Ground-Water Conditions and Effects of Mine Dewatering in Desert Valley, Humboldt and Pershing Counties, Northwestern Nevada, 1962-91

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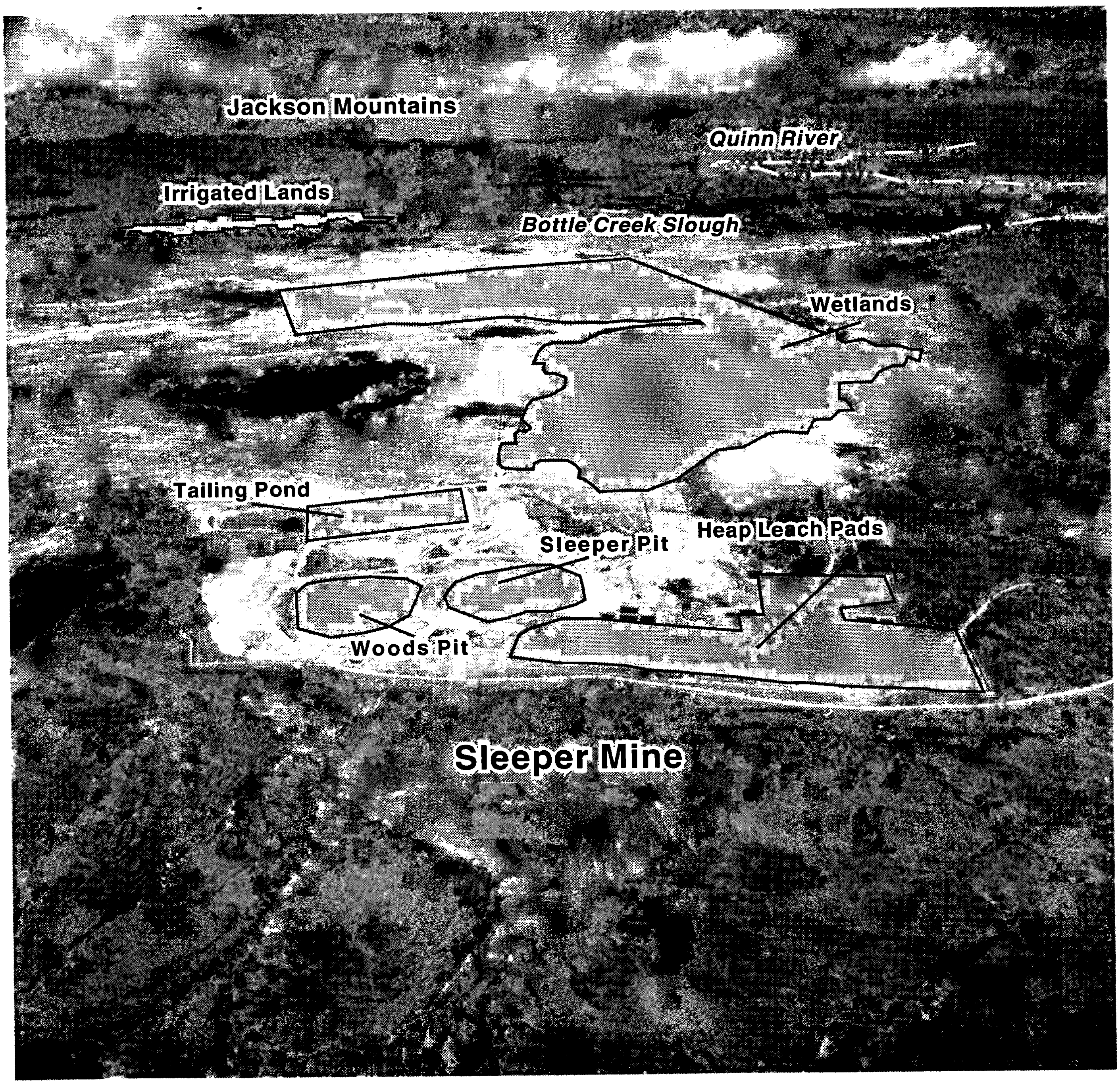

Jackson Mountains
Quinn River
Irrigated Lands
Bottle Creek Slough
Wetlands
Tailing Pond
Heap Leach Pads
Sleeper Pit
Woods Pit
Sleeper Mine

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PLATE [In pocket]

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
acre	0.4047	square hectometer
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
foot per year (ft/yr)	0.3048	meter per year
gallon per minute (gal/min)	0.06308	liter per second
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square foot per day (ft^2/d)	0.09290	square meter per day
square mile (mi^2)	2.590	square kilometer

Temperature: Degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula °F = [1.8(°C)]+32. Degrees Fahrenheit can be converted to degrees Celsius by using the formula °C = 0.556(°F-32).

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

Abbreviated water-quality units used in this report:

mg/L (milligram per liter)
μm (micrometer)
pCi/L (picocurie per liter)
μS/cm (microsiemens per centimeter at 25°C)
μg/L (microgram per liter)

Ground-Water Conditions and Effects of Mine Dewatering in Desert Valley, Humboldt and Pershing Counties, Northwestern Nevada, 1962-91

By David L. Berger

Abstract

In the Spring of 1985, dewatering began at an open-pit mine along a slope of the Slumbering Hills in the northeastern part of Desert Valley. Ground-water withdrawal for mine dewatering in 1991 was about 23,000 acre-feet, more than three times the estimated average annual recharge from precipitation in Desert Valley. The mine discharge has been allowed to flow to areas west of the mine, where it ponds on the valley floor and either is consumed by evapotranspiration or infiltrates to the basin-fill aquifer. An artificial wetlands, which has attracted various waterfowl, has subsequently formed in the discharge area. The mining operation is expected to last at least through 1998, with steadily increasing pumping rates. As a result of the apparent potential for ground-water overdraft due to mine dewatering, the U.S. Geological Survey, in cooperation with the Nevada Division of Water Resources, began a 4-year study in 1989 to evaluate probable long-term effects of ground-water withdrawal on a basin-wide scale. This report documents the change in hydrologic conditions since predevelopment (pre-1962) and describes the effects of mine dewatering.

The Desert Valley study area, which includes both the Desert Valley hydrographic area and the Sod House hydrographic subarea, encompasses about 1,200 square miles in northwestern Nevada. The basin-fill deposits make up the principal ground-water reservoir and may be as thick as 7,000 feet in the south-central part of the basin. Most ground-water recharge is generated in the northern Jackson Mountains, which bound the west side of Desert Valley. Since 1980, an average of about 5,300 acres of farmland, mostly along the west side of the valley floor, have been irrigated annually with ground water, supplemented by local runoff from the Jackson Mountains.

The components of the ground-water budget for the aquifer system beneath the study area were estimated using empirical techniques and refined using a ground-water flow model. Under predevelopment conditions (pre-1962), the total flow through the aquifer system beneath the study area was about 11,000 acre-feet per year (acre-ft/yr). The flow components are (1) total inflow that includes about 7,300 acre-ft/yr of recharge from precipitation, about 2,700 acre-ft/yr of infiltration beneath ephemeral rivers that traverse the northern part of the study area, and about 1,100 acre-ft/yr of subsurface inflow from the Quinn River and Kings River Valleys, and (2) total outflow that includes about 9,100 acre-ft/yr discharge by evapotranspiration and about 2,100 acre-ft/yr subsurface outflow.

During 1991, net ground-water withdrawals for irrigation were about 8,600 acre-feet, resulting in 10-20 feet of water-level declines near the irrigated areas since predevelopment time. The mine-dewatering operation pumped 23,000 acre-feet in 1991. As of Spring 1991, maximum water-level

declines beneath the open pits at the mine ranged from 295 to 315 feet. Changes in the ground-water flow regime between predevelopment and current conditions are predominantly near the dewatering operations and associated discharge areas. The previously undisturbed natural flow directions are interrupted by the dewatering operations, which cause capture of ground water as it enters from the Quinn River Valley and as it moves toward the exit point to Pine Valley.

A ground-water flow model was developed and then used to simulate continued mine dewatering for periods of 7 and 25 years, each followed by a 100-year recovery period during which dewatering is discontinued and irrigation pumpage is held constant. For one scenario of the model, mine-discharge water was removed from the system and not allowed to infiltrate beneath the artificial wetlands. Results from the hypothetical dewatering scenarios suggest that a new equilibrium would not be reached after 100 years of recovery following the end of simulated dewatering. Water-level declines would be significantly reduced west of the mine by infiltration beneath the wetlands and north of the mine by the capture of ground water from Quinn River Valley. Water-level declines would expand farther south as ground water is captured from storage.

INTRODUCTION

Background

This study, made in cooperation with the Nevada Division of Water Resources (NDWR), evaluates the ground-water conditions in Desert Valley with emphasis on long-term effects of open-pit mine dewatering. The study, in part, updates an earlier reconnaissance report by Sinclair (1962b), which documented the general hydrogeology of Desert Valley, including an estimate of the water budget and occurrence, movement, and chemical quality of the ground water. At the time of the reconnaissance study, ground-water development had been minimal, with an estimated pumpage of about 700 acre-ft/yr, mainly for irrigation purposes but also for stock and domestic use (Sinclair, 1962b, p. 10). Net ground-water withdrawals for irrigation steadily increased through the 1970's and 1980's to about 8,600 acre-ft/yr and have remained at that level through 1991. The average annual recharge from precipitation to the ground-water reservoir in Desert Valley was estimated as about 5,000 acre-ft by Sinclair (1962b, p. 8).

Early in 1982, a gold-silver deposit, herein designated the Sleeper Mine, was discovered at the base of the Slumbering Hills in northeastern Desert Valley (Nash and others, 1989; fig. 1). Removal of the overburden and subsequent pit dewatering began in the Spring of 1985; actual mining and milling began early in 1986 (Nash and others, 1989, p. 2). The volume of ground water pumped from the dewatering operations has increased from 2,100 acre-ft in 1985 to more than 23,000 acre-ft in 1991. The pumped water has been allowed to flow northwest of the mine, where a marsh and wildlife habitat have developed. The planned duration of the pit dewatering was at least 7 years, but may be more than twice that. Because of concerns that a ground-water overdraft may have developed, the NDWR began this 4-year study to assess the potential effects of the dewatering.

Purpose and Scope

This report documents 1991 hydrologic conditions in Desert Valley and discusses the extent of change in those conditions since 1962. It describes the basin-fill aquifer system and quantifies the components of the ground-water budget for both time periods. Changes in the ground-water flow regime and in water quality are also documented. The report includes the results of a three-dimensional, finite-difference, mathematical model used to evaluate long-term effects of ground-water withdrawals on a basin-wide scale. Simulated responses of the aquifer system to three hypothetical dewatering scenarios are also presented. (The report does not discuss possible changes in ground-water quality associated with the hypothetical scenarios.)

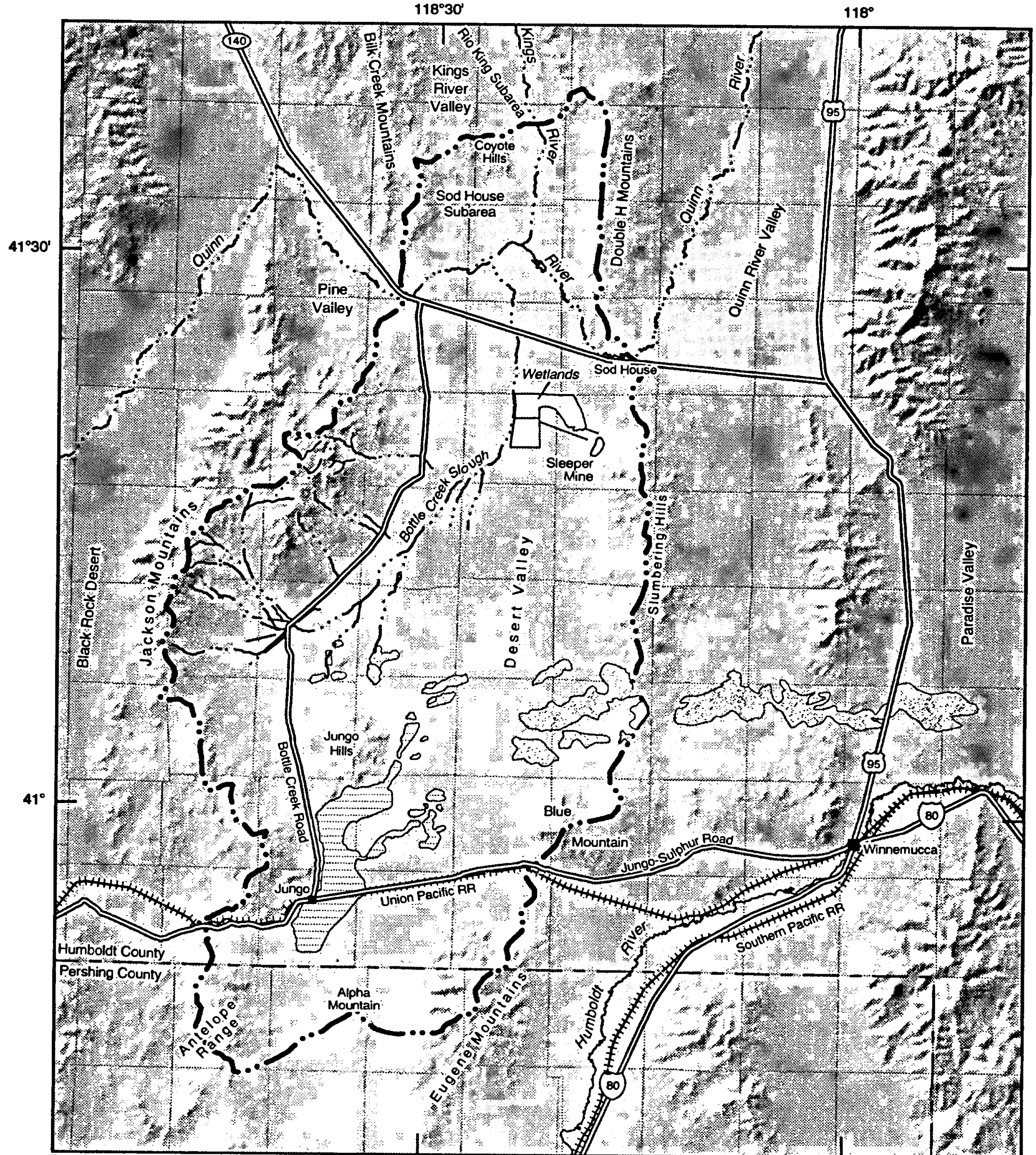
This report is based in part on an initial inventory and compilation of available data in the study area that began in the Spring of 1989, followed by a field canvass of wells and other hydrologic sites. These work elements were part of the basic-data program of the U.S. Geological Survey in Nevada. Actual project work began in October 1989 and continued through the spring of 1992. The report present the results of field work that consisted of (1) measuring water levels in about 55 wells, (2) installing 6 shallow observation wells, (3) obtaining water-chemistry samples from 16 ground-water and 3 surface-water sites, (4) measuring streamflow, (5) installing two crest-stage gages, (6) making additional gravity measurements, (7) collecting evapotranspiration data, and (8) mapping phreatophyte distribution.

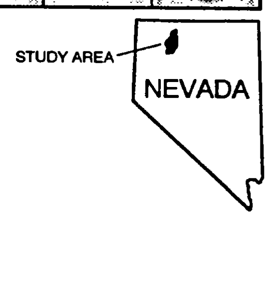
Location and General Features of the Study Area

The study area encompasses about 1,200 mi^2 in Humboldt and northern Pershing Counties in northwest Nevada (fig. 1, pl. 1*A*). The study area, herein called Desert Valley, includes both Desert Valley (hydrographic-area number 31; Rush, 1968) and the southern part of Kings River Valley that was named the Sod House subarea by Malmberg and Worts (1966, p. 4) and assigned hydrographic-subarea number 30B by Rush (1968). Desert Valley is a tributary to the Black Rock Desert and, hence, is part of the Black Rock Desert hydrographic region. In May 1975, the office of the Nevada State Engineer, declared Desert Valley a "Designated Basin," which authorizes the State Engineer to declare preferred uses of water and limit the exercise of committed ground-water rights to not exceed a basin's estimated long-term recharge (Nevada Revised Statutes, Chapters 534 and 535, 1975).

Desert Valley is a north-trending structural basin with a valley floor about 55 mi long and 12 mi wide. The valley floor is at an altitude of about 4,200 ft above sea level and has an area of about 680 mi^2. Topographic relief of the valley does not exceed 100 ft. A minor drainage divide trends northeastward from the Jungo Hills to the Slumbering Hills. The valley floor is principally composed of alkali lake sediments and eolian deposits. Large areas, particularly in the southern part of the valley, are covered by hardpan (pl. 1*A*, fig. 1). Vegetation is generally sparse; greasewood, which grows locally in scattered, dense patches, is, for the most part, of low density. Agricultural lands are generally along the bajada east of the Jackson Mountains. An average of about 5,300 acres of mostly alfalfa and meadow grass were irrigated during the period 1985 through 1991 (U.S. Department of Agriculture, written commun., 1992). An active dune field, in the southeastern part of the study area (pl. 1*A*), covers about 12,000 acres of the valley floor. (An active dune field is one in which the dune ridges slowly migrate in the direction of the prevailing wind.) This section of the dune field in Desert Valley is the trailing edge of a much larger dune field that totals about 31,000 acres, extends about 28 mi to the east, and terminates in Paradise Valley (fig. 1). The prominent surface-water feature is the ephemeral Quinn River, which traverses the northern part of the study area. During late Pleistocene time, Desert Valley was inundated by ancient Lake Lahontan, the largest pluvial lake in the Great Basin (Mifflin and Wheat, 1979, pl. 1; Morrison, 1964, fig. 1). Terraces produced by shoreline erosion and the complex assemblages of the basin fill record the fluctuations of the lake. Ancient Lake Lahontan reached a depth of nearly 200 ft in Desert Valley (Sinclair, 1962b, p. 6).

The study area is bounded on the west by the southern Bilk Creek Mountains and the Jackson Mountains (pl. 1*A*), the northern summits of which approach altitudes of 9,000 ft. The southern end of the Jackson Mountains, characterized by low relief, terminates at the pass on the Jungo-Sulphur road, where the northern Antelope Range completes the western boundary. The eastern boundary is comprised of the southern Double H Mountains, the Slumbering Hills, Blue Mountain, and the northern Eugene Mountains. Low alluvial divides occupy the areas between each mountain range that make up the eastern boundary. The Coyote Hills and a low alluvial divide between the Coyote Hills and the Double H Mountains make up the northern boundary. The northern boundary also coincides with the hydrographic boundary that divides the Kings River Valley into the Rio King and Sod House subareas (Rush, 1968). The southern boundary is made up of two alluvial divides separated by Alpha Mountain. Donna Schee Peak of the Jungo Hills, and several other bedrock outcrops along the west side, rise from the valley floor and are considered to be outliers of the Jackson Mountains (Sinclair, 1962b, p. 4).





EXPLANATION

Hardpan–Soil of hard, impervious clay that impedes the downward movement of water

Sand dunes

Hydrographic-area boundary

Figure 1. Location and general features of Desert Valley area.

State Route 140 crosses the northern part of the study area and provides access from Winnemucca to northwestern Nevada and southern Oregon. The tracks of the Union Pacific Railroad and the graded Jungo-Sulphur road cross the southern part of the study area. In addition, numerous graded and dirt roads, which are generally passable except under extremely wet conditions, crisscross the study area. Two sites of historical significance within the study area include now-deserted Sod House and Jungo. Sod House, also known as Sod House Station, in the northeastern part of the area, was probably a stagecoach stop (Malmberg and Worts, 1966). During the early 1960's, the small town of Jungo, adjacent to the railroad, had a population of less than 100 (Sinclair, 1962b, p. 3). Jungo historically functioned as the location of a railroad siding for the loading of iron ore mined in the Jackson Mountains and had a post office from 1911 to 1952 (Carlson, 1974, p. 147).

The Sleeper Mine (fig. 1, pl. 1*A*) is about 5 mi south of Sod House at the base of the Slumbering Hills in what was known as the Awakening Mining District (Calkins, 1938). The present-day mining operation consists of two separate open pits—the Sleeper Pit to the north and the Woods Pit to the south. Mining of the bedrock beneath the pits began in January 1986 at the Sleeper Pit and in October 1987 at the Woods Pit, and work is currently (1991) underway to combine the two into a single pit (Hydrotechnica, 1989, p. 1). As the pits were deepened below the local water table, arrays of wells were installed to dewater the bedrock ore body. Ground water from the dewatering operation originally formed a shallow lake, or wetlands, about 6,000 ft northwest of the Sleeper Mine (fig. 1, pl. 1*A*). A 4,500-ft unlined canal conveyed the water to the lake, where it was allowed to flow unconstrained onto the valley floor. On the basis of satellite data collected August 19, 1988, the lake covered an area of about 1,400 acres. As aquatic vegetation colonized the lake, it became an attractive wetlands habitat for wildlife. By 1991, water infiltrating beneath the wetlands was being captured and recirculated by the mine-dewatering well field. As a result of the recirculation, a new discharge area was created about 4 mi west of the Sleeper Mine (Geoffrey Beale, Water Management Consultants Inc., oral commun., 1990; fig. 1; pl. 1*A*). A 4-mi unlined canal is used to convey discharge water from the mine to the new discharge area, which also functions as an artificial wetlands. The new wetlands area covers about 4,700 acres. The initial wetlands area remains in place to collect overflow of mine-discharge water from the second wetlands.

Previous Investigations

Published reports on the general hydrogeology of Desert Valley include a reconnaissance report by Sinclair (1962b) and studies by the State of Nevada in response to a request by the Department of Energy for proposed sites for the Superconducting Super Collider (Nevada Commission on Economic Development, 1987). The Sod House subarea was included in investigations by Zones (1963) and later updated by Malmberg and Worts (1966), who documented the hydrology of the Kings River Valley. Arteaga (1978), in making a water-resources appraisal in parts of the Fort McDermitt Indian Reservation, studied the Hog John Ranch area along the Quinn River in the Sod House subarea. Numerous reports document plans and designs for the dewatering operations of the Sleeper Mine. They provide hydrogeologic data on monitoring and production-well specifications in the vicinity of the mine.

Two reports of significant geologic detail and interest were published documenting the general geology of the Jackson Mountains (Willden, 1963) and the gold deposits of the Slumbering Hills (Calkins, 1938). Willden (1964) also documented the geology and mineral deposits of Humboldt County, which provides a source of regional geology of the entire study area. A report on the geology of the southern part of the study area, in northern Pershing County, was published by Johnson (1977). In addition, and as a result of the Sleeper gold-silver discovery in the Slumbering Hills, numerous reports have been published documenting the geochemistry and geology of the Sleeper Mine area.

U.S. Geological Survey Site Designations

Each data-collection site is assigned a unique identification on the basis of geographic location. Wells and miscellaneous stream sites are identified by both a local (Nevada) system and a standard "latitude-longitude" system. For convenience, short numbers, which range from 1 to 134, also are used for all sites in this report.

A local site designation is used in Nevada to identify a site by hydrographic area (Rush, 1968) and by the official rectangular subdivision of the public lands referenced to the Mount Diablo base line and meridian. Each site designation consists of four units: The first unit is the hydrographic area number. The second unit is the township, preceded by N to indicate location north of the base line. The third unit is the range, preceded by E to indicate location east of the meridian. The fourth unit consists of the section number and letters designating the quarter section, quarter-quarter section and so on (A, B, C, and D indicate the northeast, northwest, southwest, and southeast quarters, respectively), followed by a number indicating the sequence in which the site was recorded. For example, site 31 N42 E34 15CACC1 is in Desert Valley (hydrographic-area 31). It is the first site recorded in the southwest quarter (C) of the southwest quarter (C) of the northeast quarter (A) of the southwest quarter (C) of section 15, Township 42 North, Range 34 East, Mount Diablo base line and meridian.

The standard site identification is based on the grid system of latitude and longitude. The number consists of 15 digits. The first six digits denote the degrees, minutes, and seconds of latitude; the next seven digits denote the degrees, minutes, and seconds of longitude; and the last two digits (assigned sequentially) identify the sites within a 1-second grid. For example, site 413035118090901 is at 41°30′35″ latitude and 118°09′09″ longitude, and it is the first site recorded in that 1-second grid. The assigned number is retained as a permanent identifier even if a more precise latitude and longitude are later determined.

Acknowledgments

The author sincerely thanks the local residents of Desert Valley for allowing access to their private property for data collection during the course of this study. Mr. Mel Hummel of the Willow Creek Ranch and Mr. Herb Clarno of the Bottle Creek Ranch provided considerable information about the agricultural history of the study area. Gratitude is also due to the personnel at the Sleeper Mine and to Mr. Geoffrey Beale, of Water Management Consultants, for providing valuable technical assistance. The study documented in this report was made in cooperation with the Nevada Division of Water Resources.

HYDROGEOLOGIC SETTING

Geology

The rocks and basin-fill deposits within the study area record complex geological events that include deposition of large volumes of volcanic rocks and marine sediments, intense mountain-building activity, basin-and-range extensional faulting, and cyclic fluctuations of a large, closed-basin lake. The following section briefly describes the lithology and basin structure that characterize and control ground-water movement in the Desert Valley study area. A more detailed geologic history of the study area can be obtained from the work of Willden (1958 and 1963), Stewart (1980), and Nash and others (1989).

Lithology

The several geologic units identified in the study area can be subdivided into two broad lithologic types primarily on the basis of their ability to transmit and store water. The first type, consolidated rocks, makes up the surrounding mountains and underlies the valley. The second type, basin-fill deposits, is unconsolidated to partly consolidated and consists of wind deposits and hardpan, older and younger alluvium, and lake deposits. Descriptions of age, lithology, and general hydrologic properties of the principal geologic units are given in table 1. The generalized geology of the study area is shown on plate 1*B*.

The consolidated rocks consist predominately of Tertiary-age volcanic flows, clastic sediments of Jurassic(?) and Triassic age, and Permian or older volcanic rocks. In general, the consolidated rocks have low porosity and permeability and do not store or transmit large amounts of water. However, the volcanic rocks adjacent to the low alluvial divide north of the Slumbering Hills are highly fractured and may transmit some water to the basin-fill aquifer from the Quinn River Valley to the east (Huxel and others, 1966, p. 29). Fractured volcanic rock was reported at depths of less than 500 ft in several irrigation wells of moderate yield in the Bottle Creek Ranch area (pl. 1*A*). Because the wells are perforated in both basin-fill deposits and volcanic rock, the amount of water contributed by the volcanic rock is uncertain, but may be large.

Table 1. Age, lithology, and general hydrologic properties of principal geologic units, Desert Valley, northwestern Nevada

[Descriptions based on those of Ferguson and others (1951), Nash and others (1989), and Russell (1885), Russell (1984), Stewart (1980), and Willden (1958, 1963, and 1964); geologic units shown on plate 1*B*]

Age	Geologic unit	Lithology	General hydrologic properties
		Basin-fill deposits	
Holocene and Pleistocene	Eolian deposits	Fine, well sorted sand. Predominantly barchan dunes and extensive sand sheets.	Deposits have high porosity and permeability. Continuous dune field covers about 12,000 acres, trending northeast from Donna Schee Peak to south of the Slumbering Hills.
Do.	Hardpan	Unconsolidated clay, silt, and fine sand.	Deposits have generally high porosity and low permeability that impedes the downward movement of water. Located on and near Jungo Flat in south part of study area and in other places as small deflation basins.
Do.	Younger alluvium	Unconsolidated sand, gravel, silt, and clay. Includes lacustrine deposits of Pleistocene Lake Lahontan.	Deposits have generally high porosity and permeability. Where saturated, are the principal ground-water reservoir. Located on valley floor, beneath stream channels, and in alluvial fans at margins of valley. Lacustrine deposits associated with Lake Lahontan are below ancient high lake stand (about 4,380 feet) and include gravel embarkment at south end of Double H Mountains mapped by Russell (1885).
Pleistocene and Pliocene	Older alluvium	Unconsolidated and partly consolidated, poorly sorted sand to cobbly gravel.	Deposits may transmit moderate to large amounts of water; hydraulic conductivity decreases with depth. Positioned high on alluvial fans above 4,380 feet, along east side of Jackson Mountains and west side of Slumbering Hills. Include gravel deposits of Willden (1963). Underlie younger alluvium in valley. Upper part makes up principal ground-water reservoir. Partly consolidated at depth.
Tertiary	Extrusive rocks	Basaltic and andesitic flows and related dikes, andesite-dacite welded tuffs, rhyolite ash-flow tuffs, and porphyry dikes.	Virtually no interstitial permeability; may have zones of moderate to high hydraulic conductivity related to fractures and joint-set cooling. Compose valley margin of Sod House hydrographic subarea, including Coyote Hills. In part, related to McDermitt caldera.
Do.	Sedimentary rocks	Shale, water-laid tuff, shaly sandstone, diatomaceous shale, conglomerate, and bedded opaline chert.	Generally low permeability. Crop out in Jackson Mountains. Maximum thickness, about 400 feet.
Do.	Intrusive rocks	Dacitic porphyry dikes.	Virtually no interstitial permeability; locally may transmit water where highly fractured. Represent two minor bodies in Jackson Mountains.
Tertiary and Cretaceous	Intrusive rocks	Granodiorite, quartz diorite, quartz monzonite, and related stocks.	Virtually no interstitial permeability; locally may transmit water if highly fractured. Crop out in Jackson Mountains, on north side of Donna Schee Peak, and in minor exposures in northern Antelope Range and Eugene Mountains, including Haystack Butte. Large quartz-monzonite stock in Slumbering Hills.
Do.	Sedimentary rocks	Pebble to boulder conglomerate, coarse-grained sandstone, siltstone, and fine crystalline limestone.	Water-bearing character generally unknown. Minor exposures in Jackson Mountains. Include Pansy Lee Conglomerate (about 400-500 feet thick) and King Lear Formation of Willden (1958). Make up major part of Blue Mountain.
Jurassic(?) and Triassic	Intrusive rocks	Quartz-free dioritic stocks and gabbro dikes.	No interstitial permeability; water-bearing character unknown. Stocks exposed in Jackson Mountains; gabbro dikes exposed in Blue Mountain.

Table 1. Age, lithology, and general hydrologic properties of principal geologic units, Desert Valley, northwestern Nevada—Continued

Age	Geologic unit	Lithology	General hydrologic properties
		Consolidated Rocks	
Jurassic(?) and Triassic	Sedimentary rocks	Limestone, phyllite, slate, and quartzite.	Water-bearing character generally unknown; may transmit water through fractures and along bedding-plane features. Comprise most of Eugene Mountains, Antelope Range, Alpha Mountain, and large part of Slumbering Hills and Blue Mountain. Include the Quinn River Formation of Willden (1963; about 500-600 feet thick) and may include Raspberry Formation of Ferguson and others (1951).
Triassic and Permian, or older	Metasedimentary rocks	Interbedded mafic volcanic rocks, shale, pebble conglomerate, thin-bedded chert, and carbonate rocks.	Low to no permeability; water-bearing character unknown. Major exposures in Jackson Mountains. Include Boulder Creek beds of Russell (1984).
Do.	Volcanic rocks	Massive andesitic to basaltic flows and flow breccia, agglomerates, and tuffs.	Virtually no interstitial permeability; may have fractured zones of moderate hydraulic conductivity. Comprise almost entire northern half of Jackson Mountains and most all of Jungo Hills. Include Happy Creek Group of Willden (1963), also known as the Happy Creek Igneous Complex of Russell (1984).

The basin-fill deposits compose the principal ground-water reservoir in the study area and are as much as 7,000 ft thick in the south-central part of the basin. For the most part, these deposits store and transmit much larger quantities of water than the consolidated rock because of their higher porosities and permeabilities. The lithology of the basin-fill deposits is the result of weathering and erosional processes of the rock that make up the surrounding mountains. These deposits consist of interlayered, noncontinuous beds of coarse-and fine-grained sediments. This textural variability within the deposits causes much heterogeneity in the distribution of the hydrologic properties. For example, a driller's log of a well near the abandoned town site of Jungo recorded nearly 500 ft of clay with thin lens of fine sand; however, less than 10 mi to the east, well logs showed as much as 300 ft of interbedded coarse sand and gravel with little or no clay. The water yield of wells that penetrate the basin-fill aquifer ranges from less than 5 gal/min for a well in the south-central part of the valley floor to as much as 4,000 gal/min for a well in the Bottle Creek Ranch area.

Structural Features

Basin-and-range extensional faulting appears to be the major cause of the present geometry of the basin-fill aquifer beneath Desert Valley. These range-bounding faults are high-angle faults that trend generally north and south. The estimated total vertical displacement along the prominent fault in the northeastern part of the Jackson Mountains is about 1,000 ft (Willden, 1964, p. 103-111). Geophysical data suggest that the eastern range-bounding faults of the Jackson Mountains are 1 to 2 mi east of the mountain front and are buried under alluvial deposits (Willden, 1963, p. 18). A depth-to-bedrock map, presented on plate 1*B*, indicates that the main part of Desert Valley is underlain by a north-trending, elongated structural trough. The bedrock surface of this trough appears to be made up of two depressions, one centered beneath the southern part of the valley east of Jungo and the other centered northeast of the Jungo Hills. The northern part of the bedrock surface is composed of another structural trough that trends northwest and may continue beneath Pine Valley. An isolated bedrock depression is also indicated beneath the alluvium northwest of the Jungo Hills.

Geologic History

During Permian or earlier time, thick sequences of andesitic to basaltic volcanic rocks accumulated in the area now occupied by the Jackson Mountains and are considered to be part of an extensive island-arc terrain (Stewart, 1980, p. 51). Marine deposition of clastic and carbonate sediments took place in Permian time and possibly continued into Jurassic time (Willden, 1963, p. 15). During the late Jurassic, the Permian- and Triassic-age rocks were subjected to regional metamorphism and intruded by diorite stocks. Following the low-grade regional metamorphism, a period of uplifting allowed extensive erosion of the Permian- and Triassic-age sedimentary rocks and produced geologic units such as the King Lear Formation (table 1; Willden, 1958, p. 2382). The area was then subjected to multiple phases of deformation, during Cretaceous and early Tertiary time, which included the Deer Creek thrust sheet and many high-angle faults and overturned folds. Extensive volcanic and intrusive activity occurred during much of the early Tertiary period. The large quartz monzonite stock in the Slumbering Hills and diorites in the Jackson Mountains were emplaced during this period. Regional extension commenced during the middle Tertiary period and produced the present-day basin-and-range topography that is characteristic of most of Nevada. Displacement along normal faults that bound the mountain blocks and define the lateral extent of the basin-fill deposits are a result of this regional extension (Stewart, 1980, p. 105).

Climate

The climate of the Desert Valley study area ranges from subhumid in higher altitudes of the Jackson Mountains to arid on the valley floor; precipitation is controlled primarily by the rain-shadow effects imposed by the Sierra Nevada range 150 mi to the west. The Jackson Mountains, because they border the western side of Desert Valley, cause a similar orographic effect but of a lesser magnitude and, as a result, receive most of the precipitation that falls in the study area. Precipitation is generally greater on the west-facing slopes than the east-facing slopes and increases with altitude (Huxel and others, 1966, p. 15); however, variations can be caused by local topography throughout the area. Thunderstorms are the main source of precipitation in the summer months. Snow and occasional freezing rain fall in the winter months. The growing season generally lasts from 120 to 150 days during May-September. Hay, in the form of alfalfa, is the principal crop grown in the study area, with lesser amounts of grain. About 4,000 head of range cattle winter on the valley floor (Mel Hummel, Willow Creek Ranch, oral commun., 1990; Herb Clarno, Bottle Creek Ranch, oral commun., 1990).

Precipitation data for sites in and adjacent to the study area include 23 precipitation gages with variable record lengths and 9 weather stations that have 30 years or more of record (table 2). A precipitation map (fig. 2), developed for this study from the altitude-precipitation relation shown in figure 3, is in fairly good agreement with Hardman's (1965) precipitation map that was used in the reconnaissance estimate of precipitation. The altitude-precipitation relation, developed from long-term precipitation data, has a coefficient of determination equal to 0.69. This indicates that nearly 70 percent of variation in mean annual precipitation with altitude is explained by the linear regression relation shown in figure 3. Figure 2 is based on altitude and long-term data from 25 stations and, thus, is slightly different from Hardman's map.

Weather information collected at Winnemucca (altitude, about 4,300 ft), approximately 15 mi southeast of Desert Valley (fig. 1), provides more than 70 years of continuous precipitation and temperature data. For the period 1920-91, the mean annual precipitation at Winnemucca was 8.33 in. (fig. 4*A*). The minimum precipitation during this period was 3.13 in. in 1954, and the maximum was 14.54 in. in 1945. The least amount of precipitation generally falls during the months from July through October (fig. 5*A*). Successive years with above- or below-mean annual precipitation for the period 1920-91 are shown by cumulative departure from the mean in figure 4*B*. An upward slope to the right indicates above-mean precipitation, and a downward slope indicates below mean. The duration of areas above and below zero show the length of potential effects of excessive or deficient precipitation. For example, potential effects of above-average precipitation in 1983 and 1984 (fig. 4*A*) may have persisted until 1991, even though the trend during the 1984-91 study period was one of below-average precipitation.

Table 2. Site locations and mean annual precipitation for weather stations, Desert Valley area, Nevada

[From published records of National Climatic Center, National Oceanic and Atmospheric Administration, National Weather Service, and Bureau of Land Management. Stations at sites 3 and 19 are maintained by personnel of Nevada Gold Mining, Inc.; and station at site 6 is maintained by foreman at Willow Creek Ranch; sites are listed in order of ascending altitude within each group]

Site number (figure 2)	Station name	Latitude	Longitude	Altitude (feet above sea level)	Period of record	Length of record (years)	Mean annual precipitation (inches)
		Degrees, minutes, seconds					
1	Sulphur	40 52 25	118 44 10	4,044	1915-52	38	4.82
2	Quinn River Ranch	41 34 44	118 26 01	4,087	1901-26 1947-55	35	5.75
3	Sleeper Mine [1]	41 20 08	118 03 46	4,138	1990-91	2	5.69
4	Jungo	40 55 01	118 22 55	4,165	1914-26	13	3.77
5	Denio	41 59 25	118 38 00	4,189	1952-90	39	8.85
6	Willow Creek Ranch[1]	41 12 26	118 21 08	4,190	1989-91	3	5.22
7	Jungo-Meyer Ranch	40 53 12	118 25 47	4,200	1969-86	18	8.22
8	Leonard Creek	41 31 05	118 43 00	4,224	1955-90	36	7.86
9	Kings River Valley	41 46 10	118 12 11	4,234	1957-90	34	8.78
10	Imlay	40 39 37	118 09 02	4,260	1896-1990	95	7.20
11	Orovada	41 34 09	117 47 07	4,300	1911-90	80	10.92
12	Winnemucca	40 57 50	117 42 45	4,300	1920-91	72	8.33
13	Pahute Meadows	41 18 10	118 56 02	4,375	1964-75	12	7.88
14	Paradise Hill	41 17 04	117 41 44	4,500	1961-63 1966-67	5	7.79
15	Paradise Valley	41 30 37	117 32 04	4,675	1894-1952 1955-90	95	9.20
16	Thacker Pass[1]	41 42 18	118 05 19	5,000	1962-64	3	11.53
17	Kings River Canyon[1]	41 56 03	118 18 49	5,500	1960-64	3	12.84
18	Nine-Mile Pass[1]	41 42 04	118 17 17	5,500	1960-64	3	10.14
19	Jumbo Mine[1]	41 17 57	117 59 58	5,723	1990	1	10.98
20	Jackson Mountain	41 17 24	118 27 40	6,200	1966-71	6	15.32
21	Disaster Peak	41 57 06	118 11 22	6,800	1960-64	5	17.40
		Crowley Creek Watershed					
22	Can No. 2	41 46 40	117 55 39	4,840	1962-80	19	10.27
23	Can No. 3	41 47 29	117 56 20	5,100	1962-77	16	10.59
24	Can No. 5	41 48 24	117 57 27	5,400	1962-77	16	11.44
25	Can No. 7	41 47 23	118 00 28	6,000	1962-80	19	12.04
26	Can No. 10	41 48 27	118 03 58	6,900	1962-80	19	14.50
		Cow Creek Watershed					
27	Can No. 1	40 44 03	118 44 01	4,500	1964-80	17	8.16
28	Can No. 2	40 40 56	118 42 42	4,600	1964-80	17	7.32
29	Can No. 4	40 44 06	118 35 55	5,200	1964-80	17	8.10
30	Can No. 7	40 38 32	118 43 35	5,000	1964-80	17	7.63
31	Can No. 16	40 35 58	118 45 03	5,900	1964-80	17	10.07
32	Can No. 17	40 35 54	118 45 43	6,200	1964-80	17	10.08

[1] Excluded in linear-regression analysis shown in figure 3 because of short period of record.

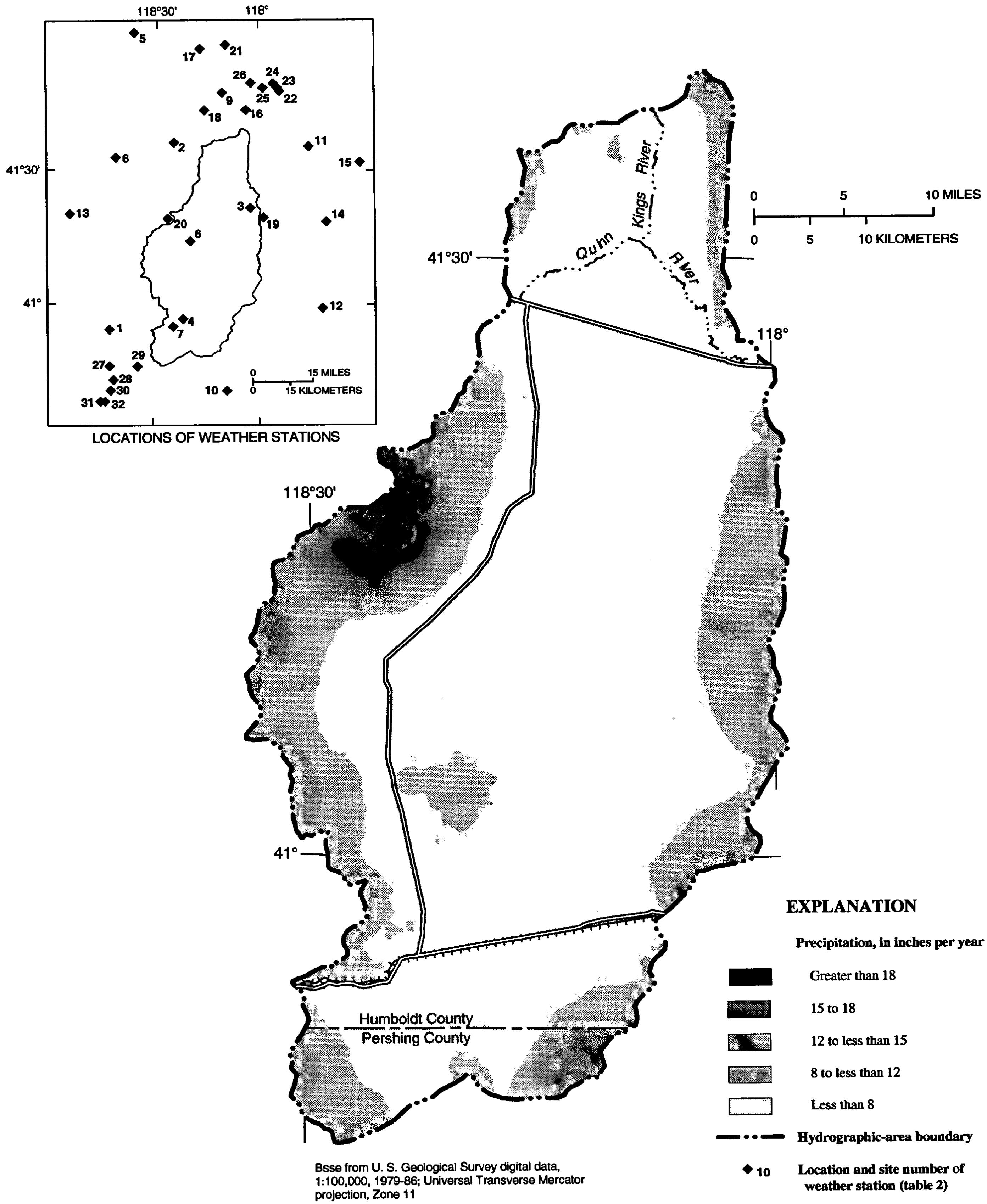


Figure 2. Areas of equal mean annual precipitation and locations of weather stations, Desert Valley area, Nevada. Site numbers listed in table 2.

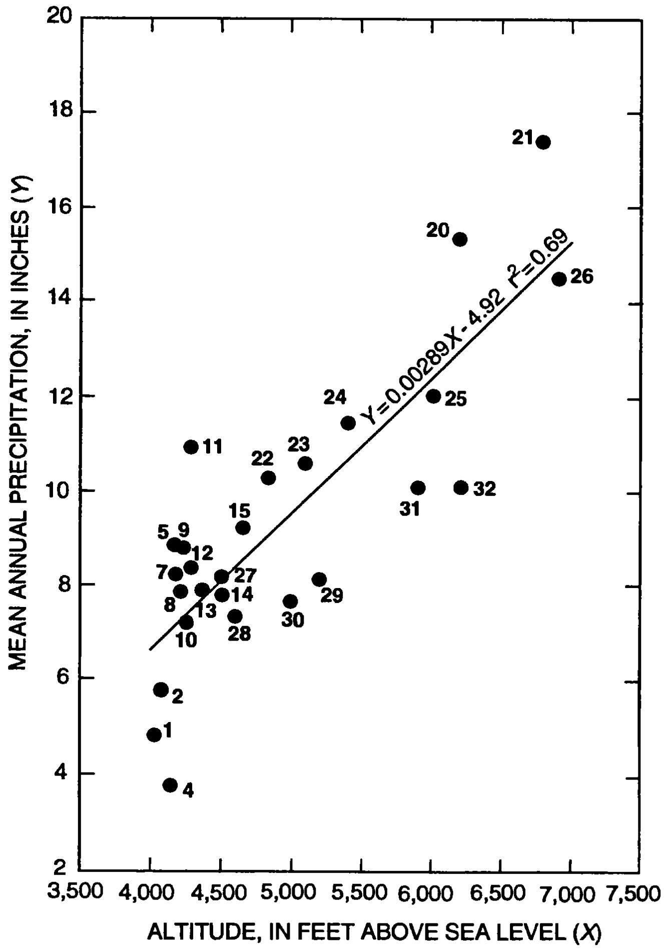


Figure 3. Relation between mean annual precipitation and altitude used in determining distribution of precipitation, Desert Valley area, Nevada. Site numbers listed in table 2. Abbreviation: r^2, statistical coefficient of determination.

Summer temperatures occasionally exceed 100°F and may fluctuate as much as 40°F in a 24-hour period. Winters are cool, with temperatures often below 0°F; the mean annual temperature at Winnemucca is 49°F (fig. 5*B*). Data collected at Rye Patch Reservoir, about 25 mi south of the study area, suggest that evaporation from free-water surfaces is on the order of 4 ft/yr (Cohen and others, 1965, p. 12). The prominent wind direction in Desert Valley is from west-southwest, which is evident from the pattern of the dune field in the south-central part of the valley (fig. 1).

Surface Water

Most streams in Desert Valley are ephemeral. The upper reaches of some streams that drain the Jackson Mountains are perennial but those streams typically cease to flow where they reach the coarse deposits of the upper alluvial fan. Streamflows from the remaining drainage basins within the study area are ephemeral and rarely debouch from the canyon mouths. During periods of Spring runoff, generally from March to early May, significant amounts of streamflow from the Jackson Mountains generated by snowmelt may reach the valley floor. However, most of the runoff probably infiltrates to the basin-fill aquifer or evaporates before reaching the valley floor. In the southwest part of the valley near Jungo, runoff from the Jackson Mountains and rainfall occasionally accumulate on hardpan surfaces and subsequently evaporate. On May 11, 1989, a large area of hardpan near Jungo had as much as 2 to 3 in. of standing water as a result of intense rain storms. During the same time, an estimated 10 to 15 ft^3/s was flowing near Bottle Creek road from both the Willow Creek and Big Creek watersheds (pl. 1*A*). The ranches are strategically placed near the terminus of each major stream channel and ranchers take advantage of the Spring streamflow and flood-irrigate for as long as possible. Streamflow that infrequently reaches the valley floor beyond the irrigated lands drains to the Quinn River by way of the Bottle Creek Slough (fig. 1).

Major streams on the valley floor include the Quinn River, the Kings River, and the Bottle Creek Slough, all of which are ephemeral. The Quinn River enters the study area from the Quinn River Valley through a low alluvial divide near Sod House, traverses west along the northern part of the study area, and exits west to Pine Valley. The drainage area of the Quinn River extends into Oregon, north of Quinn River Valley, and includes over 3,500 mi^2. The Kings River, which drains Kings River Valley, enters from the north between the Coyote Hills and the Double H Mountains and joins the Quinn River about midway through the valley (fig. 1). The poorly channelized Bottle Creek Slough drains northward to the Quinn River and collects Spring runoff and irrigation return flow from the agricultural lands east of the Jackson Mountains. Table 3 lists available discharge data for miscellaneous surface-water sites used in this study.

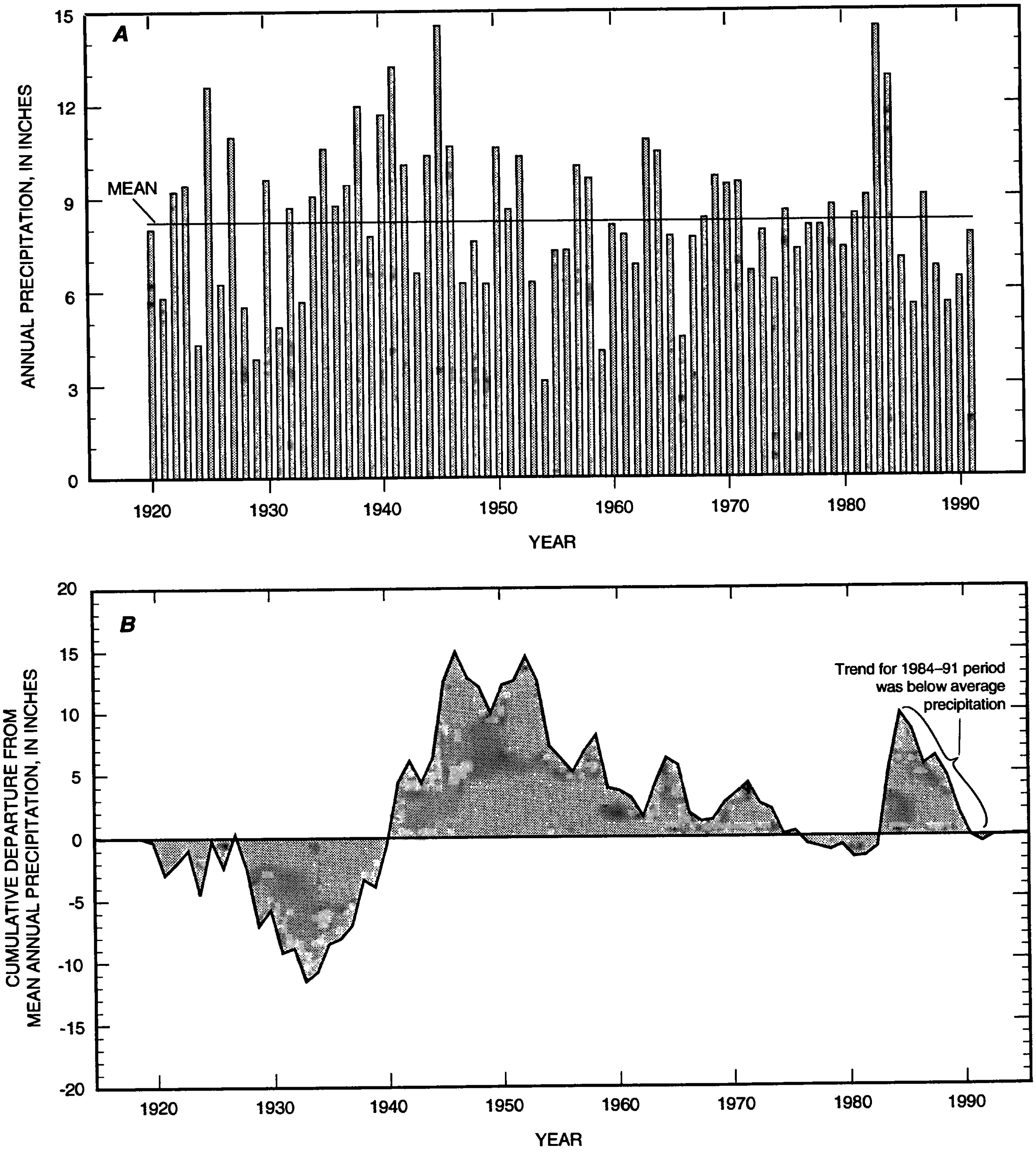


Figure 4. ***(A)*** Annual precipitation, Winnemucca, Nevada, 1920-91 (site 12, figure 2 inset; data from National Climatic Center), and ***(B)*** cumulative departure from mean annual precipitation, Winnemucca, 1920-91.

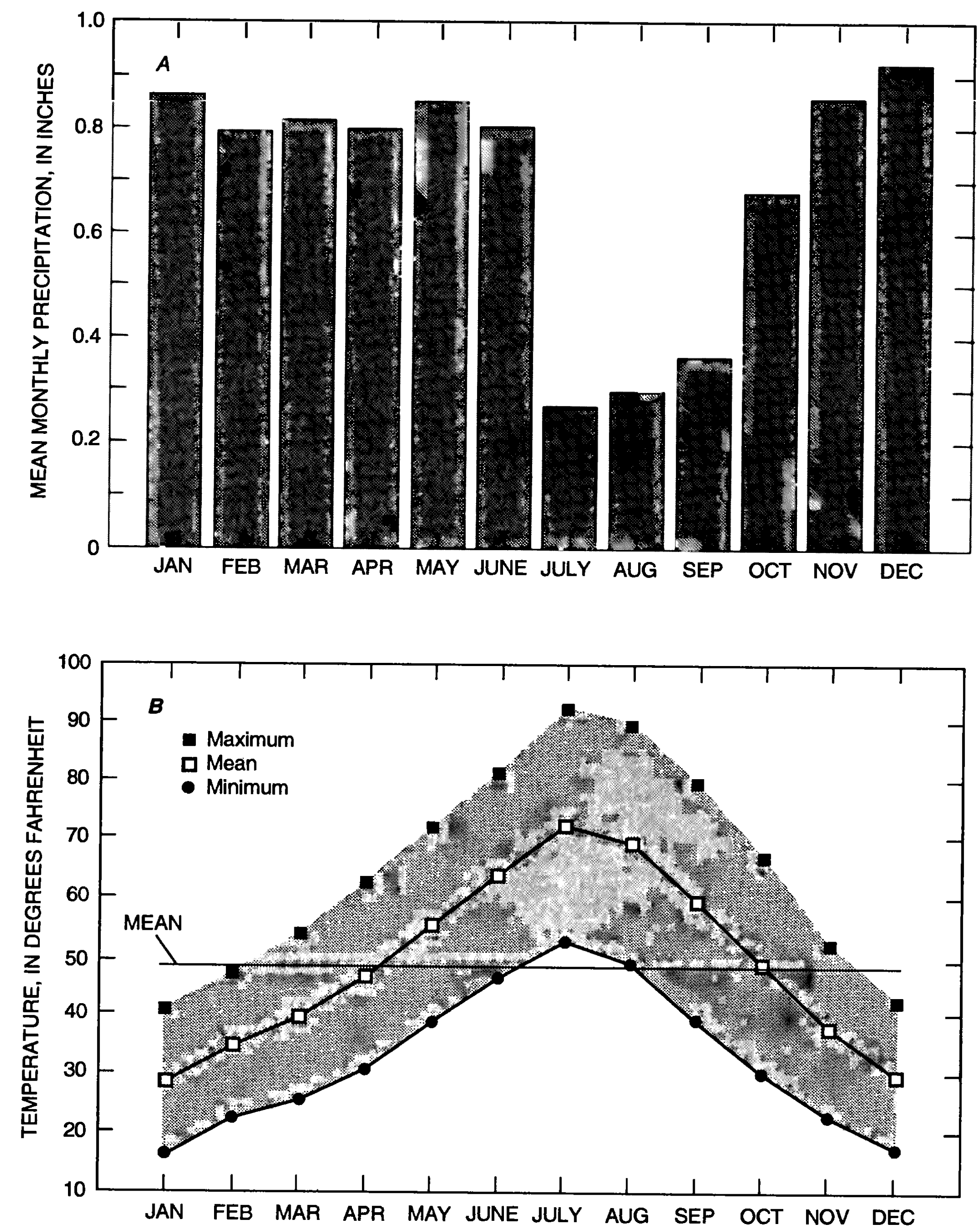


Figure 5. Precipitation and temperature data, Winnemucca, Nevada (site 12, figure 2 inset; data from National Climatic Center). ***(A)*** Mean monthly precipitation, 1920-91, and ***(B)*** maximum, minimum, and mean monthly air temperatures, 1920-90.

Table 3. Streamflow measurements for miscellaneous sites, Desert Valley, Nevada

[Data published by Garcia and others (1992)]

Site number (plate 1*C*)	Site name	Altitude (feet above sea level)	Measurement date	Measured discharge (cubic feet per second)
33	Quinn River near Denio [1]	4,120	03/27/90	1.8
			04/12/90	.19
			05/09/90	No flow
34	Quinn River [2] near Sod House	4,250	03/27/90	No flow
			04/12/90	No flow
			05/09/90	No flow
35	Bottle Creek	4,960	03/28/90	2.03
			04/12/90	2.96
			05/10/90	4.54
			09/24/90	.50
36	Big Creek	5,240	03/28/90	1.65
			04/12/90	1.94
			05/10/90	1.57
			09/25/90	.20
37	Trout Creek[2]	5,250	03/28/90	.37
			04/12/90	.43
			05/10/90	.64
38	Clover Creek	5,050	03/29/90	.64
			04/12/90	.55
			05/10/90	.19
39	Louse Creek	5,000	09/25/90	.25
40	Big Cedar Creek	4,920	03/29/90	.12
			04/13/90	.61
			05/10/90	[e] .1
41	Bull Creek	4,950	03/29/90	.04
			04/13/90	.08
			05/10/90	No flow

[1] Near exit point to Pine Valley, where continuous-record streamflow station was operated during water years 1964-67 and 1978-81; use of town name Denio is for ease of identification only.
[2] Crest-stage gage.
[e] Estimated.

A partial record from a continuously recording streamflow-gaging station, operated on the Quinn River where it exits Desert Valley (site 33 on pl. 1*C*, table 3), indicates an annual-mean discharge of about 1,300 acre-ft over an 8-year period (water years 1964-67 and 1978-81; U.S.Geological Survey, 1965-68, 1979-82, published annually). The gage was discontinued at the end of the 1981 water year. Long-term streamflow data (about 70 years) collected on Martin Creek in Paradise Valley, east of Desert Valley, were used to estimate the long-term discharge for the Quinn River at its exit point to Pine Valley. An annual average of about 1,400 acre-ft/yr was estimated and is in good agreement with the average discharge over the 8-year record for the discontinued gaging station. During the 8-year record, most of the annual flow occurred during the months of April and May and no flow was recorded for the months from July through December. In addition, during the water years 1966 and 1981 no flow was recorded at the gaging station. On April 28, 1984, during Spring flood conditions, an indirect measurement of 1,000 ft^3/s was estimated for the Quinn River near the discontinued gaging station (Rhea P. Williams, U.S. Geological Survey, written commun., 1992). If this rate of discharge were sustained for one day, it would represent more streamflow than the mean-annual estimate of 1,400 acre-ft. Table 3 includes streamflow-discharge measurements made during the months of March, April, and May for 1990 on the Quinn River. A measurement of 1.8 ft^3/s was made on the Quinn River near Denio (site 33), where the river leaves the study area and enters Pine Valley to the west. During this same time period, no flow was observed upstream in the Quinn River near Sod House (site 34), where the river enters Desert Valley from the Quinn River Valley. This no-flow observation suggests that streamflow passing the gage on the Quinn River near Denio is probably a combination of flow from ground-water discharge and the Bottle Creek Slough.

Huxel and others (1966, p. 28) estimated that the annual streamflow of the Quinn River leaving the Quinn River Valley and entering Desert Valley ranges between 1,000 and 5,000 acre-ft. Malmberg and Worts (1966, p. 29) estimated that the long-term streamflow of the Kings River, carrying outflow from the Kings River Valley to the Desert Valley study area, may average 1,000 acre-ft/yr. However, no flow was observed in the Kings River near its confluence with the Quinn River during the course of this study. This observation may be, in part, a result of sustained ground-water pumping for irrigation in the Kings River Valley.

Miscellaneous streamflow measurements were made on seven of the principal streams (sites 35-41; table 3) that drain the east side of the Jackson Mountains. Measurements were made at the contact between the bedrock and the alluvial material near the apex of the alluvial fan. Six of the streams were measured during the Spring runoff period, March through May of 1990. During this period, no streamflow reached the valley floor. Crest-stage gages were installed on the Quinn River near Sod House (site 34) and at the bedrock contact along Trout Creek (site 37). Crest-stage gages are typically installed within flood channels of active streams and are used to indicate the stage of maximum streamflow. During this period of study, 1989-91, neither gage registered high streamflow.

Ground Water

Source, Distribution, and Movement of Ground Water

Most of the ground water in the study area originates as precipitation that falls within the drainage basin. Some ground water enters the basin as subsurface inflow from the Quinn River and Kings River Valleys. Most precipitation and, consequently, most ground-water recharge, originates in the higher altitudes of the mountainous regions surrounding the basin. Recharge from precipitation and snowmelt reaches the basin-fill aquifer by infiltrating through fractured and weathered rock or during intermittent streamflow that percolates through coarse channel deposits on the alluvial fans. Following intense rain showers, some precipitation may infiltrate through areas in the south-central part of Desert Valley covered by active sand dunes. Streamflow may also infiltrate through the streambeds of the Quinn and Kings Rivers during periods of Spring runoff.

Most ground water in the study area is a component of the saturated basin-fill deposits. It is generally unconfined at shallow depths and slightly confined beneath areas containing fine-grained deposits and at greater depths. Ground water flows from areas of recharge, or high hydraulic head, downgradient toward areas of discharge, or lower head. The general depth to ground water and the configuration of the water table prior to much ground-water development in Desert Valley are shown on plate 1*D*. Table 4 lists the available data for ground-water sites used in this study. Water-level measurements made during the late 1950's to middle 1960's (see table 15 at back of report) were used to construct the predevelopment water-level contours. Differences in water-level altitudes between those listed in table 15 and those reported by earlier investigators, for identical wells, are a result of more accurate estimates of land-surface altitudes. In the eastern and western parts of the valley, adjacent to the mountains, flow is generally toward the center of the basin. In the northern part of the study area, water-level contours indicate that ground water enters Desert Valley from the Quinn River Valley near Sod House and from the Kings River Valley beneath the divide between the Coyote Hills and the northern Double H Mountains. Huxel and others (1966, p. 29) estimated that subsurface inflow from the Quinn River Valley was about 300 acre-ft/yr. Malmberg and Worts (1966, p. 31) used an average transmissivity of 7,000 ft^2/d, a hydraulic gradient of 5 ft/mi, and an effective width of about 3 mi to estimate an annual flow of nearly 900 acre-ft/yr moving southward from the Kings River Valley.

Table 4. Site number, location, and type of data available for stream and well sites, Desert Valley, Nevada

[Abbreviations for available data: Q, discharge; QW, water quality, WL, water levels. Data are listed in tables 3, 6, and 15]

U.S. Geological Survey site designations[1]			Site name	Available data
Site number (plate 1C)	Local identification	Standard identification		
		Stream stations		
33	31 N42 E33 33DC 1	411634118265601	Quinn River near Denio[2]	Q
34	31 N41 E35 23CB 1	412451118005801	Quinn River near Sod House[3]	Q
35	31 N40 E32 25AA 1	411919118195701	Bottle Creek	Q,QW
36	31 N39 E32 11CC 1	411559118215201	Big Creek	Q,QW
37	31 N39 E31 12AA 1	411634118265601	Trout Creek[3]	Q
38	31 N39 E31 26CC 1	411323118290701	Clover Creek	Q
39	31 N39 E31 34AA 1	411308118293501	Louse Creek	Q,QW
40	31 N38 E31 10AB 1	411117118294401	Big Cedar Creek	Q
41	31 N38 E31 28AD 1	410828118305201	Bull Creek	Q
		Well sites		
42	30A N44 E34 35DDBC1	413835118065801	Thacker well No. 3	WL
43	30B N43 E35 31CDDC1	413320118052501	Rimrock well	WL
44	30B N43 E34 13BBCA1	413617118070301	Thacker well No. 2	WL,QW
45	30B N43 E34 28DBBB1	413412118100201	Coyote Point well	WL
46	30B N43 E33 35AAAD1	413347118140101	Pinnacle Point well	WL
47	30B N42 E35 19ACDD1	413017118050801	Cleto well	WL
48	30B N42 E34 04BABC1	413253118101401	Thacker well No. 4	WL
49	30B N42 E33 10DDBA1	413123118151901	Radar well	WL
50	31 N42 E34 15CACC1	413035118090901	Quinn River Lakes well	WL,QW
51	31 N42 E34 30ABCC1	412916118122201	Hog John Ranch windmill	WL
52	31 N42 E34 36BBBB1	412835118071001	Sod House-Quinn River well	WL
53	31 N41 E35 20AADD1	412510118024801	Sod House No. 1	WL,QW
54	31 N41 E35 23CBCD1	412441118010801	Quinn River well No. 1	WL
55	31 N41 E35 33BBCC1	412330118033101	PI-2	WL
56	31 N41 E35 33CABC1	412312118031101	PI-3	WL
57	31 N41 E34 02CDDA1	412710118073801	Sod House well No. 3	WL
58	31 N41 E34 08BCCC1	412644118112701	Bottle Creek Slough No. 1	WL
59	31 N41 E34 13DDAD1	412518119192201	Bottle Creek Slough No. 3	WL
60	31 N41 E34 27CD 1	412354118082601	OH-50S	WL
61	31 N41 E34 27CD 2	412354118082602	OH-50D	WL
62	31 N41 E33 04BAAC1	412725118170701	Quinn River holding-corral well	WL,QW
63	31 N41 E33 10BBBD1	412636118152101	Bottle Creek well no. 2	WL
64	31 N41 E33 15DCDD1	412453118151701	Bottle Creek well no. 3	WL
65	31 N40 E35 03ADCB1	412228118013801	Franklin replacement well	WL
66	31 N40 E35 04DDCC1	412158118025101	PI-1	WL
67	31 N40 E35 09ACAD1	412137118025101	OH-22	WL
68	31 N40 E35 16ABAC1	412052118030001	Franklin well	WL
69	31 N40 E35 16ACB 1	412042118030401	OH-25	WL
70	31 N40 E35 16BCBC1	412048118034101	INJ No. 1	WL,QW
71	31 N40 E35 20ABBB1	412013118040801	OH-45S	WL

Table 4. Site number, location, and type of data available for stream and well sites, Desert Valley, Nevada—Continued

U.S. Geological Survey site designations [1]				
Site number (plate 1C)	**Local identification**	**Standard identification**	**Site name**	**Available data**
72	31 N40 E35 20ABBB2	412013118040802	OH-45D	WL
73	31 N40 E35 29CCCC1	411832118050101	Austin well	WL
74	31 N40 E35 30DDBA1	411838118050001	Austin replacement well	WL
75	31 N40 E34 08AABA1	412153118103501	OH-51S	WL
76	31 N40 E34 08AABA2	412153118103502	OH-51M	WL,QW
77	31 N40 E34 08AABA3	412153118103503	OH-51D	WL
78	31 N40 E34 09DA 1	412141118095101	OH-68	WL
79	31 N40 E34 10CD 1	412128118091801	OH-67	WL
80	31 N40 E34 13AAAD1	412100118061401	OH-49S	WL
81	31 N40 E34 13AAAD2	412100118061402	OH-49D	WL
82	31 N40 E34 22CB 1	411958118093301	OH-66	WL
83	31 N40 E34 22CA 1	411950118091901	OH-65	WL
84	31 N40 E34 24AB 1	412017118063701	OH-64	WL
85	31 N40 E33 02BABD1	412240118144001	Bottle Creek Slough No. 2	WL
86	31 N40 E33 22D 1	411921118151201	Herbs well No. 2	QW
87	31 N40 E33 23DACC1	411929118141401	Herbs well No. 1	WL
88	31 N39 E35 07DCDA1	411606118050901	Jackson well	WL,QW
89	31 N39 E34 31BDAD1	411311118122801	Presnel well No. 2	WL,QW
90	31 N39 E33 13C 1	411504118134201	Delong	WL
91	31 N39 E33 20AACD1	411445118173401	Alta well No. 2	WL
92	31 N39 E33 26B 1	411356118150101		WL
93	31 N39 E33 33D 1	411231118162901		WL
94	31 N39 E32 35DDBB1	411225118210801	Willow Creek Ranch well	WL,QW
95	31 N38 E35 27DCBC1	411205118071001	Crescent well	WL
96	31 N38 E34 01BCCD1	411209118070101	Gabica well	WL
97	31 N38 E34 16CCCC1	410957118103001	Presnel well	WL
98	31 N38 E34 24ACBB1	410935118064101	Corbeal well	WL
99	31 N38 E33 16DCAA1	410943118170101	Sand dunes well No. 1	WL
100	31 N38 E32 17DDBB1	410949118245601	Trout Creek Ranch well No. 1	WL,QW
101	31 N38 E32 35DACD1	410718118221401	Five-Mile well	WL
102	31 N37 E34 04ACDD1	410644118094501	Mormon Dan well	WL,QW
103	31 N37 E34 14CCCC1	410423118075601	Banks windmill	WL
104	31 N37 E34 28BBAD01	410338118102101	Lee windmill	WL
105	31 N37 E33 14ACCA1	410458118143201	Sand dunes well No. 2	WL
106	31 N37 E33 33AAAD1	410237118162101	McNinch well	WL
107	31 N37 E33 36DBCD1	410208118132401	Hidden Playa well	WL
108	31 N36 E34 05DCDB1	410114118111101	Delong windmill	WL
109	31 N36 E34 19ADBC1	405902118123701	Gaskell well No. 7	WL
110	31 N36 E34 19DDBB1	405838118120201	Gaskell well No. 6	WL
111	31 N36 E34 21CACD1	405838118101901	Gaskell well No. 4	WL

Table 4. Site number, location, and type of data available for stream and well sites, Desert Valley, Nevada—Continued

U.S. Geological Survey site designations [1]			Site name	Available data
Site number (plate 1*C*)	Local identification	Standard identification		
112	31 N36 E34 21DACD1	405838118094401	Gaskell well No. 5	WL
113	31 N36 E34 30DACD1	405726118121901	Corral windmill	WL,QW
114	31 N36 E34 33ADBA1	405720118093901	Gaskell well No. 2	WL
115	31 N36 E34 33BACD1	405730118101501	Gaskell well No. 3	WL
116	31 N36 E34 34CBBC1	405703118092701	Gaskell well No. 1	WL
117	31 N36 E33 04CD 1	410109118165601	Jungo Hills well	WL,QW
118	31 N36 E33 26DADB1	405750118140901	Hardpan well	WL
119	31 N36 E32 22BABD1	405813118230501	Jungo Point well	WL,QW
120	31 N35 E33 20ADAA1	405346118172701	Berg well	WL
121	31 N35 E32 10CACD1	405508118224801	Jungo city well	WL
122	31 N35 E32 10CC 1	405501118224501	Jungo	WL
123	31 N35 E32 30BCBB1	405250118263401	Jungo well No. 1	WL,QW
124	31 N34 E32 11CBCC1	404934118220101	Alpha Mtn well No. 2	WL
125	31 N34 E32 16ABDC1	404901118223601	Haystack Butte well	WL
126	32 N41 E36 31ACBB1	412331117581901	Corral well	WL
127	32 N37 E36 19ACAB1	410418117581301	Barrett Springs well No. 2	WL
128	32 N37 E36 23BDBB1	410421117540701	Barrett Springs well No. 1	WL
129	33A N41 E35 03DADB1	412719118012301	Gone with the Wind well	WL
130	33A N41 E35 23DCCD1	412436118003401	Sod House well No. 2	WL
131	33A N41 E36 17DDDB1	412538117564701	Gallagher well	WL,QW
132	70 N36 E36 30AABB1	405820117580601	Abel Flat well	WL
133	70 N35 E35 09BBDC1	405538118032801	Pronto well No. 1	WL,QW
134	70 N35 E34 01ACDB1	405620118061501	Pronto well No. 2	WL

[1] USGS site designations are described in section titled "U.S. Geological Survey Site Designations" of this report.
[2] Operated as continuous record station, water years 1964-67 and 1978-81.
[3] Crest-stage gage.

Ground water exits the basin beneath the channel of the Quinn River to Pine Valley under a gradient of about 1 ft/mi. Estimates of outflow to Pine Valley made by Sinclair (1962a, p. 10; 1962b, p. 10), Zones (1963, p. 20), and this study ranged from 100 to 400 acre-ft/yr. The difference between the estimated surface-water outflow and inflow indicates that a total of 700-4,700 acre-ft/yr of streamflow from the Quinn and Kings Rivers may recharge the shallow basin-fill aquifer system. The water table beneath the central part of the basin is nearly flat, with a gradient of less than 1 ft/mi. A broad ground-water divide exists northeast of the Jungo Hills (pl. 1*D*). Water flows north from the divide toward the Quinn River and drains to Pine Valley. The water-level contours also indicate that water flows southwest from the divide and presumably exits the basin in the vicinity of the northern Antelope Range where water-level altitudes are less than 4,100 ft. An estimated 120-1,200 acre-ft/yr may exit the basin as subsurface flow to the southwest. This estimate was based on an assumed transmissivity and effective width of the basin-fill aquifer and later refined using the ground-water flow model. No prior estimates have been made of the volume of subsurface flow moving out of the valley to the southwest. Depth to the water table beneath the valley floor in the northern part of the study area is generally less than 20 ft; however, it may be less than 5 ft in areas near the Quinn River during periods of streamflow. Beneath the central part of the valley, depths to ground water are generally greater than 30 ft and increase to nearly 70 ft in the southwest (site 124). However, at the ground-water divide (site 102), water depth was about 17 ft below land surface in 1961—an altitude of about 4,116 ft (Sinclair, 1962b, pl. 1).

Basin-Fill Aquifer

The basin-fill deposits, which occupy structural depressions in the bedrock beneath Desert Valley, constitute the primary ground-water reservoir in the study area. The basin fill is composed of stream, alluvial-fan, lacustrine, hardpan, and eolian deposits derived mostly from the adjacent mountains. However, a large volume of basin fill may have been reworked and transported from outside the present-day topographic boundary of Desert Valley. According to Davis (1982, p. 59), the Humboldt River may have been a tributary to the Quinn River through Desert Valley approximately 22,000-35,000 years ago. Davis (1982, p. 59) also suggests that the extensive dune field in the south-central part of the valley may have been derived from a Humboldt River delta that formed in the Jungo area. In general, the basin-fill deposits within the study area consist of discontinuous units and heterogeneous mixtures of gravel, sand, silt, and clay and, as such, function as a single aquifer system.

Areal Extent and Thickness

The areal extent of the basin-fill aquifer is approximated by the contact between the consolidated rock and the basin fill at the periphery of the valley floor. In the northern part of the study area, the saturated basin-fill deposits are continuous with saturated deposits in adjacent basins, allowing movement of ground water between aquifer systems. The low alluvium-covered topographic divides in the southern part of the study area are underlain by consolidated rock at relatively shallow depths and generally act as barriers to ground-water flow. The basin fill covers nearly 850 mi^2 of the study area, or about 70 percent of the total drainage area.

Wells in the study area range in depth from 10 ft to nearly 1,000 ft; however, most are completed in basin-fill deposits and are typically only about 200 ft deep. Volcanic bedrock was penetrated in a number of irrigation wells adjacent to the Jackson Mountains, along the western margin of the valley floor, at depths less than 500 ft. These wells are a few miles from the range front and support the earlier interpretation that the range-boundary faults are east of the Jackson Mountains (Willden, 1963, p. 48). Numerous observation and exploratory holes drilled for the Sleeper Mine penetrate hundreds of feet of basin fill; however, most of these drill holes are adjacent to the Slumbering Hills and provide little information on the depth to bedrock within the study area. Sites 60 and 75 (pl. 1*C*), in the north-central part of the valley, are completed in the basin fill at reported total depths of 700 and 650 ft, respectively (Nevada Gold Mining, Inc., written commun., 1991). The deepest wells drilled in the southern part of the study area include sites 110 and 122, with reported basin-fill type deposits to depths of 310 ft and 500 ft, respectively.

Estimated thicknesses of the basin fill, shown on plate 1*C* as depth to bedrock, were determined by interpretation of gravity data obtained during this study and in an earlier study (Saltus, 1988). Several gravity profiles across the study area were used as input to a two-dimensional model based on a technique described by Cordell and Henderson (1968). Lines of equal depth to bedrock were constructed from the model results and drill-hole data (pl. 1*B*). The basin can be divided into at least four structural depressions, which suggests that the bedrock geometry is complex.

Hydraulic Properties

The response to development of basin-fill aquifer systems depends, in part, on the hydraulic conductivity and storage properties of the deposits that make up the basin fill. Both of these properties are dependent on the textures and depositional histories of the basin-fill deposits. Because of the inhomogeneity and lenticular nature of these deposits within the study area, hydraulic conductivity and storage estimates were determined as the average of these properties over several depositional textures. Most deposits in the study area are flat lying, resulting in much greater hydraulic conductivities in the horizontal direction than in the vertical. Coarse-grained deposits, such as sands and gravels, commonly transmit the greatest quantity of water and tend to control ground-water flow in the horizontal direction, whereas fine-grained deposits, which impede ground-water movement, control flow in the vertical direction. For purposes of this study and because hydraulic properties below the deepest well are unknown, hydraulic conductivity was assumed to decrease 50 percent for every 1,200 ft in depth, a rate similar to that reported by Durbin and others (1978, p. 76) for basin-fill deposits beneath Salinas Valley, Calif. The initial estimates of horizontal hydraulic conductivity were adjusted during the calibration procedure of the ground-water flow model, as explained in the section "Calibration and Results of Predevelopment Simulations."

Estimates of horizontal hydraulic conductivity were made using lithologic descriptions from drillers' logs and the results of 19 specific-capacity tests. A minimum depth of 180 ft was used to optimize available drillers' logs and provide the best areal coverage. The general distribution of estimated horizontal hydraulic conductivity for the upper 180 ft of saturated basin fill is shown in figure 6. The approximation of transmissivity (hydraulic conductivity multiplied by aquifer thickness) from the specific capacity of wells is based on a method developed by Theis (1963). Transmissivity estimates computed using this method were divided by the length of the screened interval in each well to arrive at the horizontal hydraulic conductivity value of the basin fill directly adjacent to the perforations. Transmissivity estimates and, hence, horizontal hydraulic conductivity, derived from specific-capacity data may be greater than an average value because the screened interval in most wells is adjacent to the more productive zones (coarser deposits), avoiding the less permeable fine-grained deposits. Conversely, well losses tend to lower the specific-capacity value and, therefore, lower the estimate of horizontal hydraulic conductivity. However, this lower value may be somewhat compensated for if the well has a larger effective radius than what was used in the calculation. On the basis of analysis of a limited number of drillers' logs, most of the upper 180 ft of saturated basin fill appears to be fairly transmissive. Estimates of horizontal hydraulic conductivity, determined from specific-capacity data, range from 5 to 320 ft/d and average about 110 ft/d (fig. 6).

Estimates of an equivalent vertical hydraulic conductivity were made for the upper 180 ft of saturated basin fill by determining the thickness of coarse- and fine-grained deposits reported on drillers' logs and using the following equation:

$$K_v = b/\left[(b_c/K_{zc}) + (b_f/K_{zf})\right] ,$$

where K_v is equivalent vertical hydraulic conductivity (in feet per day),

b is total thickness (in feet),

b_c, b_f are the sum of thicknesses of coarse- and fine-grained deposits, respectively (in feet), and

K_{zc}, K_{zf} are the vertical hydraulic conductivities of coarse- and fine-grained deposits, respectively (in feet per day).

The vertical hydraulic conductivity used for the coarse-grained deposits equaled the estimate of horizontal hydraulic conductivity shown in figure 6. The vertical hydraulic conductivity used for the fine-grained deposits was 9×10^{-3} ft/d. Figure 7 shows the general distribution of estimated vertical hydraulic conductivity for the upper 180 ft of saturated basin fill within the study area. In areas where drillers' logs report large thicknesses of clay, vertical hydraulic conductivity is less than 15×10^{-3} ft/d. In general, these areas are beneath the large hardpan near Jungo and in the northern part of the study area. Lithologic descriptions from wells (sites 109-116) drilled in the southern part of T.34 N., R.35 E indicate the presence of coarse sand and gravel with almost no clay or silt, resulting in vertical hydraulic conductivities greater than 7.5×10^{-2} ft/d.

The amount of ground water available from storage in basin-fill aquifers depends on whether the aquifer is under unconfined or confined conditions. The term "storage coefficient" is used to describe the storage capabilities of an aquifer. Storage coefficient is defined by Lohman (1992, p. 8) as the volume of water an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in head. Under unconfined conditions, the storage coefficient is nearly equal to the specific yield. Specific yield is the amount of water released from storage by gravity drainage. Water released from storage under confined conditions depends on the elastic characteristics of the aquifer and the expansion of water. Storage coefficients for confined aquifers are three to five orders of magnitude smaller than the specific yields of unconfined aquifers.

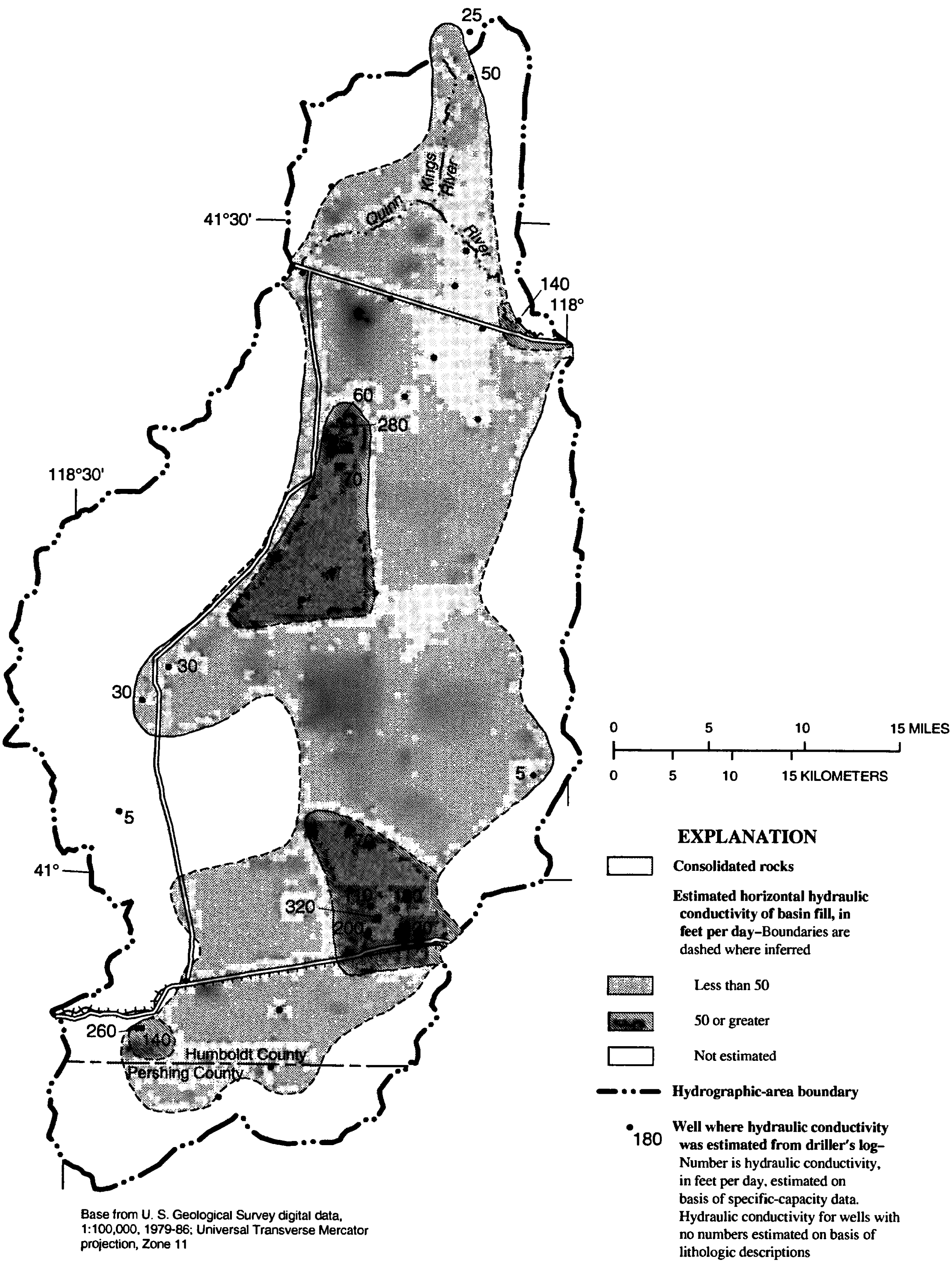


Figure 6. Distribution of estimated horizontal hydraulic conductivity in upper 180 feet of saturated basin fill, Desert Valley, Nevada.

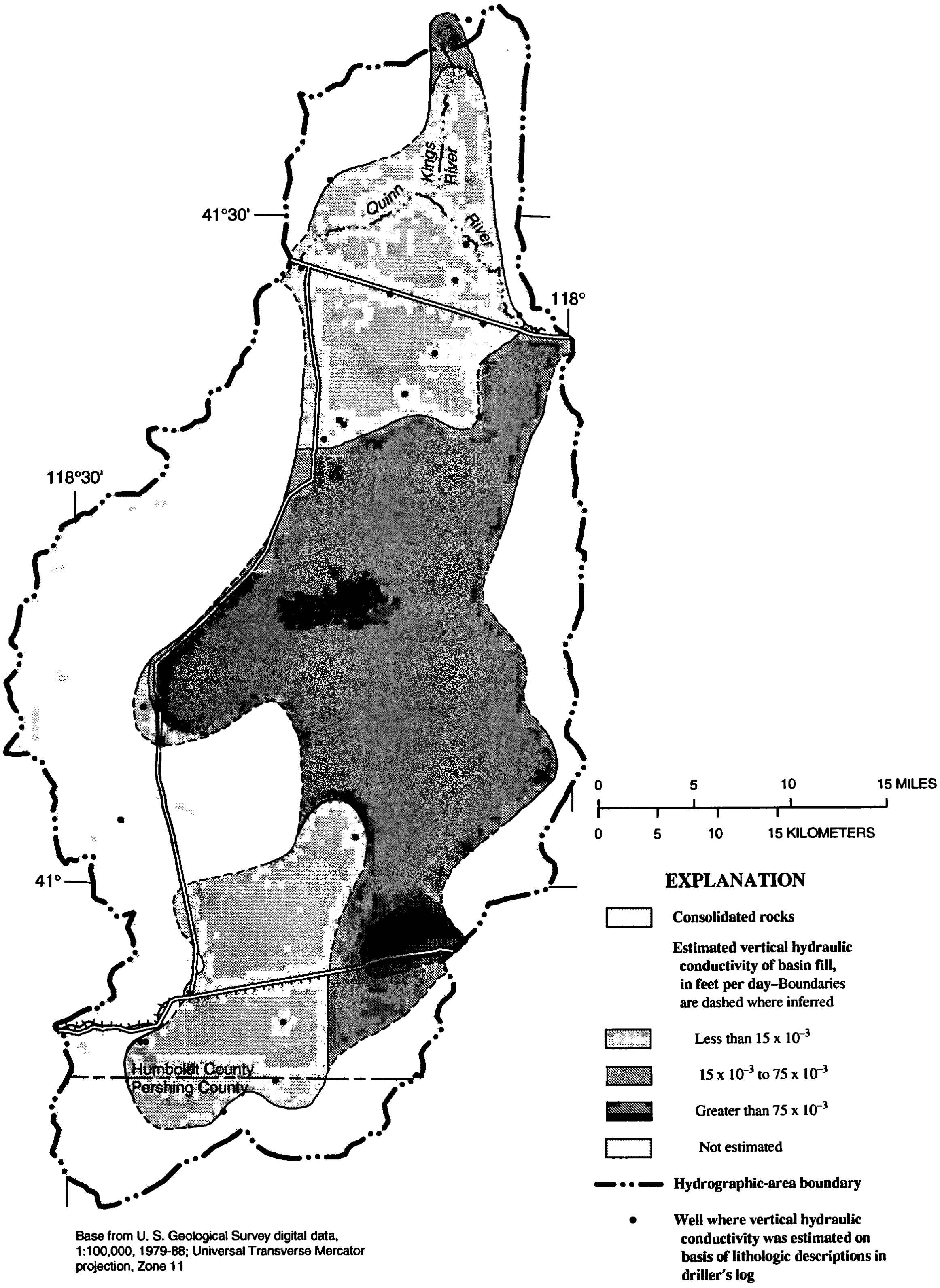


Figure 7. Distribution of estimated vertical hydraulic conductivity in upper 180 feet of saturated basin fill, Desert Valley, Nevada.

In general, specific yields of basin-fill deposits range from 5 percent for clay to about 30 percent for well-sorted sands (Morris and Johnson, 1967, tables 5 and 6). Estimates of average specific yield for the upper 180 ft of saturated basin fill in the study area were made from lithologic descriptions in drillers' logs. The lithologic descriptions were subdivided into five categories and assigned specific-yield values on the basis of the results of Cohen (1963, pl. 2), Morris and Johnson (1967, tables 5 and 6), and Harrill and Moore (1970, p. 27). Table 5 presents the five lithologic categories and their assigned specific yields.

The general distribution of estimated specific yield for the upper 180 ft of saturated basin fill is shown in figure 8. Areas underlain by fine-grained deposits, such as the large hardpan near Jungo, have specific yields of less than 10 percent. The arithmetic mean of specific-yield values estimated from 35 drillers' logs is about 15 percent. Using the distribution of specific yield shown in figure 8, estimated storage for the upper 180 ft of saturated basin fill would have been greater than 10 million acre-ft under predevelopment conditions. This estimation indicates that a large volume of ground water is stored within the basin-fill aquifer beneath the study area.

For deeper parts of the aquifer system, storage coefficients were estimated by multiplying the thickness of the deposits (in feet) by 1×10^{-6}, as suggested by Lohman (1972, p. 53). In the study area, saturated basin fill ranges from 0 to about 7,000 ft thick. If water yield is entirely from the expansion of stored water in the confined aquifer and none is from the compaction of fine-grained material, the storage coefficient for confined deposits 500-7,000 ft thick would range from 0.007 to 0.0005 percent.

Water Quality and Geochemistry

Chemical analyses were made of water from 18 wells scattered throughout the study area and 3 streams that issue from the Jackson Mountains (pl. 1*F*). Water-quality analyses for sites 70 and 76 are from the Sleeper Mine hydrochemistry data base (Geoffrey Beale, Water Management Consultants Inc., written commun., 1990). The analyses included determination of specific conductance, pH, water temperature, dissolved oxygen, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, silica, nitrate, orthophosphate, arsenic, boron, iron, manganese, selenium, deuterium, oxygen-18, and radon-222. Most of the ground water sampled is from shallow depths (less than 200 ft) and is used for stock watering. The streams sampled are generally perennial in the upper reaches and become ephemeral after they leave the mountains. The results of these analyses are presented in table 6. Of the 16 wells sampled during this study period—1988-91—6 wells (sites 53, 86, 88, 100, 102, and 119) also were sampled during 1954-61 (Sinclair, 1962b, table 3) and the results for those samples are also presented in table 6 for comparison. During this study, each site was sampled only once, except for site 123, where a second sample was collected for deuterium and oxygen-18 analyses (table 7).

Table 5. Specific yield of lithologic units described in drillers' logs, Desert Valley, Nevada

Lithologic unit described by drillers	Assigned specific yield [1] (percent)
Sand	30
Gravel; sand and gravel	25
Sand, gravel, and clay; gravel and clay cemented; gravel	15
Sand and clay; sandy clay, silt	10
Clay, silt	5

[1] Based on Cohen (1963), Morris and Johnson (1967), and Harrill and Moore (1970).

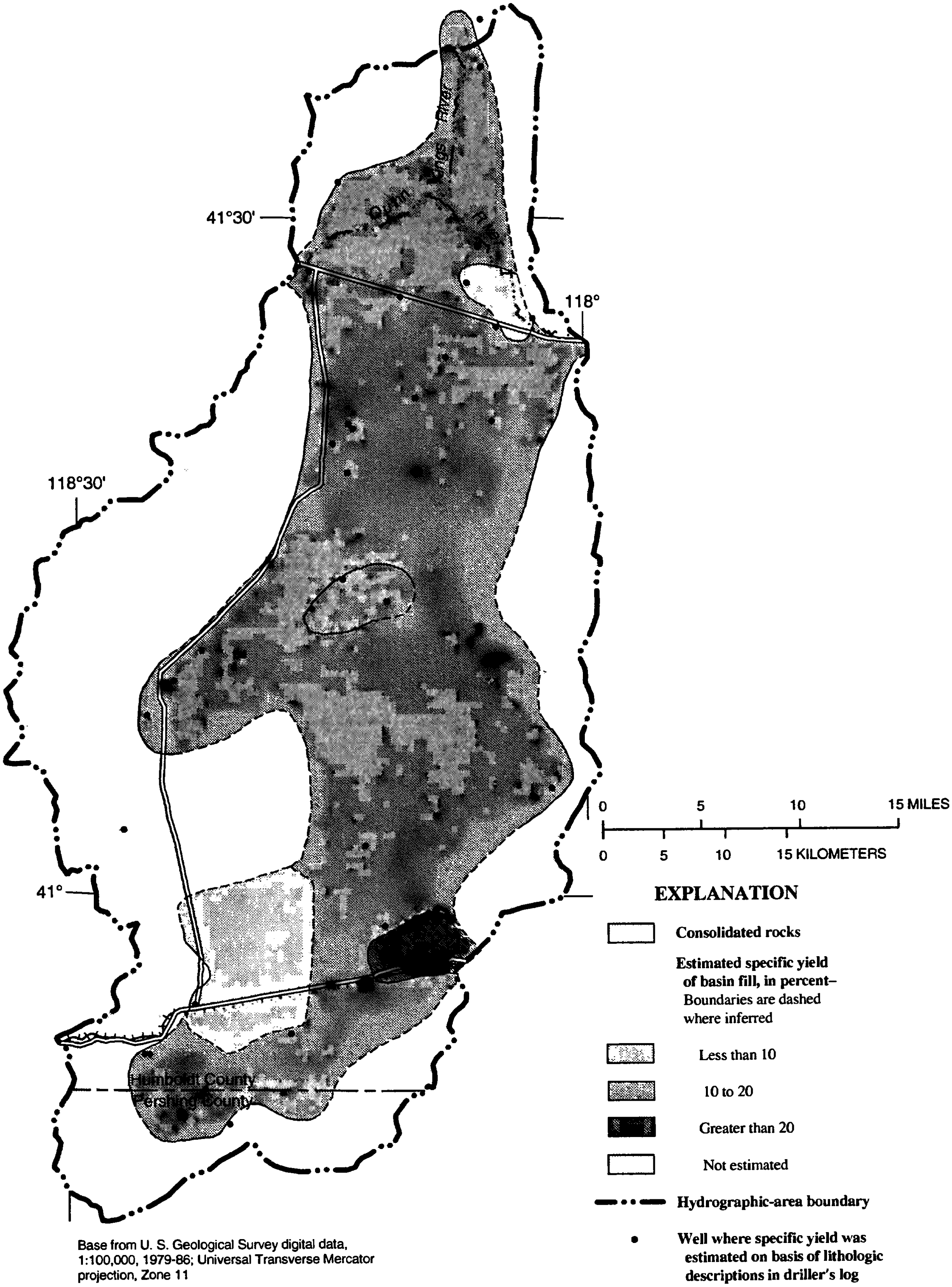


Figure 8. Distribution of estimated specific yield in upper 180 feet of saturated basin fill, Desert Valley, Nevada.

Table 6. Results of chemical analyses for water samples from selected stream and well sites, Desert Valley, Nevada

[Abbreviations and symbols: L, measured in laboratory (all other specific-conductance, pH alkalinity, and bicarbonate values are field measurements); mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25°C; °C, degrees Celsius; µg/L, micrograms per liter; <, less than; pCi/L, picocuries per liter; --, not determined. Deuterium and oxygen are relative to Vienna Standard Mean Ocean Water. Earlier (1954-61) analyses for sites 53, 86, 88, 100, 102, and 119 are from Sinclair (1962b, table 3)]

Site number (plate 1*F*)	Date sampled	Time	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Oxygen, dissolved (mg/L)	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
					Stream sites					
35	09-24-90	1315	424	8.1	14.5	--	170	43	15	23
36	09-25-90	0815	312	7.5	14.0	--	110	31	8.1	24
39	09-25-90	1300	928	8.7	19.0	--	220	56	19	100
					Well sites					
44	02-14-90	1115	473	8.1	9.5	2.3	180	46	15	34
50	06-26-91	1500	7,290	7.7 L	12.0	--	1,000	190	130	1,200
53	10-26-54	--	941	9.0	26.6	--	9	2.2	.8	197
	02-13-90	1515	744	7.8	21.0	3.5	79	22	5.9	130
62	02-14-90	1530	628	7.9	8.5	.8	92	25	7.1	100
[1]70	06-17-88	0815	--	7.9	--	--	61	18	4	195
[1]76	03-30-90	0005	2,000	8.0	--	--	490	178	11	144
86	08-06-61	--	566 L	7.8 L	11.5	--	215	58	17	30
	07-24-90	0900	787	7.4	12.5	--	330	91	25	37
88	02-26-61	--	1,000 L	7.8 L	19.5	--	154	46	9.7	146
	07-24-90	1800	975	7.7	20.0	2.9	150	44	9.4	140
89	06-26-91	1030	1,020	7.7	14.0	--	190	51	14	120
94	07-24-90	1120	394	7.2	13.0	5.2	140	38	11	26
100	[2]02-27-61	--	675 L	7.8 L	15.5	--	124	38	7.1	98
	[3]02-27-61	--	589 L	7.7 L	15.5	--	95	30	4.6	90
	[4]02-27-61	--	425 L	8.0 L	19.0	--	38	14	1.0	78
	07-24-90	1300	938	7.5	14.0	--	290	89	16	87
102	02-26-61	--	925 L	7.7 L	13.5	--	155	48	8.5	136
	02-12-90	1630	1,040	7.8	11.0	.5	150	45	9.2	150
113	02-15-90	0950	703	7.9	14.0	4.1	150	40	11	100
117	02-15-90	1400	1,620	7.7	14.0	.8	240	64	19	240
119	02-27-61	--	1,370 L	7.6 L	15.0	--	304	55	41	164
	02-16-90	0945	3,700	7.6	13.0	.8	1,200	200	170	290
123	07-25-90	0845	1,890	7.6	6.0	--	480	75	72	210
	06-25-91	1050	2,120	7.7	17.0	--	--	--	--	--
131	02-13-90	0930	3,050	8.2	11.0	1.5	340	100	22	530
133	06-25-91	1430	821	7.5	14.0	--	87	22	7.7	150

Table 6. Results of chemical analyses for water samples from selected stream and well sites, Desert Valley, Nevada—Continued

Site number (plate 1*F*)	Potassium, dissolved (mg/L as K)	Alkalinity dissolved (mg/L as $CaCO_3$)	Bicarbonate, dissolved (mg/L as HCO_3)	Carbonate, dissolved (mg/L as CO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Dissolved solids, sum of constituents (mg/L)
				Stream sites					
35	1.4	170 L	210 L	--	28	15	0.2	--	230
36	1.3	140 L	170 L	--	14	12	.2	--	170
39	5.2	170 L	210 L	--	87	140	.3	--	510
				Well sites					
44	4.0	150	180	0	51	48	0.2	58	340
50	39	520	630	0	1,600	1,400	2.0	12	4,900
53	18	--	211	36	70	106	1.4	4.8	541
	14	199	240	0	79	88	.9	71	530
62	13	180	220	0	30	90	.5	67	440
[1]70	10	168	205	--	119	140	.9	31	725
[1]76	27	154	188	--	38	435	.4	48	1,070
86	1.5	--	276	0	32	22	--	--	--
	1.9	270	330	0	46	72	.2	20	460
88	12	--	204	0	94	157	.3	63	640
	12	150	190	0	87	160	.3	63	610
89	13	130	160	0	34	210	.6	48	570
94	4.0	150	180	0	26	24	.2	39	260
100	8.8	--	224	0	43	80	.8	46	431
	9.4	--	215	0	31	61	1.0	55	385
	10	--	208	0	17	22	1.1	52	301
	2.7	250	300	0	83	120	.2	22	570
102	10	--	222	0	126	90	.9	49	606
	9.5	180	220	0	140	97	1.0	49	610
113	8.4	190	230	0	89	76	.5	31	470
117	16	210	260	0	200	270	.4	55	990
119	5.9	--	233	0	88	274	.5	16	773
	20	150	190	0	330	890	.4	55	2,100
123	3.2	160	200	0	320	370	.3	21	1,200
	--	--	--	--	--	--	--	--	--
131	1.3	150	180	0	270	730	.6	52	1,800
133	10	250	310	0	98	42	.5	21	500

Table 6. Chemical analyses of water samples from selected surface- and ground-water sites, Desert Valley, Nevada—Continued

Site number (plate 1*F*)	Nitrogen, nitrate, dissolved (mg/L as N)	Ortho-phosphate, dissolved (mg/L as P)	Arsenic, dissolved (µg/L as As)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Selenium, dissolved (µg/L as Se)	Delta deuterium (permil)	Delta oxygen-18 (permil)	Radon-222, total (pCi/L)
					Surface-water sites					
35	--	--	--	--	--	--	--	-116	-15.2	--
36	--	--	--	--	--	--	--	-118	-15.5	--
39	--	--	--	--	--	--	--	-114	-14.2	--
					Ground-water sites					
44	0.26	0.04	11	100	38	26	<1	-124	-16.1	740
50	--	--	--	3,100	7,900	2,900	--	-108	-12.6	--
53	--	--	--	--	--	<1	--	--	--	--
	.3	.02	26	530	6	<1	1	-125	-16.0	1,000
62	<.1	.10	22	460	160	240	<1	-126	-16.2	600
[1]70	.4	--	46	--	210	<1	<5	--	--	--
[1]76	0	--	30	500	210	1.2	<5	--	--	--
86	--	--	--	--	--	0	--	--	--	--
	1.9	.02	2	110	5	<1	1	-118	-15.5	500
88	--	--	--	870	--	--	--	--	--	--
	1.2	.02	<1	720	86	5	2	-121	-14.7	1,000
89	--	--	--	300	310	940	--	-121	-15.8	--
94	.7	.01	3	90	6	<1	<1	-121	-15.8	730
100	--	--	--	560	--	--	--	--	--	--
	--	--	--	530	--	--	--	--	--	--
	--	--	--	670	--	--	--	--	--	--
	1.6	.03	3	270	9	2	<1	-118	-15.2	910
102	21	--	--	890	--	--	--	--	--	--
	9.3	.07	22	700	37	39	10	-124	-14.3	760
113	.3	.06	10	600	97	2	2	-121	-15.2	900
117	<.1	.07	29	1,100	98	340	<1	-122	-14.6	350
119	--	--	--	810	--	--	--	--	--	--
	22	.02	4	630	120	370	36	-125	-15.2	1,100
123	2.4	.01	3	480	13	<1	2	-131	-16.6	500
	--	--	--	--	--	--	--	-129	-16.4	--
131	.1	.08	70	720	40	140	<1	-122	-15.9	1,000
133	--	--	--	350	99	270	--	-122	-15.2	--

[1] Data from Water Management Consultants Inc., written commun., 1990.

[2] Site 100 sampled at 100 feet.

[3] Site 100 sampled at 250 feet.

[4] Site 100 sampled at 500 feet.

Surface-water samples were collected during base-flow conditions, near the bedrock–basin-fill contact at the apex of the alluvial fans. Base flow is water that has infiltrated the rock and thin soil in the mountains and reemerges in stream channels as ground-water discharge. Chemical analyses of base flow (sites 35, 36 and 39) are assumed to be characteristic of water entering the basin-fill aquifer from the recharge areas. Most ground-water samples were collected using the existing pump at each site; however, samples from four wells (sites 50, 62, 89, and 133) were obtained using either a peristaltic or submersible pump. Specific conductance, pH, and temperature of the ground water were monitored during pumping to ensure that samples represented ground-water conditions within the aquifer and not borehole water. Samples were collected after these measured properties stabilized. Also determined onsite were alkalinity, measured by incremental-pH titration, and dissolved oxygen, measured with a dissolved-oxygen meter and probe. Samples collected for chemical analyses were filtered onsite using a pre-rinsed 0.45-µm filter and preserved according to standard U. S. Geological Survey methods (Fishman and Friedman, 1989). Samples were shipped to the U. S. Geological Survey Laboratory in Arvada, Colo., for analysis. The types of containers and preservation procedures used for the various samples are those specified by the U.S. Geological Survey (Timme, 1994). As an indication of the accuracy of the chemical analyses, an ionic balance was calculated for each sample. One sample (from site 50) had a calculated balance error of nearly 6 percent; all other samples had ionic balance errors of less than 5 percent.

Plate 1*F* presents water-quality diagrams that illustrate the relative milliequivalent-per-liter proportions of major ionic species for each chemical analysis made during this study. Predominant ionic species include sodium, potassium, magnesium, calcium, chloride, sulfate, bicarbonate, and carbonate. The water quality at sites 35 and 36 (stream baseflow in recharge-source areas) represents the most dilute water sampled in the study area (dissolved solids less than 250 mg/L) and has pH values of 8.1 and 7.5, respectively. Calcium is the most abundant cation, and bicarbonate is the most abundant anion at both sites. In contrast, the sample from Louse Creek (site 39) in the southern part of the Jackson Mountains has a dissolved-solids concentration of 511 mg/L and is dominated by sodium (cation) and chloride (anion) in nearly equal proportions. Ground water sampled during this study ranges from slightly to moderately alkaline (pH ranges from 7.2 to 8.2), and most samples have dissolved-solids concentrations between 500 and 1,000 mg/L. Sites 50, 76, 119, 123, and 131 have dissolved-solids concentrations that exceed 1,000 mg/L, with a maximum of 4,900 mg/L at site 50 (table 6).

Nevada water-quality standards for selected constituents are shown in table 7 and are used herein as a basis for comparing reported concentrations with respect to beneficial use for human consumption, aquatic life, irrigation, and watering livestock. In 1988, the State of Nevada adopted these standards from the U.S. Environmental Protection Agency (1986). On the basis of the State standards for 10 inorganic constituents and properties, most ground water sampled during this study is suitable for each designated beneficial use. However, a sample from site 131, which is within Quinn River Valley (pl. 1*C*), exceeded the primary drinking-water standard for arsenic and the secondary maximum standard for chloride and dissolved solids. The primary drinking-water standard was exceeded for selenium and nitrate (as nitrogen) in ground water at site 119, and at site 102 the sample contained selenium at the primary standard value. Secondary maximum drinking-water standards for chloride and dissolved solids are exceeded at sites 50, 76, 119, and 123 (dissolved solids only). In addition, site 50 exceeds secondary standards for fluoride, iron, and sulfate. Water-quality standards for aquatic life are exceeded for boron at sites 50, 88, 102, 113, 117, 119, and 131. Aquatic-life standards are also exceeded for iron at site 50 and for selenium at site 119. Irrigation standards are exceeded for manganese at sites 50, 62, 89, 117, 119, and 133 and for boron at sites 50, 88, and 117. Site 133 is located just outside the southeast part of the study area. Fluoride and iron standards for irrigation use meet or exceed at sites 50 and 102, and site 119 exceeds the selenium standard for irrigation. Standards for watering of livestock is exceeded in fluoride at site 50. Samples for radon-222 were analyzed for 13 sites and all exceeded the proposed standard of 300 pCi/L, having concentrations ranging from 350 to 1,100 pCi/L. Ground-water samples from near and within the Sleeper Mine generally exceed all standards for arsenic (Hydrotechnica, written commun., 1988). Hydrotechnica hydrologists believe that the arsenic concentrations are associated with the solution of arsenic minerals within the ore body, rather than the overlying basin fill.

Table 7. Selected water-quality standards for designated beneficial use

[Values in micrograms per liter, except as noted. Abbreviations and symbol: mg/L, milligrams per liter; pCi/L, picocuries per liter; --, standard does not exist for indicated constituent. Standards set by U.S. Environmental Protection Agency and adopted by State of Nevada (Nevada Bureau of Health Protection Services, 1992).]

Constituent	Public water systems		Aquatic life	Irrigation	Watering of livestock
	Primary standard[1]	Secondary maximum standard[2]			
Arsenic	50	--	[3]360	100	200
Boron	--	--	550	750	5,000
Chloride (mg/L)	--	400	--	--	--
Dissolved solids (mg/L)	--	1,000	--	--	--
Fluoride (mg/L)	4	2	--	1	2
Iron	--	600	1,000	5,000	--
Manganese	--	--	--	200	--
Selenium	10	--	[4]20	20	50
Sulfate (mg/L)	--	500	--	--	--
Nitrate, as N (mg/L)	10	--	--	--	--
Radon-222 (pCi/L)	[5]300	--	--	--	--

[1] Primary standards are health related and federally mandated.

[2] Secondary maximum standards are based on esthetic qualities and are enforceable by State of Nevada.

[3] Standard based on more toxic dissolved arsenic species (arsenic III).

[4] One-hour average; may be exceeded only once every 3 years.

[5] Proposed but not promulgated.

Trilinear diagrams are used to show the chemical character of water in terms of milliequivalent-per-liter percentages of major dissolved constituents (Hem, 1985). The trilinear diagram in figure 9 is subdivided into four general water types on the basis of major constituents making up more than 50 percent of the sample. The diagram indicates that the water sampled in the study area was overall a mixture of constituents; however, type-3 water (sodium plus potassium, sulfate plus chloride) represents nearly half the samples. The pH of ground-water ranged from 7.2 to 8.7; consequently, the bicarbonate-plus-carbonate component of the trilinear diagram is dominated by bicarbonate. Calcium was the dominant cation in all sites with water types 1 and 4 except for sites 119 and 123, where magnesium was slightly greater. Sodium was the dominant cation in water types 2 and 3 and was generally greater than 50 percent. Bicarbonate was the dominant anion in water types 1 and 2 and makes up more than 50 percent of the anions. In water types 3 and 4, chloride represents the largest percentage of anions except in samples from sites 53, 102, and 100, where sulfate is slightly greater.

Samples of water originating in the recharge-source area in the northern part of the Jackson Mountains and in the adjacent basin fill represent the most dilute water (average dissolved-solids concentration at sites 35, 36, 86, and 94 was 280 mg/L) and are a calcium-dominated bicarbonate water. This water evolves along ground-water flow paths to a more concentrated sodium chloride water (average dissolved-solids concentrations at sites 70, 88, and 89 was 640 mg/L). Similar geochemical evolution of ground water in a closed basin in central Nevada has been documented by Thomas and others (1989b).

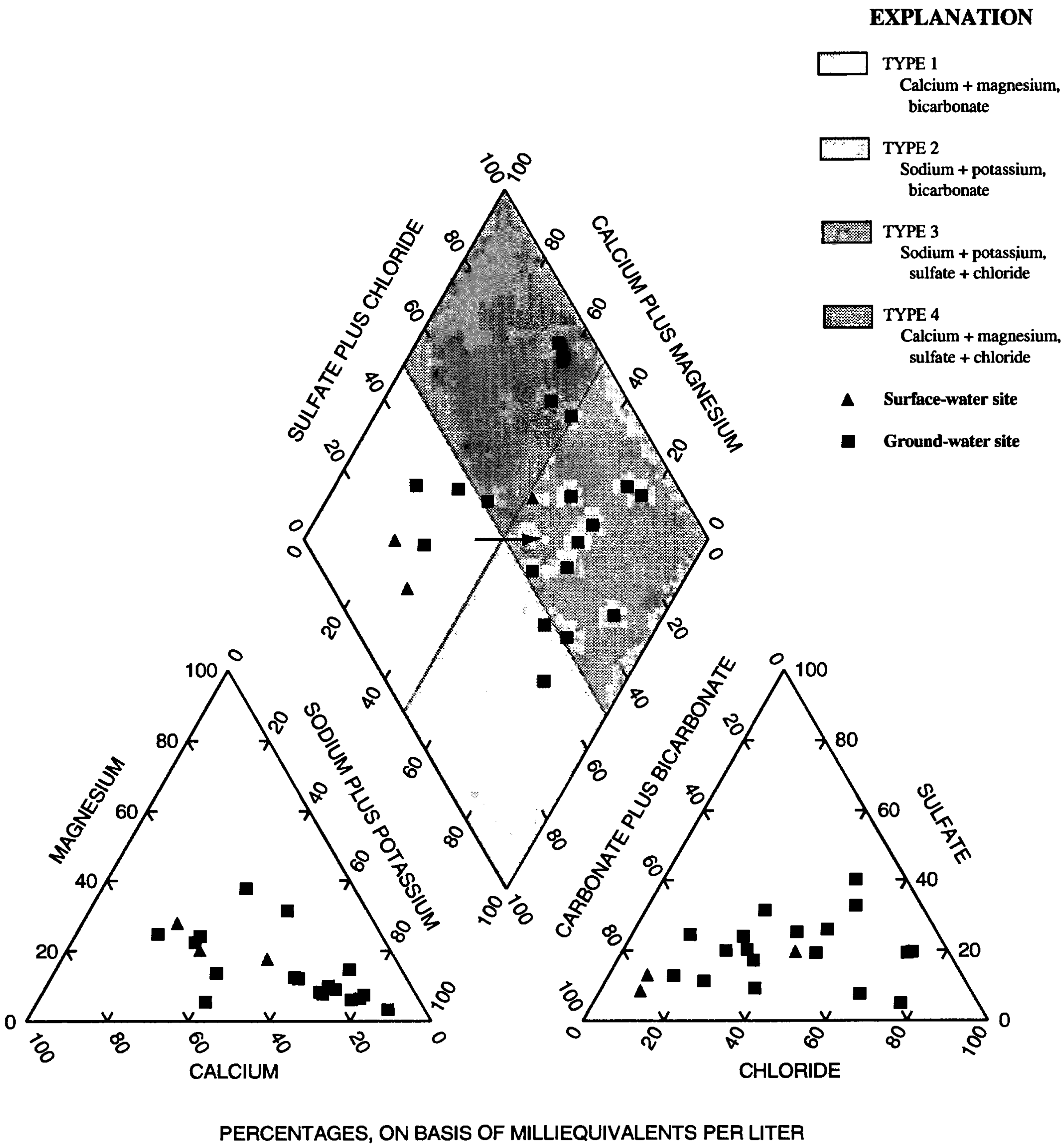


Figure 9. Proportions of major dissolved constituents in sampled stream water (sites 35, 36, and 39) and well water, Desert Valley, Nevada. Arrow indicates path of generalized chemical evolution, from recharge areas to discharge areas.

The relation between the stable hydrogen isotope of water (deuterium) and chloride concentration has been used to indicate processes concentrating ions in ground water (Welch and Preissler, 1990, p. 31; Thomas and others, 1989, fig. 16). On the basis of a plot of deuterium as a function of chloride concentration, the increase in concentration of dissolved solids in the ground water appears to be related to the dissolution of evaporative salts, or transpiration, or both, rather than evaporation (fig. 10). Salt dissolution and transpiration increase ion concentrations in solution while producing no appreciable change in deuterium composition. In contrast, evaporation results in greater proportions of deuterium relative to hydrogen (less negative delta-deuterium values) with increasing ion concentration because the ground water lost to the atmosphere by evaporation is enriched in hydrogen relative to deuterium (more negative delta-deuterium values). Water from site 50 shows approximately a 10-permil increase in deuterium above that of most ground water in the study area and has the highest chloride concentration of all the samples. This suggests that the high concentrations of chloride and other dissolved solids at this sampling site is due to evaporative processes.

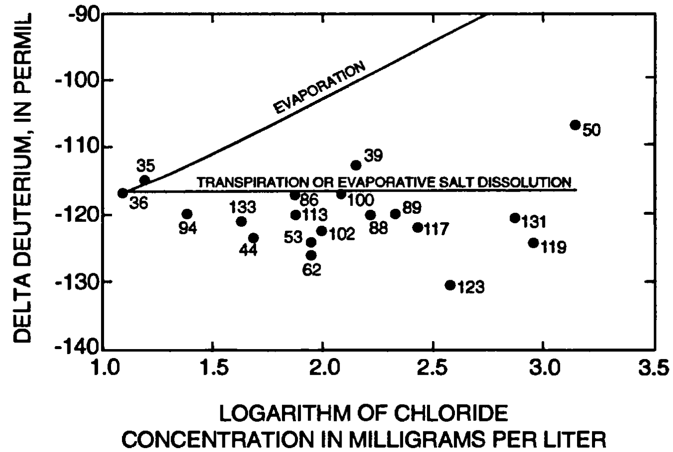


Figure 10. Relation between delta deuterium and logarithm of chloride concentrations in sampled water, Desert Valley, Nevada (site numbers listed in table 6).

GROUND-WATER RECHARGE FROM PRECIPITATION

The principal source of water that recharges the basin-fill aquifer system in the study area originates as precipitation that falls within the mountains surrounding the valley floor. Mountain-block estimates of recharge were made using an empirical method developed by Maxey and Eakin (1949) and a chloride-balance technique (Dettinger, 1989). Both methods are based on the total precipitation that falls within the recharge-source areas where annual precipitation is greater than 8 in. Recharge that occurs by direct infiltration of precipitation on the valley floor in areas covered by sand dunes was estimated using a deep-percolation model (Bauer and Vaccaro, 1987).

Estimates of average annual precipitation within the study area were made on the basis of the relation between altitude and average annual precipitation at 26 sites with 5 or more years of data (table 2). The average annual precipitation for altitude zones within the basin (fig. 2) was constructed from the relation shown in figure 3. The residual plot of predicted and measured average annual precipitation (fig. 11) indicates that the simple linear relation used in this analysis appears to be appropriate and generally fits the observed data. On the basis of this information, the total average annual precipitation that falls within the study area is estimated to be on the order of 410,000 acre-ft. Estimated precipitation, by altitude zone, is given in table 8. The average annual precipitation estimated in each corresponding altitude zone was multiplied by the area within that zone and summed to determine the total average annual precipitation within the entire basin. The areas in each altitude zone were obtained from 7.5- and 15-minute topographic maps. This annual total is about 37 percent larger then the 300,000 acre-ft originally estimated by Sinclair (1962b) and reflects the inclusion of the Sod House subarea in this study, use of an updated precipitation-altitude relation, and the better resolution of the more recent maps used in the present study to define altitude zones.

Estimates Using Maxey-Eakin Method

The Maxey-Eakin method for estimating ground-water recharge from precipitation uses a percentage of total precipitation within a specified altitude zone that potentially would become ground-water recharge. The percentages for each altitude zone are based on estimates developed by Maxey and Eakin (1949) from 13 valleys in east-central Nevada. The percentages of estimated recharge for each altitude zone and associated average annual precipitation are given in table 8. An estimated average annual recharge rate of about 6,800 acre-ft/yr was calculated using this method for the study area (table 8). This is about 26 percent greater than the estimated 5,000 acre-ft/yr of Sinclair (1962b), due to the higher rates of precipitation estimated by the current study and differences in delineation of altitude zones. More than half (about 55 percent) of the total recharge to the ground-water system is estimated to originate in the Jackson Mountains north of Trout Creek (pl. 1*A*). Over most of the valley floor, precipitation is less than 8 in. annually and is assumed to be a negligible source of recharge (Maxey and Eakin, 1949; Sinclair, 1962b; Huxel and others, 1966), although some recharge may occur in areas covered by sand dunes. Approximately 6 percent of the total precipitation that falls within the recharge-source areas (altitudes greater than 5,000 ft) is estimated to become ground-water recharge.

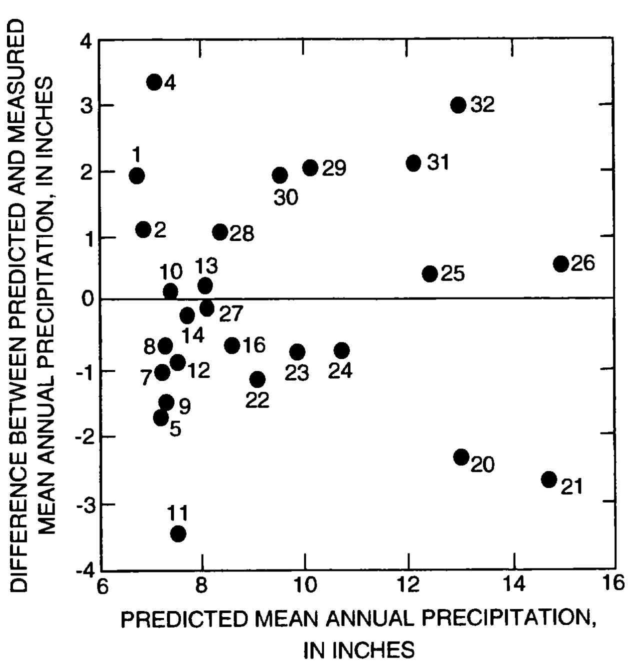


Figure 11. Difference between predicted and measured mean annual precipitation, Desert Valley area, Nevada (site numbers listed in table 2).

Table 8. Estimated annual average ground-water recharge from precipitation, Desert Valley area, Nevada

Altitude zone (feet above sea level)	Area (acres)	Estimated annual precipitation			Estimated recharge	
		Range (inches)	Average (feet)	Average (acre-feet)	Assumed percentage of precipitation	Acre-feet per year
Above 8,000	2,800	18-22	1.7	4,800	25	1,200
7,000-8,000	7,700	15-18	1.4	11,000	15	1,600
6,000-7,000	21,500	12-15	1.1	24,000	7	2,000
5,000-6,000	78,200	8-12	.9	70,000	3	2,000
Below 5,000	635,000	4-8	.5	300,000	0	0
Total (rounded)	745,000			400,000		7,000

Estimates Using Chloride-Balance Technique

The chloride-balance technique for estimating ground-water recharge has been applied in several basins within the Basin and Range Province (Dettinger, 1989; Thomas and others, 1989a; and Harrill and Preissler, 1994). This technique is based on the balance between total chloride concentration in bulk precipitation that falls in recharge-source areas and chloride concentration in water that represents ground-water recharge. The technique assumes that precipitation is the only source of chloride in the recharge water. A more detailed discussion of the assumptions and application of the chloride-balance technique is presented by Dettinger (1989). On the basis of the chloride-balance technique, the volume of recharge can be approximated as follows:

$$R = P(Cl_p/Cl_r) \quad ,$$

where R is recharge (in acre-feet per year),
P is total precipitation that falls in recharge-source area (in acre-feet per year),
Cl_p is chloride concentration in bulk precipitation (in milligrams per liter), and
Cl_r is chloride concentration of recharge water (in milligrams per liter).

Using 110,000 acre-ft/yr as the total precipitation estimated to fall in recharge-source areas (altitudes greater than 5,000 ft; table 8), 0.4 mg/L as the average chloride concentration (Dettinger, 1989) in bulk precipitation that falls in the recharge-source areas, and 13.5 mg/L as the average chloride concentration of recharge water from sites 35 and 36 sampled during base-flow conditions, the recharge is estimated to be about 3,300 acre-ft/yr. That amount is about half of the recharge estimated using the Maxey-Eakin method and may represent a minimum. However, the chloride-balance estimate is more likely to be low because of the assumption that precipitation is the only source of chloride in the recharge waters. Chloride-laden dust blown into the recharge-source areas from playas of the Black Rock Desert to the west may account for the relatively high concentration of chloride in the recharge water. Dettinger (1989) reports that chloride concentration in bulk-precipitation may be as high as 0.9 mg/L, which suggests that a larger recharge estimate could therefore be obtained due to dry fall-out of additional chloride. If an average chloride concentration of 6.6 mg/L, as reported by Malmberg and Worts (1966) from three streams sampled in the northern Bilk Creek Mountains (pl. 1*A*) is used to represent typical chloride concentrations in recharge waters, an estimate of 6,600 acre-ft/yr is calculated. These samples were taken during base-flow conditions (September) from streams that drain predominantly east-facing slopes similar to sites 35 and 36 of this study. The Bilk Creek Mountains are the northern extension of the Jackson Mountains and make up the western boundary of Kings River Valley. However, they are a considerable distance north of the Black Rock Desert and probably receive less blowing dust.

Estimates of Recharge Through Active Sand Dunes

The methods previously discussed for estimating ground-water recharge assumed an altitude below which precipitation does not contribute to the ground-water reservoir. An altitude of 5,000 ft was assumed to be the "cutoff" altitude used in the recharge estimates, which corresponds to an average annual precipitation of less than 8 in. and generally includes the entire valley floor. Because of the high evapotranspiration rates and low amounts of precipitation associated with valley floors in arid areas, annual precipitation is mostly consumed by vegetation and evaporation, resulting in negligible quantities of ground-water recharge. However, studies in other arid to semiarid areas have documented the potential for ground-water recharge to occur through sparsely or unvegetated sandy environments, such as dune fields (Allison and others, 1985; Stephens and Knowlton, 1986).

A deep percolation model (DPM), developed by Bauer and Vaccaro (1987), was used to estimate potential recharge through about 12,000 acres of valley floor in the south-central part of the study area covered by active sand dunes (Berger, 1992). The model used daily climatic data collected from the nearest weather station (Winnemucca) and soil characteristics, vegetative cover, and land use typical of the modeled region. Long-term estimates of deep percolation (recharge) are determined as the difference between precipitation and the sum of evapotranspiration and surface-water runoff simulated at the site by the DPM.

The results of the DPM indicate that ground water may recharge through unvegetated sand dunes within the study area during each month of a given year; however, the maximum rates are during December through February. Estimated recharge rates calculated by the DPM range between 0.04 and 0.11 ft/yr. Applying these rates to the area of the dune field results in an estimated range of about 500-1,000 acre-ft/yr of ground-water recharge. The observed ground-water divide in the south-central part of the valley may be produced in part by the dune field acting as a conduit for ground-water recharge.

GROUND-WATER DISCHARGE BY EVAPOTRANSPIRATION

Ground-water discharge by evapotranspiration includes losses by bare-soil evaporation and transpiration by native vegetation. In areas where the water table is only a few feet below land surface, ground water can discharge through direct evaporation. In clayey soils, typical of those in the study area, ground water can evaporate directly from the water table from a depth of almost 8 ft (Lee, 1912, p. 53). Native vegetation that grows in areas where the water table or the capillary fringe above the water table lies within reach of their roots, and thus provides a perennial source of water, are called phreatophytes (Meinzer, 1927, p. 1). Phreatophytic vegetation has been documented to consume large quantities of ground water in several sparsely vegetated basins in Nevada (Huxel and others, 1966, p. 28; Malmberg and Worts, 1966, p. 29; Harrill and Moore, 1970, p. 66; Thomas and others, 1989a, table 8). In Desert Valley, the principal phreatophyte is greasewood, which grows randomly in areas on the valley floor where the depth to water is less than about 35 ft.

The distribution and density of phreatophyte communities in Desert Valley were determined by incorporating Landsat remotely sensed satellite data with field observations. Landsat Multispectral Scanner (MSS) data from August 19, 1988, was used to map general land-cover classes on the basis of spectral-pattern recognition. The land-cover classifications that related to potential evapotranspiration zones were then compared with previous phreatophyte-distribution maps of Zones (1963, pl. 1) and Huxel and others (1966, pl. 3) and field notes made during the course of this study. Of approximately 70,000 acres of phreatophyte vegetation identified on the valley floor (fig. 12), about half the area consists primarily of low-density greasewood (plant cover, about 12 percent) and the other half consists primarily of sparse greasewood mounds (plant cover, about 5 percent). About 1,600 acres, in the northern part of the study area, were identified as bare soil where the depth to water is less than 8 ft. The area of phreatophytes outside the modeled area is assumed to be negligible.

In an effort to determine evapotranspiration for different greasewood densities, micrometeorological instruments commonly used to measure and calculate an energy budget were placed in a field-study site in the northern part of the study area (Nichols, 1992). The site, in a sparsely vegetated area approximately 100 ft west of site 43 (fig. 12, pl. 1*C*), was occupied June 6 through June 17, 1991. Data collection consisted of measurements of temperature and vapor pressure of the air at two heights above the vegetation canopy, incident and reflected short-wave radiation, incident and emitted long-wave radiation, soil heat flux, and soil temperature. The data were used to estimate evapotranspiration rates using the Bowen-ratio method (Tanner, 1960). The Bowen-ratio method estimates actual evapotranspiration, is based on the energy balance, and is dependent on temperature and humidity gradients (Gay and Fritschen, 1979; Van Hylckama, 1980). Data from similar field-study sites, together with the results from this study, were used to generate evapotranspiration rates as a function of plant-cover density and depth to water (W.D. Nichols, U.S. Geological Survey, written commun., 1992). Assuming an average depth to water of about 20 ft beneath areas identified as vegetated by phreatophytes, the evapotranspiration rate for low-density cover is estimated to be about 0.17 ft/yr. The evapotranspiration rate for sparse greasewood mounds was estimated to be about 0.07 ft/yr. Evaporation rates for bare soil having an average depth to water of about 5 ft is estimated to be about 1.1 ft/yr (W.D. Nichols, written commun., 1992). Applying these rates to the acreage of identified phreatophytes and bare soil gives an estimated 10,000 acre-ft annually consumed by evapotranspiration in Desert Valley.

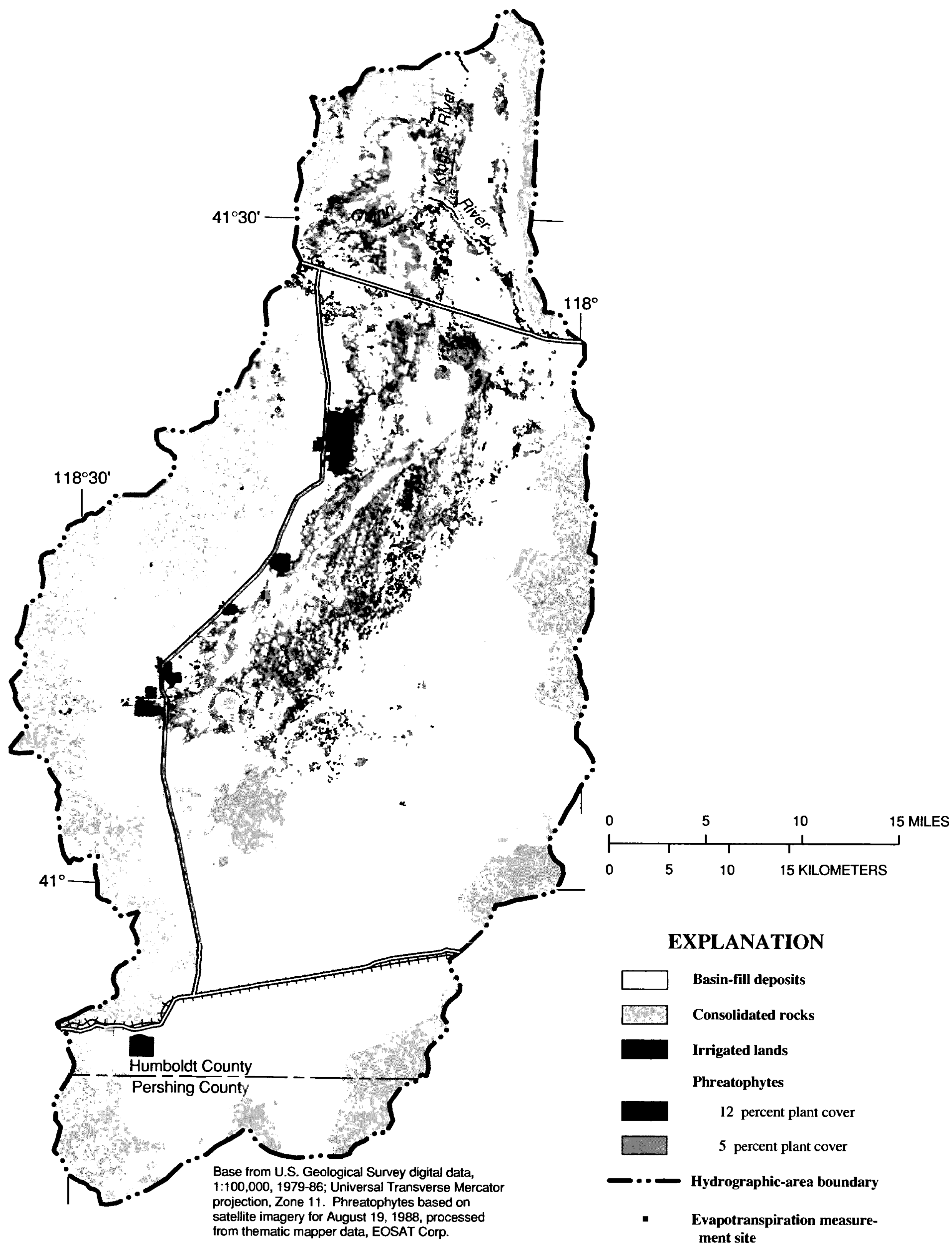


Figure 12. Distribution of phreatophytes in August 1988 and irrigated land for 1981-91, Desert Valley, Nevada

PREDEVELOPMENT GROUND-WATER BUDGET

Estimates of ground-water inflow and outflow for the study area under predevelopment conditions (pre-1962) are summarized in table 9. Ground-water withdrawals prior to 1962 are considered negligible and were not included in the predevelopment budget. In addition, surface-water diversions from major streams issuing from the Jackson Mountains, which began many years ago, are assumed to have only a slight effect on the balance of the hydrologic system and are not considered in the budget. Estimates of individual budget components, as discussed in preceding sections, are presented as a range representing minimum and maximum quantities. The long-term average is assumed to fall within the given range. Those components listed as a single value are considered to represent the long-term annual average. The water budget reflects natural (steady-state) conditions that are assumed to have existed before human development began in the area. Ground-water inflow and outflow are assumed equal under these conditions; however, each independently estimated component of the budget is subject to some uncertainty.

Recharge from precipitation in the mountains accounts for most of the ground-water inflow to the study area. Ground-water discharge by evapotranspiration accounts for more than 75 percent of the outflow. The distribution of phreatophytic vegetation determined from Landsat Multispectral Scanner data for August 1988 and recent field observations may be somewhat different than under predevelopment conditions, due to changes in depth to water since development began. The most uncertain components of the predevelopment water budget are the quantities of infiltration from rivers and subsurface outflow to the southwest. The ground-water flow model, discussed in the following sections of this report, was used to help quantify these components and select values representing the average annual predevelopment ground-water inflow and outflow for the study area.

Table 9. Estimated ground-water budget for predevelopment conditions (pre-1962), Desert Valley, Nevada

[All values in acre-feet per year]

Budget component	Estimated predevelopment conditions
Inflow	
Recharge from precipitation:	
From mountain block (p. 33, p. 34)	3,300 - 6,800
From sand dunes (p. 35)	500 - 1,000
Infiltration from rivers (p. 19)	700 - 4,700
Subsurface inflow:	
From Kings River Valley (p. 16)	900
From Quinn River Valley (p. 16)	300
Total inflow (rounded)	5,700 - 14,000
Outflow	
Evapotranspiration (p. 35)	10,000
Subsurface outflow:	
To Pine Valley (p. 19)	100 - 400
To Southwest (p. 19)	120 - 1,200
Total outflow (rounded)	10,000 - 12,000

GROUND-WATER DEVELOPMENT

Prior to open-pit mine dewatering in 1985, ground-water withdrawals were primarily for crop irrigation, with lesser amounts for domestic use and livestock watering. Prior to 1962, ground-water pumpage in the entire valley was about 700 acre-ft/yr and was assumed to have only a slight effect on the basin-fill aquifer system in Desert Valley (Sinclair, 1962b, p. 10). About 400-500 acre-ft/yr was pumped to supplement streamflow from the Jackson Mountains along the west side of the valley near the Bottle Creek Ranch area. As a result of extensive interviews with many long-time Desert Valley residents, a fairly detailed account of the agricultural history of the valley was compiled for the period 1962-91 and is summarized in the following paragraphs. Table 10 lists the estimated acreage of irrigated land and estimates of the gross and net ground-water pumpage for irrigation over the 30-yr period.

Table 10. Estimated irrigated acreage and ground-water pumpage, Desert Valley, Nevada, 1962-91

Year	Estimated irrigated land (acres)	Estimated ground-water pumpage (acre-feet)		
		Irrigation		Mine dewatering[1] (reported gross pumpage)
		Gross	Net[2]	
1962	2,100	3,700	2,600	
1963	2,100	3,700	2,600	
1964	2,100	3,700	2,600	
1965	2,600	5,200	3,500	
1966	2,600	5,200	3,500	
1967	3,000	6,500	4,200	
1968	3,000	6,500	4,200	
1969	3,000	6,500	4,200	
1970	3,000	6,500	4,200	
1971	3,000	6,500	4,200	
1972	3,000	6,500	4,200	
1973	3,500	8,000	5,100	
1974	3,500	8,000	5,100	
1975	6,400	18,000	11,000	
1976	6,400	18,000	11,000	
1977	6,400	18,000	11,000	
1978	6,400	18,000	11,000	
1979	6,400	18,000	11,000	
1980	5,300	15,000	8,800	
1981	5,300	15,000	8,800	
1982	5,300	15,000	8,800	
1983	5,300	15,000	8,800	
1984	5,300	15,000	8,800	
1985	5,600	15,000	8,700	2,100
1986	5,400	15,000	8,700	6,200
1987	5,700	15,000	8,900	8,100
1988	5,200	13,000	8,000	14,000
1989	4,900	13,000	7,600	15,000
1990	5,100	13,000	7,900	22,000
1991	5,500	14,000	8,600	23,000

[1] Mine dewatering did not begin until 1985; data from Nevada Gold Mining, Inc., written commun., 1992.

[2] Net pumpage estimated as 60 percent of gross pumpage.

During the period 1962-74, an average of about 2,900 acres were irrigated annually in four general areas along the west side of the valley floor and southwest of Jungo. From 1975 to about 1980, the area of irrigated land increased to an annual average of about 6,400 acres, mostly because of an increase of nearly 2,000 irrigated acres in the southeastern part of the valley. By 1980, the farmed area in the southeast was abandoned and the annual irrigated area had decreased to 5,300 acres and has remained at about that level through 1991. The general distribution of irrigated land for the period 1981-91 is shown in figure 12.

Estimates of ground-water pumpage for irrigation were made on the basis of the distribution of irrigated land, number of irrigation wells, percent of surface-water supplement, and cultivation practices during the years 1962-91. Most of the pumped water is consumed by evapotranspiration; however, some infiltrates beyond the plant-root systems and recharges the aquifer. The net pumpage, which is that amount of ground water completely removed from the system, is estimated to be about 60 percent of the gross pumpage (Thomasson and others, 1960, p. 235; Cohen and others, 1963, p. 93; and Harrill and Moore, 1970, p. 10). Over the period 1962-74, annual net pumpage increased from about 2,600 acre-ft to about 5,100 acre-ft and averaged about 3,900 acre-ft. Because the increased acreage in the southeastern part of the valley was irrigated solely by ground water during the period 1975-80, estimates of annual net pumpage were nearly 11,000 acre-ft. In 1980, net ground-water withdrawals for irrigation decreased to about 8,800 acre-ft, and since 1985 have averaged about 8,300 acre-ft annually.

Reported gross pumpage at the Sleeper Mine for the years 1985 through 1991 is shown in table 10 (Nevada Gold Mining, Inc., written commun., 1992). During this 7-year period, total ground-water withdrawals at the mine were about 90,000 acre-ft. About 2-3 percent of the total pumped water from the dewatering operation is consumed at the site for mining, milling, and domestic uses (Nevada Gold Mining, Inc., written commun., 1992). All the water removed from the site was channeled to a discharge area on the valley floor northwest of the mine where the ponded water created an artificial wetlands. On the basis of MSS data collected in August 1988, the wetlands covered about 1,400 acres. The average depth of water in the wetlands was about 1.5 ft (Nevada Gold Mining, Inc., written commun., 1991). An estimated 8,000 acre-ft, or about 59 percent of the total 13,600 acre-ft channeled to the wetlands during 1988, infiltrated to the ground-water system and nearly 4,700 acre-ft was lost by direct evaporation. About 900 acre-ft is estimated to have remained within the wetlands area at the end of 1988. Due to the proximity of the wetlands to pumping influences created at the mine, the potential for recirculation of infiltration from the wetlands back into the dewatering well field became a concern. As a result, a new artificial wetlands area, farther west of the dewatering operations, was created in 1991 (pl. 1*A*). The new wetlands are part of the Sleeper Mine Temporary Wetlands Enhancement Project and are managed in cooperation with the Nevada Department of Wildlife and the Bureau of Land Management. The total area covered by the new wetlands project is about 4,700 acres and incorporates the initial wetlands area.

Water-Level Changes

Water-level contours used to determine present-day (1991) conditions were constructed from measurements collected during the Spring of 1991 (pl. 1*E*). Additional control was provided by eight measurements made in 1990 and two made in 1989. Water-level measurements used to construct contours within the influence of the dewatering operation at the Sleeper Mine, including those adjacent to the wetlands, were made during the same time period in 1991. Depths to water below land surface are also shown on plate 1*E*.

The general distribution of net declines in ground-water levels between predevelopment and present-day (1991) conditions was determined by comparing the difference between lines of equal water levels constructed from measurements made during the late 1950's to early 1960's (predevelopment) and Spring 1991 (figure 13). The measured differences at 38 wells for the same period also are shown in figure 13. Three wells measured in 1961, sites 68, 73, and 122 (table 15), have since been destroyed; however, water levels in nearby sites 69, 74, and 121 were used to estimate the water-level differences in those areas. In general, ground-water levels measured during Spring 1991 are lower than those representing predevelopment conditions. Water-level declines are less than 5 ft throughout the south-central part of the valley in areas generally unaffected by substantial ground-water withdrawals. These declines may show the magnitude of effect caused by the trend of below-average precipitation over the last several years. Declines greater than 10 ft are observed just north of the study-area boundary in the area of site 42; in the southwest, near sites 122 and 124; in the northeast part near the dewatering operation; and along the western margin of the valley floor near irrigation pumping centers (sites 85, 91, and 100). Water-level declines near site 42 are probably a result of continued irrigation pumping in the Rio King subarea to the north (Malmberg and Worts, 1960, p. 41-42). Maximum water-level declines beneath the open pits at the Sleeper Mine, as of Spring 1991, range from 295 to 315 ft (Nevada Gold Mining, Inc., written commun., 1992). Elevated ground-water levels beneath and adjacent to the discharge area have produced net declines of less than 5 ft since predevelopment.

Hydraulic-head measurements from two piezometers that are separated and screened at different depths within the same well were used to indicate the vertical direction of ground-water flow. Hydrographs of water levels for wells OH-50 (sites 60 and 61) and OH-49 (sites 80 and 81) are presented in figure 14. Well OH-50 has one piezometer (site 60) perforated between 150 and 200 ft below land surface, and another piezometer (site 61) perforated between 630 and 680 ft below land surface (Nevada Gold Mining, Inc., written commun., 1989). Water-level measurements made at sites 60 and 61 (pl. 1*C*), during the later part of 1989 through 1990, indicate an upward ground-water gradient between 200 and 630 ft below land surface (fig. 14). This well (OH-50) is north of the new wetlands area. Early in 1991, the vertical gradient reversed, indicating downward movement of ground water. This change in direction appears to correspond with the relocation of the wetlands and the resulting increase in recharge to the ground-water system. Well OH-49 (sites 80 and 81; pl. 1*C*) is adjacent to the initial discharge lake. The well casing at site 80 is perforated between 70 and 90 ft below land surface and at site 81 is perforated between 325 and 490 ft below land surface. Hydrographs of water levels at these sites indicate downward ground-water flow with the vertical gradient increasing with time. The water level in site 80 is rising in response to infiltrating water from the initial discharge lake, whereas water levels measured in site 81 show a declining trend. The declining trend is a result of the dewatering operation at the mine, which is affecting the deeper part of the basin-fill aquifer in the immediate area.

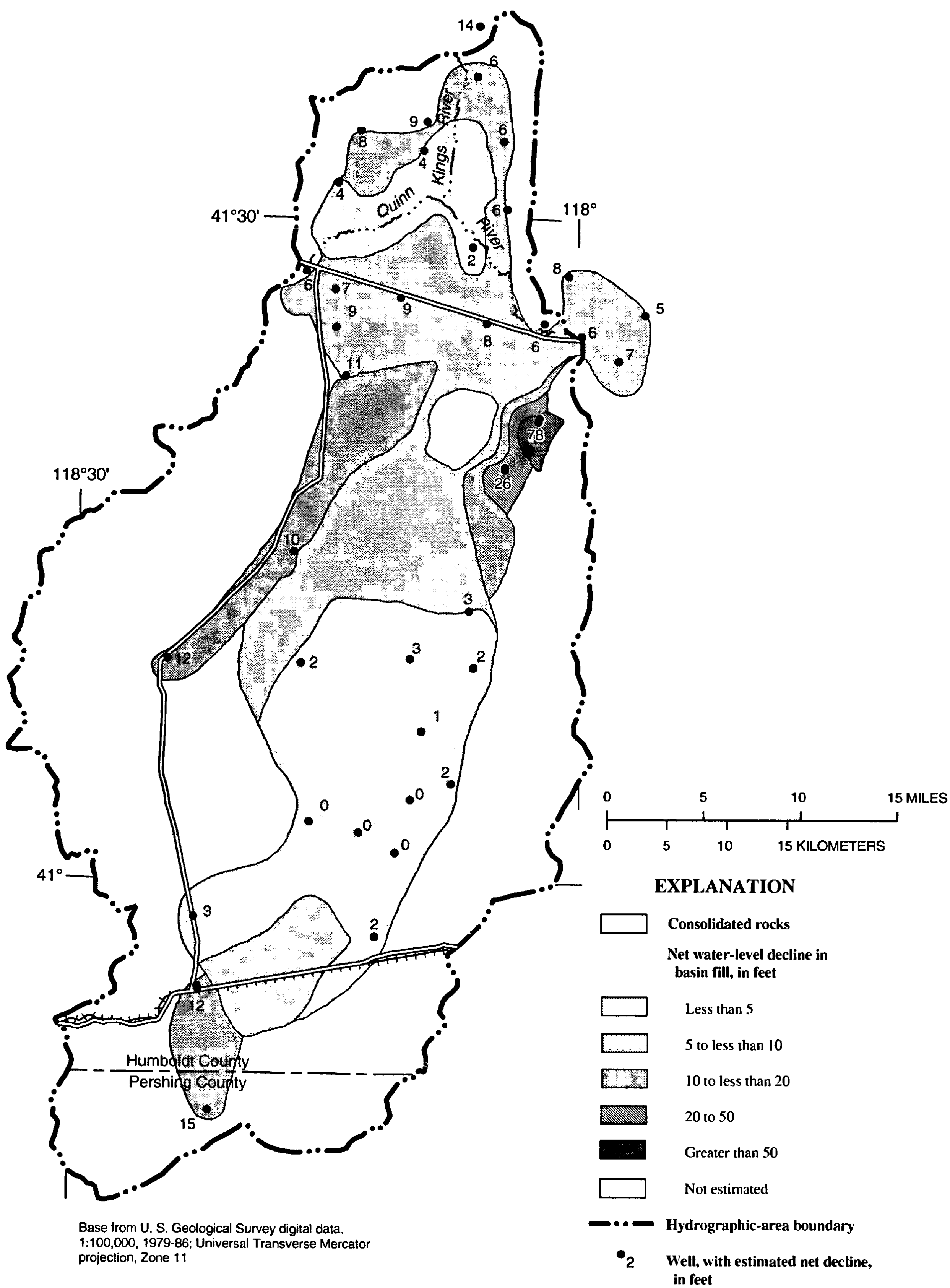


Figure 13. General distribution of estimated net declines in ground-water levels from predevelopment through Spring 1991, Desert Valley, Nevada.

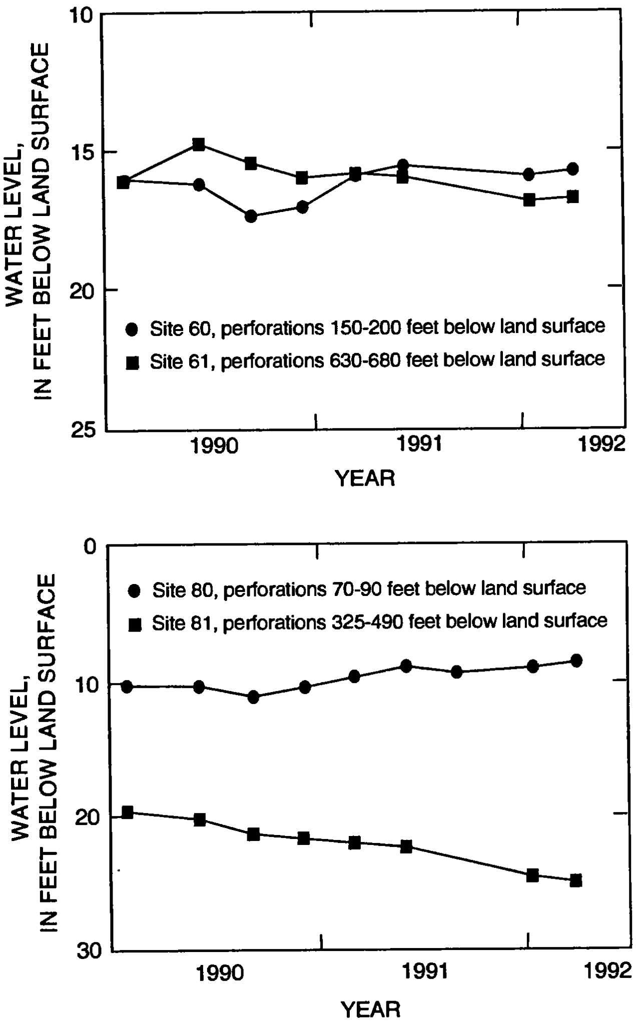


Figure 14. Water levels for wells OH-50 and OH-49 at sites 60, 61, 80, and 81, 1990-92, Desert Valley, Nevada.

Changes in the ground-water flow regime between predevelopment and present day are observed mainly in areas affected by the pit dewatering at the Sleeper Mine. Water-level contours for Spring 1991 (pl. 1*E*) suggest that some subsurface flow entering Desert Valley from Quinn River Valley is captured by wells at the mine. The general shape of the dewatering cone, created by pumping at the mine, is elongated with the long axis trending just west of north. The cone is bounded by the impermeable Slumbering Hills to the east and the wetlands area to the west. Water infiltrating beneath the wetlands has produced a ground-water divide between the Sleeper Mine and the area to the west. In addition, the Spring 1991 water-level contours also suggest that subsurface flow continues to exit the basin to the southwest. The broad ground-water divide, originally northeast of the Jungo Hills during predevelopment conditions, has migrated southward and has become somewhat more defined.

Changes in Water Quality

Changes in water quality between predevelopment and present-day conditions were determined by comparing data from six wells (sites 53, 86, 88, 100, 102, and 119; locations shown on pl. 1*F*) sampled before 1962 and again in 1990. Samples were taken at three depth intervals in 1960 by Sinclair (1962b) at site 100 and were averaged for comparison to the present-day integrated analysis. The three major water types reported by Sinclair—calcium bicarbonate, sodium bicarbonate, and sodium chloride—had a similar distribution in the basin-fill aquifer during the present study.

Present-day analyses (1990) indicate that the concentration of major ionic species has generally increased since predevelopment time at three of the six resampled sites (sites 86, 100, and 119; table 6). Results of analyses for site 119 exhibit the largest increase in total dissolved solids (about a three-fold increase), and magnesium has replaced sodium as the dominant cation. Major ion concentrations at sites 88 and 102 are nearly the same in 1990 as in 1961. Boron concentrations have decreased in samples from sites 88, 100, 102, and 119 since 1961; however, concentrations still remain above the aquatic-life criteria in all resampled sites except those from site 100.

HYDROLOGIC SIMULATIONS USING A GROUND-WATER FLOW MODEL

Flow-Model Development

A mathematical ground-water flow model was developed to simulate predevelopment conditions and used to evaluate the response of the basin-fill aquifer to ground-water development in Desert Valley. The flow model provides a means to test the conceptual model of the hydrologic system developed during this study and to estimate effects of hypothetical future ground-water development. Calibration of the flow model was done by matching simulated and measured water levels representing pre-1962 conditions and simulating water-level declines due to estimated ground-water pumpage from 1962 to 1991. Probable long-term effects of hypothetical ground-water withdrawals were then evaluated using the calibrated flow model.

The accuracy with which the flow model simulates an actual ground-water system depends on how well the hydrologic processes of the system are understood and then simulated. The quality and distribution of the input data used to describe these processes are the determining factors that limit the model in simulating the actual system. A ground-water flow model is not necessarily a unique representation of a flow system; however, by using reasonable hydraulic properties and boundary conditions, the flow model can closely simulate the natural flow system of the study area.

Mathematical Basis

The numerical technique used in this study to analyze ground-water flow and yield of the aquifer system is a finite-difference ground-water flow model written by McDonald and Harbaugh (1988). The model solves the three-dimensional equation of ground-water flow by using finite-difference approximations; the equation can be written as follows:

$$d/dx\,(K_{xx}dh/dx) + d/dy\,(K_{yy}dh/dy) + d/dz\,(K_{zz}dh/dz) - W = S_s dh/dt \quad ,$$

where K_{xx}, K_{yy} are hydraulic conductivities in the principal horizontal directions (in length per time),

K_{zz} is hydraulic conductivity in the vertical direction (in length per time),

h is hydraulic head (in length),

W is volumetric flux of recharge or discharge per unit volume (in time^{-1}),

S_s is specific storage (in length^{-1}),

t is time, and

x, y, z are Cartesian coordinates aligned along the major axes of hydraulic conductivity.

The finite-difference method is used to obtain approximate solutions to the three-dimensional flow equation by replacing the continuous partial derivatives with systems of simultaneous algebraic difference equations. The difference equations are then solved in terms of the unknown hydraulic head at discrete points, or nodes, and time. The strongly implicit procedure (McDonald and Harbaugh, 1988, p. 12-1) was used to solve the system of difference equations by iteration. Solution for each node is achieved when the head change between each iteration is less than a specified value. The value specified for the model simulations for Desert Valley was 0.001 ft. Each node is centered in a model cell that has dimensions of x, y, and z. Hydraulic properties within each cell are assumed to be homogeneous, so that the model-derived hydraulic head represents the average head over the entire cell.

General Features of the Model

To translate the conceptual model of the hydrologic system to the mathematical flow model and solve the ground-water flow equation by finite differences, a block-centered grid was superimposed over a map view of the study area. The grid is used to divide the basin-fill aquifer into discrete model cells and layers. A diagrammatic representation, shown in figure 15, illustrates the model's representation of the aquifer system and its relation to the conceptualization of the flow model.

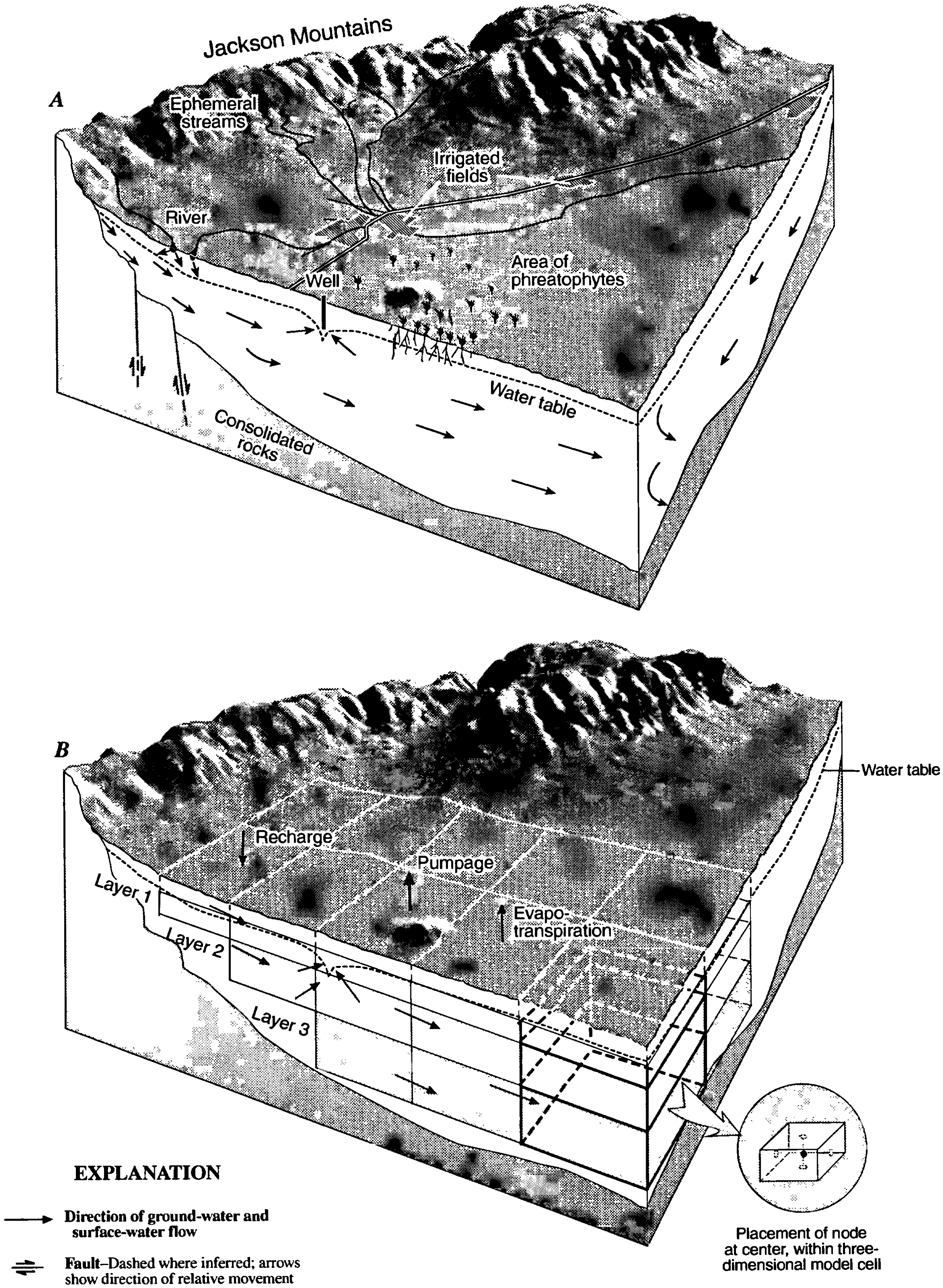


Figure 15. Three-dimensional conceptualization of ***(A)*** basin-fill aquifer and ***(B)*** computer model of aquifer, Desert Valley, Nevada.

The model grid used in this study contains 26 columns, 58 rows, and three layers. The grid is oriented so that a minimum number of cells are outside the modeled region (fig. 16). The grid lies parallel to the general direction of ground-water flow and each cell has horizontal dimensions of 1 mi on a side. The grid consists of 746 active cells in layers 1 and 2 and 207 active cells in layer 3. Processes of evapotranspiration, recharge from precipitation, and the interaction between surface water and ground water were simulated within layer 1. The top 100 ft of saturated basin fill is generally unconfined and is represented by layer 1. The middle layer (layer 2) has a maximum thickness of 500 ft and is present wherever the saturated basin-fill deposits exceed 100 ft. Ground-water discharge by wells and subsurface flows in and out of the basin-fill aquifer are simulated in both layers 1 and 2. Because of the complex interbedded nature of the basin-fill deposits determined from a limited number of drillers' logs, thicknesses were arbitrarily assigned to layers 1 and 2. Pumping stresses assigned during simulations of water-resources development were distributed between layers 1 and 2 on the basis of available data on depth of the screened intervals in pumping wells. Layer 3 represents the zone that extends from 600 ft below the water table to consolidated rock. Only a few wells, mainly near the Sleeper Mine, penetrate this interval, and the layer is used primarily to account for stored water and deep ground-water flow. Layer 2 was simulated by the model as a confined aquifer, but is allowed to convert to unconfined conditions if water levels drop below the bottom of layer 1 due to pumping. Layer 3 was treated as a confined aquifer.

Boundary Conditions

The ground-water flow equation applied in the flow model has an infinite number of solutions. To develop a more basin-specific model, additional information about the conditions at the boundary of the flow system was required. Boundary conditions were specified in the model on the basis of ground-water-flow concepts developed during this study. Model cells that represent basin-fill deposits were designated as active, whereas inactive cells were used to represent less-permeable consolidated rock. The boundary between active and inactive cells represents the model boundary, as illustrated in figure 16.

No-flow and head-dependent flow boundaries were used in the model to simulate flow conditions along the periphery of the basin. Lateral and vertical boundaries between the basin fill and consolidated rock, where ground-water flow is assumed to be negligible, were specified as no-flow boundaries. The alluvial divides in the southern part of the study area represent ground-water divides and were also simulated as no-flow boundaries.

Head-dependent flow boundaries were used to simulate subsurface inflow from the Kings River and Quinn River Valleys, and subsurface outflow to Pine Valley and the southwest in the vicinity of the northern Antelope Range (fig. 1, fig. 16). Inflow and outflow conditions were simulated in layers 1 and 2 at head-dependent flow boundaries by extending external cells beyond the modeled region and assigning head values to those cells. A conductance term provides the link between the source and external cell and is a function of the cross-sectional area of the cell perpendicular to ground-water flow and the horizontal hydraulic conductivity of the basin fill at the boundary. The assigned heads for the three areas simulated as head-dependent flow boundaries in the northern part of the study area represent water levels measured during the early 1960's. The values used for the external heads in the southwestern part were specified on the basis of the estimated hydraulic gradient in the area during predevelopment time.

Recharge was simulated in layer 1 as constant-flow boundaries in active cells along the edge of the model grid. Figure 17 shows the distribution and rate of recharge used in the model simulations. The volume of recharge simulated in the model was calculated by using the rates for each cell, as shown in figure 17, and multiplying by cell area. Not all cells along this boundary receive recharge. The amount of recharge introduced to each cell depends on its position adjacent to a particular recharge-source area. The distribution of recharge was determined for each drainage recharge source area on the basis of the Maxey-Eakin method, as previously discussed. Model cells superimposed over the area of active sand dunes (fig. 1) were also treated as constant-flow cells. Recharge was distributed to these cells on the basis of the results from the DPM.

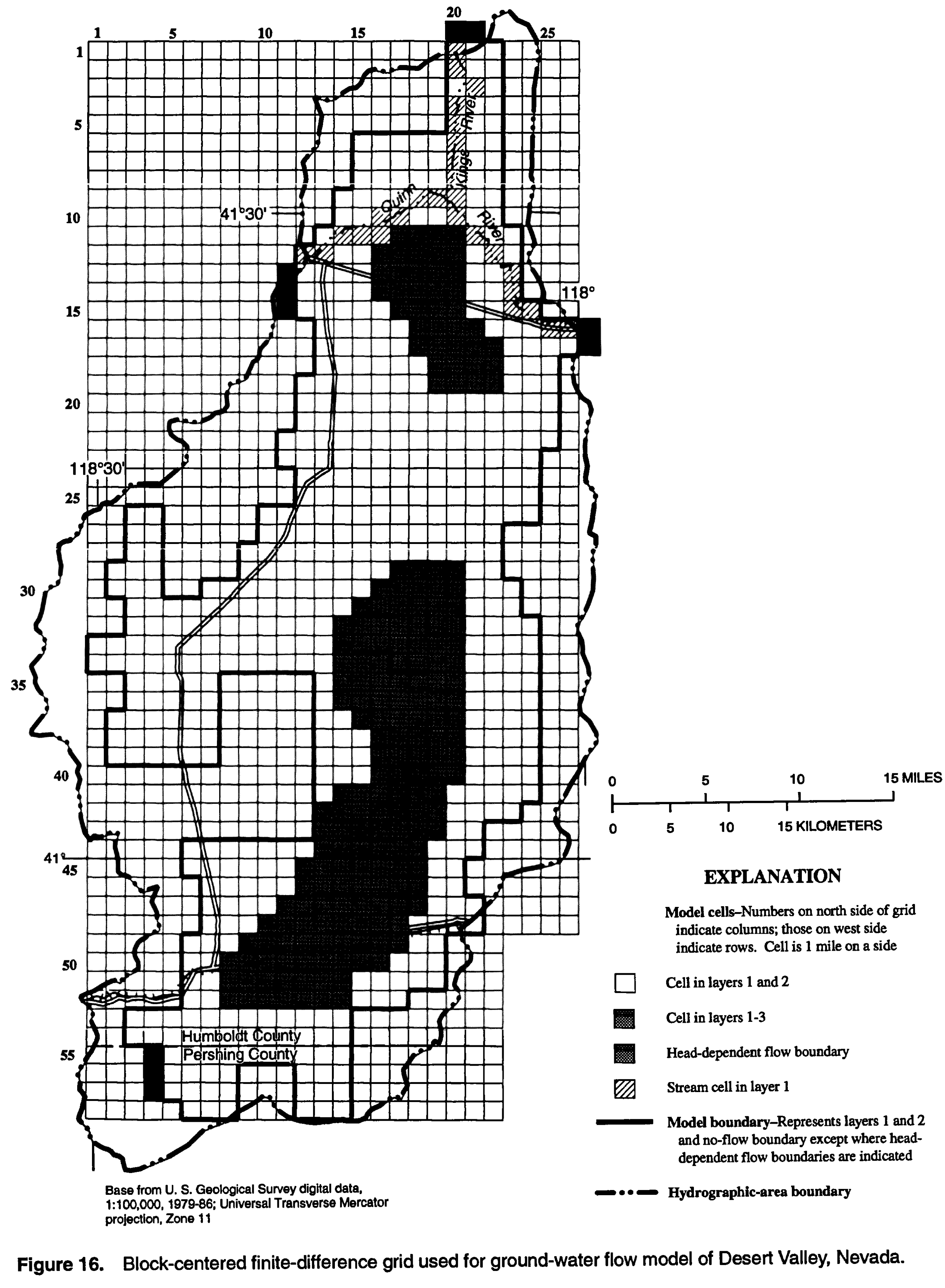


Figure 16. Block-centered finite-difference grid used for ground-water flow model of Desert Valley, Nevada.

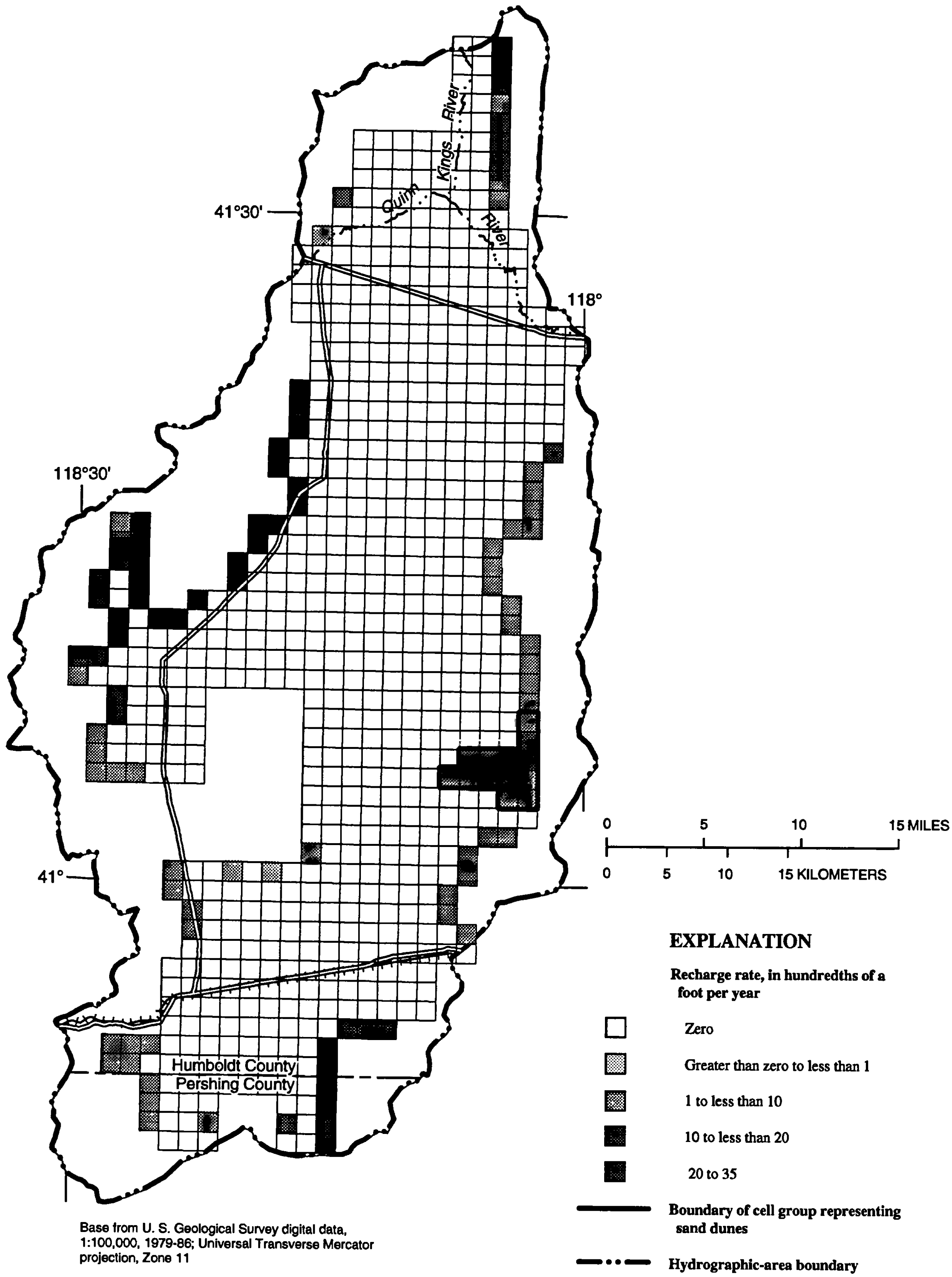


Figure 17. Distribution of model cells used to simulate recharge, and annual recharge rates used in simulation, Desert Valley, Nevada.

Interactions between surface water and ground water, including the infiltration beneath the Sleeper Mine wetlands and associated canals, which will be discussed in the section titled "Changes in Flow-Boundary Conditions," were evaluated in the model using a program to simulate stream-aquifer relations written by Prudic (1989). This computer program is a modification of the River Package described by McDonald and Harbaugh (1988, p. 6-1) and can be used in their ground-water flow model. The Quinn and Kings Rivers were simulated using 27 cells in layer 1 of the model grid (fig. 16). Leakage in or out of each cell is calculated on the basis of the head difference between the stream and aquifer in that cell and a conductance value.

Ground-water discharge by evapotranspiration was specified in layer 1 of the flow model as a head-dependent flow boundary. Evapotranspiration was simulated as a linear function of depth, and was computed from a maximum rate at land surface to the extinction depth at which evapotranspiration is assumed to cease. The model grid was digitally superimposed on the land-cover distribution shown in figure 12, and the percentage of plant cover and bare soil area was determined for each cell. In areas simulated to have evapotranspiration, the depth to water was generally 35 ft or less. Because water levels are generally several feet below the land surface, the maximum evapotranspiration rate at the surface is based on a linear extrapolation from rates at the depths where shrubs commonly are obtaining water. The maximum evapotranspiration rate assigned to each cell was then calculated on the basis of the percentage of area covered by the two different plant densities and bare soil in each cell. The distribution of cells specified to have ground-water discharge from evapotranspiration, and the maximum evapotranspiration rates simulated by the model, are shown in figure 18. Maximum evapotranspiration rates used in this report are those compiled from field studies for this project and other areas of the Great Basin by W.D. Nichols (U.S. Geological Survey, written commun., 1992): 0.38 ft/yr for low-density greasewood cover, 0.16 ft/yr for sparse greasewood mounds, and 2.5 ft/yr for bare soil. Extinction depths used were 35 ft and 8 ft for phreatophytes and bare soil, respectively.

Initial Conditions and Aquifer Properties

Prior to 1962, the ground-water system in Desert Valley was in a state of dynamic equilibrium (steady state), the long-term averages for recharge and discharge were balanced, and change in storage was negligible. Ground-water levels shown on plate *1D* for predevelopment are considered to represent steady-state conditions, and were used as initial water levels for model-layer 1. Analyses of limited water-level data suggest that only small vertical gradients existed during predevelopment time; consequently, the initial head distribution for model-layer 2 was assumed to be the same as for model-layer 1. Results of water-level measurements made at sites 60 and 61 (table 15) in 1990 suggest that the potential for upward vertical flow exists; however, it is not known if this condition was present during predevelopment time. No water-level data were available for model-layer 3 during predevelopment time, so water levels in this layer were also set equal to those in model-layer 1.

The initial distribution of transmissivity for the three layers was estimated as the product of the thickness of that layer and a hydraulic-conductivity value. The average thicknesses of saturated basin fill represented by layers 1 and 2 are 100 and 500 ft, respectively. Thickness values assigned to layer 3 varied according to the distance between the bottom of layer 2 and consolidated rock. Horizontal hydraulic-conductivity values for layers 1 and 2 were estimated from the distribution shown in figure 6. A similar distribution of horizontal hydraulic conductivity was assumed for layer 3, but values were decreased 50 percent for every 1,200 ft of depth to account for overburden pressure. During development simulations, transmissivity values in layers 1 and 2 were recalculated by the model to account for changes in the saturated thickness due to ground-water withdrawal. Transmissivity values for layer 3 were held constant.

Vertical flow between layers was simulated as an equivalent leakance term representing numerous discontinuous lenses of fine-grained deposits within the basin fill. Leakance, as defined by Lohman (1972, p. 30), is the ratio of vertical hydraulic conductivity of the confining beds to the thickness. Leakance was estimated from the distribution of vertical hydraulic conductivity, shown in figure 7, divided by the vertical distance to the centers of adjacent model layers. Initial values of leakance specified in the model did not need adjustment during calibration to obtain a best fit.

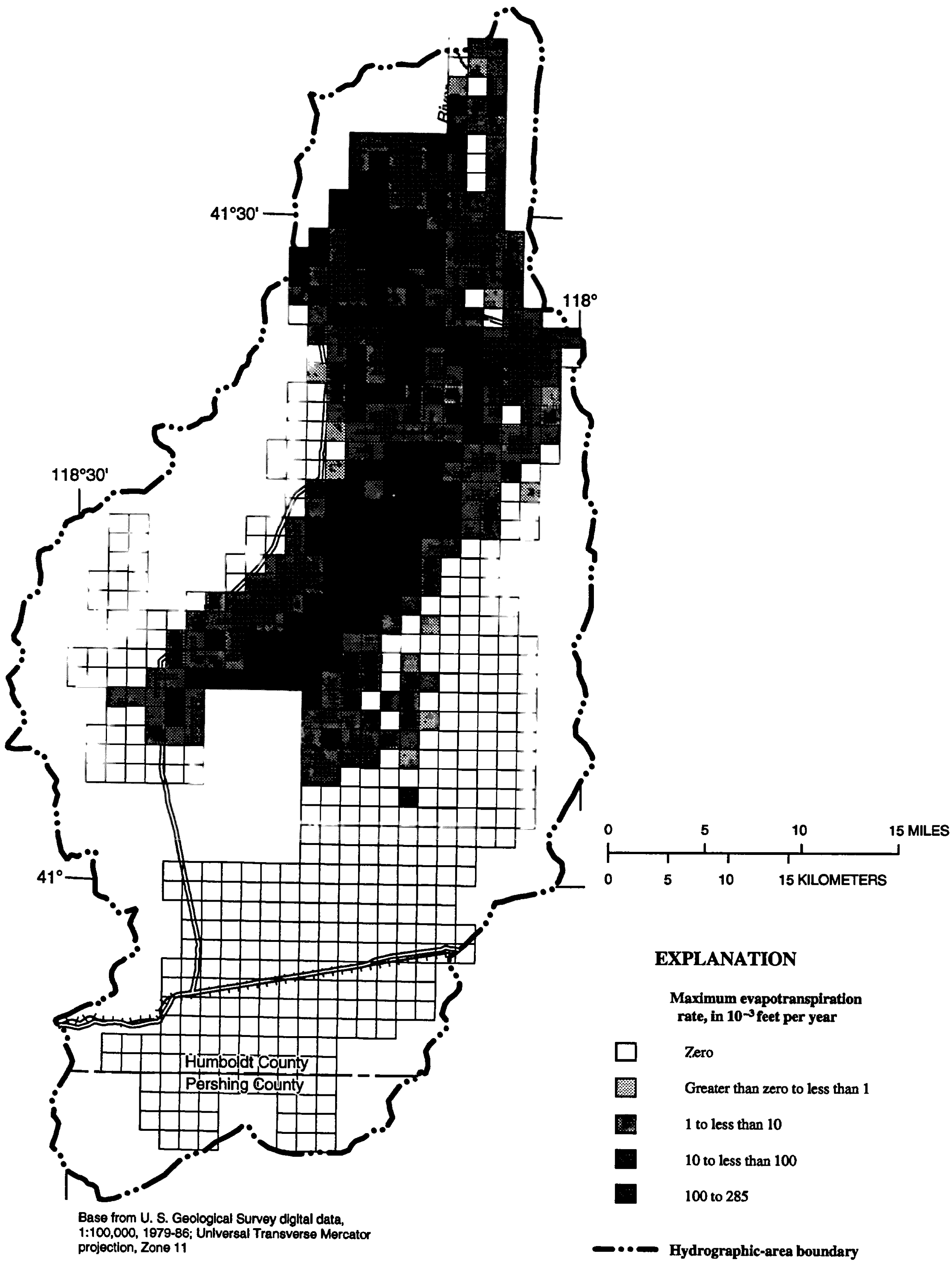


Figure 18. Distribution of model cells used to simulate evapotranspiration, and maximum evapotranspiration rates used in simulation, Desert Valley, Nevada.

Specific yields shown in figure 8 were used as the initial storage values for layer 1. Because layer 2 has the potential to go from confined to unconfined conditions during pumping, both storage-coefficient and specific-yield values were added to the flow model for layer 2. The specific-yield values used for layer 1 were also used as initial storage values for layer 2 during unconfined conditions. For confined conditions in layers 2 and 3, storage coefficients were estimated by using the approximate relation given by Lohman (1972, p. 9), multiplied by cell thickness. Storage values are required data for development (transient) simulations and are not needed for simulations of predevelopment conditions (steady state).

Simulation of Predevelopment Conditions

The predevelopment ground-water flow model was constructed by incorporating the previously discussed boundary and initial conditions that describe the hydrologic system in Desert Valley before the onset of significant ground-water development. The simulation of predevelopment conditions provides a base-line flow model that was used as initial input for simulations of ground-water development for the period of 1962-91.

Calibration and Results

Calibration of the predevelopment flow model was based on the relation between simulated and measured or estimated head values, subsurface inflow and outflow, discharge by evapotranspiration, and Quinn River outflow to Pine Valley. The model was considered calibrated when:

1. mean absolute departure of simulated heads from measured heads and the associated standard deviation were minimal for 35 model cells containing wells (see next paragraph),
2. simulated subsurface inflow and outflow at the head-dependent flow boundaries agreed with estimated values,
3. the total amount of simulated discharge by evapotranspiration agreed with the estimated amount,
4. the simulated Quinn River flow out of the modeled region matched the estimated value, and
5. the simulated mass balance of water into and out of the entire flow system had a minimal error.

Predevelopment water-level measurements at 35 wells were compared to model-derived heads computed for corresponding cells where the wells are located. Nearly 80 percent of these model-computed heads were within 5 ft or less of the measured value and all were less than 10 ft (fig. 19). The absolute departure of the simulated heads from measured heads for the 35 cells in layer 1 containing wells was 3.40 ft, with a standard deviation of 2.76 ft. The simulated and measured potentiometric surface for layer 1 and the location of the 35 cells used for comparison to the calculated potentiometric surface are shown in figure 20.

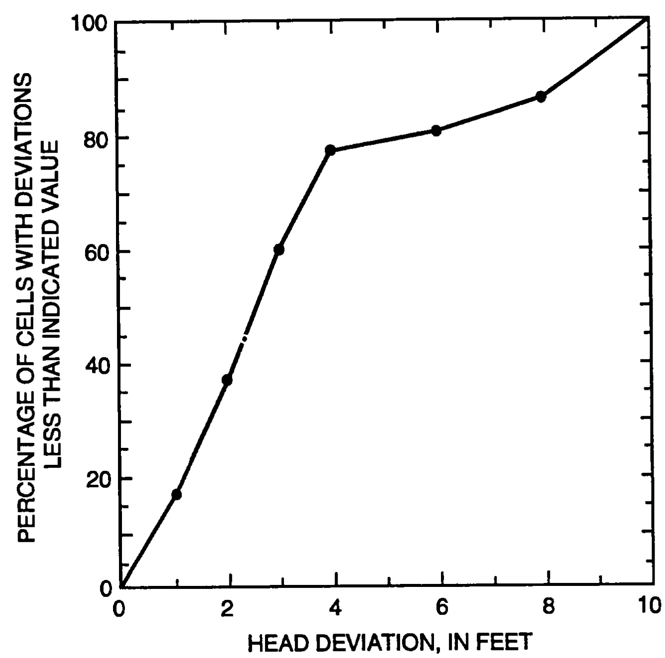
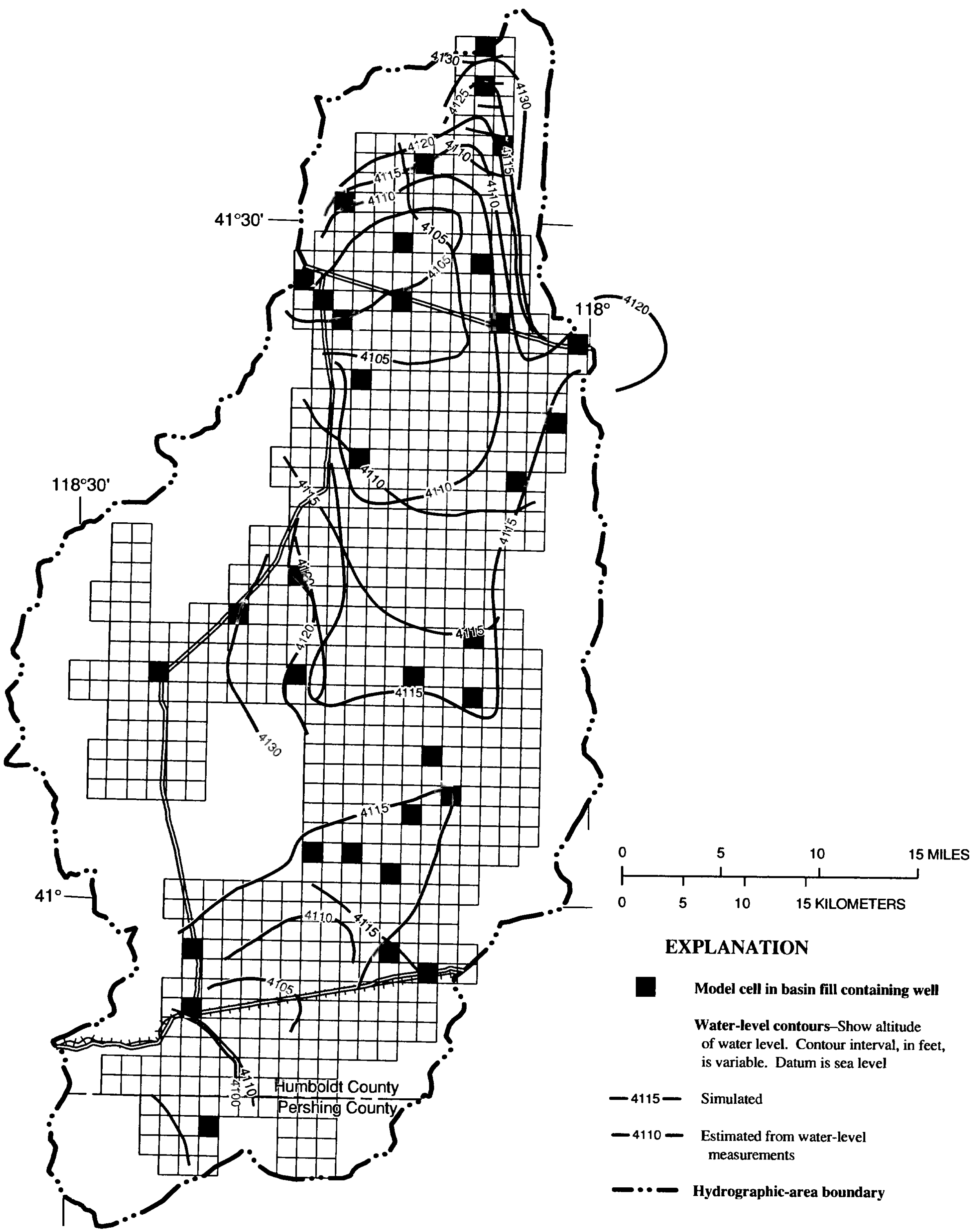


Figure 19. Frequency distribution of deviations between measured and simulated hydraulic heads for predevelopment simulation, Desert Valley, Nevada.



Base from U. S. Geological Survey digital data, 1:100,000, 1979-86; Universal Transverse Mercator projection, Zone 11

Figure 20. Simulated potentiometric surface for layer 1 and water levels estimated on basis of field data, predevelopment conditions, Desert Valley, Nevada.

The predevelopment potentiometric surface simulated for layer 1 is in reasonable agreement with the potentiometric surface describing predevelopment conditions based on field data. The potentiometric surface for layer 2, derived from the model, is generally similar to that of layer 1. Heads simulated in cells in the area southeast of the Quinn River as it exits the study area are as much as 1 ft higher in layer 2 than in layer 1, suggesting that the potential for upward flow of ground water exists. Although predevelopment water-level data are insufficient to verify the existence of upward ground-water movement, upward movement is indicated from water-level data collected at sites 60 and 61 before effects from the wetlands were observed.

Areas of greater-than-5-ft difference between simulated and estimated (predevelopment) heads were generally along the boundary of the model. Simulated and estimated heads may differ because the model-computed head is specified at the center of the cell, representing an average head, whereas the estimated head may be anywhere in that square-mile cell.

The initial distribution of hydraulic conductivity was adjusted until the best fit was obtained between measured and computed heads. The distribution of the calibrated hydraulic conductivity for layer 1 is shown in figure 21. During model calibration, hydraulic conductivities for layer 2 were decreased to one-half the calibrated values for layer 1. Transmissivity values for layer 3 were not adjusted from initial estimates. Calibrated hydraulic conductivities ranged from less than 25 ft/d along the west-central model boundary and north of the Quinn River to greater than 76 ft/d within a north-south corridor through the center of the basin. Because of the lack of lithologic information from wells, this apparent transmissive corridor was not detected. The distribution of the highest computed values in the center of the basin is similar to the distribution of hydraulic conductivity determined in Paradise Valley (Prudic and Herman, in press), where the higher values are attributed to well-sorted stream deposits. The distribution determined from this study, in part, supports the interpretation by Davis (1982, 1990) that the Humboldt River may have flowed northward through Desert Valley 22,000-35,000 years ago.

Values of total inflow and outflow calculated by the model (table 11) for predevelopment conditions are within the ranges estimated by empirical techniques (table 9). However, the simulated mountain-block recharge is slightly larger (6,900 acre-ft/yr) and sand-dune recharge is slightly smaller (440 acre-ft/yr) than the estimated values. Model-derived values of infiltration from rivers, subsurface fluxes, and evapotranspiration fall within the estimated ranges.

Table 11. Simulated ground-water budget for predevelopment conditions (pre-1962), Desert Valley, Nevada

[All values in acre-feet per year, rounded to two significant figures]

Budget component	Simulated predevelopment conditions
Inflow	
Recharge from precipitation:	
From mountain block	6,900
From sand dunes	440
Infiltration from rivers:	
Quinn River	2,600
Kings River	110
Subsurface inflow:	
From Kings River Valley	820
From Quinn River Valley	310
Total inflow	11,000
Outflow	
Evapotranspiration	9,100
Subsurface outflow:	
To Pine Valley	400
To Southwest	1,700
Total outflow	11,000

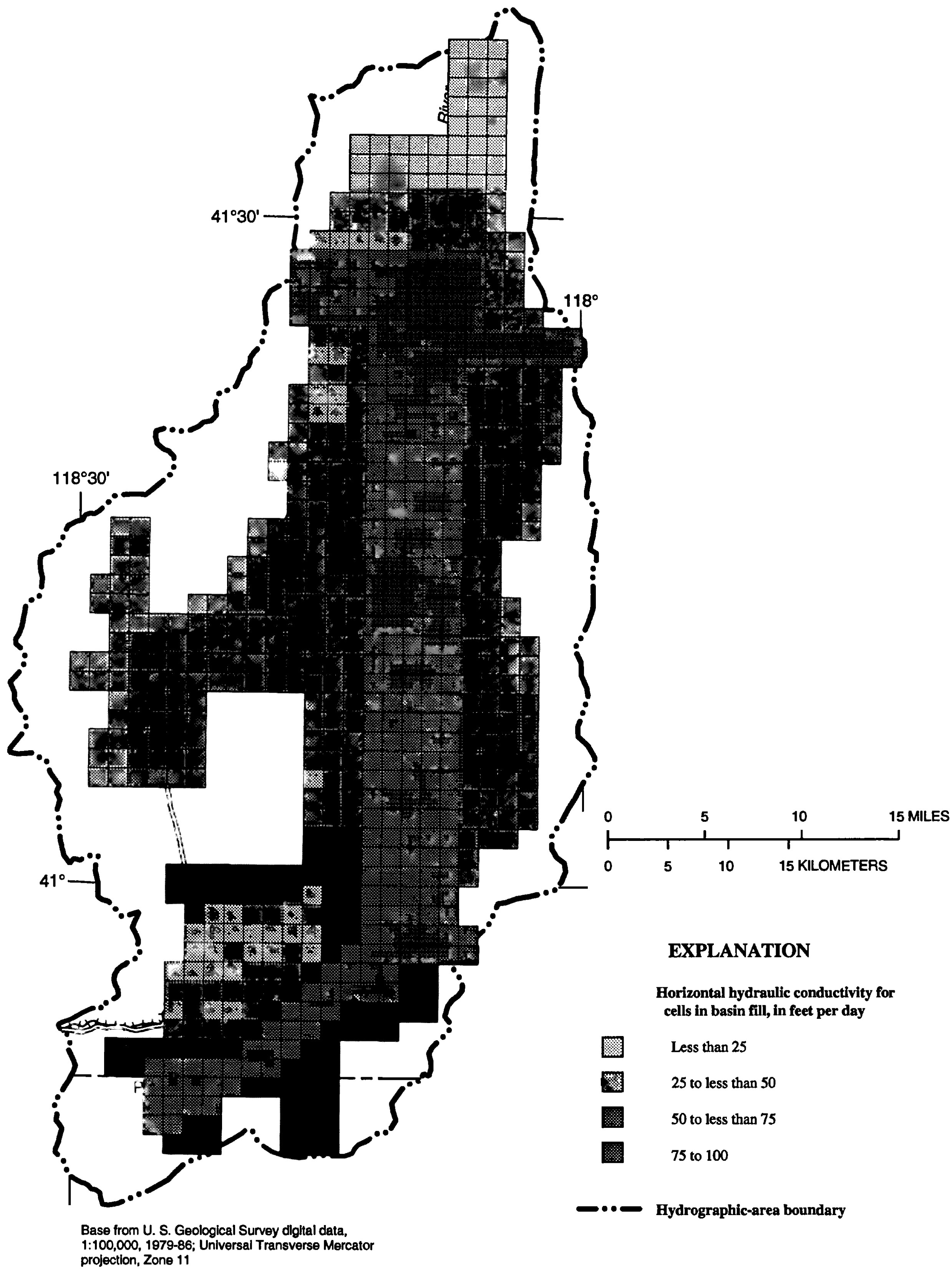


Figure 21. Distribution of hydraulic conductivity in layer 1 used in best-fit predevelopment simulation, Desert Valley, Nevada.

Sensitivity Analysis

Model sensitivity to the uncertainty in the estimates of five hydrologic properties was evaluated on the basis of 14 model simulations for predevelopment conditions (table 12). Each property was varied to determine the effects on the differences between measured and simulated head for 35 model cells (fig. 20) and the final calibrated flux rates at head-dependent boundaries. Each time the model was run, one property was uniformly varied by doubling or reducing by one-half its calibrated value while the other properties remained constant. Because solution to the predevelopment model is not unique, the sensitivity analysis cannot be used to verify the accuracy of the model; however, the analysis can be used to test the response of the model to a range of values used for initial conditions.

The results of the sensitivity analyses presented in table 12, in general, indicate that the water-level distribution and flux at head-dependent boundaries simulated by the model are not highly sensitive to uncertainties in values of transmissivity and vertical-hydraulic conductivity (average change, 12.6 percent). Simulated water levels and subsurface flux at head-dependent boundaries are most sensitive to uncertainties in recharge and ground-water discharge by evapotranspiration. Although a large percentage of change is calculated, the absolute difference in mean head is generally about 10 ft or less. Variations in recharge and discharge are equally compensated in the model by balancing subsurface inflow and outflow with discharge by evapotranspiration.

Simulation of Development, 1962-91

Hydrologic stresses on the ground-water flow system caused by pumping for irrigation along the west side of the valley floor and dewatering operations at the Sleeper Mine were simulated for the period 1962-91. Hydrologic properties, boundary conditions, distribution of evapotranspiration and recharge, and simulated heads determined from the best-fit predevelopment model were used as initial conditions for the development model. Rates of inflow, such as recharge from precipitation and surface-water inflow from the Quinn and Kings Rivers, were adjusted to reflect the percentage of the long-term average during the 30-year development simulation.

Selection of Stress Periods

The development simulation (1962-91) was divided into 10 stress periods on the basis of estimated ground-water pumpage within the Desert Valley study area. The division of stress periods and their relation to estimated annual ground-water withdrawals is illustrated in figure 22. Time intervals that could be represented by fairly constant irrigation pumpage before mine dewatering began were specified as separate stress periods. At the beginning of mine dewatering in 1985, corresponding with stress-period 4, yearly stress periods were specified. Stress periods were further subdivided into time steps which form a geometric progression that increases in length according to a specified multiplier. For the development simulation, the initial time step and each subsequent step was increased by 1.5 times the length of the preceding time step. During the simulation, all external stresses to the system were held constant throughout each stress period.

Stress-period 1 was specified as 13 years with six time steps, over the period 1962-74. Simulated net pumpage for irrigation was specified as 3,900 acre-ft annually during this period. Stress-periods 2 and 3 were both specified as 5 years with five annual time steps during 1975-79 and 1980-84. Simulated net irrigation pumpages for stress periods 2 and 3 were about 11,000 and 8,800 acre-ft/yr, respectively. Stress-periods 4 through 10, beginning in 1985 and ending in 1991, were 1 year in length and divided into four time steps. Ground-water withdrawals for both net irrigation and mine dewatering were simulated in stress-periods 4 through 10. The pumping stresses used in the simulation are presented in table 13. The distribution of model cells assigned as irrigation pumping, mine dewatering, and wetlands and canals is shown in figure 23.

Table 12. Summary of model-sensitivity simulations for Desert Valley, Nevada

[Abbreviation and symbol: ET, evapotranspiration; <, less than]

Property varied	Part of model affected	Change applied to property (percent)	Absolute mean difference, in feet, between measured and simulated head for 35 model cells (percent change in parentheses)[1]	Flux at head-dependent boundaries, in acre-feet per year (percent change in parentheses)[1]				
				Outflow to Pine Valley	Outflow to southwest	Inflow from Quinn River Valley	Inflow from Kings River Valley	Evapotranspiration
Calibrated predevelopment simulation results								
None	All layers	0	3.4	400	1,700	310	820	9,100
Sensitivity analysis								
Transmissivity	All layers	+100	3.64 (7)	486 (21)	1,955 (15)	332 (7)	1,365 (67)	8,731 (4)
		-50	6.34 (87)	257 (36)	1,393 (18)	286 (8)	475 (42)	9,178 (<1)
Do.	Layer 1	+100	3.12 (8)	434 (8)	1,793 (6)	323 (4)	985 (20)	8,999 (1)
		-50	3.80 (12)	369 (8)	1,613 (5)	305 (2)	728 (11)	9,117 (<1)
Do.	Layer 2	+100	3.42 (<1)	472 (18)	1,899 (12)	320 (3)	1,224 (49)	8,796 (3)
		-50	5.01 (45)	303 (24)	1,499 (12)	306 (1)	576 (30)	9,158 (<1)
Vertical hydraulic conductivity	Interface between layers 1 and 2	+100	3.39 (<1)	396 (1)	1,683 (1)	316 (2)	819 (<1)	9,110 (<1)
		-50	3.41 (<1)	399 (<1)	1,686 (<1)	307 (<1)	815 (<1)	9,074 (<1)
Recharge	All layers	+100	10.56 (210)	506 (26)	2,952 (74)	41 (87)	682 (17)	13,675 (50)
		-50	6.93 (104)	298 (26)	996 (41)	496 (60)	912 (11)	6,535 (28)
Maximum ET rate	Layer 1	+100	7.28 (114)	80 (80)	1,405 (17)	771 (149)	1,107 (35)	10,475 (15)
		-50	5.13 (51)	553 (38)	1,992 (17)	-17 (106)	671 (18)	6,058 (33)
Maximum ET depth	Corresponding depth in layer 1	+100	5.77 (70)	535 (34)	2,067 (22)	21 (93)	701 (14)	6,575 (28)
		-50	10.53 (210)	21 (95)	1,086 (36)	895 (188)	1,069 (30)	10,943 (20)

[1] Percent change is relative to predevelopment results.

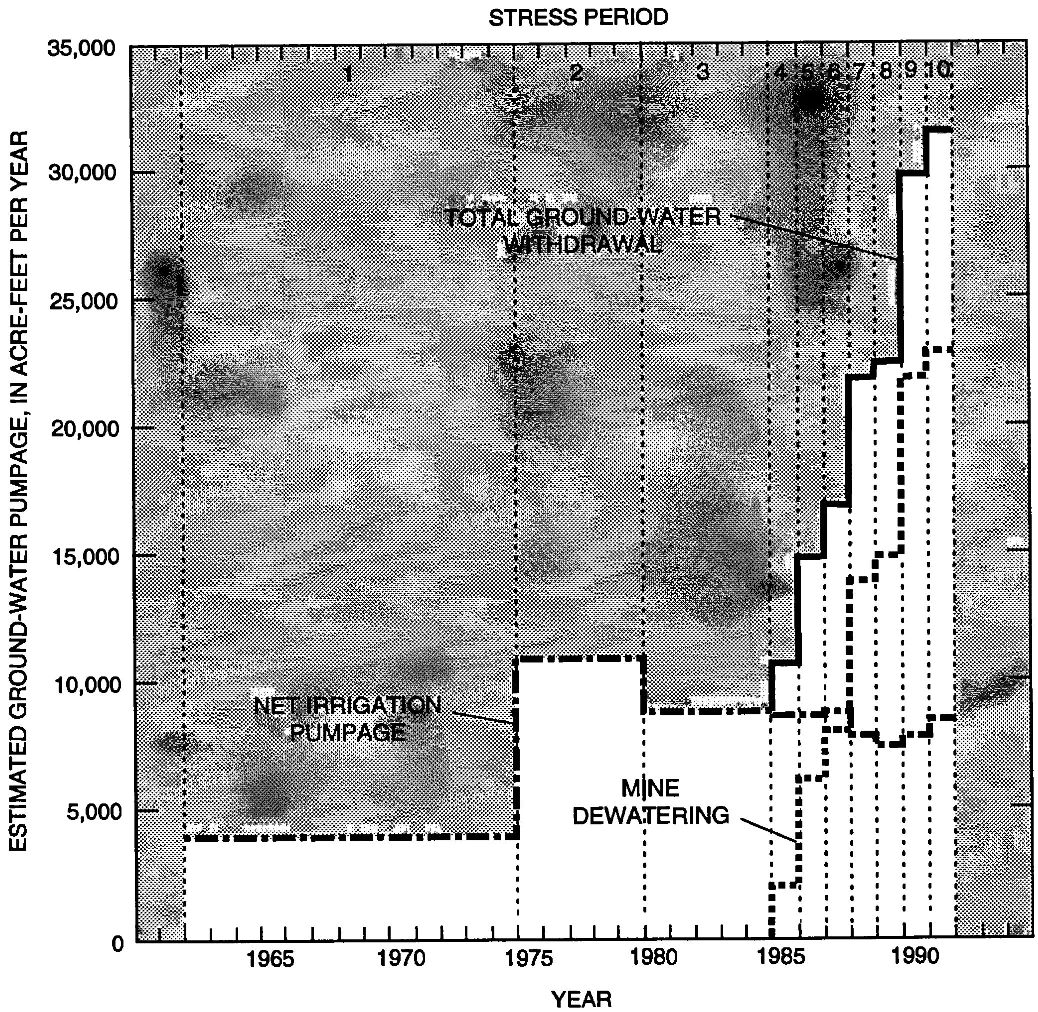


Figure 22. Estimates of net irrigation pumpage, mine-dewatering pumpage, and total ground-water withdrawals, by stress period, specified for development simulation, Desert Valley, Nevada.

Table 13. Simulated ground-water withdrawals for irrigation and mine dewatering, by stress period and corresponding year(s), Desert Valley, Nevada

Stress period	Simulated annual ground-water withdrawal			
	Years	Irrigation (acre-feet)	Mine dewatering (acre-feet)	Total average withdrawal (acre-feet)
1	1962-1974	3,900	0	3,900
2	1975-1979	11,000	0	11,000
3	1980-1984	8,800	0	8,800
4	1985	8,700	2,100	10,800
5	1986	8,700	6,200	14,900
6	1987	8,900	8,100	17,000
7	1988	8,000	14,000	22,000
8	1989	7,600	15,000	22,600
9	1990	7,900	22,000	29,900
10	1991	8,600	23,000	31,600

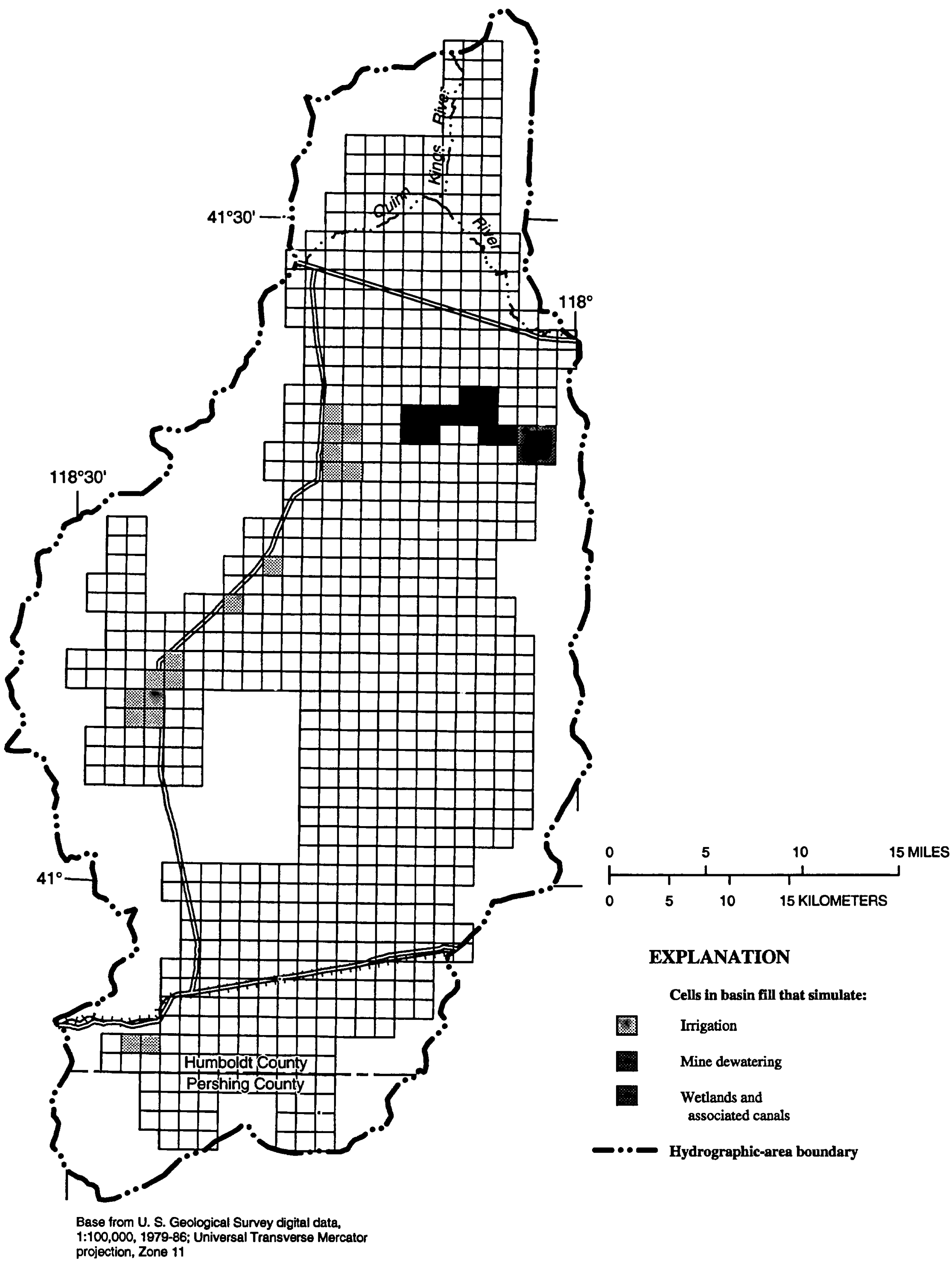


Figure 23. Distribution of model cells used to simulate irrigation pumping, mine dewatering, and discharge lakes and associated canals, Desert Valley, Nevada.

Changes in Flow-Boundary Conditions

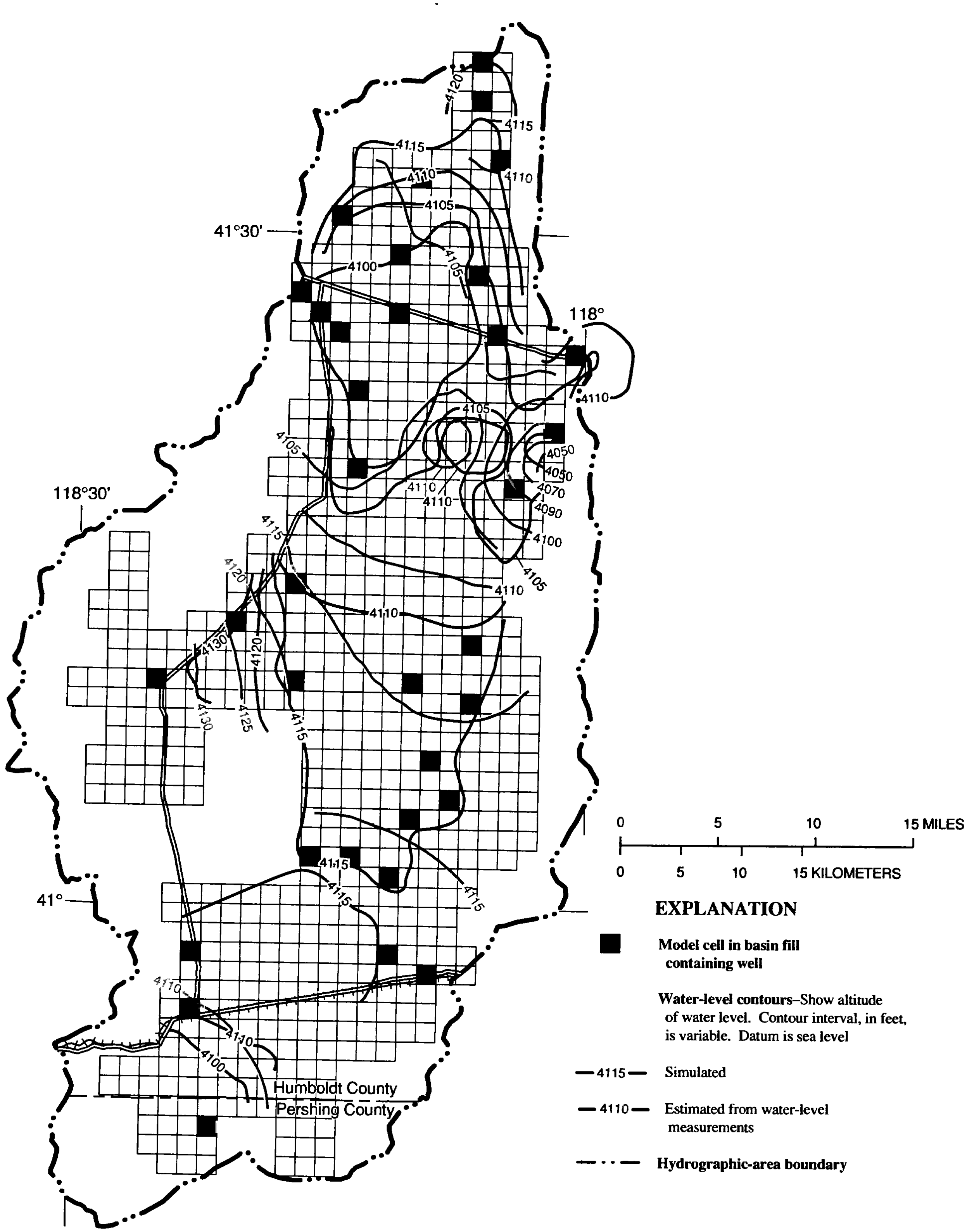
Changes in flow-boundary conditions between predevelopment and development simulations were made at the head-dependent flow boundaries used to simulate subsurface flow in the northern part of the study area. Head values assigned to external cells used to simulate subsurface flow were adjusted for each stress period on the basis of a linear relation between predevelopment head values and 1991 water-level measurements. The simulation of infiltration from the artificial wetlands and associated canals was made by modifying the input data sets for the stream-aquifer program (Prudic, 1989). In addition to the 27 stream cells for the Quinn and Kings Rivers (fig. 16), five stream cells were included in stress-periods 4 through 9 (1985 through 1990) to simulate the effects of the initial wetlands area. During stress-period 10 (1991), nine stream cells were specified to simulate the infiltration of water beneath the second wetlands area. The amount of water introduced to these cells is equal to the gross discharge from the mine minus the amount of water consumed at the mine and the estimated evaporation from the wetlands. The locations of cells containing the additional stream reaches used to simulate the artificial wetlands are shown in figure 23. Model cells that were used to simulate the original wetlands area (1985-90; stress periods 4-9) remained as active stream cells during stress-period 10 to allow infiltration of water that remained impounded at the end of stress-period 9. Recharge and streamflow rates in the model were either increased or decreased depending on the estimated departure from the long-term average (normal) during each stress period.

Calibration and Results

Calibration of the development simulation consisted of adjusting the streambed conductance values of active stream cells that were specified to represent the artificial wetlands. Streambed conductances were adjusted, within reason, until the quantity of water that remained impounded in the artificial wetlands at the end of each stress period matched the quantity that was estimated or measured at the start of the corresponding year. After evaporation losses and the water impounded within the artificial wetlands were accounted for during each stress period, the remaining water was assumed to be ground-water recharge. The final stream-bed conductance values were then held constant throughout the development simulation. Additional calibration was done by comparing simulated water- level contours to contours constructed from Spring 1991 water-level measurements and comparing simulated water-level declines with measured declines over the 30-year period of development simulation.

The configuration of the model-computed potentiometric surface for layer 1 at the end of stress-period 10 (fig. 24) is in good agreement with the measured Spring 1991 potentiometric surface. The potentiometric surface simulated for layer 2 at the end of stress-period 10 is similar to that of layer 1; however, basin-wide water-level data are insufficient to determine the quality of the match for layer 2.

Modeled water-level declines for the 30-year development simulation (1962 to 1991), shown for layer 1 in figure 25, match fairly well with the general distribution of net declines determined from field data over the same time period (fig. 13). Comparison between figures 13 and 25 indicates that the model simulation was generally able to approximate the measured water-level declines throughout the entire basin, including the area of declines due to the dewatering operation at the mine and the area of less-than-5-ft declines near the artificial wetlands. Maximum simulated declines at the four cells representing mine dewatering were about 70 ft, compared with measured declines of nearly 300 ft beneath the mine pits. This is because the simulated declines represent values averaged over each of four 1-mile-square model cells compared with measurements in wells located at the maximum points of drawdown within the pits. To more closely approximate the total drawdown beneath the pits, model cells would have to be closer in size to the area covered by the pits.



Base from U. S. Geological Survey digital data, 1:100,000, 1979-86; Universal Transverse Mercator projection, Zone 11

Figure 24. Model-simulated potentiometric surface for layer 1 at end of stress-period 10 (1991) for development simulation, Desert Valley, Nevada.

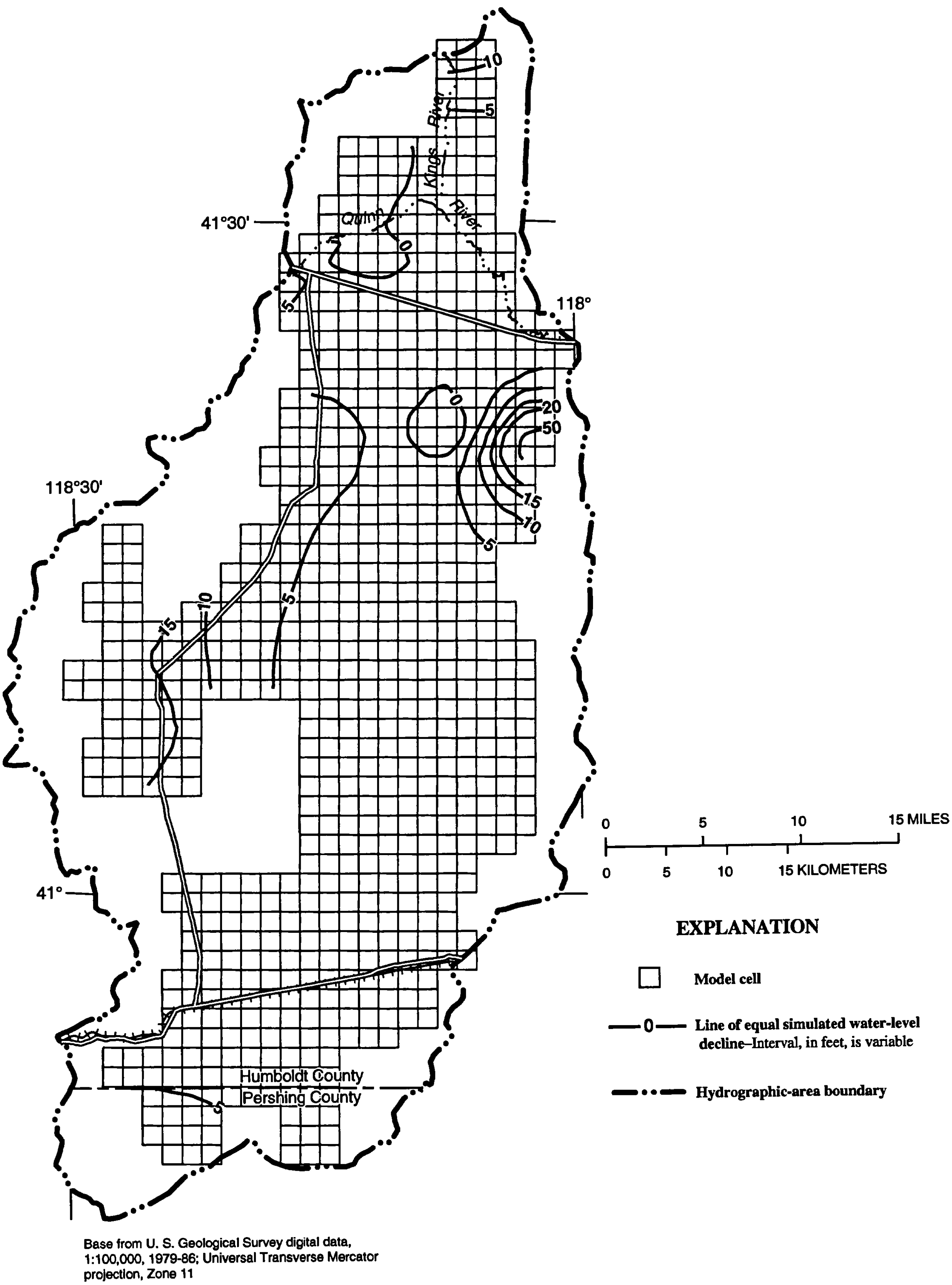


Figure 25. Model-simulated water-level declines for layer 1 at end of stress-period 10 (1991) for development simulation, Desert Valley, Nevada.

Hydrographs of measured and simulated water levels for eight wells that are screened within the equivalent of layer 1, and for the corresponding model cells, are shown in figure 26. The hydrographs show that simulated water levels closely match measured water levels on a basin-wide scale. Model-simulated hydrographs for cells unaffected by the dewatering operation (cells 3/21, 13/12, 40/18, and 47/7 [row/column]) closely match the observed hydrographs for the corresponding sites (sites 44, 62, 104, and 119). The remaining four hydrographs represent measured and simulated water-level changes associated with the mine dewatering. The general trend of water-level declines simulated for sites 67 and 69 (cells 20/25 and 21/24) are comparable to the observed trends. However, well-site 69 (cell 21/24) is closer to the mine than to the cell center, resulting in greater observed drawdowns than those simulated. The measured water-level decline at site 130 (cell 16/26) reflects the decrease in infiltration from the Quinn River due to 8 years of below-normal precipitation (fig. 4*B*), superimposed on the effects of the mine dewatering. Surface-water inflow is simulated by the model as an average daily value over one year, and is not modeled seasonally. Thus, the hydrograph of simulated water levels for the corresponding cell shows some net decline, but not as much as that measured. Site 80 (cell 20/22) is in the wetlands area where measured water levels increased slightly through 1990 (fig. 26). Simulated water levels at cell 20/22 gradually increased from 1985 to 1990 in response to simulated infiltration of water from the wetlands. In February 1991, mine discharge was rechanneled to the new wetlands area farther west, which allowed the original wetlands to dry. The effect of this change was observed in site 80 as a slight decline in water level at the end of 1991 (fig. 26). The simulated response in cell 20/22 during 1991 shows a larger water-level decline than that measured. This difference is because the cell center is closer to the original wetlands area and the dewatering at the mine than site 80.

Hydrographs for four wells screened at depths the equivalent of layer 2 (sites 60, 71, 81, and 109), two wells in layer 3 (sites 60 and 72), and the corresponding model cells are shown in figure 27. Five of the six hydrographs have simulated water levels greater than measured levels due to the location of the well in relation to the cell center. This effect is greatest where hydraulic gradients are steepest. In general, the simulated water-level trends derived from the model approximate the observed trends.

The ground-water budget summarizing the inflow to and outflow from the basin-fill aquifer of Desert Valley for 1991 conditions (end of stress-period 10) determined from the development simulation is given in table 14. On the basis of long-term streamflow data and the general trend of below-average precipitation (fig. 4*B*), 1991 ground-water recharge and surface-water flow were estimated to be about 64 percent of the long-term average. This below-average condition is reflected in the simulated decrease of inflow to the ground-water system from predevelopment time. Decreases in subsurface inflow from the Kings River and Quinn River Valleys were calculated by assigning Spring 1991 water-level values to the associated external cells.

Table 14. Simulated ground-water budget for development conditions at end of stress-period 10 (1991), Desert Valley, Nevada

[All values in acre-feet per year, rounded to two significant figures]

Budget component	Simulated 1991 conditions
Inflow	
Recharge from precipitation:	
From mountain block	4,400
From sand dunes	280
Infiltration from rivers	2,400
Infiltration from dewatering lakes	[1]16,000
Subsurface inflow:	
From Kings River Valley	240
From Quinn River Valley	160
Total inflow	23,000
Outflow	
Evapotranspiration	7,800
Subsurface outflow:	
To Pine Valley	400
To Southwest	1,800
Groundwater pumpage [2]:	8,600
For irrigation	
For mine dewatering	23,000
Total outflow	42,000
Net results	
Outflow minus inflow	19,000
Storage depletion (simulated by model)	18,000

[1] Includes about 1,200 acre-feet simulated to remain impounded in initial wetlands at end of stress-period 9.

[2] Simulated pumpage for irrigation is estimated net pumpage and simulated pumpage for mine dewatering is estimated gross pumpage.

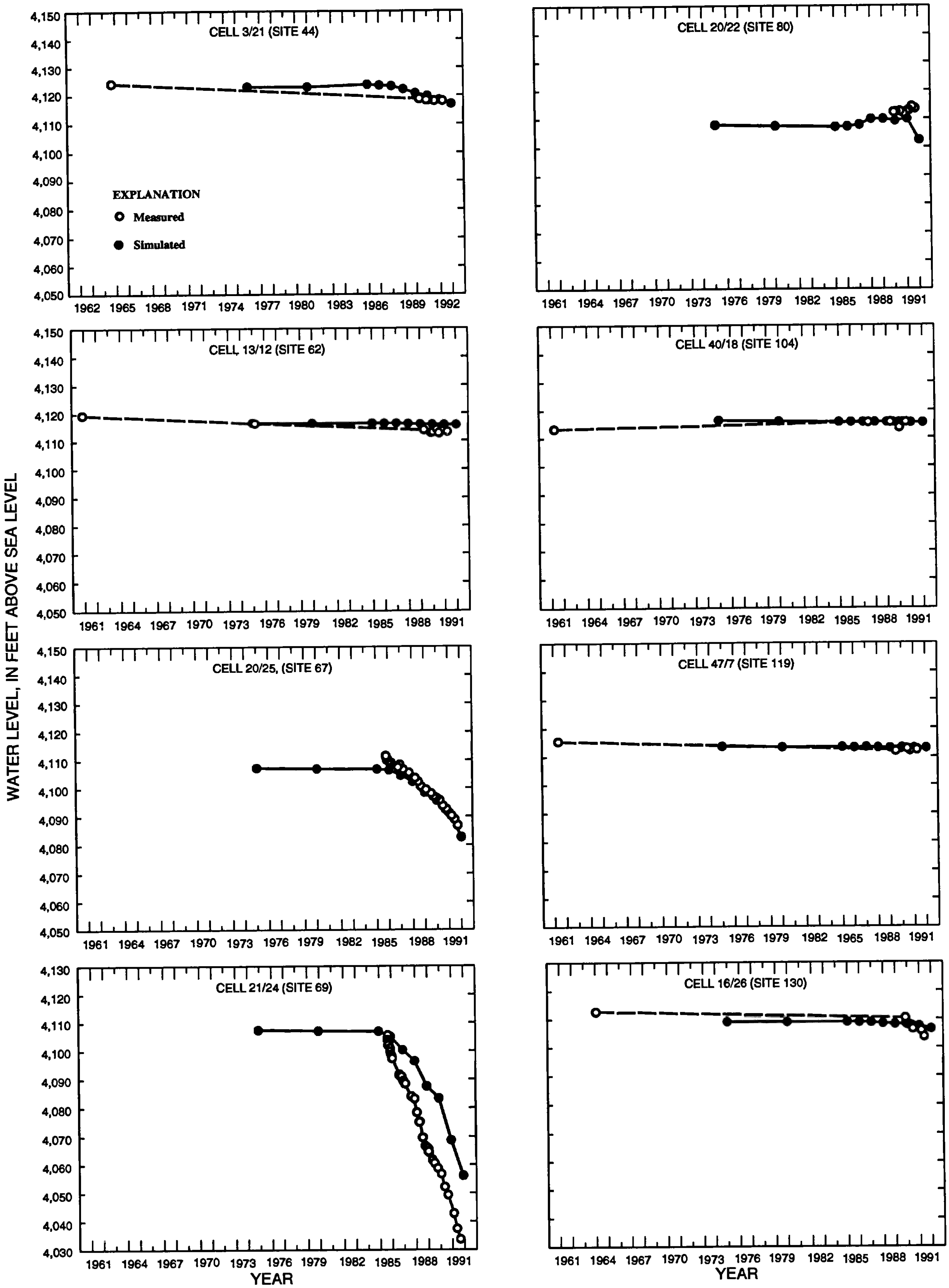


Figure 26. Measured and simulated ground-water levels for selected cells, layer 1, during development simulation, Desert Valley, Nevada. Cell location is indicated by row and column (for example, 21/24 indicates row 21, column 24).

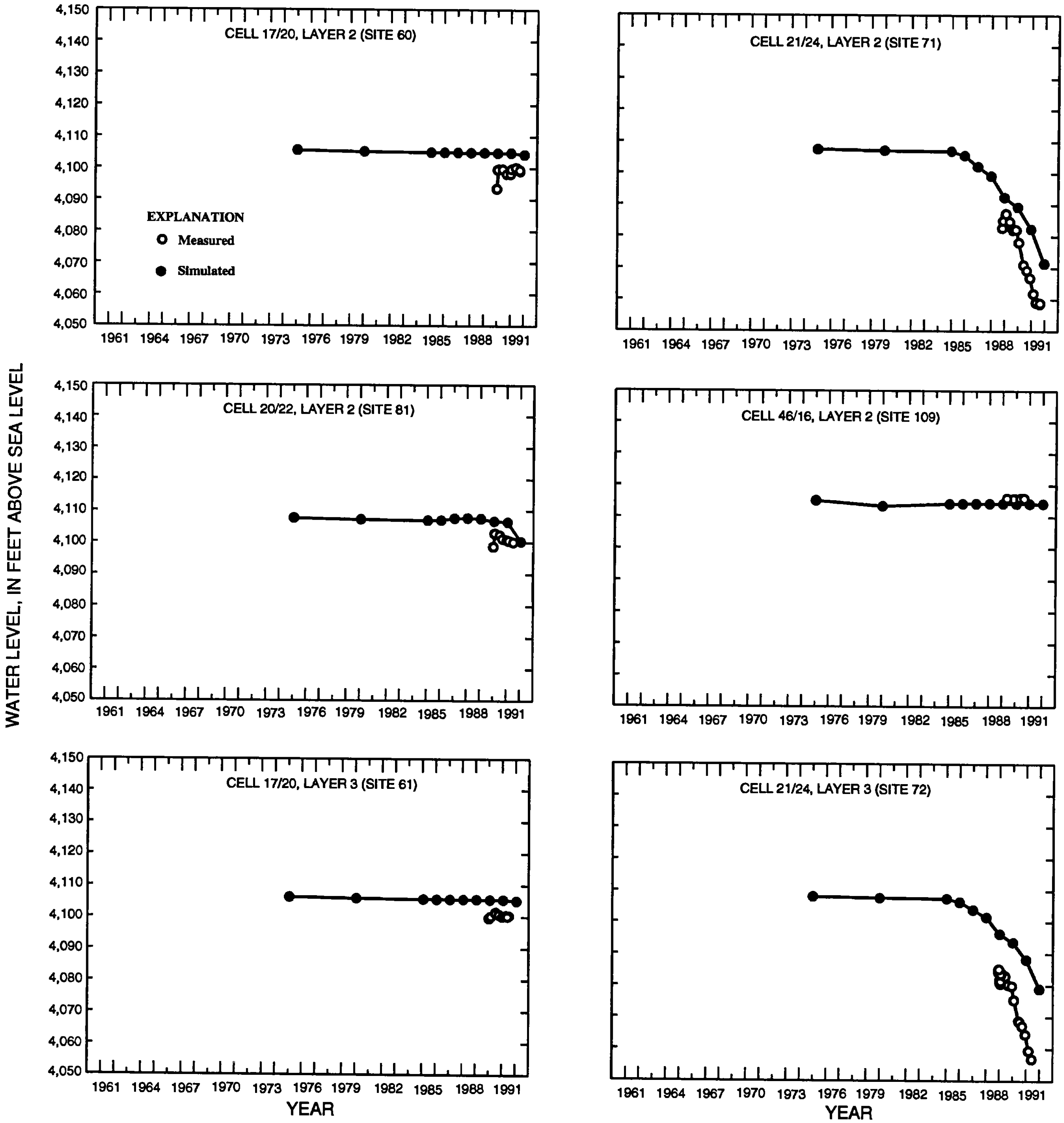


Figure 27. Measured and simulated ground-water levels for selected cells, layers 2 and 3, during development simulation, Desert Valley, Nevada. Cell location is indicated by row and column (for example, 21/24 indicates row 21, column 24).

Simulated surface-water outflow to Pine Valley by way of the Quinn River decreased from the estimated long-term average of 1,400 acre-ft/yr to about 100 acre-ft/yr for 1991. Infiltration beneath the artificial wetlands and the depletion in ground-water storage supplied nearly all the pumpage simulated at the Sleeper Mine. Declines in ground-water levels near the mine, shown in figure 25, are a result of depletion in storage. A small amount of mine discharge water may be supplied by a decrease in evapotranspiration and an increase in infiltration beneath the Quinn River. Simulated infiltration from all rivers for 1991 was only about 310 acre-ft, less than that simulated under predevelopment conditions despite the greatly reduced streamflows during 1991.

Simulation of Response to Hypothetical Mine-Dewatering Scenarios

To evaluate the probable long-term effects of ground-water withdrawals, three hypothetical dewatering scenarios were simulated using the calibrated flow model. The hypothetical scenarios were developed on the basis of the life expectancy of the Sleeper Mine and discussions with representatives from the Nevada Division of Water Resources. The results from simulated aquifer responses to the hypothetical dewatering scenarios are intended to indicate general basin-wide trends. Figures showing the distribution of model-computed water-level declines since predevelopment (figs. 28, 29, 31, 32, 34, and 35) for selected stress periods, are used to illustrate probable long-term effects of ground-water withdrawals on the basis of results from the dewatering scenarios. Simulated ground-water budgets are used to describe the overall effects of ground-water development on the recharge and discharge of the aquifer systems and changes in the cumulative depletion of ground-water storage with time (figs. 30, 33, and 36). Estimates of these elements made for predevelopment conditions are used as the initial point (where elapsed time = 0) for evaluating simulated changes since predevelopment time. The hypothetical dewatering scenarios provide a means of evaluating various management alternatives for the ground-water supply within Desert Valley. The concept of optimal yield (Bear and Levin, 1967), as a function of time and hydrologic conditions of the aquifer system may not necessarily meet sustained-yield requirements for a particular ground-water basin. However, the dewatering scenarios, in a sense, test the optimal-yield concept in terms of ground-water development in excess of equilibrium conditions for a limited length of time.

The hypothetical dewatering scenarios were constrained in regard to the model-layer assignments specified for mine dewatering, for the distribution of irrigation pumping, and for the inflow and outflow quantities. To avoid dewatering cells from going dry during the simulations, all pumping for mine dewatering was reassigned from layer 1 to layer 2. This modification in vertical- pumping distribution at the mine is not unreasonable considering the probable pumping conditions as the pits become deeper and the depth of ground-water withdrawal increases. Because Desert Valley is a Designated Basin, variations in future ground-water withdrawals for irrigation and in the general distribution of irrigation pumpage were assumed to remain virtually the same as those in 1991. Long-term estimates of streamflow, recharge from precipitation, and evapotranspiration, which were determined for predevelopment conditions and used in the predevelopment flow model, also were used for the hypothetical dewatering scenarios. The effect of this constraint is evident mostly in the discontinuity of the curve representing simulated change in subsurface inflow (bottom plot in figs. 30, 33, and 36). For each dewatering scenario, a 100-year recovery period follows the termination of simulated mine dewatering, to allow the ground-water system to approach a new equilibrium. During the recovery period, mine dewatering is specified as zero in the model and irrigation pumping continues for the entire simulation at 1991 levels. Hydraulic properties of the basin-fill aquifer determined from the calibrated flow model were used for all scenarios.

Scenario A—Continued Dewatering at Projected Rates, 1991-98

The first dewatering scenario (scenario A) was used to evaluate effects of continued mine dewatering at projected increasing rates for an additional 7 years, from 1991 through 1998 (fig. 30*A*). Annual dewatering volumes are projected to increase steadily from 24,000 acre-ft in 1992 to 32,000 acre-ft in 1998 (Nevada Gold Mining, Inc., written commun., 1992).

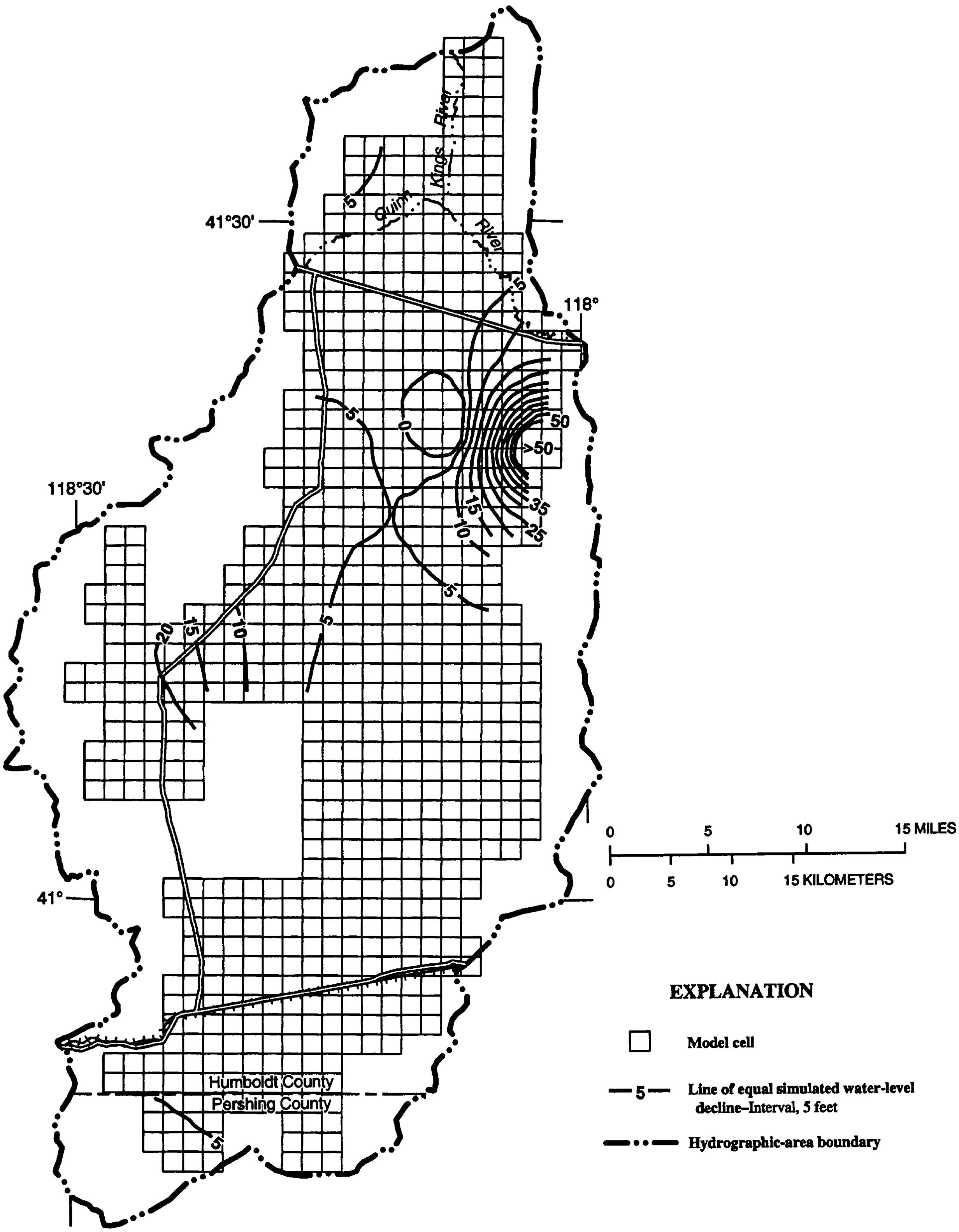
During scenario A, the pumped water is allowed to continue infiltrating beneath the artificial wetlands, as specified in stress-period 10 of the development model. Seven 1-year stress periods, each with four time steps, were added to the calibrated development model to simulate the additional mine dewatering. At the end of the dewatering period (stress-period 17), the 100-year recovery period is specified as stress-period 18, with 25 time steps.

The distribution of water-level declines since predevelopment computed by the model at the end of the simulated dewatering period for scenario A (stress-period 17; fig. 28) is similar to the distribution of declines exhibited in stress-period 10 (figure 25). By steadily increasing the ground-water withdrawal at the mine for an additional 7 years, simulated water-level declines continued to expand, generally farther south and southwest of the mine than to the north. Expansion of simulated water-level declines north of the mine is constrained by the availability of recharge to be captured from head-dependent flow boundaries and stream cells. To the south and southwest, in contrast, pumped water is obtained by depletion of ground-water storage, which causes a larger area of simulated water-level declines. At the end of the 100-year recovery period (stress-period 18), water levels have nearly recovered to predevelopment conditions in the area of the mine, and water levels in the wetlands area have returned to nearly predevelopment levels (fig. 29). Some residual effects appear to have propagated away from the mine area; these declines may be solely a result of the dewatering or, more likely, a combination of dewatering and continued pumping for irrigation. Figure 30 shows changes in budget components, with time, determined from the results of simulating continued mine dewatering for 7 years beginning in 1991 (scenario A). Large changes in the budget values during mine dewatering (elapsed time, between 24 and 36 years) indicate that the aquifer system is out of equilibrium. After mine dewatering ceases (elapsed time, 37 years), smaller changes in budget values suggest that the aquifer may be gradually approaching a new equilibrium with little or no change in storage.

Scenarios B and C—Continued Dewatering at 1991 Rate, 1991-2016

The second and third scenarios (scenarios B and C) were developed to evaluate the basin-wide effects of constant mine dewatering at the 1991 rate for 25 years (1991-2016), followed by the 100-year recovery period (fig. 33*A*, 36*A*). As in scenario A, the pumped water is allowed to infiltrate beneath the wetlands area during scenario B; however, during scenario C the pumped water is not allowed to infiltrate beneath the wetlands areas and is entirely removed from the model. For scenarios B and C, 25 additional 1-year stress periods were added to the calibrated development model (stress-periods 11-35), each with 4 time steps. Stress-period 36, with 25 time steps, is used to represent the 100-year recovery period.

Water-level declines since predevelopment, simulated by 25 years of continuous mine dewatering beginning in 1991, expand considerable distance away from the mine in both scenarios (figs. 31 and 34). However, water-level declines simulated in scenario B are similar to declines simulated in scenario A, which are both vastly different from declines simulated in scenario C. This suggest that the infiltration beneath the wetlands has a large effect on the distribution of water-level declines to the west of the mine. The additional recharge provided by the wetlands attenuates the westward propagation of effects from the mine dewatering. At the end of the 100-year simulated recovery period, the distribution of water-level declines on a basin-wide scale for scenarios B and C is similar to that for scenario A (figs. 29, 32, and 35). As a result of not allowing the mine discharge water to infiltrate beneath the wetlands area (scenario C), the pumpage for dewatering captures water from other sources, including the depletion of ground water in storage and the reduction of evapotranspiration due to lowered water levels. This difference in the source of recharge between scenarios B and C is evident in the budget-component curves shown in figures 33 and 36. Over the same time interval (elapsed time, between 30 and 56 years), the slopes of the cumulative depletion in storage and evapotranspiration curves for scenario C are steeper than those for scenario B. The steeper slope indicates that more water is obtained from storage and reduction of evapotranspiration in scenario C than in scenario B because of the absence of infiltration beneath the wetlands area. The model results also suggest that infiltration from the rivers does not increase during scenario C simulations. This lack of increase suggests that the infiltration from beneath the Quinn River was probably at its maximum prior to mine dewatering. By the end of the 100-year recovery period, the simulated aquifer system appears to be approaching a new equilibrium.



Base from U. S. Geological Survey digital data, 1:100,000, 1979-86; Universal Transverse Mercator projection, Zone 11

Figure 28. Model-simulated water-level declines since predevelopment at end of 7 years (stress-period 17) for hypothetical mine-dewatering period, scenario A (continued dewatering at projected rates, 1991-98), Desert Valley, Nevada.

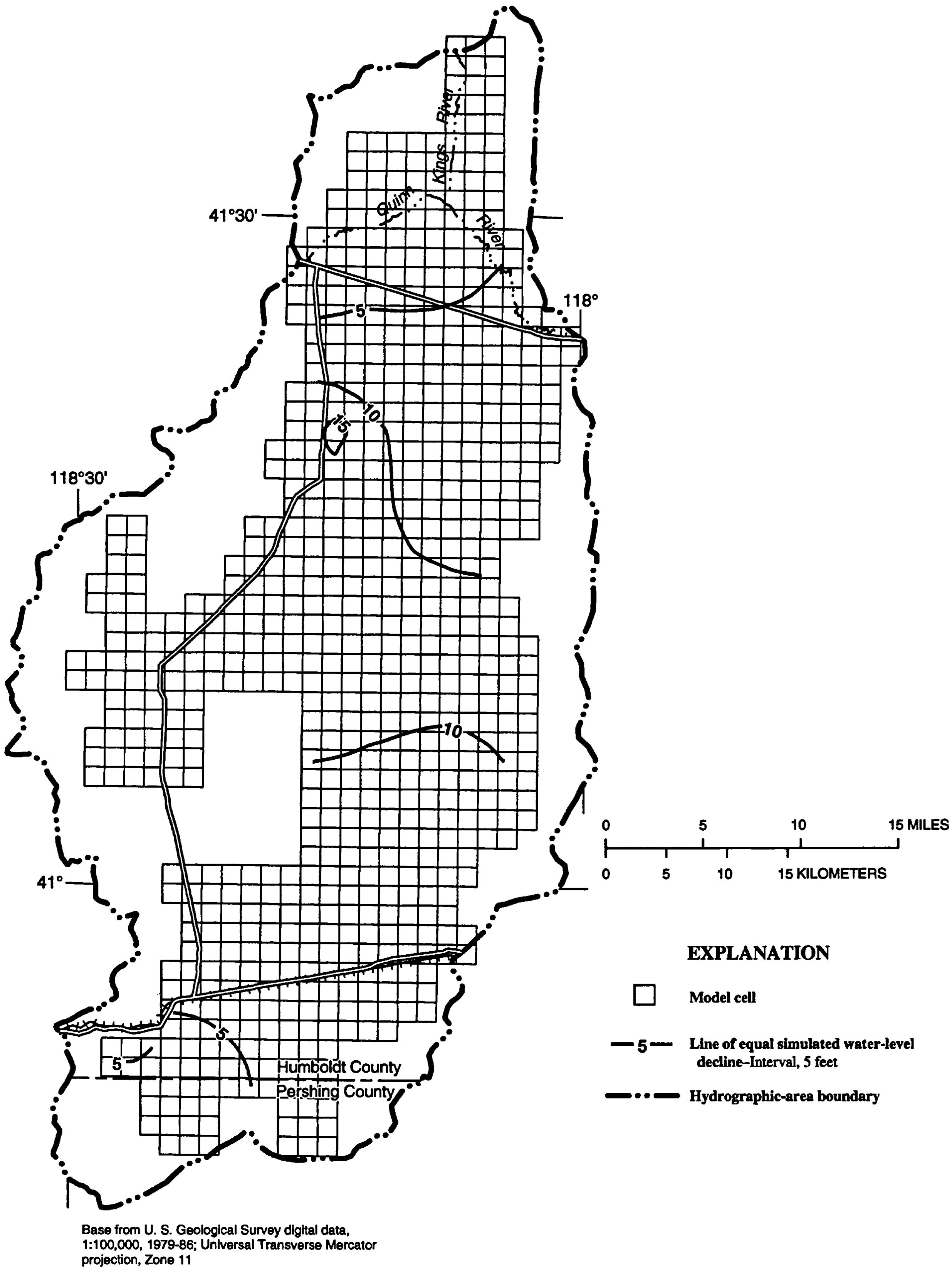


Figure 29. Model-simulated water-level declines since predevelopment at end of 100-year recovery (stress-period 18) for hypothetical mine-dewatering period, scenario A (continued dewatering at projected rates, 1991-98), Desert Valley, Nevada.

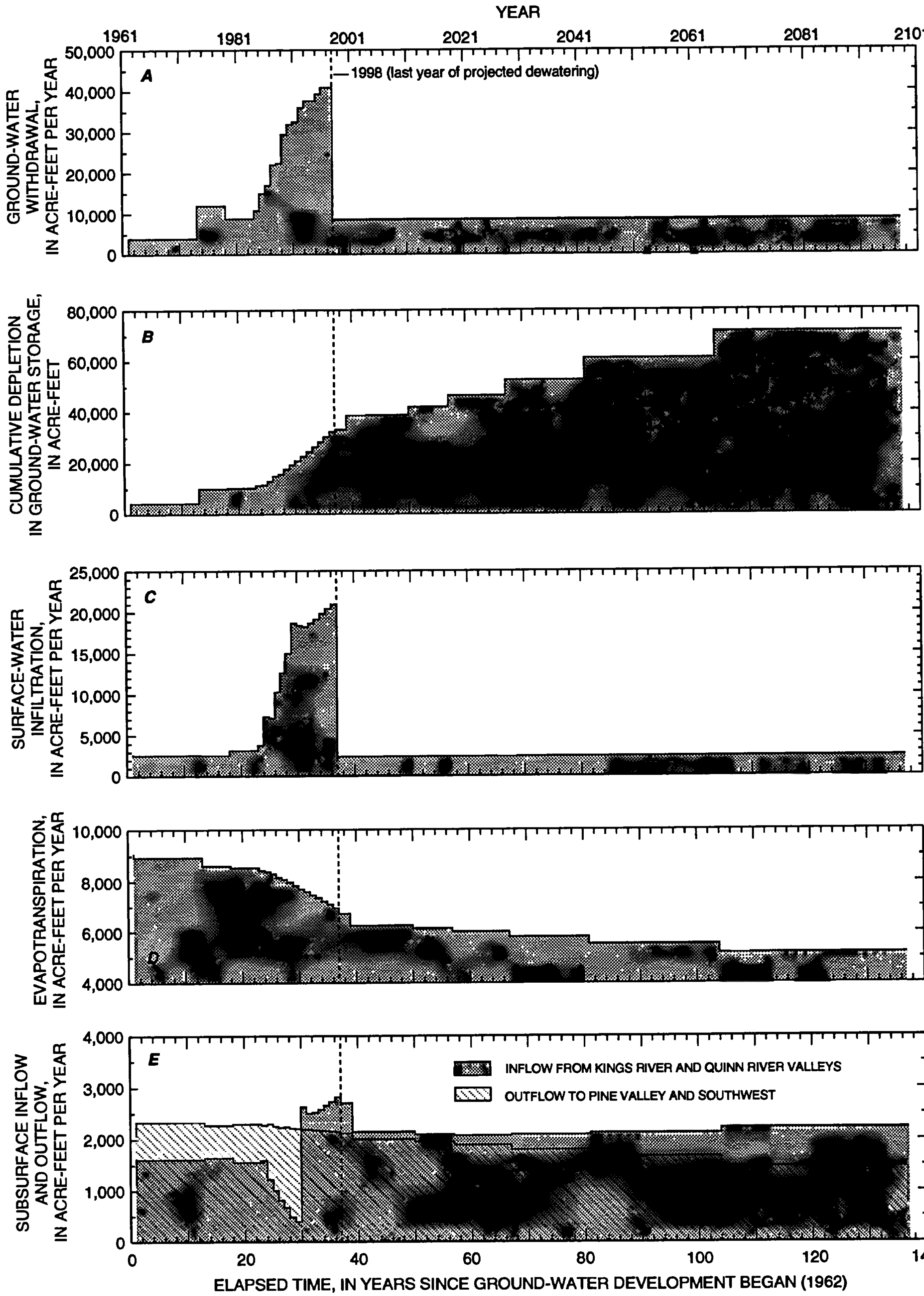


Figure 30. Scenario A, simulated response with continued mine dewatering at projected increasing rates followed by a 100-year recovery period, Desert Valley, Nevada. Mine-dewatering rate increase from 24,000 acre-feet in 1992 to 32,000 acre-feet in 1998. ***A,*** Rate of total ground-water withdrawal. ***B,*** Cumulative depletion in ground-water storage. ***C,*** Surface-water infiltration rate. ***D,*** Evapotranspiration rate. ***E,*** Rates of subsurface inflow and outflow.

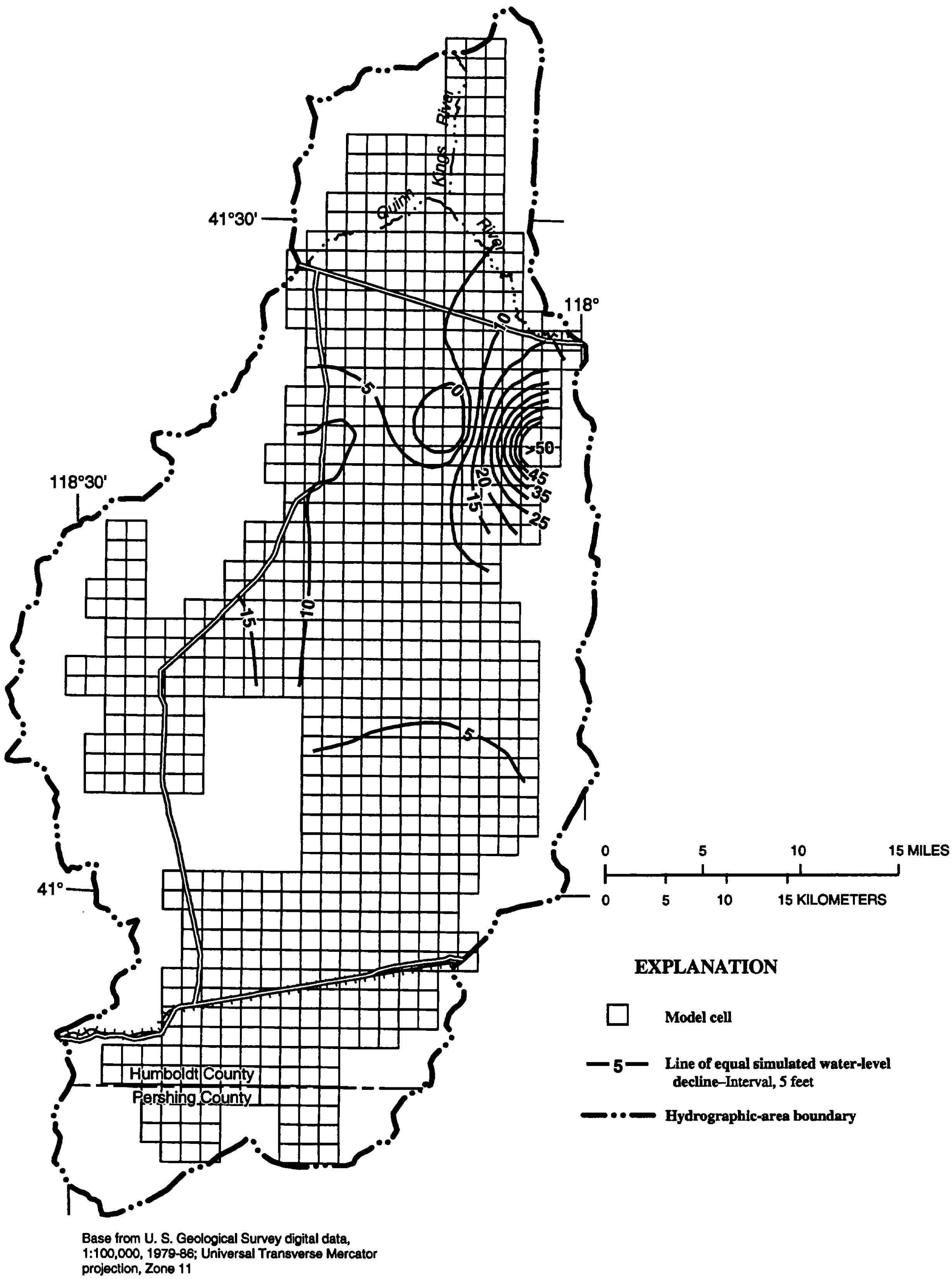


Figure 31. Model-simulated water-level declines since predevelopment at end of 25 years (stress-period 35) for hypothetical mine-dewatering period, scenario B (continued dewatering at 1991 rate), Desert Valley, Nevada.

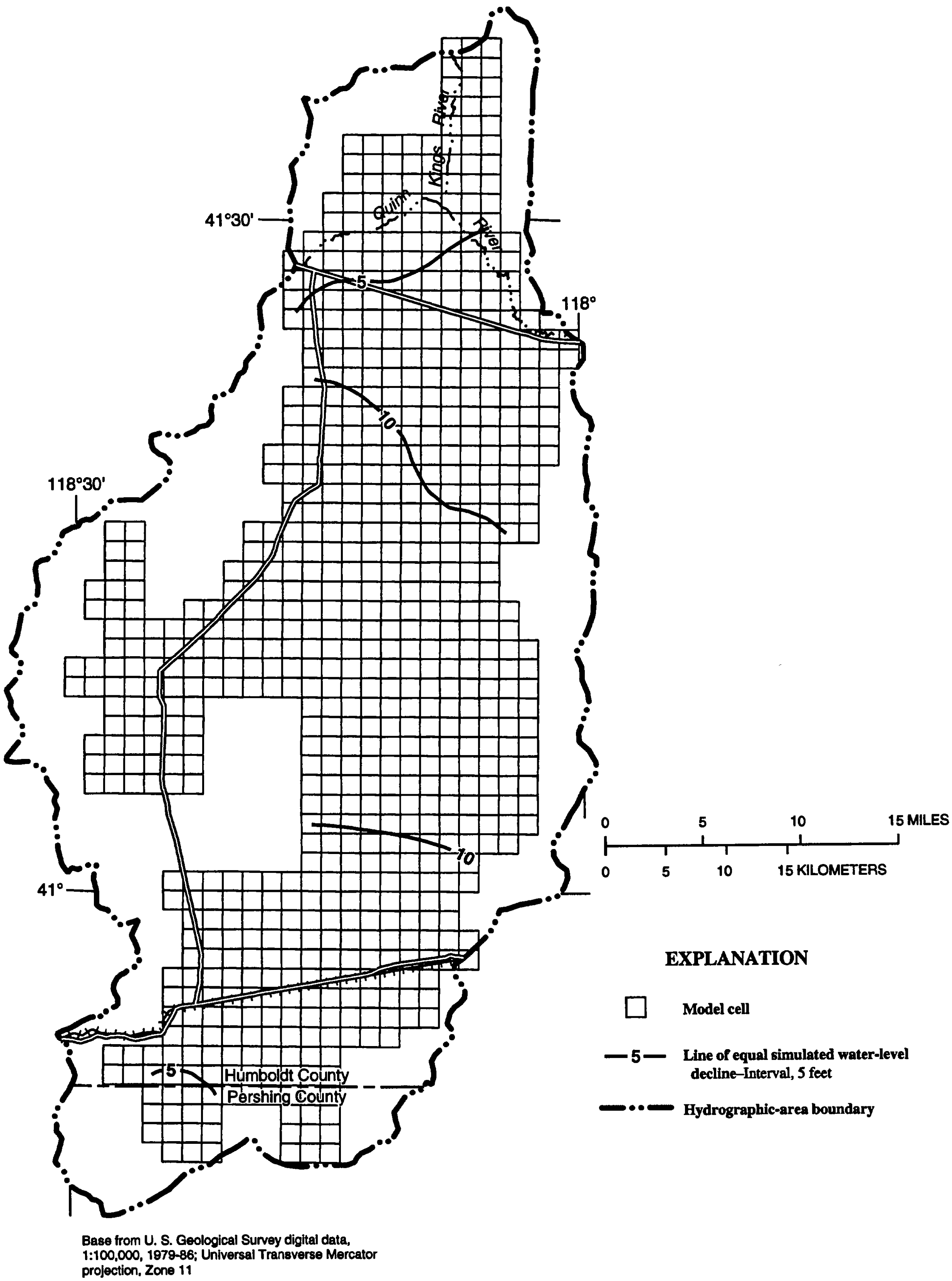


Figure 32. Model-simulated water-level declines since predevelopment at end of 100-year recovery (stress-period 36) for hypothetical mine-dewatering period, scenario B (continued dewatering at 1991 rate), Desert Valley, Nevada.

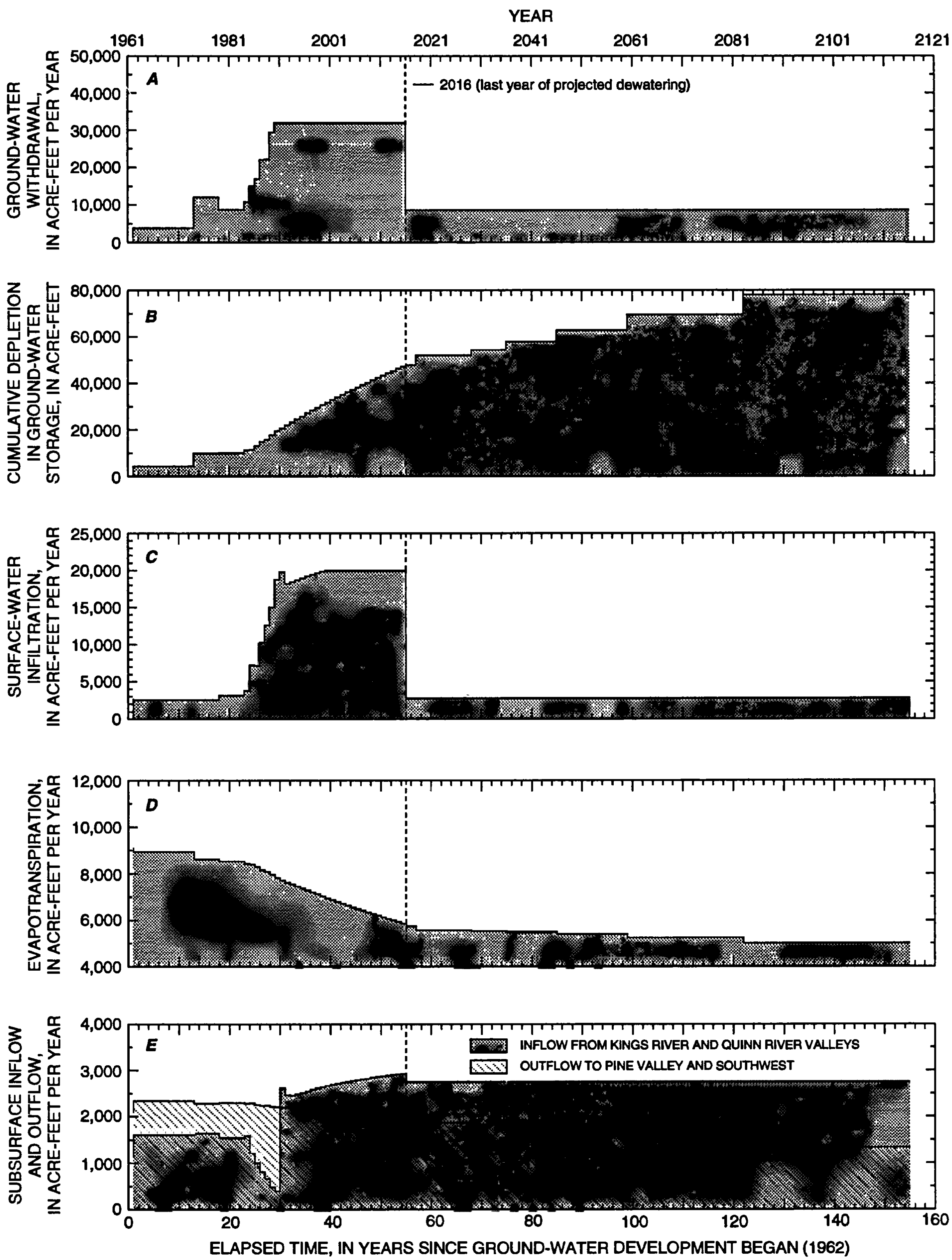


Figure 33. Scenario B, simulated response with mine dewatering at 1991 rate (23,000 acre-feet) for 25 years followed by a 100-year recovery period, Desert Valley, Nevada. Pumped mine water is allowed to infiltrate beneath wetlands area. ***A,*** Rate of total ground-water withdrawal. ***B,*** Cumulative depletion in ground-water storage. ***C,*** Surface-water infiltration rate. ***D,*** Evapotranspiration rate. ***E,*** Rates of subsurface inflow and outflow.

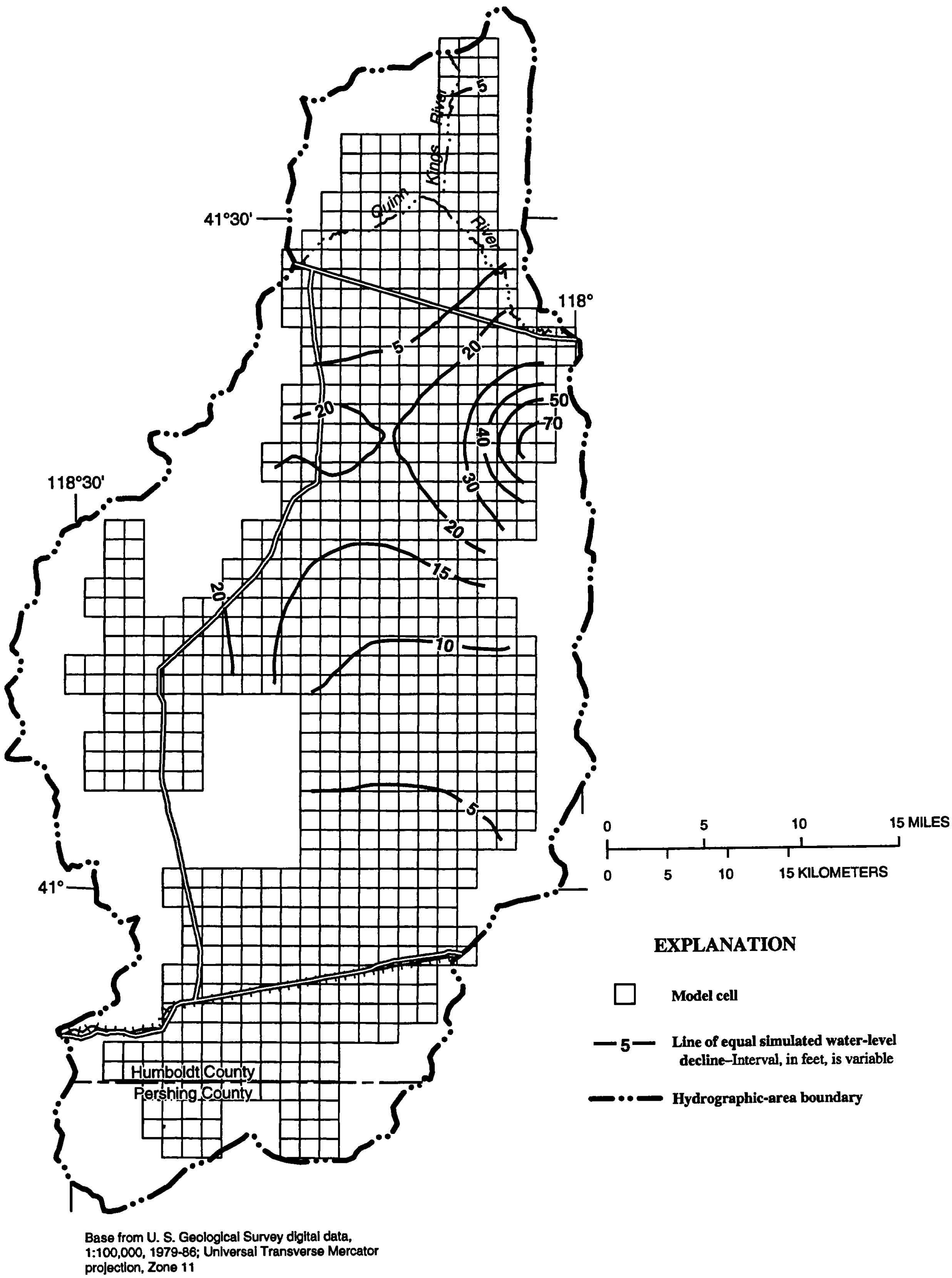


Figure 34. Model-simulated water-level declines at end of 25 years (stress-period 35) for hypothetical mine-dewatering period, scenario C (continued dewatering at 1991 rate), Desert Valley, Nevada.

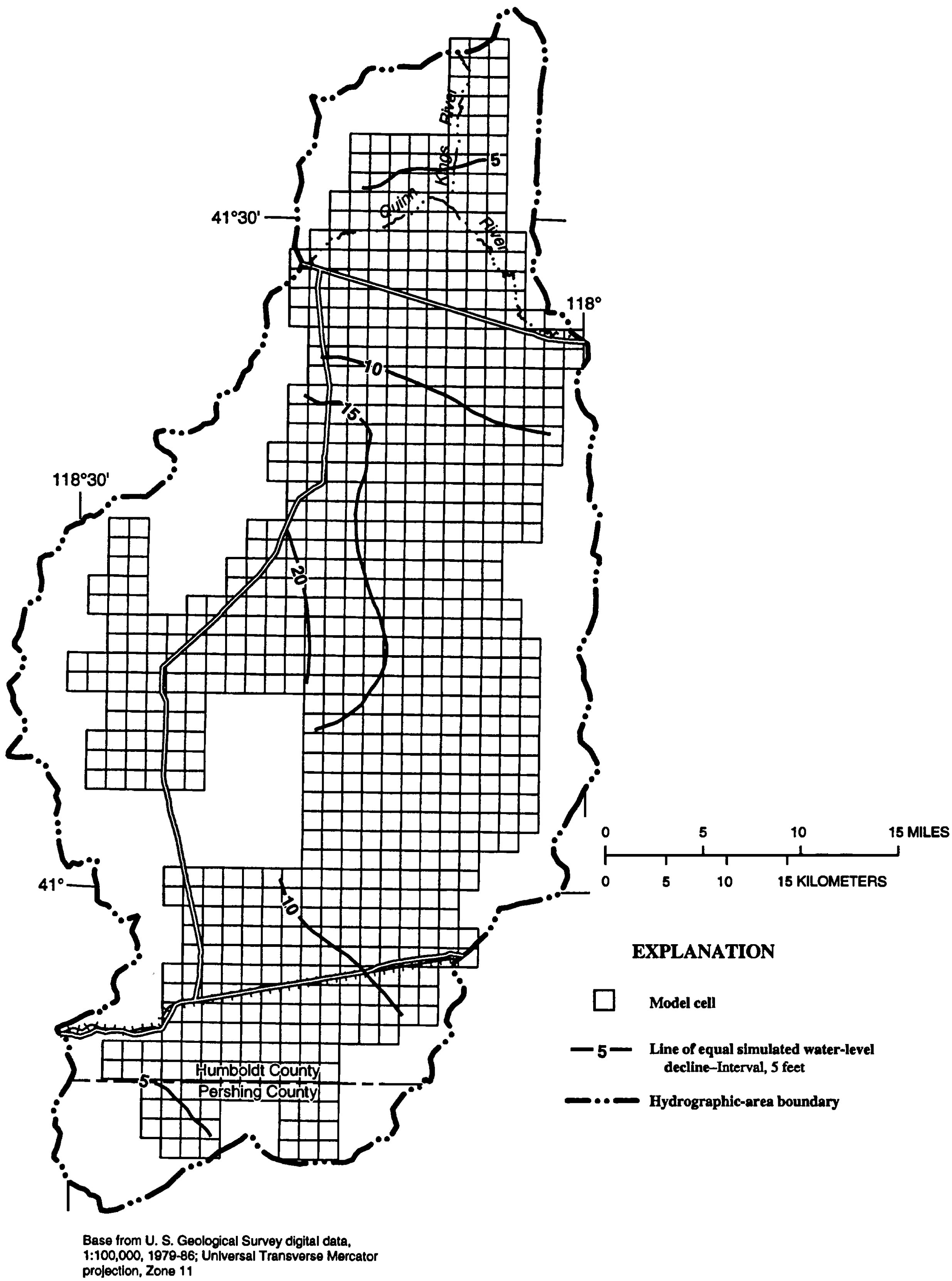


Figure 35. Model-simulated water-level declines at end of 100-year recovery (stress-period 36) for hypothetical mine-dewatering period, scenario C (continued dewatering at 1991 rate), Desert Valley, Nevada.

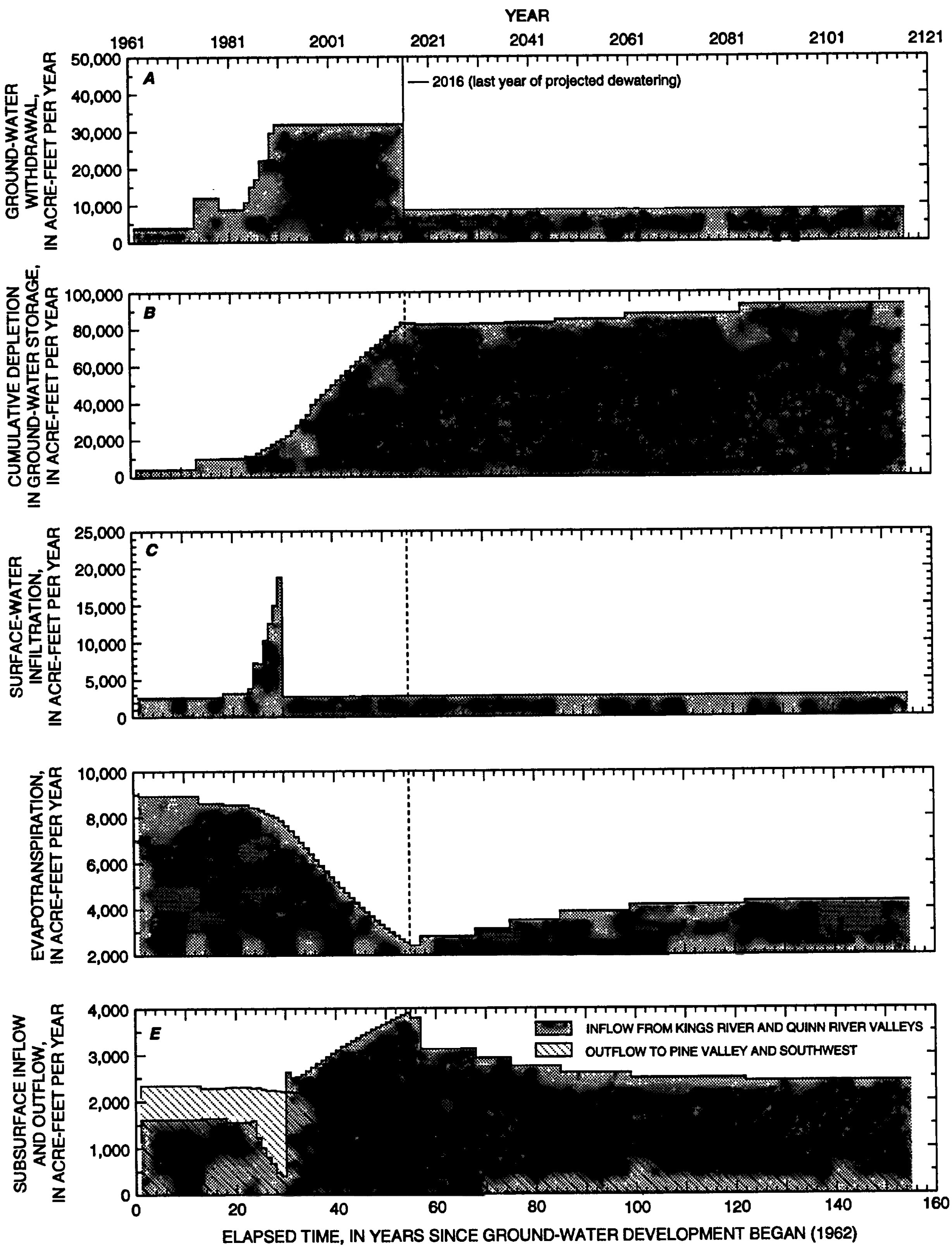


Figure 36. Scenario C, simulated response with mine dewatering at 1991 rate (23,000 acre-feet) for 25 years followed by a 100-year recovery period, Desert Valley, Nevada. Pumped mine water is not allowed to infiltrate beneath wetlands area and is entirely removed from model. ***A***, Rate of total ground-water withdrawal. ***B***, Cumulative depletion in ground-water storage. ***C***, Surface-water infiltration rate. ***D***, Evapotranspiration rate. ***E***, Rates of subsurface inflow and outflow.

Evaluation of Hypothetical Dewatering Scenarios

Simulation results from the three hypothetical dewatering scenarios indicate that water-level declines from long-term mine dewatering would not be localized and probably would affect a large area in Desert Valley. However, water-level declines of greater than 50 ft are simulated at a distance of only 1 mi or less from the mine in scenarios A and B, and about 2 mi from the mine in scenario C. The practice of discharging mine waters to the wetlands site where infiltration recharges the ground-water system, and the position of the artificial wetlands relative to the mine, effectively retard the expansion of water-level declines westward from the mine. Additional subsurface inflow from the adjacent Quinn River Valley is induced in response to dewatering at the mine; in contrast, the simulated infiltration beneath the Quinn River was not greatly increased. On the basis of simulated changes of inflow and outflow budget components with time and the change of cumulative depletion in ground-water storage, a new equilibrium may be approached slowly after 100 years of recovery from the time mine dewatering ceases.

Limitations on Use of Flow Model

To represent the ground-water flow system of Desert Valley using a mathematical flow model, many simplifying assumptions about the system were necessary. Hydraulic properties of basin-fill deposits and distributions of water levels within basin-fill aquifers are seldom known accurately. Available hydrologic information within the study area on a basin-wide scale was sparse; however, more detailed data were available in the Sleeper Mine area. Those data provided limited, localized insight into the depositional textures of the basin fill. Thus, most of the hydrologic conditions in the basin-fill aquifer had to be inferred, especially along the edges of the valley floor and at depths greater than about 200 ft.

Streamflow in the Quinn and Kings Rivers was simulated by the model as a constant daily rate during each stress period. That constant rate allowed streamflow infiltration to recharge the ground-water system uniformly over a given year. Limited discharge data suggest that actual streamflow and associated recharge generally are limited to short periods during Spring runoff. Ephemeral streamflow would cause seasonal water-level fluctuations in wells near the rivers. This seasonality was not modeled; however, an attempt was made to adjust the specified annual streamflow in the model to be proportional to the estimated long-term normal. Depending on the amount of streamflow available during any given year and the irrigation practices associated with the two rivers upstream from the study area, actual streamflow during a particular year may never enter the study area.

The calibration process was constrained by the amount of data available to determine how closely the measured data can be matched by simulation. The predevelopment model was calibrated using sparse water-level data collected during the late 1950's and early 1960's and was assumed to represent predevelopment conditions. Model calibration for the development simulation was made against changes in water levels over a 30-year period and estimated storage volumes within the artificial wetlands beginning in 1985. If the areal distribution of current ground-water pumpage remains about the same and the general location of the artificial wetlands does not change, effects of future pumping and infiltration beneath the wetlands could be simulated with about the same degree of accuracy as for the development period (1962-91). Increased pumping rates at the mine can be evaluated, but effects on the basin-fill aquifer system should be considered reliable only as general changes and trends.

SUMMARY AND CONCLUSIONS

In the Spring of 1985, open-pit mine dewatering began at the Sleeper Mine in the northeastern part of Desert Valley. Dewatering in 1991 totalled 23,000 acre-ft—more than three times the estimated annual recharge from precipitation. The mining operation is planned to continue through 1998 at a projected dewatering rate of nearly 32,000 acre-ft/yr. Unlined canals are used to convey the pumped water to an artificial wetlands northwest of the mine, where the water creates areas for wildlife habitat. The mine discharge either is consumed by evapotranspiration or infiltrates back to the basin-fill aquifer. In 1991, the discharge area was moved farther west and away from the mine because water infiltrating beneath the wetlands was recirculating back to the dewatering operation at the mine.

As a result of the apparent potential for ground-water overdraft due to mine dewatering, the U.S. Geological Survey, in cooperation with the Nevada Division of Water Resources, began a study in 1989 to evaluate the hydrologic conditions of Desert Valley. The objectives of the study were to document 1991 hydrologic conditions and determine whether these conditions had changed since predevelopment time (pre-1962). In addition, a reappraisal of the basin's ground-water budget was made on the basis of hydrologic information collected since predevelopment. A ground-water flow model was then developed and used to simulate predevelopment and 1991 conditions and evaluate probable long-term effects of ground-water withdrawals on a basin-wide scale.

The study area, which includes both the Desert Valley hydrographic area and the Sod House hydrographic subarea in northwestern Nevada, encompasses about 1,200 mi^2, of which about 70 percent is underlain by unconsolidated basin-fill deposits. Annual precipitation on the valley floor is generally less than 8 in., increasing to more than 18 in. in the higher altitudes of the Jackson Mountains. The estimated total precipitation that falls within the study area is approximately 400,000 acre-ft annually.

The geologic history of the Desert Valley area is complex and includes deposition of large volumes of volcanic rocks and marine sediments, intense mountain-building activity, basin-and-range extensional faulting, and cyclic fluctuations of a large, closed-basin lake. The unconsolidated basin-fill deposits, which may be as much as 7,000 ft thick in the south-central part of the basin, make up the principal ground-water reservoir. These deposits consist of lenticular units of gravel, sand, silt, and clay, which function as a single aquifer system. Ground water within the basin fill is generally unconfined at shallow depths and under slightly confined conditions at grater depths. Estimates of hydraulic conductivity range between 5 ft/d for fine-grained deposits to as much as 320 ft/d for coarse-grained deposits. The amount of ground water stored in the upper 180 ft of saturated basin fill is estimated to total about 10 million acre-ft.

On the basis of Nevada State standards for 10 selected inorganic constituents and properties, most ground water sampled during this study is suitable for beneficial use for human consumption, aquatic life, irrigation, and watering livestock. Although most ground water sampled contains more than 500 mg/L of dissolved solids, water at only five sites exceeded secondary maximum drinking-water standards. The concentration of dissolved solids appears to be related primarily to the dissolution of evaporative salts and transpiration, rather than to the direct evaporation of ground water. Results of chemical analyses suggest that the overall composition of the ground water is a mixture of the major dissolved constituents; however, sodium-plus-potassium and sulfate-plus-chloride-type water represent nearly half the samples collected. General water types have a distribution similar to that documented by data for 1954-61. Geochemical evolution of the ground water follows a logical sequence along estimated flow paths from recharge source areas to discharge areas.

The inflow and outflow components of the ground-water budget for the aquifer system within the study area were estimated by using empirical techniques and refined by calibration of a ground-water flow model (table 11). Under predevelopment (natural) conditions, the total flow through the aquifer system was about 11,000 acre-ft/yr. The estimate of annual recharge by precipitation is 7,300 acre-ft—about 2,000 acre-ft greater than the 1962 reconnaissance estimate. This estimate includes about 440 acre-ft of recharge to the areas covered by sand dunes. Ground-water inflow to the basin-fill aquifer from infiltration beneath rivers was about 2,700 acre-ft/yr, and subsurface inflow from adjacent Quinn River and Kings River Valleys was about 1,100 acre-ft/yr. Natural discharge was estimated to be about 9,100 acre-ft/yr by evapotranspiration and about 2,100 acre-ft/yr by subsurface outflow. Under predevelopment conditions, ground water flowed toward the center of the basin from the recharge source areas in adjacent mountains. Ground water enters the basin-fill aquifer from the adjacent Quinn River and Kings River Valleys and exits to Pine Valley beneath low alluvial divides in the northern part of the study area. The existence of a ground-water divide west of the Jungo Hills suggests that some ground water, perhaps about 1700 acre-ft/yr, exits the study area to the south near the northern Antelope Range.

During 1991, about 5,500 acres of land, generally along the western margin of the valley floor, was irrigated with ground water, supplemented by local streamflow from the Jackson Mountains. Net ground-water withdrawals for irrigation were about 8,600 acre-ft annually, which appears to have resulted in 10-20 ft of water-level declines near the irrigated areas since predevelopment time. Water levels in areas unaffected by ground-water development have declined less than 5 ft since predevelopment time, probably as a result of the recent trend of below-average precipitation. Maximum water-level declines beneath the open pits at the Sleeper Mine, as of Spring 1991, ranged from 295 to 315 ft. In contrast, water levels beneath the wetlands receiving mine discharge rose 5-10 ft. Changes in the ground-water flow regime between predevelopment and 1991 conditions are predominantly near the dewatering operations and associated wetlands. Subsurface flow continues to enter and exit beneath the low alluvial divides in the north and to the south, similar to predevelopment conditions. However, the natural flow directions are interrupted by the dewatering operations, causing capture of ground water as it enters from the Quinn River Valley and moves toward the exit point to Pine Valley. The ground-water budget, as simulated by the ground-water flow model for 1991 conditions, indicates that nearly all the water pumped at the mine is supplied by infiltration beneath the artificial wetlands and the depletion of ground water in storage. A small amount of mine discharge water may be supplied by a decrease in evapotranspiration and an increase in infiltration beneath the Quinn River Valley.

The calibrated flow model was used to evaluate the probable long-term effects of ground-water withdrawal on a basin-wide scale. On the basis of the life expectancy of the Sleeper Mine and discussions with representatives from the Nevada Division of Water Resources, three hypothetical dewatering scenarios were developed. Scenario A was used to evaluate effects of continued mine dewatering at projected increasing rates for an additional 7 years from 1991 through 1998, followed by a 100-year recovery period at which time mine dewatering is discontinued and irrigation pumping is held constant at 1991 levels. During this scenario, the mine discharge water was allowed to infiltrate beneath the wetlands area similar to the conditions used in the predevelopment model. Scenarios B and C simulated constant mine dewatering at the 1991 rate for a period of 25 years (1991-2016), followed by a 100-year recovery period with similar pumping conditions as in scenario A. Infiltration beneath the wetlands area was simulated in scenario B, but in scenario C was removed from the flow model and not allowed to recharge the system. The results of the hypothetical dewatering scenarios suggest that water level-declines from long-term mine dewatering would not be localized and probably would affect a large area in Desert Valley. Local recharge to the mine, in scenarios A and B, was predominantly from infiltration beneath the wetlands area. In contrast, recharge to the mine in scenario C was obtained by depletion of ground-water storage and reduction in evapotranspiration. In addition, the distribution of simulated water-level declines suggests that the relative position of the current wetlands area in the ground-water flow system can attenuate the westward propagation of effects from the mine dewatering. By the end of the 100-year recovery period, the simulated aquifer system in all three scenarios has not reached a new equilibrium.

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Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada

[**Water use**: H, domestic; I, irrigation; N, industrial; S, stock; U, unused. **Site status**: O, obstruction in well above water surface; R, well had been pumped recently; X, water level was affected by stage in nearby surface-water body. **Method**: S, steel tape; T, electric tape; NR, method not recorded (sites 55-57, 59-61, 66, 67, 69-72, 75-84, and 130 measured by Nevada Gold Mining, Inc.; site 53 measured by Sinclair (1962, table 1); sites 129 and 131 measured by Huxel and others (1966, table 20); sites 57, 110, 115, and 132-134 first measured by driller). **Symbol**: --, unknown]

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
42	S	76	6	4,156	12-62	09/01/59	21.10		S
						04/19/89	33.26		S
						11/14/89	34.14		S
						08/01/90	34.62		S
						04/03/91	34.72	R	S
43	S	236	10	4,135	--	09/16/63	9.51		S
						04/19/89	14.77	R	S
						11/14/89	15.18		S
						02/13/90	15.25		S
						05/08/90	15.32	R	S
						07/31/90	15.52		S
						04/03/91	16.01		S
44	S	76	6	4,135	22-76	09/19/63	10.51		S
						04/19/89	16.22	R	S
						11/14/89	16.60		S
						02/13/90	16.53		S
						08/01/90	16.91		S
						04/03/91	16.93		S
45	S	--	8	4,125	--	09/19/63	0.48		S
						04/19/89	7.85	R	S
						11/14/89	7.93		S
						05/08/90	8.11	R	S
						08/01/90	8.41		S
						04/03/91	8.56		S
46	S	--	6	4,165	--	09/19/63	41.98		S
						--/--/76	47.96		S
						04/18/89	50.50		S
						11/14/89	49.79		S
						05/08/90	49.91		S
						08/01/90	50.00		S
						04/03/91	50.35		S
47	S	182	10	4,132	--	09/19/63	12.98		S
						04/19/89	17.41	R	S
						11/14/89	17.67		S
						07/31/90	18.29		S
						04/03/91	18.87		S
48	U	22	2	4,114	--	09/19/63	0.34		S
						--/--/76	0.25		S
						05/09/89	2.58		S
						11/14/89	3.48		S
						05/08/90	3.24		S
						07/31/90	3.62		S
						04/03/91	3.94		S

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
49	S	202	6	4,143	52-220	09/19/63	31.68		S
						--/--/64	26.38		S
						--/--/76	28.70		S
						11/14/89	35.26	R	S
						08/01/90	35.95		S
						04/03/91	35.9	R	T
50	S	52	10	4,113	--	11/13/89	10.53	S	S
						05/09/90	10.76		S
						07/31/90	12.88		S
						04/03/91	12.98		S
						06/26/91	12.97		
51	S	--	8	4,113	--	--/--/76	8.49		S
						04/18/89	9.89		S
						11/14/89	13.33	R	S
						05/09/90	10.82		S
						04/03/91	12.13		S
52	S	229	8	4,118	--	05/04/61	11.8		S
						03/09/76	11.95		S
						04/18/89	12.46		S
						05/09/90	13.20		S
						08/01/90	13.47		S
						08/22/90	13.60		S
						04/03/91	14.00		S
53	S	112	16	4,121	--	04/21/51	3.1		NR
						05/09/89	8.89	X,R	S
54	S	27	6	4,124	--	06/29/89	9.46	X	S
						05/09/90	11.92		S
						07/31/90	12.57		S
55	U	525	--	4,126	--	09/05/89	17.85		NR
						11/28/89	18.15		NR
						02/28/90	18.01		NR
						06/06/90	19.41		NR
						12/10/90	20.00	O	NR
						06/06/91	20.00	O	NR
56	U	600	--	4,126	--	11/28/89	17.00		NR
						02/28/90	16.08		NR
						06/06/90	16.16		NR
						09/12/90	17.42		NR
						12/10/90	16.84		NR
						03/07/91	16.62		NR
						06/06/91	16.46		NR
						01/15/92	17.12		NR
						04/01/92	17.43		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
57	U	80	2	4,114	64-69	08/22/90	21		NR
						09/13/90	14.29		NR
						04/03/91	14.32		S
						06/06/91	14.89		NR
						01/14/92	15.24		NR
						04/01/92	15.52		NR
58	U	166	8	4,117	--	04/27/61	7.90		S
						03/--/76	13.03		S
						04/18/89	16.53		S
						11/13/89	17.75		S
						02/14/90	17.24		S
						05/09/90	17.03		S
						07/31/90	17.82		S
						04/03/91	17.34		S
59	U	248	8	4,121	--	04/27/61	10.9		S
						03/--/76	17.74		S
						05/09/90	15.46		S
						07/31/90	16.10		S
						09/13/90	17.0		NR
						04/03/91	16.64		S
						09/04/91	17.74		NR
						01/15/92	18.61		NR
						04/01/92	18.70		NR
60	U	200	2	4,116	150-200	12/13/89	22.22		NR
						02/01/90	16.01		NR
						06/13/90	16.22		NR
						09/12/90	17.36		NR
						12/10/90	17.05		NR
						03/13/91	15.90		NR
						06/06/91	15.57		NR
						09/04/91	16.65		NR
						01/15/92	15.94		NR
						04/01/92	15.78		NR
61	U	700	2	4,116	630-680	12/13/89	16.67		NR
						02/01/90	16.13		NR
						06/13/90	14.75		NR
						09/12/90	15.49		NR
						12/10/90	15.98		NR
						03/13/91	15.79		NR
						06/06/91	15.97		NR
						01/14/92	16.89		NR
						04/01/92	16.76		NR
62	U	30	6	4,109	--	11/10/60	2.60		S
						03/15/75	5.7		S
						04/18/89	8.25		S
						11/13/89	9.21		S
						02/14/90	8.94		S
						05/08/90	8.36		S
						08/01/90	9.45		S
						04/03/91	8.86		S

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
63	U	39	2	4,115	--	09/19/63	12.04		S
						--/--/76	15.28		S
						04/18/89	18.24		S
						11/13/89	19.45		S
						05/08/90	18.70		S
						08/01/90	19.63		S
						04/03/91	19.23		S
64	S	--	6	4,127	--	05/04/61	20.9		S
						05/09/89	29.29	R	S
						11/14/89	30.08	R	S
						05/08/90	30.65	R	S
						04/03/91	30.35		S
65	S	270	10	4,232	130-270	05/11/89	125.63		S
						11/13/89	128.21	R	S
66	U	600	--	4,132	--	08/23/89	29.43		NR
						11/28/89	29.82		NR
						02/28/90	30.42		NR
						06/20/90	32.35		NR
						09/12/90	33.41		NR
						12/10/90	34.00		NR
						03/07/91	35.00		NR
						06/06/91	35.90		NR
						01/15/92	38.70		NR
						04/01/92	39.54		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
67	U	125	2	4,138	115-125	10/13/85	26.58		NR
						10/20/85	26.74		NR
						10/27/85	26.85		NR
						11/03/85	27.75		NR
						11/11/85	27.15		NR
						11/23/85	27.27		NR
						12/15/85	27.73		NR
						12/22/85	27.88		NR
						12/29/85	27.90		NR
						01/05/86	28.13		NR
						01/12/86	28.50		NR
						01/19/86	28.50		NR
						01/26/86	28.50		NR
						02/02/86	28.50		NR
						02/09/86	28.31		NR
						02/23/86	28.50		NR
						09/23/86	30.00		NR
						11/13/86	29.68		NR
						02/05/87	30.77		NR
						03/11/87	31.00		NR
						09/18/87	32.35		NR
						02/29/88	34.03		NR
						05/31/88	35.27		NR
						08/15/88	36.84		NR
						08/29/88	37.04		NR
						11/29/88	38.17		NR
						02/13/89	38.58		NR
						02/28/89	38.90		NR
						05/30/89	39.41		NR
						08/29/89	40.40		NR
						11/27/89	41.14		NR
						02/28/90	41.81		NR
						06/21/90	44.01		NR
						09/12/90	45.18		NR
						12/10/90	46.22		NR
						03/07/91	47.39		NR
						06/06/91	48.65		NR
						09/09/91	50.78		NR
						01/15/92	51.46		NR
						04/01/92	53.39		NR
68	S	--	8	4,146	--	04/11/61	30.4		S

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
69	U	250	2	4,138	100-110	10/13/85	32.30		NR
						10/20/85	33.00		NR
						10/27/85	33.60		NR
						11/03/85	34.25		NR
						11/11/85	34.85		NR
						11/17/85	35.29		NR
						11/23/85	35.55		NR
						12/01/85	36.44		NR
						12/15/85	37.35		NR
						12/22/85	37.87		NR
						12/29/85	38.27		NR
						01/05/86	38.63		NR
						01/12/86	38.92		NR
						01/19/86	39.09		NR
						01/26/86	39.35		NR
						02/02/86	39.60		NR
						02/09/86	39.82		NR
						02/23/86	40.40		NR
						09/23/86	46.00		NR
						11/13/86	46.90		NR
						02/05/87	48.70		NR
						03/11/87	49.37		NR
						09/18/87	53.75		NR
						11/30/87	54.42		NR
						02/29/88	59.39		NR
						05/31/88	62.56		NR
						08/15/88	68.08		NR
						08/17/88	68.18		NR
						08/29/88	68.06		NR
						11/29/88	71.45		NR
						02/13/89	72.42		NR
						02/27/89	73.48		NR
						05/30/89	75.83		NR
						08/05/89	77.10		NR
						08/28/89	77.55		NR
						11/29/89	79.20		NR
						02/28/90	81.01		NR
						06/06/90	85.59		NR
						09/12/90	88.42		NR
						03/07/91	94.95		NR
						06/06/91	100.30		NR
						09/11/91	104.05		NR
						01/15/92	135.86		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
70	U	555	--	4,137	--	05/31/88	51.92		NR
						08/16/88	56.00		NR
						08/17/88	56.05		NR
						08/22/88	57.30		NR
						08/29/88	55.14		NR
						09/21/88	55.10		NR
						11/29/88	58.22		NR
						01/31/89	59.37		NR
						02/06/89	54.48		NR
						02/13/89	53.68		NR
						02/14/89	57.03		NR
						02/27/89	58.02		NR
						05/30/89	59.00		NR
						08/05/89	62.00		NR
						08/28/89	62.10		NR
						11/28/89	62.62		NR
						02/28/90	66.64		NR
						06/06/90	73.41		NR
						03/07/91	82.90		NR
						06/06/91	85.29		NR
						09/11/91	86.46		NR
						01/15/92	90.11		NR
						04/01/92	91.10		NR
71	U	540	2	4,133	420-540	12/05/88	49.68		NR
						12/12/88	47.65		NR
						12/19/88	47.38		NR
						01/03/89	47.75		NR
						01/09/89	47.93		NR
						01/16/89	47.99		NR
						01/23/89	48.23		NR
						01/30/89	48.14		NR
						02/06/89	46.06		NR
						02/13/89	45.50		NR
						02/14/89	46.63		NR
						02/20/89	47.45		NR
						02/27/89	47.15		NR
						03/06/89	47.98		NR
						04/10/89	48.42		NR
						05/30/89	47.96		NR
						08/05/89	50.11		NR
						08/28/89	50.24		NR
						11/29/89	50.61		NR
						02/01/90	54.52		NR
						06/12/90	61.65		NR
						09/06/90	63.38		NR
						12/10/90	65.96		NR
						03/12/91	70.92		NR
						06/06/91	73.49		NR
						09/05/91	74.10		NR
						01/15/92	74.10		NR
						04/01/92	76.26		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
72	U	820	2	4,133	740-810	12/05/88	48.17		NR
						12/12/88	49.00		NR
						12/19/88	48.33		NR
						01/03/89	51.31		NR
						01/09/89	52.14		NR
						01/16/89	52.23		NR
						01/23/89	51.81		NR
						01/30/89	51.78		NR
						02/06/89	49.45		NR
						02/13/89	48.92		NR
						02/14/89	50.05		NR
						02/20/89	51.00		NR
						02/27/89	50.55		NR
						03/06/89	51.40		NR
						04/10/89	50.40		NR
						05/30/89	49.93		NR
						08/05/89	52.73		NR
						08/28/89	52.84		NR
						11/29/89	53.26		NR
						02/01/90	57.67		NR
						06/12/90	64.20		NR
						09/12/90	65.85		NR
						12/10/90	68.49		NR
						03/12/91	73.66		NR
						06/06/91	76.29		NR
						01/15/92	76.98		NR
						04/01/92	77.32		NR
73	S	50	--	4,152	--	04/11/61	39.2		S
74	S	--	6	4,143	--	05/08/89	45.56		S
						11/15/89	47.26		S
						05/08/90	49.82		S
						07/31/90	51.72		S
						04/04/91	56.28		S
75	U	90	2	4,115	25-80	12/13/89	18.65		NR
						03/02/90	18.63		NR
						06/21/90	19.09		NR
						09/12/90	19.59		NR
						12/10/90	19.09		NR
						03/13/91	18.12		NR
						06/06/91	18.87		NR
						09/04/91	18.59		NR
						01/14/92	17.39		NR
						04/01/92	16.50		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
76	U	650	2	4,115	100-150	12/13/89	17.80		NR
						03/02/90	16.75		NR
						06/21/90	17.95		NR
						09/12/90	19.02		NR
						12/10/90	18.22		NR
						03/13/91	17.08		NR
						06/06/91	18.12		NR
						01/14/92	16.42		NR
						04/01/92	15.23		NR
77	U	640	2	4,115	600-640	12/13/89	17.28		NR
						03/02/90	16.22		NR
						06/21/90	17.50		NR
						09/12/90	19.30		NR
						12/10/90	18.39		NR
						03/13/91	17.22		NR
						06/06/91	17.62		NR
						01/14/92	18.05		NR
						04/01/92	17.31		NR
78	U	40	2	4,118	5-40	06/25/91	15.96		NR
						09/04/91	16.38		NR
						01/14/92	15.48		NR
						04/01/92	14.80		NR
79	U	40	2	4,118	5-40	06/25/91	4.46		NR
						09/04/91	4.32		NR
						01/14/92	2.76		NR
						04/01/92	1.83		NR
80	U	90	2	4,122	70-90	12/13/89	10.73		NR
						02/01/90	10.55		NR
						06/11/90	10.51		NR
						09/12/90	11.12		NR
						12/10/90	10.51		NR
						03/07/91	9.81		NR
						06/06/91	9.00		NR
						09/04/91	9.42		NR
						01/15/92	9.03		NR
						04/01/92	8.62		NR
81	U	510	2	4,122	325-490	12/13/89	23.79		NR
						02/01/90	19.60		NR
						06/11/90	20.33		NR
						09/12/90	21.40		NR
						12/10/90	21.72		NR
						03/07/91	22.02		NR
						06/06/91	22.41		NR
						01/15/92	24.53		NR
						04/01/92	25.02		NR
82	U	40	2	4,119	5-40	06/25/91	14.04		NR
						09/04/91	14.95		NR
						01/14/92	15.58		NR
						04/01/92	11.88		NR

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
83	U	40	2	4,119	5-40	06/25/91	15.71		NR
						09/04/91	15.64		NR
						01/14/92	13.92		NR
						04/01/92	8.29		NR
84	U	40	2	4,122	5-40	06/25/91	5.62		NR
						09/04/91	5.23		NR
						01/15/92	4.80		NR
						04/01/92	4.45		NR
85	S	--	6	4,146	--	04/--/61	38		S
						05/09/89	48.01		S
						11/14/89	50.03	R	S
						05/08/90	48.42		S
						04/03/91	48.62		S
87	S	--	8	4,134	--	04/27/61	33.3		S
						05/08/90	40.35		S
						08/01/90	44.62		S
						04/03/91	32.88		S
88	S	--	6	4,218	--	05/08/89	110.50	R	S
						11/15/89	111.21		S
						05/08/90	112.13		S
						07/31/90	112.30	R	S
						04/04/91	114.28	R	S
89	U	59	2	4,140	48-52	08/24/90	30.00		S
						04/04/91	29.53		S
						06/26/91	29.87		S
90	S	87	--	4,138	60-85	04/26/61	23.4		S
91	S	130	10	4,149	83-153	04/26/61	30.4		S
						04/18/89	38.17		S
						11/14/89	40.38	R	S
						05/08/90	43.51		S
						08/01/90	44.22	R	S
						04/03/91	40.25		S
92	S	87	6	4,145	65-85	04/26/61	27.3		S
93	S	95	--	4,150	70-80	04/26/61	28.3		S
94	S,H	620	16	4,196	63-620	11/14/89	65.32		S
						04/04/91	63.56		S
95	S	360	10	4,579	330-360	08/07/66	305		S
						06/15/87	303		--
						11/15/89	302.07		S
						04/04/91	302.3		T

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
96	S	--	6	4,167	--	04/11/61	52		S
						05/08/89	54.67		S
						11/15/89	54.83		S
						05/08/90	54.90		S
						07/31/90	54.91		S
97	S	55	8	4,147	--	04/16/60	32.5		S
						06/15/87	36		--
						04/20/89	34.60	R	S
						11/15/89	34.82		S
						07/16/90	34.82		S
						04/04/91	35.02	R	S
98	S	116	6	4,179	--	04/11/61	66.20		S
						06/15/87	69		--
						05/08/89	68.02		S
						11/15/89	68.02		S
						05/08/90	68.20		S
						07/31/90	68.16		S
						04/04/91	68.60	R	S
99	S	--	6	4,150	--	04/26/61	34.8		S
						06/27/89	36.74		S
						11/16/89	36.94		S
						05/10/90	36.85		S
						08/01/90	37.10		S
						04/04/91	37.09		S
100	I	300	18	4,207	--	04/14/60	62.1		S
						05/10/89	65.02		S
						11/14/89	69.67		S
						08/24/90	73.63		S
101	S	53	6	4,170	--	04/08/61	31.3		S
						04/21/89	30.7	O	S
102	S	--	8	4,132	--	04/08/61	16.5		S
						06/16/87	17.00		--
						05/08/89	17.79	R	S
						11/15/89	17.88		S
						01/18/90	17.76		S
						05/08/90	17.85		S
						07/31/90	17.79		S
						04/04/91	17.83	R	S
103	S	50	8	4,139	--	06/03/61	24.20		S
						05/08/89	25.80		S
						11/15/89	25.88		S
						05/08/90	25.93		S
						07/16/90	25.94		S
						04/04/91	26.14	R	S

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
104	S	77	8	4,148	--	04/08/61	34.8		S
						06/16/87	32.7		--
						04/20/89	32.53	R	S
						05/08/89	32.62		S
						06/26/89	32.57		S
						11/15/89	32.66		S
						01/18/90	32.64		S
						05/08/90	32.63		S
						07/31/90	32.63		S
105	S	--	6	4,156	--	06/16/87	43		--
						04/21/89	42.74		S
						11/16/89	42.77		S
						02/15/90	43.77		S
						05/10/90	42.80		S
						08/02/90	42.87		S
						04/04/91	42.89		S
106	S	--	6	4,149	--	04/08/61	34.80		S
						04/21/89	46.22	R	S
						06/27/89	34.36		S
						11/16/89	34.38		S
						05/10/90	34.44		S
						08/02/90	34.50		S
						04/04/91	34.51		S
107	S	89	6	4,148	--	01/01/67	34		S
						04/20/89	33.58		S
						11/15/89	33.66		S
						05/07/90	33.72		S
						07/31/90	33.68		S
108	S	75	6	4,166	--	04/08/61	53		S
						06/16/87	53		--
						4/20/89	52.22	R	S
						11/15/89	52.29		S
						05/07/90	52.32		S
						07/31/90	52.33		S
						04/04/91	52.55	R	S
109	U	288	14	4,169	168-288	04/20/89	53.47		S
						11/15/89	53.52		S
						05/07/90	53.50		S
						07/31/90	53.51		S
110	U	310	14	4,171	142-310	03/--/75	57		NR
						04/20/89	56.68		S
111	U	288	14	4,192	144-288	04/20/89	75.82		S
112	S	--	14	4,186	--	11/15/89	71.29		S
						05/07/90	71.32		S
						07/31/90	71.31		S
						04/04/91	71.7	R	T

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
113	S	--	6	4,175	--	04/08/61	58.8		S
						04/20/89	60.35	R	S
						06/27/89	60.39		S
						11/15/89	60.45		S
						05/07/90	60.42		S
						07/31/90	60.45		S
114	U	284	14	4,192	164-284	04/20/89	76.45		S
115	U	287	14	4,185	143-287	03/--/75	71		R
						04/20/89	72.15		S
116	N	--	8	4,194	--	04/20/89	76.38		S
						11/15/89	76.53		S
						01/17/90	76.54		S
						06/04/90	76.55		S
						08/02/90	76.67		S
						04/03/91	76.66	R	S
117	S	86	6	4,160	--	04/21/89	45.40	R	S
						06/27/89	45.41		S
						11/16/89	45.43		S
						05/10/90	45.43		S
						08/02/90	45.51		S
118	S	63	8	4,159	--	04/20/89	42.78	R	S
						11/15/89	42.82		S
						05/07/90	42.83		S
						07/31/90	42.81		S
119	S	140	8	4,169	--	04/--/61	54.5		S
						06/16/89	58		--
						11/14/89	57.48	R	S
						05/10/90	57.29	R	S
						08/01/90	57.54		S
						04/03/91	57.60	R	S
120	U	91	2	4,170	76-81	08/26/90	83.00		S
						08/27/90	68.95		S
						04/05/91	58.95		S
121	U	98	2	4,160	93-98	04/03/91	47.94		S
122	I	500	--	4,160	336-348	--/--/61	60	R	--
123	I	260	24	4,195	--	05/10/89	115.0		T
						11/16/89	113.14		S
						05/07/90	114.91		S
						04/03/91	114.44		S
124	S	153	8	4,178	83-153	04/--/61	72.2		S
						06/26/89	87.26		S
						11/16/89	87.32		S
						02/14/90	87.17		S
						05/07/90	87.19		S
						07/31/90	87.35		S

Table 15. Water-level measurements and other information for wells, Desert Valley, Nevada—Continued

Site number (plate 1*C*)	Water use	Well depth (feet)	Well diameter (inches)	Land-surface altitude (feet above sea level)	Perforated interval (feet below land surface)	Water-level measurement			
						Date	Depth (feet below land surface)	Site status	Method
125	U	152	2	4,210	147-152	11/11/90	83.20		S
						04/03/91	111.75		S
						04/04/91	111.75		S
126	S	--	10	4,154	--	02/26/64	38.34		S
						11/14/89	42.77	R	S
						05/09/90	43.40		S
						04/03/91	45.23		S
127	S	--	8	4,321	--	06/26/89	16.49		S
						11/16/89	23.28	R	S
						07/25/90	17.13	R	S
128	S	--	8	4,168	--	06/26/89	24.11		S
						11/16/89	24.22		S
129	S	300	8	4,258	--	09/26/47	134.1		NR
						04/19/89	138.64		S
						11/14/89	141.27		S
						02/13/90	141.76		S
130	U	32	2	4,123	--	02/27/64	10.26		S
						05/11/89	12.64		S
						11/13/89	14.54		S
						02/14/90	14.88		S
						05/08/90	15.19		S
						07/31/90	15.78		S
						09/13/90	16.1		NR
						04/03/91	17.16		S
						06/06/91	19.45		NR
						01/15/92	18.04		NR
						04/01/92	20.51		NR
131	S	63	8	4,127	--	09/28/47	8.70		NR
						11/14/89	12.75	R	S
						04/03/91	13.67		S
132	S	160	6	4,333	140-160	07/--/58	125		NR
						11/15/89	125.89		S
						05/07/90	125.83		S
						04/04/91	125.50	R	S
133	U	58	2	4,232	53-58	11/08/90	40		NR
						11/11/90	28.26		S
						04/04/91	28.10		S
						06/25/91	28.23		S
134	U	52	2	4,232	48-52	11/09/90	22		NR
						11/10/90	24.06		S
						11/11/90	20.30		S
						04/04/91	19.80		S

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