Steiger, J.I., and Freethey, G.W., 2001, Ground-water hydrology of
Dugway Proving Ground and adjoining area, Tooele and Juab Counties, Utah

INTRODUCTION

Dugway Proving Ground (DPG) is a U.S. Department of Defense chemical, biological, and explosives testing facility in northwestern Utah. The facility includes about 620 mi^2 in Tooele County. The town of Dugway, referred to as English Village, is the administrative headquarters for the military facility, the primary residential area, and community center. The English Village area is located at the southern end of Skull Valley and is separated from the Fries area by a surface-water divide. Most of the facility is located just to the west of Skull Valley in Government Creek Valley, Dugway Valley, and the Great Salt Lake Desert (fig. 1).

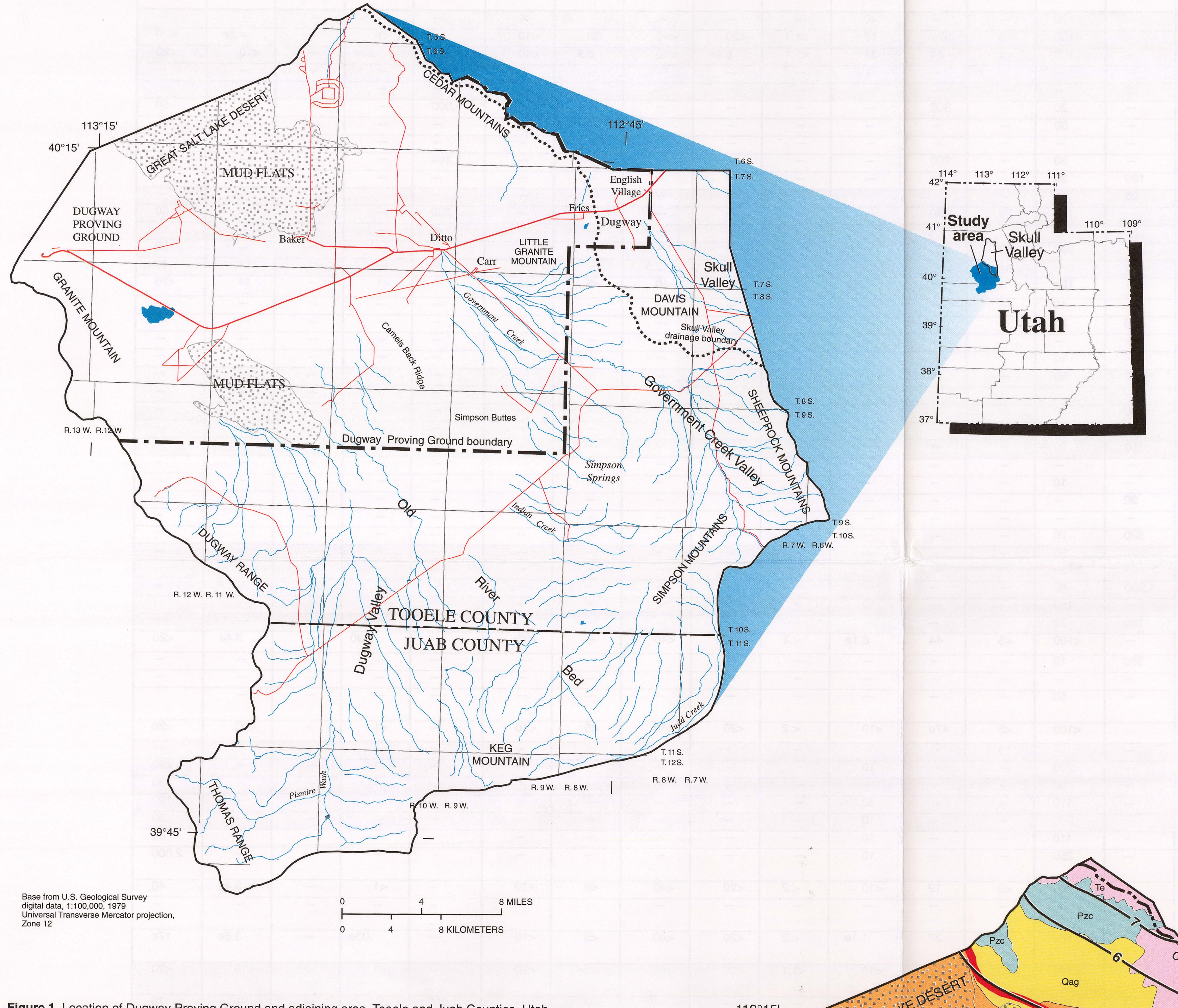

Figure 1. Location of Dugway Proving Ground and adjoining area, Tooele and Juab Counties, Utah.

Dugway Proving Ground was activated for military use in 1942 to serve as a proving ground for the testing of chemical weapons (Parsons Engineering Science, 1996). Chemical, biological, and explosives testing have been conducted within the DPG. Open-air testing of chemical and biological agents was conducted until 1969, after which all chemical and biological warfare testing was confined to sealed chambers (Parsons Engineering Science, 1996).

More than 200 sites on DPG have been identified as Solid Waste Managements Units (SWMU) or Hazardous Waste Management Units (HWMU). These sites are being investigated and managed for clean up or monitoring under the supervision of the Utah Department of Environmental Quality and the U.S. Department of the Army. Numerous consultant reports have been published to document ground-water quality, hydrologic properties, and ground-water movement at each site; however, information about ground-water conditions in the areas adjoining DPG is limited. The chemical quality of ground water in Dugway and the adjoining area was monitored in the late 1950s to early 1960s for common constituents, nutrients, and selected metals. In the early 1970s, six more ground-water samples were analyzed for similar constituents.

Environmental managers at DPG need to identify existing and historical ground-water-quality data for the basin-fill deposits and consolidated rock, the location of recharge areas for the ground-water system, and the direction of ground-water movement to assess the movement of known or potential ground-water contaminants in the ground-water system. Officials at DPG need to have a better understanding of how the ground-water system underlying and adjoining the facility functions to better manage and protect the water resources of the area.

Previous Investigations

An early study of the ground water at Dugway Proving Ground was done by P. F. Fix and others and released as an unpublished U.S. Geological Survey (USGS) report in 1951. Dumars and others completed an unpublished geologic reconnaissance of the eastern part of Dugway Proving Ground with reference to ground water in 1954, which also included a study of geophysics by Coyd Jost. Two unpublished master plans for water-resources development on Dugway Proving Ground were done by the U.S. Army Corps of Engineers, U.S. Army Engineer District, Sacramento, California, in 1966 and 1973. Waddell (1967) completed a reconnaissance of the chemical quality of water in parts of Skull Valley, Government Creek Valley, and the Dugway Valley-Old River Bed area. Hydrologic reconnaissances were completed by Hood and Waddell (1968) in Skull Valley, Stephens and Sumsion (1978) in the Dugway Valley/Government Creek area, and Gates and Kruer (1981) in the southern Great Salt Lake Desert with a summary of the hydrology of west-central Utah. Ground water in the Sevier Desert to the south of the study area, which includes the continuation of the Old River Bed, has been investigated by Mower and Feltis (1968) and Holmes (1984).

Information about the structure and lithologic character of the consolidated rocks that surround the area is available in Staatz and Carr (1964) for the Dugway and Thomas Ranges, and Shubat, Felger, and King (1999), and Shubat and Christenson (1999) for Keg Mountain. Oviatt, Sack, and Feiger (1994) have published a map of the Quaternary geology of the Old River Bed.

Purpose and Scope

This report describes the ground-water hydrology of the Dugway Proving Ground and adjoining area, including principal recharge area, discharge area, ground-water movement, water-level fluctuation, and chemical quality of ground water. Selected water-quality data from previously published reports by Waddell (1967), Hood and Waddell (1968), and Stephens and Sumsion (1978) are included in this report for convenience. The principal recharge area for the ground-water system and the ground-water flow paths between recharge and discharge areas are delineated. Estimated hydraulic gradients in the basin-fill deposits of Government Creek and Old River Bed and estimates of horizontal hydraulic conductivity also are included.

Fifteen water-quality samples were collected from wells and springs in the basin-fill deposits and consolidated rocks. Samples were analyzed for anions, cations, nutrients, metals, semivolatile and volatile organics, and explosives. One 2-in.-diameter PVC observation well was drilled and installed by the USGS in the Old River Bed on DPG for this study. Water-level measurements were made in 53 wells to determine direction of ground-water movement within and around DPG. Altitude of measuring points was surveyed for Army-owned wells in English Village.

Numerous reports documenting environmental conditions at the more than 200 SWMU and HWMU sites on DPG have been prepared by consultants. The reports provide information about the unconfined or semiconfined parts of the ground-water system throughout DPG. However, it is not within the scope of this report to summarize all the information available, but rather to use this information when it adds to the understanding of the confined part of the ground-water system and the unconfined parts in English Village and Fries areas.

Numbering System for Hydrologic-Data Sites in Utah

The system of numbering wells, springs, and other hydrologic-data sites in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the site, describes its position in the land net. The land-survey system divides the State of Utah into four quadrants by the Salt Lake Base Line and the Salt Lake Meridian. These quadrants are designated by the uppercase letters A, B, C, and D, that indicate, respectively, the northeast, northwest, southwest, and southeast quadrants. Numbers that designate the township and range (in that order) follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section and is followed by three lowercase letters that indicate the quarter section, the quarter-quarter section and the quarter-quarter-quarter section—generally 10 acres for regular sections. Although the basic land unit, the section, is theoretically 1 square mile, many sections are irregular. Such sections are subdivided into 10-acre tracts, generally beginning at the southeast corner, and the surplus or shortage is taken up in the tracts along the north and west sides of the section.

The lower case letters a, b, c, and d indicate, respectively, the northeast, northwest, southwest, and southeast quarters of each subdivision. The number after the letters is the serial number of the site within the 10-acre plot. The upper case letter "S" preceding the serial number denotes a spring. If there is no number after the letters, it indicates that the site is a surface-water site, reservoir, or mine tunnel outflow. Thus, (C-7-8)10cbd-1 designates the first well constructed or visited in the SE 1/4 NW 1/4 SW 1/4 Sec. 10, T. 7 S., R. 8 W. (fig. 2). The uppercase letter C indicates that the township is south of the Salt Lake Base Line and the range is west of the Salt Lake Meridian.

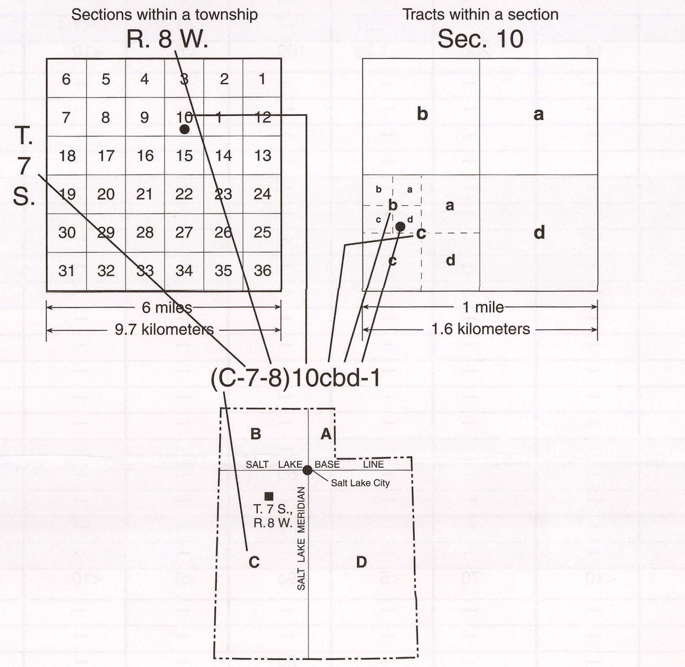

Figure 2. Numbering system used for hydrologic-data sites in Utah.

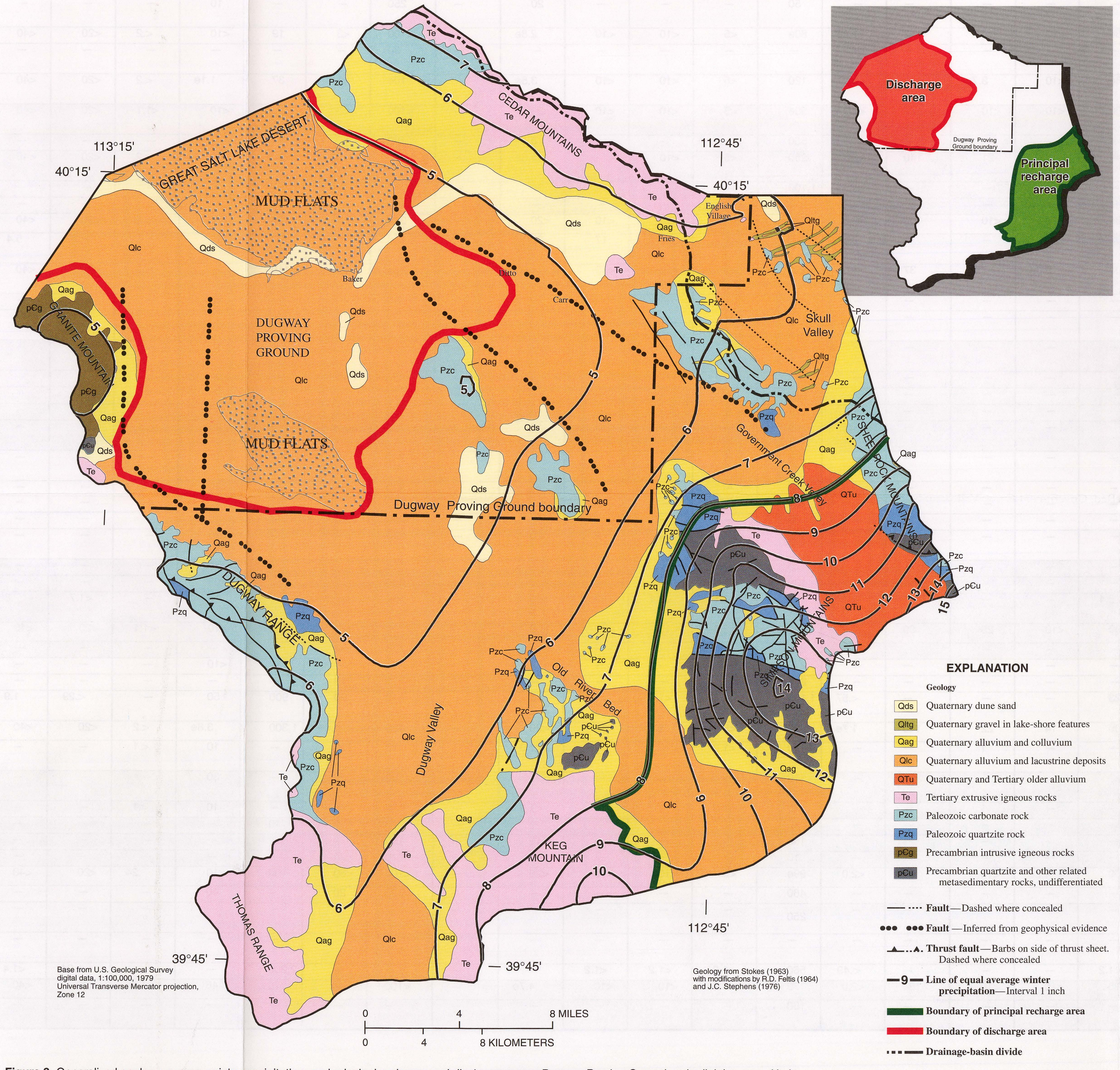

Figure 3. Generalized geology, average winter precipitation, and principal recharge and discharge areas, Dugway Proving Ground and adjoining area, Utah.

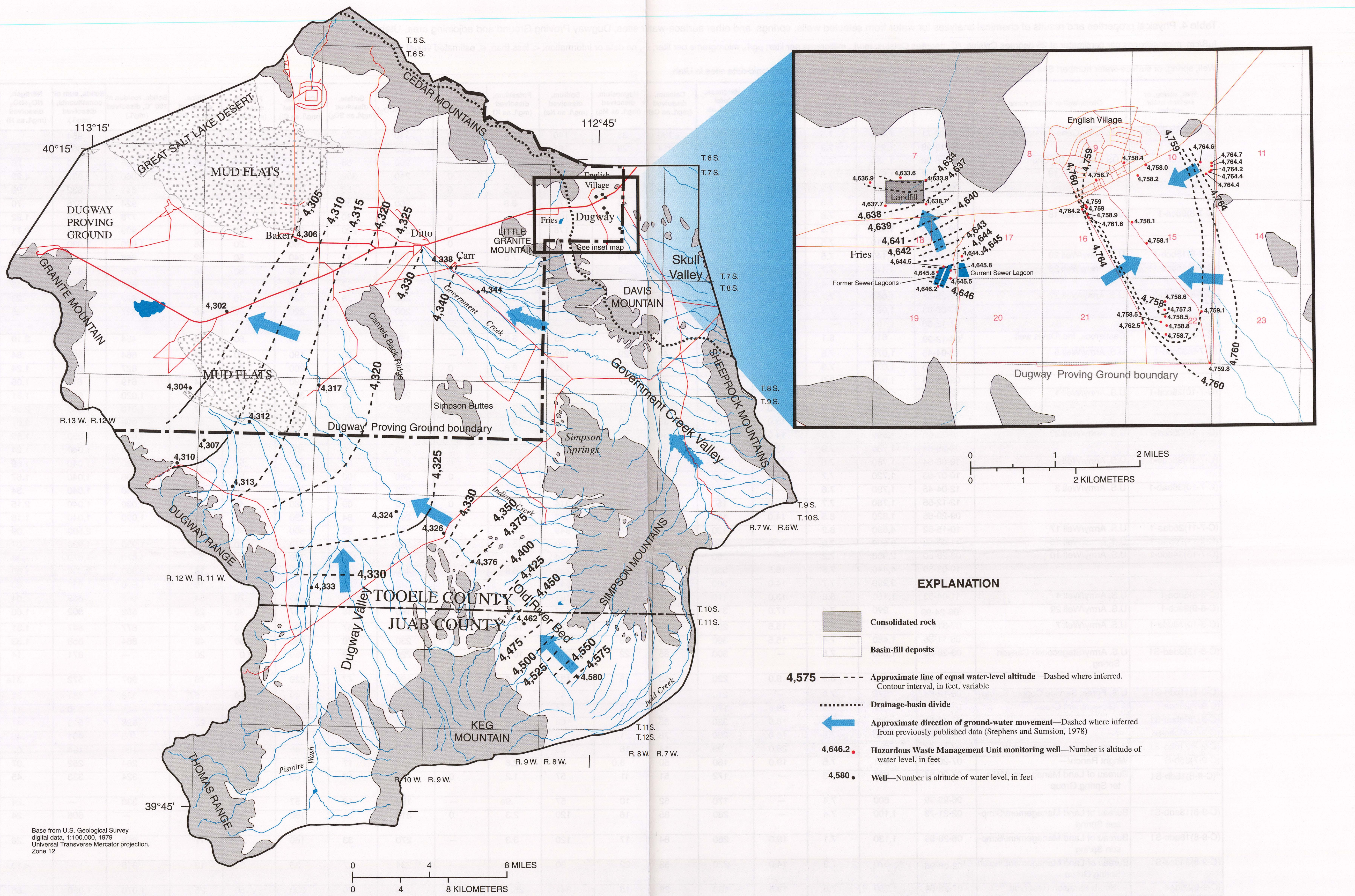

Figure 4. Approximate water-level altitude and direction of ground-water movement during March-April 1999, Dugway Proving Ground and adjoining area, Utah.

Hydrogeologic Description of the Study Area

Dugway Proving Ground and the adjoining area lie within the Basin and Range Physiographic Province (Fenneman, 1931). The area is characterized by a series of longitudinal block-faulted mountain ranges and intervening down-dropped basins. The basin-fill deposits are a complex sedimentation pattern of lake-bottom, lakeshore, stream, and alluvial-fan deposits derived from erosion and volcanism in the adjacent upthrown ranges of sedimentary, metasedimentary, and igneous rocks. Ground water occurs in the basin-fill deposits throughout the study area and is referred to as the ground-water system for this report. The boundaries of the study area are the Cedar Mountains to the northeast; the part of Skull Valley that includes English Village, Sheeprock Mountains, and Government Creek Valley to the east; Simpson Mountains, Keg Mountain, Old River Bed, and Dugway Valley to the south. The Thomas and Dugway Ranges are to the west, and Granite Mountain and the Great Salt Lake Desert are to the northwest.

Basin-Fill Deposits

The basin-fill deposits underlying DPG and the area south and east of DPG are bounded and partially divided by consolidated rock outcrops and mountain ranges. Dugway Valley, Old River Bed, Government Creek Valley, and the Fries area form subareas of the ground-water system south, southeast, and east from the main part of the Great Salt Lake Desert (fig. 3). The alluvial deposits in these subareas do not terminate at the surface-water divide at the southern and eastern ends of these drainages, but merge with the basin-fill deposits of adjacent basins of the Sevier Desert to the south and Skull Valley to the east. A surface-water divide and consolidated rock, overlain by a thin layer of alluvium, separates the English Village area from the rest of the study area. The English Village area is part of the much larger Skull Valley ground-water system to the east and northeast (Hood and Waddell, 1968).

The consolidated rock of Keg Mountain separates Dugway Valley from Old River Bed, but the basin-fill deposits in these drainages merge as the rocks of Keg Mountain dip below the accumulating alluvial deposits at the northern end. Rock outcrops, Camels Back Ridge and Simpson Buttes, and the Simpson Mountains separate the basin-fill deposits in Old River Bed from the basin-fill deposits in Government Creek Valley until the basin-fill deposits coalesce at the northwestern end of Camels Back Ridge. Little Granite Mountain and Davis Mountain separate the Fries area from Government Creek Valley to the south.

The thickness of the basin-fill deposits in the study area is not well known. Few wells have penetrated the basin-fill deposits and reached underlying consolidated rock. Those few that have been drilled into consolidated rock are near the basin margins and are of limited value in estimating thickness at the center of the valleys. The deepest well in Dugway Valley penetrated to 551 ft without encountering consolidated rock (table 1). Wells drilled in the Old River Bed have penetrated as much as 585 ft of basin-fill deposits, and the deepest well in Government Creek Valley is 450 ft deep. Well 17 in the Baker area was drilled to 1,003 ft without encountering consolidated rock. Monitoring wells in the English Village area were drilled into consolidated rock at a depth of 15 ft in the area between English Village and Fries and at 70 to 135 ft along the eastern boundary of DPG. Well 21, near the south end of DPG, was drilled to a depth of 730 ft in basin-fill deposits but was reported to have no water below 497 ft. The last 200 ft of the well were drilled primarily through clay deposits. The Fries area is separated from English Village by consolidated rock that is overlain by thin alluvium. Depth to consolidated rock to the west of the Fries area is unknown. The monitoring wells for the landfill in the Fries area were drilled to depths of from 146 to 213 ft below land surface but did not reach consolidated rock.

Complex layering and mixing of sand, clay, silt, and gravel in the basin-fill deposits have created a complex ground-water system. A cross section of the basin-fill deposits from Little Granite Mountain through the Carr-Ditto area (Parsons Engineering Science, 2000) shows a 10- to 15-ft thick clay layer near Little Granite Mountain, 60 to 70 ft below land surface, that continues to the Carr-Ditto area where it is 65 to 80 ft thick and 90 to 95 ft below land surface. Similar thick clay layers occur in wells within DPG in Dugway and Government Creek Valleys, and Old River Bed. These clay layers divide the ground-water system into multiple unconfined or semiconfined parts and a deeper confined part. Most of the numerous monitoring wells in the Ditto, Carr, and Baker areas are completed in the unconfined or semiconfined parts. Wells completed in the deeper confined part are the source of potable water in the Carr and Ditto areas. In the English Village and Fries areas, ground water occurs under unconfined conditions in a series of unconsolidated sand and gravel deposits.

Consolidated Rocks

Although the basin-fill deposits are considered to be the primary source of ground water in the study area, the consolidated rocks that make up the surrounding mountain ranges and low outcrops are an important part of the regional ground-water system. Igneous, carbonate, quartzitic and metasedimentary rocks form the boundaries of the basin-fill system (fig. 3). These rocks, especially in the southeast, receive most of the precipitation that falls over the region. The lithologic character of the consolidated rocks is not conducive to allowing rainfall or snowmelt to infiltrate, but fractures in the crystalline rocks and enlarged solution cavities in the carbonate rocks allow movement of precipitation into the subsurface, which is demonstrated by the abundance of springs in and near the margins of these consolidated-rock outcrops. Stephens and Sumsion (1978) recorded springs in every surrounding mountain range except the Thomas Range, which is primarily composed of igneous rocks. The greatest abundance of springs is in the Simpson and Sheeprock Mountains, both of which are composed mainly of carbonate and quartzite rocks and receive the greatest amount of precipitation (fig. 3 and table 2). Keg Mountain, which receives less precipitation and is composed of igneous rock, has two springs, one associated with alluvium and the other associated with a fault (Shubat and Christenson, 1999). Consolidated rock is important to the ground-water system in two ways. First, surface runoff from the consolidated rocks flows onto the basin-fill deposits, some of which infiltrates to recharge the ground-water system. Second, consolidated rocks transmit the water that penetrates the fractures of these rocks into the subsurface and eventually into the ground-water system at subsurface contacts.

Acknowledgments

Recognition and thanks are extended to all well and property owners who allowed access to their wells for sampling. Also, thanks to Thomas C. Memmett with the Bureau of Land Management in Fillmore for his help in collecting water from wells maintained by the Bureau of Land Management. Thanks to John H. Woffinden at Dugway Proving Ground for all his help with completing field work and his quick responses to information requests.

GROUND-WATER HYDROLOGY

Principal Recharge Area

Areas of principal recharge were determined on the basis of precipitation, geology, and hydrology. The amount of recharge that occurs within an area is dependent on such factors as amount and timing of precipitation, hydrologic properties of the soil, and fracturing in consolidated rock. Precipitation is the major source of recharge to the ground-water system in the Dugway area. Recharge to the ground-water system is derived from precipitation that falls in the winter months as snow or in the summer months during thunderstorms. Precipitation from summer thunderstorms provides a limited source of recharge to the basin-fill deposits. Water from rainfall generally contributes flow to stream runoff but does not persist long enough on consolidated rocks to infiltrate into fractures or openings in the rock. Water from streams recharges the ground-water system along the mountain fronts in areas where streams cross alluvial deposits. Some of the areas where streams would likely contribute ground-water recharge would be parts of Government Creek, Indian Creek on the west side of the Simpson Mountains, and Judd Creek on the south side of the Simpson Mountains.

Precipitation that falls during October through April, referred to as winter precipitation, has the greatest potential to be a major source of ground-water recharge because temperatures are cool and the evaporation rate is low. Winter precipitation in the form of snow typically melts slowly, allowing precipitation to infiltrate into soil and underlying bedrock. Average annual winter precipitation (fig. 3) ranges from less than 5 in. in most of the western part of DPG to 14 in. in the Simpson Mountains and 16 in. in the Sheeprock Mountains. Infiltration studies by Danielson and Hood (1984) generally indicate that areas with more than 8 in. of winter precipitation contributed the most ground-water recharge.

Fractures and faults in crystalline rocks and enlarged solution cavities in carbonate rock provide conduits for precipitation to infiltrate and recharge the ground-water system at subsurface contacts (fig. 3). Geologic mapping done by Pampeyan (1989) of the Lynndyl 30- by 60-minute quadrangle (area south of 40 degrees latitude) shows extensive faults in the carbonate rock of the central part of the Simpson Mountains and less faulting in the quartzite and metasedimentary rock in the southern part of the Simpson Mountains. The southern part of the Sheeprock Mountains also is mapped by Pampeyan and shows extensive faulting in the Precambrian quartzite and metasedimentary rocks. Geologic mapping for the northern Sheeprock Mountains is limited; some faulting occurs in the carbonate rock (Stokes, 1963). Most of the Sheeprock Mountains are outside the study area; however, precipitation falling on the Sheeprock Mountains can contribute recharge to basin-fill deposits in Government Creek Valley. More detailed geologic mapping of Keg Mountain by Shubat and Christenson (1999), and Shubat and others (1999) shows almost no faulting in the igneous rock and limited faulting in the carbonate rock outcrops north of the main block of Keg Mountain. The Dugway Range mapped by Staatz and Carr (1964) shows moderate faulting in the carbonate rock on the eastern flank of the range and more extensive faulting on the western flank, outside of the study area. Granite Mountain and the Cedar Mountains show no faulting (Stokes, 1963).

Unconsolidated deposits consisting of gravels and sand with little clay or silt also would allow precipitation to infiltrate and recharge the ground-water system. Areas of sedimentation along the flanks of the mountains such as alluvial fans, talus slopes, and areas of lacustrine gravel could provide potential recharge. The generalized areas of alluvial and lacustrine deposits along the Old River Bed where winter precipitation is 8 in. or more are included as potential recharge (fig. 3).

Areas with the greatest potential to contribute recharge to the deeper, confined parts of the ground-water system in the Dugway area would be the Simpson Mountains, Sheeprock Mountains, alluvium and colluvium deposits around the flanks of the Simpson Mountains, and older alluvium between the Simpson and Sheeprock Mountains. Parts of Keg Mountain receive more than 8 in. of winter precipitation, but because there are no significant faults or fractures, precipitation cannot infiltrate the ground-water system. Faulting in the Dugway Range would allow precipitation to infiltrate the consolidated rocks and recharge the basin-fill deposits, but the lack of winter precipitation would not make this area a principal recharge area. The Cedar Mountains and Granite Mountain, because of low winter precipitation and lack of faults, have a low potential for contributing recharge to the ground-water system.

Stephens and Sumsion (1978) estimated the amount of recharge from precipitation to the Dugway Valley/Government Creek area as 7,000 acre-ft per year. Ground-water flow also enters the Dugway Valley/Government Creek area as subsurface inflow from the Sevier Desert drainage basin through the unconsolidated deposits in the Old River Bed. Mower and Feltis (1968) estimated the recharge from the Sevier Desert to be less than 5,000 acre-ft per year.

Discharge Area

Ground water is discharged by evapotranspiration in areas with phreatophytes and by evaporation from mud flats and the Great Salt Lake Desert. Discharge areas are designated where ground water discharges to the surface through natural means, mainly seeps and mudflats, where phreatophyte growth is well established, or where the depth to the water table is 20 ft or less. Discharge areas were determined by Bedinger and others (1984) and modifications have been made from ground reconnaissance and depth-to-water measurements made by the USGS or reported by consultants (Ageiss Environmental, 1998). Estimates for ground-water discharge from the Dugway Valley/Government Creek area were done by Stephens and Sumsion (1978). They estimated that less than 1,000 acre-ft per year is discharged by evapotranspiration and that 8,000 acre-ft per year is subsurface outflow to the Great Salt Lake Desert.

Ground water also is discharged from the ground-water system by pumping wells. Three wells in the English Village area are used for public supply: well 30, well 27, and well 26; two wells are pumped for irrigation in the summer: well 18 and well 19. In Carr, well 5, and in Ditto, well 28

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By

Judy I. Steiger and Geoffrey W. Freethey

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For additional information write to:
District Chief
U.S. Geological Survey
2329 Orton Circle
Salt Lake City, UT 84119

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