

Prepared in cooperation with the Bureau of Land Management



# **Water-Level Surface Maps of the Carbonate-Rock and Basin-Fill Aquifers in the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and Adjacent Areas in Nevada and Utah**

Scientific Investigations Report 2007–5089

**U.S. Department of the Interior**  
**U.S. Geological Survey**



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**U.S. Geological Survey**  
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## Foreword

Water demands from the lower Colorado River system are increasing with the rapidly growing population of the southwestern United States. To decrease dependence on this over-allocated surface-water resource and to help provide for the projected increase in population and associated water supply in the Las Vegas area, water purveyors in southern Nevada have proposed to utilize the ground-water resources of rural basins in eastern and central Nevada. Municipal, land management, and regulatory agencies have expressed concerns about potential impacts from increased ground-water pumping on local and regional water quantity and quality, with particular concern on water-rights issues and on the future availability of water to support natural spring flow and native vegetation. Before concerns on potential impacts of pumping can be addressed, municipal and regulatory agencies have recognized the need for additional information and improved understanding of geologic features and hydrologic processes that control the rate and direction of ground-water flow in eastern and central Nevada.

In response to concerns about water availability and limited geohydrologic information, Federal legislation (Section 131 of the Lincoln County Conservation, Recreation, and Development Act of 2004; PL 108-424) was enacted in December 2004 that directs the Secretary of the Interior, through the U.S. Geological Survey (USGS), the Desert Research Institute (DRI), and a designee from the State of Utah, to complete a water-resources study of the basin-fill and carbonate-rock aquifers in White Pine County, Nevada, and smaller areas of adjacent counties in Nevada and Utah. The primary objectives of the Basin and Range carbonate-rock aquifer system (BARCAS) study are to evaluate: (1) the extent, thickness, and hydrologic properties of aquifers, (2) the volume and quality of water stored in aquifers, (3) subsurface geologic structures controlling ground-water flow, (4) ground-water flow direction and gradients, and (5) the distribution and rates of recharge and ground-water discharge. Geologic, hydrologic, and supplemental geochemical information will be integrated to determine basin and regional ground-water budgets.

Results of the study will be summarized in a USGS Scientific Investigations Report (SIR), to be prepared in cooperation with DRI and the State of Utah, and submitted to Congress by December 2007. The BARCAS study SIR is supported by USGS and DRI reports that document, in greater detail than the summary SIR, important components of this study. These reports are varied in scope and include documentation of basic data, such as spring location and irrigated acreage, and interpretive studies of ground-water flow, geochemistry, recharge, evapotranspiration, and geology.

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## Conversion Factors and Datums

### Conversion Factors

<b>Multiply</b>	<b>By</b>	<b>To obtain</b>
foot (ft)	0.3048	meter (m)
square mile (mi <sup>2</sup> )	2.590	square kilometer (km <sup>2</sup> )

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$^{\circ}\text{C}=(^{\circ}\text{F}-32)/1.8.$$

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32.$$

### Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83) unless otherwise stated.

Altitude, as used in this report, refers to distance above the vertical datum.

# Water-Level Surface Maps of the Carbonate-Rock and Basin-Fill Aquifers in the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and Adjacent Areas in Nevada and Utah

By J.W. Wilson

## Abstract

Water-level measurements in 418 wells were used to develop a potentiometric-surface map of the carbonate-rock aquifer and a water-table map of the basin-fill aquifer in the Basin and Range carbonate-rock aquifer system (BARCAS) study area. The BARCAS study area encompasses about 13,500 square miles and includes most of White Pine County, Nevada, and smaller areas of adjacent counties in Nevada and Utah. Current and historical data from the U.S. Geological Survey National Water Information System, previous publications, and field reconnaissance were used to define water-level surfaces.

## Introduction

The Basin and Range carbonate-rock aquifer system (BARCAS) study area encompasses about 13,500 mi<sup>2</sup> and covers about 80 percent of White Pine County, and parts of Elko, Eureka, Nye, and Lincoln Counties in Nevada, as well as parts of Tooele, Millard, Beaver, Juab, and Iron Counties in Utah ([fig. 1](#)). White Pine County is within the carbonate-rock province, a relatively large area extending from western Utah to eastern California where ground-water flow is predominantly or strongly influenced by carbonate-rock aquifers. Much of the carbonate-rock aquifer is fractured and, where continuous, forms a regional ground-water flow system that receives recharge from high-altitude areas where fractured carbonate rocks are exposed. Most areas in White Pine County, Nevada, are within four regional ground-water flow systems ([fig. 2](#))—the larger Colorado and Great Salt Lake Desert flow systems, and the smaller Goshute Valley and Newark Valley flow systems (Harrill and others, 1988). Water moving through the carbonate-rock aquifer provides some recharge to overlying basin-fill aquifers, sustains many of the large, perennial low-altitude springs, and hydraulically

connects similar carbonate-rock aquifers in adjacent basins. The regional carbonate-rock aquifer typically is overlain by a basin-fill aquifer in the intermountain basins. The basin-fill aquifer is composed of gravel, sand, silt, and clay and often reaches thicknesses of several thousand feet (Harrill and Prudic, 1998). The gravel and sand deposits typically yield water readily to wells and this aquifer is the primary water supply in the area for agricultural, domestic, or municipal use.

The carbonate-rock aquifer extends beneath numerous surface-water drainage basins, or hydrographic areas<sup>1</sup>. Past studies have combined hydrographic areas to delineate basin-fill or regional ground-water flow systems, based primarily on the direction of interconnected ground-water flow in the underlying carbonate-rock aquifer and the location of terminal discharge areas (Harrill and Prudic, 1998). Although the boundary lines between hydrographic areas generally coincide with actual topographic basin divides, some boundaries are arbitrary or represent hydrologic divisions that have no topographic basis. Hydrographic areas were further divided into subbasins that are separated by areas where pre-Cenozoic rocks are at or near the land surface (Welch and Bright, 2007). Hydrographic area names in this report generally refer to formal hydrographic areas of Harrill and others (1988) with two exceptions: (1) ‘Little Smoky Valley’ refers to hydrographic areas 155A and 155B, which are the northern and central parts of Harrill and others (1988) description of Little Smoky Valley, respectively, and (2) ‘Butte Valley’ refers only to hydrographic area 178B, which is the southern part of Harrill and others (1988) description of Butte Valley. For most figures and tables in this report, water-budget components were estimated for the northern and central parts of Little Smoky Valley, but were combined and reported as one value.

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<sup>1</sup> Formal hydrographic areas in Nevada were delineated systematically by the U.S. Geological Survey and Nevada Division of Water Resources in the late 1960s (Cardinali and others, 1968; Rush, 1968) for scientific and administrative purposes. The official hydrographic-area names, numbers, and geographic boundaries continue to be used in U.S. Geological Survey scientific reports and Division of Water Resources administrative activities.

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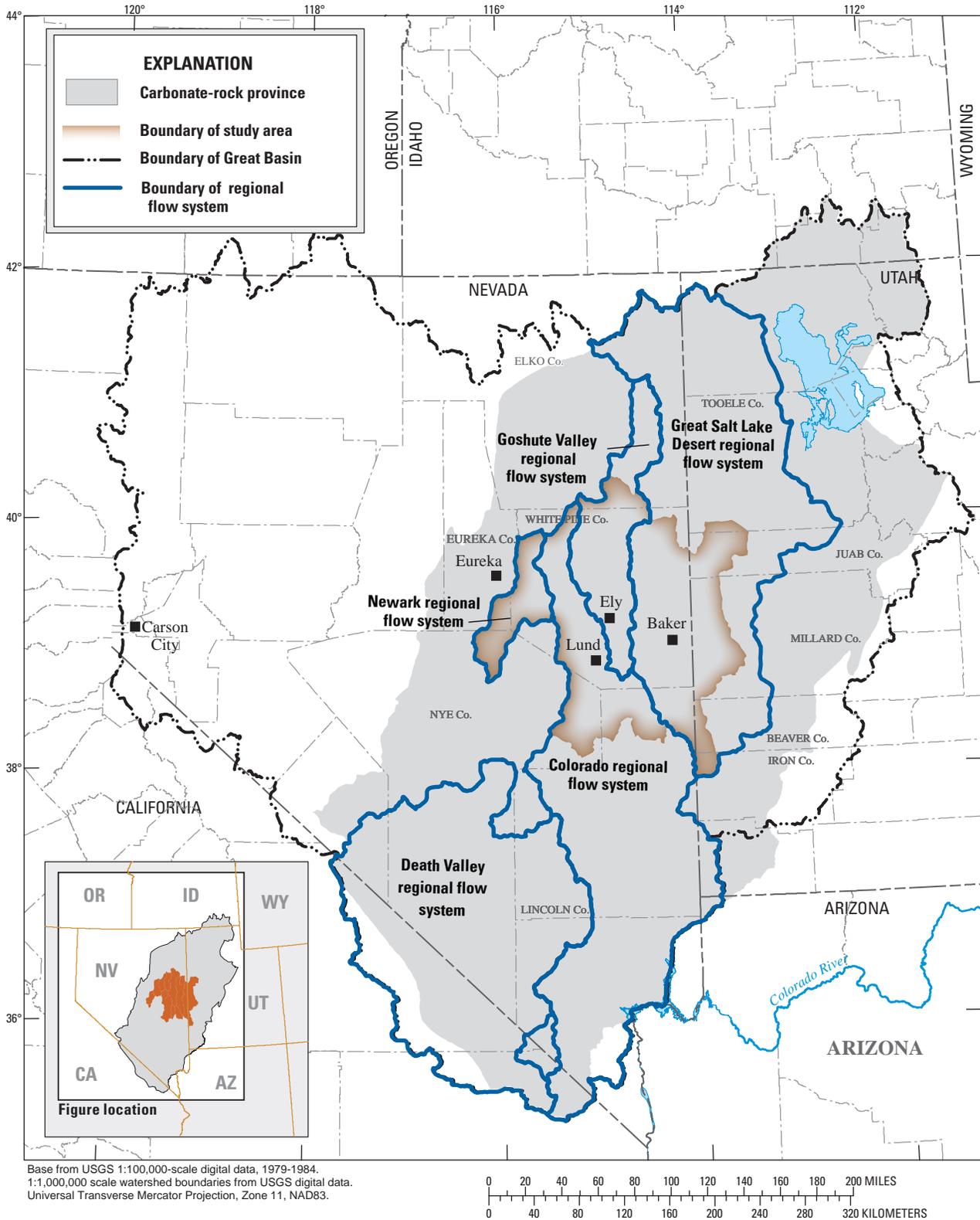
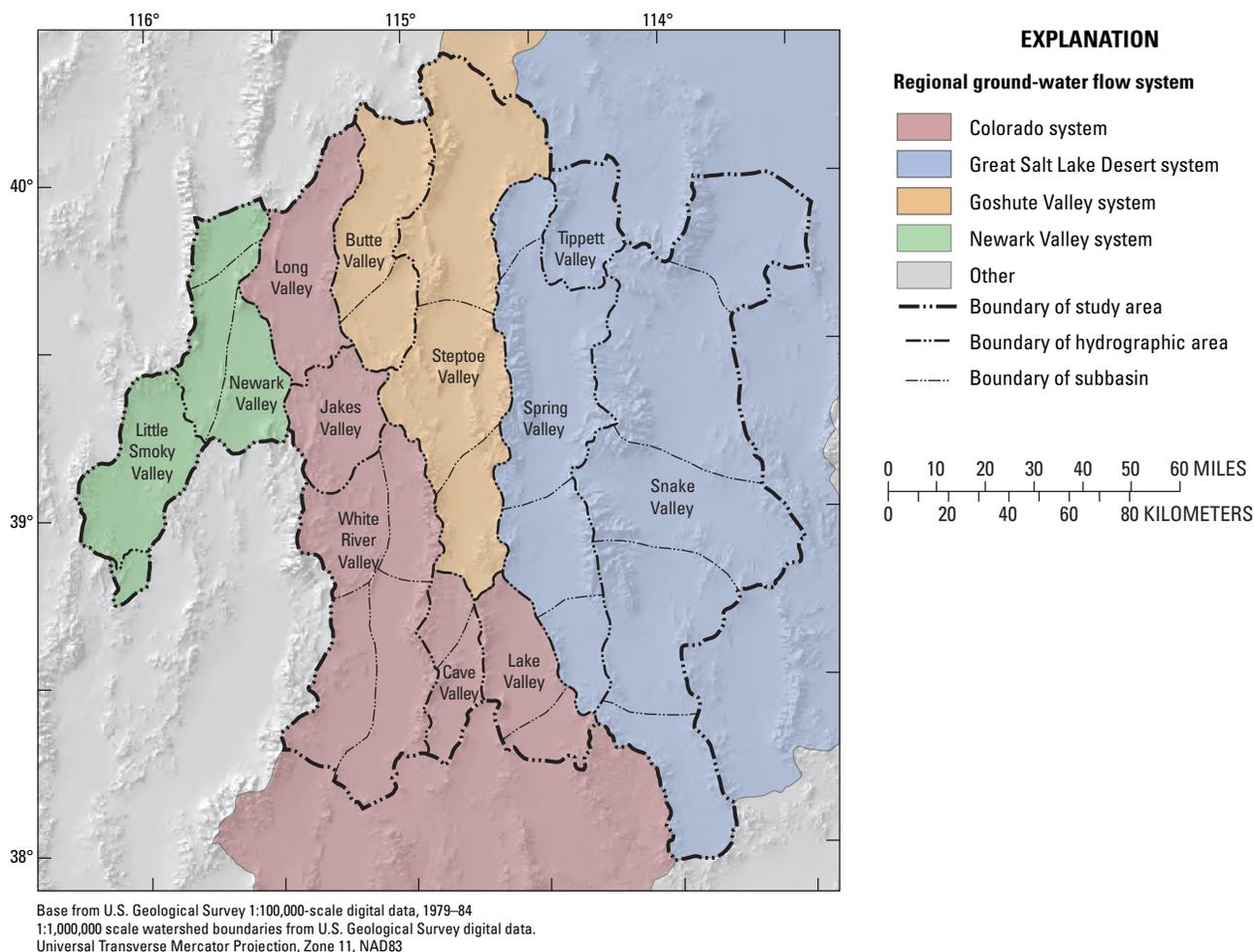


Figure 1. Carbonate-rock province, Basin and Range carbonate-rock aquifer system study area, and associated regional ground-water flow systems, Nevada and Utah.



**Figure 2.** Regional flow systems, hydrographic areas, and subbasins in the Basin and Range carbonate-rock aquifer system study area, Nevada and Utah. (Modified from Harrill and others, 1988)

Ground-water flow was assessed using a potentiometric-surface map of the regional carbonate-rock aquifer and a water-table map of the basin-fill aquifer. Potentiometric and water-level surfaces are represented by spatially interpolated contours of hydraulic head. The contours are visual representations of a surface constructed by connecting points of equal altitude. These points represent the altitude of static water levels in wells that tap the carbonate-rock aquifer or basin-fill aquifer. In addition to the altitude of hydraulic heads, the interpreted potentiometric surface or water table presented in this report is based, in part, on (1) the occurrence of aquifers and confining units along hydrographic-area boundaries, and (2) areas of recharge and ground-water discharge. These geologic features and hydrologic processes significantly influence the direction and magnitude of interbasin (regional) and intrabasin (local) ground-water flow.

## Purpose and Scope

The purpose of this report is to determine the direction of regional and intermediate ground-water flow in two primary aquifers in the BARCAS study area—regional flow through the carbonate-rock aquifer and local flow through the basin-fill aquifer. The scope of the study included collecting, compiling, and evaluating 418 water-level measurements to determine measurements that represent static water-level conditions in each aquifer. Water-level measurements were used to develop a potentiometric-surface map for the carbonate-rock aquifer and a water-table map for the basin-fill aquifer. These maps support other technical components of the BARCAS study, including the development of basin and regional ground-water budgets, and estimates of the magnitude of interbasin ground-water flow.

## Conceptual Ground-Water Flow System

Ground water in the study area is influenced by a combination of topography, climate, and geology. Ground water moves through permeable zones under the influence of hydraulic gradients from areas of recharge to areas of discharge, and this movement can be discussed in terms of local, intermediate, and regional flow systems (fig. 3). These ground-water terms are adopted from the terminology developed by Tóth (1963) and Freeze and Cherry (1979), and are defined on the basis of depth of ground-water flow and length of the flow path. Local flow systems are characterized by relatively shallow and localized flow paths that terminate at upland springs. Local springs are low volume, tend to have

temperatures similar to annual average ambient atmospheric conditions and have discharge that fluctuates according to the local precipitation. Intermediate flow systems include flow from upland recharge areas to discharge areas along the floor of the intermontane valley. Within intermediate flow systems, springs typically discharge near the intersection of the alluvial fan and the valley floor near the range front. Intermediate flow system springs often are of moderate volume and tend to have less variable flow relative to local springs.

Regional ground-water flow follows large-scale (tens to hundreds of miles) topographic gradients as water moves toward low altitudes in the region. Discharge from these regional flow systems manifests as large springs and, in some areas, extensive wetlands. Mendenhall (1909) and Meinzer (1911) recognized that certain large volume springs in the eastern Great Basin can not be supported by the available

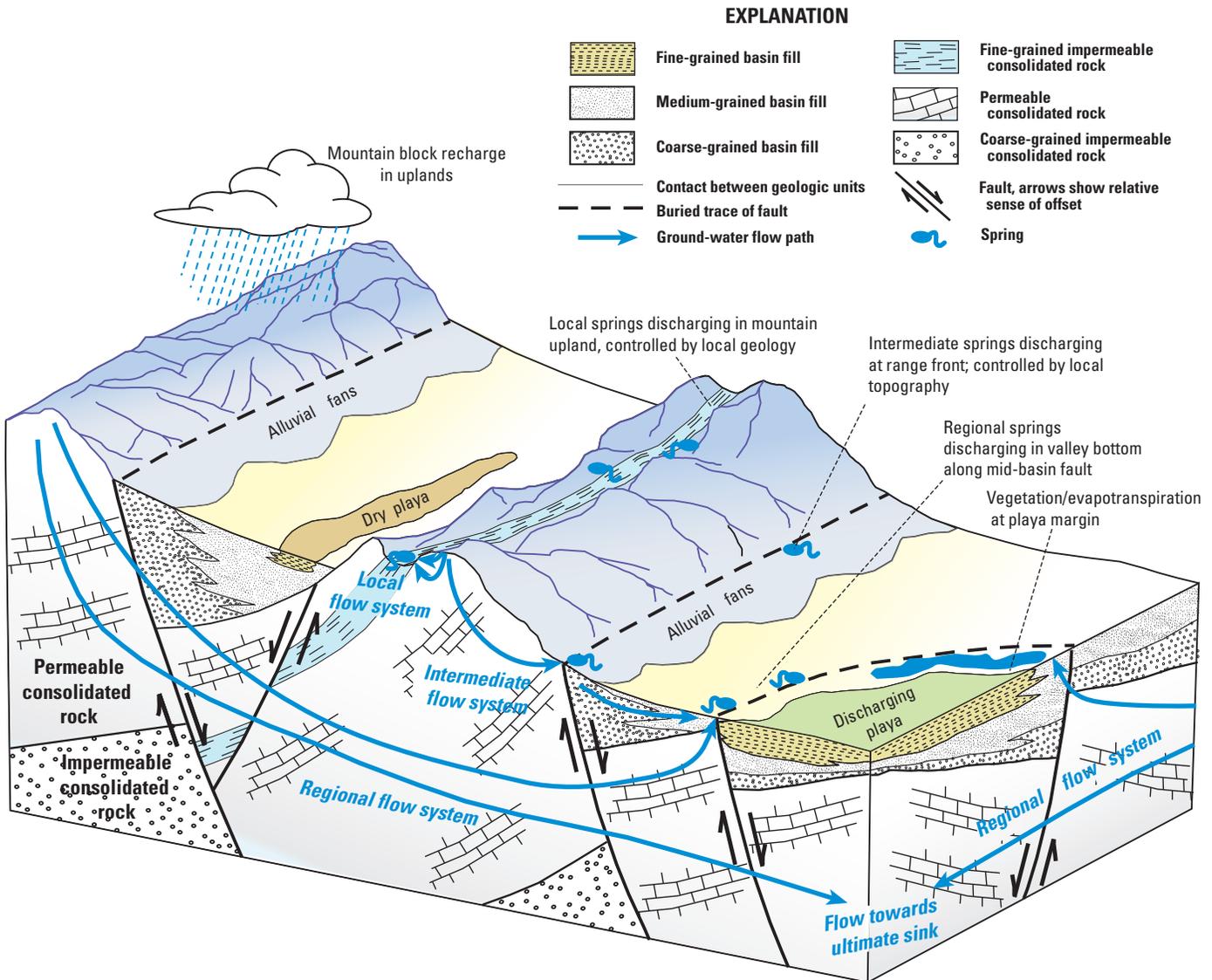


Figure 3. Conceptual ground-water flow system.

recharge from local surrounding mountain ranges, and that the flow from these springs must be supported in part from regional ground-water flow originating outside the basin. Based on chemistry, temperature, and other criteria, Mifflin (1968) identified some springs likely discharging interbasin flow, including Hot Creek in White River Valley and McGill Spring in Steptoe Valley. Regional ground-water flow is driven by hydraulic gradients that are continuous over long distances. Deep regional flow through basin-fill or consolidated bedrock aquifers is unconstrained by local topographic or drainage features. Under natural conditions, recharge to the regional ground-water flow system primarily originates in mountains and may travel beneath several basins and through multiple mountain ranges before reaching its ultimate discharge area.

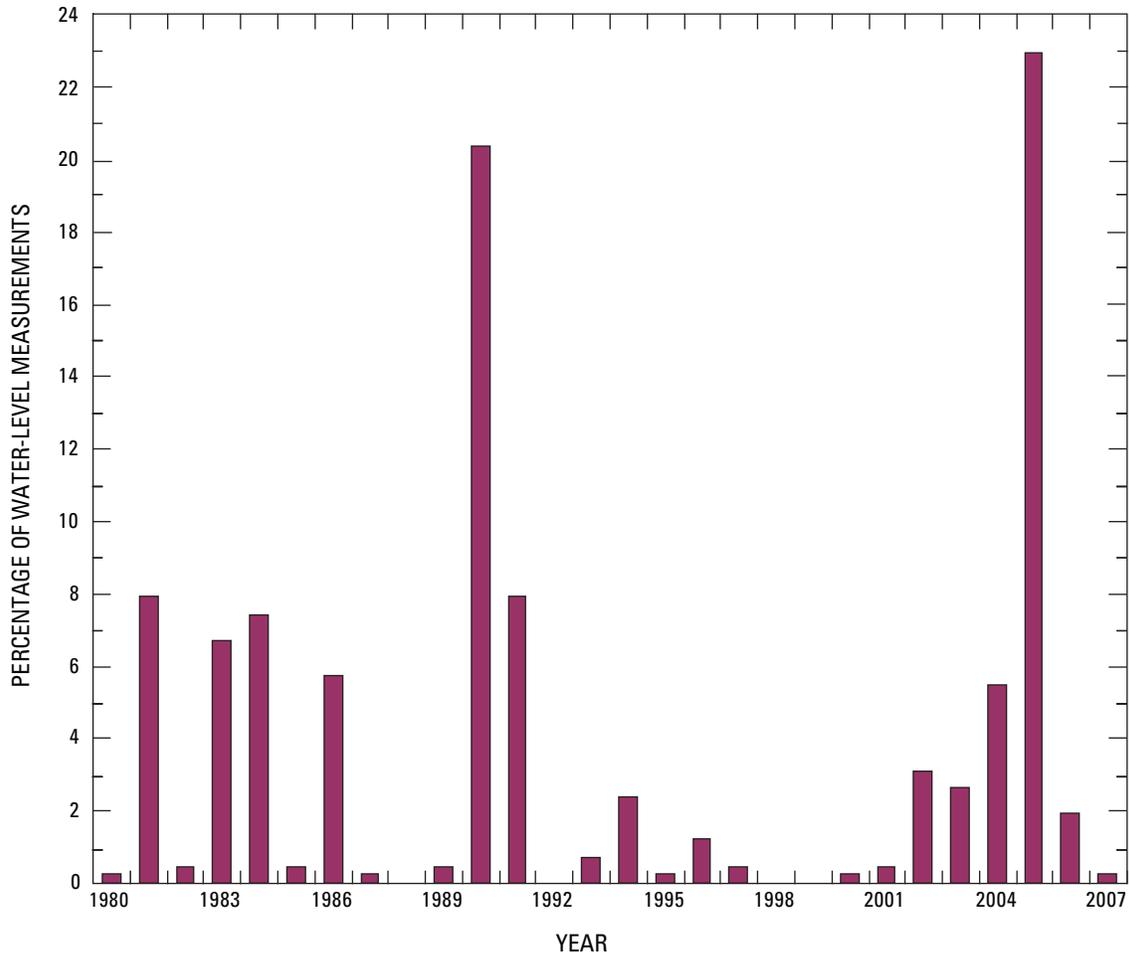
Water in the carbonate-rock aquifer generally represents interbasin ground-water flow from the regional flow system. Ground water in this aquifer flows through fractured carbonate rocks throughout most of the study area, except in the southern and western parts of the study area, where some regional ground water likely flows through fractured volcanic rocks. However, current (2007) or historic water-level measurements are not available for wells completed in volcanic rocks. Water in the basin-fill aquifer represents intrabasin ground-water flow from the local, intermediate, or regional flow systems. This aquifer is considered a mixture of flow systems because the basin fill may receive local surface inflow from adjacent mountain ranges, upward intermediate or regional ground-water flow from underlying bedrock, or discharge from intermediate or regional springs.

## Data for Water-Level Surface Maps

The potentiometric-surface map of the carbonate-rock aquifer ([pl. 1](#)) and the water-level map of the basin-fill aquifer ([pl. 2](#)) primarily are based on water-level data collected for this study and compiled from previous studies. Potentiometric-surface and water-table maps published in previous reports were used as secondary guides in developing hydraulic-head contours, particularly in areas where water-level data are sparse. Previous investigations by Thomas and others (1986), Bedinger and Harrill (2004), and Gates (2004) were used to supplement limited data in eastern and southern Snake, northern Jakes, Cave, Little Smoky, Long, and Butte Valleys. In addition to data on hydraulic heads, the influence on ground-water flow across hydrographic-area boundaries (Sweetkind and others, 2007), and the distribution and magnitude of recharge (Flint and Flint, 2007) and ground-water discharge (Moreo and others, 2007; Smith and others, 2007) were considered in the development of potentiometric-surface and water-table maps.

Water-level data used in the development of the water-level surface maps consist of water levels measured in 3 mine shafts (herein referred to as monitoring wells) and in 415 wells. Because the numbers of wells completed in the deeper carbonate-rock aquifer are relatively sparse, the potentiometric-surface map of this aquifer represents a composite of water-level measurements in wells completed in basin fill (76 wells) and deeper geologic units including carbonate rocks (43 wells). Similar to the approach used to develop potentiometric-surface maps in the Death Valley regional flow system (Belcher, 2004, appendix 1), water-level data for the basin-fill aquifer were considered representative of regional hydraulic heads if evidence of hydraulic continuity exists between the overlying basin-fill aquifer and underlying carbonate aquifer. General guidelines for identifying regional hydraulic heads may include water-level altitudes in shallow wells that are similar to nearby wells completed in the carbonate-rock aquifer, or the regional hydraulic head can be represented by shallow water levels in large areas of low topographic relief and virtually no recharge. Additional guidelines were used to identify regional heads and construct potentiometric-surface contours, such as (1) the presence of regional springs at low altitudes in a basin, indicating that the regional hydraulic head is higher than the basin-floor discharge areas, (2) the regional head is below the altitude of non-discharging dry playas, (3) the regional head is lower than the water table in areas of recharge, and (4) local springs discharging at high-basin altitudes, well above the basin floors, generally are above the regional hydraulic head. The water-table map was developed from water-level measurements for 299 wells completed in basin fill.

Water-level data were compiled from field measurements for 1980–2007 ([fig. 4](#)). For sites with temporal water-level data, hydrographs were evaluated to delineate static and transient water-level measurements, and to determine general trends in rising or declining ground-water levels. Historical water-level measurements that represent current ground-water conditions were used to develop potentiometric-surface and water-table contours and, as a result, these contours represent a composite of water-level measurements over time. Current and historical water-level data were obtained from the USGS National Water Information System (NWIS), Southern Nevada Water Authority (SNWA), and from previous reports by Bunch and Harrill (1984) and Thomas and others (1986). Most water-level measurements used in this report were made by calibrated steel or electric tapes; the accuracy of these depth-to-water measurements varies from well to well, but generally is within a foot or less of the actual depth. Water-level data used to construct the potentiometric surface of the carbonate-rock aquifer and water table in the basin-fill aquifer are given in [appendix A](#).



**Figure 4.** Distribution and year of water-level data used to develop water-level surface maps in the Basin and Range carbonate-rock aquifer system study area, Nevada and Utah.

## Ground-Water Flow in Carbonate-Rock and Basin-Fill Aquifers

The potentiometric surface of the carbonate-rock aquifer ranges in altitude from less than 4,500 ft in northern Snake Valley to more than 6,500 ft in southern Steptoe Valley in areas surrounding the southern Egan Range and southern Schell Creek Range (pl. 1). Ground water flows from high-altitude areas of recharge in the Snake Range, Schell Creek Range, and Egan Range, and these areas generally represent ground-water divides that separate the study area into multiple flow systems. Regional ground-water flow from these source areas is multi-directional — flow generally is toward the south in Long, Jakes, White River, and Cave Valleys, and generally toward the northeast in Steptoe, Spring, and Snake Valleys. Some southerly flow likely occurs in southern Steptoe Valley toward Lake Valley, to the southeast toward Spring Valley, and possibly to the southwest toward Jakes Valley and northern

White River Valley. Flow generally is east across Lake and Spring Valleys toward Snake Valley. Ground water likely exits the study area from Snake and Tippet Valleys toward the terminal discharge area of the Great Salt Lake Desert regional flow system; from Butte Valley toward the terminal discharge area of the Ruby Valley regional flow system (Harrill and others, 1988); and from White River Valley toward the terminal discharge area of the Colorado regional flow system. Regional hydraulic heads that are equal to or above heads in the basin-fill aquifer suggest that some regional ground water likely moves upward into overlying basin-fill sediments, such as in southern White River Valley and south-central Spring Valley.

The water table in the basin-fill aquifer ranges in altitude from less than 4,400 ft in northern Snake Valley to more than 6,800 ft in southern Steptoe Valley (pl. 2). Ground water in the basin fill generally flows from mountain fronts along the margin of valleys to the center of valley floors where it

is internally drained by evaporative discharge. However, in some hydrographic areas, ground water in the basin fill flows parallel to the mountain front and towards the basin boundary. Because these boundaries typically consist of bedrock highs, ground water may flow laterally into more permeable rocks, or downward if bedrock is relatively impermeable or geologic structures along the boundary inhibit lateral ground-water flow. For purposes of this study, interbasin ground-water flow through fractured bedrock along basin boundaries is considered regional ground-water flow. Ground water in the basin-fill aquifer generally flows to the north or northeast in Steptoe, northern Spring, and Snake Valleys, and to the south in Long, White River, Cave, and southern Spring Valley.

## Summary

Water-level measurements in 418 wells were used to develop a potentiometric-surface map of the carbonate-rock aquifer and a water-table map of the basin-fill aquifer in the Basin and Range carbonate-rock aquifer system (BARCAS) study area. The BARCAS study area encompasses about 13,500 square miles and includes most of White Pine County, Nevada, and smaller areas of adjacent counties in Nevada and Utah. Current and historical data from the U.S. Geological Survey National Water Information System, previous publications, and field reconnaissance were used to define water-level surfaces. Carbonate rocks form much of the Egan, Schell Creek, and Snake Ranges, and the relatively high precipitation and recharge in these mountain ranges are the source for regional ground-water flow in the carbonate-rock aquifer. The Egan Range is the primary source area for northward ground-water flow through Butte Valley, and southward flow through Long, Jakes, and White River Valleys. The Egan and Schell Creek Ranges are the primary source areas for flow through Steptoe Valley. The Schell Creek and Snake Ranges are the primary source areas for northeastward ground-water flow through northern Spring, Tippett, and Snake Valleys. Ground water in the basin-fill aquifer generally flows from mountain fronts along the margin of valleys to the center of valley floors where it is internally drained by evaporative discharge.

## Acknowledgments

The author acknowledges the assistance of Steve Mizell and Chuck Russell (Desert Research Institute) and Donald Sweetkind (U.S. Geological Survey), who provided significant comments pertinent to the development of these maps. Special thanks are extended to the homeowners who volunteered access to their land and wells, thereby making this study possible. The author also thanks Bill Butts and the White Pine Water Advisory Committee for providing updated water-level data collected throughout the study area.

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## **Appendix A. Water-level altitudes and descriptive data from selected wells in and around the Basin and Range carbonate-rock aquifer system study area, Nevada and Utah.**

The spreadsheet distributed as part of this report is in Microsoft® Excel 2003 format. Column headers are described within the spreadsheet. [Appendix A](#) data are available for download at URL: <http://pubs.water.usgs.gov/sir20075089>.

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