DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MAJOR GROUND-WATER FLOW SYSTEMS IN THE GREAT BASIN REGION OF NEVADA, UTAH, AND ADJACENT STATES

By James R. Harrill, Joseph S. Gates, and James M. Thomas

REGIONAL AQUIFER SYSTEMS OF THE GREAT BASIN

HYDROLOGIC INVESTIGATIONS ATLAS
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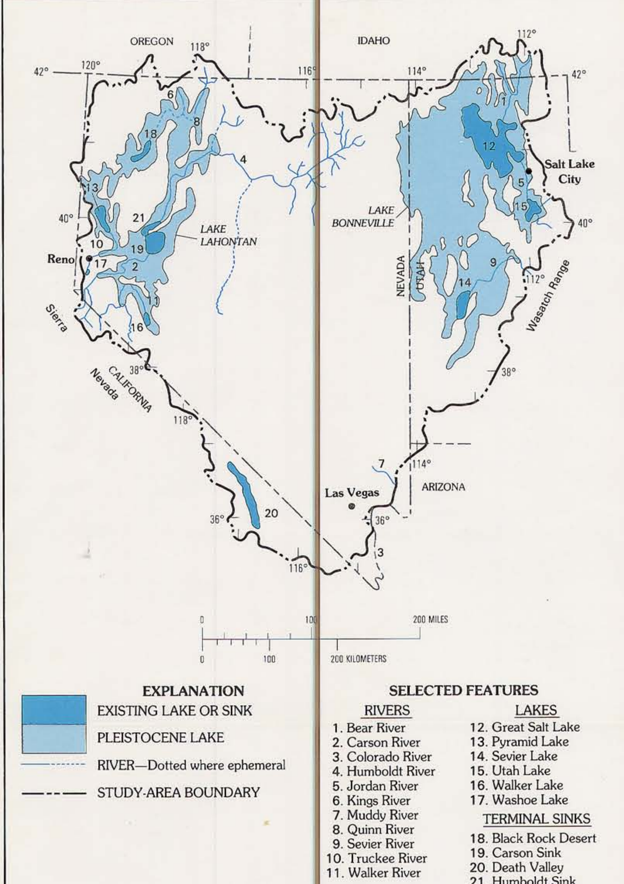

Figure 1.—Location of the study area and principal geographic features within the study area

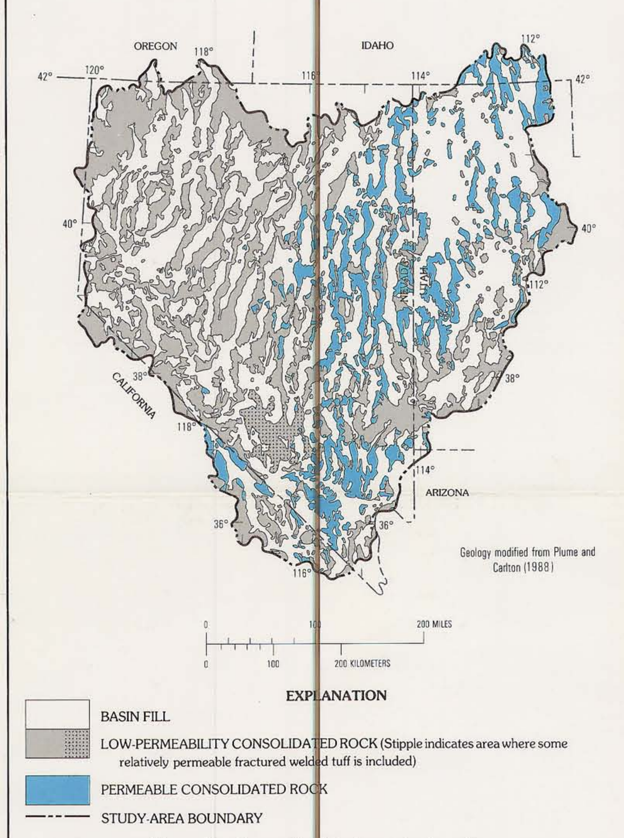

Figure 2.—Generalized hydrogeologic units

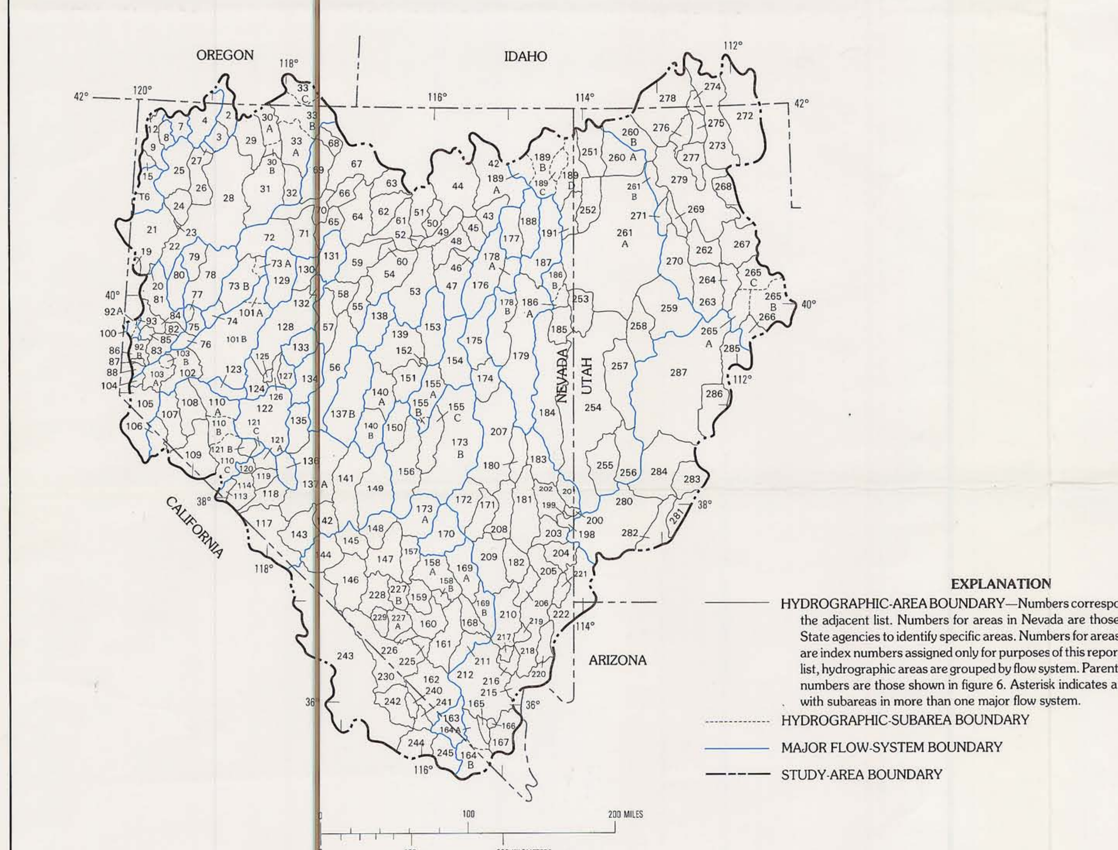

Figure 3.—Hydrographic areas

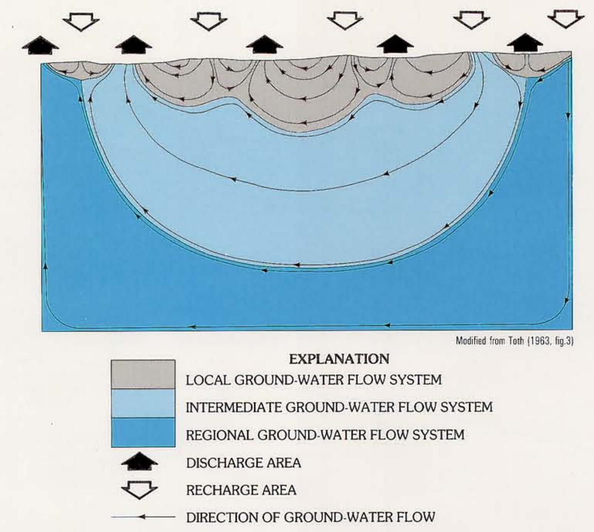

Figure 4.—Schematic cross section showing theoretical patterns of regional flow

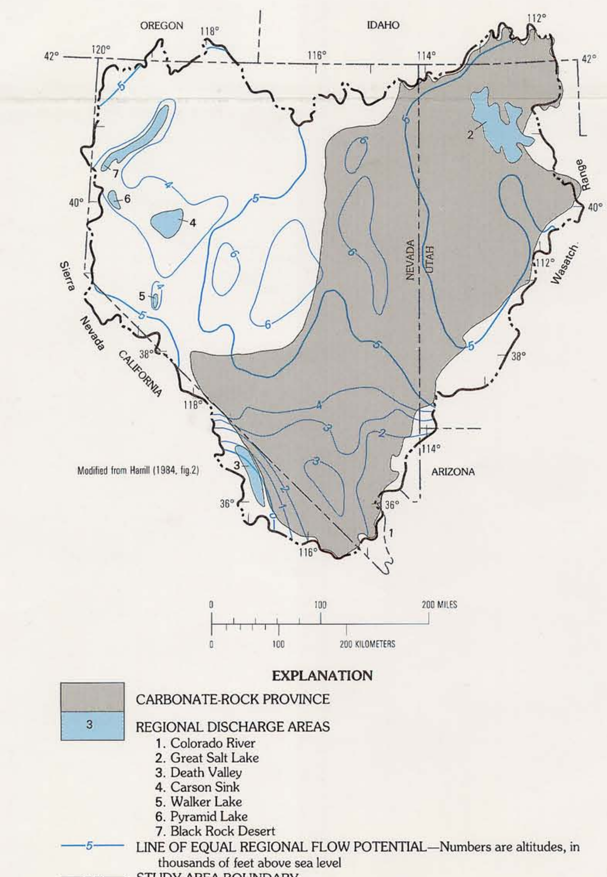

Figure 5.—Indices of regional flow potential

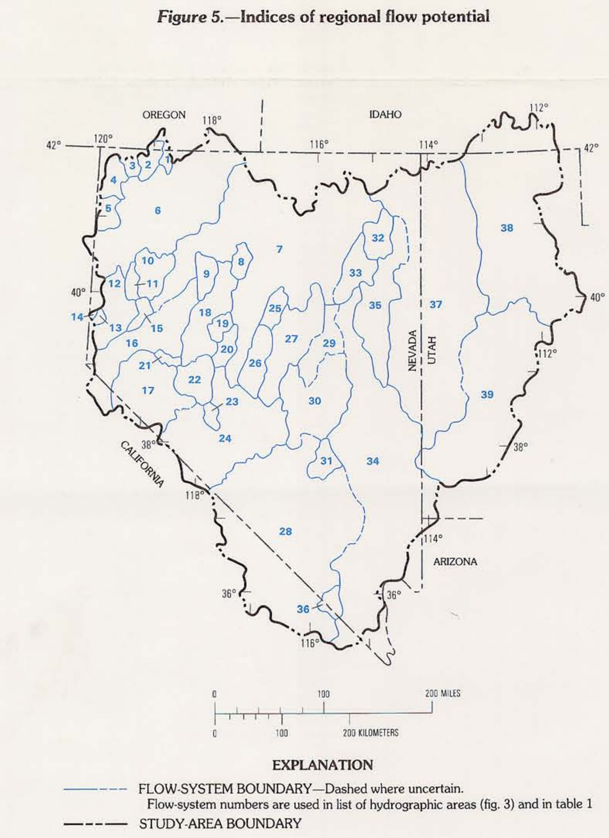

Figure 6.—Major flow systems

BASIS FOR DEFINING FLOW SYSTEMS

Theoretical aspects of ground-water flow systems were examined in the 1960's by Toth (1962, 1963) and Freeze and Witherspoon (1966, 1967), who modeled hypothetical systems along vertical sections. Toth (1963, p. 4807) used a system of uniform permeability to demonstrate that, if the potential on the surface of the system differed from a linear gradient, circulation cells would form in response to local areas of recharge and discharge that correspond with areas of localized high and low potential, respectively. Toth was able to identify three types of flow systems—local, intermediate, and regional—on the basis of the length of flow lines and whether flow passed beneath local areas of high or low potential. These types of systems are illustrated in figure 4. His findings that are most applicable to the Great Basin are (1) the concept that deep regional flow can pass beneath shallow local areas of high potential (ground-water divides) and (2) the example that variations in permeability within the system can cause appreciable discharge upgradient from the hydraulic terminus of the system.

Freeze and Witherspoon (1967, p. 626–632) evaluated the theoretical effects of subsurface permeability variations on regional ground-water flow. They developed a number of two-dimensional vertical sections that illustrate the diversity of possible regional-flow patterns. A general conclusion from their work is that when permeability in the deeper part of the system is increased, deep circulation of flow increases, discharge becomes concentrated near the terminus of the system, the vertical component of flow in the shallower parts of the system is increased, and circulation cells representing local or intermediate systems are less likely.

POTENTIAL FOR REGIONAL GROUND-WATER FLOW

Large ground-water flow systems are driven by hydraulic gradients that are continuous over long distances. These large systems generally are either the regional or intermediate types described in the preceding section. Bredehoeft and others (1982) reviewed the development of concepts relating to regional ground-water flow. One of the principles they listed as governing regional ground-water flow was that "differences in hydraulic head produced by topographic relief on the boundaries of the system are, in most instances, the driving force for the flow." This principle was used to evaluate the potential for regional flow in the Great Basin. The approach taken was to determine the lowest water-level altitude in the basin-fill deposits of each valley (which generally is only slightly below the topographically lowest point in the basin), and then to draw smooth contours through the point altitudes for each valley. Figure 5 shows indices of the regional flow potential obtained using this method. If deposits and rocks are sufficiently permeable, regional flow would be toward the Colorado River or major sinks. More detailed information on regional hydraulic gradients is presented by Thomas and Mason (1986). Bedinger, Reed, and Langer (1984) developed a rationale for mapping hydraulic head for regional flow and applied it to the Bonneville region of the Basin and Range Province. The resulting contours (Bedinger, Reed, and Langer, 1984, pl. 2) are quite similar to the indices of regional flow potential shown in figure 5.

MAJOR FLOW SYSTEMS IN THE GREAT BASIN

The general concepts outlined above were helpful in delineating the major flow systems in the study area. The "major flow system" is herein considered to be the local, intermediate, or regional system that is dominant—usually the one conveying the largest percentage of ground water in the area. Where consolidated rocks are permeable enough to afford significant identifiable hydraulic continuity on a regional scale, the local and intermediate types of systems were considered to be subsystems within major regional-flow systems. Where consolidated rocks have only low permeability and where water-budget studies do not indicate interbasin flow, regional flow was considered insignificant and the local and intermediate types of systems were considered to be the major flow systems. Where several basins are traversed by a major stream, and continuity between the basins is provided primarily by the stream, these interconnected basins are considered to consitute a complex regional-scale major flow system involving substantial interaction between ground water and surface water. The Humboldt, Truckee, Carson, and Walker River basins of Nevada are examples of this situation. A basic premise is that each flow system terminates in a discharge area. Consequently, if all of the terminal discharge areas are identified, the task of delineating a flow system is reduced to identifying areas that contribute flow toward the specified discharge area. For local systems consisting of only one basin or of a discharge area and one or more tributary basins, the task is simple, providing adequate hydrologic data are available; however, some of the larger regional systems extend for more than 100 miles and have flow paths that traverse as many as seven basins. In most instances, some water discharges at intermediate points along this path from local or intermediate flow systems; consequently, only some of the water flows all the way to the regional discharge area. Boundaries between systems are only generally defined; some may represent physical barriers to flow such as masses of intrusive rocks and others represent ground-water divides or divisions where an area of parallel flow ultimately diverges downgradient. Again, adequate hydrologic data are needed to precisely define flow-system boundaries. For much of the Great Basin, these data are not yet available.

A delineation of the major flow systems was made using the general procedures outlined in the preceding paragraphs and information published through 1984 on hydraulic heads, water budgets, and interbasin flows. This information was developed from data biased toward the shallower parts of the systems. Consequently, the boundaries of deeper major flow systems are delineated primarily on the basis of inference from information regarding the shallower part of the systems. The 39 major flow systems delineated are shown in figure 6 and, in detail, on sheet 2; some of their general characteristics are summarized in table 1.

The 39 flow systems identified in table 1 range in area from 30 to 18,000 mi^2. Sixteen are single-basin systems, the remainder are multibasin systems which may include as many as 34 hydrographic areas or subareas. Large multibasin flow systems outside of the carbonate-rock province are generally coincident with major river systems. Large multibasin systems within the carbonate-rock province typically have little surface flow; instead, they may contain ground-water flow paths more than 100 miles long that traverse several basins. Discharge from these systems is typically from large springs. This discharge generally is consumed by evapotranspiration in the vicinity of the spring. Altitudes of terminal discharge areas range from about 5,800 feet in high parts of central Nevada to a low of about 200 feet below sea level in Death Valley.

An alternate interpretation of the data for Utah is possible. The Sevier Lake, Great Salt Lake Desert, and Great Salt Lake systems could have been grouped into a large system with its terminus at the Great Salt Lake. There is some geologic and hydrologic evidence for regional continuity between these areas, but significant hydraulic gradients between the areas are virtually nonexistent; consequently, the volume of subsurface flow is relatively small. Moreover, each of the three areas has a distinctive hydrologic character. Consequently, this part of the region is described as three major flow systems with three terminal discharge areas.

In southern Nevada, the hydrologic character of parts of the western boundary of the Colorado system is not well understood and its location is uncertain. Additional information probably will allow significant refinement of this boundary.

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CONVERSION FACTORS AND ABBREVIATIONS

"Inch-pound" units of measure used in this report may be converted to International System (metric) units by using the following factors:

Multiply	By	To obtain
Feet (ft)	0.3048	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Square miles (mi^2)	2.590	Square kilometers (km^2)

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

TABLE 1.—CHARACTERISTICS OF MAJOR FLOW SYSTEMS

REFERENCES CITED IN TABLE 1

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SELECTED HYDROLOGIC CHARACTERISTICS OF THE MAJOR FLOW SYSTEMS

EXPLANATION

- AREA WHERE SHALLOW GROUND WATER IS CONSUMED BY EVAPOTRANSPIRATION
- LAKES AND RESERVOIRS
- MAJOR FLOW-SYSTEM BOUNDARY—Dotted where uncertain. Coincides with hydrographic-area or subarea boundary
- HYDROGRAPHIC-AREA BOUNDARY WITHIN MAJOR FLOW SYSTEM
- GENERAL DIRECTION OF GROUND-WATER FLOW IN BASIN-FILL DEPOSITS
- LARGE PERENNIAL STREAM OR RIVER IN HYDRAULIC CONTINUITY WITH ADJACENT AQUIFERS
- <M> <14> FLOW ACROSS HYDROGRAPHIC-AREA BOUNDARY—Number is rate of flow, in thousands of acre-feet per year; M indicates that flow is minor. Solid arrow indicates that flow is primarily through basin fill or alluvium; dashed arrow indicates that flow is primarily through permeable consolidated rock
- Bear River — LOCATION WHERE FLOW FROM HEADWATER AREA OR MAJOR RIVER ENTERS THE STUDY AREA
- (11) NATURAL GROUND-WATER RECHARGE TO A HYDROGRAPHIC AREA—Estimated rate, in thousands of acre-feet per year
- 5 LARGE SPRING—Discharge is generally greater than 1,000 gallons per minute in Utah and most of Nevada; in more arid parts of Nevada and in California, springs with discharges greater than 200 gallons per minute are shown where they are considered to have regional significance. Number indicates number of springs where more than one is indicated by a single symbol
- STUDY-AREA BOUNDARY

Base from U.S. Geological Survey State base maps:
Arizona, 1981; California, 1981; Idaho, 1976;
Nevada, 1965; Oregon, 1982; Utah, 1976.

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United States Department of the Interior

GEOLOGICAL SURVEY

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ERRATA for U.S. Geologic Survey Hydrologic Investigations Atlas 694-C ("Major Ground-Water Flow Systems in the Great Basin Region of Nevada, Utah, and Adjacent States," by James R. Harrill, Joseph S. Gates, and James M. Thomas; 1988)

Sheet 1:

In table 1, the value shown for recharge to the Death Valley flow system (Map No. 28) should be **94,000** acre-feet per year instead of 98,000 acre-feet per year.

Sheet 2:

The value shown for natural ground-water recharge to the Amargosa Desert hydrographic area (No. 230), Nev.-Calif., should be **"(0.5)"** instead of "(5)."

The value shown for subsurface flow across the hydrographic boundary between the Amargosa Desert and Death Valley hydrographic areas (Nos. 230 and 243) in California should be **"<3 to 19?>"** instead of "<3>." This indicates a possible range from about 3,000 acre-feet per year, based on spring-discharge measurements (Miller, 1977, table 4), to perhaps as much as 19,000 acre-feet per year, as discussed by Rush (1970, p. 18-19).

The boundary between the Shadow Valley and Valjean Valley hydrographic areas (Nos. 245 and 244, in California west of Mountain Pass) should contain a **dashed blue arrow** and the label **"<1.2>"** to indicate subsurface flow from Shadow Valley to Valjean Valley.

The boundary between the Valjean Valley and Death Valley hydrographic areas (Nos. 244 and 243) should contain a **dashed blue arrow** and the label **"<1.6>"** to indicate subsurface flow from Valjean Valley to Death Valley.

The boundary between the southern and northern parts of Railroad Valley (Nos. 173A and 173B), Nev., should contain a **dashed blue arrow** and the label **"<4>"** to indicate subsurface flow from southern Railroad Valley to northern Railroad Valley.

The three spring symbols shown in T. 14 S., R. 66 E., at the southern end of the Lower Meadow Valley Wash hydrographic area (No. 205), Nev., should instead be shown in T. 14 S., **R. 65 E., in the Muddy River Springs hydrographic area** (No. 219). The relative position within the township is correct.

The boundary between the Lower Meadow Valley Wash and California Wash hydrographic areas (Nos. 205 and 218) is along the channel of the Muddy River and should be shown as a **solid black line.**

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