RECHARGE AREA AND WATER QUALITY OF THE VALLEY-FILL AQUIFER, CASTLE VALLEY, GRAND COUNTY, UTAH

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Noah P. Snyder
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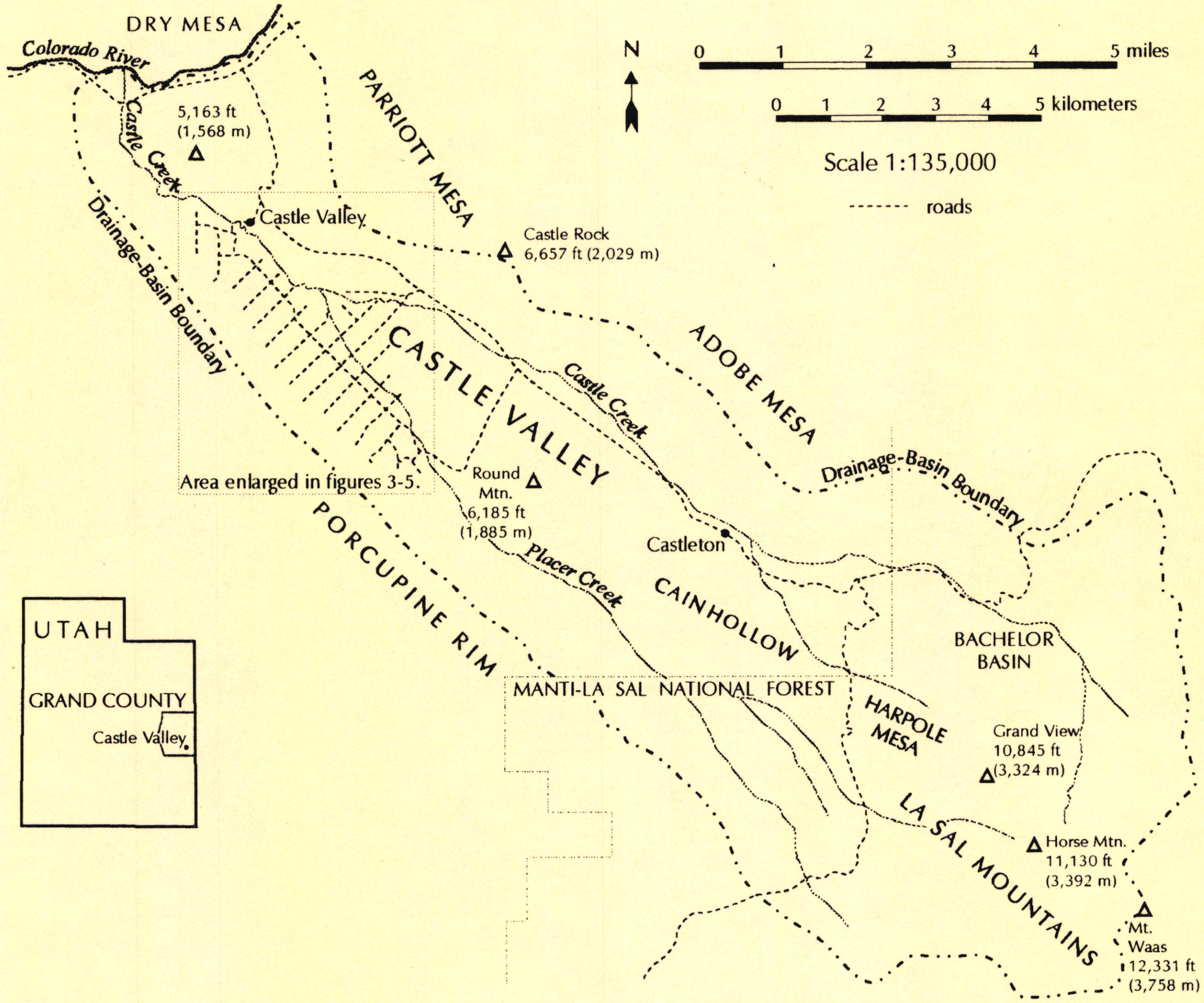

Report of Investigation 229 **April 1996**
UTAH GEOLOGICAL SURVEY
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ABSTRACT

All culinary water in Castle Valley is from wells. Increased residential development using individual wastewater-disposal systems has raised concerns for the long-term quality of ground water in the valley-fill aquifer. In this study, ground-water recharge and discharge areas, potentiometric surface elevation, and specific conductance were mapped to serve as tools for protecting ground-water quality and managing potential contaminant sources in Castle Valley.

Castle Valley is one of several northwest-trending salt anticline valleys on the Colorado Plateau in southeastern Utah. The unconsolidated valley fill is the principal aquifer in the valley and consists of coarse alluvial-fan deposits and stream alluvium, with minor clay. Some recharge to the valley-fill aquifer comes from underflow from bedrock aquifers, but most is from La Sal Mountains runoff via Castle Creek and Placer Creek. Because of the absence of protective, low-permeability confining layers, the valley-fill aquifer is unconfined, and most of the valley is classified as primary recharge area. The only discharge area is along lower Castle Creek.

Water quality in the valley-fill aquifer is generally high in upper Castle Valley, but declines in the lower valley, perhaps due to recharge from saline ground water in bedrock aquifers in contact with Paradox Formation evaporites. Wells tapping the Cutler Formation aquifer beneath the valley fill also yield poor-quality water. The coarse-grained, unconfined valley-fill aquifer is highly susceptible to contamination from surface recharge.

INTRODUCTION

Background

Ground water, chiefly from the unconsolidated valley-fill aquifer, is the only source of drinking water in Castle Valley. Recent increased development in the sparsely populated area has underscored the need to protect the aquifer from contamination. Recharge to the aquifer is mostly by runoff from the north flank of the La Sal Mountains. Recharge areas are typically underlain by fractured rock and/or coarse-grained sediment with relatively little ability to inhibit infiltration or renovate contaminated water. Ground-water flow in recharge areas has a downward component and relatively fast rate of movement. Because contaminants can readily enter an aquifer in recharge areas, management of potential contaminant sources in these areas deserves special attention to protect the quality of ground water. Ground-water recharge-area mapping is thus important to define 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). Primary recharge areas, usually the uplands and coarse-grained unconsolidated deposits along valley margins, do not contain thick, continuous, fine-grained layers and have downward ground-water gradients. Secondary recharge areas, commonly valley benches, have fine-grained layers thicker than 20 feet (6 m) and downward ground-water gradients. Because Castle Valley does not have extensive clay layers, it has no secondary recharge areas. Ground-water discharge areas are generally in valley lowlands. Ground water in the valley-fill aquifer is unconfined throughout Castle Valley. Discharge areas for unconfined aquifers are where the water table intersects the ground surface, forming springs or seeps. The extent of both recharge and discharge areas may vary seasonally and from dry to wet years.

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 Castle Valley by defining areas where ground-water aquifers are vulnerable to contamination. The study is a cooperative effort among the Utah Geological Survey (UGS), the Utah Division of Water Quality (DWQ), the Utah Division of Water Rights (DWRT), and the U.S. Environmental Protection Agency (EPA) to map recharge and discharge areas in the Castle Creek drainage basin in Grand County.

The scope of work included a literature review, geologic field reconnaissance, and field measurement of depths to water in wells and specific conductance of water in wells, springs, and Castle Creek. Logs of water wells drilled in the valley prior to October 1995 were collected from the State Engineer's office. Well-log information was entered into a data base and well locations were plotted on 1:24,000-scale U.S. Geological Survey topographic maps. Generalized recharge- and discharge-area boundaries were then drawn on the base maps.

Setting

The study area is the drainage basin of Castle Creek in Grand County, Utah (figure 1). Castle Valley is oriented northwest-southeast, and is 12 miles (19 km) long and 2 miles (3 km) wide.

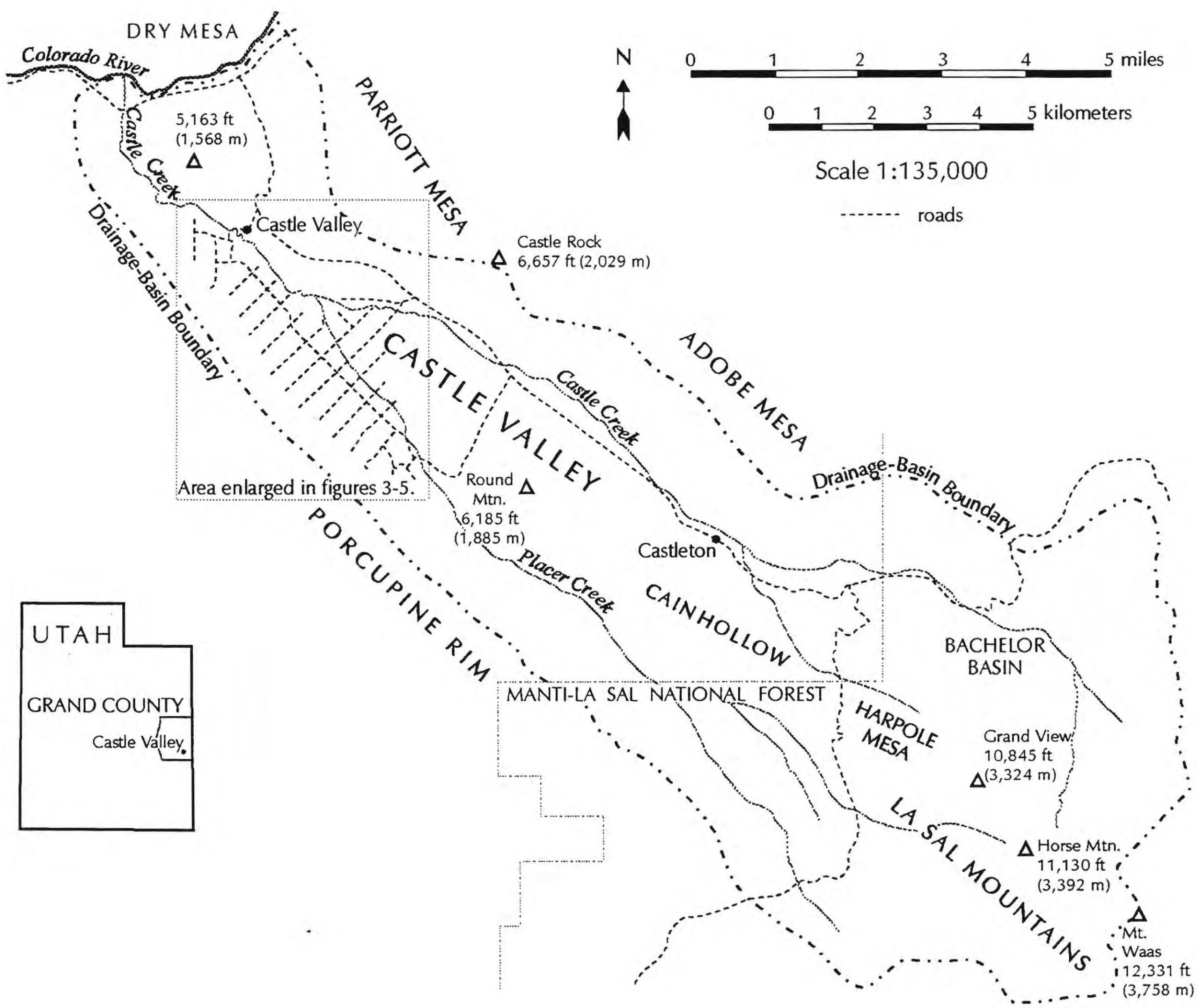

Figure 1. Castle Creek drainage basin study area.

Physiography and Drainage

Castle Valley is on the Colorado Plateau near Moab, Utah. The La Sal Mountains make up the southeast border of the study area, reaching 12,331 feet (3,758 m) in elevation at Mount Waas. The cliffs of Porcupine Rim, and Parriott and Adobe Mesas, define the southwest and northeast borders, respectively. The study area ends to the northwest at the Colorado River at an elevation of 4,120 feet (1,250 m).

The headwaters of Castle Creek and Placer Creek are in the La Sal Mountains (figure 1). These streams flow into the valley on either side of Cain Hollow and Round Mountain, and join near the town of Castle Valley. In the northwest part of the study area, cliff walls close the valley and Castle Creek flows through a short, narrow canyon and then enters the Colorado River.

Climate

Average annual precipitation ranges from 9.00 inches (22.9 cm) at elevation 4,021 feet (1,226 m) on the Colorado River in Moab to more than 30 inches (76 cm) in the La Sal Mountains (Blanchard, 1990; Ashcroft and others, 1992). The Castle Valley Institute in the town of Castle Valley, at elevation 4,720 feet (1,439 m), and the town of Castleton, farther up the valley at elevation 5,840 feet (1,780 m), receive 11.50 and 13.63 inches (29.2 and 34.6 cm) of precipitation per year, respectively (Ashcroft and others, 1992). Average annual evapotranspiration is four times precipitation (Ashcroft and others, 1992). Temperatures in Castleton average 50.2°F (10.1°C) annually, and may reach above 100°F (38°C) in the summer and below 0°F (-18°C) in the winter (Ashcroft and others, 1992).

Land Use

Castle Valley is becoming increasingly popular as a site for vacation and retirement homes. As a result, the population is growing. Many new homes have been built on 5-acre lots in the town of Castle Valley during the past few years, and this trend is continuing. Approximately 300 people reside in the valley at present (1996). Tourism is an important growth industry in the valley. Cattle graze on the flanks of the La Sal Mountains in the summer, and on the valley floor in the winter. The valley has some irrigated cropland.

Previous Studies

The hydrogeology of Castle Valley has been summarized in several previous studies, including Sumison (1971), Weir and others (1983), and Blanchard (1990). Mulvey (1992) mapped geologic hazards of Castle Valley, including ground-water contamination and flooding. Geologic mapping studies of Castle Valley include Harper (1960), Doelling and Ross (1993), and Ross (in press). Ground- and surface-water quality and supply in Castle Valley are being studied by the DWRT; some data has been published in two progress reports (Ford, 1994; Ford and Grandy, 1995).

METHODS

Recharge and Discharge Areas

The methods used in this study to identify confining layers, classify aquifers, and delineate recharge and discharge areas are modified from those of Anderson and others

(1994). I used driller's logs of water wells to delineate primary recharge areas and discharge areas, based on the presence of confining layers and water levels. The use of driller's logs requires interpretation because of the variable quality of the logs. Correlation of geology from well logs is difficult because lithologic descriptions are generalized and commonly inconsistent among various drillers. Using water-level data from well logs is also problematic because water levels were measured during different seasons and years.

For this project, confining layers are defined as any fine-grained (clay and/or silt) layer thicker than 20 feet (6 m). Because no extensive confining layers are present in Castle Valley, the valley-fill aquifer is unconfined and only primary recharge and discharge areas are delineated. Ground-water flow in primary recharge areas has a downward component. Discharge areas in unconfined aquifers are where the water table intersects the land surface (figure 2). Surface water, springs, and phreatophytic plants (wetlands) are indicators of ground-water discharge. Careful analysis of the topography, surficial geology, and ground-water hydrology must be made before using these wetlands to define discharge areas for the valley-fill aquifer.

I did not map small secondary recharge or discharge areas defined by only a few wells surrounded completely by primary recharge areas. Contaminants entering the aquifer system above these clay lenses have a high potential to reach primary recharge areas.

Potentiometric Surface and Specific Conductance

The DWRT and UGS measured depths to water in 70 wells and specific conductance of water for 50 wells, springs, and sites along Castle Creek from March 25 to 28, 1996. Depth to water was measured in about 20 per cent of the valley wells. Wellhead elevations

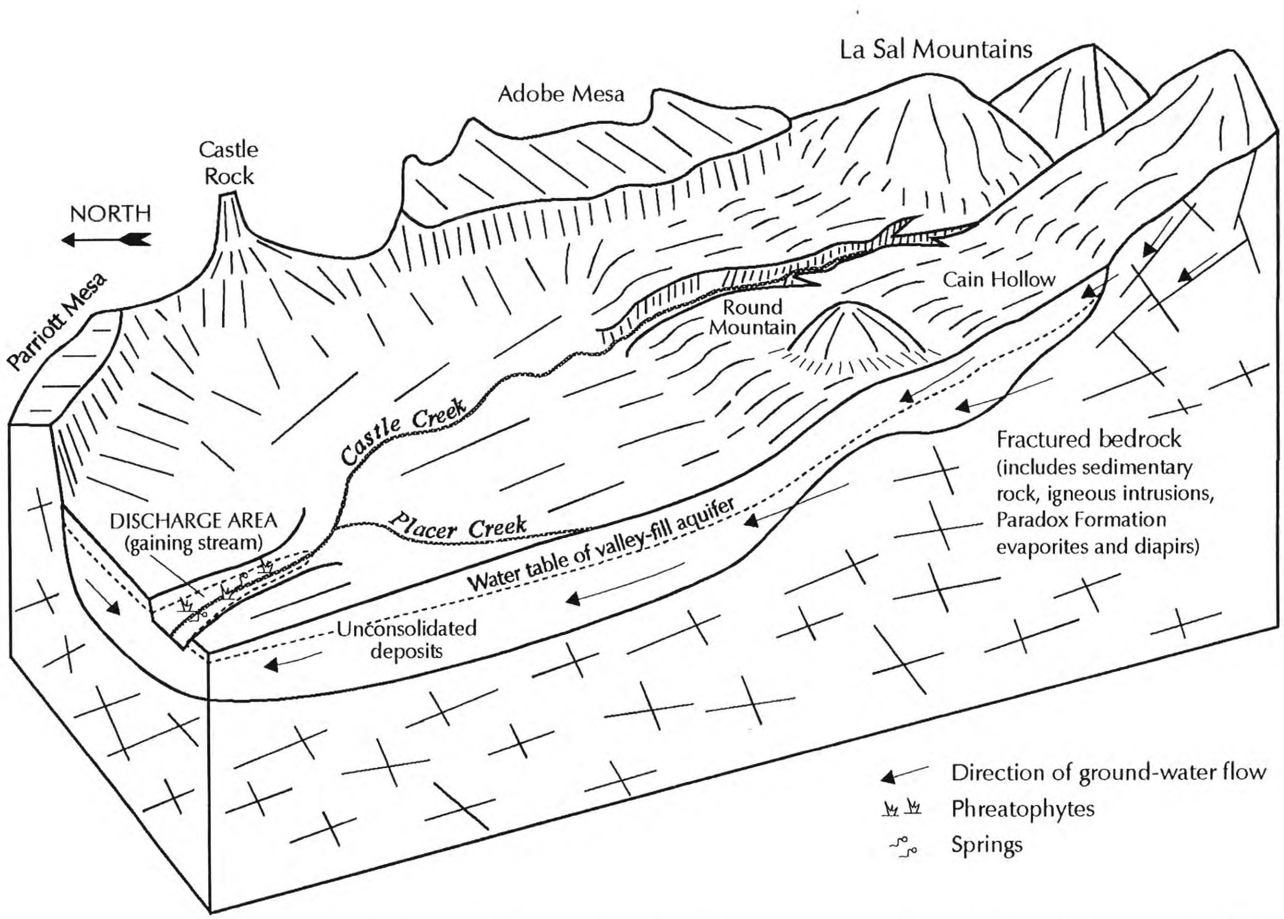

Figure 2. Schematic block diagram showing ground-water flow in Castle Valley.

were taken from 7.5' USGS topographic maps to produce the potentiometric surface map. Specific conductance was measured in the field with a YSI 33 S-C-T meter. Specific-conductance samples were obtained from only those wells having pumps. To interpret water-quality data collected previously by the DWRT (Ford, 1994; Ford and Grandy, 1995), I differentiated wells completed in bedrock from those in valley-fill aquifers for 17 selected wells.

GEOLOGY

Bedrock

Castle Valley is surrounded by Permian to Tertiary sedimentary and igneous rocks. It is part of a large, regional, collapsed salt anticline that includes Paradox Valley to the southeast (Doelling and Ross, 1993). Beneath the valley is the Pennsylvanian Paradox Formation. The Paradox Formation contains thick salt layers deposited in a shallow sea. As these salt layers were buried they became mobile and formed a diapir in what is now Castle Valley. The uplift of the Colorado Plateau in the late Tertiary increased erosion rates and allowed ground water to dissolve the salt layers from the core of the anticline (Doelling and Ross, 1993). Subsequently, the overlying rock collapsed and eroded, leaving the present Castle Valley in the core of the anticline. Mulvey (1992) mapped a suspected Quaternary fault parallel to Porcupine Rim northwest of Round Mountain. Several sinkholes along this fault are attributed to localized dissolution or piping (Mulvey, 1992).

Gypsum, mudstone, and shale of the Paradox Formation caprock crop out along the margins of Castle Valley and around Round Mountain. Sandstone, conglomerate, and shale of the Cutler Formation overlie the Paradox in cliffs at the southwest end of the valley. Triassic shale and sandstone of the Moenkopi, Chinle, Wingate, and Kayenta Formations overlie the Cutler and form the cliffs along the northeast and southwest sides of the valley. Round Mountain and the La Sal Mountains are an upper Tertiary intrusive granodiorite porphyry.

Unconsolidated Sediments

The valley fill of Castle Valley consists of alluvial-fan deposits and stream alluvium. Holocene stream deposits along Castle Creek and Placer Creek are generally poorly sorted sand, silt, and clay, with some gravel lenses, particularly in higher reaches (Doelling and Ross, 1993). Coarse-grained older alluvium is exposed in the higher parts of Castle Valley, and underlies the younger stream alluvium in lower Castle Valley (Doelling and Ross, 1993). Alluvial-fan deposits form apron-like gentle slopes at the base of Porcupine Rim. The fans consist of poorly sorted boulders, cobbles, and gravels in a fine-grained matrix (Doelling and Ross, 1993).

GROUND WATER

Ground water is in both fractured-rock and valley-fill aquifers in Castle Valley. Most of the water entering the aquifers falls initially as snow in the La Sal Mountains. All of the homes in Castle Valley use ground water for domestic purposes, although some of the residents in areas with highly mineralized ground water choose not to drink the water.

The quality of ground water in Castle Valley varies widely, depending on its source. Drinking-water and ground-water-protection regulations in Utah classify ground water based largely on total-dissolved-solids concentrations, as shown in table 1. Class IA and II waters are considered suitable for drinking, provided concentrations of individual contaminants do not exceed state and federal ground-water-quality standards. Water with total-dissolved-solids concentrations in the higher part of the class II range is generally suited for drinking water only if treated, but can be used for some agricultural or industrial purposes without treatment. Most water in Castle Valley is class IA and II.

Table 1. Drinking-water and ground-water-protection regulations in Utah.

CLASS	**TOTAL DISSOLVED SOLIDS** (milligrams per liter)	**APPROXIMATE SPECIFIC CONDUCTANCE** (micromhos per centimeter at 25°C)
IA (pristine)	less than 500	less than 750
II (drinking water quality)	500 to 3,000	750 to 4,700
III (limited use)	3,000 to 10,000	4,700 to 15,000
IV (saline)	more than 10,000	more than 15,000

Fractured-Rock Aquifers

Aquifer Characteristics

Approximately 30 wells receive water from the Cutler Formation aquifer along the base of Porcupine Rim on the west side of the valley (Blanchard, 1990). The Cutler is the only currently used fractured-rock aquifer in Castle Valley. Well depths are generally 150 to 300 feet (45 to 90 m) below the land surface. Recharge to the aquifer is partially from the La Sal Mountains (Doelling and Ross, 1993). The Chinle and Moenkopi Formations are important confining units overlying the Cutler Formation (Blanchard, 1990). Regionally, the Wingate Sandstone is an important fractured-rock aquifer, but exposures of the Wingate in

Castle Valley are too localized and do not receive sufficient recharge to be aquifers.

Water Quality

Well water in the Cutler Formation has more total dissolved solids than that in adjacent valley fill (figure 3). Water in the Cutler aquifer is mostly class II, but in some areas may be class III. Specific conductance ranges from 842 to 4,360 micromhos per centimeter at 25°C (Ford and Grandy, 1995) (figure 3); the lowest values come from shallower wells in northern Castle Valley that may be receiving some water from the valley-fill aquifer. The highest values come from areas at the base of Porcupine Rim where large quantities of gypsum along drainages indicate nearby Paradox evaporites. Blanchard (1990) reported that two wells in the Cutler Formation exceeded Utah State primary drinking water standards for selenium and sulfate, although high selenium has not been found in more recent testing (Ford and Grandy, 1995). This poor-quality water is the result of some combination of three possible factors: (1) long residence time and flow path, (2) dissolved fine-grained constituents of the Cutler Formation, and (3) hydraulic connection to the Paradox Formation evaporites beneath the Cutler Formation.

Unconsolidated Valley-Fill Aquifer

The unconsolidated valley-fill aquifer is the most important source of water in Castle Valley because it provides good quality drinking water, however, it is most susceptible to contamination.

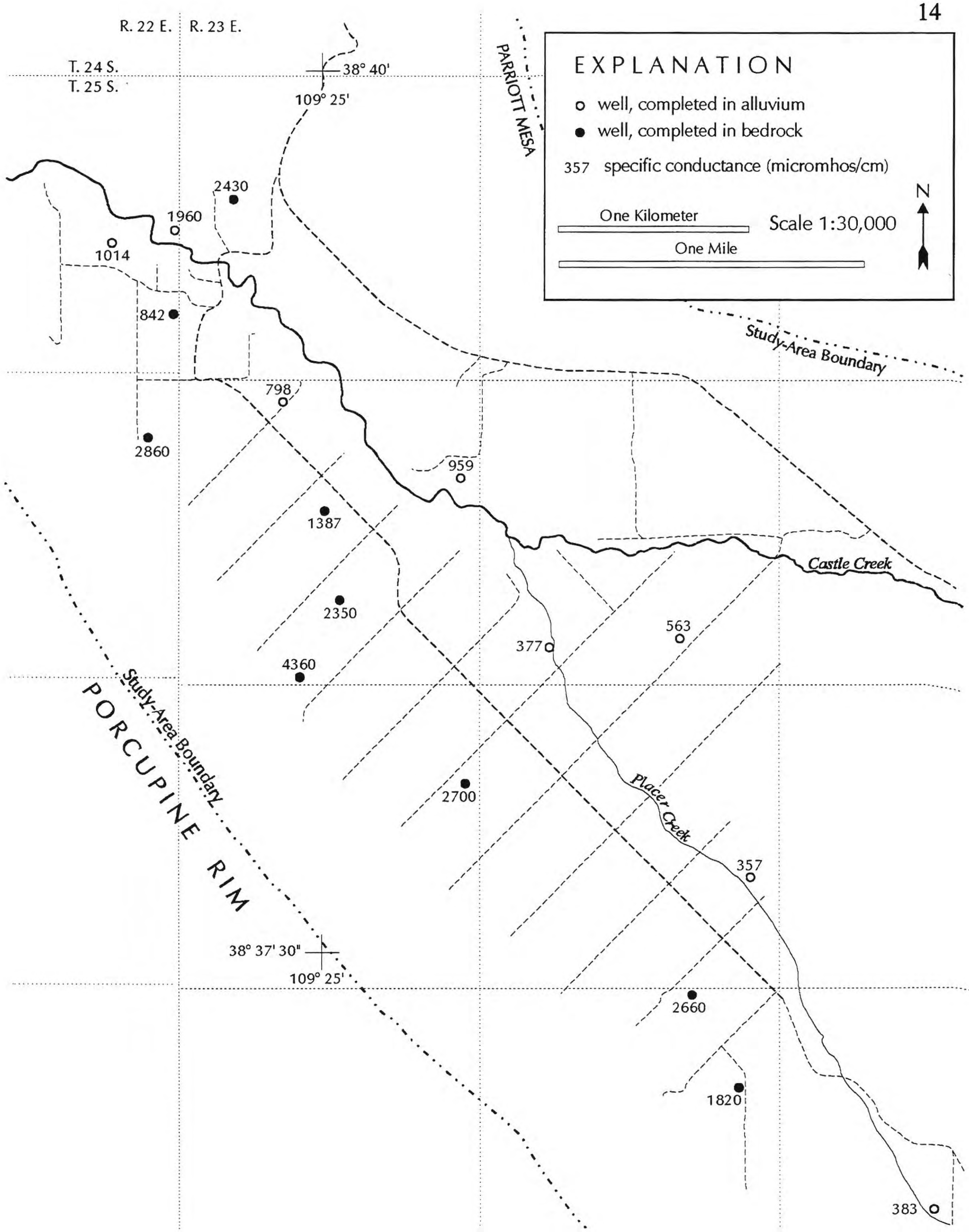

Figure 3. Northern Castle Valley area showing specific conductance of selected wells in bedrock and alluvium (data from Ford and Grandy, 1995).

Aquifer Characteristics

The valley fill consists of generally coarse-grained gravelly alluvial-fan deposits and stream alluvium. The material is coarsest near source areas at the base of Porcupine Rim and the La Sal Mountains and is finer grained along the lower reaches of Castle Creek. Well logs indicate that a few wells in the valley intersect clay lenses but none is extensive enough to confine or protect the valley-fill aquifer. The valley-fill aquifer is thus unconfined. The water table ranges from 30 feet (9 m) to over 100 feet (30 m) below the land surface. The valley fill is as thick as 350 feet in lower Castle Valley (Doelling and Ross, 1993). Wells are generally drilled less than 150 feet (45 m) into valley fill.

Recharge and Discharge

The potentiometric-surface map (figure 4) shows that water in the valley-fill aquifer flows generally northwest with Castle Creek and Placer Creek. Some additional flow into the aquifer is from fractured-rock aquifers along the southwest margin (figure 4). Most of the recharge to the valley-fill aquifer is from Castle and Placer Creeks which originate high in the La Sal Mountains. As Castle Creek crosses the coarse-grained valley fill in the southeastern part of the study area, much of the flow percolates into the aquifer. Castle Creek is a losing stream except near the town of Castle Valley (Ford and Grandy, 1995) (figure 2). The entire valley is primary recharge area except this small discharge area (figure 4). Sources of recharge other than Castle and Placer Creeks include: (1) direct percolation of precipitation, particularly in the higher parts of the valley; (2) percolation and seepage of irrigation water; and (3) inflow from adjacent fractured-rock aquifers.

The area of ground-water discharge from the valley-fill aquifer near the town of Castle

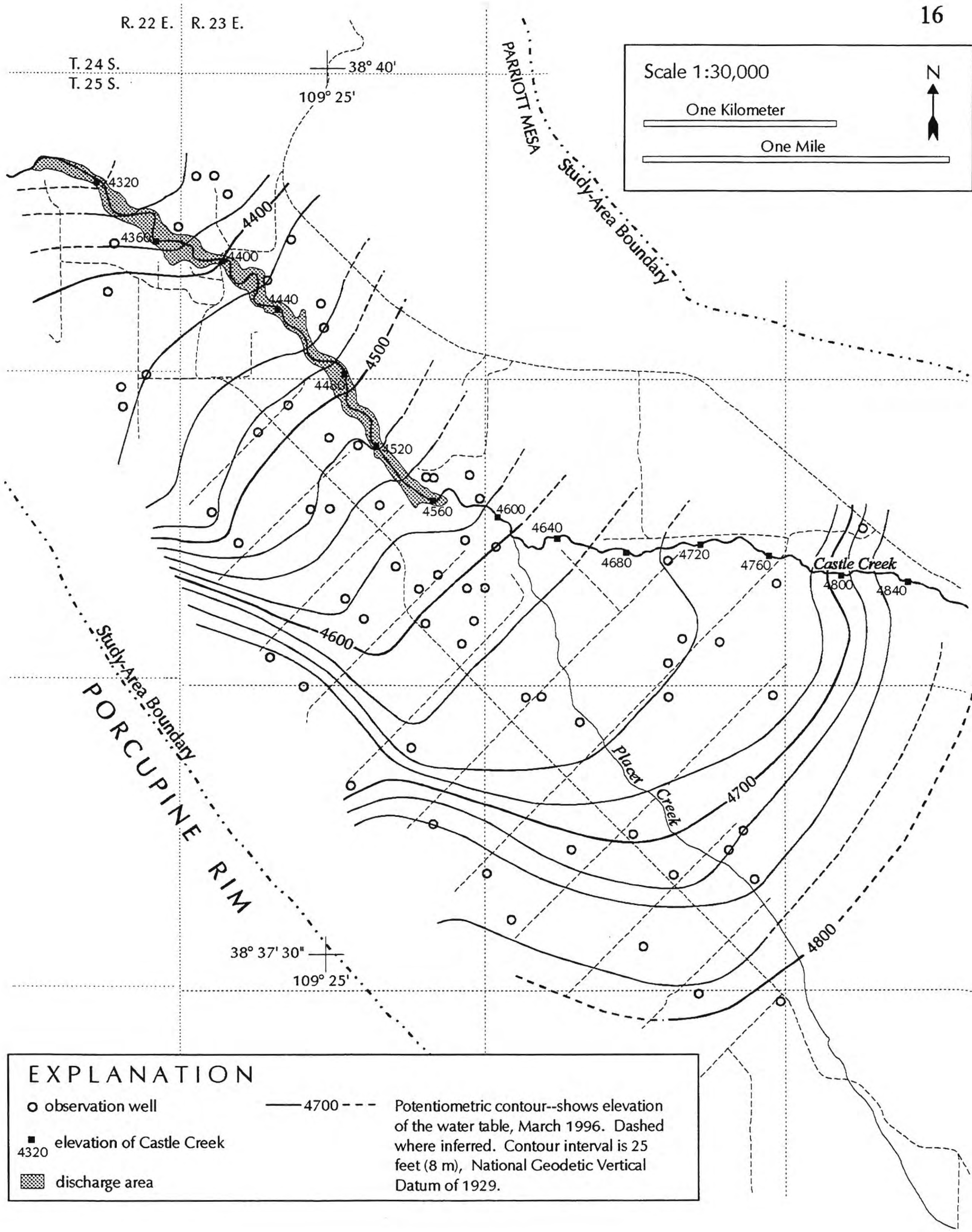

Figure 4. Potentiometric-surface map of northern Castle Valley showing discharge area and elevations of Castle Creek.

Valley is where the channel is incised up to 40 feet (12 m) into the valley fill and has intersected the water table (Ford and Grandy, 1995) (figure 4). Other discharge is from: (1) wells; (2) evapotranspiration, particularly along lower Castle Creek; and (3) underflow into the Colorado River.

Water Quality

Water in the valley-fill aquifer is class IA and II. Several researchers have noted a general down-valley increase in dissolved solids in wells and springs in the valley-fill aquifer (Weir and others, 1983; Ford, 1994). This trend is also apparent in the specific-conductance data from eight wells in the valley-fill aquifer, for which values ranged from 357 to 1,960 micromhos per centimeter at 25°C (Ford and Grandy, 1995) (figure 3). Figure 5 further documents this general down-valley decline in water quality and also shows declines toward the valley margins indicating recharge from the poor-quality Cutler Formation aquifer along the base of Porcupine Rim. The plume of high-quality water along Castle and Placer Creeks confirms that these creeks are a principal source of recharge to the valley-fill aquifer (figure 5). Salty water discharging from a small spring in the northwestern end of the valley comes from Paradox Formation evaporites (Doelling and Ross, 1993). The especially poor-quality water in valley-fill wells and Castle Creek in the far northwestern part of the valley is probably related to a local hydraulic connection to water in the Paradox Formation (figures 3 and 5).

I believe that the poor-quality ground water in the valley-fill aquifer is the result of recharge from the Cutler and Paradox Formations, not contamination from fertilizers, septic systems, or animal wastes. Nitrate concentrations are under 1 mg/L in all of the sampled wells, an order of magnitude below state and federal drinking-water standards (Ford and

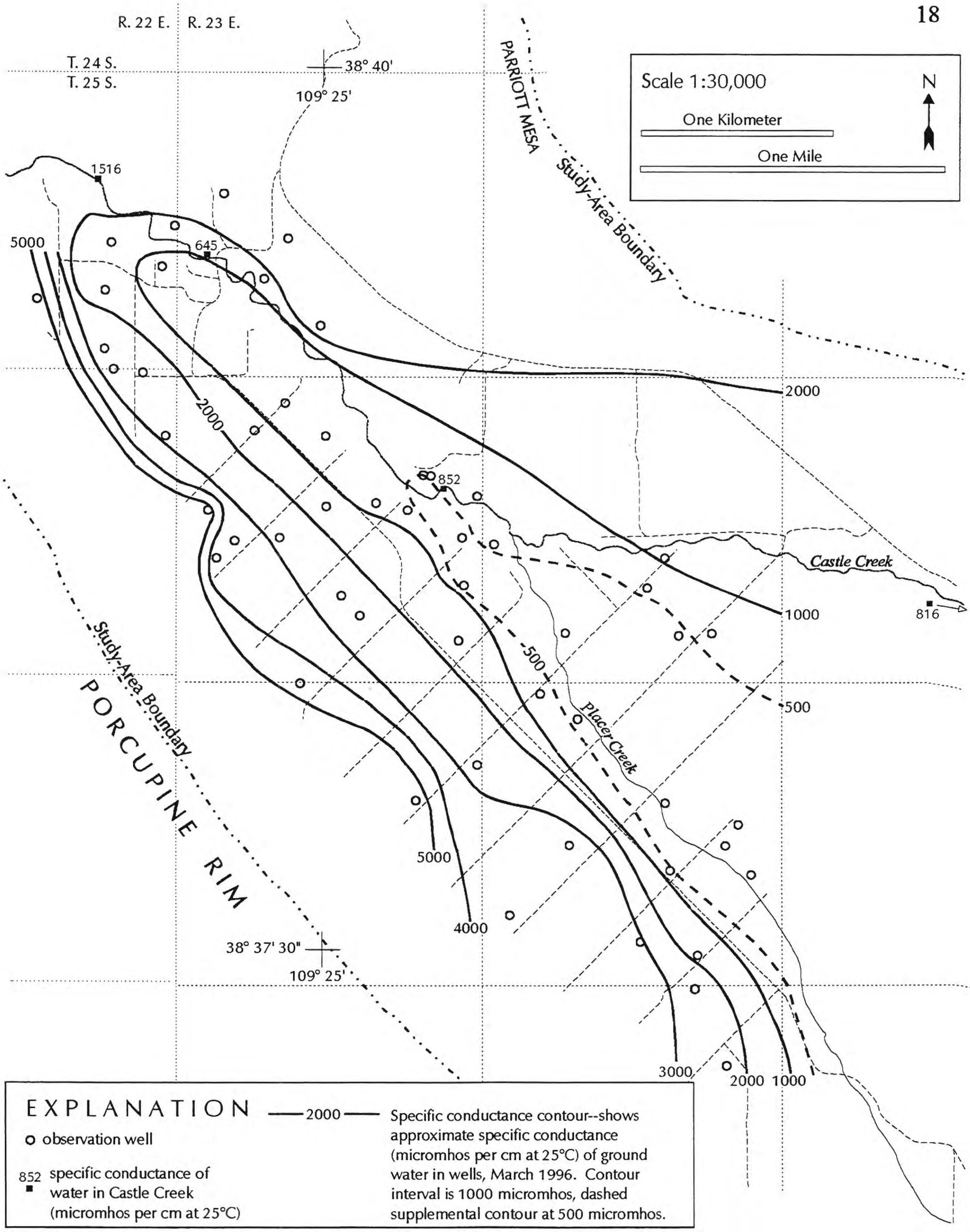

Figure 5. Specific-conductance contour map of northern Castle Valley.

Grandy, 1995). Additionally, Ford and Grandy (1995) found no evidence of high fecal coliform counts in the 15 wells sampled in Castle Valley.

Potential for Water-Quality Degradation

Although water quality is generally high in the valley-fill aquifer, the potential for contamination is significant. The valley fill of Castle Valley has no continuous clay lenses to act as protective confining layers. Pollutants can thus enter the aquifer virtually anywhere. The coarse-grained sediments also have little ability to renovate contaminants once in the system. At present, wells supply culinary water to all of the homes in Castle Valley. These homes also all use septic tanks to treat their wastes, which means that the potential for nitrate contamination of down-gradient wells is very strong. None of the wells sampled by Ford and Grandy (1995) shows such contamination, but it is a possibility, especially as more homes are built. Mulvey (1992) points out that the current practice of platting 5-acre lots helps reduce the potential for water-quality degradation.

High specific conductance in wells in the Cutler Formation indicates that the aquifer is an unsuitable source of high-quality water. Highly mineralized water from the Cutler aquifer recharges the valley-fill aquifer along the west and north sides of the valley (figures 3 to 5). At present, the large quantity of good-quality water that flows northwest in the valley-fill aquifer beneath Castle and Placer Creeks dilutes recharge from the Cutler aquifer along the base of Porcupine Rim. Increased recharge to the valley-fill aquifer from the Cutler aquifer and Paradox evaporites is a potential problem associated with increased pumping as more wells are drilled.

Mulvey (1992) lists three possible solutions to some of these potential ground-water problems: (1) culinary water sources could be developed only upgradient of septic systems; (2) a central sewage treatment system could be installed; and (3) a community-wide water system could be developed. The paradox is that these solutions generally are not economically feasible for 5-acre lot development, which has been instrumental to maintaining the current quality of ground water.

SUMMARY AND CONCLUSIONS

The valley-fill aquifer of Castle Valley is unconfined and consists of alluvial-fan deposits and stream alluvium. Infiltration of stream runoff originating as precipitation in the La Sal Mountains, south of Castle Valley, is the most important source of recharge to the valley-fill aquifer. Ground water flows with Castle Creek and Placer Creek toward the lowest part of Castle Valley, where some of it discharges back to Castle Creek. Except for this small discharge area, the entire drainage basin is primary recharge area. Water in the fractured Cutler Formation aquifer is generally poor quality, with high specific conductance in many wells. The Cutler aquifer recharges the valley-fill aquifer along the western side of the valley. Water quality in the valley-fill aquifer declines from class IA in the higher parts of Castle Valley to class II in the lower parts of the valley, due to hydraulic connections to the Cutler and Paradox Formations. This decline may worsen with increased pumping. The coarse-grained, unconfined valley-fill aquifer has little ability to renovate contaminated water or block its entry, so the potential for ground-water-quality degradation is significant.

ACKNOWLEDGMENTS

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