1506-00054

SIMULATING THE EFFECTS OF ARTIFICIAL RECHARGE IN LEMMON VALLEY, WASHOE COUNTY, NEVADA

University of Nevada

Reno

Simulating The Effects of Artificial Recharge in Lemmon Valley, Washoe County, Nevada

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Hydrology/Hydrogeology

by

Randall G. Van Hoozer

Elizabeth Jacobson, Thesis Advisor

May 1994

ACKNOWLEDGEMENTS

This thesis was made possible through the graduate student internship program of Washoe County. The Washoe County Artificial Recharge Demonstration Project is managed by Dan Dragan of the Washoe County Utility Division. The author would like to express his gratitude to Mr. Dragan for making this thesis part of the artificial recharge project. The author's graduate committee provided considerable advice and guidance. Committee members are: Elizabeth Jacobson, advisor, and Gilbert F. Cochran of the Desert Research Institute and the University of Nevada, Reno (UNR); W. Berry Lyons of the UNR Department of Geological Sciences; and Michael Widmer of the Washoe County Utility Division. Other individuals providing advice and insight are James Harrill and David Prudic of the U.S. Geological Survey, and Greg Pohl, Ph.D student of the UNR Department of Environmental and Resource Science. Professor Johannes Guitgens of the same department shared his office and computer on numerous occasions, making the study go more smoothly. Special thanks go to Don Kennedy and the UNR Department of Agriculture for their financial contribution toward the author's education. Moni Fox of Washoe County provided a great deal of assistance during preparation of figures and diagrams. And finally, I am eternally indebted to my wife Terri for her endless encouragement and understanding.

ABSTRACT

A quasi three-dimensional finite difference numerical groundwater flow model was developed to simulate the effects of artificial recharge in a topographically-closed basin in western Nevada. The basin was conceptualized as a two-layer groundwater system, an upper unconfined layer and a lower confined layer. Components of the modeled water budget include precipitation, subsurface inflow and outflow, and evapotranspiration. Other water budget components, groundwater pumpage and secondary recharge, were incorporated into the model implicitly. Stable water levels on an annual basis, along with recharge and discharge components of the water budget being nearly equal, indicate that the groundwater system was at quasi steady-state during the early 1970s. Accordingly, model calibration was completed using a quasi steady-state calibration process. Results of model calibration were the initial conditions for transient simulations of artificial recharge. All simulations indicate that artificial recharge adds water to aquifer storage and increases water levels.

TABLE OF CONTENTS

TABLE OF CONTENTS cont.

Page

LIST OF FIGURES

Page

LIST OF FIGURES cont.

LIST OF FIGURES cont.

Page

LIST OF TABLES

INTRODUCTION

The demand for groundwater continues to increase in many areas of the western United States. Because of the arid environment, it is becoming more common for demand and subsequent extraction of groundwater to exceed groundwater recharge. Various ways to replenish aquifers are being studied, one of which is injecting surplus surface water into aquifers. In western Nevada, surplus surface water is sometimes available when runoff from snowmelt in the Sierra Nevada Mountains exceeds the maximum holding capacities of surface reservoirs. Some problems associated with surface storage are losses due to evaporation, and increased suspended solid loads which occur during high flow periods. Increased levels of suspended solids increases the cost of water treatment. If suspended solid loads are too excessive, some treatment plants can not treat the water adequately for human consumption resulting in a temporary shortage of drinking water. Storing water in underground reservoirs, sometimes referred to as water banking, can eliminate evaporation loses. Underground storage will also protect stored water from additional accumulation of suspended solids, and replenish aquifers.

The Artificial Recharge Demonstration Project is currently underway in Lemmon Valley, Washoe County, Nevada. The project will help determine the feasibility of underground storage in a topographically-closed basin typical of the Basin and Range region of the western United States.

Purpose and Objectives

The purpose of this study was to investigate the effects of artificial recharge on the groundwater system in the Central Area of Lemmon Valley using a groundwater flow model. The flow model will help estimate the volume of injection water that can be stored in the groundwater system. Intuitively, most water entering storage will remain in storage until it is extracted at some future time. The model will also provide information on where and to what degree artificial recharge will influence water levels. The objectives of this modeling study are: 1) compile and use available information about geology, hydrogeology, hydrology, and climate to develop a conceptual model representing field conditions as accurately as possible; 2) approximate the conceptual model with a calibrated steady-state finite difference numerical model; and 3) use the calibrated model to simulate different scenarios of artificial recharge.

Modeling goals can be reached more efficiently if setup of the conceptual model and selection and implementation of the numerical model are approached systematically. The following protocol is the guideline used during model development for this study (from Anderson and Woessner, 1992):

1) Define purpose of modeling exercise;
2) Prepare conceptual model representative of physical system;
3) Identify appropriate mathematical (governing) equations;
4) Select a suitable model code;
5) Prepare model design (select boundary conditions etc.);
6) Calibrate model;
7) Verify model;
8) Use model for prediction (simulation);
9) Present results.

Location and Hydrographic Subdivisions

The Lemmon Valley hydrographic basin (Figure 1) is located approximately 7 miles north of Reno, Nevada along U.S. Highway 395 (Figure 2). Lemmon Valley encompasses approximately 93 square miles. Features of the valley include mountain ridges, alluvial deposits (valley fill), and playa lakes. A previous study by Harrill (1973) concluded that faults divide the basin into hydrographic subareas and even smaller areas. A fairly extensive fault, the Airport Fault, traverses northeast-southwest and divides the valley into two subareas: Silver Lake and East Lemmon Valley. Other smaller faults further divide the Silver Lake subarea into

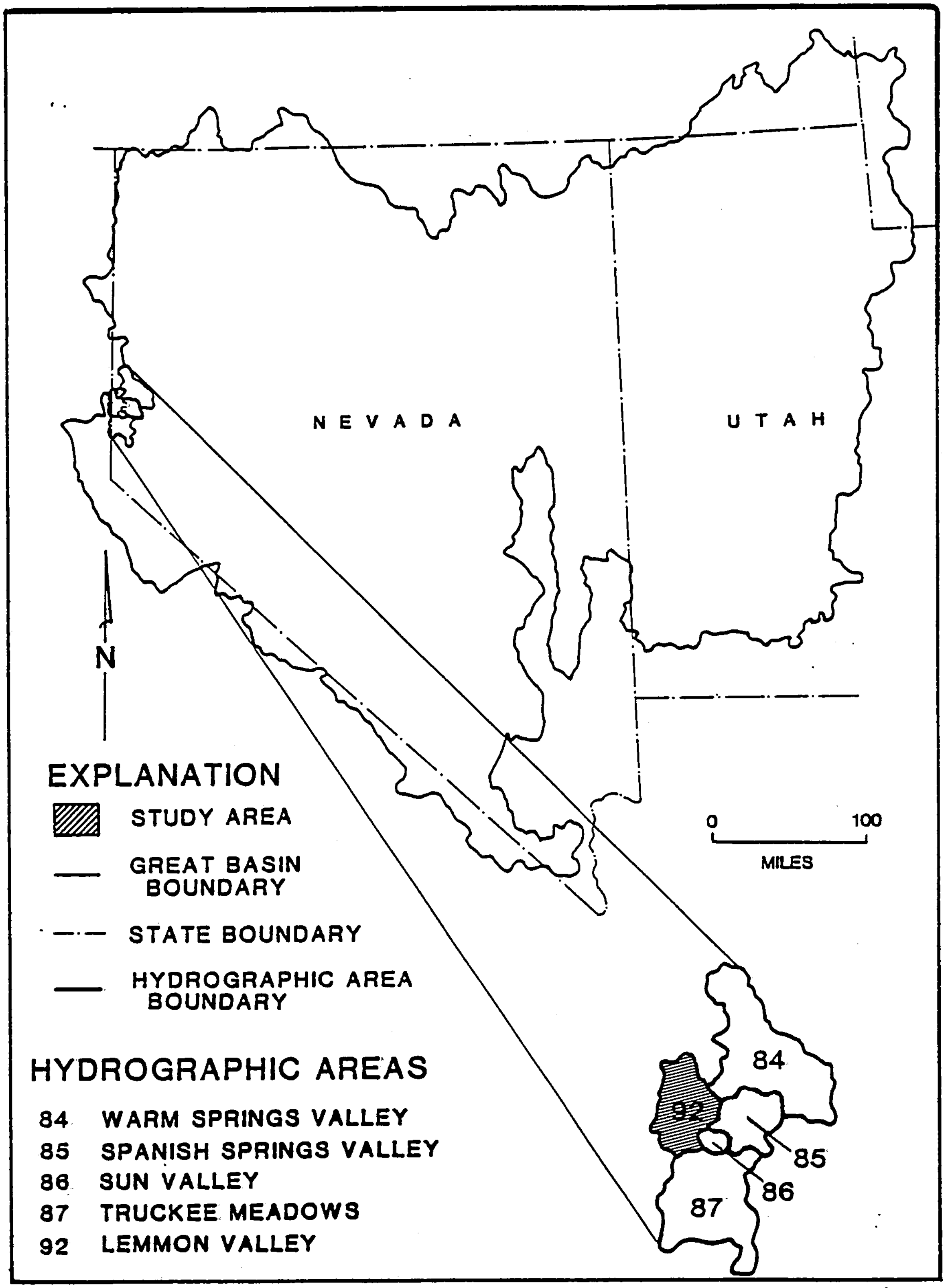

FIGURE 1. Location map of the Lemmon Valley hydrographic basin (modified from Hadiaris, 1988).

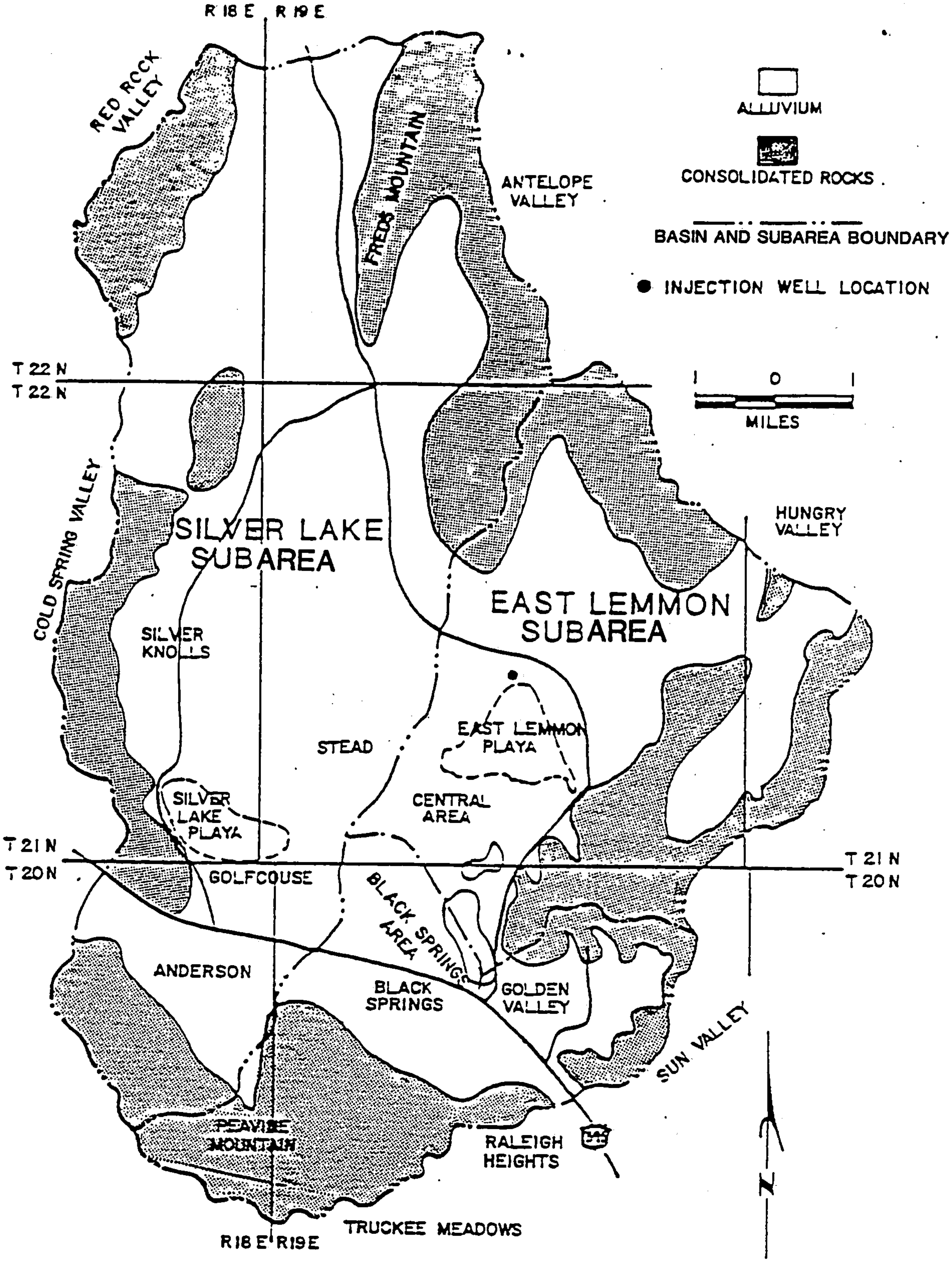

FIGURE 2. General features of Lemmon Valley.

the northern and southern areas while East Lemmon Valley is divided into the Central Area, Golden Valley, and Black Springs. The focus of this study is on the Central Area of East Lemmon Valley where the Artificial Recharge Demonstration Project is currently underway. The Central Area encompasses about 25 ~~acres~~ square miles or 60 percent of the land in the East Lemmon Valley subarea. Figure 3 shows the hydrographic subdivisions of East Lemmon Valley.

7
220
25 mi.

Previous Investigations

Lemmon Valley was previously investigated on several occasions. Individuals contributing to the understanding of the Lemmon Valley groundwater system include F. Rush and P. Glancy (1967), J. Harrill (1973), D. Shaeffer and D. Maurer (1981), F. Arteaga (1984), G. F. Cochran et.al. (1986), and D. Mahin (1988). A brief description of what each study revealed about the Lemmon Valley groundwater system follows.

Rush and Glancy (1967) conducted water-resource reconnaissance studies for 11 valleys in western Nevada, one being Lemmon Valley. Their study of Lemmon Valley identified water budget components and estimated each component's contribution to the groundwater system. Components of the Lemmon Valley water budget identified by Rush and Glancy are: 1) precipitation; 2) subsurface inflow; 3) subsurface

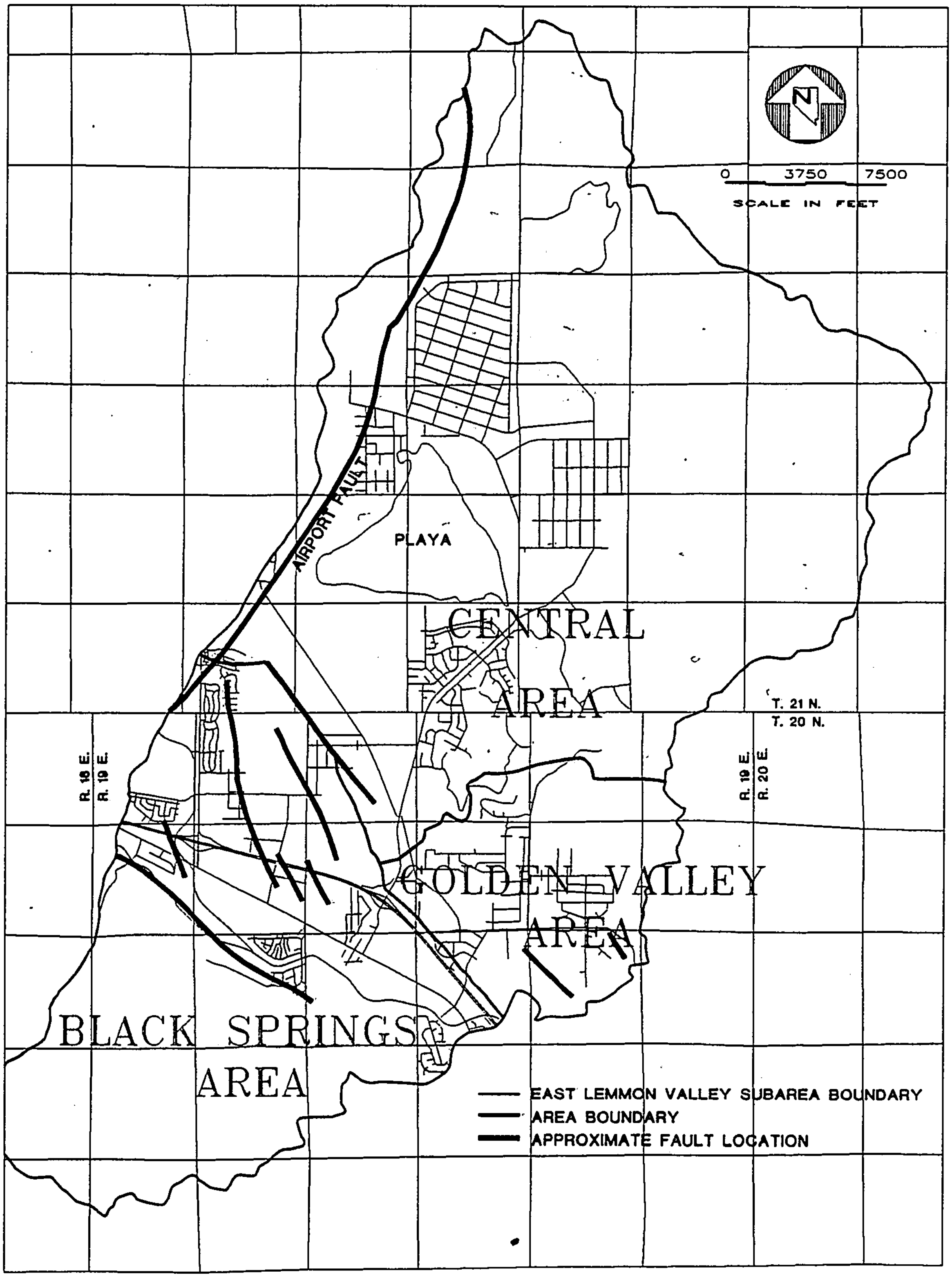

FIGURE 3. Hydrographic subdivisions of the East Lemmon Valley subarea.

outflow; and 4) evapotranspiration (ET). Rush and Glancy also described geologic structures and regional groundwater gradients of the Lemmon Valley area. Harrill (1973) conducted the second hydrology study of Lemmon Valley. Harrill's study provides additional estimates of the water budget, ET discharge areas, plant species and densities, water-level contours for natural (steady state) conditions, water-level contours for conditions in the early 1970s, and lithologic descriptions of valley-fill material. Natural conditions refer to conditions of the groundwater system before human activities may have influenced the groundwater system. Shaeffer and Maurer (1981) completed a geophysical gravity survey in Lemmon Valley. The geophysical survey provides estimates of the thickness of unconsolidated material and the depth to consolidated material (bedrock). Arteaga initiated a hydrology study of Lemmon Valley in 1984. Arteaga's study provides additional information on the water budget. Specifically, Arteaga developed draft precipitation and water yield maps of Lemmon Valley but did not prepare a final report. Cochran et. al. (1986) conducted a study which included modeling the groundwater flow system of Golden Valley. Information on one component of the water budget, subsurface outflow from Golden Valley into the Central Area of Lemmon Valley, is included in the Cochran report. Mahin (1988) initiated a groundwater modeling study of Lemmon Valley using a finite element code. His report includes information on the quantity and distribution of recharge into and discharge out of Lemmon Valley. The report by Mahin is still in draft form.

Washoe County personnel have been conducting field work for the artificial recharge project since the early 1990s. Information collected during the recharge project field study has greatly contributed to the conceptualization of the groundwater system of the Central Area. Work completed for the recharge project includes: installation of 8 groundwater monitoring wells and 1 injection well; a 72-hour constant discharge aquifer stress test on the injection well; and measurement of water levels in approximately 40 wells throughout East Lemmon Valley on a monthly basis. Types of wells being monitored include the recharge project monitoring wells, U.S. Geological Survey (USGS) observation wells, domestic wells, and county municipal wells. Washoe County personnel have also injected water into the injection well at various flow rates to determine the optimum injection rate for the well. Lithologic and hydrostratigraphic information of materials in the Central Area were obtained during drilling for the recharge demonstration project. The 72-hour aquifer test provided estimates of transmissivity, aquifer storage coefficients, and the degree of connection between shallow and deeper wells. Water-level measurements provide data on the current groundwater gradient, and seasonal and annual fluctuations of the water surface. Injecting water into the injection well provides initial information on how water levels will change in the injection well and nearby monitoring wells during artificial recharge cycles.

GEOLOGIC SETTING

Geologic Description And Features of Lemmon Valley

Geology of Lemmon Valley is described in reports by Harrill (1973), Cordy (1985), and Cochran et al. (1986). The following section summarizes geologic discussions included in these reports.

Lemmon Valley is a topographically closed basin typical of those in the Basin and Range region (Harrill, 1973). The valley is a structural depression filled with unconsolidated valley-fill material and is surrounded by mountains comprised of igneous, volcanic, and metavolcanic rocks (Figure 4). Igneous rocks are Cretaceous in age and classified as granodiorite and quartz monzonite. The granodiorite is light to dark gray, fine- to coarse-grained, consisting of equigranular to porphyritic hornblende and biotite. Granodiorite is highly resistant to weathering (Cordy, 1985), and highly fractured (Cochran et. al., 1986). The quartz monzonite is pink to pale-gray, medium- to coarse-grained, and equigranular to porphyritic. Generally, the quartz

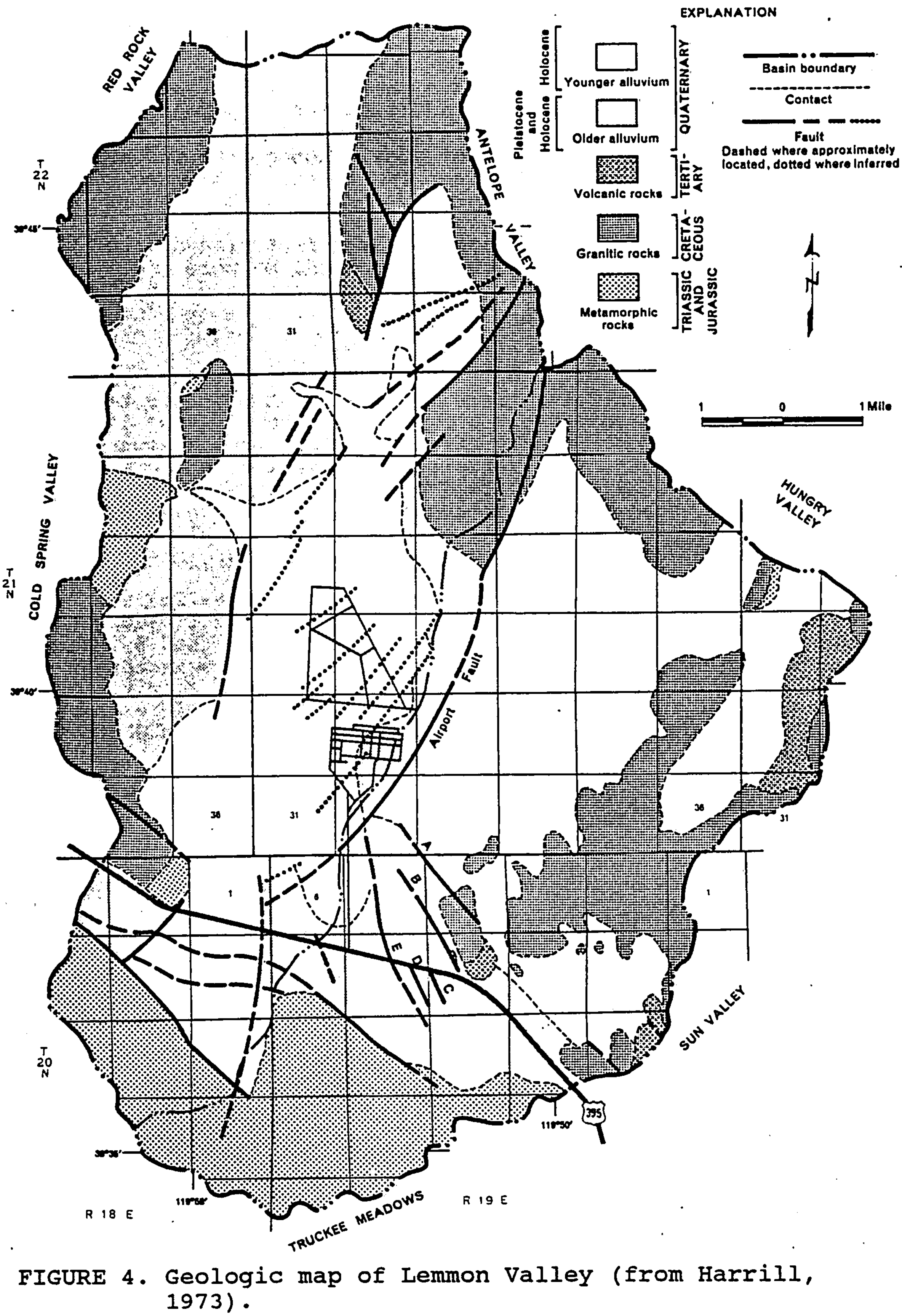

FIGURE 4. Geologic map of Lemmon Valley (from Harrill, 1973).

monzonite is deeply weathered (Cordy, 1985) and more friable than the granodiorite (Cochran et. al., 1986). Volcanic rocks are Tertiary in age and classified as Kate Peak andesites and tuffs. Kate Peak andesites are gray to reddish-gray, porphyritic to glomeroporphyritic hornblende and biotite, and are highly resistant to weathering (Cordy, 1985). Three formations of tuffs are located in Lemmon Valley. The first tuff is the Nine Hills Tuff, which is reddish-purple to pale orangish-red, pumiceous, rhyolite vitric tuff, and forms distinct ridges (Cordy, 1985). The second tuff formation is Pumice tuff which is pale- to dark gray, with very pumiceous vitric-crystal. Pumice tuff contains phenocrysts of sanidine and quartz, and is easily weathered (Cordy, 1985). The third tuff formation is Vitric tuff. Vitric tuff is cream to yellowish-tan to pale-purple rhyolite to rhyodacite and vitric to vitric-crystal. Phenocrysts include sanidine, sanidine-smokey quartz, plagioclase-biotite, and biotite. Weathering of Vitric tuff forms knobby outcrops (Cordy, 1985). The Peavine sequence outcrops at the south end of Lemmon Valley. The Peavine sequence is Jurassic to Triassic in age and is comprised of gray- to gray-green meta-andesites with lesser amounts of metamorphosed epi-clastic volcanic sedimentary rocks (Cochran et. al., 1986). The Peavine sequence is fine-grained and resists weathering.

Features other than mountain ridges in Lemmon Valley include valley-fill deposits and playa lakes. Valley fill is comprised of weathered material from the surrounding igneous, volcanic, and metavolcanic rocks. Mineral constituents of the valley fill include quartz, feldspar, and mafic minerals (Cochran et. al., 1986). Valley fill consists of clay, silt, fine- to coarse-grained sand, and gravel. Generally, valley fill is more coarse near the mountain ridges and becomes fine-grained in the center of the valley near playa lakes. Playa lake deposits are mostly clay, silt, and fine-grained sand.

The mountains surrounding and underlying the valley are complexely faulted. Regional faulting gave the mountains their large-scale size, shape, and relief (Harrill, 1973). The present topography of the basin is the result of erosion and smaller scale fault structures. Figure 5 shows the locations of faults in the Central Area of Lemmon Valley. Elevations of the valley range from approximately 4910 feet above mean sea level (amsl) at the East Lemmon Valley playa to more than 8200 feet amsl at Peavine Mountain. Topographic slopes of valley fill range from several feet per mile at the playa lakes to 800 feet per mile on the north flank of Peavine Mountain. The playa in the Central Area covers approximately 800 acres while the playa in the Silver Lake subarea is approximately 430 acres in size.

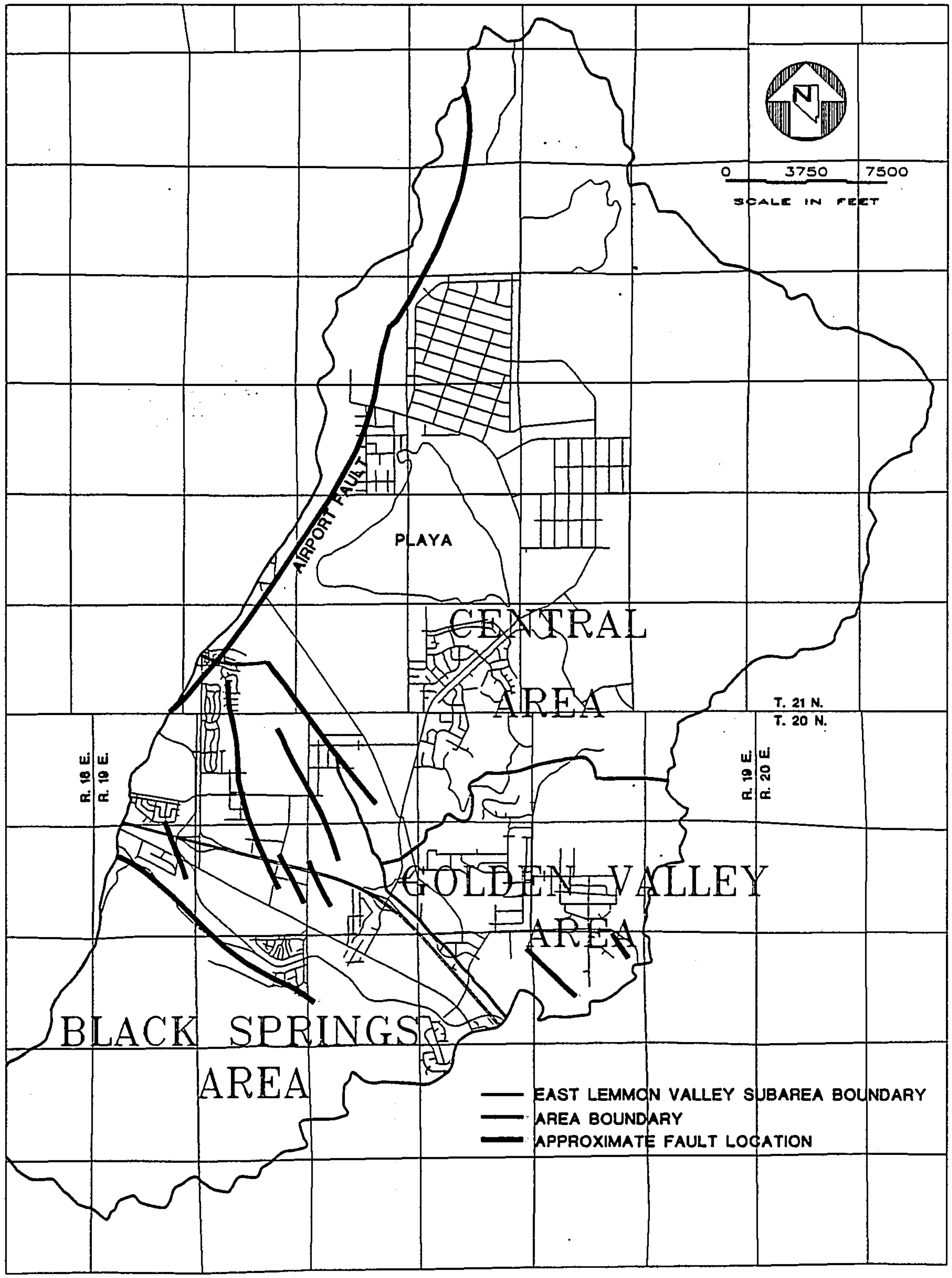

FIGURE 5. Fault locations in the Central Area of East Lemmon Valley.

HYDROGEOLOGIC SETTING

Hydrostratigraphic Units of the Central Area

Evaluation of more than 70 drilling logs from Harrill (1973), the artificial recharge project field study, and drilling logs submitted by domestic well drillers to the State of Nevada Division of Water Resources provided information on the hydrostratigraphic units of the Central Area. Each lithologic material and its associated hydrologic parameters for groundwater flow were evaluated to select the specific hydrostratigraphic units of the Central Area. Three hydrostratigraphic units were identified based on this evaluation: 1) playa deposits; 2) valley-fill material; and 3) fractured bedrock. A summary of each hydrostratigraphic unit follows.

Playa Deposits

Playa deposits are fine-grained materials consisting of clay, silt, and sand. The lateral and vertical extent of playa deposits were estimated by evaluating drilling logs since drilling logs describe the type and depth at which a specific material is encountered. Based on drilling logs, the playa unit is thickest near the center of the playa lake and thins laterally. A distinct homogeneous unit is not present but clay is abundant to a depth of approximately 200 feet in the playa lake area. Zones of coarse sand, fine sand, and silt occur at random intervals. Clay material has high porosity, high specific retention, and low specific yield, resulting in poor water yield.

Valley-Fill Material

The most productive zones of groundwater in Lemmon Valley are found in valley-fill material which is comprised of younger and older alluvium (Harrill, 1973). Lithology of valley-fill material includes clay, silt, sand, and gravel. A geophysical study was conducted in Lemmon Valley by the USGS in the early 1980s (Shaeffer and Maurer, 1981). Results of the geophysical study were used to supplement data from more than 70 drilling logs and estimate the total thickness of valley fill in the Central Area. Based on interpretation of the geophysical survey and drilling logs, valley fill is estimated to be thickest underneath the playa lake. The valley fill is estimated to have a maximum thickness of approximately 800 feet and thins toward the bedrock outcrops around the perimeter of the valley. Valley fill has a wide range of hydrologic properties since it is a mixture of materials. The most productive water-bearing zones, coarse sand and gravel, have moderate to high porosity, low specific retention, and high specific yield (Heath, 1984).

Bedrock

Groundwater wells in the northwest and southeast sections of the Central Area are screened in bedrock since valley-fill material is thin in these areas. Groundwater is present in fractures. Large fractures have the potential to transmit water readily. Conversely, bedrock with few or small fractures transmit little water. The vertical extent of the fractures has not been determined in the Central Area of East Lemmon Valley. Anderson and Woessner (1992) state that impermeable boundaries are sometimes designated when hydraulic conductivity values change by two orders of magnitude. Based on this statement, fractures were assumed to extend approximately 200 feet below the water surface where a two order of magnitude contrast in hydraulic conductivity could possibly exist. Bedrock units have a wide range of hydrologic properties depending on the degree of fracturing. Highly fractured zones will have high porosity and specific yield, and low specific retention.

Drilling for groundwater monitoring wells and the injection well provided specific data on the hydrostratigraphic units in the artificial recharge area. The deepest drilling for the recharge project was to a depth of 465 feet below ground surface. The shallowest borehole was drilled to a depth of 65 feet below ground surface. Four materials were encountered during drilling: clay, silt, sand, and gravel.

Except for a surface clay (playa deposit) layer and a deep unit (greater than 400 feet below ground surface) comprised mostly of sand, all four materials are predominately intermixed.

Typical Hydrologic Properties

The hydrostratigraphic units encountered in the Central Area are typical to those found in many basins throughout Nevada. Each type of material has different hydrologic properties and abilities to transmit water. Hydraulic conductivity (K) is a property describing the ability a material has to transmit water in the horizontal (K_h) and vertical (K_v) direction, expressed as length per time (L/t). Typical values of K_h are summarized in Table 1 (from Harrill, 1986).

TABLE 1. Typical values of horizontal hydraulic conductivity for lithologic materials found in the Central Area.

Lithologic Description	Typical Material	Typical Range of K_h (feet per day)
Playa deposits	clay, silt very fine sand	0.001 - 0.3 0.1 - 1.6
Lacustrine- fine-grained deposits	silt, clay, fine sand	0.1 - 0.5 1 - 4
Fanglomerate and coarse gravel	silt, sand, gravel sand gravel	0.1 - 4 4 - 30+ 20 - 150

Information in Table 1 indicates that coarse-grained material will transmit water more easily than fine-grained material. K_v values are typically much smaller than K_h values. Fine-grained material may have K_v values one-hundredth to one-thousandth times smaller than K_h (Harrill, 1986).

Specific yield (S_y) represents the storage term for unconfined aquifers. S_y is defined as the volume of water a unit will release due to gravity drainage per unit surface area of aquifer per unit decline of the water table. S_y ranges from 0.01 for fine-grained material to 0.3 for coarse material (Freeze and Cherry, 1979). Storage coefficient (S), defined as specific storage times aquifer thickness, is the storage term for confined aquifers. S is defined as the volume of water released from storage by compressibility of the aquifer and expansion of water per unit surface area per unit decline in the potentiometric surface. S typically ranges from 0.00005 to 0.005 (Freeze and Cherry, 1979).

WATER BUDGET COMPONENTS

Components of a groundwater budget can be categorized as primary and secondary components. Primary components of a groundwater budget are components that occur naturally such as precipitation, surface runoff, subsurface inflow, subsurface outflow, evapotranspiration (ET), and evaporation.

Precipitation, subsurface inflow, subsurface outflow, and ET are the primary components of the water budget for the Central Area. Surface runoff and evaporation are considered minor components of the system (Harrill, 1973) so are not included in the water budget for the groundwater model.

Secondary components of the water budget occur because of human activities. The two secondary components of the water budget for the Central Area are secondary recharge from discharge of septic tanks and sewage treatment, and pumpage or extraction of groundwater. The following section summarizes each primary and secondary component of the estimated water budget for the Central Area. Figure 6 is a schematic showing the general locations of primary recharge sources and discharge sinks for East Lemmon Valley.

Groundwater Recharge

Natural Recharge From Precipitation

Precipitation at upper elevations is the primary source of groundwater recharge for Lemmon Valley. A lesser amount of precipitation falls at lower elevations and has little or no contribution to recharge. Precipitation can enter the groundwater system by direct infiltration where precipitation falls or travel as surface runoff until permeable areas are

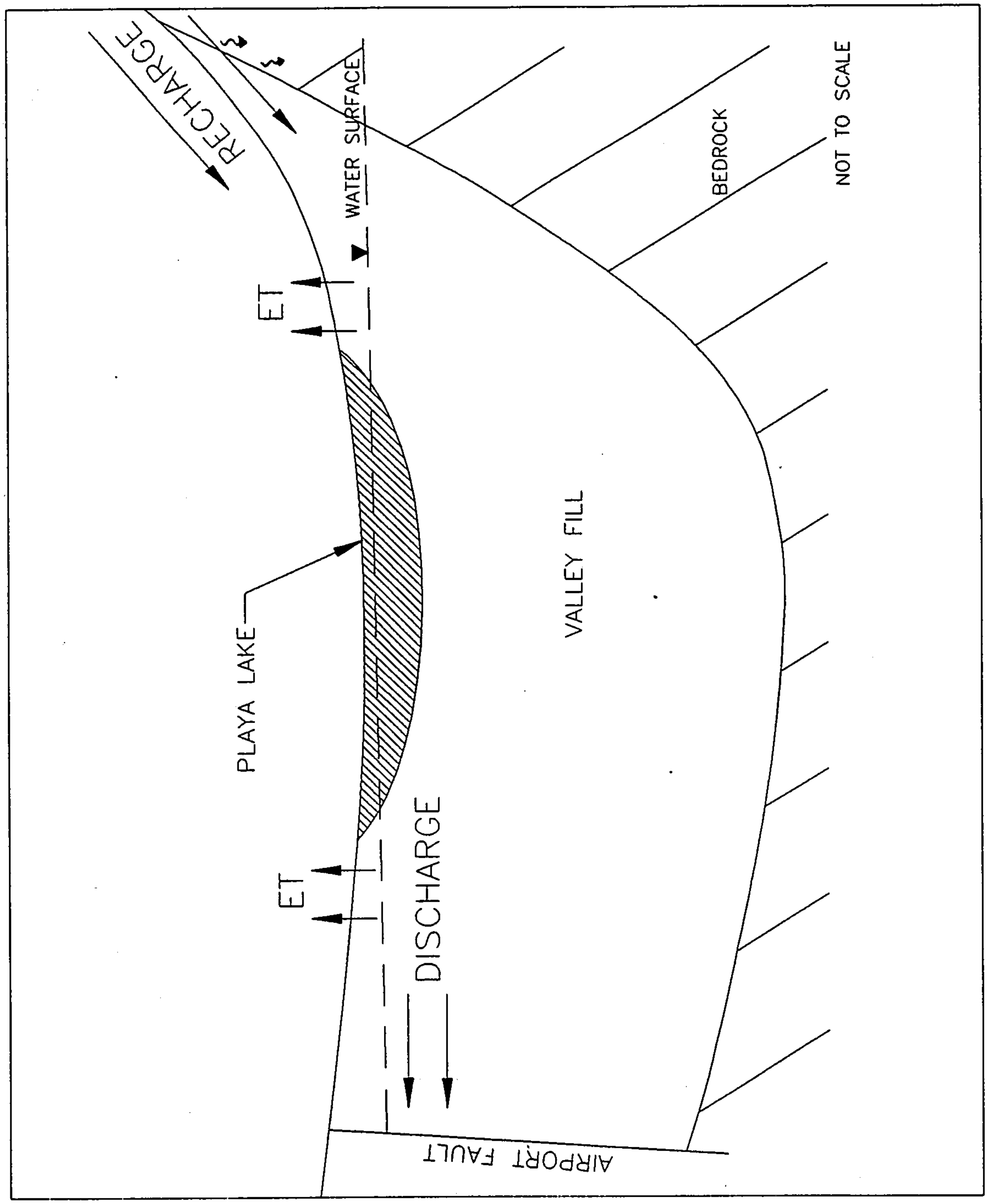

FIGURE 6. Schematic of recharge/discharge locations for the Central Area of East Lemmon Valley.

reached. Surface runoff in the Central Area occurs very infrequently because heavy, prolonged precipitation events seldom occur. Several factors determine the amount of precipitation that reaches the water table. These factors are type and thickness of soil, topography, vegetative cover, soil moisture content, intensity and duration of precipitation, and meteorogical factors such as temperature and humidity (Walton, 1988). The amount of precipitation reaching the saturated zone is described as water yield (Arteaga and Durbin, 1979) and is a percentage of total precipitation. Surface water in streams or rivers is also part of total water yield, however, there are no streams or rivers in the Central Area of Lemmon Valley. Water yield is approximated by the relationship between land altitude/mean annual precipitation, soil types, and vegetation. Basically, if soils have low permeability or vegetation is abundant, water yield will be low at that location. The quantity and distribution of precipitation in Lemmon Valley are described in a precipitation study of the Truckee River Basin (Klieforth, et.al., 1983). The range of average annual precipitation falling in the Central Area ranges from 8 to 16 inches. Figure 7 is the isohyetal map for East Lemmon Valley. Arteaga (1984) prepared a draft water yield map from data in the Klieforth precipitation study report. Arteaga developed and used the following equations to determine the relationship between precipitation and water yield:

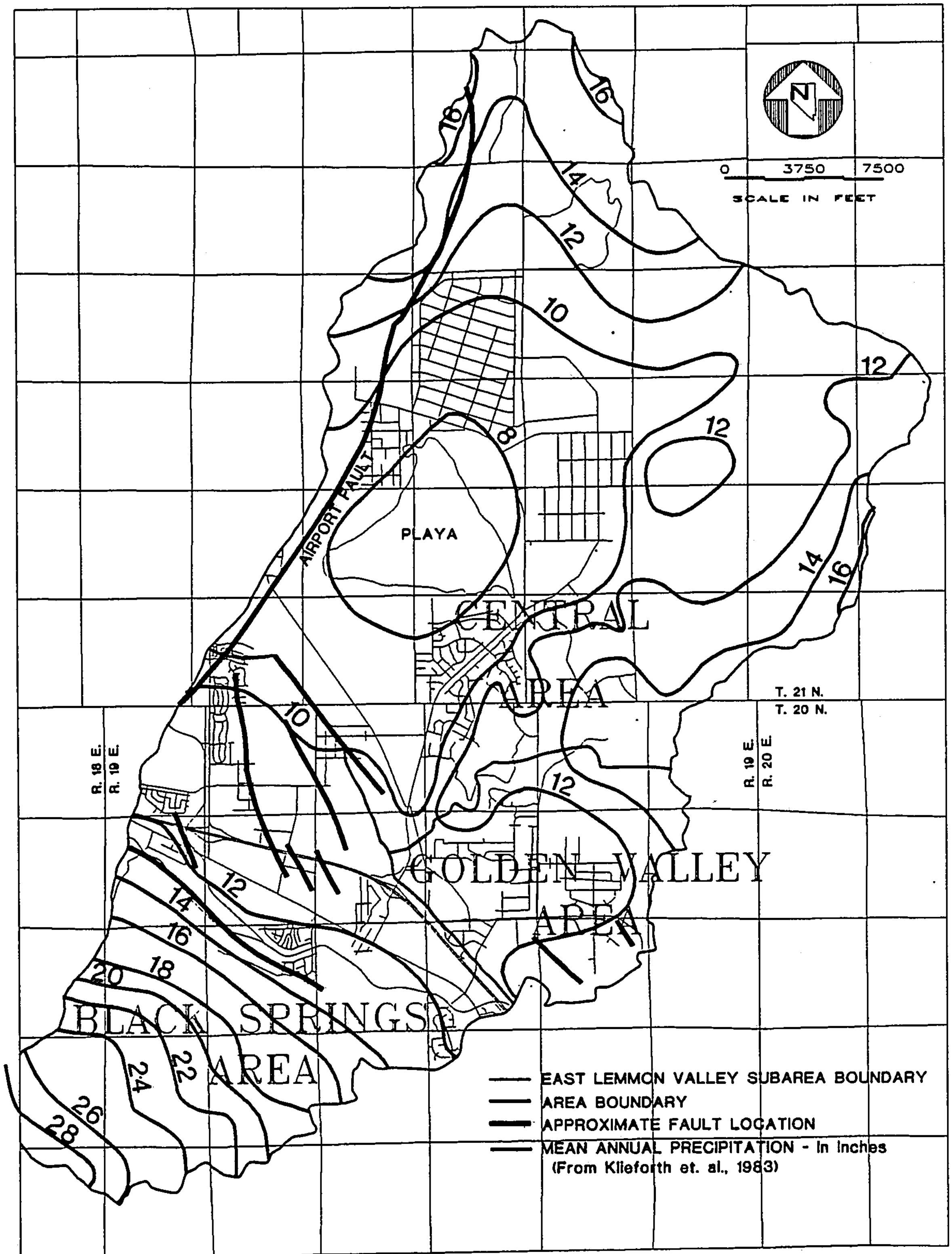

FIGURE 7. Isohyetal map for East Lemmon Valley.

1) If $10 \le P \le 27$, $Y = (0.207)P - 2.07$;

2) If $27 \le P \le 31$, $Y = -80.5 + (9.82)P - 0.391P^2 + 0.00528P^3$;

3) If $31 \le P \le 60$, $Y = P - 25.59$.

where P is mean annual precipitation in inches;

y is mean annual water yield in inches.

Based on these equations, total water yield for the Central Area is approximately 500 acre-feet per year (AFY). Harrill (1973) estimated recharge into East Lemmon Valley using a method developed by Eakin and others (1951). The Eakin method is similar to the method of Arteaga. Water yield is estimated by dividing the area of interest into precipitation zones based on surface elevations. Using the Eakin method, Harrill estimated a recharge value of 500 AFY for all of East Lemmon Valley, which includes the Central Area. Difference in recharge values between the Arteaga and Eakin methods may be attributed to the uncertainty in the estimation procedures. Harrill also used a precipitation map that was a precursor to the map used by Arteaga.

Subsurface Inflow

Another source of inflow to the Central Area is subsurface inflow from Golden Valley (Cochran et. al., 1986). The groundwater model of Golden Valley developed by Cochran et. al. has approximately 45 AFY of groundwater outflow from

Golden Valley into the Central Area. Water levels are higher in Golden Valley, supporting the direction of flow out of Golden Valley into the Central Area.

Secondary Recharge

Secondary recharge is defined as the amount of water returned to the groundwater system as the result of human activities. Sources of secondary recharge include: 1) irrigation of lawns, crops, or golf courses; and 2) discharging of septic tanks and treatment plant effluent. Not all secondary recharge returns to the groundwater system, some is lost (or consumed) by evaporation and evapotranspiration processes or remains in the unsaturated zone above the groundwater surface. Amounts of secondary recharge described in this report are considered to be amounts actually returning to the groundwater aquifer.

No golf courses or crop-producing areas are located in the Central Area, consequently, septic tanks and treatment plant effluent are the only possible sources of secondary recharge. Harrill made the assumption that secondary recharge in Lemmon Valley is a percentage of: 1) total discharge from a sewage treatment plant; and 2) total amount of water used for lawn irrigation. Harrill did not estimate secondary recharge from septic tank effluent presumably because septic tanks were a minor contributor of the water budget at the time of his study. At the time of his study, most effluent in the Central Area was discharged from a sewage treatment plant in the southwest corner of the model domain. The effluent originated in the Silver Springs subarea but was discharged into the Central Area. Based on his assumptions, Harrill estimated that about 40 percent of effluent and 30 percent of lawn irrigation water becomes secondary recharge. Presumably, the percentages used by Harrill come from studies of groundwater consumption conducted in basins similar to Lemmon Valley. Harrill (1973) estimated the amount of secondary recharge in the Central Area to be approximately 220 AF in 1971.

Groundwater Discharge

Evapotranspiration

Evapotranspiration (ET) can reduce water infiltration to the saturated zone or remove water once it reaches the saturated zone. There are many factors that control the level of impact ET has on a water budget. Some of these factors are: 1) the plant species present; 2) densities and lateral distribution of plants; and 3) depth to the saturated zone. Two important components of ET needed for a groundwater model are the depth that plant roots penetrate (the extinction depth) and rate of ET:

ET occurs along the perimeter of the playa lake in the Central Area (Harrill, 1973). Plants species found near the playa are, greasewood, rabbitbrush, wildrye, and saltgrass. These plants were mapped by Harrill and are shown in Figure 8. Harrill estimated the amount of ET in the Central Area based on his mapping of the plant populations. In 1971, there were approximately 2,000 acres of greasewood and rabbitbrush of high to low population density. Harrill used an ET rate of approximately 0.25 AFY per acre and concluded that these plant types remove approximately 500 AF from the groundwater system annually. A more dense population of plants is located in the southwest portion of the study area. Harrill estimated the denser area to be approximately 100 acres of channel-bottom vegetation (grass, willows, and tules). The rate of evapotranspiration for this area was estimated at 0.8 AFY per acre, resulting in a relatively small amount of 80 AF being removed from the system annually by the more densely populated plants.

The extinction depth in the Central Area is not known and most likely varies to some extent both regionally and locally. Danskin (1988) states that ET studies for Owens Valley have a wide range of estimated ET rates and extinction depths. The ET rates for studies completed in Owens Valley range from 5 inches to more than 31 inches per year (0.001 to

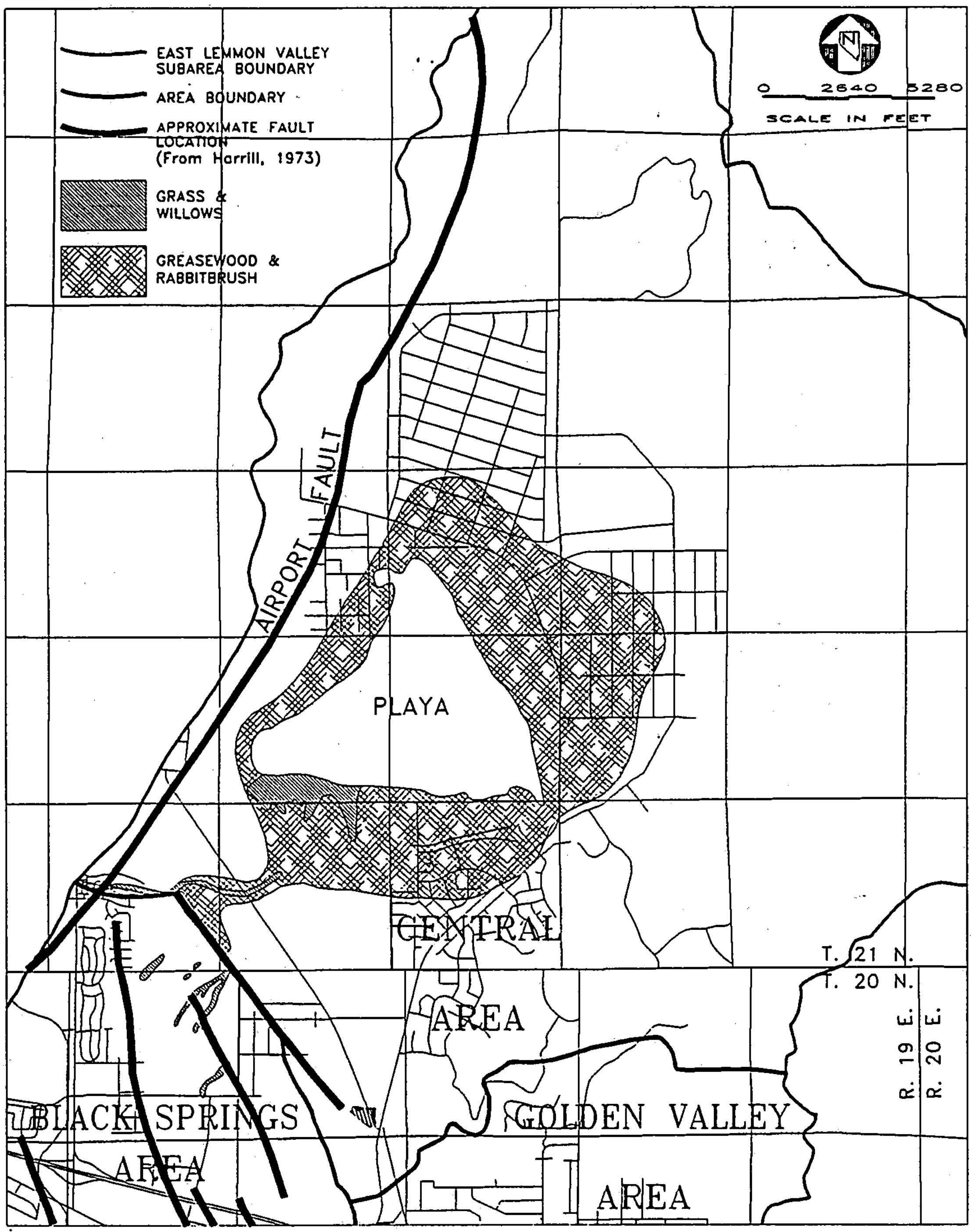

FIGURE 8. Phreatophyte areas of East Lemmon Valley in 1971 (from Harrill, 1973).

0.007 feet per day). Extinction depths range from 5 feet to more than 30 feet in modeling studies completed in basins similar to Lemmon Valley (Thomas et.al., 1989; and Danskin, 1988).

Subsurface Outflow

Water-level measurements from the early 1970s show a westward gradient toward the Airport Fault (Harrill, 1973). Harrill estimates that approximately 220 AF of groundwater exit the Central Area along the Airport Fault annually. His estimate was made by developing a flow net near the Airport Fault and using the following equation:

$Q = TIW$

where Q is volumetric flow (Length cubed/time or L^3/t);

T is transmissivity (L^2/t);

I is the groundwater gradient (L/L); and

W is width of the flow field (L).

Harrill used approximations for T, I, and W of the flow field to estimate outflow at the fault.

Groundwater Pumpage

Municipal and domestic wells extract or pump groundwater at many locations in the Central Area. The amount of pumping varies seasonally and from location to location, depending on the density or distribution of wells. Not all pumped water is lost or consumed, some is returned as secondary recharge. Harrill estimated groundwater consumption by assuming that about 40 percent of total groundwater pumpage is actually consumed. Presumably, Harrill's estimate of groundwater consumption comes from studies of groundwater consumption in basins similar to Lemmon Valley. Harrill (1973) estimated that approximately 160 AF of pumped groundwater was consumed in the Central Area during 1971.

Initial Estimate of the Water Budget

Harrill (1973) estimated water budgets for natural conditions and for the year 1971 when human activities had some contribution to the water budget of Lemmon Valley. Table 2 summarizes Harrill's estimated water budget for the Central Area of East Lemmon Valley in 1971.

TABLE. 2. Estimated water budget for the Central Area of East Lemmon Valley in 1971.

Natural Recharge	500 AFY
Subsurface Inflow	45 AFY
Secondary Recharge	220 AFY
Total Recharge	765 AFY
Evapotranspiration	580 AFY
Subsurface Outflow	220 AFY
Pumpage (amount consumed)	160 AFY
Total Discharge	960 AFY

(interpreted from Harrill, 1973; Arteaga, 1984; and Cochran et. al., 1986.)

The estimated groundwater budget has an imbalance of 195 AF. Some of the imbalance may be attributed to the uncertainty within the methods used to approximate inflows and outflows. The largest error may be related to the ET process because of the uncertainties of ET extinction depths and rates. It is also possible that discharge did exceed recharge since water was being pumped from the valley (ie., water was coming out of storage). However, water levels were stable over most of the study area on an annual basis in the early 1970s. Consistent water-level declines did not begin until the mid- to late 1970s.

GROUNDWATER MODEL DESIGN

Conceptual Model

Many types of input data are needed to conceptualize and represent a groundwater system with a three-dimensional numerical model. Required input data are:

1) Horizontal hydraulic conductivity;
2) Vertical hydraulic conductivity;
3) Elevations of tops and bottoms of the model layers;
4) Recharge estimates;
5) Discharge estimates; and,
6) Aquifer storage parameters if the model will represent transient conditions.

Numerous types of data were evaluated to develop the conceptual model of the Central Area and choose model layers. As with most basins containing valley fill, distinct and extensive layers are difficult to discern. Data reviewed to help designate model layers include drilling logs, aquifer tests, geologic maps, precipitation and ET estimates, and borehole geophysical logs. Conceptually, the three hydrostratigraphic units of the Central Area were divided into two model layers, an upper unconfined layer and a lower confined layer (Figure 9). Layer selection was based on differences in water levels for adjacent wells (well pairs), aquifer tests, and locations of well screens. The following

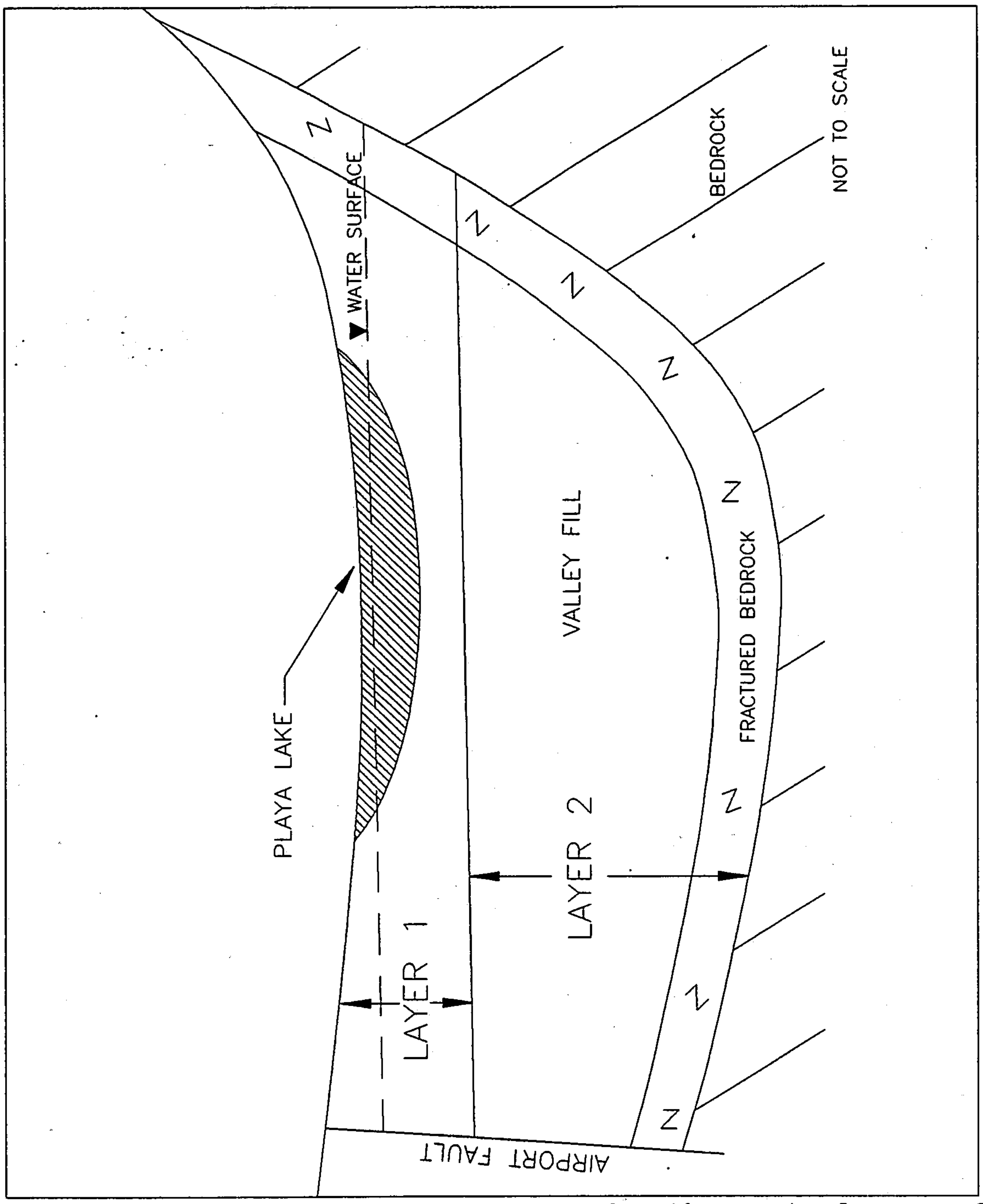

FIGURE 9. Schematic of model layers for the Central Area of East Lemmon Valley.

summary describes how model layers were selected by interpretation of the various data sets.

Differences in depth-to-water for well pairs located in the Central Area range from approximately 5 to 15 feet. Generally, the deeper well of well pairs has a water level at a higher elevation. Differences in water levels for well pairs means: 1) the wells are separated by confining material and their well screens are installed in different aquifers; or 2) the wells are screened in the same aquifer but there is a vertical gradient within the aquifer. Since the materials in the Central Area are intermixed and fine-grained material is abundant, it is likely that the well screens are separated by confining material and are located in what may be considered different aquifers.

The 72-hour constant discharge aquifer test completed for the recharge demonstration project revealed delayed or no connection between the deeper pumping well (depth of 465 feet) and shallow monitoring wells (less than 150 feet depth) during the aquifer test period. Water levels in some shallow monitoring wells initially rose during the aquifer test then declined several feet as the pumping period approached 72 hours, indicating delayed connection. One shallow well (total depth of 65 feet) located within 200 feet of the pumping well did not show any water level decline during the 72-hour test, indicating no connection during the aquifer test.

Drilling logs were also reviewed to help select model layers. Based on drilling log descriptions, clay is abundant to a depth of approximately 200 feet below ground surface, especially in the vicinity of the playa lake and artificial recharge area. In addition, most domestic wells are typically screened in the upper-most water producing zone. Most domestic wells in the Central Area are screened within the upper 150 feet of the saturated zone. Municipal wells are typically screened at greater depths where potential water yield is greater. Most municipal wells in the Central Area are screened at depths greater than 200 feet. After review of data from well pairs, aquifer test results, and drilling logs, the bottom elevation of the upper layer was designated to be approximately 150 feet below the water table, meaning the bottom of the layer was essentially flat except at the south end of the model area where elevation of the water table begins to rise. Based on the geophysical survey (Shaeffer and Maurer, 1981) and drilling logs, the maximum thickness of valley fill is approximately 800 feet below the playa lake and thins laterally. Figure 10 is a thickness map for valley-fill material in East Lemmon Valley. Both model layers are at least partially comprised of valley fill. Layer 2 extends to the bottom of the valley fill and includes fractured bedrock. It should be noted that drilling has not encountered bedrock in the thickest valley fill area

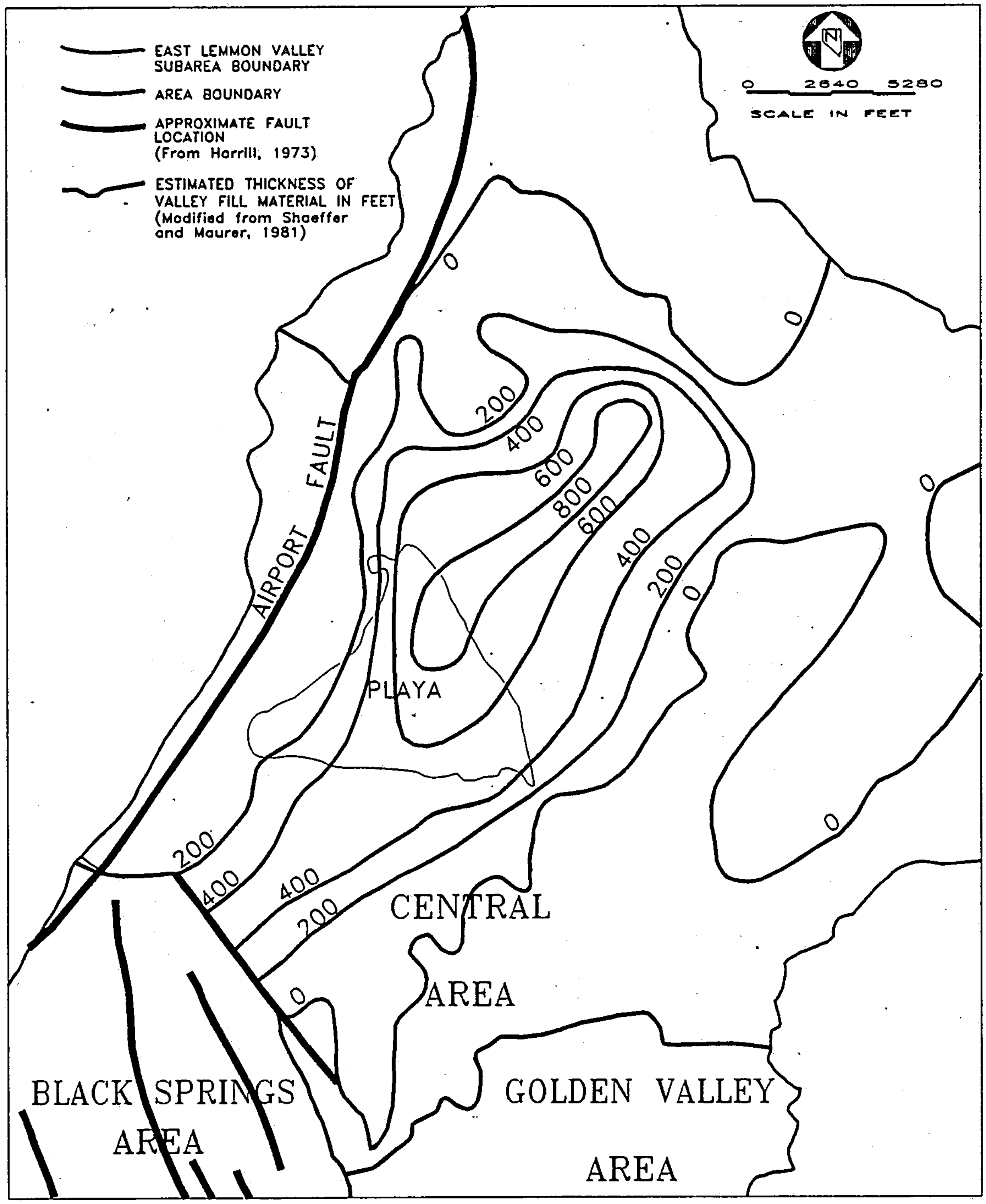

FIGURE 10. Thickness map of valley fill in East Lemmon Valley.

or at the potential sink area along the Airport Fault, the depth to bedrock along the fault is based solely on the geophysical survey.

Perimeter and bottom boundaries of the modeled area are conceptualized as specified flow. No-flow (specified flow equals 0) boundaries are associated with the contact between low permeability bedrock and higher permeability valley fill, topographic divides, or fault barriers. Specified flow representing recharge was introduced into the model at the first cell inside the no-flow boundary at locations where precipitation is presumed to infiltrate into the valley fill. Presumably, most precipitation will infiltrate into the higher permeability valley fill and not the low permeability bedrock that defines the no-flow boundary. Figure 11 shows where natural recharge enters the model area.

West, south, and northeast boundaries of the Central Area are defined with no-flow cells along faults and a topographic divide. Typically, fault zones are low permeability zones that hinder flow of water in one direction and act as a sink in another direction. A portion of the west boundary along the Airport Fault has the lowest water levels in the Central Area and is a potential sink (Harrill, 1973). Several discharge wells were positioned along this boundary just inside the no flow boundary to represent the sink and reproduce the groundwater gradient for natural conditions.

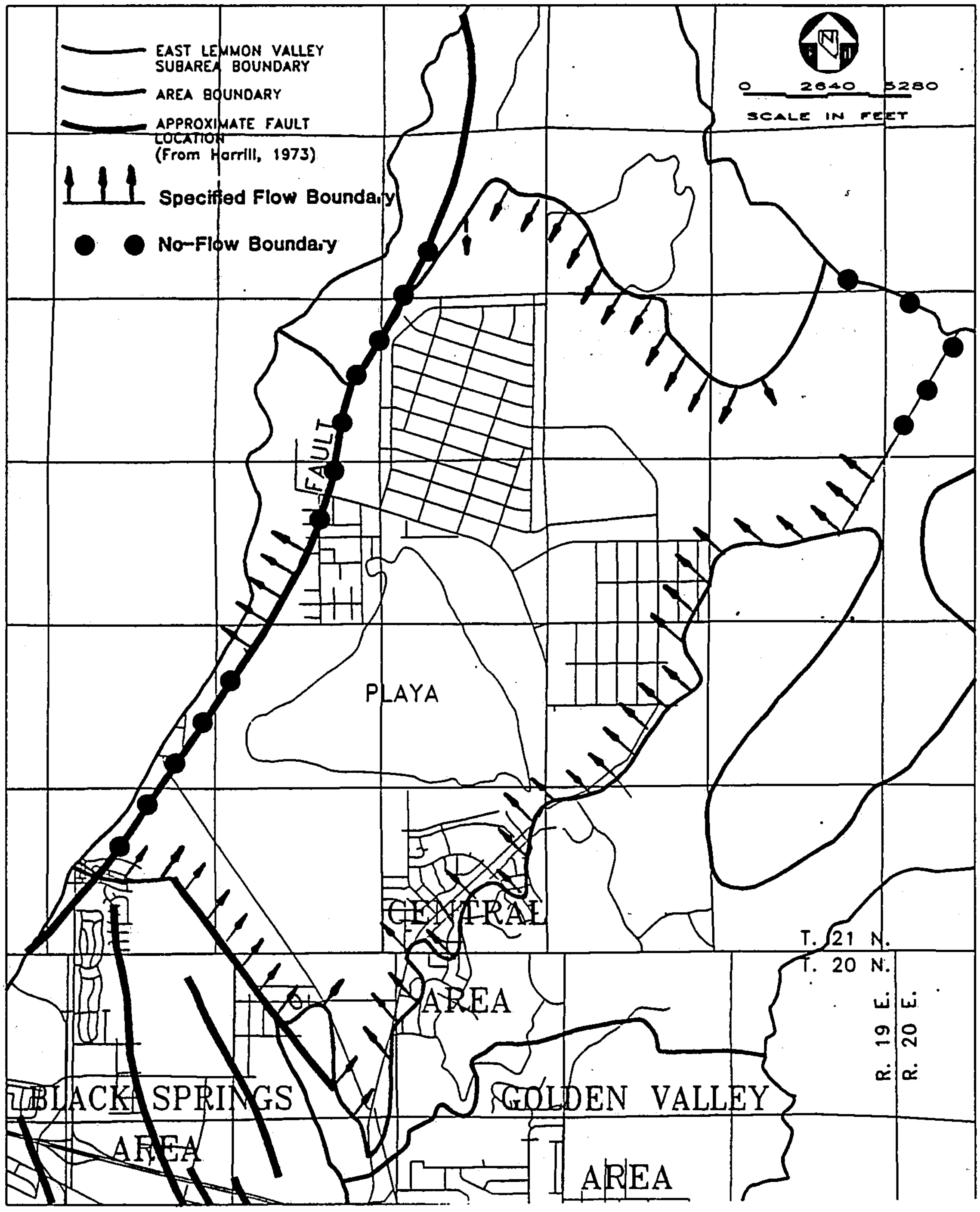

FIGURE 11. Natural recharge locations for the Central Area of East Lemmon Valley.

It should be noted that the surface elevations for some of the USGS wells in the Central Area have not been accurately surveyed, which influences the value of hydraulic head at the well. Since surface elevations influence the value of hydraulic head at the well, more wells should be surveyed to determine the exact groundwater gradient.

The northeast boundary is a topographic divide also defined as a no-flow boundary. Precipitation falling at the divide will either flow away from or into the model domain.

Quasi Steady-State Conditions

Water-level measurements collected in the early 1970s were stable on an annual basis, but did fluctuate seasonally. A groundwater system with water levels fluctuating seasonally but not annually is considered to be at quasi steady state. One portion of the Central Area did have declining water levels during the early 1970s (Harrill, 1973). However, the only available data supporting the decline of water levels were water-level measurements collected over a 5-month period from 3 municipal wells. One possible reason for the decline of water levels in the area is because transmissivity and subsequent water yield is low in the fractured bedrock where the wells are located. Documents indicate that water yield is low in the area of declining water levels since 2 of the 3 wells were inefficient water producers and were abandoned. Thus, it appears that the declining water levels were a local phenomena and did not represent the overall conditions of the Central Area in the early 1970s.

Mathematical Model

Movement of groundwater through a porous material can be described by the following partial differential equation (McDonald and Harbaugh, 1988):

$$\frac{\partial}{\partial x}(K_x\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_y\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_z\frac{\partial h}{\partial z})+W=S_s\frac{\partial h}{\partial t}$$

where K is hydraulic conductivity in the horizontal (x and y) and vertical (z) directions (Length/time or L/t);

h is the potentiometric head (L);

W is a volumetric flux per unit volume representing sources or sinks (1/t);

S_s is specific storage of the porous material (1/L);

t is time (t).

The flow equation along with values of flow and/or head conditions at boundaries and initial head conditions of the problem domain constitute a mathematical representation of a groundwater flow system (McDonald and Harbaugh, 1988). Most groundwater systems are fairly complex so the solution to the partial differential equation must be approximated with a numerical method. MODFLOW (McDonald and Harbaugh, 1988) solves the partial differential equation with a finite difference numerical method. Basically, the finite difference method approximates the solution to the flow equation at discrete points in space and time, and determines head values at these discrete points. This is done by replacing the partial differential flow equation with a set of algebraic equations. Wang and Anderson (1982) give a detailed description of how the differential flow equation is solved with the finite difference approach.

The equation described above is appropriate for layer 1 of the model since the water surface will vary with time and the vertical component of flow is needed. The flow equation for layer 2 is a simplified version of the equation for layer 1. Layer 2 is confined which implies there is only horizontal flow, meaning the vertical component of flow is not needed. The flow equation for layer 2 is (from Maclay and Land, 1988):

$$\frac{\partial}{\partial x}\left(T_x\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(T_y\frac{\partial h}{\partial y}\right)+W=S\frac{\partial h}{\partial t}$$

where T is transmissivity in the x and y directions (L^2/t);

h is the potentiometric head (L);

S is the storage coefficient (no units);

W is a volumetric flux per unit surface area representing sources or sinks (L/t); and

t is time.

NUMERICAL MODEL

Model Grid Configuration

The Central Area of Lemmon Valley was divided into distinct cells or blocks with a model grid. Initially, each grid cell was 1,000 feet by 1,000 feet with 16 rows and 32 columns for a total of 512 cells. The grid was later refined to 500 feet by 500 feet in the area where the existing artificial recharge project injection well is located. Smaller grid spacing provides greater detail (more data points) of the water surface in areas with steeper groundwater gradients, which is likely to occur near the injection well. The final grid configuration is 18 rows and 34 columns consisting of 420- 1,000 feet by 1,000 feet blocks, 176- 1,000 feet by 500 feet blocks, and 16- 500 feet by 500 feet blocks. Figure 12 shows the final grid design. The grid is oriented parallel to the boundary along the Airport Fault. Cells for each model layer were designated as being active or inactive. For layer 1, inactive (no-flow) cells represent the low permeability characteristics of bedrock outcrops. Inactive cells in layer 2 are located around the perimeter of the layer where valley fill is 150 feet thick or less and are associated with layer 1. Figures 13 and 14 show the active and inactive cells of each layer.

STEADY-STATE MODEL CALIBRATION

Based on the water budget previously discussed and the stability of water-level measurements on an annual basis during the early 1970s, a quasi steady-state calibration process was performed. Water-level measurements collected from more than 20 wells showed little annual fluctuation from 1971 through 1976. Some wells did show seasonal fluctuations but returned (rebounded) to non-stress elevations during late winter and spring months when water consumption decreases. Some of the wells used for the calibration data set are screened at shallow (less than 150 feet) depths while others are screened at deeper depths (greater than 200 feet). Thus, the calibration data set includes water levels for both model layers. Model calibration is a subjective process resulting

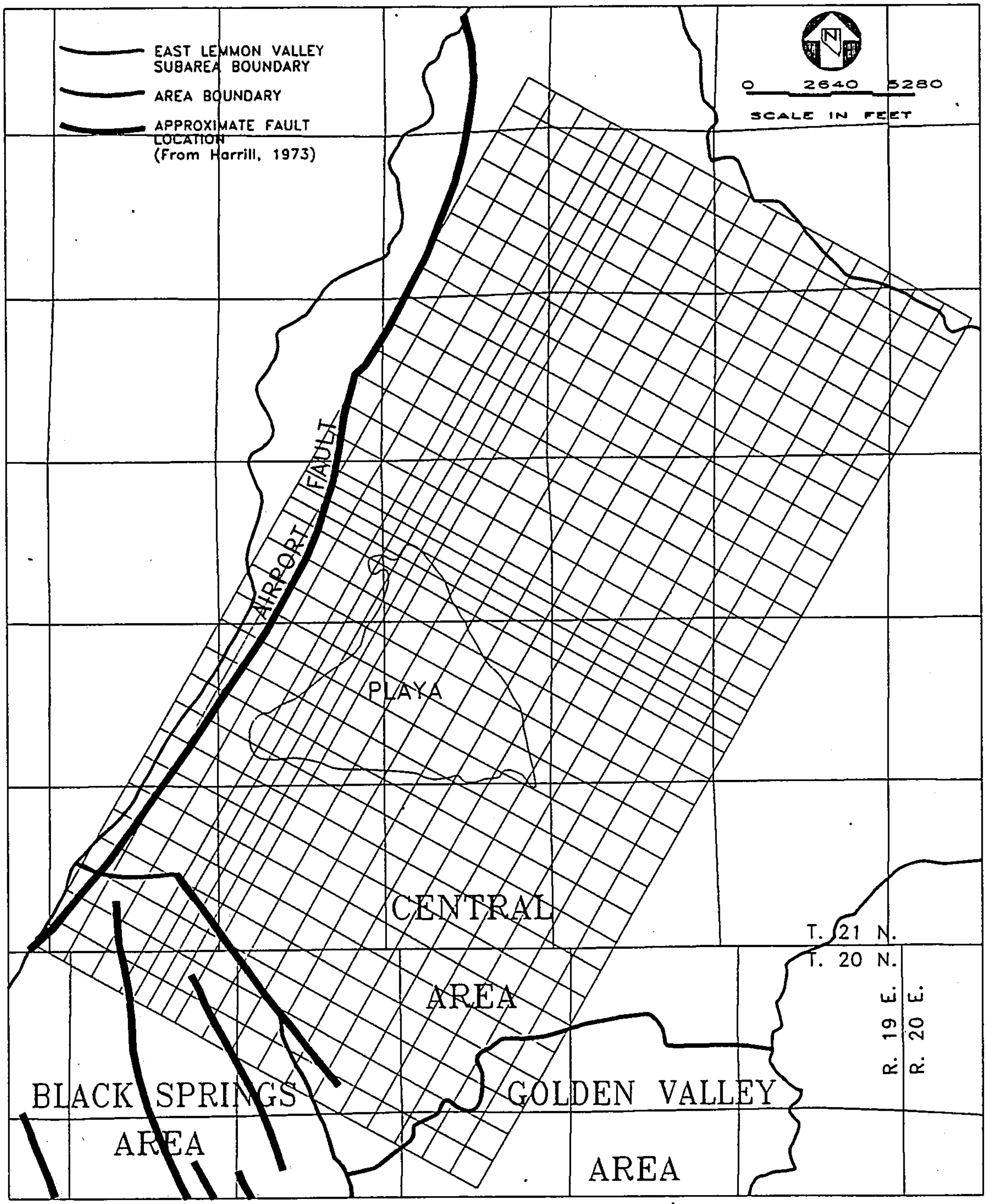

FIGURE 12. Model grid configuration.

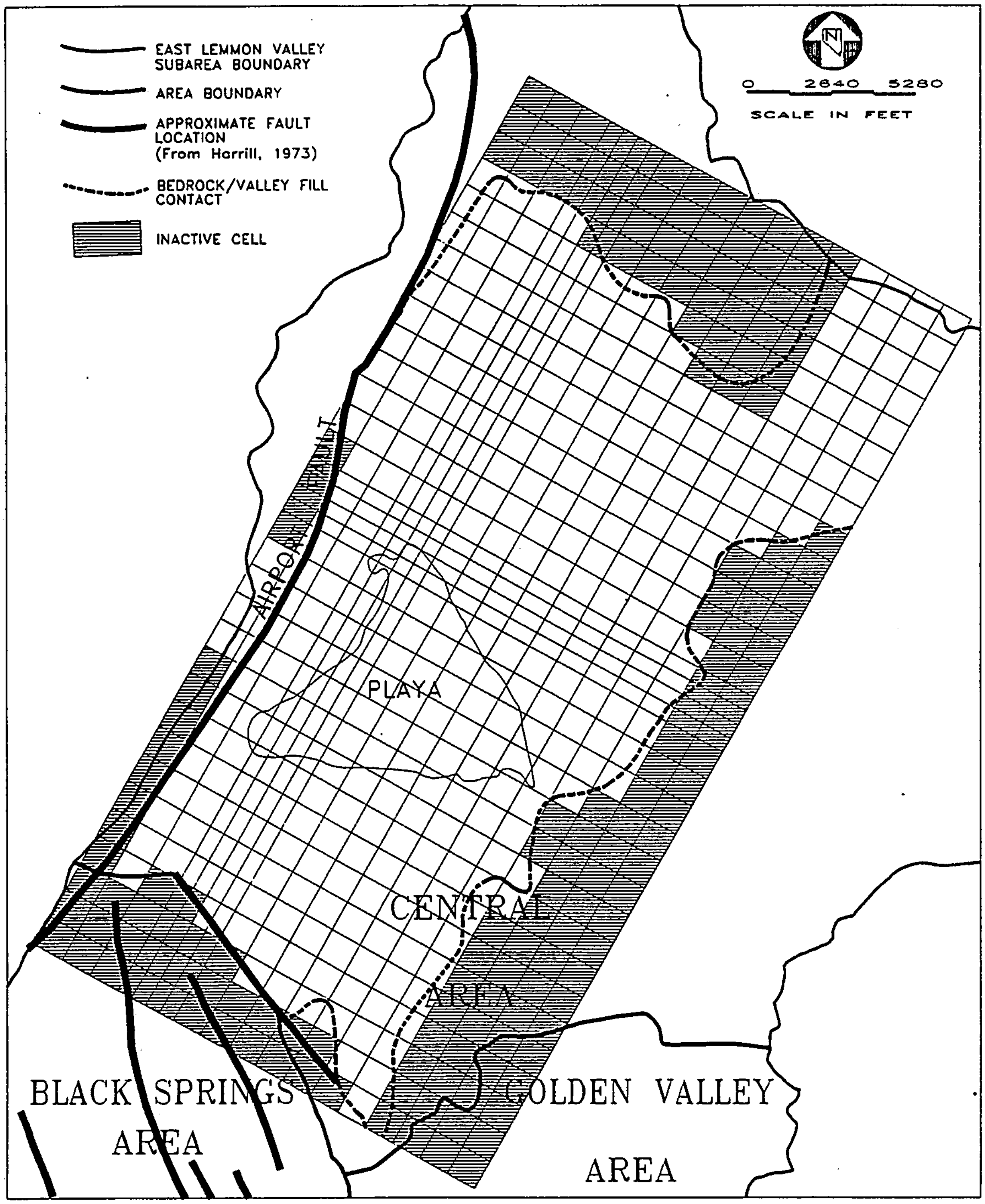

FIGURE 13. Cell types for model layer 1.

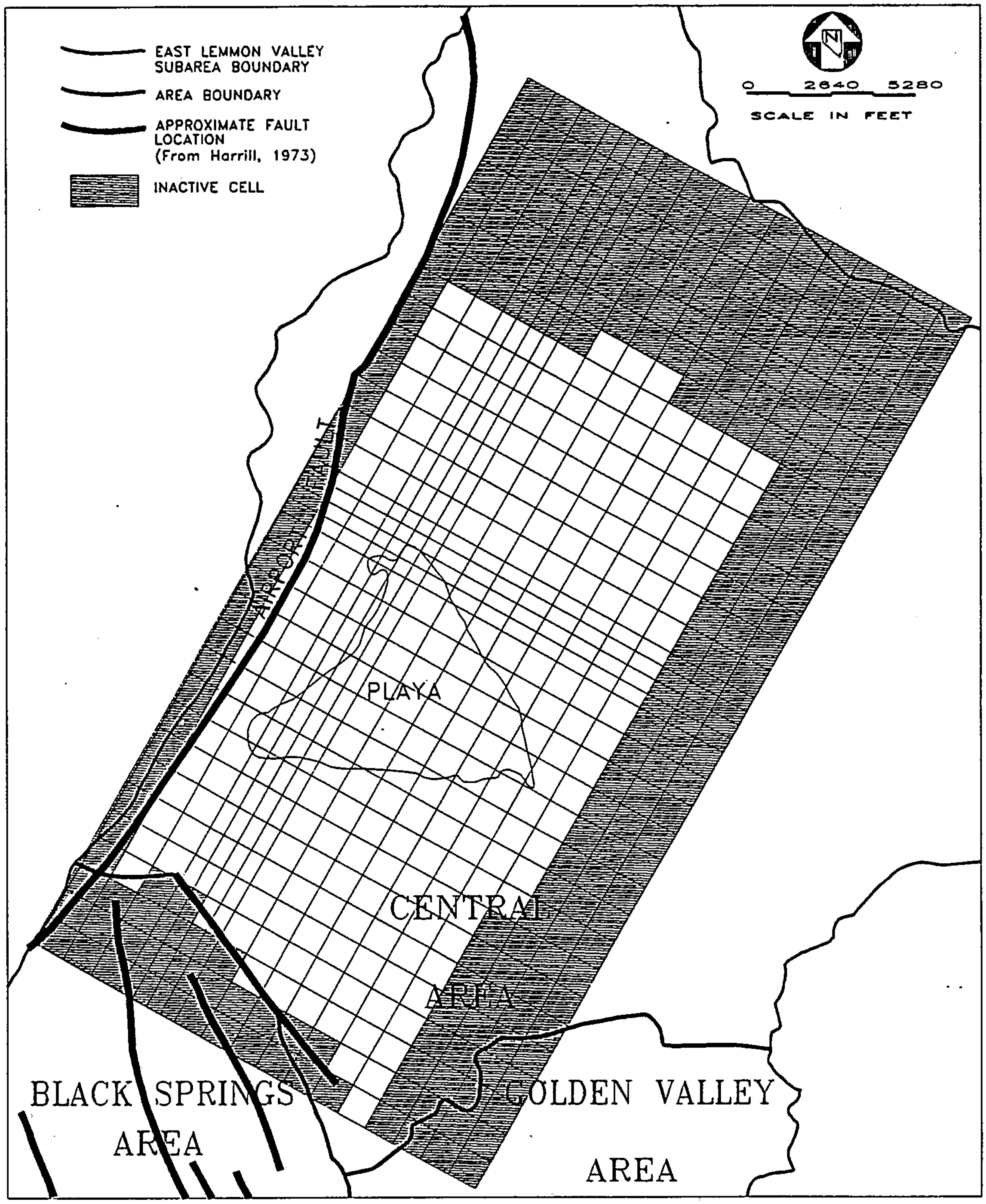

FIGURE 14. Cell types for model layer 2.

in a non-unique solution based on Darcy's equation: $Q = KAI$,

where Q is volumetric flow (L^3/t);

K is hydraulic conductivity (L/t);

A is the area where flow is occurring (L^2); and

I is the groundwater gradient (L/L).

For example, an increase in K with Q held constant produces the same effects on the computed gradient and heads as a decrease in Q with K held constant. Thus, it is possible to calibrate the model by adjusting only K, only Q, or by increasing K and decreasing Q simultaneously (Anderson and Woessner, 1992). Variables of ET can also be adjusted during model calibration. Each variable associated with model calibration for the Central Area is discussed in the following sections.

Boundary Conditions

Boundary conditions as initially conceptualized were maintained throughout the calibration process. Specified flow boundaries were placed along the north, south, and east boundaries at the groundwater recharge locations for the model. Flows representing recharge were input using wells. About 40 wells were distributed around the modeled perimeter at locations where precipitation is believed to enter the groundwater system. A well was also placed in the southeast corner of the model to input subsurface inflow from Golden Valley. Figure 15 shows the boundary conditions of the model area.

During model calibration, a constant head boundary was placed at the west boundary along the potential sink at the Airport Fault. Approximating the west boundary with constant head cells helped determine the volume of water exiting at the fault since MODFLOW computes flow at constant head boundaries and includes the computed value as part of the water budget printout. The boundary was converted to a specified flow boundary after the volume of water exiting at the fault was determined. Specified flow boundaries allow the heads to change at the boundary whereas constant heads boundaries do not allow the head to change. The model was run under steady-state conditions after the boundary was converted to specified flow to assure that the final head distribution was the same as when the constant head boundary was used. A specified flow boundary was selected based on the assumption that artificial recharge will increase groundwater gradients, but not significantly over most of the modeled area, especially at the Airport Fault boundary. Basically, groundwater flow is dependent upon the groundwater gradient. If the groundwater gradient remains relatively constant, flow will also remain relatively constant. Thus, the specified flow boundary at the fault becomes appropriate by using the assumption that gradients will not change significantly. The

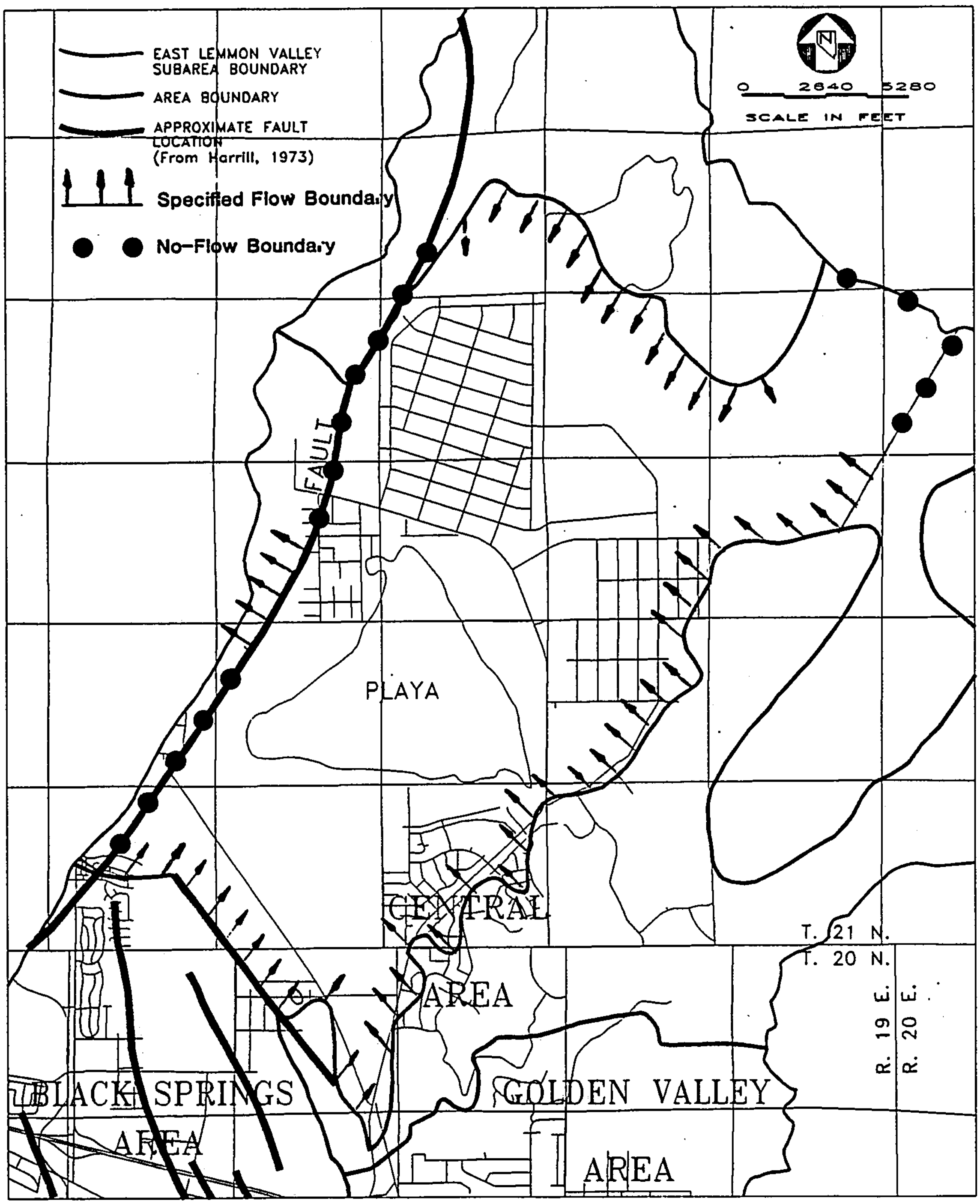

FIGURE 15. Types of boundary conditions for the calibrated model.

following equation can be used to make an estimate of how a change in gradient will effect discharge at the sink:

$Q = TIW$,

where Q is volumetric flow (L^3/t);

T is transmissivity (L^2/t);

I is groundwater gradient (L/L); and

W is width of the flow path (L).

The change in Q resulting from a change in gradient can be approximated by assuming initial and changed values for the gradient and comparing Q values resulting from the different gradient values. For example, the calibrated quasi steady-state model has a gradient of 0.0076 between the injection well and the Airport Fault. If artificial recharge causes the head near the injection well to rise 3 feet, the new gradient between the injection well and the Airport Fault is 0.0081. Having the head change only at the injection well is similar to placing a constant head boundary at the Airport Fault since constant head boundaries maintain the boundary head at a specified level. Comparing the Q value for the quasi steady-state model and the transient model causing a 3-foot rise in head reveals that outflow at the boundary will increase by about 7 percent.

This example describes what may be the maximum increase in outflow at the boundary based on the assumption that head values will increase at the injection well and not at the

Airport Fault, meaning the gradient will have a maximum increase. In reality, head may also rise at the fault which would cause a smaller change in gradient and a smaller increase in outflow at the fault. Placing a specified flow boundary at the Airport Fault represents the minimum increase of flow since head will also rise at the fault and change in gradient will be minimal. The consequences of using one type of boundary versus another should be kept in mind when results of artificial recharge simulations are evaluated.

MODFLOW represents ET as a head-dependent boundary (Anderson and Woessner, 1992). Head-dependent boundaries are used when flow varies with head. ET occurs in the middle of the study area and not at a perimeter boundary. Thus, ET is a sink or interior boundary and not a perimeter boundary in this study.

Natural Recharge From Precipitation

As previously discussed, the quantity and distribution of natural recharge were obtained from a precipitation study of the Truckee River Basin (Klieforth et.al., 1983). It should be noted that precipitation measurements were not collected specifically in the Central Area. Data for the precipitation study were collected at stations near but not in the Central Area. Arteaga (1984) prepared a draft water yield map from precipitation data included in the Klieforth report. Based on water yield, the Central Area receives approximately 500 AFY. This value was used as a preliminary estimate of recharge but was not held constant during calibration. Harrill (1973) determined the water-level contours for quasi steady-state (1971) conditions in East Lemmon Valley. Water-level contours give an indication of where recharge areas are located, based on the assumption that areas with highest water levels are the recharge areas. Both the water yield map of Arteaga and the water-level contours by Harrill provided initial estimates for the distribution of recharge. Distribution of recharge was shifted until the best fit was achieved between field-measured and model-simulated head values. A large portion of recharge was placed at the south end of the model area in order to reproduce the groundwater gradient for quasi steady-state conditions. This distribution agrees favorably with a groundwater model of Lemmon Valley initiated by Mahin (1988). Figure 16 shows the final distribution of recharge.

Recharge From Subsurface Inflow

Groundwater enters the southeast corner of the Central Area along the boundary with Golden Valley (Cochran et.al., 1986). A groundwater model of Golden Valley prepared by Cochran et.al. has approximately 45 AF entering the Central Area from Golden Valley annually. This amount of recharge was not

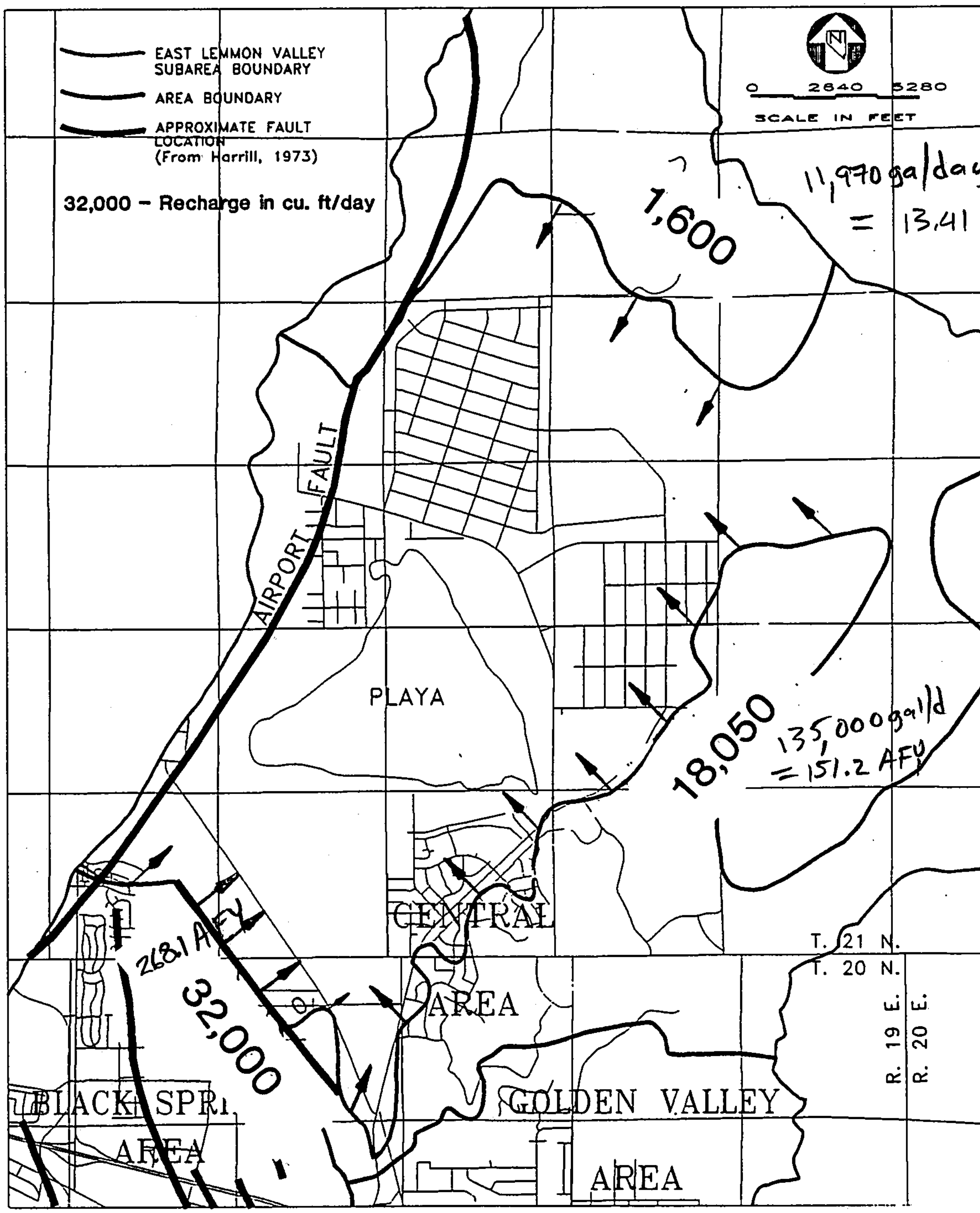

FIGURE 16. Distribution of recharge for the calibrated model.

268.1
151.2
13.4
433 AFY

adjusted during calibration. Incorporating 45 AF into the model of the Central Area helped obtain the final calibrated head distribution.

Secondary Recharge

The amount of secondary recharge was incorporated into the groundwater model by adding recharge at the model boundary where the sewage treatment plant discharges into the Central Area. No attempt was made during this study to input secondary recharge at every potential secondary recharge location (ie., septic tanks) since the majority of secondary recharge appears to come from the sewage treatment plant. The model easily reproduced quasi steady-state conditions by applying recharge at the model boundaries, and not in the interior of the model domain where most secondary recharge sources are potentially located.

Discharge From Evapotranspiration

ET in MODFLOW is represented by a depth-dependent function, meaning ET occurs at a maximum rate when the water level is at ground surface and decreases linearly until the water level reaches a predetermined depth (the extinction depth). According to Harrill, there are two categories of plants in

East Lemmon Valley: 1) greasewood and rabbitbrush; and 2) channel-bottom vegetation consisting of grass and willows. Several other groundwater modeling studies were reviewed to better understand ET rates and extinction depths (Thomas et. al., 1986; Danskin, 1988; and Hadiaris, 1988). Plant types and densities, precipitation patterns, and lithologic materials in these other studies are very similar to those of Lemmon Valley. ET rates range from 0.007 to 0.0003 feet/day in the groundwater studies completed in areas comparable to Lemmon Valley. Thus, an initial ET rate of 0.0020 feet/day was used during calibration. The initial ET rate is similar to rates presented in other studies (Thomas et. al., 1986; Danskin, 1988; and Hadiaris, 1988). The ET rate was adjusted slightly to 0.0028 feet/day during calibration in order to reproduce the water levels of the early 1970s. The rate was not adjusted significantly since the model is relatively insensitive to changes in the ET rate. Model sensitivity was tested during early stages of model calibration and is discussed further in the Model Calibration section of this report.

Extinction depths presented in other modeling studies are area-specific, and may change as the depth-to-water changes during wet or dry periods (Thomas et. al., 1986; Danskin, 1988; and Hadiaris, 1988). Since the water surface was at least 15 feet below ground surface in a majority of the ET zone in the Central Area during the calibration period, an extinction depth of 25 feet, approximately 10 feet below the water table, was initially selected. The extinction depth was decreased to 21 feet during model calibration to obtain the groundwater gradient of the calibration period.

Discharge From Subsurface Outflow

The sink at the Airport Fault was maintained throughout the model calibration process with a constant head boundary. The boundary provided the final quantity of groundwater leaving the Central Area since MODFLOW computes and prints out flow volumes at constant head boundaries. Further discussion of boundaries is included in the Boundary Conditions section of this report. The water budget for the final steady-state model includes approximately 260 AF outflow at the constant head boundary.

Groundwater Pumpage

Groundwater pumpage and ultimate consumption were incorporated into the model implicitly. As previously described, calibrating the model to quasi steady-state conditions eliminated the need to reproduce any changes (ie., effects of pumpage) of water levels through time. It was possible to calibrate the model to within the predetermined tolerance level without defining each possible location of groundwater pumpage.

Horizontal Hydraulic Conductivity

Horizontal hydraulic conductivity (K_h) values are derived from aquifer constant flow tests, specific capacity tests, and lithologic descriptions of well logs. Aquifer tests provide estimates of transmissivity (T) that can be converted to K_h using the equation $K_h = T/b$, where b is the length of the screened interval of the well. Time-drawdown data from approximately 10 constant discharge aquifer tests were evaluated to obtain K_h values using this method. The drawdown data was collected from pumping wells and monitoring wells during aquifer tests.

Specific capacity and T can be estimated from the following empirical equation. The equation originates from a modified form of the Jacob equation (Driscoll, 1986):

$$\frac{Q}{s}=\frac{T}{264\log\frac{0.3Tt}{r^2S}}$$

where Q is water yield in gallons per minute;

s is drawdown in feet;

T is transmissivity in gallons per day per foot;

t is pumping duration in days;

r is the well radius in feet;

S is the storage coefficient of the aquifer; and

Q/s is specific capacity.

The modified Jacob equation is valid when t is sufficiently large (Driscoll, 1986) and flow into and out of the well is at steady state (Heath, 1983). Driscoll states that if typical values of the variables in the log function are assumed such as t= 1 day, r= .5 feet, T = 30,000 gpd/ft, and S= 0.001, then specific capacity or T can be calculated using the equation T= 300(Q/s), where 300 converts gallons per minute per foot of drawdown to square feet per day (Driscoll, 1986). Presumably, Driscoll's typical value of t equal to 1 day is sufficiently large enough so the modified Jacob equation is valid. Also, changing the value for well radius from 0.5 feet to 0.33 feet (typical of domestic and monitoring wells) has minimal effect on the specific capacity value. K_h can then be found from the equation K_h= T/b as previously described. Specific capacity tests are typically completed on domestic wells. Over 200 drilling logs for wells located in the Central Area were reviewed to obtain specific capacity results. Review of the specific capacity data revealed that the duration of specific capacity tests ranged from 1 hour to 48 hours. K values were estimated from more than 30 24-hour specific capacity tests.

Lithologic descriptions summarized in drilling logs can be interpreted to estimate K_h values if aquifer or specific capacity tests are not available. The following equations give approximations of K_h values from drilling log interpretation (from Maurer, 1986):

$K_h = (K_c)(\%\ \text{coarse}) + (K_f)(\%\ \text{fine})$,

where K_c is a typical value of hydraulic conductivity for coarse-grained material;

K_f is a typical value of hydraulic conductivity for fine-grained material;

%coarse is the percentage of coarse-grained material in the screened interval;

%fine is the percentage of fine-grained material in the screened interval.

The percentage of fine- and coarse-grained material described in each drilling well log must be estimated in order to approximate K_h. K_h values were computed from approximately 40 drilling logs using this method. Some of the computations helped verify K values estimated from aquifer and specific capacity test data.

Based on the 3 procedures described above, estimates of K_h in Central Area range from 0.0005 ft/d for fine sediments to 35 ft/d for coarse sediments and fractured bedrock. The estimated K values were input into the model at the cell representing the drilling log location. K values for remaining cells were derived with a contouring program which uses kriging to interpolate between irregularly spaced input data and create regularly spaced data points. Kriging is based on the regional variable theory and the algorithm assumes an underlying linear variogram (Golden Software, Inc., 1990). All estimated K values were used initially and adjusted during model calibration. Most adjustment was needed for K_h values in the playa lake area. The final distribution of K_h values for model layer 1 is shown in Figure 17. Appendix A of this report includes the final K_h values for each model cell. Transmissivity (T) values, defined as K_h times aquifer thickness (b), were used to define the flow in layer 2. Discussion of T values is included in the Transmissivity subsection of the Model Calibration Section of this report.

Vertical Hydraulic Conductivity/Conductance

Lithologic descriptions summarized in well logs can be interpreted to estimate vertical hydraulic conductivity (K_v) values. The following equation can be used to compute

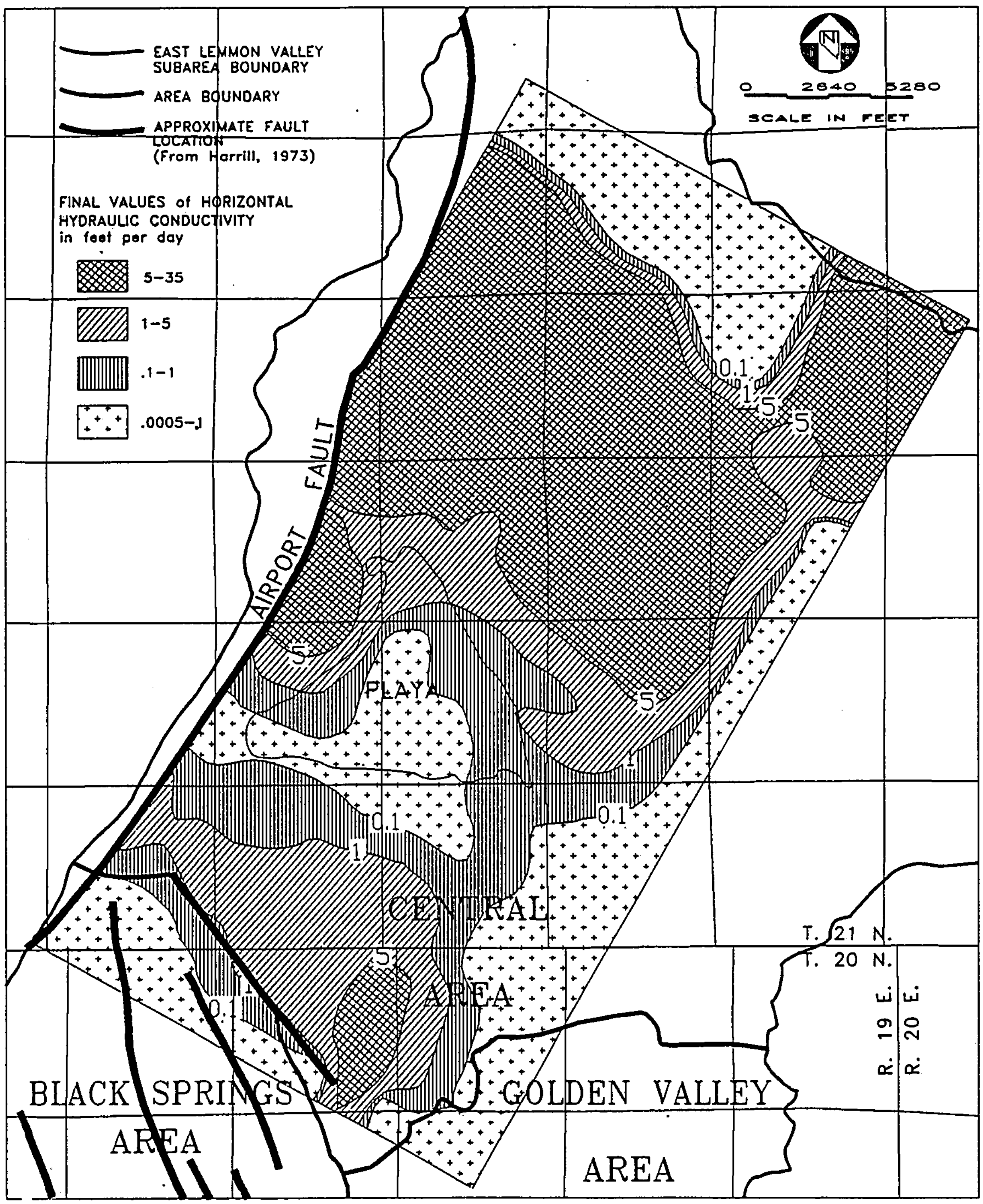

FIGURE 17. Distribution of horizontal hydraulic conductivity values for model layer 1.

approximations for K_v values from interpretation of drilling logs (from Maurer, 1986):

$K_v = 1/(\%\ coarse/K_c + \%\ fine/K_f)$,

where K_c is a typical value of hydraulic conductivity for coarse-grained material;

K_f is a typical value of hydraulic conductivity for fine-grained material;

% coarse is the percentage of coarse-grained material in the screened interval;

% fine is the percentage of fine-grained material in the screened interval.

The percentage of fine- and coarse-grained material described in each drilling log must be estimated in order to approximate K_v. K_v values were computed from approximately 40 drilling logs using this method. Based on the equation described above, estimates of K_v in Central Area range from approximately 0.000001 ft/d for fine material to 1.0 ft/d for coarse material.

K_v values are not input directly into the MODFLOW program. The modeler must compute a vertical leakance term (V_{cont}) that represents the vertical flow between model layers. V_{cont} incorporates vertical hydraulic conductivity and thickness of each aquifer layer. V_{cont} values are estimated by summing the following two values: 1) the multiple of K_v for layer 1 times one-half the thickness of layer 1, and 2) the multiple of K_v for layer 2 times one-half the thickness of layer 2. The MODFLOW program then multiplies V_{cont} by cell area to derive the conductance term representing vertical flow between two model cells. Adjustments were made to the initial V_{cont} values in the playa lake area. V_{cont} values were decreased from initial estimates in order to reproduce the field-measured head values. Smaller values of V_{cont} are indicative of an abundance of fine-grained material, which is present in the playa lake area. Decreasing V_{cont} values reduces the amount of flow between model layers 1 and 2. Final V_{cont} values range from approximately 0.004 to 0.0000001. Figure 18 shows the final distribution of leakance after model calibration. Appendix A of this report contains the final V_{cont} values for each model cell.

Transmissivity

Transmissivity values represent the aquifer flow parameter for layer 2 since the layer is confined and flow is horizontal. MODFLOW calculates T values internally from input data of K_h, the top elevation of model layer 2, and the bottom elevation of layer 2. T values generated by MODFLOW were compared to approximately 40 T values from aquifer test and specific capacity data. Most MODFLOW-generated T values were in close agreement with T values estimated from aquifer

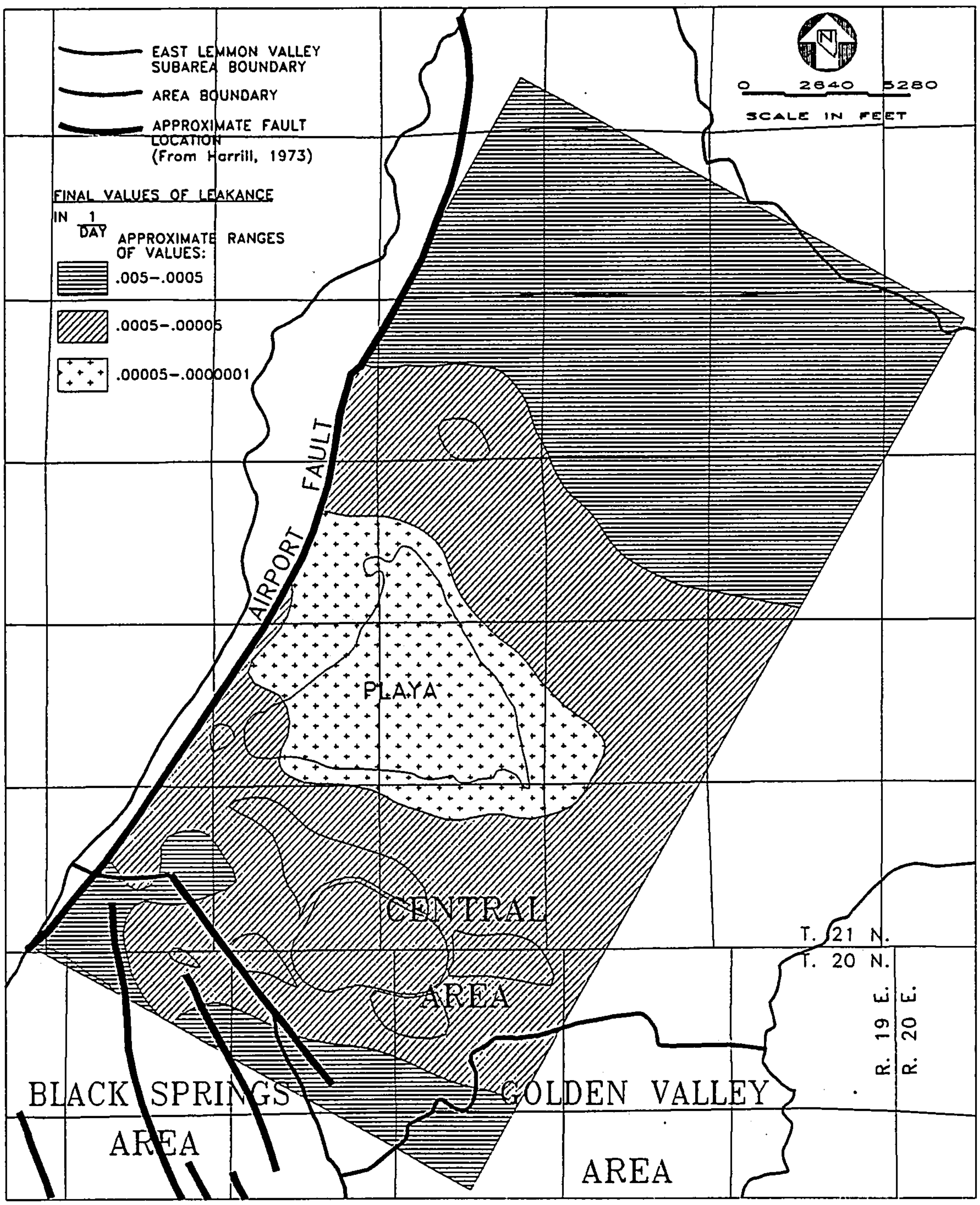

FIGURE 18. Distribution of Leakance Values between model layers 1 and 2.

test and specific capacity data. As with the K values, T values needed minor adjustments in order to reproduce field-measured heads values. The final distribution of T values ranged from about 0 to 6,000 ft^2/d and is shown in Figure 19. Appendix A includes the final T values for each model cell.

CALIBRATION RESULTS

Comparison of Field and Calibrated Heads

Water levels from 20 wells were used to calibrate the model to quasi steady-state conditions. Seventeen of the 20 wells, or 85 percent, were calibrated to within 5 feet of field measurements. It should be noted that surface elevations were selected from topographic contour maps for some of the calibration wells. Accuracy of these elevations may be at best within 5 feet of actual elevations for some locations. Other potential sources for inaccuracy in field measurements can be from reading the water measuring device improperly or recording the measured value of the water level incorrectly. Based on these possible uncertainties, calibrating the majority of heads to within 5 feet is appropriate. Since the groundwater surface in a large portion of the Central Area is relatively flat, wells should be surveyed more accurately to determine the exact groundwater gradient. All 20 wells were calibrated to within 10 feet of field measurements.

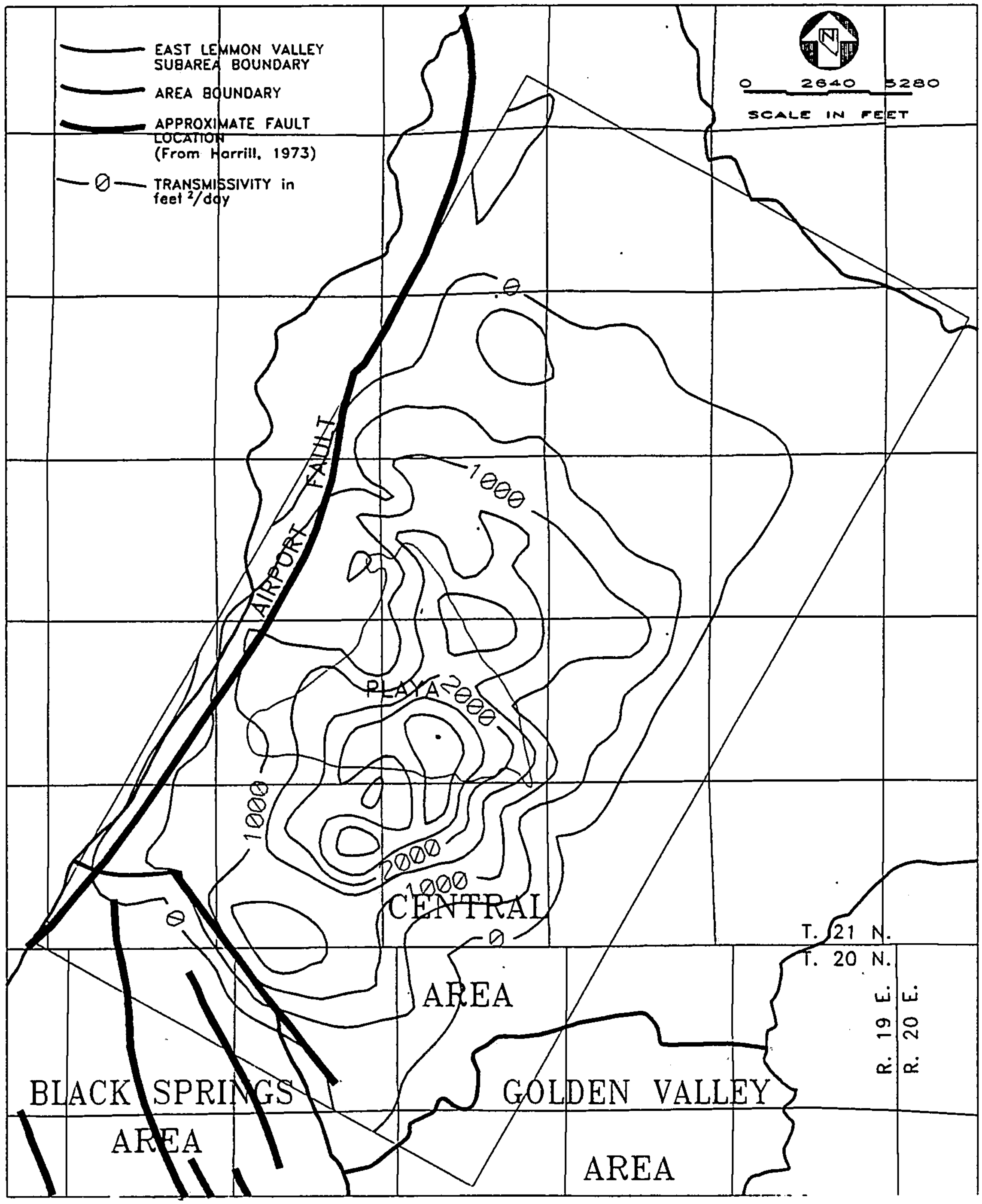

FIGURE 19. Distribution of transmissivity values for model layer 2.

Calibration results were evaluated statistically by calculating mean error (ME), mean absolute error (MAE), and root mean squared (RMS) error or standard deviation. The equations for these analyses are:

$$1)\ ME=\frac{1}{n}\sum_{i=1}^{n}(h_m-h_s)_i$$

$$2)\ MAE=\frac{1}{n}\sum_{i=1}^{n}|(h_m-h_s)_i|$$

$$3)\ RMS=[\frac{1}{n}\sum_{i=1}^{n}(h_m-h_s)_i^2]^{.5}$$

where hm is measured head and hs is simulated head.

ME is the mean difference between hm and hs. The ME is simple to calculate but is usually not a wise choice because both negative and positive differences are incorporated in the mean and may cancel out the error (Anderson and Woessner, 1992). For example, if one simulated head is 10 feet higher than the measured head and another simulated head is 10 feet lower than the measured head, the error between the simulated heads is zero. Hence, a small ME may not indicate a good calibration (Anderson and Woessner, 1992). MAE is the mean of the absolute value of the differences in measured and simulated heads. MAE is similar to ME except a numerically positive error value is obtained (Anderson and Woessner, 1992). RMS error is thought to be the best measure of error if the errors are normally distributed (Anderson and Woessner, 1992). RMS error is the average of the squared differences in measured and simulated heads (Anderson and Woessner, 1992).

Statistical results for calibration of this study are: ME= 1.29 feet; MAE= 3.67 feet; and RMS error = 4.70 feet. Figures 20 and 21 show the comparisons between field heads and calibrated heads for each model layer. Contour maps of the final calibration heads are represented in Figures 22 and 23 for layers 1 and 2, respectively.

Sensitivity Analysis

A sensitivity analysis identifies which input variables have the most influence on model results. Once identified, additional data can be collected for the variable(s) that influence results appreciably. The additional data can be incorporated into the model to improve accuracy.

Variables adjusted to determine sensitivity include horizontal and vertical hydraulic conductivity, recharge, and the ET rate. Each variable was doubled and halved while all other variables were held constant. Final determination of sensitivity was done by calculating the RMS error between computed and field measured heads for each sensitivity run

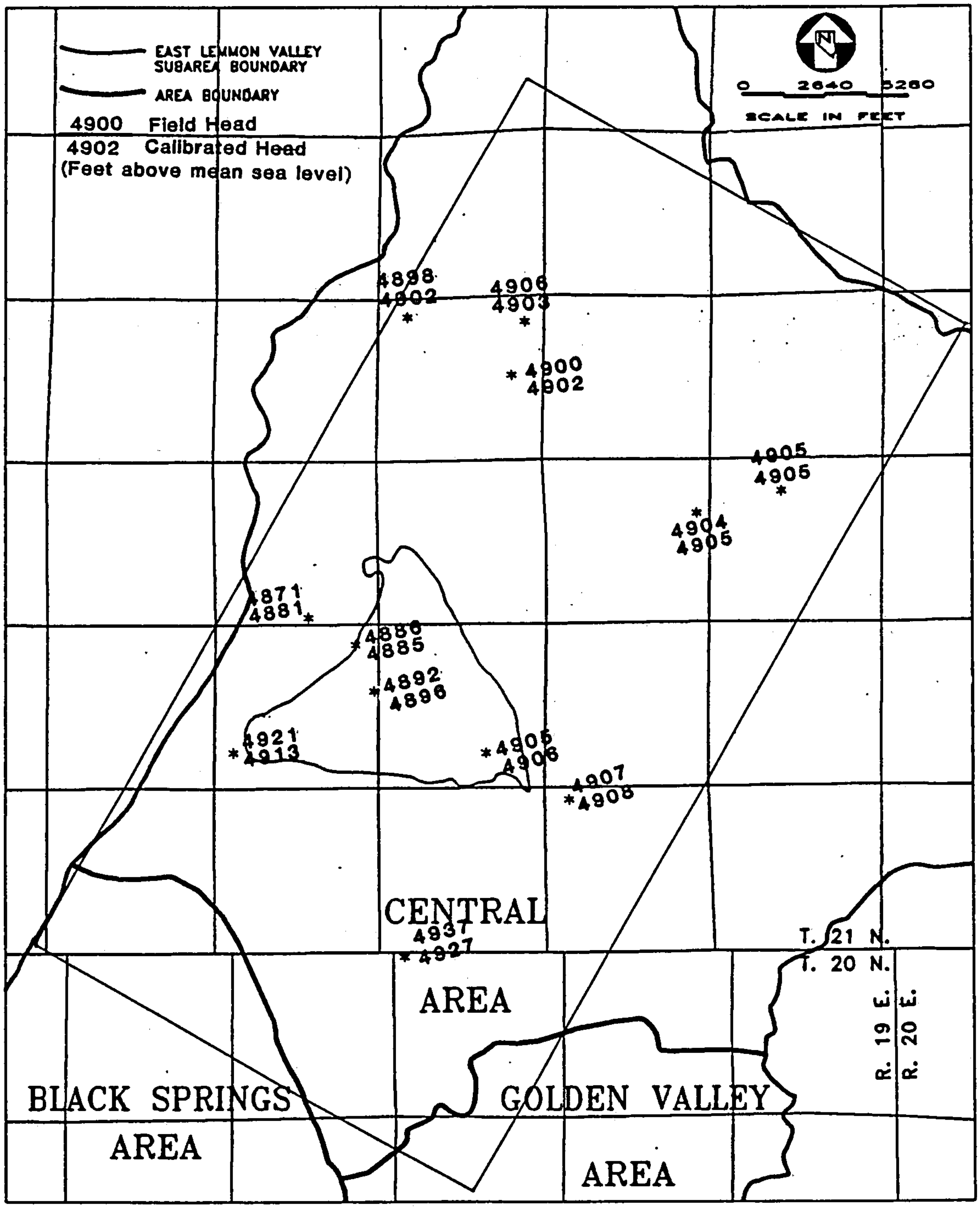

FIGURE 20. Comparison of field versus calibrated heads for model layer 1.

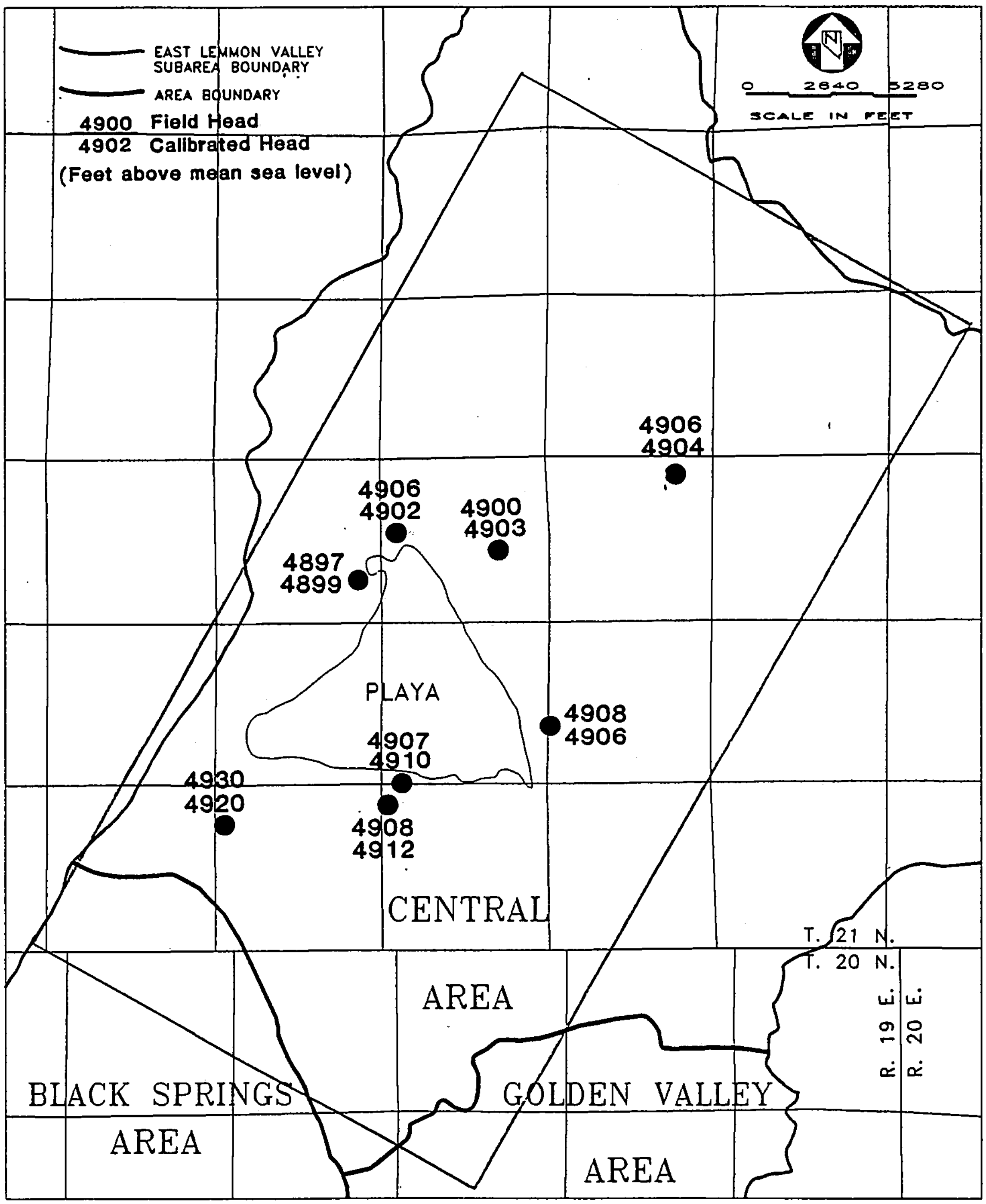

FIGURE 21. Comparison of field versus calibrated heads for model layer 2.

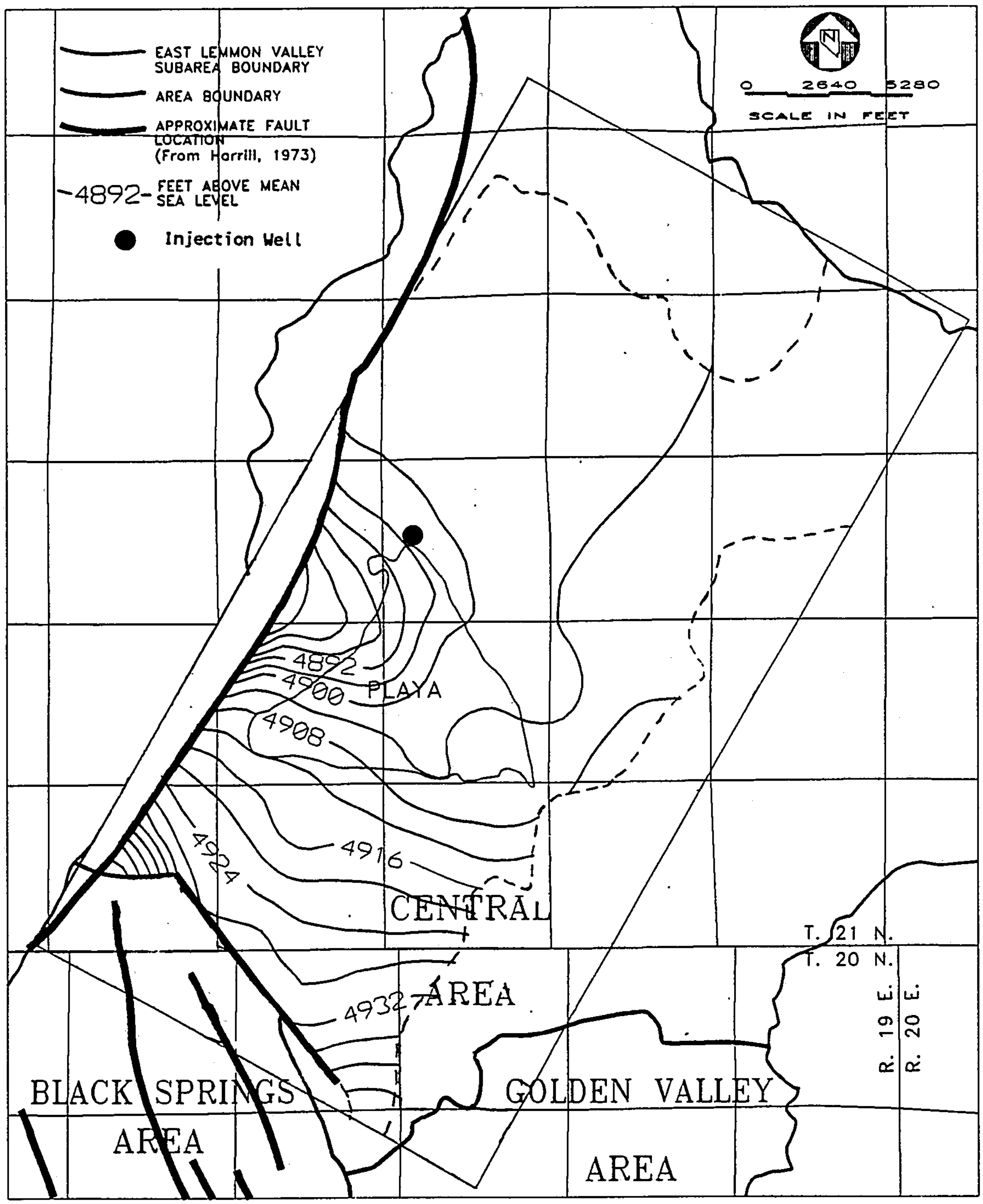

FIGURE 22. Contour map of calibrated water levels for model layer 1.

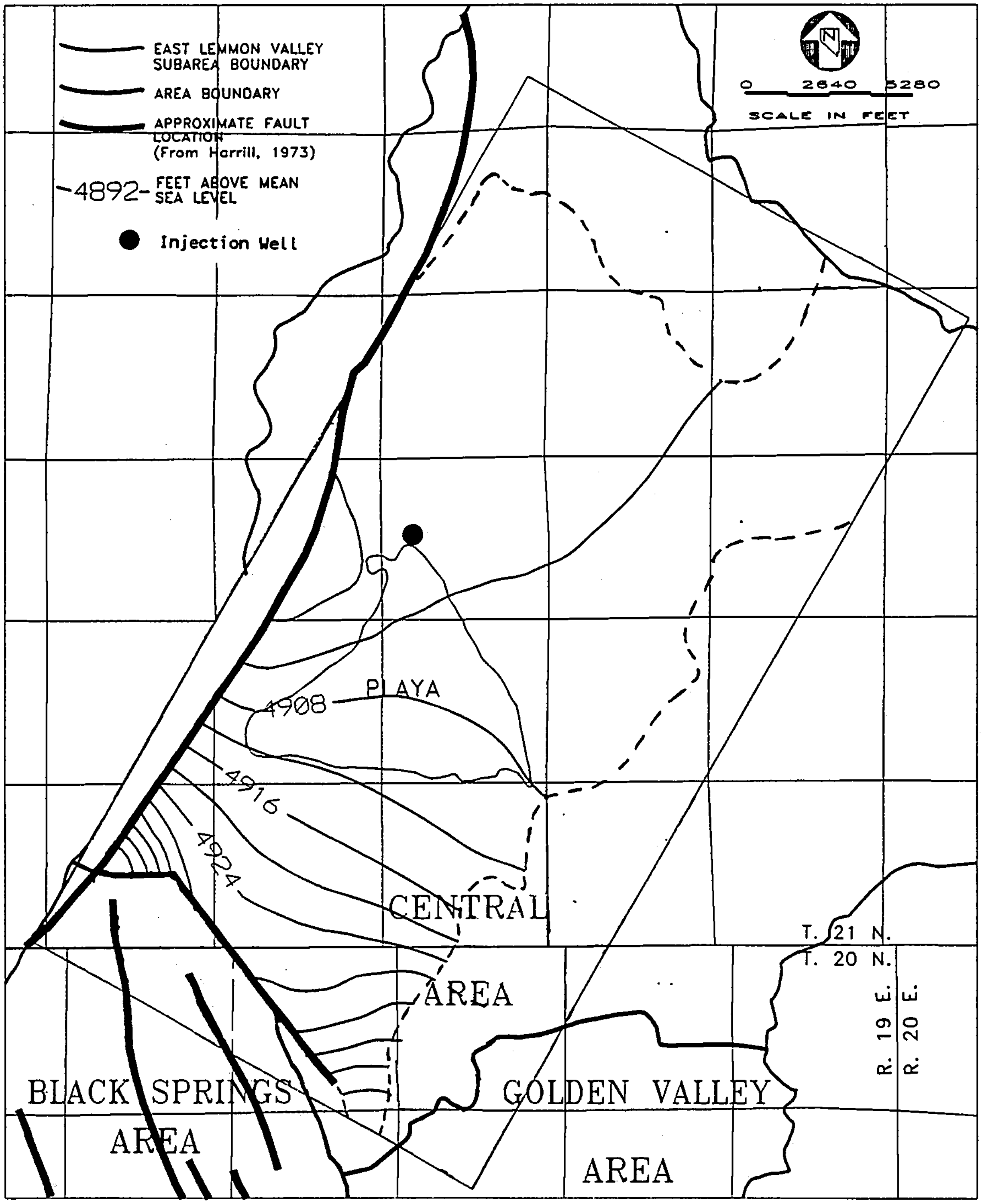

FIGURE 23. Contour map of calibrated water levels for model layer 2.

(Anderson and Woessner, 1992). Results of the sensitivity analysis are summarized in Table 3.

TABLE 3. Results of the sensitivity analysis for the calibrated groundwater model of the Central Area.

Simulation	Root Mean Squared Error Results	Maximum Head Value Above Calibrated (feet)	Maximum Head Value Below Calibrated (feet)
Calibration	4.70	10	10
2 x K_h	8.54	6	23
0.5 x K_h	5.02	13	3
2 x K_v	8.89	11	13
0.5 x K_v	4.63	8	8
2 x Recharge	6.69	12	0
0.5 x Recharge	10.74	7	27
2 x ET rate	5.31	9	12
0.5 x ET rate	5.12	11	7

K_h = calibrated horizontal hydraulic conductivity
K_v = calibrated vertical hydraulic conductivity
ET = evapotranspiration

By interpreting the RMS error results, the sensitivity analysis indicates that the model is most sensitive to a decrease in recharge, increase in K_v, increase in K_h, and an increase in recharge. Decreasing K_v gave slight improvements to the RMS error value when compared to the calibrated value. RMS error shows that additional information on recharge, K_h, and K_v could improve the model reliability.

Final Quasi Steady-State Water Budget

A summary of the final water budget for the quasi steady-state model of the Central Area is as follows:

INFLOW -

1) Primary and Secondary Recharge, and Subsurface Inflow- 51,650 $feet^3$ or 433 AFY

OUTFLOW -

1) Subsurface Outflow and Pumpage (amount consumed)- 31,135 $feet^3$ or 261 AFY
2) Evapotranspiration 20,608 $feet^3$ or 173 AFY

MODFLOW calculates the percent error difference between total inflow and total outflow of the water budget. Ideally, the percent error between inflow and outflow should be less than 1 percent for a model calibrated to steady-state conditions (Anderson and Woessner, 1992). Error in the water budget for this study was minimal at 0.18 percent.

The overall budget agrees reasonably well with the initial estimates from Harrill (1973), Arteaga (1984), and Cochran et.al. (1986). The calibrated water budget is approximately 60 percent of the initial estimated water budget. The biggest difference between the calibrated and initial water budget is in ET. The difference in ET between the calibrated model and Harrill's estimate may be due to the uncertainty in extinction depths and rates. Water loss to ET is becoming an important issue in many groundwater studies of the western United States. Additional research is needed to better understand the ET process in order to increase the accuracy of estimated water budgets that include ET.

MODEL VERIFICATION

Calibrating the model to quasi steady-state conditions prevents calibration of the aquifer storage parameters. Also, it is not known if the model will accurately simulate transient conditions when additional stresses (pumping) are incorporated into the quasi steady-state model. Model verification helps establish greater confidence in the calibrated model (Anderson and Woessner, 1992). A verification test is performed using the calibrated model to simulate and reproduce an existing data set representative of transient conditions. The procedure to complete an ideal verification test for this study would include: 1) using the final heads from the calibrated model as the initial conditions for the verification test; 2) input all stresses acting on the groundwater system from the end of the calibration period (early to mid-1970s) to the present (1993); 3) add estimates for aquifer storage, specifically S and S_y, to the model; and 4) run the model through time starting with the initial conditions, additional stresses, and storage parameters, and attempt to reproduce a data set for current (1993) water levels for the entire model domain. Presumably, additional or increased stresses on the groundwater system of the Central Area (since the quasi steady-state time period) are: 1) increased groundwater pumpage; 2) increased recharge from septic tank effluent, and 3) increased recharge from sewage treatment plant effluent. If the model does not reproduce the known transient data, model calibration would need to be repeated until the modeled results within the predetermined range of error tolerance.

Local Transient Test

A local transient test was completed instead of model verification for this study. The primary goal of this study is to estimate how much injection water will enter aquifer storage. Since water levels are currently declining in most parts of the Central Area, it can be implied that groundwater pumpage and consumption are exceeding groundwater recharge. However, it is possible to simulate artificial recharge without incorporating additional pumpage of groundwater into the model. For example, modeling artificial recharge without additional pumpage or groundwater consumption will reveal the maximum relative changes in water levels and associated water storage. Simulations of artificial recharge without current (real time) pumpage will give an indication of the minimum quantity of water that must be injected to get the modeled water levels. Conversely, there possibly will be less water entering storage under current conditions because some injection water will be pumped out of the system shortly after it is injected. Thus, model simulations were run without current pumpage to estimate the maximum relative changes in water levels resulting from artificial recharge. A local transient test was performed to test the reliability of the model. The local transient test was completed using data from the 72-hour constant discharge aquifer test on the existing injection well and monitoring wells in 1991. The calibrated quasi steady-state model was set up to simulate pumping from the injection well at the same rate as the actual aquifer test, 420 gallon per minute or 80,850 ft^3/day. A storage coefficient of 0.003 was used for model layer 2. The storage coefficient was derived during the aquifer test completed in 1991 and is a typical value for a confined aquifer comprised of sand and clay (Freeze and Cherry, 1979). A specific yield value of 0.1 was used for model layer 1, a typical value for an unconfined aquifer also comprised of sand and clay (Freeze and Cherry, 1979).

After completion of the transient test simulation, water levels for the 8 monitoring wells were evaluated by calculating the RMS error between actual and simulated heads at the cells representing the 8 monitoring wells. RMS error gives an indication of how well the quasi steady-state model reproduces transient data. RMS error was relatively low at 1.90 feet. Overall, modeled drawdowns were less than actual values. This is probably because MODFLOW represents pumping wells as fully-penetrating and the modeled stress is dispersed throughout an entire model cell. Thus, stresses applied to a fully penetrating well (ie., an entire grid cell) will produce less severe gradients, especially in the cell and model layer being stressed. The local transient test provides reasonable confidence in the transient model for the area where the injection and monitoring wells are located.

Another check of the model was completed by changing the boundary type at the Airport Fault sink from constant head to constant flow. Simulated heads near the injection well were the same no matter which boundary type was used.

TRANSIENT ARTIFICIAL RECHARGE SIMULATIONS

Final head values from the quasi steady-state model are the initial conditions for transient simulations of the effects of artificial recharge. Transient models require additional input data to simulate the effects of artificial recharge and subsequent storage within the aquifer. Components of storage are specific yield values for the upper unconfined layer and storage coefficients for the lower layer. The storage coefficient and specific yield values used in the transient test (S= 0.003 and S_y= 0.1) were maintained for all artificial recharge simulations.

Recharge from precipitation was added to the system uniformly through time during each transient simulation, as it was during calibration. In actuality, artificial recharge could take place during periods of little or no precipitation (ie., summer time). If the time of year when artificial recharge will actually occur is determined, natural recharge could be input into the model accordingly, resulting in simulations more representative of actual conditions. For example, artificial recharge could take place during summer months when natural recharge is low. Model simulations could be set up so that all natural recharge is input during winter months and no input of natural recharge during summer months. Currently, the time of year when artificial recharge will actually take place has not been determined. Also, water will be injected into the lower layer of the model for all simulations. This represents actual field conditions because the existing injection well and Washoe County municipal wells are screened in the lower layer.

Finite difference models do not accurately simulate the relatively large gradient near a well source or sink unless the model grid is the same diameter as the well since the stress is distributed throughout the grid cell (Anderson and

Woessner, 1992). Anderson and Woessner state that head values in model cells adjacent to the point source or sink cells are representative of actual head values. Consequently, one should look at head values at model blocks or cells adjacent to recharge or discharge blocks when determining overall changes in head. Head values for post-recharge (idle) periods can also be evaluated to determine the effects of recharge without well influences.

Each of the following recharge simulations includes 6 months of injection followed by 6 months of idle (no recharge) time each year. Total duration of each simulation is 5 years. Extraction of groundwater was not simulated during any of the artificial recharge simulations. Figures used to summarize each simulation show water levels immediately after the final 6-month injection period, and are identified as the 4.5-year time period. Figures representing water levels after the final idle period are identified as the 5-year time period.

Simulation A

One possible artificial recharge scenario is using one well to inject 100 AF of water annually over a 5-year period (500 AF total), at 6-month intervals each year. This scenario was input into the model with the injection well located at the existing artificial recharge site north of the playa lake.

The water level in the model cells near the injection well rose approximately 14 feet above the quasi steady-state value during each 6-month injection period.

Figure 24 shows the mounding effect around the injection well in layer 2 immediately after the final injection period, the 4.5-year time period. Smaller increases of head occurred in the upper layer (Figure 25). Head in layer 1 increased approximately 4 feet above the quasi steady-state value during each 6-month injection cycle. However, more storage occurs in the upper layer based on the definitions of specific yield and storage coefficient. The lateral extent of changes in water levels was similar for both layers.

Net changes in head were calculated by subtracting quasi steady-state head values from the values of the final idle period, the 5-year time period. Figures 26 and 27 show the net change of head for layers 2 and 1 after 5 years of intermittent recharge, respectively. Heads in both layers 1 and 2 rose about 2 feet near the injection well. Lateral spreading was similar for both layers but head increases were larger in layer 2. Increases in water levels occurred at all portions of the model domain. Water-level increases at perimeter locations are most likely caused by the build-up of natural recharge water at the boundary. Since the amount of outflow is relatively constant, injection water probably contributes to the total volume of water being discharged

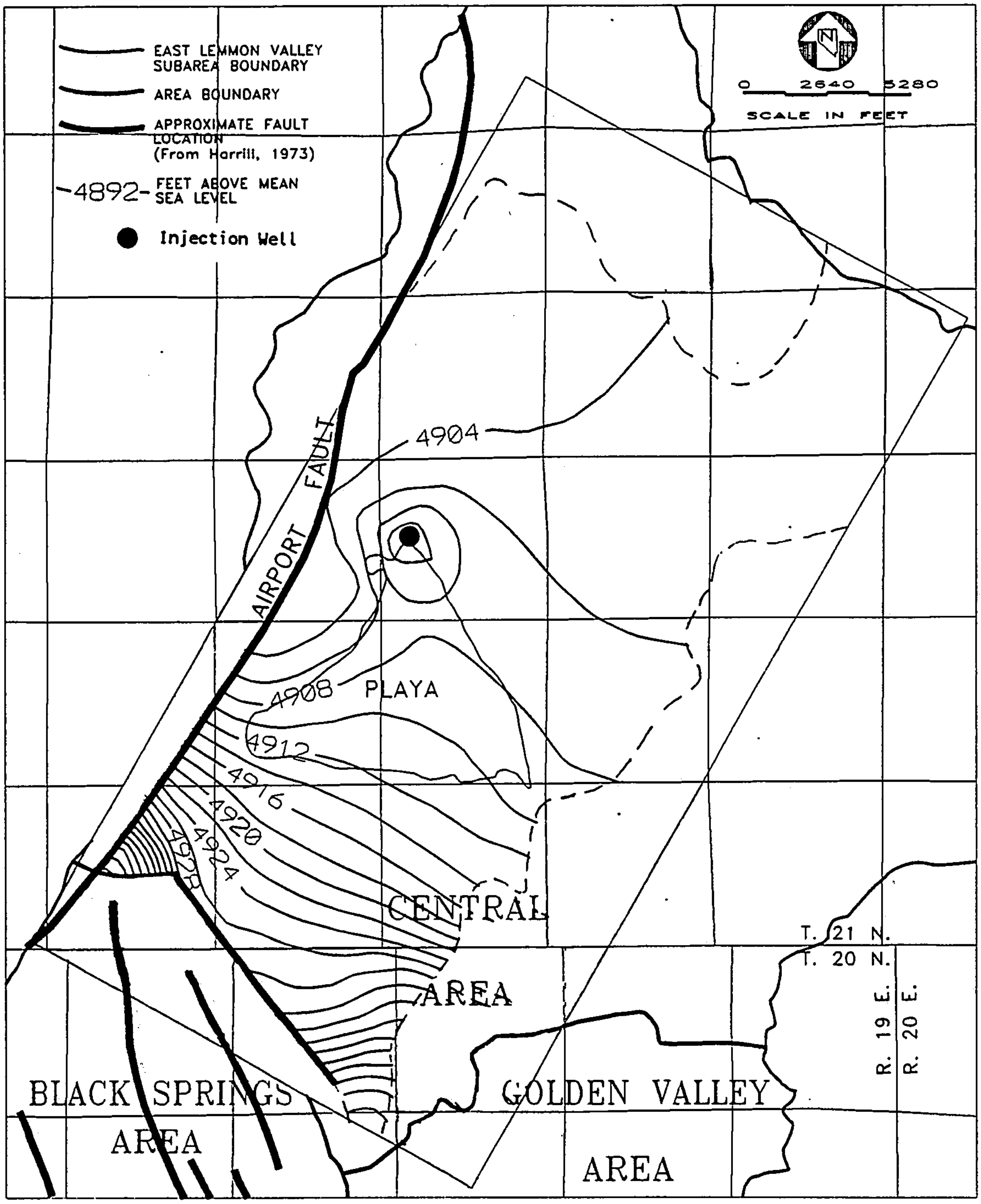

FIGURE 24. Contour map of water levels for model layer 2 at the 4.5-year period: After injecting 500 acre-feet with one well.

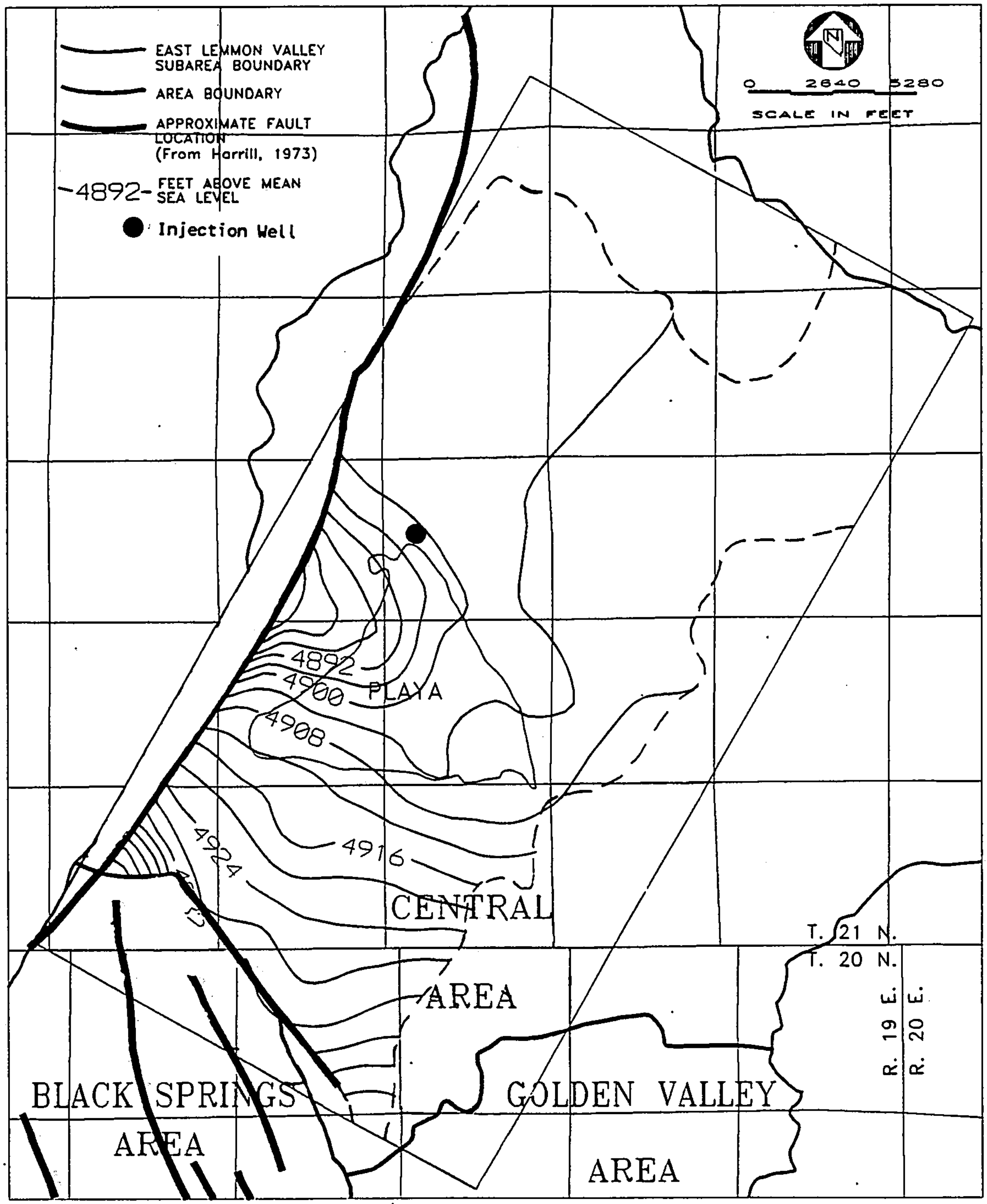

FIGURE 25. Contour map of water levels for model layer 1 at the 4.5-year period: After injecting 500 acre-feet with one well.

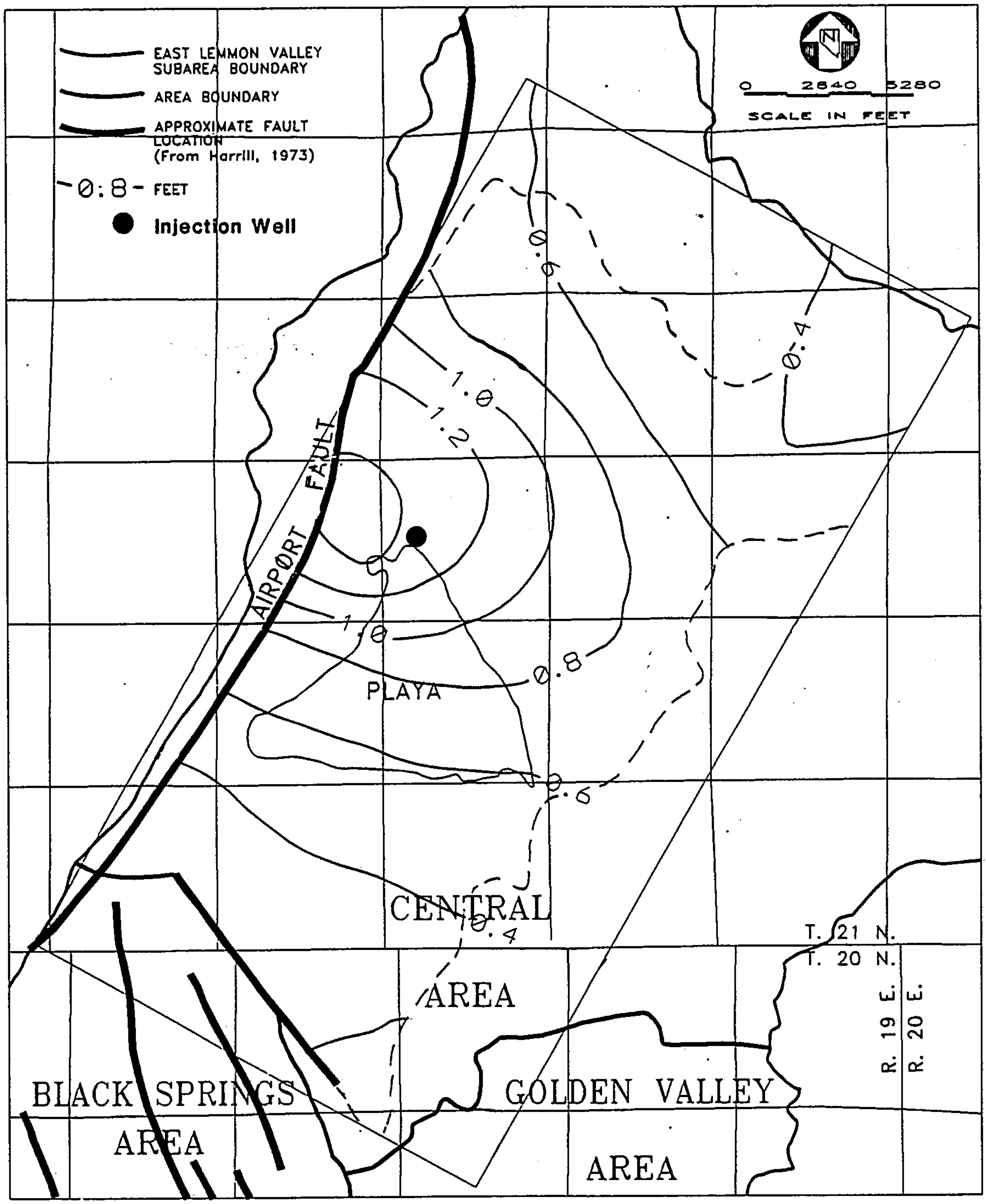

FIGURE 26. Net change in water levels from steady-state conditions for model layer 2 at the 5-year period: After injecting 500 acre-feet with one well.

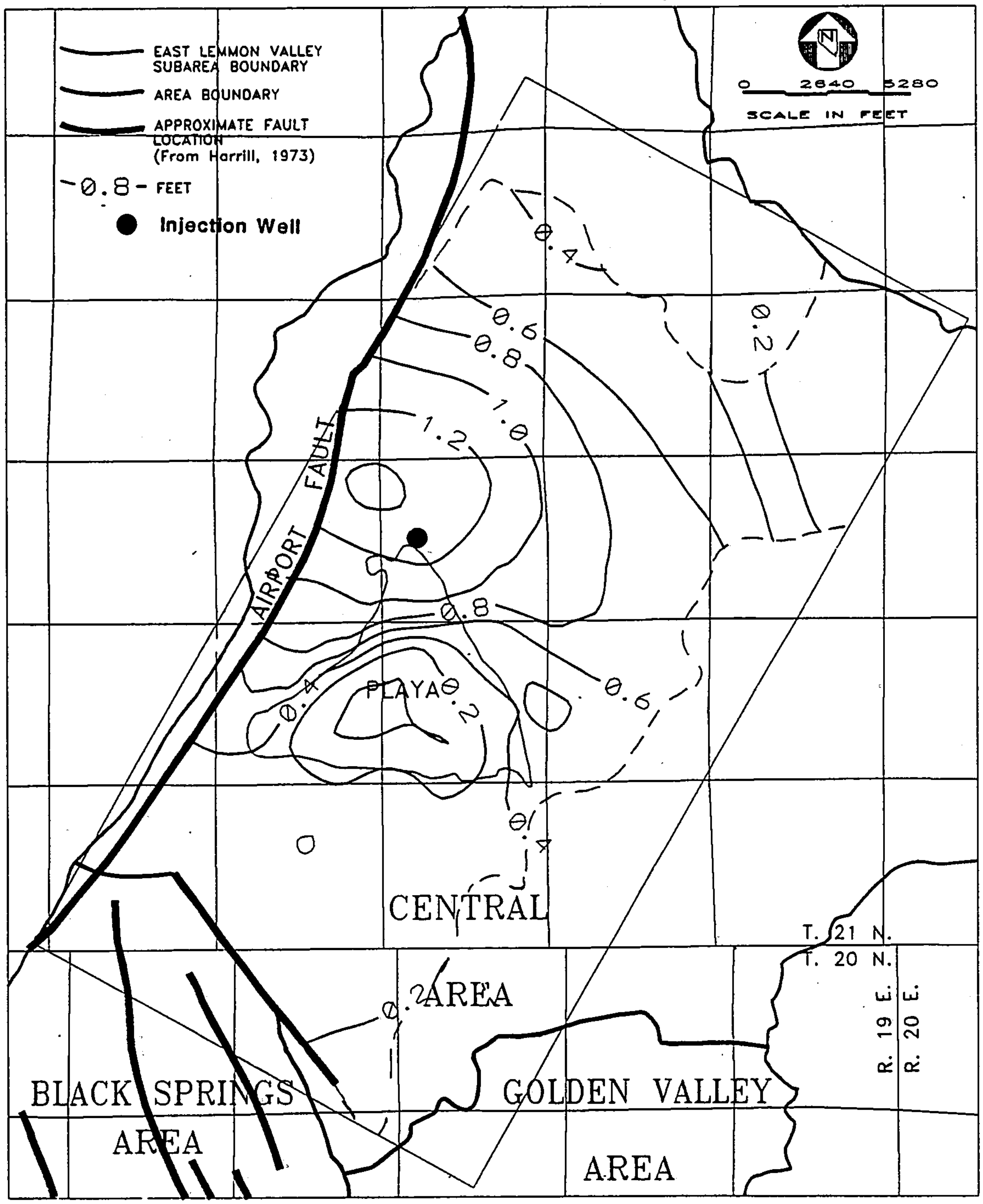

FIGURE 27. Net change in water levels from steady-state conditions for model layer 1 at the 5-year period: After injecting 500 acre-feet with one well.

from the system. This means that less natural recharge water flows out of the system, allowing natural recharge to accumulate nearer to the natural recharge source locations (ie., at the perimeter of the model). Water budget data for the five-year time period at the end of Simulation A reveals that most injection water goes into aquifer storage. A summary of the budget after 5 years for Simulation A is:

Water Entering Groundwater System -

Natural and Secondary Recharge = 2,168 AF

Artificial Recharge = 500 AF

Water Exiting Groundwater System -

Airport Fault Sink = 1,305 AF

ET = 929 AF

Water Entering Storage = 544 AF

Water Released From Storage = 110 AF

The above summary shows that MODFLOW considers water flowing into and out of storage as part of the water budget. Specifically, water accumulation in storage effectively removes water from the flow system and water released from storage effectively adds water to flow, even though neither process, in itself, involves the transfer of water into or out of the groundwater regime (McDonald and Harbaugh, 1988). Comparing the quasi steady-state and Simulation A water budgets reveals that some artificial recharge water is lost to ET after entering the upper layer. The quasi steady-state budget has ET accounting for 173 AF discharge annually, or

865 AF over 5 years. The water budget after the final injection cycle for simulation A has 929 AF lost to ET. Subtracting the quasi steady-state value of ET from the transient ET value for this injection simulation results in 64 AF additional discharge. Thus, approximately 436 AF out of 500 AF or 87 percent of the injected water goes into storage and potentially can be retrieved at some later date.

Simulation B

Simulation B represents injecting 200 AF of water annually over a period of 5 years (1,000 AF total), at 6-month intervals each year using two injection wells located adjacent to each other. Both wells are located at the north end of the playa lake near the existing injection well site. Results of Simulation B indicate that water levels near the injection cells (ie., in layer 2) will rise about 20 feet above the initial quasi steady-state value during each recharge cycle (Figure 28). As in Simulation A, the increase of head in layer 1 immediately after each injection period is less than the increases in layer 2 (Figure 29). Head in layer 1 near the injection wells increased approximately 5 feet above the quasi steady-state value during each injection cycle. Final increase of head after 5 years is approximately 3 feet in the lower layer and 2 feet in the upper layer near the injection wells (Figures 30 and 31). As with Simulation

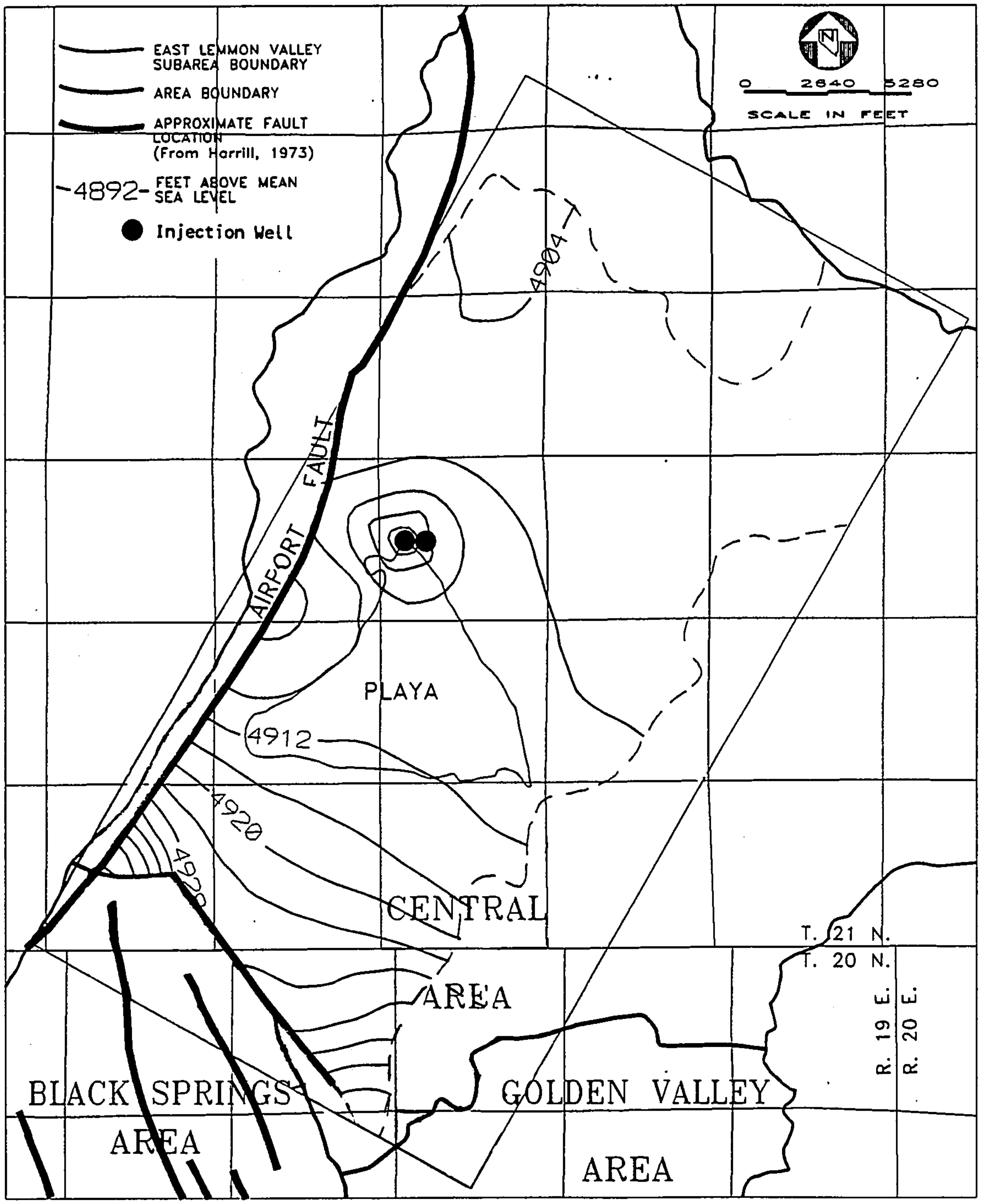

FIGURE 28. Contour map of water levels for model layer 2 at the 4.5-year period: After injecting 1,000 acre-feet with two adjacent wells.

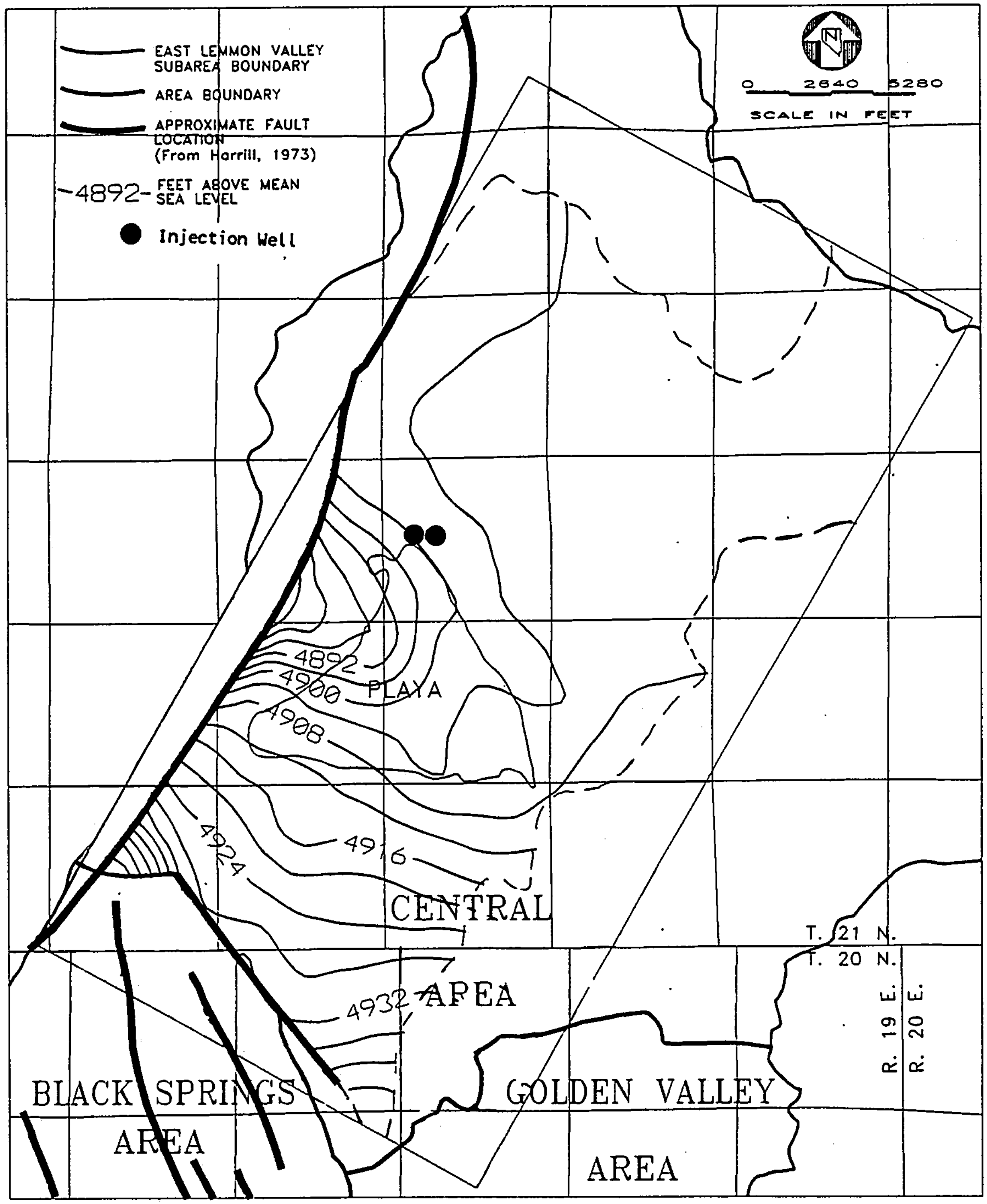

FIGURE 29. Contour map of water levels for model layer 1 at the 4.5-year period: After injecting 1,000 acre-feet with two adjacent wells.

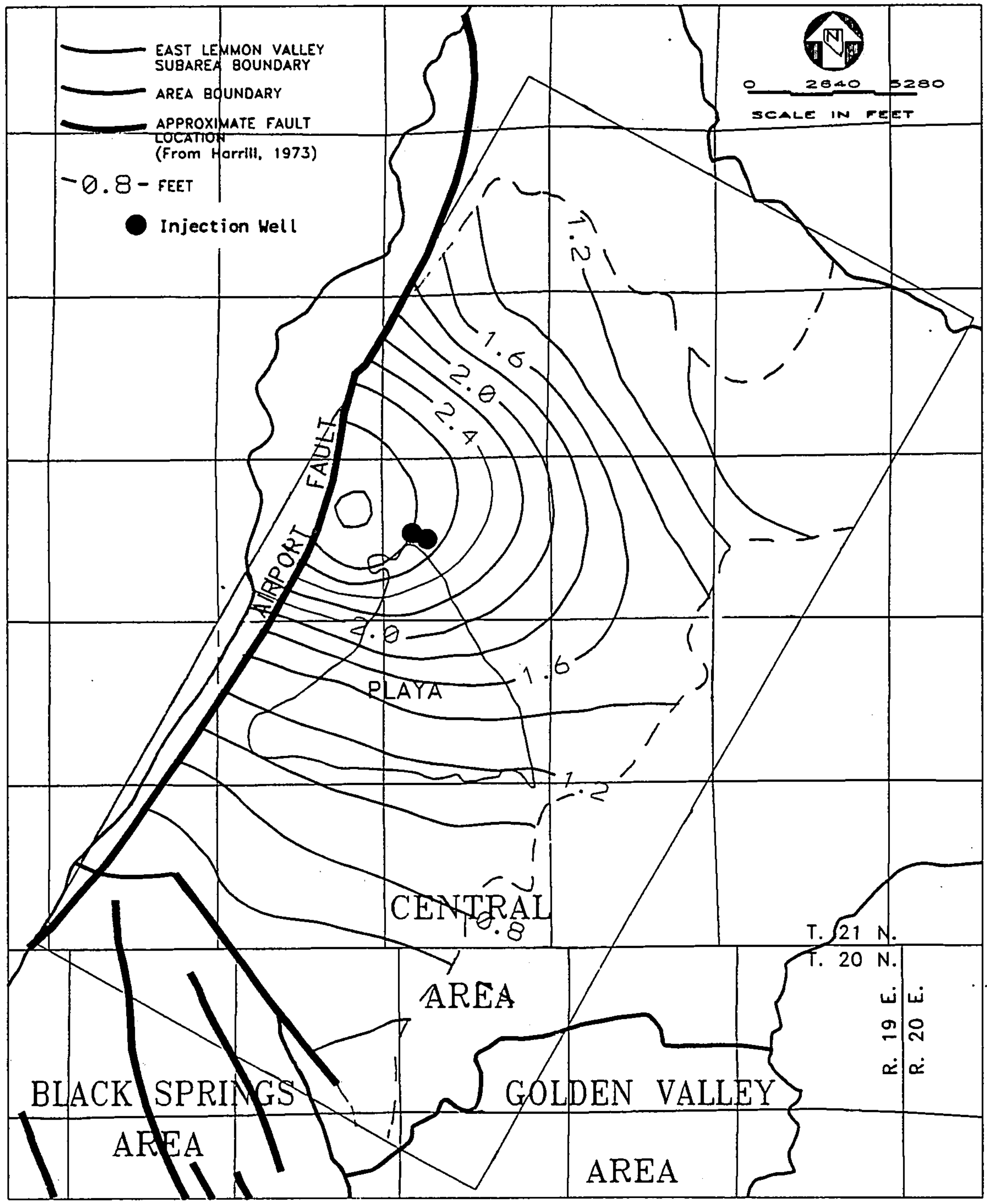

FIGURE 30. Net change in water levels from steady-state conditions for model layer 2 at the 5-year period: After injecting 1,000 acre-feet with two adjacent wells.

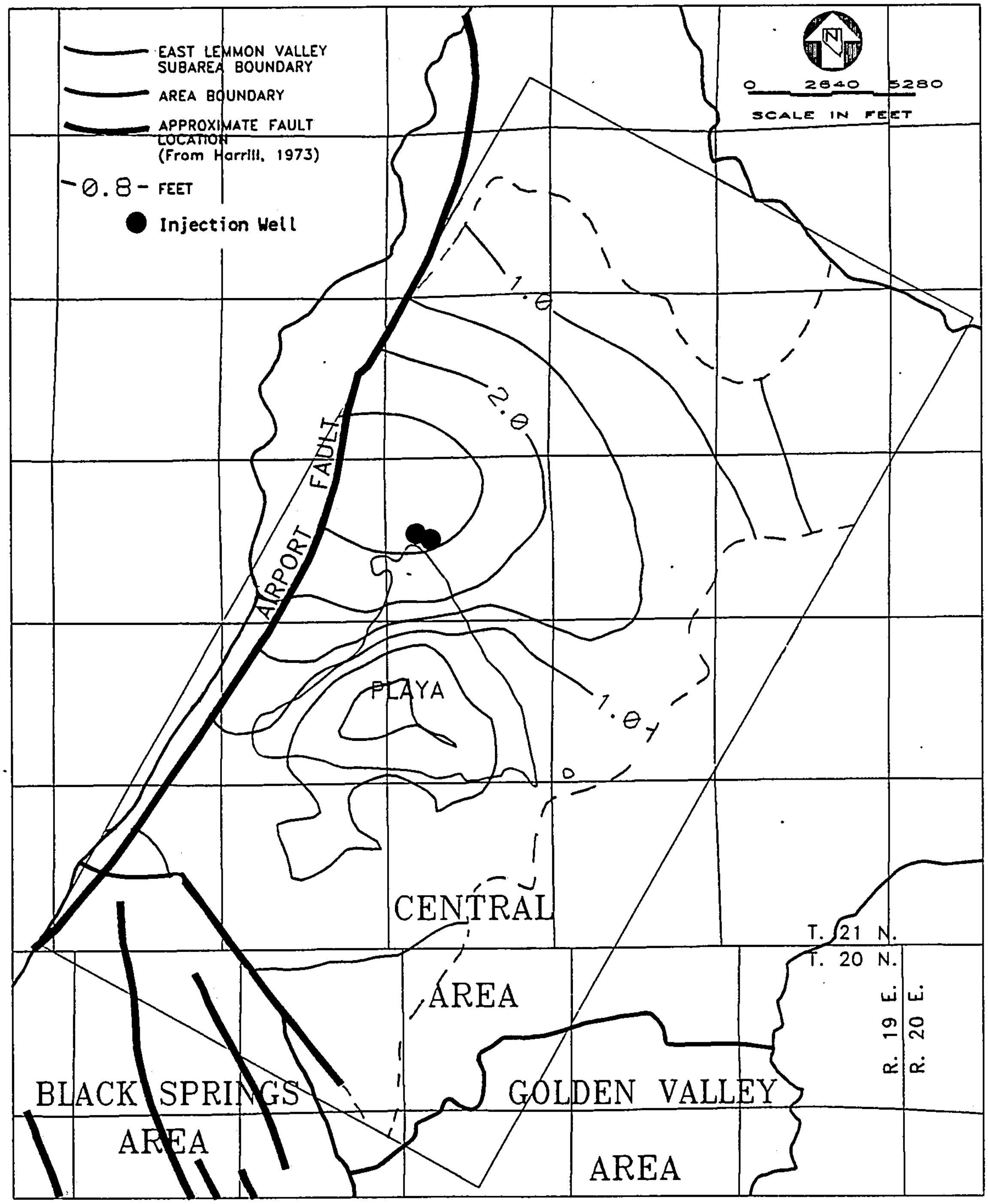

FIGURE 31. Net change in water levels from steady-state conditions for model layer 1 at the 5-year period: After injecting 1,000 acre-feet with two adjacent wells.

A, the increases in water levels extend to the model boundaries. The changes are not necessarily because injection water travels to the boundaries. The changes probably occur because some injection water contributes to the amount of water removed from the system, allowing some natural recharge water to build up at the boundaries where the natural recharge source areas are located. The water budget after 5 years of injection for Simulation B is:

Water Entering Groundwater System -

Natural and Secondary Recharge = 2,172 AF

Artificial Recharge = 1,000 AF

Water Exiting Groundwater System -

Airport Fault Sink = 1,305 AF

ET = 991 AF

Water Entering Storage = 1,096 AF

Water Released From Storage = 220 AF

Comparing the quasi steady-state and Simulation B water budgets reveals that some artificial recharge water is lost to ET. The quasi steady-state budget has ET accounting for 173 AF discharge annually, or 865 AF over 5 years. The water budget at the 5-year time period has 991 AF lost to ET. Subtracting the quasi steady-state value of ET from the transient value for Simulation B results in 126 AF additional discharge. Thus, approximately 874 AF out of 1,000 AF or 87 percent of the injected water goes into storage and potentially can be retrieved at some later date.

Simulation C

The third simulation illustrates using 2 wells at different locations to inject 200 AF annually over a 5 year period (1,000 AF total), at 6-month intervals each year. Well 1 is located at the existing injection well site north of the playa lake. Well 2 is located at the northeast corner of the model area. Both wells inject into the main production zone (layer 2) but layer 2 is relatively thin with a fairly large leakance value near well 2, meaning water can move upward into layer 1 more easily. Water levels in layer 2 rose about 16 feet near well 1 and 20 feet near well 2 during each recharge interval (Figure 32). As with Simulations A and B, head increases in layer 1 were less than in layer 2 at well 1 (Figure 33). Layer 1 heads near injection wells 1 and 2 rose approximately 4 feet above the quasi steady-state value immediately after each injection cycle. Final increases in head, at the 5-year time period, were larger in layer 2 at well 1 and similar for both layers at well 2. Layer 2 increased approximately 1.75 feet at well 1 and 4.5 feet at well 2. Layer 1 increased approximately 1.5 feet at well 1 and 4.5 feet at well 2. Total head increases for each layer after 5 years of injection are shown in Figures 34 and 35.

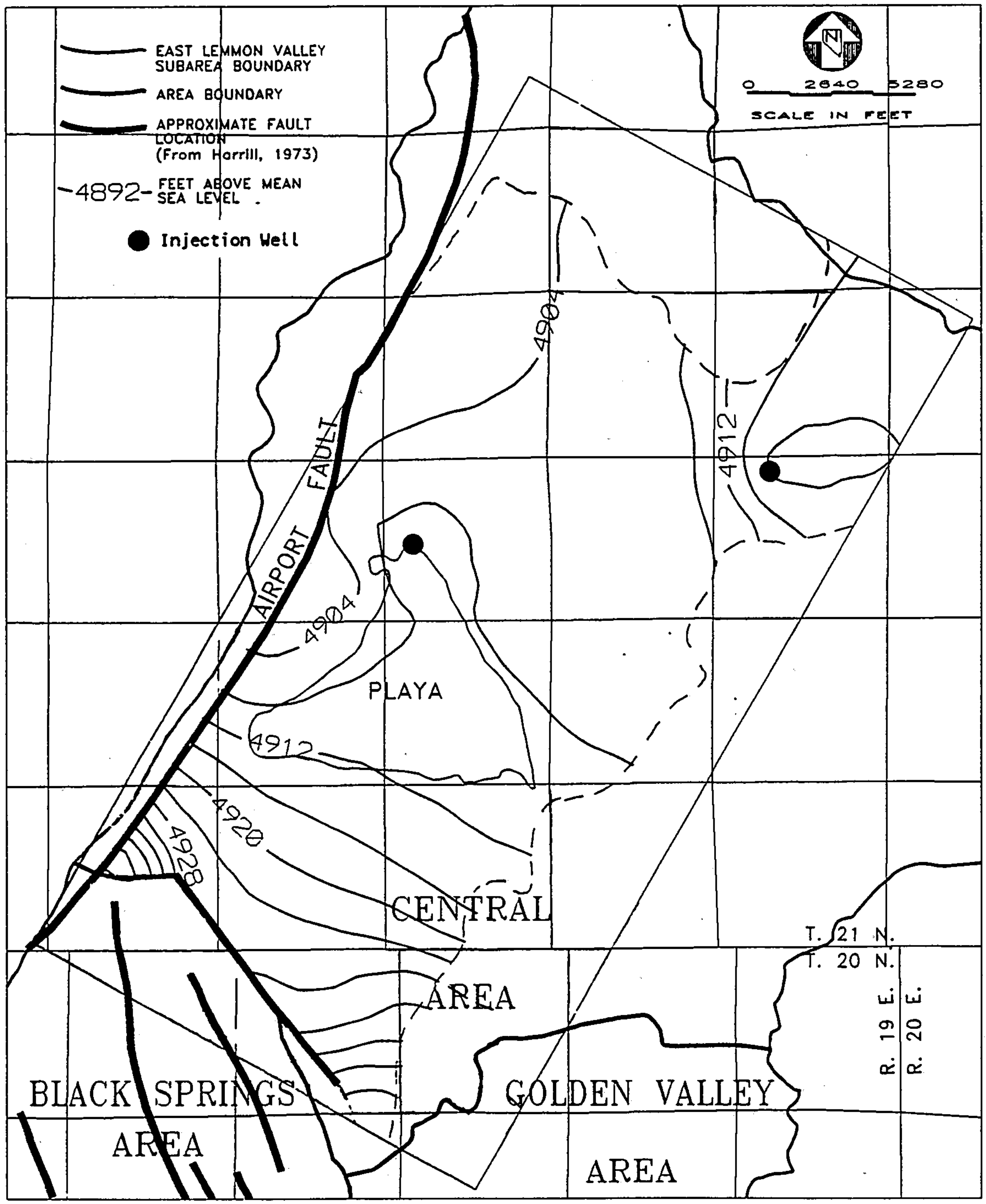

FIGURE 32. Contour map of water levels for model layer 2 at the 4.5-year period: After injecting 1,000 acre-feet with two wells located two miles apart.

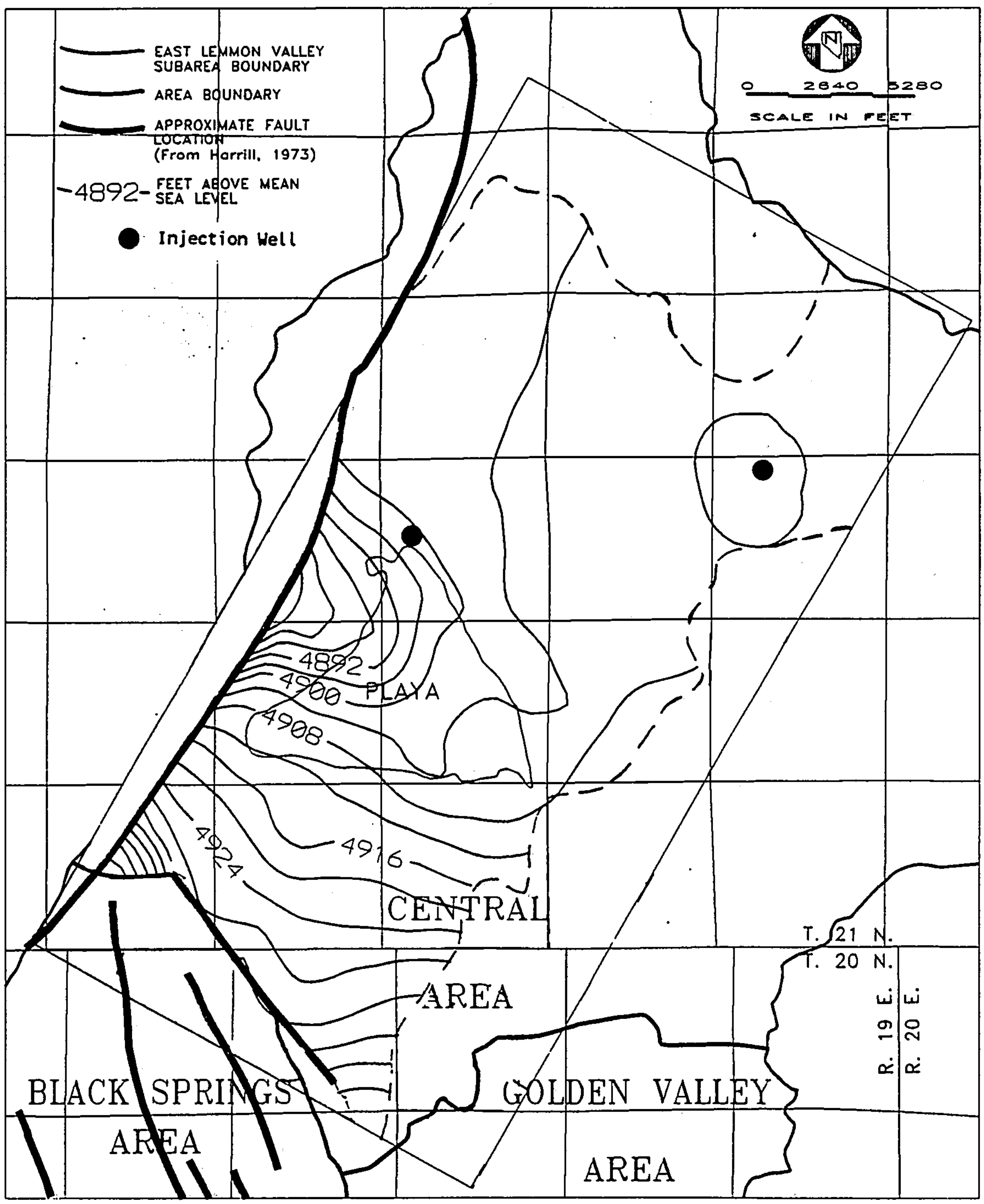

FIGURE 33. Contour map of water levels for model layer 1 at the 4.5-year period: After injecting 1,000 acre-feet with two wells located two miles apart.

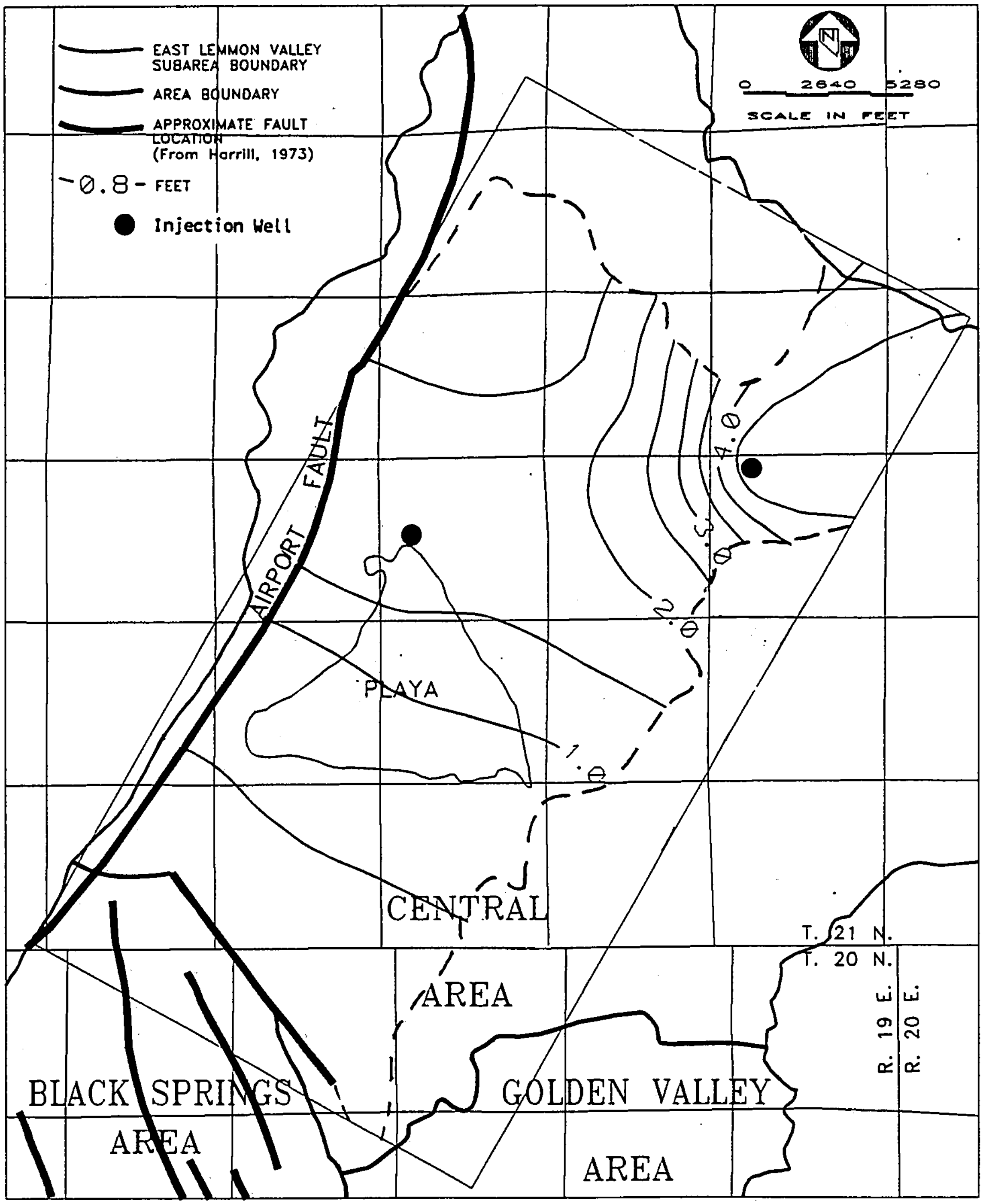

FIGURE 34. Net change in water levels from steady-state conditions for model layer 2 at the 5-year period: After injecting 1,000 acre-feet with two wells located two miles apart.

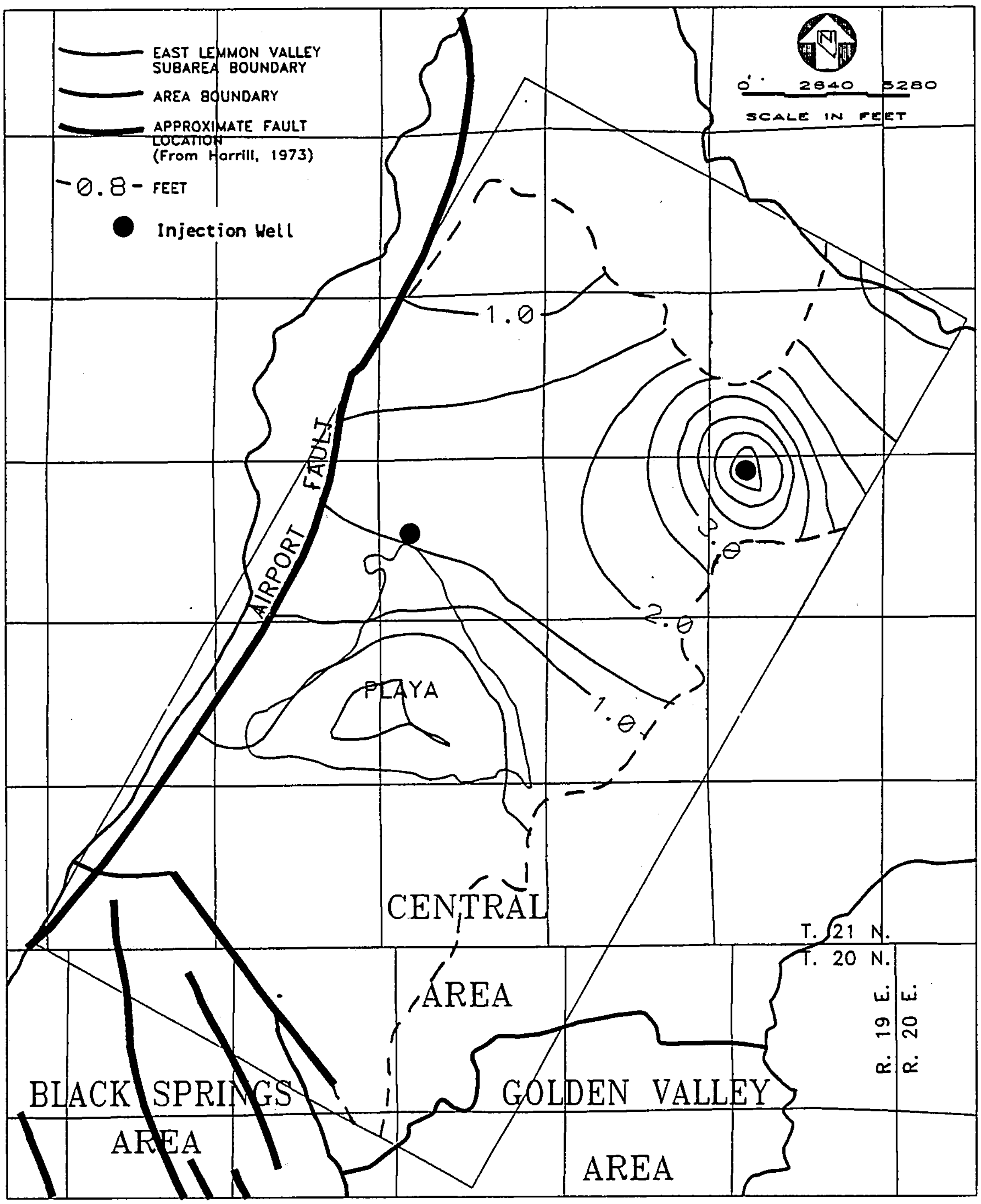

FIGURE 35. Net change in water levels from steady-state conditions for model layer 1 at the 5-year period: After injecting 1,000 acre-feet with two wells located two miles apart.

The water budget after 5 years for Simulation C is:

Water Entering Groundwater System -

Natural and Secondary Recharge = 2,172 AF

Artificial Recharge = 1,000 AF

Water Exiting Groundwater System -

Airport Fault Sink = 1,305 AF

ET = 942 AF

Water Entering Storage = 1,159 AF

Water Released From Storage = 235 AF

The water budget shows most injection water entering storage. Approximately 77 AF of injection water are lost to ET. Thus, 923 AF out of 1,000 AF or 92 percent of the injected water enters storage and potentially can be extracted in the future. It appears that locating the injection well away from ET areas eliminates loss of some injection water.

SUMMARY AND CONCLUSIONS

Fault structures divide the Lemmon Valley hydrographic basin into subareas and even smaller areas. The Washoe County Artificial Recharge Demonstration Project is currently underway in the Central Area of the East Lemmon Valley subarea. A quasi three-dimensional finite difference numerical flow model was developed to simulate the effects of artificial recharge in the Central Area. Objectives to be accomplished during model development were: 1) compile existing geologic, hydrogeologic, and climatic data and develop a conceptual model representative of actual field conditions; 2) approximate the conceptual model with a calibrated numerical model; and 3) simulate different scenarios of artificial recharge to determine the amount of injection water going into aquifer storage, observe any changes in water levels, and reveal which injection scenario adds the most water to the groundwater system.

Overall, data compilation and development of a representative conceptual model was accomplished. Numerous types of data were compiled and a large data base was developed. Drilling logs, geophysical data, and climatic (precipitation) data were obtained from various agencies or found in published reports. Data were evaluated and a conceptual model was developed. Based on evaluation of available data, three hydrostratigraphic units were identified in the Central Area: 1) playa deposits; 2) valley-fill material; and 3) fractured bedrock. Hydrologic parameters imply that playa deposits have low water yield while valley fill and fractured bedrock have the potential to produce relatively large volumes of water. Except for the playa unit being comprised mostly of clay, the valley-fill material is a mixture of clay, silt, sand, and gravel. Consequently, the hydrostratigraphic units were only divided into 2 layers for modeling purposes: an upper unconfined layer and a deeper confined layer. A definite confining unit separating layer 1 from layer 2 was not evident in any of the drilling logs. Thus, the layers were separated using a leakance term, making the model quasi three-dimensional. The upper unconfined layer extends approximately 150 feet below the water table. Most domestic wells are located in the upper portion of the unconfined layer. The lower confined layer has a maximum depth of approximately 800 feet and includes valley fill and fractured bedrock. Larger-producing municipal wells are located in the deeper confined unit.

In addition to hydrostratigraphic units and model layers, a water budget is needed to represent a groundwater system numerically. The primary water budget components for the Central Area are: precipitation, subsurface inflow, evapotranspiration, and subsurface outflow. Secondary components of the water budget include secondary recharge from a sewage treatment plant and groundwater pumpage. Initial estimates of the water budget were obtained from previous studies by Harrill (1973), Arteaga (1984), and Mahin (1988).

The second objective of this study, approximating the conceptual model with a calibrated steady-state finite difference model, was also accomplished. The model was calibrated to water-level measurements representing quasi steady-state conditions. Quasi steady-state conditions occurred in the Central Area during the early 1970s when water-level measurements were stable on an annual basis but fluctuated seasonally. Secondary components of the water budget were incorporated into the model implicitly since model calibration was achieved by placing all recharge and discharge components at the model boundaries and at ET areas. Previous field studies concluded that approximately 500 acre-feet enter and exit the groundwater system under steady-state (natural) conditions. This value along with estimates of hydrologic parameters were the initial values incorporated into the numerical model. A summary of the final water budget for the quasi steady-state calibration follows:

INFLOW

1) Primary and Secondary Recharge = 388 AF
2) Subsurface Inflow = 45 AF

OUTFLOW

1) Evapotranspiration = 173 AF
2) Subsurface Outflow = 261 AF

A sensitivity analysis was completed to determine which parameters have greater impact on model results. The sensitivity analysis revealed that the model is most sensitive to decreases in recharge and increases in horizontal and vertical hydraulic conductivity. The model was less sensitive to changes in the ET rate and decreases in horizontal and vertical hydraulic conductivity. Thus, additional information on recharge and K values could increase the reliability of the model.

Three simulations were input into the calibrated model in order to meet the third study objective, determining if a specific scenario can potentially put more water into aquifer storage. Aquifer parameters and final heads from the quasi steady-state model were used under transient conditions to simulate artificial recharge. A local verification test of the transient model was performed by simulating an aquifer pumping test and comparing the results with actual aquifer test data from 1991. Verification tests help the modeler decide whether the calibration process produced a model adequate for transient simulations. The model reproduced the aquifer test data set reasonably well, simulated heads matched to less than 2 feet of actual aquifer test values based on a root mean squared error calculation.

After the local verification test was completed, the model was used to simulate three artificial recharge scenarios. All three simulations produced increases in aquifer storage and water levels. The lateral extent of head changes was similar for both layers. Increase in head values was greater in the lower layer where the injection wells were placed. The upper layer showed smaller head increase but more storage, based on the definitions of specific yield and storage coefficients.

Based on the assumptions made to prepare the model, artificial recharge will mitigate declines in water levels for the Central Area. All three simulations had increased loss of recharge water by ET in addition to the loss for quasi steady-state conditions according to the model water budgets. Simulation C, which had two injection wells located two miles apart, had less loss by ET because one of the injection wells was placed several miles from the modeled phreatophyte areas.

RECOMMENDATION FOR FUTURE STUDIES

Future studies should be set up to provide additional information on the components of the groundwater model outlined in the following list. The additional information could be incorporated into the groundwater model to increase the reliability of model results.

1) Additional information on the distribution of precipitation in the valley is needed. The sensitivity analysis completed for the study revealed that the model is sensitive to changes in natural recharge, more so to decreases than increases in natural recharge. Current approximations of natural recharge were estimated by correlating land surface elevations with precipitation zones and are not supported by data collected specifically from the

Central Area of Lemmon Valley. Precipitation zones are approximated using the assumption that higher elevations receive more precipitation (Arteaga, 1986). Collecting data in the Central Area using precipitation gauges, evaporation pans, and other devices may provide more reliable recharge input values specifically for the model domain.

2) Performing constant discharge aquifer tests on shallow wells will increase confidence in hydraulic conductivity values and storage parameters. The sensitivity analysis completed for the quasi steady-state model indicates that the model is most sensitive to increases in K_h and K_v. Most values of K_h and K_v input for layer 1 were calculated from drilling logs and specific capacity tests. Aquifer parameters are well defined in the artificial recharge area but are not well defined in other parts of the valley. Pumping tests will provide more accurate K values in other parts of the model domain and increase model reliability.

3) Performing engineering land surveys on all wells used for water-level measurements is needed to determine the exact groundwater gradient in the valley. Well elevations are important because the gradient in the north part of the valley is relatively flat. The model was prepared with estimates of land surface elevations for some of the calibration wells. If these elevations are not accurate, the field-measured water levels would also be inaccurate.

4) Installing deeper monitoring wells in several areas of the valley could better define the thickness of valley fill and depth-to-bedrock. Depth-to-bedrock along the Airport Fault and in the northeast portion of the valley is based on the geophysical survey completed in 1981. Drilling to bedrock would verify the results of the 1981 geophysical study.

5) More information is needed on ET rates and extinction depths. Transient simulations revealed that some artificial recharge water is lost to ET, especially when the injection well is located near the modeled ET areas. If the ET rate and extinction depth used in the model are incorrect, it is possible that more or less water can be lost to ET. Collecting additional data on ET should be considered since ET is a important part of the water budget. The biggest difference between the estimated water budget and the modeled water budget was in ET.

6) More information is needed to better understand subsurface outflow at the Airport Fault. Outflow at the fault is dependent upon the variables of Darcy's law $Q = KAI$,

where Q is flow;

K is horizontal hydraulic conductivity;

A is the cross-sectional area perpendicular to flow;

I is the groundwater gradient.

Whether or not Q will increase at the fault during injection is largely determined by the values of K and I. It is possible that K is a small enough value that realistic increases in I resulting from artificial recharge will produce only small increases in Q. Additional information could be obtained by installing wells on both side of the fault and performing an aquifer test to get a better understanding of the K values in the vicinity of the fault, and the horizontal connection across the fault.

REFERENCES

Anderson, Mary P. and Woessner, William W., 1992. Applied Groundwater Modeling. Academic Press, Incorporated.

Arteaga, Freddy E., 1986. Mathematical Model Analysis of the Eagle Valley Groundwater Basin, West-Central Nevada. State of Nevada Department of Conservation and Natural Resources Division of Water Resources Water-Resources Bulletin 45.

Arteaga, Freddy E., and Durbin, Timothy J., 1978. Development of a Relation for Steady-State Pumping Rate for Eagle Valley Groundwater Basin, Nevada. U.S. Geological Survey Open-File Report 79-261.

Arteaga, Freddy E., 1984. Hydrogeology of Lemmon Valley, Washoe County, Nevada. U.S. Geological Survey unfinished Open-File Report (maps).

Bear, Jacob, 1979. Hydraulics of Ground Water. McGraw-Hill Incorporated.

Cochran, G.F., Barry, J.M., Dale, M.W., Sones, P.R., 1986. Water Harvest From Peavine Mountain with Artificial Recharge in Golden Valley, Nevada: Hydrologic Feasibility and Effects. Desert Research Institute- University of Nevada System Water Resources Center Publication No. 41103.

Cordy, Gail E., 1985. Reno NE Quadrangle Geologic Map. Nevada Bureau of Mines and Geology.

Dale, Michael W., 1987. Hydrology of the Southern Part of the Peavine Mountain - Silver Lake Sub-basin. University of Nevada Master of Science thesis.

Danskin, Wesley R., 1988. Preliminary Evaluation of the Hydrogeologic System in Owens Valley, California. U.S. Geological Survey Water-Resources Investigations Report 88-4003.

Driscoll, Fletcher G., 1986. Ground Water and Wells. Johnson Filtration Systems, Incorporated.

Eakin, T.E., and others, 1951. Contributions to the Hydrology of Eastern Nevada. Nevada State Engineer Water Resource Bulletin 12.

Freeze, R. Allen, and Cherry, John A., 1979. Groundwater. Prentice-Hall Incorporated.

Golden Software, Inc., 1990. SURFER (software package) Reference Manual.

Hadiaris, Amy K., 1988. Quantitative Analysis of Groundwater Flow In Spanish Springs Valley, Washoe County, Nevada. University of Nevada Master of Science thesis.

Harrill, James R., 1973. Evaluation of the Water Resources of Lemmon Valley, Washoe County, Nevada, with Emphasis on Effects of Groundwater Development to 1971. State of Nevada Department of Conservation and Natural Resources- Division of Water Resources, Water Resource Bulletin No. 42.

Harrill, James R., 1986. Groundwater Storage Depletion In Pahrump Valley, Nevada-California, 1962-75. U.S. Geological Survey-Water Supply Paper 2279.

Heath, Ralph, 1984. Basic Groundwater Hydrology. U.S. Geological Survey Water Supply Paper 2220.

Klieforth, Harold, Albright, William, and Ashby, James, 1983. Measurement, Tabulation, and Analysis of Rain and Snowfall In the Truckee River Basin. University of Nevada Desert Research Institute.

Maclay, R.W., and Land, L.F., 1988. Simulation of Flow in the Edwards Aquifer, San Antonio Region, Texas, and Refinement of Storage and Flow Concepts. U.S. Geological Survey Water Supply Paper 2336.

Mahin, Donald A., 1988. Draft report- Recharge Estimate and Model of the Lemmon Valley Hydrographic Basin, North of Reno, Nevada.

Maurer, Douglas K., 1986. Geohydrology and Simulated Response to Groundwater Pumpage in Carson Valley, A River-Dominated Basin Douglas County, Nevada, and Alpine County, California. U.S. Geological Survey Water-Resources Investigations Report 86-4328.

McDonald, Michael G., and Harbaugh, Arlen W., 1988. A Modular Three-Dimensional Finite-Difference Groundwater Flow Model. U.S. Geological Survey Techniques of Water-Resources Investigations of the United States Geological Survey, Chapter A1 Book 6.

Peters, James G., 1987. Description and Comparison of Selected Models for Hydrologic Analysis of Groundwater Flow, St. Joseph River Basin, Indiana. U.S. Geological Survey Water-Resources Investigations Report 86-4199.

Reynolds, Richard J., 1987. Hydrogeology of the Surficial Outwash Aquifer at Cortland, Cortland County, New York. U.S. Geological Survey Water-Resources Investigations Report 85-4090.

Rush, F.E., and Glancy, P.A., 1967. Water-Resources Appraisal of Warm Springs-Lemmon Valley Area, Washoe County, Nevada. U.S. Geological Survey Water-Resources Reconnaissance Series Report No. 43.

Shaeffer, Donald, H. and Maurer, Douglas K., 1981. Geophysical Reconnaissance of Lemmon Valley, Washoe County, Nevada. U.S. Geological Survey Water-Resources Investigations open file report 80-1123.

Thomas, James M., Carlton, Stephen M., and Hines, Lawrence B., 1989. Groundwater Hydrology and Simulated Effects of Development in Smith Creek Valley, a Hydrologically Closed Basin in Lander County, Nevada. U.S. Geological Survey Professional Paper 1409-E.

Walton, William C., 1988. Practical Aspects of Groundwater Modeling. Reprint from National Water Well Association.

Wang, Herbert F. and Anderson, Mary P., 1982. Introduction to Groundwater Modeling. W.H. Freeman and Company.

APPENDIX A

MODFLOW Output File For Steady-State Conditions

```
          MODFLOW -- Serial Number SER03291
 LICENSED TO   Greg Pohll -- University of Nevada, Reno, Neva
 The File-Name input unit is 99
 modinp.nam has been opened on unit 99
 The listing file output unit is  6
 ss.out has been opened on unit  6
 The Basic Package input unit is  1
 modinp.bas has been opened on unit  1
 modinp.bcf has been opened on unit 11
 modinp.wel has been opened on unit 12
 modinp.evt has been opened on unit 15
 modinp.sip has been opened on unit 19
 modinp.ocf has been opened on unit 22
 sshed.out has been opened unformatted on unit 50
1                    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL
0LEMMON VALLEY STEADY-STATE CONDITIONS                                       WITH VARIABLE GRID
    2 LAYERS         18 ROWS         34 COLUMNS
   1 STRESS PERIOD(S) IN SIMULATION
 MODEL TIME UNITS ARE UNDEFINED
0I/O UNITS:
 ELEMENT OF IUNIT:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
         I/O UNIT: 11 12  0  0 15  0  0  0 19  0  0 22  0  0  0  0  0  0  0  0  0  0  0  0
0BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT  1
 ARRAYS RHS AND BUFF WILL SHARE MEMORY.
 START HEAD WILL NOT BE SAVED -- DRAWDOWN CANNOT BE CALCULATED
     10464 ELEMENTS IN X ARRAY ARE USED BY BAS
     10464 ELEMENTS OF X ARRAY USED OUT OF  900000
0BCF2 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 2, 7/1/91 INPUT READ FROM UNIT 11
 STEADY-STATE SIMULATION
 HEAD AT CELLS THAT CONVERT TO DRY=  0.00000
 WETTING CAPABILITY IS NOT ACTIVE
       LAYER  AQUIFER TYPE
       ------------------
          1          1
          2          0
      1226 ELEMENTS IN X ARRAY ARE USED BY BCF
     11690 ELEMENTS OF X ARRAY USED OUT OF  900000
0WEL1 -- WELL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM 12
 MAXIMUM OF    44 WELLS
       176 ELEMENTS IN X ARRAY ARE USED FOR WELLS
     11866 ELEMENTS OF X ARRAY USED OUT OF  900000
0EVT1 -- EVAPOTRANSPIRATION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 15
 OPTION 1 -- EVAPOTRANSPIRATION FROM TOP LAYER
      1836 ELEMENTS OF X ARRAY USED FOR EVAPOTRANSPIRATION
     13702 ELEMENTS OF X ARRAY USED OUT OF  900000
0SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 19
 MAXIMUM OF 200 ITERATIONS ALLOWED FOR CLOSURE
  5 ITERATION PARAMETERS
      5701 ELEMENTS IN X ARRAY ARE USED BY SIP
     19403 ELEMENTS OF X ARRAY USED OUT OF  900000
1LEMMON VALLEY STEADY-STATE CONDITIONS                                       WITH VARIABLE GRID
0
```

BOUNDARY ARRAY FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (16I5)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0
0	2	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
0	3	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
0	4	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
0	5	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
0	6	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
0	7	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
0	8	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
0	9	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
0	10	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
0	11	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
0	12	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
0	13	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
0	14	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
0	15	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1
0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

0

BOUNDARY ARRAY FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (16I5)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
0 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0 2	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
0 3	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 4	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 5	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 6	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 7	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 8	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 9	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
0 10	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
0 11	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 12	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 13	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 14	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 15	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0AQUIFER HEAD WILL BE SET TO 999.00 AT ALL NO-FLOW NODES (IBOUND=0).
0

INITIAL HEAD FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (8G10.3)

	1 11 21 31	2 12 22 32	3 13 23 33	4 14 24 34	5 15 25	6 16 26	7 17 27	8 18 28	9 19 29	10 20 30
0 1	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 2	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 3	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 4	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 5	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 6	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 7	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 8	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 9	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 10	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 11	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	[illegible]	[illegible]	[illegible]	[illegible]						

	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 12	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 13	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 14	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 15	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 16	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 17	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 18	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0										

INITIAL HEAD FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (8G10.3)

	1	2	3	4	5	6	7	8	9	10
	11	12	13	14	15	16	17	18	19	20
	21	22	23	24	25	26	27	28	29	30
	31	32	33	34						
0 1	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 2	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 3	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 4	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 5	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 6	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						

0 7	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 8	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 9	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 10	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 11	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 12	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 13	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 14	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 15	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 16	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 17	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						
0 18	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.	4910.
	4910.	4910.	4910.	4910.						

```
OHEAD PRINT FORMAT IS FORMAT NUMBER   0    DRAWDOWN PRINT FORMAT IS FORMAT NUMBER   0
OHEADS WILL BE SAVED ON UNIT 50    DRAWDOWNS WILL BE SAVED ON UNIT  0
OOUTPUT CONTROL IS SPECIFIED EVERY TIME STEP
                                          COLUMN TO ROW ANISOTROPY =   1.000000
0
0
                                DELR WILL BE READ ON UNIT 11 USING FORMAT: (10G11.4)
                     ----------------------------------------------------------------------------

   1000.0     1000.0     1000.0     1000.0     1000.0     1000.0     1000.0     1000.0     1000.0     1000.0
   1000.0     1000.0     1000.0     1000.0     1000.0     1000.0     500.00     500.00     500.00     500.00
   1000.0     1000.0     1000.0     1000.0     1000.0     1000.0     1000.0     1000.0     1000.0     1000.0
   1000.0     1000.0     1000.0     1000.0
0
                                DELC WILL BE READ ON UNIT 11 USING FORMAT: (10G11.4)
                     ----------------------------------------------------------------------------

   1000.0     1000.0     1000.0     500.00     500.00     500.00     500.00     1000.0     1000.0     1000.0
   1000.0     1000.0     1000.0     1000.0     1000.0     1000.0     1000.0     1000.0
0
```

HYD. COND. ALONG ROWS FOR LAYER 1 WILL BE READ ON UNIT 11 USING FORMAT: (8G10.3)

	1 11 21 31	2 12 22 32	3 13 23 33	4 14 24 34	5 15 25	6 16 26	7 17 27	8 18 28	9 19 29	10 20 30
0 1	2.380	2.220	2.040	1.840	2.260	1.710	1.200	0.3880	3.8000E-02	4.0300E-02
	0.3640	0.4370	7.540	10.30	7.580	6.430	5.710	4.780	7.430	7.580
	6.830	7.930	14.90	13.40	6.050	24.70	29.48	29.72	11.20	11.30
	11.40	11.40	11.50	11.50						
0 2	2.390	2.210	2.010	1.750	1.030	0.8990	1.080	0.1000	3.5300E-03	3.2700E-02
	0.3880	1.030	7.820	23.40	8.880	6.510	5.440	1.740	7.030	7.430
	10.30	8.350	10.10	14.60	11.60	15.80	3.580	9.970	11.20	11.30
	11.40	11.40	11.50	11.50						
0 3	2.440	2.240	2.020	1.760	1.170	1.340	0.1170	0.1000	1.1100E-03	1.0600E-02
	0.3830	1.370	5.210	24.60	9.180	5.990	4.820	2.240	5.890	6.910
	10.00	8.140	11.20	9.590	15.60	6.000	10.00	10.10	10.10	10.00
	11.30	11.40	11.50	11.50						
0 4	2.490	2.270	2.040	1.800	2.480	1.360	0.7000	0.3780	1.0600E-02	3.6100E-02
	0.3380	0.5570	6.830	22.90	7.280	5.230	4.130	4.000	3.070	4.610
	9.880	7.850	30.00	12.40	8.000	27.30	4.250	9.880	9.980	9.950
	9.890	11.40	11.50	11.50						
0 5	2.540	2.300	2.050	1.820	2.610	0.9000	5.5000E-02	0.4270	3.8200E-02	4.0500E-02
	0.9000	5.0000E-02	7.9300E-02	1.950	3.260	4.760	3.820	1.780	1.500	3.590
	5.710	7.530	10.10	12.00	18.30	18.50	4.710	9.560	9.880	9.890
	9.850	11.40	11.50	11.50						
0 6	2.590	2.340	2.050	1.800	2.620	1.610	0.1070	0.4840	4.3200E-02	4.3500E-02
	5.0000E-03	5.0000E-03	7.1100E-02	1.000	2.690	4.490	3.610	1.650	3.220	4.050
	5.340	7.300	10.60	19.08	15.80	9.280	3.770	9.530	9.810	9.840
	9.810	9.760	11.50	11.50						
0 7	2.660	2.380	2.030	1.710	2.530	1.940	0.1720	0.5450	0.2860	4.5400E-02
	5.0000E-03	5.0000E-03	5.0000E-03	5.0000E-02	0.5000	4.110	3.440	1.550	4.410	4.620
	5.180	7.070	8.430	7.720	14.10	7.490	3.290	9.590	9.750	9.780
	9.750	9.710	11.50	11.50						
0 8	2.820	2.500	2.110	0.6860	2.290	2.380	0.2410	0.3360	0.2750	4.5100E-02
	5.0000E-03	5.0000E-03	9.0000E-03	5.0000E-02	5.0000E-02	1.000	3.080	1.630	4.990	4.560
	6.280	6.680	8.460	8.440	15.10	10.30	3.160	9.640	9.670	9.690
	9.670	9.630	9.600	11.60						

0 9	3.120	2.820	2.350	1.950	2.760	2.880	2.360	0.7970	0.2310	3.7600E-02
	5.0000E-03	5.0000E-03	5.0000E-03	5.0000E-03	5.0000E-02	5.0000E-02	0.5460	0.7650	4.920	3.960
	1.490	6.560	8.900	11.70	11.90	9.570	9.520	9.540	9.560	9.550
	9.530	9.510	9.490	11.60						
0 10	3.580	3.340	3.030	2.790	2.760	3.420	2.000	0.7650	9.0000E-02	4.8300E-03
	8.3900E-03	5.0000E-04	9.0000E-03	0.5000	1.600	1.230	0.2750	0.5780	6.430	6.180
	8.430	8.270	10.10	12.40	12.80	9.470	9.430	9.400	9.380	9.380
	9.370	9.370	9.370	9.370						
0 11	4.200	4.040	3.800	3.600	3.300	3.220	2.120	1.550	0.1850	5.1400E-02
	5.0000E-02	5.0000E-03	5.0000E-03	5.0000E-02	0.6200	0.5780	0.4500	0.9500	8.540	8.730
	9.260	11.00	12.20	13.50	13.90	9.230	9.170	9.140	9.140	9.150
	9.170	9.200	9.220	9.250						
0 12	5.530	6.000	4.660	4.150	5.510	4.270	2.870	1.800	0.2010	0.1060
	5.0000E-02	5.0000E-03	5.0000E-02	0.7500	0.7640	0.6970	1.340	1.290	11.00	11.60
	12.60	14.90	15.40	14.30	15.00	8.850	8.770	8.750	8.790	8.860
	8.930	9.000	9.060	9.120						
0 13	7.430	8.790	6.810	6.280	6.540	1.770	4.010	0.2060	0.1560	0.1280
	0.1870	0.2450	0.3410	2.130	0.7280	0.7660	1.450	1.480	13.40	14.80
	23.40	30.80	25.90	16.60	16.10	8.290	8.160	8.190	8.320	8.500
	8.660	8.790	8.900	8.980						
0 14	10.00	10.90	8.940	6.750	6.730	8.440	0.2500	0.3040	0.1950	0.1490
	0.2140	0.2400	0.2780	2.120	0.8050	0.7990	1.520	1.590	15.00	17.10
	26.60	35.00	28.40	18.20	16.90	7.150	6.850	6.990	7.390	8.110
	8.390	8.590	8.740	8.860						
0 15	9.790	10.30	8.990	6.860	6.550	5.850	0.2490	0.3060	0.1950	0.1600
	0.2270	0.2390	0.2230	1.930	1.570	1.590	1.630	1.690	15.40	17.20
	25.50	32.80	27.20	18.30	17.20	5.940	5.060	5.700	6.640	7.310
	8.120	8.400	8.590	8.740						
0 16	7.470	7.560	7.150	6.670	6.340	4.060	2.370	0.2080	0.1730	0.2490
	0.1970	0.2030	9.4700E-02	0.7910	1.600	1.590	1.600	7.840	14.80	15.70
	16.40	19.70	18.80	17.30	17.10	4.950	2.000	2.260	6.140	6.980
	7.920	8.240	8.470	8.640						
0 17	6.810	6.840	6.660	6.390	4.270	3.940	2.150	1.760	0.2580	0.2550
	0.2000	0.2030	9.1800E-02	2.020	1.670	1.660	1.660	7.650	14.10	14.60
	14.70	16.60	17.10	16.30	16.70	5.440	4.560	5.170	6.240	6.940
	7.850	8.170	8.400	8.570						
0 18	4.740	4.710	4.570	4.350	4.110	3.860	2.060	1.730	0.2620	0.2610
	0.2020	0.2040	0.2000	2.660	1.720	1.710	1.710	7.400	13.40	13.70
	13.70	15.30	16.00	15.90	16.30	6.260	5.940	6.140	6.590	7.070
	7.880	8.160	8.370	8.540						
0										

BOTTOM FOR LAYER 1 WILL BE READ ON UNIT 11 USING FORMAT: (8G10.3)

	1	2	3	4	5	6	7	8	9	10
	11	12	13	14	15	16	17	18	19	20
	21	22	23	24	25	26	27	28	29	30
	31	32	33	34						
0 1	4810.	4810.	4810.	4820.	4820.	4820.	4790.	4800.	4810.	4800.
	4780.	4780.	4770.	4770.	4770.	4770.	4770.	4770.	4780.	4780.
	4780.	4770.	4760.	4750.	4750.	4750.	4780.	4750.	4760.	4760.
	4750.	4750.	4750.	4750.						
0 2	4800.	4810.	4810.	4820.	4840.	4840.	4780.	4800.	4820.	4810.
	4780.	4780.	4780.	4790.	4770.	4770.	4770.	4770.	4780.	4790.
	4780.	4780.	4770.	4760.	4760.	4750.	4790.	4770.	4770.	4760.
	4750.	4750.	4750.	4750.						
0 3	4800.	4810.	4810.	4820.	4830.	4820.	4780.	4800.	4840.	4820.
	4780.	4790.	4790.	4790.	4770.	4770.	4770.	4770.	4780.	4790.
	4780.	4780.	4770.	4770.	4800.	4760.	4820.	4790.	4770.	4770.
	4750.	4750.	4750.	4770.						
0 4	4800.	4800.	4800.	4810.	4810.	4810.	4780.	4800.	4810.	4800.
	4780.	4780.	4780.	4790.	4770.	4770.	4770.	4770.	4770.	4790.
	4780.	4780.	4770.	4780.	4820.	4780.	4850.	4810.	4780.	4770.
	4750.	4750.	4750.	4770.						
0 5	4800.	4800.	4800.	4810.	4800.	4800.	4780.	4790.	4800.	4800.
	4770.	4780.	4770.	4770.	4770.	4770.	4770.	4770.	4770.	4770.
	4770.	4780.	4780.	4780.	4820.	4800.	4860.	4810.	4780.	4770.
	4750.	4750.	4770.	4770.						
0 6	4810.	4810.	4810.	4810.	4800.	4800.	4780.	4790.	4800.	4790.
	4770.	4770.	4770.	4760.	4770.	4770.	4770.	4770.	4770.	4770.
	4770.	4780.	4780.	4780.	4780.	4810.	4850.	4810.	4780.	4770.
	4770.	4770.	4770.	4770.						
0 7	4800.	4810.	4810.	4810.	4800.	4800.	4780.	4770.	4790.	4790.
	4770.	4770.	4760.	4770.	4770.	4770.	4770.	4770.	4770.	4770.
	4770.	4770.	4780.	4790.	4790.	4820.	4830.	4800.	4780.	4770.
	4770.	4770.	4770.	4770.						
0 8	4800.	4800.	4810.	4810.	4800.	4790.	4780.	4780.	4780.	4780.
	4770.	4770.	4760.	4770.	4770.	4770.	4770.	4770.	4770.	4770.
	4770.	4770.	4780.	4780.	4800.	4800.	4820.	4790.	4770.	4770.
	4770.	4770.	4770.	4770.						

0 9	4790.	4800.	4800.	4810.	4800.	4790.	4780.	4770.	4780.	4780.
	4770.	4770.	4760.	4760.	4770.	4770.	4760.	4770.	4770.	4770.
	4770.	4770.	4780.	4790.	4790.	4810.	4790.	4780.	4770.	4750.
	4750.	4750.	4750.	4770.						
0 10	4790.	4800.	4800.	4810.	4800.	4790.	4780.	4780.	4780.	4770.
	4770.	4770.	4760.	4760.	4770.	4770.	4770.	4770.	4770.	4770.
	4770.	4770.	4780.	4780.	4790.	4800.	4780.	4780.	4750.	4750.
	4750.	4750.	4750.	4750.						
0 11	4800.	4800.	4800.	4800.	4790.	4790.	4770.	4780.	4770.	4770.
	4770.	4770.	4760.	4760.	4760.	4770.	4770.	4770.	4770.	4770.
	4780.	4770.	4780.	4780.	4800.	4800.	4780.	4750.	4750.	4750.
	4750.	4750.	4750.	4750.						
0 12	4800.	4800.	4800.	4790.	4790.	4780.	4770.	4770.	4770.	4770.
	4770.	4770.	4750.	4760.	4770.	4770.	4770.	4770.	4770.	4770.
	4770.	4780.	4780.	4780.	4800.	4800.	4770.	4750.	4750.	4750.
	4750.	4750.	4750.	4750.						
0 13	4790.	4790.	4790.	4780.	4780.	4750.	4760.	4760.	4770.	4770.
	4770.	4770.	4760.	4760.	4770.	4770.	4770.	4770.	4770.	4770.
	4780.	4780.	4780.	4780.	4800.	4800.	4780.	4750.	4750.	4750.
	4750.	4750.	4750.	4750.						
0 14	4790.	4780.	4810.	4780.	4780.	4760.	4760.	4750.	4760.	4770.
	4770.	4770.	4760.	4760.	4760.	4760.	4770.	4770.	4770.	4770.
	4780.	4790.	4780.	4790.	4810.	4800.	4800.	4780.	4750.	4750.
	4750.	4750.	4750.	4750.						
0 15	4790.	4790.	4800.	4780.	4780.	4780.	4760.	4750.	4760.	4770.
	4770.	4770.	4770.	4760.	4760.	4760.	4770.	4770.	4770.	4770.
	4770.	4790.	4770.	4780.	4810.	4790.	4810.	4790.	4770.	4770.
	4750.	4750.	4750.	4750.						
0 16	4790.	4790.	4800.	4780.	4780.	4780.	4760.	4760.	4750.	4760.
	4770.	4770.	4770.	4750.	4750.	4760.	4760.	4770.	4760.	4760.
	4770.	4770.	4770.	4770.	4800.	4790.	4830.	4800.	4770.	4770.
	4750.	4750.	4750.	4750.						
0 17	4790.	4790.	4790.	4790.	4780.	4780.	4760.	4760.	4760.	4760.
	4770.	4770.	4760.	4750.	4760.	4760.	4760.	4750.	4750.	4750.
	4770.	4770.	4770.	4770.	4800.	4770.	4760.	4800.	4770.	4770.
	4750.	4750.	4750.	4750.						
0 18	4790.	4790.	4790.	4790.	4780.	4780.	4760.	4760.	4760.	4770.
	4770.	4770.	4760.	4760.	4760.	4760.	4760.	4750.	4750.	4750.
	4770.	4780.	4770.	4770.	4800.	4760.	4780.	4790.	4770.	4770.
	4750.	4750.	4750.	4750.						
0										

VERT HYD COND /THICKNESS FOR LAYER 1 WILL BE READ ON UNIT 11 USING FORMAT: (8G10.3)

	1 11 21 31	2 12 22 32	3 13 23 33	4 14 24 34	5 15 25	6 16 26	7 17 27	8 18 28	9 19 29	10 20 30
0 1	1.1000E-03	1.0900E-03	1.1600E-03	1.0100E-03	1.1100E-03	1.3300E-03	1.2000E-03	9.6200E-05	2.0700E-04	2.0600E-04
	1.4900E-04	1.3600E-04	1.1400E-04	8.6300E-03	4.8500E-05	4.8400E-05	4.9200E-05	2.3800E-05	1.3100E-04	1.3300E-04
	3.1300E-04	3.3300E-04	3.7100E-04	2.9900E-04	5.1500E-04	8.3000E-04	9.7300E-04	9.1200E-04	1.0300E-03	1.0200E-03
	9.9000E-04	9.9800E-04	9.9400E-04	9.8800E-04						
0 2	1.0700E-03	1.0400E-03	1.0900E-03	1.0700E-03	1.2700E-03	4.4300E-04	1.1300E-03	9.4600E-05	8.5000E-03	2.2400E-04
	1.4900E-04	1.3400E-04	8.9500E-05	1.3600E-04	4.3000E-05	4.4600E-05	4.4600E-05	9.7500E-06	1.2100E-04	1.3100E-04
	1.5300E-04	3.5200E-04	3.6800E-04	3.5000E-04	4.2500E-04	2.8900E-04	1.1700E-03	1.1800E-03	1.1700E-03	1.1100E-03
	1.0300E-03	1.0100E-03	1.0100E-03	1.0000E-03						
0 3	1.0300E-03	9.8400E-04	1.0000E-03	8.5100E-04	1.2000E-03	1.1700E-03	9.9100E-04	8.7500E-05	2.2000E-03	2.4200E-03
	1.5000E-03	1.3900E-03	9.4700E-05	1.0100E-05	4.0800E-05	3.9800E-05	3.6700E-05	7.2200E-06	1.1200E-04	1.2200E-04
	1.2100E-04	3.2100E-04	3.3200E-04	4.1200E-04	4.1200E-04	2.5600E-04	1.9700E-03	1.7200E-03	1.3800E-03	1.2300E-03
	1.0800E-03	1.0300E-03	1.0300E-03	1.0900E-03						
0 4	1.0200E-03	9.4000E-04	8.0600E-04	7.7000E-04	8.9200E-04	1.0800E-03	6.6300E-04	7.7500E-05	1.8100E-04	2.0100E-04
	1.5100E-04	1.3100E-04	8.2000E-05	6.5300E-05	3.4800E-05	4.0500E-05	1.9100E-05	3.0800E-06	5.0800E-05	8.3000E-05
	1.4000E-04	2.6500E-04	3.0300E-04	3.8200E-04	3.8200E-04	1.6900E-04	3.9900E-03	5.1800E-03	1.6000E-03	1.3100E-03
	1.1100E-03	1.0700E-03	1.0400E-03	1.1000E-03						
0 5	1.0100E-03	9.1700E-04	7.6600E-04	7.1300E-04	7.9700E-04	9.7900E-04	3.3300E-04	7.3900E-05	1.5100E-04	1.5700E-06
	1.5100E-09	1.3000E-06	7.7300E-05	5.7700E-05	3.2800E-05	4.0700E-05	2.1500E-05	7.1500E-06	3.7800E-05	4.5900E-05
	1.6200E-04	2.4100E-04	3.3000E-04	4.0500E-04	3.8900E-04	3.5900E-04	5.8700E-03	5.2200E-03	1.6500E-03	1.3400E-03
	1.1300E-03	1.0800E-03	1.1300E-03	1.1100E-03						
0 6	9.7300E-04	8.6700E-04	6.8000E-04	7.8000E-04	7.4900E-04	8.3700E-04	3.6200E-04	7.2300E-05	1.3800E-04	1.5100E-06
	1.5100E-07	1.3000E-07	9.0300E-07	3.9700E-07	3.0700E-07	2.7000E-05	2.3900E-05	9.0700E-06	2.6300E-05	3.7400E-05
	1.6100E-04	2.6900E-04	3.2300E-04	4.3700E-05	4.2600E-04	6.7500E-04	3.7300E-03	2.4900E-03	1.6400E-03	1.4000E-03
	1.2400E-03	1.1700E-03	1.1400E-03	1.1100E-03						
0 7	9.4100E-04	8.6700E-04	6.6200E-04	7.2300E-04	6.9900E-04	7.4900E-04	3.3900E-04	6.1100E-05	1.2600E-04	1.4600E-06
	1.5100E-06	1.3000E-07	9.0800E-07	5.3000E-07	4.5600E-07	2.8000E-07	2.6300E-05	1.4800E-05	1.2600E-05	3.5500E-05
	1.6200E-04	2.4000E-04	3.2500E-04	4.7300E-04	4.6600E-04	7.2500E-04	2.7300E-03	2.1700E-03	1.5800E-03	1.3900E-03
	1.2400E-03	1.1800E-03	1.1400E-03	1.1200E-03						
0 8	1.0200E-03	9.0400E-04	7.0100E-04	5.7300E-04	6.2900E-04	5.9900E-04	2.3600E-05	3.8300E-05	1.1300E-04	1.4000E-05
	1.5000E-07	1.3600E-07	1.0100E-09	7.1700E-07	3.1000E-06	3.0200E-05	2.9500E-05	2.2800E-05	4.8000E-05	5.0900E-05
	1.3300E-04	2.2300E-04	3.2300E-04	4.2200E-04	5.5500E-04	5.6300E-04	2.1400E-03	1.7800E-03	1.4600E-03	1.3300E-03
	1.2200E-03	1.1700E-03	1.1400E-03	1.1100E-03						

0 9	3.3000E-03	9.8300E-04	7.1000E-04	6.0500E-04	5.3000E-04	4.4200E-04	1.3200E-05	6.0700E-05	1.1600E-04	1.3300E-04
	1.5900E-07	1.3700E-07	1.0500E-07	5.5200E-07	3.5100E-06	3.3400E-05	3.1900E-05	2.3700E-05	6.5000E-05	5.7500E-05
	3.4100E-05	1.9600E-04	2.9500E-04	3.4100E-04	4.9700E-04	1.9200E-03	1.6600E-03	1.4400E-03	1.3100E-03	1.1300E-03
	1.0600E-03	1.0500E-03	1.0300E-03	1.1100E-03						
0 10	3.5900E-03	1.0400E-03	8.1400E-04	5.3000E-04	5.1700E-04	5.3000E-04	2.3600E-04	8.3100E-05	1.2100E-04	9.0800E-04
	8.7800E-05	1.5400E-09	1.2900E-09	6.2700E-06	3.9800E-05	3.6100E-05	2.7100E-05	1.7500E-05	1.2200E-04	1.1600E-04
	1.9100E-04	2.5800E-04	3.0900E-04	3.4100E-04	4.1000E-04	1.7900E-03	1.5300E-03	1.3300E-03	1.1400E-03	9.3800E-04
	1.0000E-03	1.0200E-03	1.0100E-03	1.0000E-03						
0 11	1.2100E-03	1.0900E-03	9.4000E-04	7.2200E-04	6.2500E-04	5.0800E-04	3.4600E-04	9.4800E-05	1.2300E-04	1.1900E-04
	5.7800E-05	1.7300E-07	1.5900E-07	7.3800E-06	5.1600E-05	5.2200E-05	4.5900E-05	3.0900E-05	1.6700E-04	1.7500E-04
	2.6100E-04	3.2000E-04	3.3900E-04	3.5700E-04	4.5800E-04	1.4900E-03	1.4600E-03	1.2100E-03	1.1700E-03	9.1900E-04
	9.2200E-04	9.2500E-04	9.2200E-04	9.1600E-04						
0 12	1.3500E-03	1.3000E-03	1.1800E-03	8.8500E-04	6.1100E-04	6.4700E-04	3.9000E-04	9.8800E-05	1.3300E-04	1.2100E-04
	1.4500E-04	1.4000E-07	1.9000E-07	8.4100E-05	7.2100E-05	7.3000E-05	6.5100E-05	5.6400E-05	2.1000E-04	2.3000E-04
	3.3900E-04	3.9200E-04	3.8600E-04	4.3300E-04	4.9900E-04	1.7000E-03	1.4100E-03	1.3600E-03	1.2000E-03	1.0900E-03
	9.1400E-04	9.0900E-04	9.0700E-04	9.0400E-04						
0 13	3.1400E-03	3.7200E-03	2.1300E-03	1.1600E-03	9.1600E-04	1.9800E-02	3.7600E-04	9.5400E-05	1.5600E-04	1.2700E-04
	2.1400E-04	2.8100E-04	2.4000E-04	8.7800E-05	5.6100E-05	8.6100E-05	9.1800E-05	8.1200E-05	2.5100E-04	2.8700E-04
	4.6900E-04	6.3400E-04	4.9600E-04	4.5500E-04	5.4000E-04	1.6400E-03	1.3700E-03	1.0900E-03	1.1000E-03	1.0300E-03
	1.0400E-03	8.9200E-04	8.9100E-04	8.9200E-04						
0 14	4.5600E-03	5.8200E-03	6.2900E-03	1.9100E-03	9.7800E-04	1.9800E-03	7.8400E-05	1.0000E-04	1.1700E-04	1.2400E-04
	2.6500E-04	3.5900E-04	2.7500E-04	1.4100E-04	8.2800E-05	1.0700E-04	1.2100E-04	1.1800E-04	2.7600E-04	2.9200E-04
	5.2900E-04	6.9300E-04	7.0400E-04	5.3000E-04	3.5700E-04	1.6500E-03	1.6700E-03	1.2300E-03	1.0300E-03	9.7900E-04
	1.0100E-03	8.6100E-04	8.8200E-04	8.9000E-04						
0 15	4.4900E-03	5.1600E-03	4.9400E-03	1.6000E-03	7.3600E-04	8.3500E-04	7.6200E-05	9.6900E-05	1.1000E-04	1.0800E-04
	3.0300E-04	3.7400E-04	3.5500E-04	1.9600E-04	1.0100E-04	1.3000E-04	1.8500E-04	2.0100E-04	2.7900E-04	2.9000E-04
	5.0700E-04	6.6100E-04	6.7000E-04	4.7500E-04	6.8700E-04	1.6400E-03	1.8800E-03	1.2200E-03	1.2500E-03	1.2400E-03
	9.7900E-04	9.5300E-04	8.6700E-04	8.8500E-04						
0 16	3.3100E-03	3.3900E-03	2.6000E-03	1.2600E-03	1.2400E-03	8.0700E-04	3.5600E-04	7.7900E-05	1.2500E-04	1.6300E-04
	2.2000E-04	3.4600E-04	2.7300E-04	2.4400E-04	1.0400E-04	1.2600E-04	1.4100E-04	1.3200E-04	2.4300E-04	2.6000E-04
	4.1400E-04	4.8300E-04	4.6300E-04	4.3500E-04	6.7000E-04	1.5800E-03	1.2500E-03	1.3200E-03	1.2800E-03	1.2600E-03
	9.9900E-04	1.0500E-03	9.0000E-04	9.0500E-04						
0 17	2.5700E-03	2.5000E-03	1.9600E-03	1.1400E-03	1.2300E-03	7.9200E-04	3.8000E-04	7.6800E-05	1.4100E-04	1.6500E-04
	1.9900E-04	2.3300E-04	2.0600E-04	2.2000E-04	9.1300E-05	1.1600E-04	1.1900E-04	8.4000E-05	2.1900E-04	2.2900E-04
	3.9100E-04	4.6200E-04	4.4300E-04	4.2300E-04	6.7900E-04	1.6100E-03	8.7500E-04	1.2800E-03	1.3000E-03	1.2700E-03
	1.0500E-03	1.1800E-03	9.4000E-04	9.1800E-04						
0 18	2.3100E-03	1.4500E-03	1.4100E-03	1.0500E-03	1.1900E-03	7.4000E-04	4.0200E-04	3.2900E-04	1.5800E-04	1.6900E-04
	1.9600E-04	1.9900E-04	1.9500E-04	1.3800E-04	8.9100E-05	9.4900E-05	9.5500E-05	7.3700E-05	2.1000E-04	2.1800E-04
	3.7800E-04	4.5100E-04	4.3200E-04	4.1200E-04	6.4500E-04	1.6700E-03	1.6600E-03	1.2400E-03	1.3000E-03	1.3000E-03
	1.0300E-03	1.1300E-03	9.3800E-04	9.1900E-04						
0										

TRANSMIS. ALONG ROWS FOR LAYER 2 WILL BE READ ON UNIT 11 USING FORMAT: (8G10.3)

	1 11 21 31	2 12 22 32	3 13 23 33	4 14 24 34	5 15 25	6 16 26	7 17 27	8 18 28	9 19 29	10 20 30
0 1	982.0	977.0	798.0	956.0	869.0	688.0	816.0	819.0	886.0	817.0
	1470.	1390.	1580.	535.0	1100.	1070.	938.0	1430.	579.0	521.0
	1080.	784.0	568.0	26.40	22.70	21.70	195.0	0.0000	83.40	50.20
	0.0000	0.0000	0.0000	0.0000						
0 2	1010.	1020.	836.0	818.0	556.0	374.0	823.0	712.0	662.0	841.0
	1410.	1230.	1320.	179.0	1140.	966.0	935.0	1380.	455.0	172.0
	1000.	854.0	676.0	148.0	138.0	27.50	299.0	168.0	113.0	74.50
	0.0000	0.0000	0.0000	0.0000						
0 3	1040.	1080.	912.0	1070.	633.0	584.0	713.0	673.0	270.0	859.0
	1450.	919.0	849.0	231.0	1040.	48.80	798.0	1570.	381.0	144.0
	809.0	872.0	835.0	270.0	368.0	134.0	599.0	372.0	178.0	111.0
	0.0000	0.0000	0.0000	106.0						
0 4	1060.	1140.	1220.	1220.	962.0	540.0	463.0	784.0	932.0	1010.
	1600.	1340.	1580.	369.0	1000.	29.80	712.0	2100.	870.0	266.0
	1330.	1020.	922.0	343.0	471.0	299.0	1120.	737.0	226.0	138.0
	0.0000	0.0000	0.0000	109.0						
0 5	1060.	1170.	1300.	1340.	1110.	542.0	104.0	914.0	1180.	1210.
	1740.	1510.	1790.	400.0	990.0	39.10	774.0	1760.	1310.	1060.
	1640.	1090.	911.0	385.0	488.0	426.0	1390.	789.0	253.0	149.0
	0.0000	0.0000	105.0	111.0						
0 6	1120.	1270.	1660.	1210.	1200.	759.0	1340.	1110.	1410.	1400.
	1890.	1640.	1830.	144.0	999.0	823.0	974.0	1790.	1490.	1300.
	1560.	1120.	720.0	422.0	457.0	521.0	1060.	570.0	238.0	154.0
	128.0	113.0	109.0	113.0						
0 7	1000.	1260.	1720.	1340.	1320.	975.0	1690.	1880.	1630.	1620.
	2080.	1760.	1890.	197.0	1100.	1110.	1250.	1850.	1930.	1420.
	1470.	1420.	703.0	457.0	469.0	496.0	764.0	474.0	219.0	150.0
	131.0	117.0	112.0	111.0						
0 8	891.0	1190.	1610.	2040.	1470.	1240.	1840.	2530.	1930.	2190.
	2460.	2060.	519.0	356.0	1500.	1440.	1740.	1590.	1260.	1230.
	1040.	1490.	639.0	416.0	453.0	346.0	514.0	318.0	177.0	132.0
	126.0	117.0	113.0	112.0						

	3410.	2890.	2590.	1810.				[illegible]	[illegible]	[illegible]
	2530.	1030.	625.0	813.0	1820.	2200.	2900.	1640.	1080.	1130.
	0.0000	0.0000	0.0000	112.0	332.0	372.0	280.0	223.0	122.0	0.0000
0 10	0.0000	851.0	1130.	1790.	1820.	1100.	1490.	5740.	1830.	900.0
	900.0	3390.	3400.	1820.	1990.	2270.	2000.	2460.	1430.	1460.
	1460.	1270.	607.0	412.0	326.0	325.0	212.0	166.0	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 11	726.0	811.0	933.0	1230.	1330.	1500.	1000.	1650.	2750.	3410.
	4250.	3380.	3390.	1550.	1310.	2070.	2390.	1940.	1390.	1290.
	1230.	1170.	566.0	405.0	363.0	309.0	162.0	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 12	659.0	674.0	722.0	987.0	1450.	1820.	713.0	1380.	1700.	2740.
	2560.	1630.	3050.	1190.	1090.	1420.	1190.	1260.	1350.	1210.
	1250.	940.0	389.0	400.0	367.0	322.0	146.0	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 13	204.0	198.0	320.0	720.0	873.0	15.90	529.0	499.0	1270.	1570.
	1690.	1130.	2910.	930.0	636.0	1030.	918.0	821.0	1490.	1300.
	1080.	649.0	392.0	178.0	429.0	322.0	157.0	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 14	141.0	83.60	81.60	339.0	870.0	38.70	671.0	190.0	859.0	1150.
	740.0	236.0	1200.	713.0	774.0	918.0	693.0	617.0	1390.	1390.
	966.0	819.0	390.0	236.0	136.0	346.0	345.0	226.0	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 15	147.0	113.0	134.0	482.0	1340.	1030.	594.0	310.0	702.0	889.0
	576.0	341.0	812.0	512.0	743.0	869.0	449.0	364.0	1230.	1210.
	890.0	860.0	237.0	168.0	495.0	409.0	499.0	379.0	168.0	113.0
	0.0000	0.0000	0.0000	0.0000						
0 16	195.0	189.0	254.0	722.0	619.0	1140.	583.0	225.0	316.0	649.0
	1650.	516.0	1410.	13.00	278.0	688.0	323.0	416.0	300.0	612.0
	885.0	494.0	238.0	132.0	613.0	422.0	1000.	528.0	192.0	135.0
	0.0000	0.0000	0.0000	0.0000						
0 17	230.0	242.0	369.0	827.0	627.0	1210.	603.0	263.0	452.0	595.0
	1710.	1630.	1620.	34.90	590.0	877.0	354.0	332.0	82.80	162.0
	923.0	539.0	323.0	146.0	541.0	126.0	134.0	467.0	163.0	130.0
	0.0000	0.0000	0.0000	0.0000						
0 18	260.0	612.0	617.0	893.0	659.0	1260.	660.0	351.0	611.0	656.0
	1740.	1680.	1730.	568.0	864.0	938.0	478.0	353.0	123.0	228.0
	977.0	592.0	339.0	157.0	490.0	81.10	278.0	360.0	143.0	125.0
	0.0000	0.0000	0.0000	0.0000						
0										

SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE

MAXIMUM ITERATIONS ALLOWED FOR CLOSURE = /200
ACCELERATION PARAMETER = 1.0000
HEAD CHANGE CRITERION FOR CLOSURE = 0.10000E-01
SIP HEAD CHANGE PRINTOUT INTERVAL = 999
CALCULATE ITERATION PARAMETERS FROM MODEL CALCULATED WSEED
STRESS PERIOD NO. 1, LENGTH = 1.000000

NUMBER OF TIME STEPS = 1

MULTIPLIER FOR DELT = 1.000

INITIAL TIME STEP SIZE = 1.000000

44 WELLS

LAYER	ROW	COL	STRESS RATE	WELL NO.
1	14	1	9000.0	1
1	14	2	3000.0	2
1	14	3	1500.0	3
1	14	4	1500.0	4
1	14	5	1000.0	5
1	13	6	900.00	6
1	14	7	500.00	7
1	14	8	800.00	8
1	15	9	300.00	9
1	15	10	300.00	10
1	14	11	500.00	11
1	14	12	500.00	12
1	15	13	250.00	13
1	16	14	800.00	14
1	16	15	800.00	15
1	16	16	1000.0	16
1	16	17	1200.0	17
1	16	18	900.00	18
1	16	19	900.00	19
1	15	22	800.00	20
1	15	23	100.00	21
1	15	24	100.00	22
1	16	25	100.00	23
1	17	26	100.00	24
1	18	27	100.00	25
1	18	28	100.00	26
1	13	28	100.00	27
1	12	28	100.00	28
1	11	29	100.00	29
1	10	30	100.00	30
1	9	30	100.00	31
1	8	30	100.00	32
1	5	31	100.00	33
1	2	31	300.00	34
1	1	30	200.00	35
1	7	30	200.00	36
1	8	4	6000.0	37
1	9	3	6000.0	38
1	2	4	11000.	39
1	3	31	200.00	40
1	1	12	-1100.0	41
1	1	13	-4635.0	42
1	1	14	-19600.	43
1	1	15	-5800.0	44

ET SURFACE WILL BE READ ON UNIT 15 USING FORMAT: (8G10.3)

	1 11 21 31	2 12 22 32	3 13 23 33	4 14 24 34	5 15 25	6 16 26	7 17 27	8 18 28	9 19 29	10 20 30
0 1	4970.	4980.	4980.	4980.	4970.	4970.	4940.	4940.	4940.	4940.
	4920.	4920.	4920.	4930.	4920.	4920.	4930.	4930.	4930.	4930.
	4930.	4970.	5020.	5090.	5070.	5100.	5130.	5200.	5170.	5190.
	5190.	5180.	5180.	5180.						
0 2	4970.	4970.	4980.	4980.	4990.	4990.	4950.	4940.	4930.	4940.
	4920.	4920.	4920.	4940.	4920.	4920.	4920.	4920.	4930.	4950.
	4930.	4940.	5000.	5050.	5050.	5040.	5110.	5160.	5170.	5180.
	5200.	5200.	5180.	5180.						
0 3	4970.	4970.	4970.	4970.	4990.	4970.	4940.	4940.	4940.	4930.
	4920.	4930.	4930.	4940.	4920.	4920.	4920.	4920.	4940.	4940.
	4930.	4940.	4980.	5010.	5030.	5040.	5070.	5120.	5500.	5170.
	5200.	5200.	5180.	5160.						
0 4	4970.	4970.	4970.	4970.	4960.	4960.	4940.	4940.	4930.	4940.
	4920.	4920.	4920.	4940.	4920.	4920.	4920.	4920.	4930.	4950.
	4930.	4950.	4970.	4990.	5020.	5020.	5040.	5100.	5140.	5160.
	5190.	5190.	5180.	5150.						
0 5	4970.	4970.	4960.	4970.	4960.	4950.	4940.	4940.	4940.	4940.
	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4930.
	4920.	4950.	4960.	4970.	5010.	5010.	5030.	5090.	5140.	5160.
	5190.	5180.	5160.	5150.						
0 6	4980.	4970.	4960.	4970.	4960.	4950.	4940.	4940.	4940.	4940.
	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4920.
	4920.	4950.	4970.	4960.	4970.	4990.	5030.	5100.	5140.	5150.
	5150.	5160.	5150.	5150.						
0 7	4980.	4970.	4960.	4970.	4960.	4950.	4940.	4940.	4940.	4940.
	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4930.
	4920.	4950.	4970.	4950.	4960.	4990.	5040.	5100.	5140.	5150.
	5150.	5150.	5150.	5150.						
0 8	4980.	4970.	4960.	4960.	4960.	4950.	4930.	4930.	4940.	4930.
	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4930.	4930.	4930.
	4930.	4940.	4970.	4960.	4990.	5010.	5040.	5110.	5150.	5160.
	5150.	5150.	5150.	5150.						

0 9	4990.	4980.	4960.	4960.	4950.	4950.	4930.	4940.	4930.	4930.
	4920.	4920.	4920.	4920.	4920.	4920.	4910.	4930.	4930.	4920.
	4920.	4940.	4970.	4970.	5010.	5010.	5060.	5120.	5150.	5200.
	5190.	5180.	5180.	5140.						
0 10	4990.	4980.	4970.	4960.	4950.	4950.	4940.	4940.	4930.	4920.
	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4930.	4930.	4930.
	4930.	4950.	4970.	4980.	5010.	5010.	5070.	5120.	5180.	5230.
	5190.	5180.	5170.	5170.						
0 11	4980.	4980.	4970.	4960.	4960.	4950.	4950.	4940.	4930.	4930.
	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4930.	4930.	4930.
	4950.	4950.	4970.	4970.	4990.	5000.	5060.	5130.	5140.	5180.
	5180.	5170.	5170.	5170.						
0 12	4980.	4980.	4980.	4960.	4950.	4950.	4950.	4950.	4940.	4930.
	4920.	4920.	4920.	4920.	4920.	4920.	4920.	4930.	4930.	4930.
	4940.	4950.	4970.	4960.	4980.	5000.	5060.	5060.	5110.	5150.
	5160.	5160.	5160.	5160.						
0 13	4980.	4980.	4980.	4960.	4960.	4960.	4960.	4960.	4940.	4940.
	4920.	4920.	4920.	4920.	4920.	4920.	4930.	4940.	4940.	4940.
	4940.	4950.	4960.	4970.	4980.	4990.	5050.	5120.	5120.	5150.
	5150.	5160.	5160.	5160.						
0 14	4980.	4980.	4970.	4960.	4960.	4960.	4960.	4940.	4950.	4940.
	4920.	4920.	4920.	4930.	4920.	4920.	4930.	4940.	4940.	4950.
	4940.	4940.	4960.	4960.	4960.	4980.	5010.	5080.	5140.	5150.
	5150.	5160.	5150.	5150.						
0 15	4980.	4980.	4970.	4960.	4950.	4950.	4970.	4940.	4960.	4950.
	4920.	4920.	4920.	4930.	4930.	4930.	4930.	4930.	4950.	4960.
	4950.	4940.	4970.	4970.	4970.	4980.	4980.	5060.	5060.	5080.
	5150.	5170.	5150.	5150.						
0 16	4980.	4980.	4970.	4960.	4970.	4950.	4980.	5000.	5020.	4970.
	4920.	4920.	4920.	4950.	4940.	4930.	4940.	4950.	4990.	4980.
	4950.	4960.	4970.	4980.	4990.	4980.	4980.	5040.	5050.	5070.
	5130.	5120.	5130.	5130.						
0 17	4980.	4980.	4980.	4960.	4970.	4950.	4990.	5010.	4990.	4970.
	4920.	4920.	4920.	4950.	4940.	4930.	4940.	4990.	5010.	5000.
	4950.	4950.	4970.	4980.	4980.	4980.	4990.	5060.	5050.	5060.
	5110.	5080.	5110.	5120.						
0 18	4980.	4980.	4970.	4960.	4970.	4950.	4980.	5000.	4970.	4970.
	4920.	4920.	4920.	4940.	4930.	4930.	4940.	4990.	5000.	5000.
	4950.	4950.	4970.	4980.	4990.	4980.	4990.	5070.	5040.	5060.
	5110.	5090.	5100.	5120.						
0										

```
0
0AVERAGE SEED = 0.00122103                                              EXTINCTION DEPTH =   21.00000
 MINIMUM SEED = 0.00000021
0
    5 ITERATION PARAMETERS CALCULATED FROM AVERAGE SEED:

  1          0.0000000E+00  0.8130689E+00  0.9650568E+00  0.9934680E+00  0.9987790E+00
0
    37 ITERATIONS FOR TIME STEP    1 IN STRESS PERIOD   1
0MAXIMUM HEAD CHANGE FOR EACH ITERATION:
0 HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL
 ------------------------------------------------------------------------------------------------------------------------------------
    30.17      (  1,  2,  4)   11.55      (  2, 14,  1)  -10.76      (  1,  1, 15)   10.48      (  1, 14,  3)   6.145      (  2,  2, 11)
   -3.182      (  1,  8, 10)  -1.621      (  1,  1, 12)   2.084      (  2, 14,  1)  -1.774      (  1,  1, 15)  -2.294      (  1, 10, 30)
   -1.248      (  1, 15, 29) -0.5369      (  1, 16, 29) -0.3980      (  1,  1, 15)  -2.268      (  1, 16, 34) -0.4357      (  2,  8,  7)
  -0.5339      (  1, 15, 28) -0.9637E-01 (  2, 14, 27) -0.1731      (  1, 14, 28)  0.1178      (  2,  2,  6) -0.2046      (  1, 14, 28)
  -0.1076      (  1, 15, 29) -0.3098E-01 (  1, 16, 29) -0.2673E-01 (  1, 15, 13) -0.8697E-01 (  1, 16, 34) -0.3499E-01 (  1,  2, 17)
  -0.3430E-01 (  1, 15, 29) -0.1071E-01 (  1, 17, 27) -0.2161E-01 (  1, 18, 27) -0.1549E-01 (  1,  1, 15) -0.7714E-01 (  1, 11, 29)
  -0.3626E-01 (  1, 15, 29) -0.1640E-01 (  1, 16, 29) -0.1607E-01 (  1,  1, 15) -0.7370E-01 (  1, 16, 34) -0.3247E-01 (  2,  8,  7)
  -0.1867E-01 (  1, 14,  7) -0.6478E-02 (  1, 15,  9)
0
0HEAD/DRAWDOWN PRINTOUT FLAG = 1     TOTAL BUDGET PRINTOUT FLAG = 1     CELL-BY-CELL FLOW TERM FLAG = 0
0OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:
   HEAD    DRAWDOWN  HEAD  DRAWDOWN
 PRINTOUT  PRINTOUT  SAVE    SAVE
 ----------------------------------
     1         0       1       0
```

EVAPOTRANSPIRATION RATE WILL BE READ ON UNIT 15 USING FORMAT: (8G10.4)

	1 11 21 31	2 12 22 32	3 13 23 33	4 14 24 34	5 15 25	6 16 26	7 17 27	8 18 28	9 19 29	10 20 30
0 1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 3	0.0000	0.0000	0.0000	0.0000	2.8000E-03	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03
	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 4	0.0000	0.0000	0.0000	0.0000	2.8000E-03	0.0000	0.0000	0.0000	2.8000E-03	0.0000
	0.0000	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03
	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 5	0.0000	0.0000	0.0000	0.0000	2.8000E-03	0.0000	0.0000	2.8000E-03	2.8000E-03	0.0000
	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	0.0000	2.8000E-03	2.8000E-03	2.8000E-03
	2.8000E-03	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 6	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	0.0000	2.8000E-03	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03
	2.8000E-03	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 7	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03
	2.8000E-03	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03
	2.8000E-03	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						

0 9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03
	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03
	2.8000E-03	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03
	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03
	2.8000E-03	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03
	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03
	2.8000E-03	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03
	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03
	2.8000E-03	2.8000E-03	0.0000	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03
	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.8000E-03
	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03
	2.8000E-03	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	2.8000E-03	2.8000E-03	2.8000E-03	2.8000E-03	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						
0 18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000						

1

HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10
	11	12	13	14	15	16	17	18	19	20
	21	22	23	24	25	26	27	28	29	30
	31	32	33	34						
0 1	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	4870.	4869.	4866.	4869.	999.0	999.0	999.0	999.0	999.0
	999.0	4901.	4901.	4901.	4902.	4902.	4902.	4903.	4903.	4903.
	4903.	999.0	999.0	999.0						
0 2	999.0	999.0	999.0	4957.	4938.	4928.	4922.	4918.	4913.	4908.
	4902.	4890.	4878.	4877.	4879.	4885.	4888.	4892.	4896.	4898.
	4899.	4900.	4901.	4902.	4902.	4902.	4902.	4903.	4903.	4903.
	4903.	999.0	999.0	999.0						
0 3	999.0	999.0	999.0	999.0	4929.	4926.	4921.	4918.	4913.	4909.
	4905.	4900.	4884.	4881.	4883.	4887.	4890.	4893.	4896.	4898.
	4899.	4900.	4901.	4902.	4902.	4902.	4903.	4903.	4903.	4903.
	4903.	999.0	999.0	999.0						
0 4	999.0	999.0	999.0	999.0	4926.	4924.	4921.	4917.	4911.	4910.
	4905.	4899.	4885.	4883.	4884.	4888.	4891.	4894.	4896.	4898.
	4900.	4901.	4901.	4902.	4902.	4902.	4903.	4903.	4903.	4903.
	4903.	999.0	999.0	999.0						
0 5	999.0	999.0	999.0	999.0	4925.	4923.	4920.	4916.	4913.	4910.
	4905.	4899.	4894.	4884.	4886.	4890.	4892.	4894.	4897.	4899.
	4900.	4901.	4902.	4902.	4902.	4902.	4903.	4903.	4903.	4903.
	4903.	999.0	999.0	999.0						
0 6	999.0	999.0	999.0	4926.	4925.	4923.	4919.	4916.	4913.	4910.
	4906.	4899.	4892.	4885.	4887.	4891.	4893.	4896.	4898.	4899.
	4900.	4901.	4902.	4902.	4902.	4902.	4903.	4903.	4903.	4903.
	999.0	999.0	999.0	999.0						
0 7	999.0	999.0	999.0	4927.	4925.	4922.	4918.	4915.	4914.	4911.
	4907.	4900.	4894.	4887.	4889.	4892.	4894.	4897.	4899.	4900.
	4901.	4901.	4902.	4902.	4902.	4903.	4903.	4903.	4903.	4903.
	999.0	999.0	999.0	999.0						
0 8	999.0	999.0	999.0	4932.	4925.	4922.	4915.	4913.	4913.	4910.
	4907.	4902.	4896.	4892.	4894.	4895.	4897.	4898.	4900.	4900.
	4901.	4902.	4902.	4903.	4903.	4903.	4903.	4903.	4903.	4903.
	999.0	999.0	999.0	999.0						

[illegible]	999.0	999.0	4933.	4928.	4924.	4922.	4918.	4916.	4912.	4910.
	4907.	4903.	4901.	4900.	4901.	4901.	4898.	4900.	4901.	4901.
	4902.	4903.	4903.	4903.	4903.	4903.	4903.	4903.	4903.	4903.
	999.0	999.0	999.0	999.0						
0 10	999.0	999.0	4929.	4927.	4925.	4922.	4920.	4918.	4912.	4910.
	4903.	4903.	4903.	4903.	4903.	4901.	4901.	4902.	4903.	4903.
	4903.	4903.	4903.	4903.	4903.	4903.	4903.	4903.	4904.	4904.
	999.0	999.0	999.0	999.0						
0 11	999.0	999.0	4929.	4928.	4926.	4923.	4921.	4919.	4913.	4910.
	4903.	4904.	4904.	4904.	4903.	4902.	4902.	4903.	4904.	4904.
	4904.	4904.	4904.	4904.	4904.	4904.	4904.	4904.	4904.	999.0
	999.0	999.0	999.0	999.0						
0 12	999.0	999.0	4931.	4930.	4928.	4925.	4922.	4919.	4914.	4911.
	4905.	4905.	4906.	4905.	4903.	4902.	4903.	4904.	4904.	4904.
	4904.	4904.	4904.	4904.	4904.	4904.	4904.	4904.	999.0	999.0
	999.0	999.0	999.0	999.0						
0 13	999.0	4939.	4935.	4932.	4930.	4927.	4923.	4919.	4914.	4911.
	4906.	4906.	4907.	4904.	4903.	4903.	4904.	4904.	4905.	4905.
	4905.	4904.	4904.	4904.	4904.	4904.	4904.	4904.	999.0	999.0
	999.0	999.0	999.0	999.0						
0 14	4947.	4942.	4938.	4934.	4932.	999.0	4926.	4922.	4915.	4912.
	4908.	4907.	4905.	4906.	4904.	4904.	4905.	4905.	4905.	4905.
	4905.	4905.	4905.	4904.	4904.	4904.	4904.	4904.	999.0	999.0
	999.0	999.0	999.0	999.0						
0 15	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	4915.	4915.
	999.0	999.0	4908.	4908.	4908.	4907.	4907.	4906.	4906.	4905.
	4905.	4905.	4905.	4905.	4904.	4904.	4904.	4904.	4905.	4905.
	4905.	4905.	4905.	4905.						
0 16	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	4912.	4911.	4910.	4909.	4907.	4906.	4906.
	4906.	999.0	999.0	999.0	4905.	4905.	4905.	4905.	4905.	4905.
	4905.	4905.	4905.	4905.						
0 17	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	4905.	4905.	4905.	4905.	4905.
	4905.	4905.	4905.	4905.						
0 18	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	999.0	4905.	4905.	4905.	4905.
	4905.	4905.	4905.	4905.						

1 HEAD IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1 11 21 31	2 12 22 32	3 13 23 33	4 14 24 34	5 15 25	6 16 26	7 17 27	8 18 28	9 19 29	10 20 30
0 1	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 2	999.0	999.0	999.0	4950.	4937.	4928.	4922.	4918.	4913.	4909.
	4906.	4903.	4901.	4897.	4898.	4899.	4899.	4900.	4900.	4900.
	4901.	4901.	4901.	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 3	999.0	999.0	999.0	999.0	4929.	4925.	4921.	4917.	4913.	4909.
	4906.	4903.	4902.	4900.	4899.	4898.	4900.	4900.	4900.	4901.
	4901.	4901.	4901.	4902.	4902.	4902.	4903.	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 4	999.0	999.0	999.0	999.0	4926.	4924.	4920.	4916.	4913.	4910.
	4907.	4905.	4904.	4902.	4901.	4899.	4901.	4901.	4901.	4901.
	4901.	4901.	4902.	4902.	4902.	4902.	4903.	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 5	999.0	999.0	999.0	999.0	4925.	4923.	4920.	4916.	4913.	4910.
	4908.	4906.	4905.	4902.	4902.	4901.	4902.	4902.	4902.	4902.
	4902.	4902.	4902.	4902.	4902.	4902.	4903.	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 6	999.0	999.0	999.0	4926.	4925.	4922.	4919.	4916.	4913.	4911.
	4909.	4907.	4906.	4904.	4903.	4903.	4902.	4902.	4902.	4902.
	4902.	4902.	4902.	4902.	4902.	4903.	4903.	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 7	999.0	999.0	999.0	4926.	4924.	4922.	4918.	4916.	4914.	4911.
	4909.	4908.	4906.	4905.	4904.	4903.	4903.	4903.	4902.	4902.
	4902.	4902.	4902.	4902.	4902.	4903.	4903.	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 8	999.0	999.0	999.0	4926.	4924.	4921.	4918.	4916.	4914.	4912.
	4910.	4909.	4908.	4906.	4904.	4904.	4904.	4903.	4903.	4903.
	4903.	4903.	4902.	4903.	4903.	4903.	4903.	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						

0 9	999.0	999.0	4928.	4926.	4924.	4922.	4918.	4916.	4914.	4912.
	4910.	4909.	4908.	4907.	4905.	4905.	4904.	4904.	4904.	4903.
	4903.	4903.	4903.	4903.	4903.	4903.	4903.	4903.	999.0	999.0
	999.0	999.0	999.0	999.0						
0 10	999.0	999.0	4928.	4926.	4925.	4922.	4918.	4916.	4914.	4912.
	4910.	4909.	4908.	4907.	4906.	4905.	4905.	4904.	4904.	4904.
	4904.	4903.	4903.	4903.	4903.	4903.	4903.	4903.	999.0	999.0
	999.0	999.0	999.0	999.0						
0 11	999.0	999.0	4928.	4927.	4925.	4923.	4919.	4916.	4914.	4912.
	4911.	4909.	4908.	4907.	4906.	4905.	4905.	4905.	4904.	4904.
	4904.	4904.	4904.	4904.	4904.	4904.	4904.	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 12	999.0	999.0	4930.	4929.	4927.	4924.	4920.	4916.	4914.	4912.
	4911.	4909.	4908.	4907.	4906.	4905.	4905.	4905.	4905.	4905.
	4904.	4904.	4904.	4904.	4904.	4904.	4904.	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 13	999.0	4939.	4934.	4931.	4930.	999.0	4919.	4916.	4913.	4912.
	4910.	4909.	4908.	4907.	4906.	4906.	4905.	4905.	4905.	4905.
	4905.	4904.	4904.	4904.	4904.	4904.	4904.	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 14	4947.	4942.	4938.	4934.	4932.	999.0	999.0	4916.	4913.	4912.
	4910.	4908.	4908.	4907.	4906.	4906.	4905.	4905.	4905.	4905.
	4905.	4905.	4905.	4904.	4904.	4904.	4904.	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 15	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	4913.	4913.
	999.0	999.0	4907.	4907.	4906.	4906.	4906.	4905.	4905.	4905.
	4905.	4905.	4905.	4905.	4904.	4904.	4904.	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 16	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 17	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						
0 18	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0	999.0
	999.0	999.0	999.0	999.0						

0HEAD WILL BE SAVED ON UNIT 50 AT END OF TIME STEP 1, STRESS PERIOD 1

```
                    VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  1 IN STRESS PERIOD  1
                    ------------------------------------------------------------------------------
      CUMULATIVE VOLUMES      L**3                                 RATES FOR THIS TIME STEP      L**3/T
      ------------------                                           ------------------------

           IN:                                                          IN:
           ---                                                          ---
             STORAGE =   0.00000                                          STORAGE =   0.00000
       CONSTANT HEAD =   0.00000                                    CONSTANT HEAD =   0.00000
               WELLS =    51650.                                            WELLS =    51650.
                  ET =   0.00000                                               ET =   0.00000
            TOTAL IN =    51650.                                         TOTAL IN =    51650.
          OUT:                                                         OUT:
          ----                                                         ----
             STORAGE =   0.00000                                          STORAGE =   0.00000
       CONSTANT HEAD =   0.00000                                    CONSTANT HEAD =   0.00000
               WELLS =    31135.                                            WELLS =    31135.
                  ET =    20608.                                               ET =    20608.
           TOTAL OUT =    51743.                                        TOTAL OUT =    51743.
            IN - OUT =   -92.844                                         IN - OUT =   -92.844
 PERCENT DISCREPANCY =               -0.18                    PERCENT DISCREPANCY =               -0.18


TIME SUMMARY AT END OF TIME STEP  1 IN STRESS PERIOD  1
                   TIME STEP LENGTH =    1.00000
                  STRESS PERIOD TIME =    1.00000
               TOTAL SIMULATION TIME =    1.00000
```