO_2} have sinusoidal cycles with semi-annual peaks in summer and winter and lows in fall and spring, which is 180° out of phase with calcite SI variations. This system is driven by annual temperature variations and the common-ion effect. According to the proposed model, higher CO_2 concentrations in the soil atmosphere in summer leads to higher P_{CO_2}'s in the water. High summer P_{CO_2}'s in summer coupled with the lowered solubility of calcite at elevated temperatures causes a drop in the SI of calcite in summer. As the SI of calcite drops, more gypsum can be dissolved due to the common ion effect and the SI of gypsum rises. In the winter, lower temperatures increase the solubility of gypsum, which results in dissolution of gypsum. a decrease in the saturation state of calcite, and the production of $CO_{2(aq)}$.

All samples were oversaturated with respect to quartz but were undersaturated with respect to amorphous silica. Silica saturation is higher in summer and lower in winter, most likely due to the effects of temperature upon silica solubility.

MCL's were exceeded 22 times: twice for arsenic, 11 times for selenium, and 9 times for nitrate. SMCL's were exceeded 241 times, the majority of which were for chloride (58 excedences), sulfate (87 excedences), and total dissolved solids (89 excedences.

Tritium activity averaged around 21 TU and suggested that no tritium had been added to the shallow aquifer zone since 1971-73. Tritium was below background levels in the northern valley because untritiated principal aquifer zone water is the main source of the public water supply in this part of the valley. Delta deuterium and δ^{18} O plot within a low humidity evaporation envelope of principal aquifer zone water, indicating that the water in the shallow aquifer zone originated as principal aquifer zone water. There is no spatial trend across the valley for either δD or δ^{18} O. The interpretation of isotopic data was severely restricted by both the unquantified spatial and temporal variation in the isotopic signature of secondary recharge waters and the lack of data on secondary recharge rates.

Suitable natural tracers present in the shallow aquifer zone that might be used to trace the downward leakage of water from the shallow to the principal zone are chloride, sulfate, total dissolved solids (TDS), silica, flouride, nitrate, total organic carbon (TOC), orthophosphate (PO_4^{3-}), boron, manganese, selenium, and tritium.

Comparison of the data gathered during this investigation indicates that TDS concentrations rose by around 570 mg/l from 1971-73 to 1988-89. The ions responsible for this increase are Ca^{2+}, Mg^{2+}, HCO_3^-, SO_4^{2-}, and NO_3^-. The central and eastern parts of the valley that experienced rapid population growth between the early 1970's and late 1980's also experienced the greatest increase in TDS content of shallow zone waters, suggesting that the initiation of overirrigation in these areas may have caused TDS to rise. Water levels rose in the valley by an average of around 0.5 meter between 1981 and 1989. The areas experiencing the greatest water level rises are the southwest and west while water levels appear to have declined in the northeastern, eastern, and south-central parts of the valley. If current water use practices in the valley continue, it is expected that water levels in the Las Vegas Valley shallow alluvial aquifer zone will continue to rise and that water quality will continue to degrade.

FURTHER RESEARCH

Spatial and temporal variations of the physical parameters, hydrogeology, and isotopic composition of the Las Vegas Valley shallow alluvial aquifer zone need to be better quantified through expansion of the monitoring well network and continued data collection. The areal extent of the monitoring well network used in this investigation was defined by the presence of previously existing wells. Consequently, there are few wells in and little hydrogeological data from most of the areas of the valley that are experiencing rapid development, such as the northwest, southwest, and southeast (Henderson). Shallow monitoring wells should be drilled to at least several meters below the water table in these areas. Water-level, physical parameter, hydrogeochemistry, and isotopic data should then be gathered from the entire shallow zone monitoring network annually in order both to establish base lines for these parameters in areas with no previous hydrogeological data and to quantify long-term valley-wide trends in these parameters.

As stated in the introduction, this document describes the results of the first phase of a five phase long-term research project. The other four stages of this research project also need to be completed to increase the understanding of the Las Vegas Valley shallow alluvial aquifer zone. The four uncompleted phases are: (1) the quantification of secondary recharge rates from over irrigation, (2) the evaluation of the hydraulic properties of the shallow aquifer zone and the hydraulic connection between the shallow and principal aquifers, (3) the calculation of the leakage rate between the shallow and principal aquifer zones, and (4)

changes caused by artificial recharge of CRW may be difficult to separate from changes caused by downward leakage of water from the shallow aquifer zone.

Effects upon water levels and water quality due to the large man-made lake and adjacent development on the Las Vegas Wash in Henderson, named the "Lake at Las Vegas", need to be determined. The Lake at Las Vegas is going to be lined with a layer of compacted clay and filled with 123,000,000 m^3 of potable water. Although the developer of the Lake at Las Vegas project claims that the clay liner will not leak, it is likely that some water will leak from the lake into the surrounding soil. It is also quite likely that new residents of the area will over-irrigate and secondary recharge to the shallow ground-water system in the area will occur.

A monitoring network should be designed and installed in this area during the construction phase of the project and baseline water level and water quality data should be collected. Data collection should continue after completion of the Lake at Las Vegas to determine if there are any long-term impacts of leakage from the lake and secondary recharge from the adjacent development upon water levels and water quality in this area.

REFERENCES

Back, W., 1966, Hydrochemical facies and ground-Water flow patterns in the northern part of the Atlantic Coastal Plain: U. S. Geological Survey Professional Paper 498A.

Bateman, R.L., 1976, Analysis of effects of modified waste-water disposal practices on lower Las Vegas Wash: Reno, Nevada, Desert Research Institute Water Resources Center, project report no. 39, 60 p.

Bell, John W., and Smith, E.I., 1980, Geologic map of the Henderson quadrangle, Nevada: Nevada Bureau of Mines and Geology Map 67

Bell, J.W., 1981, Subsidence in Las Vegas Valley, Nevada: Nevada Bureau of Mines and Geology Bulletin 95, 84 p.

Bierly and Associates, 1980, Las Vegas Wash environmental assessment for Clark County Wetlands Park: Las Vegas, Nevada, The Office of Robert Perron, EDCON and Montgomery Engineers of Nevada, unpublished consulting report, 103 p.

Bingler, E.C., 1977, Geologic map, Las Vegas SE quadrangle: Nevada Bureau of Mines and Geology Urban Maps Series, Las Vegas SE Folio, Map 3 Ag.

Bohannon, R.G., 1984, Nonmarine sedimentary rocks of Tertiary Age in the Lake Mead region, southeastern Neveda and northwestern Arizona: U. S. Geological Survey Professional Paper 1259, 72 p.

Bohm, B., and Jacobson, R.L., 1981, WATEQDR, An updated version of WATEQF-A computerized chemical model of natural waters: M.S. Thesis, University of Nevada, Reno and Desert Research Institute, 79 p.

Brook, G.A, Folkoff, M.E., and Box, E.O., 1983, A world model of soil carbon dioxide: Earth Surface Processes and Landforms 8, p. 79-88.

Brothers, Kay, and Katzer, Terry, 1987, Artificial recharge to the Las Vegas Valley ground-water system, Clark County, Nevada: Geological Society of America, Abstracts with Programs, 1987 Annual Meeting and Exposition, p. 602.

_________________________________, 1988, Ground-water chemistry changes resulting from stressed aquifer systems in Las Vegas Valley, Clark County, Nevada: Nevada Division of Environmental Protection, 66 p.

Carpenter, E., 1915, Ground water in southeastern Nevada: U.S. Geological Survey, Water Supply Paper 365, 86 p.

Chebotarev, I.I., 1955, Metamorphism of natural waters in the crust of weathering: Geochemica et Cosmochemica Acta, vol. 8, p. 22-48, 137-170, 198-212.

Claasen, H.C., 1982, Guidelines and techniques for obtaining water samples that accurately represent the water chemistry of an aquifer: U.S. Geological Survey Open-File Report 82-1024, 49 p.

Cochran, G.F., Fitzsimmons, D.L., Fowler, D.D., Garrett, J.R., Leland, J., and Reichert, L., 1977, Management of water quality in an arid urban environment: A study of Las Vegas Valley, Nevada: Desert Research Institute Water Resources Center Technical Report Series H-W #33, 215 p.

Converse Consultants, 1985, Shallow ground water and geotechnical investigation: unpublished consulting report prepared for the Clark County Department of Comprehensive Planning, 107 p.

Craig, H., 1961, Standard for reporting concentrations of deuterium and oxygen-18 in natural waters: Science, v. 133, p. 1833-1834.

Desert Research Institute Water Resources Center, 1984, Review of site hydrogeology and existing monitoring network, TIMET, Inc., Henderson, Nevada: Reno, Nevada, Desert Research Water Resources Center, unpublished consulting report, 120 p.

Dettinger, M.D., 1987, Ground-water quality and geochemistry of Las Vegas Valley, Clark County, Nevada, 1981-1983: implementation of a monitoring network: U.S. Geological Survey, Water Resources Investigations Report 87-4007, 69 p.

Dinger, J.S., 1977, Relation between surficial geology and near-surface ground-water quality, Las Vegas Valley, Nevada: University of Nevada, Reno, unpublished Ph.D. dissertation, 215 p.

Dixon, E.C., 1990, Hydrogeology and ground-water quality in the Sanders area, western Puerco River Basin, Arizona: M.S. thesis, University of nevada, Las Vegas, 157 p.

Domenico, P.A; Stephenson, D.A.; and Maxey, G.B., 1964, Ground water in Las Vegas Valley: Desert Research Institute, Technical Report No. 7, 53 p.

Drever, J.I., 1982, The Geochemistry of Natural Waters: Englewood Cliffs, New Jersey, Prentice-Hall, 388 p.

Dugan, J.P. Jr., Borthwick, J., Harmon, R.S., Gagnier, M.A., Glahn, J.E., Kinsel, E.P., MacLeod, S., Viglino, J.A., and Hess, J.W., 1985, Guanidine hydrochloride method for the determination of water oxygen isotope ratios and the oxygen-18 fractionation between carbon dioxide and water at 24 degrees Celcius: Analytical Chemistry, vol. 57, p. 1734-1736.

Ecology and Environment Inc., 1985, Technical summary of soil and in situ gas sampling, Basic Management, Inc., Henderson, Nevada: San Francisco, Ecology and Environment, Inc., unpublished consulting report, 18 p.

Fleck, R.J., 1970, Age and possible origin of the Las Vegas Valley Shear Zone, Clark and Nye Counties, Nevada: Geological Society of Americal Abstracts with Programs, v. 2, no. 5, p. 333.

French, R.H., Mifflin, M.D., and Edkins, J., 1982, Salt storage in lower Las Vegas Valley: Desert Research Institute Water Resources Center, Las Vegas, Nevada, 312 p.

Friedmund, L., 1953, Deuterium content of natural waters and other substances: Geochem. et Cosmochim. Acta, v 4., p. 84-103.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, New Jersey, Prentice-Hall, 604 p.

Fritz, P., and Fontes, J.Ch., 1980, Handbook of Environmental Isotope Geochemistry, Volume 1, The Terrestrial Environment: New York, Elsevier, 545 p.

Garn, H.S., 1988, Seasonal changes in ground-water levels in the shallow aquifer near Hagerman and the Pecos River, Chaves County, New Mexico: U.S. Geological Survey Open-File Report 88-197, 19 p.

Geraghty & Miller, Inc., 1980, Ground-water investigation, Stauffer Chemical Company, Henderson, Nevada: Syosset, New York, Geraghty and miller, Inc., unpublished consulting report, 41 p.

Gilbert, G., 1875, Report on the geology of portions of Nevada, Utah, California, and Arizona: U. S. Geological Survey, 100th Mer. Rpt., vol. 3.

Hanks, R.J., and Ashcroft, G.L., 1980, Applied Soil Physics, Soil Water and Temperature Applications: New York, Springer-Verlag, p. 132-135.

Hardman, G., and Miller, M.R., 1934, The quality of waters of southeastern Nevada: University of Nevada, Agricultural Experiment Station, Bulletin 136, 62 p.

Harrill, J.R., 1976a, Pumping and depletion of ground-water storage in Las Vegas Valley, Nevada, 1955-74: Nevada Department of Conservation and Natural Resources Division of Water Resources, Water Resources Bulletin No. 44, 69 p.

______________ 1976b, Water-level changes associated with ground-water development in Las Vegas Valley, Nevada, 1971-75, fourth progress report-summary of data: Nevada Department of Conservation and Natural Resources in cooperation with U.S. Geological Survey, Water Resources-Information Series, Report 22, 46 p.

______________ 1977, Water-level changes associated with ground-water development in Las Vegas Valley, Nevada, 1971-75: Nevada Department of Conservation and Natural Resources in cooperation with U.S. Geological Survey, Water Resources-Information Series, Report 26, 31 p.

Haynes, C.V., 1967, Quaternary geology of the Tule Springs Area, Clark County, Nevada: Pleistocene Studies in Southern Nevada, Nevada State Museum Anthropological Papers, no. 13, p. 15-104.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 836-B, 263 p.

Hess, J.W., and Mifflin, M.D., 1978, A feasibility study of water production from deep carbonate aquifers in Nevada: Desert Research Institute, Water Resources Center, Publication No. 41054, 125 p.

__________, and Patt, R.O., 1977, Nitrogen contamination sources in shallow ground water, Las Vegas Area, Nevada: Desert Research Institute, Water Resources Center, Technical Report Series HW-32, 60 p.

Hillel, D., 1980, Fundamentals of Soil Physics: New York, Academic Press, p. 303-308.

Houghton, J.G., Sakamoto, C.M., and Gifford, R.O., 1975, Nevada's weather and climate: Nevada Bureau of Mines and Geology, Special Publication 2, 78 p.

Johns, F.L., 1975, Handbook of radiochemical analytical methods, program element 1HA325: National Environmental Research Center, Office of Research and Development, U.S. Environmental Protection Agency, Las Vegas, Nevada, 5 p.

JRB Associates, 1981, Henderson indutrial complex hazardous waste investigation: Ann Arbor, Michigan, JRB Associates, Environmental Research Group, unpublished consulting report, 47 p.

Kaufmann, R., 1978, Land and water use effects of ground-water quality in Las Vegas Valley: U.S. Environmental Protection Agency, EPA-600/2-78-179, 215 p.

Katzer, T., 1977, Water-level changes associated with ground-water development in Las Vegas Valley, Nevada, March 1976 to March 1977: NV Dept. Cons. and Nat. Res., Water Res. Info. Series Rept. 27, 35 p.

Kleinfelder & Associates, 1983, Geology/hydrogeology evaluation, TIMET, Henderson, Nevada; Las Vegas, Nevada, J.H. Kleinfelder and Associates, unpublished consulting report, 18 p.

Lico, M.S., Welch, A.H., and Hughes, J.L., 1987, Geochemistry of ground water in the shallow alluvial aquifer, Carson Desert, western Nevada *in* Chemical Quality of Water and the Hydrologic Cycle (R.C. Averett and D.M. McKnight, eds.): Chelsea, Michigan, Lewis Publishers, p. 89-109.

Loeltz, Ground-water conditions in the vicinity of Lake Mead Base, Las Vegas Valley, Nevada: U.S. Geological Survey Water Supply Paper 1669-Q, 17 p.

Longwell, C.R., Pampeyon, E.H., Bowyer, Ben, and Roberts, R.J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines and Geology, Bulletin 62, 218 p.

Malmberg, G.T, 1964, Land subsidence in Las Vegas Valley, Nevada, 1935-63: Nevada Department of Conservation and Natural Resources Information Report 5, 10 p.

________________ 1965, Available water-supply of the Las Vegas ground water basin, Nevada. U.S. Geological Survey, Water Supply Paper 1780, 116 p.

Matti, J.C., and Bachhuber, F.C., 1982, Preliminary geologic map of the Las Vegas SW quadrangle: Nevada Bureau of Mines and Geology Open-File Map 82-6.

Matti, J.C., and Morton, D.M., 1982a, Preliminary geologic map of the Las Vegas NW quadrangle: Nevada Bureau of Mines and Geology Open-File Map 82-4.

________________ 1982b, Preliminary geologic map of the Las Vegas NE quadrangle: Nevada Bureau of Mines and Geology Open-File Map 82-5.

Maurer, D.K., 1989, Water-level data for Las Vegas Valley, Clark County, Nevada, 1986-87: U.S. Geological Survey, Open-File Report 88-200, 45 p.

Maxey, G.B., and Jameson, C.H., 1948, Geology and water resources of Las Vegas, Pahrump and Indian Spring Valleys, Clark and Nye Counties, Nevada: Nevada Department of Conservation and Natural Resources, Water Resources Bulletin No. 5, 121 p.

Mendenhall, W.C., 1909, Some desert watering places in southeastern California and southwestern Nevada: U.S. Geological Survey, Water Supply Paper 224.

Mindling, Anthony, 1965, An investigation of the relationship of the physical properties of fine-grained sediments to land subsidence in Las Vegas Valley, Nevada: Reno, Nev., University of Nevada, M.S. thesis, 90 p.

________________ 1971, A summary of data relating to land subsidence in Las Vegas Valley: University of Nevada, Desert Research Institute Report, 55 p.

Mifflin, M.D., 1968, Delineation of ground-water flow systems in Nevada: Desert Research Institute, Water Resources Center, Technical Report Series H-W, Publication No. 4, 110 p.

____________, and Wheat, M.M., 1979, Pluvial lakes and estimated climates of Nevada: Nevada Bureau of Mines and Geology Bulletin 94, 57 p.

Miller, M.R.; Hardman, George; and Mason, H.G., 1953, Irrigation waters of Nevada: University of Nevada, Reno, Agricultural Experiment Staion Bulletin 187, 63 p.

Morton, T.G., Gold, A.J., and Sullivan, W.M., 1988, Influence of overwatering and fertilization on nitrogen losses from home lawns. Journal of Environmental Quality, vol. 17, p. 124-130.

Naff, R.L., Maxey, G.B., and Kaufmann, R.F., 1974, Interbasin ground-water flow in southern Nevada: Nevada Bureau of Mines and Geology Report 20, 28 p.

Noack, R.E., 1988, Sources of ground-water recharging the principal alluvial aquifers in Las Vegas Valley, Nevada: M.S. thesis, University of Nevada, Las Vegas, 160 p.

Orcutt, R.G., and Cochran, G.F., 1967, A reconnaissance of the technology for recharging reclaimed waste water into the Las Vegas Valley ground-water basin. Water Resources Center, Desert Research Institute, Report No. 42002, Reno, Nevada, 123 p.

Patt, R.O., 1978, Las Vegas Valley water budget: relationship of distribution, consumptive use, and recharge to shallow ground water: U.S. Environmental Protection Agency, EPA-600/2-78-159, 60 p.

Peter, K.D., 1987, Ground-water flow and shallow-aquifer properties in the Rio Grande inner valley south of Albuquerque, Bernalillo county, New Mexico: U.S. Geological Survey Water Resources Investigations Report 87-4015, 26 p.

Piper, A.M., 1944, A graphical procedure in the geochemical interpretation of water analysis: Transactions of the American Geophysical Union, vol. 25, p. 914-923.

Plume, R.W., 1984, Ground-water conditions in Las Vegas Valley, Clark County, Nevada: Part I. Hydrogeologic Framework: U.S. Geological Survey Open-File Report 84-130, 25 p.

____________ 1989, Ground-water conditions in Las Vegas Valley, Clark County, Nevada: Part I. Hydrogeologic Framework: U.S. Geological Survey Water-Supply Paper 2320-A, 14 p.

Plummer, L.N., Jones, B.F., and Truesdell, A.H., 1976, WATEQF - A FORTRAN IV version of WATEQ, a computer program for calculating chemical equilibrium of natural waters: U.S. Geological Survey Water Resources Investigations 76-13, 61 p.

Price, C.E., Jr., 1966, Surficial geology of the Las Vegas quadrangle, Nevada: Salt Lake City, Utah, University of Utah, unpublished M.S. thesis, 60 p.

Quade, J., 1986, Late Quaternary environmental changes in the upper Las Vegas Valley, Nevada: Quaternary Research, vol. 26, p. 340-357.

Rabinowitz, D.D., Gross, G.W., and Holmes, C.H., 1977, Environmental tritium as hydrometric tool in the Roswell Basin, New Mexico, 1. Tritium input function and precipitation-recharge relation: Journal of Hydrology, vol. 32, p. 3-17.

Roline, R.A., and Sartoris, J.J., 1988, Changes in the morphometry of Las Vegas Wash and the impact on water quality: Lake and Reservoir Management, v. 4, pp 135-142.

Seiler, R.L., and Waddell, K.M., 1984, Reconnaissance of the shallow-unconfined aquifer in Salt Lake Valley, Utah: U.S. Geological Survey Water Resources Investigations Report 83-4272, 24 p.

Stauffer Chemical Company, 1982, Henderson groundwater investigation project--1981, Las Vegas, Nevada, 37 p.

Stiff, H.A.,Jr., 1951, The Interpretation of chemical water analysis by means of patterns: Journal of Petroleum Technology, vol. 3, no. 10, p. 15-17.

Stumm, W., and Morgan, J.J., 1981, Aquatic Chemistry: New York, John Wiley & Sons, 780 p.

Tabor, L.L., 1970, Geology of the Las Vegas area: John A. Blume and Associates, Research Division, San Francisco, California, 65 p.

Technos Inc., 1983, Geophysical investigation of the Henderson site plume, Henderson (Las Vegas), Nevada: Miami, Florida, Technos, Inc., unpublished consulting report prepared for Lockheed Engineering and Management Services Company, Inc. and the U.S. EPA, 35 p.

URS Company, 1977a, Subsurface water management interim report #1: Las Vegas, Nevada, URS Company, unpublished consulting report, 52 p.

____________ 1977b, Water policies for Clark county and the Colorado River Basin water quality report series: Las Vegas, Nevada, URS Company, unpublished consulting report, 93 p.

U.S. Bureau of Reclamation, 1982, Hydrogeoloic analysis of lower Las Vegas Valley: Boulder City, Nevada, U.S. Bureau of Reclamation, Colorado River Basin Salinity Control Project Title II, 260 p.

U.S. Federal Water Pollution Control Administration, 1967, Report on pollution in Las Vegas Wash and Las Vegas Bay: Cincinnati, Ohio, U.S. Federal Water Pollution Control Administration, 18 p.

Van Denburgh, A.S., Seitz, H.R., Durbin, T.J., and Harrill, J.R., 1982, Proposed monitoring network for ground-water quality, Las Vegas Valley, Nevada: U.S. Geological Survey Open-File Report 80-1286, 25 p.

Weaver, S.C., 1982, The hydrogeochemistry of the principal alluvial aquifers in Las Vegas Valley, Nevada and the chemical effects of artificial recharge of Colorado River water, M.S. thesis, University of Nevada, Reno, 159p.

Westphal, J.A., 1977, Simulation modeling of the shallow ground water system in Las Vegas Valley, Nevada: University of Nevada, Desert Research Institute Project Report 41047C, 57 p., appendix 1, 137 p.

White, W.B., 1988, Geomorphology and Hydrology of Karst Terrains: New York, New York, Oxford University Press, 464 p.

Wigley, T.M.L., 1973, Chemical evolution of the system calcite-gypsum-water: Canadian Jour. Earth Sci., vol. 10, p. 306-315.

Woessner, W.W., 1980a, Qualitative assessment of the economic impact of a rising water table, Las Vegas, Nevada: Las Vegas, Nevada, Desert Research Institute Water Resources Center Publication no. 41068, 23 p.

____________ 1980b, Reconnaissance evaluation of water quality- salinty loading relationship of intermittent flow events in a desert environment-Las Vegas, Nevada: Las Vegas, Nevada, Desert Research Institute Water Resources Center Report YA-512-CT-200.

Wood, D.B., 1979, Water-level changes associated with ground-water development in Las Vegas Valley, Nevada, March 1977 to March 1978: NV Dept. Cons. and Nat. Res., Water Res. Info. Series Rept. 29, 38 p.

__________ 1988a, Water-Level changes associated with ground-water development in Las Vegas Valley, Nevada, 1978-79: NV Dept. Cons. and Nat. Res., Water Res. Info. Series Rept. 30, 34 p.

__________ 1988b, Water-level changes associated with ground-water development in Las Vegas Valley, Nevada, 1979-81: NV Dept. Cons. and Nat. Res., Water Res. Info. Series Rept. 31, 41 p.

APPENDIX A.

Well Location and Construction Data

Site Number ttrrssqqqq#	Site Name(s)	Latitude ddmmss	Longitude dddmmss	Elev meters (ft)	Depth meters (ft)	Screen meters (ft)	Owner	Water Use	Data Source(s)
20610113341	USGS #19 #19 #8 Craig & I-15 S20 E61 01ACC 1 #8	361425	1150615	584.9 (1919)	25.60 (84.0)	25-25.6 (82-84)	USGS	U	Wild, 1990 Maurer, 1989 B & K, 1988* Wood, 1988b Dettinger, 1987
20611433331	USGS #15 #15 #10 Carey & I-15 Carey & I-15 Well #10	361212	1150659	582.2 (1910)	14.02 (46.0)	13.1-14 (43-46)	USGS	U	Wild, 1990 Maurer, 1989 B & K, 1988 Noack, 1988 Dettinger, 1987
20612433122	NLVWD CollegePark#2-Shall Tonopah Park	361131	1150644	561.1 (1841)	9.14 (30.0)	6.1-9.1 (20-30)	LVVWD	U	Wild, 1990
20612933341	MDB3 Meadows Detention Basin 3	361026	1151110	643.1 (2110)	9.11 (29.9)	3.0-8.9 (9.9-29.9)	LVVWD	U	Wild, 1990
20613024301	USGS #34 #34 #15 Municipal Golf Course S20 E61 30ACC 1 #15	361053	1151205	609.6 (2000)	9.14 (30.0)	7.6-9.1 (25-30)	USGS	U	Wild, 1990 Maurer, 1989 B & K, 1988 Wood, 1988b Dettinger, 1987
20613111411	MDB6 Meadows Detention Basin 6	361018	1151113	649.2 (2130)	10.06 (33.0)	4-7 (13-23)	LVVWD	U	Wild, 1990
20613143401	USGS #37 #37 #46 Hinson/Charleston Hinson Park Well S20 E61 31DCD 1 #46	360937	1151134	656.8 (2155)	5.49 (18.0)	4.3-5.5 (14-18)	USGS	U	Wild, 1990 Maurer, 1989 B & K, 1988 Noack, 1988 Wood, 1988b Dettinger, 1987
20613221121	MDB5 Meadows Detention Basin 5	361023	1151043	640.4 (2101)	16.22 (53.2)	13.2-16.2 (43.2-53.2)	LVVWD	U	Wild, 1990
20613431101	USGS #48 #48 S20 E61 34CAA 1 Clark Co Public Works	360837	1150955	612.6 (2010)	6.71 (22.0)	5.5-6.7 (18-22)	USGS	U	Wild, 1990 Maurer, 1989 Wood, 1988b
20613644402	LG048 Charleston Blvd 40 #18 DRI LG048 #18 LG048 Charleston Blvd 40	360933	1150551	550.877 (1807.34)	12.19 (40.0)	11-11.9 (36-39)	DRIWRC	U	Wild, 1990 B & K, 1988 Dettinger, 1987 Kaufmann, 1978
21610113331	USGS #11 #11 Boulder Hwy Well S21 E61 01ACC 1 #48	360908	1150629	560.8 (1840)	7.16 (23.5)	5.9-7.2 (19.5-23.5)	USGS	U	Wild, 1990 Maurer, 1989 Noack, 1988 Wood, 1988b Dettinger, 1987

Site Number ttrrssqqqq#	Site Name(s)	Latitude ddmmss	Longitude dddmmss	Elev meters (ft)	Depth meters (ft)	Screen meters (ft)	Owner	Water Use	Data Source(s)
21610311141	USGS #47 #47 Circle Park Well S21 E61 03AAA 1 #49 Maryland & Charleston	360924	1150811	606.6 (1990)	4.57 (15.0)	3.4-4.6 (11 15)	USGS	U	Wild, 1990 Maurer, 1989 Noack, 1988 Wood, 1988b Dettinger, 1987
21610412301	USGS #43 #43 #24 Wall & I-15 Wall Street Well S21 E61 04ABC 1 #24	360921	1150936	623.9 (2047)	5.18 (17.0)	4.0-5.2 (13-17)	USGS	U	Wild, 1990 Maurer, 1989 B & K, 1988 Noack, 1988 Wood, 1988b Dettinger, 1987
21610922221	USGS #3a #3 Sahara & I-15 Well S21 E61 09BBB 1 #50 Sahara & I-15	360838	1151018	632.5 (2075)	7.62 (25.0)	6.4-7.6 (21-25)	USGS	U	Wild, 1990 Maurer, 1989 Noack, 1988 Wood, 1988b Dettinger, 1987
21611324121	C11 Converse Well #11	360734	1150640	575.715 (1888.83)	7.62 (25.0)	2.7-5.2 (9-17)	Clark Co.	U	Wild, 1990 Converse, 1985
21611341341	C12 Converse Well #12	360708	1150606	578.510 (1898.00)	9.14 (30.0)	7.6-9.1 (25-30)	Clark Co.	U	Wild, 1990 Converse, 1985
21611544441	Maryland Pkway & Flamingo S21 E61 15DDDD1 #51	360701	1150813	609.6 (2000)	7.35 (24.1)	6.4-7.3 (21-24)	Clark Co.	U	Wild, 1990 Maurer, 1989 Dettinger, 1987
21611721441	USGS #40 #40 #28 Spring Mtn & I-15 Spring Mtn & I-15 Well S21 E61 17BAD 1 #28	360735	1151052	646.2 (2120)	13.72 (45.0)	12.5 13.7 (41-45)	USGS	U	Wild, 1990 Maurer, 1989 B & K, 1988 Noack, 1988 Wood, 1988b Dettinger, 1987
21612431401	USGS #56 #56 Paradise Val.Co.Park Well S21 E61 24CAD 1 #53 Paradise Park	360617	1150638	594.4 (1950)	7.32 (24.0)	6.1-7.3 (20-24)	USGS	U	Wild, 1990 Maurer, 1989 Noack, 1988 Wood, 1988b Dettinger, 1987
21612542111	C36 Converse Well #36	360534	1150617	596.356 (1956.55)	8.23 (27.0)	6 1 7.9 (20 26)	Clark Co.	U	Wild, 1990 Converse, 1985
21612644221	Paradise Vista Park S21 E61 26DDBB1 Roan & Stirrup Roan & Clydesdale	360522	1150721	612.6 (2010)	9.05 (29.7)	7 8 9.1 (25.7-29.7)	Clark Co.	U	Wild, 1990 Maurer, 1989 Noack, 1988

Site Number ttrrssqqqq#	Site Name(s)	Latitude ddmmss	Longitude dddmmss	Elev meters (ft)	Depth meters (ft)	Screen meters (ft)	Owner	Water Use	Data Source(s)
21613614303	USGS #68 #68 Patrick & Pecos S21 E61 36ADC 3	360449	1150612	593.8 (1948)	7.89 (25.9)	7.0-7.9 (22.9-25.9)	USGS	U	Wild, 1990 Maurer, 1989 Noack, 1988 Wood, 1988b
21621711201	USGS #5 #5 #30 Desert Inn Estates DI & Nellis Trailer Park S21 E62 17DAB 1 #30	360749	1150508	527.3 (1730)	3.35 (11.0)	2.1-3.4 (7-11)	USGS	U	Wild, 1990 Maurer, 1989 B & K, 1988 Noack, 1988 Wood, 1988b Dettinger, 1987
21621822321	C10 Converse Well #10	360738	1150559	565.755 (1856.15)	5.18 (17.0)	3.4-4.3 (11-14)	Clark Co.	U	Wild, 1990 Converse, 1985
21621913111	C24 Converse Well #24	360640	1150516	570.482 (1871.66)	7.77 (25.5)	6.1-7.6 (20-25)	Clark Co.	U	Wild, 1990 Converse, 1985
21621932321	C27 Converse Well #27	360620	1150600	590.574 (1937.58)	8.99 (29.5)	7-9 (23-29.5)	Clark Co.	U	Wild, 1990 Converse, 1985
21621942431	C25 Converse Well #25	360617	1150519	577.060 (1893.24)	7.92 (26.0)	6.4-7.9 (21-26)	Clark Co.	U	Wild, 1990 Converse, 1985
21621943321	C33 Converse Well #33	360606	1150527	582.473 (1911.00)	7.32 (24.0)	5.8-7.3 (19-24)	Clark Co.	U	Wild, 1990 Converse, 1985
21622022411	C49 Converse Well #49	360646	1150440	539.014 (1768.42)	7.62 (25.0)	6.1-7.6 (20-25)	Clark Co.	U	Wild, 1990 Converse, 1985
21622642102	LG030 Duck Ck @ LV Wash30 #31 DRI LG030 S21 E62 26DBA 2 #31 LG030 Duck Ck @ LV Wash30	360529	1150100	486.769 (1597.01)	9.14 (30.0)	8.2-8.8 (27-29)	DRIWRC	U	Wild, 1990 B & K, 1988 Wood, 1988b Dettinger, 1987 Kaufmann, 1978
21622811301	USGS #3b #3 East Las Vegas Well S21 E62 28AAC 1 #54 Boulder Hwy & Missouri	360548	1150246	507.4 (1665)	8.23 (27.0)	7-8.2 (23-27)	USGS	U	Wild, 1990 Maurer, 1989 Noack, 1988 Wood, 1988b Dettinger, 1987
21622931441	C28 Converse Well #28	360521	1150422	549.414 (1802.54)	6.10 (20.0)	4.3-5.8 (14-19)	Clark Co.	U	Wild, 1990 Converse, 1985
21623014111	C42 Converse Well #42	360547	1150454	557.464 (1828.95)	9.45 (31.0)	5.8-9.1 (19-30)	Clark Co.	U	Wild, 1990 Converse, 1985
21623014331	C43 Converse Well #43	360535	1150509	570.509 (1871.75)	6.10 (20.0)	4.3-5.5 (14-18)	Clark Co.	U	Wild, 1990 Converse, 1985

Site Number ttrrssqqqq#	Site Name(s)	Latitude ddmmss	Longitude dddmmss	Elev meters (ft)	Depth meters (ft)	Screen meters (ft)	Owner	Water Use	Data Source(s)
21623024111	C32 Converse Well #32	360546	1150530	585.018 (1919.35)	9.75 (32.0)	7.3-8.8 (24-29)	Clark Co.	U	Wild, 1990 Converse, 1985
21623024341	C29 Converse Well #29	360537	1150537	582.994 (1912.71)	7.62 (25.0)	5.2-7.0 (17-23)	Clark Co.	U	Wild, 1990 Converse, 1985
22610133301	USGS #66 #66 Warm Springs & Eastern	360328	1150655	619.4 (2032)	16.76 (55.0)	15.5-16.8 (51-55)	USGS	U	Wild, 1990 Maurer, 1989

*B & K, 1988 - Brothers and Katzer, 1988

APPENDIX B.

Water Level and Physical Parameter Data

Site Number--Site Name
20610113341--USGS #19

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1485	790920	18.882	61.95				Wood, 1988b
1486	791022	18.812	61.72				Wood, 1988b
1487	800226	18.672	61.26				Wood, 1988b
1488	800610	18.727	61.44				Wood, 1988b
1489	800929	19.044	62.48				Wood, 1988b
1490	810501	18.575	60.94				Wood, 1988b
15	812110				670	21.0	Dettinger, 1987
507	820000	18.898	62				Dettinger, 1987
16	820517			7.80	600	23.5	Dettinger, 1987
17	820823			7.50	520	25.0	Dettinger, 1987
1387	860314	18.959	62.20				Maurer, 1989
1388	860630	19.163	62.87				Maurer, 1989
1389	860915	19.617	64.36				Maurer, 1989
1390	861217	19.272	63.23				Maurer, 1989
1391	870317	19.126	62.75				Maurer, 1989
388	871100			7.29	501		B & K, 1988*
444	880630	19.629	64.40	7.65	493	23.5	Wild, 1990
698	880700	19.404	63.66				Wild, 1990
699	880800	19.565	64.19				Wild, 1990
700	880900	19.644	64.45				Wild, 1990
701	881000	19.650	64.47				Wild, 1990
702	881100	19.519	64.04				Wild, 1990
1009	890100	19.379	63.58				Wild, 1990
1041	890200	19.333	63.43				Wild, 1990
1114	890317	19.309	63.35				Wild, 1990
1144	890421	19.257	63.18				Wild, 1990
1164	890524	19.419	63.71				Wild, 1990
1196	890600	19.608	64.33				Wild, 1990
1234	890800	19.745	64.78				Wild, 1990
1279	890915	19.751	64.80				Wild, 1990
1312	891000	19.751	64.80				Wild, 1990
1345	891124	19.443	63.79				Wild, 1990

Site Number--Site Name
20611433331--USGS #15

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
21	811022				650	21.0	Dettinger, 1987
508	820000	8.534	28				Dettinger, 1987
22	820824			7.60	525	22.5	Dettinger, 1987
1397	860314	8.925	29.28				Maurer, 1989
1398	860626	9.053	29.70				Maurer, 1989
1399	860916	9.056	29.71				Maurer, 1989
1400	870106	9.019	29.59				Maurer, 1989
1401	870317	8.967	29.42				Maurer, 1989
390	870500			7.56	528	25.0	B & K, 1988
914	870626	8.900	29.20	7.05	572	24.8	Noack, 1988
441	880620	9.110	29.89	7.46	693	21.4	Wild, 1990
704	880700	9.132	29.96				Wild, 1990
705	880800	9.138	29.98				Wild, 1990
925	880926	9.153	30.03	7.68	544	21.3	Wild, 1990
953	881014	9.043	29.67	7.40	559	21.5	Wild, 1990
954	881114	9.153	30.03	6.92	653	20.9	Wild, 1990
955	881212	9.062	29.73	7.42	588	21.0	Wild, 1990
995	890118	8.894	29.18	7.20	689	20.7	Wild, 1990
1029	890200	8.967	29.42	7.18	598	21.0	Wild, 1990
1115	890322	8.885	29.15	7.37	637	21.6	Wild, 1990
1133	890422	9.129	29.95	7.40	575	21.6	Wild, 1990
1165	890525	9.159	30.05	7.42	594	21.6	Wild, 1990
1197	890626	9.214	30.23	6.81	571	21.6	Wild, 1990
1268	890728	9.281	30.45	7.31	558	24.4	Wild, 1990
1235	890800	9.281	30.45				Wild, 1990
1280	890915	9.327	30.60				Wild, 1990
1313	891000	9.312	30.55				Wild, 1990
1346	891130	9.114	29.90	7.41	590	21.0	Wild, 1990
1378	891218	9.028	29.62	7.41	582	20.9	Wild, 1990

Site Number--Site Name
20612433122--NLVWD CollegePark#2-Shall

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1227	890627	5.038	16.53	7.08	4330	21.2	Wild, 1990
1266	890800	5.075	16.65				Wild, 1990
1311	890915	5.075	16.65				Wild, 1990
1344	891000	5.044	16.55				Wild, 1990
1377	891124	5.063	16.61				Wild, 1990

Site Number--Site Name
20612933341--MDB3

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1230	890622	6.815	22.36	11.16	1201	20.6	Wild, 1990

Site Number--Site Name
20613024301--USGS #34

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1491	810302	3.633	11.92				Wood, 1988b
1492	810425	3.243	10.64				Wood, 1988b
33	811021				1190	21.0	Dettinger, 1987
509	820000	2.743	9				Dettinger, 1987
34	820517			7.50	1250	20.0	Dettinger, 1987
35	820824			7.40	1200	20.0	Dettinger, 1987
1407	860312	3.100	10.17				Maurer, 1989
1408	860630	2.585	8.48				Maurer, 1989
1409	860910	2.451	8.04				Maurer, 1989
1410	870107	2.417	7.93				Maurer, 1989

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1411	870320	2.798	9.18				Maurer, 1989
395	870500			7.16	1270	20.0	B & K, 1988
510	870600	2.743	9.00				B & K, 1988
709	880100	2.704	8.87				LVVWD
710	880200	2.679	8.79				LVVWD
711	880300	2.576	8.45				LVVWD
712	880400	2.655	8.71				LVVWD
713	880500	2.533	8.31				LVVWD
440	880620	2.597	8.52	7.39	1340	17.7	Wild, 1990
715	880700	2.673	8.77				Wild, 1990
716	880800	2.691	8.83				Wild, 1990
717	880900	2.670	8.76				Wild, 1990
967	881004	2.704	8.87	7.39	1312	20.7	Wild, 1990
718	881100	2.768	9.08				Wild, 1990
968	881207	2.816	9.24	6.94	1350	18.7	Wild, 1990
1010	890100	2.795	9.17				Wild, 1990
1042	890200	2.871	9.42				Wild, 1990
1116	890322	2.804	9.20	7.49	1390	19.4	Wild, 1990
1145	890421	2.765	9.07				Wild, 1990
1166	890524	2.777	9.11				Wild, 1990
1198	890613	2.728	8.95	7.22	1416	15.7	Wild, 1990
1236	890800	2.347	7.70				Wild, 1990
1281	890915	2.256	7.40				Wild, 1990
1314	891000	2.316	7.60				Wild, 1990
1347	891124	2.271	7.45				Wild, 1990
1385	891218	2.454	8.05	7.25	1320	19.0	Wild, 1990

Site Number--Site Name
20613111411--MD86

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1233	890622	1.067	3.50	11.76	2150	19.4	Wild, 1990

Site Number--Site Name
20613143401--USGS #37

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1493	810302	4.026	13.21				Wood, 1988b
1494	810405	3.688	12.10				Wood, 1988b
93	811019				2230	22.0	Dettinger, 1987
511	820000	3.353	11				Dettinger, 1987
1412	860313	2.932	9.62				Maurer, 1989
1413	860625	2.810	9.22				Maurer, 1989
1414	860910	2.490	8.17				Maurer, 1989
1415	861218	2.640	8.66				Maurer, 1989
1416	870302	2.777	9.11				Maurer, 1989
422	870600	2.621	8.60	6.99	2810		B & K, 1988
909	870623	2.621	8.60	7.12	2750	20.3	Noack, 1988
719	880100	2.444	8.02				LVVWD
720	880200	2.478	8.13				LVVWD
721	880300	2.444	8.02				LVVWD
722	880400	2.438	8.00				LVVWD
723	880500	2.274	7.46				LVVWD
438	880615	2.252	7.39	7.01	2290	17.9	Wild, 1990
725	880700	2.292	7.52				Wild, 1990
726	880800	2.118	6.95				Wild, 1990
921	880920	1.972	6.47	6.97	2160	20.5	Wild, 1990
728	881000	2.201	7.22				Wild, 1990
729	881100	2.295	7.53				Wild, 1990
960	881207	2.323	7.62	6.80	2650	19.7	Wild, 1990
1011	890100	2.444	8.02				Wild, 1990
1043	890200	2.423	7.95				Wild, 1990
1117	890322	2.423	7.95	6.86	2490	17.4	Wild, 1990
1146	890421	2.390	7.84				Wild, 1990
1167	890524	2.323	7.62				Wild, 1990
1199	890615	2.316	7.60	6.75	2390	18.5	Wild, 1990
1237	890800	2.713	8.90				Wild, 1990
1282	890915	2.761	9.06				Wild, 1990
1315	891000	2.774	9.10				Wild, 1990
1348	891124	3.008	9.87				Wild, 1990

Site Number--Site Name
20613221121--MDB5

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1232	890626	4.761	15.62	7.98	1430	19.8	Wild, 1990

Site Number--Site Name
20613431101--USGS #48

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1495	810415	2.100	6.89				Wood, 1988b
1417	860319	2.057	6.75				Maurer, 1989
1418	860626	2.301	7.55				Maurer, 1989
1419	860916	2.185	7.17				Maurer, 1989
1420	861230	1.649	5.41				Maurer, 1989
1421	870316	1.594	5.23				Maurer, 1989
730	880100	2.210	7.25				LVVWD
731	880200	1.835	6.02				LVVWD
732	880300	1.862	6.11				LVVWD
733	880400	1.911	6.27				LVVWD
734	880500	1.817	5.96				LVVWD
735	880600	1.911	6.27				Wild, 1990
736	880700	2.027	6.65				Wild, 1990
737	880800	2.118	6.95				Wild, 1990
738	880900	2.039	6.69				Wild, 1990
739	881000	2.155	7.07				Wild, 1990
1012	890100	2.012	6.60				Wild, 1990
1044	890200	1.957	6.42				Wild, 1990
1118	890317	1.935	6.35				Wild, 1990

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1147	890421	1.920	6.30				Wild, 1990
1170	890524	1.920	6.30				Wild, 1990
1201	890600	2.048	6.72				Wild, 1990
1239	890800	1.875	6.15				Wild, 1990
1284	890915	1.792	5.88				Wild, 1990
1317	891000	1.829	6.00				Wild, 1990
1350	891124	1.701	5.58				Wild, 1990

Site Number--Site Name
20613644402--LG048 Charleston Blvd 40

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
290	710609			7.50	2765		Kaufmann, 1978
291	710913			7.55	2723	22.2	Kaufmann, 1978
292	711203			7.07	2272	18.9	Kaufmann, 1978
293	720201			7.29	2487	21.0	Kaufmann, 1978
294	720731			7.80	2578	23.3	Kaufmann, 1978
295	721101			6.86	2838	20.6	Kaufmann, 1978
296	730212			7.40	2302	20.6	Kaufmann, 1978
297	730504			7.55	2051	22.2	Kaufmann, 1978
298	730802			7.37	2482	23.3	Kaufmann, 1978
1496	790228	3.993	13.10				Wood, 1988b
1497	800205	4.048	13.28				Wood, 1988b
1498	800303	3.895	12.78				Wood, 1988b
1499	800402	3.789	12.43				Wood, 1988b
1500	801105	4.301	14.11				Wood, 1988b
1501	801208	4.093	13.43				Wood, 1988b
1502	810105	3.917	12.85				Wood, 1988b
1503	810212	3.776	12.39				Wood, 1988b
1504	810306	3.716	12.19				Wood, 1988b
1505	810416	3.648	11.97				Wood, 1988b
1506	810505	3.706	12.16				Wood, 1988b
512	820000	3.962	13				Dettinger, 1987
40	820825			6.90	3800	24.0	Dettinger, 1987
399	870600	3.536	11.60	6.88	4700	25.0	B & K, 1988
443	880628	3.536	11.60	7.01	5250	25.9	Wild, 1990
741	880700	3.551	11.65				Wild, 1990
742	880800	3.584	11.76				Wild, 1990
926	880926	3.548	11.64	7.01	4710	24.0	Wild, 1990
744	881000	3.618	11.87				Wild, 1990
745	881100	3.597	11.80				Wild, 1990
969	881211	3.520	11.55	7.03	5360	24.2	Wild, 1990
1013	890100	3.459	11.35				Wild, 1990
1045	890200	3.426	11.24				Wild, 1990
1119	890323	3.405	11.17	7.02	5390	23.0	Wild, 1990
1148	890421	3.408	11.18				Wild, 1990
1172	890524	3.520	11.55				Wild, 1990
1203	890621	3.603	11.82	6.95	4620	23.1	Wild, 1990
1241	890800	3.621	11.88				Wild, 1990

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1286	890915	3.636	11.93				Wild, 1990
1319	891000	3.627	11.90				Wild, 1990
1352	891124	3.450	11.32				Wild, 1990

Site Number--Site Name
21610113331--USGS #11

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1507	790913	2.332	7.65				Wood, 1988b
1508	790923	2.356	7.73				Wood, 1988b
1509	800226	2.140	7.02				Wood, 1988b
1510	800611	2.298	7.54				Wood, 1988b
1511	800930	2.399	7.87				Wood, 1988b
1512	810405						Wood, 1988b
95	811021				6000	25.0	Dettinger, 1987
528	820000	2.438	8				Dettinger, 1987
1422	860313	2.313	7.59				Maurer, 1989
1423	860625	2.316	7.60				Maurer, 1989
1424	860915	2.362	7.75				Maurer, 1989
1425	870107	2.204	7.23				Maurer, 1989
1426	870316	2.210	7.25				Maurer, 1989
911	870624	2.131	6.99	6.86	4990	23.4	Noack, 1988
746	880100	2.234	7.33				LVVWD
747	880200	2.213	7.26				LVVWD
748	880300	2.240	7.35				LVVWD
749	880400	2.243	7.36				LVVWD
750	880500	2.225	7.30				LVVWD
434	880613	2.271	7.45	7.04	5090	23.4	Wild, 1990
456	880707	2.298	7.54	7.02	5040	23.2	Wild, 1990
471	880805	2.323	7.62	7.05	4680	24.5	Wild, 1990
949	880929	2.307	7.57	7.00	4570	24.0	Wild, 1990
950	881014	2.304	7.56	7.03	4660	24.4	Wild, 1990
951	881114	2.307	7.57	6.95	5030	23.1	Wild, 1990
952	881208	2.289	7.51	6.95	5170	23.6	Wild, 1990
994	890118	2.320	7.61	7.01	5070	23.5	Wild, 1990
1028	890200	2.313	7.59	6.92	4960	22.6	Wild, 1990
1120	890322	2.310	7.58	6.95	4970	22.6	Wild, 1990
1132	890420	2.329	7.64	6.99	4850	23.2	Wild, 1990
1173	890526	2.338	7.67	6.89	4790	23.0	Wild, 1990
1204	890613	2.347	7.70	6.93	4970	23.3	Wild, 1990
1267	890727	2.499	8.20	6.94	4760	23.9	Wild, 1990
1242	890831	2.393	7.85	6.98	4780	23.9	Wild, 1990
1287	890915	2.380	7.81				Wild, 1990
1320	891000	2.377	7.80				Wild, 1990
1353	891201	2.332	7.65	6.99	4770	23.8	Wild, 1990

Site Number--Site Name
2161031l141--USGS #47

Sam-ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1513	791022	2.265	7.43				Wood, 1988b
1514	800226	2.185	7.17				Wood, 1988b
1515	800609	2.566	8.42				Wood, 1988b
1516	800930	2.201	7.22				Wood, 1988b
1517	810405	2.259	7.41				Wood, 1988b
96	811019				1750	22.0	Dettinger, 1987
545	820000	2.438	8				Dettinger, 1987
1427	860314	2.259	7.41				Maurer, 1989
1428	860626	2.286	7.50				Maurer, 1989
1429	860910	2.316	7.60				Maurer, 1989
1430	861230	2.289	7.51				Maurer, 1989
1431	870318	2.249	7.38				Maurer, 1989
912	870624	2.131	6.99	7.16	2590	21.0	Noack, 1988
757	880100	2.252	7.39				LVVWD
758	880200	2.237	7.34				LVVWD
759	880300	2.243	7.36				LVVWD
760	880400	2.240	7.35				LVVWD
761	880500	2.256	7.40				LVVWD
451	880617	2.271	7.45	7.37	2700	19.1	Wild, 1990
763	880700	2.295	7.53				Wild, 1990
764	880800	2.256	7.40				Wild, 1990
765	880900	2.219	7.28				Wild, 1990
964	881014	2.262	7.42	7.32	2630	21.2	Wild, 1990
965	881114	2.274	7.46	7.30	2760	20.0	Wild, 1990
966	881212	2.271	7.45	7.36	2580	19.8	Wild, 1990
997	890118	2.265	7.43	7.07	3010	17.7	Wild, 1990
1031	890200	2.252	7.39	7.34	2730	18.2	Wild, 1990
1121	890331	2.246	7.37	7.27	2720	18.6	Wild, 1990
1141	890422	2.228	7.31	7.25	2630	20.0	Wild, 1990
1171	890525	2.265	7.43	7.15	3080	18.2	Wild, 1990
1202	890627	2.286	7.50	7.11	2110	19.7	Wild, 1990
1276	890728	2.188	7.18	7.21	2040	20.8	Wild, 1990
1240	890801	2.204	7.23	7.25	1977	21.3	Wild, 1990
1285	890915	2.210	7.25				Wild, 1990
1318	891000	2.173	7.13				Wild, 1990
1351	891130	2.265	7.43	7.21	2470	19.7	Wild, 1990
1384	891218	2.262	7.42	7.23	2400	18.4	Wild, 1990

Site Number--Site Name
21610412301--USGS #43

Sam-ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1518	810302	2.908	9.54				Wood, 1988b
1519	810403	2.835	9.30				Wood, 1988b
52	811022				5930	23.0	Dettinger, 1987
563	820000	2.743	9				Dettinger, 1987
53	820517			6.90	5510	22.0	Dettinger, 1987
54	820824			6.60	4940	23.0	Dettinger, 1987
1432	860314	2.792	9.16				Maurer, 1989
1433	860625	2.944	9.66				Maurer, 1989
1434	860910	3.054	10.02				Maurer, 1989
1435	861218	2.917	9.57				Maurer, 1989
1436	870318	2.786	9.14				Maurer, 1989
405	870500			6.75	4770	23.0	B & K, 1988
564	870600	2.804	9.20				B & K, 1988
910	870623	2.560	8.40	7.01	4550	24.1	Noack, 1988
768	870900	2.801	9.19				LVVWD
769	871100	2.746	9.01				LVVWD
770	871200	2.688	8.82				LVVWD
771	880100	2.618	8.59				LVVWD
772	880200	2.560	8.40				LVVWD
773	880300	2.536	8.32				LVVWD
774	880400	2.563	8.41				LVVWD
775	880500	2.566	8.42				LVVWD
436	880614	2.557	8.39	6.85	5990	20.6	Wild, 1990
454	880707	2.609	8.56	6.82	5110	21.0	Wild, 1990
472	880805	2.643	8.67	6.87	4710	23.2	Wild, 1990
922	880920	2.643	8.67	6.86	4580	23.3	Wild, 1990
976	881014	2.566	8.42	6.84	4520	23.3	Wild, 1990
977	881114	2.737	8.98	6.75	4850	22.6	Wild, 1990
978	881211	2.758	9.05	6.92	4760	22.3	Wild, 1990
999	890118	2.728	8.95	6.83	5380	21.7	Wild, 1990
1033	890200	2.676	8.78	6.73	4770	21.1	Wild, 1990
1122	890322	2.661	8.73	6.81	4760	20.9	Wild, 1990
1143	890420	2.664	8.74	6.81	4540	21.6	Wild, 1990
1168	890525	2.697	8.85	6.81	4590	21.5	Wild, 1990
1200	890620	2.765	9.07	6.82	4450	21.7	Wild, 1990
1278	890728	2.819	9.25	6.77	4260	22.7	Wild, 1990
1238	890801	2.768	9.08	6.74	4210	23.1	Wild, 1990
1283	890915	2.768	9.08				Wild, 1990
1316	891000	2.774	9.10				Wild, 1990
1349	891130	2.768	9.08	6.85	4290	22.8	Wild, 1990
1386	891218	2.755	9.04	6.84	4170	22.3	Wild, 1990

Site Number--Site Name
21610922221--USGS #3a

Sam-ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1520	790914	5.227	17.15				Wood, 1988b
1521	791022	3.776	12.39				Wood, 1988b
1522	800226	3.414	11.20				Wood, 1988b
1523	800612	3.231	10.60				Wood, 1988b
1524	800930	3.639	11.94				Wood, 1988b
1525	810327	4.206	13.80				Wood, 1988b
97	811022				2780	21.0	Dettinger, 1987
565	820000	3.962	13				Dettinger, 1987
1465	860226	3.755	12.32				Maurer, 1989
1466	860626	3.871	12.70				Maurer, 1989

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1467	860912	3.161	10.37				Maurer, 1989
1468	861218	3.588	11.77				Maurer, 1989
1469	870318	3.676	12.06				Maurer, 1989
916	870708	3.380	11.09	7.21	2140	26.7	Noack, 1988
782	870900	3.021	9.91				LVVWD
783	871100	2.667	8.75				LVVWD
784	871200	2.737	8.98				LVVWD
785	880100	2.365	7.76				LVVWD
786	880200	2.557	8.39				LVVWD
787	880300	2.728	8.95				LVVWD
788	880400	2.804	9.20				LVVWD
789	880500	2.256	7.40				LVVWD
790	880600	1.908	6.26				Wild, 1990
791	880700	2.444	8.02				Wild, 1990
792	880800	2.432	7.98				Wild, 1990
793	880900	2.332	7.65				Wild, 1990
794	881000	2.377	7.80				Wild, 1990
795	881100	2.411	7.91				Wild, 1990
1014	890100	2.600	8.53				Wild, 1990
1046	890200	2.697	8.85				Wild, 1990
1123	890317	2.838	9.31				Wild, 1990
1161	890421	2.920	9.58				Wild, 1990
1193	890524	2.896	9.50				Wild, 1990
1223	890600	2.841	9.32				Wild, 1990
1262	890800	2.469	8.10				Wild, 1990
1307	890915	2.484	8.15				Wild, 1990
1340	891000	2.454	8.05				Wild, 1990
1373	891204	2.536	8.32				Wild, 1990

Site Number--Site Name
21611324121--C11

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
494	850400	2.865	9.40				LVVWD
495	850500	2.896	9.50				LVVWD
496	870200	2.908	9.54				LVVWD
497	870900	3.045	9.99				LVVWD
498	871000	3.033	9.95				LVVWD
499	871100	2.749	9.02				LVVWD
500	871200	2.914	9.56				LVVWD
501	880100	2.963	9.72				LVVWD
502	880200	2.963	9.72				LVVWD
503	880300	2.990	9.81				LVVWD
504	880400	3.011	9.88				LVVWD
505	880500	3.082	10.11				LVVWD
429	880609	3.024	9.92	7.05	4740	19.4	Wild, 1990
463	880712	3.158	10.36	7.07	4700	22.7	Wild, 1990
464	880805	3.155	10.35	7.06	4360	22.1	Wild, 1990
927	880928	3.121	10.24	7.03	4260	23.9	Wild, 1990

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
928	881017	3.152	10.34	7.04	4500	23.7	Wild, 1990
929	881115	3.094	10.15	7.05	5110	23.2	Wild, 1990
930	881211	3.124	10.25	6.95	4290	22.5	Wild, 1990
989	890118	2.957	9.70	6.94	4690	20.7	Wild, 1990
1022	890200	2.975	9.76	6.98	4270	20.0	Wild, 1990
1102	890321	3.024	9.92	7.04	4300	19.7	Wild, 1990
1134	890420	3.054	10.02	7.00	4240	20.8	Wild, 1990
1192	890526	3.124	10.25	7.01	4130	20.5	Wild, 1990
1222	890615	3.158	10.36	7.02	4180	21.4	Wild, 1990
1269	890727	3.231	10.60	6.89	3940	23.0	Wild, 1990
1261	890831	3.170	10.40	6.94	3890	24.5	Wild, 1990
1306	890915	3.185	10.45				Wild, 1990
1339	891000	3.170	10.40				Wild, 1990
1372	891201	3.078	10.10	6.99	3860	22.7	Wild, 1990

Site Number--Site Name
21611341341--C12

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
450	880617	6.523	21.40	7.28	6020	18.6	Wild, 1990
513	880700	6.184	20.29				Wild, 1990
514	880800	6.035	19.80				Wild, 1990
515	880900	5.919	19.42				Wild, 1990

Site Number--Site Name
21611544441--Maryland Pkway & Flamingo

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
98	811019				3320	24.5	Dettinger, 1987
566	820000	5.182	17				Dettinger, 1987
1470	860228	4.706	15.44				Maurer, 1989
1471	860626	4.621	15.16				Maurer, 1989
1472	860912	4.654	15.27				Maurer, 1989
1473	861229	4.377	14.36				Maurer, 1989
1474	870302	4.801	15.75				Maurer, 1989
796	880100	4.706	15.44				LVVWD
797	880200	4.724	15.50				LVVWD
798	880300	4.755	15.60				LVVWD
799	880400	4.749	15.58				LVVWD
800	880500	4.709	15.45				LVVWD
439	880616	4.642	15.23	7.46	3710	19.3	Wild, 1990
802	880700	4.575	15.01				Wild, 1990
803	880800	4.548	14.92				Wild, 1990
924	880921	4.514	14.81	7.39	3280	22.8	Wild, 1990
805	881000	4.569	14.99				Wild, 1990
806	881100	4.645	15.24				Wild, 1990
963	881212	4.700	15.42	7.03	3020	22.7	Wild, 1990
1015	890100	4.770	15.65				Wild, 1990
1047	890200	4.807	15.77				Wild, 1990
1124	890323	4.810	15.78	7.20	3100	20.9	Wild, 1990

Sam-ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1162	890421	4.746	15.57				Wild, 1990
1195	890524	4.633	15.20				Wild, 1990
1225	890615	4.581	15.03	7.17	2800	21.6	Wild, 1990
1264	890800	4.450	14.60				Wild, 1990
1309	890915	4.432	14.54				Wild, 1990
1342	891000	4.420	14.50				Wild, 1990
1375	891124	4.468	14.66				Wild, 1990

Site Number--Site Name
21611721441--USGS #40

Sam-ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
62	811022				3410	21.0	Dettinger, 1987
567	820000	7.010	23				Dettinger, 1987
63	820517			7.30	3360	25.0	Dettinger, 1987
64	820823			7.30	3300	25.0	Dettinger, 1987
1437	860318	6.645	21.80				Maurer, 1989
1438	860625	6.102	20.02				Maurer, 1989
1439	860916	5.236	17.18				Maurer, 1989
1440	870107	4.886	16.03				Maurer, 1989
1441	870318	4.295	14.09				Maurer, 1989
568	870600	4.023	13.20				B & K, 1988
913	870625	3.770	12.37	7.10	3060	24.1	Noack, 1988
807	870900	3.383	11.10				LVVWD
808	871100	3.106	10.19				LVVWD
410	871100			6.98	3350		B & K, 1988
809	871200	3.063	10.05				LVVWD
810	880100	3.033	9.95				LVVWD
811	880200	3.139	10.30				LVVWD
812	880300	3.210	10.53				LVVWD
813	880400	3.210	10.53				LVVWD
814	880500	3.018	9.90				LVVWD
437	880614	3.127	10.26	6.98	4250	22.0	Wild, 1990
455	880707	3.078	10.10	6.98	3740	22.4	Wild, 1990
473	880805	3.021	9.91	7.00	4620	23.5	Wild, 1990
972	880929	2.993	9.82	7.04	3550	24.5	Wild, 1990
973	881017	2.969	9.74	7.03	3480	23.5	Wild, 1990
974	881115	2.941	9.65	7.02	3970	22.7	Wild, 1990
975	881207	2.990	9.81	6.80	3710	23.0	Wild, 1990
998	890119	3.136	10.29	6.98	3860	22.4	Wild, 1990
1032	890200	3.161	10.37	6.84	3730	22.3	Wild, 1990
1125	890323	3.158	10.36	6.96	4130	22.8	Wild, 1990
1142	890422	3.109	10.20	6.99	3640	22.8	Wild, 1990
1194	890525	3.115	10.22	7.00	3650	22.4	Wild, 1990
1224	890621	3.088	10.13	6.94	3490	23.0	Wild, 1990
1277	890728	3.002	9.85	6.98	3450	23.1	Wild, 1990
1263	890801	2.926	9.60	6.89	3470	23.0	Wild, 1990
1308	890915	2.923	9.59				Wild, 1990
1341	891000	2.926	9.60				Wild, 1990

Sam-ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1374	891204	2.978	9.77	6.99	3410	22.9	Wild, 1990

Site Number--Site Name
21612431401--USGS #56

Sam-ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1526	810302	4.359	14.30				Wood, 1988b
1527	810309	4.356	14.29				Wood, 1988b
100	811020				6480	22.0	Dettinger, 1987
581	820000	3.962	13				Dettinger, 1987
1442	860314	4.225	13.86				Maurer, 1989
1443	860625	4.151	13.62				Maurer, 1989
1444	860912	3.993	13.10				Maurer, 1989
1445	861229	3.923	12.87				Maurer, 1989
1446	870302	4.023	13.20				Maurer, 1989
906	870622	3.831	12.57	7.05	5750	22.5	Noack, 1988
821	880100	3.658	12.00				LVVWD
822	880200	3.743	12.28				LVVWD
823	880300	3.810	12.50				LVVWD
824	880400	3.862	12.67				LVVWD
825	880500	3.865	12.68				LVVWD
826	880600	3.856	12.65				Wild, 1990
827	880700	3.853	12.64				Wild, 1990
828	880800	3.609	11.84				Wild, 1990
829	880900	3.481	11.42				Wild, 1990
830	881000	3.359	11.02				Wild, 1990
831	881100	3.261	10.70				Wild, 1990
1016	890100	3.661	12.01				Wild, 1990
1048	890200	3.807	12.49				Wild, 1990
1126	890317	3.719	12.20				Wild, 1990
1156	890421	3.709	12.17				Wild, 1990
1185	890524	3.703	12.15				Wild, 1990
1216	890600	3.655	11.99				Wild, 1990
1254	890800	3.338	10.95				Wild, 1990
1299	890915	3.237	10.62				Wild, 1990
1332	891000	3.216	10.55				Wild, 1990
1365	891204	3.252	10.67				Wild, 1990

Site Number--Site Name
21612542111--C36-

Sam-ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
627	850400	3.414	11.20				LVVWD
628	850500	3.475	11.40				LVVWD
629	870200	3.773	12.38				LVVWD
630	870900	2.899	9.51				LVVWD
631	871000	3.210	10.53				LVVWD
632	871100	3.027	9.93				LVVWD
633	871200	3.100	10.17				LVVWD
634	880100	3.164	10.38				LVVWD

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
635	880200	3.136	10.29				LVVWD
636	880300	3.146	10.32				LVVWD
637	880400	3.185	10.45				LVVWD
638	880500	3.173	10.41				LVVWD
445	880610	3.142	10.31	7.11	9260	20.2	Wild, 1990
462	880712	3.121	10.24	7.08	8650	22.0	Wild, 1990
469	880805	3.078	10.10	7.15	8350	22.7	Wild, 1990
475	880908	2.999	9.84	7.13	8410	22.8	Wild, 1990
942	881017	3.024	9.92	7.15	8510	22.9	Wild, 1990
943	881115	3.054	10.02	7.19	9640	22.3	Wild, 1990
944	881212	3.094	10.15	7.03	8830	21.7	Wild, 1990
992	890119	3.155	10.35	7.06	9210	21.6	Wild, 1990
1026	890200	3.170	10.40	7.05	9230	20.5	Wild, 1990
1110	890331	3.185	10.45	7.08	9240	21.2	Wild, 1990
1138	890420	3.210	10.53	6.96	9190	21.5	Wild, 1990
1182	890526	3.164	10.38	7.04	9080	21.2	Wild, 1990
1213	890627	3.142	10.31	6.99	8820	21.9	Wild, 1990
1273	890727	3.109	10.20	7.06	9200	21.6	Wild, 1990
1251	890831	3.033	9.95	7.07	8660	22.4	Wild, 1990
1296	890915	3.011	9.88				Wild, 1990
1329	891000	2.987	9.80				Wild, 1990
1362	891201	3.018	9.90	7.11	8640	21.9	Wild, 1990
1382	891219	3.033	9.95	7.08	8470	21.3	Wild, 1990

Site Number--Site Name
21612644221--Paradise Vista Park

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1475	860226	5.151	16.90				Maurer, 1989
1476	860625	4.877	16.00				Maurer, 1989
1477	860911	4.459	14.63				Maurer, 1989
1478	861229	4.545	14.91				Maurer, 1989
1479	870302	4.724	15.50				Maurer, 1989
905	870618	4.481	14.70	7.10	3740	21.2	Noack, 1988
832	880100	4.270	14.01				LVVWD
833	880200	4.356	14.29				LVVWD
834	880300	4.343	14.25				LVVWD
835	880400	4.285	14.06				LVVWD
836	880500	4.246	13.93				LVVWD
435	880613	4.148	13.61	7.08	3870	21.6	Wild, 1990
838	880700	4.231	13.88				Wild, 1990
839	880800	4.084	13.40				Wild, 1990
840	880900	3.898	12.79				Wild, 1990
970	881003	4.011	13.16	7.30	3800	22.0	Wild, 1990
842	881100	3.990	13.09				Wild, 1990
971	881208	4.097	13.44	6.90	3950	21.6	Wild, 1990
1017	890100	4.356	14.29				Wild, 1990
1049	890200	4.426	14.52				Wild, 1990
1127	890317	4.407	14.46	7.21	3160	20.3	Wild, 1990

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1154	890421	4.185	13.73				Wild, 1990
1184	890524	4.170	13.68				Wild, 1990
1215	890613	4.328	14.20	6.88	3220	20.6	Wild, 1990
1253	890800	4.389	14.40				Wild, 1990
1298	890915	4.273	14.02				Wild, 1990
1331	891000	4.206	13.80				Wild, 1990
1364	891204	4.313	14.15				Wild, 1990

Site Number--Site Name
21613614303--USGS #68

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1528	770803	5.182	17.00				Wood, 1988b
1529	780223	5.730	18.80				Wood, 1988b
1530	780710	6.276	20.59				Wood, 1988b
1531	781025	6.523	21.40				Wood, 1988b
1532	790123	5.895	19.34				Wood, 1988b
1533	790227	5.855	19.21				Wood, 1988b
1534	790605	5.965	19.57				Wood, 1988b
1535	791109	6.529	21.42				Wood, 1988b
1536	800301	5.867	19.25				Wood, 1988b
1537	800611	6.050	19.85				Wood, 1988b
1538	800930	6.757	22.17				Wood, 1988b
1539	810226	6.066	19.90				Wood, 1988b
1447	860307	6.480	21.26				Maurer, 1989
1448	860625	7.056	23.15				Maurer, 1989
1449	860911	7.739	25.39				Maurer, 1989
1450	861229	6.748	22.14				Maurer, 1989
1451	870302	6.349	20.83				Maurer, 1989
915	870708	6.459	21.19	7.10	3030	25.4	Noack, 1988
843	880100	5.745	18.85				LVVWD
844	880200	5.633	18.48				LVVWD
845	880300	5.645	18.52				LVVWD
846	880400	5.553	18.22				LVVWD
847	880500	5.508	18.07				LVVWD
452	880617	5.593	18.35	7.29	2600	21.8	Wild, 1990
849	880700	5.681	18.64				Wild, 1990
850	880800	5.715	18.75				Wild, 1990
851	880900	5.572	18.28				Wild, 1990
852	881100	5.425	17.80				Wild, 1990
1018	890100	5.066	16.62				Wild, 1990
1050	890200	5.093	16.71				Wild, 1990
1128	890317	5.084	16.68				Wild, 1990
1155	890421	5.130	16.83				Wild, 1990
1183	890524	5.191	17.03				Wild, 1990
1214	890600	5.316	17.44				Wild, 1990
1252	890800	5.319	17.45				Wild, 1990
1297	890915	5.307	17.41				Wild, 1990
1330	891000	5.304	17.40				Wild, 1990

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1363	891204	5.066	16.62				Wild, 1990

Site Number--Site Name
21621711201--USGS #5

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1540	810302	2.070	6.79				Wood, 1988b
1541	810317	1.951	6.40				Wood, 1988b
66	811020				5620	22.0	Dettinger, 1987
67	820518			7.10	5050	20.0	Dettinger, 1987
68	820518			7.10	5050	20.0	Dettinger, 1987
69	820824			7.10	4470	23.0	Dettinger, 1987
1452	860313	2.149	7.05				Maurer, 1989
1453	860626	2.225	7.30				Maurer, 1989
1454	860911	2.536	8.32				Maurer, 1989
1455	870107	2.231	7.32				Maurer, 1989
1456	870316	1.911	6.27				Maurer, 1989
412	870500			7.03	5480	29.5	B & K, 1988
908	870622	1.951	6.40	7.22	5600	20.8	Noack, 1988
853	880100	2.030	6.66				LVVWD
854	880200	1.875	6.15				LVVWD
855	880300	1.759	5.77				LVVWD
856	880400	1.588	5.21				LVVWD
857	880500	1.737	5.70				LVVWD
433	880613	1.899	6.23	7.18	5560	18.5	Wild, 1990
457	880707	2.118	6.95	7.15	5550	20.3	Wild, 1990
470	880805	2.362	7.75	7.11	5460	21.3	Wild, 1990
956	880929	2.487	8.16	7.09	5240	23.0	Wild, 1990
957	881014	2.606	8.55	7.05	4980	23.0	Wild, 1990
958	881115	2.579	8.46	7.14	5960	20.6	Wild, 1990
959	881208	2.530	8.30	7.00	5470	20.2	Wild, 1990
1019	890100	2.390	7.84				Wild, 1990
996	890118	2.390	7.84	7.13	5290	17.8	Wild, 1990
1030	890216	2.246	7.37	6.97	5140	16.6	Wild, 1990
1129	890321	2.103	6.90	7.11	5370	16.5	Wild, 1990
1140	890420	2.012	6.60	7.12	5260	17.4	Wild, 1990
1174	890526	2.115	6.94	6.93	5030	18.2	Wild, 1990
1205	890613	2.225	7.30	7.07	4910	19.3	Wild, 1990
1275	890727	2.621	8.60	6.85	5080	21.3	Wild, 1990
1243	890831	2.652	8.70	6.99	4900	21.9	Wild, 1990
1288	890915	2.667	8.75				Wild, 1990
1321	891000	2.652	8.70				Wild, 1990
1354	891204	2.475	8.12	7.08	4700	19.8	Wild, 1990

Site Number--Site Name
21621822321--C10

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
476	850400	2.103	6.90				LVVWD
477	850500	2.103	6.90				LVVWD

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
478	870200	2.070	6.79				LVVWD
479	870900	1.871	6.14				LVVWD
480	871000	1.850	6.07				LVVWD
481	871100	1.637	5.37				LVVWD
482	871200	1.695	5.56				LVVWD
483	880100	1.902	6.24				LVVWD
484	880200	1.948	6.39				LVVWD
485	880300	1.996	6.55				LVVWD
486	880400	2.060	6.76				LVVWD
487	880500	2.106	6.91				LVVWD
488	880617	2.134	7.00	7.53	6530	23.6	Wild, 1990
489	880707	2.124	6.97				Wild, 1990
490	880800	2.137	7.01				Wild, 1990
491	880900	2.036	6.68				Wild, 1990
492	881000	1.969	6.46				Wild, 1990
493	881100	1.948	6.39				Wild, 1990
1001	890100	2.176	7.14				Wild, 1990
1034	890200	2.210	7.25				Wild, 1990
1101	890317	2.246	7.37				Wild, 1990
1160	890421	2.231	7.32				Wild, 1990
1191	890524	2.198	7.21				Wild, 1990
584	890600	2.249	7.38				Wild, 1990
1260	890800	2.179	7.15				Wild, 1990
1305	890915	2.164	7.10				Wild, 1990
1338	891000	2.164	7.10				Wild, 1990
1371	891124	2.030	6.66				Wild, 1990

Site Number--Site Name
21621913111--C24

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
516	850400	4.298	14.10				LVVWD
517	850500	4.511	14.80				LVVWD
518	870200	4.624	15.17				LVVWD
519	870900	4.630	15.19				LVVWD
520	871000	4.633	15.20				LVVWD
521	871100	4.398	14.43				LVVWD
522	871200	4.346	14.26				LVVWD
523	880100	4.346	14.26				LVVWD
524	880200	4.319	14.17				LVVWD
525	880300	4.264	13.99				LVVWD
526	880400	4.218	13.84				LVVWD
527	880500	4.237	13.90				LVVWD
449	880610	4.285	14.06	6.97	6020	21.2	Wild, 1990
529	880700	4.267	14.00				Wild, 1990
530	880800	4.490	14.73				Wild, 1990
531	880900	4.487	14.72				Wild, 1990
532	881000	4.447	14.59				Wild, 1990
1003	890100	4.343	14.25				Wild, 1990

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1035	890200	4.310	14.14				Wild, 1990
1103	890317	4.270	14.01				Wild, 1990
1158	890421	4.249	13.94				Wild, 1990
1189	890524	4.343	14.25				Wild, 1990
1220	890600	4.724	15.50				Wild, 1990
1258	890800	4.572	15.00				Wild, 1990
1303	890915	4.554	14.94				Wild, 1990
1336	891000	4.542	14.90				Wild, 1990
1369	891124	4.398	14.43				Wild, 1990

Site Number--Site Name
21621932321--C27-

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
551	850400	6.431	21.10				LVVWD
552	850500	6.248	20.50				LVVWD
553	870200	6.224	20.42				LVVWD
554	870900	5.203	17.07				LVVWD
555	871000	5.105	16.75				LVVWD
556	871100	4.816	15.80				LVVWD
557	871200	5.188	17.02				LVVWD
558	880100	5.572	18.28				LVVWD
559	880200	5.502	18.05				LVVWD
560	880300	5.547	18.20				LVVWD
561	880400	5.627	18.46				LVVWD
562	880500	5.663	18.58				LVVWD
430	880609	5.343	17.53	7.12	7200	21.5	Wild, 1990
458	880712	4.752	15.59	7.14	7600	21.4	Wild, 1990
465	880805	4.935	16.19	7.13	7370	21.6	Wild, 1990
917	880919	4.810	15.78	7.12	7810	22.2	Wild, 1990
931	881017	4.688	15.38	7.17	7490	22.2	Wild, 1990
932	881115	4.776	15.67	7.18	8800	22.2	Wild, 1990
933	881208	4.855	15.93	7.04	8510	22.6	Wild, 1990
990	890119	5.468	17.94	7.08	7740	22.5	Wild, 1990
1023	890200	5.721	18.77	7.05	6990	22.5	Wild, 1990
1105	890321	5.986	19.64	6.98	6760	21.8	Wild, 1990
1135	890420	6.050	19.85	7.05	6470	22.3	Wild, 1990
1186	890526	5.968	19.58	7.07	6540	21.7	Wild, 1990
1217	890615	5.639	18.50	7.01	6690	21.5	Wild, 1990
1270	890729	5.608	18.40	6.97	6150	22.4	Wild, 1990
1255	890831	5.502	18.05	7.03	6130	22.1	Wild, 1990
1300	890915	5.505	18.06				Wild, 1990
1333	891000	5.502	18.05				Wild, 1990
1366	891201	5.669	18.60	7.06	5840	21.8	Wild, 1990
1379	891219	5.806	19.05	7.12	5710	22.0	Wild, 1990

Site Number--Site Name
21621942431--C25-

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
533	850400	4.511	14.80				LVVWD
534	850500	4.572	15.00				LVVWD
535	870200	5.639	18.50				LVVWD
536	870900	4.886	16.03				LVVWD
537	871000	4.791	15.72				LVVWD
538	871100	4.609	15.12				LVVWD
539	871200	4.511	14.80				LVVWD
540	880100	4.523	14.84				LVVWD
541	880200	4.511	14.80				LVVWD
542	880300	4.517	14.82				LVVWD
543	880400	4.545	14.91				LVVWD
544	880500	4.578	15.02				LVVWD
447	880610	4.633	15.20	7.12	7480	20.8	Wild, 1990
546	880700	4.715	15.47				Wild, 1990
547	880800	4.779	15.68				Wild, 1990
548	880900	4.712	15.46				Wild, 1990
549	881000	4.712	15.46				Wild, 1990
550	881100	4.648	15.25				Wild, 1990
1004	890100	4.618	15.15				Wild, 1990
1036	890200	4.618	15.15				Wild, 1990
1104	890317	4.602	15.10				Wild, 1990
1157	890421	4.587	15.05				Wild, 1990
1188	890524	4.651	15.26				Wild, 1990
1257	890800	4.740	15.55				Wild, 1990
1302	890915	4.715	15.47				Wild, 1990
1335	891000	4.679	15.35				Wild, 1990
1368	891124	4.572	15.00				Wild, 1990

Site Number--Site Name
21621943321--C33-

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
448	880610	5.745	18.85	7.08	8140	21.8	Wild, 1990
459	880712	5.773	18.94	6.92	7780	21.9	Wild, 1990
466	880805	5.758	18.89	7.09	8970	22.5	Wild, 1990
474	880908	5.672	18.61	7.01	7590	23.0	Wild, 1990
939	881000	5.596	18.36	7.06	7520	23.2	Wild, 1990
940	881115	5.560	18.24	7.12	8100	22.2	Wild, 1990
941	881212	5.550	18.21	7.01	7650	22.9	Wild, 1990
1000	890119	5.624	18.45	7.02	7770	22.8	Wild, 1990
1025	890217	5.651	18.54	6.98	7280	22.4	Wild, 1990
1109	890331	5.709	18.73	6.99	6740	22.6	Wild, 1990
1137	890420	5.755	18.88	6.96	6600	22.7	Wild, 1990
1187	890526	5.809	19.06	6.94	6440	22.1	Wild, 1990
1218	890627	5.822	19.10	7.03	6330	22.3	Wild, 1990
1272	890729	5.761	18.90	6.90	6170	22.8	Wild, 1990
1256	890831	5.654	18.55	6.96	6280	23.3	Wild, 1990
1301	890915	5.584	18.32				Wild, 1990
1334	891000	5.547	18.20				Wild, 1990

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1367	891204	5.456	17.90	7.02	6440	23.1	Wild, 1990
1381	891219	5.450	17.88	6.97	6300	22.9	Wild, 1990

Site Number--Site Name
21622022411--C49

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
680	850400	2.652	8.70				LVVWD
681	850500	2.743	9.00				LVVWD
682	870200	2.691	8.83				LVVWD
683	870900	2.560	8.40				LVVWD
684	871000	2.539	8.33				LVVWD
685	871100	2.320	7.61				LVVWD
686	871200	2.411	7.91				LVVWD
687	880100	2.548	8.36				LVVWD
688	880200	2.527	8.29				LVVWD
689	880300	2.560	8.40				LVVWD
690	880400	2.499	8.20				LVVWD
691	880500	2.621	8.60				LVVWD
431	880609	2.606	8.55	6.96	3310	22.2	Wild, 1990
693	880700	2.832	9.29				Wild, 1990
694	880800	2.838	9.31				Wild, 1990
920	880919	2.804	9.20	7.10	3610	23.9	Wild, 1990
696	881000	2.755	9.04				Wild, 1990
697	881100	2.816	9.24				Wild, 1990
948	881208	2.822	9.26	6.85	3970	23.2	Wild, 1990
1008	890100	2.798	9.18				Wild, 1990
1040	890200	2.819	9.25				Wild, 1990
1113	890321	2.758	9.05	6.99	3760	22.0	Wild, 1990
1159	890421	2.816	9.24				Wild, 1990
1190	890524	2.893	9.49				Wild, 1990
1221	890614	2.868	9.41	6.83	3490	22.8	Wild, 1990
1259	890800	2.621	8.60				Wild, 1990
1304	890915	2.777	9.11				Wild, 1990
1337	891000	2.743	9.00				Wild, 1990
1370	891124	2.765	9.07				Wild, 1990

Site Number--Site Name
21622642102--LG030 Duck Ck @ LV Wash30

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
174	710609			7.70	8737		Kaufmann, 1978
175	710914			7.70	8369	19.4	Kaufmann, 1978
176	711203			7.18	8000	17.8	Kaufmann, 1978
177	720202			7.28	8395	17.0	Kaufmann, 1978
178	720731			7.55	8608	23.3	Kaufmann, 1978
179	721103			7.26	8379	18.9	Kaufmann, 1978
180	730208			7.30	8057	17.8	Kaufmann, 1978
181	730508			7.10	7908	25.6	Kaufmann, 1978
182	730801			7.30	8486	22.2	Kaufmann, 1978

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1542	770307	1.615	5.30				Wood, 1988b
1543	780311	1.759	5.77				Wood, 1988b
1544	790228	2.009	6.59				Wood, 1988b
1545	800212	1.963	6.44				Wood, 1988b
1546	800303	1.838	6.03				Wood, 1988b
1547	800402	1.896	6.22				Wood, 1988b
1548	801105	3.136	10.29				Wood, 1988b
1549	801210	2.710	8.89				Wood, 1988b
1550	810105	2.341	7.68				Wood, 1988b
1551	810209	2.042	6.70				Wood, 1988b
1552	810310	1.829	6.00				Wood, 1988b
1553	810416	1.960	6.43				Wood, 1988b
1554	810504	2.112	6.93				Wood, 1988b
506	820000	3.353	11				Dettinger, 1987
70	820519			7.00	9720	19.0	Dettinger, 1987
71	820825			7.00	7600	21.0	Dettinger, 1987
413	870600	2.134	7.00	7.13	9150	22.0	B & K, 1988
442	880628	2.819	9.25	7.12	9030	22.0	Wild, 1990
864	880700	2.673	8.77				Wild, 1990
865	880800	3.124	10.25				Wild, 1990
866	880900	2.944	9.66				Wild, 1990
961	881004	2.886	9.47	7.08	8050	21.7	Wild, 1990
962	881211	1.646	5.40	6.99	9230	20.7	Wild, 1990
1051	890200	1.140	3.74				Wild, 1990
1130	890323	1.222	4.01	7.05	8430	18.8	Wild, 1990
1150	890421	1.430	4.69				Wild, 1990
1176	890524	1.609	5.28				Wild, 1990
1207	890621	2.198	7.21	6.89	7020	17.3	Wild, 1990
1245	890800	2.682	8.80				Wild, 1990
1290	890915	2.871	9.42				Wild, 1990
1323	891000	2.743	9.00				Wild, 1990
1356	891124	2.871	9.42				Wild, 1990

Site Number--Site Name
21622811301--USGS #3b

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1555	810302	6.050	19.85				Wood, 1988b
1556	810317	5.267	17.28				Wood, 1988b
101	811020				6030	23.0	Dettinger, 1987
599	820000	5.486	18				Dettinger, 1987
1457	860307	5.837	19.15				Maurer, 1989
1458	860625	5.685	18.65				Maurer, 1989
1459	860915	5.483	17.99				Maurer, 1989
1460	861219	5.645	18.52				Maurer, 1989
1461	870302	5.614	18.42				Maurer, 1989
868	880100	5.514	18.09				LVVWD
979	880200	5.691	18.67				LVVWD
980	880300	5.648	18.53				LVVWD

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	(ft)	Field pH	EC umhos/cm	Temp (C)	Data Source
981	880400	5.575	18.29				LVVWD
982	880500	5.550	18.21				LVVWD
983	880600	5.700	18.70				Wild, 1990
984	880700	5.608	18.40				Wild, 1990
985	880800	5.642	18.51				Wild, 1990
986	880900	5.617	18.43				Wild, 1990
987	881000	5.624	18.45				Wild, 1990
988	881100	5.636	18.49				Wild, 1990
1021	890100	5.724	18.78				Wild, 1990
1052	890200	5.739	18.83				Wild, 1990
1131	890317	5.752	18.87				Wild, 1990
1149	890421	5.706	18.72				Wild, 1990
1175	890524	5.700	18.70				Wild, 1990
1206	890600	5.721	18.77				Wild, 1990
1244	890800	5.669	18.60				Wild, 1990
1289	890915	5.678	18.63				Wild, 1990
1322	891000	5.685	18.65				Wild, 1990
1355	891124	5.614	18.42				Wild, 1990

Site Number--Site Name
21622931441--C28

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	(ft)	Field pH	EC umhos/cm	Temp (C)	Data Source
569	850400	3.048	10.00				LVVWD
570	850500	3.109	10.20				LVVWD
571	870200	2.932	9.62				LVVWD
572	870900	2.826	9.27				LVVWD
573	871000	2.701	8.86				LVVWD
574	871100	2.725	8.94				LVVWD
575	871200	2.728	8.95				LVVWD
576	880100	2.740	8.99				LVVWD
577	880200	2.728	8.95				LVVWD
578	880300	2.697	8.85				LVVWD
579	880400	2.652	8.70				LVVWD
580	880500	2.588	8.49				LVVWD
432	880613	2.542	8.34	7.18	7140	21.7	Wild, 1990
582	880700	2.463	8.08				Wild, 1990
583	880800	2.435	7.99				Wild, 1990
923	880920	2.195	7.20	6.90	6120	21.8	Wild, 1990
585	881000	2.579	8.46				Wild, 1990
586	881100	2.533	8.31				Wild, 1990
1005	890100	2.524	8.28				Wild, 1990
1037	890200	2.621	8.60				Wild, 1990
1106	890320	2.603	8.54	7.17	5810	21.2	Wild, 1990
1151	890421	2.557	8.39				Wild, 1990
1177	890524	2.524	8.28				Wild, 1990
1208	890614	2.521	8.27	6.91	5590	22.4	Wild, 1990
1246	890800	2.423	7.95				Wild, 1990
1291	890915	2.320	7.61				Wild, 1990

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	(ft)	Field pH	EC umhos/cm	Temp (C)	Data Source
1324	891000	2.301	7.55				Wild, 1990
1357	891124	2.374	7.79				Wild, 1990

Site Number--Site Name
21623014111--C42

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	(ft)	Field pH	EC umhos/cm	Temp (C)	Data Source
645	850400	3.231	10.60				LVVWD
646	850500	3.231	10.60				LVVWD
647	870200	3.036	9.96				LVVWD
648	870900	2.993	9.82				LVVWD
649	871000	2 978	9.77				LVVWD
650	871100	2 780	9.12				LVVWD
651	871200	2.871	9.42				LVVWD
652	880100	2.871	9.42				LVVWD
653	880200	3.069	10.07				LVVWD
654	880300	3.075	10.09				LVVWD
655	880400	3.130	10.27				LVVWD
656	880500	3.152	10.34				LVVWD
426	880608	3.142	10.31	6.76	5040	20.1	Wild, 1990
460	880712	3.191	10.47	6.87	4860	21.4	Wild, 1990
467	880805	3.139	10.30	7.00	4860	22.1	Wild, 1990
919	880919	3.014	9.89	7.00	4600	23.0	Wild, 1990
945	881017	3.109	10.20	6.98	4640	23.5	Wild, 1990
946	881115	2.926	9.60	6.98	4980	23.0	Wild, 1990
947	881208	2.969	9.74	6.82	5100	23.1	Wild, 1990
993	890119	2.963	9.72	6.90	5160	22.7	Wild, 1990
1027	890200	3.091	10.14	6.88	4780	22.2	Wild, 1990
1111	890320	3.121	10.24	6.93	4780	21.6	Wild, 1990
1139	890420	3.103	10.18	6.91	4440	21.6	Wild, 1990
1178	890526	3.042	9.98	6.86	4470	21.3	Wild, 1990
1209	890614	3.030	9.94	6.81	4400	21.7	Wild, 1990
1274	890727	3.200	10.50	6.82	4360	22.1	Wild, 1990
1247	890831	3.027	9.93	6.89	4250	22.1	Wild, 1990
1292	890915	3 045	9.99				Wild, 1990
1325	891000	3.018	9.90				Wild, 1990
1358	891201	3.078	10.10	6.74	4220	22.3	Wild, 1990
1383	891219	3.094	10.15	6.93	4040	22.7	Wild, 1990

Site Number--Site Name
21623014331--C43

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	(ft)	Field pH	EC umhos/cm	Temp (C)	Data Source
663	850400	2 012	6 60				LVVWD
664	850500	2 073	6.80				LVVWD
665	870200	1.957	6.42				LVVWD
666	870900	1.966	6.45				LVVWD
667	871000	1.960	6.43				LVVWD
668	871100	1.771	5.81				LVVWD
669	871200	2.249	7 38				LVVWD

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	(ft)	Field pH	EC umhos/cm	Temp (C)	Data Source
670	880100	2.131	6.99				LVVWD
671	880200	2.036	6.68				LVVWD
672	880300	2.021	6.63				LVVWD
673	880500	2.012	6.60				LVVWD
446	880610	1.987	6.52	7.15	5880	19.0	Wild, 1990
675	880700	1.990	6.53				Wild, 1990
676	880800	1.981	6.50				Wild, 1990
677	880900	1.905	6.25				Wild, 1990
678	881000	1.948	6.39				Wild, 1990
679	881100	1.948	6.39				Wild, 1990
1007	890100	1.911	6.27				Wild, 1990
1039	890200	2.045	6.71				Wild, 1990
1112	890317	2.042	6.70				Wild, 1990
1152	890421	2.045	6.71				Wild, 1990
1179	890524	2.039	6.69				Wild, 1990
1210	890600	2.067	6.78				Wild, 1990
1248	890800	2.042	6.70				Wild, 1990
1293	890915	1.935	6.35				Wild, 1990
1326	891000	1.890	6.20				Wild, 1990
1359	891124	2.003	6.57				Wild, 1990

Site Number--Site Name
21623024111--C32

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	(ft)	Field pH	EC umhos/cm	Temp (C)	Data Source
605	850500	5.334	17.50				LVVWD
606	870200	5.206	17.08				LVVWD
607	870900	5.102	16.74				LVVWD
608	871000	5.099	16.73				LVVWD
609	871100	4.868	15.97				LVVWD
610	871200	4.983	16.35				LVVWD
611	880100	5.163	16.94				LVVWD
612	880200	5.197	17.05				LVVWD
613	880300	5.197	17.05				LVVWD
614	880400	5.264	17.27				LVVWD
615	880500	5.291	17.36				LVVWD
428	880608	5.215	17.11	7.25	5085	21.9	Wild, 1990
617	880700	5.197	17.05				Wild, 1990
618	880800	5.121	16.80				Wild, 1990
937	880928	4.971	16.31	7.22	4780	22.3	Wild, 1990
620	881000	4.898	16.07				Wild, 1990
621	881100	4.880	16.01				Wild, 1990
938	881208	4.923	16.15	7.09	5400	21.3	Wild, 1990
1006	890100	5.075	16.65				Wild, 1990
1038	890200	5.160	16.93				Wild, 1990
1108	890320	5.236	17.18	7.18	4900	21.2	Wild, 1990
1153	890421	5.261	17.26				Wild, 1990
1180	890524	5.176	16.98				Wild, 1990
1211	890614	5.176	16.98	7.00	4450	22.1	Wild, 1990

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	(ft)	Field pH	EC umhos/cm	Temp (C)	Data Source
1249	890800	4.938	16.20				Wild, 1990
1294	890915	4.807	15.77				Wild, 1990
1327	891000	4.755	15.60				Wild, 1990
1360	891124	4.776	15.67				Wild, 1990

Site Number--Site Name
21623024341--C29

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	(ft)	Field pH	EC umhos/cm	Temp (C)	Data Source
587	850400	4.481	14.70				LVVWD
588	850500	4.481	14.70				LVVWD
589	870200	3.786	12.42				LVVWD
590	870900	3.645	11.96				LVVWD
591	871000	3.597	11.80				LVVWD
592	871100	3.417	11.21				LVVWD
593	871200	3.847	12.62				LVVWD
594	880100	3.780	12.40				LVVWD
595	880200	3.609	11.84				LVVWD
596	880300	3.588	11.77				LVVWD
597	880400	3.648	11.97				LVVWD
598	880500	3.648	11.97				LVVWD
427	880608	3.527	11.57	7.05	5850	20.4	Wild, 1990
461	880712	3.502	11.49	7.10	5950	20.9	Wild, 1990
468	880805	3.414	11.20	7.10	5670	21.5	Wild, 1990
918	880919	3.347	10.98	7.12	5580	21.9	Wild, 1990
934	881017	3.319	10.89	7.08	5760	22.0	Wild, 1990
935	881111	3.313	10.87	7.11	6150	21.2	Wild, 1990
936	881208	3.386	11.11	6.96	6270	21.5	Wild, 1990
991	890119	3.456	11.34	7.02	6460	21.1	Wild, 1990
1024	890217	3.530	11.58	6.98	6130	20.9	Wild, 1990
1107	890321	3.597	11.80	6.91	6000	20.2	Wild, 1990
1136	890420	3.566	11.70	7.01	5780	21.0	Wild, 1990
1181	890526	3.481	11.42	6.99	5640	21.1	Wild, 1990
1212	890614	3.459	11.35	7.03	5490	21.2	Wild, 1990
1271	890727	3.414	11.20	6.98	5430	21.2	Wild, 1990
1250	890831	3.237	10.62	7.03	5350	21.3	Wild, 1990
1295	890915	3.200	10.50				Wild, 1990
1328	891000	3.139	10.30				Wild, 1990
1361	891201	3.243	10.64	7.03	5370	21.2	Wild, 1990
1380	891219	3.301	10.83	7.07	5140	21.2	Wild, 1990

Site Number--Site Name
22610133301--USGS #66

Sam- ple#	Sample Date yymmdd	Static Water Level (m)	(ft)	Field pH	EC umhos/cm	Temp (C)	Data Source
1462	860307	14.944	49.03				Maurer, 1989
1464	860307	15.517	50.91				Maurer, 1989
1463	860625	15.950	52.33				Maurer, 1989
1163	890421	15.380	50.46				Wild, 1990
1169	890524	15.603	51.19				Wild, 1990

Sample#	Sample Date yymmdd	Static Water Level (m)	Static Water Level (ft)	Field pH	Field EC umhos/cm	Temp (C)	Data Source
1226	890600	15.773	51.75				Wild, 1990
1265	890800	dry					Wild, 1990
1310	890915	dry					Wild, 1990
1343	891000	dry					Wild, 1990
1376	891204	dry					Wild, 1990

*B & K, 1988 - Brothers and Katzer, 1988
LVVWD - unpublished data from the Las Vegas Valley Water District

APPENDIX C.

Major Ion Data

Site Number----Site Name
20610113341----USGS #19

Samp#	Date yymmdd	Lab pH	Lab EC	Field HCO3- mg/l	Lab HCO3- mg/l	Cl- mg/l	SO4-- mg/l	Ca++ mg/l	Mg++ mg/l	Na+ mg/l	K+ mg/l	SiO2 mg/l	TDS mg/l	EPM bal	Lab Code	Data Source
15	812110	7.60			281	4.7	43.0	30.0	44.0	11.00	4.70	64.0	321		80020	Dettinger, 1987
16	820517			290		14.0	41.0	37.0	42.0	10.00	4.20	65.0	300		32017	Dettinger, 1987
17	820823			310		3.0	25.0	33.0	41.0	11.00	3.00	92.0	328		32017	Dettinger, 1987
388	871100	7.59		303		3.8	34.4	27.2	47.2	10.50	3.53	64.0	308		DRIWRC	B & K, 1988*
444	880630	8.12	490	328	303	4.1	34.2	27.0	46.8	10.90	3.90	64.0	322		DRIWRC	Wild, 1990

Site Number----Site Name
20611433331----USGS #15

Samp#	Date yymmdd	Lab pH	Lab EC	Field HCO3- mg/l	Lab HCO3- mg/l	Cl- mg/l	SO4-- mg/l	Ca++ mg/l	Mg++ mg/l	Na+ mg/l	K+ mg/l	SiO2 mg/l	TDS mg/l	EPM bal	Lab Code	Data Source
21	811022	7.90			268	7.5	63.0	59.0	30.0	8.60	2.30	21.0	337		80020	Dettinger, 1987
22	820824			280		7.0	34.0	63.0	31.0	8.00	2.00	18.0	324		32017	Dettinger, 1987
390	870500	8.11		304		3.9	37.7	28.1	47.3	11.40	3.86	66.0	321		DRIWRC	B & K, 1988*
441	880620	8.00	533	280	291	11.9	47.7	58.4	33.5	8.26	2.97	21.0	319		DRIWRC	Wild, 1990
925	880926	8.24	482	290	294	13.1	47.2	61.2	29.3	8.34	2.40	20.0	321	1.051	DRIWRC	Wild, 1990
955	881212	7.84	567	277	295	15.7	51.4	55.2	34.6	8.48	2.36	20.3 c	358	1.057	DRIWRC	Wild, 1990
1115	890322	7.87	588	290	297	17.8	62.9	58.0	35.9	10.00	2.71	20.6	336	1.057	DRIWRC	Wild, 1990
1197	890626	7.66	554	298	292	14.5	52.7	60.1	34.7	8.25	2.38	20.3	322	1.008	DRIWRC	Wild, 1990
1378	891218	8.16	592		301	17.5	65.0	66.0	36.1	8.53	2.40	20.1	350	1.016	DRIWRC	

Site Number----Site Name
20612433122----NLVWD CollegePark#2b-Shall

Samp#	Date yymmdd	Lab pH	Lab EC	Field HCO3- mg/l	Lab HCO3- mg/l	Cl- mg/l	SO4-- mg/l	Ca++ mg/l	Mg++ mg/l	Na+ mg/l	K+ mg/l	SiO2 mg/l	TDS mg/l	EPM bal	Lab Code	Data Source
1227	890627	7.62	4710	476	451	302.0	2220.0	197.0	376.0	441.00	62.80	63.9	4130	1.017	DRIWRC	Wild, 1990

Site Number----Site Name
20612933341----MDB3

Samp#	Date yymmdd	Lab pH	Lab EC	Field HCO3- mg/l	Lab HCO3- mg/l	Cl- mg/l	SO4-- mg/l	Ca++ mg/l	Mg++ mg/l	Na+ mg/l	K+ mg/l	SiO2 mg/l	TDS mg/l	EPM bal	Lab Code	Data Source
1230	890622	11.55	1100			40.0	214.0	132.0	.3	33.70	8.73	9.4	548	1.038	DRIWRC	Wild, 1990

Site Number----Site Name
20613024301----USGS #34

Samp#	Date yymmdd	Lab pH	Lab EC	Field HCO3- mg/l	Lab HCO3- mg/l	Cl- mg/l	SO4-- mg/l	Ca++ mg/l	Mg++ mg/l	Na+ mg/l	K+ mg/l	SiO2 mg/l	TDS mg/l	EPM bal	Lab Code	Data Source
33	811021	7.50			232	94.0	250.0	97.0	68.0	26.00	5.10	24.0	726		80020	Dettinger, 1987
34	820517			230		110.0	290.0	130.0	61.0	27.00	6.50	21.0	680		32017	Dettinger, 1987
35	820824			440		130.0	250.0	170.0	85.0	26.00	4.00	17.0	896		32017	Dettinger, 1987
395	870500	8.14		241		125.0	296.0	125.0	79.2	29.20	4.21	19.0	810		DRIWRC	B & K, 1988
440	880620	7.98	1300	224	241	127.0	314.0	120.0	83.5	31.60	4.98	19.0	880		DRIWRC	Wild, 1990
967	881004	7.58	1230	241	243	120.0	308.0	118.0	83.4	30.70	4.65	19.0	828	0.991	DRIWRC	Wild, 1990
968	881207	7.82	1340	228	247	129.0	333.0	129.0	88.1	33.00	5.14	19.1 c	904	0.981	DRIWRC	Wild, 1990
1116	890322	8.00	1360	243	245	130.0	323.0	127.0	84.6	33.30	4.98	19.1	900	0.992	DRIWRC	Wild, 1990
1198	890613	7.86	1340	232	251	131.0	351.0	129.0	88.8	37.20	5.12	19.0	959	1.001	DRIWRC	Wild, 1990
1385	891218	8.00	1400		260	132.0	382.0	135.0	92.5	36.80	5.09	19.4	954	1.014	DRIWRC	

Samp#	Date yymmdd	Lab pH	Lab EC	Field HCO3- mg/l	Lab HCO3- mg/l	Cl- mg/l	SO4-- mg/l	Ca++ mg/l	Mg++ mg/l	Na+ mg/l	K+ mg/l	SiO2 mg/l	TDS mg/l	EPM bal	Lab Code	Data Source
Site Number----Site Name																
20613111411----MDB6																
1233	890622	11.81	2030			63.0	178.0	185.0	.2	55.10	22.40	5.0	728	1.057	DRIWRC	Wild, 1990
Site Number----Site Name																
20613143401----USGS #37																
93	811019	7.00			403	120.0	570.0	130.0	120.0	85.00	55.00	45.0	1440		80020	Dettinger, 1987
422	870600	7.75		606		170.0	802.0	191.0	193.0	140.00	30.40	42.0	1860		DRIWRC	B & K, 1988
438	880615	7.74	2170	584	579	118.0	590.0	141.0	147.0	141.00	22.30	39.0	1590		DRIWRC	Wild, 1990
921	880920	7.32	2090	561	581	138.0	592.0	158.0	148.0	138.00	24.00	42.0	1650	0.990	DRIWRC	Wild, 1990
960	881207	7.46	2740	515	556	217.0	850.0	216.0	202.0	160.00	26.60	39.5 c	1779	0.974	DRIWRC	Wild, 1990
1117	890322	7.75	2490	550	557	178.0	743.0	186.0	183.0	144.00	24.00	36.7	1920	0.949	DRIWRC	Wild, 1990
1199	890615	7.58	2420	512	563	172.0	739.0	175.0	165.0	145.00	22.40	37.0	1855	1.043	DRIWRC	Wild, 1990
Site Number----Site Name																
20613221121----MDB5																
1232	890626	8.20	1420	55	58	14.5	747.0	255.0	20.7	33.20	39.00	18.5	1185	1.004	DRIWRC	Wild, 1990
Site Number----Site Name																
20613644402----LG048 Charleston Blvd 40																
290	710609			225		117.0	1308.0	202.0	208.0	148.00	26.00		2121			Kaufmann, 1978
291	710913			175		129.0	1258.0	196.0	200.0	168.00	28.00		2065			Kaufmann, 1978
292	711203			216		126.0	1110.0	192.0	173.0	135.00	23.00		1866			Kaufmann, 1978
293	720201			196		125.0	1181.0	171.0	192.0	134.00	68.00		1969			Kaufmann, 1978
294	720731			120		124.0	1185.0	150.0	190.0	135.00	26.00		1871			Kaufmann, 1978
295	721101			92		126.0	1168.0	136.0	184.0	125.00	24.00		1810			Kaufmann, 1978
296	730212			157		113.0	1090.0	155.0	171.0	127.00	23.00		1757			Kaufmann, 1978
297	730504			127		120.0	1083.0	136.0	180.0	137.00	20.00		1739			Kaufmann, 1978
298	730802			134		124.0	1140.0	143.0	184.0	129.00	22.00		1808			Kaufmann, 1978
40	820525			210		3.7	1500.0	290.0	290.0	240.00	43.00	64.0	3300		32017	Dettinger, 1987
399	870600	7.20		217		408.0	2370.0	347.0	383.0	338.00	55.60	24.0	4390		DRIWRC	B & K, 1988
443	880628	7.38	4880	275	255	420.0	2460.0	336.0	392.0	348.00	57.80	29.0	4390		DRIWRC	Wild, 1990
926	880926	7.66	4920	262	273	422.0	2370.0	324.0	387.0	364.00	61.20	30.0	4420	1.006	DRIWRC	Wild, 1990
969	881211	7.20	5090	253	261	447.0	2600.0	333.0	411.0	380.00	67.00	29.9 c	4580	1.035	DRIWRC	Wild, 1990
1119	890323	7.81	5180	304	296	441.0	2510.0	344.0	420.0	399.00	67.60	35.5	4740	0.984	DRIWRC	Wild, 1990
1203	890621	7.26	5020	287	274	421.0	2540.0	324.0	400.0	379.00	61.70	29.8	4580	1.034	DRIWRC	Wild, 1990
Site Number----Site Name																
21610113331----USGS #11																
95	811021	7.10			281	420.0	2400.0	370.0	320.0	530.00	28.00	30.0	4780		80020	Dettinger, 1987
434	880613	7.70	4830	354	305	368.0	2250.0	331.0	276.0	512.00	39.70	28.0	4200		DRIWRC	Wild, 1990
949	880929	7.51	4820	360	303	372.0	2270.0	320.0	274.0	512.00	41.80	28.0	4230	1.011	DRIWRC	Wild, 1990
952	881208	7.53	4840	284	301	380.0	2300.0	324.0	276.0	491.00	41.40	28.5 c	4230	1.043	DRIWRC	Wild, 1990
1120	890322	7.68	4920	306	301	394.0	2250.0	328.0	278.0	511.00	43.10	28.1	4280	1.012	DRIWRC	Wild, 1990
1204	890613	7.72	5020	278	301	410.0	2370.0	345.0	287.0	522.00	43.70	28.1	4410	1.023	DRIWRC	Wild, 1990

Samp#	Date yymmdd	Lab pH	Lab EC	Field HCO3- mg/l	Lab HCO3- mg/l	Cl- mg/l	SO4-- mg/l	Ca++ mg/l	Mg++ mg/l	Na+ mg/l	K+ mg/l	SiO2 mg/l	TDS mg/l	EPM bal	Lab Code	Data Source
Site Number----Site Name 21610311141----USGS #47																
96	811019	7.20			232	130.0	480.0	130.0	67.0	120.00	22.00	28.0	1130		80020	Dettinger, 1987
966	881212	7.68	2650	247	255	166.0	1240.0	218.0	211.0	141.00	14.90	24.6 c	2360	1.001	DRIWRC	Wild, 1990
Site Number----Site Name 21610412301----USGS #43																
52	811022	7.50			390	480.0	2800.0	480.0	510.0	230.00	14.00	48.0	5160		80020	Dettinger, 1987
53	820517			390		230.0	2700.0	480.0	430.0	200.00	50.00	52.0	5140		32017	Dettinger, 1987
54	820824			380		250.0	3500.0	520.0	460.0	230.00	48.00	50.0	5000		32017	Dettinger, 1987
405	870500	7.67		377		206.0	2810.0	470.0	447.0	226.00	40.70	48.0	4650		DRIWRC	B & K, 1988
436	880614	7.55	4810	410	388	214.0	2730.0	447.0	435.0	229.00	41.90	51.0	4740		DRIWRC	Wild, 1990
922	880920	7.55	4690	366	379	214.0	2660.0	444.0	434.0	227.00	43.60	49.0	4740	0.992	DRIWRC	Wild, 1990
978	881211	7.21	4730	362	382	214.0	2840.0	443.0	435.0	234.00	46.10	50.0 c	4720	1.042	DRIWRC	Wild, 1990
1122	890322	7.65	4720	381	391	210.0	2640.0	449.0	429.0	229.00	41.60	50.2	4690	0.990	DRIWRC	Wild, 1990
1200	890620	7.39	4660	360	387	208.0	2760.0	433.0	423.0	222.00	41.20	49.5	4830	1.048	DRIWRC	Wild, 1990
Site Number----Site Name 21610922221----USGS #3a																
97	811022	7.90			244	170.0	1000.0	170.0	140.0	230.00	14.00	23.0	2050		80020	Dettinger, 198
Site Number----Site Name 21611324121----C11																
429	880609	7.68	4740		264	264.0	2510.0	442.0	309.0	368.00	57.10	41.0	4410		DRIWRC	Wild, 1990
927	880928	7.74	4430	255	266	236.0	2370.0	434.0	294.0	331.00	53.50	44.0	4130	0.985	DRIWRC	Wild, 1990
930	881211	7.60	4280	247	267	224.0	2350.0	411.0	281.0	306.00	56.00	42.9 c	3990	1.028	DRIWRC	Wild, 1990
1102	890321	7.75	4260	272	268	219.0	2230.0	408.0	280.0	297.00	51.30	40.2	3970	0.996	DRIWRC	Wild, 1990
1222	890615	7.62	4270	238	270	216.0	2320.0	411.0	304.0	292.00	49.60	39.8	3990	0.993	DRIWRC	Wild, 1990
Site Number----Site Name 21611544441----Maryland Pkway & Flamingo																
98	811019	7.50			305	150.0	1600.0	420.0	200.0	130.00	28.00	48.0	2890		80020	Dettinger, 1987
439	880616	7.95	2980		317	153.0	1420.0	329.0	195.0	140.00	20.70	36.0	2630		DRIWRC	Wild, 1990
924	880921	7.83	3280	273	309	172.0	1620.0	366.0	217.0	177.00	26.20	37.0	3000	0.986	DRIWRC	Wild, 1990
963	881212	7.69	3030	293	313	167.0	1510.0	341.0	196.0	156.00	27.60	37.1 c	2720	1.022	DRIWRC	Wild, 1990
1124	890323	8.02	2970	318	319	158.0	1360.0	326.0	196.0	144.00	22.80	34.9	2630	0.970	DRIWRC	Wild, 1990
1225	890615	7.79	2860	287	320	149.0	1380.0	317.0	186.0	146.00	20.80	33.8	2515	1.006	DRIWRC	Wild, 1990

Samp#	Date yymmdd	Lab pH	Lab EC	Field HCO3- mg/l	Lab HCO3- mg/l	Cl- mg/l	SO4-- mg/l	Ca++ mg/l	Mg++ mg/l	Na+ mg/l	K+ mg/l	SiO2 mg/l	TDS mg/l	EPM bal	Lab code	Data Source
Site Number----Site Name																
21611721441----USGS #40																
62	811022	7.60			183	250.0	1500.0	350.0	210.0	180.00	7.40	15.0	2740		80020	Dettinger, 1987
63	820517			180		210.0	1400.0	340.0	200.0	120.00	8.10	16.0	2710		32017	Dettinger, 1987
64	820823			230		240.0	1600.0	310.0	220.0	210.00	9.00	17.0	3000		32017	Dettinger, 1987
410	871100	7.02		246		224.0	1440.0	340.0	194.0	167.00	14.40	22.0	2760		DRIWRC	B & K, 1988
437	880614	7.50	3480	242	251	268.0	1530.0	360.0	212.0	198.00	17.00	22.0	2970		DRIWRC	Wild, 1990
972	880929	7.53	3600	253	255	288.0	1590.0	359.0	219.0	222.00	17.50	22.0	3050	1.011	DRIWRC	Wild, 1990
975	881207	7.45	3640	336	255	296.0	1620.0	388.0	218.0	239.00	17.30	22.2 c	3100	0.986	DRIWRC	Wild, 1990
1125	890323	7.72	3730	256	258	307.0	1600.0	367.0	221.0	249.00	17.90	22.3	3190	0.994	DRIWRC	Wild, 1990
1224	890621	7.76	3730	256	260	307.0	1690.0	357.0	223.0	254.00	18.60	22.4	3212	1.034	DRIWRC	Wild, 1990
Site Number----Site Name																
21612431401----USGS #56																
100	811020	7.40			183	650.0	2900.0	610.0	410.0	340.00	20.00	38.0	5400		80020	Dettinger, 1987
Site Number----Site Name																
21612644221----Paradise Vista Park																
435	880613	7.63	3740		217	259.0	2250.0	379.0	225.0	247.00	18.80	24.0	3290		DRIWRC	Wild, 1990
970	881003	7.66	3720	217	220	252.0	1790.0	371.0	227.0	253.00	19.30	24.0	3300	0.999	DRIWRC	Wild, 1990
971	881208	7.50	3710	210	221	251.0	1850.0	370.0	225.0	250.00	19.70	24.7 c	3280	1.031	DRIWRC	Wild, 1990
1127	890320	7.91	3300	207	208	225.0	1580.0	351.0	185.0	212.00	15.50	22.8	2920	1.020	DRIWRC	Wild, 1990
1215	890613	7.65	3600	201	216	238.0	1750.0	394.0	203.0	225.00	17.20	22.8	3230	1.015	DRIWRC	Wild, 1990
Site Number----Site Name																
21621711201----USGS #5																
66	811020	7.20			281	370.0	2500.0	490.0	260.0	440.00	61.00	61.0	4730		80020	Dettinger, 1987
67	820518	7.20		270	281	340.0	2300.0	500.0	260.0	370.00	57.00	54.0	4190		80020	Dettinger, 1987
68	820518					350.0		500.0				62.0	3650		32017	Dettinger, 1987
69	820824			300		350.0	2400.0	403.0	280.0	410.00	63.00	54.0	4340		32017	Dettinger, 1987
412	870500	7.63		323		457.0	2470.0	526.0	305.0	440.00	56.50	57.0	4780		DRIWRC	B & K, 1988
433	880613	7.67	5410	310	319	480.0	2590.0	505.0	308.0	458.00	61.00	58.0	4880		DRIWRC	Wild, 1990
956	880929	7.54	5320	322	320	472.0	2640.0	487.0	298.0	447.00	68.40	62.0	4800	1.052	DRIWRC	Wild, 1990
959	881208	7.73	5190	323	323	466.0	2540.0	480.0	303.0	422.00	58.40	60.3 c	4680	1.040	DRIWRC	Wild, 1990
1129	890321	7.98	5300	317	319	482.0	2480.0	485.0	314.0	437.00	60.70	55.9	4820	1.002	DRIWRC	Wild, 1990
1205	890613	7.65	5410	299	321	487.0	2650.0	513.0	320.0	446.00	67.20	57.2	4940	1.020	DRIWRC	Wild, 1990
Site Number----Site Name																
21621932321----C27																
430	880609	7.69	7220	348	269	374.0	4640.0	476.0	784.0	566.00	24.40	32.0	7580		DRIWRC	Wild, 1990
917	880919	7.59	7960	497	268	483.0	5000.0	475.0	831.0	644.00	31.40	30.0	8470	1.013	DRIWRC	Wild, 1990
933	881208	7.62	8210	259	267	502.0	5250.0	480.0	796.0	687.00	35.00	30.0 c	8680	1.067	DRIWRC	Wild, 1990
1105	890321	7.77	6770	247	250	337.0	4180.0	453.0	661.0	509.00	30.30	29.7	7110	1.009	DRIWRC	Wild, 1990
1217	890615	7.76	6920	223	256	359.0	4490.0	464.0	715.0	527.00	33.60	29.0	7370	1.022	DRIWRC	Wild, 1990
1379	891219	7.74	6570		262	272.0	4350.0	461.0	661.0	485.00	39.20	29.5	7050	1.032	DRIWRC	

Sampl	Date yymmdd	Lab pH	Lab EC	Field HCO3- mg/l	Lab HCO3- mg/l	Cl- mg/l	SO4-- mg/l	Ca++ mg/l	Mg++ mg/l	Na+ mg/l	K+ mg/l	SiO2 mg/l	TDS mg/l	EPM bal	Lab Code	Data Source
Site Number----Site Name																
21622022411----C49																
431	880609	7.60	3690	265	255	280.0	1640.0	316.0	210.0	297.00	21.20	36.0	3170		DRIWRC	Wild, 1990
920	880919	7.48	3730	265	255	274.0	1720.0	315.0	213.0	300.00	23.40	37.0	3230	1.026	DRIWRC	Wild, 1990
948	881208	7.47	3710	240	256	264.0	1740.0	319.0	213.0	306.00	23.40	36.9 c	3200	1.020	DRIWRC	Wild, 1990
1113	890321	7.86	3670	253	257	272.0	1650.0	315.0	209.0	297.00	22.40	36.1	3160	1.005	DRIWRC	Wild, 1990
1221	890614	7.71	3620	232	258	270.0	1640.0	314.0	202.0	286.00	22.00	36.2	3120	1.026	DRIWRC	Wild, 1990
Site Number----Site Name																
21622642102----LG030 Duck Ck @ LV Wash30																
174	710609			270		1168.0	3228.0	632.0	456.0	885.00	111.00		6616			Kaufmann, 1978
175	710914			260		1346.0	3249.0	616.0	433.0	897.00	100.00		6771			Kaufmann, 1978
176	711203			229		1337.0	3268.0	597.0	482.0	958.00	105.00		6865			Kaufmann, 1978
177	720202			259		1326.0	3338.0	588.0	469.0	925.00	126.00		6906			Kaufmann, 1978
178	720731			148		1330.0	3285.0	558.0	438.0	922.00	109.00		6719			Kaufmann, 1978
179	721103			263		1283.0	3082.0	581.0	424.0	903.00	111.00		6521			Kaufmann, 1978
180	730208			190		1243.0	3184.0	512.0	414.0	921.00	109.00		6482			Kaufmann, 1978
181	730508			198		1272.0	2958.0	526.0	397.0	862.00	104.00		6217			Kaufmann, 1978
182	730801			213		1337.0	2903.0	545.0	397.0	875.00	113.00		6275			Kaufmann, 1978
70	820519			290		1500.0	2500.0	590.0	370.0	790.00	120.00		7200		32017	Dettinger, 1987
71	820825			290		1500.0	2400.0	590.0	370.0	890.00	120.00	7.0	6570		32017	Dettinger, 1987
413	870600	7.27		290		1520.0	3280.0	619.0	426.0	1130.00	111.00	72.0	7640		DRIWRC	B & K, 1988
442	880628	7.49	8350	243	266	1340.0	3200.0	564.0	388.0	982.00	102.00	71.0	7030		DRIWRC	Wild, 1990
961	881004	7.24	8330	241	258	1370.0	3040.0	570.0	392.0	992.00	97.10	70.0	6940	1.000	DRIWRC	Wild, 1990
962	881211	7.47	8400	246	261	1370.0	3160.0	558.0	378.0	975.00	104.00	70.1 c	7420	1.046	DRIWRC	Wild, 1990
1130	890323	7.53	7650	255	250	1160.0	2870.0	545.0	335.0	874.00	94.40	68.8	6370	1.016	DRIWRC	Wild, 1990
1207	890621	7.65	7470	244	238	1123.0	2940.0	510.0	345.0	883.00	94.30	68.4	6290	1.023	DRIWRC	Wild, 1990
Site Number----Site Name																
21622811301----USGS #3b																
101	811020	7.00			525	650.0	2400.0	570.0	240.0	520.00	55.00	55.0	4970		80020	Dettinger, 1987
Site Number----Site Name																
21622931441----C28																
432	880613	7.63	6700	318	313	863.0	2640.0	530.0	304.0	758.00	54.20	54.0	5640		DRIWRC	Wild, 1990
923	880920	7.60	6410	313	307	829.0	2520.0	495.0	290.0	721.00	54.20	55.0	5480		DRIWRC	Wild, 1990
1106	890320	7.84	5890	296	305	724.0	2360.0	458.0	269.0	621.00	50.60	55.1	5000	1.020	DRIWRC	Wild, 1990
1208	890614	7.57	5850	287	308	733.0	2360.0	464.0	274.0	610.00	31.00	54.1	4930	1.028	DRIWRC	Wild, 1990

Samp#	Date yymmdd	Lab pH	Lab EC	Field HCO3- mg/l	Lab HCO3- mg/l	Cl- mg/l	SO4-- mg/l	Ca++ mg/l	Mg++ mg/l	Na+ mg/l	K+ mg/l	SiO2 mg/l	TDS mg/l	EPM bal	Lab Code	Data Source
Site Number----Site Name 21623014111----C42																
426	880608	7.55	4790	240	248	356.0	2340.0	520.0	262.0	362.00	29.10	28.0	4460	0.988	DRIWRC	Wild, 1990
919	880919	7.55	7960	207	253	354.0	2440.0	502.0	265.0	352.00	33.10	29.0	4340	1.037	DRIWRC	Wild, 1990
947	881208	7.35	4730	240	255	346.0	2480.0	517.0	268.0	351.00	33.70	29.9	c 4370	1.032	DRIWRC	Wild, 1990
1111	890320	7.83	4710	241	252	351.0	2320.0	517.0	265.0	338.00	34.20	29.1	4400	0.993	DRIWRC	Wild, 1990
1209	890614	7.58	4700	220	254	351.0	2390.0	513.0	265.0	335.00	34.50	28.3	4380	1.025	DRIWRC	Wild, 1990
Site Number----Site Name 21623024111----C32																
428	880608	7.67	4960	154	165	298.0	2740.0	432.0	398.0	343.00	19.70	30.0	4790	0.985	DRIWRC	Wild, 1990
937	880928	7.70	5060	167	170	292.0	2820.0	423.0	410.0	353.00	24.60	31.0	4920	0.991	DRIWRC	Wild, 1990
938	881208	7.59	5070	165	168	294.0	3010.0	434.0	403.0	370.00	21.60	31.2	c 4910	1.039	DRIWRC	Wild, 1990
1108	890320	7.84	4950	168	171	276.0	2840.0	431.0	390.0	343.00	21.00	31.1	4860	1.016	DRIWRC	Wild, 1990
1211	890614	7.64	4780	165	176	248.0	2780.0	420.0	380.0	317.00	19.60	30.3	4650	1.027	DRIWRC	Wild, 1990
Site Number----Site Name 21623024341----C29																
427	880608	7.58	5830	217	207	510.0	2960.0	525.0	396.0	449.00	51.60	44.0	5520	1.000	DRIWRC	Wild, 1990
918	880919	7.72	5800	207	207	497.0	3040.0	518.0	392.0	453.00	52.10	44.0	5500	1.023	DRIWRC	Wild, 1990
936	881208	7.49	5980	192	204	538.0	3170.0	531.0	415.0	489.00	56.50	44.9	c 5670	1.017	DRIWRC	Wild, 1990
1107	890321	7.82	6100	200	200	567.0	3030.0	544.0	420.0	478.00	54.40	44.9	5790	0.985	DRIWRC	Wild, 1990
1212	890614	7.57	5820	184	205	500.0	3050.0	518.0	390.0	460.00	52.90	44.2	5530	1.025	DRIWRC	Wild, 1990

*B & K, 1988 = Brothers and Katzer, 1988

c - TDS calculated from electrical conductivity

APPENDIX D.

Nutrient, Minor Constituent, and Isotope Data

Sample Number	Sample Date yymmdd	F mg/l	NO3 mg/l	NO3 as N mg/l	NO2 as N mg/l	NO2 +NO3 as N mg/l	NH4 mg/l	DOC mg/l	TOC mg/l	PO4 Dissolved mg/l	PO4 Total mg/l	Gross Alpha ug/l as U-Nat	Gross Beta PCi/l as Cs-137	Tritium Enriched TU	Delta Deuterium per mil	Delta Oxygen 18 per mil	Data Source
Site Number--Site Name																	
20610113341--USGS #19																	
16	820517	0.95							8.40			< 16.0	9.3				*1Detting
444	880630		0.44	0.10										< 5	-100	-13.6	*2Wild, 1
Site Number--Site Name																	
20611433331--USGS #15																	
441	880620		1.24	0.28										< 5	-101	-13.8	Wild, 1
925	880926		1.15	0.26						0.010	0.013				-100	-13.8	Wild, 1
955	881212		1.55	0.35						<0.005	0.012				- 99	-14.0	Wild, 1
1115	890322	0.20	2.22	0.50				0.95	0.93						-100	-13.7	Wild, 1
1197	890627	0.22	1.82	0.41				1.20	0.50						- 99	-13.7	Wild, 1
Site Number--Site Name																	
20612433122--NLVWD CollegePark#2-Shall																	
1227	890627	0.52	26.80	6.04				2.40	2.20						- 99	-12.7	Wild, 1
Site Number--Site Name																	
20612933341--MDB3																	
1230	890622		0.04	0.01											-100	-13.7	Wild, 1
Site Number--Site Name																	
20613024301--USGS #34																	
34	820517	0.20			<0.02	1.70			2.20	0.030		< 23.0	17.0				Detting
440	880620		18.80	4.25										< 5	- 98	-13.5	Wild, 1
967	881004		18.30	4.14						<0.005	<0.005				- 98	-13.3	Wild, 1
968	881207		21.04	4.73						<0.005	<0.005				- 96	-13.3	Wild, 1
1116	890322	0.18	21.20	4.78				1.20	2.00						- 97	-13.0	Wild, 1
1198	890613	0.18	24.50	5.53				2.50	2.70						- 99	-12.7	Wild, 1
Site Number--Site Name																	
20613111411--MDB6																	
1233	890622		1.68	0.38											-104	-12.2	Wild, 1
Site Number--Site Name																	
20613143401--USGS #37																	
438	880615		41.10	9.27										15+/-3	- 95	-12.6	Wild, 1
921	880920		41.00	9.25						<0.005	<0.005				- 92	-12.1	Wild, 1
960	881207		73.50	16.60						<0.005	<0.005				- 93	-12.4	Wild, 1
1117	890322	0.18	54.00	12.20				8.10	8.50						- 94	-12.3	Wild, 1
1199	890615	0.18	60.20	13.60				9.40	9.40						- 94	-11.9	Wild, 1

Sample Number	Sample Date yymmdd	F mg/l	NO3 mg/l	NO3 as N mg/l	NO2 as N mg/l	NO2 +NO3 as N mg/l	NH4 mg/l	DOC mg/l	TOC mg/l	PO4 Dissolved mg/l	PO4 Total mg/l	Gross Alpha ug/l as U-Nat	Gross Beta PCi/l as Cs-137	Tritium Enriched TU	Delta Deuterium per mil	Delta Oxygen 18 per mil	Data Source
Site Number--Site Name 20613221121--MDB5																	
1232	890626		0.97	0.22											- 99	-13.5	Wild, 1
Site Number--Site Name 20613644402--LG048 Charleston Blvd 40																	
290	710609	0.40	< 0.10							<0.100				4			Kaufman
443	880628		2.92	0.66										18+/-3	-100	-13.2	Wild, 1
926	880926		3.28	0.74						<0.005	<0.005				- 99	-13.5	Wild, 1
969	881210		3.06	0.69						<0.005	<0.005				- 99	-13.8	Wild, 1
1119	890323	0.31	5.14	1.16				2.70	2.80						- 99	-13.2	Wild, 1
1203	890621	0.30	3.59	0.81				1.90	1.90						-100	-13.0	Wild, 1
Site Number--Site Name 21610113331--USGS #11																	
434	880613		23.20	5.24										30+/-3	- 97	-12.5	Wild, 1
949	880929		22.90	5.18						<0.005	<0.005				- 99	-12.8	Wild, 1
952	881208		24.00	5.42						<0.005	<0.005				- 98	-12.9	Wild, 1
1120	890322	0.23	25.30	5.72				2.70	2.70						- 99	-12.5	Wild, 1
1204	890613	0.23	16.30	3.68				2.50	2.80						-100	-12.5	Wild, 1
Site Number--Site Name 21610412301--USGS #43																	
53	820517	0.25			<0.02	9.80			3.60	0.020		<200.0	98.0				Detting
436	880614		43.70	9.86										21+/-3	- 97	-11.8	Wild, 1
922	880920		42.80	9.67						0.005	0.005				- 97	-12.6	Wild, 1
978	881210		45.60	10.30						<0.005	<0.005				- 97	-12.6	Wild, 1
1122	890322	0.21	44.10	9.95				3.40	3.40						- 97	-12.5	Wild, 1
1200	890620	0.21	41.30	9.32				3.20	3.30						- 97	-12.4	Wild, 1
Site Number--Site Name 21611324121--C11																	
429	880609		23.30	5.26										27+/-4	- 94	-11.8	Wild, 1
927	880928		20.70	4.67						<0.005	<0.005				- 95	-12.3	Wild, 1
930	881210		22.40	5.05						<0.005	<0.005				- 96	-12.6	Wild, 1
1102	890321	0.59	22.50	5.07				1.80	1.70						- 95	-12.5	Wild, 1
1222	890615	0.58	16.80	3.79				1.80	1.60						- 98	-12.3	Wild, 1

Sample Number	Sample Date yymmdd	F mg/l	NO3 mg/l	NO3 as N mg/l	NO2 as N mg/l	NO2 +NO3 as N mg/l	NH4 mg/l	DOC mg/l	TOC mg/l	PO4 Dis-sol-ved mg/l	PO4 Total mg/l	Gross Alpha ug/l as U-Nat	Gross Beta PCi/l as Cs-137	Tritium Enriched TU	Delta Deuterium per mil	Delta Oxygen 18 per mil	Data Source
Site Number--Site Name 21611544441--Maryland Pkway & Flamingo																	
439	880616		4.56	1.03										21+/-3	- 95	-12.1	Wild, 1
924	880921		13.20	2.99						0.065	0.070				- 95	-12.4	Wild, 1
963	881212		14.20	3.20						0.028	0.047				- 94	-12.7	Wild, 1
1124	890323	0.76	4.47	1.01				2.60	2.80						- 97	-12.4	Wild, 1
1225	890615	0.70	3.72	0.84				2.00	2.00						- 97	-12.1	Wild, 1
Site Number--Site Name 21611721441--USGS #40																	
63	820517	0.31			<0.02	2.80			3.10	0.020		< 79.0	33.0	0			Detting
437	880614		62.00	14.00										19+/-3	- 94	-11.9	Wild, 1
972	880929		69.60	15.70						<0.005	0.005				- 93	-12.1	Wild, 1
975	881207		74.90	16.90						<0.005	<0.005				- 93	-12.2	Wild, 1
1125	890323	0.19	80.20	18.10				2.00	2.00						- 93	-12.1	Wild, 1
1224	890621	0.21	73.10	16.50				1.90	1.90						- 94	-11.9	Wild, 1
Site Number--Site Name 21612644221--Paradise Vista Park																	
435	880613		37.80	8.54										25+/-3	- 98	-11.7	Wild, 1
970	881003		40.10	9.05						<0.005	<0.005				- 97	-12.3	Wild, 1
971	881208		38.50	8.70						<0.005	<0.005				- 95	-12.5	Wild, 1
1127	890320	0.26	32.60	7.35				2.20	2.10						- 98	-12.8	Wild, 1
1215	890613	0.26	36.70	8.29				2.30	2.60						- 99	-12.1	Wild, 1
Site Number--Site Name 21621711201--USGS #5																	
67	820518	0.50			<0.02	3.30			3.90	0.030		<140.0	81.0				Detting
433	880613		11.00	2.48										18+/-3	- 98	-12.3	Wild, 1
956	880929		9.70	2.19						<0.005	0.005				- 99	-12.9	Wild, 1
959	881208		11.30	2.56						<0.005	0.016				- 98	-13.1	Wild, 1
1129	890321	0.52	17.40	3.92				3.80	3.80						- 98	-13.0	Wild, 1
1205	890613	0.50	20.70	4.67				4.40	4.20						- 99	-12.8	Wild, 1
Site Number--Site Name 21621932321--C27																	
430	880609		15.50	3.51										30+/-4	- 96	-12.4	Wild, 1
917	880919		20.20	4.56						<0.005	<0.005				- 96	-12.3	Wild, 1
933	881208		22.10	4.98						<0.005	<0.005				- 97	-12.5	Wild, 1
1105	890321	0.46	11.60	2.62				3.00	3.40						- 96	-12.5	Wild, 1
1217	890615	0.46	19.30	4.36				2.80	2.80						- 99	-12.1	Wild, 1

Sample Number	Sample Date yymmdd	F mg/l	NO3 mg/l	NO3 as N mg/l	NO2 as N mg/l	NO2 +NO3 as N mg/l	NH4 mg/l	DOC mg/l	TOC mg/l	PO4 Dissolved mg/l	PO4 Total mg/l	Gross Alpha ug/l as U-Nat	Gross Beta PCi/l as Cs-137	Tritium Enriched TU	Delta Deuterium per mil	Delta Oxygen 18 per mil	Data Source
Site Number--Site Name 21622022411--C49																	
431	880609		22.20	5.00										23+/-3	- 99	-12.6	Wild, 1
920	880919		22.90	5.17						0.007	0.006				- 98	-12.8	Wild, 1
948	881208		26.40	5.95						<0.005	0.007				- 98	-13.0	Wild, 1
1113	890321	0.44	24.50	5.53				1.80	1.60						-100	-12.3	Wild, 1
1221	890614	0.47	29.80	6.72				1.60	1.50						- 99	-12.8	Wild, 1
Site Number--Site Name 21622642102--LG030 Duck Ck @ LV Wash30																	
70	820519	1.70			<0.02	4.70			5.10	0.020		<230.0	110.0				Detting
442	880628		6.91	1.56										13+/-3	- 93	-11.5	Wild, 1
961	881004		7.71	1.74						<0.005	0.007				- 89	-11.6	Wild, 1
962	881210		6.91	1.56						<0.005	<0.005				- 91	-12.0	Wild, 1
1130	890323	1.67	5.80	1.31				2.80	2.90						- 93	-12.0	Wild, 1
1207	890621	1.60	4.30	0.97				2.50	2.50						- 93	-11.8	Wild, 1
Site Number--Site Name 21622931441--C28																	
432	880613		12.00	2.70										27+/-3	- 98	-12.2	Wild, 1
923	880920		10.70	2.42						0.032	0.003				- 96	-12.4	Wild, 1
1106	890320	1.32	10.10	2.29				1.10	1.00						-100	-12.7	Wild, 1
1208	890614	1.40	11.30	2.56				0.90	2.00						- 97	-12.4	Wild, 1
Site Number--Site Name 21623014111--C42																	
426	880608		24.50	5.52										21+/-2	-100	-12.6	Wild, 1
947	881208		26.40	5.96						<0.005	<0.005				- 96	-12.4	Wild, 1
1111	890320	0.37	25.60	5.78				2.50	2.10						- 98	-12.5	Wild, 1
1209	890614	0.39	37.20	8.40				2.40	2.30						- 97	-12.4	Wild, 1
919	890919		24.20	5.46						<0.005	<0.005				- 94	-12.3	Wild, 1
Site Number--Site Name 21623024111--C32																	
428	880608		31.20	7.04										16+/-3	- 97	-11.2	Wild, 1
937	880928		27.40	6.19						<0.005	<0.005				- 99	-12.7	Wild, 1
938	881208		30.70	6.94						<0.005	<0.005				- 97	-12.8	Wild, 1
1108	890320	0.51	28.00	6.32				1.80	1.80						-100	-12.8	Wild, 1
1211	890614	0.51	35.10	7.93				2.40	2.30						- 98	-12.3	Wild, 1

Sample Number	Sample Date yymmdd	F mg/l	NO3 mg/l	NO3 as N mg/l	NO2 as N mg/l	NO2 +NO3 as N mg/l	NH4 mg/l	DOC mg/l	TOC mg/l	PO4 Dissolved mg/l	PO4 Total mg/l	Gross Alpha ug/l as U-Nat	Gross Beta PCi/l as Cs-137	Tritium Enriched TU	Delta Deuterium per mil	Delta Oxygen 18 per mil	Data Source
Site Number--Site Name																	
21623024341--C29																	
427	880608		14.00	3.17										13+/-2	- 97	-12.5	Wild, 1
936	881208		17.00	3.83						<0.005	<0.005				- 96	-12.8	Wild, 1
1107	890321	0.49	16.70	3.78				2.50	2.20						- 98	-12.9	Wild, 1
1212	890614	0.52	17.80	4.02				1.90	2.30						- 97	-12.1	Wild, 1
918	890919		14.00	3.16						<0.005	<0.005				- 95	-12.6	Wild, 1

*1 Detting = Dettinger, 1987
*2 Wild, 1 = Wild, 1990

APPENDIX E.

Trace Metal Data

Sample#	Sample Date yymmdd	Ag mg/l	As mg/l	B mg/l	Ba mg/l	Cd mg/l	Cr mg/l	Cu mg/l	Fe mg/l	Hg mg/l	Mn mg/l	Ni mg/l	Pb mg/l	Se mg/l	Zn mg/l	Data Source
21611721441--USGS #40																
63	820517	<0.120	0.001	<0.25	<0.050	0.0003	<0.002	<0.025	0.02	<0.0010	0.02	<0.00	<0.005	0.0006	0.020	Detting
64	820823	<0.012	0.001	0.37	<0.250	<0.0010	<0.002	<0.020	0.02		0.06	0.15	0.046	<0.0020	<0.050	Detting
1224	890621	<0.005	<0.002	1.10	0.014	<0.0050	0.040	0.014	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0160	<0.005	Wild, 1
21612644221--Paradise Vista Park																
1215	890613	<0.005	0.007	0.90	0.017	<0.0050	<0.020	0.019	0.06	<0.0002	<0.01	<0.01	<0.020	0.0150	0.008	Wild, 1
21621711201--USGS #5																
67	820518	<0.001	0.010	2.60	<0.100	<0.0010	0.002	0.001	0.09	0.0001	0.02	0.00	0.001	0.0050	0.020	Detting
68	820518	<0.012	0.006	<0.25	<0.050	<0.0001	<0.002	<0.025	0.02	0.0010	0.01	<0.00	<0.005	<0.0005	0.020	Detting
69	820824	<0.012	0.002	0.58	<0.250	<0.0010	<0.002	<0.020	0.30		0.01	0.20	0.048	<0.0020	<0.050	Detting
412	870500	<0.005	0.012	2.20	0.000	<0.0050	<0.020	0.018	0.02	<0.0002	<0.01	<0.01	<0.050	0.0060	<0.010	B & K,
1205	890613	<0.005	0.010	2.60	0.011	<0.0050	<0.020	0.020	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0090	<0.005	Wild, 1
21621932321--C27																
1217	890615	<0.005	0.016	3.50	0.008	<0.0050	<0.020	0.025	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0450	<0.005	Wild, 1
21622022411--C49																
1221	890614	<0.005	0.013	1.70	0.012	<0.0050	<0.020	0.013	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0190	<0.005	Wild, 1
21622642102--LG030 Duck Ck @ LV Wash30																
70	820519	<0.012	0.030		<0.050	<0.0001	<0.002	<0.025	0.46	0.0010	0.11	<0.02	<0.005	<0.0005	0.030	Detting
71	820825	<0.012	0.017	0.63	<0.250	<0.0010	0.007	0.060	1.00		0.06	7.00	0.032	<0.0020	0.140	Detting
413	870600	<0.005	0.070	3.50	0.000	<0.0050	<0.020	0.023	0.64	<0.0002	0.18	<0.01	<0.050	0.0070	0.026	B & K,
1207	890621	<0.005	0.060	3.20	0.007	<0.0050	<0.020	0.024	0.61	<0.0002	0.09	<0.01	<0.020	0.0080	<0.005	Wild, 1
21622931441--C28																
1208	890614	<0.005	0.055	2.00	0.013	<0.0050	<0.020	0.018	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0060	<0.005	Wild, 1
21623014111--C42																
1209	890614	<0.005	0.010	3.00	0.012	<0.0050	<0.020	0.020	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0360	<0.005	Wild, 1
21623024111--C32																
1211	890614	<0.005	0.021	5.00	0.009	<0.0050	<0.020	0.017	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0210	<0.005	Wild, 1
21623024341--C29																
1212	890614	<0.005	0.040	3.30	0.009	<0.0050	<0.020	0.020	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0400	<0.005	Wild, 1

*1 Detting - Dettinger, 1987
*2 B & K, - Brothers and Katzer, 1988
*3 Wild, 1 - Wild, 1990

Sam-ple#	Sample Date yymmdd	Ag mg/l	As mg/l	B mg/l	Ba mg/l	Cd mg/l	Cr mg/l	Cu mg/l	Fe mg/l	Hg mg/l	Mn mg/l	Ni mg/l	Pb mg/l	Se mg/l	Zn mg/l	Data Source
20610113341--USGS #19																
16	820517	<0.012	0.003	0.19	0.090	<0.0001	<0.002	<0.025	0.08	0.0010	0.01	<0.02	<0.005	<0.0005	0.050*1	Detting
17	820823	<0.012	0.002	0.19	<0.250	<0.0010	0.003	<0.020	0.48		0.05	<0.02	0.012	<0.0020	<0.050	Detting
20611433331--USGS #15																
22	820824	<0.012	<0.001	0.34	<0.250	<0.0010	<0.002	<0.020	0.03		0.04	0.02	<0.003	<0.0020	<0.050	Detting
390	870500	<0.005	0.008	0.06	0.110	<0.0050	<0.020	<0.005	0.03	<0.0002	0.01	<0.01	<0.050	<0.0020	0.006*2	B & K,
1197	890620	<0.005	0.002	0.05	0.183	<0.0050	<0.020	<0.005	<0.01	<0.0002	0.03	<0.01	<0.020	<0.0020	0.005*3	Wild, 1
20612433122--NLVWD CollegePark#2-Shall																
1227	890627	<0.005	0.007	2.60	0.025	<0.0050	<0.020	0.016	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0300	0.007	Wild, 1
20613024301--USGS #34																
34	820517	<0.012	0.004	0.37	<0.050	<0.0001	<0.002	<0.025	0.01	0.0010	0.00	<0.02	<0.005	0.0010	0.020	Detting
35	820824	0.012	0.008	0.39	0.250	0.0010	0.002	0.020	2.50		0.08	0.04	0.003	0.0020	0.050	Detting
395	870500	<0.005	<0.002	0.14	0.110	<0.0050	<0.020	<0.005	0.01	<0.0002	<0.01	<0.01	<0.050	0.0070	0.160	B & K,
1198	890613	<0.005	0.002	0.10	0.043	<0.0050	<0.020	0.006	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0080	<0.005	Wild, 1
20613143401--USGS #37																
422	870600	<0.005	0.005	0.27	0.080	<0.0050	<0.020	0.015	0.02	<0.0002	0.06	<0.01	<0.050	<0.0020	0.030	B & K,
1199	890615	<0.005	0.002	0.30	0.029	<0.0050	<0.020	0.015	<0.01	<0.0002	0.03	<0.01	<0.020	0.0020	0.059	Wild, 1
20613644402--LG048 Charleston Blvd 40																
40	820525	<0.012	<0.001	0.44	<0.250	<0.0010	<0.002	<0.020	4.60		0.03	0.16	0.040	<0.0020	0.050	Detting
399	870600	<0.005	<0.002	1.30	0.070	<0.0050	<0.020	0.013	2.80	<0.0002	0.19	<0.01	<0.050	<0.0020	0.017	B & K,
1203	890621	<0.005	<0.002	1.30	0.024	<0.0050	<0.020	0.016	8.40	<0.0002	0.13	<0.01	<0.020	<0.0020	0.029	Wild, 1
21610113331--USGS #11																
1204	890613	<0.005	0.002	2.70	0.018	<0.0050	<0.020	0.017	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0190	<0.005	Wild, 1
21610412301--USGS #43																
53	820517	<0.012	0.002	0.60	<0.050	0.0010	<0.002	<0.025	0.02	0.0010	0.02	<0.02	0.005	0.0005	0.220	Detting
54	820824	<0.012	<0.001	0.49	<0.250	<0.0010	<0.002	<0.020	0.03		0.01	0.28	0.005	<0.0020	<0.050	Detting
405	870500	<0.005	0.004	2.16	0.160	<0.0050	<0.020	0.020	0.03	0.0017	<0.01	<0.01	<0.050	0.0270	0.014	B & K,
1200	890620	<0.005	0.003	1.90	0.019	<0.0050	<0.020	0.022	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0230	<0.005	Wild, 1
21611324121--C11																
1222	890615	<0.005	0.003	1.60	0.014	<0.0050	<0.020	0.016	<0.01	<0.0002	<0.01	<0.01	<0.020	0.0220	<0.005	Wild, 1
21611544441--Maryland Pkway & Flamingo																
1225	890615	<0.005	0.004	0.80	0.022	<0.0050	<0.020	0.062	0.23	<0.0002	0.10	<0.01	<0.020	0.0080	0.005	Wild, 1

APPENDIX F.

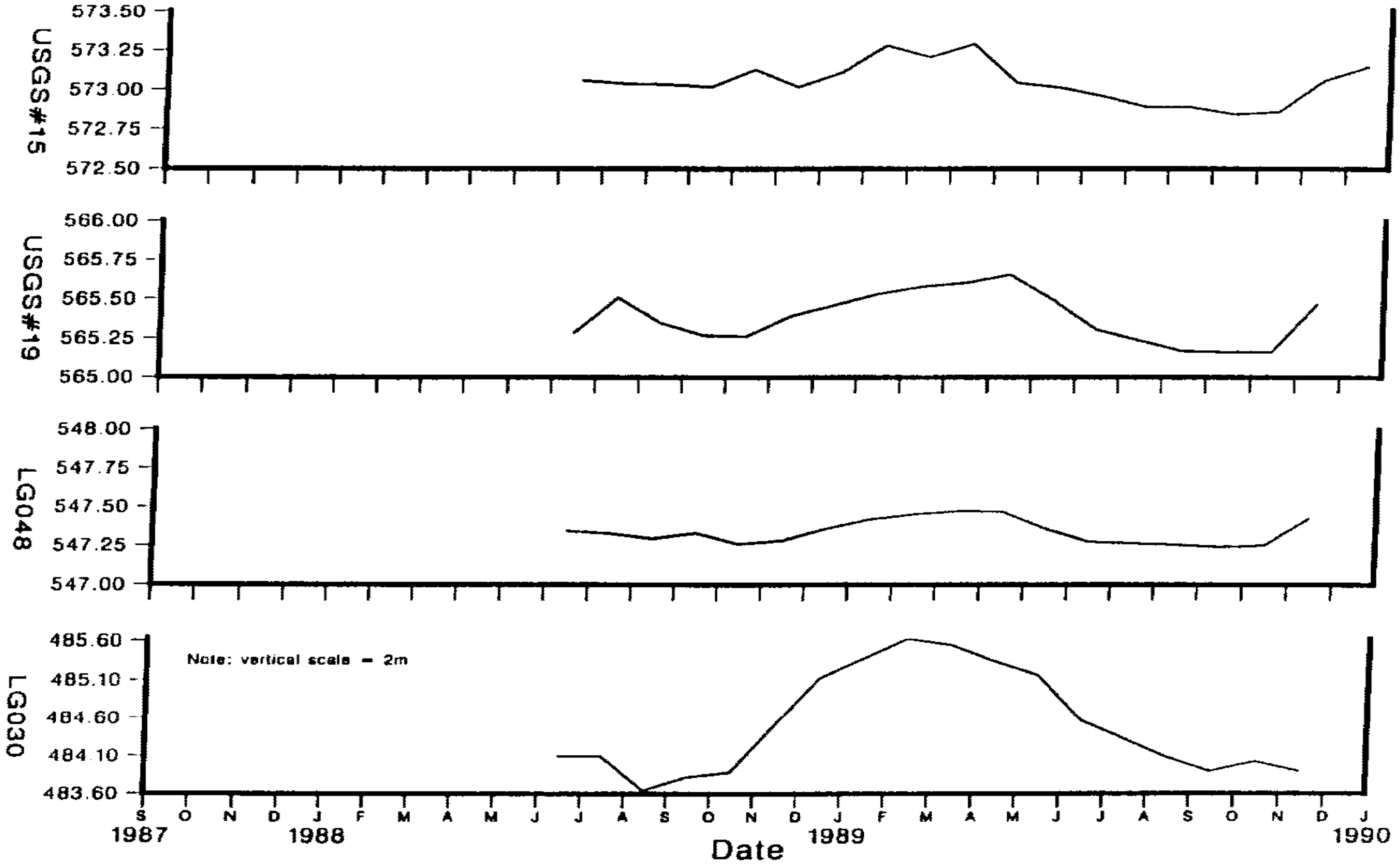
Pesticide and Herbicide Data

Sample#	Sample Date yymmdd	Silvex ug/l	2,4-D ug/l	Toxaphene ug/l	Endrin ug/l	Methoxychlor ug/l	Lindane ug/l	Analyzing Lab	Data Source
20613024301----USGS #34									
967	881004	<0.05	<0.5	<0.5	<0.01	<0.5	<0.01	alpha	Wild, 1990
21610113331----USGS #11									
949	880928	<0.05	<0.5	<0.5	<0.01	<0.5	<0.01	alpha	Wild, 1990
21611324121----Converse Well #11									
927	880928	<0.05	<0.5	<0.5	<0.01	<0.5	<0.01	alpha	Wild, 1990
21611721441----USGS #40									
972	880929	<0.05	<0.5	<0.5	<0.01	<0.5	<0.01	alpha	Wild, 1990
21612644221----Paradise Vista Park									
970	881003	<0.05	<0.5	<0.5	<0.01	<0.5	<0.01	alpha	Wild, 1990
21621711201----USGS #5									
956	880929	<0.05	<0.5	<0.5	<0.01	<0.5	<0.01	alpha	Wild, 1990
21622642102----LG030 Duck Ck @ LV Wash30									
961	881004	<0.05	<0.5	<0.5	<0.01	<0.5	<0.01	alpha	Wild, 1990
21623024111----Converse Well #32									
937	880928	<0.05	<0.5	<0.5	<0.01	<0.5	<0.01	alpha	Wild, 1990

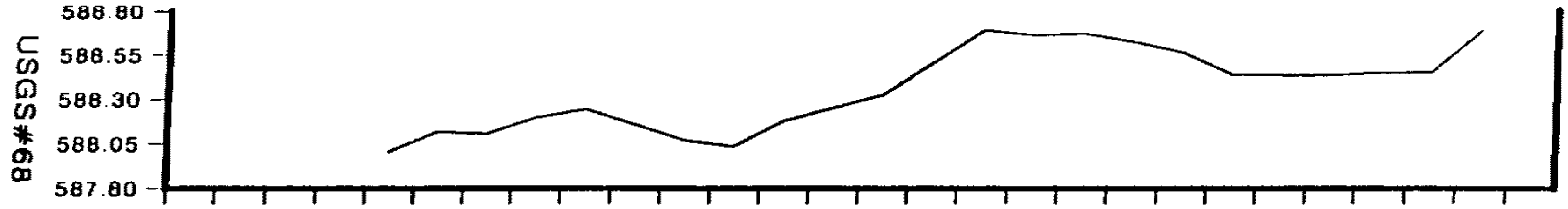
APPENDIX G.

Water Level Hydrographs

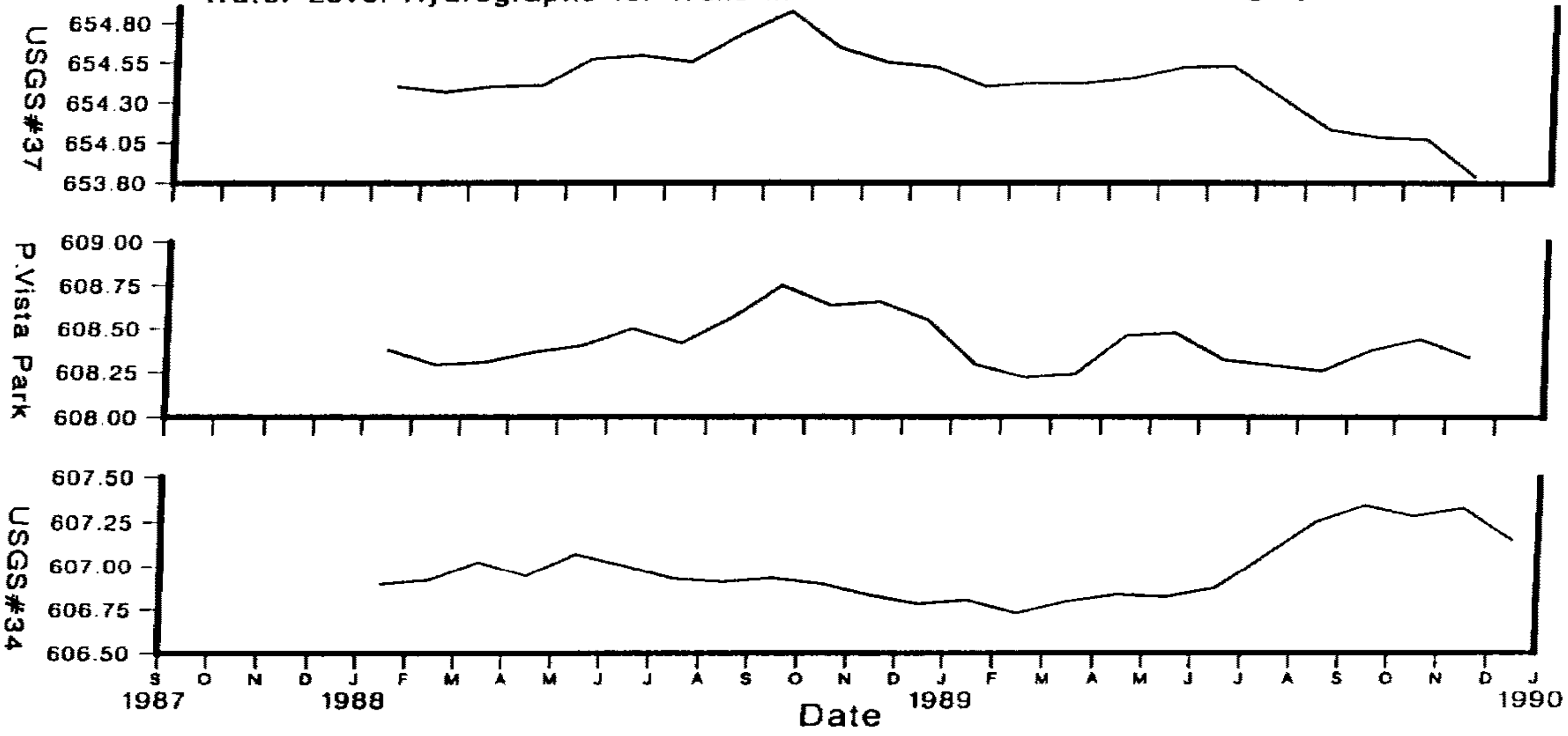
Water Level Hydrographs for Wells in "Undeveloped" Land Use Category



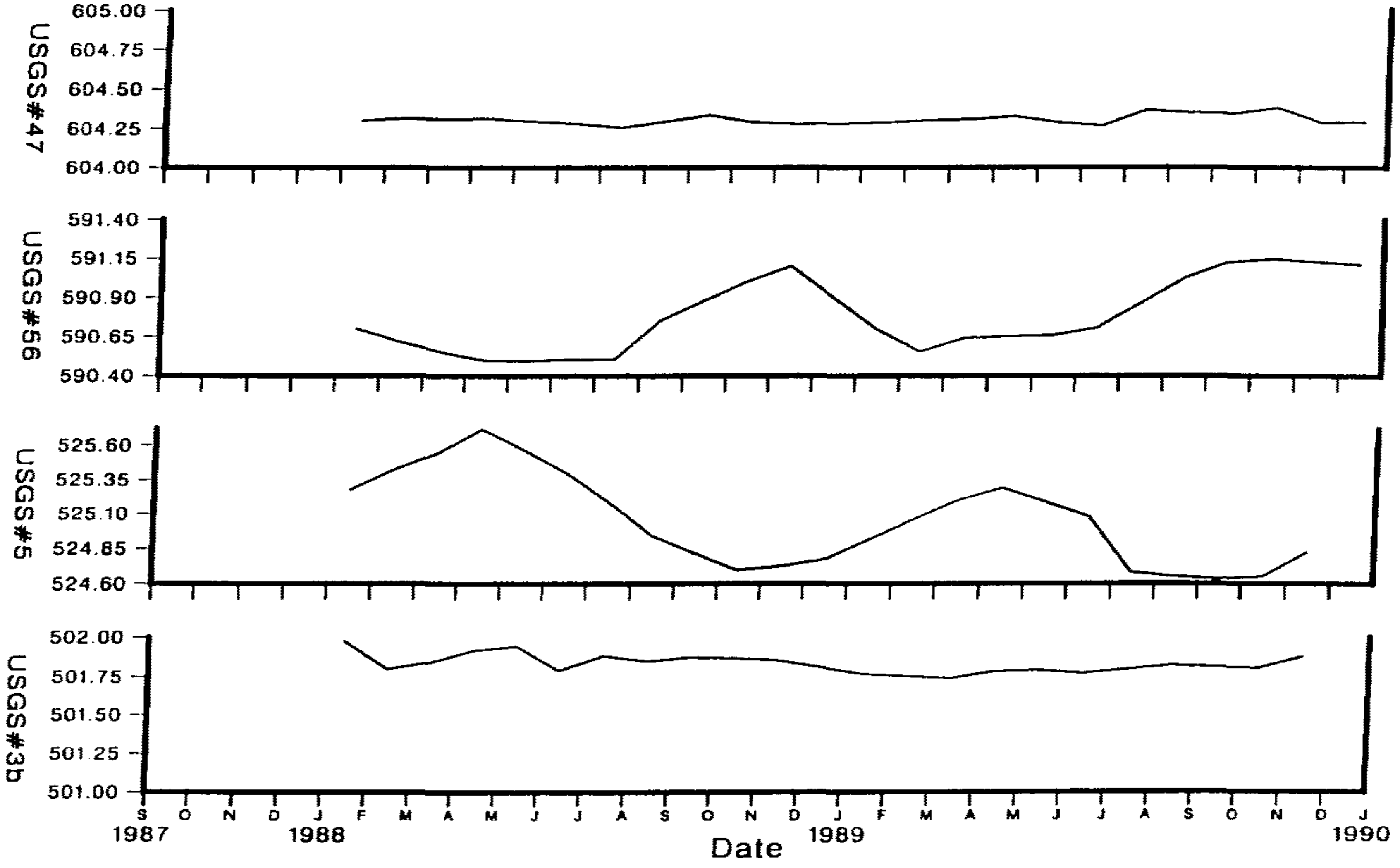
Water Level Hydrographs for Wells in "Undeveloped" Land Use Category



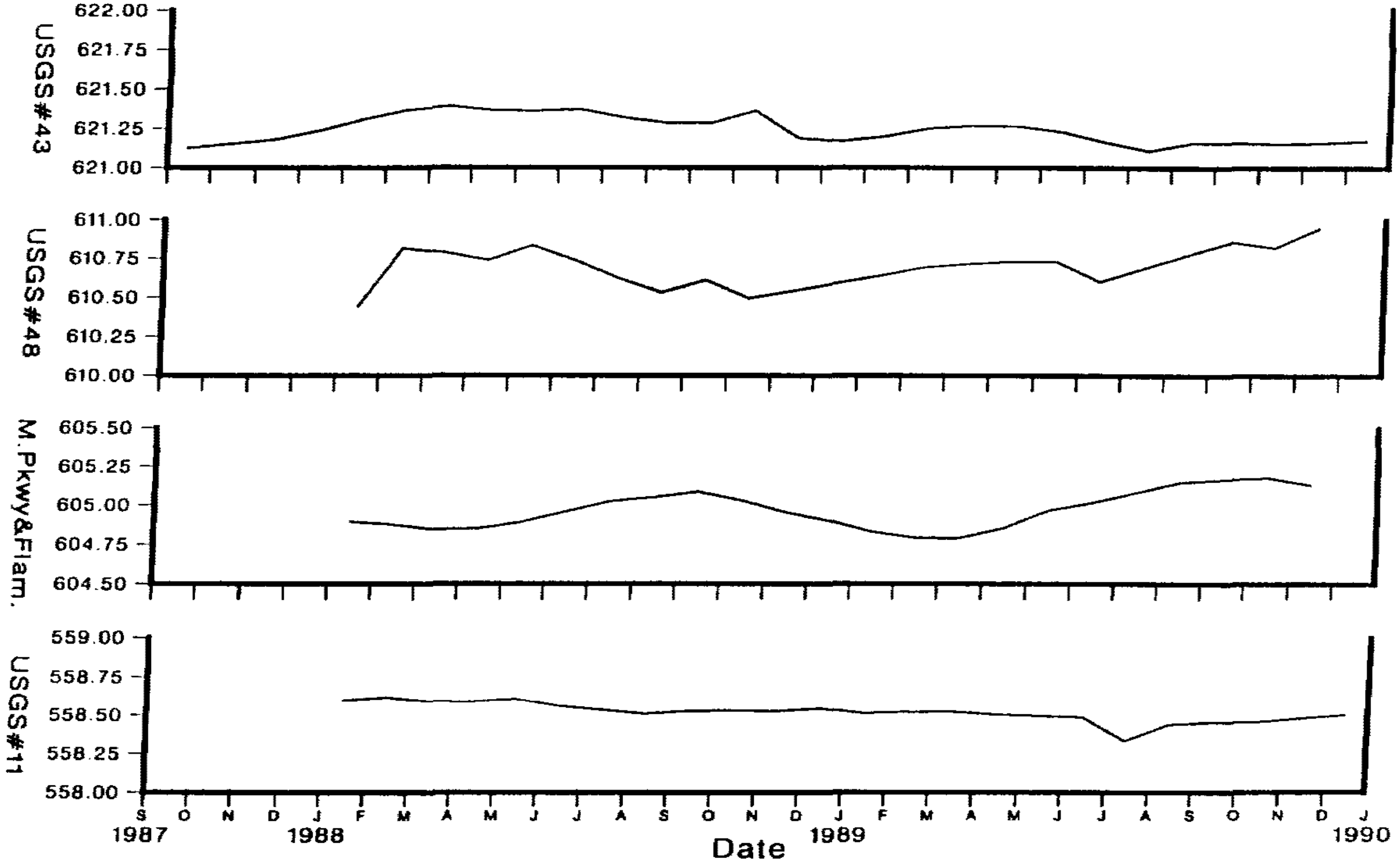
Water Level Hydrographs for Wells in "Turf Areas" Land Use Category

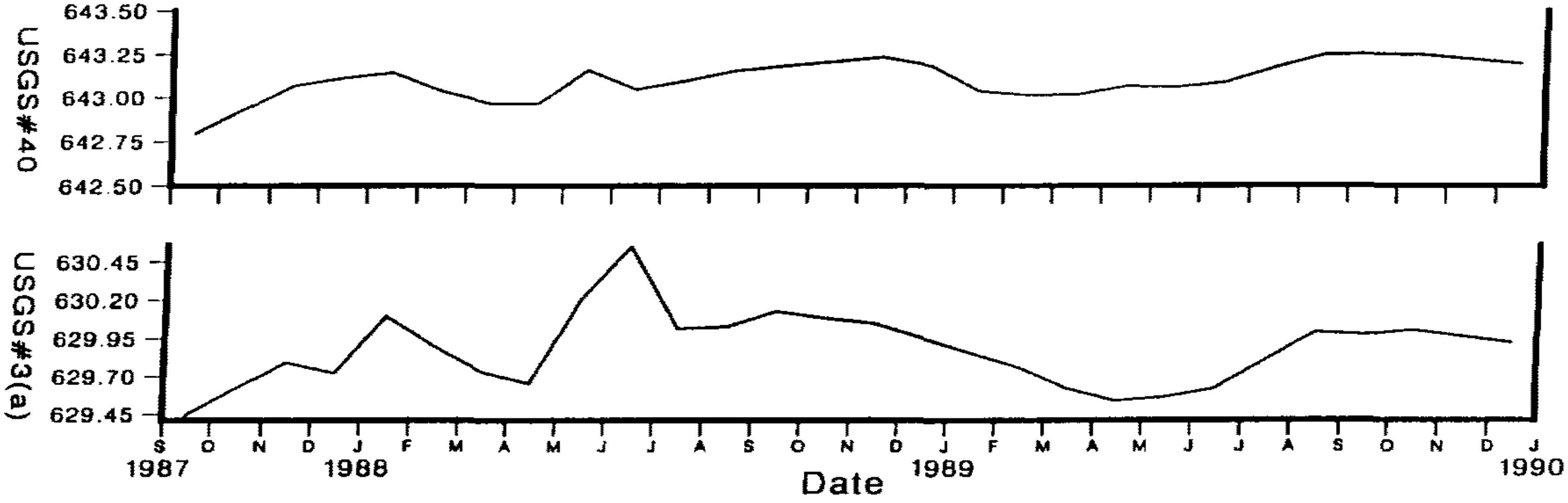


Water Level Hydrographs for Wells in "Turf Areas" Land Use Category

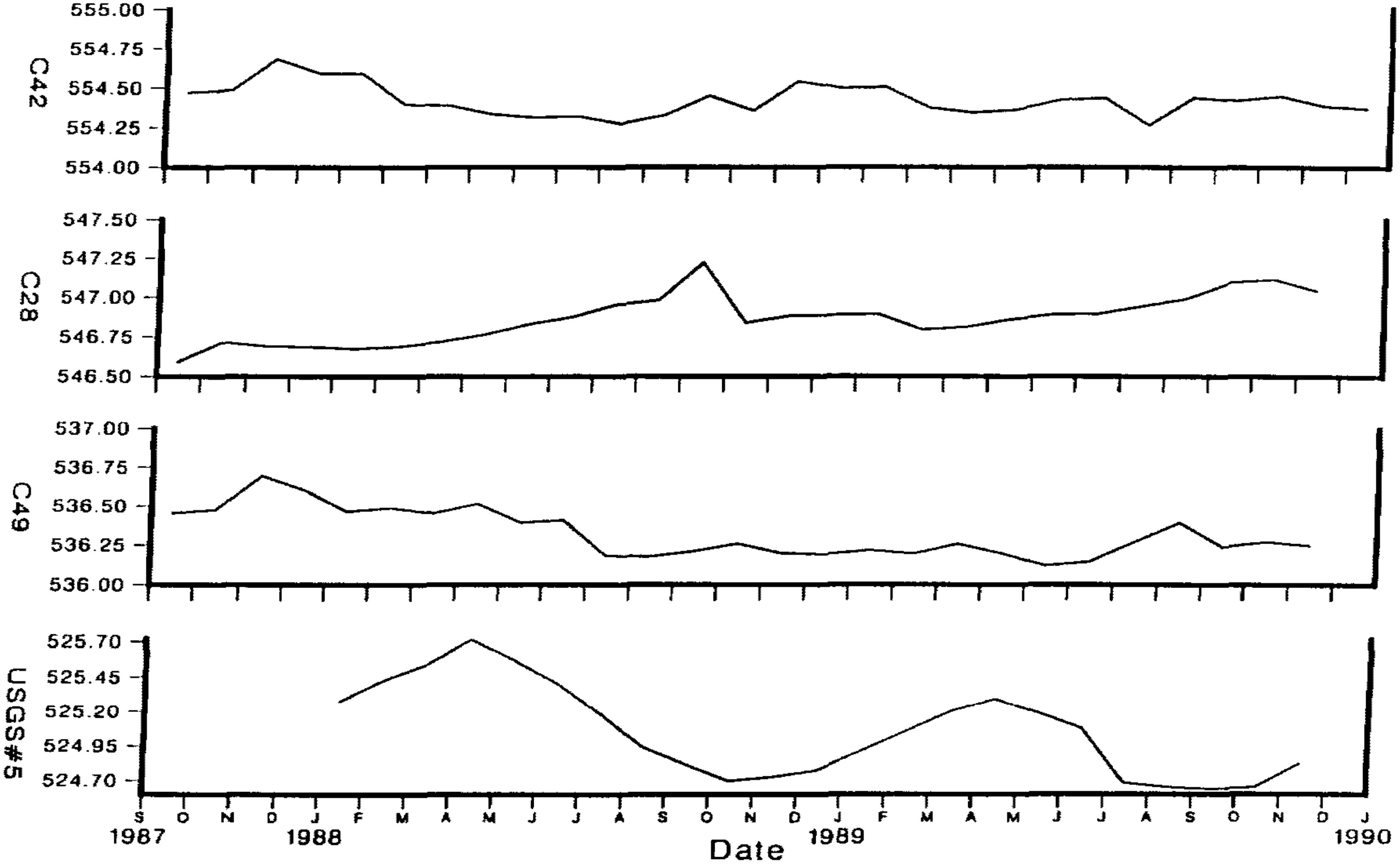


Water Level Hydrographs for Wells in "Commercial" Land Use Category

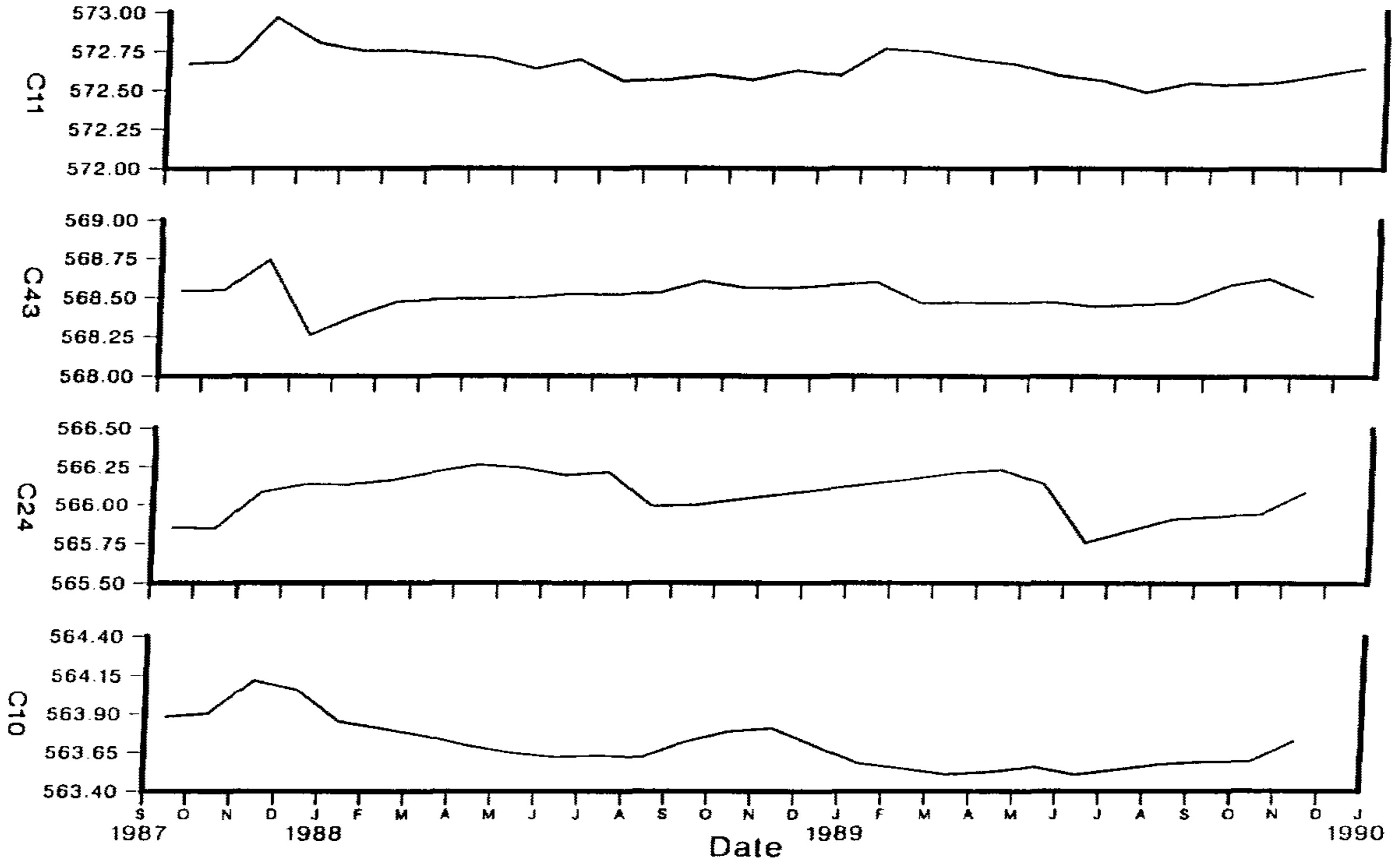



Water Level Hydrographs for Wells in "Commercial" Land Use Category

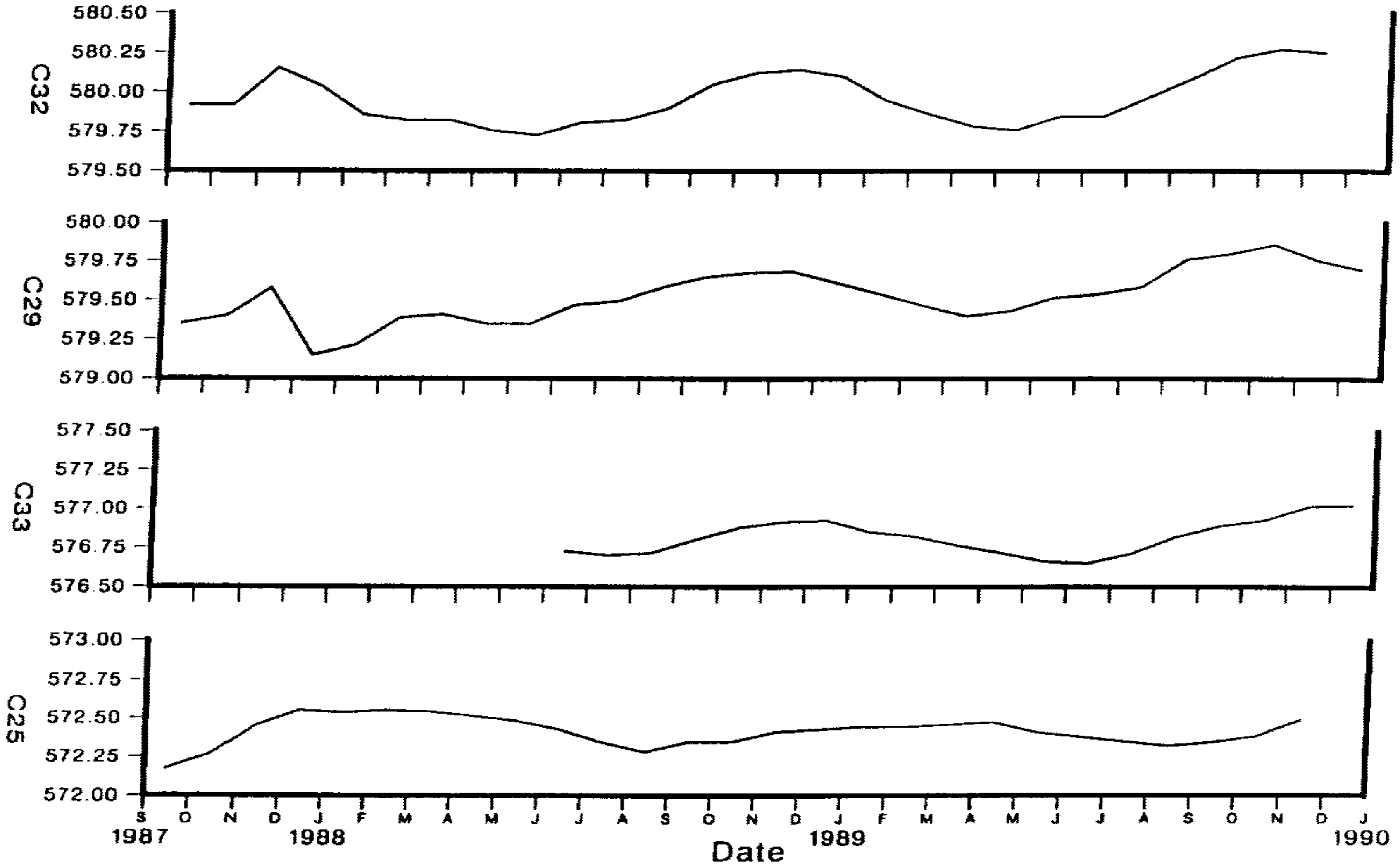
Water Level Hydrographs for Wells in "Residential" Land Use Category



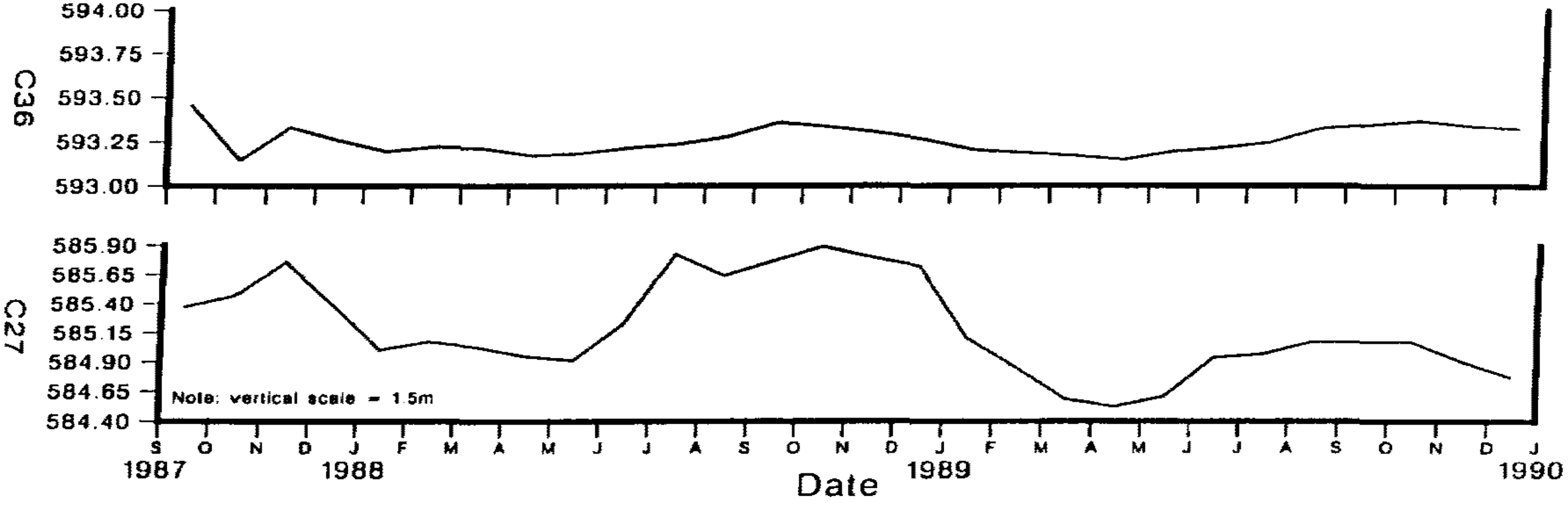
Water Level Hydrographs for Wells in "Residential" Land Use Category



Water Level Hydrographs for Wells in "Residential" Land Use Category



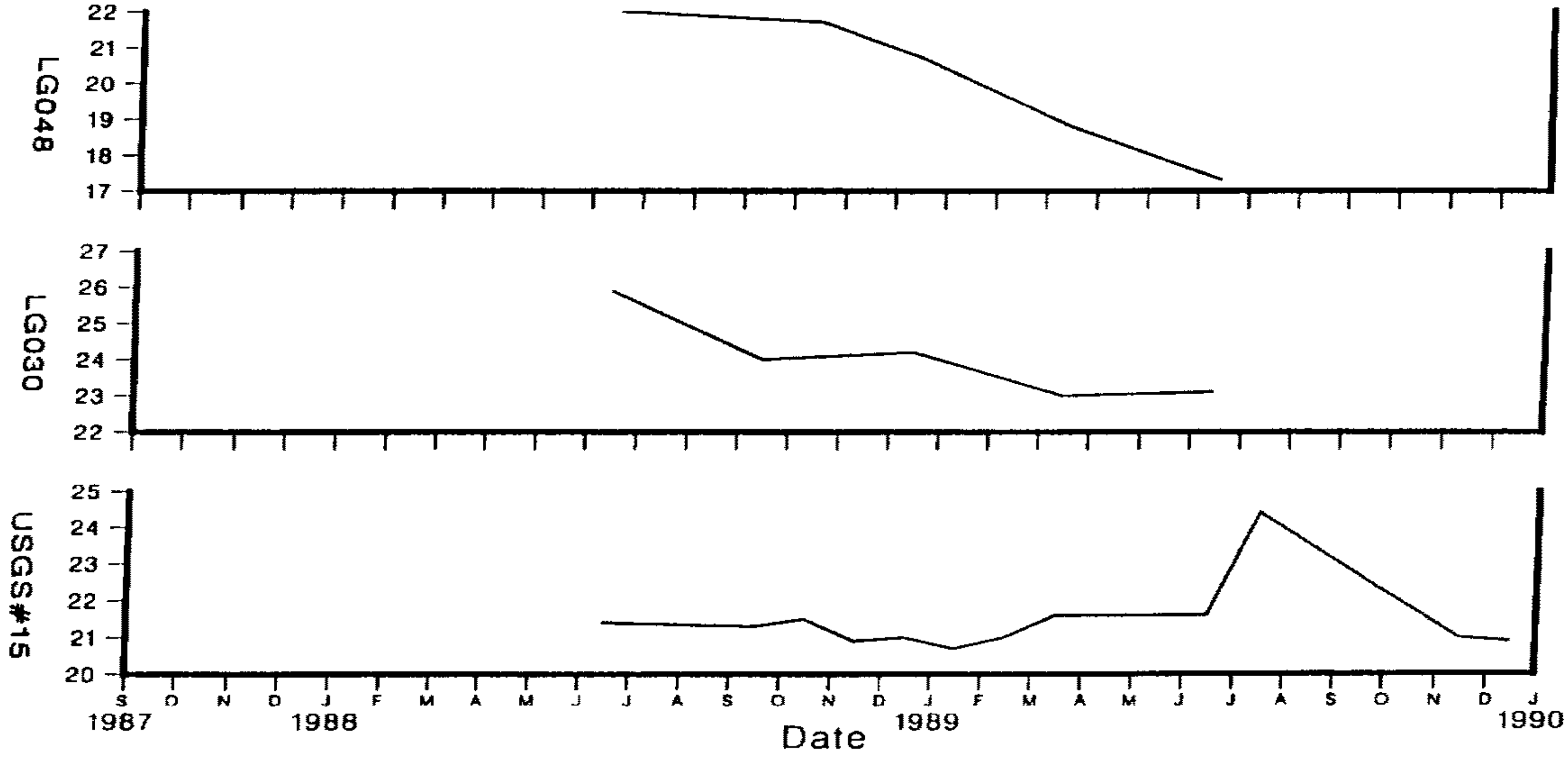
Water Level Hydrographs for Wells in "Residential" Land Use Category



Note: vertical scale = 1.5m

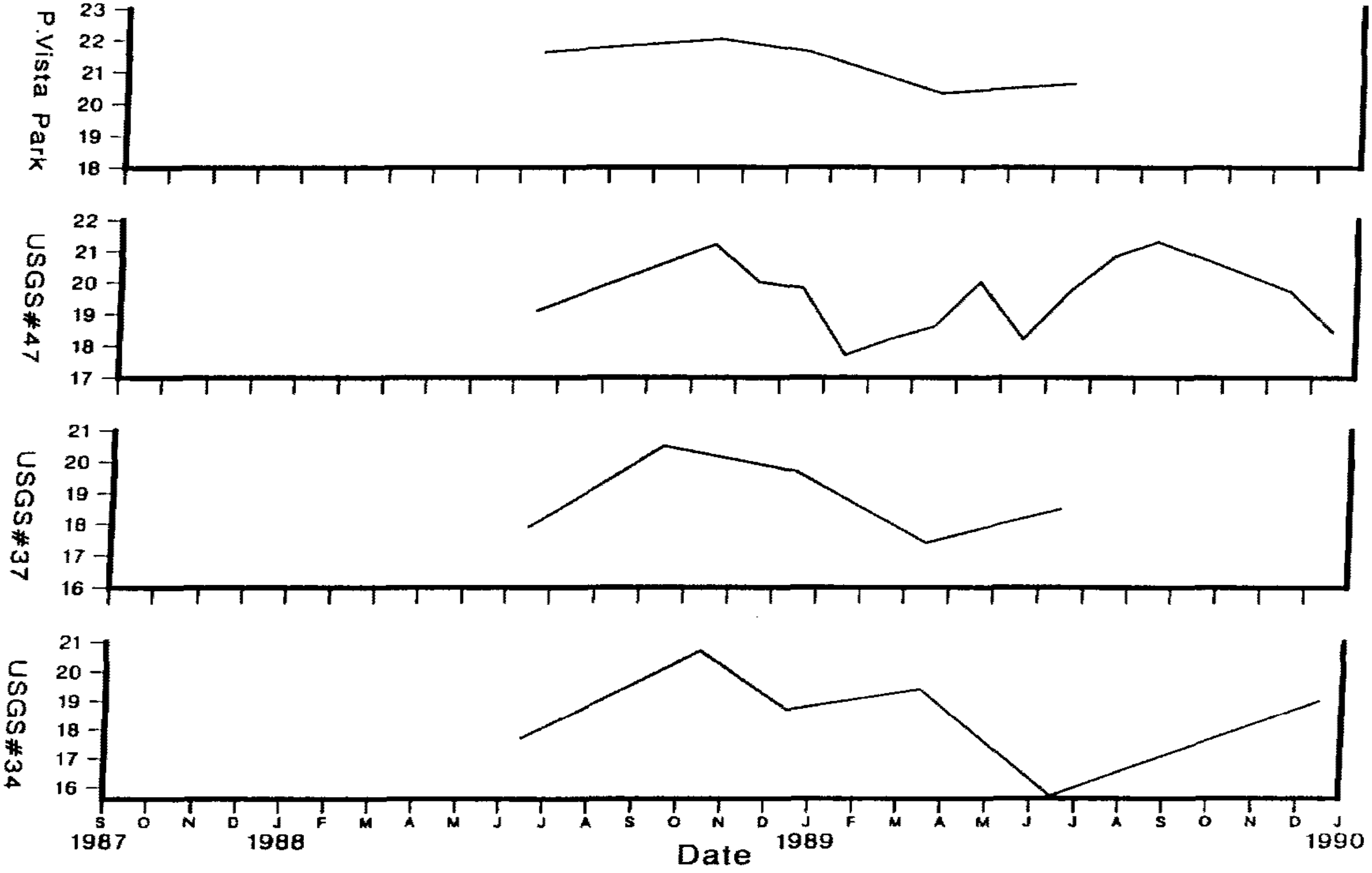
APPENDIX H.

Time Series Temperature Plots

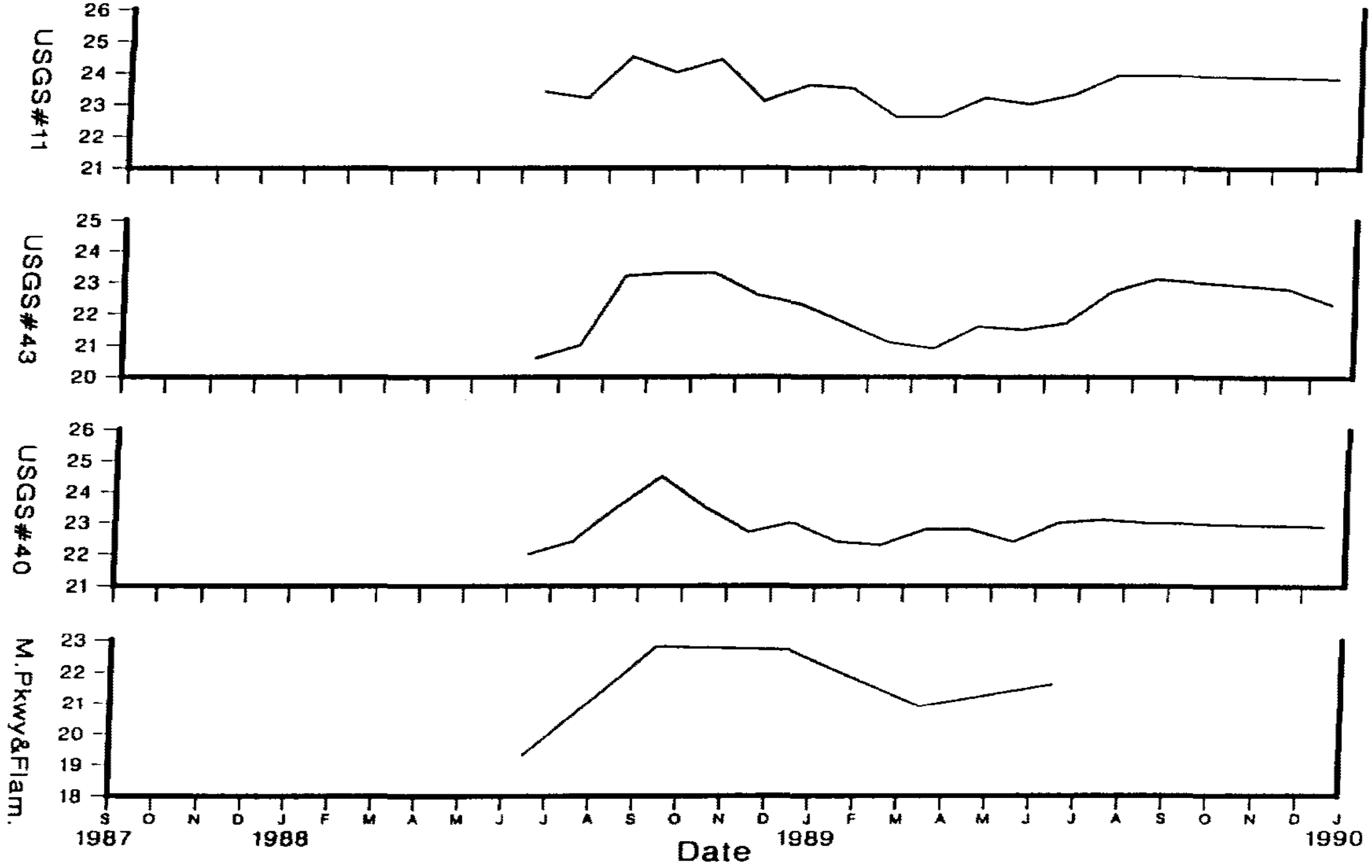


Temperature Plots for Wells in "Undeveloped" Land Use Category

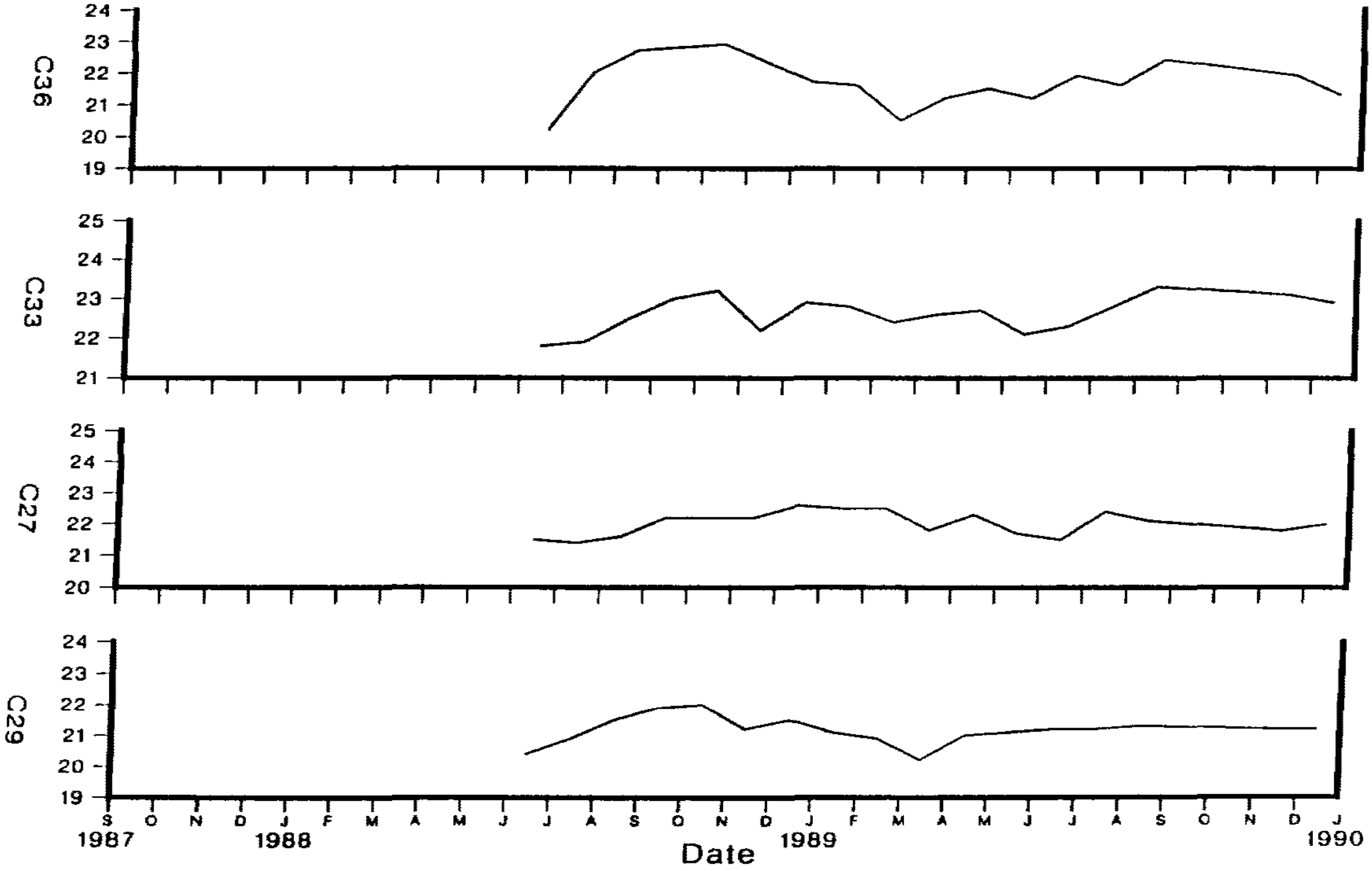
Temperature Plots for Wells in "Turf Areas" Land Use Category



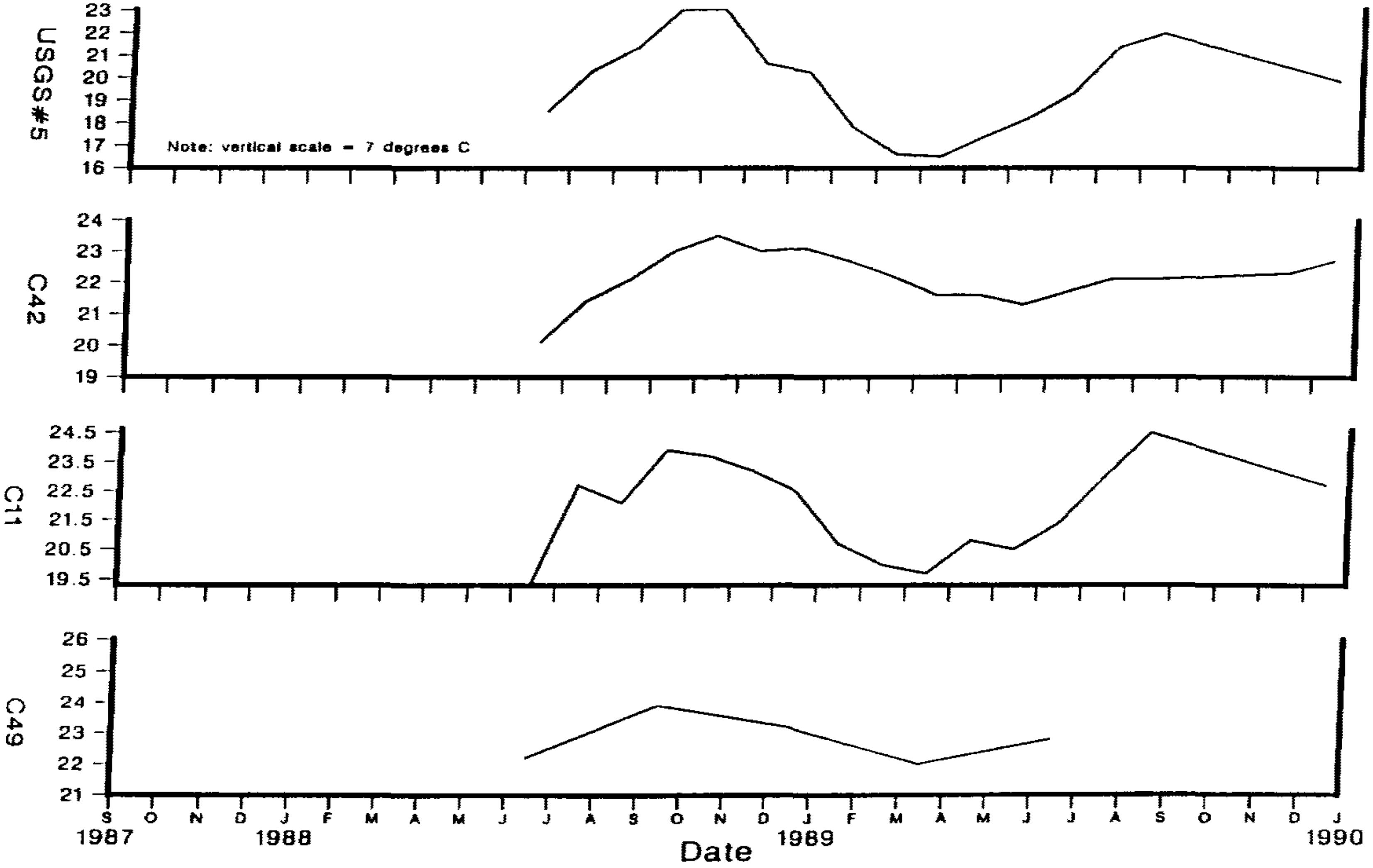
Temperature Plots for Wells in "Commercial" Land Use Category



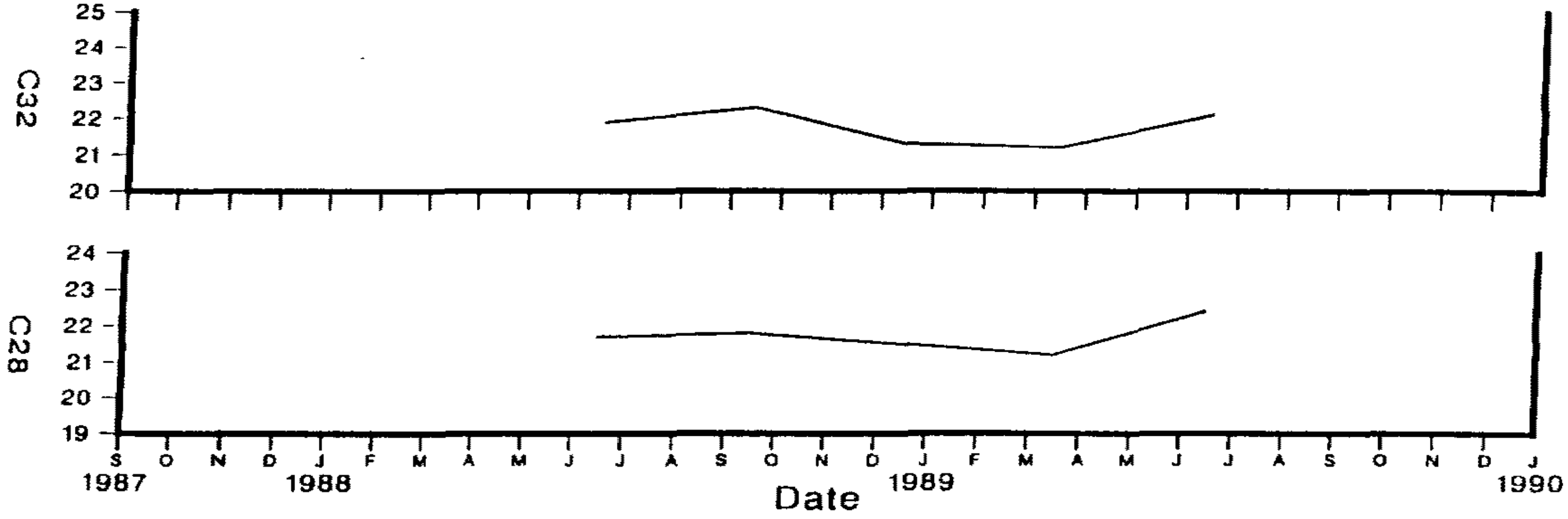
Temperature Plots for Wells in "Residential" Land Use Category



Temperature Plots for Wells in "Residential" Land Use Category



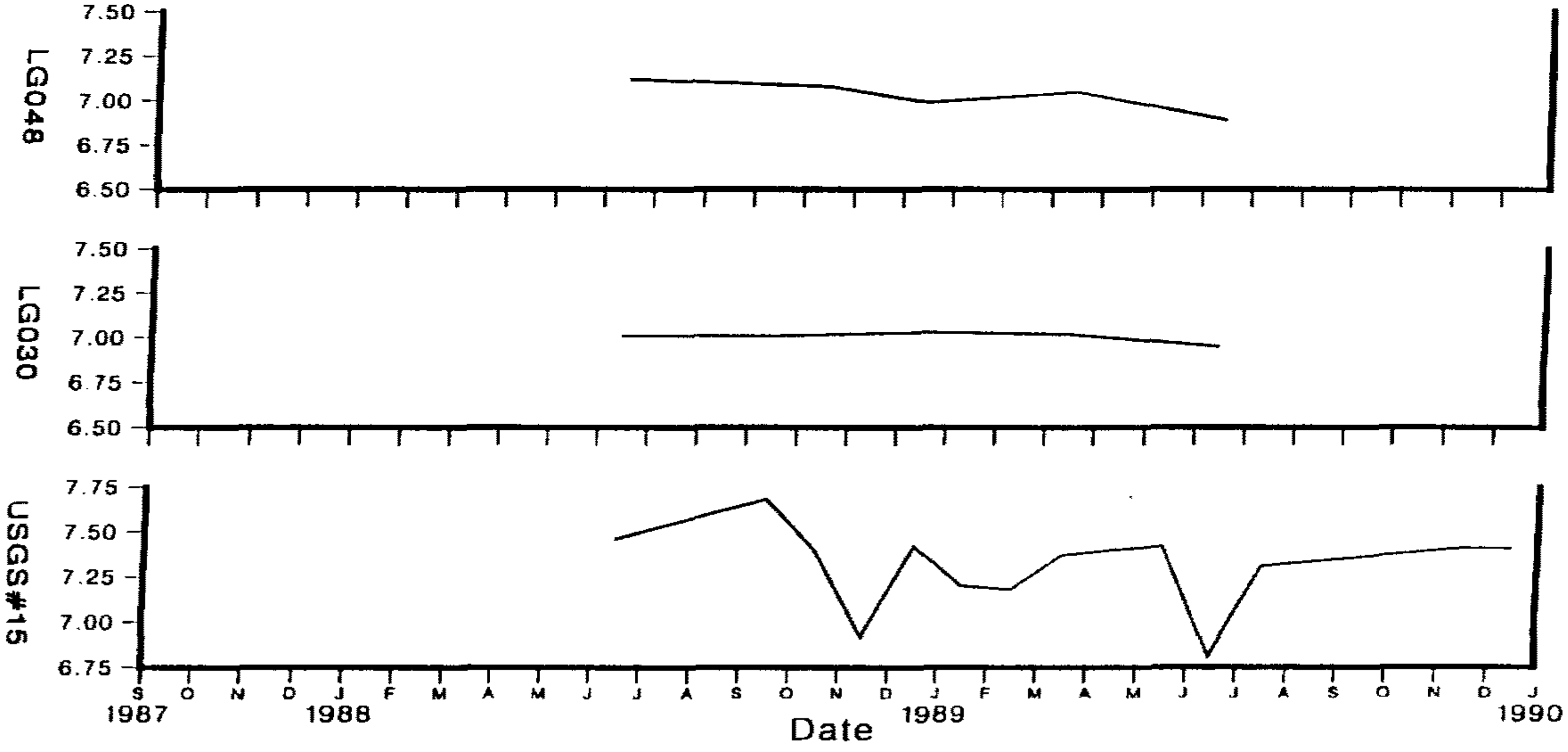
Temperature Plots for Wells in "Residential" Land Use Category



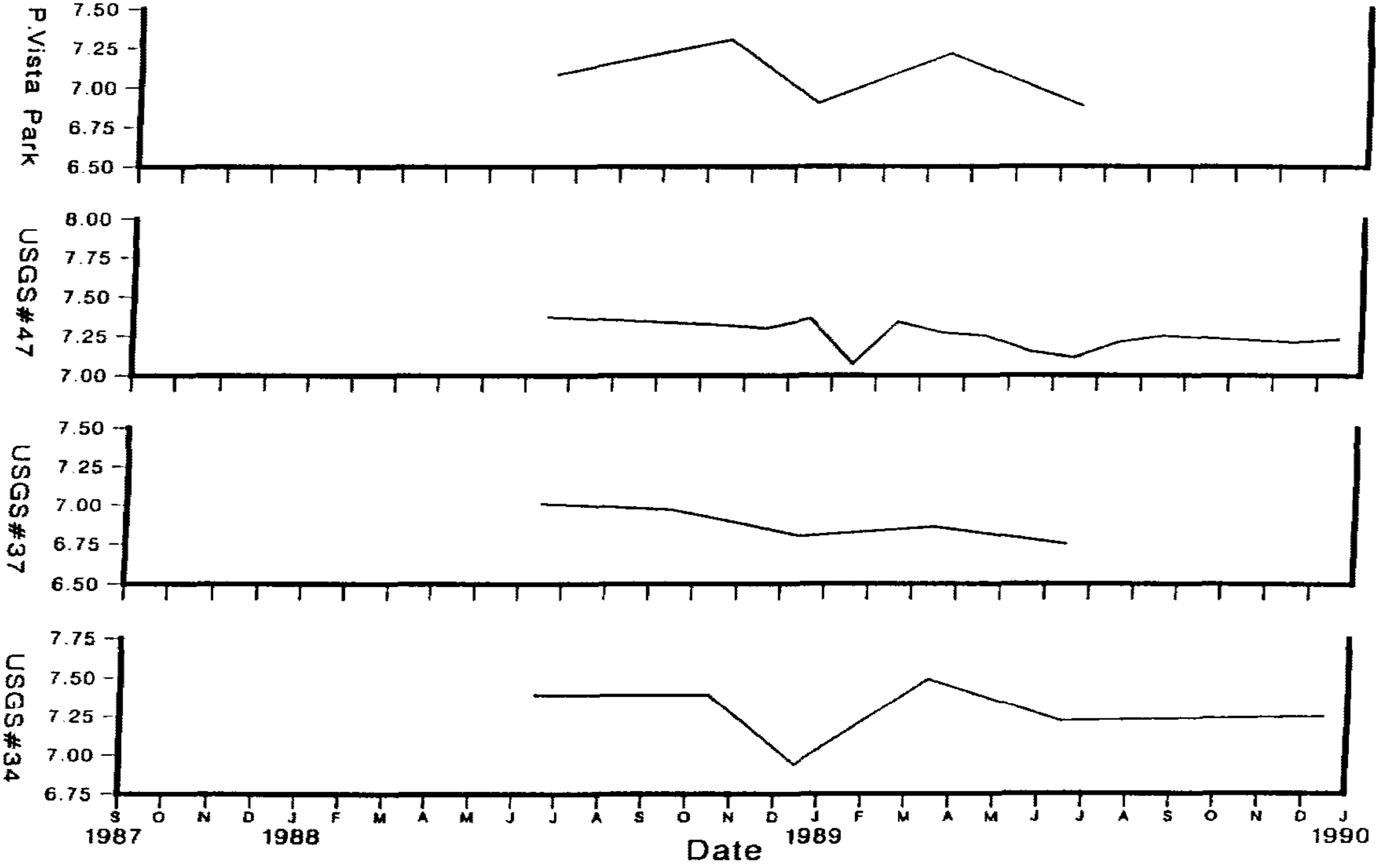
APPENDIX I.

Time Series pH Plots

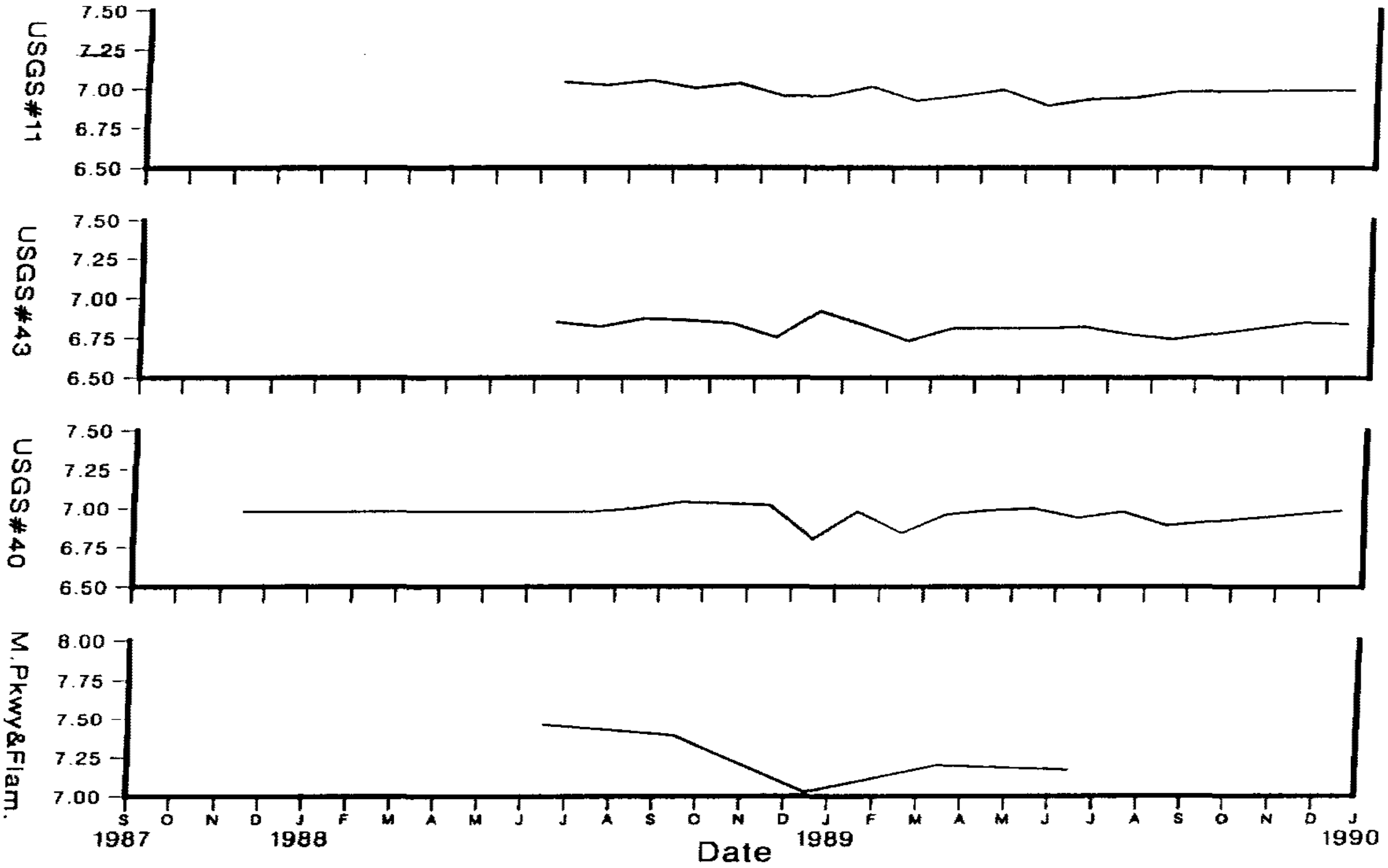
pH Plots for Wells in "Undeveloped" Land Use Category



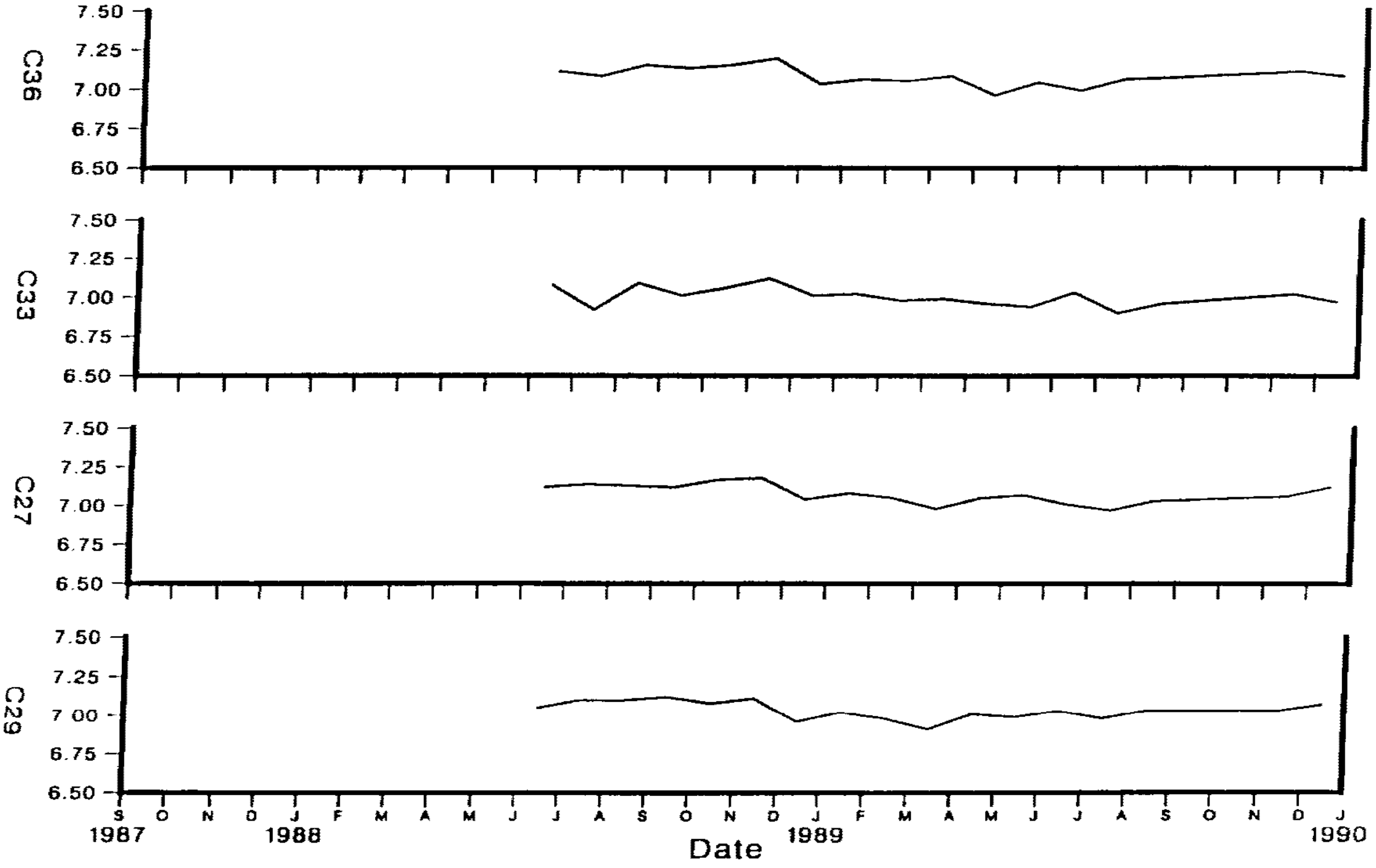
pH Plots for Wells in "Turf Areas" Land Use Category



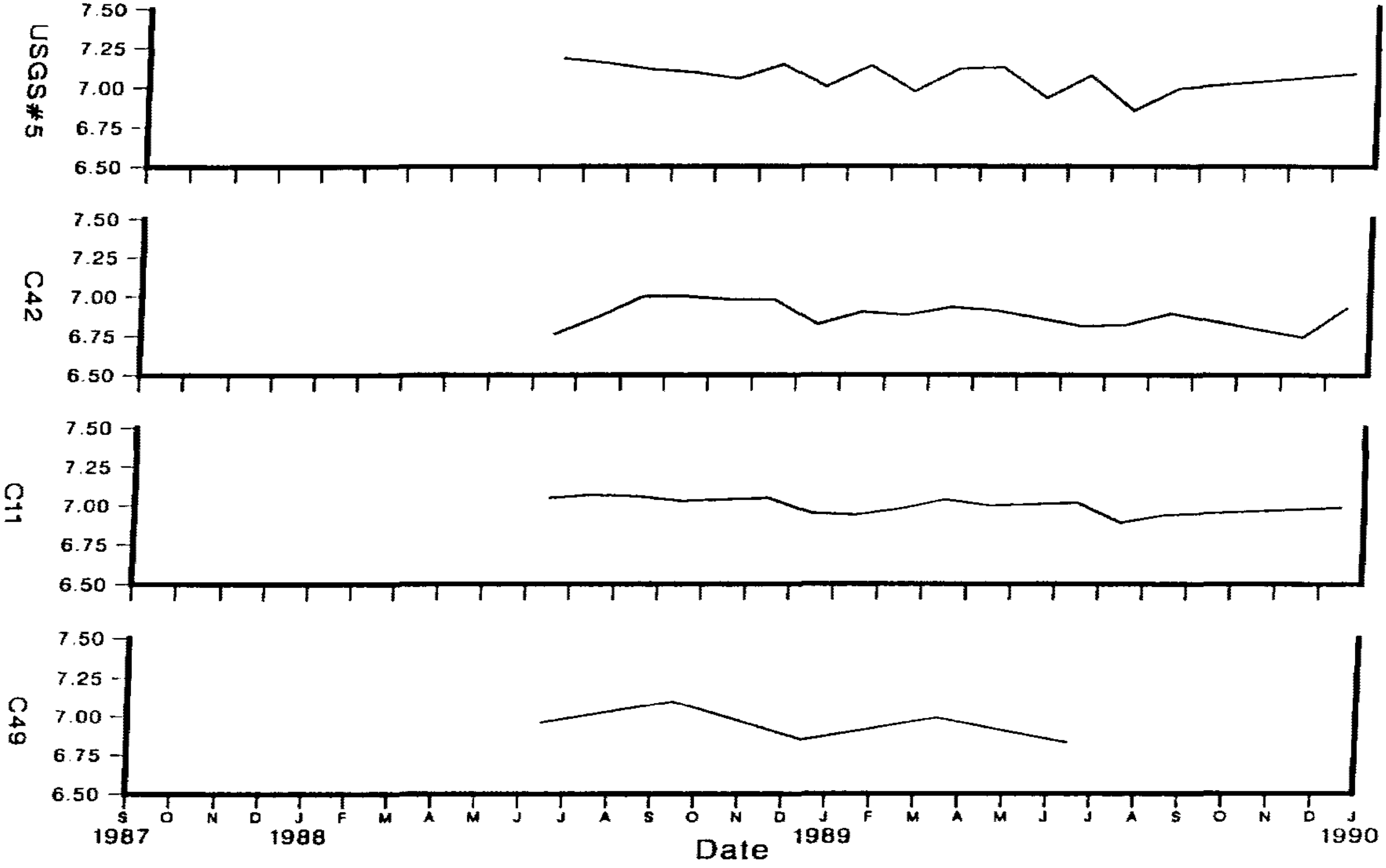
pH Plots for Wells in "Commercial" Land Use Category



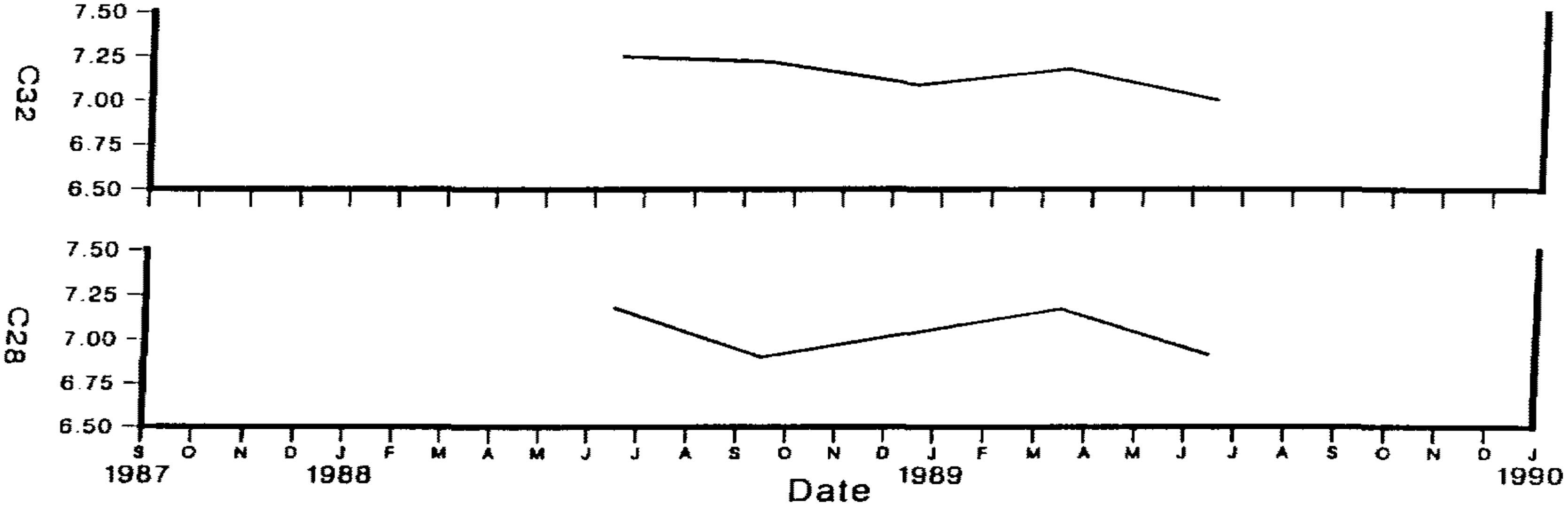
pH Plots for Wells in "Residential" Land Use Category



pH Plots for Wells in "Residential" Land Use Category



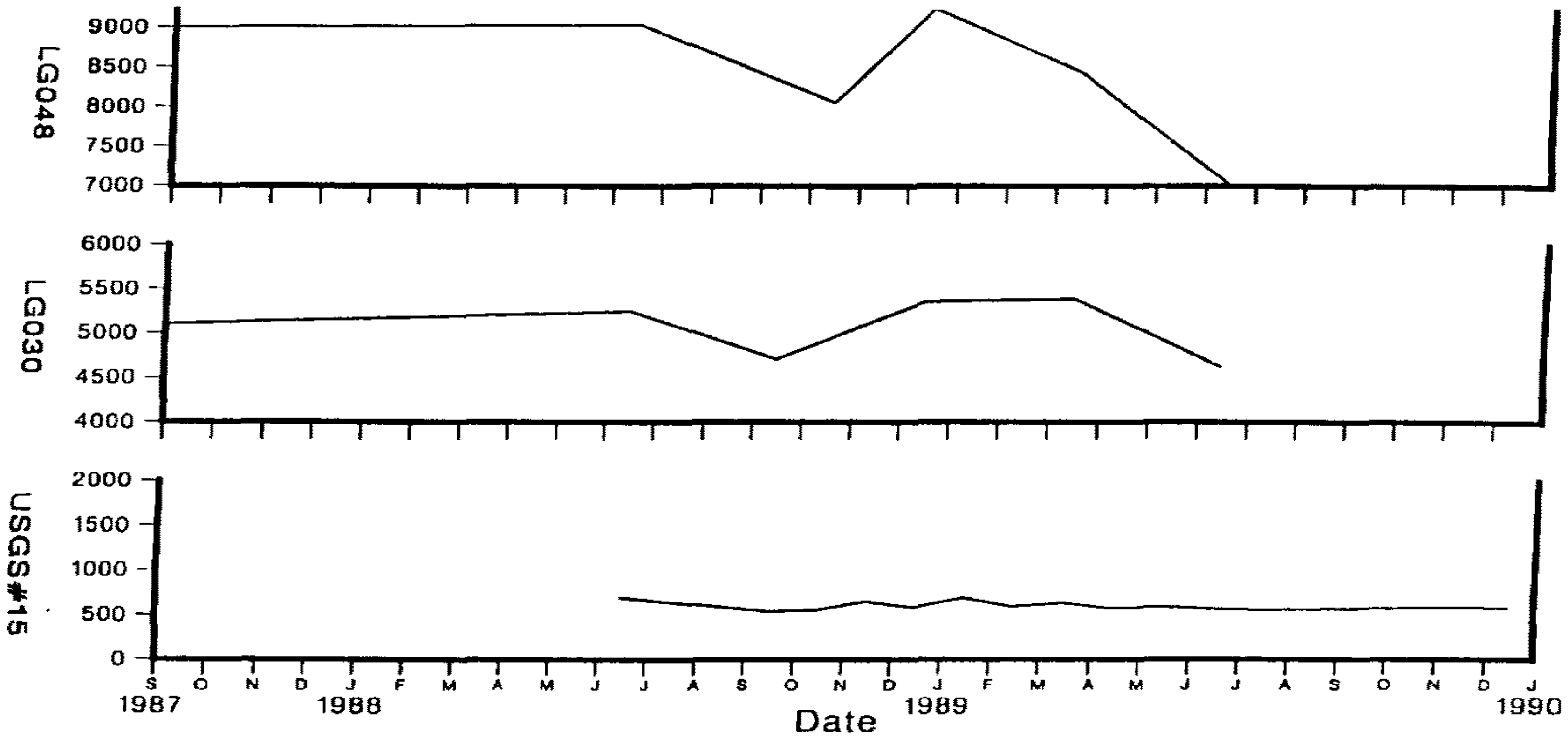
pH Plots for Wells in "Residential" Land Use Category



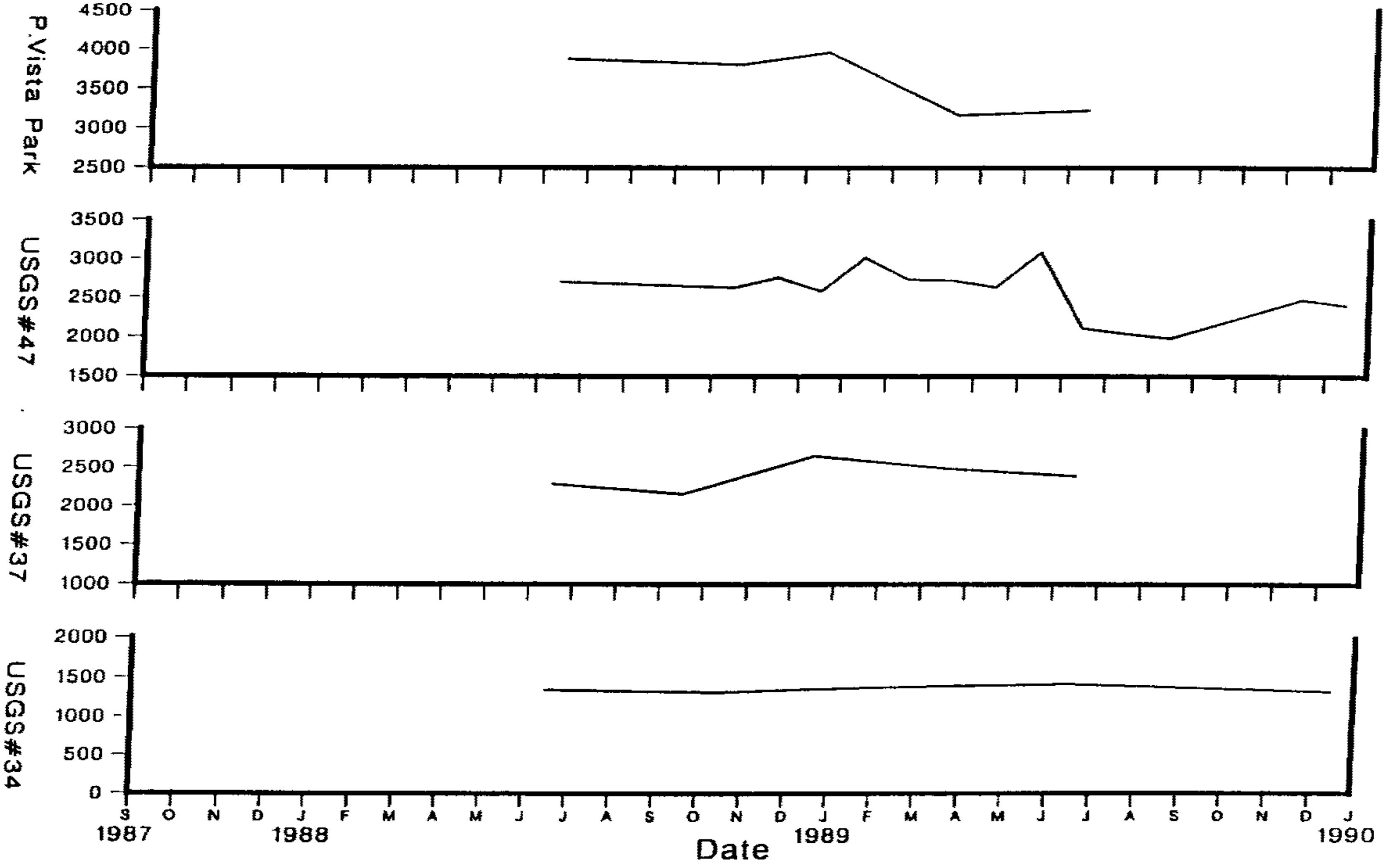
APPENDIX J.

Time Series EC Plots

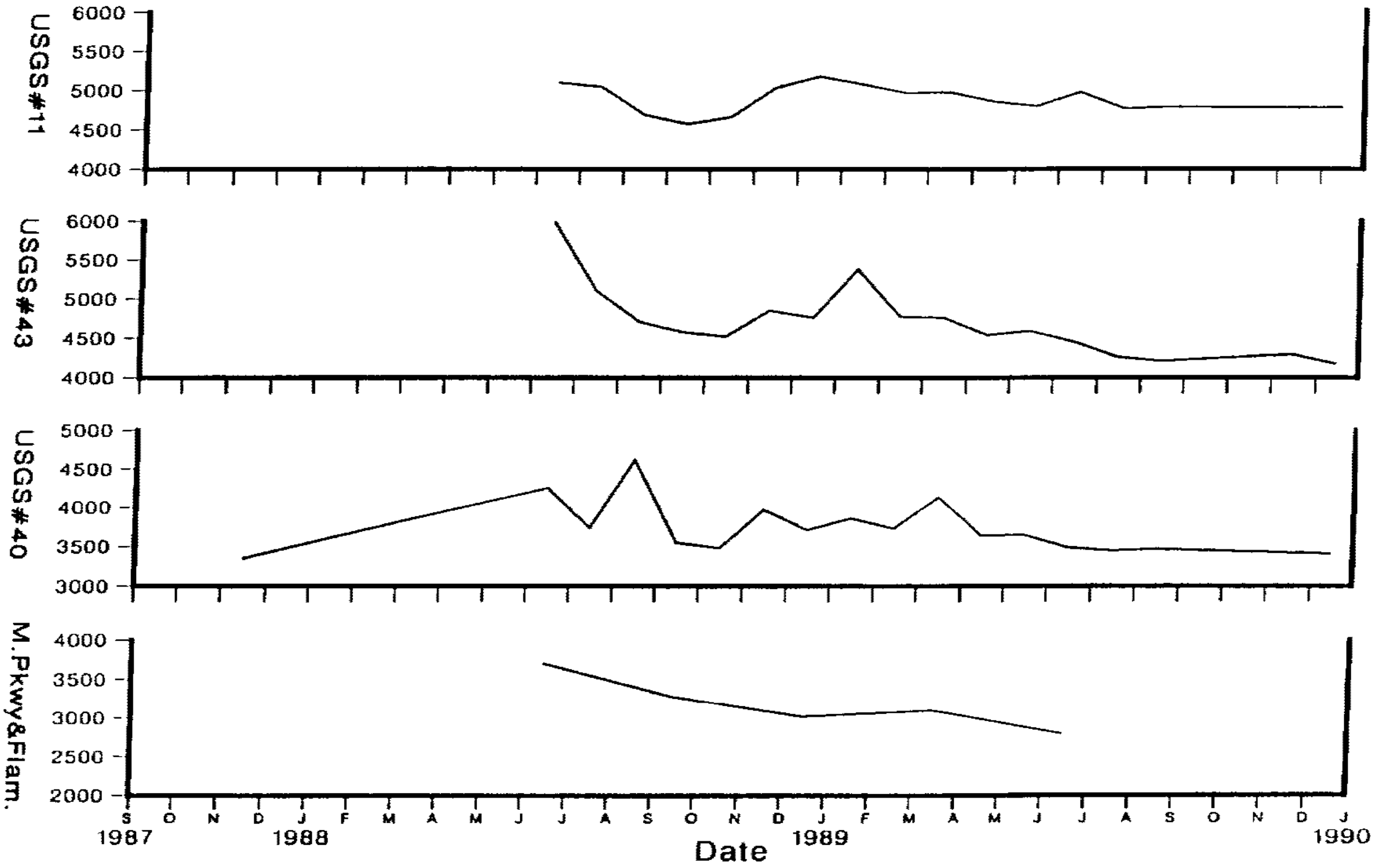
Electrical Conductivity Plots for Wells in "Undeveloped" Land Use Category



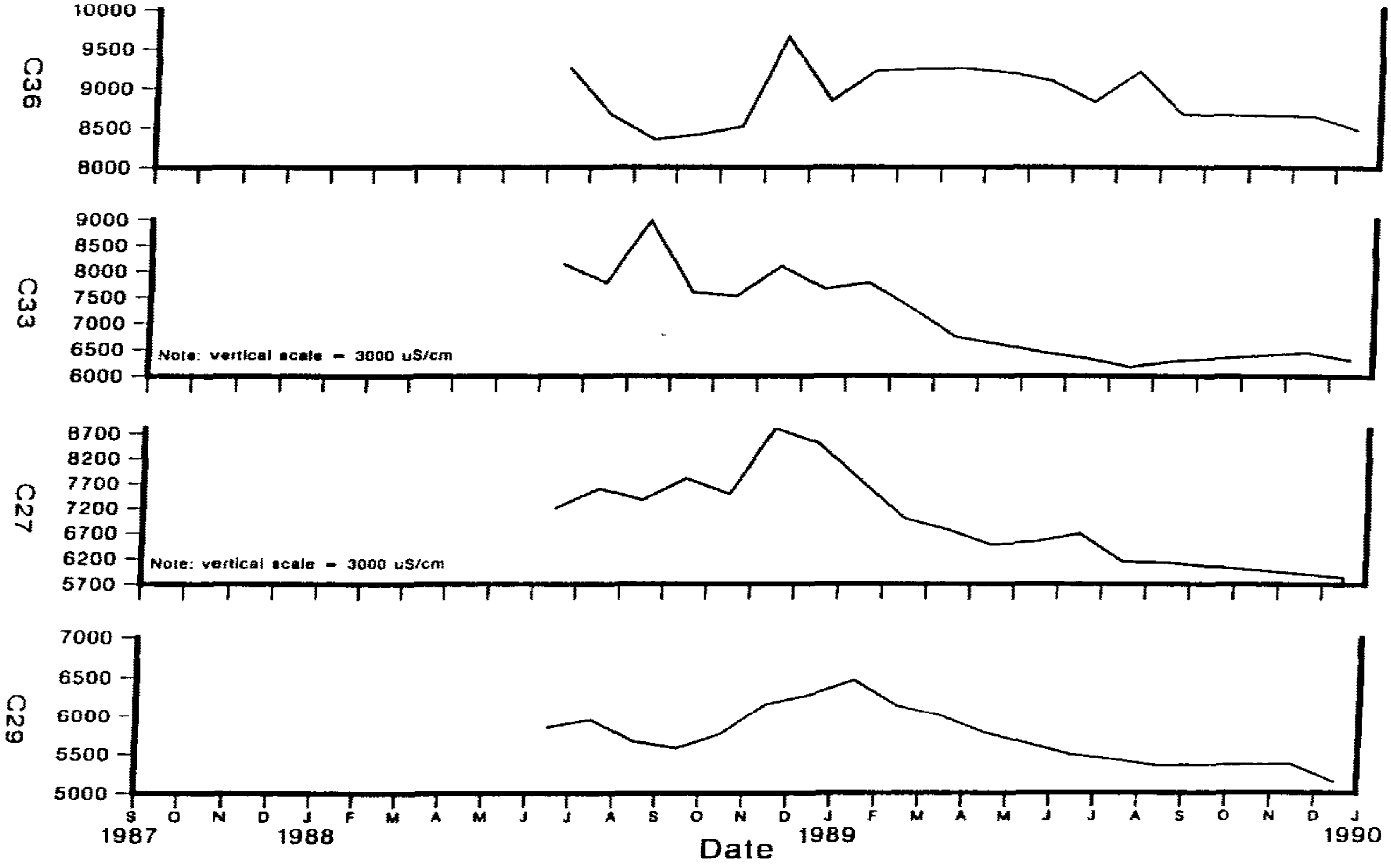
Electrical Conductivity Plots for Wells in "Turf Areas" Land Use Category



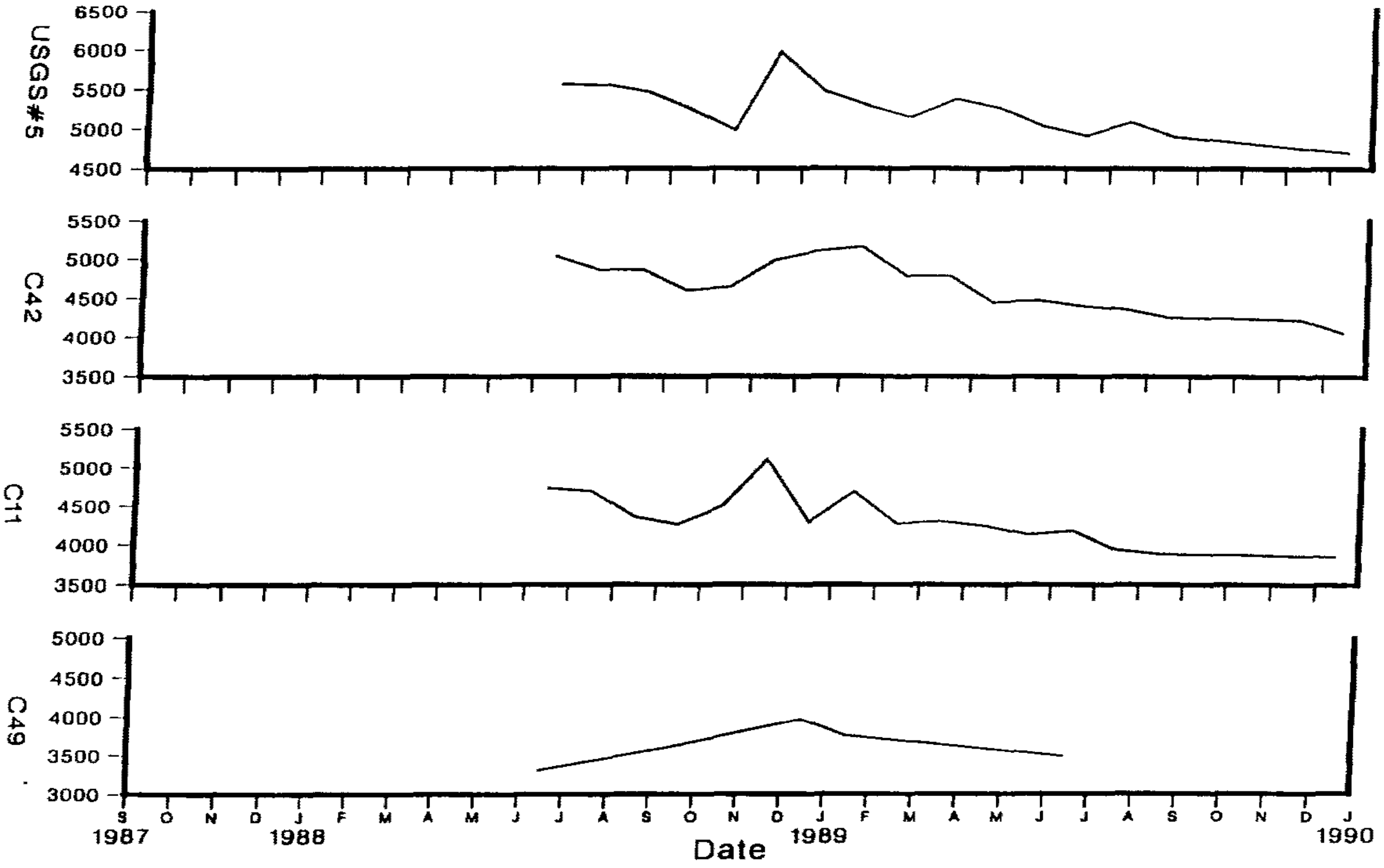
Electrical Conductivity Plots for Wells in "Commercial" Land Use Category



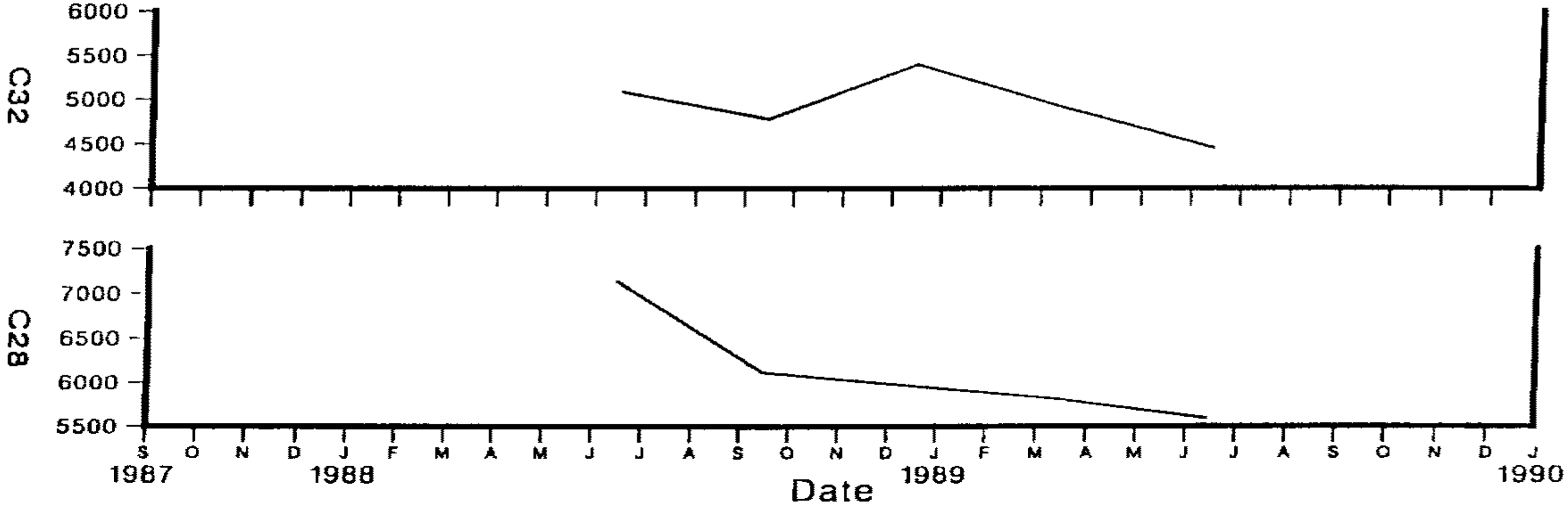
Electrical Conductivity Plots for Wells in "Residential" Land Use Category



Electrical Conductivity Plots for Wells in "Residential" Land Use Category



Electrical Conductivity Plots for Wells in "Residential" Land Use Category



APPENDIX K.

Laboratory Chemical Analysis Methods

Water Analysis Laboratory
Water Resources Center
Desert Research Institute

REFERENCE LIST

STANDARD WATER ANALYSIS

pH

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 150.1 (Electrometric)

ELECTRICAL CONDUCTIVITY

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 120.1 (Specific Conductance, μmhos at 25 ° C)

ALKALINITY

Techniques of Water-Resources Investigations of the United States Geological Survey, Methods for the Determination of Inorganic Substances in Water and Fluvial Sediments, Book 5, Chapter A1, 1979, Editors: Marvin W. Skougstad, Marvin J. Fishmann, Linda C. Friedman, David E. Erdmann, and Saundra S. Duncan. U.S. Government Printing Office, Washington D.C. 20402, Pages 519, 520 (Alkalinity, electrometric titration, automated) (I-2030-78)

CHLORIDE

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 325.1 (Colorimetric, Automated Ferricyanide AAI)

Test Method EPA-600/4-84-017 March 1984, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 300.0 (The Determination of Inorganic Anions in Water by Ion Chromatography)

SULFATE

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 375.4 (Turbidimetric)

Test Method EPA-600/4-84-017 March 1984, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 300.0 (The Determination of Inorganic Anions in Water by Ion Chromatography)

SODIUM

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 273.1 (Atomic Absorption, direct aspiration)

POTASSIUM

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 258.1 (Atomic Absorption, direct aspiration)

CALCIUM

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 215.1 (Atomic Absorption, direct aspiration)

MAGNESIUM

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 242.1 (Atomic Absorption, direct aspiration)

SILICA

Techniques of Water-Resources Investigations of the United States Geological Survey, Methods for the Determination of Inorganic Substances in Water and Fluvial Sediments, Book 5, Chapter A1, 1979, Editors: Marvin W. Skougstad, Marvin J. Fishmann, Linda C. Friedman, David E. Erdmann, and Saundra S. Duncan. U.S. Government Printing Office, Washington D.C. 20402, Pages 519, 520 (Silica, dissolved, colorimetric, molybdate blue, automated) (I-2700-78)

NITRATE

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 353.2 (Colorimetric,Automated,Cadmium Reduction)

Test Method EPA-600/4-84-017 March 1984, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 300.0 (The Determination of Inorganic Anions in Water by Ion Chromatography)

METALS

SILVER

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 272.1 (Atomic Absorption, direct aspiration)

ARSENIC

Techniques of Water-Resources Investigations of the United States Geological Survey, Methods for the Determination of Inorganic Substances in Water and Fluvial Sediments, Book 5, Chapter A1, 1985, Editors: Marvin J. Fishmann and Linda C. Friedman, Open-File Services Section, Western Distribution Branch, U.S. Geological Survey, MS 306, Box 24525, Denver Federal Center, Denver, Colorado 80225, Pages 119, 124 (Arsenic, atomic absorption, hydride)(I-1062-85) and (I-3062-85)

BARIUM

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 208.1 (Atomic Absorption, direct aspiration)

CADMIUM

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 213.1 (Atomic Absorption, direct aspiration)

CHROMIUM

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of

Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 218.1 (Atomic Absorption, direct aspiration)

COPPER

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 220.1 (Atomic Absorption, direct aspiration)

IRON

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 236.1 (Atomic Absorption, direct aspiration)

MERCURY

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 245.1 (Manual Cold Vapor Technique)

MANGANESE

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 243.1 (Atomic Absorption, direct aspiration)

NICKEL

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 249.1 (Atomic Absorption, direct aspiration)

LEAD

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 239.1 (Atomic Absorption, direct aspiration)

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 239.2 (Atomic Absorption, furnace technique)

SELENIUM

Techniques of Water-Resources Investigations of the United States Geological Survey, Methods for the Determination of Inorganic Substances in Water and Fluvial Sediments, Book 5, Chapter A1, 1985, Editors: Marvin J. Fishmann and Linda C. Friedman, Open-File Services Section, Western Distribution Branch, U.S. Geological Survey, MS 306, Box 24525, Denver Federal Center, Denver, Colorado 80225, Pages 534, 539 (Selenium, atomic absorption, hydride) (I-1667-85) and (I-3667-85)

ZINC

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 289.1 (Atomic Absorption, direct aspiration)

NUTRIENTS

TOTAL PHOSPHOROUS

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 365.1 (Colorimetric, Automated, Ascorbic Acid)

Techniques of Water-Resources Investigations of the United States Geological Survey, Methods for the Determination of Inorganic Substances in Water and Fluvial Sediments, Book 5, Chapter A1, 1979, Editors: Marvin W. Skougstad, Marvin J. Fishmann, Linda C. Friedman, David E. Erdmann, and Saundra S. Duncan. U.S. Government Printing Office, Washington D.C. 20402, Pages 491, 493 (Phosphorous, total, colorimetric, phosphomolybdate, automated) (I-4600-78)

ORTHO PHOSPHOROUS

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 365.1 (Colorimetric, Automated, Ascorbic Acid)

NITRATE

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 353.2 (Colorimetric, Automated, Cadmium Reduction)

MISCELLANEOUS

BORON

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 212.3 (Colorimetric, Curcumine)

BROMIDE

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-84-017 March 1984, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 300.0 (The Determination of Inorganic Anions in Water by Ion Chromatography)

FLUORIDE

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 340.2 (Potentiometric, Ion Selective Electrode)

ORGANIC CARBON TOTAL

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 March 1979, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, Method 415.1 (Combustion or Oxidation).

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431

REFERENCE LIST

PESTICIDES

TOXAPHENE

Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater, EPA-600/4-82-057 1982, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protestion Agency, Cincinnatti, Ohio 45268, Method 608.

ENDRIN

Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater, EPA-600/4-82-057 1982, Environmental Monitoring and Support

Laboratory, Office of Research and Development, U.S. Environmental Protestion Agency, Cincinnatti, Ohio 45268, Method 608.

METHOXYCHLOR

Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater, EPA-600/4-82-057 1982, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protestion Agency, Cincinnatti, Ohio 45268, Method 608.

LINDANE

Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater, EPA-600/4-82-057 1982, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protestion Agency, Cincinnatti, Ohio 45268, Method 608.

HERBICIDES

SILVEX

Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater, EPA-600/4-82-057 1982, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protestion Agency, Cincinnatti, Ohio 45268, Method 615.

2,4-D

Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater, EPA-600/4-82-057 1982, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protestion Agency, Cincinnatti, Ohio 45268, Method 615.

APPENDIX L.

WATEQDR Output

Table L1. WATEQDR calculated log P_{CO_2}'s of ground-water samples from the Las Vegas Valley, Nevada shallow alluvial aquifer zone.

Site	Sample Collection Date					Mean
	06/88	09/88	12/88	03/89	06/89	
USGS #19	-2.17					-2.17
USGS #15	-2.05	-2.26	-2.02	-1.95	-1.38	-1.93
NLVWD-CP#2b					-1.52	-1.52
USGS #34	-2.13	-2.08	-1.66	-2.18	-1.95	-2.00
USGS #37	-1.34	-1.31	-1.19	-1.23	-1.14	-1.24
LG048	-1.67	-1.70	-1.73	-1.65	-1.60	-1.67
USGS #11	-1.59	-1.54	-1.60	-1.57	-1.59	-1.58
USGS #47			-2.07			-2.07
USGS #43	-1.36	-1.41	-1.48	-1.35	-1.38	-1.40
C11	-1.34	-1.72	-1.66	-1.73	-1.76	-1.65
M.Pkwy&Flam.	-1.36	-2.05	-1.65	-1.80	-1.81	-1.74
USGS #40	-1.70	-1.72	-1.37	-1.65	-1.63	-1.61
P.Vista Park	-1.70	-2.07	-1.68	-2.00	-1.68	-1.83
USGS #5	-1.83	-1.69	-1.62	-1.75	-1.73	-1.72
C27	-1.73	-1.57	-1.77	-1.73	-1.80	-1.74
C49	-1.63	-1.77	-1.56	-1.68	-1.56	-1.64
LG030	-1.87	-1.83	-1.74	-1.79	-1.65	-1.78
C28	-1.80	-1.53		-1.82	-1.57	-1.68
C42	-1.50	-1.79	-1.55	-1.66	-1.58	-1.62
C32	-2.18	-2.12	-2.00	-2.08	-1.90	-2.05
C29	-1.85	-1.93	-1.80	-1.74	-1.89	-1.84

Table L2. WATEQDR calculated log SI calcite of groundwater samples from the Las Vegas Valley, Nevada shallow alluvial aquifer zone. A SI of 0 represents saturation while positive and negative SI's represent over- and undersaturation, respectively.

Site	Sample Collection Date					Mean
	06/88	09/88	12/88	03/89	06/89	
USGS #19	0.09					0.09
USGS #15	0.13	0.38	0.06	0.05	0.048	
NLVWDCP#2b					0.06	0.06
USGS #34	0.09	0.16	0.31	0.27	0.07	0.18
USGS #37	0.10	0.13	0.01	0.01	0.14	0.08
LG048	0.04	0.02	0.02	0.05	0.07	0.04
USGS #11	0.15	0.11	0.04	0.02	0.06	0.08
USGS #47			0.20			0.20
USGS #43	0.84	0.08	0.11	0.03	0.00	0.21
C11	0.09	0.12	0.01	0.09	0.03	0.07
M.Pkwy&Flam.	0.55	0.49	0.15	0.32	0.25	0.35
USGS #40	0.02	0.12	0.02	0.03	0.00	0.04
P.Vista Park	0.02	0.28	0.15	0.15	0.16	0.15
USGS #5	0.32	0.29	0.17	0.23	0.21	0.24
C27	0.21	0.35	0.01	0.07	0.10	0.15
C49	0.03	0.13	0.17	0.02	0.21	0.11
LG030	0.20	0.17	0.06	0.12	0.11	0.13
C28	0.39	0.08		0.30	0.05	0.21
C42	0.15	0.04	0.06	0.04	0.12	0.08
C32	0.06	0.06	0.09	0.01	0.17	0.08
C29	0.06	0.12	0.08	0.11	0.03	0.08

Table L3. WATEQDR calculated log SI gypsum of ground-water samples from the Las Vegas Valley, Nevada shallow alluvial aquifer zone. A SI of 0 represents saturation while positive and negative SI's represent over- and undersaturation, respectively.

	Sample Collection Date					
Site	06/88	09/88	12/88	03/89	06/89	Mean
USGS #19	-2.46					-2.46
USGS #15	-1.99	-1.97	-1.98	-1.88	-1.94	-1.95
NLVWD-CP#2b					-0.46	-0.46
USGS #34	-1.07	-1.09	-1.03	-1.04	-1.00	-1.05
USGS #37	-0.87	-0.83	-0.63	-0.71	-0.73	-0.75
LG048	-0.23	-0.24	-0.22	-0.21	-0.23	-0.23
USGS #11	-0.23	-0.24	-0.23	-0.23	-0.20	-0.23
USGS #47			-0.49			-0.49
USGS #43	-0.08	-0.09	-0.08	-0.09	-0.09	-0.09
C11	-0.08	-0.11	-0.12	-0.13	-0.12	-0.11
M.Pkwy&Flam.	-0.30	-0.24	-0.28	-0.32	-0.32	-0.29
USGS #40	-0.26	-0.26	-0.23	-0.25	-0.25	-0.25
P.Vista Park	-0.14	-0.21	-0.20	-0.24	-0.18	-0.19
USGS #5	-0.03	-0.05	-0.05	-0.05	-0.02	-0.04
C27	0.01	0.02	0.04	-0.01	0.01	0.01
C49	-0.29	-0.29	-0.28	-0.29	-0.29	-0.29
LG030	0.01	0.00	0.01	0.00	-0.02	0.00
C28	-0.03	-0.07		-0.10	-0.10	-0.08
C42	-0.03	-0.04	-0.02	-0.04	-0.03	-0.03
C32	-0.09	-0.09	-0.06	-0.07	-0.09	-0.08
C29	0.00	0.00	0.02	0.01	0.00	0.01

Table L4. WATEQDR calculated log SI quartz of groundwater samples from the Las Vegas Valley, Nevada shallow alluvial aquifer zone. A SI of 0 represents saturation while positive and negative SI's represent over and undersaturation, respectively.

Site	Sample Collection Date					Mean
	06/88	09/88	12/88	03/89	06/89	
USGS #19	1.05					1.05
USGS #15	0.61	0.58	0.60	0.59	0.59	0.59
NLVWDCP#2b					1.10	1.10
USGS #34	0.62	0.57	0.61	0.60	0.66	0.61
USGS #37	0.93	0.92	0.91	0.92	0.90	0.92
LG048	0.69	0.73	0.73	0.82	0.74	0.74
USGS #11	0.71	0.70	0.71	0.72	0.71	0.71
USGS #47			0.70			0.70
USGS #43	1.01	0.95	0.98	1.00	0.98	0.98
C11	0.08	0.94	0.90	0.91	0.92	0.89
M.Pkwy&Flam.	0.88	0.84	0.84	0.84	0.81	0.84
USGS #40	0.62	0.58	0.61	0.62	0.62	0.61
P.Vista Park	0.67	0.66	0.68	0.66	0.66	0.67
USGS #5	1.10	1.06	1.09	1.12	1.08	1.09
C27	0.80	0.77	0.76	0.76	0.76	0.77
C49	0.83	0.82	0.83	0.84	1.12	0.89
LG030	1.14	1.14	1.16	1.18	1.20	1.16
C28	1.02	1.03		1.04	1.01	1.03
C42	0.76	0.73	0.74	0.75	0.74	0.74
C32	0.76	0.77	0.79	0.79	0.76	0.77
C29	0.95	0.93	0.95	0.97	0.94	0.95