## Introduction

The Humboldt River Basin encompasses an area of nearly 17,000 $mi^2$ in north-central Nevada; it is the only major river basin that begins and ends entirely within the State (fig. 1). The study area for this report is the middle Humboldt River Basin, which consists of 14 hydrographic areas that encompass 7,400 $mi^2$ (fig. 1 and table 1). The principal tributaries to the Humboldt River in the study area are Pine Creek, Rock Creek, and Reese River.

Streamflow of the Humboldt River and its tributaries and ground water are used by diverse, and sometimes, competing interests. Streamflow historically has been used for agricultural purposes—mainly irrigation of crops and meadows and watering of livestock. However, wetlands along the river and its tributaries also provide wildlife habitat, and infiltration of streamflow is a source of recharge to underlying aquifers. Prior to 1980, most ground-water withdrawals in the Humboldt River Basin were for municipal and domestic purposes, irrigation of crops, and industrial purposes at a few mines.

During the last 10 to 15 years ground-water withdrawals in the Humboldt River Basin have increased, mostly as a result of the development of large open-pit gold mines. Of the 17 mines in the Humboldt River Basin that reported pumping withdrawals to the Nevada Division of Water Resources in 1996, 14 were in the middle Humboldt River Basin (fig. 1). Gold mines in the middle Humboldt River Basin withdrew about 24,200 acre-ft of ground water for mining and milling purposes in 1996 (table 2). However, ground water also was withdrawn to dewater six of the mines that have been excavated below local ground-water levels. In 1996, these mines were dewatered at annual rates ranging from 967 to 40,244 acre-ft/yr, and total withdrawals for mine dewatering were about 89,300 acre-ft (table 2). Total withdrawals for all mining uses including dewatering were 113,000 acre-ft (table 2).

Agencies of Federal, State, and local governments and other groups are interested in the long-term viability of the water resources of the Humboldt River Basin because of the many and varied uses of water in the basin. In response to recent increases in mining use and the effects associated with mine dewatering, the U.S. Geological Survey (USGS) has undertaken coordinated hydrologic and mineral-resources assessments of the Humboldt River Basin. This report is the result of the combined efforts of the Geologic and Water Resources Divisions of the USGS.

The Water Resources Division of the USGS, in cooperation with the Nevada Department of Conservation and Natural Resources, began phase 1 of the Humboldt River Basin Assessment in October 1995. This phase of the assessment was completed in September 1998. The objectives of phase 1 were to (1) make hydrologic data for the Humboldt River Basin more easily accessible by way of an Internet Web site, which is **<http://nevada.usgs.gov/humb/>**, (2) improve methods for estimating water-budget components and begin using those methods to refine basin water budgets for the middle Humboldt River Basin, (3) quantify ground-water withdrawals for agriculture, generation of electricity, industrial use, mining, and municipal use in the middle Humboldt River Basin, and (4) define the hydrogeologic framework and shallow ground-water conditions in the middle Humboldt River Basin, both of which are the subject of this report.

In 1996, the Geologic Division of USGS, in cooperation with the Bureau of Land Management, began an assessment of the mineral-resources potential, regional geologic framework, mineral–environmental characteristics, and cultural-resources potential of the entire Humboldt River Basin ecosystem. As part of this effort, existing gravity data were compiled, and additional gravity data were collected, in the Humboldt River Basin (Jewel and others, 1997; Ponce, 1997a). These gravity data were used to estimate thicknesses of volcanic rocks and basin-fill deposits. (See section titled "Hydrogeologic Framework.")

## Purpose and Scope of This Report

The purpose of this report is to describe the hydrogeologic framework and ground-water levels in the middle Humboldt River Basin. The hydrogeologic framework (sheet 1, fig. 2) describes (1) the rocks and deposits that either store and transmit ground water or impede its movement and (2) the thicknesses of volcanic rocks and basin-fill deposits. The maps of shallow ground water (sheet 2, figs. 3 and 4) show water levels in 1982 and 1996 and describe water-level changes for differing periods of record.

## Acknowledgments

The successful completion of this report has depended, in large part, on the cooperation, support, and contributions of many people. The Humboldt River Basin Assessment was done in cooperation with the Nevada Department of Conservation and Natural Resources. The study also received support from the Bureau of Land Management, Barrick Goldstrike Mines, Inc., Newmont Gold Company, Santa Fe Gold Corporation, and Getchell Gold Corporation. The mineral-resources assessment was done separately in cooperation with the Bureau of Land Management.

Private landowners and managers or owners of large ranches in the middle Humboldt River Basin granted the authors access to their lands and wells. Staff at the Betze–Post, Cortez, Lone Tree, McCoy Cove, Pipeline, and Twin Creeks Mines provided water-level data for observation wells at the mines. Finally, water levels measured in 1996 by the staff of the Nevada Division of Water Resources greatly reduced the need for the USGS to locate and measure wells in several parts of the middle Humboldt River Basin.

## Hydrogeologic Framework

The many different rock types and deposits in the middle Humboldt River Basin were grouped together as seven hydrogeologic units for purposes of this report (fig. 2). The seven units are (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.

Ground water is present in all seven hydrogeologic units. It occupies the intergranular pore space in basin-fill deposits and fractures and solution cavities in the other five units. Four of the units— carbonate rocks, volcanic rocks, and older and younger basin-fill deposits—are the principal aquifers in the middle Humboldt River Basin. Carbonate rocks in eastern parts of the study area are part of an extensive regional aquifer system in eastern Nevada and western Utah (Prudic and others, 1995). Carbonate rocks also are exposed in western parts of the study area and may underlie other parts of the area at depth. Carbonate rocks can be highly permeable, and they can readily store and transmit ground water, especially where fractures have been widened by dissolution.

Volcanic rocks are exposed over much of the study area and underlie or are interbedded with older basin-fill deposits in most of the middle Humboldt River Basin. The importance of volcanic rocks as aquifers in the study area has been documented only for the Sheep Creek Range and unnamed mountains to the north. Ground-water flow in these rocks is discussed in the section titled "Hydrographic Areas North of the Humboldt River," on sheet 2 of this report.

Basin-fill deposits contain the most widespread and extensively developed aquifers in the middle Humboldt River Basin. These deposits and underlying or interbedded volcanic rocks range in combined thickness from less than 1,000 ft near basin margins to more than 9,000 ft in parts of Pine Valley, Crescent Valley, Upper Reese River Valley, and Antelope Valley (fig. 2). Abrupt decreases in the thickness and width of basin-fill aquifers can result in areas of flowing wells and gaining stream reaches.

Clastic sedimentary rocks, siliceous sedimentary rocks, and granitic rocks can store and transmit ground water, especially where fractured along fault zones. Over large areas, however, these rocks probably impede ground-water flow because of their relatively low permeability.

Carbonate rocks, clastic and siliceous sedimentary rocks, and granitic rocks are collectively referred to as basement in this report. Basement is exposed in mountain ranges, underlies deep structural basins, and forms the surface upon which volcanic rocks and the two units of basin fill were deposited.

Depths to basement in the middle Humboldt River Basin (fig. 2), which are the combined thickness of basin-fill deposits and volcanic rocks, were derived from the interpretation of gravity data using a procedure modified from Jachens and Moring (1990). The method uses existing gravity data (Jewel and others, 1997; Ponce, 1997a, 1997b), drillhole information, surface geology, and the large difference between the density of combined basin-fill and volcanic material and the density of underlying basement rocks. The thickness is constrained independently where basement rocks are exposed and by the available drillhole information. The accuracy of the method is sensitive to the gravity-data coverage, the distribution of basement rocks, and uncertainties in rock densities.

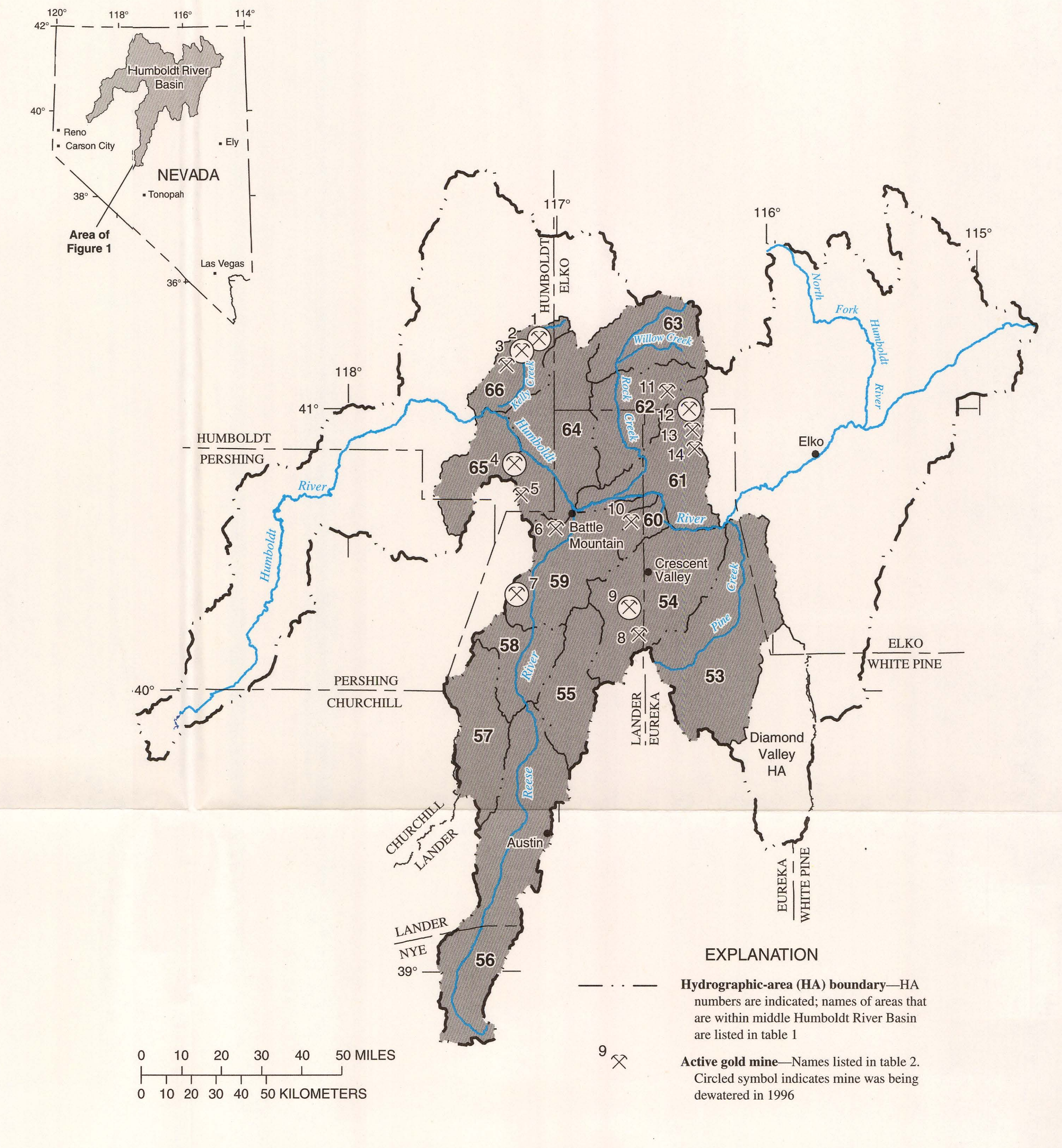

**Figure 1.** Location of middle Humboldt River Basin (shaded), hydrographic areas, and gold mines active in 1996.

Table 1. Hydrographic areas in middle Humboldt River Basin

| Hydrographic area[1] Number (see fig. 1) | Name | Area (square miles) |
|---|---|---|
| 53 | Pine Valley | 1,000 |
| 54 | Crescent Valley | 750 |
| 55 | Carico Lake Valley | 380 |
| 56 | Upper Reese River Valley | 1,100 |
| 57 | Antelope Valley | 450 |
| 58 | Middle Reese River Valley | 320 |
| 59 | Lower Reese River Valley | 600 |
| 60 | Whirlwind Valley | 98 |
| 61 | Boulder Flat | 540 |
| 62 | Rock Creek Valley | 450 |
| 63 | Willow Creek Valley | 410 |
| 64 | Clovers Area | 720 |
| 65 | Pumpernickel Valley | 310 |
| 66 | Kelly Creek Area | 300 |
| | Total | 7,400 |

[1] Formal hydrographic areas in Nevada were delineated systematically by the U.S. Geological Survey and Nevada Division of Water Resources in the late 1960's (Cardinalli and others, 1968; Rush, 1968). These areas have been the basic units for assembling hydrologic data and for regulating water use in the State since then. The official hydrographic-area names, numbers, and geographic boundaries continue to be used in Geological Survey scientific reports and Nevada Division of Water Resources administrative activities.

Table 2. Active open-pit gold mines and reported ground-water withdrawals in middle Humboldt River Basin, 1996

| Mines: Number (see fig. 1) | Mines: Name | Ground-water withdrawals[1] (acre-feet): Mining and milling | Mine dewatering[2]: Infiltration and injection | Mine dewatering[2]: Discharge to surface-water drainage | Total |
|---|---|---|---|---|---|
| 1 | Twin Creeks | 3,808 | [3]985 | [3]3,371 | 8,164 |
| 2 | Getchell | 2,516 | 967 | 0 | 3,483 |
| 3 | Pinson | 1,087 | 0 | 0 | 1,087 |
| 4 | Lone Tree | 3,097 | 0 | [4]40,244 | 43,341 |
| 5 | Marigold | 665 | 0 | 0 | 665 |
| 6 | North Copper Basin | 123 | 0 | 0 | 123 |
| 7 | McCoy Cove | 2,054 | 23,565 | 0 | 25,619 |
| 8 | Cortez | 745 | 0 | 0 | 745 |
| 9 | Pipeline | 449 | 3,864 | 0 | 4,313 |
| 10 | Mule Canyon | 57 | 0 | 0 | 57 |
| 11 | Dee | 796 | 0 | 0 | 796 |
| 12 | Betze–Post | 8,163 | [5]16,285 | 0 | 24,448 |
| 13 | Genesis[6] | 428 | 0 | 0 | 428 |
| 14 | Carlin | 175 | 0 | 0 | 175 |
| | Totals[7] | 24,200 | 45,700 | 43,600 | 113,000 |

[1] Unpublished data from Nevada Division of Water Resources (1997). Values for total withdrawals and mining and milling use are reported to Nevada Division of Water Resources as fractions of an acre-foot. Tabulated values for each mine have been rounded to nearest whole acre-foot.

[2] Except where noted otherwise, individual values computed as difference between total withdrawals and consumptive use for mining and milling. Nevada Division of Water Resources priority for managing this excess water is to keep it in same hydrographic area and to either return it to aquifer by infiltration and injection or, if necessary, substitute it in exchange for other existing uses. Excess water is discharged to nearby surface-water drainages or to Humboldt River only if neither infiltration nor exchange is feasible.

[3] Reported values. Surface-water discharge is to channel of Kelly Creek near mine.

[4] Excess water discharged to Humboldt River channel.

[5] Part of this excess water returned to aquifer and part used for irrigation in Boulder Flat.

[6] Also includes ground-water withdrawals at two nearby mines.

[7] Column totals have been rounded to three significant figures.

**CONVERSION FACTORS AND VERTICAL DATUM**

| Multiply | By | To obtain |
|---|---|---|
| acre | 4,047 | square meter |
| acre-foot (acre-ft) | 0.001233 | cubic hectometer |
| acre-foot per year (acre-ft/yr) | 1,233 | cubic meter per year |
| foot (ft) | 0.3048 | meter |
| foot per day (ft/d) | 0.3048 | meter per day |
| foot per mile (ft/mi) | 0.1894 | meter per kilometer |
| foot squared per day ($ft^2/d$) | 0.09290 | meter squared per day |
| mile (mi) | 1.609 | kilometer |
| square mile ($mi^2$) | 2.590 | square kilometer |

**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.

EXPLANATION

**Younger basin-fill deposits (Quaternary and Tertiary)**—Unconsolidated to poorly consolidated clay, silt, sand, gravel, and boulders of alluvial fans, basin lowlands, and stream flood plains. These deposits form shallow basin-fill aquifers that underlie each hydrographic area in study area. Hydraulic conductivity of stream flood-plain deposits, estimated from well drillers' pumping tests, is 26 ft/d in Whirlwind Valley Hydrographic Area, 35 ft/d in Boulder Flat Hydrographic Area, and 42 to 1,100 ft/d in Middle and Lower Reese River Valley Hydrographic Areas (Bredehoeft and Farvolden, 1963, p. 210)

**Volcanic rocks (Quaternary and Tertiary)**—Flows, cinder cones, and related shallow intrusive rocks of basalt, basaltic andesite, andesite, and dacite composition in Sheep Creek Range, northern Shoshone Range, Cortez Mountains, Fish Creek Mountains, northern Shoshone Mountains, northern Toiyabe Range, northern Edna Mountain, and southern Osgood Mountains. Rhyolitic flow domes in Sheep Creek Range. Ash-flow tuffs and subordinate flows and related shallow intrusive rocks of rhyolite and quartz latite composition mostly in mountain ranges south of Humboldt River. Rocks in Sheep Creek Range and unnamed mountain ranges farther north are permeable and permit westward movement of ground water across Willow Creek Valley and Rock Creek Valley Hydrographic Areas to Clovers Area (see fig. 4). Estimated hydraulic conductivity of fractured volcanic rocks in northern Boulder Flat Hydrographic Area ranges from 0.01 to 10 ft/d (Stone and others, 1991, p. 29)

**Older basin-fill deposits (Tertiary)**—Tuffaceous conglomerate, sandstone, siltstone, mudstone, and limestone. Typically interbedded with volcanic rocks and probably underlie younger basin-fill deposits in most basins. These deposits constitute deeper parts of basin-fill aquifers. Transmissivity ranges from 240 to 290 $ft^2/d$ near Betze–Post Mine in northern Boulder Flat Hydrographic Area (Stone and others, 1991, p. 28). Transmissivity and storage coefficient, estimated from aquifer tests, are 33 $ft^2/d$ and 0.006, respectively, in fine-grained lake deposits at Lone Tree Mine in northern Pumpernickel Valley Hydrographic Area (Stock and others, 1992, p. 12 and 21) and 1,900 to 8,000 $ft^2/d$ and 0.0001, respectively, in alluvial-fan deposits at Twin Creeks Mine in northern Kelly Creek Area (WESTEC, 1993, chap. 4, p. 10)

**Granitic rocks (Tertiary to Jurassic)**—Intrusive bodies of granodiorite and quartz monzonite in Osgood Mountains, Sonoma Range, Edna Mountain, Buffalo Mountain, Dry Hills, Cortez Mountains, and Toiyabe Range. Estimated hydraulic conductivity of rocks exposed by operations at Betze–Post Mine in northern Boulder Flat Hydrographic Area is 3 to 5 ft/d in fractured rock and 0.1 to 0.5 ft/d in unfractured rock (Hydro–Geo Consultants, 1990, p. 9, and 1992, p. 3)

**Siliceous sedimentary rocks (Triassic to Cambrian)**—Chert, siliceous shale, siltstone, sandstone, quartzite, conglomerate, and subordinate limestone, dolomite, and volcanic rocks. Limestone and dolomite of Triassic age locally predominant in Tobin Range, Augusta Mountains, and New Pass Range. Transmissivity and storage coefficient, estimated from aquifer tests, are 58,000 to 190,000 $ft^2/d$ and 0.0012 to 0.003, respectively, along a fault zone at Lone Tree Mine in Pumpernickel Valley Hydrographic Area (Stock and others, 1992, p. 21) and 40 to 420 $ft^2/d$ and 0.00005 to 0.0001, respectively, at Betze–Post Mine in northern Boulder Flat Hydrographic Area (Hydro–Geo Consultants, 1992, p. 3)

**Clastic sedimentary rocks (Permian to Cambrian)**—Quartzite of Cambrian age in Osgood Mountains. Quartzite, shale, and subordinate laminated limestone of Cambrian, Ordovician, Mississippian, and Pennsylvanian age in Toiyabe Range. Conglomerate, sandstone, and shale of Mississippian and Pennsylvanian age in Piñon Range. Conglomerate, shale, and subordinate limestone of Permian age in Sulphur Spring Range. Unit generally may be poorly permeable and impede movement of ground water

**Carbonate rocks (Devonian to Cambrian)**—Limestone and dolomite and subordinate shale, sandstone, quartzite, conglomerate, and chert of Cambrian to Devonian age in Pine Valley, Crescent Valley, Boulder Flat, and Upper Reese River Valley Hydrographic Areas and in western Kelly Creek Area. Limestone and dolomite can be extremely permeable where fractures have been solution-widened by ground water. Estimated transmissivity ranges from 200 to 2,000 $ft^2/d$ in poorly fractured rock and from 3,000 to 6,000 $ft^2/d$ in highly fractured rock. Storage coefficient ranges from 0.0001 to 0.01 at Betze–Post Mine in northern Boulder Flat Hydrographic Area (Hydro–Geo Consultants, 1990, p. 9)

3,000 — **Line of equal combined thickness of basin-fill deposits and volcanic rocks**—Shows combined thickness, in feet, of younger basin-fill deposits, volcanic rocks, and older basin-fill deposits. Interval 3,000 ft, with supplemental lines at 1,000 and 2,000 ft

**Boundary of hydrographic area**—Modified from Rush (1968)

• 3,848 **Well that penetrates to base of basin-fill deposits and volcanic rocks**—Number indicates combined thickness, in feet, of basin-fill and volcanic units. Thicknesses from Ponce and Moring (1998)

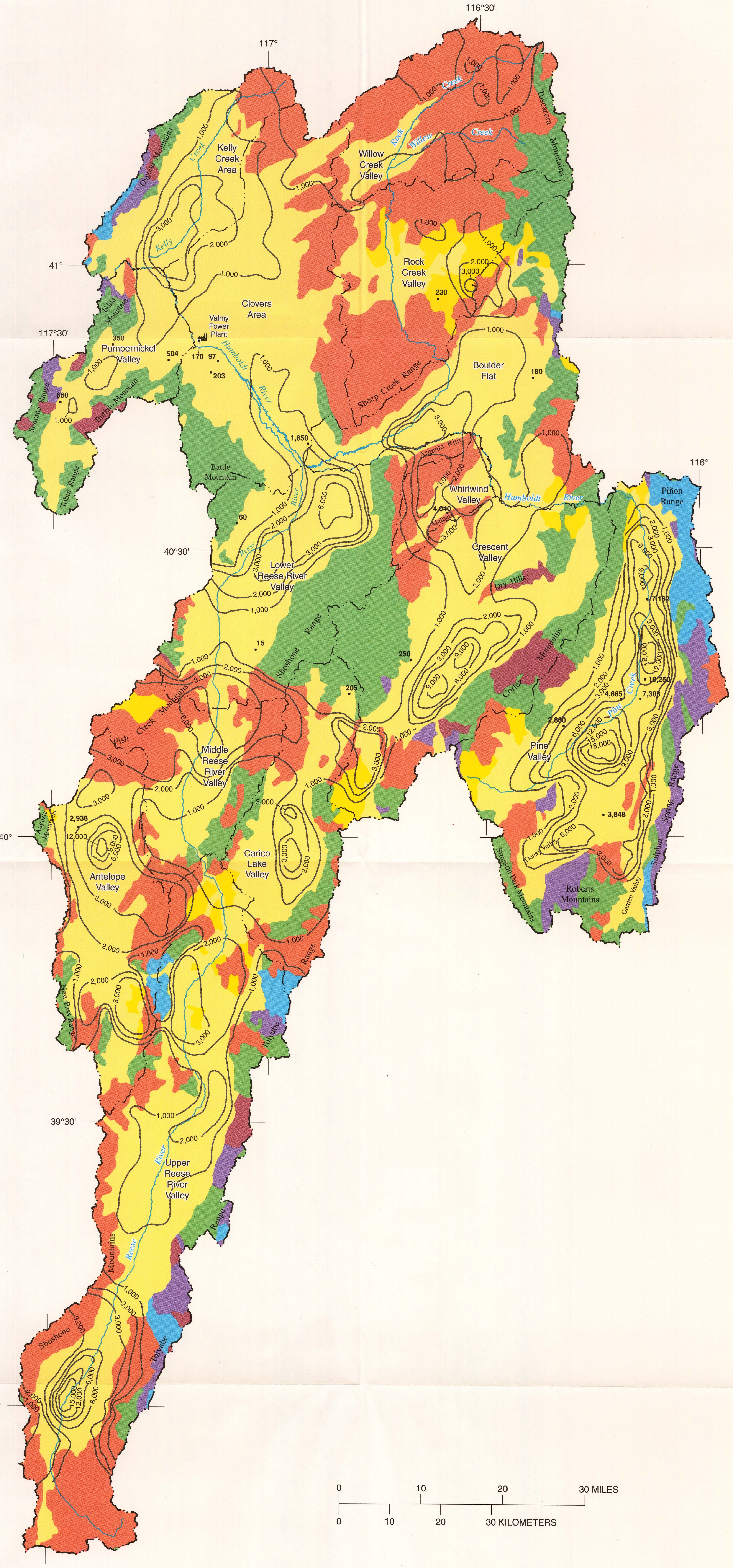

**Figure 2.** Hydrogeologic units and thickness of combined volcanic rocks and basin-fill deposits.

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
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1999