## Ground-Water Levels

Ground-water levels in the middle Humboldt River Basin are based on measurements made (1) in the spring of 1982 (fig. 3), before most of the present-day mining activities were underway, and (2) again in the spring of 1996 (fig. 4), 5 to 10 years after mining had begun. In 1982, water levels were measured at 250 wells, 185 by the U.S. Geological Survey (USGS) and 65 by the Nevada Division of Water Resources (NDWR). In 1996, water levels were measured at 510 wells; 211 by the USGS, 115 by the NDWR, and 184 by mining companies at 6 mines. Water-level changes are shown in figure 4 at individual wells for the period 1982–96 and as graphs for 11 wells, one of which has a period of record beginning in 1946.

Ground-water levels are shown in figures 3 and 4 as contour lines of water-level altitude. Although the contours are based on water-level measurements, they can be uncertain for two reasons. First, the water-level altitudes are based on estimated land-surface altitudes at the wells. The land-surface altitudes, estimated from topographic maps, have uncertainties ranging from 5 to 20 ft, which is half the range of contour intervals of maps used for the study. As a result, the water-level contours have similar uncertainties. Also, uncertainties in water-level contours are introduced by the distribution of wells. Contours are believed to be fairly well defined where there is a concentration of wells and wells are on both sides of the contours. Water-level contours are poorly defined where wells are sparsely distributed.

Each of the 14 hydrographic areas of the middle Humboldt River Basin consists of a single topographic basin (fig. 1 and table 1). The 14 basins are connected, to differing degrees, by streamflow and by ground-water flow. Except for ground-water flow between Pine Valley and Diamond Valley (fig. 1), which is outside the study area, no subsurface ground-water flow is thought to cross the outer boundary of the 14-basin area. However, subsurface flow is a source of inflow and outflow among several of the basins. The principal sources of recharge to each basin are rain and snow that fall in the surrounding mountains and infiltration of streamflow. Ground water discharges as evapotranspiration in lowlands, as seepage to stream channels, and as pumping withdrawals at wells.

## Hydrographic Areas South of the Humboldt River

Of the 14 hydrographic areas in the middle Humboldt River Basin, 9 are south of the Humboldt River: Pine Valley, Carico Lake Valley, Crescent Valley, Whirlwind Valley, Upper Reese River Valley, Antelope Valley, Middle Reese River Valley, Lower Reese River Valley, and Pumpernickel Valley (fig. 1 and table 1). Ground-water flow, from recharge area to discharge area, is mostly within the topographic boundaries of each of the nine areas. However, four of these areas are hydraulically connected to an adjacent area to the north or northeast, within the middle Humboldt River Basin, by streamflow and by small quantities of ground-water flow.

### Pine Valley

Water levels were measured in Pine Valley at 11 wells by the USGS in 1982. No measurements were made in 1996 because the basin was not included in the study area at that time. Thus, the following discussion of ground water is based on the 1982 measurements and on a previous study by Eakin (1961).

The southern part of Pine Valley Hydrographic Area includes Denay and Garden Valleys. Ground water in this area flows from mountainous recharge areas toward the axis of each basin and then northeastward and northward toward the Humboldt River (fig. 3). The principal recharge areas are the Sulphur Spring Range and Piñon Range to the east, Cortez Mountains to the west, and the Simpson Park Range and Roberts Mountains to the south. Ground water discharges as evapotranspiration in basin lowlands, as spring flow, as seepage to stream channels, and as subsurface outflow eastward from Garden Valley to Diamond Valley (fig. 1; Harrill, 1968, p. 25–26), which is outside the study area, and northward to the Humboldt River (Eakin, 1961, p. 10, 23–24). More than half the annual flow of Pine Creek at its mouth (fig. 3) has been estimated to originate as ground-water seepage to the stream channel (Eakin, 1961, p. 10).

Ground water in Pine Valley is withdrawn for domestic use, watering stock, irrigation, and during extraction of oil. Until 1996, ground water also had been withdrawn for mining use in the Cortez Mountains. Water-level changes that may have resulted from these uses of ground water or from natural conditions cannot be quantified because water levels have not been measured regularly in the past.

### Carico Lake Valley

As of 1996, ground-water levels in Carico Lake Valley (figs. 3 and 4) were probably similar to natural water levels over most of the basin. Ground water flows from recharge areas in the Toiyabe Range and Shoshone Range toward the basin axis and then northeastward toward a bedrock constriction that leads to Crescent Valley. Small amounts of ground water may enter the basin from the northern part of Upper Reese River Valley. (See section titled "Upper Reese River Valley.") Ground water in Carico Lake Valley discharges mostly as evapotranspiration in the basin lowlands, and as minor seepage to the stream channel that passes through the bedrock constriction, and as subsurface outflow beneath the constriction (Zones, 1961, p. 20; Everett and Rush, 1966, p. 17).

Ground water in Carico Lake Valley is withdrawn from wells at a ranch for domestic use, for irrigation, and for watering stock. In addition, ground water was withdrawn at a mine in the northern part of the basin in the 1980's. From 1982 to 1996, water levels at two stock wells in the southern and east-central parts of the basin rose 4 ft and 5 ft, respectively (fig. 4). Because the basin is sparsely developed, the water-level rises at the two wells probably are the result of natural recharge.

### Crescent Valley

Ground-water flow in Crescent Valley is somewhat complex because of the irregular shape of the basin and the influence of the Dry Hills. In the eastern arm of Crescent Valley, ground water flows from recharge areas in the central and northern Cortez Mountains toward the axis of this part of the basin and then to the southwest toward the western arm of the basin. In the western arm of Crescent Valley, ground water flows from recharge areas in the Cortez Mountains, Toiyabe Range, and Shoshone Range toward the axis of this part of the basin and then northward toward the Humboldt River. Ground water in Crescent Valley discharges as evapotranspiration in the basin lowlands and as seepage to the Humboldt River channel, which forms the north boundary of the hydrographic area. Measurements made in October 1992 indicate that this reach of the Humboldt River gains streamflow (Emett and others, 1994, p. 475). Water-level contours (fig. 4) indicate that part of this gain can be attributed to ground-water discharge from Crescent Valley.

Flowing wells in the southern part of Crescent Valley (fig. 4) indicate the presence of confined ground water (Zones, 1961, p. 18). This part of the basin is underlain by fine-grained deposits (Zones, 1961, p. 15–16), which probably function as confining beds. The area of confined ground water also could be caused, in part, by a reduction of the width and thickness of the basin-fill aquifer. The distance between bedrock of the Shoshone Range and Cortez Mountains is about 10 to 15 mi in southern parts of the basin (fig. 4). Farther north, the distance between bedrock of the Shoshone Range and Dry Hills is about 6 mi. Perhaps more important is the northward thinning of the basin-fill aquifer. Basin-fill deposits and volcanic rocks are as much as 9,000 ft thick in southern parts of the basin, but are less than 2,000 ft thick between the Shoshone Range and Dry Hills (fig. 2).

Ground water in Crescent Valley is withdrawn for domestic use, municipal use for the town of Crescent Valley, mining at the Cortez and Pipeline Mines, watering stock, and irrigation. Ground-water withdrawals at the two mines were 745 acre-ft and 4,313 acre-ft, respectively, in 1996 (table 2). Sharp inflections of the 4,750-ft contour in the southern part of Crescent Valley (fig. 4) probably have resulted from a combination of withdrawals for the Cortez Mine and for irrigation. Westward inflections of the 4,775-ft and 4,800-ft contours on the southwest side of the basin (fig. 4) are the result of withdrawals for the Pipeline Mine. Although dewatering had not begun at this mine when water levels were measured in 1996, pumping for mine development was underway.

Ground-water levels in Crescent Valley also changed between 1982 and 1996 because of changes in either irrigation withdrawals or natural conditions. The annual water-level fluctuation at an irrigation well in the central part of the basin was more than 10 ft from 1958 to 1968 (graph 1, fig. 4). Since 1968, the water level has risen steadily at this well because it is no longer used for irrigation. In other parts of Crescent Valley, water-level changes at six wells ranged from a 1-ft decline at one well to a 3-ft rise at another. These relatively minor water-level changes probably represent natural fluctuations.

### Whirlwind Valley

The ground-water flow system in Whirlwind Valley consists of a deep geothermal system and a shallow water-table aquifer (Olmsted and Rush, 1987, p. 44). Present conditions in both aquifers probably differ from natural conditions because the geothermal system has been used for electric-power generation since 1985. Ground water in Whirlwind Valley flows from recharge areas in the Argenta Rim and Malpais toward the axis of the basin and then eastward toward the Humboldt River. Part of the recharge enters the deep geothermal system and part enters the water-table aquifer. The deep geothermal system discharges upward into the water-table aquifer, which in turn discharges as evapotranspiration in the basin lowlands and possibly as seepage into the Humboldt River channel (Olmsted and Rush, 1987, p. 32).

Shallow ground water in Whirlwind Valley is withdrawn for domestic use, irrigation, watering stock, power-plant cooling, and, since early 1996, for exploration, development, and operation of the Mule Canyon Mine. Total ground-water withdrawals at the mine in 1996 were 57 acre-ft (table 2). Between 1982 and 1996, water levels declined from 1 to 2 ft at three wells in central and eastern parts of the basin (fig. 4). The water level at two adjacent stock wells in the southwestern part of the basin declined at least 19 ft between 1982 and 1996 (fig. 4). Such a water-level decline may have resulted from declining heads in the deep geothermal aquifer, an extended drought in the late 1980's and early 1990's, or a combination of the two. Olmsted and Rush (1987, p. 38) noted that as early as 1972, shallow ground-water levels in parts of Whirlwind Valley had declined because vandalized geothermal wells had vented to the surface and reduced the flow of thermal water into the shallow system.

### Upper Reese River Valley

Ground water in Upper Reese River Valley flows from recharge areas in the Shoshone Mountains and Toiyabe Range toward the basin axis and then northward parallel to the Reese River (figs. 3 and 4). Ground water discharges as evapotranspiration, spring flow, seepage to some reaches of the Reese River channel, and subsurface outflow at the north end of the basin.

The ground-water surface defined by the contours in figs. 3 and 4 slopes northward at gradients ranging from 20 to 200 ft/mi in southern parts of Upper Reese River Valley and 10 to 30 ft/mi in northern parts of the area. The steep gradient of 200 ft/mi, defined by the 5,900-ft and 6,000-ft water-level contours in figure 4, coincides with northward decreases in the thickness and width of the basin-fill aquifer. The southern part of Upper Reese River Valley is underlain by as much as 15,000 ft of basin-fill deposits and volcanic rocks (sheet 1, fig. 2). The distance between areas of volcanic rocks along the margins of this part of the basin is nearly 10 mi. About 10 mi farther north, however, the basin is less than 1,000 ft deep, and its width is less than 5 mi. This abrupt decrease in the cross-sectional area of the basin-fill aquifer restricts the northward flow of ground water, which results in the steep gradient and seepage of ground water into the channel of the Reese River. Late-summer flow in this reach of the river was documented in September 1916, whereas most other reaches of the river were dry at that time (Waring, 1918, p. 104).

Water-level contours at the north end of Upper Reese River Valley suggest that ground water may flow to the northwest to Middle Reese River Valley and to the northeast to Carico Lake Valley. Eakin and others (1965, p. 29 and table 5) recognized the potential for ground-water flow to Middle Reese River Valley. However, basin-fill deposits and volcanic rocks that form the divide between Upper Reese River Valley and Carico Lake Valley are about 1,000 ft thick (sheet 1, fig. 2) and also could permit flow between these two areas.

Ground water in Upper Reese River Valley is withdrawn for domestic use, municipal use for the town of Austin, irrigation, and watering stock. Between 1982 and 1996, water levels in the basin rose as much as 36 ft, mostly in areas along the Reese River and its tributaries. These water-level rises (recharge) probably indicate the effects of variations in runoff. Elsewhere, mostly in irrigated areas in the west-central part of the basin, water levels declined. The declines are indicated by the 5,800-ft and 5,810-ft contours, which were offset to the west side of the basin in 1982 (fig. 3), and by the 5,750-ft and 5,800-ft contours, which were offset to the south and west in 1996 (fig. 4). Water levels at two wells in the irrigated area declined 40 ft and 18 ft, respectively, from 1965 to 1996 (fig. 4, graphs 2 and 3).

### Antelope Valley

Under natural conditions, ground water in Antelope Valley flowed from mountainous recharge areas to the basin lowlands, and, in the northern part of the basin, eastward through a bedrock constriction, formed by volcanic rocks, to Middle Reese River Valley (Crosthwaite, 1963, p. 10). The main recharge areas for the basin are the Shoshone Mountains to the east, New Pass Range and Augusta Mountains to the west, and Fish Creek Mountains to the north. Ground water was discharged as evapotranspiration in the basin lowlands and as subsurface outflow through the bedrock constriction.

Ground water in Antelope Valley is withdrawn for domestic use, irrigation, and watering stock. Withdrawals for irrigation use began in the 1950's, and by 1982, a total of about 2,800 acres was being irrigated in the basin (Nevada Division of Water Resources, unpub. data, 1997). Ground-water levels and flow directions in Antelope Valley changed as a result of these ground-water withdrawals. By 1982, a cone of depression had developed in the lowlands of the northern part of the basin (fig. 3). The deeper part of the cone, defined by the 4,860-ft water-level contour, encompassed an area of about 5 $mi^2$. In addition, an east–west-trending ground-water divide separated southerly flow toward the cone of depression from northeasterly flow through the bedrock constriction to Middle Reese River Valley.

By 1996, the irrigated area in Antelope Valley was 4,300 acres (Nevada Division of Water Resources, unpub. data, 1997), and the cone of depression had expanded as a result of continued pumping and expansion of the irrigated area. The deeper part of the cone, defined by the 4,860-ft water-level contour, encompassed an area of more than 20 $mi^2$ (fig. 4). Water levels declined 1 to 22 ft at nine wells between 1982 and 1996, and more than 30 ft between 1963 and 1996 at a well in the western part of the basin (fig. 4, graph 4). In addition, the divide between southerly flow to the cone and northeasterly flow to Middle Reese River Valley appeared to have a northwest trend and to have moved a few miles to the northeast.

The limited westward expansion of the cone of depression since 1982 suggests that it may have encountered the relatively impermeable siliceous sedimentary rocks of the Augusta Mountains. When water-level declines reach this boundary, the cone of depression probably will cease expanding to the west. This could result in more rapid expansion to the north, east, and south and more rapid rates of decline in the cone.

### Middle Reese River Valley

Under natural conditions, ground water in Middle Reese River Valley flowed from recharge areas toward the basin axis and then northward parallel to the Reese River (Crosthwaite, 1963, p. 10). The Fish Creek Mountains on the west and Shoshone Range on the east are the principal recharge areas for the basin. Subsurface inflow also entered the basin from both Upper Reese River Valley and Antelope Valley. Ground water was discharged as evapotranspiration and as northward subsurface outflow to Lower Reese River Valley. The water table in the basin-fill aquifer is well below the Reese River channel and probably was below the channel even before irrigation withdrawals began 30 to 40 years ago. As of 1996, measured depths to water ranged from 97 to 176 ft in the basin, and the river channel always is dry except during years of exceptional snowmelt runoff. As far back as 1916, Waring (1918, p. 104) noted that this reach of the Reese River was dry throughout the summer.

Ground water in Middle Reese River Valley is withdrawn for domestic use, irrigation, and stock watering. Withdrawals for irrigation began in the 1950's, and by 1982, a total of about 9,100 acres was being irrigated in the basin (Nevada Division of Water Resources, unpub. data, 1997). Ground-water levels and flow directions in Middle Reese River Valley changed as a result of these ground-water withdrawals. By 1982, a cone of depression had developed in the southern part of the basin (fig. 3). The deeper part of the cone, defined by the 4,760-ft contour, encompassed an area of 3 to 4 $mi^2$ (fig. 3). In addition, an east–west-trending ground-water divide extended across the basin, and it separated the southward ground-water flow to the cone of depression from the northward flow to Lower Reese River Valley.

By 1996, the irrigated area in Middle Reese River Valley was about 6,000 acres (Nevada Division of Water Resources, unpub. data, 1997). The cone of depression had expanded as a result of continued pumping even though the irrigated area had decreased. The deeper part of the cone, defined by the 4,760-ft contour, encompassed an area of about 30 $mi^2$ (fig. 4). Water levels declined from 3 to 26 ft at three wells between 1982 and 1996 (fig. 4), and nearly 70 ft between 1961 and 1996 at a well in the central part of the cone (fig. 4, graph 5). In addition, the ground-water divide extending across the basin appears to have moved several miles to the north.

Directions of ground-water flow in Middle Reese River Valley, modified by irrigation withdrawals, suggest that much of the ground water that once flowed northward in the basin now flows southward to the cone of depression. This situation eventually could reduce the rate of subsurface inflow to Lower Reese River Valley or even induce southward ground-water flow from Lower Reese River Valley.

### Lower Reese River Valley

Under natural conditions, ground water in Lower Reese River Valley flowed from recharge areas in the Shoshone Range, northern Fish Creek Mountains, and Battle Mountain toward the basin axis and then northward toward the Humboldt River flood plain. Subsurface inflow also entered the basin from Middle Reese River Valley (Crosthwaite, 1963, p. 15). Eastward subsurface inflow between the Fish Creek Mountains and Battle Mountain from Buffalo Valley, which is outside the study area (just to the west of Lower Reese River Valley), is thought to have been negligible. Ground water discharged as subsurface outflow northwestward beneath the Humboldt River flood plain and as evapotranspiration in the basin lowlands. The water table in the basin-fill aquifer is below the Reese River channel. The river channel is dry except for years of above-average snowmelt runoff. The water table in the basin-fill aquifer was below the river channel probably even before irrigation withdrawals began 30 to 40 years ago. As far back as 1916, Waring (1918, p. 104) noted that this reach of the Reese River was dry throughout the summer.

Ground-water levels in most of Lower Reese River Valley in spring 1982 (fig. 3) probably were similar to natural conditions. The 4,650-ft water-level contour was offset to the south in the southwestern part of the basin in an area of irrigation withdrawals. Ground water also was being withdrawn for irrigation use in the eastern part of the basin, but any effects were too localized to be defined at the scale of the map in figure 3.

Ground water in Lower Reese River Valley is withdrawn for domestic use; municipal use at Battle Mountain; irrigation; watering stock; and mining, including dewatering at the McCoy Cove Mine in the southwestern part of the basin. Total ground-water withdrawals at this mine were 25,619 acre-ft in 1996, of which 23,565 acre-ft was for dewatering (table 2). Ground-water levels have declined in areas of pumping for mine dewatering and have risen in nearby areas where water from the mine is returned to the basin-fill aquifer by way of infiltration ponds. The area of mine dewatering is underlain by a cone of depression defined by the southernmost 4,650-ft contour (fig. 4). Water-level declines in this cone had exceeded 250 ft as of spring 1996. Water levels have risen in the area of infiltration ponds 1 to 2 mi north of the area being dewatered. This area of water-level rise, defined by abrupt inflections of the 4,650-ft and 4,700-ft contours, partly coincides with the area where water levels were declining as of 1982 (fig. 3) in response to ground-water withdrawals for irrigation. Water levels in other parts of Lower Reese River Valley declined by 1 to 14 ft between 1982 and 1996 in response to withdrawals for domestic and municipal use at Battle Mountain and for irrigation (fig. 4), by 7 ft between 1963 and 1996 at an irrigation well in the southern part of the basin (fig. 4, graph 6), and by 7 ft between 1946 and 1996 at an abandoned stock well in the central part of the basin (fig. 4, graph 7).

The area around the town of Battle Mountain is underlain by a confined aquifer that never has been defined completely. In 1916, 43 flowing wells in the vicinity reportedly were producing from depths of 100 to 300 ft and had artesian heads as much as 16 ft above land surface (Waring, 1918, p. 112). Declining water levels in the confined aquifer also were documented in 1916 (Waring, 1918, p. 112). Several flowing wells were identified in the town in 1952 (Loeltz, 1953). At present, no flowing wells are known in the vicinity of Battle Mountain.

### Pumpernickel Valley

Except for northeastern parts of the basin, ground-water conditions in Pumpernickel Valley, documented in 1982 and 1996 (figs. 3 and 4), are probably similar to natural conditions. Ground water in Pumpernickel Valley flows from recharge areas in the Sonoma Range, Buffalo Mountain, Tobin Range, and Edna Mountain toward the basin axis and then northeastward. Ground water is discharged as evapotranspiration in the basin lowlands and as seepage to the Humboldt River channel, which forms the north boundary of the basin.

Ground water in Pumpernickel Valley is withdrawn for domestic use; watering stock; irrigation in the central part of the basin; and mining, including dewatering at the Lone Tree Mine. From 1982 to 1996, water levels in central and southern parts of the basin rose about 6 ft and 15 ft, respectively, at two irrigation wells because withdrawals ceased sometime after 1982. Water levels have declined in the northeastern part of Pumpernickel Valley in the vicinity of the Lone Tree Mine. The cone of depression that has developed is defined by the closed 4,400-ft contour that extends east and west of the boundary between Pumpernickel Valley and the Clovers Area. Total ground-water withdrawals at the mine in 1996 were 43,341 acre-ft, of which 40,244 acre-ft was for mine dewatering (table 2). As of 1996, this excess water was being discharged to the Humboldt River.

## Hydrographic Areas North of the Humboldt River

Five hydrographic areas compose that part of the middle Humboldt River Basin that is north of the river: Boulder Flat, Willow Creek Valley, Rock Creek Valley, the Clovers Area, and the Kelly Creek Area (fig. 1 and table 1). These five areas are similar to the nine hydrographic areas south of the river in terms of recharge sources and discharge processes. In other respects, however, the five areas to the north are hydrologically different from those to the south. With a few exceptions, each of the nine hydrographic areas south of the Humboldt River appears to function as a separate ground-water system. In contrast, the five areas to the north function as a single, extensive ground-water flow system in which ground-water divides do not coincide with topographic divides and much of the flow is in volcanic rocks and basin-fill deposits (sheet 1, fig. 2). Thus, the five areas are discussed as a single unit in this section.

The eastern and northeastern extent of the flow system is in the Tuscarora Mountains and unnamed mountains on the north side of Willow Creek Valley. The direction of ground-water flow from this extensive recharge area is to the west and southwest across Boulder Flat, Rock Creek Valley, and Willow Creek Valley. East–northeast-trending faults that cut volcanic rocks (Wallace, 1993), in addition to zones between individual lava flows, may provide conduits for the southwestward movement of ground water in this part of the study area. The Sheep Creek Range and unnamed mountains between Willow Creek Valley and Rock Creek Valley function as intermediate recharge areas before ground-water flow enters the Clovers Area. In the western part of this flow system, ground water flows southward and southeastward across the Kelly Creek Area from recharge areas in the Osgood Mountains. The principal discharge area for this flow system is the Humboldt River flood plain, where ground water discharges as evapotranspiration and as seepage to the river channel.

Ground water in the five hydrographic areas north of the Humboldt River is withdrawn for domestic and municipal use, watering stock, electric-power generation, irrigation of crops, and mining use, including dewatering. Irrigation and mining uses appear to have had the greatest effects on water levels in the flow system.

In 1982, ground water was being used for irrigation of crops in the eastern part of Boulder Flat, in the western part of Willow Creek Valley, in eastern and southern parts of the Clovers Area, and in the west-central part of the Kelly Creek Area. Ground water also was being used for mining in the northeastern part of Boulder Flat and the western part of the Kelly Creek Area. However, the effects of this pumping are not readily apparent (fig. 3), partly because of the sparse distribution of wells that were measured in 1982 and partly because the effects may have been minimal at that time. The main exception is the eastward inflection of the 4,650-ft water-level contour in an irrigated area in the eastern part of Boulder Flat (fig. 3).

By 1996, the effects of ground-water withdrawals were apparent as several cones of depression that had resulted from long-term irrigation withdrawals and from more recent withdrawals for mining purposes, including dewatering. The most prominent cone of depression is the one in the northeastern part of Boulder Flat and adjacent parts of Rock Creek Valley (fig. 4). This cone has developed since ground-water withdrawals began in the late 1980's at the Betze–Post, Genesis, and Carlin Mines and especially since dewatering began at the Betze–Post Mine in 1990. The cone of depression has developed in permeable carbonate rocks at depth and the overlying clastic sedimentary rocks of Paleozoic age and, as of 1993, was 8 mi long and more than 800 ft deep (Maurer and others, 1996, p. 62–64). By 1996, the cone was about 12 mi long (fig. 4), and water levels had declined more than 1,000 ft (fig. 4, graph 10). The configuration of this cone indicates that northwestward-trending faults on the east and west have strongly influenced its orientation and east–west extent. Total ground-water withdrawals at the three mines in 1996 were about 25,000 acre-ft, of which 16,285 acre-ft was for mine dewatering (table 2). Between 1991 and 1996, shallow ground water in basin-fill deposits near the mines had declined only about 24 ft (fig. 4, graph 9), which resulted in a zone of perched ground water. This relatively small ground-water decline in the basin-fill deposits indicates a poor hydraulic connection between the basin fill and underlying bedrock.

Water from the Betze–Post Mine initially was stored in a reservoir. However, infiltration through volcanic rocks in the reservoir floor resulted in water-level rises and eventual saturation of the central part of Boulder Flat, along with water-level rises in adjacent parts of Rock Creek Valley (Maurer and others, 1996, p. 63). The rate of ground-water withdrawal at the mine was reduced in 1995 while alternate means of managing the water were developed. As a result, the rate of water-level decline at the Betze–Post Mine slowed in 1995, and water levels rose nearly 200 ft in 1996 (fig. 4, graph 10). During the same span of time, water levels in the basin-fill aquifer in the central part of Boulder Flat rose when water was infiltrating the reservoir floor and then began to decline in 1995 when the ground-water withdrawal rate at the mine was reduced (fig. 4, graph 11). Water levels in the basin-fill aquifer in Boulder Flat may eventually decline to near premining levels because water from the mine now (1998) is used to water crops during the irrigation season and is released to the Humboldt River during other times of the year.

Water levels in southwestern and eastern parts of the Clovers Area changed from 1982 to 1996, mostly in response to withdrawals for irrigation. However, production wells that supply water to the Valmy Power Plant also could account for some of the changes. In the southwestern part of the area, the 4,500-ft water level was about 1 mi farther south in 1996 than in 1982 (figs. 3 and 4). Water levels in this part of the area declined 7 to 20 ft from 1982 to 1996 (fig. 4).

Water-level changes between 1982 and 1996 in the eastern part of the Clovers Area, indicated by sharp inflections of the 4,475-ft contour (fig. 4), are related to ground-water withdrawals for agricultural purposes and possibly for use at the Valmy Power Plant. Between 1982 and 1996, water levels in this part of the Clovers Area declined 7 to 17 ft at three wells (fig. 4) and more than 50 ft at another well (fig. 4, graph 8).

Water levels in the Kelly Creek Area changed between 1982 and 1996 in response to ground-water withdrawals for irrigation in the central part of the area and for dewatering the Twin Creeks Mine in the northern part of the area. A small cone of depression, defined by the closed 4,475-ft contour and northward inflection of the 4,500-ft contour, developed in the irrigated area (figs. 3 and 4). The water level at one well declined about 10 ft (fig. 4).

Another cone of depression has developed during the past several years in the northern part of the Kelly Creek Area in response to dewatering of the Twin Creeks Mine. This cone is defined by the closed 4,600-ft water-level contour and the northward inflection of the 4,700-ft contour (fig. 4). Both contours indicate that water levels in basin-fill deposits and underlying bedrock had declined 100 to 200 ft by 1996. Ground-water withdrawals at this mine in 1996 totaled 8,164 acre-ft, of which 4,356 acre-ft was for dewatering (table 2).

## Summary

This report describes the results of a study of the hydrogeologic framework, ground-water levels, and water-level changes in the middle Humboldt River Basin of north-central Nevada.

The middle Humboldt River Basin consists of 14 hydrographic areas or basins that are tributary to the Humboldt River: Pine Valley, Crescent Valley, Carico Lake Valley, Upper Reese River Valley, Antelope Valley, Middle Reese River Valley, Lower Reese River Valley, Whirlwind Valley, Boulder Flat, Rock Creek Valley, Willow Creek Valley, Clovers Area, Pumpernickel Valley, and Kelly Creek Area. The 14 areas are underlain by 7 hydrogeologic units: (1) carbonate rocks, generally limestone and dolomite, of Cambrian to Devonian age, (2) clastic sedimentary rocks of Cambrian to Permian age, (3) siliceous sedimentary rocks of Cambrian to Triassic age, (4) granitic rocks of Jurassic to Tertiary age, (5) older basin-fill deposits of Tertiary age, (6) volcanic rocks of Tertiary and Quaternary age, and (7) younger basin-fill deposits of Tertiary and Quaternary age. Basin-fill deposits, volcanic rocks, and carbonate rocks constitute the principal aquifers in the middle Humboldt River Basin. Carbonate-rock aquifers are mostly in eastern parts of the study area.

The first four hydrogeologic units listed above form the basement upon which volcanic rocks and the two units of basin fill were deposited. The combined thickness of volcanic rocks and basin-fill deposits was determined for this study by analysis of gravity data. The analysis indicates that basins exceeding depths of 9,000 ft underlie Pine Valley, Crescent Valley, southernmost Upper Reese River Valley, and Antelope Valley Hydrographic Areas. Abrupt decreases in the combined thickness of volcanic rocks and basin-fill deposits help to explain the presence of an area of flowing wells in Crescent Valley and a reach of the Reese River having perennial flow in Upper Reese River Valley.

Ground-water flow in the middle Humboldt River Basin differs between the nine hydrographic areas south of the Humboldt River and the five areas north of the river. With a few exceptions, south of the river, ground-water flow from recharge area to discharge area is mostly within each basin. Ground-water recharge comes from rain and snow in mountains and from infiltration of streamflow. Ground water is discharged as evapotranspiration in basin lowlands and as seepage to stream channels, including the Humboldt River channel. The only known exceptions to this are ground-water flow (1) from Pine Valley to Diamond Valley, which is outside the study area, (2) from northern Upper Reese River Valley to adjacent parts of Middle Reese River Valley and perhaps to Carico Lake Valley, (3) from Carico Lake Valley to Crescent Valley, (4) from Antelope Valley to Middle Reese River Valley, and (5) from Middle Reese River Valley to Lower Reese River Valley.

The five hydrographic areas north of the Humboldt River are underlain by a single extensive ground-water flow system that extends from recharge areas in the Tuscarora Mountains on the east and Osgood Mountains on the west to discharge areas along the Humboldt River flood plain. In this system, part of the ground-water flow is in volcanic rocks, especially to the east, and ground-water divides typically do not coincide with topographic divides.

Ground-water levels changed in the middle Humboldt River Basin between 1982 and 1996 as a result of natural conditions, withdrawals for irrigation use, and, since the late 1980's, withdrawals for mining use and mine dewatering. Natural water-level fluctuations generally were less than 10 ft in sparsely developed areas. Water levels declined 10 to 70 ft in several areas where ground water was withdrawn for irrigation purposes. The most extensive of these areas of water-level decline are in Upper Reese River Valley, Antelope Valley, Middle Reese River Valley, and the Clovers Area.

Since the late 1980's, ground water has been withdrawn for mining use and for the dewatering of six large open-pit gold mines in the middle Humboldt River Basin. Water-level declines have ranged from tens to hundreds of feet at several of the mines and were more than 1,000 ft at the largest of the mines, in northern Boulder Flat. Total ground-water withdrawal for both mining use and dewatering at the six mines was 113,000 acre-ft in 1996, of which 89,300 acre-ft was for dewatering. Ground water from the mines presently (1998) is re-infiltrated into basin-fill aquifers, used for irrigating crops, and used for cooling at a power plant; however, two of the largest mines also release part of the water directly to the Humboldt River channel.

## References Cited

Bredehoeft, J.D., and Farvolden, R.N., 1963, Disposition of aquifers in intermontane basins of northern Nevada: International Association of Scientific Hydrology, Commission of Subterranean Waters, Publication 64, p. 197–212.

Cardinalli, J.L., Roach, L.M., Rush, F.E., and Vasey, B.J., comps., 1968, State of Nevada hydrographic areas: Nevada Division of Water Resources map, scale 1:500,000.

Crosthwaite, E.G., 1963, Ground-water appraisal of Antelope and Middle Reese River Valleys, Lander County, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources—Reconnaissance Report 19, 32 p.

Eakin, T.E., 1961, Ground-water appraisal of Pine Valley, Eureka and Elko Counties, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources—Reconnaissance Report 2, 41 p.

Eakin, T.E., Moore, D.O., and Everett, D.E., 1965, Water resources appraisal of the Upper Reese River Valley, Lander and Nye Counties, Nevada: Nevada Department of Conservation and Natural Resources, Water Resources—Reconnaissance Report 31, 47 p.

Emett, D.C., Hutchinson, D.D., Jonson, N.A., and O'Hair, K.L., 1994, Water resources data, Nevada, water year 1993: U.S. Geological Survey Water-Data Report NV–93–1, 596 p.

Everett, D.E., and Rush, F.E., 1966, A brief appraisal of the water resources of Grass and Carico Lake Valleys, Lander and Eureka Counties, Nevada: Nevada Department of Conservation and Natural Resources, Water Resources—Reconnaissance Report 37, 28 p.

Harrill, J.R., 1968, Hydrologic response to irrigation pumping in Diamond Valley, Eureka and Elko Counties, Nevada, 1950–65: Nevada Department of Conservation and Natural Resources, Water Resources Bulletin 35, 85 p.

Hydro–Geo Consultants, 1990, Preliminary hydrologic study, Deep Post Project: Lakewood, Colo., Hydro–Geo Consultants, Inc., report, 42 p.

———1992, Hydrologic study, Deep Star Project: Lakewood, Colo., Hydro–Geo Consultants, Inc., report, 53 p.

Jachens, R.C., and Moring, B.C., 1990, Maps of the thickness of Cenozoic deposits and the isostatic residual gravity over basement for Nevada: U.S. Geological Survey Open-File Report 90–404, 15 p.

Jewel, E.B., Ponce, D.A., and Morin, R.L., 1997, Gravity data of Nevada: U.S. Geological Survey Open-File Report 97–519, 17 p.

Loeltz, O.J., 1953, Results of a pumping test of an artesian well near Battle Mountain, Lander County, Nevada: U.S. Geological Survey Open-File Report 53–158, 25 p.

Maurer, D.K., Plume, R.W., Thomas, J.M., and Johnson, A.K., 1996, Water resources and effects of changes in ground-water use along the Carlin trend, north-central Nevada: U.S. Geological Survey Water-Resources Investigations Report 96–4134, 146 p.

Olmsted, F.H., and Rush, F.E., 1987, Hydrogeologic reconnaissance of the Beowawe Geysers geothermal area, Nevada: Geothermics, v. 16, no. 1, p. 27–46.

Plume, R.W., and Carlton, S.M., 1988, Hydrogeology of the Great Basin region of Nevada, Utah, and adjacent States: U.S. Geological Survey Hydrologic Investigations Atlas HA–694–A, 1 sheet.

Ponce, D.A., 1997a, Gravity data of Nevada: U.S. Geological Survey Digital Data Series DDS–42, 27 p. and CD-ROM.

———1997b, Mapping the Humboldt River Basin using gravity and magnetic methods, Winnemucca 1- by 2-degree quadrangle, northern Nevada (abs.): Geological Society of America, Abstracts with Programs, v. 1, p. 304.

Ponce, D.A., and Moring, B.C., 1998, Drill-hole lithology of the Winnemucca 1:250,000-scale quadrangle, Nevada: U.S. Geological Survey Open-File Report 98–220, scale 1:250,000.

Prudic, D.E., Harrill, J.R., and Burbey, T.J., 1995, Conceptual evaluation of regional ground-water flow in the carbonate-rock province of the Great Basin, Nevada, Utah, and adjacent states: U.S. Geological Survey Professional Paper 1409–D, 102 p.

Rush, F.E., 1968, Index of hydrographic areas in Nevada: Nevada Division of Water Resources, Information Report 6, 38 p.

Stock, M.D., Herzog, D.J., Butler, R.G., Jr., and Ruefer, J.M., 1992, Expanded dewatering ground-water flow model, Lone Tree Mine, Valmy, Nevada: Reno, Nev., Simon Hydro–Search report, 57 p., 3 apps.

Stone, W.J., Leeds, Todd, Tunney, R.C., Cusack, G.A., and Skidmore, S.A., 1991, Hydrogeology of the Carlin trend, northeastern Nevada—A preliminary report: Carlin, Nev., Newmont Gold Company report, 123 p.

Wallace, A.R., 1993, Geologic map of the Snowstorm Mountains and vicinity, Elko and Humboldt Counties, Nevada: U.S. Geological Survey Miscellaneous Investigations Map I–2394, scale 1:50,000.

Waring, G.A., 1918, Ground water in Reese River Basin and adjacent parts of Humboldt River Basin, Nevada: U.S. Geological Survey Water-Supply Paper 425–D, p. 95–129.

WESTEC, 1993, Twin Creeks Mine—Phase I baseline report: Reno, Nev., WESTEC report, 71 p., 7 apps.

Zones, C.P., 1961, Ground-water potentialities in the Crescent Valley, Eureka and Lander Counties, Nevada: U. S. Geological Survey Water-Supply Paper 1581, 50 p.

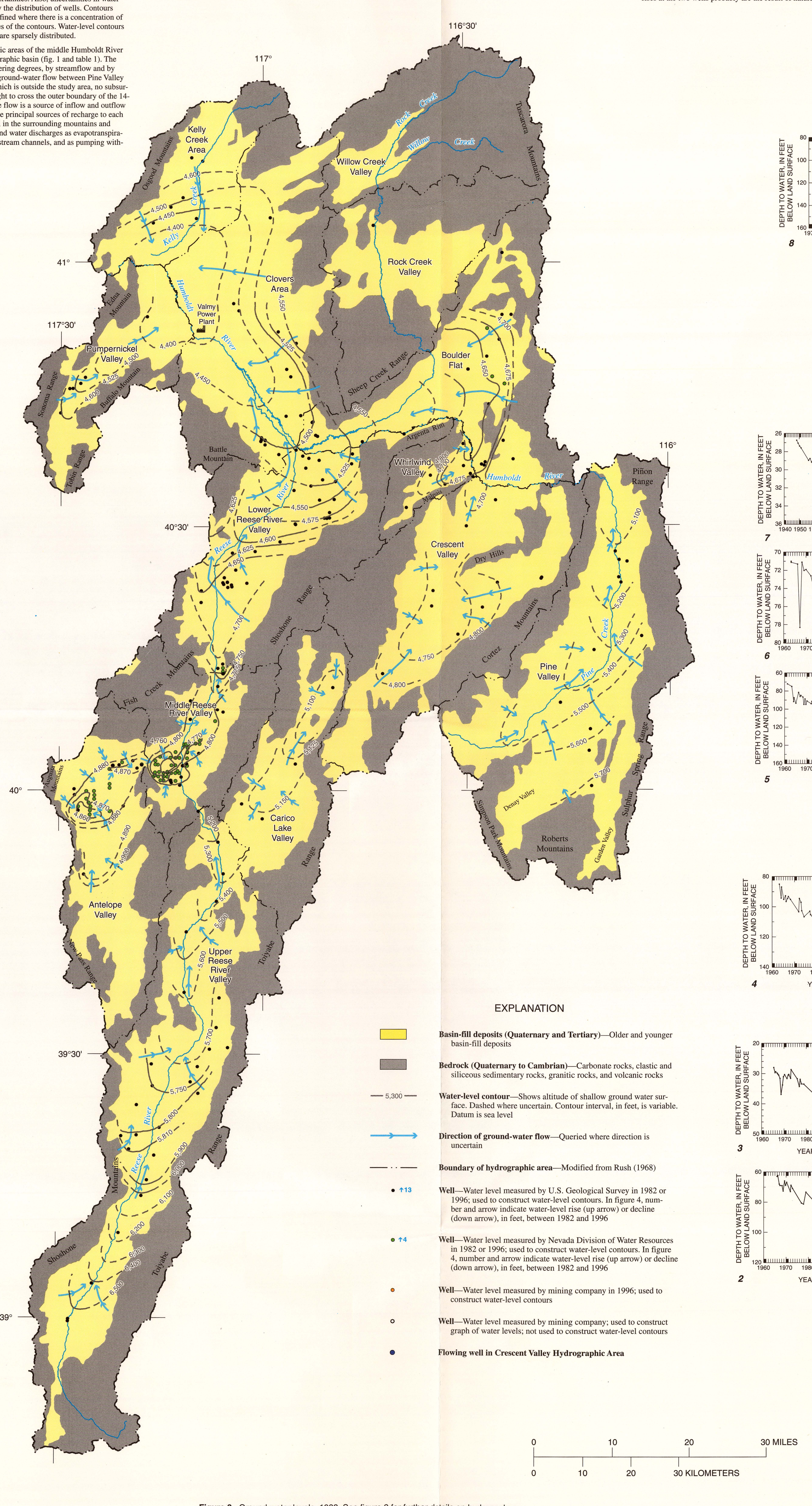


Figure 3. Ground-water levels, 1982. See figure 2 for further details on hydrogeology.

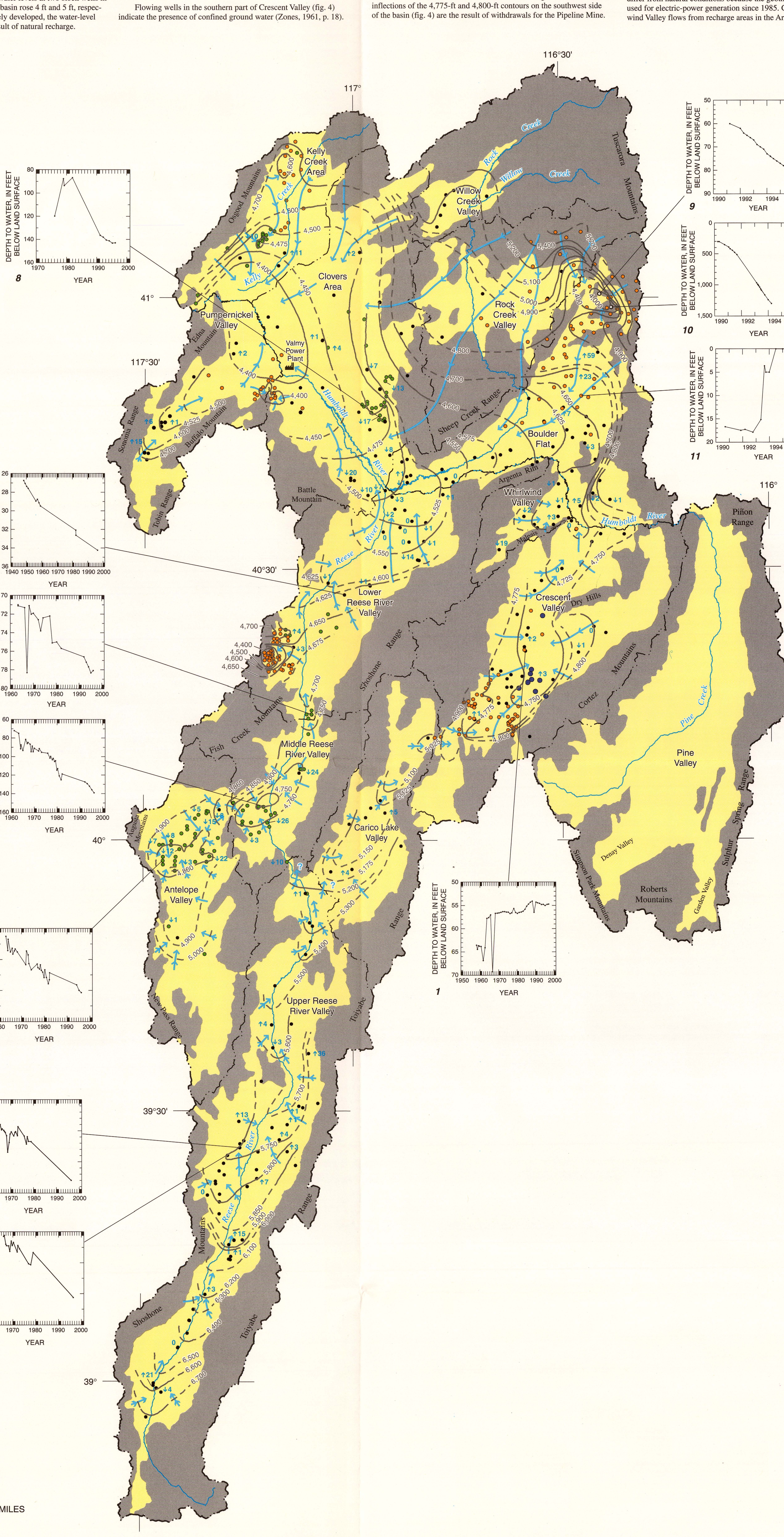


Figure 4. Ground-water levels, 1996, and water-level changes of record from 1948 through 1996. See figure 2 for further details on hydrogeology.

Base from U.S. Geological Survey digital data, 1:100,000, 1977–88
Universal Transverse Mercator projection
Zone 11

Hydrogeology modified from Plume and Carlton (1988)
INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1999

# HYDROGEOLOGIC FRAMEWORK AND GROUND-WATER LEVELS, 1982 AND 1996, MIDDLE HUMBOLDT RIVER BASIN, NORTH-CENTRAL NEVADA

By
Russell W. Plume and David A. Ponce
1999