Recharge and Discharge Areas for the Principal Basin-Fill Aquifer, Beryl-Enterprise Area, Iron, Washington, and Beaver Counties, Utah

by Kevin Thomas and Mike Lowe

Map 225
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
2007

UTAH DNR GEOLOGICAL SURVEY

Recharge and Discharge Areas for the Principal Basin-Fill Aquifer, Beryl-Enterprise Area, Iron, Washington, and Beaver Counties, Utah

by Kevin Thomas and Mike Lowe

ISBN 1-55791-770-1

Map 225
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
2007

STATE OF UTAH
Jon Huntsman, Jr., Governor

DEPARTMENT OF NATURAL RESOURCES
Michael Styler, Executive Director

UTAH GEOLOGICAL SURVEY
Richard G. Allis, Director

PUBLICATIONS
contact
Natural Resources Map & Bookstore
1594 W. North Temple
Salt Lake City, UT 84116
telephone: 801-537-3320
toll-free: 1-888-UTAH MAP
Web site: http://mapstore.utah.gov
email: geostore@utah.gov

THE UTAH GEOLOGICAL SURVEY
contact
1594 W. North Temple, Suite 3110
Salt Lake City, UT 84116
telephone: 801-537-3300
fax: 801-537-3400
Web site: http://geology.utah.gov

CONTENTS

FIGURES

PLATE

Recharge and Discharge Areas for the Principal Basin-Fill Aquifer, Beryl-Enterprise Area, Iron, Washington, and Beaver Counties, Utah

by Kevin Thomas and Mike Lowe

ABSTRACT

The primary source of drinking and irrigation water in the Beryl-Enterprise area is ground water from the principal basin-fill aquifer. We mapped recharge and discharge areas for the principal aquifer to provide a tool for management of potential contaminant sources to help protect ground-water quality. Areas are delineated based primarily on the presence or absence of thick (> 20 feet) clay or silt confining layers and net ground-water gradient as determined from drillers' logs of water wells. Primary discharge areas lack thick confining layers, secondary recharge areas have thick confining layers and a downward vertical gradient, and discharge areas have thick confining layers and an upward vertical gradient.

The Beryl-Enterprise area includes Escalante Valley and part of the Escalante Desert in southwestern Utah. The principal basin-fill aquifer of the Beryl-Enterprise area consists of interbedded alluvial-fan and lacustrine deposits. Water quality is generally moderately good with total-dissolved-solids values at or below 1000 mg/L recorded across much of the Beryl-Enterprise area, but most ground water is hard to very hard. Table Butte, the mountains surrounding the Beryl-Enterprise area basin floor, and the upper parts of alluvial fans along the margins of these uplands make up the primary recharge areas. The principal discharge area occupies the central and northeastern parts of the basin floor, based on water levels at the time the wells were drilled. Discharge exceeds recharge in the basin-fill aquifer, resulting in a declining water table throughout much of the Beryl-Enterprise area. Consequently, the discharge area is shrinking and should be treated as a secondary recharge area for land-use planning.

INTRODUCTION

Background

The principal basin-fill aquifer is the most important source of both drinking and irrigation water in the Beryl-Enterprise area. Recharge to this unconsolidated aquifer is mainly from precipitation in mountainous areas, with the recharge primarily occurring as infiltration from stream channels or subsurface inflow from bedrock along the valley margins (Mower and Sandberg, 1982). Recharge areas are typically underlain by fractured rock and/or coarse-grained sediment with relatively little ability to inhibit infiltration of contaminated water. Ground-water flow in recharge areas has a significant downward component and relatively fast rate of movement. Because contaminants can readily enter an aquifer system in recharge areas, management of potential contaminant sources in these areas deserves special attention to protect ground-water quality. Ground-water recharge-area mapping delineates these vulnerable areas.

Ground-water recharge-area maps typically show: (1) primary recharge areas, (2) secondary recharge areas, and (3) discharge areas (Anderson and others, 1994; Lowe and Snyder, 1996). Primary recharge areas, commonly bedrock uplands and coarse-grained unconsolidated deposits along the basin margins, do not contain thick, continuous, fine-grained layers, and have a downward ground-water gradient. Secondary recharge areas, commonly basin-margin benches, have fine-grained layers thicker than 20 feet (6 m) and downward ground-water gradients. Ground-water discharge areas are generally in basin lowlands. Discharge areas for unconfined aquifers are where the water table intersects the ground surface, causing springs or seeps. Discharge areas for confined aquifers are where the ground-water gradient is upward and water is discharging to a shallow unconfined aquifer above the upper confining bed, or to a spring or flowing well. The extent of recharge and discharge areas for an aquifer may vary both seasonally and annually due to changes in the amount of recharge.

Purpose and Scope

The purpose of this study is to help state and local government officials and local residents protect the quality of ground water in the Beryl-Enterprise area by delineating areas where ground-water aquifers are vulnerable to contamination from land-surface sources of pollution. The scope of work included a literature review and analyses of drillers' logs of water wells to define hydrogeologic conditions in the Beryl-Enterprise area. Relevant information, such as well depth, lithology, and water level, was recorded from each water-well log (appendix) and well locations were plotted on 1:24,000-scale base maps. Generalized recharge- and discharge-area boundaries were then delineated and entered, along with well locations, into a geographic information system database.

Setting

The Beryl-Enterprise area (figure 1) includes Escalante Valley and part of the Escalante Desert in southwest Utah. The larger community centers include Newcastle, Beryl Junction, Enterprise, Modena, Beryl, and Lund. The basin floor covers an area of about 890 square miles (2300 km^2).

Physiography and Drainage

The Beryl-Enterprise area is in the Tonoquints Volcanic section of the Basin and Range physiographic province (Stokes, 1977). The basin is bounded on the west by the Cedar Range, on the south by the Bull Valley Mountains; on the southeast by the Harmony Mountains and Antelope Range; on the east by a series of low hills; on the northeast by the Black Mountains; on the north by the Wah Wah Mountains, Indian Peak Range, and Needle Range; and on the northwest by the Paradise Mountains. This report covers only the part of the basin west of the Utah-Nevada state line, however the portion of the basin in Nevada appears to be underlain entirely by bedrock and not basin fill. Peaks in the drainage basin reach elevations of up to 8200 feet (2500 m) above sea level. The valley floor ranges in elevation from 5400 feet (1650 m) along the basin margin in Washington County to 5080 feet (1550 m) northwest of Lund. The generally uniform southwest to northeast slope of the basin floor is interrupted south of Lund by Table Butte (figure 1).

Little Pine, Spring, and Pinto Creeks are perennial streams draining the mountains in the southern part of the drainage basin (figure 1) (Mower and Sandberg, 1982). All other drainages are intermittent or ephemeral (Mower and Sandberg, 1982). In the southern part of the drainage basin, some of these ephemeral drainages can produce large floods, sometimes carrying debris several miles out onto the basin floor (Mower and Sandberg, 1982; Lund and others, 2005). Mud Spring Wash and Iron Springs Canyon are two gaps in the mountains on the east side of the drainage basin where surface flow into the Beryl-Enterprise area occurs during floods resulting from intense local rainstorms or from local snowmelt (Mower and Sandberg, 1982). The Beryl-Enterprise area is part of the Beaver River drainage basin, but there is no evidence that surface flow out of the Beryl-Enterprise basin through its lowest point northeast of Lund has occurred during the past several hundred years (Mower and Sandberg, 1982).

Climate

Four weather stations in the study area provide climatic data for different periods (Enterprise, 1954–92 period; Enterprise Beryl Junction, 1948–92 period; Lund, 1950–1967 period; and Modena, 1948–92 period), but only Enterprise Beryl Junction and Modena provide normal climatic data for the 1961–90 period. Because the normal climatic information represents a more complete data set, those values (taken from Ashcroft and others, 1992) are discussed herein. Temperatures reach a normal minimum of 11.4˚F (-11.4˚C) in January at Enterprise Beryl Junction and a normal maximum of 91.4˚F (33.0˚C) in July at Modena. The normal mean annual temperature ranges from 47.6˚F (8.7˚C) at Enterprise Beryl Junction to 49.1˚F (9.5˚C) at Modena. Normal annual precipitation ranges from 10.21 inches (25.93 cm) at Enterprise Beryl Junction to 10.32 inches (26.21 cm) at Modena. Normal annual evapotranspiration (using the Hargreaves equation [based on perennial rye grass or Alt fescue as reference crop]) ranges from 51.56 inches (130.96 cm) at Enterprise Beryl Junction to 52.06 (132.23 cm) at Modena. The average number of frost-free days ranges from 98 at Enterprise Beryl Junction to 113 at Modena.

Population and Land Use

The Beryl-Enterprise area is sparsely populated, but, like most areas in Utah, is experiencing an increase in population. The population of rural Iron County (i.e., excluding Brian Head, Cedar City, Enoch, Kanarraville, Paragonah, and Parowan), within which most of the study area lies, increased from 2882 in 1990 to 6321 in 2000 (Demographic and Economic Analysis Section, 2001), and by 2030 the population is expected to be 10,671 (Demographic and Economic Analysis Section, 2005). However, much of this population growth is likely to take place in eastern Iron County, outside of the study area.

The economy is dominated by agriculture, mainly cultivation of irrigated crops, but mining and rock collecting are also important sources of income (Travel Guides, 2006). Alfalfa has replaced potatoes as the most important crop, and dairies and feedlots have become an increasingly important source of income (Lund and others, 2005). Cultivated land is irrigated mostly by water wells (Mower and Sandberg, 1982).

Previous Studies

White (1932) reported on evapotranspiration by plants, estimates of water usage, and water levels in some wells for parts of southwestern Utah, including the Beryl-Enterprise area. Clyde (1941) estimated the extent and success of ground-water dependent agriculture for the Beryl area, and evaluated costs of ground water to farmers. Three progress reports to the Utah State Engineer provide descriptions of ground-water conditions in the Beryl-Enterprise area (Fix and others, 1950; Thomas and others, 1952; Waite and others, 1954). Conner and others (1958) compiled the quality of ground and surface water in Utah, including the Beryl-Enterprise area. Sandberg (1963) compiled ground-water data for several ground-water basins in southwestern Utah, including the Beryl-Enterprise area. Sandberg (1966) correlated the results of previous ground-water studies for several ground-water basins in southwestern Utah, including the Beryl-Enterprise area, to give a

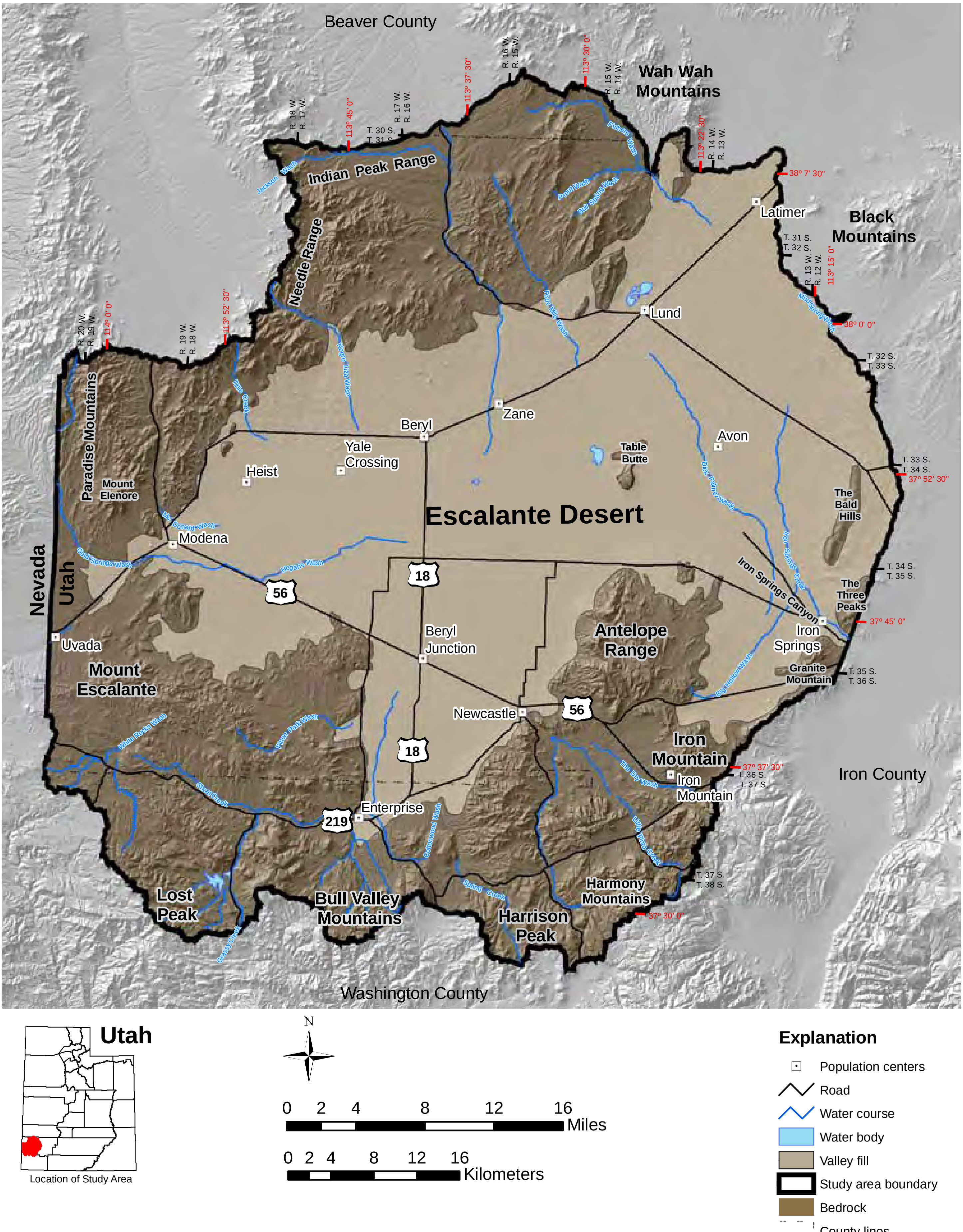


Figure 1. *Geographic features of the Beryl-Enterprise area, southwestern Utah.*

unified concept of ground-water conditions in those basins. Mower (1981) compiled ground-water data for the Beryl-Enterprise area. These data were used to produce the most recent comprehensive evaluation of ground-water conditions for the area (Mower and Sandberg, 1982). Burden and others (2005) evaluated water-level changes in wells in Utah from March 1970 to March 2005, including the Beryl-Enterprise area. Lund and others (2005) evaluated the origin and extent of earth fissures in Escalante Valley and the southern Escalante Desert.

METHODS

In this study, we used the methods of Anderson and others (1994) as modified by Snyder and Lowe (1998) for identifying confining layers, and delineating recharge and discharge areas for basin-fill aquifers; much of the text in this section is from Snyder and Lowe (1998). To delineate recharge and discharge areas, we evaluated both the principal aquifer and local overlying shallow unconfined aquifers (figure 2). The principal aquifer is the most important source of ground water, and may be confined or unconfined. The principal aquifer begins at the mountain front along the valley margins where coarse-grained alluvial-fan sediments predominate and ground water is generally unconfined. Away from bedrock exposures, fine-grained silt and clay may form confining layers above and within the principal aquifer. Water in sediments above the upper confining layer is in a shallow unconfined aquifer. Shallow unconfined aquifers are generally not an important source of drinking water.

We used drillers' logs of water wells to delineate primary and secondary recharge areas and discharge areas, based on the presence or absence of confining layers and relative water levels in the principal and shallow unconfined aquifers. Well-log information is summarized in the appendix. The use of drillers' logs requires careful interpretation because of the variable quality of the logs. Correlation of geology from water-well logs is difficult because lithologic descriptions are generalized and commonly inconsistent among various drillers. The use of water-level data from water-well logs is also problematic because levels in the shallow unconfined aquifer are commonly not recorded, and because water levels were measured during different seasons and years.

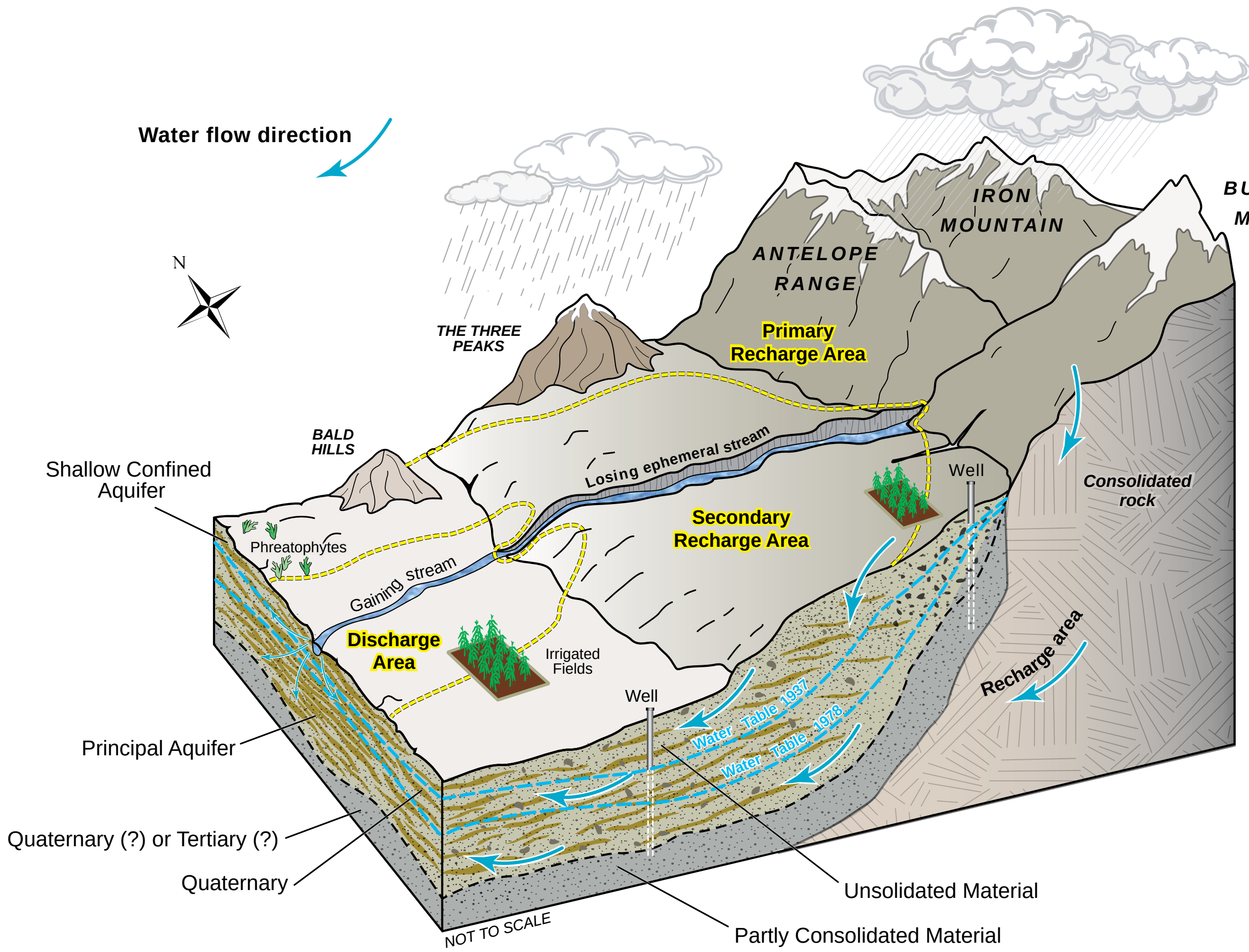


Figure 2. Schematic block diagram showing recharge areas, location of the water table during 1937 and 1978, direction of ground-water movement, and discharge areas in the Beryl-Enterprise area (modified from Mower and Sandberg, 1982).

Confining layers are defined as any fine-grained (clay and/or silt) layer thicker than 20 feet (6 m) (Anderson and others, 1994). Some logs note both clay and sand in the same depth interval, without giving relative percentages; these are not classified as confining layers (Anderson and others, 1994). If both clay and sand are checked and the word "sandy" is written in the remarks column, then the layer is assumed to be a primarily clay confining layer (Anderson and others, 1994). Sometimes a driller will mark clay and gravel, cobbles, or boulders; these units also are not classified as confining layers, although in parts of the Beryl-Enterprise area, they may behave as confining layers.

The primary recharge areas for the principal aquifer are the bedrock uplands surrounding and within the valley, and basin fill lacking thick clay layers, generally along valley margins (figure 3). Ground-water flow in primary recharge areas has a significant downward component. If present, secondary recharge areas begin where clay layers are thicker than 20 feet (6 m) and the hydraulic gradient is downward. Areas of secondary recharge extend toward the valley center until the hydraulic gradient is upward (figure 3). The hydraulic gradient is upward when the potentiometric surface of the principal aquifer is higher than the water table in the shallow unconfined aquifer (Anderson and others, 1994). Water-level data for the shallow unconfined aquifer are not common, but are recorded on some water-well logs. Where confining layers extend to the ground surface, secondary recharge is mapped when the potentiometric surface in the principal aquifer is below the ground surface.

Ground-water discharge areas are at lower elevations than recharge areas. In discharge areas, the water in confined aquifers discharges to the land surface or to a shallow unconfined aquifer (figure 3). For this to happen, the hydraulic head in the principal aquifer must be higher than the water table in the shallow unconfined aquifer. Otherwise, downward pressure from the shallow aquifer will exceed the upward pressure from the confined aquifer, creating a net downward hydraulic gradient indicative of secondary recharge areas. Flowing (artesian) wells are marked on drillers' logs and some flowing wells are shown on U.S.

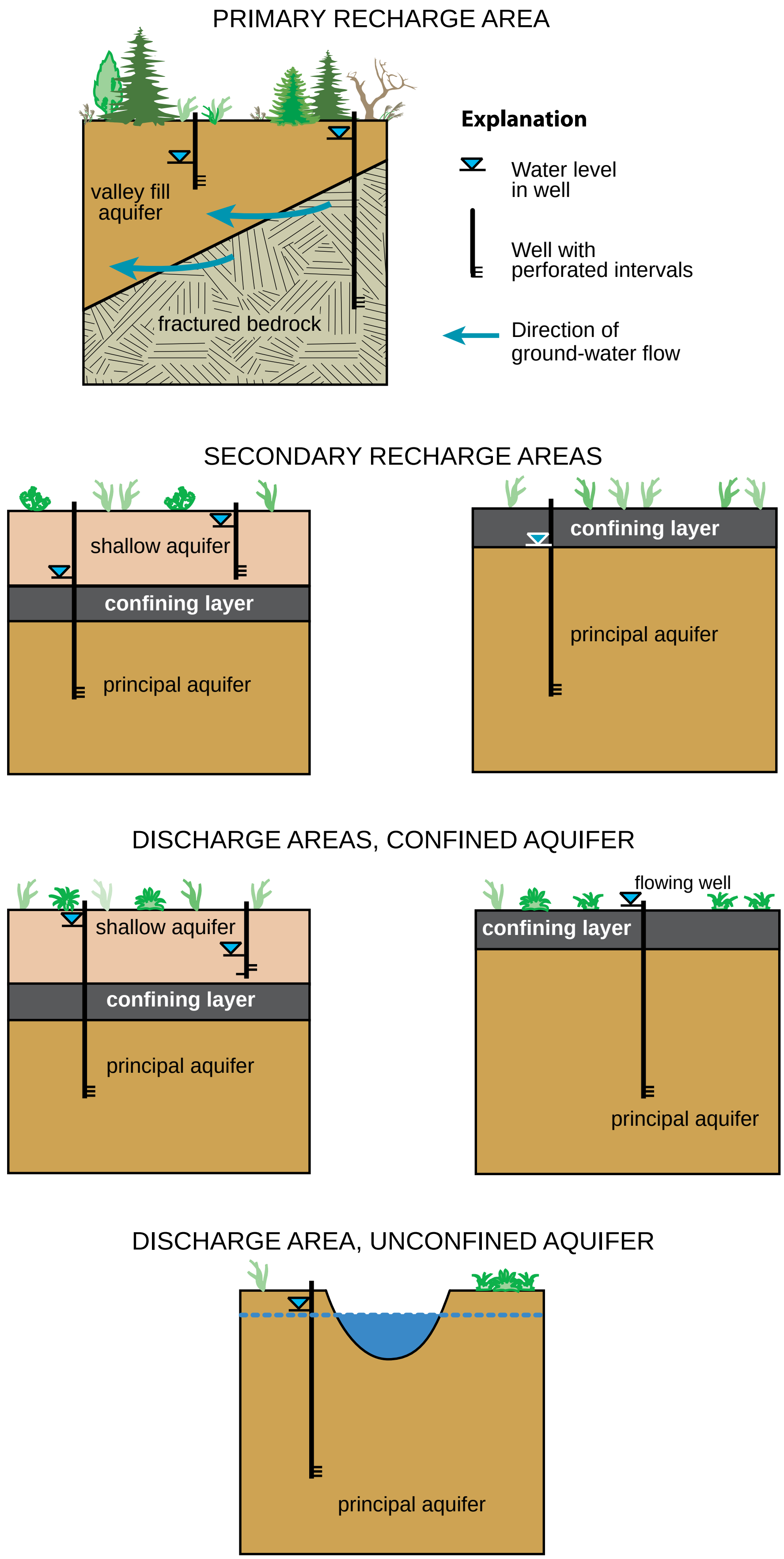


Figure 3. *Relative water levels in wells in recharge and discharge areas (modified from Snyder and Lowe, 1998).*

Geological Survey 7.5′ quadrangle maps. Wells having potentiometric surfaces above the top of the confining layer can be identified from water-well logs. Wetlands, shown by surface water, springs, or phreatophytes, can also indicate ground-water discharge. In some instances, however, this discharge may be from a shallow unconfined aquifer. The topography, surficial geology, and ground-water hydrology must be understood before using wetlands to map discharge from the principal aquifer.

We generally did not map small discharge areas defined by single well logs where surrounded completely by secondary recharge. Contaminants entering the aquifer system above these wells may be less likely to affect the principal aquifer than in the surrounding areas of secondary recharge.

The numbering system for wells in this study is based on the U.S. government cadastral land-survey system that divides Utah into four quadrants (A-D) separated by the Salt Lake Base Line and Meridian (figure 4). The study area is entirely within the southwest quadrant (C). The wells are numbered with this quadrant letter C, followed by township and range, enclosed in parentheses. The next set of characters indicates the section, quarter section, quarter-quarter section, and quarter-quarter-quarter section designated by letters a through d, indicating the northeastern, northwestern, southwestern, and southeastern quadrants, respectively. A number after the hyphen corresponds to an individual well within a quarter-quarter-quarter section. For example, (C-34-17) 33dcc-1 would be the first well in the southwestern quarter of the southwestern quarter of the southeastern quarter of section 33, Township 34 South, Range 17 West (SW1/4SW1/4SE1/4 section 33, T. 34 S., R. 17 W.), Salt Lake Base Line and Meridian.

GEOLOGY

Bedrock

Bedrock in the Beryl-Enterprise area ranges in age from Cambrian to Tertiary (figure 5). Cambrian, Ordovician, and Mississippian sedimentary rocks are exposed in the Indian Peak Range and Wah Wah Mountains in the northern part of the study area. Jurassic and Cretaceous sedimentary rocks are exposed in the Bull Valley and Harmony Mountains, Iron Mountain, and The Three Peaks in the southern and southeastern parts of the study area. Tertiary igneous rocks (predominantly extrusive) are exposed in upland areas throughout the study area (Fix and others, 1950). Tertiary sedimentary rocks cover much of the uplands in the southern and southeastern part of the study area. Quaternary basalt is found in the uplands in the southern part of the study area. Extension, primarily during the Tertiary, along low- and high-angle normal faults deformed existing bedrock, forming basins that filled with locally derived sediments. The absence of prominent fault scarps in basin-fill deposits indicates that significant displacement along these faults has not occurred during the Holocene (Fix and others, 1950).

Unconsolidated Sediments

Unconsolidated to semi-consolidated basin fill consists primarily of interbedded alluvial and lacustrine deposits of Quaternary age (Mower and Sandberg, 1982) with eolian deposits also found in some areas (figure 5). The uppermost basin-fill deposits comprise the principal basin-fill and shallow unconfined aquifers, and consist of predominantly sand and gravel with some fine-grained clay and silt layers at the basin margins (Fix and others, 1950). Fine-grained clay and silt deposits become predominant towards the basin center, and deposits become semi-consolidated at depth (Mower and Sandberg, 1982). The basin-fill material is highly variable within short distances, and does not form well-defined aquifers or confining beds over large areas (Lofgren, *in* Fix and others, 1950). Basin-fill thickness ranges from zero at the basin margins to likely more than 1,000 feet (300 m) in the basin center (Mower and Sandberg, 1982). Normal-faults in the unconsolidated basin fill may exert strong control on ground-water movement and availability (Fix and others, 1950), but the effect of these structures on ground-water movement has not been evaluated in the Beryl-Enterprise area.

GROUND WATER

Ground water resides in both fractured bedrock and unconsolidated deposits beneath and surrounding the Beryl-Enterprise area. The principal aquifer in the Beryl-Enterprise area includes confined and unconfined parts of the unconsolidated basin fill.

Fractured-Rock Aquifers

This recharge-discharge area map does not address potentially important bedrock ground-water resources. In the area between Modena and Enterprise, volcanic rocks of Tertiary age are saturated and hydraulically well connected to groundwater in basin-fill deposits; Mower and Sandberg (1982) considered these rocks to be part of the principal aquifer, but herein we treat them as separate bedrock units. Potential for contamination of bedrock aquifers is generally high (Anderson and others, 1994).

Unconsolidated Basin-Fill Aquifer

Occurrence

Ground water in most of the Beryl-Enterprise area is under unconfined conditions (Fix and others, 1950). Unconfined conditions are to be expected along the basin margins, where basin-fill deposits consist predominantly of

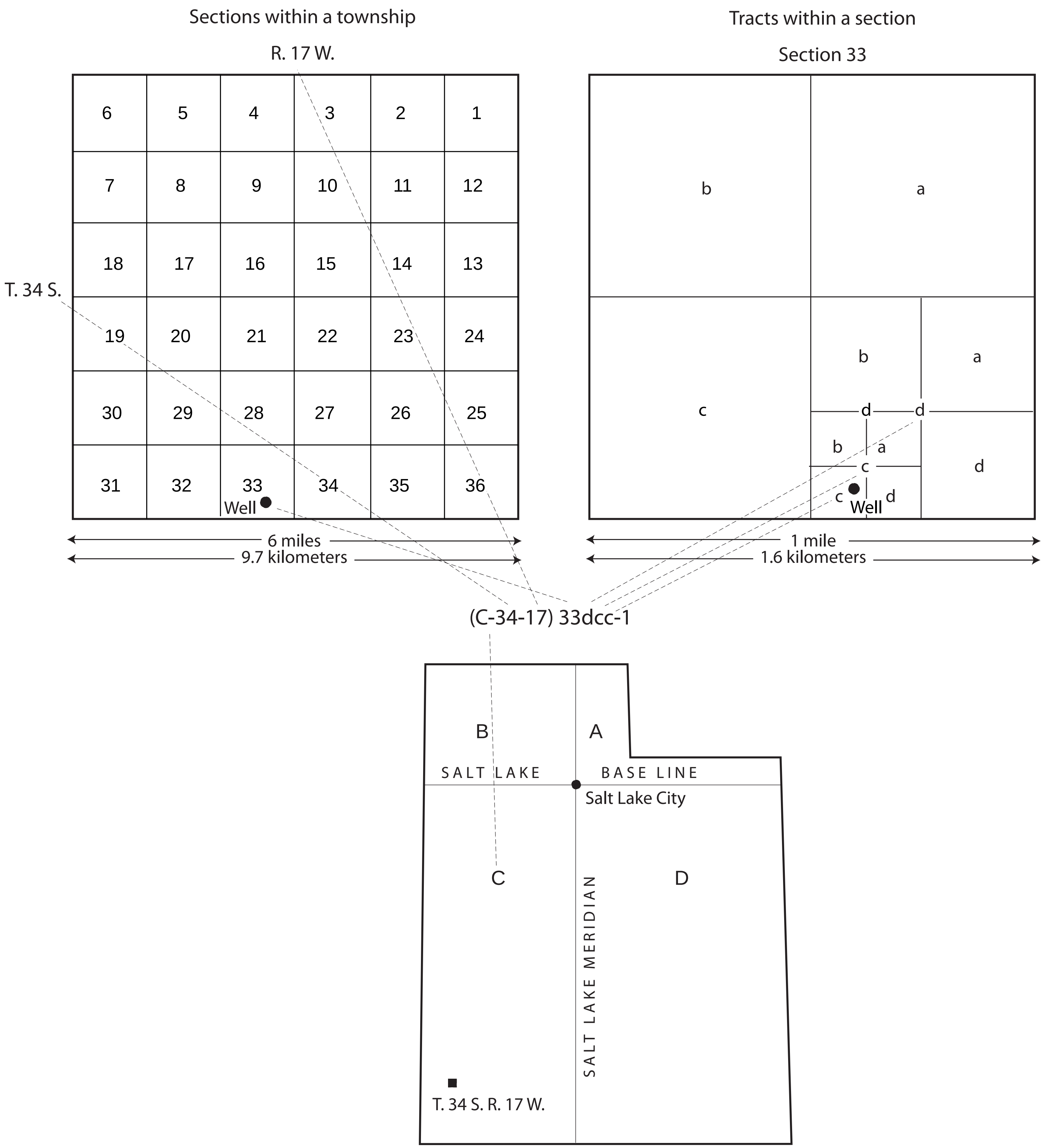


Figure 4. *Numbering system for wells in Utah (see text for additional explanation).*

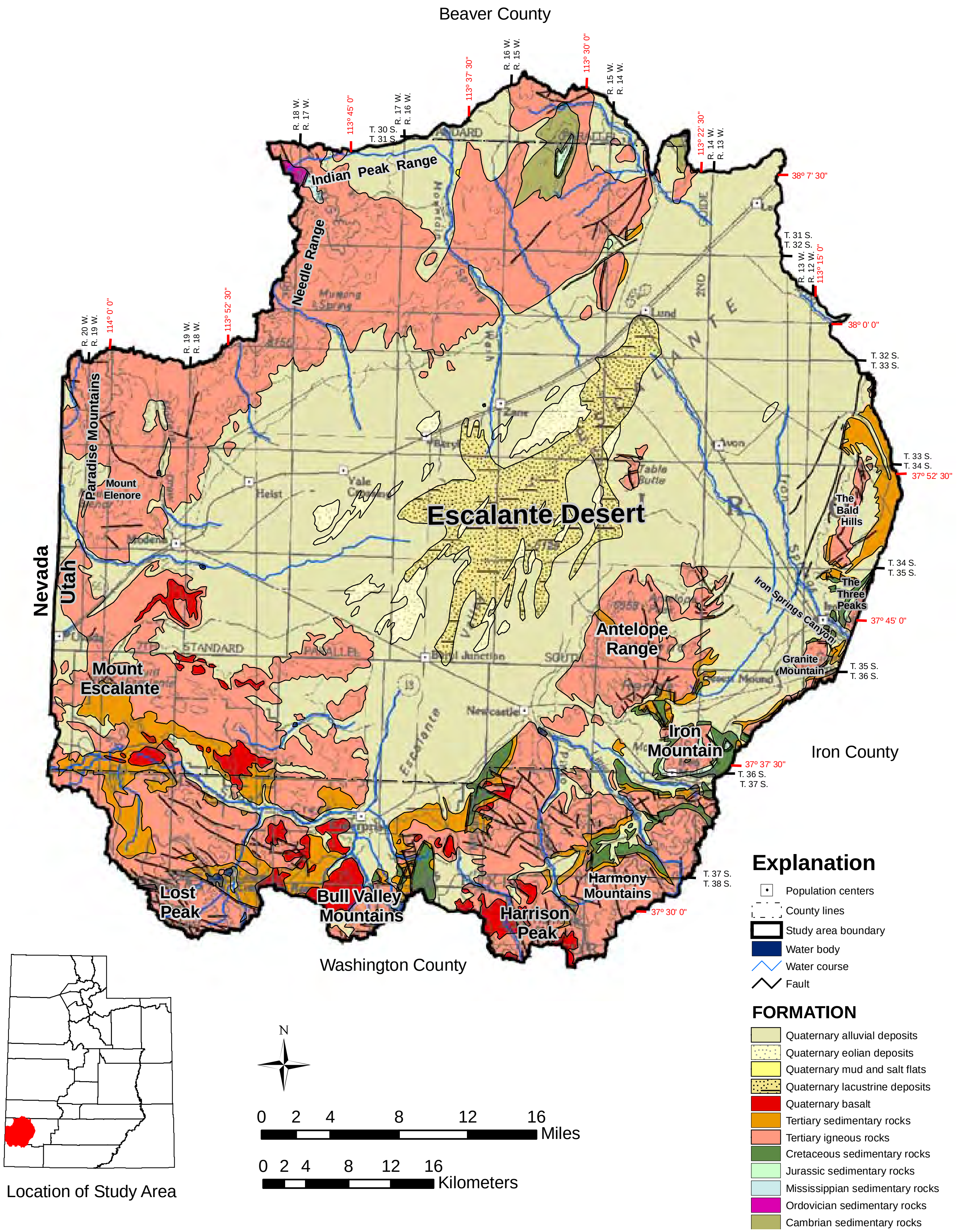


Figure 5. Simplified geologic map of the Beryl-Enterprise area, southwestern Utah (modified from Hintze and others, 2000).

coarse-grained alluvial deposits and readily yield water to wells (Mower and Sandberg, 1982). But the lack of confined conditions over much of the central part of the basin, in spite of the predominance of fine-grained sediments, is unusual based on studies of other Utah basins (Fix and others, 1950). Most of the principal aquifer contains less than 25% sand and gravel, based on an examination of drillers' logs of water wells (Mower and Sandberg, 1982). The fine-grained sediments throughout much of the study area may be sufficiently impermeable to prevent the downward movement of ground water and precipitation (Fix and others, 1950), and a shallow unconfined aquifer overlies the principal aquifer in many areas of the basin center (figure 2). Most water wells in the Beryl-Enterprise area are greater than 300 feet (90 m) deep, and some wells are over 1200 feet (370 m) deep.

Aquifer Characteristics

Transmissivity of the principal basin-fill aquifer varies. Based on aquifer tests, Mower and Sandberg (1982, table 5) reported a range of 200 to 120,000 square feet per day (19-11,000 m^2/d) for wells in unconsolidated deposits. The largest value was from a well about midway between Enterprise and Beryl Junction. Specific yields calculated from the aquifer tests in the unconfined parts of the principal aquifer range from 0.0014 to 0.037 (Mower and Sandberg, 1982, table 5). Mower and Sandberg (1982) estimated the amount of ground water in storage in the principal basin-fill aquifer in 1978 to be 72 million acre-feet (89,000 hm^3).

Recharge and Discharge to the Basin-Fill Aquifer

Recharge to the basin-fill aquifer system (principal and shallow unconfined aquifers) in the Beryl-Enterprise area is from (1) precipitation in uplands surrounding the drainage basin, (2) infiltration from irrigated land, (3) precipitation on the valley floor, and (4) subsurface flow from other basins (Mower and Sandberg, 1982). Recharge from precipitation in the uplands, which occurs as either subsurface inflow from bedrock or infiltration from stream channels at the basin margins, was estimated to be about 31,000 acre-feet per year (38 hm^3/yr) in 1977 (Mower and Sandberg, 1982). Recharge from infiltration from farms was estimated to be 20% of the 81,400 acre feet (100 hm^3) of the irrigation water pumped from wells or diverted from streams in 1977 (Mower and Sandberg, 1982); this amounts to 16,300 acre-feet per year (20.1 hm^3/yr). Recharge from precipitation falling on the valley floor is low, due to the low precipitation and high evapotranspiration rates noted in the Climate section above, and was estimated to be about 500 acre-feet per year (0.6 hm^3/yr) in 1977 (Mower and Sandberg, 1982). Subsurface inflow from Cedar Valley to the Beryl-Enterprise area through Mud Springs Wash and Iron Springs Canyon, based on estimates by Thomas and Taylor (1946), is about 320 acre-feet per year (0.39 hm^3/yr) (Mower and Sandberg, 1982). Mower and Sandberg (1982, table 6) estimated total recharge to the basin-fill aquifer system in 1977 at 48,000 acre-feet (59 hm^3).

Discharge from the basin-fill aquifer system in the Beryl-Enterprise area is by (1) ground-water withdrawal from wells, (2) evapotranspiration, and (3) subsurface outflow (Mower and Sandberg, 1982). Ground-water withdrawals from wells, mostly irrigation wells, was estimated to have increased from 3000 acre-feet per year (4 hm^3) in 1937 to 92,000 acre-feet per year (110 hm^3) in 1974, from the increasing importance of agriculture as a land use; well withdrawals decreased to 81,000 acre-feet per year (100 hm^3) in 1977 (Mower and Sandberg, 1982) following the change from flood irrigation to sprinkler irrigation on many farms. Mower and Sandberg (1982) noted that these estimates may be as much as 25% too low, based on data collected during 1961-77 by the Utah Division of Water Rights. Evapotranspiration in 1977 was estimated at 6000 acre-feet (7 hm^3) (Mower and Sandberg, 1982). This was a decrease from an average annual evapotranspiration of 26,000 acre-feet per year (32 hm^3/yr) estimated in 1927, caused by a decline in the potentiometric surface for the basin-fill aquifer system (Mower and Sandberg, 1982). Evapotranspiration may continue to decrease as average annual discharge continues to exceed average annual recharge. Mower and Cordova (1974) estimated subsurface flow of ground water out of the study area northeast of Lund to be about 1000 acre-feet per year (1 hm^3/yr). Mower and Sandberg (1982, table 8) estimated total discharge from the basin-fill aquifer in 1977 to be 88,000 acre-feet (110 hm^3).

Water Quality

Ground water in the Beryl-Enterprise area is generally suitable for domestic and stock use, except for hardness (Fix and others, 1950); hardness, which results mostly from calcium and magnesium concentrations in the water, is hard to very hard in most wells completed in the basin-fill aquifer. Based on data reported in Fix and others (1950), Sandberg (1966), and Mower (1981), total-dissolved-solids concentrations range from 232 to 5,650 mg/L. Total-dissolved-solids concentration in the principal aquifer varies from one part of the study area to another (figure 6). The best quality ground water in the principal aquifer, having total-dissolved-solids concentrations of less than 375 mg/L, is found in a narrow belt along Shoal Creek south and west of Beryl Junction, and in the area east of Modena. The highest total-dissolved-solids concentrations in the principal aquifer are found northeast of Beryl, where ground water may have total dissolved solids concentrations exceeding 2,000 mg/L. Total-dissolved-solids concentrations tend to increase along ground-water flow paths and with depth. This is likely related to increased ground-water residence time allowing more opportunity to dissolve minerals from the basin-fill sediments. Water in the shallow unconfined aquifer generally has higher total dissolved solids concentrations than the underlying principal aquifer (Fix and

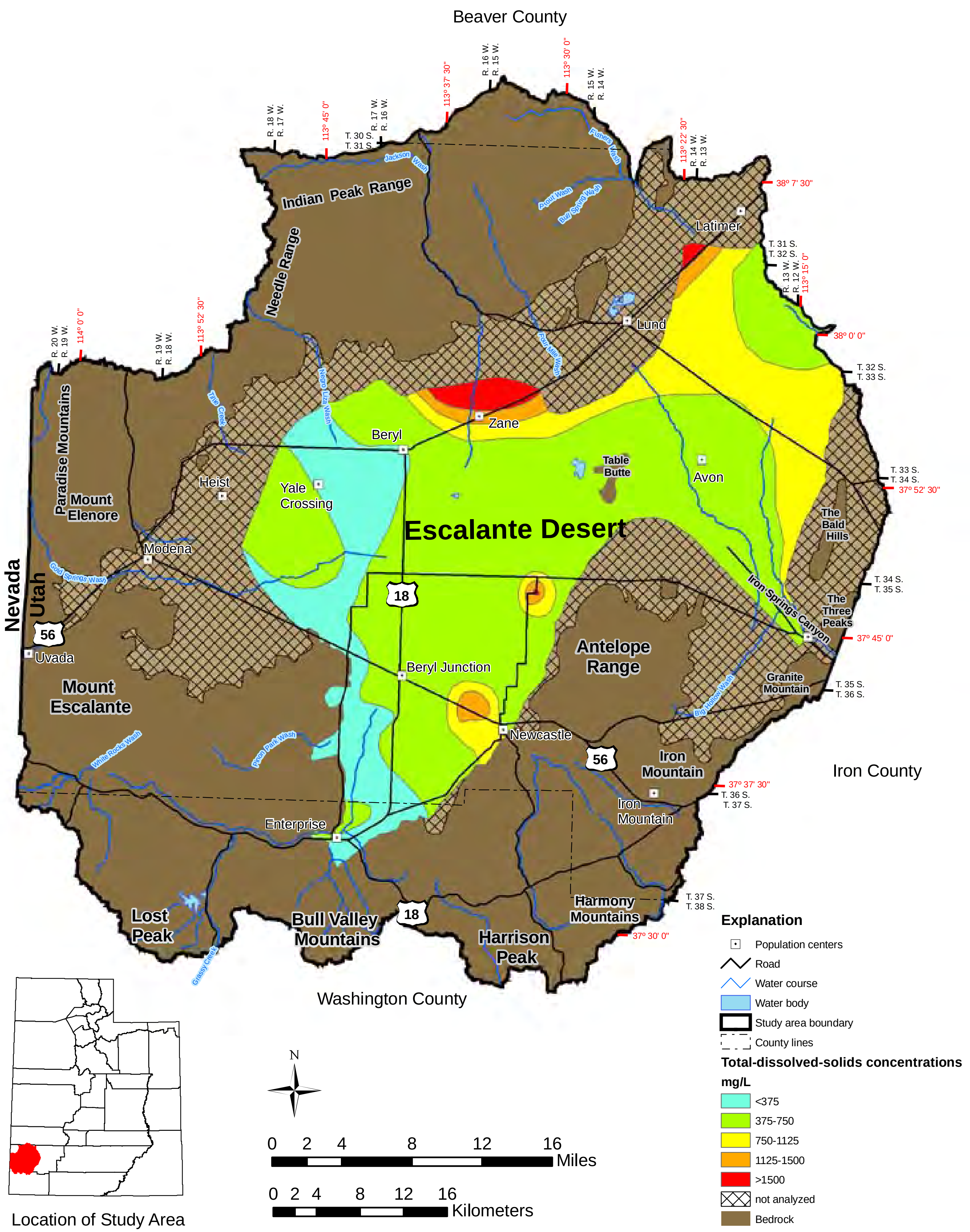


Figure 6. *Total-dissolved-solids concenration for ground water in the Beryl-Enterprise area, southwestern Utah (modified from Mower and Sandberg, 1982).*

others, 1950). Some wells in the study area have exceeded primary water-quality (health) standards for nitrate and fluoride, and some wells have exceeded secondary water-quality (taste, odor, etc.) for sulfate and chloride (Fix and others, 1950; Mower and Sandberg, 1982).

Ground-Water Flow Direction and Water Levels in Wells

Prior to large-scale water-well pumping in the Beryl-Enterprise area, ground-water flow in the principal aquifer was from the valley margins toward the valley center, and then to the northeast out of the study area (Fix and others, 1950). Large-scale water-well pumping, needed to support the predominantly agricultural land uses in this arid area, caused decline of the water table by more than 5 feet (1.5 m) over a 30 square-mile (80 km^2) area between 1945 and 1949 (Fix and others, 1950). By 1951, water-level declines of as much as 13 feet (4 m) were observed in some water wells in the southern end of the Beryl-Enterprise area (Thomas and others, 1952), and Fix and others (1950) attributed these declines to discharge from water wells exceeding natural replenishment to the principal aquifer. From 1951 to 1953, water levels in some wells in the central part of the basin declined an additional 5 feet (1.5 m) despite an above-average precipitation year in 1952 (Waite and others, 1954). Between 1952 and 1962, water-level declines of up to 32 feet (10 m) occurred in some wells in the southern part of the basin (Sandberg, 1966). For the period between 1937 to 1978, water levels in some wells in the southern part of the basin had declined as much as 70 feet (20 m) (Mower and Sandberg, 1982, figure 5), and had caused ground water in the southern part of the basin to flow towards the Beryl Junction area (Mower and Sandberg, 1982, plate 8) rather than northward. Figure 7 shows the change in water level between 1975 and 2005 (illustrating a consistent trend in water-level declines over time in the Beryl-Enterprise area). In addition to altering the configuration of the potentiometric surface, dewatering of the upper part of the principal aquifer and concomitant aquifer compaction may have caused ground-surface subsidence and resultant earth fissures, identified in the southern part of the basin following a flood in January 2005 (Lund and others, 2005).

RESULTS

Recharge and Discharge Areas

Primary recharge areas (plate 1) include the bedrock uplands (including Table Butte) and the upper parts of alluvial fans along the basin margins in the western, southern, and southeastern part of the study area; an area of basin fill north of Lund is also a primary recharge area. Basin fill in these areas consists mostly of sand and gravel lacking thick silt and clay layers (figure 2). Areas of secondary recharge (plate 1), having a thick confining layer and a downward vertical ground-water flow gradient (figure 2), cover much of the central and northwestern parts of the study area.

We mapped discharge areas (plate 1) in a zone extending from the central part of the basin north of Beryl Junction to the northeastern study area boundary. This mapping is based on the presence of thick clay layers and an upward ground-water gradient (figure 2) derived from information recorded on water-well drillers' logs at the time the wells were drilled. Because the potentiometric surface of the principal aquifer has been lowered, as discussed above, the discharge areas within the Beryl-Enterprise area have likely shrunk and became secondary recharge areas. Defining the current potentiometric surface by obtaining new-water level data for existing wells is beyond the scope of this study.

Potential for Water-Quality Degradation

Based solely on ground-water recharge- and discharge-area mapping, the potential for ground-water contamination in the Beryl-Enterprise area is moderate. Much of the water in the principal basin-fill aquifer comes from bedrock uplands where few pollutants exist that could enter the system, but many potential contamination sources exist on the basin-fill deposits.

Some of these potential contamination sources are in primary recharge areas where the principal aquifer has no significant hydrogeologic barriers to contamination by pesticides or other water-borne contaminants. Care must be taken in siting potential contaminant sources, such as feed lots and septic tanks, especially in primary recharge areas. The widespread clay layers in the center of the Beryl-Enterprise area may provide some protection to the principal aquifer, but their lateral continuity is not assured. Ground water in discharge areas in the central part of the basin is least susceptible to potential contaminants, but the areal extent of these discharge areas is likely decreasing as the potentiometric surface for the aquifer lowers because of ground-water pumping. Consequently, the discharge areas should be treated as secondary recharge areas for land-use planning purposes. Additionally, earth fissures associated with land-surface subsidence from aquifer compaction may provide preferential pathways for aquifer contamination. Further study is required to make specific evaluations of sources and fate of contaminants.

SUMMARY AND CONCLUSIONS

The principal basin-fill aquifer of the Beryl-Enterprise area consists of interbedded alluvial-fan and lacustrine deposits. Confined and unconfined parts of the principal aquifer provide both culinary and agricultural water. Most ground water resides in unconfined parts of the principal aquifer. The mountains that surround the basin-fill

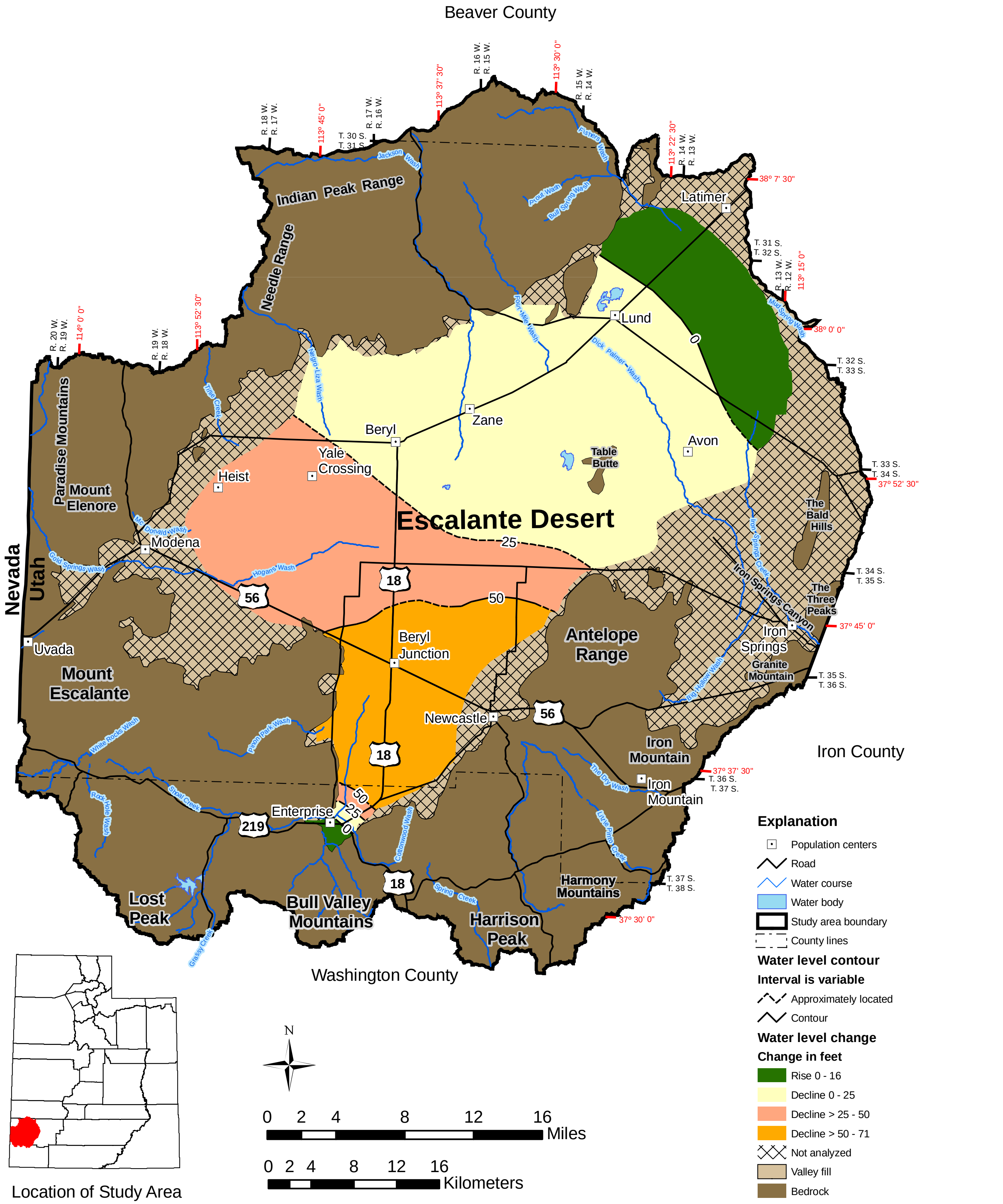


Figure 7. Water-level change from 1975 to 2005 in the Beryl-Enterprise area, southwestern Utah (modified from Burden and others, 2005).

deposits, Table Butte, and the uppermost parts of alluvial fans along the margins of the basin make up the primary recharge areas. Secondary recharge areas, which contain clay or silt confining layers greater than 20 feet (6 m) thick, cover much of the central part of the basin fill. Discharge areas for the principal aquifer occur in the central part of the basin in a zone extending from north of Beryl Junction to the northeastern study area boundary. Declining ground-water levels in the principal basin-fill aquifer are causing the discharge area to shrink, while the secondary recharge area is expanding. Accordingly, zones currently plotted as discharge areas should be treated as secondary recharge areas for land-use planning. Ground-water flow is generally from the mountains toward the center of the valley, and then northeastward toward the Milford area. Water quality is generally moderate, with total-dissolved-solids concentrations of less than 1000 mg/L across most of the Beryl-Enterprise area, but most ground water is hard to very hard. High nitrate concentrations in some wells completed in the basin-fill aquifer underscore the need to consider the potential for ground-water contamination in land-use decisions.

ACKNOWLEDGMENTS

We thank Lucy Jordan, Robert Ressetar, and Kimm Harty, Utah Geological Survey, for their comments and reviews. Scott Horn and Kim Nay assisted with preparing the map and figures used in this report.

REFERENCES

Anderson, P.B., Susong, D.D., Wold, S.R., Heilweil, V.M., and Baskin, R.L., 1994, Hydrogeology of recharge areas and water quality of the principal aquifers along the Wasatch Front and adjacent areas, Utah: U.S. Geological Survey Water-Resources Investigations Report 93-4221, 74 p., scale 1:100,000.

Ashcroft, G.L., Jensen, D.T., and Brown, J.L., 1992, Utah climate: Utah Climate Center, Utah State University, 127 p.

Burden, C.B., and others, 2005, Ground-water conditions in Utah, spring of 2005: Utah Division of Water Resources Cooperative Investigations Report No. 46, 138 p.

Clyde, G.D., 1941, Irrigation water pumping costs in Beryl area, investigated: Farm and Home Science, v. 2, no. 1, p. 7-8.

Connor, J.G., Mitchell, C.G., and others, 1958, A compilation of chemical quality data for ground and surface waters in Utah: Utah State Engineer Technical Publication 10, 276 p.

Demographic and Economic Analysis Section, 2001, Utah data guide, spring 2001: Salt Lake City, Utah Governor's Office of Budget and Planning, 16 p.

—2005, Utah data guide, summer/fall 2005: Salt Lake City, Utah Governor's Office of Budget and Planning, 12 p.

Fix, P.F., Nelson, W.B., Lofgren, B.E., and Butler, R.G., 1950, Ground-water in the Escalante Valley, Beaver, Iron, and Washington Counties, Utah: Utah State Engineer 27th Biennial Report, p. 109-210.

Hintze, L.F., Willis, G.C., Laes, D.Y.M., Sprinkel, D.A., and Brown, K.D., 2000, Digital geologic map of Utah: Utah Geological Survey Map 179DM, CD-ROM.

Lowe, M., and Snyder, N.P., 1996, Protecting ground water at its source through recharge-area mapping: Utah Geological Survey, Survey Notes, v. 28, no. 1, p. 6-7.

Lund, W.R., DuRoss, C.B., Kirby, S.M., McDonald, G.N., Hunt, G., and Vice, G.S., 2005, The origin and extent of earth fissures in Escalante Valley, southern Escalante Desert, Iron County, Utah: Utah Geological Survey Special Study 115, 30 p., CD-ROM.

Mower, R.W., 1981, Ground-water data for the Beryl-Enterprise area, Escalante Desert, Utah: Utah Hydrologic-Data Report 35, 64 p.

Mower, R.W., and Cordova, R.M., 1974, Water resources of the Milford area, Utah, with emphasis on ground water: Utah Department of Natural Resources Technical Publication No. 43, 106 p.

Mower, R.W., and Sandberg, G.W., 1982, Hydrology of the Beryl-Enterprise area, Escalante Desert, Utah, with emphasis on ground water: Utah Department of Natural Resources Technical Publication No. 73, 66 p.

Sandberg, G.W., 1963, Ground-water data, parts of Washington, Iron, Beaver, and Millard Counties: Utah Basic-Data Report No. 6, 26 p.

—1966, Ground-water resources of selected basins in southwestern Utah: Utah State Engineer Technical Publication No. 13, 46 p.

Snyder, N.P., and Lowe, M., 1998, Map of recharge and discharge areas for the principal valley-fill aquifer, Sanpete Valley, Sanpete County, Utah: Utah Geological Survey Map 174, 21 p., scale 1:125,000.

Stokes, W.L., 1977, Subdivisions of the major physiographic provinces in Utah: Utah Geology, v. 4, no. 1, p. 1-17.

Thomas, H.E., Nelson, W.B., Lofgren, B.E., and Butler, R.G., 1952, Status of development of selected ground-water basins in Utah: Utah State Engineer Technical Publication No. 7, p. 22-56.

Thomas, H.E., and Taylor, G.H., 1946, Geology and ground-water resources of Cedar City and Parowan Valleys, Iron County, Utah: U.S. Geological Survey Water-Supply Paper 993, 210 p.

Travel Guides, 2006, Escalante Valley: available online at http://escalantevalley.com/, accessed September 29, 2006.

Utah Division of Water Rights, 2005, Water well drilling database, available online at http://www.waterrights.utah.gov/wellinfo/default.asp, accessed August 10, 2005.

Waite, H.A., Nelson, W.B., Lofgren, B.E., Barnell, R.L., and Butler, R.G., 1954, Progress report on selected ground-water basins in Utah: Utah State Engineer Technical Publication 9, 128 p.

White, W.N., 1932, A method of estimating ground-water supplies based on discharge by plants and evaporation from soil: U.S. Geological Survey Water Supply Paper 569-A, p. 48-74.

APPENDIX

Records of Wells, Beryl-Enterprise Area, Utah

Explanation

Site number: See plate 1 for well location. Wells not used to define recharge and discharge areas are not plotted.

Local well number or spring cadastral identifier: See text for explanation of well numbering system; spring names and locations from the Utah Division of Water Rights.

Northing: UTM northing coordinate, NAD 27.

Easting: UTM easting coordinate, NAD 27.

Year drilled.

Elevation of wellhead: In feet above sea level.

Total depth: In feet below land surface.

Water level: In feet below land surface; F, flowing well.

Recharge type: P, primary recharge area; S, secondary recharge; D, discharge area.

Top of confining layer: Depth to first confining layer, in feet below land surface.

Bottom of confining layer: Depth to bottom of first confining layer, in feet below land surface.

Site #	Local well number	Northing	Easting	Year drilled	Elevation	Total depth	Water level	Recharge type	Top confining layer	Bottom confining layer
1	(C-31-13) 18acd	4220205	294026	2001	5145	91	77	P	-	-
2	(C-31-13) 18aac	4220619	294200	2001	5129	83	68	S	42	66
3	(C-36-15) 20bcb	4170638	273756	2001	5275	350	170	S	100	170
4	(C-31-13) 7cbc	4221408	293008	2001	5183	135	123	P	-	-
5	(C-31-13) 7cbd	4221465	293193	2001	5173	125	109	P	-	-
6	(C-36-15) 20bca	4170600	273896	2001	5288	500	170	P	-	-
7	(C-35-13) 26bcb	4178259	298549	2002	5496	200	-	S	0	25
8	(C-36-16) 16ccc-1	4170040	265430	2003	5219	593	190	S	0	45
9	(C-37-17) 15abd-1	4161695	257995	2003	5507	200	10	P	-	-
10	(C-31-16) 21cac-1	4218988	267544	2003	5989	275	190	P	-	-
11	(C-37-15) 34adc	4157156	277959	2003	6067	100	15	P	-	-
12	(C-36-13) 29cdd	4167520	293867	1995	6080	613	-	P	-	-
13	(C-31-13) 18bcc	4220176	292968	1996	5200	128	121	P	-	-
14	(C-31-13) 7cdc	4221005	293332	1997	5164	116	-	P	-	-
15	(C-31-13) 7dcb	4221213	293728	1997	5142	93	79	P	-	-
16	(C-31-13) 7ddb	4221124	294118	1997	5134	88	69	S	0	34
17	(C-31-13) 7dda	4221164	294352	1997	5111	76	57	S	0	30
18	(C-35-16) 9ccb	4183311	266174	1998	5154	200	-	S	17	110
19	(C-36-15) 16ccc	4171228	275339	1998	5363	200	-	P	-	-
20	(C-31-15) 19dda	4218465	275072	1999	6120	83	68	P	-	-
21	(C-31-13) 30abb	4217500	293672	1999	5139	97	82	S	40	74
22	(C-31-13) 30aba	4217641	293839	1999	5138	91	78	S	57	77
23	(C-35-16) 33cbd	4176877	266142	1999	5183	225	85	S	40	85
24	(C-35-17) 7dbb-1	4184059	254216	1999	5240	200	120	P	-	-
25	(C-35-17) 12ddc	4183047	262540	1949	5165	200	35	P	-	-
26	(C-35-16) 22ccd	4179666	267999	1999	5166	445	95	D	199	236
27	(C-32-16) 27abc	4208240	269210	1993	5664	200	40	P	-	-
28	(C-35-16) 16aca	4182379	267305	1998	5159	306	120	S	82	108
29	(C-34-17) 33dcc-1	4186450	257355	2001	5196	500	138	S	125	161
30	(C-35-15) 22dcd	4179341	278508	1994	5174	390	60	S	26	66
31	(C-35-16) 31cdd	4176573	263410	1993	5189	262	115	S	165	225
32	(C-35-16) 16bdd	4182178	266816	1997	5158	300	102	S	135	155
33	(C-36-16) 8dcc	4171577	264536	1994	5210	505	130	P	-	-
34	(C-36-16) 6cbc-1	4173751	262132	1994	5214	318	160	S	130	195

Site #	Local well number	Northing	Easting	Year drilled	Elevation	Total depth	Water level	Recharge type	Top confining layer	Bottom confining layer
35	(C-35-16) 23bcd	4180431	269479	2002	5164	255	96	P	-	-
36	(C-35-16) 31bcc	4177390	262739	1997	5186	400	120	S	21	45
37	(C-35-16) 14dcc	4181230	270205	2002	5161	570	80	D	175	240
38	(C-35-16) 10acb	4183924	268656	2003	5153	340	104	S	170	195
39	(C-36-16) 29cdc	4166775	263980	1998	5250	530	181	P	-	-
40	(C-35-15) 10acc-1	4183367	278230	1998	5148	365	80	D	22	43
41	(C-36-16) 4cab	4175590	265945	2003	5189	649	137	S	58	90
42	(C-33-12) 29adc	4197465	305008	1997	5308	200	125	S	107	140
43	(C-35-16) 18cdc	4181571	263330	2001	5161	402	107	S	17	60
44	(C-35-17) 12bdc	4183912	261694	1994	5168	660	-	P	-	-
45	(C-36-16) 4cdc-1	4173207	265823	1996	5199	250	150	S	2	40
46	(C-34-16) 28dcc	4187750	267069	2002	5143	205	60	D	50	75
47	(C-35-16) 9bbc	4184162	266167	1997	5152	257	95	S	73	114
48	(C-35-12) 7cad	4182379	302125	1993	5347	275	115	P	-	-
49	(C-35-16) 33cbc	4176952	266058	1999	5182	300	120	S	59	79
50	(C-36-16) 21abc	4169722	266096	1999	5221	702	168	S	65	90
51	(C-35-15) 30acc	4178723	273309	1997	5168	235	90	S	2	50
52	(C-36-16) 5dda	4175227	265452	2002	5193	410	160	P	-	-
53	(C-37-15) 34aca-1	4157341	277776	1996	6065	220	21	P	-	-
54	(C-36-16) 1ccd	4174511	270657	1977	5200	502	112	S	0	112
55	(C-34-12) 19dad	4189079	303251	2000	5474	406	285	S	4	54
56	(C-35-16) 32dcd	4176502	265496	1995	5186	283	140	S	35	102
57	(C-36-16) 4abb	4176335	266303	2002	5184	300	140	S	64	98
58	(C-36-13) 30aac	4168796	292938	1956	6208	195	115	P	-	-
59	(C-36-16) 16ccc-2	4169994	265336	1996	5220	300	120	S	0	20
60	(C-35-16) 15bbd	4182652	268098	1984	5158	180	76	D	-	-
61	(C-36-16) 16bbc	4171353	265389	2002	5209	460	166	S	0	60
62	(C-35-16) 33ccd	4176593	266140	1987	5185	300	80	P	-	-
63	(C-34-16) 28bca	4188965	266657	1996	5139	325	68	D	32	75
64	(C-36-16) 20dcc	4168362	264432	2002	5235	598	186	P	-	-
65	(C-35-17) 36dcc	4176650	261942	1993	5195	250	160	S	20	64
66	(C-35-17) 20add	4180917	256263	2000	5214	305	145	S	58	78
67	(C-35-17) 30abd	4179706	254164	1993	5220	277	143	S	0	94
68	(C-35-16) 32ddd	4175646	265420	2002	5190	260	130	S	0	50

Site #	Local well number	Northing	Easting	Year drilled	Elevation	Total depth	Water level	Recharge type	Top confining layer	Bottom confining layer
69	(C-35-16) 33cdc	4176646	266362	1986	5184	403	80	P	-	-
70	(C-36-16) 4cbb	4173896	265478	1991	5201	265	135	S	12	34
71	(C-35-17) 36cdc	4176732	261554	2000	5196	280	150	P	-	-
72	(C-35-16) 17bad	4182580	265216	1996	5157	257	80	S	22	65
73	(C-36-16) 4aaa	4176300	267030	2003	5184	300	150	P	-	-
74	(C-37-14) 12cdd	4162814	290533	1997	6678	128	17	P	-	-
75	(C-34-16) 32aca	4187317	265678	1999	5144	200	80	D	50	75
76	(C-36-16) 6cbc-2	4173751	262132	1994	5214	318	160	S	130	170
77	(C-35-17) 7cac	4183708	253589	1999	5249	403	180	P	-	-
78	(C-34-18) 32ccb	4187014	245282	1986	5389	310	258	P	-	-
79	(C-37-16) 5aaa	4165082	264982	2001	5293	500	270	S	250	278
80	(C-35-17) 3cdc	4184789	258640	1983	5189	155	90	P	-	-
81	(C-35-16) 3dcd	4184491	268791	1999	5153	305	60	D	80	102
82	(C-36-15) 17dcc	4171200	274502	1983	5293	496	120	P	-	-
83	(C-36-16) 9abb	4173110	266211	1986	5198	321	258	P	-	-
84	(C-35-17) 16cca	4181876	256620	1994	5213	265	122	S	6	152
85	(C-36-15) 20cba	4170249	273916	1999	5337	950	180	P	-	-
86	(C-36-16) 29acd	4167536	264748	1998	5240	505	180	P	-	-
87	(C-35-16) 33dcd	4176580	266986	1986	5184	305	148	S	14	35
88	(C-37-17) 14bbd	4161725	258885	1986	5334	76	20	P	-	-
89	(C-36-13) 32cdd	4165961	293868	1995	6380	615	240	P	-	-
90	(C-35-17) 7dbb-2	4183999	254192	1999	5240	300	120	P	-	-
91	(C-37-13) 6caa	4165023	292203	1994	6362	300	-	P	-	-
92	(C-36-15) 20bbc	4170791	273736	1998	5266	500	181	S	110	133
93	(C-35-16) 9cbd	4183348	266374	2002	5155	300	80	S	190	275
94	(C-35-17) 17ddb	4181993	255962	1998	5220	480	180	S	55	76
95	(C-36-15) 19abb	4171141	272933	2002	5233	610	189	S	0	25
96	(C-36-15) 19aca-1	4170684	273079	1993	5247	472	168	S	109	168
97	(C-37-16) 6cdb	4163886	262404	1995	5296	280	160	S	0	25
98	(C-34-13) 28ddc	4187012	296393	1993	5283	650	175	S	47	72
99	(C-34-13) 34ccc	4185384	296907	1993	5328	800	125	S	100	129
100	(C-37-13) 6aba	4165831	292577	2002	6245	700	190	P	-	-
101	(C-37-16) 4cba	4164251	265235	1995	5325	395	260	P	-	-
102	(C-35-16) 29dda	4178313	265928	1995	5174	442	127	S	0	50

Site #	Local well number	Northing	Easting	Year drilled	Elevation	Total depth	Water level	Recharge type	Top confining layer	Bottom confining layer
103	(C-36-14) 32bcc	4166957	283495	1995	5810	394	23	P	-	-
104	(C-36-13) 32abc	4167223	294018	1996	6101	210	45	P	-	-
105	(C-35-16) 16bcb	4182379	266212	1997	5158	204	76	S	20	47
106	(C-33-12) 5cbb	4203709	303867	1998	5236	140	78	S	0	62
107	(C-37-16) 18cca	4160599	261965	1999	5591	150	-	P	-	-
108	(C-34-18) 20dac	4190475	246695	1999	5357	350	240	P	-	-
109	(C-35-16) 23cbd	4180114	269677	2000	5164	200	75	P	-	-
110	(C-37-18) 12bda	4163400	250921	2001	5530	190	10	P	-	-
111	(C-37-14) 8bdc-1	4163652	283766	1999	5925	200	100	P	-	-
112	(C-37-15) 34ddd	4156374	278187	1999	6132	202	50	P	-	-
113	(C-36-16) 36cdd	4164947	270759	2000	5841	495	240	P	-	-
114	(C-36-16) 4acc	4174172	266279	2000	5194	210	140	S	40	73
115	(C-35-17) 16aba	4183072	257511	2001	5198	198	118	P	-	-
116	(C-37-16) 4cac	4164047	265552	2001	5348	450	285	P	-	-
117	(C-34-17) 33dcc-2	4186450	257355	2001	5196	500	138	S	125	161
118	(C-35-16) 21acd	4180473	267168	2002	5165	625	112	S	80	110
119	(C-37-17) 14acb	4161498	259355	2000	5332	350	39	P	-	-
120	(C-37-14) 21acd	4160472	286063	1999	6159	305	40	P	-	-
121	(C-35-15) 21aaa	4180968	277353	2002	5159	500	72	D	139	160
122	(C-35-16) 14acc	4182046	270107	2002	5156	540	80	D	180	210
123	(C-36-16) 12bdd	4172321	270947	2000	5201	405	115	S	90	130
124	(C-35-17) 8cbb	4183940	254841	1987	5229	204	80	P	-	-
125	(C-36-16) 20abb	4169954	264488	2000	5224	697	160	S	0	20
126	(C-35-17) 36acc	4177441	262069	2003	5190	404	142	P	-	-
127	(C-36-16) 9adc	4172367	266676	2001	5200	605	157	S	78	130
128	(C-36-16) 3ddc	4173163	268370	1993	5194	305	143	P	-	-
129	(C-36-15) 20bbb	4171004	273764	1998	5266	513	183	S	110	135
130	(C-36-16) 26cbb	4167426	268530	1993	5259	352	270	P	-	-
131	(C-35-17) 24ddd	4179900	262692	1994	5174	240	110	P	-	-
132	(C-34-16) 23cba	4190001	269846	1984	5133	196	28	D	110	130
133	(C-36-16) 4cdc-2	4175028	266008	2002	5193	282	175	P	-	-
134	(C-34-15) 23cbd	4189460	279456	1996	5124	400	68	D	90	340
135	(C-36-16) 11ccb	4171880	268571	1986	5198	496	95	S	66	130
136	(C-35-16) 4dcc	4184552	267028	1993	5153	250	85	S	40	60

Site #	Local well number	Northing	Easting	Year drilled	Elevation	Total depth	Water level	Recharge type	Top confining layer	Bottom confining layer
137	(C-36-16) 13dad	4170339	271775	1986	5220	685	150	S	5	34
138	(C-35-18) 2abb	4186567	251009	1986	5277	226	125	P	-	-
139	(C-34-16) 32dba	4186853	265688	1987	5146	200	56	D	15	35
140	(C-37-16) 4cbb	4164092	265089	1999	5326	350	280	P	-	-
141	(C-37-16) 4bcc-1	4164376	265099	1995	5318	340	230	S	0	21
142	(C-35-18) 2cdb	4185407	250500	1986	5283	307	120	P	83	105
143	(C-35-17) 25dca	4178577	262233	2002	5182	300	160	S	30	60
144	(C-37-18) 14add	4161573	250241	1997	5478	304	15	P	-	-
145	(C-35-19) 1bca	4186291	242331	1994	5422	310	310	P	-	-
146	(C-36-15) 19bdb	4170806	272266	1993	5220	600	168	S	226	252
147	(C-37-13) 6cac	4164801	291910	1993	6414	360	230	P	-	-
148	(C-37-16) 9acc	4162637	265982	1996	5501	290	180	P	-	-
149	(C-37-16) 8aac	4163074	264673	1993	5370	310	145	P	-	-
150	(C-37-16) 10bca	4162977	267062	1993	5505	300	230	P	-	-
151	(C-37-17) 17bcb	4161728	253677	1995	5389	205	15	P	-	-
152	(C-35-16) 28aad	4179271	267631	1993	5167	392	392	S	80	107
153	(C-34-18) 33dad	4187249	248316	1993	5334	362	240	P	-	-
154	(C-37-13) 6acc	4165099	292293	1993	6331	300	100	P	-	-
155	(C-34-16) 19add	4190303	264617	1999	5140	200	60	D	54	101
156	(C-37-16) 5dbc	4163981	264452	1994	5305	295	235	P	-	-
157	(C-37-15) 34dda	4156706	278191	1994	6128	210	180	P	-	-
158	(C-37-16) 7cac	4162333	262175	1994	5368	303	115	P	-	-
159	(C-37-16) 4bad	4164602	265749	1995	5329	325	225	P	-	-
160	(C-35-17) 21bba	4181483	256675	1994	5211	327	120	S	135	290
161	(C-37-17) 18abc	4161875	252866	1994	5578	320	120	P	-	-
162	(C-35-14) 6baa	4185506	283031	1994	5138	340	45	D	2	200
163	(C-37-16) 7abc	4163112	262731	1994	5322	310	142	S	0	21
164	(C-34-16) 32ddc	4186257	265885	1995	5148	210	58	D	128	157
165	(C-36-15) 19aca-2	4170638	273086	1997	5249	510	195	S	4	32
166	(C-36-15) 19aac	4170821	273238	1996	5247	604	160	S	115	150
167	(C-36-15) 16ddb	4171535	276616	1996	5450	320	90	P	-	-
168	(C-36-15) 15dbd	4171763	278003	1999	5485	375	175	P	-	-
169	(C-35-17) 19cab	4180865	253538	1995	5233	394	160	P	-	-
170	(C-35-17) 19dba	4180820	254290	1995	5230	400	165	P	-	-

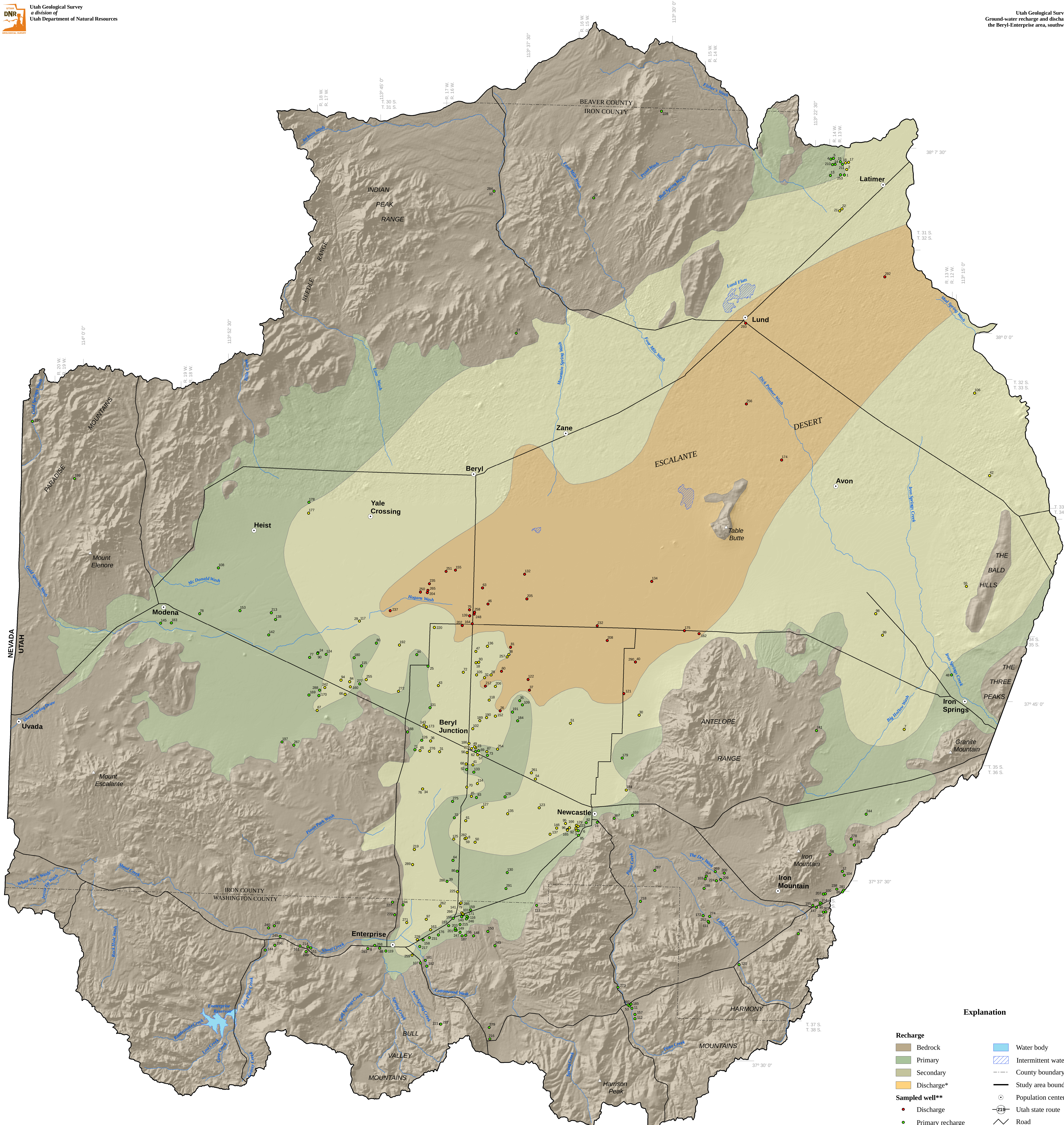
Site #	Local well number	Northing	Easting	Year drilled	Elevation	Total depth	Water level	Recharge type	Top confining layer	Bottom confining layer
171	(C-37-16) 4cab	4164130	265486	2002	5340	312	250	P	-	-
172	(C-37-14) 8bbc	4164176	283343	1996	5859	300	18	P	-	-
173	(C-35-17) 25ddb	4178458	262425	1999	5179	302	120	S	4	62
174	(C-33-14) 23ccb	4198647	289274	1995	5138	210	40	D	32	153
175	(C-34-15) 36ddc	4185734	281937	1997	5132	246	83	D	91	205
176	(C-37-16) 7add	4162712	263330	1996	5355	300	184	P	-	-
177	(C-34-18) 1ddd	4194623	253518	1995	5229	438	80	S	5	35
178	(C-34-18) 1daa	4195435	253533	1995	5237	358	80	P	-	-
179	(C-36-15) 3bba	4176092	277220	1994	5217	310	130	P	-	-
180	(C-35-17) 9cac	4183679	256960	1999	5203	300	300	P	-	-
181	(C-37-16) 18cac	4160794	262341	1997	5471	160	45	P	-	-
182	(C-37-16) 18cdd	4160352	262454	1997	5519	200	45	P	-	-
183	(C-35-19) 1aca	4186316	243131	1996	5413	325	280	P	-	-
184	(C-35-16) 26bcc	4178911	269318	1997	5164	202	123	P	-	-
185	(C-37-15) 34adb	4157473	277888	1998	6083	180	10	P	-	-
186	(C-35-16) 32dab	4177208	265638	1996	5181	369	120	S	17	48
187	(C-37-16) 9bcc	4162644	265116	1996	5441	295	196	P	-	-
188	(C-35-17) 35aaa	4178070	261000	1996	5230	245	198	P	-	-
189	(C-35-16) 28bdc	4178923	266458	2002	5172	500	112	S	285	310
190	(C-35-16) 28acb	4179147	266968	2002	5174	500	102	S	65	95
191	(C-35-16) 27aab	4179580	268927	1996	5165	322	120	P	-	-
192	(C-35-17) 11baa	4184640	260387	1996	5175	230	98	S	60	100
193	(C-37-13) 6bdd	4165143	292191	1996	6371	415	120	P	-	-
194	(C-37-17) 1bac	4164976	260662	1997	5294	275	175	P	-	-
195	(C-37-13) 6cba	4164950	291638	1997	6411	500	260	P	-	-
196	(C-37-18) 13bad	4161938	250959	2000	5653	300	22	P	-	-
197	(C-35-18) 36cbc	4177312	251505	1992	5284	360	330	P	-	-
198	(C-36-14) 32cbc	4166228	283413	1998	5781	450	150	P	-	-
199	(C-33-19) 32cbc	4197239	235824	1997	6781	150	56	P	-	-
200	(C-36-14) 32aad	4167386	284938	1997	5892	500	105	P	-	-
201	(C-37-16) 8abd-1	4163076	264592	1997	5364	430	187	P	-	-
202	(C-35-16) 5bab	4186130	265125	1998	5148	200	80	D	104	125
203	(C-37-16) 8abd-2	4163199	264610	1999	5354	560	230	P	-	-
204	(C-34-17) 25dba	4188609	262488	1997	5150	300	68	D	213	286

Site #	Local well number	Northing	Easting	Year drilled	Elevation	Total depth	Water level	Recharge type	Top confining layer	Bottom confining layer
205	(C-34-16) 26cac	4188139	270014	2000	5138	265	60	D	-	-
206	(C-35-16) 16dda	4181510	267638	1999	5162	200	110	S	60	110
207	(C-37-13) 6abb	4165810	292432	1998	6264	380	240	P	-	-
208	(C-35-15) 4cba	4184981	276090	1999	5139	204	45	D	4	55
209	(C-36-14) 32adc	4166904	284677	1999	5846	205	32	P	0	32
210	(C-31-13) 7ccd	4220993	293133	1998	5166	360	100	P	-	-
211	(C-31-13) 7dcd	4221010	293878	1998	5138	340	100	P	-	-
212	(C-36-15) 16dcb	4181538	266885	1998	5160	300	75	D	20	110
213	(C-34-18) 35cad	4187094	250694	2001	5279	261	200	P	-	-
214	(C-37-17) 18aad	4161815	253468	2001	5427	195	26	P	-	-
215	(C-37-16) 5ddd	4163496	264967	1998	5344	400	291	P	-	-
216	(C-38-16) 3bdd	4154843	267223	1999	5917	265	55	P	-	-
217	(C-37-16) 18bbb	4161838	261916	1998	5392	235	110	P	-	-
218	(C-37-15) 2cba	4165252	278612	2002	5642	300	20	P	-	-
219	(C-36-17) 24dba	4169187	261506	1998	5244	405	202	S	0	22
220	(C-35-16) 6bbc	4185977	263024	1998	5154	260	123	S	40	86
221	(C-37-16) 32cbc	4155969	263471	2002	6245	1220	406	P	-	-
222	(C-37-16) 32cbd	4155969	263507	1995	6268	720	80	P	-	-
223	(C-36-15) 20aac	4170940	273886	1998	5272	505	180	S	0	31
224	(C-36-14) 32dbb	4166809	284349	1999	5913	400	65	P	-	-
225	(C-36-16) 32adc	4165974	264763	1999	5266	350	-	S	25	112
226	(C-37-17) 12dad	4162357	261726	1999	5357	212	94	S	12	70
227	(C-37-17) 2aab	4165195	259856	1999	5649	510	385	P	-	-
228	(C-31-15) 2bbb	4225028	280193	1999	6318	800	345	P	-	-
229	(C-35-16) 32dda	4176837	265850	1999	5184	300	100	S	46	75
230	(C-33-20) 23aaa	4201569	232628	1998	7087	180	20	P	-	-
231	(C-37-16) 7dbb	4162508	262653	1999	5362	454	187	P	-	-
232	(C-34-15) 32dcd	4186104	275341	2000	5134	200	60	D	0	30
233	(C-37-16) 8baa	4163415	264098	2001	5325	500	260	P	-	-
234	(C-36-15) 10bdd	4173673	277532	1999	5361	430	230	S	0	25
235	(C-34-17) 25aab	4189283	262655	1999	5148	140	57	D	47	72
236	(C-37-16) 9bcd	4162688	265394	1999	5452	300	240	P	-	-
237	(C-34-17) 34add	4187248	259682	1999	5174	250	70	D	83	128
238	(C-36-13) 34cca	4166178	293448	1999	6200	250	62	P	-	-

Site #	Local well number	Northing	Easting	Year drilled	Elevation	Total depth	Water level	Recharge type	Top confining layer	Bottom confining layer
239	(C-36-13) 20dad	4169522	294771	2000	6050	260	57	P	-	-
240	(C-37-18) 12bcc	4163244	250491	1999	5503	440	47	P	-	-
241	(C-35-13) 30bcc	4178178	291913	1999	5864	305	160	P	-	-
242	(C-35-17) 19aaa	4181431	254742	2000	5233	705	149	S	180	420
243	(C-37-16) 10dcc	4161897	267605	2002	5487	300	200	P	-	-
244	(C-36-13) 16bda	4171855	295675	2002	5811	335	294	P	-	-
245	(C-37-18) 12dca	4162599	251354	2000	5472	300	18	P	-	-
246	(C-37-16) 4cbd	4163920	265439	2000	5348	400	240	P	-	-
247	(C-37-16) 6ada	4162920	264965	2000	5398	360	195	P	-	-
248	(C-34-16) 32add-2	4186991	266021	2000	5145	265	58	D	130	185
249	(C-37-17) 18adc	4161458	253313	2000	5653	255	60	P	-	-
250	(C-34-17) 25cab	4188651	261975	2002	5152	240	85	D	0	138
251	(C-34-16) 19dbb	4190208	263911	2001	5141	250	60	D	38	196
252	(C-37-14) 8bdc-2	4163740	283718	2001	5908	293	72	P	-	-
253	(C-31-13) 18acc	4220220	293733	2001	5144	300	85	P	-	-
254	(C-35-16) 34cca	4176768	267801	2000	5176	200	135	S	0	27
255	(C-35-17) 16dad	4182032	257867	2001	5199	210	97	S	29	51
256	(C-33-14) 9bdb	4202877	286614	2002	5106	200	22	D	50	70
257	(C-35-16) 10bdd	4183748	268524	2001	5154	402	100	S	80	105
258	(C-34-16) 32add-1	4187119	266053	2001	5145	160	70	D	0	95
259	(C-37-17) 13acd	4161187	261336	2002	5397	404	98	S	0	35
260	(C-37-15) 34aca-2	4157417	277669	2003	6049	100	12	P	-	-
261	(C-36-16) 1ccb	4174976	270358	2001	5194	304	145	S	15	75
262	(C-37-16) 5bbc	4164894	263450	2001	5269	700	222	S	80	105
263	(C-37-13) 6dca	4164461	292626	2002	6462	490	36	P	-	-
264	(C-36-14) bcb	4167162	283589	2002	5816	350	40	P	-	-
265	(C-34-17) 25acd	4188785	262533	2002	5149	200	62	D	55	89
266	(C-37-16) 4bcc-2	4164302	265179	2002	5322	400	267	S	50	85
267	(C-35-18) 4dca	4177079	252400	2002	5303	400	160	P	-.	-
268	(C-37-17) 15aaa	4161918	258510	2002	5315	200	22	P	-	-
269	(C-36-14) 32abb	4167499	284260	2002	5817	245	50	P	-	-
270	(C-37-17) 2daa	4164238	260022	2002	5416	400	300	P	-	-
271	(C-37-17) 1cdd	4163645	260932	2002	5296	700	122	S	0	45
272	(C-35-17) 23bad	4181141	260316	2002	5179	310	147	S	3	50

Site #	Local well number	Northing	Easting	Year drilled	Elevation	Total depth	Water level	Recharge type	Top confining layer	Bottom confining layer
273	(C-37-15) 27cba	4158748	276911	2003	6001	143	6	P	-	-
274	(C-37-14) 8bac	4164118	283837	2002	5865	200	15	P	-	-
275	(C-36-16) 8bad	4172815	264399	2002	5214	700	188	P	-	-
276	(C-35-17) 36ddd	4176597	262652	2003	5192	350	160	S	20	45
277	(C-35-17) 16dcd	4181706	257382	1998	5203	245	110	P	-	-
278	(C-36-13) 20adc	4169972	294526	2003	6080	620	500	P	-	-
279	(C-37-16) 34cad	4155712	267167	2003	5932	437	145	P	-	-
280	(C-37-13) 6dcb	4164444	292430	2003	6478	400	180	P	-	-
281	(C-36-13) 32dcb	4166107	293982	2003	6318	400	130	P	-	-
282	(C-36-16) 16ccc-3	4170040	265430	2003	5219	593	190	S	0	45
283	(C-37-17) 15abd-2	4161695	257995	2003	5507	200	10	P	-	-
284	(C-31-16) 21cac-2	4218988	267544	2003	5989	275	190	P	-	-
285	(C-36-16) 32ddd	4165126	265033	1987	5292	368	-	S	162	184
286	(C-36-16) 29cdc-2	4166775	263980	1998	5250	530	181	P	-	-
287	(C-36-15) 35aab	4167599	279687	1983	5619	140	40	P	-	-
288	(C-35-17) 19aac	4181227	254343	1984	5233	300	105	P	-	-
289	(C-36-17) 25abd	4168043	261375	1997	5259	400	200	S	0	30
290	(C-35-15) 10acc-2	4183367	278230	1998	5148	365	80	D	106	131
291	(C-36-16) 35bbc	4166222	268444	1993	5321	305	240	P	-	-
292	(C-32-13) 9bdd	4212502	297076	1963	5105	300	44	D	147	189
293	(C-32-14) 21cba	4209001	286554	1986	5081	414	10	D	17	98

Utah Geological Survey
a division of
Utah Department of Natural Resources



Explanation

Recharge

- Bedrock
- Primary
- Secondary
- Discharge*

Sampled well**

- Discharge
- Primary recharge
- Secondary recharge

- Water body
- Intermittent water body
- County boundary
- Study area boundary
- Population center
- Utah state route
- Road
- Water course

* Due to falling water levels should be treated as secondary recharge for land-use planning purposes

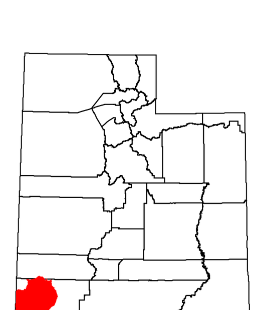
** Recharge/discharge category at the time of drilling; number refers to site number in appendix

GROUND-WATER RECHARGE AND DISCHARGE AREAS OF THE BERYL-ENTERPRISE AREA, SOUTHWESTERN UTAH

by
Kevin Thomas and Mike Lowe

2007

Digital compilation by Scott Horn and Richard Emerson



Location of Study Area

DISCLAIMER

Although this product represents the work of a professional scientist, the Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, expressed or implied, regarding its suitability for a particular use. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

For use at a scale of 1:125,000. If viewed/plotted at a smaller scale, it may not be accurate for the purposes for which it is intended. The UGS does not guarantee accuracy or completeness of data.

Scale 1:125,000

0 1 2 4 6 8 Kilometers

0 1 2 4 Miles

Projection: UTM Zone 12
Units: Meters
Datum: 1927 North America
Spheroid: Clarke1866

Utah Geological Survey
1594 W. North Temple, P.O. Box 146100
Salt Lake City, UT 84112-6200
Phone: 801-537-3300: fax: 801-537-3400
geology.utah.gov

ISBN 1-55791-770-1