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QUASI THREE-DIMENSIONAL MODELING OF GROUNDWATER FLOW IN THE MESILLA BOLSON, NEW MEXICO AND TEXAS

Technical Completion Report

Project No. 1235645

QUASI THREE-DIMENSIONAL MODELING OF GROUNDWATER FLOW IN THE MESILLA BOLSON, NEW MEXICO AND TEXAS

by

David M. Peterson
Graduate Research Assistant
New Mexico Institute of Mining and Technology

Raz Khaleel
Assistant Professor of Hydrology
New Mexico Institute of Mining and Technology

and

John W. Hawley
Senior Environmental Geologist
New Mexico Bureau of Mines and Mineral Resources

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ABSTRACT

A quasi three-dimensional model of groundwater flow has been developed for the Mesilla Bolson and Mesilla Valley stream-aquifer system in south-central New Mexico. The quasi three-dimensional model solves the two-dimensional horizontal flow equations in the Santa Fe Group and flood-plain alluvium aquifers, while simulating the steady state vertical leakage across the aquitards that separate the two aquifers. The model can account for groundwater-surface water interaction through stream infiltration, canal losses, drain discharge, and evapotranspiration.

A calibrated version of the quasi three-dimensional model was developed through steady state and transient analysis of the Mesilla Bolson and Mesilla Valley stream-aquifer system. In addition to quantitative estimates of the mountain front recharge, improved estimates of aquifer properties and confining bed characteristics were obtained through steady state calibration. Transient simulations during the 18-year period of 1966 to 1983 showed that groundwater-surface water exchange processes in the Mesilla Valley dominate the current head distributions in both aquifers from year to year. The mean annual volume of applied irrigation water during the period 1966-1983 was estimated as 240,300 acre-feet, while the average annual seepage loss from surface waterways for the same period was simulated as 116,200 acre-feet.

Predictive runs with the quasi three-dimensional model suggest that with continued and increased pumping for 100 years in the vicinity of Las Cruces only, the piezometric head levels in the Santa Fe Group within the cone of depression may be as much as 60 feet lower than existing levels. With the proposed El Paso wells on the West Mesa, piezometric head levels in the vicinity of the proposed well field may be as much as 200 to 400 feet lower than existing levels after 100 years of pumping, depending on recharge conditions in the Mesilla Valley and the behavior of storativity in the Santa Fe Group. The effects of proposed El Paso pumping on the West Mesa will be propagated to the Mesilla Valley; increased pumping will reduce drain flows and increase downward moving leakage.

Several limitations of the quasi three-dimensional model have been identified during the course of this modeling investigation. Consequently, the results of the predictive simulations should be used with caution. It is recommended that predictive simulation results be used primarily as qualitative (rather than as quantitative) indexes of the Mesilla Bolson's response to future stresses on the groundwater system.

Keywords: numerical simulation, subsurface hydrology, Mesilla Valley, stream-aquifer system.

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I. INTRODUCTION

The Mesilla Bolson, located in south-central New Mexico, is part of the Lower Rio Grande Basin. The agriculturally productive Mesilla Valley of the Rio Grande runs northwest-southeast through the eastern part of the bolson. The West Mesa (also known as La Mesa), an extensive bolson-floor remnant of middle Pleistocene age, and bordering mountain ranges east and west complete the physiographic features of the bolson (Figure 1). An alluvial aquifer approximately 60-100 feet thick underlies the modern Rio Grande channel and floodplain in the Mesilla Valley area. The Santa Fe Group aquifer underlies the alluvial aquifer and extends east-west from the valley to mountain ranges which enclose the bolson area.

This report documents the investigative procedures and results obtained during the second phase of a two-year project to model groundwater flow in the Mesilla Bolson. Our efforts during the second phase of study have centered around the simulation of three-dimensional groundwater movement in the bolson and the influence of pumping, surface water bodies, and other variables on the existing hydrologic budget of the region. Many of the recommendations from Phase I research (Khaleel et al., 1983) have been implemented.

It has been the continued intent of this research to provide a working and useful model of Mesilla Bolson groundwater flow, while taking into consideration the data and resource constraints that tend to limit the type of simulation that can be accomplished. Considerable time has, therefore, been devoted to determining feasible modeling objectives in addition to establishing the most important hydrologic concerns in the Mesilla Bolson from a water management perspective. Therefore, the model developed from this research cannot be considered as the most advanced analysis of the Mesilla Bolson's groundwater regime; rather, it represents the authors' best conceptualization

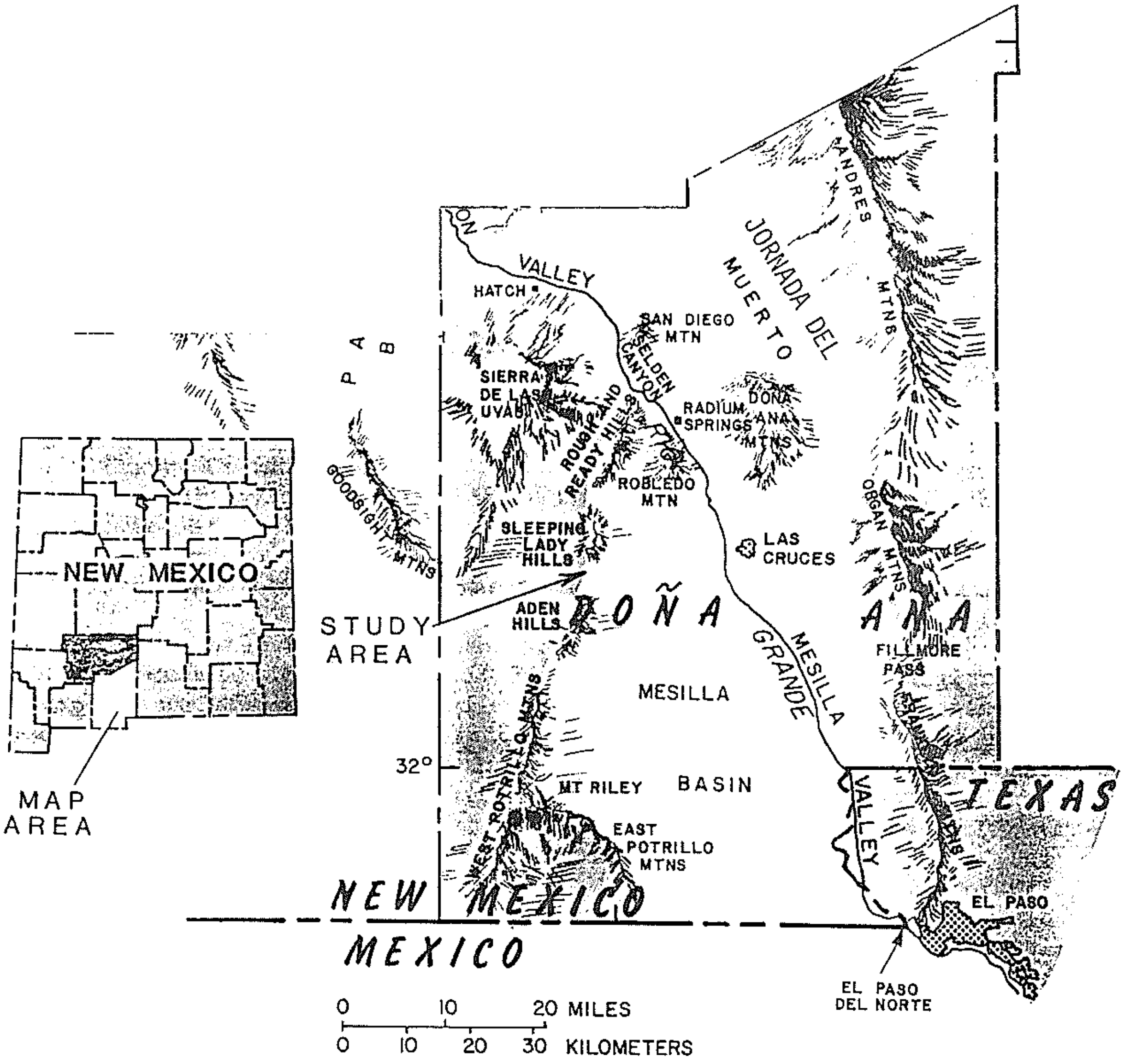


Figure 1. Location of the Study Area

of the area's geohydrology based on the limited data that exist for the region and what are believed to be the most significant modeling needs.

During the second phase of research, hydrogeologic cross sections of the Mesilla Bolson were completed. These crosssections provide valuable insight into the many diverse structural controls on groundwater movement and shed light on the relative ability of various geologic units to transmit water within the bolson. Accordingly, they have been utilized a great deal in developing the groundwater flow model. In the following sections, reference is frequently made to the cross sections; consequently, they have been appended to this report.

In Phase I (Khaleel et al., 1983) of the study, efforts were focused on modeling of two-dimensional groundwater flow within the Santa Fe Group geologic unit. Aside from some very preliminary simulations with a quasi three-dimensional model, limited attention was given to the concurrent flow of water in the Rio Grande flood-plain alluvium, which overlies the Santa Fe Group. The scope of Phase II investigation was expanded to further analyze flow within each of these two major hydrogeologic units and the exchange of water between them. A more thorough understanding of the influence of surface water on the stream-aquifer system that comprises the Rio Grande flood plain alluvium was also achieved.

As proposed in Phase I (Khaleel et al., 1983), work in Phase II has focused on (1) continued development, documentation, and verification of an existing three-dimensional numerical model to better represent actual groundwater flow conditions in a typical southwest alluvial basin, and (2) improved calibration and refined simulations of Mesilla Bolson groundwater flow conditions. Some of the steps originally suggested for meeting these two major goals have been carried out while others have not, reasons for which are discussed in subsequent sections of the report.

II. OBJECTIVES

The primary purpose of this study was to develop a numerical model that adequately simulates three-dimensional (horizontal and vertical) groundwater flow in the Mesilla Bolson. The model that has been developed is not truly three-dimensional; instead it is more accurately classified as quasi three-dimensional (quasi 3-D). A quasi 3-D model treats a groundwater system as a series of aquifers separated from each other by lesser permeable units called confining beds, or aquitards. It couples the horizontal flow equations applicable to each aquifer with the equations describing vertical leakage across aquitards.

Specific project objectives were as follows:

1. Develop a quasi 3-D finite difference model capable of representing groundwater movement in typical southwest alluvial basins. The model should be able to quantify all hydrologic processes that are known to influence or be influenced by an irrigated basin such as the Mesilla Bolson.

2. Produce a preliminary model of the study area by performing a steady state calibration with the quasi 3-D code.

3. Conduct a transient calibration with the model by utilizing pumping and head data over one or several historical periods.

4. Simulate the response of the Mesilla Bolson groundwater flow domain and the stream-aquifer system of the Rio Grande alluvium to hydrologic stresses imposed by projected future water demands, and by other proposed future groundwater withdrawals, if any.

A primary goal of Phase II was to quantify many components of the hydrologic budget that the two-dimensional simulations in the first phase were incapable of handling. Specifically, it was hoped that the quasi 3-D model would yield reasonable values for stream losses, evapotranspiration and drain discharge. More refined estimates of mountain front recharge to the Santa Fe Group and leakage from and to each of the two main aquifers were also desired products of the multilayered simulations.

The expected use of the model prepared for Phase II work was mostly for predictive simulations several years into the future. Therefore, the authors decided at the outset to develop a model that is capable of simulating conditions on a year-to-year basis. This is not to say that the resulting model is unable to handle short duration changes in hydrologic processes; rather, minor alterations of the quasi three-dimensional computer code would perhaps be necessary if simulations for much smaller time durations, say months or days, are desired.

III. STUDY AREA

The boundaries of the study area are as shown in Figure 1. The northern boundary extends up to the Leasburg Dam, located between the Dona Ana and Robledo Mountains on the southern end of Selden Canyon. The eastern border is formed by the Dona Ana Mountains, the southern reach of the Jornada del Muerto Basin, the Organ Mountains, and the Franklin Mountains. The western boundary extends up to the Robledo Mountains, the Rough and Ready Hills, Sleeping Lady Hills, the Aden Hills, the West Potrillo Mountains and the East Potrillo Mountains. The southern boundary of the study area is the international border with the Republic of Mexico and the El Paso Narrows, a constricted section of the Rio Grande Valley just north of El Paso, Texas.

The most dominant natural hydrologic feature of the bolson is the Rio Grande which enters the bolson on its north end through Selden Canyon and traverses the basin in a northwest-southeast direction. Diversions of water from the river to a large network of canals help to support extensive irrigated agriculture for over 70,000 acres of land. All surface water leaving the basin does so via the Rio Grande in the El Paso Narrows.

Most of the study area lies in New Mexico, but a small portion in the southeast corner of the basin lies in Texas. The New Mexico portion of the Mesilla Bolson lies entirely within Dona Ana County, while the Texas portion is in El Paso County. Las Cruces, New Mexico, is the largest municipality within the study region. Smaller towns and villages are found along the Rio Grande. The city of El Paso, Texas, is located outside of the basin near its south boundary.

Physiographic basins bordering the Mesilla Bolson include the Rincon Valley to the north, the Jornada del Muerto Basin to the northeast, the Hueco Bolson to the east and the Mimbres Basin to the west. Groundwater in a relatively thin veneer of alluvial sediments in the northern Mesilla Valley is connected to that in the Rincon Valley in the Selden Canyon region. An equally thin and constricted section of saturated alluvium exists adjacent to and under the Rio Grande in the El Paso Narrows. Small quantities of groundwater are transported through the Narrows from the southern end of the Mesilla Valley to the El Paso area, which is situated on the western fringe of the Hueco Bolson. A relatively thick section of unconsolidated material in the Fillmore Pass region on the basin's east boundary also connectes Hueco Bolson groundwater with that of the study area. Similarly, the saturated groundwater domains of the Jornada del Muerto and the Mesilla Bolson are connected via alluvial sediments in the area of a broad topographic saddle located between the Organ and Dona Ana Mountains near the study area's northeast boundary. The depth and areal extent of alluvial deposits connecting the Mimbres and Mesilla basins near the complex of mountains consisting of the Potrillo Mountains (East and West) and Aden-Sleeping Lady-Rough and Ready Hills is not well understood.

Some confusion may exist concerning the boundary separating the Mesilla Bolson from the Jornada del Muerto which lies to the northeast. Previous investigators (e.g., King et al., 1971; Wilson et al., 1981) have preferred to align that boundary along an uplifted, elongated section of bedrock that extends from the Dona Ana Mountains south-southeastward toward the southern tip of the Organ Mountains. Such a demarcation is logical in light of the fact that this bedrock "high" forms a distinct structural divide (King et al., 1971) between the two basins. However, the previously mentioned topographic saddle found between the Dona Ana and Organ Mountains generally lies about 3 to 5 miles northeast of the axis of the uplifted bedrock. Although there may be no distinct surface runoff divide in the area of the broad saddle (King et al., 1971), examination of topographic maps and local arroyo alignments (e.g., Wilson et al., 1981) indicate that the surface water catchment of the Mesilla Basin actually encompasses several square miles of land that is commonly included in the structural basin of the Jornada del Muerto. Similarly, measured and estimated groundwater heads in the area (e.g., King et al., 1971; Wilson et al., 1981) show that much of the groundwater emanating from the northern portion of the Organ Mountains moves westward toward the Mesilla Valley, and consequently across the structural boundary between the two basins.

In accordance with the overall purpose of this study to examine the groundwater regime of the Mesilla Bolson, the authors have chosen the groundwater divide that roughly parallels the topographic saddle situated between the Dona Ana and Organ Mountains to represent the northeast boundary of the study region. Consequently, subsequent reference to the Mesilla Bolson in this report should be interpreted as including that area which lies northwest of the structural boundary between the Jornada del Muerto and Mesilla Bolsons yet within the groundwater catchment of the Mesilla Bolson. Accordingly, readers should be aware that the hydrogeologic cross sections (Appendix C) establish the borderline between basins at the structural boundary, and may not be in complete accordance with the convention used in the remainder of this report.

Similar difficulties arise when attempting to delineate hydrogeologic boundaries between the Mesilla and Mimbres Basins. The surface water divide separating these two basins travels along a line extending from the West Potrillo Mountains through the Aden, Sleeping Lady and Rough and Ready Hills. However, there is evidence of a groundwater divide (Conover, 1954; King et al., 1971) existing several miles to the west of this line, thus apparently making the groundwater catchment of the Mesilla Basin in this region somewhat larger than the collection area for surface runoff. For reasons discussed in somewhat more detail later, this region of "uncertainty" has been excluded from the area of groundwater flow simulation. Consequently, the authors have chosen simply to mention the problems associated with boundary determination on the western side of the study area, but have avoided any attempts to establish the exact location of that boundary.

Approximately 94 percent of the study area is characterized as arid continental, "with small but variable annual precipitation, large annual and diurnal temperature ranges, low relative humidity, and plentiful sunshine" (Wilson et al., 1981, p. 6; Houghton, 1972, p. 1). Based on a 125-year period (1851-1976), the average annual precipitation at Las Cruces (Figure 1) is 8.39 inches. Pan evaporation is reported to average 93.76 inches per year (Wilson et al., 1981, p. 9).

General Physiography and Geology

The physiography of the bolson can be divided into four major groups (Hawley, 1965). The first category consists of the mountains that form the basin boundaries. A second group, valley border and flood plain surfaces (Hawley, 1965), is located in a northwest-southeast trending strip that encompasses the Rio Grande. This physiographic feature, which is typically referred to as the Mesilla Valley, has been formed mostly by erosional and subsequent aggradational processes of the river during the Pleistocene and Holocene Epochs. The third group, basin fill and basin remnants (Hawley, 1965), is associated with the mid-Tertiary to Pleistocene deposits that predominate on either side of the Mesilla Valley and extend to the mountainous border regions. Basin fill in the western portion of the bolson comprises the expansive West Mesa, or La Mesa, as it is sometimes called. Alluvial fans, emanating from the Organ and Franklin Mountains, and that have coalesced into a narrow piedmont slope, make up the basin fill on the east side of the basin. As a rule, the piedmont slope is much steeper than the West Mesa. The fourth and final category of physiographic features consists of volcanic cones and lava flows (Hawley, 1965), most of which appear to be associated with faulting on the West Mesa. A map showing the relative location of mountains, basin fill and valley border-flood plain units is presented in Figure 2.

The major groundwater bearing materials of the basin are divided into two main geologic units: the Santa Fe Group and Rio Grande flood-plain alluvium (King et al., 1971). The Santa Fe Group makes up the majority of the basin fill in the West Mesa and on the piedmont slope downgradient from the Organ and Franklin Mountains. At least four separate formations (Wilson et al., 1981) have been identified as sub-units of the Santa Fe Group. The flood plain alluvium comprises most of the Mesilla Valley physiographic feature previously discussed.

The Santa Fe Group of Miocene to middle Pleistocene age is an intermontane basin fill unit primarily composed of thick alluvial deposits of clay, silt, sand, and gravel. Consolidated sediments in the form of sandstone and conglomerate are locally present, as are interbedded basalt flows and mafic intrusives. Clay lenses in the alluvial materials become thicker toward the south and reflect deltaic and lacustrine environments in central bolson areas. Structural, depositional, erosional, and igneous activity have resulted in a varied thickness for the Santa Fe Group, as this unit could range in thickness from less than 100 feet in the northern part of the study area to as much as 3700 feet in the West Mesa area (King et al., 1971, p. 22). The sediments of this group are generally well-sorted, and medium grained at intermediate depths. Values or porosity and hydraulic conductivity are favorable to water well development.

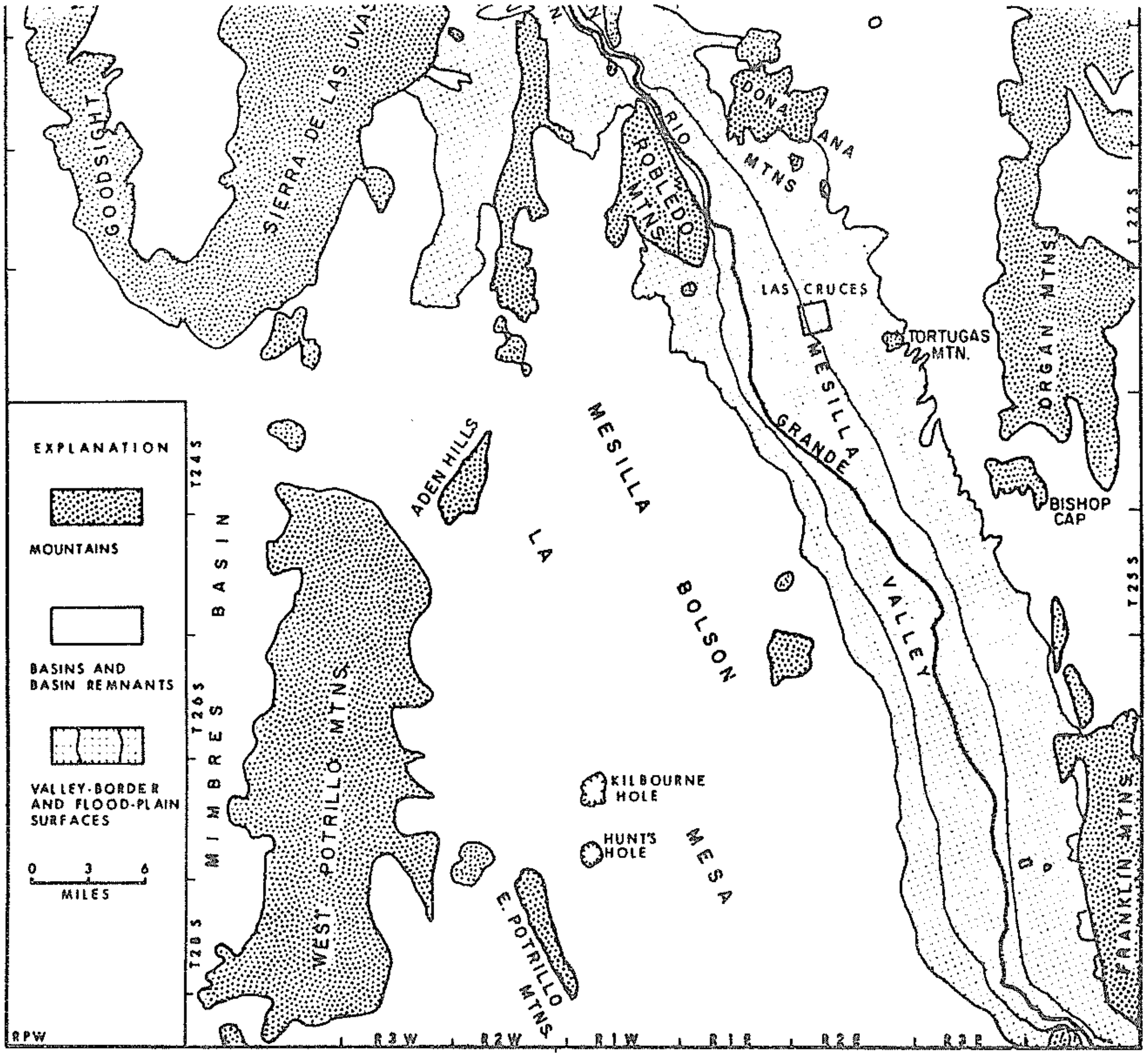


Figure 2. Physiography of the Study Area
(after King et al., 1971)

Rio Grande flood-plain alluvium deposits overlie the Santa Fe Group in the Mesilla Valley region. They are younger in age than the Santa Fe Group basin fill deposits, having been deposited in late Pleistocene and Holocene times (King et al., 1971). The alluvium is comparatively shallow, ranging in depth from 50 to 125 feet (Wilson, et al., 1981). The composition of this unit ranges from well-rounded gravels in its basal part to interfingering sand and clay layers at shallower depths. Many irrigation wells and private domestic wells withdraw water from the alluvium. Some water quality degradation occurs in flood-plain materials apparently as a result of surface irrigation practices (Wilson et al., 1981). The quality of groundwater appears to become worse in the southern end of the Mesilla Valley.

IV. PREVIOUS WORK

Several studies have been reported concerning the geology, hydrogeology, and water resources development of the Mesilla Valley and Mesilla Bolson. The works cited under geology do not comprise a complete list.

Geology

A geologic map of the New Mexico portion of the area, with cross sections and gravity profiles, has recently been compiled by Seager et al. (1984, scale 1:125,000); and the structural and volcanic evolution of this part of the Rio Grande rift has been reviewed by Seager and Morgan (1979). Detailed descriptions of mountain ranges flanking the Mesilla Bolson include maps and reports by Seager et al. (1976-Dona Ana Mountains), Seager (1981-Organ Mountains), Kelley and Matheny (1983-northern Franklin Mountains), Harbour (1972-central Franklin Mountains, Lovejoy (1975-southern Franklin Mountains), Lovejoy (1976-Cerro de Cristo Rey), and Hoffer (1969, 1971, 1975, 1976-Santo Tomas, Black Mountain, and Potrillo volcanic centers). A gravity study of central Dona Ana county was completed by Brown (1977). Other geophysical studies are described by Seager and Morgan (1979) and Wilson et al. (1981). Hawley et al. (1969) present a comprehensive review of the stratigraphy of Santa Fe Group bolson deposits in south-central New Mexico and western Texas. Hawley et al. (1969) and Hawley (1975) also describe post-Santa Fe bolson and river-valley evolution in detail. Finally, Gile et al. (1981) have completed a very detailed study of Quaternary features and soil-geomorphic relationships in the northeastern Mesilla Bolson.

Hydrogeology

The earliest comprehensive reports on hydrogeology of the area are contained in U.S. Geological Survey Water Supply Papers by Sayre and

Livingston (1945), Conover (1954), Knowles and Kennedy (1958), and Leggat et al. (1963). King et al. (1971) present a detailed report on the hydrogeology of central and western Dona Ana County and discuss recharge mechanisms in the Rio Grande Valley. King and Hawley (1975) also described the geology and groundwater resources of the Las Cruces area. The most recent detailed work on hydrogeology, involving both test drilling and geophysical surveys (surface and subsurface), is presented in a New Mexico State Engineer's Technical report on the water resources of the Rincon and Mesilla Valleys and adjacent areas (Wilson et al., 1981).

Water Resources Development

Slichter (1905) inventoried wells, discussed pumping rates, and measured depth to water for wells in the alluvium of the Rio Grande Valley. The geology, depth to water, hydraulic gradients, and water quality for shallow alluvium wells in the Mesilla Valley are discussed by Lee (1907).

Sayre and Livingston's (1945) report on groundwater resources includes the southeastern part of the study area. In addition to the geomorphology of the area, well locations, water levels, water level fluctuations, water quality, stratigraphic well logs, and pump test results are included in their report. Recharge and discharges to the valley alluvium and the Santa Fe Group are discussed by Conover (1954). His report includes well logs and geochemical data; and he developed a water level elevation map for the Rincon and Mesilla Valleys, and the West Mesa area of the Mesilla Bolson. Leggat et al. (1963) studied the groundwater resources of the lower Mesilla Valley in Texas and New Mexico. In addition to groundwater quality data, a water level contour map for January 1957 is included in their report. Groundwater resources of the Hueco Bolson area east of the Franklin Mountains are decribed by Knowles and Kennedy (1958).

A breakdown of water use by categories for all counties and river basins of New Mexico is given by Sorensen (1977; 1982). The most extensive study to date on the water resources of the Mesilla Bolson is presented by Wilson et al. (1981). In their report, data are presented on water well locations, aquifer properties, water quality, and water level measurements. In addition to large scale hydrogeologic cross sections, contour maps of groundwater elevation reflecting January 1976 conditions, and transmissivity maps for the study area are included in the report.

Meyer and Gordon (1972) performed a water budget analysis of the lower Mesilla Valley and El Paso region. In studying the Mesilla Valley alluvium, Richardson (1971) developed a water budget of the valley using a conjunctive groundwater-surface water numerical simulator. Additional water resource studies which include the study area are: Blaney and Hanson (1965), Dinwiddie et al. (1966), Meyer and Gordon (1972), Lansford et al. (1974), Updegraff and Gelhar (1977), and Gates et al. (1978). These studies deal with the various uses of water resources in New Mexico and Texas. Two bibliographies that include the study area are Stone et al. (1979), and Borton (1980).

Recent Studies

Several recent publications have greatly assisted in the model conceptualization and in providing data for our second phase of research. White (1983) provided a summary of hydrologic information for the lower portions of the Mesilla Valley from the early 1900's to present. Gates et al. (1984) documented a study of groundwater flow in the lower Mesilla Valley in which a three-dimensional model was applied. Wilson and White (1984) reported the results of test pumping of deep irrigation wells in an area located a few miles south of Las Cruces. This last report is the only known investigation that provides hydraulic conductivity estimates, based on pump test analyses, for confining units that separate the flood plain alluvium from the major water-transmitting sediments of the Santa Fe Group in the Mesilla Valley.

V. CONCEPTUALIZATION OF HYDROGEOLOGY AND DATA ASSESSMENT

Before attempting to develop a model of the study area, it was first necessary that the groundwater flow domain and influential hydrologic processes of the study region be characterized in order to develop an adequate conceptualization of the hydrogeologic regime. Upon attaining a sufficient conceptualization of the basin's groundwater system, the next step was to decide which of the various hydrologic phenomena known to occur within the basin were important enough to be included in the modeling process. Moreover, a detailed evaluation of available data for the region was necessary to determine whether some hydrologic processes could be simulated, if at all, to the extent desired.

A review of the hydrologic publications previously referred to allowed the authors to identify possible sources of groundwater recharge as well as the most significant mechanisms for groundwater discharge. Geological investigations and, in particular, cross-sections (Appendix C), were instrumental in determining model boundaries and delineating notable structural controls of groundwater movement. In the following text, the geologic and hydrologic features of the Mesilla Bolson that influenced model conceptualization are discussed.

Geologic Controls and Other Boundaries

Major groundwater sources in the study are comprised of the unconsolidated deposits that are found in the Santa Fe Group and the flood plain alluvium. Consolidated materials, including the various igneous, sedimentary and metamorphic rocks in the area, are nearly impermeable to groundwater movement. As a result, the mountains that border the basin are effective boundaries to groundwater flow.

Previous geologic studies (King et al., 1971) have shown that Tertiary faults in the Basin represent potentially significant controls on subsurface flow patterns. A map showing the location of the more notable faults is presented in Figure 3. Because the fault blocks on either side of these features are commonly displaced by considerable vertical distances (sometimes as much as a few thousand feet), large and abrupt changes in material permeability are frequently observed.

The fault block located between the two major northwest-southeast trending faults found immediately east of Las Cruces (see Figure 3) is an uplifted section of bedrock, or horst. As previously mentioned, this bedrock "high" forms the structural divide between the Mesilla Bolson and the Jornada del Muerto. The lithologic composition of this structural feature varies from Paleozoic limestone to andesitic and rhyolitic volcanics. The top of the horst, which extends from the Dona Ana Mountains in thenorth to just north of Bishop Cap Mountain at its southernmost point, generally lies several hundreds of feet below the ground surface. However, it does surface in the form of a Paleozoic limestone hill at Tortugas Mountain. The horst is a partial barrier (King et al., 1971) to groundwater flow whichoriginates fromprecipitation in the Organ Mountains and gradually travelswestwardin the piedmont slope region toward the Mesilla Valley.

The hydrogeologic cross sections illustrate in considerable detail how the horst feature on the east side of the basin acts a groundwater barrier. Cross section C-C' (see Appendix C), which traverses the basin in an east-west direction and is aligned with US highway 70 east of Las Cruces, clearly depicts a groundwater body that has backed up behind (east of) the uplifted volcanic rock in the area. The observed effect on the piezometric head surface is somewhat analogous to the damming of water in a river with the resulting creation of a "reservoir" upstream of the dam. Flow out of a

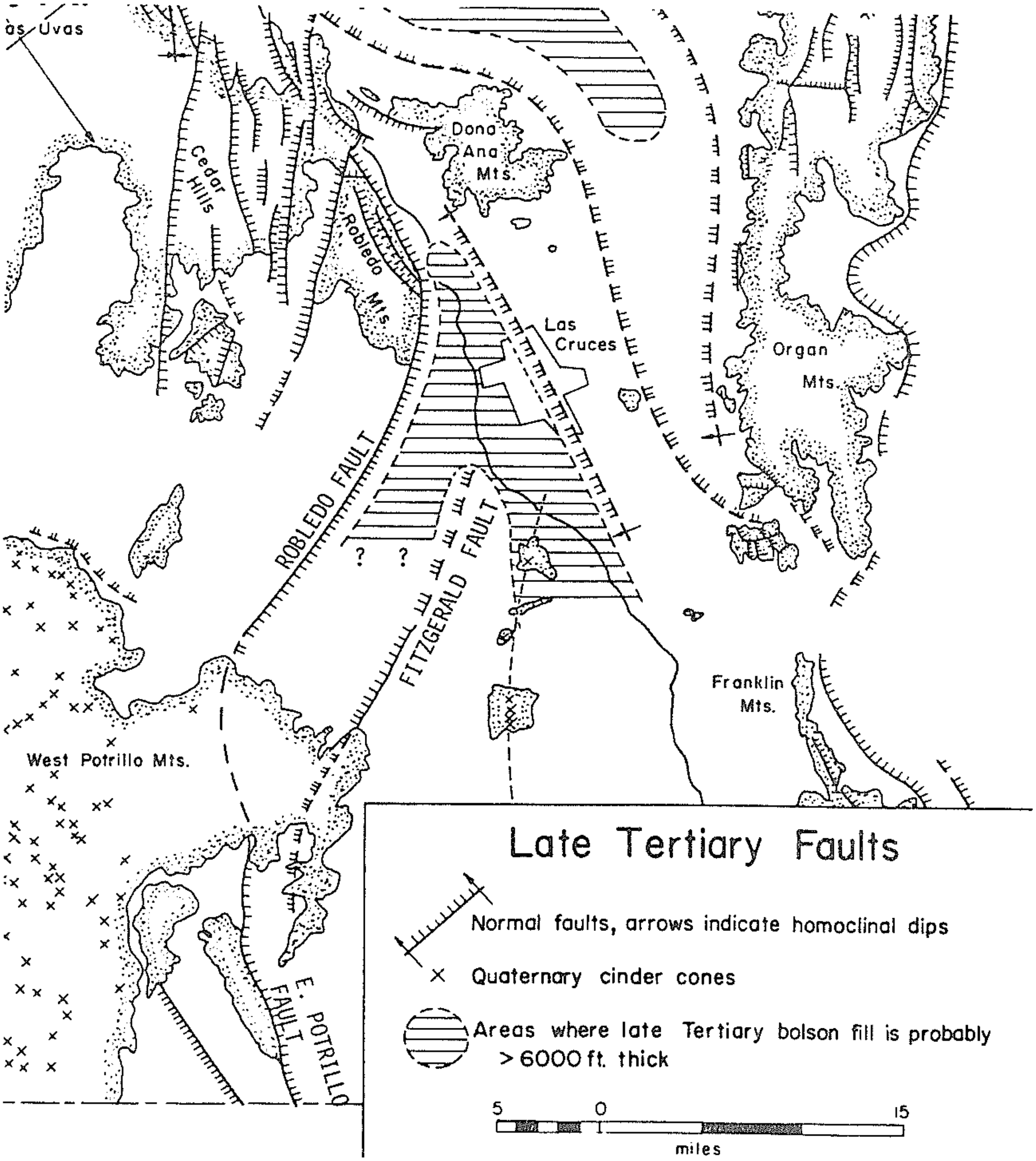


Figure 3. Geologic Faults in the Study Area (after Seager, 1975)

reservoir occurs through low points at the top of the dam, or spillways. Indeed, in an analogous fashion, groundwater from the Organ Mountains passes westward to the Mesilla Valley mostly in areas where the top of the horst is lower in elevation than elsewhere. Section H-H' of the hydrogeologic cross sections (Appendix C), which lies on the axis of the horst, shows such low points occurring on the north and south sides of Tortugas Mountain as well as at other localities.

The hydrogeologic cross sections (see for example, Section G-H' and Section J-J', Appendix C) also delineate a second horst which is found on the West Mesa about 2 to 4 miles west of the Mesilla Valley. However, in this case, the uplifted fault block of volcanic bedrock situated just east of the Fitzgerald Fault (see Figure 3) appears on the average to have only been elevated a few hundred feet above adjacent blocks. Therefore, little to no effect on the southeast moving groundwater in the upper 1,500 feet of saturated thickness of the Santa Fe Group on the West Mesa is anticipated.

The Robledo fault, extending about 30 miles in a north-south direction on the west side of the Mesilla Bolson, is also of notable importance. Bedrock on the west side of the fault has been uplifted with respect to the east side. Along the first dozen or so miles of the fault immediately south of the Robledo Mountains, the uplift is extensive enough to severely reduce the saturated thickness of permeable deposits overlying the bedrock, as cross sections D-D' and E-E' (Appendix C) aptly illustrate. Water wells drilled in this area have penetrated mostly clay and shale (King et al., 1971). Further south along the fault in the vicinity of Aden Crater, the degree to which saturated thickness is reduced is not as well known. In general, little is known about the hydrogeologic deposits on the west side of the Robledo Fault; yet it seems that the basin fill on the east side of the fault "wedges out" against the Aden-Sleeping Lady Hills (King et al., 1971). Consequently, for all intents and purposes, the Robledo Fault can be considered the western boundary of the groundwater basin. Although groundwater fluxes from the west do move eastward over this boundary, it can be assumed that transmissivities of unconsolidated materials between the fault and Aden-Sleeping Lady Hills are decreased because of reduced saturated thicknesses.

The East Potrillo Fault, in the southwest sector of the basin, appears to be the natural extension of the Robledo Fault. Volcanic rocks comprising the East Potrillo Mountains on the west side of the fault form what appears to be an impermeable boundary to groundwater flow. It is not clear whether the West Potrillo Mountains provide a barrier to groundwater movement. Due to a lack of subsurface, geological, and geophysical information in this region, it is not known whether the volcanic rocks in the West Potrillos are underlain by thick basin fill deposits or by bedrock (King et al., 1971).

An uplifted region of volcanic rock has also been shown to exist (King et al., 1971) in an area stretching from the U.S. - Mexico border to as far north as the southernmost sections in Township 28S., R.3E. The hydrogeologic cross sections (Appendix C) suggest that this bedrock high may extend in an east-west direction from the western border of the Mesilla Valley, to as much as 10 miles west of the river.

Unfortunately, little, if any, hydrogeologic information exists for those portions of the basin that extend south of the U.S.-Mexico border. King et al. (1971) state that the "Santa Fe Group extends an unknown distance into the Lake Palomas Basin" of northern Chihuahua, Mexico, "probably at least 75 miles". Thus it is likely that considerable quantities of groundwater exist in the alluvial facies lying south of the international boundary. However, we are currently unable to ascertain the detailed subsurface flow patterns in the

Mexican portion of the basin. Conover (1954, p. 33) states that is probable that a groundwater divide exists just south of the U.S. - Mexican border, somewhere between the East Potrillo Mountains and the Rio Grande near El Paso. Yet the location of this divide, if it exists, has not been determined.

It is virtually impossible, given the limited hydrologeologic information that exists for the Mexican side, to know how groundwater south of the border will interact with that on the U.S. side. Consequently, the political boundary separating the two countries is arbitrarily treated as a physical one for modeling purposes, a step which may tend to lead to somewhat erroneous simulations of groundwater flow in the vicinity of the border.

Aquifer Properties

The Rio Grande flood-plain alluvium generally behaves as a phreatic, or unconfined, aquifer. In contrast, substantial thicknesses of clay strata and other fine-grained alluvial materials in the Santa Fe Group throughout the basin appear to confine most of the groundwater located in the basin fill. Therefore, it appears that groundwater in the Santa Fe Group generally occurs, in the short term, under leaky confined conditions.

Measured transmissivities in the Santa Fe Group range from 1.3 to 21,100 feet squared per day (Wilson et al., 1981). The highest transmissivities have been observed in the Mesilla Valley area, the lowest determined from wells drilled in the vicinity of the bedrock high associated with the horst east of Las Cruces.

Data on permeability of Santa Fe Group materials under the piedmont slope on the east side of the bolson is limited. However, descriptions of the alluvial fan materials that comprise the piedmont slope (King et al., 1971, pp. 18 and 21) infer that these unconsolidated sediments are considerably less permeable than the Santa Fe Group alluvium in the Mesilla Valley. The cross sections (see Sections C-C', D-D', E-D', F-F' and G-G', Appendix C) also indicate that piedmont slope materials are less transmissive than basin fill facies in the center of the bolson. King et al. (1971, p. 18) and Wilson et al. (1981, p. 85) report that piedmont slope deposits north of U.S. highway 70 and within the bolson generally appear to be coarser-grained, and thus more permeable, than those found south of the highway. The few transmissivities that have been estimated (Wilson et al., 1981, p. 406) based on data from wells near Highway 70 are relatively low in value (1.3 - 3,370 feet squared per day).

Although very little hydrogeologic and pumping data exists for the West Mesa (e.g., Gates et al., 1984), estimates of transmissivities in this region (e.g., Conover, 1954; Wilson et al., 1981) are, as a rule, significantly lower than those determined for the Santa Fe Group in the Mesilla Valley. However, the cross sections (Appendix C) infer the existence of relatively thick saturated sections of sandy material underlying the West Mesa. The natural implication is that actual measured transmissivities over much of the West Mesa may actually be higher than previously thought.

Wilson et al. (1981, Plate 11) provide a contour map of transmissivity estimates in the upper 150 feet of saturated thickness of alluvial deposits under the Mesilla Valley. To a large degree, the values shown are reflective of the permeability of the flood-plain alluvium; consequently, feasible estimates of hydraulic conductivity in the shallow phreatic aquifer can be developed. A similar map of transmissivity contours (Wilson et al., 1981) for the upper 1,000 feet of saturated thickness was developed by extrapolating reported and estimated transmissivity values from wells constructed somewhat shallower than the full 1,000-foot depth. This information, along with additional information contained in the hydrogeologic cross sections, formed the base from which initial estimates of transmissivity in the Santa Fe Group, both under the Mesilla Valley and in outlying areas, could be constructed.

Reported storage coefficients (Wilson et al., 1981) from wells tapping the Santa Fe Group range from 0.00003 to as much as 0.002. The lowest values are generally observed in wells of moderately shallow depth (less than 400 feet) and screened intervals less than 100 feet in length. Taking into consideration the fact that the amount of confined water released due to elastic storage properties normally increases as the screened interval of a well increases, storage coefficients in the upper 1,000 feet of saturated Santa Fe Group materials are probably closer to a value of 0.001. Such reasoning is substantiated by extensive pump test analyses of a deep irrigation well (approximately 700 feet deep) located south of Las Cruces (Wilson and White, 1984), in which the storage coefficient was computed to be 0.001 using curve matching techniques for a leaky aquifer (e.g., Lohman, 1972).

To date, no precise measurements of specific yield in the river alluvium have been documented. Estimates of a representative value of specific yield in the Mesilla Valley range from 0.20 (Richardson, 1971) to 0.25 (Conover, 1954). A value of 0.21 was successfully used in a lumped parameter groundwater model of the Mesilla Valley (Updegraff and Gelhar, 1977).

The preceding discussion on aquifer storage properties raises some concerns regarding the water yielding behavior of the Santa Fe Group hydrologic unit(s). For instance, it may be argued that the very upper part of the Santa Fe Group in the Mesilla Valley area releases its stored water as if it were unconfined. Although this may be the case, there is considerable evidence to indicate that the majority of groundwater in the Santa Fe Group occurs under confined (or leaky confined) conditions. Geologic logs from wells drilled in the valley (e.g., King et al., 1971; Wilson and White, 1984) tend to support this. In those cases where the base of the flood-plain alluvium has been located, substantial thicknesses of clayey strata and other fine-grained alluvium have usually been logged in the first 50 feet of Santa Fe Group materials that lie below the boundary between the major geologic units. These fine-grained materials tend to confine the more permeable water-bearing materials located below them; thus, it is possible that confined conditions become dominant within very short depths below the base of the flood-plain alluvium.

Similarly, it might be suggested that Santa Fe Group groundwater in the uppermost portions of the saturated domain underlying the West Mesa and the eastern piedmont slope are also confined. To answer such concerns, the aforementioned reasons can be cited in these cases as well. Most geologic information on the textural and mineralogic make-up of Santa Fe Group alluvium in these two regions indicates that the more permeable materials are heavily interstratified with fine-grained sediments; consequently, there is a strong possiblity that the majority of groundwater contained in the West Mesa and eastern piedmont slope flows as if it were confined. If any portions of the total saturated thickness of basin fill are currently unconfined, it is possible that such portions are limited to the very upper parts of the saturated region. Gates et al. (1984, p. 19) have developed a similar assessment of groundwater conditions in the West Mesa during the course of modeling groundwater flow in the Lower Mesilla Valley.

An example of a West Mesa well whose geologic log tends to support the reasoning that groundwater in the West Mesa section of the basin is mostly confined by clayey facies is presented in King et al. (1971, p. 47, Well 25. 1E. 21. 331). The storage coefficient values (0.00003 - 0.0018) determined for the Santa Teresa wells (Wilson et al., 1981, pp. 414-417), located in the southern Mesilla Bolson and on the east fringe of the West Mesa, are indicative of confined aquifer conditions.

Although pump test analyses (Wilson et al., 1981) indicate that most of the Santa Fe Group tends to respond to short-term pumping as a confined hydrologic unit, it is believed that long term and increased pumping may reduce piezometric head levels in the bolson to the extent that deeper aquifer materials will gradually behave more like a water table aquifer. In other words, water released from storage will increasingly be due to gravitational forces rather than due to the elastic nature of the aquifer. Consequently, storage coefficients for wells in the Santa Fe Group will increase. However, the transition from predominantly confined to largely phreatic conditions at any one site will not be instantaneous. Rather, the complex interbedding of clays and sands in the bolson suggest that dewatering of much of the confined alluvium will be a gradual process, and so will the transfer from mostly confined to largely phreatic conditions.

Sources of Recharge

During Phase I of the modeling study, recharge to the Santa Fe Group was attributed solely to mountain front recharge and downward leakage from the Rio Grande alluvium. However, the initial two-dimensional model was incapable of simulating the processes by which the river alluvium is recharged. Analysis of a variety of data in the Mesilla Valley indicate that these latter sources are extremely important. Moreover, because the recharge attributed to one of these processes, namely river and canal infiltration, is known to fluctuate considerably from year to year, the resulting effects on leakage to the Santa Fe Group can be significant. Potential recharge sources to the Mesilla Bolson groundwater system are discussed in the following sections.

Mountain Front Recharge. Precipitation was initially considered to be a potential source of recharge to the groundwater system. However, previous investigations (Wilson et al., 1981) indicate that little, if any, precipitation that falls on the valley floor is expected to reach saturated zones in the subsurface. This observation is attributed primarily to the fact that monthly evapotranspiration rates generally exceed precipitation rates, thus leaving no net source of water. Furthermore, caliche and clay horizons at shallow depths in the basin fill tend to inhibit the downward seepage of subsurface water derived from precipitation (King et al., 1971). That portion of precipitation believed to reach the saturated zone probably occurs in the elevated border areas where water moves through fractures in the consolidated rock, or is collected as thunderstorm runoff in arroyos and eventually infiltrates into the subsurface. Thus, although precipitation cannot be considered a source of recharge that is uniformly spread over the basin's areal extent, it can be treated as a source of water near the mountain-alluvium boundaries. This type of groundwater source is referred to as mountain front recharge elsewhere in the report, and is addressed in more detail in a subsequent section.

Applied Irrigation Water. One of the most important sources of recharge in the study area is that of applied irrigation water, most of which occurs in the river valley. During recent years, over 70,000 acres of cropland in the Mesilla Valley has been irrigated annually. This valley region is serviced by surface water diverted from the Rio Grande by the Elephant Butte Irrigation District (EBID) in New Mexico and the El Paso County Water Improvement District (EPWID) in Texas. From data provided in Lansford et al. (1974), it is estimated that about 3,200 acres of New Mexico land are irrigated on the upland regions east of the river alluvium and on the West Mesa, areas which lie outside of and above the Mesilla Valley. Based on information given in White (1983), an estimated 500 acres, outside of the surface water delivery area in the Texas portion of the valley, is also irrigated.

Rio Grande and Canal Seepage. Recharge from infiltration of stream and canal water appears to be of equal, if not greater, importance than irrigation applications as a source of groundwater. Summary reports from the U.S. Bureau of Reclamation indicate that conveyance losses on the large network of irrigation canals that exist in the valley normally range from 35 to 50 percent of the total gross diversion of water from the Rio Grande. Although the reported canal losses are explained by the cumulative effects of infiltration, evaporation from the free water surface, transpiration by plants that line the canals and flow measurement errors (Wilson et al., 1981), it is apparent that a substantial portion of these large quantities of water loss is attributed to seepage from surface waters to the subsurface. Richardson (1971) estimated that yearly infiltration losses from canals in the Mesilla Valley amounted to about 60 percent of the total annual conveyance losses reported by the U.S. Bureau of Reclamation.

Significant conveyance losses from the Rio Grande have also been reported (e.g., Conover, 1954; Wilson et al., 1981). These studies have generally shown that the river gains slightly from groundwater discharges in its upper reaches within the study area, i.e., in the 5 to 6 mile stretch just below Leasburg Dam. Along the remaining portions of the river in the Mesilla Valley, however, the river appears to become a predominantly losing waterway, at least during portions of most years. Reported losses, depending on the reach studied, vary from 0.27 to 4.8 cubic feet per second (cfs) per river mile. An additional study by the authors, in which the differences in flow between the Rio Grande at Anthony (U.S. Geological Survey, Water Resources

Data for Texas) and at El Paso (U.S. Geological Survey, Water Resources Data for New Mexico) were analyzed, also tended to illustrate the losing nature of the river in its lower reaches within the valley.

In addition to the above, studies on Rio Grande seepage losses have been conducted by the New Mexico State University (NMSU) Civil Engineering Department (1956, 1957, 1958, 1959, 1960, 1961), and by the NMSU Engineering Experiment Station (1961). These unpublished investigations were part of a general assessment of surface water and groundwater conditions existing in the Mesilla Valley during the years 1955-1960. The seepage studies consisted of field measurements as well as analyses of reported surface water and meteorological data. The field work concentrated on the monitoring of river flows and depths to groundwater below the Rio Grande channel prior to each irrigation season of the study period. Analysis of reported river discharges resulted in the determination of daily, monthly, and annual seepage quantities along several stretches of the Rio Grande. The total river reach examined extended from Leasburg Dam in the north to Courchesne Bridge just north of El Paso (distance between the two stations is approximately 60 miles).

Preliminary analyses of the above-mentioned NMSU studies tend to support the general observations made by Conover (1954) and Wilson et al. (1981) regarding Rio Grande seepage. That is, over the course of a year, slight gains in river flow due to discharging groundwater are observed in the first few miles downstream of Leasburg Dam, while a net loss is commonly observed over much of the remainder of the river's length within the Mesilla Valley. In addition, there is some evidence (NMSU Civil Engineering Department, 1960) to indicate that the river becomes a gaining waterway in its very lower reaches, immediately upstream of Courchesne Bridge.

It is important to mention that past field observations on the Rio Grande losses are very general, and that specific seepage magnitudes and directions can vary both spatially and temporally from general trends. For example, some data suggest that, over those river reaches where annual net losses are common, smaller subreaches may show a net gain in flow. Similarly, since the stream-aquifer system of the Mesilla Valley is continually affected by a variety of time-variant hydraulic processes, it is possible that some sections of the river lose water via seepage at certain times of a year and gain in flow from groundwater discharge during other times.

With regard to temporal fluctuations of seepage on the Rio Grande, it is relevant to analyze the general hydrologic conditions that occurred during the study period of the NMSU investigations. The first three years (1955-1957) of the study period were quite dry. During that period, river flows and water table levels were lower than normal (Wilson et al., 1981), yet seepage losses remained relatively constant. In contrast, the last three years (1958-1960) were characterized by above normal surface water flows. Computed annual seepage losses from the total observed length of the Rio Grande during these later years of the study period were observed to gradually decrease (NMSU Civil Engineering Department, 1961). Such changes in river losses, which can be explained hydraulically, demonstrate the propensity of river seepage processes to vary over the long-term as well as seasonally. Moreover, this information further illustrates why past seepage study results are perhaps best utilized for developing qualitative perceptions of river loss mechanisms and should not be considered totally representative of river-aquifer interrelationships at all places and times.

For the purposes of this investigation, groundwater and river water are hereinafter described as being hydraulically "connected" at sites where the water table lies above or within a foot or so below streambed elevation. Surface and subsurface waterbodies are referred to as "disconnected" where groundwater levels lie several feet below stream bottom. This distinction is made because different types of seepage phenomenon are implied by each case. Under hydraulic connection, seepage to or from the river is likely to be dependent upon the difference in heads observed between the stream surface and the adjacent groundwater table. The case of disconnection, however, infers that an unsaturated zone lies between the streambed and water table. Moreover, the rate of infiltration loss from a disconnected surface waterway is not measurably affected by water table elevation and is, therefore, effectively constant (Moore and Jenkins, 1966), as long as the stream surface level does not change.

One factor that may contribute to the creation of a hydraulically disconnected waterway is the formation of a semipervious streambed, or clogging layer, as it is sometimes called. This low permeability silt and clay layer, which is frequently found in the beds and banks of streams and canals, tends to impede infiltration rates from losing streams (e.g., Matlock, 1965). If seepage from the stream is significantly reduced, it is possible that the water entering the soil below the streambed is of insufficient quantity to saturate the pores of the soil. As a consequence, unsaturated conditions prevail in the zone immediately beneath the waterway channel, and rate of seepage from the stream is affected only by the height of the surface water in the channel relative to the base of the clogging layer.

The NMSU Civil Engineering Department (1956) found considerable evidence of clogging layer formation in several irrigation laterals located in the Mesilla Valley. The effect on canal infiltration rates was found to be substantial. In addition, field studies (NMSU Civil Engineering Department, 1956; 1957) indicated that sewage effluent from the Las Cruces sewage plant was leaving organic deposits in the bed of the Rio Grande along one of its reaches and, consequently, was rendering it "impervious".

In the interest of assessing connection/disconnection phenomena along the Rio Grande, available data have been examined by the authors to establish the general relationship of water table elevations with those of the river bed and canal beds. Preliminary analyses of Rio Grande bed profiles supplied by the International Boundary and Water Commission (IBWC) indicate that the water table can possibly lie above the riverbed in: (1) the Leasburg Dam area, and (2) along a 20-mile reach extending from the vicinity of Berino (located about 17 miles downstream from Las Cruces) to the El Paso Narrows. As suggested by the preceding review, and confirmed by the IBWC profiles, the water table over at least a portion of the northernmost of these two stretches is high enough such that groundwater is lost to the river. The IBWC river bed profiles also indicate that, from a few miles north of Las Cruces to near Berino, the water table will often lie anywhere from a few feet to as much as 10 feet below streambed levels.

Profiles of river bed and groundwater elevations from the NMSU investigations also provide information regarding connection/disconnection occurrences on the Rio Grande. Prior to the irrigation season of each of the dry years of 1955 and 1956, the water table was observed to lie below the river bed (generally 3-9 feet) from a few miles downstream of Leasburg Dam to the vicinity of Vado (located about 14 miles downstream of Las Cruces and about 3.5 miles upstream of Berino). Pre-irrigation water table levels below the river bed in 1955 and 1956 could not be measured for several miles downstream of the Vado area because discharges to the river from agricultural drains prevented access to the river bed for such measurements. During March of 1957, the drains contributed little flow to the river, and water table levels remained "well" below the mean river bed (NMSU Civil Engineering Department, 1958) near Leasburg Dam to about 10 miles downstream of Vado. In the early Spring of 1956 and 1957, monitoring of the Rio Grande showed that the water table was commonly 4 to 5 feet below river bed elevation in the lower valley reach between the town of Canutillo and Courchesne Bridge (distance between the two stations being about 11.0 miles). Indeed, it was reported (NMSU Civil Engineering Department, 1958) that, during the irrigation seasons of all three of the initial years of study (1955-1957), the river acted as if it were "perched" and that water table levels had no measurable effect on river losses. Thus, it appeared that a very large section of the river, if not most of its entire length, was hydraulically disconnected from underlying groundwater during this dry period.

During the last three years (1958-1960) of the NMSU investigations, efforts to determine depth to groundwater below the Rio Grande in pre-irrigation periods were thwarted due to substantial flows in the river along much of its length. Sources of this flow presumably included direct discharge to the river from a gradually rising water table, as well as contributions from drains that emptied into the river. Above average surface water availability for irrigation during the three-year period was the primary reason for the increased water table elevations. Nevertheless, hydraulic disconnection was still observed prior to the start of each irrigation season along a section of river located between the Mesilla Dam (near Las Cruces) and Vado (NMSU Civil Engineering Department, 1961). Depth to groundwater below the river bed over this reach (with an approximate length of 15 miles) commonly ranged from 2 to 6 feet.

Seepage losses from the entire study reach of the Rio Grande decreased from 1958 to 1959, and an apparent net gain in from groundwater discharge to the river was observed in 1960 (NMSU Civil Engineering Department, 1961). These observations indicated that the rising water table was influencing the rate of seepage from and to the river, and that hydraulic connection prevailed at many locations along the river.

Initial evaluation of the NMSU studies tends to suggest that the Rio Grande fluctuates between being hydraulically connected and disconnected from the underlying water table, depending on the availability of surface water for irrigation. Although this may have been the case during some past years, there is evidence to suggest that hydraulic disconnection is more dominant in recent years. In addition, there is cause to believe that river loss calculations for the wet years of 1958-1960 are anomalous and, therefore, not truly representative of present-day average conditions. Observations that tend to support this reasoning include:

(1) Conover (1954, p. 72) has determined the average conveyance loss for the Rio Grande in the Mesilla Valley for the 17-year period, 1930-1946. His computed loss is at least three times larger than the comparable mean loss during 1958-1960 determined by the NMSU Civil Engineering Department (1959; 1960; 1961). Yet surface water diversions from the Rio Grande for irrigation during 1930-1946 averaged 24 percent higher than the mean quantity of diverted water from 1958 through 1960. This, in turn, suggests that high water table elevations during 1958-1960, and the effect that they had on river losses, is not very representative of long-term behavior of the river-aquifer system in response to surface water availability.

(2) Annual applications of surface water for irrigation in the entire Mesilla Valley during the last 20 years has been considerably less than observed in earlier years (see, for example, Conover, 1954; Wilson et al., 1981; U.S. Bureau of Reclamation, Monthly Water Distribution Summaries, 1966-1981). Moreover, the per-acre allotment of surface irrigation water has also been much less over the past few decades than observed, for instance, between 1930 and 1946 and between 1958 and 1960. With less surface water being available, a greater portion of the consumptive need of crops in the valley has been met by the pumping of irrigation wells. Accordingly, groundwater levels in the Mesilla Valley have presumably been lower in more recent times than during earlier periods of high surface water availability.

(3) Pumpage for municipal and industrial purposes during the last 15 to 20 years has also been much greater than in previous years. This is particularly true in the lower Mesilla Valley, where pumping in the vicinity of Canutillo, Texas, has been increased (e.g., White, 1983) to help meet public water supply demands of El Paso. In response to the greater groundwater withdrawals, water table levels near Canutillo (and near the river) over the past 20 years have

> frequently been as much as 15 feet lower than observed from the mid-1950's to early 1960's (e.g., Gates et al., 1984). The likelihood that additional seepage from the Rio Grande was induced by lower groundwater levels in the Canutillo area which in turn was brought on by substantial pumping for municipal purpose is collaborated by a 1974 seepage study by the U.S. Geological Survey (Water resources data for New Mexico, 1974, p. 233). The maximum measured seepage loss along a stretch of the river in the lower valley in February of 1974 occurred over a reach located just north of Canutillo.

Based on the NMSU studies, and the preceding discussion on the prevailing conditions in more recent years within the stream-aquifer system, the authors have assumed that disconnected conditions currently tend to dominate along a reach of the river stretching from a few miles downstream of Leasburg Dam to near Vado (i.e., over a total river reach of about 25-32 miles). Hydraulic connection may indeed be observed, at least during portions of some years, in the next 10-13 miles downstream of Vado. Further downstream, in the vicinity of Canutillo, disconnection of river from groundwater is more likely to prevail due to intense pumping in this locality. The total length of river in this area in which large seepage losses are commonly observed is about 10 to 15 miles. The potential for connected conditions to dominate near the very low end of the valley (from the Courchesne Bridge to as far as 3-6 miles upstream) appears strong, as it is likely that the water table rises in this area because groundwater is backed up behind the flow constriction in the El Paso Narrows. In summary, it appears to the authors that present-day seepage losses on a very large portion, if not most, of the Rio Grande in the Mesilla Valley occurs under the condition of hydraulic disconnection.

Most infiltration losses from irrigation canals in the Mesilla Valley also appear to fall under the case of disconnection. The authors have used U.S. Bureau of Reclamation canal profiles to make a cursive inspection of canal bed levels relative to water table elevations. In nearly all sections of the valley, the water table is observed to lie several feet below the elevations of canal bottoms. This finding appears to hold true not only for non-irrigation season conditions, when water table levels are at their lowest, but also in cases where mid-summer water table elevations (e.g., Conover, 1954, p. 75) have been compared with canal bed profiles. A cross-section of the Mesilla Valley near Las Cruces, along with measured water table profiles in the early 1900's (Conover, 1954; Plate 4) does indeed clearly show the canals of this area to be hydraulically disconnected from underlying groundwater. This result is not surprising since irrigation canals are typically elevated above surrounding land in the interest of providing hyraulic head sufficient to drive irrigation water the full length of irrigated fields. Furthermore, numerous agricultural drains in the valley help to keep water table levels from becoming too high in irrigated areas.

As will be demonstrated in a later section of this report, most of the recharge contributed to the Mesilla Valley groundwater system by seepage from surface waterways appears to come from irrigation canals rather than from the Rio Grande. Since the canals remain largely disconnected from the phreatic surface in the flood-plain alluvium, and since much of the river losses also occurs under disconnected conditions, it is reasonable to assume that total annual recharge of groundwater in the study area by stream seepage is dominated by disconnection phenomena.

In the Mesilla Valley, the implication is that river and canal losses are not strongly dependent on the phreatic aquifer heads. Updegraff and Gelhar (1978) concluded that a lumped parameter groundwater flow model of the Mesilla Valley was most accurate when based upon stream-aquifer disconnection, i.e., the "perched" river case. Parameter estimation techniques applied with their model under the assumption of surface water-groundwater connection resulted in the computation of a negative storage coefficient, which is physically impossible (Updegraff and Gelhar, 1978).

Subsurface Inflow. Another possible category of recharge sources to the Mesilla Bolson is that of subsurface inflow from adjacent basins. In considering this possibility, four separate locales were evaluated: (1) Selden Canyon, where the Rio Grande enters the bolson on its northern boundary; (2) the northeast border of the basin along the hydraulic boundary that separates Jornada del Muerto from the study area; (3) Fillmore Pass on the east boundary; and (4) the west boundary between the Rough and Ready Hills and the northern extent of the Potrillo Mountains.

Southward moving inflow of groundwater from the Rincon Valley in the unconsolidated sediments of Selden Canyon is thought to be minor in comparison to the recharge emanating from precipitation in the Robledo-Dona Ana Mountains. As for the northeast boundary, hydrogeologic studies (King et al., 1971) show that a groundwater divide exists under the topographic saddle in this region. A limited quantity of groundwater is fed to the saddle area from the Dona Ana Mountains and the Organ Mountains. Groundwater then sheds off the divide in both northerly and southerly directions to both basins. This observation seems to somewhat contradict that of Conover (1954), who suggested that substantial quantities of groundwater move into the Las Cruces area from the north-northeast.

A groundwater divide also seems to exist at the Fillmore Pass (Wilson et al., 1981), with recharge in the vicinity originating from the Organ and Franklin Mountains. As a consequence, neither the northeast border of the groundwater basin nor the Fillmore Pass region can be considered as areas of recharge due to groundwater flow from contiguous basins. Rather, they receive recharge from nearby mountain front sources and then tranmit water into the basin.

The groundwater head contours developed by Wilson et al. (1981) for the West Mesa suggest that substantial quantities of water are transported toward the Mesilla Valley from the northwest and west. Obvious sources for some of the water include mountain front recharge from the Robledo, West Potrillo and East Potrillo Mountains. Recharge from precipitation in the Aden-Sleeping Lady-Rough and Ready Hills complex is also a probable source. However, it can also be inferred from groundwater contour maps (e.g., King et al., 1971) that some of the water is derived from subsurface inflow of groundwater lying west of the Aden-Sleeping Lady Hills region, i.e., from a region that underlies a part of the surface water catchment area of the Mimbres Basin. Due to the paucity of data along the western boundary, detailed simulation of groundwater movement in this region is not easily achieved. Based on hydrogeologic cross section information, the southeastward moving recharge to the West Mesa could be best simulated by accounting for subsurface fluxes along the Robledo Fault.

Comprehensive piezometric head contour maps (Conover, 1954; King et al., 1971; Wilson et al., 1981) show a preponderant north-northwest orientation of groundwater equipotentials in the vicinity of the U.S.-Mexico border just east of the East Potrillo Mountains. This trend is explained by recharge emanating from the east front of the East Potrillos, whose axis is also aligned in a north-northwest direction. But this same orientation of equipotentials also seems to exist further east along the international boundary (e.g., Wilson et al., 1981) toward the Rio Grande. This in turn indicates that some subsurface inflow to the study region from the Mexican side of the border may occur, with the general direction of groundwater movement being toward the east-northeast. Conover (1954) presents information to support the contention that groundwater does flow northward and eastward, i.e., from Mexico to the United States. To the author's knowledge, no quantitative estimates of the flux across the international boundary have been published.

Groundwater Discharge

By far, the greatest amount of discharge of subsurface water occurs as evapotranspiration and pumping. Depending on the amount of Rio Grande water that is available for irrigation in any given year, pumping volumes may or may not exceed the evapotranspiration component. Another major type of subsurface discharge is groundwater seepage to agricultural drains in the Mesilla Valley. In a somewhat similar manner, the Rio Grande, in its very upper reaches within the bolson, acts as a drain as the river gains in flow from groundwater seepage in this area. Further evaluation of groundwater discharge mechanisms is presented in the following sections.

Evapotranspiration. Approximations of total annual evapotranspiration can be derived by adding estimates of crop consumptive use to estimates of phreatophyte water consumption both within and outside of the Mesilla Valley. Crop irrigation takes place mostly in the Mesilla Valley within the surface water delivery area serviced by local irrigation districts (the EBID in New Mexico, and the EPWID in Texas). But a substantial amount of irrigation also occurs outside of the valley. Phreatophyte losses are observed almost exclusively within the bounds of the river valley.

Based on irrigation use summaries presented in Lansford et al. (1974), the authors chose to use a common consumptive use rate of 1.85 acre-feet per acre (acre-feet/acre) per year for the crops typically grown in the Mesilla Valley. For the lands lying outside of the surface water delivery area, an annual rate of 2.23 acre-feet/acre was selected. Since in recent years the total cropped acreage within the local irrigation districts in the Mesilla

Valley has exceeded 70,000 acres, total annual evapotranspiration volumes are estimated to exceed 130,000 acre-feet. The total New Mexico irrigated acreage outside of the EBID in the study area is estimated at about 3,200 acres, while the irrigated Texas land outside of the EPWID is estimated to be near 500 acres. This tranlates into an annual crop consumption for all of the outlying regions of about 8,000 acre-feet.

Phreatophyte consumption of groundwater along the Rio Grande and numerous canals within the Mesilla Valley is also a significant component of discharge. The major types of phreatophytes known to grow in the valley are saltgrass and salt cedar. An annual consumptive use of over 22,500 acre-feet by phreatophytes in the Mesilla Valley was estimated by Richardson et al. (1971).

Pumpage. Groundwater pumpage that occurs in the basin can be roughly categorized into six general types of water use: (1) irrigated agriculture, (2) urban and rural, (3) industrial, (4) power, (5) livestock, and (6) mining. Analyses of available data indicated that the last two uses are essentially negligible and can be safely ignored in this investigation. Irrigation and urban uses normally constitute the largest consumers of groundwater. In years of plentiful surface water, however, groundwater pumpage for irrigation in the Mesilla Valley is very minor.

Urban use of groundwater is mostly attributed to the municipalities of Las Cruces and El Paso. The Las Cruces well field is centered on the eastern portion of the city, while El Paso withdraws groundwater from the so-called Canutillo well field near Canutillo, Texas. Other entities, such as small towns, villages, residential developments, and New Mexico State University also maintain their own community water systems. In the more rural areas of the basin, individual domestic wells rather than community systems supply drinking water. The exact number and locations of such individual supply wells is not known, but it can be assumed that many of them are concentrated in the numerous small towns of the Mesilla Valley that have not yet converted to community water supplies. The annual cumulative groundwater withdrawals from these rural communities can, therefore, be estimated using their populations and assumed consumption rates.

Groundwater withdrawals for industrial use are poorly documented for the New Mexico portion of the basin. This presents only a slight problem, however, as it has been estimated (e.g., Sorensen, 1977; 1982) that pumpage for manufacturing in New Mexico is quite small. On the other hand, records and estimates of industrial pumpage in the Texas portion of the basin are readily available (U.S. Geological Survey, Pumpage Summaries for the Lower Mesilla Valley). Pumpages for power use have also been reported (U.S. Geological Survey, Pumpage Summaries for the Lower Mesilla Valley; White, 1983).

Records of irrigation pumpage are virtually nonexistent. Therefore, a method for estimating the annual groundwater withdrawal for agricultural purposes was developed by the authors. The approach taken centered around the assumption that the annual consumptive use per acre of crops in the valley remained constant from year to year. Furthermore, it was assumed that the total irrigation requirement (i.e., the water actually applied to the land surface) could be computed each year based on a uniform irrigation efficiency of 60 percent (Lansford et al., 1974). Finally, knowing that portion of the total irrigation requirement that was supplied by surface water (U.S. Bureau of Reclamation, Monthly Water Distribution Summaries), the remaining portion could be assigned to groundwater pumpage. This approach produces high irrigation pumpages in years of low surface water supply, and low pumpages in years when surface water diversions for agriculture are large. That indeed such a reciprocal relationship exists between surface water availability and groundwater withdrawals for irrigation is substantiated by information presented in White (1983) and Gates et al. (1978).

Cropped acreage outside of the Mesilla Valley surface water delivery area is totally dependent on groundwater as an irrigation source. Lansford et al. (1974) estimated an annual irrigation application of about 12,000 acre-feet for New Mexico land that is believed to be in this category for the year 1969. Similarly, White (1983) estimated an annual application of 2,000 acre-feet for land in Texas irrigated exclusively by groundwater. Neglecting the irrigation of land in and near Santa Teresa Estates, which began using water for agricultural and recreation purposes in the early 1970's, it was felt by the authors that the above given annual pumpages were adequate approximations of irrigation withdrawals in areas outside of the Mesilla Valley during the last twenty years.

The lack of reported pumpage quantities is not the only problem associated with the modeling of groundwater flow in irrigated sections of the basin. Because the depths and screened intervals of so many irrigation wells go unreported (see, for example, Wilson et al., 1981, Table 2), it is difficult to tell which hydrogeologic formation (or depth within a formation) a well is pumping from. Wilson et al. (1981) maintain that most irrigation wells in the Mesilla Valley are perforated in both the flood-plain alluvium and the upper part of the Santa Fe Group.

Drain Discharge. Total drain flow in the Mesilla Valley fluctuates considerably from year to year. The U.S. Bureau of Reclamation, which monitors drain discharge continually, reports total annual flow ranging from as low as 5,000 acre-feet during drought periods to as much as 130,000 acre-feet during wet years.

Obviously, annual drain flow is a function of the water table elevation within the Mesilla Valley, which in turn is mostly dependent on the amount of irrigation, river and canal water that infiltrates the subsurface and on the quantity of pumping that occurs. Assuming, as stated before, that pumping for irrigation increases in years of low surface water supply, it is apparent that drain flow declines during such dry periods. Accordingly, drain flow is expected to increase during wet periods, as irrigation pumping is reduced and infiltration losses from canals and the river increase due to increased surface water flows. Using this reasoning, along with the observation that irrigated acreage (and, therefore, applied irrigation water) does not change much from year to year, the annual drain flow from the Mesilla Valley should show a distinct correlation with canal diversions from the Rio Grande. In other words, the larger quantities of canal water infiltrating into the subsurface over a wet period are expected to contribute greater amounts of discharge to the drains.

Indeed, Conover (1954, Figures 3 through 5) has graphically illustrated the correlation between surface water diversions and drain flows on both a monthly and annual basis. There is evidence to indicate that a long term lag effect (Conover, 1954) exists between these two processes, i.e., increase or decrease in total diversion from the Rio Grande in a given year may not be manifested in a corresponding increase or decrease, respectively, of drain discharge within the same year. Instead, the effects may be not fully noticed until one to two years later.

Water table contour maps of various locales in the Mesilla Valley (e.g., Conover, 1954; White, 1983; Wilson and White, 1984) help to physically illustrate the correlation between the canal and drain flows. Invariably, seepage losses from the canals (and the river) create ridges in the water table (Wilson et al., 1981) below canal beds, flow from which then occurs toward the minor water table troughs at drain sites. The relatively large distances (perhaps as much as a half mile or greater) that sometimes exist between irrigation waterways and the closest drains may help to explain why lags can exist in the response time of drains to changes in canal seepage losses.

Subsurface Discharge. A final type of groundwater discharge from the bolson that was considered in the basin conceptualization was that of subsurface flow out of the valley, specifically southward moving groundwater through the thin veneer of alluvial material at the El Paso Narrows. Because Slichter (1905) demonstrated that very little subsurface water escaped from the valley at this site, it was not included in the modeling.

Spatial and Temporal Behavior of Hydraulic Head

The predominant direction of groundwater flow in the bolson is from northwest to southeast (Conover, 1954; King et al., 1971; Wilson et al., 1981). Observations of head on the narrow zone of piedmont slope below the Organ Mountains show relatively steep piezometric head gradients sloping toward the Mesilla Valley. The steepness of the potentiometric surface in this area is partially attributed to the low permeabilities of local alluvial fan material, but is also explained by the partial barrier effect created by the horst east of Las Cruces.

Contour maps estimating the potentiometric surface on the West Mesa (Conover, 1954; King et al., 1971) showed flow patterns in which local groundwater mounds were superimposed on the general southeasterly direction of flow. The more recent map by Wilson et al. (1981) indicates that the head distribution on the West Mesa is somewhat simpler than what had been conceptualized previously. In this modeling investigation, the potentiometric surface as envisioned by Wilson et al. (1981) for this section of the Santa Fe Group was assumed to supercede all of those prepared by foregoing investigators. Depths to groundwater on the West Mesa may be as large as 400 feet.

In general, hydraulic heads in the flood plain alluvium are slightly higher than the piezometric levels measured from wells in the Santa Fe Group. Preliminary studies from Phase I (Khaleel et al., 1983, Figure A-1) indicated that this general observation appears to be reversed along a section of the Mesilla Valley lying a few miles south of Las Cruces to the vicinity of Berino.

In the various studies (Conover, 1954; King et al., 1971; Richardson, 1971; Wilson, 1981) in which comprehensive maps of groundwater levels have been developed, distinctions have been made as to whether the plotted contours represent either water table elevations in the Mesilla Valley or piezometric head levels in the Santa Fe Group. However, careful inspection of these maps seems to indicate that the depths of wells from which head data were taken to prepare the maps varies from study to study; thus, what may be interpreted as either a water table elevation or piezometric head level in a previous investigation may not necessarily be considered the same for this modeling investigation. Consequently, the authors have spent considerable time singling out the hydraulic head data that are applicable to the aquifer levels used in the three dimensional simulation.

Withdrawals of groundwater for municipal supply by Las Cruces in the northern half of the basin and by El Paso near Canutillo have produced distinct cones of depression in the respective municipal well fields. In the Las Cruces area, groundwater levels have been lowered about 30 to 50 feet below elevations that appeared to exist prior to extensive urbanization of the area. Similarly, piezometric heads in the Canutillo well field are probably

20 to 40 feet below predevelopment levels. Heads measured in the flood-plain alluvium near Canutillo are commonly as much as 25 feet higher than those observed at deeper levels (White, 1983).

From the analyses of various time series plots of groundwater levels (e.g., Conover, 1954; Leggat et al., 1962; King et al., 1971; Updegraff and Gelhar, 1978; Wilson et al., 1981; White, 1984), the following general observations can be made regarding the temporal behavior of hydraulic head in the Mesilla Bolson:

1. Shallow groundwater levels in the Mesilla Valley undergo fluctuations of annual cycle in response to irrigation and non-irrigation seasons. During spring and early summer months, the water table rises due to the diversion of surface water into the irrigation canal network and application of irrigation water on cropped lands. Peak water table elevations are usually observed in the late summer. With the gradual decline and eventual termination of irrigation in the fall, water levels slowly decline over winter months. Minimum water table elevations are commonly observed in late winter-early spring, just prior to the commencement of irrigation activity and the start of a new seasonal cycle. The annual range of observed heads in the shallow groundwater depends on location and the year, but reported fluctuations are commonly 2 to 5 feet. Depths to the water table vary from 5 to 25 feet below ground surface (e.g., Richardson, 1971; Wilson et al., 1981).

2. Piezometric head levels of the Santa Fe Group in areas subjected to pumping for irrigation will also frequently exhibit seasonal fluctuations that are more irregular and more sporadic than those observed in the flood-plain alluvium. Most often, heads in the confined aquifer drop during the summer in response to irrigation pumping. Recovery of piezometric head levels occurs in the winter. Fluctuations in measured levels over a given season can be significantly greater than those observed in the shallow water table.

3. Groundwater levels dropped noticeably throughout the Mesilla Valley from 1952 to 1957 (King et al., 1971). The uniform decline in groundwater heads was attributed to successive years of drought, which consequently signified low surface water supplies and increased pumping to meet irrigation needs.

4. After the mid-1950's drought, groundwater levels gradually recovered to pre-drought elevations. Prior and subsequent to the years in which drought-induced effects were observed, most wells in the valley have appeared to maintain relatively constant piezometric head levels. Thus, no long term lowering of groundwater levels due to irrigation pumping has occurred in the Mesilla Valley (Wilson et

al., 1981).

5. Despite the cone of depression created by the Las Cruces well field, hydrographs of selected wells in the area over a recent five-year period (Wilson et al., 1981, Figure 19) show no distinct or consistent decline in piezometric head levels. Similarly, no persistent reduction in local heads during the last 15 years can be discerned from hydrographs of observation wells in the Canutillo well field (White, 1983).

The tendency of piezometric heads in the Mesilla Valley and throughout the bolson to maintain relatively constant levels with time strongly infers that the groundwater flow domain, in recent years, has reached a virtual state of equilibrium. But to say that the current groundwater system is in a steady state is a somewhat incorrect description. Pumping rates, surface water diversions and drain flow quantities are all hydrologic variables affecting the subsurface flow regime that can change radically from year to year. Consequently, the groundwater system could probably be more correctly described as being in a quasi steady state, a term that will occasionally be used in this report.

Leakage

As previously discussed, hydraulic heads in the flood-plain alluvium are usually higher than those reported for the Santa Fe Group, indicating a net downward flux of groundwater leakage. Only along the middle one-third of the Mesilla Valley, from a few miles south of Las Cruces to near Berino, does there appear to be a possibility of reversal of the predominant downward movement (see Khaleel et al., 1983, Figure A-1). Indeed, it is the net downward leakage that primarily prevents groundwater levels in the Santa Fe Group in areas of intense pumping from dropping at rapid rates.

Although the predominant direction of leakage between the flood-plain alluvium and the Santa Fe Group is well-documented, much remains to be learned about the hydraulic properties of the low permeability beds lying between the two aquifers that act to confine the deeper groundwater. For instance, a single continuous confining layer of clay or silt spread uniformly along the length of the Mesilla Valley does not appear to exist. Rather, several interstratified layers of relatively clean sand and fine-grained, less permeable alluvium, of varying thicknesses and areal extent, are commonly observed. Detailed simulation of such complex stratification over the entire region is almost impossible. However, the retarding effect that low permeability materials have on water leaking from one formation to the other can be effectively simulated by approximating several interbedded layers of fine-grained alluvium as a single confining unit (e.g., Helm, 1975). Such an approach, indeed, is taken in the quasi three-dimensional simulation presented in this report. Consequently, the expression "confining bed", or "confining layer", should not be construed as meaning a single continuous aquitard, when used in subsequent sections of this report. Rather, such terminology is only utilized for convenience in describing general leakage processes in the model. Similar reasoning has been applied by Dunlap et al. (1985) in modeling a multilayered alluvial basin.

Even under the assumption that a single confining unit can be used to effectively represent many smaller interbedded deposits of high and low permeability materials, geologic logs from the Mesilla Valley region are not of sufficient quantity and quality that spatial variations of confining bed thickness and hydraulic conductivity can be documented. Therefore, estimates must be made of these physical parameters to facilitate the numerical simulation of regional groundwater flow.

A pumping test investigation in the early 1970's by Wilson and White (1984) of deep wells owned by the EBID appears to be the only study conducted in the basin which attempted to directly measure aquitard properties. Their report summarizes observed hydraulic properties of confining beds from three separate wells located about 5 miles south of Las Cruces. Using the techniques of Neuman and Witherspoon (1972), aquitard hydraulic conductivities ranging from 0.03 to 0.30 feet/day were calculated. Estimates of thicknesses of the confining, clayey strata in the test area range from 22 to 78 feet (Wilson and White, 1984).

Analysis of concurrently measured heads in the flood-plain alluvium and Santa Fe Group at a single location seems to indicate that leakage from one aquifer to the other is virtually a steady state process. For instance, hydrographs from shallow and deep observation wells (e.g., Wilson et al., 1981, Figures 17 and 18) show that water levels in one aquifer respond to changes in head in the other aquifer within a very short time. Thus, there is little evidence that water stored in confining, fine-grained sediments must be slowly released in response to stresses in either aquifer before good hydraulic communication between the aquifers is established. Substantiation of this observation was provided in the test pumping of EBID wells (Wilson and White, 1984), in which leakage from shallow layers apparently caused steady state conditions in a deep pumping well after two days of continuous groundwater withdrawals.

Data on aquitard properties for the basin fill aquifer materials on the West Mesa and on the piedmont slope east of the valley are even more scarce. Since few wells have been drilled in either of these areas, geologic logs showing local stratigraphy, let alone measured hydraulic head data, are very sparse. As a result, until such time that adequate evaluation of aquitard behavior in these outlying regions can be made, there is little justification for attempting to account for leakage processes in these regions.

Groundwater System Response to Hydrologic Stresses

An understanding of the mechanisms by which the bolson's flow domain responds to fluctuations in surface water supply and varied pumping rates is important to the conceptualization of hydrogeologic conditions, since it helps in determining which hydrologic processes the model will be most sensitive to. Furthermore, rough estimates of response times at various sections of the basin to hydrologic stresses imposed elsewhere assist in predicting the behavior of the groundwater flow system when subjected to increased groundwater pumping in the future.

Perhaps one of the most obvious features of the shallow flood-plain alluvium aquifer is its relatively rapid response to the infiltration of surface water during the irrigation season. As mentioned in an earlier discussion of temporal changes in hydraulic head, good hydraulic communication between surface water and groundwater is confirmed by the fact that rises in water table elevation are correlated with the increased irrigation applications and large flows in the canals occurring in the summer. The shallow depth of the water table (5 to 25 feet below ground surface) in the Mesilla Valley provides the probable explanation for the relatively quick response time to changes in surface infiltration.

Although interbedded, low permeability sediments may cause leakage from the flood-plain alluvium to the Santa Fe Group to occur at a somewhat slower rate than the rate of recharge to the shallow water table, existing information indicates that the speed with which changes in head in one aquifer are transmitted to another is still probably quite rapid. The previous section on leakage alluded to such a possibility based on observations of hydrographs in both aquifers.

A quantitative method for analyzing the rate at which head changes are transmitted from one aquifer to another is based on an analysis originally developed by Hantush (1960) to determine time required to reach steady state leakage. The procedure uses a dimensionless time measure (Bredehoeft and Pinder, 1970), which is expressed as:

$$(K't/m^2S_s) \qquad (1)$$

where K' = the hydraulic conductivity of the confining bed separating two aquifers (L/T);

t = the elapsed time since a change in head has occurred in one of the aquifers (T);

m = the thickness of the confining bed (L); and

S_s = the specific storage of the confining layer (1/L).

When the magnitude of above dimensionless time is greater than 0.5, sufficient time has elapsed for the complete release of water stored in a confining bed, which in turn signifies that leakage from one aquifer to another has reached a steady state. Using confining bed hydraulic properties that were either determined or estimated by Wilson and White (1984) (e.g., K' = 0.03 feet/day, m = 78 feet, and $S_s = 1 \times 10^{-5}$/feet), the criterion of Equation 1 suggests a time period of only 1 day before steady state leakage occurs. Even in the more conservative case, wherein K' = 0.01 feet/day, b = 200 feet and $S_s = 1 \times 10^{-4}$/feet, the required time for reaching an equilibrium condition is only 50 days. Therefore, based on what limited information exists for aquitard properties in the Mesilla Valley area, it is likely that the transmission of head changes from one aquifer to another is a relatively fast process. Correspondingly, the transient release of water stored in confining materials is not believed to play a significant role in vertical leakage from the flood-plain alluvium to the more permeable strata in the upper portions of the Santa Fe Group.

It should be noted the values of hydraulic conductivity (K') and specific storage (S_s) applied in the above computations using Equation 1 are somewhat representative of confining beds which contain significant amounts of coarse-grained materials. This may be partly due to the fact that many of the strata that tend to confine the more permeable alluvial materials are not pure clay or silt, and are perhaps more accurately described as mixtures of sand or gravel with fine-grained deposits. Indeed, well logs from the area (Wilson and White, 1984, pp. 48-50) for which some of the above parameter values were determined tend to show frequent mixtures of fine and coarse-grained materials in the upper parts of the Santa Fe Group. Detailed logs given in King et al. (1971) also illustrate the tendency of so-called confining beds in the upper Sant Fe Group of the Mesilla Valley to contain substantial quantities of sand and gravel.

Another measure of groundwater system response is the time needed for pumping in the Mesilla Valley to affect piezometric heads at mountain front boundaries. As a general rule, response times to stresses such as pumping become larger as hydraulic conductivity decreases (Bear, 1979) and distance from the stress increases. Therefore, times needed for the effects of pumping in the valley to be felt at the mountain ranges that form the east and west boundaries of the basin are expected to be long. With surface water sources annually recharging the valley in areas of pumping, the effects of groundwater withdrawals in the Rio Grande Valley may never actually be felt at distant basin borders. Preliminary calculations by the authors, using semi-empirical formulas in Bear (1979, p. 306) and reasonable values for aquifer properties on the West Mesa and the piedmont slope east of Las Cruces, suggest that years of continuous pumping in the valley may occur before any significant decreases in groundwater levels at the mountain fronts are observed.

In summary, it can be said that the tendency of piezometric head levels in the Mesilla Valley to show no long term decline is probably attributed to a plentiful supply of surface water, infiltration of which and subsequent leakage to deeper layers occurs rapidly enough to replace pumped groundwater. The large annual recharge component from surface water, along with considerable distances separating the river alluvium from the mountainous boundaries of the basin, and the existence of lesser permeable basin fill outside of the Mesilla Valley, suggest that potentiometric surfaces in areas located some distance away from the valley are nearly identical to natural or predevelopment head configurations.

VI. MODELING STRATEGY

In order to produce a meaningful simulation of the groundwater conditions in the Mesilla Bolson, it was important to seek a mathematical model that closely resembled the real groundwater basin and was consistent with the field data currently available. Various models of saturated subsurface flow of varying degrees of sophistication were evaluated for their appropriateness. It was decided that a two-dimensional, single layer, areal model was too simplified for the dynamic groundwater conditions occurring simultaneously in both the Mesilla Valley stream-aquifer system and the Santa Fe Group. Two-dimensional, vertical cross-sectional models were also eliminated from further consideration due to the fact that groundwater flow in the basin does not generally occur within vertical slices of unit thickness. Clearly, groundwater flow in the bolson occurs in three-dimensions. However, the question arises as to what degree such three-dimensional flow can be adequately simulated given the limited data base that exists for the study area.

Initial quasi three-dimensional modeling in Phase I was based on the conceptualization of the basin as a two-layer system, with the shallow river alluvium aquifer comprising one of the aquifers and the Santa Fe Group the other. Upon termination of the initial modeling investigation, it was suggested (Khaleel et al., 1983) that improved simulation might be achieved if the basin's groundwater domain were broken into several additional aquifers. The completion of the hydrogeologic cross sections during the past year did initially lend encouragement to the hope that the groundwater flow system could be discretized into many more layers. The cross sections do successfully delineate the locations of various rock, alluvial deposits, and sediment groups, each of which varies from the other in terms of its relative ability to transmit subsurface water. Nonetheless, within many of the classifications used in the cross sections, large variations in material texture and permeability are observed. Consequently, at this time, it remains a formidable, if not impossible, task to discern just exactly how the basin's stratigraphy affects changes in hydraulic conductivity and storage properties with depth (e.g., Gates et al., 1984).

In addition to a lack of information on vertical variations of aquifer properties, the three-dimensional distribution of hydraulic head is also poorly documented at this time. This is true not only for the upland areas of the basin (i.e., on the eastern piedmont slope, the West Mesa and at mountain front boundaries) but also within the Santa Fe Group under the Mesilla Valley. Consequently, there appears to be a limited quantity of data that could be utilized in a full three-dimensional (full 3-D) model of the basin. Accordingly, there may be some question as to whether a complex, full 3-D model of the basin is justified in this case. As other investigators (e.g., Premchitt and Das Gupta, 1981) have pointed out, the high computation cost and great manpower often needed for such a model may sometimes be impractical, particularly when the possibility exists that full 3-D analysis may be too sophisticated for the quantity and quality of data that are available.

Considering the data and resource constraints of this study, the authors opted to continue simulating Mesilla Bolson groundwater system with a two-layer quasi 3-D model. As in Phase I, the uppermost layer represented the flood-plain alluvium and the second layer represented the Santa Fe Group. The approach taken was in many ways similar to that of Dunlap et al. (1985), who used a modified form of a three-dimensional simulator to model an irrigated basin containing a stream-aquifer system. Justification for a two-layer quasi 3-D model was partly based on Meyer's (1976) multi-layered simulation of the Hueco Bolson, which lies east of the Mesilla Bolson and whose groundwater domain strongly resembles that of the study area. Gates et al. (1984) also utilized a quasi 3-D approach to simulate groundwater flow in the Lower Mesilla Valley.

A quasi 3-D model, in a sense, is a simplified version of a full 3-D model. As mentioned in an earlier section, this simplified model treats the water bearing strata as "aquifers", which are separated from each other by "aquitards". By virtue of the approach taken in a quasi 3-D model, these alternating layers of high and low permeability are assumed to extend continuously over the entire domain that is being simulated.

It is generally recognized that the simplifications associated with a quasi 3-D model sometimes are not entirely compatible with the conditions existing in a real groundwater system. However, a quasi 3-D approach still often provides an attractive alternative to full 3-D simulation due to: (1) its lower cost, (2) its potential for being more easily adapted to the available hydrogeologic data, and (3) the fact that the desired accuracy of flow simulation may not justify the additional effort involved with a full 3-D model. Potential errors with the simplified approach can be minimized if the rigid concept of "aquifers separated by continuous aquitards" can be altered (e.g. Premchitt and Das Gupta, 1981). Indeed, that is the approach that has been taken in this study. The two-layer quasi 3-D model is used primarily to account for simultaneous groundwater flow in the two major hydrogeologic units within the Mesilla Bolson, while attempting to simply approximate the exchange of water between them. Since the flood-plain alluvium only lies within a narrow areal strip relative to the total expanse of the Santa Fe Group, mostly vertical leakage of water occurs from one unit to the other only within that same limited area. Therefore, no attempt is made in the model to account for vertical flow (leakage) processes occurring elsewhere in the basin. Moreover, as was discussed earlier, the interstratified fine-grained deposits underlying the flood-plain alluvium that tend to confine Santa Fe Group groundwater are not actually believed to be a single continuous aquitard. Rather, leakage parameters representative of those low permeability sediments are applied in the model only in an attempt to approximate the predominantly vertical flow of groundwater between the flood-plain alluvium and major water bearing strata within the Santa Fe Group.

Only the upper 1,000 feet of saturated thickness in the basin are simulated, as this is the depth for which Wilson et al. (1981) developed a transmissivity map. Furthermore, no water wells in the bolson are known to exceed this depth; thus, assuming that wells in the basin are generally screened over large and perhaps many different intervals, most head data collected from existing wells are probably representative of average values of hydraulic potential rather than point values. It is, therefore, much easier to attempt to match these observed heads with a simpler two-layer model in which vertically averaged heads are simulated in each layer. Using such reasoning, it can be seen that the geologic cross sections are most useful for estimating mean transmissivities over the full 1,000 feet of saturated thickness that is modeled.

Methods of Steady State and Transient Calibration

Another recommended step stemming from Phase I research was to conduct a steady state calibration of hydrologic conditions that existed in the bolson in the early 1900's, prior to extensive well development. Unfortunately, upon further inspection of the data available for the early part of the century (e.g., Slichter, 1905), the authors realized that little to none of the hydraulic head field in the Santa Fe Group had been quantified. As an alternative, therefore, the authors chose to base their steady state calibration on the "quasi steady state" conditions that were previously alluded to, as existing in post-drought years since the 1950's. In particular, the year 1975 was selected as a representative year for simulation, primarily because the most comprehensive hydrologic data base for the region exists for this time period (i.e., Wilson et al., 1981).

In all simulations reported herein, leakage was only accounted for in the Mesilla Valley area, since this is the only part of the basin for which leakage behavior has been reported. The virtual nonexistence of information pertaining to the occurrence of leakage on the West Mesa and eastern piedmont slopes, suggested that simulation of leakage in these areas was not justified at this time.

Both steady state and transient calibrations were accomplished using a trial-and-error method. Although some consideration was originally given to the proposed use of a parameter estimation technique (Khaleel et al., 1983) for the purpose of allowing the model to calibrate itself, this idea was ultimately discarded. The complexity of subsurface flow and large spatial variability of aquifer characteristics, especially near the partial barrier to groundwater movement on the eastern piedmont slope, were the major reasons for not attempting a parameter estimation approach at this time.

From an earlier discussion of basin conceptualization, it seems probable that most existing pumping stresses in the Mesilla Valley do not significantly affect head distributions in the outlying mountain front recharge regions on the east and west sides of the basin. Based on such an assumption, boundary nodes used to simulate the mountain borders were treated as prescribed head boundaries in the steady state analysis. The resulting fluxes occurring across each prescribed head node were computed and printed by the model. Upon completion of the calibration effort, the final computed fluxes were treated as initial estimates of mountain front recharge.

A major purpose of the steady state simulation was to calibrate the model for aquifer media hydraulic properties such as transmissivities, hydraulic conductivities, and aquitard characteristics. Initial estimates of stream and canal seepage were also sought.

Simulation of quasi steady state conditions were to be followed by a transient analysis over a selected historical period. Although several different time spans were considered, the authors once again opted for simulation of recent conditions. Specifically, the period from January of 1966 through December 1983 was selected for the transient analysis. As was the case for steady state considerations, the availability of comprehensive data influenced the decision to choose this time period. The year 1966 was believed to be an appropriate starting time as detailed head maps are available for this time (or close to this time) in the Mesilla Valley and elsewhere (King et al., 1971; Richardson, 1971).

Based on the relatively long estimated response times of groundwater near the basin boundaries to hydrologic stresses in the Mesilla Valley, and the comparatively short times required for steady state leakage in the valley to occur, it was believed that only minor effects on piezometric heads near mountain boundaries during the transient calibration would be observed. For this reason, the same prescribed head nodes used at mountain front sources during the steady state calibration were also considered in the transient analysis. If indeed, boundary nodes were to be only slightly affected during the 18-year simulation period, computed fluxes at the specified head nodes would show only minor changes at each time step.

Parameters that were to be analyzed and refined during the transient simulation included storage coefficients, aquitard properties, and parameters that controlled surface water-groundwater exchange such as stream surface elevations and drain water surface levels. Alterations to the transmissivity field developed from steady state calibration were expected only in the event that considerable difficulties arose in the simulation of the transient head field.

Although the transient analysis spanned an 18-year period, the primary goal was to optimally match the computed heads at the end of 10 years of simulation with those observed at the end of the 1975 calendar year. An additional eight years of simulation was performed for two reasons. First, it was hoped that the model could be tested to discern its ability to match the annual drain flows reported by the U.S. Bureau of Reclamation. The authors felt that improved simulation of this hydrologic process would, to some degree, reflect an improved model of the Rio Grande flood-plain alluvium. Secondly, modeling of the basin through the year 1983 would produce hydraulic head fields in both aquifers that could be used as a starting point for predictive simulations of future conditions.

In summary, the transient calibration was to be performed in the interest of improving the model's ability to simulate two separate hydrologic variables. The first of these, hydraulic head, is the state parameter computed by the numerical model that approximates the governing equations of groundwater flow. The second, namely drain discharge, is one component of the total flux that affects the groundwater system budget.

Schematic Representation of the Conceptual Model

Figure 4 pictorially summarizes the authors' conceptualization of the Mesilla Bolson groundwater system using a hypothetical cross section of the study area. Illustrated are the types of subsurface flow that were modeled, along with potential recharge-discharge processes and the boundary conditions that could be considered.

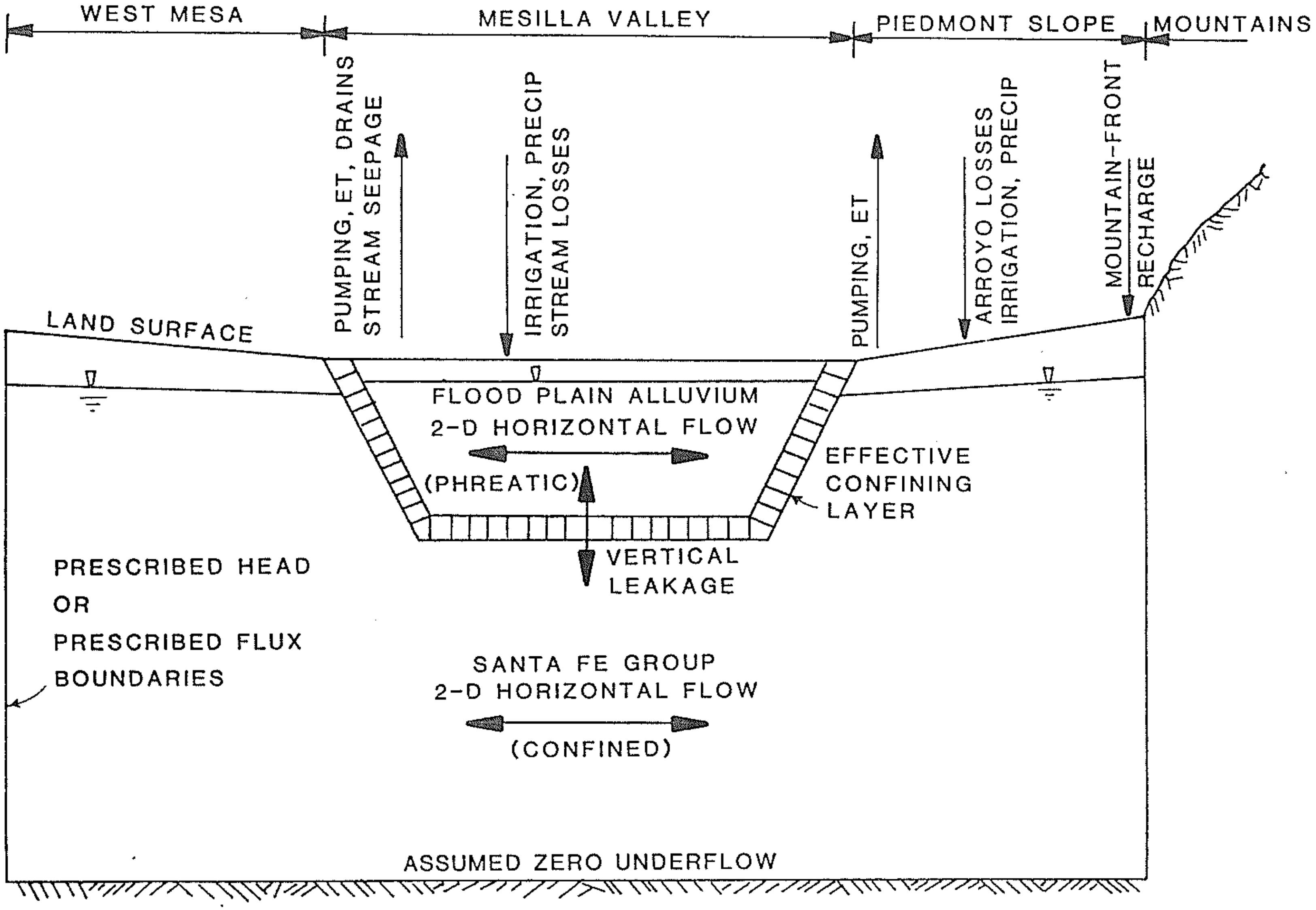


Figure 4. Conceptual Model of the Mesilla Bolson Groundwater System

Modeling of Future Conditions

After accomplishing an adequate transient calibration, the model was then used for three separate simulations of future conditions. The first of these was designed to assess the impact of increased groundwater withdrawals for urban use in the vicinity of the city of Las Cruces. The second and third predictive simulations were based upon projected increases of groundwater pumping as proposed by the El Paso Water Utilities Public Service Board (Wilson & Associates, 1981). In all three cases, attempts were made to evaluate the effects of possible groundwater stresses on the basin 100 years in the future

VII. NUMERICAL MODEL

Based on the conceptualization of bolson hydrogeology, analysis of available hydrologic data, and the selected modeling strategy, a numerical model of groundwater flow was designed in an ad hoc manner to suit the Mesilla Bolson. For reasons previously cited, the computer code used for the model simulated quasi three dimensional (quasi 3-D) flow of subsurface water. As stated earlier, advantages of this type of simulator, as opposed to a full three dimensional model, are 1) less demanding data requirements, 2) reduced computational effort, and 3) lower project expenses.

The existing version of the model was written in a FORTRAN language compatible with New Mexico Tech's DEC-20 computer. It allows for flow in as many as three separate aquifers. However, alteration of the code to account for several more permeable layers is an easy task, if needed.

Governing Equations

The equation governing two-dimensional horizontal groundwater flow in a confined aquifer is

$$\frac{\partial}{\partial x}\left(T_{xx}\,\frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(T_{yy}\,\frac{\partial H}{\partial y}\right) = S\;\frac{\partial H}{\partial t} + W(x,y,t) \qquad (2)$$

where T_{xx} and T_{yy} = principal components of the transmissivity tensor (L^2/T);

H = hydraulic head (L);

S = storage coefficient; and

$W(x,y,t)$ = volumetric flux of recharge or withdrawal per unit surface area of the aquifer (L/T) (Trescott et al., 1976).

If one of the layers is phreatic, or unconfined, the governing equation becomes

$$\frac{\partial}{\partial x}\left(K_{xx}b\,\frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_{yy}b\,\frac{\partial H}{\partial y}\right) = S_y\frac{\partial H}{\partial t} + W(x,y,t) \qquad (3)$$

where H and W are as defined in Equation 2. Because saturated thickness b is not constant in the unconfined case, transmissivity T is a function of head. Therefore, in Equation 3, T has been replaced by the product of hydraulic conductivity K (L/T), and saturated thickness b (L). In addition, specific yield S_y is used in lieu of storage coefficient.

Because saturated thickness remains constant in the confined case, Equation 2 is a linear differential equation. In contrast, the value of saturated thickness b must be known before the phreatic aquifer Equation 3 can be solved; thus, the governing equation for unconfined flow is a nonlinear one.

The source term on the right hand side of Equations 2 and 3 can include well discharge, leakage from or across a confining bed, prescribed recharge from point, areal or boundary sources, evapotranspiration losses and drain discharge. The flood-plain alluvium in the Mesilla Bolson is affected by all of these processes. However, there is no need to account for the evapotranspiration and drain flux components in the source term when simulating groundwater flow in the largely confined aquifer material comprising the Santa Fe Group.

Finite Difference Formulation

In order to solve Equation 2 or 3 for a heterogeneous aquifer system with irregular boundaries, a distributed parameter numerical model is most appropriate. The method of finite differences is used in this study. The approach taken is to divide the groundwater flow region into rectangular blocks, or grids, in which aquifer properties are assumed to be uniform. In addition, the spatial and time derivatives in the governing equations of flow are replaced by finite difference approximations of the derivatives at a point located in the middle of each grid. This scheme is commonly referred to as a node-centered finite difference approach, wherein the nodes at which heads are calculated are located in the center of each rectangular block. The procedure results in the generation of a finite difference equation for each node in each aquifer. All of the equations for one aquifer are solved simultaneously to produce computed heads at the nodes.

A detailed derivation of the finite difference equations is not included in this report. However, some of the more pertinent aspects of the numerical algorithm that forms the basis of the quasi 3-D code are summarized.

The multiple layers of the quasi 3-D model are numbered consecutively from top to bottom. The finite difference equations for each layer are solved in the same order. Therefore, heads are first computed for the uppermost layer (Layer 1), and are then utilized for leakage calculations in solving for the heads in the next deeper aquifer (Layer 2). The procedure is repeated until all layers have been accounted for.

The numerical solution scheme known as the Strongly Implicit Procedure (SIP) is incorporated in the model to solve the equations of flow for each layer. SIP is an iterative method for solving simultaneous equations as opposed to a direct solution technique such a Gaussian elimination. Therefore, the heads computed in each aquifer are not assumed final until the computational procedure has been repeated several times over all layers; the iterative process is terminated only when the minimum difference in computed heads between successive iterations is less than a predetermined convergence criterion. The basic two-dimensional SIP algorithm appears to have first been reported by Stone (1968). The SIP method applied in the quasi 3-D code of this study closely follows the step-by-step numerical solution scheme outlined by Remson et al. (1971).

In Phase I (Khaleel et al., 1983), the initial quasi 3-D code utilized Prickett and Lonnquist's (1971) version of the iterative alternating direction implicit (IADI) procedure to solve the numerical equations. However, the IADI method was found to be very inefficient and did not converge to a solution in many steady state simulations. Consequently, application of SIP during Phase II was recommended (Khaleel et al., 1983). Incorporation of the two-dimensional SIP algorithm into the quasi 3-D code has convincingly demonstrated its improved efficiency and ability to solve steady state problems as compared to the IADI technique.

Derivation of the finite difference equations that approximate Equations 2 and 3 produces a parameter that is sometimes referred to as "transmissibility", a term that is frequently used in the numerical simulation of reservoirs in the petroleum industry (see, for example, Peaceman, 1977, p. 135). In essence, transmissibility is an average, or representative, value of transmissivity (or hydraulic conductivity) that occurs between two adjacent nodes. Most commonly, the arithmetic or harmonic means of transmissivity are used to compute this parameter. A user of the quasi 3-D code developed for this project has the option of selecting either harmonic or geometric mean transmissibilities. The alternative of choosing a geometric average has been included inasmuch as stochastic analyses of spatial variability of hydraulic conductivity (Gutjahr et al., 1978) in two dimensions have demonstrated that the "effective" conductivity between adjacent points in a heterogeneous medium is identical to the geometric mean value.

Head Dependent Fluxes

Other than pumping and prescribed inflow and outflow quantities, the components comprising the source term W in Equations 2 and 3 are dependent on head values computed by the model. Specifically, the head dependent fluxes include 1) leakage, 2) stream seepage, 3) evapotranspiration, and 4) drain discharge. The algorithms used to compute each of these source term components are discussed in the following sections. It should be noted that many of the symbols used to represent parameters in the equations that follow are identical to variable names utilized in the computer code.

Leakage. Since leakage between the flood-plain alluvium and the Santa Fe Group in the Mesilla Valley is assumed to be mostly a steady state process, an algorithm for approximating the transient release of water stored in confining layers is not incorporated into the model. Even if delayed leakage from extensive clay bodies was proven to be significant in some sections of the Mesilla Valley, or on the West Mesa for instance, existing information on aquitard properties and their spatial variations is very limited. Therefore, incorporating methods of estimating the gradual release of water stored in fine-grained deposits is probably not justified at this time. If future investigations identify locales within the bolson where non-steady leakage phenomena are prevalent, the techniques developed for transient release of stored water by several investigators (e.g., Bredehoeft and Pinder, 1970; Tracy and Chirlin, 1984) can be easily incorporated within the quasi 3-D code.

The equation for computing steady-state leakage to a finite difference grid in one aquifer from the corresponding grid in an adjacent aquifer is:

$$QLEAK_{i,j} = \frac{K'_{i,j}}{M_{i,j}} (\hat{H}_{i,j} - H_{i,j}) \qquad (4)$$

where: i,j = column and row identifiers, respectively, of the finite difference grid;

$H_{i,j}$ = hydraulic head in the aquifer (L);

$\hat{H}_{i,j}$ = the hydraulic head in the adjacent aquifer on the other side of the confining bed (L);

$K'_{i,j}$ = the vertical hydraulic conductivity of the confining bed (L/T);

$M_{i,j}$ = thickness of the confining bed (L); and

$QLEAK_{i,j}$ = leakage rate per unit area of the grid (L/T).

Stream Seepage. Equations for calculating seepage between surface waterways and groundwater in the flood-plain alluvium assume the existence of a semipervious streambed, which is a low permeability silt and clay layer that is commonly found in the bed and banks of rivers and canals (Matlock, 1965). This "clogging layer", as it is frequently called, is known to impede infiltration rates from losing streams. In fact, the semipervious streambed phenomenon can help contribute to the hydraulic "disconnection" of stream and the adjacent water table, a phenomenon that was previously referred to.

Seepage either to or from a stream in the case of hydraulic connection is dependent on the elevation of the adjacent water table. However, when the stream and aquifer become disconnected, the leakage through the streambed is virtually constant (Townley and Wilson, 1980) as long as the streamflow depth does not change. The difference between the two cases is shown by the following equation that is used in the model to compute stream seepage in a single grid:

$$QSTR_{i,j} = \begin{cases} \dfrac{K''_{i,j}A_{i,j}}{B_{i,j}} (HSTR_{i,j} - H_{i,j}) & \text{if } H_{i,j} > HBED_{i,j} \\ \\ \dfrac{K''_{i,j}A_{i,j}}{B_{i,j}} (HSTR_{i,j} - HBED_{i,j}) & \text{if } H_{i,j} \leq HBED_{i,j} \end{cases} \tag{5}$$

where:

$A_{i,j}$ = surface area of the streambed within the grid (L^2);

$B_{i,j}$ = thickness of the clogging layer (L);

$HBED_{i,j}$ = the elevation at the bottom of the clogging layer (L);

$HSTR_{i,j}$ = the stream surface elevation (L);

$K''_{i,j}$ = hydraulic conductivity of the clogging layer (L/T);

$\frac{K''_{i,j}A_{i,j}}{B_{i,j}}$ = the stream seepage coefficient (L^2/T); and

$QSTR_{i,j}$ = stream leakage (L^3/T).

Figure 5a shows the spatial relationship of the parameters used in Equation 5. The general behavior of net stream seepage into the aquifer with changing head is illustrated in Figure 5b.

Evapotranspiration

The rate of evapotranspiration (ET) as computed in the model depends on the depth of the water table below ground surface. When the phreatic surface below a prescribed level, evapotranspiration is assumed to be zero. The equation for calculating the ET rate in a finite difference grid is:

$$QET_{i,j} = \begin{cases} ETMAX_{i,j} & \text{if } H_{i,j} \geq HLND_{i,j} \\ ETMAX_{i,j} - \dfrac{ETMAX_{i,j}}{ETDPTH_{i,j}}(HLND_{i,j} - H_{i,j}) & \text{if } H_{i,j} > (HLND_{i,j} - ETDPTH_{i,j}) \\ 0 & \text{if } H_{i,j} \leq (HLND_{i,j} - ETDPTH_{i,j}) \end{cases} \quad (6)$$

where: $ETDPTH_{i,j}$ = the depth below land surface at which evapotranspiration ceases (L);

$ETMAX_{i,j}$ = the potential evapotranspiration rate (L/T);

$HLND_{i,j}$ = elevation of the land surface (L); and

$QET_{i,j}$ = evapotranspiration rate per unit area (L/T).

Figures 6a and 6b show the relationships of the various evapotranspiration variables and the nature of computed ET rates with changes in hydraulic head, respectively.

A head-dependent algorithm to compute ET rates has been included in the

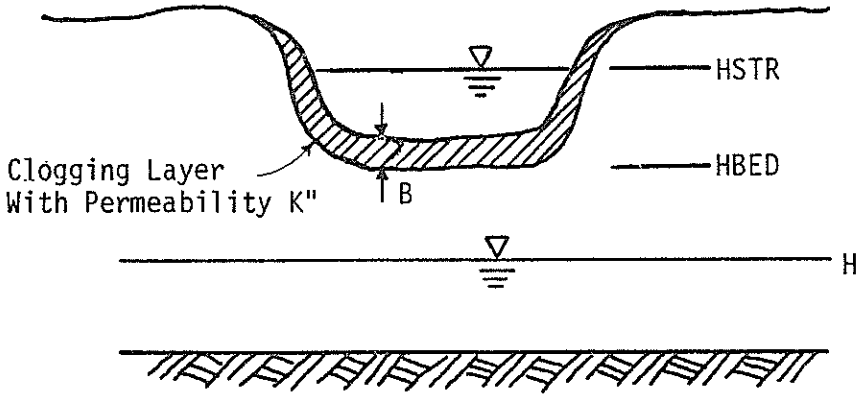


Figure 5a. Spatial Relationship of Stream Seepage Parameters

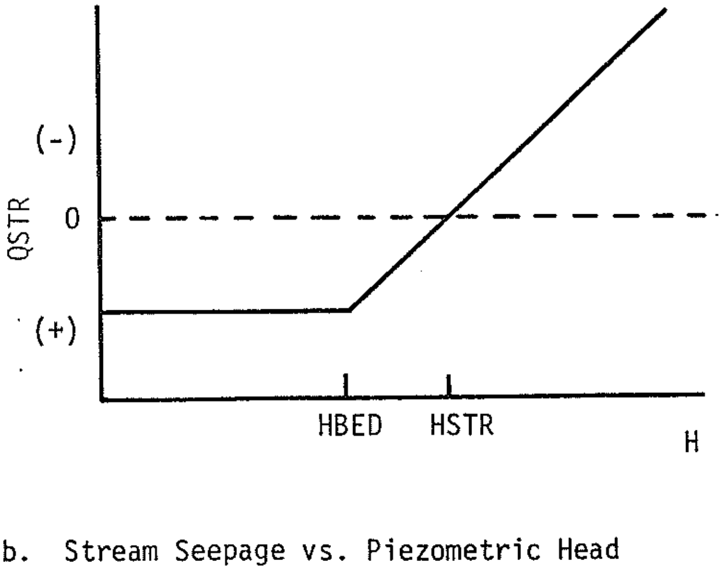


Figure 5b. Stream Seepage vs. Piezometric Head

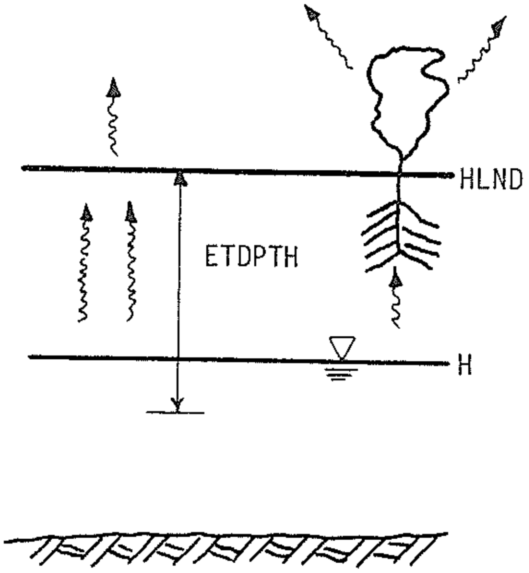


Figure 6a. Spatial Relationship of Evapotranspiration Parameters

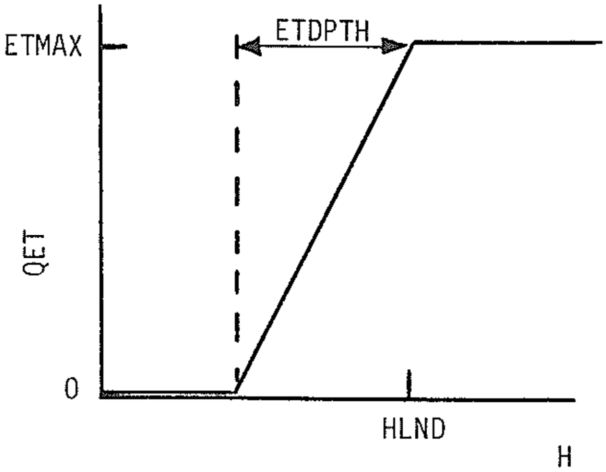


Figure 6b. Evapotranspiration vs. Piezometric Head

model in an attempt to account for changes in this form of groundwater discharge as the water table undergoes minor fluctuations. Robinson (1964) demonstrated that, in a region with a shallow water table, ET rates are dependent on depth to the phreatic surface. It has also been shown that, for some cases, the process of evapotranspiration may be stopped when groundwater levels drop to such an extent that ET is no longer possible (e.g., Robinson, 1964; Dunlap et al., 1985, p. 19). Several groundwater flow models (e.g., Trescott et al., 1976; Townley and Wilson, 1980; Torak, 1982) incorporate a depth-dependent algorithm similar to that given by Eq. 6 to account for this phenomenon. Prickett and Lonnquist (1971) used this approach to successfully simulate increasing ET in an area with a steadily rising water table created by the infiltration of water from an irrigation canal system.

The fact that the head-dependent method for computing ET rates is applicable to shallow water table aquifers should make it usable in the Mesilla Valley as well. The mean depth to the water table measured in 39 shallow observation wells located throughout the valley usually ranges from 5 to 8 feet below ground surface (King et al., 1971, p. 56). Only during the drought of the mid 1950's did the mean level of observed water table depths come close to reaching 20 feet. As will be illustrated later, the head-dependent method of quantifying the combined ET from both crops and phreatophytes in the Mesilla Valley under current conditions seems to be satisfactory. However, when applied to possible future situations, wherein the water table drops significantly in response to increased groundwater withdrawals, shortcomings of this approach will be demonstrated.

Drain Discharge. Using a relationship similar to that given by Equation 5, groundwater seepage to a drain can be approximated by knowing the difference in head between the drain water surface and the adjacent water table (Updegraff and Gelhar, 1978). The equation used in this model to compute drain flows in a given grid is

$$QDRN_{i,j} = \begin{cases} DRCOF_{i,j}(H_{i,j} - HDRN_{i,j}) & \text{if} \quad H_{i,j} > HDRN_{i,j} \\ 0 & \text{if} \quad H_{i,j} \leq HDRN_{i,j} \end{cases} \tag{7}$$

where: $DRCOF_{i,j}$ = the drain coefficient (L^2/T);

$HDRN_{i,j}$ = the drain water surface elevation (L); and

$QDRN_{i,j}$ = discharge into the drain (L^3/T).

A variety of factors, including drain dimensions and hydraulic conductivity of the surrounding aquifer, constitute the lumped drain coefficient DRCOF (Updegraff and Gelhar, 1978, p. 9). Instead of attempting to derive or estimate values for each of the input parameters in DRCOF, a frequently used approach is to make an initial guess for the coefficient and then gradually change its value by trial-and-error until a fit to drain discharge is achieved.

Linear Dependence of Flux Terms

It is noteworthy to point out that the formulas used herein to compute stream seepages, evapotranspiration and drain flow (Equations 5, 6, and 7, respectively), other than when threshold conditions are met, are all based on assumed linear relationships between the flux term and the head H in the aquifer. In some cases, a linear dependence between the two variables may not be physically realistic. For instance, Trescott et al. (1976) report that evapotranspiration rates may be more accuratelty treated as exponential functions of the water table depth. McClin (19678) found that, when dealing with very low drain flow situations, a nonlinear equation relating drain discharge to the head differential between drain surface elevation and water table elevation was more appropriate than a linear relationship. Despite such findings, the authors felt that incorporation into the model of nonlinear algorithms for computing stream seepage, drain flow and evapotranspiration rates was not warranted at this time.

Boundary Conditions

The quasi 3-D code allows either prescribed head (first type) or prescribed flux (second type) boundary conditions to be invoked along the borders of each aquifer. A no flow boundary, which represents a prescribed flux of zero, is established by setting tranmissivity (or hydraulic conductivity) equal to a value of zero outside of the area of simulation. Prescribed head boundary grids are denoted by negative storage coefficients. Head dependent boundary conditions (third type) were addressed earlier in the discussions of leakage, stream seepage, drain discharge and evapotranspiration.

General Simulation Capabilities

Grid dimensions in the quasi 3-D model can be of uniform or variable size. Aquifer properties, aquitard characteristics, and parameters controlling the various fluxes that affect an unconfined aquifer can be read into the model as default values or on a grid-by-grid basis. Pumping rates can be varied with time by establishing pumping periods of varying duration, over each of which specified discharge-recharge fluxes are assumed to remain constant.

The model user can specify whether the uppermost aquifer is phreatic or confined. Underflow to the deepest aquifer via leakage from deeper aquifers is also allowed.

Steady state simulations are conducted by setting all storage coefficients (other than at prescribed head boundaries) equal to zero. This step is tantamount to setting the time derivatives of head in Equations 2 and 3 equal to zero.

Anisotropic flow in any or all of the aquifers is handled by aligning the finite difference grid with the principal components of the transmissivity (or hydraulic conductivity) tensor. Individual values of T_{xx} and T_{yy} (or K_{xx} and K_{yy}) can then be read directly into the model.

Model results are given as output at the end of each simulation period and at prescribed time intervals. A mass balance summary, which tabulates flow rates and volumes of all components of each layer's hydrologic budget, can also be requested.

Additional Model Features

To assist in modeling the hydrogeologic conditions observed in the Mesilla Bolson, the basic quasi 3-D code was augmented to allow the model user to change the following sets of input data at the commencement of each new pumping period:

1. recharge/discharge rates,
2. storage coefficients (S and S_y),
3. stream surface elevations, and
4. drain surface elevations.

The first of these items not only allowed pumping quantities to change with time, but also permitted second type boundary fluxes and/or their locations to be changed as well. Having the option to alter storage properties allowed the first type boundary locations to be revised, if necessary. But this latter feature was originally intended for use as a means of approximating the gradual transformation of an aquifer that mostly responds as a confined unit under current conditions, such as the Santa Fe Group, to a predominantly unconfined system upon increased pumping stresses.

Alteration of stream and drain surface elevations was permitted to reflect the fact that depths of flow in both types of waterways were affected, as surface water discharges changed. Increases and decreases in flow stage were believed to have a significant effect on stream and drain seepages computed by Equations 5 and 7, respectively.

Verification of the Model

The quasi 3-D code was verified by a successful duplication of a two-layer aquifer flow problem for which a closed form analytical solution was originally developed by Hantush (1967). The model's ability to adequately simulate stream seepage, evapotranspiration and leakage was evaluated using individual test cases for each of these hydrologic variables presented in Prickett and Lonnquist (1971). A single-layer simulation involving variable grid sizes and second type boundaries (Trescott et al., 1975) was successfully duplicated using the quasi 3-D model. Based on such verification results and repeated use of the code for a variety of Mesilla Bolson simulations, the authors felt that the quasi 3-D computer code was reasonably free of error and was appropriately handling the algorithms for which it was designed.

VIII. GRID DESIGN AND MODEL INPUTS

Spatial Discretization of the Flow Domain

The finite difference grid system that was utilized for the Mesilla Bolson flow domain is presented in Figure 7. Several points are worth noting with respect to the selected spatial discretization scheme.

1. The grid network has a northwest-southeast orientation so that it parallels the Mesilla Valley as well as the prevailing direction of groundwater flow in the basin. The design also facilitates influx of water at mountain front boundaries, as recharge in these areas mostly enters the region in a direction perpendicular to the finite difference blocks. Furthermore, should anisotropy of hydraulic conductivity in the flood-plain aquifer ever be found to be significant, the model orientation could easily handle such a condition.

2. Simulation boundaries on the east and west sides of the basin have not been selected to coincide with the surface water basin boundaries; rather, they are located at the mountain front-basin fill interfaces as there is little reason for extending the modeled area into rock facies zones that are practically impermeable. The western boundary between the Potrillo and Robledo Mountains follows the Robledo Fault, for reasons cited in the model conceptualization section.

3. Prescribed heads in the Santa Fe Group are denoted by asterisks. No prescribed head nodes were assigned in the flood plain-alluvium.

4. The modeled area has been slightly extended to the south of the U.S.-Mexico border. Prescribed head boundaries have also been used in this region in the interest of accounting for northeastward moving influx of groundwater from the Lake Palomas Basin in northern Chihuahua, Mexico.

5. The finite difference grid network is 24 columns wide by 28 rows long. Column widths are 2 miles near the east and west boundaries and 1 mile in the Mesilla Valley. A column width of 0.75 mile is used in the vicinity of the Las Cruces well field. Each row is 2 miles long, with the exception of rows 7, 8, 9, and 10, where the row dimensions are 1.5, 1.0, 1.0, and 1.5 miles, respectively. The finest discretization occurs mostly in areas where existing piezometric head gradients are steepest due to either pumping, such as in the Las Curces area, or where geologic structure influences groundwater movement, as in the vicinity of the bedrock high east of Las Cruces.

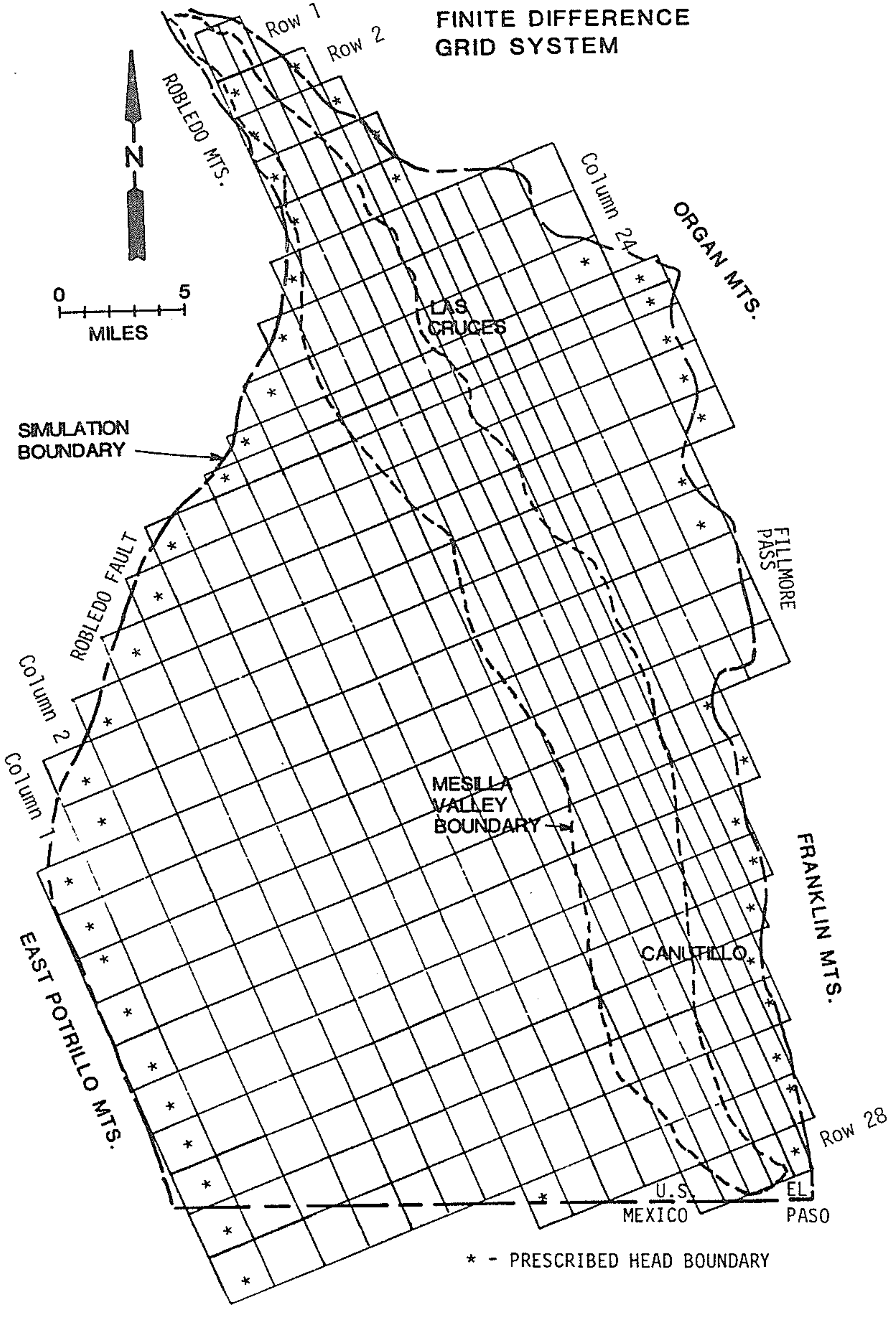


Figure 7. Finite Difference Grid System

Input Data

The input data used in the finite difference model during steady state, transient and predictive simulations were derived from a variety of sources. Some of the parameters needed to execute the model, such as irrigation pumping rates, had to be estimated from whaever descriptive information was available. The following section briefly described the procedures and references utilized in developing necessary input data.

Aquifer Characteristics. Initial estimates of transmissivity in the Santa Fe Group and hydraulic conductivity in the flood-plain alluvium were obtained from or computed using information presented in Wilson et al. (1981). For those areas where little to no information existed for these parameters, the hydrogeologic cross sections prepared by Dr. Hawley were utilized to locate areas with similar basin fill units for which transmissivity information is available.

A calibrated transmissivity field of the Santa Fe Group was developed as a result of two-dimensional modeling efforts in Phase I (Khaleel et al., 1983). Therefore, must of the calibration work involved in this second phase of the study was minimized. The method of kriging, a statistically based procedure of spatial interpolation, was also applied by Khaleel et al. (1983) for the purpose of quantifying the transmissivity distribution in areas where data is either sparse or nonexistent. During the second pahse of modeling, quantities developed from the kriging analysis have been used cautiously as it has been shown (O'Brien and Stone, 1984) that such geostatistical interpolation procedures may fail to account for structural controls on groundwater flow, such as the fault block barrier east of Las Cruces.

Because Phase II modeling was to incorporate both major aquifer systems in the Bolson, it was suggested (Khaleel et al., 1983) that kriging could also be used to quantify the transmissivity field in the flood-plain alluvium. However, this idea was ruled out as further inspection of pumping test results showed that insufficient data existed to warrant its application.

Storage coefficients and specific yield parameters were not needed for the steady state analysis. Due to the fact that little is known about the spatial distribution of either of these hydraulic variables in the bolson, representative uniform values were selected for transient simulations. Based on previously mentioned references (Conover, 1954; Richardson, 1971; Updegraff and Gelhar, 1978; Wilson et al., 1981; Wilson and White, 1984), a specific yield of 0.20 was assumed for the phreatic aquifer, whereas a uniform value of 0.001 was assumed for the storage coefficient in the Santa Fe Group.

Confining Layer Parameters. Variables controlling the rate of steady state leakage between the two aquifers include confining layer hydraulic conductivity, confining layer thickness, and the difference in heads between layers. The interbedded fine-grained deposits separating the two aquifers do not actually form a single confining layer with a distinct measurable thickness. Therefore, as the water level in the Santa Fe Group is drawn below the base of the so-called confining layer, immediate transition from mostly confined to largely phreatic conditions probably does not occur; rather, the transition is most likely a gradual process. As a result, an algorithm to handle an immediate switch from one condition to another was not included in the model source code.

Because the model did not account for an instantaneous conversion from confined to unconfined flow conditions, the thicknesses assigned to aquitards in the Mesilla Valley grids had no effect on simulation results, except to increase the resistance to leakage as the confining layer thickness increased. Therefore, for convenience, aquitard thickness was allowed to vary spatially in the steady state and transient simulations, while the hydraulic conductivity of the confining layer was maintained at a uniform value of 0.01 throughout the Mesilla Valley.

Phreatic Aquifer Descriptors. Because no explicit information describing the spatial variations of depth of the flood-plain alluvium has been developed, a uniform depth of 90 feet throughout the valley was assumed in the model. Representative ground surface elevations were taken from U.S. Geological Survey topographic maps.

During the winter of 1983-84, personnel from New Mexico Tech studied U.S. Bureau of Reclamation engineering profiles of several canals and drains throughout the Mesilla Valley. Pertinent data regarding canal bed elevations, water levels, and drain elevations were recorded. From this information, along with bed profiles of the Rio Grande, estimates were made of stream bed, stream surface and drain water surface elevations for use in both the steady state and transient simulations.

Unfortunately, no measurements of clogging layer parameters for the Rio Grande have been made. However, the NMSU Civil Engineering Department (1956) has made numerous measurements of channel bed permeability along several irrigation laterals in the Mesilla Valley. Initial estimates of values that could be used for clogging layer characteristics were taken from this NMSU report and from Rovey (1975). These parameters were, however, adjusted during the trial-and-error calibration process. Cumulative stream and canal widths for each of the finite difference grids used to simulate the river alluvium were estimated from topographic maps and data collected in the field.

The coefficient used in Equation 7 for computing drain flows would normally be a parameter for which initial guesses would have to be made, and then gradually adjusted until calibration was achieved. Fortunately, a single representative value of the drain coefficient based on a lumped parameter model of the Mesilla Valley was previously determined by Updegraff and Gelhar (1978). Rather than attempting to vary this parameter spatially in the model, the lumped parameter value was applied uniformly throughout the valley. Using an assumed stage-discharge relationship, changes in drain flow within a grid were accomplished by either raising or lowering the drain surface elevation.

A maximum evapotranspiration rate of 0.0195 feet/day was used in the algorithm given by Equation 6. This value was felt to be representative for the Mesilla Valley, based on consumptive use studies by Sammis et al. (1979). The depth to which evapotranspiration could occur was assumed to be 15 feet. The acreage within each grid over which significant evapotranspiration was believed to occur was estimated from maps of the region.

Starting Heads. The quasi three-dimensional model requires the input of initial heads. In the case of steady state analyses, the starting heads are identical to actual observed heads in both aquifers during January of 1976. These initial values are used in the first iteration of the SIP algorithm to compute the various head dependent source terms comprising W in Equations 2 and 3, as well as to calculate the initial flow volumes between grids. The goodness-of-fit of a steady state simulation is quantitatively evaluated by assessing the deviation of computed heads from the starting values used as initial input.

Piezometric heads in each aquifer were determined using a variety of sources. Assumed starting heads for the Mesilla Valley area in 1966, the starting year of the transient calibration, were largely obtained from the groundwater contour map of King et al. (1971). The comprehensive groundwater contour map by Wilson et al. (1981) for January 1976 conditions was utilized for three purposes: (1) to determine starting (1966) heads in the Santa Fe

Group outside of the Mesilla Valley area, assuming that the piezometric head configuration in upland areas of the Bolson has essentially remained unaltered over the last twenty five years; (2) as a basis from which initial heads could be developed for the steady state calibration; and (3) for comparison with heads computed for the year 1975 in the transient analysis.

A contour map of observed piezometric heads in the flood-plain alluvium in January 1976 is presented in Figure 8. Figure 9 shows the observed head configuration in the Santa Fe Group at the same time.

Pumping Rates. Of all the necessary input data for execution of the model, perhaps the most difficult to develop were the pumping rates (both reported and estimated) of the many wells known to exist in the basin. It is likely that there were more than 1,000 water wells operating in the basin in recent years. Although the annual groundwater withdrawals from many of these wells were so minor that they could be safely ignored in model simulations, a majority of them needed to be included in all simulations. For a groundwater use category in which only total annual pumpages were either reported or estimated, reasonable assumptions were made as to how best to distribute those totals among the many wells that fit into that category. The additional task of assigning annual pumpages to either the flood-plain alluvium, the Santa Fe Group, or both aquifers, was frequently a problem, particularly at well sites where well construction information was limited to nonexistent.

During many of the years included in the transient simulation, annual pumping volumes were reported for each of the numerous wells located in the municipal well fields at Las Cruces and Canutillo. In this case, actual groundwater withdrawal rates were assigned to the affected grids accordingly. In some years, however, only the total combined pumpages from the municipal fields were reported, in which case it was assumed that these totals were

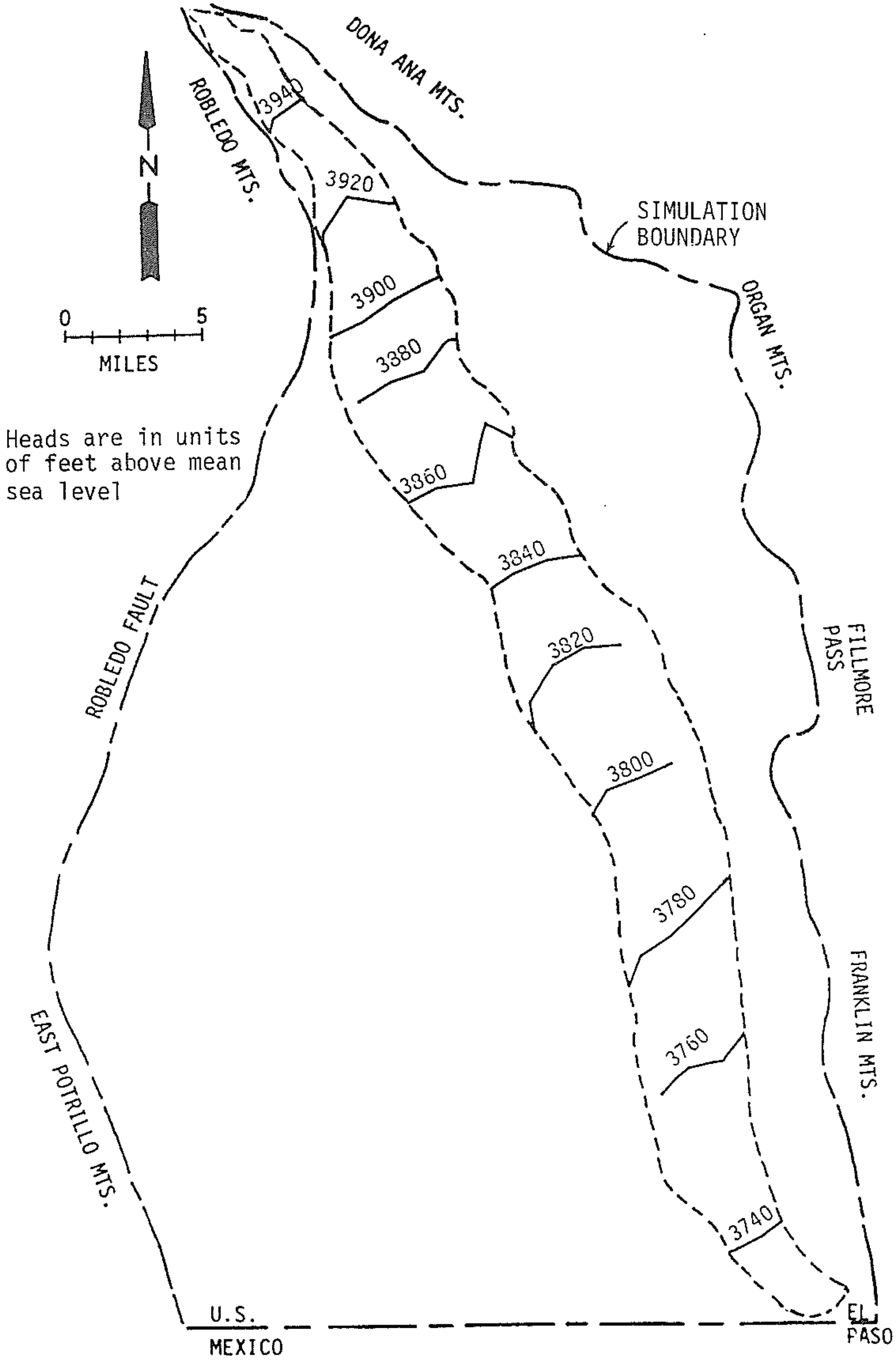


Figure 8. Contour Map of Observed Piezometric Heads in the Flood-Plain Alluvium in January 1976

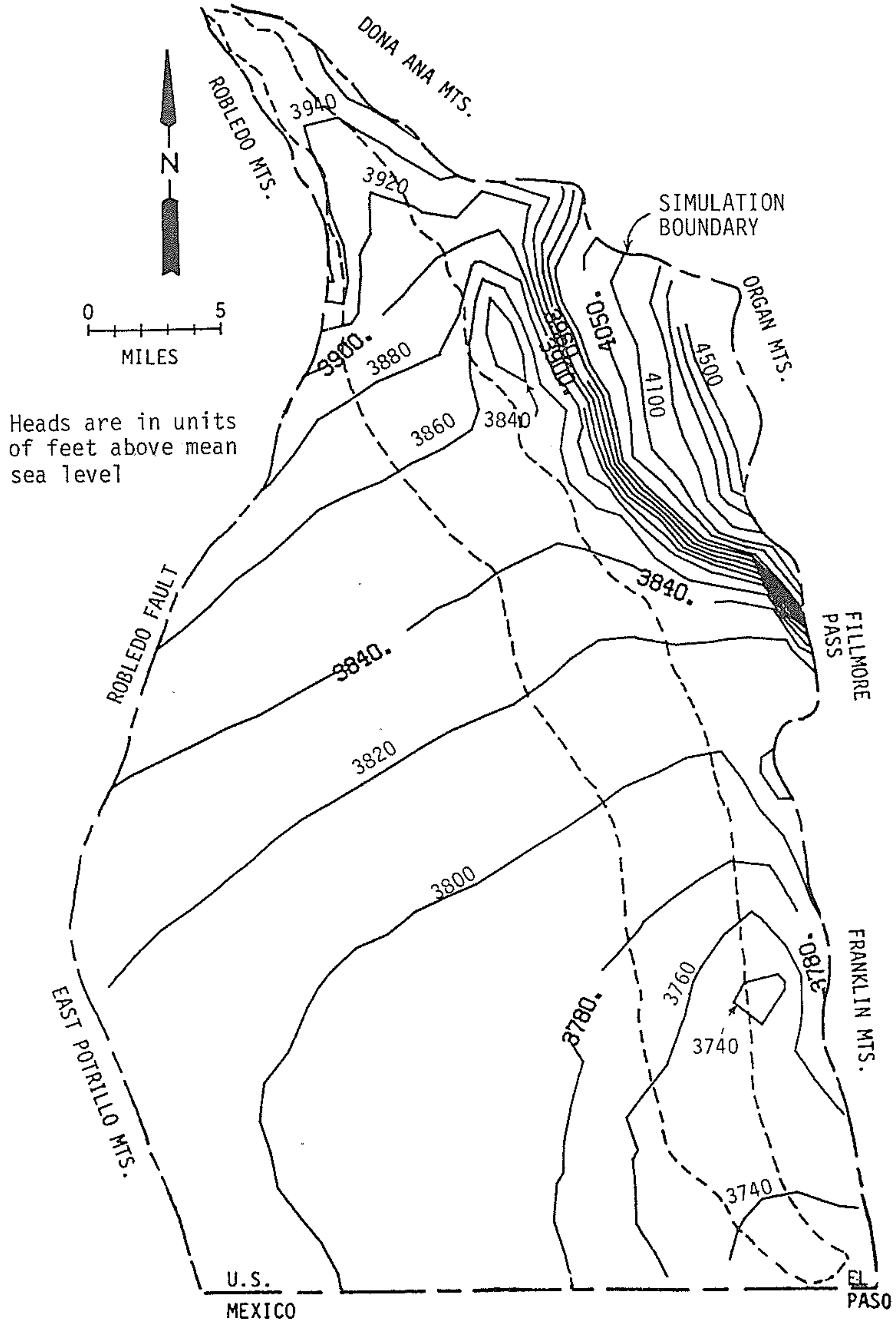


Figure 9. Contour Map of Observed Piezometric Heads in the Santa Fe Group in January 1976

divided equally between all wells known to be operating in that year. The pumping data for the Las Cruces wells were obtained from records maintained by the city of Las Cruces, while those from the Canutillo area were derived from U.S. Geological Survey summaries.

Annual groundwater withdrawals were also available in some years for a few small New Mexico community water systems, such as those maintained by the Jornada Water Company and the Dona Ana Municipal Development Water Company. However, as is the case with the larger municipal systems, many yearly pumpages had to be estimated. Records or estimates of pumping quantities in most years for the smaller public supply entities in the Texas portion of the Mesilla Bolson, as well as some New Mexico communities in the Lower Mesilla Valley (e.g., Santa Teresa Estates) were tabulated by the U.S. Geological Survey (Pumpage Summaries for the Lower Mesilla Valley).

Estimated annual pumpages for many of the small villages in the New Mexico portion of the Mesilla Valley, whether community supplies or individual domestic wells are used, have been computed using population figures (reported or assumed) and assumed per capita consumption rates. Useful references for arriving at such estimates included Dinwiddie et al. (1966) and Sorensen (1977; 1982). Annual enrollment figures along with estimated consumption rates have also been used to compute approximate volumes of yearly public water use at New Mexico State University. These latter pumpages were assumed to be equally divided between three wells at the institution.

Annual depletions of groundwater attributed to industrial and power uses in the Mesilla Valley were obtained from U.S. Geological Survey records (Pumpage Summaries for the Lower Mesilla Valley). Pumpages for these same two use categories elsewhere in the basin appeared to be minor, and were consequently disregarded in the model simulations.

Irrigation pumpages within the irrigation districts (EBID and EPWID) in the Mesilla Valley have varied from year to year depending on available surface water supplies. When canal diversions have failed to meet the annual crop irrigation requirement, which is assumed to be 3.08 acre-feet/acre in this study, it has been assumed that the deficiency was made up by the pumping of irrigation wells in the valley. Based on water well summaries given in Wilson et al. (1981), an estimated 502 wells were pumped each year during the period 1966-1977 to help meet agricultural needs. Since 1978, 26 additional deep irrigation wells (Wilson and White, 1984) have also been used, bringing the total number of irrigation wells in the Mesilla Valley to 528. Because records of withdrawal rates at individual pumping sites have not been maintained, computed irrigation pumpages based on the aforementioned crop requirement were assumed to be divided equally between all known irrigation wells.

From 1976 through 1978, five deep wells owned by the EBID were pumped to augment surface water diversions in the canal network downstream of the Mesilla diversion dam. Combined annual withdrawals at EBID wells were summarized by Wilson and White (1984). These data were used to estimate pumping rates at each well for input to the model.

The number of irrigation wells in the Mesilla Valley that have been in operation during the last several years varies from 502 to 528; however, nearly 224 of them, or about 40 percent of the total, are characterized by incomplete construction records (Wilson et al., 1981). Thus, it is difficult to determine which aquifer(s) these wells withdraw water from. For those pumping sites where such a determination is virtually impossible, it was arbitrarily assumed that computed annual withdrawals were divided equally between the Santa Fe Group and the flood-plain alluvium. This approach was felt to be the most reasonable one, as Wilson et al. (1981, p. 40) have reported that most irrigation wells in the valley tap both shallow and deep groundwater systems. A questionable alternative would have been to arbitrarily assign a portion of the 224 wells to one aquifer and the remainder to the other aquifer. Equally questionable would have been an approach wherein unknown formation wells were totally omitted from the simulation, which would most likely produce serious errors in the assumed areal distribution of pumping.

Irrigation Applications.

The amount of irrigation water applied (i.e., the quantity of water applied to the crops prior to any consumptive use) each year in the Mesilla Valley was estimated using reported irrigated acreages (U.S. Bureau of Reclamation, Monthly Water Distribution Summaries) and the previously mentioned crop requirement. In agricultural areas lying outside the irrigation districts, volumes of applied irrigation water were calculated using a crop requirement of 3.71 acre-feet per acre (Lansford et al., 1974). However, in those upland areas not served by surface water diversions, only the net groundwater recharge (i.e., irrigation application minus crop consumption) was used as a source to the subsurface flow domain.

IX. STEADY STATE CALIBRATION

Procedure

As previously mentioned, the steady state calibration was performed utilizing the estimated head fields in both aquifers for January 1976 conditions. Using these heads as starting values, the goodness of fit of the model to actual conditions was evaluated by considering the deviations of the final computed heads from assumed initial values. Parameters that were adjusted during each run to improve the model fit included hydraulic conductivity in the flood-plain alluvium, transmissivity in the Santa Fe Group, confining layer thickness, stream seepage coefficient and drain surface elevation. The hydraulic conductivity of the so-called aquitard separating the two aquifers was assumed to have a uniform value of 0.01 feet/day. Values of storage coefficient were not considered as they are not required in a steady state calibration.

The trial and error procedure of calibration proved to be quite laborious, particularly in the piedmont slope area lying upgradient of the horst east of Las Cruces. This result was expected, since piezometric head gradients immediately west of the Organ Mountains and just east of Las Cruces are very steep. It is difficult to select a representative head for the grids in such locales, let alone attempt to match such observed heads with values computed by the model. Moreover, simulation of the barrier effect created by the horst that dominates the northeast section of the basin is complicated. During the steady state runs, it was observed that small changes in transmissivity within the region created very large changes in head. Thus, calibration consisted of numerous trial-and-error runs in which the transmissivity field was repeatedly adjusted, while at the same time maintaining transmissivity values within reasonable bounds based on reported data (e.g., Wilson et al., 1981) and geologic cross sections.

Steady State Results

A printout summarizing the input data and results for the calibrated steady state model is presented in Appendix B. The flood-plain alluvium is represented by Layer 1, and the Santa Fe Group by Layer 2.

The maximum discrepancy between observed heads (tabulated as starting heads in Appendix B) and final computed heads (listed as computed steady state heads in Appendix B) was 11.9 feet. The table of computed drawdowns summarizes the discrepancies between starting and computed head levels for each grid. Positive values signify drawdowns whereas a negative value indicates that the computed head is larger than the initial head. The largest differences between starting and computed values are observed in Layer 2, i.e., the Santa Fe Group. Also, as might be expected, these large discrepancies are most prevalent in the piedmont slope region east of Las Cruces where piezometric head gradients are steep. Differences between starting and final values of head in the flood-plain alluvium (Layer 1) are generally quite small, ranging in absolute magnitude from a minimum of 0.1 feet to a maximum of 4.4 feet.

A plot of absolute magnitude of differences between observed and computed values of hydraulic head for both aquifers versus the percentage of nodes with absolute values less than the corresponding difference is presented in Figure 10. The relative fit of the calibrated model to the observed head field is seen to be quite good, inasmuch as 90 percent of the total number of simulated nodes show an absolute deviation of less than 5 feet.

Contour maps of the computed steady state head fields in the two modeled aquifers are shown in Figures 11 and 12. These can be compared with Figures

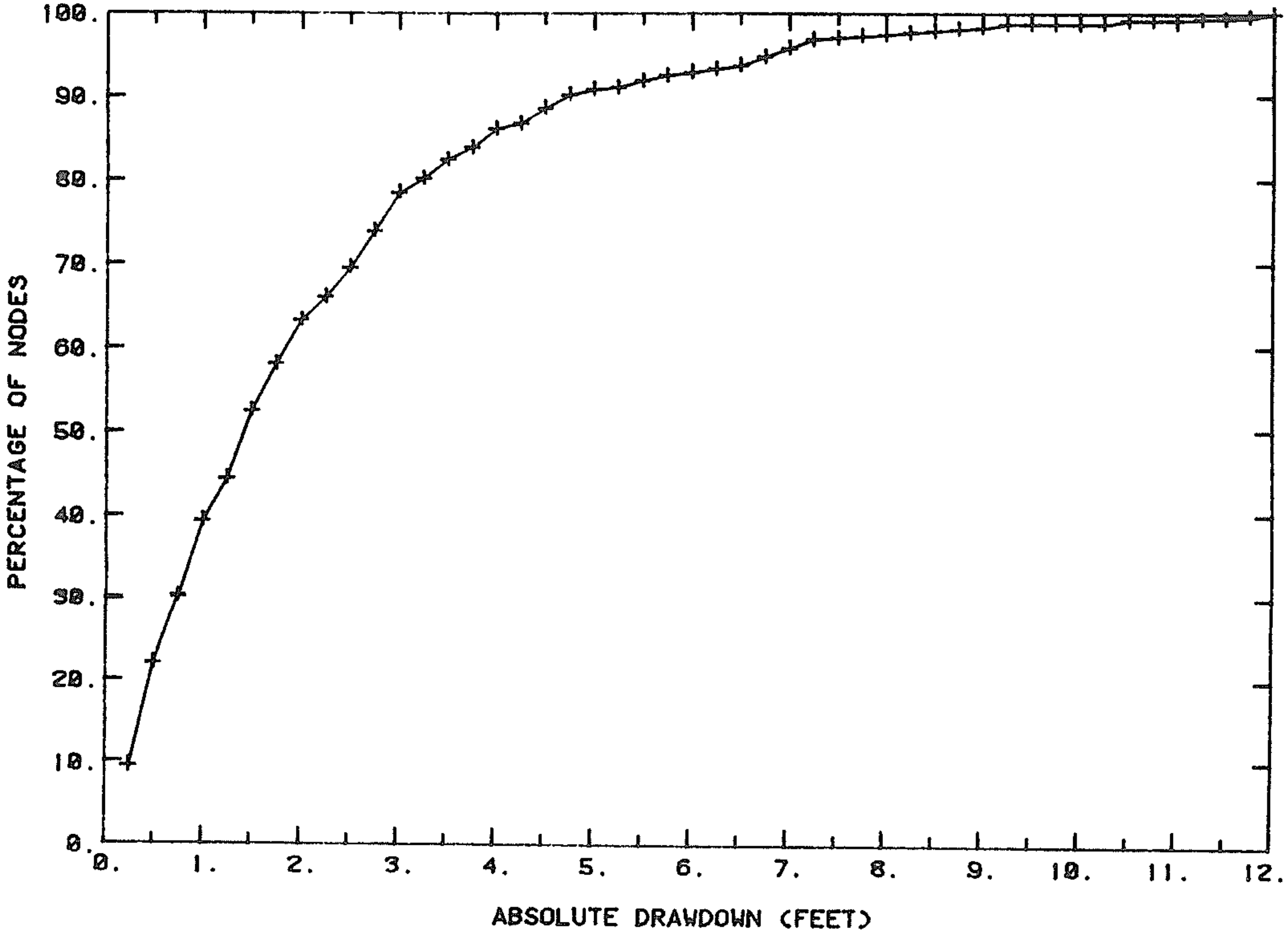


Figure 10. Goodness of Fit - Steady State Calibration

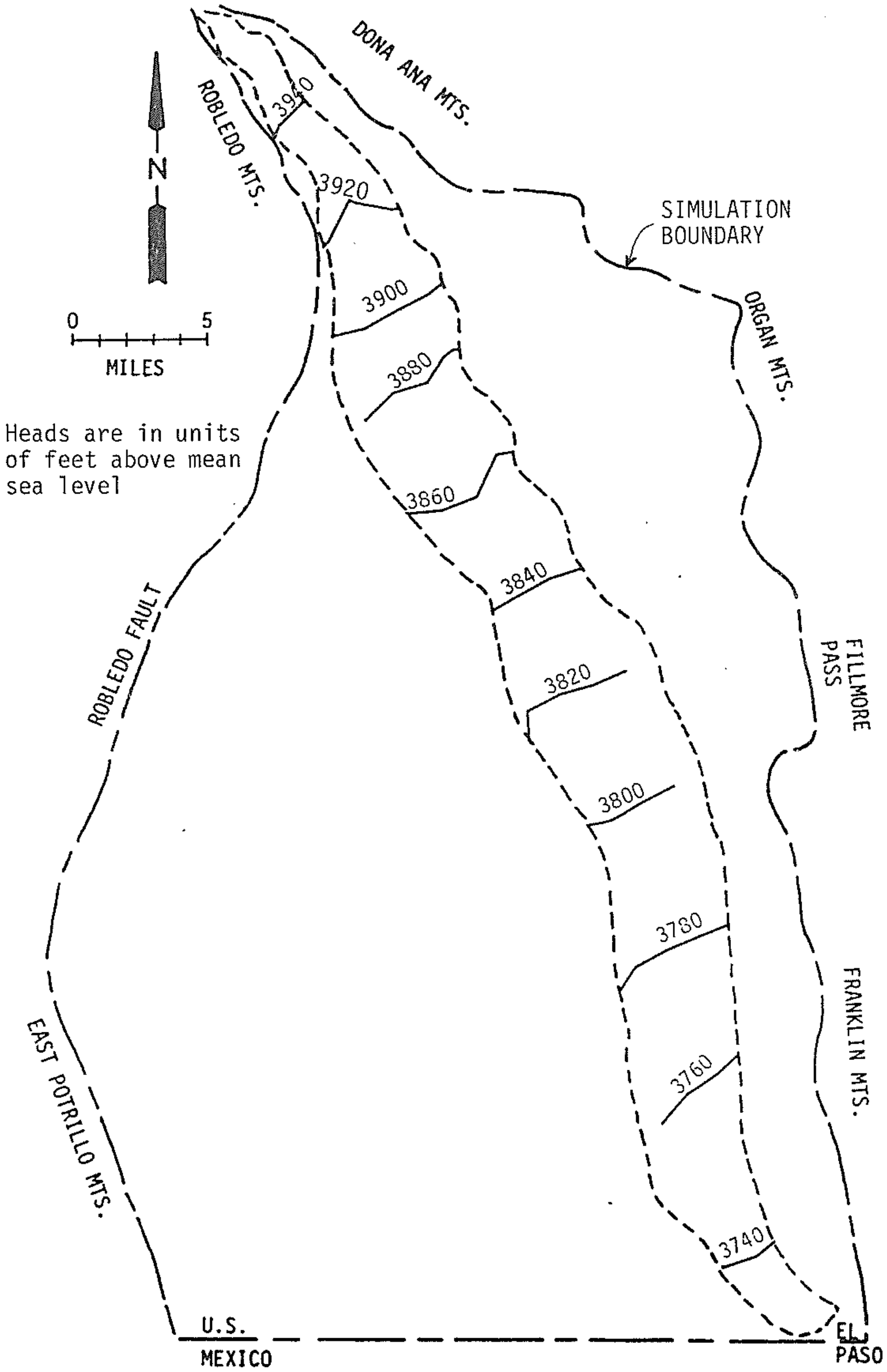


Figure 11. Contour Map of Simulated Steady State Heads in the Flood-Plain Alluvium

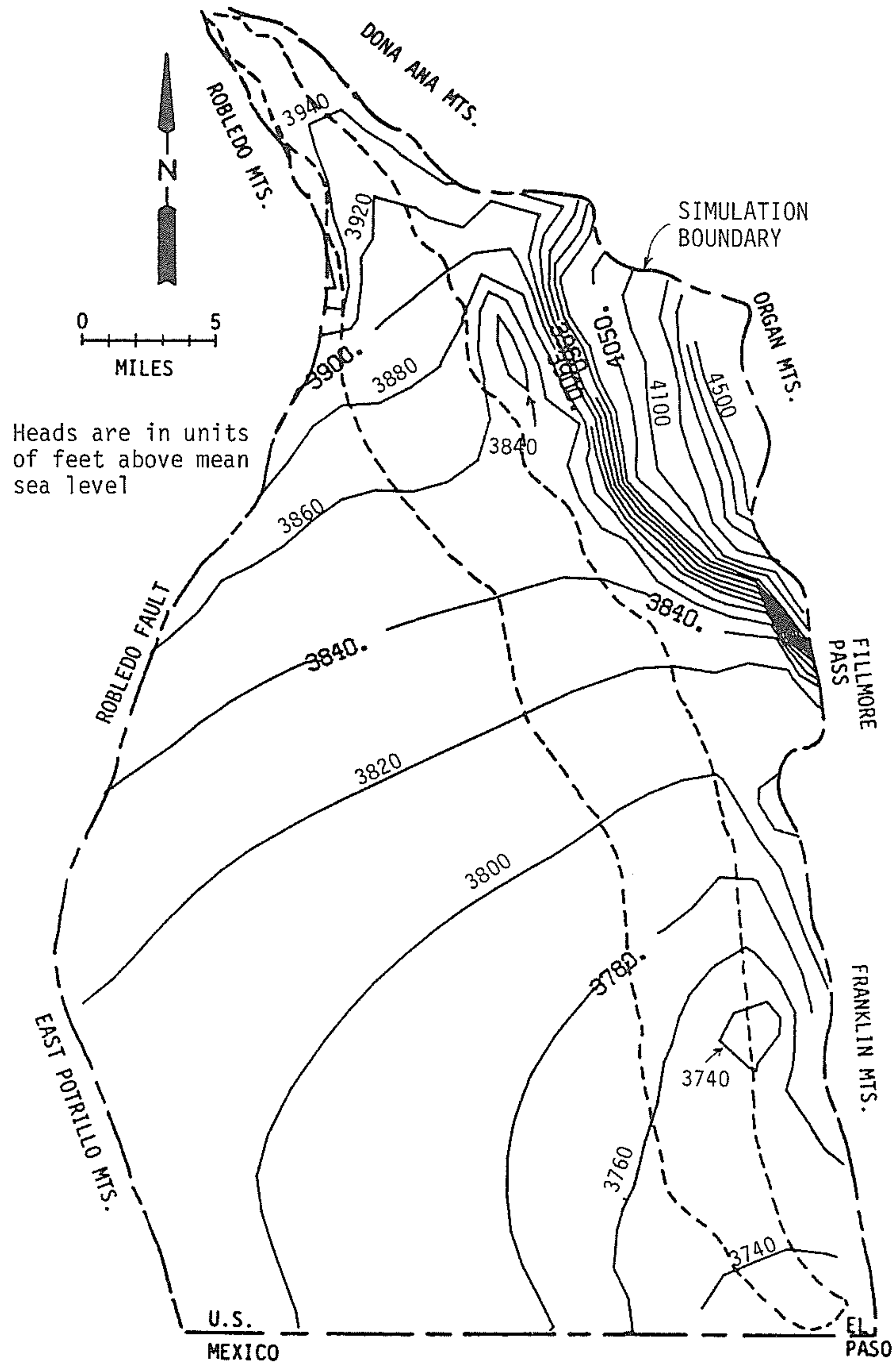


Figure 12. Contour Map of Simulated Steady State Heads in the Santa Fe Group

8 and 9 which delineate observed heads at the end of the year 1975. Differences between the two sets of maps are negligible.

Mountain Front Recharge

Although prescribed head boundaries were not used with the flood-plain alluvium during the steady state calibration, it was necessary to utilize prescribed boundary flux conditions in nodes located at the interface of the Robledo Mountains with the Mesilla Valley. In order to achieve an acceptable fit of computed heads with observed heads, a total flux of 4.0 cfs into Model Layer 1 was prescribed in this region. This implied that mountain front recharge from the Robledo Mountains to the flood-plain alluvium occurs directly, rather than first entering the Santa Fe Group aquifer and gradually moving towards the shallow unconfined aquifer. Indeed, because of the constriction of the Mesilla Valley in the northern most part of the basin, flood plain deposits appear to abut directly against the Robledo Mountains. Due to the probable limited thickness of alluvial facies in the area, it might also be inferred that the vertical extent of Santa Fe Group deposits in the upper Mesilla Valley is very limited, and perhaps may not be present at all.

A total of about 37 cfs of mountain front recharge to the Santa Fe Group (Model Layer 2) was computed with the calibrated steady state model. This is due to influx attributed to constant head sources, as indicated in the mass balance summary in Appendix B. Using the model to compute prescribed head fluxes on a node by node basis, it was determined that about 36 percent of the total mountain front recharge originated from the Organ Mountains, 21 percent from the west side of the Robledo Fault in the Aden-Sleeping Lady Hills region, 9 percent from the Dona Ana Mountains, 9 percent from the Franklin Mountains, 7 percent from the Robledo Mountains, and about 7 percent from the Potrillo Mountains. Approximately 11 percent of the total, or roughly 4 cfs, was attributed to the groundwater moving east-northeastward from the Mexican side of the international border. The authors felt that this latter quantity was somewhat high, but was nevertheless an unavoidable consequence of having to use inappropriate boundary conditions along the border.

The combined model-calibrated recharge from mountain front sources for both aquifers is 41 cfs. The total boundary influx is believed to be slightly high, due to problems of assigning correct boundary conditions along the U.S.-Mexico border. Comparable estimates of total natural recharge to the basin in past investigations have been both lower (e.g., Conover, 1954; Leggat et al., 1963) and higher (Khaleel et al., 1983). Therefore, total groundwater influx at mountain fronts as developed from the steady state calibration appear, at the very least, to be plausible.

Components of the Mesilla Valley Water Budget

The mass balance summary in Appendix B shows a mean drain discharge during 1975 of about 160 cfs, which compares quite favorably with the observed average drain flow of 158.5 cfs (U.S. Bureau of Reclamation, Monthly Drain Flow Summaries for the Mesilla Valley) in that year. Other components of the flood-plain alluvium water budget (i.e., stream losses and gains, evapotranspiration) that were computed by the steady state calibration were also within feasible ranges, based on estimates from previous investigations. A thorough discussion of all hydrologic components that influence the study area's groundwater regime are presented in the next section on transient simulation.

X. TRANSIENT ANALYSIS

Transient simulation of groundwater flow in the Mesilla Bolson was carried out for the 18-year period of 1966 through 1983. Much of the basic data used as model input have been described in an earlier section. In the text that follows, the results of transient simulations are presented, along with a discussion of steps taken to attain an improved calibration.

Calibration Procedure

Because the primary expected use of the quasi 3-D model was for prediction of long-term effects of future groundwater withdrawals on the existing hydrologic regime, simulation of changes in groundwater level over periods of less than a year were not considered in the transient analysis. Therefore, discharge and recharge rates used in the model were mean yearly values, and all time steps were one year in length. Accordingly, hydraulic heads computed at the end of each time step were representative of groundwater levels that existed at the end of each year of simulation. Flow quantities presented in the mass balance summary of each year of simulation consisted of the mean annual rates and total yearly volumes occurring in that year.

A major objective of the transient simulation was to determine appropriate values for specific yield in the flood-plain alluvium, and storage coefficient in the Santa Fe Group. For reasons previously cited, uniform values for these parameters were used. The initial transient simulation was conducted with a specific yield of 0.20 for the Rio Grande flood-plain alluvium and a storage coefficient of 0.001 in the Santa Fe Group. All other aquifer and aquitard properties in the initial transient run were the same as those developed from the steady state calibration.

The prescribed head boundaries utilized in the steady state model were also used in the transient case. It was anticipated that piezometric heads in the Santa Fe Group on the east and west boundaries of the basin would be only mildly affected during the 18-year simulation. Consequently, the recharge fluxes computed at the prescribed head nodes in outlying areas were also expected to vary only slightly from year to year.

The annual supply of surface water for agricultural use from 1966 to 1983 fluctuated considerably. Hence, variations in calculated yearly groundwater withdrawals were also substantial. A bar graph summarizing the estimated water use in the study area during the 18-year simulation period is presented in Figure 13.

A feature incorporated into the quasi 3-D model specifically for use in the transient simulations was the option to change streamflow depths (i.e., Rio Grande and irrigation canal stages) and drainage canal water depths on a grid-by-grid basis at the beginning of each pumping period. Such a feature allowed the authors to better account for fluctuations in annual seepage losses from the canals and the river as well as attempt to find a better match between computed and observed yearly drain discharges.

Flow stages in the river and canals were initially assumed to change in direct proportion to the reported net diversions to irrigation canals. All streamflow depths were determined with respect to the stages used in the steady state calibration of 1975 conditions. The equation for determining the mean stream stage in a grid for a given year was:

$$\frac{d_s}{d_{s75}} = \frac{Q_s}{Q_{s75}} \qquad (8)$$

where: d_s = mean depth of flow (or stage) for the year (L);

d_{s75} = mean depth of flow in 1975 (L);

Q_s = net diversion to irrigation canals for the year (L^3); and

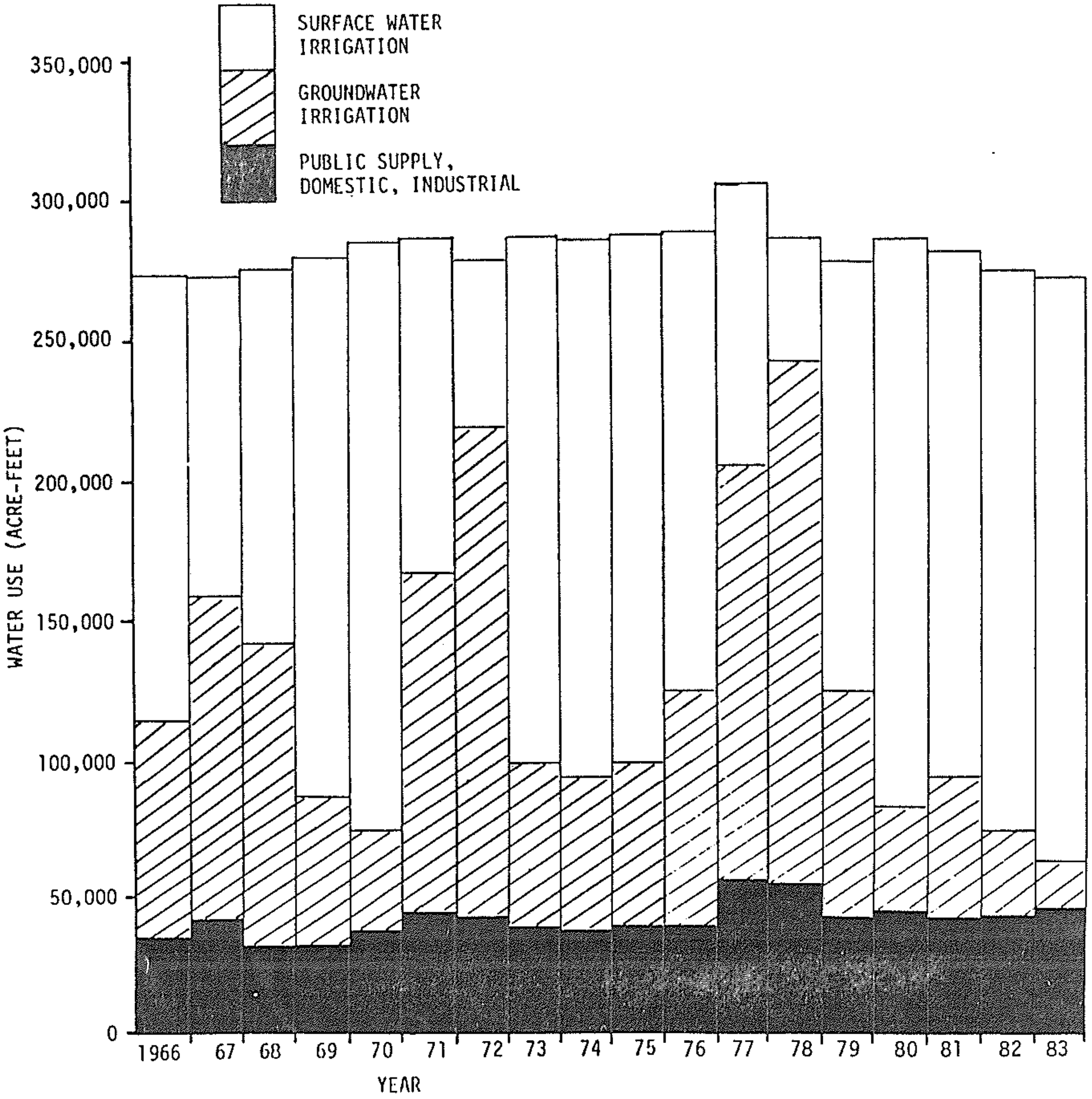


Figure 13. Estimated Water Uses in the Mesilla Bolson, 1966-1983

Q_{s75} = net diversion to irrigation canals in 1975 (L^3).

A formula similar to the linear relationship implied by Equation 8 was applied to estimate drain depths. Drain stages were assumed to be proportional to recorded mean annual drain discharges from the Mesilla Valley. An average drain depth of 2 feet was assumed to exist in 1975 for all grids where drain discharge was possible.

The computed head fields at the end of 1975 from the initial transient simulation were found to closely match the observed potentiometric surface in January 1976. This observation led to an obvious conclusion, one that was not entirely unexpected because of apparent basin features that were outlined in the model conceptualization stage. Specifically, the behavior of the water table and piezometric head levels in the Mesilla Valley under existing conditions is primarily dependent on the amount of surface water that recharges the flood-plain alluvium and the total quantity of groundwater pumped each year. In other words, the yearly surface water supply and applied irrigation water, along with pumpage, are the most influential variables that affect groundwater levels in the basin. Consequently, the starting heads of early 1966, the aquifer parameters and fluctuating groundwater withdrawals over the first 10 years of simulation had little effect on the computed head configuration at the end of 1975. Rather, the quantity of surface water infiltrating into the flood-plain alluvium in 1975, and the speed with which steady downward leakage helped meet the pumping stresses in the Santa Fe Group during that year, had the most pronounced effect on the resulting head distribution.

Since the model was highly responsive primarily to pumping and recharge from surface water sources, it tended to limit its utility for transient simulation purposes. In other words, little, if any, improvement in the estimation of aquifer and aquitard properties could have been expected due to the model's relatively low sensitivity to such parameters. Furthermore, the ability of the model to reproduce past changes in head configurations could not be properly tested because:

1. the piezometric head field in the basin during 1966-1983 had probably not undergone extreme changes; however, had such large changes taken place, comparisons of model results with them would have helped determine the model's ability to simulate large variations in hydraulic head; and

2. comprehensive maps of the groundwater potentiometric surface, over the entire bolson, of sufficient refinement for comparison with model results, had not been prepared for years other than 1966 and 1975.

In light of these constraints, it appeared that an improved transient calibration could have been achieved if adequate comprehensive groundwater contour maps had been developed for years prior to 1966, particularly during the drought experienced in the 1950's. Preparation of maps of this nature was considered to be beyond the scope of this study.

Computed annual drain flows during the initial transient simulation generally followed the observed pattern of increases and decreases over the 18-year simulation period. However, during wet periods, the model had a tendency to compute drain discharges that were higher than observed drain flow quantities. Even larger discrepancies were observed in years of low water supply in which simulated drain discharges were much lower than observed quantities. Three potential explanations for the model's apparent inability to duplicate drain flows were considered:

1. incorrect confining bed parameters which allowed leakage from the flood-plain alluvium to occur at a rate faster than actual, thus lowering water table elevations to the extent that computed drain flows were lower than observed;

2. a low specific yield for the flood-plain alluvium, thus creating annual water table fluctuations that were larger than actual; and

3. inability of the assumed linear relationships between stream flow depth and canal diversions (as given by Equation 8), and between drain stage and drain flow, to properly simulate stream seepage and drain

discharge, respectively.

To test the effect of confining bed properties on computed drain flows, confining layer thicknesses in each grid were gradually increased from twice their original value to as much as ten times. Only when a ten-fold increase in bed thickness was applied did the calculated drain flows in dry years begin to approach observed values. However, increasing aquitard thicknesses to such a large extent also created enormous resistances to leakage from one aquifer to another. The result was that computed heads in the Santa Fe Group were hundreds of feet lower than those observed. Consequently, the confining layer properties were not considered to be a possible cause of discrepancies between observed and computed drain flows.

Model runs over the historical simulation period were also performed using specific yield values in the flood-plain alluvium of 0.25 and 0.30. Although this approach did yield slightly less fluctuations in annual drain flow than did the original simulation with a specific yield of 0.20, the discrepancies between observed and simulated drain flows were still quite large. Hence, a low specific yield was no longer considered a viable explanation for the model's inability to match observed drain fluxes.

As a final alternative, power relationships between stream depth and stream flow, and between drain stage and drain discharge, were tested to see if better model reproductions of recorded drain flows could be achieved than with the previously mentioned linear relations. Inasmuch as power functions are frequently used to fit stage-discharge curves developed in stream gaging practice (Leopold et al., 1964), the use of such relationships seemed justified.

The power relationship for computing stream flow stages relative to 1975 conditions was:

$$\frac{d_s}{d_{s75}} = \left(\frac{Q_s}{Q_{s75}}\right)^f \tag{9}$$

where the exponent f is a constant that depends on stream geometry and other factors. When the value of f is 1.0, Equation 9 becomes identical to the linear relationship expressed in Equation 8. Magnitudes of f less than 1.0 indicate that discharge increases faster than depth of water in a channel. For natural streams, Leopold et al. (1964) found that measured values of the exponent range from 0.30 to 0.45.

Several transient simulations were made with the model using a variety of f values to express stage-discharge relations in streams (river and canals) as well as drains. A reasonable match of computed and observed drain flows was attained using an f value of 0.35 for the river and canals, and 0.60 for the drains. The larger value derived for the drains suggested that drain discharges do not increase as rapidly as canal flows for equivalent increases in stage. This phenomenon is probably explained by the much narrower bed widths and debris-clogged channels that characterize the Mesilla Valley drains.

The use of Equation 9 appeared to overcome most of the previously mentioned difficulties in simulating annual drain discharges. No further attempts were made to alter the numerical model for the purpose of duplicating yearly drain fluxes.

Transient Simulation Results

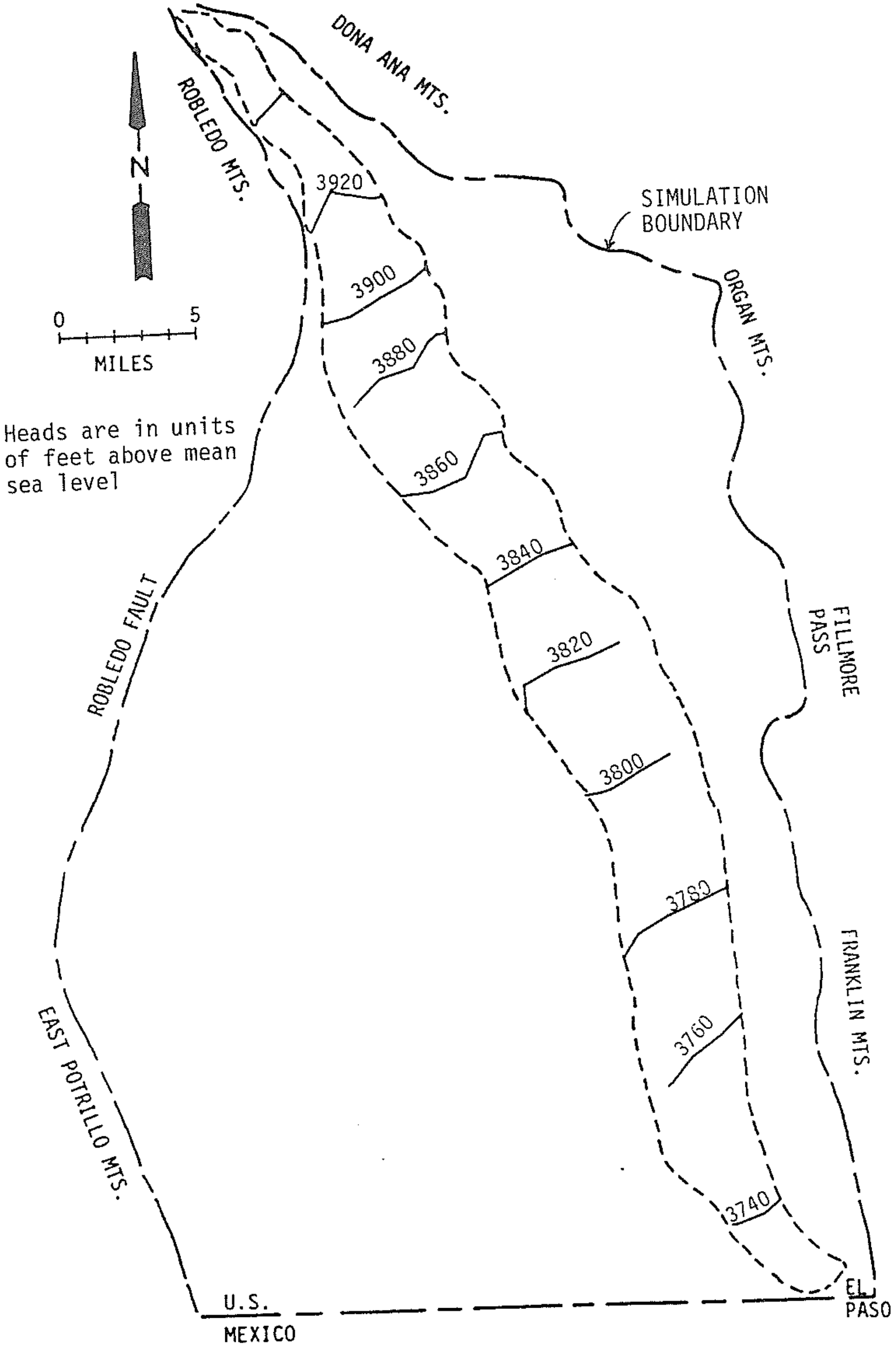
Hydraulic heads determined by the model for the Mesilla Valley were highly dependent on availability of surface water and total pumpage in a given year. Therefore, during transient simulations, further adjustment of aquifer and aquitard properties, as determined from the steady state calibration, was not warranted. Simulated head distributions in both aquifers at the end of

1975, using the steady state aquifer parameters and the preceding power function relationship between stage and surface water flows, are presented in Figures 14 and 15. The results are virtually the same as those illustrated in the head contour maps developed from the steady state analysis (Figures 11 and 12).

A plot comparing simulated and observed magnitudes of mean annual drain flow from the Mesilla Valley is presented in Figure 16. As can be seen, the model does an acceptable job of simulating drain discharge fluctuations. Nevertheless, significant deviations from recorded values are observed, especially during the years in which the modeled values seem to exceed recorded quantities by sizable amounts. A variety of factors, including poor estimates of annual pumpage, inaccurate determinations of evapotranspiration, and inability of the assumed stage-discharge relations to represent actual conditions, are potential reasons for the observed discrepancies.

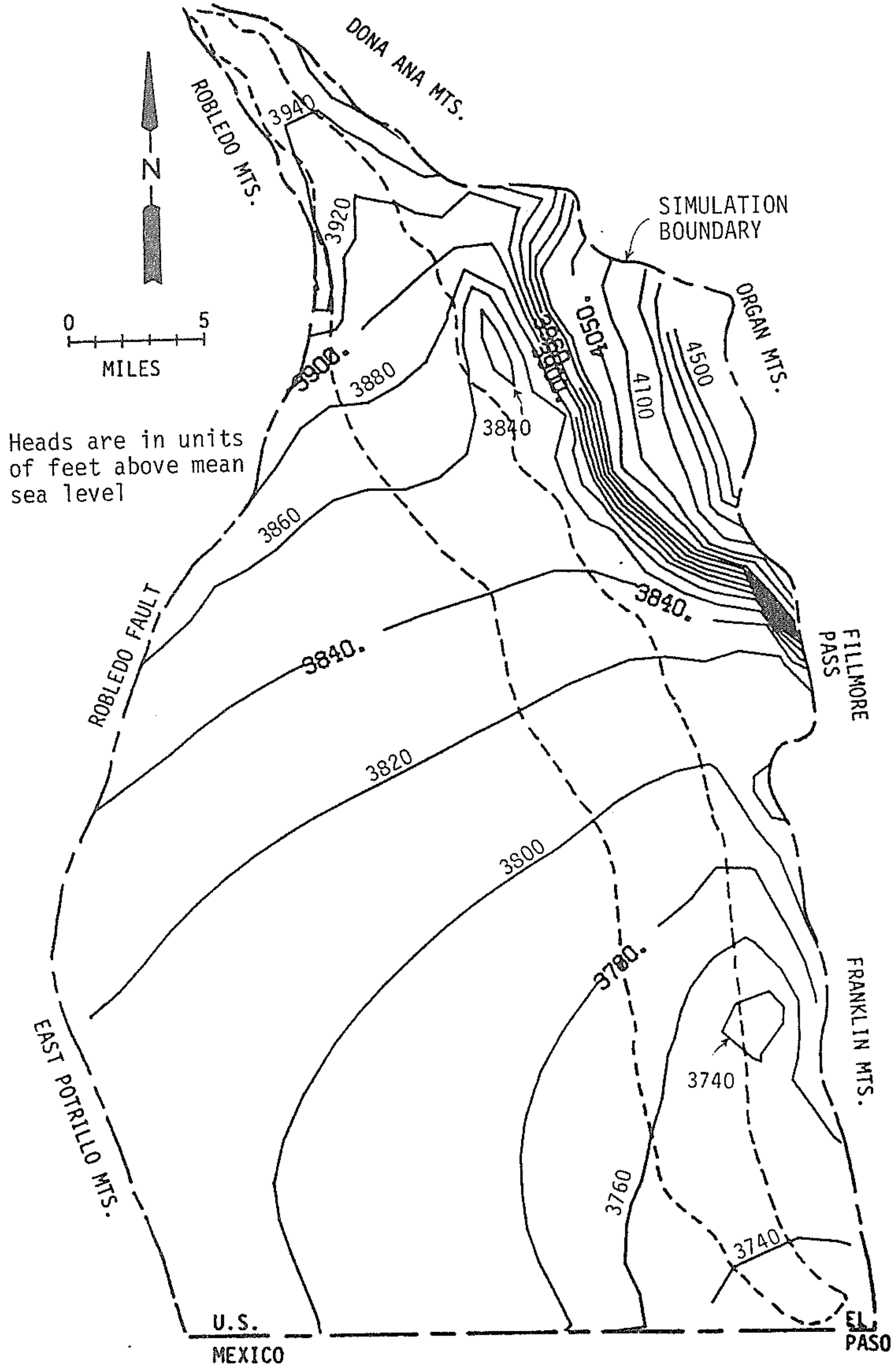
A possible explanation for the very large overestimation of drain flows in 1973 is the previously mentioned time lag that may exist between changes in canal diversions and associated changes in drain flux. In other words, the groundwater ridges that were created below the river and canals due to sharp increases in surface water flow in 1973 may not have had sufficient time during the year to fully dissipate and contribute significant discharge to drains located some distance away. If indeed such a lag phenomenon was taking place in the Mesilla Valley, improved simulation of drain flow might have been accomplished by using smaller grid sizes and time step durations of less than a year.

Despite the difficulties of reproducing actual drain discharge each year, the quasi 3-D model appeared to produce acceptable estimates of the long term average flux. The mean annual recorded drain flow for the period 1966-1983 was about 126 cubic feet per second (cfs), whereas mean annual modeled flow



Heads are in units of feet above mean sea level

Figure 14. Contour Map of Transient Simulation Heads in the Flood-Plain Alluvium in Late 1975



Heads are in units of feet above mean sea level

Figure 15. Contour Map of Transient Simulation Heads in the Santa Fe Group in Late 1975

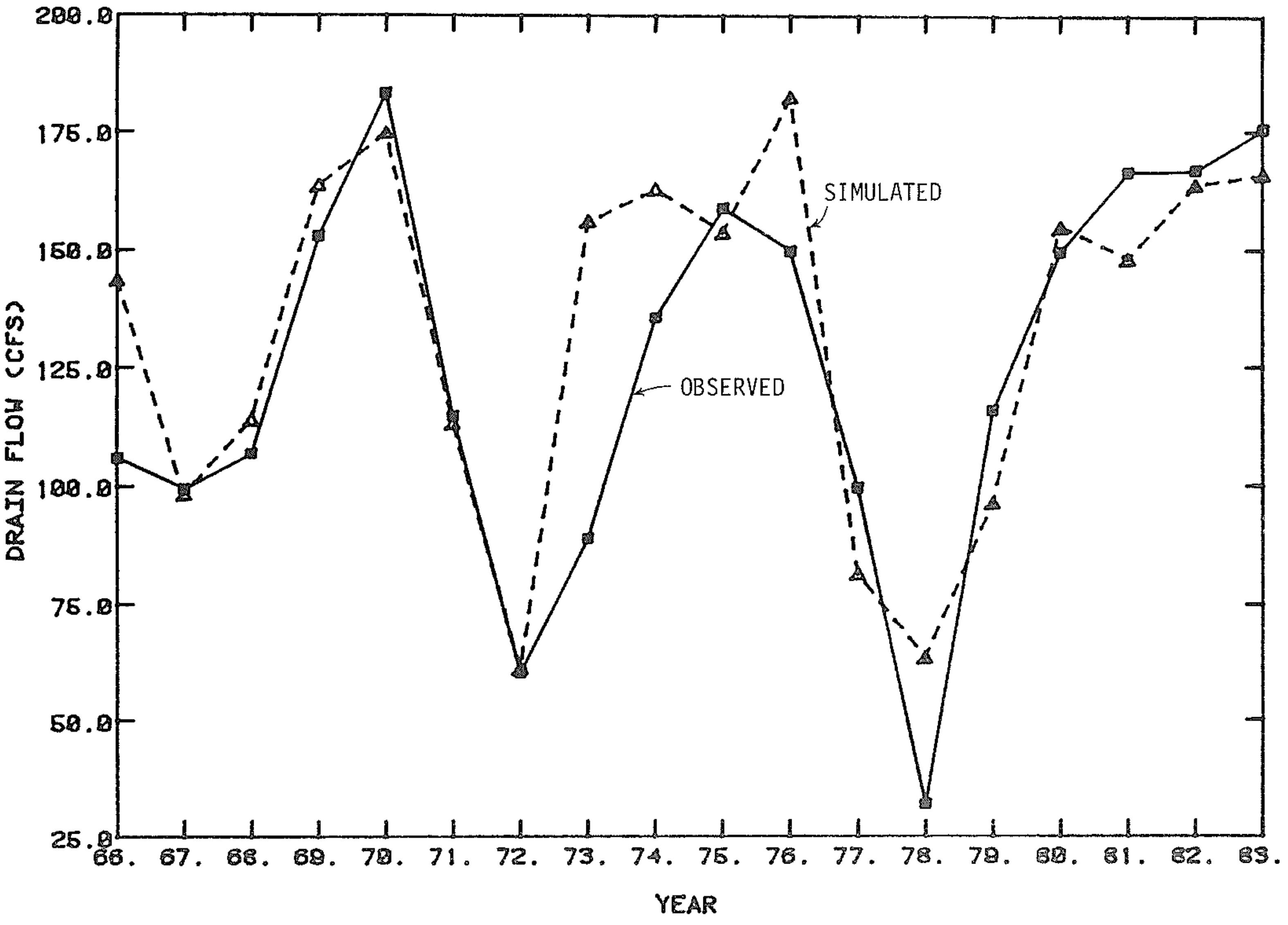


Figure 16. Observed and Simulated Mean Annual Drain Flows, 1966-1983

was approximately 133 cfs.

As expected, the quantities of inflow computed at prescribed head grids along mountain front boundaries did not change much from year to year. The lowest net rate influx from all constant head boundaries in the Santa Fe Group was 35.9 cfs and the largest was 40.9 cfs. The mean net inflow rate was about 37.4 cfs. The percentages of total mountain front recharge emanating from each of the several boundary segments in the Santa Fe Group were essentially the same as those reported from the steady state calibration.

Although the difference between the minimum and maximum rates of net influx from prescribed head boundaries was only 5 cfs, it should be mentioned that this result is largely due to the fact that a uniform storage coefficient of 0.001 was used throughout the Santa Fe Group. If smaller values of this parameter had been used in regions where the saturated thickness of the Santa Fe Group is limited, the range of computed mountain front recharge quantities would have been larger. Even though no measured data have been reported for storage properties in the basin fill on the piedmont slope west of the Organ Mountains, the hydrogeologic cross sections for this region do indicate the presence of an abundance of low permeability sediments that may confine the local groundwater. This observation, combined with the likelihood that the total thickness of moderate to high permeable materials on the piedmont slope is much less than that existing in the Mesilla Valley, suggests that storage coefficients determined from short term stresses in this upland area are probably lower than 0.001.

As a further check on the accuracy of prescribed head fluxes, an additional steady state run was made. In this simulation, the mean annual recharge rates determined at each boundary node during the transient simulation were used as prescribed fluxes in the grids that had previously been treated as prescribed head boundaries. With the exception of a few nodes at the base of the Organ Mountains, the simulated head fields were very close to those obtained during the steady state calibration. Deviations from the observed head configuration on the western border of the piedmont slope were not considered important as piezometric head gradients in this area are very steep; consequently, representative values of observed head determined for each of the grids on the west side of the Organ Mountains are questionable to begin with.

Water Budget

The transient analysis was useful for quantifying components of the Mesilla Bolson hydrologic budget. Table 1 summarizes the average annual water budget for the study area based on the 1966-1983 simulation. Pertinent observations regarding the various inflow and outflow quantities in Table 1 are summarized in the following paragraphs.

The two most important sources of subsurface water in the Mesilla Bolson are applied irrigation water and seepage losses from surface waterways. However, the reader is cautioned not to interpret the average annual volume attributed to irrigation sources in Table 1 as being recharge to the water table. Instead, a very large portion of the applied irrigation water is probably lost to evapotranspiration before infiltrating water reaches saturated depths. As a consequence, it is possible that more net recharge to the saturated subsurface regime is actually contributed by stream losses than from irrigation water. The proportionate quantities of recharge attributable to each of these components cannot be accurately determined. Nonetheless, the combined supply of irrigation and stream seepage is unquestionably the major source of subsurface water in the basin.

The mean annual stream seepage loss of 116,200 acre-feet (Table 1)

TABLE 1

MEAN ANNUAL HYDROLOGIC BUDGET OF THE MESILLA BOLSON SUBSURFACE DOMAIN, 1966-1983

Sources	Acre-Feet	Percent of Total
Irrigation	240,300	62.2
Stream Losses	116,200	30.0
Mountain Front Recharge	30,000	7.8
TOTAL	386,500	
Discharges		
Evapotranspiration	166,400	43.0
Pumping	122,800	31.8
Drain Flow	96,300	24.9
Discharge to Rio Grande	1,200	0.3
TOTAL	386,700	

Net leakage from the flood-plain alluvium to the Santa Fe Group = 61,000 acre-feet per year.

generated by the model can be compared to other estimates of this quantity developed from different methods. For instance, Conover (1954) calculated a mean yearly combined loss (from the Rio Grande and the canals) of about 170,000 acre-feet for the years 1930-1946. But the mean discharge of the Rio Grande at Leasburg Dam during those years was about 60 percent higher than it was over the period 1966-1983. Therefore, as an additional check, total stream seepages for several recent years were estimated using methods of earlier investigators (Conover, 1954; Richardson, 1971) and then compared with model computed losses for an identical period.

Conover's (1954, p. 72) technique for determining seepage losses on the Rio Grande utilized annual flows at the north and south ends of the valley, total diversions to the irrigation canals, recorded drain discharge, and wastages from the canals that were assumed to be 5 percent greater than the reported values. Applying this same approach to the period 1966-1975, the mean annual loss from the Rio Grande was determined to be about 38,000 acre-feet. Using Richardson's (1971) estimate that 60 percent of reported canal losses are attributable to seepage, the calculated loss from Mesilla Valley canals during the same 10-year period was 80,000 acre-feet. Thus, the total combined yearly loss determined from these independent techniques was 118,000 acre-feet. The model generated value of mean annual loss for the period 1966-1975 was 114,000 acre-feet. Thus, there is a difference of only 4,000 acre-feet between our model generated estimates and those obtained based on techniques employed by other investigators. The difference can be partly explained by the fact that Conover's (1954, p. 72) technique for determining river loss probably overestimates the actual stream seepage component, as there is no means of separating out evaporation loss from the total loss.

As the water budget in Table 1 shows, mountain front recharge comprises only a minor portion of the total annual inflow of groundwater. The mean yearly volume of 30,000 acre-feet is somewhat larger than estimates made by some previous investigators (e.g., Leggat et al., 1962; 18,000 acre-feet) and considerably lower than quantities determined during Phase I (Khaleel et al., 1983; 47,000 acre-feet) of this research.

The average yearly evapotranspiration volume of 166,400 acre-feet (Table 1) also appears to be reasonable when compared with independent estimates of this quantity. The average irrigated area in the Mesilla Bolson during the years 1966-1983 was estimated at approximately 77,500 acres. Using previously mentioned consumptive use rates for agricultural land, computed evapotranspiration from the cropped acreage amounted to about 144,000 acre-feet annually. Subtraction of this quantity from the total evapotranspiration volume in Table 1 yields a residual evapotranspiration volume of 22,400 acre-feet, which is almost identical to the annual phreatophyte loss of 22,500 acre-feet estimated by Richardson (1971).

Although the average annual pumpage (122,800 acre-feet) shown in Table 1 is less than the mean yearly evapotranspiration volume, groundwater withdrawals in many years probably exceed the combined discharge attributed to consumptive use by plants and evaporation from the subsurface. During the transient simulation period, estimated yearly pumpage volumes ranged from a low of 63,200 acre-feet in 1983 to a high of 241,200 acre-feet in 1978.

The ability of the model to duplicate annual and mean long-term drain flows in the Mesilla Valley was evaluated in an earlier section. The transient simulations showed that some groundwater (about 1,200 acre-feet annually) was discharging into the Rio Grande, all in the upper Mesilla Valley.

Mean annual net leakage from the flood-plain alluvium to the Santa Fe Group during the transient analysis was determined to be 61,000 acre-feet. The highest volume of net downward leakage observed during the 1966-1983 period was about 138,600 acre-feet, whereas the lowest was approximately 26,900 acre-feet.

The sum of mean yearly sources of subsurface water (386,500 acre-feet) over the 18-year transient simulation period is close in magnitude to the estimated yearly discharges (386,700 acre-feet). Therefore, the contention that the groundwater system in recent years has been in a virtual steady state is at least substantiated by the transient modeling analysis.

Sensitivity of Model to Influential Variables

Quantitative evaluation of the model's sensitivity to changes in aquifer properties and other influential parameters has not been made. Nonetheless, the transient simulations helped the authors to develop rather apparent conclusions regarding the relative ability of several model variables to affect calculated head fields.

It is clear from the foregoing discussion that simulation results appear to be most strongly affected by the quantity of surface water that infiltrates into the subsurface domain as well as total pumpage. Since it has been demonstrated that, in a normal year, irrigation application and stream seepage losses together comprise the greater portion of recharge sources, the importance of surface water is clearly evident. Pumping rates are probably of equal importance in affecting computed heads, insofar as there is a correlation between stream losses and pumping. In other words, groundwater withdrawals increase in years when surface water supplies and canal seepage losses are reduced. In fact, the total pumping rate may exceed the rate of recharge from surface water during a dry year or series of dry years. At such times, it is likely that slightly altered pumping withdrawals would have a larger influence on simulated heads than would comparable changes in surface water recharge. Richardson (1971) found that his numerical model of the Mesilla Valley was quite sensitive to changes in both pumping and seepages from the Rio Grande.

Under current conditons, the model is not expected to be very sensitive to transmissivity and hydraulic conductivity. Once again, the dominating effects of recharge from surface water sources tend to diminish the influence of these aquifer properties. This observation was brought out at times during the transient analysis when changes in transmissivity or hydraulic conductivity did little to affect annual head configurations. Richardson (1971) came to a similar conclusion based on monthly simulations of groundwater flow in the Mesilla Valley.

Although aquifer storage properties would also likely have less of an effect than specified recharge-discharge quantities, it does seem probable that storage coefficient and specific yield would exert a greater influence on simulation results than would aquifer permeabilities. Changes in storativity on the flood-plain alluvium had a significant effect on water table elevations determined by Richardson's (1971) model. Variations in the storage coefficient of the Santa Fe Group may very well have an even greater effect.

It would be expected that model calculations are also strongly influenced by time step durations. Shorter time steps would likely improve the model accuracy.

XI. PREDICTIVE SIMULATIONS

Procedure

All predictive runs with the computer model were made for the 100-year period, 1984-2083. Three separate predictive simulations, which are also sometimes referred to as "production runs", were considered:

Predictive Simulation A - Groundwater withdrawals from the Las Cruces well field and the New Mexico State University public supply wells were increased one percent annually above their 1983 pumpages. All pumping rates from irrigation wells in the valley were kept at a constant level, equal to the average estimated irrigation pumpage during the transient simulation period 1966-1983. Groundwater withdrawals in the Canutillo well field were also maintained at average rates reported during the 18 years of transient analysis. Pumpages for small community systems, industrial and power uses were kept constant at the rates used during 1983.

Predictive Simulation B - The same pumping stresses used in Simulation A were considered. In addition, estimated groundwater withdrawals from 266 wells proposed by the City of El Paso (Wilson and Associates, 1983) for augmenting the city's public supply were used. A uniform storage coefficient of 0.001 was utilized for the Santa Fe Group aquifer.

Predictive Simulation C - Simulation B pumpages were invoked. The storage coefficient of the Santa Fe Group was set at a uniform value of 0.15.

Simulation A was intended to be representative of a continuation of existing groundwater uses in the study area. Gradual increases of pumpage in the vicinity of Las Cruces were assumed because pumping data from this urban area has indicated a steady increase in groundwater withdrawals. The assumed one percent annual increase was, for the most part, based on projected population increases for the area (Lansford et al., 1974). Pumping of groundwater in the Canutillo well field has fluctuated during the last several years, but no long term increase in annual pumpages has been indicated. Some projections (e.g., Lansford et al., 1974) suggest that irrigation use of groundwater will increase in the future, but the extent and manner in which they would is not clear. Therefore, no estimated increases in irrigation pumpage were assumed in any of the predictive simulation runs.

The locations of the 266 proposed well sites (nearly all of which are located on the West Mesa) used in Simulations B and C were obtained from a report by Wilson and Associates (1983). The projected gradual increase in pumpage from the wells was determined from a plot showing estimated total groundwater withdrawals over a total duration of about 110 years (Wilson and Associates, 1983, p. C-15). The proposed groundwater withdrawal rates for the El Paso wells 100 years beyond the start of pumping is about 230,000 acre-feet per year.

The utilization of two very different storage coefficients for the Santa Fe Group in Simulations B and C was intended to show how the groundwater system might react to extensive pumping both under leaky confined conditions that tend to currently predominate in the basin fill and possible conversion to generally unconfined conditions in the future. As stipulated earlier, the change from one type of general condition to another would likely be a gradual process, rather than an abrupt one. For this reason, the quasi 3-D code has been designed to allow for time varying storage coefficients. But the temporal behavior of storage properties in response to pumping is still not properly understood. Therefore, the authors have instead opted for simulation of the system's response under two possible extreme conditions. Response of the bolson's groundwater domain to stresses imposed by the proposed El Paso wells would probably lie somewhere between the two cases produced by Simulations B and C.

It has been assumed in this investigation that all of the proposed wells would be installed and used for pumping at the commencement of each of Predictive Simulations B and C. Of course, such an assumption is physically unrealistic as actual well construction would be carried out gradually over many years. However, without knowing the projected time schedule of installation at proposed well sites, this assumption is largely unavoidable. As a consequence, the results from Simualtions B and C should be viewed as tentative at this time, and only as general indicators of the groundwater system response.

During all production runs, irrigation applications, stream stages and prescribed mountain front fluxes were kept constant at the mean annual values of these variables developed from the 18-year transient analysis. An algorithm was built into the quasi 3-D code that allowed drain flow stages to be changed automatically in accordance with the previously discussed power function relationship between depth and flow. Simulation results were printed out for every ten years of simulation.

Predictive Results

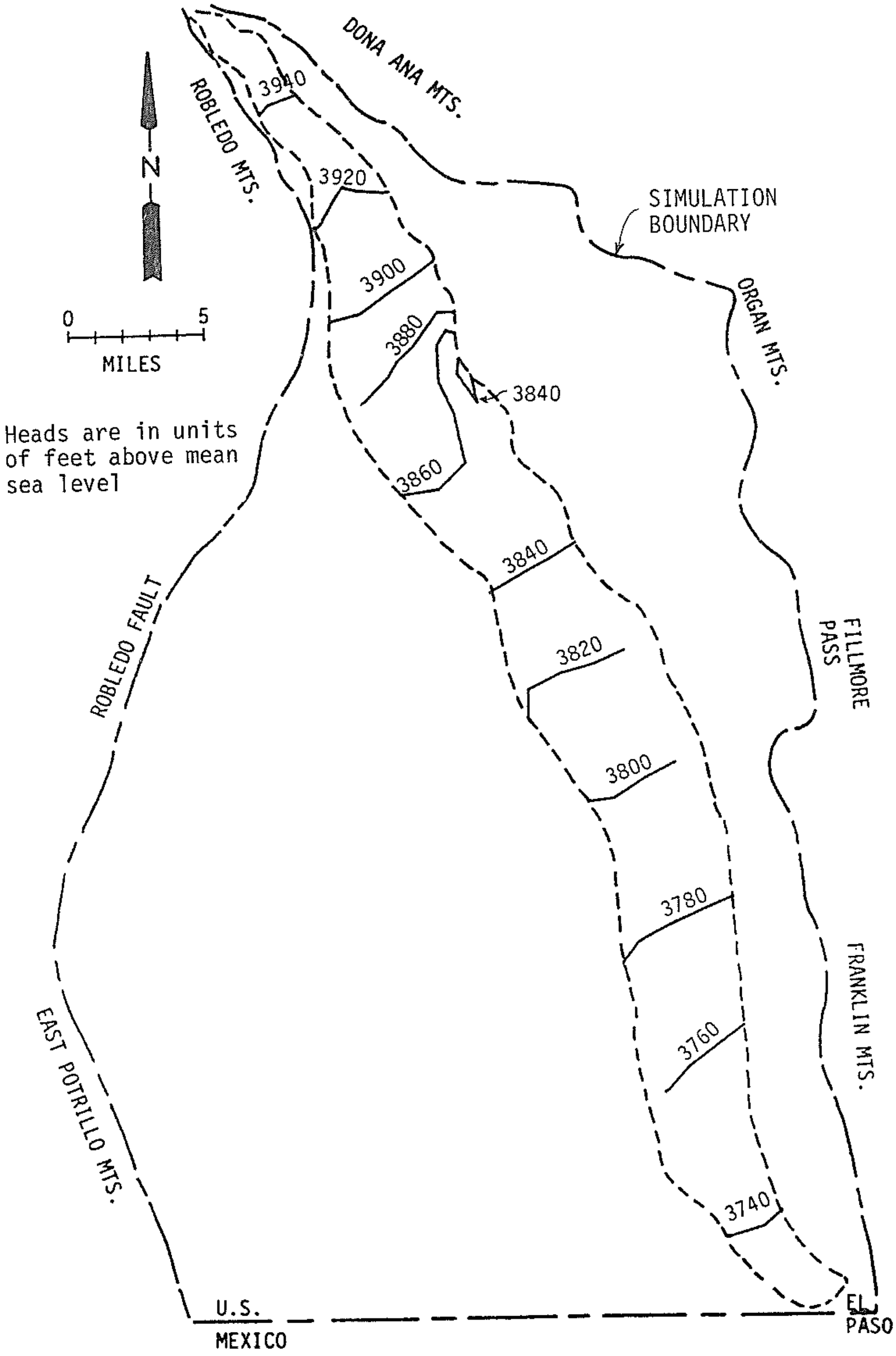
Production runs A and C were successfully performed for the full 100-year simulation period. Simulation B was terminated after 70 years because water table elevations in parts of the flood-plain alluvium had declined to the extent that some grids in the shallow aquifer were dry.

Simulation A. Final computed heads in the flood-plain alluvium and the

Santa Fe Group, after 100 years of pumping under Simulation A conditions, are presented in contour form in Figures 17 and 18, respectively. Comparison of these maps with those of the observed head contours in January 1976 (Figures 8 and 9) shows that increased pumping in the Las Cruces area has lowered local groundwater levels in both aquifers. Flood plain-alluvium heads are 15 to 25 feet lower than 1976 levels, while those in the Santa Fe Group have declined 40 to 60 feet. The cone of depression near Las Cruces has propagated as well.

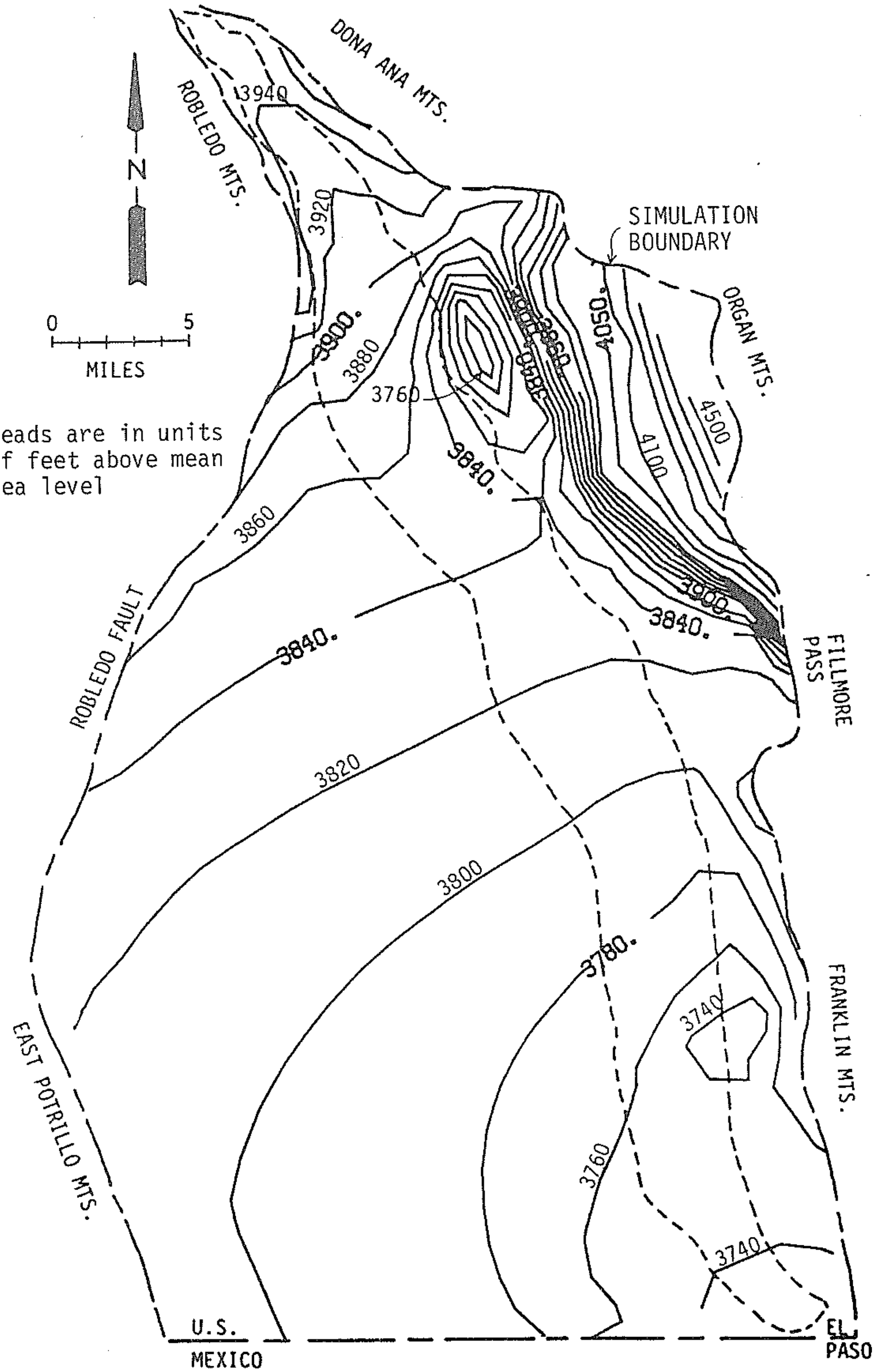
The annual water budget of the Mesilla Bolson at the end of the 100-year predictive period is given in Table 2. Drain flow quantities have been reduced below the mean annual values developed from the transient analysis. Annual net leakage from the flood-plain alluvium to the Santa Fe Group exceeds the mean annual quantity from the 1966-1983 simulation by some 26,000 acre-feet.

At this time, it is important to mention an inherent difficulty of simulating future groundater conditions with a model that uses an algorithm such as Equation 6 to determine evapotranspiration (ET) fluxes. The method assumes that evapotranspiration ceases when the water table drops below a specified threshold elevation. Therefore, even though the amount of applied irrigation water may remain constant, the portion of that water which is consumed by crops, as determined by the model, gradually becomes less when groundwater levels continue to drop. Consequently, the volume of evapotranspiration as listed in Table 2 is probably slightly lower than what actually would be observed if annual irrigation applications during the next 100 years do indeed remain close to the quantities observed today. Furthermore, if crops consume more water than is indicated in Table 2, less water will recharge the saturated zone of the flood-plain alluvium and water table elevations will drop at a faster rate than computed by the model. A declining water table will also result in a lower drain discharge than is listed in Table 2. Net downward leakage would be affected as well.



Heads are in units of feet above mean sea level

Figure 17. Contour Map of Simulated Heads in the Flood-Plain Alluvium 100 Years in the Future - Predictive Simulation A



Heads are in units of feet above mean sea level

Figure 18. Contour Map of Simulated Heads in the Santa Fe Group 100 Years in the Future - Predictive Simulation A

TABLE 2

SIMULATED ANNUAL HYDROLOGIC BUDGET OF THE MESILLA BOLSON SUBSURFACE DOMAIN 100 YEARS IN THE FUTURE - PREDICTIVE SIMULATION A

Sources	Acre-Feet	Percent of Total
Irrigation	242,300	62.0
Stream Seepage	118,700	30.3
Mountain Front Recharge	30,000	7.7
TOTAL	391,000	
Discharges		
Evapotranspiration	156,800	40.3
Pumping	146,500	37.6
Drain Discharge	85,400	21.9
Discharge to Rio Grande	600	0.2
TOTAL	389,300	

Net leakage from the flood-plain alluvium to the Santa Fe Group = 87,300 acre-feet per year.

Simulation B. Contour maps of head at the termination of Simulation B (70 years) are shown in Figures 19 and 20. The most obvious feature of the head configurations is a pervasive change in groundwater flow direction from existing conditions. Groundwater that currently moves southeastward in the Mesilla Valley would be largely induced to flow toward the proposed El Paso wells under Simulation B conditions. Both aquifers in the southern half of the basin are affected by the El Paso wells.

Comparison of Figures 9 and 20 indicates that piezometric head levels in the West Mesa would be as much as 400 feet lower than those currently observed. The limited boundary fluxes coming from the west do little to reduce the effect of pumping on drawdowns along the basin's west boundary. However, it should be realized that the effects of the El Paso wells would likely be felt in the region west of the Potrillo Fault if Simulation B conditions did actually occur. As a consequence, eastward moving influxes in the Aden-Sleeping Lady Hills region might be increased and observed drawdowns would be somewhat less than illustrated in Figure 20.

Table 3 lists components of the groundwater budget after 70 years of pumping under Simulation B. Drain discharge has been reduced drastically below current levels. Net downward leakage is increased to 227,000 acre-feet per year.

The same problems encountered in Simulation A regarding the underestimation of evapotranspiration become more pronounced in Simulation B. Irrigation application has been maintained at a rate (242,300 acre-feet per year) that is reflective of current conditions, yet the total computed evapotranspiration (71,900 acre-feet per year) amounts to only 30 percent of the applied water. Actual crop (and phreatophyte) consumption - should today's level of irrigation be maintained - would likely constitute more than

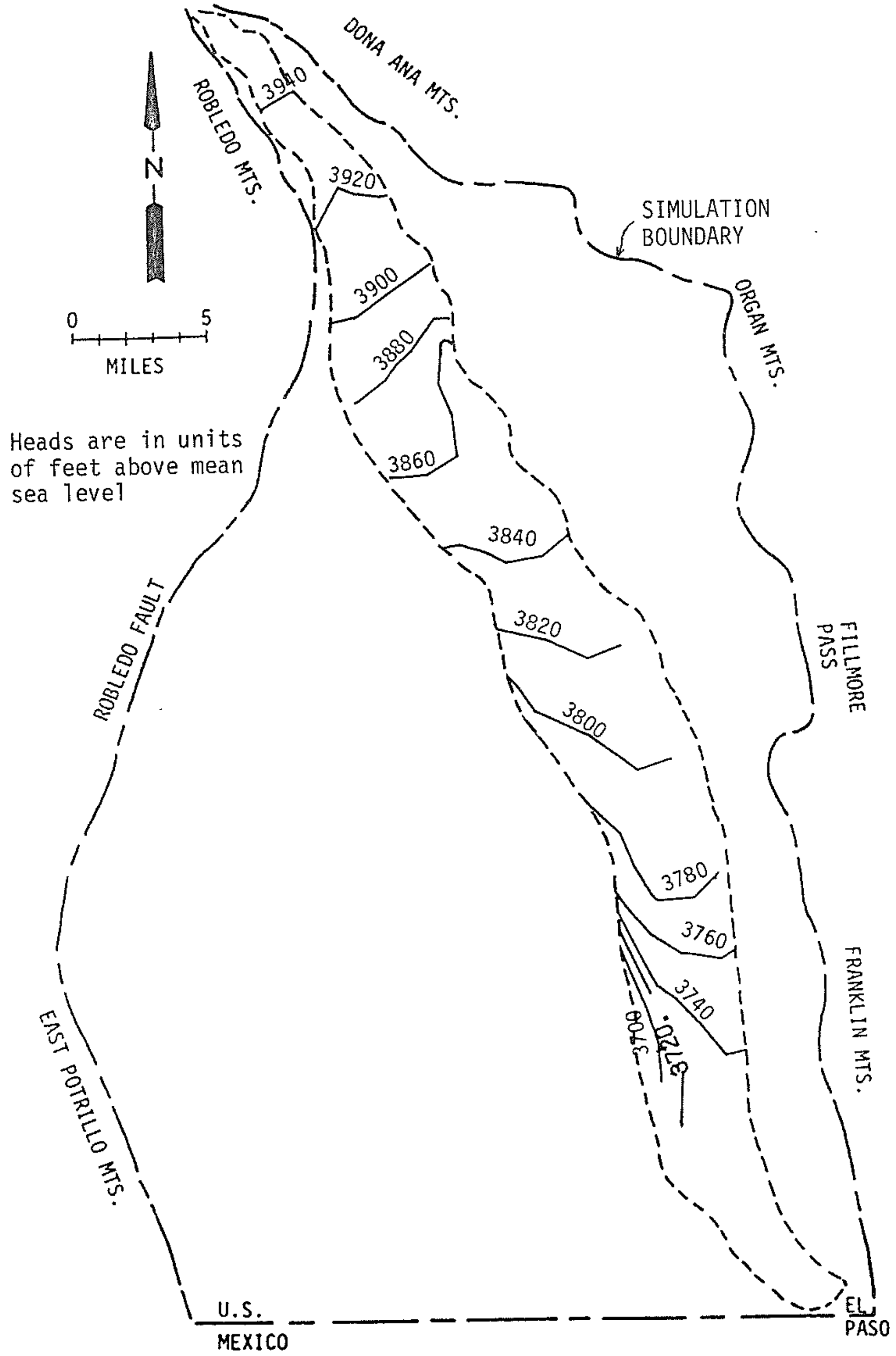


Figure 19. Contour Map of Simulated Heads in the Flood-Plain Alluvium 70 Years in the Future - Predictive Simulation B

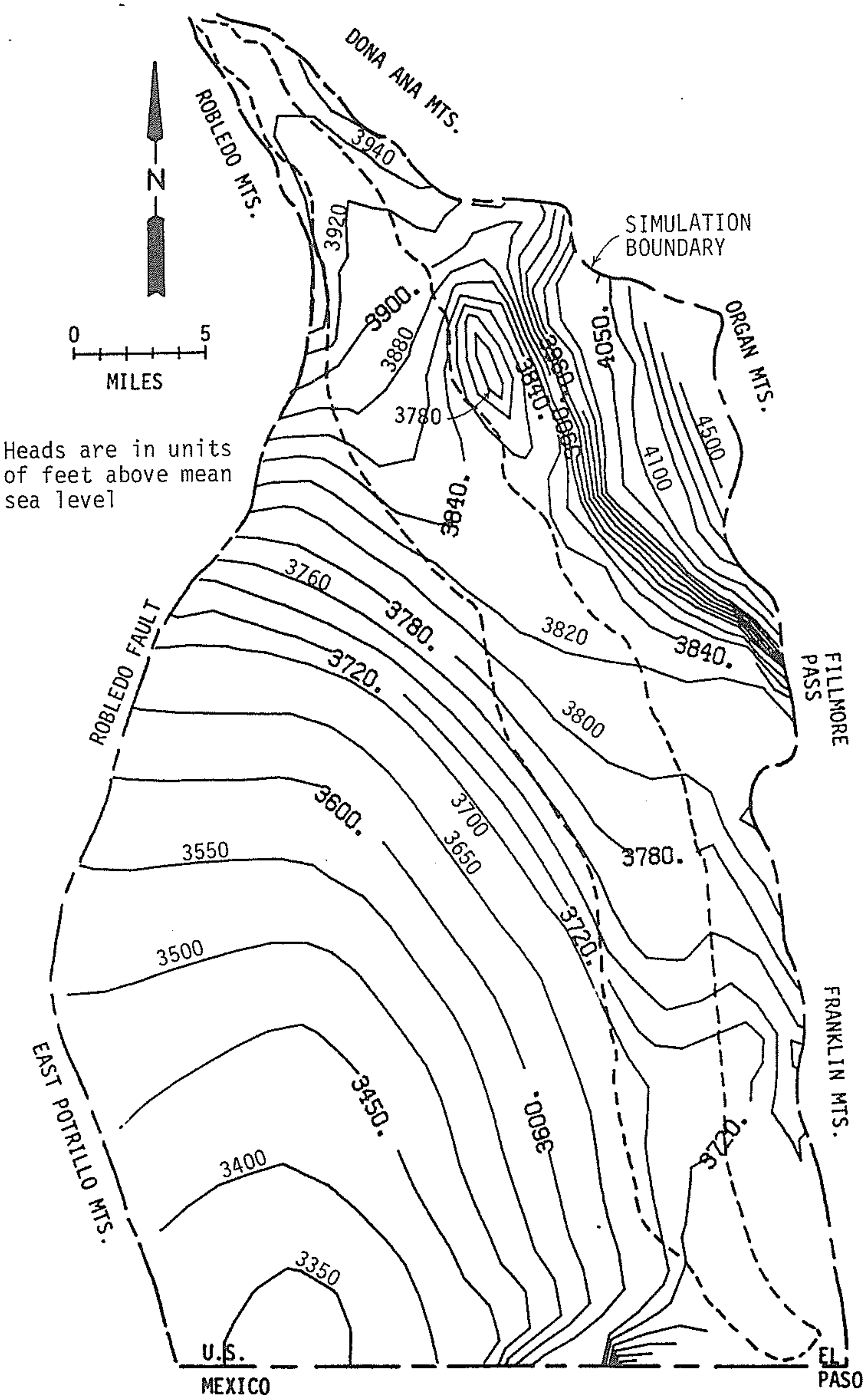


Figure 20. Contour Map of Simulated Heads in the Santa Fe Group 70 Years in the Future - Predictive Simulation B

TABLE 3

SIMULATED ANNUAL HYDROLOGIC BUDGET OF THE MESILLA BOLSON SUBSURFACE DOMAIN 70 YEARS IN THE FUTURE - PREDICTIVE SIMULATION B

Sources	Acre-Feet	Percent of Total
Irrigation	242,300	61.8
Stream Seepage	119,900	30.6
Mountain Front Recharge	30,000	7.6
TOTAL	392,200	
Discharges		
Evapotranspiration	71,900	18.6
Pumping	286,300	74.2
Drain Discharge	26,900	7.0
Discharge to Rio Grande	600	0.2
TOTAL	385,700	

Net leakage from the flood-plain alluvium to the Santa Fe Group = 227,000 acre-feet per year.

50 percent of the total irrigation application. Assuming 50 percent of the applied irrigation water would actually be used by plants, total annual evapotranspiration in Table 3 would be closer to 121,000 acre-feet. In addition, the drains in the Mesilla Valley would probably dry up due to a reduced water table elevation. Moreover, total groundwater withdrawals from the basin would exceed total recharge.

Simulation C. Piezometric heads from Production Run C at the end of 100 years of pumping are shown in Figures 21 and 22. Water budget results for the same time period are summarized in Table 4.

Changes in groundwater flow direction brought on by the pumping of proposed El Paso wells are similar to those observed in Predictive Simulation B. However, the effects on piezometric head levels in the West Mesa and water budget components are less than indicated by Simulation B. Despite the fact that the model computed evapotranspiration in Table 4 is probably too small, inflow and outflow totals clearly show that a net depletion of groundwater would be occurring 100 years after commencement of pumping.

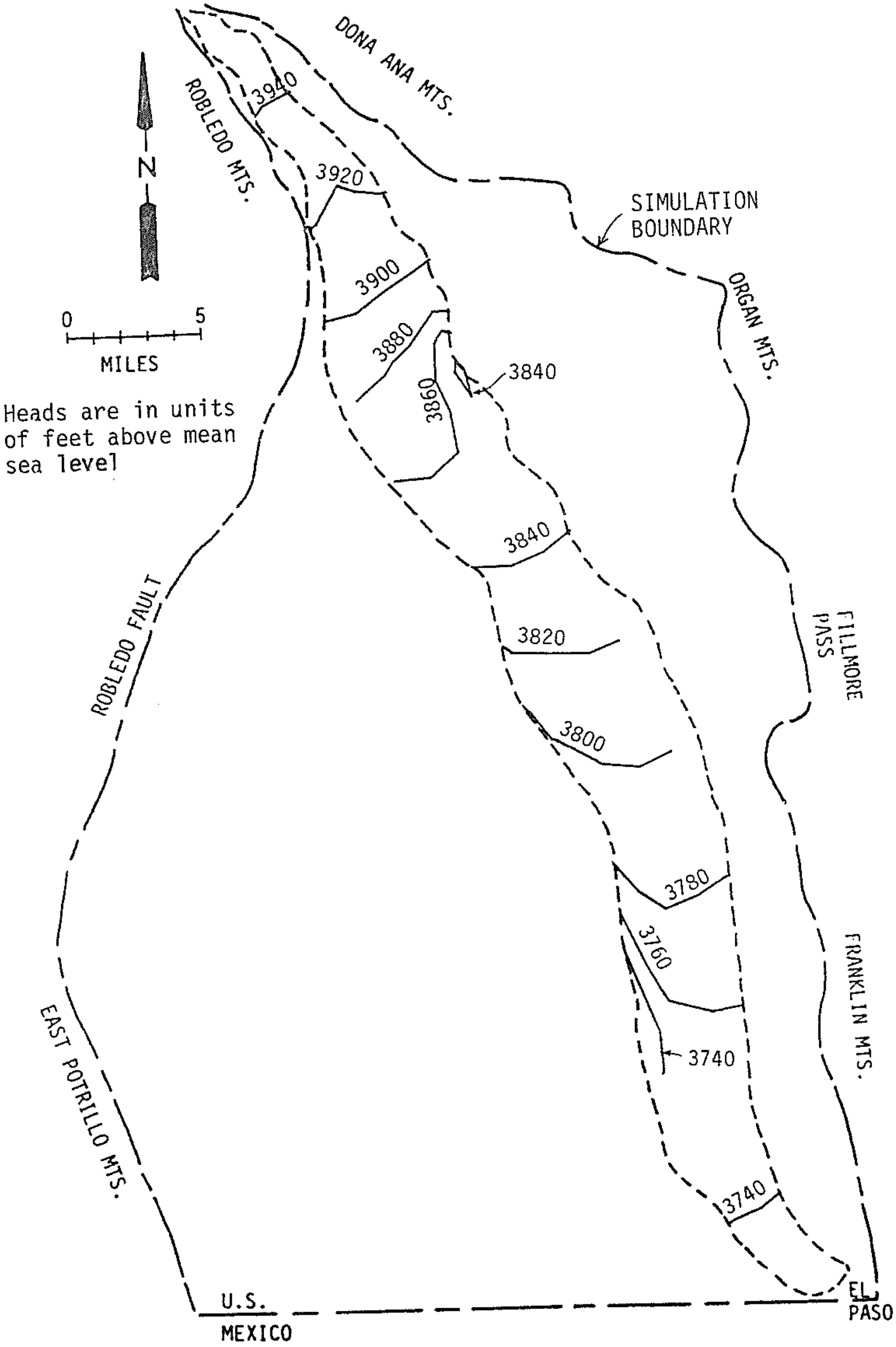
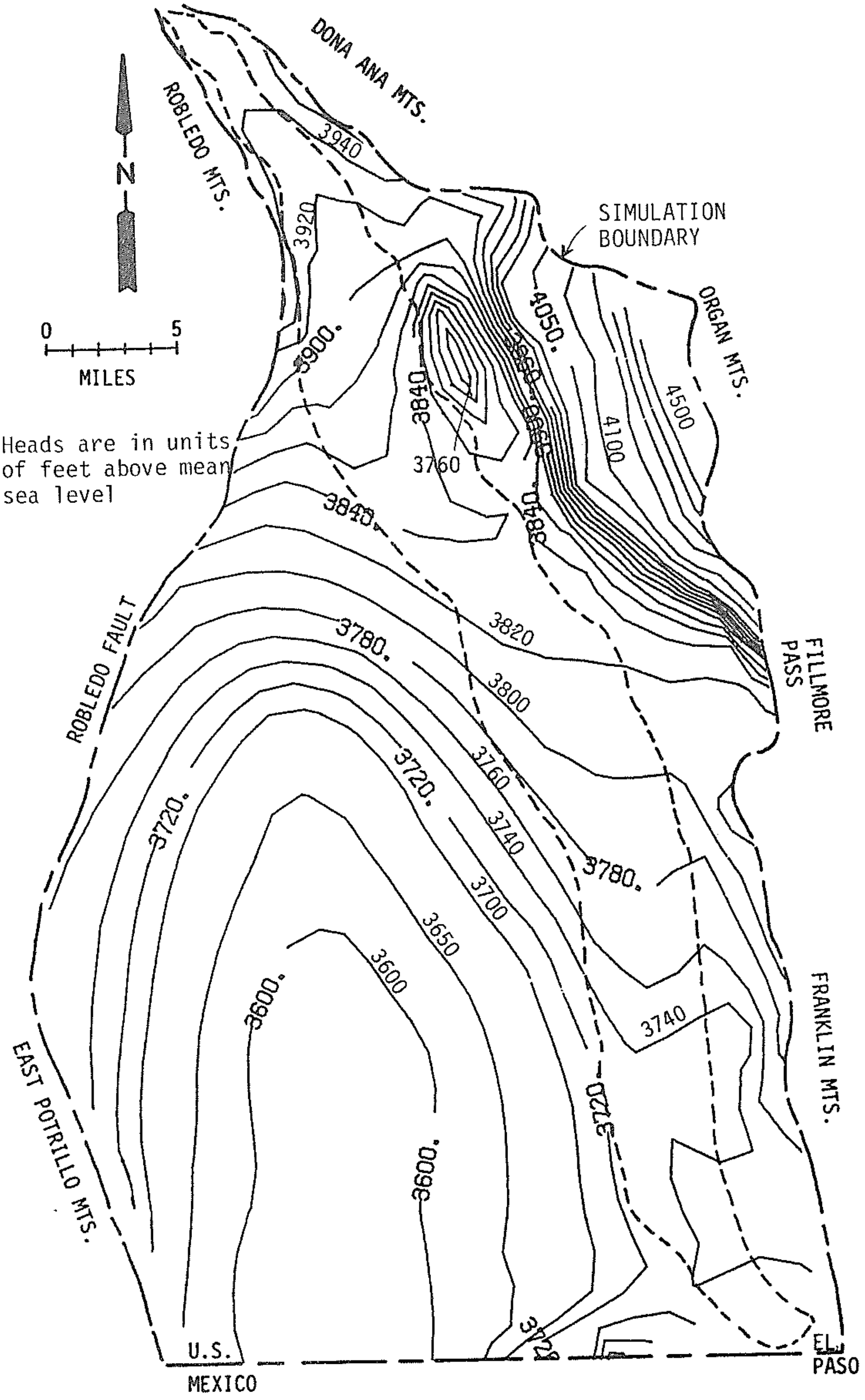


Figure 21. Contour Map of Simulated Heads in the Flood-Plain Alluvium 100 Years in the Future - Predictive Simulation C



Heads are in units of feet above mean sea level

Figure 22. Contour Map of Simulated Heads in the Santa Fe Group 100 Years in the Future - Predictive Simulation C

TABLE 4

SIMULATED ANNUAL HYDROLOGIC BUDGET OF THE MESILLA BOLSON SUBSURFACE DOMAIN

100 YEARS IN THE FUTURE - PREDICTIVE SIMULATION C

Sources	Acre-Feet	Percent of Total
Irrigation	242,300	61.8
Stream Seepage	119,900	30.6
Mountain Front Recharge	30,000	7.6
TOTAL	392,200	

Discharges	Acre-Feet	Percent of Total
Evapotranspiration	108,900	22.5
Pumping	334,700	69.2
Drain Discharge	39,700	8.2
Discharge to Rio Grande	600	0.1
TOTAL	483,900	

Net leakage from the flood-plain alluvium to the Santa Fe Group = 183,100 acre-feet per year.

Temporal Behavior of Hydrologic Variables

Stream losses to the flood-plain alluvium in Simulation A were always slightly higher than the seepage losses observed during Predictive Simulations B and C. Such a result was expected because hydraulic connection between surface waterways and the water table was more common during Simulation A. However, because hydraulic "disconnection" appears to dominate surface waterways in the basin, stream seepage losses computed by all three predictive runs were virtually constant over the total simulation period.

Drain discharges were gradually reduced during the three predictive runs. Figure 23 shows the temporal behavior of drain flow for the three simulations. Due to the inability of the model to accurately account for evapotranspiration, the drain discharges shown in Figure 23 are probably higher than expected. Reductions in drain discharges with time signify corresponding decreases in stream flow, since during late fall and winter, the flow in the Rio Grande is largely sustained by drain flows.

Temporal changes in net leakage from the shallow flood-plain alluvium to the Santa Fe Group for the predictive runs are illustrated in Figure 24. Downward moving leakage increases with increasing groundwater withdrawals.

Limitations of Predictive of Simulations

The various calibration (steady state and transient) and production runs that have been performed with the quasi 3-D model have helped to illustrate some of its limitations and deficiencies when used for predictive purposes. Consequently, the results of this section should be used with caution. The authors, realizing that the model does have its shortcomings, have presented their findings from the predictive simulations only in the interest of providing some general indicators of the Mesilla Bolson's response to future

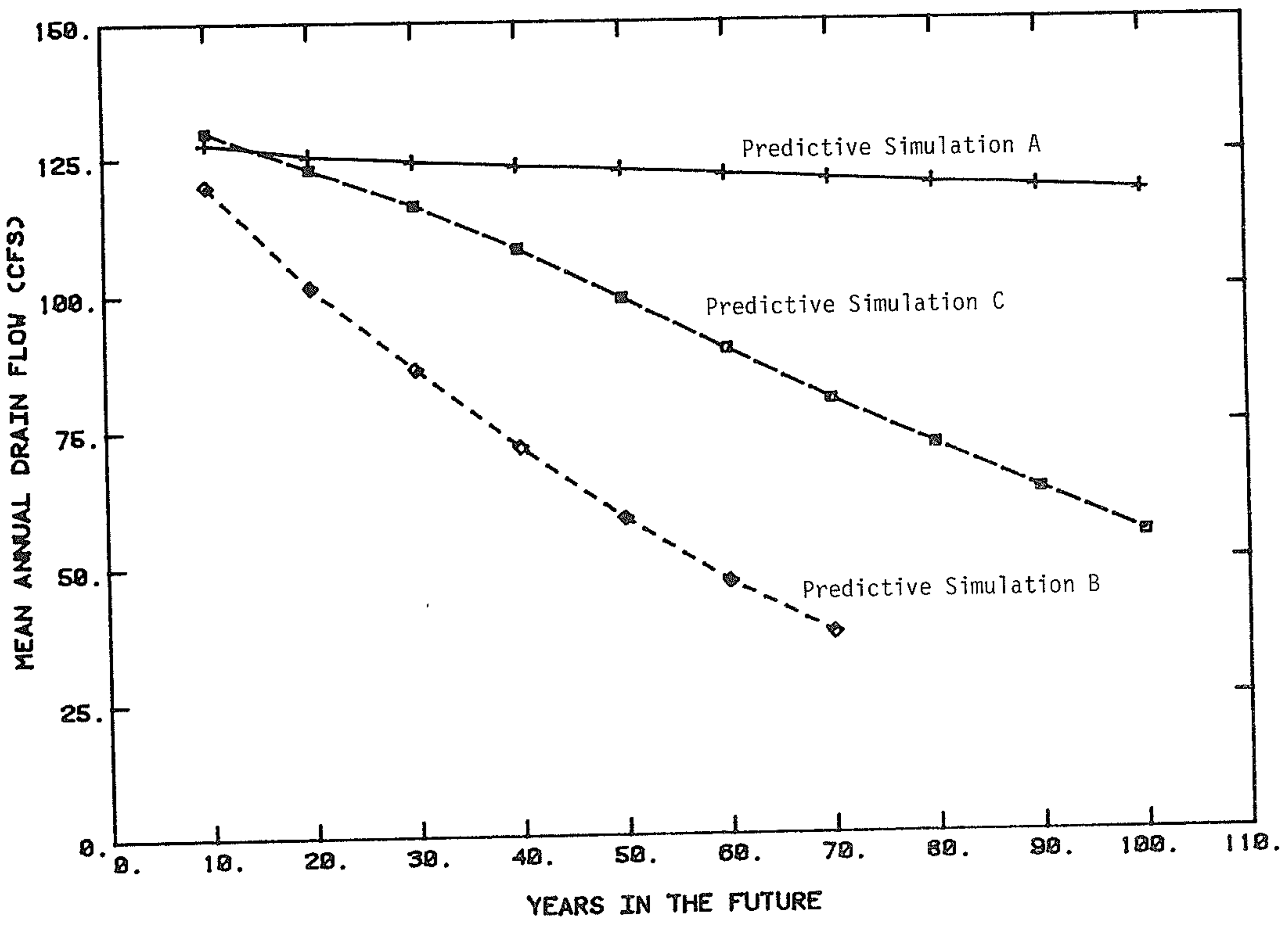


Figure 23. Simulated Drain Discharge From the Mesilla Valley, 1984-2083

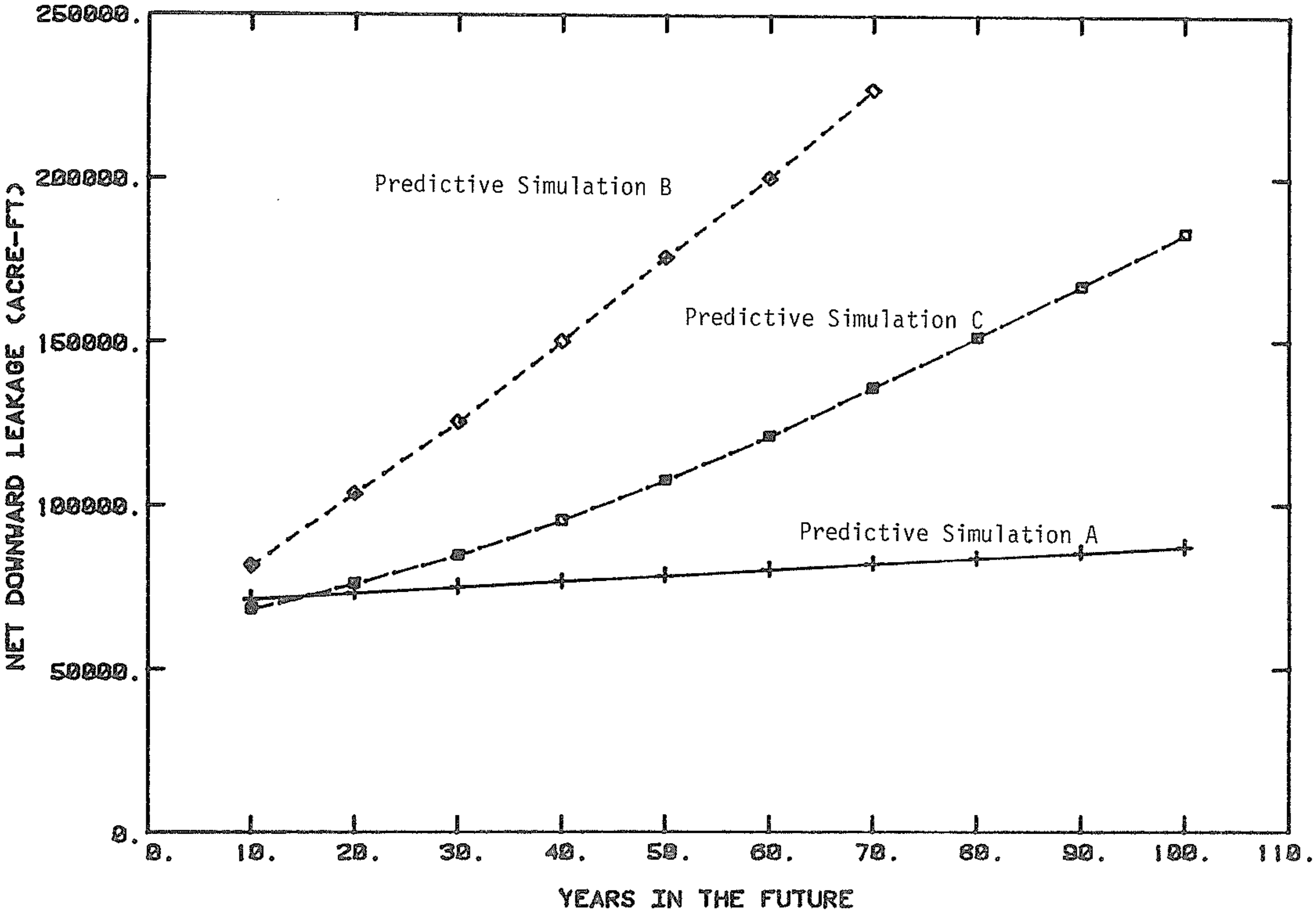


Figure 24. Simulated Net Leakage From the Flood-Plain Alluvium to the Santa Fe Group, 1984-2083

groundwater withdrawals. A summary of the more notable limitations and concerns with the model is given below.

1. Groundwater flow in the Mesilla Bolson is truly three-dimensional. Yet data and resource constraints have prompted the authors to represent the flow system with a two-layer quasi three-dimensional model. Therefore, no attempt has been made to simulate vertical variations in hydraulic head within each of the two main hydrogeologic units that have been modeled. Accordingly, heads computed by the model are assumed to be vertically averaged, and flow within each aquifer is assumed to be horizontal.

2. Due to the dominating influence of surface water recharge and Mesilla Valley pumpage on the model, the transient calibration was helpful in developing values for parameters that influence groundwater - surface water exchange processes in the flood-plain alluvium, but did little to assist in refining aquifer and aquitard properties. Moreover, the model could not be truly tested for its ability to match historic head patterns. This latter difficulty arose partly due to the groundwater system's tendency to maintain a virtual state of equilibrium, and partly due to a lack of detailed potentiometric head maps for the basin from years past.

3. The method incorporated in the model to determine ET is dependent on depth to the water table. As groundwater levels in the flood-plain alluvium steadily decline due to increased pumping, this technique does not adequately estimate the amount of ET that would occur should irrigation activity be maintained near today's levels. Consequently, model simulated heads are probably maintained at levels that are greater than would actually occur. As groundwater levels decline, source and discharge values computed in the mass balance segment of the model are also affected by the inappropriate ET algorithm.

4. Other concerns are related to the future managment of the Mesilla Bolson's resources. Specifically, will the amount of irrigated acreage in the Mesilla Valley remain the same as the water table continues to decline, or will affected lands be withdrawn from agricultural usage? Moreover, with less land being irrigated, will the mean annual quantity of surface water diverted to the irrigation canal network be reduced, thereby effectively decreasing the volume of recharge attributed to stream losses? Such questions concerning future management of the Mesilla Bolson's water resources are not easily answered and are certainly subject to conjecture.

5. Finally, it is important to emphasize that, due to a paucity of hydrogeologic information for the Mexican portion of the groundwater basin, the international boundary between the U.S. and Mexico has been assumed a physical boundary in the model. Since Predictive Simulations B and C show significant changes occurring in the potentiometric surface near the border, it is possible that predictive simulation results would be noticeably different than those presented herein, if more realistic boundary conditions could be used for this part of the basin.

XII. SUMMARY AND CONCLUSIONS

A quasi three-dimensional finite difference model was designed to simulate multi-layered groundwater flow in the Mesilla Bolson. In addition to accounting for horizontal subsurface seepage of water in both the Santa Fe Group and flood-plain alluvium aquifers, the model simulated steady state leakage across the confining beds of clay that separate the two aquifers. Important hydrologic processes occurring in the shallow aquifer, specifically, stream losses, drain discharge and evapotranspiration, have also been adequately simulated in the model.

Considerable time and effort was devoted to a suitable conceptualization of hydrogeologic factors that are known to affect the Mesilla Bolson's groundwater system. The relative importance of recharge and discharge mechanisms, as well as aquifer properties, leakage characteristics, and geologic controls on subsurface water movement in the study region were established.

The finite difference model was designed in an ad hoc manner to best account for the key groundwater and surface water processes that take place in the basin, while still utilizing the existing limited data base in an effective manner. The model source code was primarily developed for long-term simulations, using time step durations of a year or more.

A calibrated version of the quasi 3-D model was developed through steady state and transient simulations. In addition to quantitative estimates of the mountain front recharge, improved estimates of aquifer properties and confining bed characteristics were the major benefits derived from the steady state calibration. Transient simulations during the 18-year period of 1966 to 1983 showed that groundwater-surface water exchange processes and pumping in the Mesilla Valley currently dominate hydraulic head configurations in both aquifers from year to year. Consequently, the transient analysis was found to be of limited utility in terms of calibrating the model. Rather than assisting in the development of refined values for those variables that affect subsurface movement of water, the transient simulations were most helpful for determining appropriate quantities of seepage loss from the Rio Grande and irrigation canals, and for computing reliable values of discharge to the drains in the flood-plain alluvium.

From the conceptualization of the study area's hydrogeologic regime, and steady state and transient analyses with the quasi three-dimensional model, the following conclusions are made regarding the existing hydrology of the Mesilla Bolson:

1. During the last 25 years, the groundwater system in the basin has been in a virtual equilibrium or steady state. Over the long term, recharge to the subsurface domain from irrigation applications and canal seepage are sufficiently large to keep the water table in the flood-plain alluvium and piezometric head levels in the Santa Fe Group from showing a gradual decline, even though groundwater pumpage is very large in some years.

2. The largest sources of subsurface water in the basin today are applied irrigation water and river and canal losses. The mean annual volume of applied irrigation water during the historical period 1966-1983 has been estimated at 240,300 acre-feet. The average annual computed stream losses for the same period were 116,200 acre-feet. Because more than half of the applied irrigation water is likely to be lost to evapotranspiration before it reaches the water table, it is possible that stream losses represent a larger recharge source than irrigation water.

3. Since the total irrigated acreage in the study area does not change drastically from year to year, it is estimated that the annual quantity of water used to irrigate crops remains relatively constant. In contrast, river and canal losses appear to fluctuate annually depending on the availability of surface water. Simulated yearly stream losses during the period 1966-1983 varied from a low of 89,400 acre-feet to a high of 126,900 acre-feet.

4. Recharge from precipitation in mountainous basin boundaries comprises only about 18 percent of all subsurface water sources. An estimated average of 30,000 acre-feet per year is derived from mountain front sources.

5. During an average year, evapotranspiration by crops and phreatophytes comprise the largest component of discharge of subsurface water. However, in periods of low surface water supply, pumpages can exceed the

consumptive use of water by plants. Estimated mean annual evapotranspiration from the Mesilla Bolson during 1966-1983 was 166,400 acre-feet, while estimated yearly pumpage averaged 122,800 acre-feet.

6. Discharge of groundwater to drains is also a major mechanism of groundwater outflow, representing more than 24 percent of the total discharge of subsurface water observed in an average year. Mean annual drain flows observed in the Mesilla Valley during 1966-1983 fluctuated considerably, ranging from as low as 32 cubic feet per second (cfs) to as much as 183 cfs. A very small quantity of groundwater discharges to the Rio Grande in the upper Mesilla Valley.

7. Leakage between the shallow flood-plain alluvium and Santa Fe Group aquifers occurs predominantly in a downward direction, although some upward leakage may take place along a 10 to 15 mile stretch of the Mesilla Valley from just south of Las Cruces to near Berino. The average net leakage from the flood-plain alluvium to the Santa Fe Group computed by the model for the years 1966-1983 was 61,000 acre-feet per year. Groundwater level hydrographs and pump tests suggest that steady state leakage between aquifers is probably common, and that confining clays in the Mesilla Valley likely release stored water relatively quickly when affected by pumping stresses.

8. A northwest-southeast trending fault block of volcanic and sedimentary bedrock has been elevated in an area just to the east of Las Cruces, creating a submerged horst that acts as a partial barrier to groundwater flow coming from the piedmont slope in the northeast section of the basin. Groundwater passes westward over the structure in areas where the top of the bedrock is lower than at others. The "damming" effect of the horst partly contributes to the steep piezometric head gradient observed in the alluvial facies below the Organ Mountains.

9. Measured yearly drain flows and estimates of annual stream seepage losses were duplicated best by the quasi three-dimensional model when stream and drain stages were allowed to change each year. Stream depths were assumed to be dependent on net diversions into the Mesilla Valley irrigation canals, whereas drain flow stages were related to measured annual drain discharge. A power relationship between stage and flow appeared to be the most appropriate one, for both streams and drains.

10. Currently, the majority of water wells and groundwater withdrawals are found in the Mesilla Valley. Development of groundwater on the West Mesa and eastern piedmont slope remains limited. The large distances separating the river valley from most mountain front recharge areas, along with the tendency of surface water recharge to maintain groundwater heads at virtually constant levels, suggest that piezometric heads at mountain front boundaries remain largely unaffected by pumping in the Mesilla Valley.

Three predictive simulations were made with the numerical model. The first was based on assumed modest increases of pumpage in the Las Cruces area, while groundwater withdrawals elsewhere and other hydrologic variables were kept at levels representative of current conditions. The second and third predictive runs both accounted for the effects of increased groundwater withdrawals on the West Mesa as proposed by the city of El Paso (Wilson and Associates, 1981). The latter two simulations differed from each other with respect to the value of storage coefficient assumed for the Santa Fe Group.

The predictive simulations illustrated the shortcomings of an algorithm used in the model to compute evapotranspiration in the Mesilla Valley. The method that was utilized allowed evapotranspiration rates to change as the depth to groundwater varied. Although this approach appeared to adequately account for evapotranspiration under the shallow water table conditions that currently exist in the valley, it was found to be inappropriate when applied to possible future situations in which the water table undergoes significant declines. Because of the apparent deficiencies in this method of determining evapotranspiration, and due to the uncertainty regarding the model's ability to duplicate transient head configurations, predictive simulation results should be used primarily as qualitative (rather than quantitative) indicators of the basin's response to future stresses.

General findings from the predictive simulations are:

1. Increased pumping in the future will cause total annual drain flow to decrease and downard moving leakage to increase. The degree to which these effects are observed depends on the extent and location of pumping, future irrigation practices, consumptive use of water by crops and other vegetation, and the behavior of storage properties in the Santa Fe Group as groundwater levels decline.

2. Average stream seepage losses from the Rio Grande and irrigation canals will probably not increase much above current values if use of surface water for irrigation is maintained at today's levels. The relatively constant stream seepage rates would be attributed to the fact that most surface waterways would be hydraulically "disconnected" from the adjacent water table.

3. With continued and increased pumping in the vicinity of Las Cruces, the existing cone of depression surrounding the municipal well field can be expected to deepen and expand. After 100 years of pumping, piezometric head levels in the Santa Fe Group within the cone of depression may be as much as 60 feet lower than existing levels.

4. Installation of the proposed El Paso wells and pumping of them in accordance with projected water needs (Wilson and Associates, 1981) will induce groundwater flow from the Mesilla Valley toward the West Mesa. Depending on recharge conditions in the Mesilla Valley and the behavior of storativity in the Santa Fe Group, piezometric levels in the center of the proposed well field may be as much as 200 to 400 feet lower than existing levels.

5. Pumping of the El Paso wells at projected capacities and for long durations will probably induce additional groundwater influx from the region lying to the west of the study area. Hydrologic response of the basin to the proposed scheme of groundwater removals (Wilson and Associates, 1981) may ultimately create a situation in which total discharge from the bolson exceeds total sources of subsurface water.

XIII. RECOMMENDATIONS FOR FUTURE STUDY

This modeling investigation has helped identify research topics that are important to future water management in the Mesilla Bolson. Recommendations for future work include:

1. continued collection of hydrologic data, particularly aquifer and aquitard properties in areas that have not experienced extensive well development;
2. preparation of comprehensive groundwater contour maps for several time periods prior to 1966; followed by transient quasi 3-D simulations of those periods for model calibration purposes;
3. additional predictive quasi 3-D simulations using algorithms more appropriate than depth dependent solutions to account for crop and phreatophyte transpiration in the Mesilla Valley;
4. expansion of the quasi 3-D model to include simulation of uniform flow of surface water in the Rio Grande, irrigation canals and drain ditches;
5. simulation of monthly groundwater and surface water conditions in the Mesilla Bolson;
6. numerical simulation of the effects of unsaturated flow on groundwater recharge from stream and irrigation seepage in areas where large declines in the water table of the Mesilla Valley are anticipated;
7. field monitoring to determine the transient behavior of aquifer storage coefficients as continued pumping in the basin gradually lowers piezometric levels;
8. a study of the delayed release of water stored in clay bodies, including measurements of clay matrix consolidation and possible subsidence; and
9. numerical simulation of the transient release of water stored in clay layers, using algorithms that incorporate the effects of changing pore pressure-specific storage relationships with increasing compaction of clays.

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APPENDIX A

EXPLANATION OF HYDROGEOLOGIC CROSS SECTIONS (NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES, OPEN FILE REPORT 190)

Open-file Report 190
New Mexico Bureau of Mines
and Mineral Resources

HYDROGEOLOGIC CROSS SECTIONS OF THE MESILLA BOLSON AREA, DONA ANA COUNTY, NEW MEXICO AND EL PASO COUNTY, TEXAS

John W. Hawley, Senior Environmental Geologist
New Mexico Bureau of Mines and Mineral Resources
Socorro, NM 87801

Spring-Summer, 1984

HYDROGEOLOGIC CROSS SECTIONS OF THE MESILLA BOLSON AREA, DONA ANA COUNTY, NEW MEXICO, AND EL PASO COUNTY, TEXAS

John W. Hawley, Senior Environmental Geologist
New Mexico Bureau of Mines and Mineral Resources

The purpose of this phase of research on numerical modeling of groundwater flow in the lower Rio Grande basin of New Mexico (Khaleel et al, 1983; in progress) is to illustrate the hydrogeologic framework of the Mesilla Bolson utilizing all available surface and subsurface information. Emphasis is on physical properties of the intermontane-basin fill related to storage and transmission of ground water, and on the structural and lithologic properties of rock units forming basin boundaries. Information is presented in a combined surface-map and cross-section format (Plates 1 to 16) in order to provide 3-dimensional hydrogeologic models that interface directly with numerical models developed for the hydrologic phase of the study. Basic map scale (1:125,000) and cross-section dimensions (1:1 and 10:1 vertical exaggeration) conform with map and section formats used in ongoing hydrologic and geologic investigations by the U.S. Geological Survey, New Mexico State Engineer, and New Mexico Bureau of Mines and Mineral Resources (Wilson and others, 1981; Seager and others, in press).

Any valid characterization of bolson hydrogeology must be based on the best possible understanding of the local geologic framework, particularly in the context of relatively recent geologic history, since the major water-bearing units are fills of intermontane structural basins of late Cenozoic age. The bulk of these units, and associated confining beds, are components of the Santa Fe Group and include deposits of the ancestral Rio Grande. Recent mapping (summarized by Seager and others, in press) of exposed geologic units and structures is of excellent quality. However, hydrologic investigations focus on basin- and valley-fill units that are rarely well exposed; and in much of the area, subsurface data from drill holes and geophysical surveys are not available. Therefore, portrayals of bolson hydrogeology (e.g. King and others, 1971; King and Hawley, 1975; Wilson and others, 1981), including materials in this report, should be regarded only as reasonable state-of-the-art models that will be subject to testing and revision. The reference list indicates sources of most of the data used in preparation of cross sections. The only unpublished data used were preliminary well logs, mainly from files at the Las Cruces and El Paso offices of the U.S. Geological Survey, and some geophysical information. It must be emphasized, however, the interpretations presented in this study are strictly those of the author.

Plates 1 to 16 illustrate the major hydrogeologic features of the Mesilla Bolson and the format used for presenting hydrogeologic information in this ongoing study. Plate 1 is a topographic map view of the area showing location of 1) major basin-range boundary faults, 2) well-control points, and 3) sixteen cross sections that form the basis for the hydrogeologic model. Plates 2 to 9 and 11 to 14 are preliminary versions of twelve transverse sections (AA', BB', CC', DD', ED', FF', GG', GH', JJ', KK', LL', and MM') across the bolson and adjacent parts of the Jornada and Hueco basins. Plate 10 comprises two longitudinal sections (HH' and II') along the structural uplifts that form the east margin of the Mesilla Bolson; these sections extend from the Dona Ana to the Franklin Mountains. Plate 15 is a longitudinal profile (NN') down the Mesilla Valley from north of Las Cruces to south of Anthony. Plate 16 is a longitudinal section (AN') extending from north to south down the bolson floor west of the Mesilla Valley. The orientation of sections in Plates 15 and 16 is down regional slope and approximately parallel to major ground-water flow lines. The base line of all sections is mean sea level, and geologic information to that depth is given wherever possible. The bulk of hydrogeologic data is from a zone between 2,500 ft elevation and the land surface, with the top of the zone of saturation at about 4,000 ft. However, a few well and geophysical control points extend to or below an elevation of 2,000 ft.

General distribution patterns of 10 hydrogeologic subclasses of valley and basin fills are shown on Plates 2 to 16 (sections with 10:1 vertical exaggeration). These deposits of late Oligocene to Holocene age (<25 million years) are listed in order of decreasing aquifer potential and include six subdivisions that form important aquifers in the Mesilla Bolson area (Plate 1). Units I to IV form the major aquifers of the region and include deposits of a large fluvial-fan system constructed by the ancestral Rio Grande in Pliocene to middle Pleistocene time (5 to 0.5 million years ago). Clean sand or gravelly sand zones are extensive and thick, and have relatively large hydraulic conductivities. Estimated transmissivities commonly exceed 10,000 ft^2/day and water quality is good (tds usually <1,000 mg/L). Units V and VI form thinner and less extensive aquifers that are locally important water sources, particularly in the southern Jornada del Muerto Basin. These piedmont-slope and basin-floor alluvial deposits include elongate sand and gravel lenses that are in part transitional to more extensive deposits of the ancestral Rio Grande. Transmissivities locally may be as high as 10,000 ft^2/day. Units VII to X rarely form aquifers and include fine-grained basin fill (playa and lake beds) and indurated fan-piedmont deposits. Hydraulic conductivities are very low and water quality is usually poor.

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This work is dedicated to the memory of Clyde A. Wilson, who headed the U.S.G.S. office in Las Cruces from 1971 until his untimely death in 1980. This unassuming and highly motivated public servant played the key role in putting ground-water hydrology and hydrogeology of the Mesilla Bolson area on a sound technical and scientific footing. Clyde's expertise and common-sense approach to water resource investigations are greatly missed.

Explanation--Plate 1

Well-Control Points

700 ○	Water-well (test or production) with depth indicated; water-level information usually available; sample and/or drillers logs also available for many holes
890+ ● 902	Water-well (test or production) with geophysical log(s); sample and/or drillers logs commonly available; upper and lower members indicate thickness of basin fill and total depth, respectively.
2430+ -●- -○-	Oil test control point, with thickness of basin fill indicated; geophysical, driller, and sample logs usually available

Boundary Faults

━━╤━━ ━	High-angle normal fault; bar and ball on downthrown side
D •••••••• U	Buried high-angle normal fault

Cross Sections

A——A'	Location of transverse hydrogeologic cross sections (Plates 2-9, 11-14)
A │ N'	Location of longitudinal hydrogeologic cross sections (Plates 10, 15, 16)

Explanation--Plates 2 to 16

Valley-Fill and Basin-Fill (QTa) Subdivisions

Valley-fill unit

I. Sand and gravel, with local silt-clay lenses. Upper Quaternary Rio Grande Valley fill. Forms upper part of "shallow aquifer" of Leggat et al. (1962) and "flood-plain alluvium of Wilson et al. (1981).

Younger basin-fill units (basin-floor fluvial to deltaic facies)

II. Sand, with pebble gravel, clay-silt, and sandstone lenses; partly cemented with calcite. Plio-Pleistocene ancestral river facies; includes upper Santa Fe Gp-Camp Rice Fm fluvial facies. Unit mainly unsaturated; where saturated forms part of major Mesilla Bolson aquifers.

III. Sand and some fine pebble gravel, interbedded with clay-silt; broadly lenticular to sheet-like strata; partly cemented with calcite (sand ≥ clay-silt-sandstone; sand bodies estimated to make up about 50-60% of section). Pliocene-lower Pleistocene transitional facies; fluvial-deltaic deposits of upper Santa Fe Gp, including parts of Camp Rice and Fort Hancock Fms. Includes parts of "medial aquifer" of Leggat et al. (1962).

IIIs. Zones where sand bodies are the major constituent (sand>clay-silt-sandstone; sand bodies estimated to make up about 60-80% of section).

Younger basin-fill units (piedmont-slope and basin-floor facies)

IV. Sand, with discontinuous thin clay layers. Pliocene-upper Miocene? eolian facies; unnamed upper Santa Fe Gp unit. Includes major part of "deep aquifer of Leggat et al. (1962).

V. Pebbly sand to clay mixtures, interbedded with clean pebbly sand, and clay-silt; broadly lenticular bodies of clean sand and pebble gravel (20-30%). Plio-Pleistocene distal piedmont facies, mainly coalescent fan (bajada) deposits, and local basin-floor alluvium that intertongue with units II to IV and VII. Upper Santa Fe Gp--Camp Rice and Fort Hancock Fms. Includes "NASA well I-J aquifer" of Doty (1963) in southern Jornada Basin.

VI. Coarse gravelly sand to clay mixtures, with thin lenticular bodies of clean sand and gravel (10-20%), and discontinuous zones of calcite cementation. Pleistocene proximal piedmont facies, mainly alluvial fan deposits. Upper Santa Fe Gp-Camp Rice and Fort Hancock Fms.

VII. Clay-silt, with interbedded sand and sandstone lenses; broadly lenticular to sheet-like strata (clay-silt-sandstone>sand; sand lenses less than 10% of section); locally with calcium and sodium sulphates. Pliocene-lower Pleistocene deltaic-lacustrine and playa facies that intertongue with units III, IV, and V. In central basin areas transitional downward with unit X. Upper Santa Fe Gp-Fort Hancock Fm.

Older basin-fill units (piedmont-slope and basin-floor facies)

VIII. Conglomeratic sandstone and mudstone and conglomerate; with discontinuous zones of gravelly sand and clay-silt. Miocene to lower Pleistocene fanglomerate facies; Santa Fe Gp--mainly correlative with Rincon Valley and Hayner Ranch Fms., but also include basal Camp Rice fan deposits.

IX. Fine conglomeratic sandstone and mudstone, interbedded with sandstone to mudstone. Miocene to lower Pleistocene distal piedmont facies, coalescent fan (bajada) deposits that intertongue with units VIII and X). Mainly lower Santa Fe-Rincon Valley Fm.

X. Clay-silt, mudstone, and shale, with local sandstone and conglomeratic lenses; locally with calcium and sodium sulphates. Miocene to lower Pliocene playa-lake facies; mainly lower Santa Fe Group-Rincon Valley Fm.

Bedrock Units*

Qb	Basaltic volcanics, mostly flows, with local cinder-cone and conduit material. Quaternary
Tb	Basaltic plugs. Miocene and Pliocene
Tr	Rhyolitic volcanics, with some interbedded sandstone and conglomerate mostly ash-flow tuff and lava. Oligocene
Tri	Rhyolitic intrusive complexes; mostly sills, plugs and associated lava domes. Oligocene
Ti	Silicic to intermediate plutonic rocks. Oligocene and Eocene
Tv	Andesitic and other intermediate volcanic and volcaniclastic rocks, including lavas and laharic breccias. Oligocene and Eocene
Trv	Undivided Tr and Tv
Tl	Mudstone, sandstone, and conglomerate with local gypsum beds. Lower tertiary, mainly Eocene
Tvl	Undivided Tv and Tl
M	Mesozoic rocks--undivided; includes limestone, sandstone, shale and marine limestone. Cretaceous
TM	Undivided Ti, Tv, Tl, M
Pu	Upper Paleozoic rocks; includes limestone, shale, sandstone and mudstone, with local gypsum beds.
MP	Undivided M and Pu
Pl	Lower Paleozoic rocks--undivided; includes limestone, shale, and minor sandstone.
P	Undivided Pu and Pl
P€	Precambrian metasedimentary rocks, metavolcanics, and granite.
PP€	Undivided Pu, Pl, and P€

* Primarily hydrogeologic boundary units with very low transmissivities. However, limestones may locally be highly transmissive in zones with solution-enlarged joints and fractures; and sandstone, conglomerate, and fractured tuffs and lavas may also form aquifers in a few areas.

APPENDIX B

MODEL OUTPUTS FROM STEADY STATE CALIBRATION

```
STEADY STATE SIMULATION OF GROUNDWATER FLOW IN THE MESILLA BOLSON
LAYER 1 = FLOOD PLAIN ALLUVIUM, LAYER 2 = SANTA FE GROUP

   GENERAL SIMULATION DESCRIPTORS:
         STEADY STATE =  T
         SHALLOWEST AQUIFER UNCONFINED =  T
         UNDERFLOW TO THE DEEPEST AQUIFER =  F
         MODEL ADJUSTED DRAIN STAGES  =  F
         MEAN TRANSMISSIBILITY =  HARM
         NUMBER OF PUMPING PERIODS =  1

   MODEL GEOMETRIC DESCRIPTORS:
         NUMBER OF COLUMNS =  24
         NUMBER OF ROWS =  28
         NUMBER OF LAYERS =   2
         VARIABLE GRID DIMENSIONS =  T

   EQUATION SOLVING SCHEME:
         SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE (SIP)
         NUMBER OF ITERATION PARAMETERS = 10
         MAXIMUM PERMITTED NUMBER OF ITERATIONS =  75
         BETA PARAMETER = 1.000
         ERROR CRITERION FOR CLOSURE =  0.00500 FEET
         STEADY STATE ERROR CRITERION =  .010000 FEET

   OUTPUT CONTROL:
   (T SIGNIFIES THAT THE DATA ARE PRINTED)
         AQUIFER AND AQUITARD PROPERTIES =  T
         UNCONFINED AQUIFER DESCRIPTORS =  T
         STARTING HEADS =  T
         INDIVIDUAL DISCHARGE-RECHARGE RATES =  T
         TOTAL DISCHARGE-RECHARGE RATES =  T
         MASS BALANCE QUANTITIES =  T




   GRID DIMENSIONS, IN FEET:

         BY COLUMNS:
    10560.0  10560.0  10560.0  10560.0   7920.0   7920.0   7920.0   7920.0   7920.0   7920.0
     7920.0   5280.0   5280.0   5280.0   5280.0   5280.0   3960.0   3960.0   3960.0   5280.0
     5280.0   7920.0  10560.0  10560.0

         BY ROWS:
    10560.0  10560.0  10560.0  10560.0  10560.0  10560.0  10560.0   7920.0   5280.0   5280.0
     7920.0  10560.0  10560.0  10560.0  10560.0  10560.0  10560.0  10560.0  10560.0  10560.0
    10560.0  10560.0  10560.0  10560.0  10560.0  10560.0  10560.0  10560.0

   INDICATORS OF METHODS USED TO INPUT AQUIFER AND AQUITARD PROPERTIES:
   (T SIGNIFIES THAT DEFAULT VALUES ARE USED)

                                                       LAYER
                                                       1      2

         TRANSMISSIVITY IN THE Y-DIRECTION             F      F
         TRANSMISSIVITY IN THE X-DIRECTION             F      F
         STORAGE COEFFICIENT                           T      F
         HYDRAULIC CONDUCTIVITY OF CONFINING BED              T
         THICKNESS OF CONFINING BED                           F
```

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                    HYDRAULIC CONDUCTIVITY IN THE Y-DIRECTION (FT/DAY)
                    --------------------------------------------------
LAYER 1
  1       60.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
  2       80.    85.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
  3        0.    80.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
  4        0.    80.    80.     0.     0.     0.     0.     0.     0.     0.     0.     0.
  5        0.    90.   135.   120.     0.     0.     0.     0.     0.     0.     0.     0.
  6       80.    95.   135.   135.     0.     0.     0.     0.     0.     0.     0.     0.
  7      125.    85.    65.    50.     0.     0.     0.     0.     0.     0.     0.    70.
  8      135.   140.    70.    55.     0.     0.     0.     0.     0.     0.     0.    85.
  9      145.   185.   180.    55.     0.     0.     0.     0.     0.     0.     0.    75.
 10      200.   200.   125.    60.     0.     0.     0.     0.     0.     0.     0.    75.
 11      100.   120.   100.    60.     0.     0.     0.     0.     0.     0.     0.    60.
 12       65.   130.    75.    50.     0.     0.     0.     0.     0.     0.     0.     0.
 13       70.    80.    75.    65.    50.     0.     0.     0.     0.     0.     0.     0.
 14        0.    65.    85.    75.    65.     0.     0.     0.     0.     0.     0.     0.
 15        0.    75.    85.    80.    65.    55.     0.     0.     0.     0.     0.     0.
 16        0.    85.   120.   120.   120.    60.     0.     0.     0.     0.     0.     0.
 17        0.    95.   140.   140.    45.    55.     0.     0.     0.     0.     0.     0.
 18        0.    85.   185.   180.    85.    40.     0.     0.     0.     0.     0.     0.
 19        0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.


           0.    95.   200.   100.    55.     0.     0.     0.     0.     0.     0.     0.
 20        0.   105.   165.   125.    55.     0.     0.     0.     0.     0.     0.     0.
 21       85.   135.   120.    80.    55.     0.     0.     0.     0.     0.     0.     0.
 22       65.    95.    80.    55.     0.     0.     0.     0.     0.     0.     0.     0.
 23       75.    75.    65.     0.     0.     0.     0.     0.     0.     0.     0.    55.
 24       75.    70.    65.     0.     0.     0.     0.     0.     0.     0.     0.    60.
 25       80.    70.     0.     0.     0.     0.     0.     0.     0.     0.     0.    65.
 26       80.    85.     0.     0.     0.     0.     0.     0.     0.     0.     0.    60.
 27       80.    80.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
 28       65.    65.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
```

```
                         TRANSMISSIVITY IN THE Y-DIRECTION (FT2/DAY)
                         -------------------------------------------
LAYER 2
  1      0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
       400.   550.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
  2      0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
       400.  3000.  2500.   300.     0.     0.     0.     0.     0.     0.     0.     0.
  3      0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
       300.  4500.  6000.  4500.   500.     0.     0.     0.     0.     0.     0.     0.
  4      0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
       300.  4000.  6000.  5000.  3000.  1000.     0.     0.     0.     0.     0.     0.
  5      0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.
       300. 10000. 11000. 10000.  5000.   600.     0.     0.     0.     0.     0.     0.
  6      0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.   300.
     13000. 13000. 11000.  8000.  2000.   600.   100.    50.    10.   150.   400.     0.
  7      0.     0.     0.     0.     0.     0.     0.     0.     0.     0.   300.  8000.
      9000. 17000. 10000.  6000.  4000.  4000.    50.    10.    15.   175.   500.     0.
  8      0.     0.     0.     0.     0.     0.     0.     0.     0.   200.  3000.  4000.
     10000. 10000. 12000. 10000.  7000.  5000.   250.    60.   400.   600.   200.     0.
  9      0.     0.     0.     0.     0.     0.     0.     0.  4000.  5000.  5000.  5000.
      5000.  8000. 10000. 11000. 10000.  6000. 12000.  1300.  3000.   650.   500.   150.
 10      0.     0.     0.     0.     0.     0.     0.  7400.  7000. 10000. 10000. 10600.
     11000. 10000. 15000. 12000. 12000. 10000. 15000.   750.  4000.  3750.  1250.   200.
 11      0.     0.     0.     0.     0.  4450.  6000.  6000. 10000. 12500. 11000. 11000.
     12000. 17000. 16000. 15000. 15000. 15000.  8000.  4000.   150.  1500.   200.   100.
 12      0.     0.     0.     0.  4500.  4500.  7500. 10000. 17000. 17000. 25000. 20000.
     21000. 21000. 25000. 24000. 24000. 15000.  6000.   500.  2000.  2000.  1000.   300.
 13      0.     0.     0.  4500.  4000.  7000. 11500. 11500. 17000. 20000. 22500. 27000.
     27000. 30000. 30000. 24000. 24000. 17000. 11000.   600.   800.   600.   600.   200.
 14      0.     0.  4500.  4500.  9000.  7000. 11500. 13000. 16000. 20000. 22000. 26000.
     27000. 27000. 26000. 25000. 20000. 20000. 15000.  7500.   900.   800.   500.     0.
 15      0.  4500.  4500.  5500.  8500. 12000. 12000. 15000. 19000. 21000. 24000. 25000.
     22000. 26000. 28000. 22000. 22000. 18000.  9000.  7500.  2000.  1500.   500.     0.
 16      0.  4500.  5000.  8000. 11000. 12100. 15000. 15700. 15000. 21000. 23000. 27000.
     24200. 25000. 25000. 18000. 18000. 17000.  9000.  7000.  6000.  5500.  2000.     0.
 17   4500.  4500.  6000.  9000. 12000. 12000. 15000. 17500. 17500. 20000. 25000. 25000.
     18000. 16000. 15000. 15000. 16000. 13000.  9000.  4000.  9000.  8000.  5000.     0.
 18   3800.  4000.  5500.  8500. 12000. 14500. 15000. 17500. 21000. 23000. 24000. 26500.
     26000. 19000. 17000. 18000. 17000. 18000. 11000.  8000.  7000.  6000.  4000.     0.
 19   1500.  4000.  6000. 10000. 12000. 14000. 17500. 20000. 21000. 22000. 26000. 26000.



     20000. 21000. 20500. 21000. 15000. 12000. 16000.  3000.   200.     0.     0.     0.
 20   3000.  4400.  7500. 10000. 12000. 15000. 17000. 20000. 22500. 22500. 26500. 13000.
      9000. 10000. 16000. 16000. 14000. 13000.  7000.   600.   200.     0.     0.     0.
 21   1000.  5000.  7000.  9000. 12000. 16000. 18000. 18500. 22000. 25000. 27000. 28000.
     20000. 16000. 16000. 17500. 17500. 18000.  2000.   100.     0.     0.     0.     0.
 22   1000.  5000.  9000. 12500. 16000. 17000. 18000. 18000. 20000. 24500. 26000. 26000.
     17500. 17000. 22000. 20000. 13000. 15000.  2000.   100.     0.     0.     0.     0.
 23   2000.  7000.  9000. 11000. 15000. 14000. 13000. 16000. 20000. 25000. 26000. 21000.
     21000. 21000. 22000. 21000. 19000.  5000.   100.     0.     0.     0.     0.     0.
 24   4000.  6000. 10500. 12000. 15000. 11500.  9500.  8000. 10000. 15000. 15000. 23000.
     21000. 21000. 19000. 18000.  5000.   100.     0.     0.     0.     0.     0.     0.
 25   5500.  9000. 13000. 15000. 17500. 11000.  8500.  8000.  9000. 12000. 15000. 20000.
     21000. 18000. 16000. 14000.  3000.   100.     0.     0.     0.     0.     0.     0.
 26      0.     0.     0. 11000. 11000.  6000.  6000.  4000.  2000.  5000.  6000. 15000.
     18000. 14000. 14000.  2000.   100.     0.     0.     0.     0.     0.     0.     0.
 27      0.     0.     0.     0.     0.     0.     0.  2500.  1000.  1000.  1500. 10000.
     16000. 16000.  1000.   100.   100.     0.     0.     0.     0.     0.     0.     0.
 28      0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.  7000.
     15000. 15000.   250.   100.     0.     0.     0.     0.     0.     0.     0.     0.
```

HYDRAULIC CONDUCTIVITY IN THE X-DIRECTION (FT/DAY)

```
LAYER 1
  1        0       0       0       0       0       0       0       0       0       0       0       0
          60.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  2        0       0       0       0       0       0       0       0       0       0       0       0
          60.     65.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  3        0       0       0       0       0       0       0       0       0       0       0       0
           0.     80.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  4        0       0       0       0       0       0       0       0       0       0       0       0
           0.     80.     80.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  5        0       0       0       0       0       0       0       0       0       0       0       0
           0.     90.    135.    120.      0.      0.      0.      0.      0.      0.      0.      0.
  6        0       0       0       0       0       0       0       0       0       0       0       0
          80.     95.    135.    135.      0.      0.      0.      0.      0.      0.      0.      0.
  7        0       0       0       0       0       0       0       0       0       0       0      70
         125.     85.     65.     50.      0.      0.      0.      0.      0.      0.      0.      0.
  8        0       0       0       0       0       0       0       0       0       0       0      85
         135.    140.     70.     55.      0.      0.      0.      0.      0.      0.      0.      0.
  9        0       0       0       0       0       0       0       0       0       0       0      75
         145.    185.    100.     55.      0.      0.      0.      0.      0.      0.      0.      0.
 10        0       0       0       0       0       0       0       0       0       0       0      75
         200.    200.    125.     60.      0.      0.      0.      0.      0.      0.      0.      0.
 11        0       0       0       0       0       0       0       0       0       0       0      60
         100.    120.    100.     60.      0.      0.      0.      0.      0.      0.      0.      0.
 12        0       0       0       0       0       0       0       0       0       0       0       0
          65.    130.     75.     50.      0.      0.      0.      0.      0.      0.      0.      0.
 13        0       0       0       0       0       0       0       0       0       0       0       0
          70.     80.     75.     65.     50.      0.      0.      0.      0.      0.      0.      0.
 14        0       0       0       0       0       0       0       0       0       0       0       0
           0.     65.     85.     75.     65.      0.      0.      0.      0.      0.      0.      0.
 15        0       0       0       0       0       0       0       0       0       0       0       0
           0.     75.     85.     80.     65.     55.      0.      0.      0.      0.      0.      0.
 16        0       0       0       0       0       0       0       0       0       0       0       0
           0.     65.    120.    120.    120.     60.      0.      0.      0.      0.      0.      0.
 17        0       0       0       0       0       0       0       0       0       0       0       0
           0.     75.    140.    140.     95.     55.      0.      0.      0.      0.      0.      0.
 18        0       0       0       0       0       0       0       0       0       0       0       0
           0.     65.    105.    100.     65.     40.      0.      0.      0.      0.      0.      0.
 19        0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.



           0.     95.    200.    100.     55.      0.      0.      0.      0.      0.      0.      0.
 20        0       0       0       0       0       0       0       0       0       0       0       0
           0.    105.    165.    125.     55.      0.      0.      0.      0.      0.      0.      0.
 21        0       0       0       0       0       0       0       0       0       0       0       0
          85.    135.    120.     60.     55.      0.      0.      0.      0.      0.      0.      0.
 22        0       0       0       0       0       0       0       0       0       0       0       0
          65.     95.     60.     55.      0.      0.      0.      0.      0.      0.      0.      0.
 23        0       0       0       0       0       0       0       0       0       0       0      55
          75.     75.     65.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 24        0       0       0       0       0       0       0       0       0       0       0      60
          75.     70.     65.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 25        0       0       0       0       0       0       0       0       0       0       0      65
          80.     70.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 26        0       0       0       0       0       0       0       0       0       0       0      60
          80.     85.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 27        0       0       0       0       0       0       0       0       0       0       0       0
          80.     80.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 28        0       0       0       0       0       0       0       0       0       0       0       0
          65.     65.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
```

TRANSMISSIVITY IN THE X-DIRECTION (FT2/DAY)

```
LAYER 2
  1      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
       400.    550.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  2      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
       400.   3000.   2500.    300.      0.      0.      0.      0.      0.      0.      0.      0.
  3      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
       300.   4500.   6000.   4500.    500.      0.      0.      0.      0.      0.      0.      0.
  4      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
       300.   4000.   6000.   5000.   3000.   1000.      0.      0.      0.      0.      0.      0.
  5      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
       300.  10000.  11000.  10000.   5000.    600.      0.      0.      0.      0.      0.      0.
  6      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.    300.
     13000.  13000.  11000.   8000.   2000.    600.    100.     50.     10.    150.    400.      0.
  7      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.    300.   8000.
      9000.  17000.  10000.   6000.   4000.   4000.     50.     10.     15.    175.    500.      0.
  8      0.      0.      0.      0.      0.      0.      0.      0.      0.    200.   3000.   4000.
     10000.  10000.  12000.  10000.   7000.   5000.    250.     60.    400.    600.    200.      0.
  9      0.      0.      0.      0.      0.      0.      0.      0.   4000.   5000.   5000.   5000.
      5000.   8000.  10000.  11000.  10000.   6000.  12000.   1300.   3000.    650.    500.    150.
 10      0.      0.      0.      0.      0.      0.      0.   7400.   7000.  10000.  10000.  10600.
     11000.  10000.  15000.  12000.  12000.  18000.  15000.    750.   1000.   3750.   1250.    200.
 11      0.      0.      0.      0.      0.   4450.   6000.   6000.  10000.  12500.  11000.  11000.
     12000.  17000.  16000.  15000.  15000.  15000.   8000.   4000.    150.   1500.    200.    100.
 12      0.      0.      0.      0.   4500.   4500.   7500.  10000.  17000.  17000.  25000.  20000.
     21000.  21000.  25000.  24000.  24000.  15000.   6000.    500.   2000.   2000.   1000.    300.
 13      0.      0.      0.   4500.   4000.   7000.  11500.  11500.  17000.  20000.  22500.  27000.
     27000.  30000.  30000.  24000.  24000.  17000.  11000.    600.    600.    800.    600.    200.
 14      0.      0.   4500.   4500.   6000.   7000.  11500.  13000.  16000.  20000.  22000.  26000.
     27000.  27000.  26000.  25000.  20000.  20000.  15000.   7500.    900.    800.    500.      0.
 15      0.   4500.   4500.   5500.   8500.  12000.  12000.  15000.  19000.  21000.  24000.  25000.
     22000.  26000.  28000.  22000.  22000.  18000.   9000.   7500.   2000.   1500.    500.      0.
 16      0.   4500.   5000.   8000.  11000.  12100.  15000.  15000.  15000.  21000.  23000.  27000.
     24200.  25000.  25000.  18000.  18000.  17000.   9000.   7000.   6000.   5500.   2000.      0.
 17   4500.   4500.   6000.   9000.  12000.  12000.  15000.  17500.  17500.  20000.  25000.  25000.
     18000.  16000.  15000.  15000.  16000.  13000.   9000.   4000.   9000.   8000.   5000.      0.
 18   3800.   4000.   5500.   8500.  12000.  14500.  15000.  17500.  21000.  23000.  24000.  26500.
     26000.  19000.  17000.  18000.  17000.  18000.  11000.   6000.   7000.   6000.   4000.      0.
 19   1500.   4000.   6000.  10000.  12000.  14000.  17500.  20000.  21000.  22000.  26000.  26000.



     20000.  21000.  20500.  21000.  15000.  12000.  15000.   3000.    200.      0.      0.      0.
 20   3000.   4400.   7500.  10000.  12000.  15000.  17000.  20000.  22500.  22500.  26500.  13000.
      9000.  10000.  16000.  16000.  14000.  13000.   7000.    800.    200.      0.      0.      0.
 21   1000.   5000.   7000.   9000.  12000.  16000.  18000.  18500.  22000.  25000.  27000.  28000.
     20000.  16000.  16000.  17500.  17500.  18000.   2000.    100.      0.      0.      0.      0.
 22   1000.   5000.   9000.  12500.  16000.  17000.  18000.  18000.  20000.  24500.  26000.  26000.
     17500.  17000.  22000.  20000.  18000.  15000.   2000.    100.      0.      0.      0.      0.
 23   2000.   7000.   9000.  11000.  15000.  14000.  13000.  16000.  20000.  25000.  26000.  21000.
     21000.  21000.  22000.  21000.  19000.   5000.    100.      0.      0.      0.      0.      0.
 24   4000.   6000.  10500.  12000.  15000.  11500.   9500.   8000.  10000.  15000.  15000.  23000.
     21000.  21000.  19000.  18000.   5000.    100.      0.      0.      0.      0.      0.      0.
 25   5500.   9000.  13000.  15000.  17500.  11000.   8500.   8000.   9000.  12000.  15000.  20000.
     21000.  18000.  16000.  14000.   3000.    100.      0.      0.      0.      0.      0.      0.
 26      0.      0.      0.  11000.  11000.   8000.   6000.   4000.   2000.   5000.   6000.  15000.
     18000.  14000.  14000.   2000.    100.      0.      0.      0.      0.      0.      0.      0.
 27      0.      0.      0.      0.      0.      0.      0.   2500.   1000.   1000.   1500.  10000.
     16000.  16000.   1000.    100.    100.      0.      0.      0.      0.      0.      0.      0.
 28      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.   7000.
     15000.  15000.    250.    100.      0.      0.      0.      0.      0.      0.      0.      0.
```

```
                          STORAGE COEFFICIENT (DIMENSIONLESS)
                          -----------------------------------
                 (NEGATIVE NUMBERS DENOTE PRESCRIBED HEAD BOUNDARIES)
LAYER 1

   1       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

   2       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

   3       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

   4       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

   5       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

   6       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

   7       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

   8       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

   9       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  10       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  11       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  12       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  13       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  14       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  15       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  16       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  17       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  18       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000



  19       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  20       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  21       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  22       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  23       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  24       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  25       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  26       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  27       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  28       0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
            0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
```

```
LAYER 2

  1     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  2     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
        -1.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  3     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
        -1.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  4     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
        -1.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  5     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
        -1.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  6     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  7     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

  8     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000

  9     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000

 10     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000

 11     0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000

 12     0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000

 13     0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000

 14     0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000

 15     0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000

 16     0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

 17    -1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

 18    -1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

 19    -1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000

 20    -1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000

 21    -1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000

 22    -1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000

 23    -1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000

 24    -1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

 25    -1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

 26     0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

 27     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000

 28     0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
         0.00000 0.00000 0.00000-1.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000
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                     HYDRAULIC CONDUCTIVITY OF CONFINING BED ABOVE LAYER (FT/DAY)
                     ------------------------------------------------------------
LAYER 2

    1        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

    2        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

    3        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

    4        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

    5        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

    6        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

    7        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

    8        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

    9        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   10        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   11        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   12        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   13        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   14        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   15        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   16        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   17        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   18        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   19        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01



              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   20        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   21        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   22        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   23        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   24        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   25        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   26        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   27        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01

   28        .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
              .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01 .10E-01
```

```
                      THICKNESS OF CONFINING BED ABOVE LAYER (FT)
                      -------------------------------------------
LAYER 2
  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
         30.0    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    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
         30.0   30.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  3       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   30.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  4       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   30.0   30.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  5       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   20.0   20.0   30.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  6       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
         20.0   20.0   20.0   25.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  7       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   15.0
         15.0   15.0   20.0   25.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  8       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   15.0
         15.0   15.0   20.0   20.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  9       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   15.0
         15.0   15.0   20.0   20.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 10       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   20.0
         20.0   20.0   25.0   25.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 11       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   25.0
         25.0   25.0   25.0   25.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 12       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
         20.0   25.0   20.0   20.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 13       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
         30.0   20.0   20.0   20.0   20.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 14       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   20.0   20.0   20.0   20.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 15       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   20.0   20.0   20.0   20.0   20.0    0.0    0.0    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   20.0   20.0   20.0   20.0   20.0    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   20.0   20.0   20.0   20.0   20.0    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   20.0   20.0   20.0   20.0   20.0    0.0    0.0    0.0    0.0    0.0    0.0
 19       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   20.0   20.0   20.0   20.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 20       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   25.0   25.0   25.0   25.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 21       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
         25.0   25.0   25.0   25.0   30.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 22       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
         25.0   25.0   25.0   30.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 23       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   20.0
         25.0   25.0   40.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 24       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   20.0
         20.0   20.0   30.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 25       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   20.0
         20.0   20.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 26       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   20.0
         25.0   20.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 27       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
         20.0   25.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 28       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
         20.0   20.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
```

```
                                 ELEVATION OF BASE OF PHREATIC ACUIFER (FT)
                                 ------------------------------------------
 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
      3873.0       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       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      3862.0    3860.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 3       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    3845.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 4       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    3838.0    3838.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 5       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    3835.0    3837.0    3837.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 6       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      3830.0    3825.0    3822.0    3822.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 7       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3809.0
      3810.0    3812.0    3812.0    3820.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 8       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3805.0
      3800.0    3797.0    3812.0    3816.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 9       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3800.0
      3790.0    3793.0    3795.0    3800.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
10       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3788.0
      3790.0    3791.0    3792.0    3798.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
11       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3782.0
      3785.0    3786.0    3786.0    3787.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
12       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      3780.0    3783.0    3778.0    3775.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
13       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      3772.0    3770.0    3768.0    3770.0    3780.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
14       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    3758.0    3755.0    3758.0    3760.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
15       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    3750.0    3749.0    3750.0    3750.0    3753.0       0.0       0.0       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    3736.0    3735.0    3738.0    3738.0    3741.0       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    3730.0    3728.0    3727.0    3732.0    3734.0       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    3726.0    3725.0    3724.0    3722.0    3721.0       0.0       0.0       0.0       0.0       0.0       0.0
19       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    3711.0    3708.0    3708.0    3711.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0


20       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    3706.0    3705.0    3705.0    3706.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
21       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      3700.0    3699.0    3699.0    3699.0    3702.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
22       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      3704.0    3693.0    3692.0    3692.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
23       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3687.0
      3686.0    3684.0    3682.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
24       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3681.0
      3675.0    3675.0    3677.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
25       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3675.0
      3670.0    3670.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
26       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3665.0
      3659.0    3665.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
27       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      3659.0    3660.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
28       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
      3650.0    3650.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

```
                                   LAND SURFACE ELEVATION (FT)
                                   ---------------------------

  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
        3962.0       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       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
        3952.0    3950.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

  3        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    3935.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

  4        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    3928.0    3928.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

  5        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    3922.0    3923.0    3925.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

  6        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
        3920.0    3915.0    3912.0    3912.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

  7        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0    3899.0
        3900.0    3902.0    3902.0    3910.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

  8        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0    3893.0
        3890.0    3887.0    3902.0    3906.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

  9        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0    3690.0
        3879.0    3883.0    3885.0    3890.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 10        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0    3878.0
        3880.0    3881.0    3882.0    3888.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 11        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0    3872.0
        3875.0    3875.0    3876.0    3877.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 12        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
        3870.0    3871.0    3868.0    3865.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 13        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
        3861.0    3859.0    3858.0    3860.0    3870.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 14        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    3847.0    3845.0    3848.0    3850.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 15        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    3830.0    3839.0    3840.0    3840.0    3843.0       0.0       0.0       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    3826.0    3825.0    3828.0    3828.0    3837.0       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    3820.0    3818.0    3817.0    3822.0    3824.0       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    3816.0    3815.0    3814.0    3812.0    3811.0       0.0       0.0       0.0       0.0       0.0       0.0

 19        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    3801.0    3798.0    3798.0    3801.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0



 20        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    3796.0    3795.0    3795.0    3796.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 21        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
        3790.0    3789.0    3789.0    3789.0    3792.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 22        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
        3784.0    3783.0    3782.0    3782.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 23        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0    3777.0
        3776.0    3774.0    3772.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 24        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0    3771.0
        3765.0    3765.0    3764.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 25        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0    3765.0
        3760.0    3760.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 26        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0    3754.0
        3749.0    3753.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 27        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
        3745.0    3750.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

 28        0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
        3737.0    3737.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
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                              STREAM SURFACE ELEVATION (FT)
                              -----------------------------

  1         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
         3948.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  2         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
         3940.00   3944.30      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  3         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
            0.00   3932.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  4         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
            0.00   3920.00   3927.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  5         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
            0.00   3917.00   3925.00   3920.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  6         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
         3916.00   3910.00   3911.00   3913.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  7         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00 3898.00
         3895.00   3900.00   3900.00   3906.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  8         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00 3889.00
         3888.00   3898.00   3898.00   3902.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  9         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00 3887.00
         3878.00   3880.00   3881.00   3888.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 10         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00 3874.00
         3877.00   3879.00   3880.00   3886.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 11         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00 3872.00
         3875.00   3877.00   3877.00   3882.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 12         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
         3864.00   3862.00   3865.00   3862.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 13         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
         3854.00   3857.00   3855.00   3857.00   3859.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 14         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
            0.00   3848.00   3847.00   3844.00   3847.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 15         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
            0.00   3835.00   3834.00   3834.00   3840.00   3843.00      0.00      0.00      0.00      0.00      0.00      0.00

 16         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
            0.00   3826.00   3825.00   3825.00   3828.00   3829.00      0.00      0.00      0.00      0.00      0.00      0.00

 17         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
            0.00   3817.00   3815.00   3814.00   3820.00   3821.00      0.00      0.00      0.00      0.00      0.00      0.00

 18         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
            0.00   3803.00   3807.00   3806.00   3806.00   3809.00      0.00      0.00      0.00      0.00      0.00      0.00

 19         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
            0.00   3799.00   3797.00   3796.00   3798.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00



 20         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
            0.00   3793.00   3791.00   3791.00   3791.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 21         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
         3784.00   3783.00   3782.00   3784.00   3786.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 22         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
         3778.00   3778.00   3776.00   3774.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 23         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00 3771.00
         3770.00   3769.00   3765.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 24         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00 3765.00
         3760.00   3758.00   3759.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 25         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00 3759.00
         3754.00   3754.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 26         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00 3749.00
         3747.00   3750.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 27         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
         3742.00   3744.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

 28         0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
         3735.00   3733.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
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                          STREAM BED ELEVATION (FT)
                          -------------------------

  1       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3946.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  2       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3938.00   3940.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  3       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3930.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  4       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3918.00   3923.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  5       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3914.00   3921.00   3922.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  6       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3912.00   3906.00   3907.00   3909.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  7       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3894.00
       3891.00   3890.00   3896.00   3900.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  8       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3885.00
       3884.00   3894.00   3894.00   3898.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  9       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3883.00
       3875.00   3876.00   3877.00   3884.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 10       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3873.00
       3874.00   3875.00   3876.00   3882.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 11       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3868.00
       3871.00   3873.00   3873.00   3878.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 12       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3860.00   3856.00   3861.00   3858.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 13       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3851.00   3853.00   3851.00   3853.00   3855.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 14       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3844.00   3843.00   3840.00   3843.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 15       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3831.00   3830.00   3830.00   3830.00   3840.00      0.00      0.00      0.00      0.00      0.00      0.00
 16       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3822.00   3821.00   3821.00   3824.00   3825.00      0.00      0.00      0.00      0.00      0.00      0.00
 17       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3813.00   3811.00   3810.00   3810.00   3817.00      0.00      0.00      0.00      0.00      0.00      0.00
 18       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3805.00   3803.00   3802.00   3802.00   3806.00      0.00      0.00      0.00      0.00      0.00      0.00
 19       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3795.00   3793.00   3792.00   3794.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00



 20       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3789.00   3787.00   3787.00   3787.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 21       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3780.00   3779.00   3778.00   3780.00   3782.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 22       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3774.00   3774.00   3772.00   3770.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 23       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3767.00
       3766.00   3765.00   3761.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 24       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3761.00
       3756.00   3755.00   3754.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 25       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3755.00
       3750.00   3750.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 26       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3745.00
       3743.00   3745.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 27       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3738.00   3740.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
 28       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3731.00   3729.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
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                       STREAM SEEPAGE FACTOR (FT2/DAY)
                       -------------------------------
   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
            20000.0     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     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
            20000.0 40000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   3           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 30000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4           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 20000.0 50000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   5           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 40000.0 20000.0 30000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   6           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
            40000.0 50000.0 30000.0 30000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   7           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0 60000.0
            70000.0 30000.0 30000.0 20000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   8           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0 20000.0
            25000.0 30000.0 30000.0 10000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   9           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0 20000.0
            20000.0 20000.0 30000.0 15000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  10           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0 50000.0
            40000.0 40000.0 20000.0 20000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  11           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0 20000.0
            20000.0 20000.0 20000.0 15000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  12           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
            30000.0 30000.0 40000.0 40000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  13           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
            30000.0 30000.0 35000.0 40000.0 40000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  14           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 60000.0 60000.0 20000.0 20000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  15           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 20000.0 20000.0 20000.0 20000.0 20000.0     0.0     0.0     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 60000.0 60000.0 50000.0 40000.0 20000.0     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 20000.0 20000.0 20000.0 20000.0 20000.0     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 20000.0 20000.0 30000.0 30000.0 30000.0     0.0     0.0     0.0     0.0     0.0     0.0
  19           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 20000.0 40000.0 60000.0 20000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0



  20           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
                0.0100000.0 90000.0 80000.0 60000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  21           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
            40000.0 40000.0 50000.0 40000.0 40000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  22           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
            30000.0 50000.0 60000.0 50000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  23           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0 30000.0
            40000.0 40000.0100000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  24           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0 30000.0
            40000.0 40000.0 60000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  25           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0 40000.0
            40000.0 40000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  26           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0 50000.0
            50000.0 40000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  27           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
            40000.0 30000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  28           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
            80000.0 20000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
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                         DRAIN SURFACE ELEVATION (FT)
                         ----------------------------

   1      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3950.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

   2      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3942.00   3941.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

   3      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3931.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

   4      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3923.00   3921.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

   5      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3916.00   3917.00   3918.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

   6      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3911.00   3905.00   3905.00   3903.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

   7      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3891.00
       3891.00   3892.00   3892.00   3893.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

   8      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3880.00
       3879.00   3881.00   3891.00   3895.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

   9      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3877.00
       3872.00   3872.00   3874.00   3881.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  10      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3867.00
       3868.00   3869.00   3871.00   3879.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  11      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3862.00
       3864.00   3867.00   3867.00   3873.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  12      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3856.00   3856.00   3855.00   3854.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  13      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3847.00   3846.00   3846.00   3847.00   3848.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  14      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3837.00   3836.00   3835.00   3836.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  15      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3826.00   3826.00   3826.00   3826.00   3826.00      0.00      0.00      0.00      0.00      0.00      0.00

  16      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3816.00   3816.00   3817.00   3817.00   3817.00      0.00      0.00      0.00      0.00      0.00      0.00

  17      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3808.50   3808.00   3807.00   3808.00   3809.00      0.00      0.00      0.00      0.00      0.00      0.00

  18      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3803.00   3802.00   3801.00   3801.00   3800.00      0.00      0.00      0.00      0.00      0.00      0.00

  19      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3790.00   3789.00   3789.00   3789.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00



  20      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
          0.00   3788.00   3787.00   3786.00   3786.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  21      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3779.00   3778.00   3778.00   3778.00   3781.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  22      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3773.00   3772.00   3769.00   3768.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  23      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3765.00
       3764.00   3763.00   3761.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  24      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3758.00
       3755.00   3755.00   3755.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  25      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3753.00
       3750.00   3749.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  26      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00   3745.00
       3743.00   3745.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  27      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3738.00   3738.50      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

  28      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
       3728.50   3728.50      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
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                    DRAIN LOSS COEFFICIENT (FT2/DAY)
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  1     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

  2     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

  3     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

  4     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

  5     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

  6     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

  7     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .31E+06
         .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

  8     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .31E+06
         .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

  9     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .31E+06
         .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 10     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .31E+06
         .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 11     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .31E+06
         .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 12     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 13     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .31E+06 .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 14     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 15     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .31E+06 .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 16     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .31E+06 .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 17     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .31E+06 .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 18     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .31E+06 .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 19     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00



 20     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .00E+00 .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 21     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .31E+06 .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 22     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .31E+06 .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 23     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .31E+06
         .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 24     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .31E+06
         .31E+06 .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 25     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .31E+06
         .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 26     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .31E+06
         .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 27     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00

 28     .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
         .31E+06 .31E+06 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00 .00E+00
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                        EVAPOTRANSPIRATION AREA (ACRES)
                        -------------------------------
               (MAX. ET RATE =  .0195 FT/DAY, MAX. ET DEPTH = 15.0 FT)

 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
       450.0     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     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
       300.0   750.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 3       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   850.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 4       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   550.0  1000.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 5       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  1000.0  1050.0   800.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 6       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
       500.0  1000.0   950.0   950.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 7       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0   425.0
      1025.0  1000.0   650.0   900.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 8       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0   800.0
       775.0   675.0    75.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 9       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0   600.0
       600.0   450.0   400.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

10       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0   600.0
       600.0   500.0   400.0    25.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

11       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0   700.0
       850.0   800.0   650.0   150.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

12       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
       950.0  1000.0  1000.0   775.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

13       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
       650.0  1000.0  1000.0  1000.0   250.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

14       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  1050.0  1000.0  1000.0   500.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

15       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  1000.0  1000.0  1000.0   500.0    75.0     0.0     0.0     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   700.0   950.0  1000.0   900.0   550.0     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  1050.0  1000.0  1050.0   850.0   550.0     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  1000.0  1050.0  1050.0   850.0   450.0     0.0     0.0     0.0     0.0     0.0     0.0

19       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  1050.0  1050.0  1050.0   900.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0



20       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  1000.0  1000.0  1050.0   850.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

21       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
      1000.0  1050.0  1050.0  1050.0   550.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

22       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
      1050.0  1050.0   800.0   750.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

23       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0   150.0
      1050.0   800.0   850.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

24       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0   950.0
       800.0   750.0   400.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

25       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0   600.0
       900.0   450.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

26       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0   500.0
       600.0   450.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

27       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
      1050.0   250.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

28       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
       250.0   250.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
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```
                         STARTING HEADS (FT)
                         -------------------
LAYER 1
  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
      3950.0      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      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
      3945.0   3942.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  3      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   3931.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  4      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   3921.0   3922.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  5      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   3917.0   3913.0   3917.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  6      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
      3909.0   3906.0   3905.0   3904.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  7      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3693.0
      3894.0   3892.0   3892.0   3892.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  8      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3879.0
      3879.0   3880.0   3879.0   3871.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  9      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3876.0
      3874.0   3872.0   3872.0   3865.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 10      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3869.0
      3868.0   3868.0   3867.0   3862.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 11      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3863.0
      3864.0   3864.0   3864.0   3856.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 12      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
      3854.0   3855.0   3856.0   3855.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 13      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
      3847.0   3846.0   3847.0   3848.0   3850.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 14      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   3835.0   3834.0   3834.0   3834.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 15      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   3825.0   3823.0   3824.0   3825.0   3826.0      0.0      0.0      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   3816.0   3814.0   3813.0   3815.0   3816.0      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   3808.0   3807.0   3807.0   3807.0   3807.0      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   3800.0   3800.0   3800.0   3800.0   3800.0      0.0      0.0      0.0      0.0      0.0      0.0
 19      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   3790.0   3790.0   3790.0   3789.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 20      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   3788.0   3787.0   3786.0   3786.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 21      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
      3781.0   3780.0   3779.0   3777.0   3775.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 22      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
      3772.0   3771.0   3770.0   3768.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 23      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3765.0
      3764.0   3764.0   3764.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 24      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3757.0
      3754.0   3753.0   3757.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 25      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3754.0
      3750.0   3749.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 26      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3747.0
      3744.0   3747.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 27      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
      3739.0   3738.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 28      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
      3729.0   3729.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
```

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LAYER 2
  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
        3950.0   3947.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  2        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
        3955.0   3942.0   3947.0   3980.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  3        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
        3955.0   3931.0   3936.0   3940.0   3980.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  4        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
        3960.0   3922.0   3922.0   3928.0   3935.0   3950.0      0.0      0.0      0.0      0.0      0.0      0.0
  5        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
        3955.0   3915.0   3912.0   3915.0   3920.0   3930.0      0.0      0.0      0.0      0.0      0.0      0.0
  6        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3950.0
        3906.0   3904.0   3902.0   3898.0   3895.0   3890.0   3886.0   3900.0   3940.0   3970.0   4050.0      0.0
  7        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3900.0   3892.0
        3892.0   3888.0   3880.0   3885.0   3860.0   3840.0   3848.0   3915.0   4005.0   4060.0   4090.0      0.0
  8        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3881.0   3876.0   3876.0
        3876.0   3877.0   3875.0   3858.0   3840.0   3822.0   3852.0   3930.0   4020.0   4080.0   4200.0      0.0
  9        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3840.0   3870.0   3870.0   3870.0
        3870.0   3870.0   3868.0   3853.0   3840.0   3830.0   3860.0   3920.0   4005.0   4070.0   4230.0   4750.0
 10        0.0      0.0      0.0      0.0      0.0      0.0      0.0   3875.0   3869.0   3865.0   3865.0   3865.0



        3865.0   3864.0   3862.0   3856.0   3852.0   3850.0   3855.0   3915.0   4020.0   4085.0   4250.0   5100.0
 11        0.0      0.0      0.0      0.0      0.0   3871.0   3865.0   3863.0   3859.0   3858.0   3858.0   3855.0
        3855.0   3854.0   3853.0   3851.0   3857.0   3850.0   3860.0   3875.0   4000.0   4100.0   4320.0   5100.0
 12        0.0      0.0      0.0      0.0   3861.0   3858.0   3856.0   3853.0   3852.0   3852.0   3851.0   3851.0
        3850.0   3851.0   3853.0   3852.0   3858.0   3860.0   3860.0   3940.0   4050.0   4140.0   4330.0   4950.0
 13        0.0      0.0      0.0   3853.0   3852.0   3851.0   3850.0   3850.0   3849.0   3847.0   3846.0   3845.0
        3846.0   3844.0   3845.0   3846.0   3846.0   3852.0   3855.0   3890.0   4000.0   4110.0   4350.0   4900.0
 14        0.0      0.0   3843.0   3843.0   3842.0   3842.0   3841.0   3840.0   3839.0   3838.0   3836.0   3836.0
        3835.0   3833.0   3832.0   3829.0   3832.0   3838.0   3840.0   3850.0   3900.0   4050.0   4400.0      0.0
 15        0.0   3836.0   3834.0   3833.0   3832.0   3831.0   3830.0   3830.0   3829.0   3828.0   3827.0   3826.0
        3826.0   3824.0   3823.0   3823.0   3822.0   3823.0   3830.0   3840.0   3855.0   3880.0   4000.0      0.0
 16        0.0   3829.0   3828.0   3827.0   3825.0   3823.0   3822.0   3821.0   3820.0   3819.0   3819.0   3819.0
        3819.0   3817.0   3816.0   3815.0   3815.0   3817.0   3819.0   3820.0   3822.0   3828.0   3835.0      0.0
 17     3828.0   3824.0   3821.0   3819.0   3816.0   3815.0   3815.0   3814.0   3812.0   3812.0   3811.0   3811.0
        3811.0   3809.0   3808.0   3808.0   3808.0   3808.0   3808.0   3809.0   3810.0   3812.0   3817.0      0.0
 18     3819.0   3815.0   3815.0   3812.0   3810.0   3809.0   3807.0   3806.0   3805.0   3805.0   3804.0   3804.0
        3804.0   3802.0   3802.0   3802.0   3802.0   3801.0   3802.0   3803.0   3806.0   3809.0   3811.0      0.0
 19     3817.0   3810.0   3808.0   3805.0   3802.0   3800.0   3800.0   3799.0   3799.0   3796.0   3797.0   3795.0
        3796.0   3793.0   3789.0   3789.0   3789.0   3790.0   3791.0   3792.0   3830.0      0.0      0.0      0.0
 20     3815.0   3809.0   3805.0   3800.0   3797.0   3796.0   3796.0   3799.0   3792.0   3790.0   3789.0   3788.0
        3787.0   3785.0   3783.0   3784.0   3784.0   3785.0   3786.0   3788.0   3810.0      0.0      0.0      0.0
 21     3812.0   3804.0   3799.0   3797.0   3795.0   3793.0   3792.0   3790.0   3768.0   3786.0   3784.0   3782.0
        3779.0   3776.0   3775.0   3771.0   3768.0   3763.0   3765.0   3785.0      0.0      0.0      0.0      0.0
 22     3811.0   3803.0   3798.0   3795.0   3793.0   3791.0   3789.0   3788.0   3785.0   3780.0   3775.0   3769.0
        3770.0   3765.0   3758.0   3750.0   3750.0   3750.0   3750.0   3785.0      0.0      0.0      0.0      0.0
 23     3810.0   3802.0   3798.0   3793.0   3794.0   3789.0   3787.0   3785.0   3782.0   3780.0   3772.0   3764.0
        3763.0   3755.0   3745.0   3735.0   3739.0   3742.0   3780.0      0.0      0.0      0.0      0.0      0.0
 24     3815.0   3804.0   3799.0   3795.0   3792.0   3789.0   3787.0   3783.0   3781.0   3765.0   3758.0   3756.0
        3755.0   3754.0   3748.0   3745.0   3755.0   3770.0      0.0      0.0      0.0      0.0      0.0      0.0
 25     3810.0   3805.0   3799.0   3795.0   3792.0   3789.0   3784.0   3780.0   3775.0   3762.0   3758.0   3753.0
        3752.0   3750.0   3750.0   3750.0   3750.0   3762.0      0.0      0.0      0.0      0.0      0.0      0.0
 26        0.0      0.0      0.0   3793.0   3791.0   3789.0   3783.0   3779.0   3771.0   3755.0   3749.0   3745.0
        3743.0   3746.0   3745.0   3750.0   3755.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 27        0.0      0.0      0.0      0.0      0.0      0.0      0.0   3778.0   3773.0   3760.0   3745.0   3740.0
        3738.0   3735.0   3738.0   3740.0   3743.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 28        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0   3735.0
        3730.0   3729.0   3734.0   3736.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
```

```
DISCHARGE-RECHARGE, PRESCRIBED BOUNDARY FLUX AND TIME DESCRIPTORS - STEADY STATE:

      TIME INTERVAL USED FOR MASS BALANCE COMPUTATIONS  (DAYS) =        1.0000
                                                        (YEARS) =     0.002740

      NUMBER OF DISCHARGE-RECHARGE VALUES = 341

      DIFFUSE DISCHARGE-RECHARGE RATES USED IN LAYER 1 =  F


                        TOTAL DISCHARGE-RECHARGE RATES - STEADY STATE (FT3/SEC)
                        -------------------------------------------------------
                                (DISCHARGES GIVEN AS NEGATIVE VALUES)
LAYER 1

   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
          1.5610  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   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
          1.2170  2.3810  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   3     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  4.7870  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   4     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  1.9660  3.8570  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   5     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  5.9230  4.0600  3.1780  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   6     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
          1.8300  4.0550  3.7200  3.5220  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   7     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  1.3930
          4.0240  3.8570  2.4380  3.2540  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   8     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  3.2440
          3.1130  2.4730  0.2360 -0.1320  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   9     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  2.3010
          2.3310  1.6930  1.4300  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  10     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  2.4330
          2.3670  1.7640  1.5560 -0.2290  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  11     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  2.8390
          3.0510  3.0460  2.2400  0.1460  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  12     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
          3.6540  3.5930  3.7910  2.4170  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  13     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
          2.6360  3.7910  3.5270  3.7910  0.6180  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  14     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  4.1260  4.0550  3.5270  2.0280  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  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  3.1250  3.7910  3.8570  1.8960  0.3040  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  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  2.5090  3.4560  3.5930  3.1220  2.1640  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  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  3.8620  3.6590  3.7960  3.3150  2.2300  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  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  3.9230  3.9940  3.7960  3.2490  1.5070  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000




  19     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  4.2030  4.1260  4.1260  3.6500  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  20     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  3.7910  4.0550  3.9280  3.4470  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  21     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
          4.0550  3.8620  3.9940  3.9280  0.1920  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  22     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
          3.9940  3.9940  2.9470  2.6890  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  23     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.2120
          3.9280  2.9970  3.2550  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  24     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  3.4560
          2.6500  2.9830  1.5710  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  25     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  2.2680
          3.5180  1.5600  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  26     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  1.8960
          2.1690  1.7590  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  27     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
          4.0930  0.9480  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  28     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
         -0.1020  1.0140  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
```

```
LAYER 2
   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
   2      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  1.0000  0.0000
          0.0000 -0.1320  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   3      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 -0.5280 -0.1320  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   4      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 -0.2640 -0.4620  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   5      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 -0.5280 -0.7260 -0.1480  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   6      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
         -0.3300 -0.2640 -0.5280 -0.4620  0.0000  0.0000  0.0000  0.0000  0.0000 -0.3820  0.0000  0.0000
   7      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.3300
         -0.2640 -0.4620 -0.2820 -0.2640 -0.1320 -2.4640  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   8      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.1320 -0.5280
         -0.2640 -0.2640 -0.1980 -0.1320 -2.4840 -2.4840  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
   9      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.3960
         -0.1320 -0.3960 -0.2640  0.0000 -0.8280 -4.2720  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000



  10      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.5280
         -0.0660 -0.3900 -0.0660 -0.0660  0.0000 -0.8280  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  11      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
         -0.2640 -0.3300 -0.2150 -1.6760 -2.7880  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  12      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
         -0.3300 -0.7260 -0.7920 -0.7260 -0.5070  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  13      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.1320
          0.0000 -0.7920 -0.6600 -1.1880 -0.3960 -0.1320  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  14      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.1320
          0.0000 -0.1320  0.0000 -0.9240  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  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 -0.7920 -0.7920 -0.5170 -0.7920 -0.1320  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  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 -0.3300 -0.6440 -0.3300 -0.6690 -0.0660 -1.2790  0.0000  0.0000  0.0000 -0.3820  0.0000
  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 -0.3960 -0.9240 -0.5940 -0.3330 -0.2640 -0.3820  0.0000  0.0000 -1.5290  0.0000  0.0000
  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 -0.2640 -0.3960 -0.5940 -0.0660 -0.1950  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  19      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 -0.1320 -0.3960 -0.2640  0.0000 -0.6370 -1.4520  0.0000  0.0000  0.0000  0.0000  0.0000
  20      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
         -0.1320 -0.2640 -0.1320 -0.3300  0.0000 -0.3820 -0.3620  0.0000  0.0000  0.0000  0.0000  0.0000
  21      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
         -0.3960 -1.1880 -0.2640 -0.3300 -0.8930 -1.5510  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  22      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
         -0.3960 -0.5280 -4.0490 -7.4250 -2.9710  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  23      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.6600
         -0.4620 -1.3160 -4.8750 -9.2530 -0.6330 -0.1410  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  24      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.6600
         -0.5280 -0.1980 -2.0310  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  25      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.2330  0.0000 -0.0990
         -0.3300 -0.4290  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  26      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.4660 -0.9310 -0.0660
         -0.1320 -0.1320  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  27      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.1320 -0.5530
         -0.9410  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
  28      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
         -2.5260  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
```

```
STEADY STATE SIMULATION RESULTS:

      NUMBER OF ITERATIONS =  22

      MAXIMUM CHANGES IN HEAD (FT) AT EACH ITERATION:
            11.9642  8.0562  1.3620  0.6901  0.3350  0.1571  0.0720  0.0395  0.0295  0.0257
             0.0224  0.0195  0.0170  0.0150  0.0130  0.0114  0.0099  0.0087  0.0077  0.0066
             0.0058  0.0051  0.0044

      MAXIMUM CHANGE IN HEAD FOR THIS TIME STEP =   11.654 FEET
```

```
                         COMPUTED  STEADY STATE HEADS (FT)
                         -----------------------------------

LAYER 1
  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
       3950.1       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       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       3915.4    3941.2       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  3       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    3930.1       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  4       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    3920.1    3921.1       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  5       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    3915.6    3914.7    3916.1       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  6       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       3909.0    3905.6    3904.5    3903.3       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  7       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3891.4
       3891.6    3892.2    3892.2    3893.5       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  8       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3880.6
       3879.6    3879.6    3879.8    3870.7       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  9       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3877.1
       3872.1    3872.4    3874.1    3867.9       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 10       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3867.4
       3868.6    3869.5    3870.8    3866.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 11       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3862.3
       3864.3    3865.2    3864.9    3860.4       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 12       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       3856.7    3856.9    3855.8    3854.3       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 13       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       3847.7    3846.8    3846.6    3847.7    3848.4       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 14       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    3837.6    3836.6    3835.8    3836.7       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 15       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    3826.7    3826.7    3826.9    3826.6    3826.3       0.0       0.0       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    3816.8    3816.6    3817.6    3817.6    3817.8       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    3809.0    3808.3    3807.5    3808.8    3809.7       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    3803.6    3802.6    3801.7    3801.5    3800.4       0.0       0.0       0.0       0.0       0.0       0.0



 19       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    3790.7    3789.7    3789.8    3789.7       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 20       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    3788.6    3787.5    3786.6    3786.6       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 21       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       3779.6    3778.6    3778.5    3778.3    3778.3       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 22       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       3773.3    3772.3    3769.4    3768.1       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 23       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3765.2
       3764.6    3763.1    3761.6       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 24       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3758.7
       3755.5    3755.2    3755.3       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 25       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3753.6
       3750.6    3749.6       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 26       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0  3745.6
       3743.5    3745.5       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 27       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       3738.6    3738.9       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 28       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
       3728.9    3728.9       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

```
LAYER 2
  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
       3950.0  3947.3     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  2       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
       3955.0  3941.7  3945.1  3980.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  3       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
       3955.0  3931.0  3934.6  3941.1  3980.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  4       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
       3960.0  3921.4  3921.9  3920.7  3933.4  3950.0     0.0     0.0     0.0     0.0     0.0     0.0
  5       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
       3955.0  3913.9  3913.3  3914.8  3917.2  3930.0     0.0     0.0     0.0     0.0     0.0     0.0
  6       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0  3950.0
       3905.8  3904.0  3902.7  3901.5  3898.3  3893.7  3854.7  3904.4  3943.4  3967.4  4051.0     0.0
  7       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0  3900.0  3890.5
       3891.0  3890.6  3889.3  3884.4  3863.6  3843.3  3854.6  3919.5  4014.2  4063.1  4101.1     0.0
  8       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0  3881.0  3874.1  3878.8
       3879.1  3878.4  3875.2  3865.2  3843.6  3830.1  3848.0  3931.0  4021.1  4072.8  4200.0     0.0
  9       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0  3880.0  3867.1  3867.1  3872.3
       3871.6  3870.6  3868.6  3861.4  3847.0  3834.9  3850.9  3912.9  3994.7  4076.4  4241.7  4750.0



 10       0.0     0.0     0.0     0.0     0.0     0.0     0.0  3875.0  3868.3  3862.8  3862.5  3864.6
       3865.9  3865.5  3864.2  3859.1  3851.4  3848.9  3853.0  3912.1  4016.1  4083.7  4249.6  5100.0
 11       0.0     0.0     0.0     0.0     0.0  3871.0  3861.9  3862.5  3859.3  3857.5  3857.4  3859.7
       3860.4  3860.1  3858.6  3853.6  3849.0  3851.8  3857.1  3872.2  4000.1  4106.5  4313.0  5100.0
 12       0.0     0.0     0.0     0.0  3861.0  3857.1  3853.3  3851.9  3850.9  3850.3  3850.4  3851.3
       3852.6  3852.4  3851.9  3851.1  3850.9  3852.7  3857.3  3937.9  4056.9  4132.9  4332.3  4950.0
 13       0.0     0.0     0.0  3853.0  3846.7  3845.6  3844.0  3843.3  3843.0  3842.8  3843.1  3843.4
       3844.2  3844.2  3844.4  3844.7  3845.9  3847.3  3850.3  3901.9  4002.4  4110.6  4349.9  4900.0
 14       0.0     0.0  3843.0  3840.7  3837.6  3836.3  3835.7  3835.2  3835.0  3834.9  3835.0  3835.2
       3835.6  3835.9  3835.9  3835.8  3837.4  3839.5  3842.7  3849.9  3900.6  4038.2  4400.0     0.0
 15       0.0  3836.0  3833.9  3831.0  3829.0  3828.1  3827.7  3827.5  3827.3  3827.0  3826.8  3826.6
       3826.4  3825.8  3825.7  3826.1  3826.4  3827.7  3830.7  3835.7  3850.8  3888.6  4000.0     0.0
 16       0.0  3829.0  3826.3  3823.6  3822.2  3821.5  3820.7  3820.2  3819.8  3819.3  3818.8  3818.3
       3817.9  3817.2  3816.7  3816.8  3816.0  3816.9  3816.3  3820.4  3823.8  3829.0  3839.3     0.0
 17    3828.0  3823.6  3820.3  3817.8  3816.2  3815.1  3814.1  3813.1  3812.2  3811.6  3811.0  3810.4
       3809.7  3808.6  3807.5  3807.2  3807.6  3807.9  3807.7  3809.8  3811.3  3810.7  3817.1     0.0
 18    3819.0  3817.4  3814.6  3812.2  3810.5  3809.1  3807.8  3806.6  3805.5  3804.6  3803.7  3802.9
       3802.2  3801.5  3800.5  3799.8  3799.9  3799.8  3800.3  3802.6  3806.2  3809.0  3812.7     0.0
 19    3817.0  3812.5  3809.5  3807.2  3805.3  3803.7  3802.1  3800.6  3799.2  3797.9  3796.6  3795.9
       3794.7  3792.6  3790.9  3790.1  3789.3  3787.4  3786.0  3791.2  3830.0     0.0     0.0     0.0
 20    3815.0  3809.0  3805.5  3803.0  3800.8  3798.9  3797.0  3795.2  3793.2  3791.2  3789.5  3788.1
       3786.6  3785.8  3784.6  3783.2  3781.8  3779.4  3779.0  3785.5  3810.0     0.0     0.0     0.0
 21    3812.0  3805.3  3802.3  3799.4  3796.8  3794.8  3792.6  3790.2  3787.4  3784.6  3781.9  3779.3
       3777.3  3774.7  3773.0  3770.5  3767.5  3764.5  3765.8  3765.0     0.0     0.0     0.0     0.0
 22    3811.0  3803.2  3799.8  3796.8  3794.1  3791.8  3789.1  3785.8  3782.3  3778.7  3775.2  3772.2
       3769.1  3763.8  3755.5  3748.2  3740.0  3748.2  3751.0  3765.0     0.0     0.0     0.0     0.0
 23    3810.0  3802.8  3798.9  3795.3  3792.4  3789.8  3786.3  3782.2  3777.8  3773.4  3769.0  3764.2
       3760.1  3753.7  3743.6  3733.3  3735.2  3737.3  3780.0     0.0     0.0     0.0     0.0     0.0
 24    3815.0  3803.8  3798.3  3794.5  3791.5  3788.6  3784.6  3779.3  3773.4  3768.0  3762.6  3757.7
       3754.8  3752.1  3747.7  3745.0  3744.5  3770.0     0.0     0.0     0.0     0.0     0.0     0.0
 25    3810.0  3803.0  3798.0  3793.9  3790.9  3787.9  3783.3  3777.1  3769.8  3762.5  3757.1  3753.2
       3750.8  3749.3  3748.3  3747.6  3747.9  3762.0     0.0     0.0     0.0     0.0     0.0     0.0
 26       0.0     0.0     0.0  3793.0  3790.5  3787.5  3783.3  3777.3  3766.7  3754.8  3748.5  3746.9
       3746.1  3746.2  3746.7  3747.4  3755.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 27       0.0     0.0     0.0     0.0     0.0     0.0     0.0  3778.0  3768.7  3755.3  3744.2  3739.5
       3739.0  3738.9  3739.1  3740.6  3743.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 28       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0  3728.8
       3728.8  3728.9  3730.5  3736.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
```

```
                         COMPUTED STEADY STATE DRAWDOWNS (FT)
                         ------------------------------------
LAYER 1

  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
           -0.1       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       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
           -0.4       0.8       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  3      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       0.9       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  4      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       0.9       0.9       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  5      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       1.4      -1.7       0.9       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  6      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       0.4       0.5       0.7       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  7      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       1.6
            2.4      -0.2      -0.2      -1.5       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  8      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0      -1.6
           -0.6       0.4      -0.8       0.3       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  9      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0      -1.1
            1.9      -0.4      -2.1      -2.9       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 10      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       1.6
           -0.6      -1.5      -3.8      -4.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 11      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.7
           -0.3      -1.2      -0.9      -4.4       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 12      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
           -2.7      -1.9       0.2       0.7       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 13      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
           -0.7      -0.8       0.4       0.3       1.6       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 14      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      -2.6      -2.6      -1.6      -2.7       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 15      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      -1.7      -3.7      -2.9      -1.6      -0.3       0.0       0.0       0.0       0.0       0.0       0.9
 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      -0.8      -2.6      -4.6      -2.6      -1.8       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      -1.0      -1.3      -3.5      -1.8      -2.7       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      -3.6      -2.6      -1.7      -1.5      -0.4       0.0       0.0       0.0       0.0       0.0       0.0
 19      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      -0.7       0.3       0.2      -0.7       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 20      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      -0.6      -0.5      -0.6      -0.6       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 21      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
            1.4       1.4       0.5      -1.3      -3.3       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 22      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
           -1.3      -1.3       0.6      -0.1       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 23      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0      -0.2
           -0.6       0.9       2.4       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 24      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0      -1.7
           -1.5      -2.2       1.7       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 25      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.4
           -0.6      -0.6       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 26      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       1.4
            0.5       1.5       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 27      0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
            0.4      -0.9       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 28      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       0.1       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

```
LAYER 2
  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    -0.3     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  2         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     0.3     1.9     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  3         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     1.4    -1.1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  4         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     0.6     0.1     1.3     1.6     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  5         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    -1.3     0.2     2.8     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  6         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    -0.7    -3.5    -3.3    -3.7    -6.7    -4.4    -3.4     2.6    -1.0     0.0
  7         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     1.5
                 1.0    -2.6    -3.3     0.6    -3.6    -3.3    -6.8    -4.5    -9.2    -3.1   -11.1     0.0
  8         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     2.9    -2.8
                -3.1    -1.4    -0.2    -7.2    -3.6    -8.1     4.0    -1.0    -1.1     7.2     0.0     0.0
  9         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     2.9     2.9    -2.3
                -1.6    -0.6    -0.6    -8.4    -7.0    -4.9     9.1     7.1    10.3    -6.4   -11.7     0.0
 10         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.7     2.2     2.5     0.4



               -0.9    -1.5    -2.2    -3.1     0.6     1.1     2.0     2.9     3.9     1.3     0.4     0.0
 11         0.0     0.0     0.0     0.0     0.0     0.0     3.1     0.5    -0.3     0.5     0.6    -4.7
                -5.4    -6.1    -5.6    -2.6     8.0    -1.8     2.9     2.8    -0.1    -6.5     7.0     0.0
 12         0.0     0.0     0.0     0.0     0.0     0.9     2.7     1.1     1.1     1.7     0.6    -0.3
                -2.6    -1.4     1.1     0.9     7.1     7.3     2.7     2.1    -0.9     7.1    -2.3     0.0
 13         0.0     0.0     0.0     0.0     3.3     5.4     6.0     6.7     6.0     4.2     2.9     1.6
                 1.8    -0.2     0.6     1.3     0.1     4.7     4.7   -11.9    -2.4    -6.6     0.1     0.0
 14         0.0     0.0     0.0     2.3     4.4     5.7     5.3     4.8     4.0     3.1     1.0     0.8
                -0.6    -2.9    -3.9    -6.6    -5.4    -1.5    -2.7     0.1    -6.6    11.8     0.0     0.0
 15         0.0     0.0     0.1     2.0     3.0     2.9     2.3     2.5     1.7     1.0     0.2    -0.6
                -0.4    -1.8    -2.7    -3.1    -4.4    -4.7    -0.7     4.3     4.2    -8.6     0.0     0.0
 16         0.0     0.0     1.7     3.4     2.8     1.5     1.3     0.8     0.2    -0.3     0.2     0.7
                 1.1    -0.2    -0.7    -1.8    -1.6     0.1     2.7    -0.4    -1.8    -1.0    -6.3     0.0
 17         0.0     0.4     0.7     1.2    -0.2    -0.1     0.9     0.9    -0.2     0.4     0.0     0.6
                 1.3     0.4     0.5     0.8     0.4     0.1     0.3    -0.8    -1.3     1.3    -0.1     0.0
 18         0.0    -2.4     0.4    -0.2    -0.5    -0.1    -0.8    -0.6    -0.5     0.4     0.3     1.1
                 1.8     0.5     1.5     2.2     2.1     1.2     1.7     0.4     0.2     0.0    -1.7     0.0
 19         0.0    -2.5    -1.5    -2.2    -3.3    -3.7    -2.1    -1.6    -0.2     0.1     0.4    -0.9
                 1.3     0.4    -1.9    -1.1    -0.3     2.6     5.0     0.6     0.0     0.0     0.0     0.0
 20         0.0     0.0    -0.5    -3.0    -3.8    -2.9    -1.0     3.8    -1.2    -1.2    -0.5    -0.1
                 0.4    -0.6    -1.6     0.8     2.2     5.6     7.0     2.5     0.0     0.0     0.0     0.0
 21         0.0    -1.3    -3.3    -2.4    -1.8    -1.8    -0.6    -0.2     0.6     1.4     2.1     2.7
                 1.7     1.3     2.0     0.5     0.5    -1.5    -0.8     0.0     0.0     0.0     0.0     0.0
 22         0.0    -0.2    -1.8    -1.8    -1.1    -0.8    -0.1     2.2     2.7     1.3    -0.2    -3.2
                 0.9     1.2     2.5     1.6     4.0     1.6    -1.0     0.0     0.0     0.0     0.0     0.0
 23         0.0    -0.8    -0.9    -2.3    -0.4    -0.8     0.7     2.8     4.2     6.6     3.0    -0.2
                 2.9     1.3     1.4     1.7     3.8     4.7     0.0     0.0     0.0     0.0     0.0     0.0
 24         0.0     0.2     0.7     0.5     0.5     0.4     2.4     3.7     7.6    -3.0    -4.6    -1.7
                 0.2     1.9     0.3     0.0    10.5     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 25         0.0     2.0     1.0     1.1     1.1     1.1     0.7     2.9     5.2    -0.5     0.9    -0.2
                 1.2     0.7     1.7     2.4     2.1     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 26         0.0     0.0     0.0     0.0     0.5     1.5    -0.3     1.7     4.3     0.2     0.5    -1.9
                -3.1    -0.2    -1.7     2.6     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 27         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     4.3     4.7     0.8     0.5
                -1.0    -3.9    -1.1    -0.6     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 28         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.2
                 1.2     0.1     3.5     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
```

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                     STEADY STATE MASS BALANCE
                     -------------------------

                               FLOW RATES                                        FLOW VOLUMES (FT3)
                               (FT3/SEC)                                    TIME STEP            CUMULATIVE
                               ---------                                    ---------            ----------
LAYER 1
                   RECHARGE =   320.4590              SOURCES:
           CONSTANT FLUX:                             --------
                         IN =     4.0000                      RECHARGE =   27687657.25          27687657.25
                        OUT =     0.0000                 CONSTANT FLUX =     345600.00            345600.00
           CONSTANT HEAD:                                CONSTANT HEAD =          0.00                 0.00
                         IN =     0.0000                       LEAKAGE =     709436.52            709436.52
                        OUT =     0.0000               STREAM RECHARGE =   14294960.25          14294960.25
         STREAM EXCHANGE:                                TOTAL SOURCES =   43037676.00          43037676.00
                         IN =   165.4512
                        OUT =    -1.7766              DISCHARGES:
                    PUMPING =   -27.6080              -----------
            DRAIN DISCHARGE =  -159.4252                       PUMPAGE =    2385331.16           2385331.16
         EVAPOTRANSPIRATION =  -238.4413                 CONSTANT FLUX =          0.00                 0.00
                LEAKAGE IN:                              CONSTANT HEAD =          0.00                 0.00
FROM PREVIOUS PUMPING PERIOD =                                 LEAKAGE =    6142938.56           6142938.56
                      TOTAL =     8.2111               DRAIN DISCHARGE =   13774335.00          13774335.00
               LEAKAGE OUT:                         EVAPOTRANSPIRATION =   20601324.75          20601324.75
FROM PREVIOUS PUMPING PERIOD =                        STREAM DISCHARGE =     153446.66            153446.66
                      TOTAL =   -71.0986               TOTAL DISCHARGE =   43057376.50          43057376.50
    RATE OF CHANGE IN STORAGE =     0.0000
                                                     CHANGE IN STORAGE =          0.00                 0.00
               SUM OF RATES =    -0.2280               SUM OF VOLUMES =      19700.50             19700.50
                                                    PERCENT DIFFERENCE =         0.046                0.046

LAYER 2
                   RECHARGE =     7.2860              SOURCES:
           CONSTANT FLUX:                             --------
                         IN =     0.0000                      RECHARGE =     629510.40            629510.40
                        OUT =     0.0000                 CONSTANT FLUX =          0.00                 0.00
           CONSTANT HEAD:                                CONSTANT HEAD =    3190895.97           3190895.97
                         IN =    36.9317                       LEAKAGE =    6142938.56           6142938.56
                        OUT =    -0.3340               STREAM RECHARGE =
         STREAM EXCHANGE:                                TOTAL SOURCES =    9963345.00           9963345.00
                         IN =
                        OUT =                         DISCHARGES:
                    PUMPING =  -108.8300              -----------
            DRAIN DISCHARGE =                                  PUMPAGE =    9402911.88           9402911.88
         EVAPOTRANSPIRATION =                            CONSTANT FLUX =          0.00                 0.00
                LEAKAGE IN:                              CONSTANT HEAD =      28853.74             28853.74
FROM PREVIOUS PUMPING PERIOD =                                 LEAKAGE =     531390.43            531390.43
                      TOTAL =    71.0986               DRAIN DISCHARGE =
               LEAKAGE OUT:                         EVAPOTRANSPIRATION =
FROM PREVIOUS PUMPING PERIOD =                        STREAM DISCHARGE =
                      TOTAL =    -6.1504               TOTAL DISCHARGE =    9963156.00           9963156.00
    RATE OF CHANGE IN STORAGE =     0.0000
                                                     CHANGE IN STORAGE =          0.00                 0.00
               SUM OF RATES =     0.0022                SUM OF VOLUMES =       -189.00              -189.00
                                                    PERCENT DIFFERENCE =        -0.002               -0.002
```